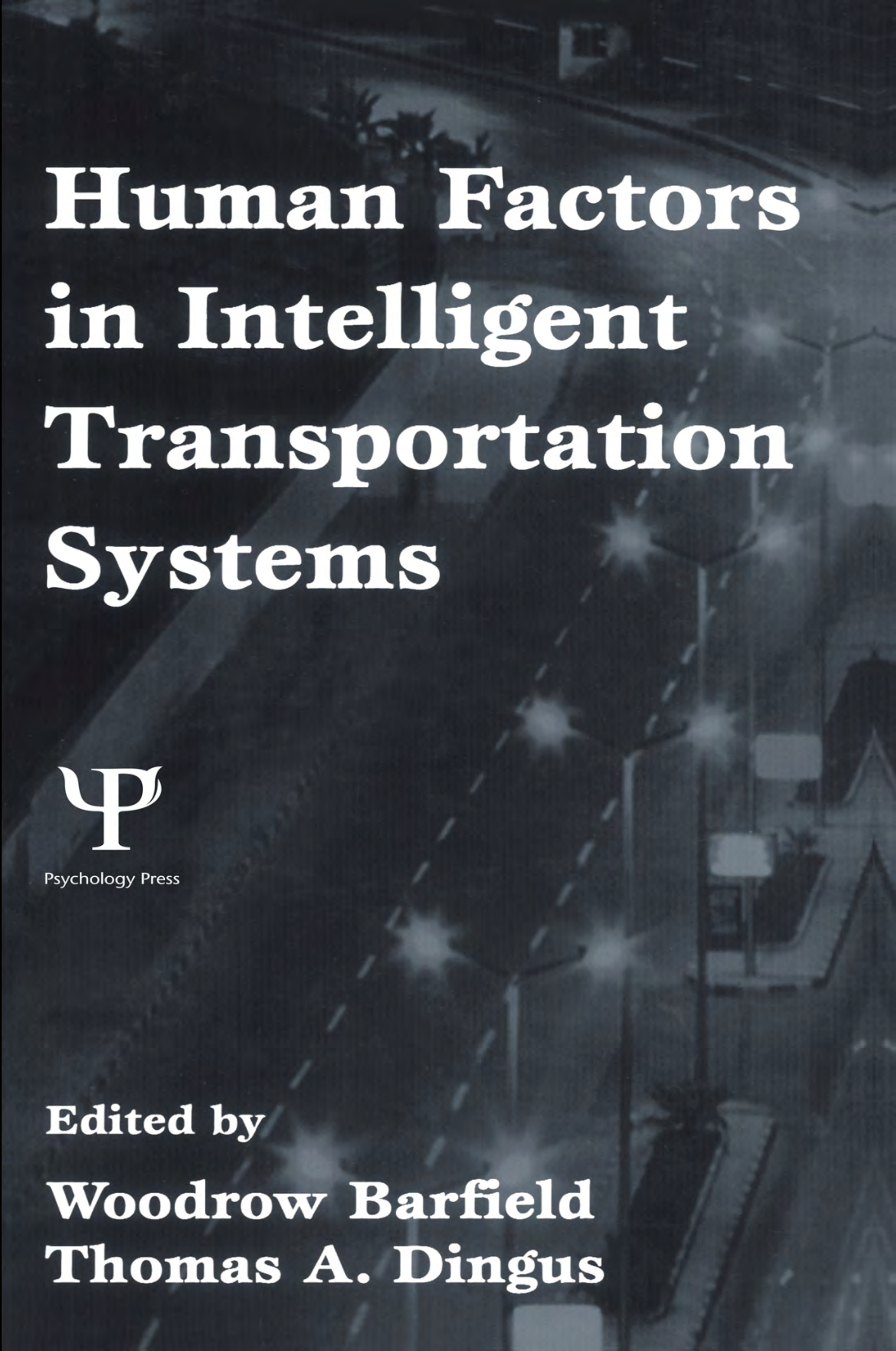
Human Factors in Transportation



Human Factors in Intelligent Transportation Systems

Psychology Press

Edited by

Woodrow Barfield

Thomas A. Dingus

HUMAN FACTORS IN INTELLIGENT TRANSPORTATION SYSTEMS

HUMAN FACTORS IN TRANSPORTATION
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HUMAN FACTORS IN INTELLIGENT TRANSPORTATION SYSTEMS

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SERIES FOREWORD

Barry H. Kantowitz
Battelle Human Factors Transportation Center

The domain of transportation is important for both practical and theoretical reasons. All of us are users of transportation systems as operators, passengers, and consumers. From a scientific viewpoint, the transportation domain offers an opportunity to create and test sophisticated models of human behavior and cognition. This series covers both practical and theoretical aspects of human factors in transportation, with an emphasis on their interaction.

The series is intended as a forum for researchers and engineers interested in how people function within transportation systems. All modes of transportation are relevant, and all human factors and ergonomic efforts that have explicit implications for transportation systems fall within the series purview. Analytic efforts are important to link theory and data. The level of analysis can be as small as one person, or international in scope. Empirical data can be from a broad range of methodologies, including laboratory research, simulator studies, test tracks, operational tests, fieldwork, design reviews, or surveys. This broad scope is intended to maximize the utility of the series for readers with diverse backgrounds.

I expect the series to be useful for professionals in the disciplines of human factors, ergonomics, transportation engineering, experimental psychology, cognitive science, sociology, and safety engineering. It is intended to appeal to the transportation specialist in industry, government, or academic, as well as the researcher in need of a testbed for new ideas about the interface between people and complex systems.

This volume focuses on intelligent transportation systems, an exciting new research area for human factors. It is far too expensive to increase the capacity of the U.S. highway system by building more and more new roads. Instead, the Federal Highway Administration is funding research to demonstrate that adding intelligence to the system is a cost-effective solution. Because the human driver is the key to successful implementation of this solution, human factors plays a prominent role in intelligent transportation systems. The chapters in this book represent the cutting edge of this human factors research. Both practical and theoretical aspects of transportation human factors are illustrated in these chapters, thus achieving a major goal of this book series.

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PREFACE

Techniques to improve driving safety or to reduce urban congestion have often focused on capital intensive strategies such as the development of new roads, new road designs, or light rail to increase the system capacity. An alternative strategy that is currently being explored, and which is less capital intensive, is to design an "intelligent transportation system" (ITS). Such a system will provide the driver with a vast variety of information—information about alternative routes or roadside services to information about crash avoidance.

However, an ITS is only one of many possible approaches to solving the critical and difficult problems of reducing traffic congestion or vehicle crashes, and it is highly unlikely that any single solution will produce a quick fix, given the complexity of the problems associated with the movement of people and material from one location to another. For example, we all know that urban travel patterns are intrinsically related to developments in city structure, the location of workplaces and drivers' residences, and the characteristics and activities of drivers.

However, information-based solutions to transportation problems do present a number of attractive features. They are relatively inexpensive compared to traditional solutions to transportation problems (e.g., building new roads and bridges are very expensive); they have low social and environmental impact; and in addition to their primary goal of improving the safety and efficiency of roadway use, they can produce a number of secondary benefits by carrying public relations and educational messages.

Further, the importance of an ITS is clear when one considers the specific benefits that are expected to occur from its usage. For example, an ITS is expected to reduce traffic congestion, improve navigational performance, decrease the likelihood of accidents, reduce fuel costs and air pollution, and improve driver efficiency. The safety aspects of an ITS are expected to occur because an ITS will provide timely and accessible information delivered in the car on traffic regulations, alternative routes to take, the avoidance of hazardous situations, and safety advisory and warning messages. This information will be especially beneficial in decreased visibility situations due to poor weather or congestion.

This book is concerned with human factors issues that relate to the design and use of the ITS. Intelligent transportation systems emcompass a wide range of cutting-edge technologies being applied to the driver–vehicle–highway infrastructure system in order to improve throughput, safety, and efficiency. Generally, these technologies include advanced sensor, computer, communication (radio/optical), and control technologies which are being used to avoid crashes and regulate the flow of vehicles along roads and highways. The potential of the ITS to make a significant contribution to the problem of transporting people and goods, and the amount of funding being directed toward ITS development, has attracted attention from researchers in several fields—these include behavioral scientists, policy analysts, and others, in addition to engineers.

In this volume, a major effort is made to integrate information from diverse academic fields, including behavioral science, human factors engineering, and civil and transportation engineering, on the topic of the design and use of ITS. It is our belief that ITS technology should be designed from the user's perspective, that is, considering their needs for information, and their cognitive, motor, and visual information-processing abilities. Thus, for ITS to be successful, from a human factors perspective, it is important to determine what information should be provided to users, and in what form. The design of ITS from a user's perspective will involve many complex design issues; we expect that these issues will not be adequately addressed in a few studies, or in a relatively short time period. Rather, we advocate a continuing research program focusing on field and laboratory studies that is adequately funded by the U.S. government and appropriate industries so that our highway infrastructure remains second-to-none.

Based on the thoroughness in which a variety of topics related to ITS development and use are covered, the book can be used as a textbook on the topic of human factors in ITS for courses in civil engineering, industrial engineering, and psychology. Further, the volume will also provide a valuable technical reference source for those involved in the development of ITS technologies, or highways and transportation systems and automotive industries in general. Finally, we hope the book serves as a stimulant for more thorough research on the design and use of ITS, and that the resulting systems that comprise the ITS are "usable" from the driver and traffic engineer–manager points-of-view.

We acknowledge the help we received from Ray O'Connell and his staff at Lawrence Erlbaum Associates. Further, Sondra Guideman provided technical support in the preparation of the manuscript. Finally, without the oustanding technical contribution of the chapter authors this book would not be completed.

Woodrow Barfield
Tom Dingus

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Introduction to ITS

Truman Mast
Federal Highway Administration

WHAT IS ITS?

The Intelligent Transportation System (ITS) Program is a cooperative effort by government, private industry, and academia to apply advanced technology to resolving the problems of surface transportation. The objective is to improve travel efficiency and mobility, enhance safety, conserve energy, provide economic benefits, and protect the environment. The current demand for mobility has exceeded the available capacity of the roadway system. Because the highway system cannot be expanded, except in minor ways, the available capacity must be used more efficiently to handle the increased demand. Traffic congestion in urban areas and on heavily traveled intercity corridors continues to rise rapidly with the annual cost to the nation in lost productivity alone being about $100 billion. The enormous costs of wasted fuel and environmental damage are not included in this estimate. Moreover, traffic accidents kill more than 40,000 people and injure another five million every year (DOT IVHS Strategic Plan, 1992).

ITS will apply advanced information processing, communications, sensing, and computer control technologies to the problems of surface transportation. Considerable research and development efforts will be required to produce these new technologies and to convert technologies developed in the defense and space programs to solve surface transportation problems.

IMPORTANT ROLE OF HUMAN FACTORS

Human factors considerations are critical to the eventual success of solving surface transportation problems. ITS will substantially change the driving task and the way traffic is managed. Human factors considerations play a vital role in ITS development and application, from the design of in-vehicle navigation displays and controls, to the provision of safe and efficient transition from manual to automatic control in highly automated systems.

The extensive use of operational tests in the ITS program makes development of substantive human factors guidelines particularly important. Early and continued acceptance of ITS by the public and policy makers relates directly to the human engineering that goes into the early design prototypes. The public often believes that the system they see in operational tests will be the final product, making quality human factors imperative to the success of the program.

ITS TECHNOLOGY AREAS

ITS has been subdivided into six interlocking technology areas. This book addresses human factors concerns for four of these areas.

ATIS. Advanced Traveler Information Systems include a variety of systems that provide real-time, in-vehicle information to drivers regarding navigation and route guidance, motorist services, roadway signing, and hazard warnings.

AVCS. Advanced Vehicle Control Systems refer to systems that aid drivers in controlling their vehicle particularly in emergency situations and ultimately taking over some or all of the driving tasks.

CVO. Commercial Vehicle Operations address the application of ITS technologies to the special needs of commercial roadway vehicles including automated vehicle identification, location, weigh-in-motion, clearance sensing, and record keeping.

ATMS. Advanced Traffic Management Systems monitor, control, and manage traffic on streets and highways to reduce congestion using vehicle route diversion, automated signal timing, changeable message signs, and priority control systems.

Two technical areas are not specifically addressed here in individual chapters, but many aspects of them are covered in associated chapters. These technical areas are:

ARTS. Advanced Rural Transportation Systems include systems that apply ITS technologies to the special needs of rural systems and include emergency notification and response, vehicle location, and traveler information.

APTS. Advanced Public Transportation Systems enhance the effectiveness, attractiveness, and economics of public transportation and include fleet management, automated fare collection, and real-time information systems.

ADVANCED TRAVELER INFORMATION SYSTEMS (ATIS)

The major human factors problem area in ATIS is the design of in-vehicle displays and controls. The wide range of equipment designs and the extensive diversity of the driving population make this task particularly challenging. The four ATIS functional subareas are referred to as In-Vehicle Information Systems (IVIS) and are discussed next.

IRANS (In-Vehicle Routing and Navigation Systems)

IRANS provide individual motorists with real-time congestion information, depict the best route to their destination and provide explicit turning directions at each choice point. Use of such systems will reduce congestion because drivers will either know what alternate routes to take when a major route is congested, or can postpone discretionary trips. Safety will be increased because drivers can focus on the primary driving task. Designing safe and effective interfaces for in-vehicle navigation and routing advisory displays is an important human factors challenge for ATIS. Driver needs must be accounted for with regard to the amount and coding of information on maps and other in-vehicle displays.

IMSIS (In-Vehicle Motorist Services Information Systems)

Virtually any consumer service listed in the telephone yellow pages can be incorporated into IMSIS. In conjunction with IRANS, motorists will derive significant mobility benefits because they can easily make efficient en route trip changes and combine multiple purpose trips. Motorists will always have ready access to information on hospitals and emergency medical services, increasing safety and comfort. Driver interaction with the IMSIS is an important human factors issue. Making the systems safely accessible to drivers while traveling on high-speed expressways is highly desirable, but it definitely poses a formidable human factors challenge.

ISIS (In-Vehicle Signing Information Systems)

Highway signing deficiencies are among the most frequent complaints received by automobile clubs and traffic engineers, ranging from "the signs don't have the information I need," to "there is too much information." ISIS will supplement and augment information presented on existing on-road signs. The major human factors challenge is to design ISIS so they can be easily tailored to individual driver requirements in terms of information processing capabilities as well as individual trip needs.

IVSAWS (In-Vehicle Safety Advisory Warning Systems)

Using radio transmission devices, IVSAWS provide safety warnings for moving or fixed hazards that are beyond the drivers' sight distance. A major safety benefit will be experienced by motorists traveling in rural areas where the highest percentage of accidents occur. Human factors studies are required to determine the signal strength and sensory mode for the warning display to sufficiently attract and divert the driver's attention toward the potential hazard. To retain credibility, false alarms must be minimized, and the messages must be reserved for highly dangerous situations where the violation of driver expectancy is an important factor.

ADVANCED TRAFFIC MANAGEMENT SYSTEMS (ATMS)

ATMS integrate vehicle detection, communication, and control functions to be responsive to dynamic traffic conditions to increase the efficiency of roadway networks. The central ATMS component, the Traffic Management Center (TMC), is the element with the most human factors concerns. The operations of the TMC include receiving incoming information from a variety of sources including pavement sensors, video cameras, mobile phones, probe vehicles, police cruisers, and fleet managers. This information is fused and processed to determine the location and severity of problems and ascertain optimal re-routing strategies and appropriate changes to traffic control devices. Finally, the TMC must output the information to a variety of receivers, ranging from individual vehicles to fleet managers to traffic control devices.

Control Room Ergonomics

Optimal operator-machine interfaces must be incorporated into the TMC workstation designs. Some TMC response outputs will be determined automatically via computer simulation models and will require operator monitoring tasks. Other outputs will be carried out manually by the operator and will often require utilization of various decision aids, particularly when different sources provide conflicting incoming information.

Operator Team Configuration and Training

The number of personnel, their skill levels, and training requirements must be determined to guarantee efficient and reliable TMC operation during normal, emergency, and system failure operations. To maintain credibility, the TMC failure modes must be designed such that most breakdowns are transparent to the motoring public, making team configuration, coordination and communication among operators crucial to TMC system design.

This introduction provides a broad overview of ITS and a general discussion of some of the important human factors issues. A detailed examination of these issues and related research is presented in the following chapters.

ADVANCED VEHICLE CONTROL SYSTEMS (AVCS)

AVCS will enhance the human capacity to perceive or respond to the driving environment and will significantly change the driving task. Appropriate incorporation of human factors in the design of the AVCS will be imperative to assure that the potential safety benefits are realized and that the systems achieve public acceptance. AVCS consist of the three functional subareas discussed next.

SES (Sensory Enhancement Systems)

Sensory enhancement systems will expand human sensory capabilities beyond normal limits by providing an extended line of sight in darkness, fog, and other reduced visibility conditions. The major human factors challenges in the design of SES focus on determining what visual cues are most essential to safe operation of the vehicle and how these augmented cues should be displayed. Human factors investigations of the amount of information, location of displays, and required mapping to the external world are required.

ODAS (Obstacle Detection and Avoidance Systems)

ODAS consist of two related subsystems, obstacle detection and obstacle avoidance. Detection systems will alert drivers when their vehicle's trajectory puts them in danger of colliding with a fixed object or another vehicle.

Avoidance systems will actually take control of the vehicle and maneuver it out of harm's way in situations where human responses are not adequate to avoid a collision. Human factors investigation in this area will focus on methods of alerting drivers to hazards.

ACS (Automated Control Systems)

The technology for automatic control of vehicles exists, to some extent, today. Systems such as adaptive cruise control, in which the accelerator and brake are automatically regulated to maintain a pre-set distance from a lead car, have been demonstrated. The full realization of ACS is the Automated Highway System (AHS) in which coordinated groups of vehicles will be under automatic, centralized control. The benefits of these systems include enhanced safety and increases in throughput, as more vehicles are moved faster and more efficiently in a highly controlled environment. The most critical human factors issues in the ACS and AHS relate to methods of transferring control between the driver and the system and user acceptance. The system designs must make sure drivers do not lose situational awareness of the driving task, to avoid problems when control is transferred back to the driver and to assure that negative carryover effects do not jeopardize safety. With the high speeds and close headways projected in the AHS, user acceptance issues will be paramount.

COMMERCIAL VEHICLE OPERATIONS (CVO)

The term CVO includes a wide variety of commercial vehicles. It represents a unique application of ITS because of the characteristics of the subpopulation of drivers, vehicle design, commercial aspects, pertinent roadway features, and the nature of long-haul trucking operations. Due to the demand for efficient and economically competitive operations, CVO will be the vanguard for implementing many ITS systems.

MAJOR AREAS OF CONCERN

Regulatory Demands

Commercial vehicles are regulated by federal, state, and local governments, and enforcement of these regulations can cause delays and congestion on the road. A variety of ITS technologies are under development to automate many of these activities such as computerized record-keeping systems to file licenses and permits, report registration information, calculate fuel taxes, maintain log books, and collect tolls. The variety of regulations and reporting needs of CVO requires increased information processing by the operators. Human factors investigations addressing the combination of cognitive and physical workloads involved, as well as possible ITS-related solutions, are required.

Fleet Management

Fleet management is concerned with the timeliness and reliability of commercial carriers. ITS technologies in this area are likely to include automatic vehicle tracking and in-vehicle routing displays. Navigation and route guidance systems for CVO must accommodate specific routing regulations governing the weight, size, and cargo of the vehicle. In-vehicle displays for CVO will present more information than similar displays in personal vehicles. Furthermore, the physical environment of a truck cab including the windshield design, and the excessive noise and vibrations, present unique human factors challenges for the design of in-vehicle displays.

Safety

Many ITS technologies are designed to improve CVO safety, including ODAS, warning systems for load shifts, and impending vehicle rollover messages on freeway ramps. Driver impairment issues due to fatigue and other factors are critical in the CVO area. Human factors research will determine the optimal methods for providing safety information to CVO drivers. Furthermore, methods of detecting possible safety problems before they become emergencies, such as driver fatigue or excessive speed, will require significant human factors investments.

REFERENCE

Intelligent Vehicle Highway Society of America. (1992). *Strategic plan for intelligent vehicle-highway systems in the United States*. Washington, DC: Author.

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CHAPTER

1

DESCRIPTION AND APPLICATIONS OF ADVANCED TRAVELER INFORMATION SYSTEMS

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To alleviate traffic congestion and to more effectively use existing transportation resources, a major national and international effort is currently made to integrate knowledge on driver behavior and decision making into the design of Advanced Traveler Information systems (ATISs). In-vehicle ATISs are often viewed as one of the cornerstones of an Intelligent Transportation System (ITS), also known as an Intelligent Vehicle Highway System (IVHS), which involves the use of sensor, computer, communication (radio-optical), and control technologies for regulating the flow of vehicles along roads and highways. In this chapter, we provide an overview of several existing ITSs, including a broad overview of the technologies associated with the design of an ITS. These systems are described in more detail in subsequent chapters along with the human factors issues associated with their design and use.

Techniques to reduce urban congestion have typically focused on capital-intensive strategies such as the development of new roads or light rail to increase the system capacity. However, an alternative strategy, which is less capital-intensive, calls for designing an information system based specifically on the traffic information needs of private and commercial drivers. Along these lines, a number of major new efforts to alleviate traffic congestion have centered around the development of transportation information systems. For example, foreign development efforts in the areas of motorist navigation and information systems are already well underway in West Germany, Great Britain, France, and Japan; in West Germany, Great Britain, and Japan, these efforts are already to the point of public testing. In the United States, recent initiatives in this area have been spurred by an announcement from the Federal Highway Administration (FHWA) of a High Priority National Program Area in Advanced Motorist Information Systems for Improved Traffic Operations. The single largest effort in the United States at this time is a cooperative project between the FHWA, the California Department of Transportation, and General Motors known as Pathfinder. Pathfinder, as its name implies, focuses on the assessment of communications technology for route guidance and in-car navigation in response to incidents and traffic congestion.

An ATIS is only one of many possible approaches to reducing traffic congestion, and it is highly unlikely that any single solution will produce a quick fix given the tremendous increase in the amount of traffic on our major roadways and the complexity of the problems associated with the movement of people and material from one location to another. For example, it is well known that urban travel patterns are intrinsically related to developments in city structure, the locations of workplaces, the locations of drivers and their residences, and the characteristics and activities of drivers (Barfield, Haselkorn, Spyridakis, & Conquest, 1989). However, information-based solutions to transportation problems do present a number of attractive features: They are relatively inexpensive compared to other solutions (e.g., the building of new roads); they have low social and environmental impact; and in addition to their primary goal of improving the efficiency of roadway use, they can produce a number of secondary benefits by carrying public relations and educational messages. Furthermore, the importance of an ATIS is clear when one considers the specific benefits expected from its usage. For example, an ATIS is expected to reduce traffic congestion, improve navigational performance, decrease the likelihood of accidents, reduce fuel costs and air pollution, and improve driver efficiency. Another benefit associated with an ATIS is that this system will provide safety advisory and warning messages to the motorist. The safety aspects of an ATIS are expected to occur because an ATIS will provide additional, more timely, and more accessible information on traffic regulations, guidance, and hazardous situations. This information will be especially beneficial in decreased visibility situations because of poor weather or congestion (Mobility 2000, 1989).

In the context of designing an in-vehicle transportation system, several researchers have stated that for an ATIS to be effective, its design must be based on a comprehensive understanding of the traffic information needs of drivers (Barfield, Haselkorn, Spyridakis, & Conquest, 1989; Barfield, Spyridakis, Conquest, & Haselkorn, 1989). Specifically, an ATIS is expected to affect four aspects of driver behavior: departure time, means of transportation (buses, train, car pools, etc.), pretrip route choice, and on-road route modification. However, to positively affect driver behavior, we must first understand the decision-making processes of drivers and driving behavior (Barfield, Haselkorn, Spyridakis, & Conquest, 1991; Conquest, Spyridakis, Haselkorn, & Barfield, 1993; Ng, Barfield, & Mannering, 1995; Wenger, Spyridakis, Haselkorn, Barfield, & Conquest, 1990). This idea represents the human factors approach to the design of transportation systems. The application of human factors knowledge and guidelines has already proved beneficial in the design of airplane cockpits, automobiles, computer software, and input devices, and is expected to have a major impact on the design of the ATIS. The following sections discuss the ATIS in detail, including the benefits expected from the use of the ATIS, a description of the basic ATIS components, and a description of ATISs currently in use or being developed in the United States and worldwide.

EXPECTED ATIS BENEFITS

Congestion

It has been suggested that by the year 2020, highway traffic in many areas of the United States will be reduced to 11 miles per hours (mph). In fact, the average highway speeds on some southern California freeways are already down to 31 mph, while the average speeds during the morning and evening rush hours are lower yet. Congestion is a serious problem in urban and suburban areas and will continue to be so until major steps are made to alleviate it. An ATIS is designed to give drivers real-time traffic information in their cars, allowing them to avoid areas of high congestion, select alternative modes of travel that decrease the amount of traffic on congested roads, or delay departure times, thereby further decreasing the amount of traffic during times of peak congestion. Reduced levels of congestion will improve air quality, decrease personal stress, and likely improve worker health, attitude, and job performance (Mobility 2000, 1989, p. 8).

Environment

It has been argued that implementing the ATIS will have a positive effect on the environment. With better routing information given directly to drivers through in-vehicle displays, less time will be spent driving, thus curtailing car emissions and other pollutants and also reducing the need for fuels. As noted by Mobility 2000, an "IVHS will improve energy efficiently by reducing congestion and improving travel planning and routing. . . . IVHS has environmental benefits through fuel savings, reduced vehicle emissions, and reduced noise levels" (p. 4).

Mobility

Another objective for the ATIS is to increase the mobility of vehicles, which can be accomplished by reaching other objectives, including the reduction of congestion and improving routing efficiency via the implementation of a system such as the In-Vehicle Routing and Navigation System (IRANS), an In-Vehicle Signing Information System (ISIS), the In-Vehicle Safety and Warning System (IVSAWS), and the In-Vehicle Motorist Service Information System (IMSIS). As a result, urban areas will more efficiently manage their existing streets and freeways through improved traveler information and traffic control systems, and both rural and urban area travelers will benefit from improved security, comfort, and convenience. Measured, quantified improvements to mobility will include reduced congestion, accommodation of increased travel and higher trip speeds, less motorist confusion and aggravation, augmented and enhanced driver capabilities, lower cost in the transportation element of producing goods and services, and reduced driver fatigue and frustration (Mobility 2000, 1989, p. 4).

Productivity

Individuals who drive for business-related purposes, especially carriers, can use ITS technologies as key tools to reduce costs and improve productivity. New ITS technologies allow faster dispatching, fuel-efficient routing, and more timely pickups and deliveries.

Safety

Implementing various systems into the driving scenario requires consideration of safety issues as well. Mobility 2000 notes that "many believe that IVHS technologies, such as traveler information systems providing in-vehicle advisory and warning messages, plus future control assist systems, will usher in a new, substantially increased level of motoring safety. . . . Safety benefits will be substantial; they will include reduced fatalities, injuries, and property damage. Further, reducing accidents will keep lanes open and minimize the frustration that can contribute to further accidents" (p. 4). However, if human factors knowledge is not considered in the design of the ITS, these safety benefits may not occur; in fact, the resulting systems may be highly dangerous!

OVERVIEW OF THE ATIS

To accomplish the overall ATIS goal of safer and more efficient travel, several classes of systems have been identified within the ATIS umbrella: the IRANS, IMSIS, ISIS, and IVSAWS (Perez & Mast, 1992). Lee, Morgan, Wheeler, Hulse, and Dingus (1993) outlined the following proposed functional capabilities for each of these systems.

In-vehicle Routing and Navigation System (IRANS)

An IRANS provides drivers with information about how to get from one place to another, as well as information on traffic operations and recurrent and nonrecurrent urban traffic congestion. At this time, seven functional components have been identified: (a) trip planning, (b) multimode travel coordination and planning, (c) predrive route and destination selection, (d) dynamic route selection, (e) route guidance, (f) route navigation, and (g) automated toll collection.

Trip Planning. This component involves route planning for long or multiple-destination journeys. It may involve identifying scenic routes and historical sites, as well as coordinating hotel accommodations, restaurants, and vehicle service information.

Multimode Travel Coordination and Planning. This feature provides the driver with information for coordinating different modes of transportation (such as buses, trains, and subways) in conjunction with driving a vehicle. Such information might include real-time updates of actual bus arrival times and anticipated travel times.

Predrive Route and Destination Selection. This function allows the driver to select any destination or route while the vehicle is in PARK. These predrive selections include entering and selecting the destination, a departure time, and a route to the destination. System information might include real-time or historical congestion information, estimated travel time, and routes that optimize a variety of parameters.

Dynamic Route Selection. This component encompasses any route selection system while the vehicle is not in PARK and includes presenting updated traffic and incident information that might affect the driver's route selection. In addition, the system would alert the driver if he or she makes an incorrect turn and leaves the planned route. Dynamic route selection can generate a new route that accommodates the driver's new position.

Route Guidance. This capability includes turn-by-turn and directional information and can be in the form of a highlighted route on an electronic map, icons indicating turn directions on a headup display (HUD), or a voice commanding turns.

Route Navigation. This function provides information to help the driver arrive at a selected destination, but does not include route guidance. It supplies information typically found on paper maps, which might include an in-vehicle electronic map with streets, direction orientation, current location of vehicle, destination location, and location services or attractions.

Automated Toll Collection. This system would allow a vehicle to travel along a toll roadway without stopping to pay tolls, which would be deducted automatically from the driver's account as the vehicle is driven past toll collection areas.

In-vehicle Motorist Service Information System (IMSIS)

An IMSIS provides (a) broadcast information on services or attractions, (b) access to a directory of services and attractions, (c) coordination destinations, and (d) message transfer capability.

Broadcast Information on Services–Attractions. This information is similar to what might otherwise be found on roadside signs. It may be very similar to the directory of services and attractions information, but the driver does not need to look for this broadcast information; it is presented as the vehicle travels down the road.

Directory of Services–Attractions. This directory provides information about motels; hotels; automobile fuel and service stations; and emergency medical, entertainment, and recreational services.

Coordination with Destination. This function enables the driver to communicate and make arrangements with various destinations. This may include restaurant and hotel reservations.

Message Transfer. This capability enables drivers to communicate with others while driving. Currently, cellular telephones and CB radios provide this capability. In the future, the ATIS may improve upon this technology by automatically generating preset messages at the touch of a button and by receiving messages for future use. Message transfer might involve both text and voice messages.

In-vehicle Signing Information Systems (ISIS)

An ISIS provides noncommercial routing, warning, regulatory, and advisory information.

Roadway Sign Guidance Information. Guidance information includes street signs, interchange graphics, route markers, and mile posts.

Roadway Sign Notification Information. Notification information alerts drivers to potential hazards or changes in the roadway. This information includes merge signs, advisory speed limits, chevrons, and curve arrows.

Roadway Sign Regulatory Information. Regulatory information includes speed limits, stop signs, yield signs, and turn prohibitions.

In-Vehicle Safety and Warning System (IVSAWS)

An IVSAWS provides warnings on immediate hazards and road conditions affecting the roadway ahead of the driver. It provides sufficient advanced warning to permit the driver to take remedial action such as slowing down and offers the capability of both automatic and manual aid requests. This system does not encompass in-vehicle safety warning devices for imminent danger requiring immediate action such as lane-change/blind-spot warning devices or imminent collision warning devices.

Immediate Hazard Warning. An IVSAWS may provide proximate hazard information to the driver by indicating the relative location of a hazard, the type of hazard, and the status of emergency vehicles in the area. Specifically, this might include notifying the driver of an approaching emergency vehicle or warning the driver of an accident immediately ahead.

Road Condition Information. This function provides information on traction, congestion, construction, and so forth within some predefined proximity to the vehicle or the driver's route.

Automatic Aid Request. This feature provides a Mayday signal in circumstances requiring an emergency response where a manual aid request is not feasible and where immediate response is essential, such as in the case of severe accidents. The signal will provide location information and potential severity information to the emergency response personnel.

Manual Aid Request. This component encompasses those services needed in an emergency such as those of police, ambulance, wrecker, or fire department. It will allow the driver to request emergency service from a vehicle without needing to locate a phone, know the appropriate phone number, or even know the current location. This function might also include feedback to notify the driver of the status of the response, such as the expected arrival time of the service.

Thus far in the evolution of the ATIS, the vast majority of developed systems and empirical research has centered around IRANS applications. IMSIS functions are represented in a few instances, and the ISIS and IVSAWS are greatly underrepresented in early system development. A summary of the functions of recent ATIS projects provided by Rillings and Betsold (1991) illustrates the emphasis on the IRANS up to the present time. These projects include the Pathfinder, TravTek, AMTICS, RACS, AUTOGUIDE, ATLAS, CARMINAT, CARIN, HAR, ARI, and RDS, which are described in greater detail in later sections of this chapter.

A major reason for the development activity centered around IRANS applications apparently is the number of potential benefits and the perceived marketability of such systems. Navigating to an unknown destination is a difficult task that in most cases is performed inefficiently or unsuccessfully. Outram and Thompson (1977) as cited in Lunenfeld (1990) estimate that between 6% and 15% of all highway mileage is wasted due to inadequate navigation techniques. This results in a monetary loss of at least 45 billion dollars per year (King, 1986). An additional cost that potentially can be reduced by widespread use of navigation systems is traffic delay. Several systems under development are designed to interface with advanced traffic management centers that eventually will be based in metropolitan areas. Once such systems are in place, real-time information on traffic delays can be broadcast to in-vehicle systems. These systems then can continuously calculate the fastest route to a destination during travel. Such a capability, if widely used, has the potential for increasing efficiency for an entire traffic infrastructure.

Although most effort to date has been expended on IRANS development, the other ATIS subsystems, namely the IMSIS, ISIS, and IVSAWS, hold promise for improving driving efficiency and safety. A paper by Green, Serafin, Williams, and Palke (1991) rated the relative costs and benefits of ATIS features. Based on ratings by four IVHS human factors experts regarding the costs and benefits associated with accidents, traffic operations, and driver needs and wants, several IVSAWS features were found to be most desirable in future systems. Several in-car signing features were also highly ranked. In contrast, some IRANS features were ranked relatively low, primarily because of the potential safety cost of using such systems. (Green et al., 1991).

TECHNOLOGY ISSUES

The following sections describe some of the technology components associated with the design of an ATIS. This material is presented to give the reader a broad overview of the emerging technologies being used to design ATISs.

Communication Technology

Media currently used for data and voice communications include infrared systems, FM sideband, mobile satellite services, cellular systems, radio frequency (RF) data networks, inductive loop systems, and the Shared Trunked Radio System (STRS) (Kirson, 1991; Weld, 1989).

Infrared Systems

Infrared systems use roadside beacons to transmit and receive information, respectively, to and from equipped automobiles. Relative to other technologies these systems provide an excellent rate of data transfer and have a low cost. However, they must be in proximity to the car, and environmental conditions can disrupt the signal. Infrared beacons could be used to support Automatic Vehicle Identification (AVI) systems with either one-way or two-way communications. Beacons can also be used for navigation aids. The beacons can update an automobile's position on the map database as the car passes by and provide information about upcoming intersections (Weld, 1989).

FM Sideband

FM sideband technology takes advantage of sideband radio and TV frequencies and broadcast information. This format is inexpensive and requires no additions to the automobile. The United States has used a highway advisory system on the AM dial since the 1970s. Several European companies have developed more complex systems that broadcast a code at the start of the message so that it will be received only by the cars that will be affected by the information. Other advances allow the drivers to listen to noncritical information at their leisure and have critical information mute their radio or tape player (Davies, Hill, & Klein, 1989). These more advanced systems require a device to decode and present the information. Possible display formats include in-dash information displays and speech synthesis. Usability of this system is limited because it provides only one-way communication and because some areas of the country are not suitable for receiving FM transmissions.

One possible short-term use of sideband technology involves providing up-to-date traffic information to all drivers in a local area. For example, units could be sold with varying degrees of complexity. The low-end model would intercept all information and display it on a small monitor. More expensive models would use coded signals to present information that is relevant only to the driver in the area. These systems would be ideal for the traveler who does not need route guidance or trip planning, but needs to know current traffic and road conditions.

Mobile Satellite Services

Mobile satellite services are advantageous because they can transmit and receive information directly to and from an automobile regardless of geographic location. Relative costs for satellite systems are low, and transmission speeds are relatively high (about 2,400 bits/sec). A disadvantage of satellites is their large footprint requiring several cities to use the same channel, which limits the total usage.

Cellular Systems

Cellular technologies use land-based centers, each with several cells or transmission channels capable of transmitting information. A mobile unit uses the strongest cell to communicate and can be handed off to another cell when a stronger one comes into range. Newer digital cellular links being formed will improve the reliability and transfer rate of information. At the time of this writing, approximately 2% of Americans use cellular technology, and cells are already becoming overloaded. This problem, plus the fact that many areas are not cellular equipped, suggests that cellular technology as it exists today will not be beneficial to large-scale ATIS uses. For cellular communications to be a useful source for communications in the future, cells will have to accept more users at one time and will need a greater range.

Radio Frequency (RF) Data Networks

RF data networks may prove to be an expandable resource for ITS applications. The system operates in a manner similar to the cellular communication links but does so at a much lower cost. This cost is lessened both on the users' end and on the transmitter construction end. Each new location of coverage requires its own antenna. RF technology is a mature area and has proven to be successful. An application of radio transmission called Packet Access Radio (PAR) uses short spikes of data either sent through normal RF nodes or bounced off satellites or meteor scatter (Williams, 1989). Williams claimed that meteor bounce could be an excellent low-cost data communication medium. The biggest drawback of PAR is its speed of transmission. Some transfers can take several minutes.

Inductive Loop Systems

Inductive loop systems are mounted under the roadway surface and used mainly to detect and track vehicles. An alternate use would allow communications between the loop and the automobile. The major drawbacks of this system include a low data rate and a range limited to the length of the loop. Also, cost of installation is high because each loop must be buried under the road surface. ATIS use of this technology includes AVI. For example, commercial drivers entering an area may need to follow a specific path to avoid dangerous areas. Loop systems could be used to guide the vehicles in the right direction and inform a control center when a vehicle has entered a dangerous area.

Shared Trunked Radio System

The Shared Trunked Radio System (STRS) operates in the same way as cellular radio but uses a 300 MHz band. Mobile units either lock onto a control channel or scan available channels for transmission. The major difference between a cellular unit and STRS is that a cellular unit needs enough dedicated cells to cover all users, whereas STRS users share cells that are not being used. STRS covers only about 30% of the land area of the United States, and adding more transmission units would be very expensive.

DISPLAY TECHNOLOGY

As automotive-compatible technologies to display information increase, the need to present more information quickly and saliently has become more important. For the ITS, the major categories of current, near-term, and future displays are, respectively, vacuum fluorescent displays (VFDs), cathode ray tubes (CRTs), liquid crystal displays (LCDs), and head-up displays (HUDs).

Vacuum Fluorescent Displays (VFDs)

VFDs are currently the most common type of displays found in automobiles. They are used in clocks, digital speedometers, message centers, audio systems, and temperature control systems. VFDs are produced by exciting a phosphor-coated anode. The current colors available are blue, green, yellowish-green, greenish-yellow, yellowish-orange, orange, and reddish-yellow. With filters, the color combinations increase. VFDs provide high luminance at low-voltage cost, are highly readable, and have a life span of more than 10,000 hours. Recent advances in VFD technology have increased the size of the display area, created a greater range of colors, and reduced the voltage use to half-duty cycle. Future advances will give full-color displays larger than the current maximum of five-by-seven inches, utilize graphics, increase luminance to 24,000 ml for HUD technology, and run at a much lower power consumption rate. (See Akiba et al., 1991; Iwasa, Kikuchi, Yamaguchi, Minato, & Ohtsuka, 1991, for more detailed information on VFDs.)

Cathode Ray Tube Displays (CRTs)

CRTs are now being used in some automotive applications, but are more commonly seen in computer displays and TV screens. CRTs have high resolution, can present many colors, and because of their maturity are currently the least expensive of the major display technologies. The major disadvantages of CRTs for automotive uses are their large size, weight, and power consumption. Another disadvantage is that as the screen size gets larger, the image gets dimmer, a critical factor in the glare-ridden vehicle environment.

Liquid Crystal Displays (LCDs)

LCDs are the type of display currently receiving the most attention by far from researchers in display development. According to Nordwall (1989), "LCDs generally offer savings of about 60% in volume, 70% in weight, and 80% in power compared with cathode ray tubes" (p. 56). LCDs can also display color using built-in filters. However, LCDs are nonemissive with a narrow viewing angle, and some types have difficulty operating under high and low temperatures (Erskine, Troxell, & Harrington, 1988).

There are several different types of LCD displays available. The type currently used in automobiles is the twisted nematic (TN) configuration. In its simplest form, an LCD works by applying voltage to a "sandwich" cell consisting of a polarizer, a glass substrate, a transparent conductor, and an alignment layer on either side of the twisted nematic liquid crystals. When voltage is applied to the cell, the conductors cause the alignment layers to "untwist" the liquid crystals. When this happens, the polarizers line up and let light through. A good general description of LCD technology is presented in Firester (1988). A more recent type of LCD called a double-layered super-twisted nematic liquid crystal display (DL-STN LCD) also has been developed. Its major benefits are a wider range of temperature operation, lower voltage usage, and increased contrast ratio (Matsumoto, Nakagawa, & Muraji, 1991).

Although the technology exists to create large flat-panel displays, they are expensive. Nearly half of this cost is in the fabrication process. Much of the current research is focused on creating cheaper and larger panels to house displays (for an example, see Takeda et al., 1989). A large flat-panel LCD would allow one large panel to replace the several smaller gauges and dials in most current automobiles. These displays could be made to fit the sizes of each manufacturer's models and could be programmed to have different appearances. The displays could also be user-definable so that they include only the information that the users want to see.

Because LCDs are nonemissive, they need an external source to light them. The two most common types of backlighting lamps for LCDs are the cold-cathode fluorescent lamp (CFL) and the hot-cathode fluorescent lamp (HFL). The HFL provides a higher luminance than the CFL, but does so at the cost of a higher operating temperature and a shorter life (approximately 3,000 hours). A newly developed type is the warm-cathode fluorescent lamp (WFL). The WFL offers twice the intensity of the CFL and 10,000 hours of operation, equal to that of the CFL. The WFL also operates at a lower voltage level and can be constructed with a thin film heater to help the liquid crystals operate better at temperatures below 20°C (Itoh, Yoshida, Terada, Horil, & Kuniyasu, 1991).

Head-Up Displays (HUDs)

A HUD can use one of several projection sources to project an image such as a speedometer display or warning indicator onto the windshield. This information appears to be floating in space in front of the vehicle. A HUD has the advantage of allowing the drivers to keep their eyes forward and observe information without having to accommodate them to the dashboard. HUDs have been successfully used in aircraft by giving the pilot a "window" through which to fly. An automotive HUD is different from an avionics HUD in that the scenery behind the display is often more complex for the driver than for the pilot. A second difference is that automotive HUDs are displayed, not at optical infinity as in an aircraft, but at a closer distance, somewhere between 6 and 24 feet (Stokes, Wickens, & Kyte, 1991).

HUDs are commonly produced either by reflecting an LCD off the windshield with a half mirror or direct reflection, or by using a light source to illuminate a holographic element on the windshield. Proponents of both systems claim success with each, and much research is currently being conducted to create the best optical picture at the lowest cost. (For detailed information, see Patterson, Farrer, & Sargent, 1988; Wood & Thomas, 1988.) A high-luminance VFD has also been proposed as an alternate HUD projector because it needs no backlighting and is resistant to shock and temperature conditions.

NAVIGATION TECHNOLOGY

According to French (1988), there are three basic types of navigation systems that include autonomous navigation systems, radio navigation systems, and proximity beacon systems. Autonomous navigation systems are capable of operating without the need for external sources such as satellites or road beacons. To track the distance and angles traveled most autonomous systems use dead reckoning, which employs wheel rotations and directions turned to estimate the current position of the car. The Japanese Multi-AV system uses a new optical fiber gyroscope to more accurately sense vehicle turns (Harrell, 1991; Oshishi & Suzuki, 1992). Dead reckoning systems have historically been relatively reliable, but periodically get out of calibration. The result is that the driver is given incorrect information about location or route status. Therefore, provisions for out-of-position information and simple location adjustment are necessary. These features necessarily utilize route-map displays. (See Fig. 1.1B for an example of a route-map display.)

Radio navigation systems use satellites to keep track of an automobile's position. Each vehicle to be tracked has a unique code that can be "seen" by the satellite and reported to a base station. The most commonly used satellite system is the Global Positioning Satellite (GPS) system, but there are many companies around the world competing for the market. Most systems that use radio navigation also use dead reckoning to account for areas where signals may be blocked. Currently the GPS system of satellites is incomplete over the United States. In addition, satellite signals are often blocked by tall structures in major cities. Therefore, it appears likely that many IVHSs will always require backup navigation systems if a GPS is used.

Proximity beacon systems use short-range transmitters to send signals to passing cars with receivers. These beacons are also usually combined with dead reckoning and satellite signals. The beacons allow a correction factor to update the position indicated by the other methods. A drawback to beacon technology is its cost of construction and maintenance.

Navigation Interfaces

The most common method of presenting information to drivers with navigation systems is through video monitors that display a map of the area and the automobile's current position (see previous sections). Some systems also use voice synthesis to convey messages to the driver. Much research must yet be conducted to determine which properties of voice are most salient in the driving situation. The Back Seat Driver, an MIT-developed navigation system, uses only speech to guide drivers around the Boston area. (See Davis & Schmandt, 1989, for a detailed discussion of some potential problems with speech-based directions.)

Synthesized speech is not as intelligible as digitized speech (Marics & Williges, 1988). Intelligibility is particularly important in vehicle environments because vehicle interiors are often noisy. It may be some time before intelligibility is of sufficient quality, particularly in low-cost speech synthesis systems required for in-vehicle use. However, despite its lower intelligibility, synthesized speech is desirable for many IVHS applications because large databases are sometimes required for communication of certain information (e.g., next street name in a large city; Dingus & Hulse, 1993).

DESCRIPTION OF U.S.-BASED ATIS PROJECTS/SYSTEMS

Most available reports of U.S.-based ATIS systems and projects are of a descriptive nature. Field or laboratory evaluations are lacking with the exception of the TravTek system and Pathfinder. Pathfinder had a limited scope (25 cars) and was the first domestic IVHS project. It was primarily undertaken to demonstrate the feasibility of IVHS and promote further study. The TravTek operational testing phase was completed in March of 1993. A description of each planned or completed U.S. ATIS project is presented below.

TravTek

Travel Technology (TravTek) a demonstration system developed by General Motors and involving the City of Orlando, the Florida Department of Transportation (DOT), the Federal Highway Administration (FHWA), and the American Automobile Association (AAA), is nearing completion. The TravTek system was a complete IVHS infrastructure, including a traffic management center (TMC), traffic monitoring and sensing, and route-guidance information. The goal of TravTek was to reduce congestion and provide information on geographic attractions and services. The TravTek interface linked the drivers of 100 test vehicles to real-time information via digital data broadcasts. Avis rental car customers and solicited subjects participated in the testing.

The majority of ATIS reports discuss the TravTek system. To those who understand the constructs involved in TravTek, the constellation of in-vehicle navigation systems is roughly represented. Using the latest technology, the driver is aided in various tasks of navigation, route selection, route guidance, local information, and system interface. Human factors design considerations have been utilized since the inception of the system. The driver accesses information in three vehicle modes: predrive (PARK), drive (vehicle in motion), and zero speed. Both visual and auditory sensory channels are used to inform the driver of navigation, route selection, route guidance, local information, and system interface information. Extensive research into the needs and functions of both driver interface modalities was accomplished prior to the start of data collection. In addition, two visual display formats were available to the driver: a turn-by-turn graphic guidance screen (see Fig. 1.1A) and a color route map (see Fig. 1.1B; Fleischman et al., 1991). Several reports and publications are available describing the system. For system architecture, see the report by Rillings and Lewis (1991). Information on task analysis can be found in an article by Krage (1991). Human factors design aspects are described by Carpenter et al. (1991) and by Fleischman et al. (1991). Finally, the design of the auditory interface is described in Means et al. (1992).

Results reported by Fleischman, Thelen, and Dennard (1993) found that drivers familiar with the area (local drivers) using TravTek used the route guidance feature for approximately half of their trips. The same was true for drivers unfamiliar with the area (rental car drivers). Rental drivers used

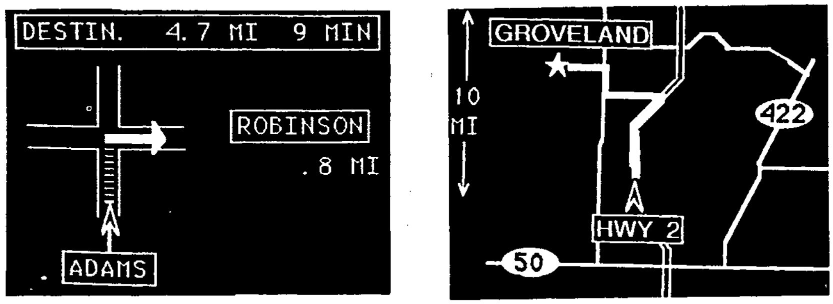

FIG. 1.1. (a) TravTec turn-by-turn guidance map display example; (b) route map display example.

the yellow pages feature most often in entering a destination, whereas local drivers more often used exact street addresses. Both groups chose "fastest" for the type of route they preferred to use in getting to the destination, as opposed to the alternative choices of "no interstates" or "no toll roads." The results also showed that all drivers used the "turn-by-turn" map type most often when driving in comparison to the route map. Furthermore, drivers used an optional supplementary voice guidance feature the majority of the time when driving to a destination.

Pathfinder

As the first in-vehicle navigation system project in the United States, Pathfinder involved CalTrans, General Motors, and the FHWA. This project focused on a 13-mile stretch of the Santa Monica Freeway, where 25 vehicles were equipped with Etak modified displays. Information on accidents, congestion, highway construction, and route diversion was presented to the driver either on the map display or through digital voice. The final phase of evaluation took place in the spring of 1992.

Pathfinder is one of the few projects with a publication describing human factors aspects of system design. Mammano and Sumner (1989) made the following general design observations: (a) By digitizing common words and synthesizing less common ones, voice messaging intelligibility was improved and space was saved in the computer memory; (b) data was filtered to avoid overload of messages during peak traffic times.

ADVANCE

The largest operational test of IVHS will be based in Chicago and its northwest suburbs. The Advanced Driver and Vehicle Advisory Navigation ConcEpt (ADVANCE) brings together the efforts of major IVHS manufacturers:

Ford, Toyota, Nissan, Saab, Volvo, Peugeot, Etak, Navigation Technologies, DonTech, Motorola, and Sun Microsystems. Institutional bodies of Illinois are also involved, including the Illinois Universities Transportation Research Consortium, the City of Chicago, and the Illinois DOT. This project is still in the data collection stage, but it is nearing completion. The ADVANCE operational test is very similar to TravTek, yet also focuses on both arterial roadways and highways.

Travelpilot

A joint project of Bosch and Etak, Travelpilot is a second-generation navigation system. This device forms the core of the Pathfinder system. It is also used in over 400 emergency vehicles in Los Angeles. The system consists of wheel sensors, compass, microcomputer with CD-ROM map data base, and a 4.5-in. vector-drawn monochrome display. It uses dead reckoning to update the navigation display. In addition, Travelpilot can be linked to communication systems for real-time data display.

DriverGuide

Pretrip out-of-vehicle route guidance is conducted using this system. Users enter origin-destination pairs and receive a printed set of instructions. The system was tested on French air travelers visiting San Francisco.

Oldsmobile Guidestar/Zexel Navigation System

The Oldsmobile Guidestar/Zexel System is a navigation system available on selected 1995 Oldsmobile models and via several rental car agencies in Florida and California. The system utilizes scroll lists for destination entry and has a choice of visual displays including a route map and a turn-by-turn display presented via a color LCD measuring approximately 4 inches diagonally. A voice guidance feature is also available. The system control and display unit is depicted in Fig. 1.2.

Delco Electronics Telepath 100

The Telepath 100 provides a simple form of navigation guidance by displaying dynamic heading and distance information to a selected destination (Wu & Welk, 1994). As shown in Fig. 1.3, this system utilizes a low-cost LCD-based display to show approximate direction to the destination and alphanumeric instructions via a seven-segment display. As a driver approaches a turn, the heading indicator points in the direction of the turn. When the vehicle approaches the destination, a text message alerts the driver that the destination is near.

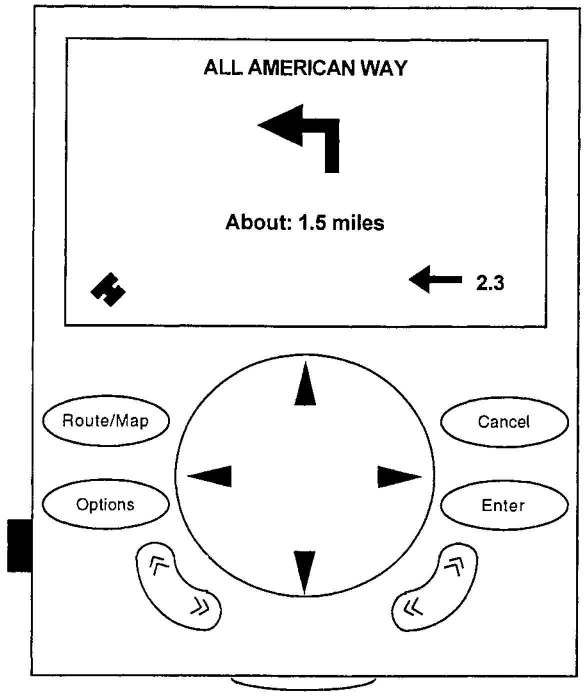

FIG. 1.2. Depiction of the Oldsmobile Guidestar control and display unit.

FAST-TRAC

The Ali-Scout system developed as a joint project of the Federal Republic of Germany, Siemens, Volkswagen, Blaupunkt, and others is used as part of the FAST-TRAC project in Oakland County, Michigan. The display is a simple LCD readout that shows driving instructions with arrows at appropriate intersections. Infrared communication occurs at beacons located at key intersections to update the vehicle information systems. FAST-TRAC is a relatively low-cost system on a per vehicle basis, but it requires intersections equipped with transmitting beacons.

ROGUE

Navigation Technologies Corporation has developed the ROute GUidance Expert system (ROGUE) for daily in-vehicle navigation. The ROGUE software draws on the NavTech digital streetmap databases. Embedded in the CD-ROM database is information that simulates human intuition about routing, such as time of day (e.g., rush hour). The system can run on a stand-alone

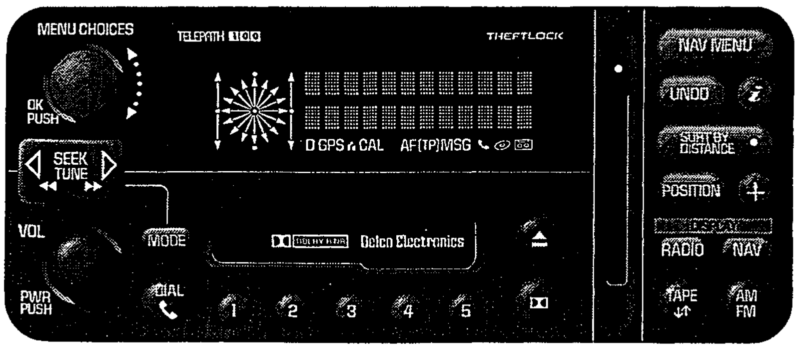

FIG. 1.3. Delco Electronic's Telepath 100.

basis or with an infrastructure updating its information. The stand-alone option is used as a selling point because global position satellites (GPS) and communication infrastructures can be cost prohibitive. Points of interest are also coded into the database. ROGUE uses an in-dash CRT display.

The expert system for the ROGUE in-vehicle route guidance is described in a report by Silverman (1988). Six design concepts were used in developing ROGUE: (1) provide route planning expertise; (2) provide effective and efficient directions; (3) provide navigation guidance during travel; (4) detect driving errors; (5) operate without external equipment; and (6) maximize driver comfort and safety.

The driver interface is also described in the Silverman report. A VDT mounted in the instrument cluster delivers requested navigation information. The display is monochrome, but provides line graphics as well as text capability. Also, a speech synthesis unit aurally provides directions. The system can be toggled to give spoken directions or a chime when directions are updated on the screen, alerting the driver to glance at them. Driver input is provided via an alphanumeric keyboard.

CARIN

Philips Corporation's CAR Information and Navigation system is an early implementation of the CD-interactive format for storing digital maps (Thoone, Dreissen, Hermus, & van der Valk, 1987). Vehicle location is accomplished by dead reckoning and map matching. Included in the system design is a radio datalink for traffic information. The driver is guided with synthesized speech in conjunction with a pictogram display (similar to that of the ALI-Scout).

The system requires a keyboard for driver input, whereas a supplemental color touchscreen is optional. A flat-panel display is used in the basic configuration, which shows stylized map graphics to supplement the audio. Maps are presented "heading up."

SmartRoutes

Liebesny (1992) discussed the SmartRoutes system that will service the Boston metropolitan area. This system will use real-time data from a traffic information center. Drivers will be able to access this information through the use of land line or cellular phone, e-mail, cable television, direct fax, or computer modem. Various automated mechanisms such as interactive audiotext and video graphics have been developed to disseminate the information. Liebesny (1992) recommended that the information be kept current and the system design updated continuously with a maximum acceptable aging period of 15 minutes. He also suggested developing a coordinated public-private partnership to handle the full aspects of incident management.

TRIPS

The Transportation Resources Information Processing System (TRIPS) includes dispatching of single-trip car pooling or parataxi systems, enabling drivers and riders to use Touch-Tone telephones, personal computers, and videotext terminals to obtain information on local traffic information and alternative route information (Ratcliff & Behnke, 1991).

TRAFFIC REPORTER

Traffic Reporter (TR) is a PC- and graphic-based ATIS developed by researchers from the University of Washington. The system seeks to improve traffic flow by influencing commuter behavior and decisions concerning alternative routes, departure times, and transportation modes. The system provides up-to-the minute information about freeway speeds and congestion by using information generated from on-freeway sensors. The system is PC-based and designed to be installed and used in locations such as malls, home, work, and lobbies of office buildings.

OVERVIEW OF ATIS SYSTEMS-PROJECTS OUTSIDE THE UNITED STATES

Other countries seem to be ahead of the United States in IVHS technology development. This advantage stems partly from pure need because the traffic congestion in areas such as Europe and Japan is considerably worse than it is in this country. We would do well, however, to begin implementing a structured system of traffic management before our problems grow to the levels observed in other parts of the world. The systems in other countries were all formed as joint operations between government, industry, and research institutions. Without such collaborative effort, projects of this magnitude will have little chance of success.

Generally, the goal of organizing groups within other countries has been to establish an entire system, complete to the last detail and designed to be country- or citywide, not just to limit a system to individual units within cars. This form of organization has not been adopted in the United States, at least not on a scale equivalent to that of the European and Japanese systems. In addition to traffic flow and route navigation information, developments from other countries include driving aids such as collision avoidance and driving condition monitors.

EUROPEAN ATIS PROJECT-SYSTEMS

Europe has several large-scale programs in progress under the umbrella of Road Transport Informantics (RTI), which is the equivalent of the U.S. ITS thrust. The main programs are DRIVE and PROMETHEUS. These two programs are separated by the organizations that formed them, but their goals are largely the same. DRIVE is under the control of the Commission of European Communities (CEC), whereas PROMETHEUS is part of the EUREKA platform, an industrial research initiative involving 19 countries and European vehicle manufacturers. Although the projects are in fact separate, close cooperation exists between the two in order to reach a common goal. Actual system development is the primary goal of the PROMETHEUS project, whereas DRIVE tends to focus on issues of human behavior and implementation of systems into the entire European community. Material describing these programs in more detail can be found in McQueen and Catling (1991), Hellaker (1990), Kemeny (1990), and Transport Canada (1992).

DRIVE

The intention of Dedicated Road Infrastructure for Vehicle Safety in Europe (DRIVE) is to move Europe toward an Integrated Road Transport Environment (IRTE) by improving traffic efficiency and safety and by reducing the adverse environmental effects of the motor vehicle. DRIVE focuses on the infrastructure requirements, traffic operations, and technologies of interest to public agencies responsible for the European road transport systems. Another focus of the DRIVE project is the human user and related issues that will necessarily be addressed in the implementation of in-vehicle systems.

The first phase of the project, DRIVE I, started in 1989. Its goal was to establish the overall working plan from which a European IRT environment could be developed. In the beginning, the DRIVE program was seen only as a feasibility study. However, as DRIVE progressed, it became apparent that it offered a realistic opportunity for system development. This resulted in DRIVE II, which emphasized the implementation of pilot projects developed as a result of DRIVE I. DRIVE II was scheduled to end in 1995, and products were released into the marketplace at that time. The DRIVE II workplan identified seven pilot project areas: (1) demand management, (2) traffic and travel information, (3) integrated urban traffic management, (4) integrated interurban traffic management, (5) driver assistance and cooperative driving, (6) truck fleet management, and (7) public transit management.

Groeger (1991) discussed the task of learning to drive and proposed a intelligent vehicle system that could continue to teach drivers as their skills mature or deteriorate. The Personalized Support And Learning Module (PSALM) is a concept derived as part of the DRIVE project. It will use the sensors likely to be in place in many IVHS-equipped automobiles to monitor driver performance. Individualized and task-specific instruction will be possible with PSALM. (For detailed individual project descriptions of DRIVE, see Keen & Murphy, 1992.)

PROMETHEUS

The PROgraM for European Traffic with Highest Efficiency and Unprecedented Safety (PROMETHEUS) project was initiated in 1986 as part of the EUREKA program, a pan-European initiative aimed at improving the competitive strength of Europe by stimulating development in such areas as information technology, telecommunications, robotics, and transport technology. The project is slated to last 7 years. PROMETHEUS is a precompetitive research project whose output will be a common technological platform to be used in turn by the participating companies once the product development phase begins. The overall aims of PROMETHEUS fall into four categories:

1. *Improved driver information:* To provide the driver with information from new sources of technology that were not previously available. Currently the lack of information or the inability to assess a hazard is often the primary cause of accidents.
2. *Active driver support:* To aid the driver in an informative way or by active intervention when the driver fails in some way at the driving task.
3. *Cooperative driving:* To establish a network of communication between vehicles in order to provide drivers with relevant information for areas en route to their destination.
4. *Traffic and fleet management:* To establish systems for the efficient use of the road network, ranging from highway flow control to fleet operations.

The emphasis of PROMETHEUS is on systems with a large in-vehicle component in their design. The ultimate aim is for every vehicle to have an on-board computer to monitor vehicle operation, provide the driver with information, and assist with the actual driving task. A centralized communications network will also be a component of the system to provide two-way communications between each vehicle and a control center.

The research phase, covering the past 4 years, has largely been completed. The current thrust is a move into the definition phase, in which the emphasis has shifted to field tests and demonstrations. To evaluate systems in each of the following areas, 10 common European demonstrations have been identified: vision enhancement, emergency systems, proper vehicle operation, commercial fleet management, collision avoidance, test sites for traffic management, cooperative driving, dual mode route guidance, autonomous intelligent systems, travel information systems, and cruise control.

These demonstrations were largely competed in 1994. The second phase will be somewhat modified to reflect the near-market status of some products under development, thus moving away from the program's noncompetitive origins.

To bring products to market more quickly in Europe, European Road Transport Telematics Implementation Coordination Organization (ERTICO) was created in November 1991. Its objectives are to pool the information from the many individual projects and identify strategies for exploiting the results of DRIVE, PROMETHEUS, and other individual programs. The goal is for ERTICO to create a climate for market-driven investments to ensure European dominance in advanced vehicle technologies.

Descriptions of Individual RTI/IVHS Systems

Many individual RTI/IVHS systems are now being tested throughout Europe. A short description of some individual systems is presented to enhance the reader's understanding of the development currently taking place in Europe. Descriptions largely describe the driver interface rather than the actual system hardware and communication network information.

Autoguide and the Ali-Scout are dynamic in-vehicle route guidance systems. That is, the system gives routing recommendations to drivers who are dependent on real-time traffic conditions. The display unit is mounted on the dashboard of the car and controlled with a hand-held remote control similar to a television remote. At the start of a journey, the driver can enter a grid reference or a preprogrammed destination. The system uses dead reckoning and roadside infrared transmitter-receiver beacons to guide the driver to the selected destination. The beacons serve the system by correcting cumulative errors and updating traffic information. The navigation information is presented to the driver through the use of icons and arrows to indicate directions. There is also a digitized speech unit that supplements the visual directions. The Autoguide system has undergone extensive testing in London, whereas Ali-Scout systems are being tested in Berlin. (For more information, refer to one of the following articles: Catling & Belcher, 1989; Jeffery, Russam, & Robertson, 1987; Jurgen, 1991; Morans, Kamal, & Okamoto, 1991; von Tomkewitsch, 1989.)

Trafficmaster from the United Kingdom was the first commercially available in-vehicle system to provide dynamic traffic information to the driver. It is a map-based system that provides only information on traffic flow; it does not actively suggest routes. The display screen is a 101 × 82 mm LCD. "Hard" push buttons for control of guidance functions are mounted next to the display (Jurgen, 1991).

TRAVELPILOT is a German autonomous navigation system based on the American ETAK Navigator sold by Blaupunkt Bosch Telecom. This system displays vehicle location on a dashboard-mounted CRT map stored on CD-ROM. The maps move relative to the vehicle's position, which is determined through the use of dead reckoning and map matching. The display is a small CRT that can show maps with highlighted routes or driving instructions with intersection maps and street names. Hard buttons mounted on either side of the CRT are changeable function controls. The system has reportedly sold over 1,000 units in its first year on the market and will be available soon in the United States for certain areas. (For more information, refer to Suchowerskyj, 1990; Morans et al., 1991.)

JAPANESE PROJECTS AND SYSTEMS

Japan is far ahead of any other country in implementing a large-scale traffic control system that utilizes in-vehicle technology. The reason for this accelerated pace is largely because the Japanese have the greatest need for such a system. Over vast portions of metropolitan areas in Japan, the average traffic speed is below 10 mph during much of the day. The small geographic area and large population has led the government to install traffic control systems in all large cities and on most urban and interurban freeways in Japan. These systems employ the latest technology, such as fiber optics communications and LED changeable message signs displaying both text and graphics in color. Japan has also made substantial investments in the development of driver information systems. Over 50 corporations have collaborated to develop in-vehicle systems marketed as units to be purchased by individuals who use the governmental road network system. The main IVHS initiatives currently are RACS, AMTICS, and VICS. Within RACS, the Ministry of Construction (MC) promoted and funded the Digital Road Map Association. This group was given the task of preparing and maintaining a national digitized roadmap database. The results of this work are available on compact disc in a standard format. This format is used by both RACS and AMTICS, as well as by the various manufacturers of autonomous vehicle navigation systems (Ervin, 1991).

RACS

The Road/Automobile Communication System (RACS) is sponsored by MC, the Highway Industry Development Organization (HIDO), and 25 private companies. The system consists of vehicles equipped with dead reckoning navigation systems, roadside communication units (beacons) that are distributed about 2 km apart throughout the road network, and a control center. There are three types of roadside beacons: Type 1 transmits location to the vehicle to zero-out cumulative navigation errors; type 2 transmits congestion and other traffic information in addition to location; and type 3 provides two-way communications with the vehicle so that information about the vehicle, such as vehicle locations and automatic debiting of tolls as well as emergency calls, can be transmitted to the control center. The MC recently announced a major beacon installation program consisting mostly of type 1. At present there are about 1,000 beacons around Tokyo. Beacon installation was scheduled to proceed throughout Japan at a rate of about 10,000 per year until 1994, with a gradual increase in the number of types 2 and 3 beacons. Travel-time savings of 3% to 5% are expected, representing a significant reduction in fuel consumption and air pollution.

AMTICS

The Advanced Mobile Traffic Information and Communications System (AMTICS) is sponsored by the National Police Agency (NPA), the Ministry of Posts and Telecommunications (MPT), the Japan Traffic Management and Technology Association (JSK), and 59 private companies. It employs in-vehicle equipment very similar to that of RACS, with the exception of the communication interface. The AMTICS datalink is essentially a one-way means of broadcasting traffic data from a cellular system of terminals. It is intended to convey a wide variety of information, including congestion information, travel-time predictions, traffic regulations, railway timetables, and advice on special events. This information is available from static terminals at railway stations, hotel lobbies, and other public locations, as well as in the vehicle. A large-scale test of AMTICS was held in Osaka in 1990. The results suggest that an individual travel-time reduction of about 7% could be achieved with in-vehicle navigation systems that provide congestion information to the driver. This would amount to individual travel-time savings of about $300 million in the Osaka area if all cars were equipped, with similar savings to the community because of reduced congestion. (For more information on the AMTICS system, see Okamoto, 1988; Okamoto & Nakahara, 1988; Okamoto & Hase, 1990.)

VICS

The Vehicle Information and Control System (VICS) is a new program formed under the combined direction of the MPT, MC, and NPA, with the goals of attempting to resolve the competition between RACS and AMTICS and to define a common system that would use the best features of both. This venture is meeting with some opposition, however, by those who feel that the competition between the two systems was improving them both. A digital microcellular radio system has been proposed to provide two-way road–vehicle communications and location information, essentially combining the tools used by each respective system. Although VICS may have a long-term future as part of an integrated driver information system for Japan, it will take some years to implement it. In the meantime, a common RACS–AMTICS system using RACS type 1 beacons and the broadcast of information to drivers via their FM car radios (such as RDS-TMC) is the likely direction for further development.

A Nissan System

A digital map-based system is sold with the Nissan Cedric, Gloria, and Cima models in Japan. It is very similar in design to the ROGUE and Travelpilot systems discussed in the previous section. Three scales of map display are available: 1:25,000 (street grid by blocks), 1:100,000 (default arterial roads), and 1:4000,000 (macro). The heading of the map can be toggled to either "north up" or "direction of travel" at the top. Vehicle location is always positioned in the center of the scrolling map display. For safety, minor roads are not displayed while the vehicle is in motion, thus reducing eye-glance time. Also, while the car is being driven, the system inhibits all switch operation, except for "changing of scale" and "display rotation mode." It is not clear what the "display rotation mode" feature entails from the research described (Tanaka, Hirano, Nobuta, Itoh, & Tsunoda, 1990).

SUMMARY AND CONCLUSIONS

To summarize, this chapter describes the potential benefits that could arise from using an ATIS. These include a reduction in traffic congestion, improved navigational performance, a decrease in the likelihood of an accident, reduced fuel costs and air pollution, and improved driver efficiency. In addition to the description of system benefits, the chapter lays a foundation for further discussion of human factors ATIS issues by providing a description of current ATIS technology, systems in production or under development, and projects underway or completed. As discussed in several subsequent chapters, for ATIS benefits to be realized, designers of traffic information systems must implement human factors knowledge and design principles into the design of these systems.

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