

**A PILOT STUDY OF THE MARKETABILITY
OF IN-VEHICLE SYSTEMS**

by

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EXECUTIVE SUMMARY

In an attempt to more efficiently manage existing transportation facilities, traffic and transportation engineers are directing their efforts towards providing accurate and timely information to drivers. A wide variety of driver information and communication technologies exist. This report, however, examines only Advanced Driver Information Systems (ADIS), which focus on providing drivers with information via on-board equipment. Several emerging technologies are instrumental in achieving this goal. These include in-vehicle video display systems, head-up displays, and voice systems.

In-vehicle route guidance and navigation systems use these emerging technologies to convey various types of information to drivers and to perform a combination of either route planning, route guidance or navigation functions. In-vehicle systems typically use one of two visual display formats. One format, used extensively in Japan and on the early U.S. systems, displays a roadmap of the area around the vehicle. The other format displays a series of route guidance instructions to drivers to direct them along a preferred route.

Autonomous, or totally self-contained navigation systems were first introduced in the mid-1980s. Now many systems ranging from the most simple to the very complex have been developed and tested, however, only four have been available commercially. This report provides some insight on several in-vehicle systems, the technology behind the systems, and some applications of in-vehicle technology to the real world.

The marketability of in-vehicle route guidance and navigation systems is a subject which has not been fully addressed. Currently, the cost of the components of a typical route guidance/navigation system total more than what the average motorist is willing to pay. Furthermore, before a greater market demand develops for route guidance and navigation systems, several issues must be fully addressed. These issues include safety, human factors, and traffic management issues. This report examines the overall marketability of in-vehicle systems, namely route guidance and navigation systems. Most information was obtained from discussions with professionals and from an independent survey of drivers in several urban areas. Several recommendations are made regarding the use of route guidance and navigation systems based on the results of the study.

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INTRODUCTION

In the recent history of transportation engineering, the focus has shifted from building more capacity to more efficiently managing existing transportation facilities. Several traffic and transportation management methods have been introduced in the past. Two examples of traffic management methods are demand management and traveler information systems. The latter attempts to provide timely and accurate information to motorists (1). By providing the proper information to motorists, traveler information systems can be used to better manage the transportation infrastructure.

A wide variety of information and communication technologies exist. Among these are standard signs, changeable message signs (CMS), Highway Advisory Radio (HAR), Highway Advisory Telephone (HAT), cellular phones, pre-trip information, commercial radio traffic reports, in-vehicle systems, and many more. This report focuses on advanced driver information systems. Advanced Driver Information Systems (ADIS) use advanced and emerging technologies to provide drivers with visual or auditory information, or a combination of both. Specifically, this report addresses route guidance and navigation systems.

Background

Advanced Traveler Information Systems (ATIS) focus on providing accurate and timely information to motorists. ATIS is one of the five elements of Intelligent Vehicle Highway Systems (IVHS). Most ATIS provide information to all drivers on the roadway. However, some systems provide information to drivers in their vehicles utilizing on-board equipment. These systems are classified as Advanced Driver Information Systems (ADIS). ADIS is a component of ATIS.

Autonomous navigation systems were introduced on the market in the mid 1980s (2). Autonomous systems operate independently of the external infrastructure. "External" refers to the vehicle. Thus, autonomous systems rely only on the vehicle's own resources. Navigation in an autonomous system is accomplished using stored maps, distance and direction sensors and driver input. The result is a system which can display the location and heading of the vehicle in relation to the traffic network.

Currently, in-vehicle systems are evolving. Autonomous navigation systems are slowly being replaced with more advanced systems that incorporate real-time information to provide dynamic route guidance. J.H. Rillings and R.J. Betsold defined the following three evolutionary stages of Advanced Driver Information Systems (ADIS) (3):

- Information Stage (1990 - 1995)
- Advisory Stage (1995 - 2000)
- Coordination Stage (2000 - 2010)

New system features will be added during each stage in the evolutionary process(3). In the Information stage drivers will be presented with information which facilitates the trip planning and decision making processes. Most information provided during this stage will come from the vehicle, with limited support from the infrastructure. The first in-vehicle navigation systems exemplify the characteristics of an Information stage system. In the Advisory stage traffic information will be transmitted to vehicles where it will be processed and used by the vehicle's on-board system to guide the driver over an optimal route. A system developed in this stage would use real-time information to provide dynamic route guidance, as well as navigation. Finally, in the Coordination stage the vehicle and the infrastructure will exchange information freely and automatically. In addition to the dynamic route guidance function provided in the Advisory stage, vehicles equipped with an on-board device in the Coordination stage would be used as probes to transmit travel times back to a traffic management center. At this time the full benefits of ADIS--including increased network capacity, lower and more predictable individual trip times, improved fuel economy and improved air quality--should be realized.

Currently, although the technology exists, many obstacles lie in the evolutionary path. One major obstacle facing the evolution of ADIS is the consumer market which, for the most part, does not exist.

Objectives

The three objectives defined for this report are:

1. Identify various types of in-vehicle systems and describe the uses of each system;
2. Assess the marketability of various in-vehicle systems using information obtained from in-vehicle system manufacturers, the auto industry, and from a pilot study of drivers in urban areas; and
3. Recommend several uses of in-vehicle driver information systems based on the results of the marketability survey and information obtained from other sources.

Scope

The scope of the project includes all in-vehicle driver information systems. The intent of this report is to identify and describe those in-vehicle systems which are currently available on the market as well as those products that are under development, examine the market for these systems, and make recommendations concerning the potential use of the systems. The information presented in the report was obtained from the available literature, discussions and correspondence with various professionals, and from an independent survey of drivers in urban areas.

Organization of Report

Following the introduction, the report is organized into four chapters. Chapter 2 provides a description of the components of an advanced driver information system (ADIS) as well as the descriptions of several in-vehicle systems. Chapter 3 addresses the marketability of in-vehicle systems. The information provided in Chapter 3 was obtained primarily from two sources--phone conversations with representatives of the automobile industry and with several in-vehicle system developers and an independent survey of drivers in several urban areas. The conclusions are provided in Chapter 4. Finally, Chapter 5 recommends some potential uses of in-vehicle systems based on the results obtained from the survey and from information obtained from system representatives.

DESCRIPTION OF IN-VEHICLE DRIVER INFORMATION SYSTEMS

The first objective of this report is to describe some of the many Advanced Driver Information Systems (ADIS) which have been developed. To date, many driver information systems have been tested, evaluated and some systems have even been marketed. This chapter begins with an outline of the components of ADIS, followed by a brief description of several emerging technologies, and ends with a description of several in-vehicle systems and devices which have been developed in the past. In addition, some of their applications are discussed.

Many in-vehicle systems have been developed as prototypes or are in different stages of development and a few have been introduced on the consumer market. However, this report provides a description of only eleven of these systems. The aim is to give the reader an understanding of the similarities and differences in the current technology of in-vehicle driver information systems.

Advanced Driver Information Systems

Advanced Driver Information Systems (ADIS) provide drivers with various information while they are in their vehicle. Depending on the type of system, this information can come from various sources, either on-board the vehicle or from an outside source. ADIS require some of the following information to operate:

Map Data Base

An important feature of some in-vehicle systems is a computerized map of the traffic network. The systems require differing levels of complexity and detail, depending on the needs of the particular in-vehicle system. Simple route guidance systems may not require as much detail as a more advanced route guidance/navigation system which uses map-matching technology. Advanced route guidance systems require map data bases which contain turn-restrictions by time of day, one-way streets, bridge heights and other information such as truck exclusion zones (4).

A first generation system may have used a cassette tape as a storage medium for its map data base. However, several problems exist with the use of cassette tapes, including low storage capacity and slow data access. Today most route guidance and navigation systems use CDROM disks to store the large amount of information contained in a map data base.

Real-Time Traffic Information

Real-time traffic information plays an important role in the operation of an ADIS. A system can be much more useful if it can plan routes based on current traffic conditions and provide dynamic route guidance based on real-time information it receives from a traffic control center (4).

Examples of real-time traffic information include link travel times, congestion and incident information, weather reports, parking lot status and special events information (5). Systems which use real-time information require an extensive infrastructure which can effectively gather, process and transmit the information to equipped vehicles.

Other Information

In-vehicle systems may also provide drivers with other types of useful information such as yellow page information. Although this information is not required by the system to perform route planning, guidance or navigation, the information may be useful to drivers, especially those who are not familiar with the area. For instance, a driver may use yellow page information to look up a restaurant, a hotel, or even an automatic teller machine (ATM). If this information is integrated with the navigation function of an in-vehicle system, the driver may then select the restaurant, hotel, or ATM as a destination.

In-vehicle systems use this information--map data bases, real-time information, and other information--to perform several functions. The following sections describe the primary functions of an in-vehicle system.

Route Planning

Route planning is simply the ability to choose an optimal path from one location, the origin, to another location, the destination. Several criteria are used for the selection of an optimal route. A preferred or recommended route may be the fastest, shortest, cheapest, or even most scenic route (4,6). More advanced systems are capable of dynamically changing or altering the recommended route according to changing travel conditions. That is, if congestion begins to develop or an incident is detected along the preferred route, the system would automatically compute a new recommended route, diverting the driver around the problem.

Navigation

Navigation is the ability to locate the position of the vehicle with respect to the surrounding transportation system. Navigation systems most commonly use a Global Positioning System (GPS), dead-reckoning, or a combination of the two, however, several other navigational methods exist (4).

Dead-reckoning is a navigation method in which the vehicle location is calculated using a known position and distance and direction estimates obtained from sensors installed on the vehicle. Distance can be measured with speed input from the odometer, wheel sensors that measure distance traveled, or by some other means. Direction is simply measured with a compass or magnetic field sensor. Dead-reckoning systems invariably accumulate errors from inaccurate distance and direction estimates (7). Accumulated errors can usually be eliminated by resetting the vehicle's position using a known source. Many navigation systems use a computerized roadmap to update the position of the vehicle, a feature known as map-matching.

Route Guidance

Route guidance involves the provision of a series of instructions to drivers, directing them along preferred routes to their destinations. Route guidance instructions can be presented to drivers as text, voice, or symbols or a combination thereof. Most systems under development combine route guidance with navigation, however, route guidance can be provided without navigation. In this case, the system would not know the position of the vehicle, therefore the user would have to notify the system after each maneuver to request instructions for the next maneuver (4).

Discussion of Emerging Technologies

The ability to provide timely and accurate traffic information is essential in any traffic management program. Currently drivers receive traffic information from changeable message signs (CMS), highway advisory radio (HAR), lane control signals (LCS), commercial radio traffic reports, and cellular telephone (1). Except for cellular telephone, these technologies communicate information to nearly all drivers.

Several emerging technologies provide the means of communicating tailored information to drivers in their vehicles. These technologies include in-vehicle video display terminals, head-up displays (HUD) and auditory systems (1). While these emerging technologies facilitate the transfer of traffic information from public agencies directly to individual drivers, their success depends, in part, on how well they are received on the consumer market. This section provides a brief description of each of the emerging technologies.

In-Vehicle Video Display Terminals (1)

Route guidance and navigational information can be communicated to drivers via in-vehicle video display terminals which can be mounted on or near the dashboard or can be an integral component of the vehicle's dashboard. Two formats are typically used to display information to drivers on the video display. The first is a map display, which shows the current location of the vehicle and the road network around the vehicle. Recommended routes can be highlighted on some systems as well as destination icons to help the driver choose a suitable path. Some systems can even display text, symbols or a combination of both to convey current (real-time) traffic information broadcast from a traffic management center.

The other in-vehicle display format uses simple directional symbols, text messages, or a combination of both to guide the driver along a recommended route. In-vehicle systems which use this format present turn-by-turn instructions to the driver on the video display.

Auditory Systems (1)

Auditory systems use audible tones or buzzers, digitized or synthesized speech to warn and/or inform drivers of important situations while in their vehicles. Synthesized

speech, a relatively new technology, can be used to inform drivers of various events, such as fuel and vehicle status, traffic and weather conditions, and navigation and route guidance instructions. Auditory systems can be used to complement the visual information displayed to a driver on a video display terminal or, as discussed next, a head-up display.

Head-Up Displays

Head-up displays are optical devices which project visual images onto the windshield of the vehicle. Currently, HUDs present only simple information such as speed indications. However, future HUDs may use alphanumeric segments and icons to convey vehicle speed, navigation and route guidance, basic vehicle information, lane recommendations, warning indications, and short text messages (8). The HUD image is reflected from the windshield into the driver's field of view at an apparent distance equal to elements in the driving environment. This reduces visual scanning between two sources of information, such as the instrument panel or an in-vehicle display and the outside environment (1).

Route Guidance and Navigation Systems

In this section of the report, twelve route guidance and navigation systems are described. The systems described herein are in various stages of development or in prototype form as shown in Table 1. While many systems have been developed as prototypes, only four systems have been commercially available (only two in the U.S.). These are the ETAK NavigatorTM, Bosch TravepilotTM, the Nissan Drive Guide, and the Toyota CD Information System (9,10,11). Except for the Toyota system, these in-vehicle driver information systems are described in the following section.

NavigatorTM

Etak, Inc. developed the Navigator in-vehicle navigation system in 1985 (10). The Navigator is a first-generation computerized map system capable of showing the driver's origin, position and destination on a computerized display. The Navigator system, removed from the consumer market in 1990 (11), used a unique heading-up map display concept. The heading-up concept involves the rotation of the map relative to the vehicle. Because the vehicle always faces up on the display, the driver views the map as he/she does the outside environment.

The Navigator in-vehicle system uses dead-reckoning and map-matching technology as its navigation method. This first-generation system stored the digital maps on 3 Megabyte cassette tapes. Although the Navigator was withdrawn from the consumer market, it was the model used for the development of the Bosch Travepilot.

Table 1. Summary of In-Vehicle Systems Included in Report.

System	Type of System	Stage of Development	Developer(s)
Navigator™	Navigation	Removed from market	Etak, Inc.
Travelpilot™	Navigation	Market product	Etak, Inc. and Robert Bosch GmbH
Nissan Drive Guide	Navigation and audio-visual	Market product in Japan	Nissan Motor Co., Ltd.
Ali-Scout	Navigation and dynamic route guidance	Extensively field tested and evaluated	Siemens Automotive
TravTek	Navigation and dynamic route guidance	Extensively field tested and evaluated	GM, Motorola, et al.
Pathfinder	Navigation with real-time information	Field tested and evaluated	Travelpilot-Etak and Bosch; project-GM, Caltrans, FHWA
Navmate	Navigation and route guidance	Prototype; limited field testing	Zexel USA Corporation
ADVANCE	Navigation and dynamic route guidance	Proposed demonstration	IDOT, FHWA, Motorola, and IUTRC
CARMINAT	Navigation and dynamic route guidance	Demonstration system	Renault, Philips, Sagem, and T I Diffusion de France
TravelGuide	Portable dynamic route guidance system	Concept system	Ministry of Transportation of Ontario
Telepath	Navigation and route guidance	Concept system	GM and Delco Electronics

Travelpilot IDS™

The Travelpilot, a second-generation automobile navigation system developed jointly by Etak, Inc. and Robert Bosch GmbH, was modeled after Etak's Navigator. The system is now available in the U.S., Germany, and the Netherlands (12,13). In the United States, a Travelpilot navigation system costs approximately \$2500 (13). It is an autonomous (totally self-contained) system, meaning it does not rely on the external infrastructure to operate. Like the Navigator, it uses dead-reckoning and map-matching navigation techniques.

The Travelpilot displays the position of the vehicle, a roadmap of the area around the driver's vehicle, and a destination (Figure 1). The system allows the driver to input a destination by street address, cross-street, or single street. To aid the driver in reaching his/her destination the display shows the crows-flight (straight-line) direction and distance from the current position of the vehicle to the destination (7). Other features of the Travelpilot include zoom functions for the map display and access to a menu and several submenus for destination entry, choice of language to display, and a vehicle position relocater if the system is off-track.

The Travelpilot hardware is similar to a personal computer (see Figure 2). The processor, which measures 10.2 x 22.9 x 30.5 centimeters (4 x 9 x 12 inches) and fits in the trunk of the vehicle, contains the bulk of the system's electronics. This unit contains the Compact Disk Read Only Memory (CDROM) player. The maps, produced by Etak, are stored on CDROM disk. Another component of the Travelpilot system is the compass, which can be mounted on the rear window or between the headliner and the roof. Speed sensors are mounted on the wheels of the vehicle. The display unit is a 11.4 centimeter (4.5) inch Cathode Ray Tube (CRT) which can be mounted to the dash or to the transmission hump with a stalk.

As of 1991, the Travelpilot did not have route guidance or pathfinding capabilities. Thus, it was not capable of computing optimal routes for drivers. Rather, the driver was responsible for his/her own pathfinding and route guidance. Future Etak CDROMs with more detailed maps will give pathfinding capability to the Travelpilot. In addition, the Travelpilot can process real-time traffic information and display it as symbols, text or with digitized voice.

Nissan Drive Guide (9)

Nissan developed a navigation system called the Nissan Drive Guide. The system was offered as standard equipment in Japan on the 1989 Nissan Cedric, Gloria and CIMA. The actual cost to consumers was not available.

Drive guide provides drivers with a map of the local area and the current position of the vehicle. In addition, a destination can be input and is shown on the map display. Currently, the system can only aid the driver in navigation; route guidance is not a feature of the Drive Guide system. The functions of the system are listed in Table 2. Drive Guide navigates using dead-reckoning and corrects the location with map-matching techniques. For safety reasons, only a simplified map is displayed when the vehicle is moving.

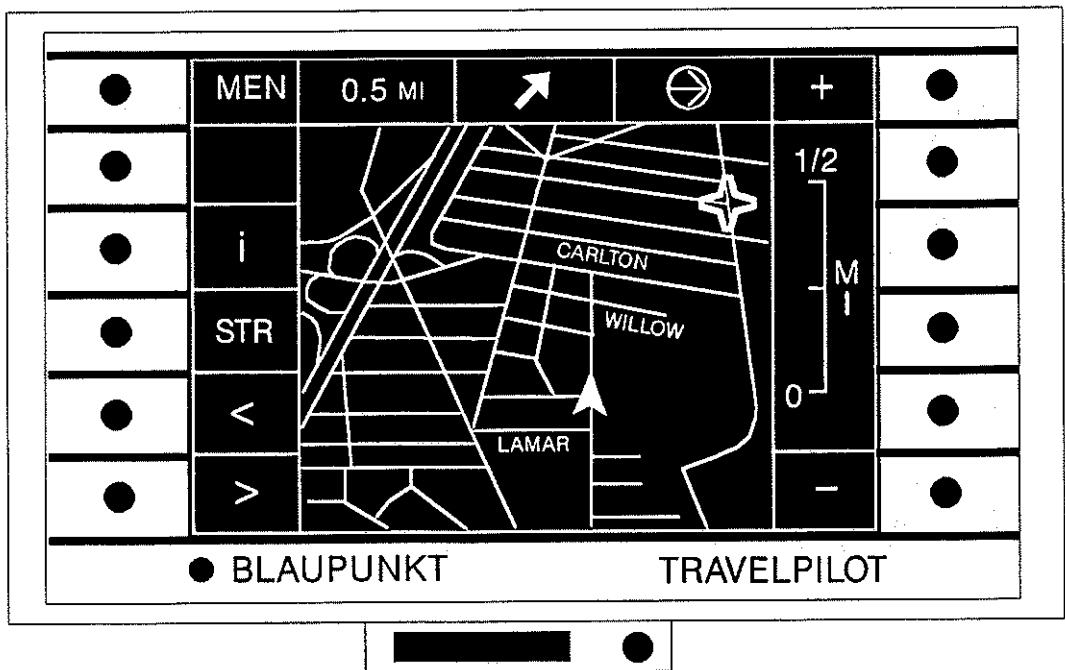


Figure 1. Bosch Travepilot IDS™ Display (7).

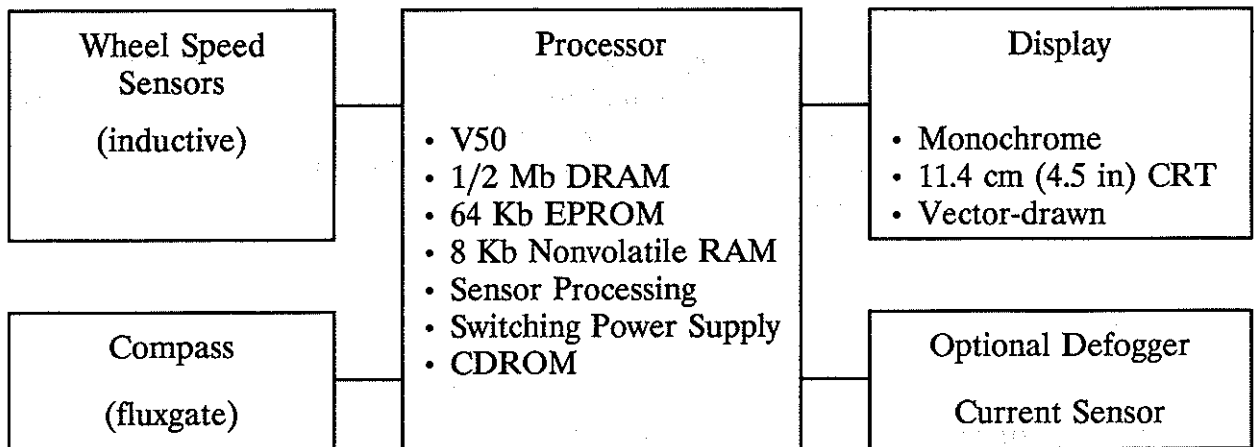


Figure 2. Travepilot IDS hardware block diagram. Source: (7).

Table 2. Functions of the Nissan Drive Guide System (9)

Function	Description
Basic Navigation Display	<ul style="list-style-type: none"> • Map with Variable Scale and North Arrow • Current Location in Center of Screen • Heading Denoted by Direction of Arrow • Destination Icon • Direction to Destination • Straight-line Distance to Destination
Map Scrolling	<ul style="list-style-type: none"> • Smooth Map Scrolling
Map Rotation	<ul style="list-style-type: none"> • North Reference Display • Vehicle Reference Display
Location Pre-Registration	<ul style="list-style-type: none"> • Five Location Capability
Landmark Detection	<ul style="list-style-type: none"> • Names and Locations of Approximately 12,000 Landmarks
Selective Road Display	<ul style="list-style-type: none"> • Detailed Road Display when Vehicle is Parked • Simplified Display when Vehicle is Moving
Facilities Information Display	<ul style="list-style-type: none"> • Names and Addresses of Approximately 6,100 Places

In addition to the Drive Guide navigation system, the 1989 Nissan Cedric, Gloria, and CIMA are outfitted with an audio-visual system which is integrated into one package. The audio-visual system allows the driver to obtain radio and television broadcasts and listen to compact disk and cassette recordings. The same display screen used for navigation can be used to select from preset radio stations (including highway radio service) and CDs, as well as to control audio-visual system output (volume, bass, treble, etc.). Many on-board components comprise the entire complex system.

Ali-Scout

Ali-Scout is a dynamic route guidance system developed by Siemens Automotive. The system is composed of external infrastructure equipment and in-vehicle equipment. External infrastructure equipment consists of infrared beacons and a central computer (14). The beacons are mounted on existing traffic signal systems and are directed at oncoming traffic. They have a range of about 100 meters (328 feet) (6). The central computer is connected to the beacons, and is located in a traffic control center. It transmits and receives information from the beacons.

A display control unit (input keyboard), display unit, dead-reckoning computer navigation system and an infrared transmitter/receiver comprise the on-board equipment. The display unit consists of an arrow indicator guidance display screen, an input keyboard, and a voice messaging system. The display unit, weighing approximately two pounds, can be detached from the main unit for destination input away from the parked vehicle. The dead-reckoning computer navigation system is the heart of the on-board system. The computer performs navigation with dead-reckoning and map-matching and also performs route guidance. The final on-board component, the infrared transmitter/receiver, can be mounted on the back of the rear view mirror. This unit receives guidance information from and transmits travel times to beacons. It has a range of about 60 meters (197 feet) (14).

Ali-Scout equipped vehicles receive guidance recommendations from the central computer each time a roadside infrared beacon is passed. The beacons, in turn, receive travel and congestion times from equipped vehicles as they pass between beacons. The beacons then relay this information to the central computer for processing.

The driver must only input a destination into the programmable keyboard. The system then guides the driver, turn by turn, to his destination using visual symbols supplemented by audible messages (Figure 3). The Ali-Scout does not have a map display.

TravTek

Both the private and the public sectors combined to carry out the largest ADIS project so far in the United States. This project, which took place in the Orlando, Florida metropolitan area, is called TravTek (Travel Technology). The purpose of TravTek was "to develop, test and evaluate an integrated advanced driver information system and supporting infrastructure (5)." The private sector was represented by General Motors, the American Automobile Association, Motorola and Avis. The public sector was represented by the Federal Highway Administration, the Florida Department of Transportation and the city of Orlando. General Motors served as the project manager.

In the demonstration, one hundred 1992 Oldsmobile Toronados were fitted with the TravTek system. These vehicles were chosen for their integral color cathode ray tube (CRT) with a touch-screen matrix, hands-off cellular phone, and other advanced features. Seventy-five of the vehicles fitted with the system were part of the Avis rental fleet and were tested by visitors to the Orlando area. The other twenty-five vehicles were tested by local residents or were used for other tests.

The TravTek system architecture is composed of three segments: (1) the TravTek Information and Services Center (TISC), (2) the Traffic Management Center (TMC), and (3) the Travtek vehicles (5). Although the TISC and the TMC are vital components of the Travtek system, this report only focuses on the TravTek vehicles.

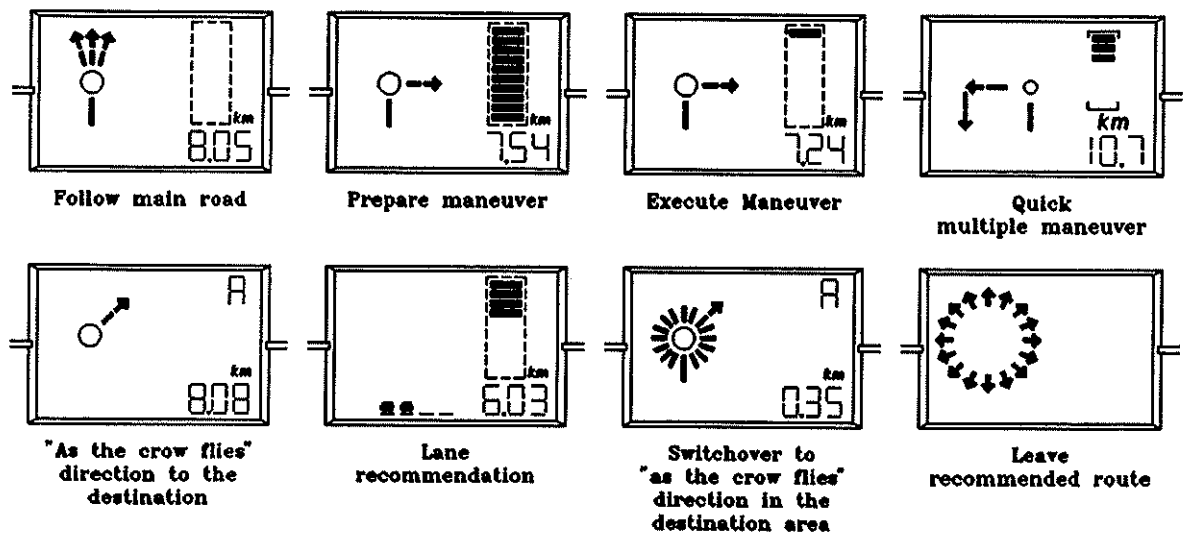


Figure 3. Symbols for Guidance Recommendations. Source: (14).

The TravTek system features navigation, real-time traffic information, route selection and guidance, local information, location assistance for emergency services, traffic probe capabilities, and other functions and characteristics. The in-vehicle display provides information to the driver on a heading-up navigation map display, simple guidance displays, or on local information screens. The display shown depends on the driver's preference and whether or not the car is moving. Drivers can choose to receive navigational, route guidance and traffic information from either the map display screen or the route guidance displays. However, for safety reasons, drivers can only access local information databases from special menu screens when the vehicle is in park. The navigation map displays the vehicle's position and destination on a variable-scale color map (Figure 4). The map moves relative to the vehicle symbol, which is always positioned up. Congestion and incident information can also be displayed on the navigation screen, as shown in Figure 4. The hollow circles and shaded circles represent moderate and heavy congestion, respectively. The star icon represents an incident.

The route guidance display gives turn-by-turn instructions to the driver. On-board equipment calculates an optimal (minimal-time) route from the driver's location to his/her destination based on existing traffic conditions and can dynamically adjust the route as the vehicle receives real-time traffic information from the traffic management center (TMC). The system guides the driver along the optimal route with simple guidance displays (Figure 5). An optional computer-synthesized voice notifies the driver of the next maneuver, the distance to the maneuver, and the name of the street on which to turn.

TravTek is a complex route guidance and navigation system which uses a separate on-board 80386 based computer with 4 MByte of RAM and a 20 MByte removable disk drive for each function. The navigation computer navigates using dead-reckoning and map-matching with GPS corrections. It also performs many other functions. The routing computer performs the route selection and route guidance and handles real-time traffic information, traffic probe, and data logging functions (5). Table 3 lists the functions of each computer.

In addition to the navigation computer and the routing computer, many other components are located in the vehicle. However, because one of the goals of the project was to create a system which resembled a showroom floor model, the other in-vehicle components are located in hidden but easily accessible areas. Figure 6 illustrates the location of all of the TravTek in-vehicle components. The complete TravTek vehicle architecture is shown in Figure 7.

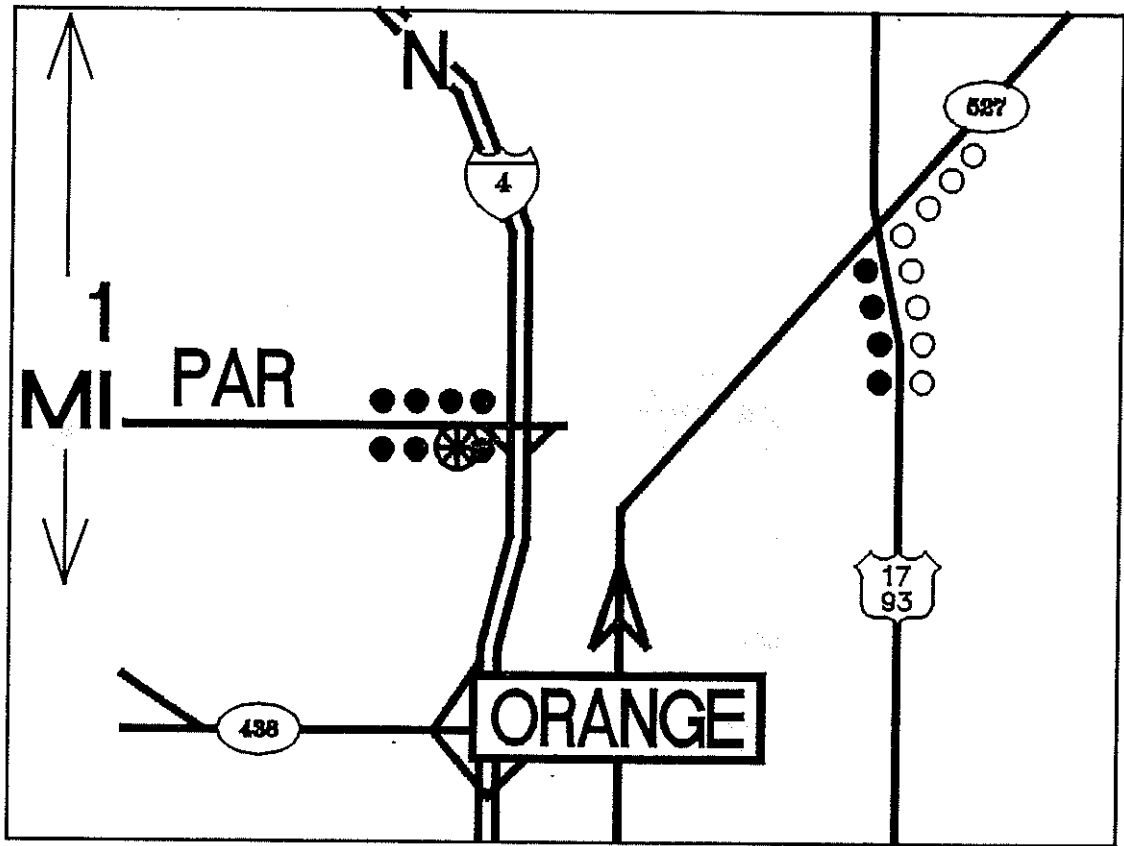


Figure 4. TravTek Navigation Map Screen (5).

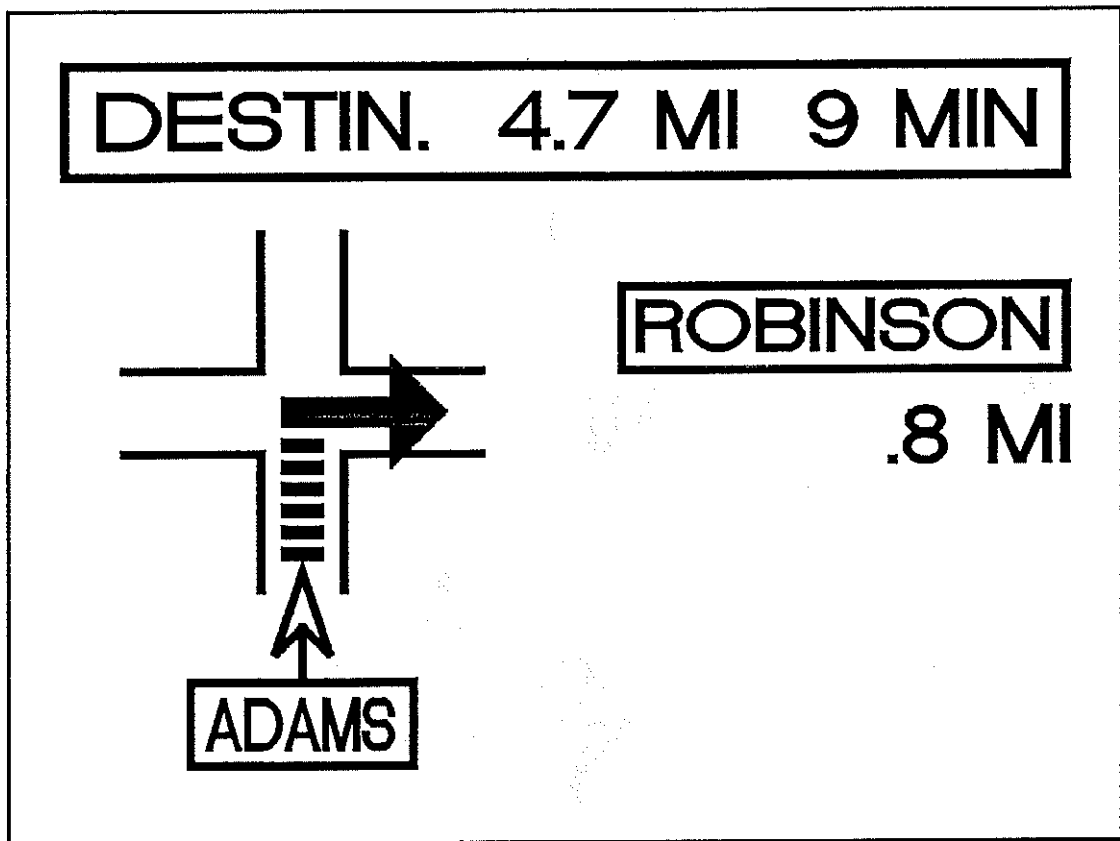


Figure 5. TravTek Route Guidance Display (5).

Table 3. Software Functions of the Two On-board TravTek Computers (15).

Navigation Computer Functions	Routing Computer Functions
<ul style="list-style-type: none"> • Navigation • Draw Map • Driver Interface • Local Information • Draw Visual Display • System Services • Interprocessor Communications 	<ul style="list-style-type: none"> • Route Selection • Route Guidance • Generate Guidance Screens • Generate Voice Messages • Probe Report • System Services • Interprocessor Communications • Manage RF Communications • Manage Traffic Information • Log Data • Control Program

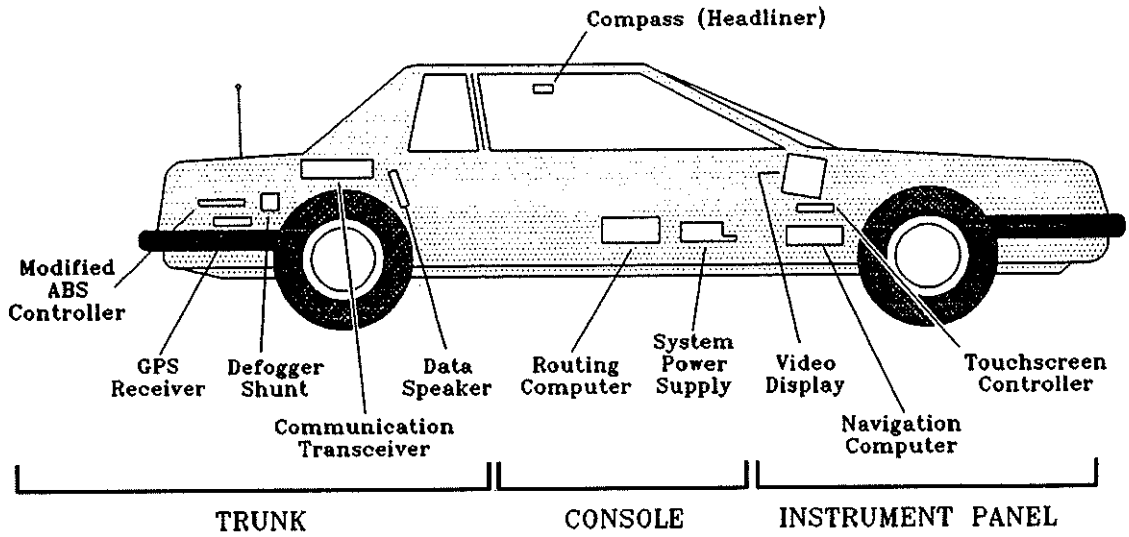


Figure 6. Location of the TravTek In-Vehicle Components (15).

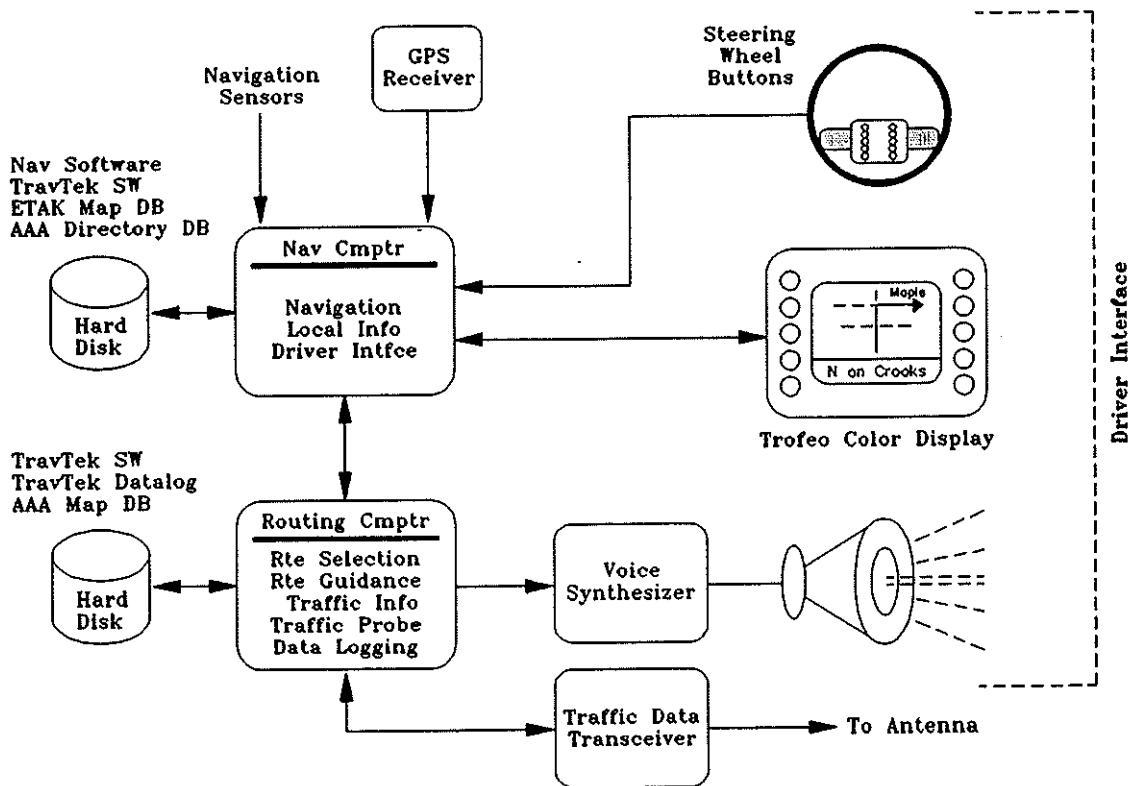


Figure 7. TravTek Architecture-Simplified (5).

Pathfinder

Pathfinder, the first Intelligent Vehicle Highway System (IVHS) operational field test in the United States, was a joint effort of the Federal Highway Administration (FHWA), the California Department of Transportation (Caltrans), and the General Motors Corporation (16). The purpose of the Pathfinder project was to test advanced communication and information techniques. The test was conducted in Los Angeles in what is known as the "Smart Corridor." The "Smart Corridor" is a 20.9 kilometer long (13 mile) segment of the Santa Monica Freeway and includes freeway service roads and five major parallel arteries (17). The Pathfinder test includes twenty-five GM vehicles outfitted with the Bosch Travepilot, a map-based navigation system.

The roadways are equipped with detectors, observation cameras, and changeable message signs. Roadway detectors transmit traffic flow data to traffic control centers. The control centers process this data and relay the information to the Pathfinder vehicles once every minute. The on-board equipment processes this data and displays it on the screen as congestion symbols and text messages or digitized voice messages. Drivers can select routes knowing real-time information about the traffic conditions in the area.

The Pathfinder project has been completed and evaluated. However, when this report was written, the results were not obtainable.

Navmate

Navmate, a prototype in-vehicle navigation system, was developed in the Sunnyvale, California office of the Zexel Corporation. Navmate, Zexel's second generation system, navigates using dead-reckoning and corrects accumulated errors using GPS (18). Drivers must enter a destination into the system. For safety reasons, destination input can only occur when the vehicle is stationary. The computer then calculates the best, or fastest, route and displays this information to the driver. Flexibility is provided by allowing the driver to choose the format with which information is displayed.

The first format, similar to the Travepilot system, is map based. The Navmate display shows the driver a color coded route map of the area surrounding his/her vehicle. The optimal route chosen by the computer is highlighted on the map display with a destination icon indicating the end of the route. Therefore, it is up to the driver to perform his/her own route guidance.

The other route information display format available to the driver is a turn-by-turn route guidance display, similar to the Ali-Scout system. Simple directional arrows indicate the direction of the next turn. These arrow indicators are supplemented with text and numeric information indicating street names, distances to next maneuver and distances to the destination. A graphic distance bar displayed on the route guidance screen shrinks as the vehicle approaches the turn, and a chime sounds to inform the driver of the approaching maneuver. In addition, Navmate allows the driver to preview the previous or next maneuver.

Navmate has several other features of interest. For example, if for some reason the driver leaves the recommended route (i.e. missed a turn), then a map screen with the highlighted best route is displayed to inform the driver of the error. The driver can then either use the map to get back on the route or have the system compute a new route to the same destination. Other features include guidance cancel functions, choice of map display mode (north up or heading up), and choice of map size.

Navmate in-vehicle equipment consists of a color display unit, a compass, a processing and storage unit, and a GPS antenna. The on-board computer, a unit similar in size to a VCR and fits in the trunk of the vehicle, contains the brains of the system. The business-card sized GPS antenna attaches to the lid of the trunk (12).

ADVANCE (19)

ADVANCE, Advanced Driver and Vehicle Advisory Navigation Concept, is a proposed large scale demonstration of an in-vehicle navigation and route guidance system. The system was developed and is being tested and evaluated by the Illinois Department of Transportation, Federal Highway Administration, Motorola, Inc., and Illinois Universities Transportation Research Consortium. The idea behind ADVANCE is to use the existing highway infrastructure more efficiently by informing motorists of traffic problems and helping them to make more informed travel decisions.

The demonstration is being conducted in suburban Cook County, an area northwest of the city of Chicago. Preliminary research found that between 4,000 and 5,000 vehicles are needed for the demonstration. Drivers will be recruited from the area based upon several criteria, including the provision of their own private automobile to and a willingness to have their driving behavior recorded and analyzed.

ADVANCE combines on-board equipment with an external infrastructure. The infrastructure, composed of a communications system and a traffic information center (TIC), is responsible for collecting traffic data from various sources and disseminating the information to equipped vehicles. On-board equipment consists of wheel speed and direction sensors, a Global Positioning System (GPS) receiver, a radio frequency dynamic information transceiver, a navigation, navigation computer, and color liquid crystal display (LCD) or cathode ray tube (CRT) (Figure 8).

The in-vehicle system features navigation, route planning, route guidance, and traffic probe capabilities. The navigation system will constantly monitor the vehicle's position and location. Position is defined as the latitude, longitude, and elevation of the vehicle (i.e. the x, y, and z coordinates). Location is the address of the vehicle on the traffic network. The system navigates with dead-reckoning and the errors are corrected with a combination of map-matching and GPS.

Drivers will input a destination using a keypad and color LCD and the system will calculate the optimal route and dynamically guide the driver along this optimal route using real-time information provided by the traffic information center. Optimal routes will be selected according to the driver's preferences (i.e. shortest time, shortest distance, no

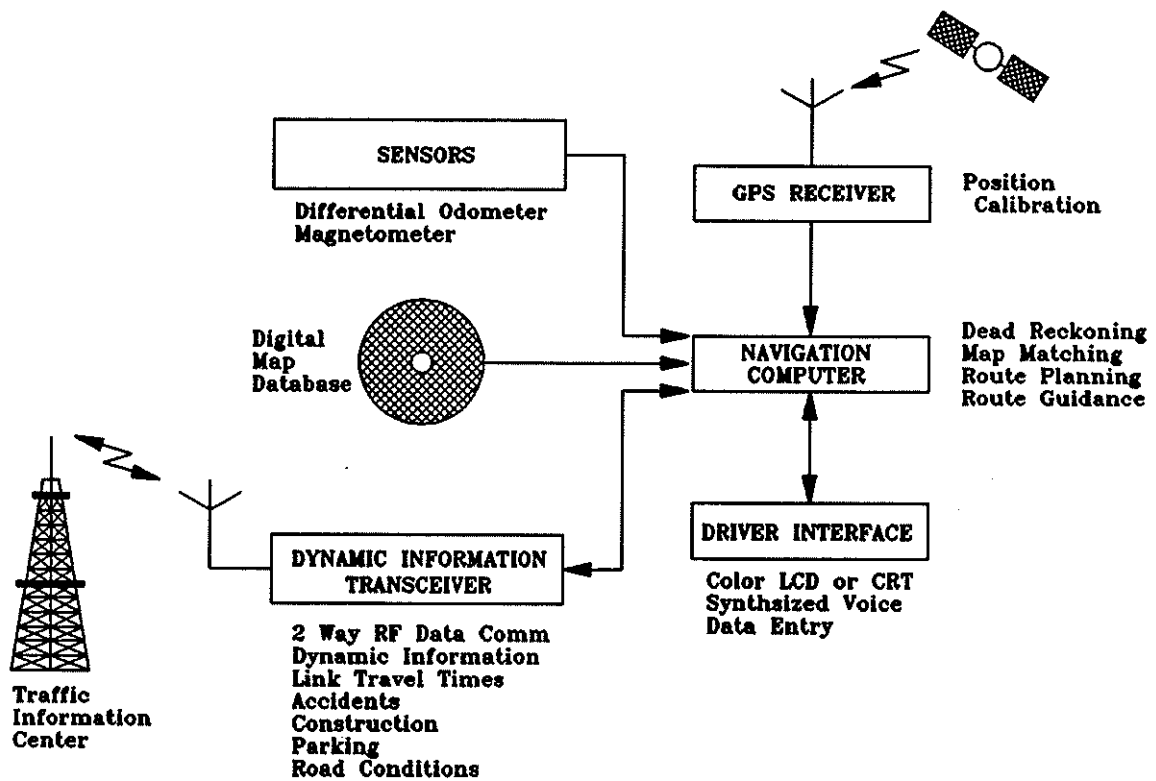


Figure 8. ADVANCE In-Vehicle System Components (19).

expressways, etc.). The driver will be guided along the recommended route with maneuver instructions on the color display supplemented by a digitized voice.

CARMINAT (20)

CARMINAT is an integrated information and Guidance System developed and operated in France. The project combines the efforts of three research projects: ATLAS, MINERVE, and CARIN under one program and name. The name is derived from a combination of the three projects (i.e. CARIN, MINERVE, and ATLAS). The group responsible for CARMINAT consists of an automobile manufacturer (Renault), two automobile electronics and navigation suppliers (Philips, Sagem), and a broadcaster (TéléDiffusion de France).

The research group developed and built three demonstration vehicles, each directed towards a different segment of the market. The result was a commercial vehicle with a traffic information system, a passenger car with a full information system and a passenger car with a dynamic guidance system. Collectively these demonstration vehicles contain systems which perform one or more of the following functions:

- Display traffic information on a graphic map display
- Display of local and service information (hospitals, parking availability, etc.)
- Route planning and dynamic route guidance

CARMINAT in-vehicle equipment consists of wheel and other vehicle sensors, a central computer, keyboard input device, vehicle radio with radio data system (RDS) capabilities, a voice module, a 15.2 centimeter (6 inch color) LCD screen and a 10.2 centimeter (4 inch) monochromic LED display for the guidance system.

TravelGuide (4)

TravelGuide is a portable traveller information/guidance concept system developed by the Ministry of Transportation of Ontario (MTO). TravelGuide features route guidance and planning without navigation capabilities. Because navigation components are not provided, the TravelGuide system will be less expensive to produce than other in-vehicle systems.

The TravelGuide device is a palm-sized computer with a digital map data base, a radio receiver to collect real-time traffic information, a graphical and text display capability, route guidance software, and synthesized voice (Figure 9). The device may be used in the vehicle to guide the driver along a preferred route, or may be removed from the vehicle to guide a person on foot. At the beginning of the trip the driver must provide TravelGuide with a destination. The system then calculates the optimal route and provides turn-by-turn instructions to guide the driver along the route. An example of an instruction is as follows:

- Turn left onto Main Street in 0.3 kilometers (0.2 miles)

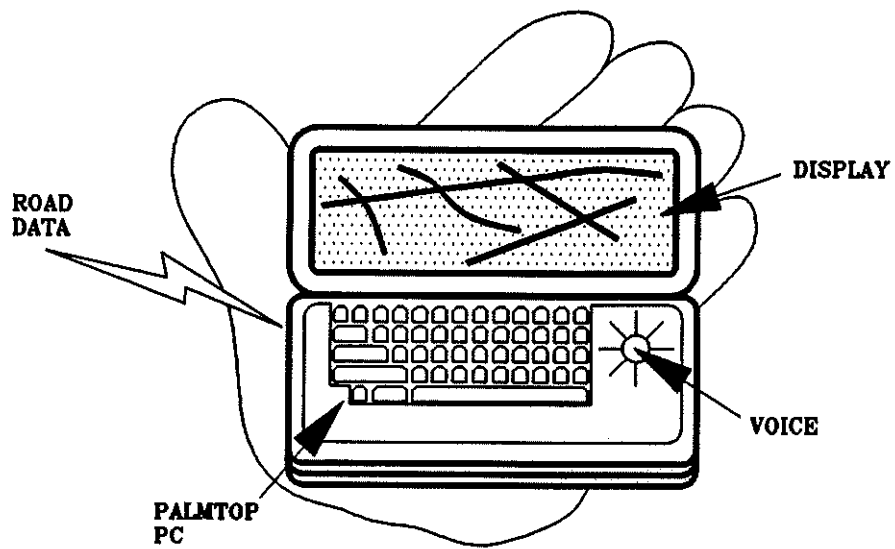


Figure 9. TravElGuide Unit (4).

Since the system does not have navigation capabilities, the user must act as the navigator. Thus, the user must know when 0.3 kilometers (0.2 miles) has been traveled and that main street has been reached. In addition, the driver must then prompt the system for the next instruction. A summary of TravelGuide's capabilities and features is provided in Table 4.

Table 4. Summary of System Capabilities and Features (4).

TravelGuide Capabilities	TravelGuide Features
<ul style="list-style-type: none"> • Route planning 	<ul style="list-style-type: none"> • Portable, off-the-shelf palm-top computer
<ul style="list-style-type: none"> • Step-by-step route guidance 	<ul style="list-style-type: none"> • Graphical and text display with keyboard
<ul style="list-style-type: none"> • Real-time link travel time reception 	<ul style="list-style-type: none"> • Synthesized voice
<ul style="list-style-type: none"> • Route selection based on user-set criteria 	<ul style="list-style-type: none"> • Digitized map data base
<ul style="list-style-type: none"> • Display of area map with traffic conditions 	<ul style="list-style-type: none"> • Built in RF receiver
<ul style="list-style-type: none"> • Reception and display of transit information 	<ul style="list-style-type: none"> • Low cost
<ul style="list-style-type: none"> • Possible use as paging receiver 	

Telepath

Telepath (8), an IVHS concept system developed by Delco Electronics and the General Motors Corporation, is a collection of emerging automotive and IVHS technologies. The Telepath program combines radio frequency (RF) communication, display, and navigation technologies, as well as several other innovative concepts into one conceptual vehicle.

In-vehicle display technologies include the head-up display (HUD) of alphanumeric segments and icons to convey vehicle information, navigation and communications functions and an active matrix liquid crystal display (AMLCD). The AMLCD displays a map-based navigation system in an adjustable hide-a-way housing. The navigation system used in the Telepath vehicle is modelled after the TravTek system.

In-Vehicle System Applications

The eleven route guidance and navigation systems described in the previous section are just a fraction of the systems that exist. It can be seen, however, that many levels of complexity and cost are represented. The applications of these systems also vary. Eventually, a market will develop for public, private and commercial vehicles. In Japan, a strong market exists for drivers of private automobiles. In the U.S., however, most systems are being used in public service fleets (i.e. emergency and fire departments, etc.). While the U.S. consumer market has not yet matured, system developers are using public, private and commercial vehicle fleets to test prototype route guidance and navigation technologies. This section of the report describes a few of the applications of in-vehicle technology to several vehicle fleets.

Rental Car Fleets

Rental car fleets are obvious applications for in-vehicle route guidance and navigation system prototypes or products because rental car users usually are not as familiar with the specific area and are more apt to realize the potential benefits of such systems. Rental car companies can even benefit from experimental programs because of the potential for added business. Therefore, it is not surprising to know that several rental car companies have been used to test and evaluate route guidance and navigation systems.

The largest and most well known demonstration of route guidance and navigation technology in the United States is the TravTek system. TravTek was tested in the Orlando, Florida area. Seventy-five 1992 Oldsmobile Toronado fitted with the TravTek system were made available to visitors of the Orlando area through the AVIS Rent-A-Car Company. The TravTek system is being evaluated by a team which includes the Texas Transportation Institute and Science Applications International Corporation (SAIC) (21). The results of this evaluation have not yet been released.

AVIS is also testing the NAVMATE prototype system developed by the Zexel Corporation. Five Oldsmobile Toronado Trofeos equipped with the NAVMATE system are being tested in the San Francisco Bay area. The vehicles are based at San Jose International Airport. Rental rates for the equipped vehicles amount to just \$5 a day more than the regular rate. AVIS is also testing NAVMATE in Orlando and is hoping to expand testing in the Bay area to include 100 vehicles (12).

Commercial Fleets

Commercial fleets such as delivery services could reap major benefits from route guidance and navigation systems, especially small fleets desiring high operating efficiency. Maximum efficiency can be obtained by planning routes which reduce travel times or distances between destinations, allowing more deliveries. These goals may be obtained with route guidance and navigation systems utilizing real-time traffic information, especially in urban environments.

Emergency and Fire Department Fleets

Emergency and fire department fleets are ideal subjects for route guidance and navigation technology. In fact, response times to emergency situations can be reduced, sometimes resulting in lives saved. Combined with a fleet management program, the possibilities are endless.

Pinellas County, Florida is currently using a computer aided dispatch (CAD) system to manage LifeFleet, the on-site service provider for the county. The system uses Etak digital maps and Etak Navigator in-vehicle units to monitor the location of its emergency vehicles and to dispatch the closest available vehicle to an emergency. When a call is received, the dispatch center converts the call to a geographic location. The location of the call is then displayed on a wall-sized map. Also displayed on the map are the locations of all emergency vehicles, color coded to indicate their status. A dispatcher then notifies the closest available unit by pressing a button. The location of the emergency appears on the emergency unit's Navigator in-vehicle display, as well as any specialized text information. The driver of the vehicle notifies the dispatcher that the call was taken and that the unit is enroute with the push of a button (22).

The Travepilot system, similar to the Navigator, is being used in several fleets, including the City and County of Los Angeles, the Seattle Fire Department and the Kansas City Fire Department (10,11).

Private Fleets

Several projects are demonstrating route guidance and navigation technologies using fleets of privately owned vehicles. Most notable are the ADVANCE, TravTek, and Pathfinder projects. Perhaps the largest project will take place in Chicago, under the ADVANCE demonstration. In this demonstration, up to 5000 personal and commercial vehicles will be equipped with in-vehicle route guidance/navigation systems (19). TravTek and Pathfinder also used private automobiles and in-vehicle route guidance and navigation systems to test advanced communication and information techniques. See the previous section of this report for a more detailed description of the ADVANCE, TravTek, and Pathfinder projects.

MARKETABILITY OF IN-VEHICLE DRIVER INFORMATION SYSTEMS

One goal of this pilot study was to compare the actual costs of in-vehicle systems with the results of a survey of drivers. A survey was designed to determine what features motorists are looking for and what prices they are willing to pay for in-vehicle systems with route guidance, navigation, and information capabilities. The survey was constructed with little effort, however, some problems were encountered in the process of contacting various representatives. This section presents the results of the attempt at describing the marketability of in-vehicle route guidance and navigation systems.

Perspectives from the Automobile and In-Vehicle System Industries

Several representatives of the auto industry and representatives of in-vehicle system developers were contacted for this study. The idea was to inquire about what types of products were available on the market and to obtain information about such products. The results of these efforts were quite fruitless. Most representatives were willing to spare some of their time, however, when questioned about products and price information, most were reluctant to talk. The reason for this is that now, in the U.S., only one in-vehicle route guidance or navigation system, the Bosch Travelpilot, is available on any market. Although several route guidance and navigation systems have been developed, tested and evaluated here in the U.S., no other system has reached the consumer market. Therefore, no one is willing to disclose precious market information about a product which is not yet on the market.

The market for route guidance and navigation systems is twofold. In-vehicle route guidance and navigation devices can, just like car stereos, be obtained in the aftermarket (i.e. from a car stereo or electronics store) or from an original equipment manufacturer (OEM or before market). An OEM market product is a factory installed system available as an option with the purchase of a new automobile. Currently, in the U.S., the aftermarket is the only source to purchase a route guidance or navigation system, the only available product being the Travelpilot. In Japan, however, the market for these systems is more advanced than in the U.S. To date, over 400,000 navigation systems have been sold in Japan as OEM-installed equipment (23).

Market research on in-vehicle route guidance/navigation devices performed by the Zexel Corporation indicates that at \$3000 virtually no market exists and at \$2000 only very little. However, twenty (20) percent of luxury car buyers are willing to purchase such a device at \$1500, forty (40) percent at \$1200, and sixty (60) percent at \$1000 (24). Currently, however, the components of an in-vehicle route guidance/navigation system, purchased individually, would total between \$4000 and \$5000. These components include an in-vehicle computer and display, similar to a color monitor laptop PC, a GPS system, and a CDROM disk and player. At this cost essentially no market exists.

Given that an acceptable market exists for a navigation system with a price range of between \$1000 and \$1500 and knowing that the cost of the equipment is much more, then how can such systems be marketed? Mr. Vincent O'Connor of the Zexel USA Corporation

(24) believes a system can be marketed if the major costs are hidden in other existing systems in the automobile. For example, if head-up displays (HUD) provide the turn-by-turn instructions, audio CD changers read the map information, and if the navigation map displays are removed completely, then the overall costs can be either hidden in other systems or significantly reduced by eliminating some of the extra equipment (i.e. the display screen). In about three years, Zexel hopes to introduce the Navmate system as a factory-installed option for under \$1500.

In Japan, Sumitomo Electric Industries, a primary supplier of Nissan, developed and released a self-contained (aftermarket) navigation system for a retail price of about \$3000. The system includes a 10.2 centimeter (4 inch) LCD display and a CDROM. Market research by Nippondenso, a competitor of Sumitomo's, indicates that the average motorist would be willing to pay up to \$1600 for a route guidance system with all the functions. This figure closely matches the dollar figures obtained by the Zexel Corporation.

Here in the U.S., the Travelpilot, which retails for about \$2500 (not including installation costs), is available as an aftermarket product (12). It can be installed to either the dashboard or to the transmission hump with a stalk. However, this poses some problems, as discovered in the Pathfinder project. In the Pathfinder Oldsmobile Eighty Eights no convenient place was available to mount the stalk for the Travelpilot navigation system. The only alternative was to mount it on the dashboard. Even this was difficult because the dashboard, which is made of plastic, vibrates and oscillates with the engine, and so did the Travelpilot. In the end a customized bracket was used to mount the display to a seam in the dash (16).

Opinions differ on which market, the aftermarket or the before (OEM) market, will develop first, as well when new products will be placed on the market. However, the most likely candidates for new in-vehicle route guidance/navigation systems are the 1995 Lincoln Continental, the 1996 Oldsmobile Aurora, and with 1998 Chryslers (24). The market for in-vehicle systems, fueled by the IVHS initiative, is developing in a big industry which will see "new developments...in the very near future (11)."

Route Guidance and Navigation System Survey

A small survey was formulated to determine drivers' attitudes toward and acceptance of in-vehicle route guidance and navigation technology. The survey was sent to twenty-one drivers in several urban areas as indicated in Table 5.

Table 5. Locations and Numbers of Surveys.

Location of Survey	Number of Surveys Sent
San Francisco, California	2
Houston, Texas	2
Dallas, Texas	6
Milwaukee, Wisconsin	1
Washington, D.C.	10

Five objectives of the survey were defined as follows:

1. To determine if drivers have a general interest in route guidance and navigation;
2. To find out which display format drivers preferred;
3. To determine the reasons drivers preferred one format over another;
4. To determine the source from which drivers would be willing to purchase a route guidance or navigation system; and
5. To determine the price motorists are willing to pay for an in-vehicle system.

A copy of the actual survey given to the drivers is provided in the Appendix. The survey briefly describes two alternative in-vehicle systems: Bosch's Travelpilot and the Ali-Scout system from Siemens Automotive. These two systems were chosen because they have different display formats. A series of ten questions related to the Travelpilot and Ali-Scout were asked for the purpose obtaining marketability information which satisfied the stated objectives of the survey.

A more complete survey could have been formulated, however, it was anticipated that a long, complicated survey would not draw much response and would cause participants to lose interest. So for that reason, and because of time constraints, the survey was kept as simple and as short as possible.

Before the survey was distributed to the areas shown in Table 3, a pilot survey was conducted using five drivers from the city of College Station, Texas. The pilot survey was conducted to refine the survey. The objective of this pilot survey was to make the final survey simple and easy to understand, and to achieve the original objectives of the survey. After a review, the pilot survey was revised and was distributed to the participants. The following two sections provide the results of the survey and some discussion of the results.

Survey Results

All twenty-one surveys were returned and are summarized in Tables 6 through 11. Summary tables were prepared only for questions which were not open-ended. Other survey results are referred to in the discussion.

One hundred percent of the people surveyed expressed some interest in obtaining a route guidance and information system (Table 6). Capturing 86 percent of subjects' responses, the most significant benefit desired in an in-vehicle system is the ability to minimize travel times by optimizing the route (Table 7). Locating unknown addresses ranked a close second, however, at 81 percent. Seventy-one percent of drivers chose both travel distance reduction and congestion avoidance and 52% chose reduction in fuel consumption as reasons to obtain a route guidance and navigation system. However, only 48% of the participants were interested in a system's ability to avoid incidents in the roadway.

The third question drew some erroneous replies. As shown in Table 8, six out of the twenty-one survey participants selected more than one response for this question although only one choice was desired. These six respondents would be willing to purchase an in-vehicle device either as an aftermarket product or as an option package from an auto dealer. Including the six extra responses, more drivers surveyed would purchase an in-vehicle route guidance/navigation system with their next automobile purchase.

The most popular display format among those surveyed is the map-based, as 90% of drivers surveyed preferred alternative 2 (Table 9). One driver indicated that a combination of both the map and the turn-by-turn instructions would be a good format and chose this as an alternative. For this reason, the percentages in Table 9 do not total 100%. Several of the reasons Alternative 2 (map-based) were chosen are listed below:

- Information is simpler and more direct;
- The ability to know where your location, direction and destination in relation to the surrounding environment;
- Heading-up map format
- User friendliness
- Familiarity with maps
- The ability to choose routes at the driver's discretion

Approximately 36% of the participants indicated they would not pay more than \$500 for an in-vehicle route guidance/navigation device. At approximately 45%, an even greater proportion of the subjects are willing to pay between \$501 and \$1000 for an in-vehicle device. Five percent indicated they would purchase a system at price ranges of both \$1001 to \$1500 and \$1501 to \$2000, however only a small percentage of drivers surveyed would pay more than about \$2000. Table 10 shows that twenty-two responses were received when the total number surveyed was only twenty-one. The reason for the extra response was that one driver selected two price ranges. The same driver selected the two highest price ranges recorded--\$2501 to \$3000 and \$3001 to \$4000.

Table 6. Responses to Survey Question Number 1.

Question 1: Would you be interested in owning an in-vehicle route guidance and navigation system?		
Response Item	Number of Responses	Percentage of Respondents
Yes	8	38
No	0	0
Maybe	13	62

Table 7. Responses to Survey Question Number 2.

Question 2: Why would you be interested in owning an in-vehicle system?		
Response Item	Number of Responses	Percentage of Respondents*
Minimize Travel Time	18	86
Minimize Travel Distance	15	71
Avoid Congestion	15	71
Avoid Incidents	10	48
Reduce Fuel Consumption	11	52
Locate Unknown Addresses	17	81

* Percentages do not total 100% because subjects were able to select more than one item.

Table 8. Responses to Survey Question Number 3.

Question 3: Indicate which source you would be willing to purchase the system from.		
Response Item	Number of Responses*	Percentages of Respondents
Self-Contained System	11	41
Option on Next Auto	16	59

* Number of responses do not total 21 because six respondents chose more than one source.

Table 9. Responses to Survey Question Number 4.

Question 4: Which alternative do you prefer?		
Response Item	Number of Responses	Percentage of Respondents*
Alternative 1 (Turn-by-Turn)	1	5
Alternative 2 (Map Based)	19	90

* Percentages do not total 100% because one respondent selected a third, self-made alternative.

Table 10. Responses to Survey Question Number 6.

Question 6: What do you think is a reasonable price for the alternative you chose?		
Response Item	Number of Responses*	Percentage of Respondents
Less Than \$500	8	36.36
\$501 - \$1000	10	45.44
\$1001 - \$1500	1	4.55
\$1501 - \$2000	1	4.55
\$2001 - \$2500	0	0
\$2501 - \$3000	1	4.55
\$3001 - \$4000	1	4.55
More Than \$4000	0	0

* Number of responses do not total 21 because one respondent selected two price ranges.

Finally, Table 11 indicates that most of the respondents reside in or commute to urban areas where route guidance and navigation may be more beneficial.

Table 11. Responses to Survey Question Number 9.

Question 9: How often do you drive in this area (the urban area in which you reside or commute)?		
Response Item	Number of Responses*	Percentage of Respondents
Every Day	16	73
Two to Four Times per Week	4	18
One Time per Week	0	0
Less than One Time per Week	2	9

* Number of responses do not total 21 because one subject selected more than one response.

Discussion of Results

One survey participant inquired, "Seems like these systems have been discussed, and built, for 5-8 years but few are in operation. Why?" The answer to this question is not so direct. From section 2 of this report, one can see that the technology exists. Numerous systems have been developed, tested, and evaluated for several years but few are on the market. In fact only one system, Bosch's Travelpilot, has been introduced in the U.S. consumer market. In Japan, however, things are different; over 400,000 navigation systems have now been sold as factory-installed and as add-on equipment.

The survey showed that most people prefer the map-based system over turn-by-turn instructions. Most surveyed felt that the map gave them a better overall perspective on where they were and in what direction they were headed. Research shows, however, that complex map displays affect the driving task, in an urban environment. A recent study compared the visual attention required of subjects using the Bosch Travelpilot, a map-based system, and the LISB/Ali-Scout, a displayed symbol, guidance system (25). The results indicate that glance durations were significantly longer on the information display with the Travelpilot. A survey of the subjects in the same experiment indicated that the Travelpilot display was more distracting. A solution to this problem might be to allow the user to choose the display format and to limit the amount of information displayed while the vehicle is in motion.

Market research performed by the Zexel USA Corporation indicated that the ideal cost range of an in-vehicle route guidance/navigation system is between \$1000 and \$1500 (24). The survey showed that about 82% of drivers would pay no more than \$1000 for an in-vehicle system. However, now the cost of the components of an average in-vehicle system with route planning, guidance, and navigation capabilities total more than what market research and the survey indicate drivers will pay. Therefore, before these systems can be successfully marketed the cost must be reduced.

The discussion above is evidence that the marketability question has yet to be resolved. Before the systems are to become more marketable additional research must be conducted, the costs to the motorist must be reduced, and the conflict of what information to provide the motorist must be resolved.

CONCLUSIONS

Advanced Driver Information Systems (ADIS) utilize on-board equipment to convey various types of information to drivers. Development of ADIS has concentrated on the provision of route guidance, navigation, and real-time information functions to drivers using in-vehicle video display systems and other emerging technologies. In this report, eleven in-vehicle driver information systems have been described and their applications discussed. In addition, an attempt was made to assess their marketability through discussions with various professionals and an independent survey of motorists in several urban areas.

Currently, each of the evolutionary stages defined by Rillings and Betsold (3) have been represented by an ADIS project or product. The Travelpilot navigation system, the Ali-Scout dynamic route guidance system and the TravTek project with probe capabilities span the three stages--Information stage, Advisory stage, and Coordination stage--respectively. However, none of the four commercially offered systems have had features more advanced than the Information stage. Therefore, the status of the evolution of Advanced Driver Information Systems is progressing as predicted by Rillings and Betsold.

Many route guidance and navigation systems have been developed, however, only four systems have been placed on the consumer market--Etak's Navigator, the Bosch Travelpilot, the Nissan Drive Guide and the Toyota CD Information System. The descriptions provided of the eleven route guidance/navigation products, demonstrations, and concepts illustrate the variations in design and function of each system.

While the technology has been demonstrated in numerous projects, the market has been slow to develop. It is no surprise that cost is an important market issue. According to market research performed by the Zexel corporation, the cost of route guidance/navigation system components total more than what the average motorist is willing to pay. A survey of twenty-one drivers supports this statement; in the survey most drivers would only pay up to \$1000 for a system in which the cost of the on-board components alone may total more than \$4000.

It is difficult to completely assess the marketability of in-vehicle systems for several reasons. This study has identified an interest in route guidance and navigation systems among the driving population. It has also identified a large amount activity among the developers of route guidance/navigation systems, in terms of research and development.

RECOMMENDATIONS

Few recommendations can be made concerning the marketability of in-vehicle route guidance and navigation systems. Although many systems have been developed, the lack of commercially available systems is evidence that more research and development is required to determine more effective and more marketable systems. Many issues must be addressed before more route-guidance and navigation systems will be available to consumers. These include the safe presentation of information to drivers, an acceptable man/machine interface, and issues concerning the collection, processing and transmission of traffic data to the motorist.

An important consideration in the design and operation of an in-vehicle system is flexibility. Previous research and the survey conducted for this report show that drivers prefer the map display format to the provision of route guidance instructions. Research also shows that the map display format is more distracting in an urban environment. Flexibility may be provided by allowing the user to choose the display format and by limiting the amount of information displayed when the vehicle is in motion. Several projects and prototype systems have already addressed this issue.

Before the market develops, a communications infrastructure must be established. This requires a cooperation among the private and public sectors. The standardization of the infrastructure and in-vehicle communications equipment is key to the widespread operation of programs which allow equipped vehicles to receive current traffic information. Standardizing communications will allow an equipped vehicle receive valid information regardless of its whereabouts.

Before the infrastructure has been developed and in-vehicle systems are more abundant on the market, large-scale demonstrations and evaluations should be continued. Projects such as TravTek and ADVANCE, which use large fleets to test in-vehicle system and information communication technologies, are vital to the future implementation of operating systems.

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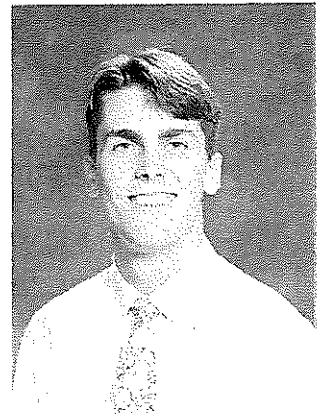
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APPENDIX

June 25, 1993

Dear Driver:

Tired of fooling with confusing highway maps? Sick of getting caught in traffic jams? What if you had a computerized navigation system which could give you visual and verbal trip information while driving in your car? Well, although they aren't readily available, such systems do exist and within a few years will invade the market.

A small study is being performed to examine public interest in and knowledge of several types of Advanced Driver Information Systems (ADIS). ADIS provide information to drivers in their vehicles. The driver can use this information to make his or her travel more efficient.

Several emerging technologies, such as in-vehicle video display terminals, voice displays, and heads-up displays, add a new dimension to existing driver information systems. These technologies allow transportation agencies to communicate more directly with drivers. For example, a traffic control center could broadcast special traffic information to drivers with route guidance and navigation systems. A route guidance and navigation system displays the information to drivers to help them plan trips and avoid congestion and incidents, thus increasing speeds and decreasing travel times, fuel consumption and vehicle emissions. Currently, route guidance and navigation systems use two display formats. One format is a map based system which displays a map of the local traffic network and the vehicle location. The other format provides the driver with turn-by-turn instructions using text and symbolic messages.

Several route guidance and navigation system formats are currently being tested and evaluated in the U.S. and abroad. They probably will be introduced on the market in several years as integrated systems with new automobiles or as totally self-contained systems. As more research is conducted on route guidance and navigation systems, the current prototype systems will become greatly improved and widely available driver tools.

Please take a moment to review two alternative route guidance and navigation systems and then complete the survey. The information you provide will be used in a report that is being written for a summer course. Your participation in this survey is greatly appreciated.

Sincerely,

P. Scott Beasley
Graduate Research Assistant

ALTERNATIVE 1: TURN-BY TURN SYSTEM

DESCRIPTION:

Turn-by-turn systems use symbolic signals (arrow indicators), text instructions, or both to guide the driver along a recommended route. The route, which is chosen by a computer processing unit, minimizes the travel-time to the driver's destination. All the driver must do is provide the system with his or her destination; the system then determines the optimal route based on historical and real-time traffic information.

The Ali-Scout Dynamic Vehicle Route Guidance System from Siemens Automotive (see figures below) provides drivers with a graphic display which indicates the turn direction, distance to the next maneuver, number of lanes and recommended lane, and the distance to the destination. The recommended route is dynamically adjusted as the in-vehicle unit receives information from outside. For example, if congestion develops the system can re-route the vehicle around the congestion on a quicker route.

IN-VEHICLE COMPONENTS (Ali-Scout System):

Display and Control Unit - Graphic display of turn-by-turn instructions; alphanumeric keyboard for destination input; audible speaker to signal driver. This unit can be mounted in or on the dash and can be easily detached and carried in a briefcase or coat pocket. It weighs approximately two pounds.

Dead-Reckoning Computer Navigation System - Performs dead reckoning (calculation of vehicle position) and route guidance using a magnetic field sensor and wheel speed sensors. This unit is unseen by the driver.

Infrared Transmitter/Receiver - Receives guidance information and transmits travel times between specific points. This device is mounted on the back of the rear view mirror.

ALTERNATIVE 2: MAP BASED SYSTEM

DESCRIPTION:

Map based route guidance and navigation systems provide the driver with a map of the traffic network in which he or she is driving and the location of the vehicle in the network. Recommended routes can be highlighted on the display, as well as any related traffic information, such as areas of congestion.

The Travelpilot IDS™, developed jointly by Etak and Bosch, is a map based automobile navigation system (see figure below). This system provides a map of the area around the vehicle (white arrow in center of map), the location of the vehicle, and the trip destination. Travelpilot is unique in that the map is always oriented so that the direction which the car is heading is always pointing up on the video display. Thus, the driver views the video map as he or she views the outside environment through the windshield.

IN-VEHICLE COMPONENTS (Travelpilot IDS™):

Video Display - Displays a map of the traffic network, the location of the vehicle and the trip destination. The display can be mounted to the dash or to the transmission hump with a stalk.

Compass - This unit can be mounted in the rear window and measures 2 x 2 x 1/2 inch.

Speed Sensors - These devices are mounted on the two non-driven wheels.

Processing Unit - Processor and CDROM disk player; performs the navigation by dead-reckoning and map- matching. A CDROM disk can store an entire roadmap of the U.S. This unit measures 4 x 9 x 12 inches and can be mounted in the trunk of the vehicle.

ROUTE GUIDANCE AND NAVIGATION SYSTEM SURVEY

1. Based on the information you have been provided and on your own knowledge, would you be interested in owning an in-vehicle route guidance and navigation system?

Yes No Maybe

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Questions 2-6 pertain to those who answered YES or MAYBE to Question 1. If you answered NO to Question 1, please skip to Question 7.

2. If yes, why? (Select all that apply.)

- To Minimize Travel Time to Destination To Avoid Incidents (Accidents)
 To Minimize Travel Distance to Destination To Reduce Fuel Consumption
 To Avoid Congested Areas To Locate Unknown Addresses
 Other (briefly describe) _____

3. Indicate which source you would be willing to purchase the system from.

- As a self-contained system from an electronics equipment store; or
 As an option on the purchase of your next automobile

4. After reviewing both alternatives, which one do you prefer?

- Alternative 1 (Turn-by-Turn System) Alternative 2 (Map Based System)

5. In selecting this alternative, what factors influenced you? (List all that apply.)

6. What do you think is a reasonable price for the alternative you chose?

- Less Than \$500 \$1501 - \$2000 \$3001 - \$4000
 \$501 - \$1000 \$2001 - \$2500 More Than \$4000
 \$1001 - \$1500 \$2501 - \$3000

Please skip to Question 8.

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