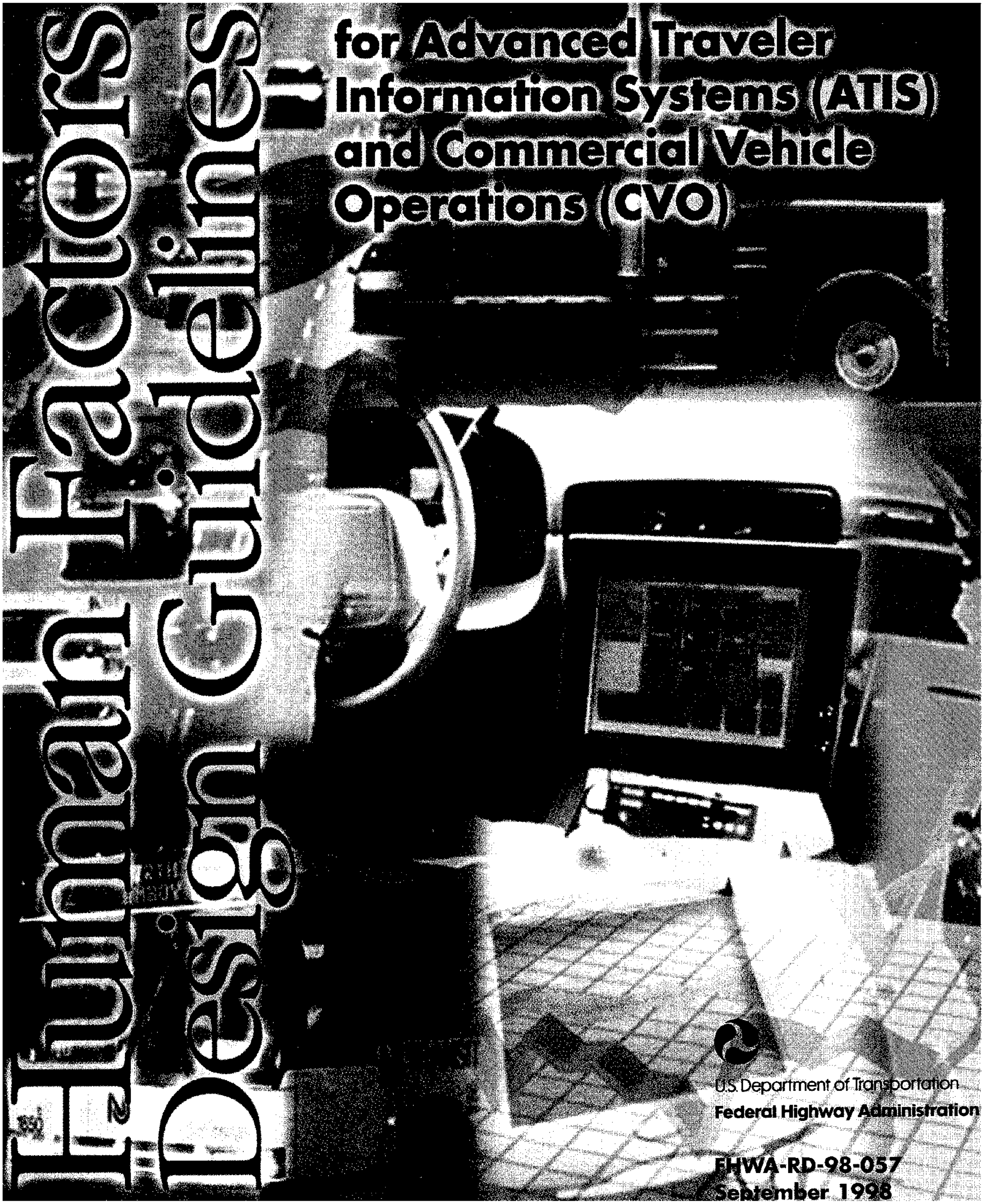
PB2001-100373

# Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO)



U.S. Department of Transportation
Federal Highway Administration

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# *Human Factors Design Guidelines* for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO)

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16. Abstract

Significant advances in electronics and microcomputing during the past few decades have led to the feasibility of a functionally powerful, computer-based ATIS as part of the automotive environment. Although these systems range in functionality, they all have the goal of acquiring, analyzing, communicating, and presenting information to assist travelers in moving from a starting location to a desired destination. While systems under development or in production promise to improve travel safety, efficiency, and comfort, they represent a new frontier in ground transportation. This handbook is intended to address a growing information gap between the advanced and diverse status of automotive technologies such as ATIS devices, and the availability of human factors design criteria that can be used during the system design process. Specifically, while ATIS and CVO systems offer great potential benefits, their effectiveness depends on driver acceptance of the new technology, the ability of the systems to integrate the information with other driving tasks, and the extent to which the systems conform to driver physical and cognitive limitations and capabilities. The handbook summarizes human engineering data, guidelines, and principles for use by creative designers, engineers and human factors practitioners during the ATIS design process. These summaries take the form of design guidelines for 75 distinct ATIS design parameters. These design guidelines are intended to: (1) be concise, (2) be unambiguous, (3) be traceable to specific references, where applicable, and (4) highlight implications for driver performance, where appropriate.

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## FOREWORD

This report is one of a series of reports produced as part of a contract designed to develop precise, detailed human factors design guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO). The contractual effort consists of three phases: analytic, empirical, and integrative. This report is a product of the integrative phase. This handbook summarizes human engineering data, guidelines, and principles for use by creative designers, engineers and human factors practitioners during the ATIS design process. These summaries take the form of design guidelines for 75 distinct ATIS design parameters. These guidelines are intended to be used by anyone responsible for the conceptualization, development, design, testing, or evaluation of ATIS and CVO devices.

Copies of this report can be obtained through the Research and Technology Report Center, 9701 Philadelphia Court, Unit Q, Lanham, Maryland 20706, telephone: (301) 577-0818, fax: (301) 577-1421, or the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161, telephone: (703) 487-4650, fax: (703) 321-8547.

A. George Ostensen, Director
Office of Safety and Traffic
Operations Research and Development

## NOTICE

# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | **AREA** | | |
| in$^2$ | square inches | 645.2 | square millimeters | mm$^2$ |
| ft$^2$ | square feet | 0.093 | square meters | m$^2$ |
| yd$^2$ | square yards | 0.836 | square meters | m$^2$ |
| ac | acres | 0.405 | hectares | ha |
| mi$^2$ | square miles | 2.59 | square kilometers | km$^2$ |
| | | **VOLUME** | | |
| fl oz | fluid ounces | 29.57 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| ft$^3$ | cubic feet | 0.028 | cubic meters | m$^3$ |
| yd$^3$ | cubic yards | 0.765 | cubic meters | m$^3$ |

NOTE: Volumes greater than 1000 l shall be shown in m$^3$.

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **MASS** | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams (or "metric ton") | Mg (or "t") |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5(F-32)/9 or (F-32)/1.8 | Celcius temperature | °C |
| | | **ILLUMINATION** | | |
| fc | foot-candles | 10.76 | lux | lx |
| fl | foot-Lamberts | 3.426 | candela/m$^2$ | cd/m$^2$ |
| | | **FORCE and PRESSURE or STRESS** | | |
| lbf | poundforce | 4.45 | newtons | N |
| lbf/in$^2$ | poundforce per square inch | 6.89 | kilopascals | kPa |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | **AREA** | | |
| mm$^2$ | square millimeters | 0.0016 | square inches | in$^2$ |
| m$^2$ | square meters | 10.764 | square feet | ft$^2$ |
| m$^2$ | square meters | 1.195 | square yards | yd$^2$ |
| ha | hectares | 2.47 | acres | ac |
| km$^2$ | square kilometers | 0.386 | square miles | mi$^2$ |
| | | **VOLUME** | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| m$^3$ | cubic meters | 35.71 | cubic feet | ft$^3$ |
| m$^3$ | cubic meters | 1.307 | cubic yards | yd$^3$ |
| | | **MASS** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg (or "t") | megagrams (or "metric ton") | 1.103 | short tons (2000 lb) | T |
| | | **TEMPERATURE (exact)** | | |
| °C | Celcius temperature | 1.8C + 32 | Fahrenheit temperature | °F |
| | | **ILLUMINATION** | | |
| lx | lux | 0.0929 | foot-candles | fc |
| cd/m$^2$ | candela/m$^2$ | 0.2919 | foot-Lamberts | fl |
| | | **FORCE and PRESSURE or STRESS** | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | lbf/in$^2$ |

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

## ACKNOWLEDGMENTS

This Human Factors Design Guideline Handbook is the product of five years of analytical and empirical investigation into human factors design issues, research needs, and driver requirements for ATIS/CVO information. While only three authors are listed for this handbook, the conduct of the ATIS/CVO project, given its size, scope, and length, required considerable participation and support by a number of individuals.

In particular, the authors would like to express their sincere appreciation to Joe Moyer, our FHWA COTR, and to Dr. Tom Granda of FHWA (formerly of SAIC), for their assistance during this project. The invaluable guidance and advice that they provided on many technical and substantive matters associated with this effort were essential to the timely and successful completion of the project.

We also wish to thank the 40 designers and developers of ATIS/CVO devices who agreed to be interviewed as part of our User Requirements Analysis and to review the draft ATIS/CVO handbook. We are deeply indebted to this talented group for their time, expertise, and insights into their own ATIS/CVO design efforts, as well as their unique requirements for the content, organization, and format of this handbook.

We are also grateful for the direct assistance in the development of these guidelines provided by Dr. Michael McCauley and Tom Sharkey, of Monterey Technologies, Inc., and by Melissa Hulse and Dr. Tom Dingus (now at Virginia Polytechnic Institute) from the University of Iowa's Center for Computer Aided Design.

We would also like to thank our support staff, Sharon Groves and Mary Winter, for their hard work, patience, and resourcefulness during the development and production of the guidelines.

Finally, we offer our colleagues, Susan Kantowitz, Dr. John Lee, Sheila (Charlie) Garness, and Ozgur Simsek, our sincere thanks for their constructive comments and insightful suggestions during the development, review, and production of this handbook.

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# CHAPTER 1: HOW TO USE THESE DESIGN GUIDELINES

## INTRODUCTION

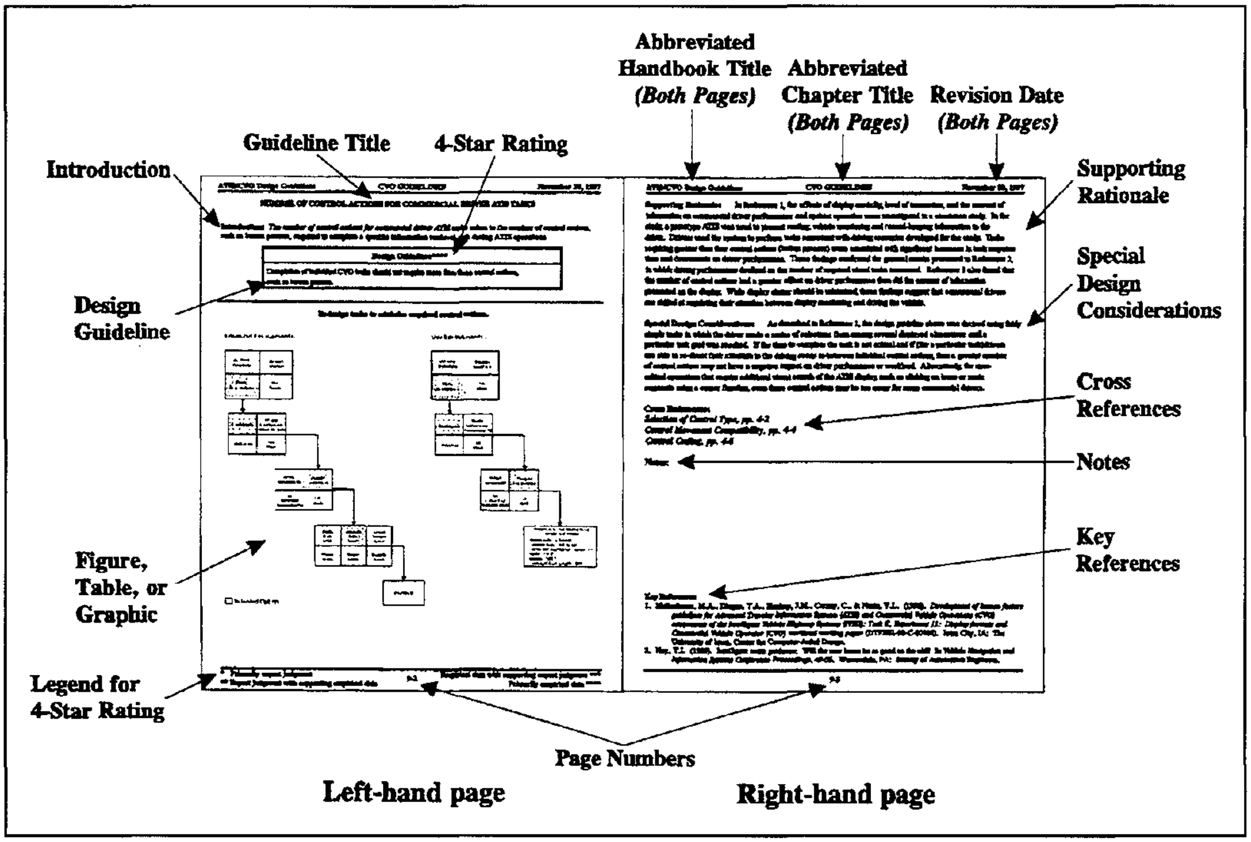
These guidelines are intended to be used by anyone responsible for the conceptualization, development, design, testing, or evaluation of Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) devices.

Chapter 2 provides an overview of ATIS and CVO and summarizes the subsystems and functions of ATIS/CVO devices. Chapters 3 through 9 contain the design guidelines produced through this effort. Chapter 3 provides general design guidelines for ATIS/CVO displays, and focuses on issues associated with symbol legibility, use of color, and display content for ATIS/CVO. Chapter 4 provides general design guidelines for ATIS/CVO controls, and focuses on the selection of control types, control design, and population stereotypes for control movement. Chapters 5 through 8 provide, respectively, the design guidelines for Routing and Navigation, Motorist Services, Safety/Warning, and Augmented Signage Information. While chapters 3 through 8 will be of value to all designers of ATIS/CVO devices, chapter 9 provides guidelines specific to CVO systems and functions. A set of Design Tools, useful for determining the sensory mode and trip status associated with individual ATIS/CVO messages, is provided in chapter 10.

This handbook can be used by individual designers in any number of ways. For example, it can be read through, from start to finish, if one desires an overview of human factors issues, principles, data sources, and guidelines associated with ATIS/CVO devices. Also, individual chapters can be reviewed by designers who would like to focus on specific ATIS functions, such as routing and navigation. Finally, designers may simply refer to specific guidelines, equations, terms, and references as their individual needs warrant. Thus, there is no "right" way to use this handbook—the day-to-day needs of the individual ATIS/CVO designer dictate how and when it should be used.

## THE TWO-PAGE FORMAT

In this handbook, a two-page format is used to present each design guideline. On each page, the ATIS/CVO function (e.g., Routing and Navigation, Safety/Warning, etc.) addressed by the guideline is indicated by centered, bold type within the header. As described in more detail below, the left-hand page presents the title of the guideline, an introduction and overview of the design guideline, the design guideline itself, the 4-star rating associated with the guideline, and a graphic, table, or figure that augments the text information. The right-hand page provides the more detailed supporting rationale for the design guideline that a designer may need in order to perform his or her day-to-day design tasks, as well as special design considerations, a space for designer notes, and a list of key references. A sample guideline, with key features highlighted, is shown in the following figure.




Sample Guideline

## THE LEFT-HAND PAGE

The guideline title is indicated by centered, bold type at the top of the left-hand page.

### Introduction

This subsection briefly defines the ATIS/CVO design guideline and provides basic information about the design parameter and the guideline. For example, this subsection might be used to provide the unit of measurement (e.g., visual angle, meters, footlamberts, etc.) for the guideline, or to provide equations for the derivation of certain parameters.

### Design Guideline

This subsection presents a quantitative design guideline (when possible), either as a point value, a range, or an explicit recommendation. The design guideline is always presented prominently and is enclosed in a yellow/blue box that is centered on the page.

In some cases, the design guideline is presented qualitatively in general terms; e.g., "Higher reliability levels may be required by drivers in a familiar setting than in an unfamiliar setting." However, in most cases, the design guideline is presented quantitatively; e.g., "Traffic information should be at least 70 percent reliable."

Importantly, the guidelines do not present requirements for ATIS/CVO devices, either for system content or design. However, if an ATIS/CVO device includes a function covered by these guidelines, then this handbook presents a summary of human factors design practice.

### The 4-Star Rating System

For some ATIS/CVO design parameters, there is enough empirical data to provide well-supported design guidelines, and the use of expert judgment is minimal. For others, empirical data has only provided the foundation for a decision about what the design guideline should be, but experience and judgment have been used to determine the final design guideline. For yet other topics, there was little or no empirical data available and the design guideline was based primarily on expert judgment.

To aid ATIS designers in making design trade-offs, individual design guidelines have been assigned a rating, using a "star rating" system, that corresponds to the relative contribution that empirical data and expert judgment have each made to the design guideline (Landau, Hanley, & Hein, 1998). Specifically, each design guideline has been assigned either 1, 2, 3, or 4 stars, using the following criteria:

**** Based on high quality and consistent data sources that apply directly to the guideline. Empirical data from highly relevant content domains (e.g., transportation human factors, navigation system design) were primarily used to develop this design guideline. Little expert judgment was required to develop this design guideline.

*** Based on high quality and generally applicable data sources with at least some consistency across the sources. Empirical data from related content domains (e.g., nuclear power, military systems) were primarily used to develop this design guideline. Expert judgment was used, mostly as support, to develop this design guideline.

** Based on limited empirical data; research findings may not all agree. Expert judgment was primarily used to develop this design guideline, although the empirical sources were used as secondary sources.

* Based primarily on expert judgment or design convention. Little or no empirical data were used to develop this design guideline.

Users of this handbook should be cautious as they interpret the 4-star ratings. Again, the ratings only refer to the relative contribution of expert judgment versus empirical data to the development of the guideline. Although the ratings are correlated with the quality or validity of the guidelines, users should not infer that a guideline with four stars is "better" or more valid than a guideline with one star—it simply has more empirical support. Furthermore, the relative importance of any particular guideline depends on the design situation and the designer's solution to trade-offs among system goals.

### Figure, Table, or Graphic

This subsection provides a figure, table, or graphic to augment the design guideline. This figure, table, or graphic provides "at-a-glance" information considered to be particularly important to the conceptualization and use of the design guideline. It serves to provide a visual representation of the design guideline (or some aspect of the design guideline) that may be difficult to grasp from the design guideline itself, which is quantitative and text-based.

This figure, table, or graphic might take many forms, including: a drawing depicting a generic application of a design guideline or a particular design issue, a flowchart of measurement procedures for the design guideline, a table that summarizes the design guideline, or graphics such as icons or in-vehicle signs.

Many of the figures in this handbook present digital maps depicting actual highways, landmarks, and city streets. Such figures are used in order to increase the usability and relevance of the guidelines and to illustrate general design principles. They are schematic examples for their associated guideline. Unless it is indicated otherwise, they are not intended to convey specific recommendations on the color, design, or format of ATIS displays.

## THE RIGHT-HAND PAGE

### Supporting Rationale

This subsection briefly summarizes the rationale behind the choice of the design guideline. In particular, the Supporting Rationale explains the logic, premises, assumptions, and the train-of-thought associated with the development of the design guideline. The Supporting Rationale can take many forms, including a brief review of applicable empirical studies, references to traditional design practice, or an analysis of relevant information.

The Supporting Rationale is presented primarily to help ATIS designers understand the design guideline and to help them explain or justify the design guideline to other members of the ATIS development team. Also, since these human factors design guidelines are expected to be revised as additional empirical data become available, this subsection will be useful to future developers of ATIS/CVO design guidelines. In particular, the Supporting Rationale will enable future design guideline developers to determine how new human factors information can (or should) be integrated into the existing design guidelines.

For example, the design guideline for daytime symbol contrast has been developed through consideration of expected "worst case" ambient luminance, anticipated driver populations, and contrast requirements under representative laboratory conditions. If new data for the "worst case" ambient luminance are obtained (or if new assumptions are made), future design guideline developers will be able to assess the role and relative importance of ambient luminance associated with the current design guideline for daytime symbol contrast and determine what (if any) changes should be made to the design guideline.

### Special Design Considerations

This subsection presents special design considerations associated with a particular design guideline. These special considerations might include design goals from the perspective of other disciplines (e.g., optics, packaging, displays), interactions with other ATIS/CVO design guidelines, cross references to other design guidelines, special difficulties associated with the guideline's conceptualization or measurement, or special human performance implications associated with the design guideline. This discussion is organized around specific issues considered important to the design of the ATIS.

### Cross References

This subsection lists the titles and page numbers of other guidelines within the handbook that are relevant to the current guideline.

### Notes

Where space is available, this subsection provides a convenient space for handbook users to record pecial notes, ideas, questions, etc., associated with a particular design guideline.

### Key References

This subsection lists the key references associated with the formulation of the ATIS/CVO design guideline. Each of these references will already have been noted within the text of the design guideline (e.g., as part of the discussion included in the Introduction, Supporting Rationale, or Special Design Considerations), and assigned a reference number. A complete reference section is provided in chapter 14 of this document.

## OTHER FEATURES

Within the text of the design guidelines, technical words and phrases are defined in the Glossary (chapter 12) and listed in the Index (chapter 20). Also, equations are numbered sequentially and listed separately in chapter 11 of this document.

Additional reference materials are also included. A General Human Factors Bibliography is provided in chapter 15. Publications that have been produced during this effort (i.e., project reports, journal articles, book chapters, and conference papers) are provided in chapter 16. Finally, relevant U.S. Department of Transportation (DOT) and Society of Automotive Engineers (SAE) documents are listed in chapter 17.

The Scope and Limitations for these guidelines are discussed in chapter 18. A brief description of the methods used to produce these guidelines is provided in chapter 19.

# CHAPTER 2: OVERVIEW OF THE ADVANCED TRAVELER INFORMATION SYSTEM (ATIS) SUBSYSTEMS AND FUNCTIONS

Components of the Intelligent Transportation System (ITS) are currently at various stages of research, development, and implementation. Numerous private firms are modifying products developed in Europe and Japan, or developing new systems to support their product development objectives. At the same time, the U.S. DOT is supporting research and development (R&D), system architecture development, operational tests, institutional and policy projects, and deployment projects through the national ITS program, as a means of stimulating the development of systems that will meet institutional and consumer objectives.

Two major areas of ITS development are ATIS and CVO. These types of systems will provide the primary means by which private and commercial vehicle drivers will interact with ITS. Thus, determination of the system characteristics that will enhance acceptance and usability of these systems is critical to the success of the ITS initiative. In recognition of this human factors challenge in developing ATIS and CVO systems, the Federal Highway Administration (FHWA) initiated the present project, which is being conducted to develop human factors guidelines for the design of ATIS and CVO systems. This project has addressed the impact of driver interfaces, information type, behavioral factors, and user demographics on the development of specific information subsystems.

## Overview of Advanced Traveler Information Systems.

| SUBSYSTEM | FUNCTIONAL CHARACTERISTICS |
|---|---|
| **Routing and Navigation** | Trip planning |
| | Multi-mode travel coordination and planning |
| | Predrive route and destination selection |
| | Dynamic route selection |
| | Route guidance |
| | Route navigation |
| | Automated toll collection |
| | CVO-specific (route scheduling) |
| **Motorist Services** | Broadcast services/attractions |
| | Services/Attractions directory |
| | Destination coordination |
| | Message transfer |
| **Safety/Warning** | Immediate hazard warning |
| | Road condition information |
| | Automatic aid request |
| | Manual aid request |
| | Vehicle condition monitoring |
| | CVO-specific (cargo and vehicle monitoring) |
| **Augmented Signage Information** | Roadway guidance sign information |
| | Roadway notification sign information |
| | Roadway regulatory sign information |
| | CVO-specific (road restriction information) |
| **Commercial Vehicle Operations (CVO)-Specific** | Fleet resource management |
| | Dispatch |
| | Regulatory administration |
| | Regulatory enforcement |

The above table summarizes the subsystems and functions associated with ATIS/CVO. More detailed summaries of each subsystem are provided below.

### Capabilities of Routing and Navigation Functions

Routing and Navigation Functions provide drivers with information about how to get from one place to another. When integrated with an Advanced Traffic Management System (ATMS), Routing and Navigation provides information on recurrent and nonrecurrent traffic congestion and is capable of calculating, selecting, and displaying optimum routes based on real-time traffic data. A sample of potential Routing and Navigation capabilities identified through interviews and a review of the literature is provided below. Basic capabilities of Routing and Navigation include:

- Providing drivers with route guidance information (how to get from one place to another).
- Providing drivers with navigation information (where they are in relation to their destination).
- Providing information on recurrent and nonrecurrent traffic congestion.
- Calculating, selecting, and displaying optimum routes based on real-time traffic data.

Some additional capabilities common among Routing and Navigation prototypes and emerging systems include:

- Turn-by-turn guidance (visual and voice displays).
- Notification of driver error.
- Recommended modifications inroute, due to traffic conditions or driver error.
- Selection of multiple-scale maps by the driver.

A number of variations of the basic capability to develop a route, including multiple destinations, have been cited in the literature. This capability has several applications for both private vehicles and CVO. Variations of this capability include:

- Planning a route for an extended vacation.
- Planning a route for a series of local deliveries.
- Planning a route for a business trip with several stops.

Several existing prototype and emerging Routing and Navigation technologies allow the driver to select from multiple criteria prior to the determination of a route to a destination. Some such criteria include fastest route, shortest route, route avoiding tollways, most scenic route, and route avoiding complex intersections.

Private industry representatives who have been involved in a recent Routing and Navigation technology development effort noted information that would be difficult to implement, but useful, including:

- Location of turn bays.
- Number of lanes.
- Exit numbers.
- Landmark information.
- Location of toll booths.
- Cost of tolls.

### Capabilities of Motorist Services Functions

Motorist Services Functions provide motorists with commercial logos and signing for motels, eating facilities, service stations, and other signing displayed inside the vehicle to direct motorists to recreational areas, historical sites, etc. Motorist Services Functions provide routing information for local destinations. A sample of specific Motorist Services capabilities identified through interviews and a review of the literature is provided below:

- Provides a source for a city's best hotels, restaurants, and just about all other vital services.
- Provides local routing information.
- Provides routing for any means of transportation—walking, driving, bus, train, and ferry.

Some have noted the value of having selection criteria available to aid the user in selecting restaurants, hotels, and other services. Restaurant selection criteria could include location, price range, type of food, and review rating. Hotel selection criteria could include location, price range, types of rooms, guest amenities, and review rating. A commonly discussed capability is that of being able to make reservations or purchases with a cellular phone link integrated with the Motorist Services device. Although Motorist Services Functions provide local routing information, closer integration with Routing and Navigation would provide additional capabilities by allowing selected services to be used as destinations in more sophisticated route guidance functions. Some means of integrating ATIS with public transit is desirable, and Motorist Services Functions provide an appropriate platform for this. Specific information that could be provided includes transit schedules, paratransit opportunities, costs, trip times, and dependable departure and arrival times.

### Capabilities of Safety/Warning Functions

Safety/Warning Functions provide warnings of unsafe conditions and situations affecting the driver on the roadway ahead. Safety/Warning Functions provide sufficient advance warning to permit the driver to take remedial action. Safety/Warning Functions provide messages related to relatively transient conditions, requiring modifications to the messages at irregular intervals. It should also be noted that mayday systems have been subsumed under Safety/Warning Functions for the purposes of the present discussion. Safety/Warning Functions do not encompass in-vehicle warnings of imminent danger requiring immediate action (e.g., collision avoidance devices). A sample of specific Safety/Warning Functions capabilities identified through interviews and a review of the literature is provided below. A basic capability of

Safety/Warning Functions is that they are not limited simply to warnings of conditions. Advisory messages could also include recommended actions. It is important to note that Safety/Warning Functions, like Augmented Signage Information, could have the capability of transmitting multiple messages, with only a subset of messages appropriate for any class of vehicles. This has particular value to CVO, where truck-specific warnings could be provided for the following:

- Steep downgrades.
- Tight ramps and intersections.
- Railroad-grade crossings with limited sight distances.

Some have noted that Safety/Warning Functions could provide the capability of dynamic speed limits, which could facilitate trip smoothness (dynamic speed limits are currently used in Germany). Some law enforcement officials foresee the capability of Safety/Warning transmitters being installed on rolling hazards, such as emergency vehicles and school buses, providing an additional mode for warning signals. They also recognize the value of having portable transmitters available for their use in case of accidents. Several documents discuss the potential for automatic mayday systems that would be triggered by unusual events, such as a rollover or extreme deceleration of the type that would trigger airbags. The capability of linking a mayday system with a Global Positioning System (GPS) was identified as advantageous by many in the ITS community. Safety/Warning technology could be integrated with ATMS, or a more limited system of sensors and data processing capabilities, to provide dynamic messaging based upon prevailing conditions. One brochure for a prototype system extends the capability of a Safety/Warning device to provide real-time congestion information.

### Capabilities of Augmented Signage Information Functions

Augmented Signage Information Functions provide noncommercial routing, warning, regulatory, and advisory information that is currently depicted on external roadway signs inside the vehicle. Augmented Signage Information Functions are distinguished from Safety/Warning Functions on the basis of the relative permanence of the information displayed by this system. A sample of specific Augmented Signage capabilities identified through interviews and a review of the literature is provided below.

The basic capability of Augmented Signage Information is to warn drivers of conditions requiring their attention, prior to the conditions being easily determined by the driver without such a warning. Some have noted the potential capability of providing information specific to the characteristics of a particular vehicle. Such information could include:

- Curve speed for specific vehicle sizes.
- Braking requirements for specific grades.
- Routing restrictions for specific vehicle cargoes.

Augmented Signage Information Functions could respond to a limited set of queries by the driver to repeat messages that were not initially comprehended or attended to by the driver. Displays could be provided in a manner that could reduce the time spent by the driver looking away from the roadway.

Augmented Signage Information Functions could provide more detailed instructions than are practical on roadway signs, and could display information reliably under adverse weather conditions. Augmented Signage Information displays could be optimized for use by elderly drivers, resulting in better information transfer than would be possible with external roadway signs. Specific capabilities would involve displays that could be better read at night and displays that avoid the problem of limited visual acuity.

### Capabilities Specific to CVO

CVO systems cover a broad spectrum of capabilities that have been identified to meet specific operational requirements. The scope of the present review has excluded crash avoidance systems, such as automatic clearance sensing. Following is a sample of CVO-specific system capabilities identified through interviews and a review of the literature.

Much of the technology being proposed for CVO-specific system development is currently available and implemented in limited degrees. This has allowed the transportation community an opportunity to become quite familiar with alternative capabilities. It has also resulted in a well-developed set of descriptions for these capabilities in the *Strategic Plan for Intelligent Vehicle- Highway Systems in the United States* (Intelligent Vehicle Highway Society of America, 1992). Because of the excellent, comprehensive nature of the strategic plan, it serves as the primary reference in the following discussion. Specific capabilities identified and described in that report are excerpted below:

- *Electronic Credentials (EC)* — would enable a motor carrier to electronically file for, obtain, and pay for all required licenses, registrations, and permits. An electronic record of the credential could be sent to the motor carrier's headquarters or other desired location.
- *Hazardous Material Information Systems* — could provide enforcement and incident management response teams with timely, accurate information on cargo contents, enabling them to react properly in emergency situations.
- *Automatic Vehicle Classification (AVC)* — employs EC technology to provide a readable, electronic record of vehicle type and contents.
- *Automated Vehicle Location (AVL)* — employs GPS, or other triangulation technologies, to provide real-time information regarding the location and status of vehicles.
- *Driver/Vehicle Real-time Safety Monitoring* — could include records of duty logs, medical qualifications data, and commercial driver's license information. Vehicle-related elements could include operational data and conditional information, such as status of brakes, lights, tires, and steering.
- *Electronic Log Book* — could replace the manual trip log typically prepared by the motor carrier. The fuel tax rates for each state and the number of vehicle-miles traveled within each state could be recorded electronically if electronic beacons were provided at all site boundaries.
- *Automated Vehicle Classification/Identification (AVC/AVI)* — would allow uninterrupted movement of the vehicle through inspection or weighing stations.

- *Weigh in Motion (WIM)* — allows motor carriers equipped with special transponders to proceed on the highway at normal speeds through instrumented weigh stations as their weight is electronically inspected by in-pavement scales and readers.
- *Automated (Electronic) Toll Collection* — would apply the same technologies as those used in automated credential checking.
- *Two-Way Real-Time Communications (TWC)* — would provide ATIS and ATMS information concerning congestion, incidents, and optimum routing to drivers or dispatchers.
- *Advanced Fleet Management* — uses advanced vehicle routing algorithms that collect real- time congestion information to balance routes and loads, and predict travel times.

# CHAPTER 3: GENERAL GUIDELINES FOR ADVANCED TRAVELER INFORMATION SYSTEM (ATIS) DISPLAYS

This chapter provides human factors design guidelines relevant to the displays associated with ATIS devices. ATIS displays represent the primary method used to communicate ATIS messages to the drivers, and, therefore, their design is important to the overall usability and acceptance of ATIS devices. The following design topics are included in this chapter:

## ■ SYMBOLS



## ■ COLORS



## ■ GENERAL

# SYMBOL CONTRAST

**Introduction:** Symbol contrast refers to the relationship between the luminance of a symbol and the luminance of the symbol's background. Contrast requirements have not been empirically studied under a wide range of representative driving situations and conditions, and there are few empirical data that can be directly used to specify design guidelines for the symbol contrast of automotive ATIS displays.

Here, we define contrast as a ratio between maximum and minimum luminance values, or: *(Eq. 1)*

$$\text{Contrast ratio} = \frac{\text{Luminance}_{max}}{\text{Luminance}_{min}}$$

where:

$\text{Luminance}_{max}$ = luminance emitted by the area or element of greatest intensity.
$\text{Luminance}_{min}$ = luminance emitted by the area or element of least intensity.

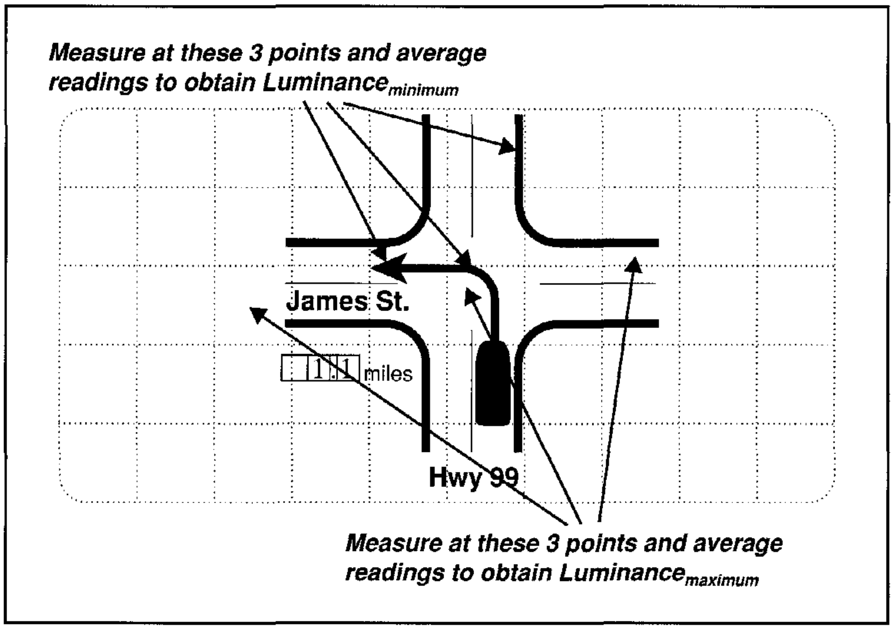
**Design Guidelines****

3:1 Minimum symbol contrast
7:1 Preferred symbol contrast

## Example of Measuring Contrast

*The figure below may be used to aid contrast measurements.*

*NOTE: The spot size of the photometer used to take luminance measurements must be small enough to fit inside the ATIS display elements to be measured.*



**Supporting Rationale:** Contrast requirements can vary greatly as a function of display medium (e.g., electronic display vs. hardcopy), viewing environment (e.g., low vs. high glare), and user characteristics (e.g., young vs. older drivers). Most human factors reference sources that provide contrast recommendations do not address the effects of these, and other, variables on contrast requirements. Reference 1 describes a series of studies investigating the legibility of displays, and concludes that contrast ratios of 10:1 to 18:1 are required for Visual Display Terminal (VDT) displays. Reference 2 indicates that a contrast ratio of 10:1 has become "a generally accepted industrial standard for display design." Reference 3 suggests that a contrast ratio of 7:1 is preferred, but that 3:1 is required; the guidelines given here reflect the recommendations in Reference 3. However, other data sources suggest that far less contrast may be adequate.

*Daytime.* An ambient background luminance of 2500 fL. is considered to be a representative "worst case" background luminance for daytime driving (see Reference 4). Reference 5 indicates that symbol contrast of 1.2:1 is sufficient for young military pilots. In Reference 6, contrast requirements for both younger and older subjects were investigated under laboratory conditions. The data from Reference 6 indicate that 1.4:1 contrast may be sufficient for older drivers under those conditions.

*Nighttime.* Reference 7 indicates that with a background luminance of 0.01 fL., older individuals (e.g., approximately 55 years and older) will require 2:1 contrast and that with a background luminance of 10 fL., older individuals will require 1.6:1 contrast. In Reference 8, contrast requirements for both younger and older subjects were investigated under low luminance laboratory conditions. The data obtained in Reference 8 indicated that 2:1 contrast is required for older drivers under low luminance conditions; in this study, adequate legibility was not obtained at contrast levels below 2:1 (i.e., 1.25:1).

**Special Design Considerations:** The contrast ratios provided above will lead to adequate ATIS legibility as long as other design parameters, such as symbol height and luminance, are sufficient.

**Cross References:**
*Symbol Height, p. 3-4*
*Symbol Font, p. 3-8*

**Notes:**

**Key References:**
1. Shurtleff, D. A. (1980). *How to make displays legible.* La Mirada, CA: Human Interface Design.
2. Smith, M. J., & Cohen, W. J. (1997). Chapter 50: Design of computer terminal workstations. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (pp. 1637-1688). New York: J. Wiley & Sons.
3. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
4. Schaeffer, M. S. (1989). *Luminance control requirements for head-up and instrument panel displays* (Report Number 89-27-07/G7696-002). Culver City, CA: Hughes Aircraft Company.
5. MIL-D-87213A. (1986). *Military specification displays, airborne, electronically/optically generated.* Washington, DC: U.S. Government Printing Office.
6. Blackwell, O. M., & Blackwell, H. R. (1971). Visual performance data for 156 normal observers of various ages. *Journal of the Illuminating Engineering Society,* pp. 3-13.
7. Schaeffer, M. S. (1987). *Hologram luminance study* (HAC IDC Ref. No. 061187.MSS). El Segundo, CA: Hughes Aircraft Company.
8. Mourant, R. R., & Langolf, G. D. (1976). Luminance specifications for automobile instrument panels. *Human Factors, 18*(1), pp. 71-84.

# SYMBOL HEIGHT

Introduction: Symbol height refers to the vertical distance between the top and bottom edges of an unaccented letter or number. Since ATIS devices can be used at a broad range of display distances, symbol height is best defined and specified as the visual angle subtended by the symbology (at the driver's eye) in minutes of arc.

| | Use These Formulas for Calculating These Unknowns | | |
|---|---|---|---|
| **If Known** | **Visual Angle** | **Symbol Height** | **Distance** |
| **Distance and Symbol Height** | $\text{Arc Tan}\left(\frac{\text{Symbol Height}}{\text{Distance}}\right)$ *(Eq. 2)* | — | — |
| **Distance and Visual Angle** | — | Distance x (Tangent (Visual Angle)) *(Eq. 3)* | — |
| **Visual Angle and Symbol Height** | — | — | $\frac{\text{Symbol Height}}{\text{Tangent (Visual Angle)}}$ *(Eq. 4)* |

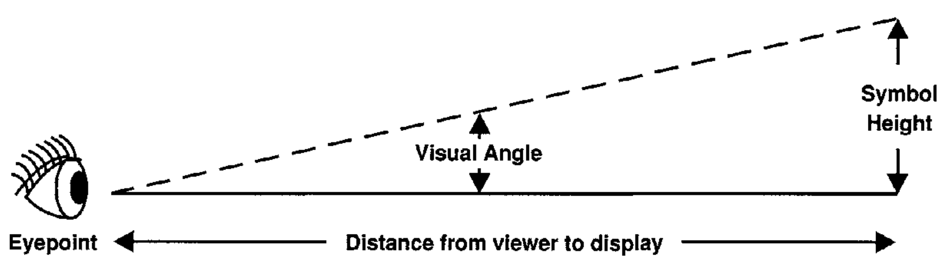
where:

Symbol Height = the height of the symbology
Distance = distance from viewer's eyepoint to the display
Visual Angle = angle in degrees
Height and Distance use the same unit of measure

**Design Guidelines****

Titles and other key elements = .50 degrees or 30 arcmin., minimum
Dynamic or critical elements = .33 degrees or 20 arcmin., minimum
Static or noncritical elements = .266 degrees or 16 arcmin., minimum

**Relationship Between Viewing Distance, Symbol Height, and Visual Angle**



**Supporting Rationale:** The design guidelines for other ATIS elements are consistent with the legibility requirements suggested by standard human factors reference sources (e.g., References 1 and 2). They are also supported by the empirical data obtained in References 3, 4, and 5. Briefly, these three studies were intended to investigate symbol height requirements as a function of various levels of symbol contrast and symbol luminance. Considered as a whole, the data from these studies indicate: (1) that symbols should subtend at least 20 arcminutes if they are associated with dynamic or critical display elements; (2) that legibility begins to decrease with symbol heights of less than about 18 arcminutes; and (3) that designers should avoid using symbols that subtend less than 16 arcminutes.

**Special Design Considerations:** *Driver Age.* Older drivers generally have poorer visual acuity than do younger drivers. Thus, the design guidelines specified above assume that, all other factors being equal, design objectives for symbol height that meet the legibility needs of older drivers will always meet the legibility needs of younger drivers. These design guidelines have been developed to meet the needs of older drivers.

**Cross References:**
*Symbol Contrast, p. 3-2*
*Symbol Font, p. 3-8*

**Notes:**

**Key References:**
1. Shurtleff, D. A. (1978). *Legibility criteria in display design, selection, and evaluation.* Unpublished technical document.
2. *American National Standards Institute. (1988). American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
3. Mourant, R. R., & Langolf, G. D. (1976). Luminance specifications for automobile instrument panels. *Human Factors,* 18(1), pp. 71-84.
4. Howell, W. C., & Kraft, C. L. (1959). *Size, blur, and contrast as variables affecting the legibility of alpha-numeric symbols on radar-type displays* (WADC Technical Report 59-536). Wright-Patterson Air Force Base, OH: Wright Air Development Center (DTIC No. AD-232 889).
5. Giddings, B. J. (1972). Alpha-numerics for raster displays. *Ergonomics,* 15(1), pp. 65-72.

# SYMBOL LUMINANCE UNIFORMITY

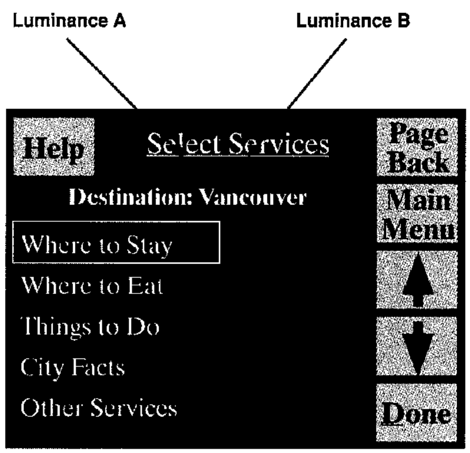
**Introduction:** *Symbol luminance uniformity* refers to the consistency of luminance values across a display.

**Design Guidelines*****

Provide no more than 33% Element Uniformity (within an individual element or segment).

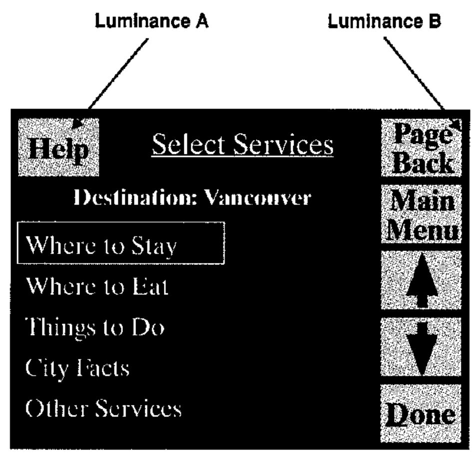
Provide no more than 50% Display Uniformity (across the entire field of view (FOV) of the display).

## Measuring Luminance Uniformity




**Measuring segment or element uniformity**

Within a segment or element of the ATIS display, measure at two locations using a photometer with a spot size small enough to fit inside the segment or element.




**Measuring whole display uniformity**

Within two areas of the ATIS display, measure at two locations using a photometer

$$\%\ \text{Element Uniformity} = \frac{|(\text{Luminance}_{min}) - (\text{Luminance}_{max})|}{(\text{Luminance}_{max})} \quad (Eq.\ 5)$$

$$\%\ \text{Display Uniformity} = \frac{|(\text{Luminance}_{min}) - (\text{Luminance}_{max})|}{(\text{Luminance}_{max})} \quad (Eq.\ 6)$$

where: $\text{Luminance}_{min}$ = the smaller luminance value
$\text{Luminance}_{max}$ = the greater luminance value

**Supporting Rationale:** *Threshold Luminance Discrimination Data.* Although observers in Reference 1 could discriminate lights that differed in luminance by as little as 10 percent, these data were obtained when they were trying to detect a luminance difference between a background and a target under ideal laboratory conditions (see Reference 2 also). Thus, 10 percent represents a threshold luminance discrimination value and is far too conservative for ATIS use, in which the issue of concern is the driver's ability to notice luminance differences under normal driving or normal viewing conditions.

*Tolerance for Luminance Variations.* Reference 3 indicates that luminance in cathode ray tubes (CRTs) typically varies by as much as 37 percent and is either not noticed or is considered to be acceptable by observers. Reference 4 recommends that luminance variations remain below 50 percent. Reference 5 indicates that while the preferred limit for luminance variation across optical projection displays is 33 percent, an unacceptable limit is 66 percent.

*Conclusions.* The design objectives provided above reflect a composite of the information provided by References 3, 4, and 5. Specifically, if luminance differences up to 37 percent are not always noticed by observers and if 33 percent represents a preferred limit, then 33 percent seems to be an acceptable limit for small-area luminance nonuniformities (i.e., within an individual element or segment). Both 50 percent and 66 percent have been suggested as upper limits on luminance nonuniformities. The 50 percent value has been selected as the maximum luminance nonuniformity across the entire FOV, in an effort to be conservative.

**Special Design Considerations:** Causes. Luminance nonuniformities are generally caused by the display itself. In vacuum fluorescent displays (VFDs) being viewed directly, for example, these might be caused by poor phosphor distribution on the inside of the anodes, or by fluctuations in the power supply output. In a head-up display (HUD), however, deficiencies in one or more of the optical elements (e.g., nonuniform reflective properties) can also lead to nonuniformities in perceived luminance.

*Consequences.* Moderate nonuniformities in luminance may only lead to the perception, by the driver, that the display is of poor quality. With great nonuniformities in luminance, however, drivers may not be provided with sufficient luminance and contrast to ensure adequate legibility in certain areas of the display.

*Subjective Measurement.* In operational terms, luminance uniformity refers to the concept of looking at a particular location on a display, looking at another location, and then deciding if the two locations seemed equally bright. More precise measurement procedures are described in the key references.

**Cross References:** None.

**Notes:**

**Key References:**

1. Mueller, C. G. (1951). Frequency of seeing functions for intensity discrimination at various levels of adapting intensity. *Journal of General Psychology,* 34, pp. 463-474.
2. Boff, K. R., Kaufman, L., & Thomas, J. P. (1986). *Handbook of perception and human performance.* New York: J. Wiley & Sons.
3. Farrell, R. J., & Booth, J. M. (1984). *Design handbook for imagery interpretation equipment.* Seattle, WA: Boeing Aerospace Company.
4. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
5. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.

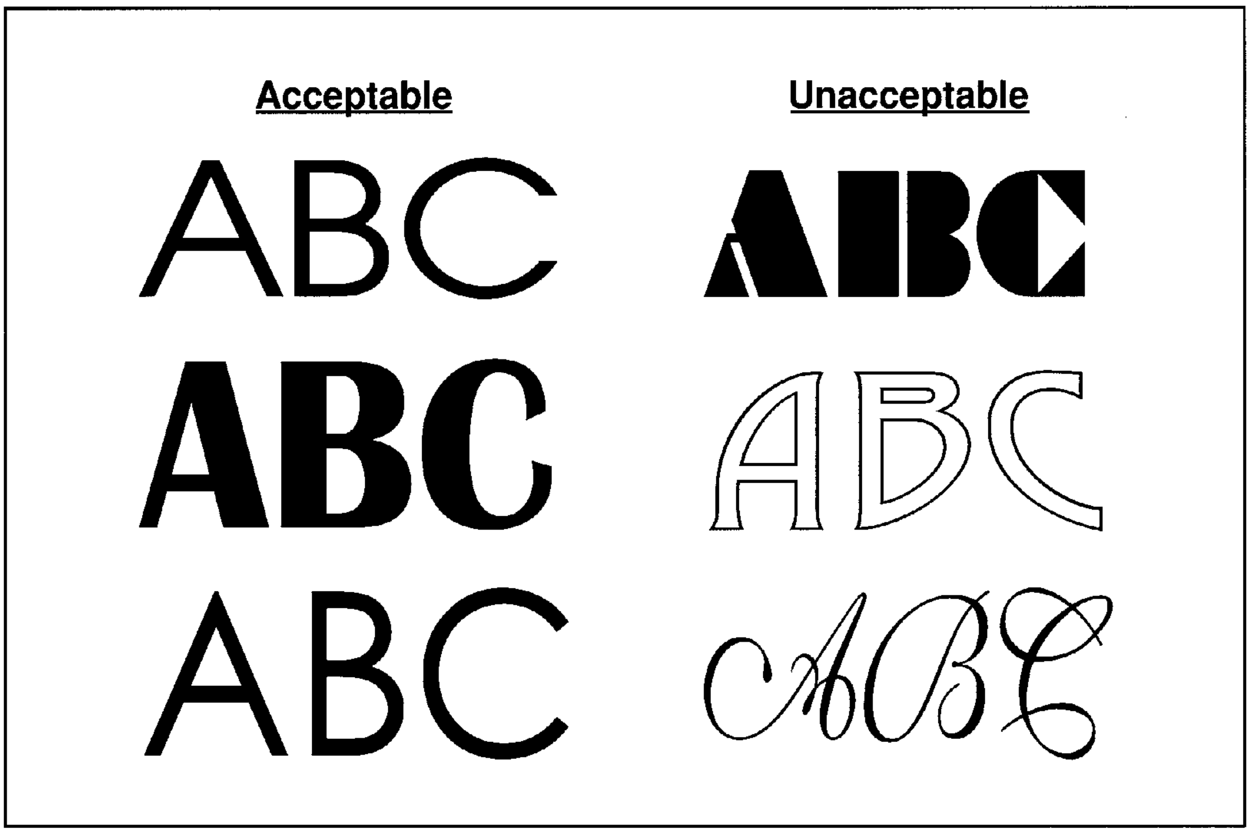
## SYMBOL FONT

**Introduction**: *Symbol font* refers to the geometrical characteristics or style of symbology (Reference 1). Design goal for symbol font is to avoid extensive flourishes and embellishments of the symbols.

### Design Guidelines***

- Provide a clear and simple font. Examples include Hazeltine, Leroy, Lincoln-mitre, Huddleston, and many Modern Gothic fonts, among others.
- For dot-matrix display elements, a 5 x 7 matrix size may be used to display static or noncritical alphanumerics; a 7 x 9 matrix size should be used to display dynamic or critical properties (matrix sizes should be consistent within a single display).
- For segmented display elements, a 7-segment pattern may be used to display numerals; for complete alphanumeric sets, either a 14- or 16-segment pattern may be used.

**Examples of Acceptable and Unacceptable Fonts**



**Supporting Rationale:** *General Font Type.* Most conventional fonts that are clear and simple will be legible as long as other symbol parameters, such as character size and contrast, are adequate. The design objective above is consistent with those provided for military applications (References 2 and 3) and with those provided by standard human factors references sources (References 3, 4, and 5).

*Dot-Matrix Display Elements.* Empirical studies (e.g., References 6 and 7) indicate essentially no legibility differences between dot-matrix sizes for character heights greater than about 22 arcminutes. However, for smaller characters, References 8 and 9 indicate that a 7 x 9 matrix will lead to faster recognition time and fewer reading errors than a 5 x 7 matrix. Reference 5 indicates that a 5 x 7 matrix should only be used for numeric and uppercase presentations, and that a 7 x 9 matrix should be used for continuous reading or when individual alphabetic character legibility is important. On the whole, the literature supports the recommendation that a 7 x 9 matrix size should be used to display dynamic or critical alphanumerics.

*Segmented Elements.* There are no published empirical data that describe the relationship between the number of character segments and legibility. Common design practice indicates that a 7-segment pattern will be sufficient to assure legibility of numeric characters.

**Special Design Considerations:** *Font Generation Techniques.* There is a relationship between symbol font and the technique used to generate or construct the characters on a display. Three techniques are primarily used on electronic displays: stroke, dot-matrix, and segmented techniques. The stroke technique produces characters as whole continuous units, not as composites of dots or lines; it is used primarily on printed or silk-screen displays. The dot-matrix technique uses individual points of light (dots or pixels) to generate symbols; it is used primarily in raster, or matrix-addressable, systems. Dot-matrix characters are typically described by their size (e.g., 5 x 7, 7 x 9, or 9 x 11), as well as by their font. In the segmented technique, characters are formed by illuminating discrete segments within a basic symbol pattern. The majority of electronic displays using this technique employ 7-segment patterns to generate numerals (e.g., digital speedometers and clocks); however, 14-segment and 16-segment patterns are also available for the generation of complete alphanumeric sets.

**Cross References:**
*Symbol Contrast, p. 3-2*
*Symbol Height, p. 3-4*

**Key References:**
1. Decker, J. J., Pigion, R. D., & Snyder, H. L. (1987). *A literature review and experimental plan for research on the display of information on matrix-addressable displays.* Blacksburg, VA: Human Engineering Laboratory, VPI & SU.
2. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.
3. Heglin, H. J. (1973). *NAVSHIPS display illumination guide: II. Human factors* (NELC/TD223). San Diego, CA: Naval Electronics Laboratory Center.
4. Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design (5th ed.).* New York: McGraw-Hill.
5. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
6. Shurtleff, D. A. (1970). *Studies of display symbol legibility, XXI: The relative legibility of symbols formed from matrices of dots* (ESD-TR-69-423). Hanscom, MA: Electronic Systems Division, Air Force Systems Command (DTIC No. AD 702 491).
7. Vanderkolk, R. J., Herman, J. A., & Hershberger, M. L. (1975). *Dot matrix display symbology study.* Culver City, CA: Hughes Aircraft Company.
8. Vartabedian, A. G. (1970). Effects of parameters of symbol formation on legibility. *Information Display,* pp. 23- 26.
9. Snyder, H. L. & Maddox, M. E. (1978). *Information transfer from computer-generated, dot-matrix displays* (Technical Report HFL-78-3). Blacksburg, VA: Human Engineering Laboratory, VPI & SU.

# SYMBOL WIDTH-TO-HEIGHT RATIO

**Introduction:** *Symbol width-to-height ratio* refers to the ratio of the width to the height of the symbology.

Design Goals:

(1) Provide adequate symbol width-to-height ratios so that 95 percent of drivers can comfortably and quickly read the ATIS symbology 95 percent of the time.

(2) To the extent possible, provide a wider symbol (up to a 1:1 ratio) as the criticality of the display information increases (e.g., hazard warnings).

(3) To the extent possible, provide a wider symbol (up to a 1:1 ratio) as the number of alternate cues to legibility (e.g., consistent position, color) decreases.

(4) To the extent possible, provide a wider symbol (up to a 1:1 ratio) for dynamic symbology (e.g., next turn) than for static symbology (e.g., legends).

## Design Guidelines***

0.6:1 – 1:1 (width:height)

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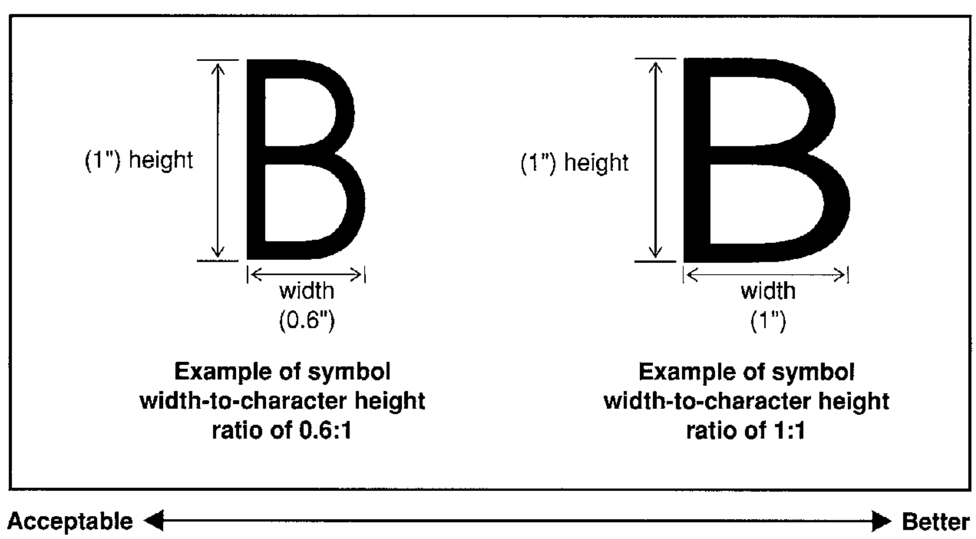
## Examples of Recommended Symbol Width-to-Height Ratios



**Supporting Rationale:** The design guideline above is consistent with the requirements for symbol width-to-height ratio suggested by standard human factors reference sources (e.g., see References 1, 2, and 3). Reference 2 indicates that while a symbol width-to-height ratio of 1:1 is best supported by empirical data, a symbol width-to-height ratio of 0.6:1 can be used without serious loss in legibility.

**Special Design Considerations:** *Relative Importance of Symbol Width-to-Height Ratio.* The standard human factors reference sources do not discuss symbol width-to-height ratio in great detail and do not reference empirical data sources associated with this symbol variable. Compared to character height, contrast, and luminance, symbol width-to-height ratio will generally be a less critical ATIS design parameter. Nonetheless, it can have an impact on ATIS legibility, particularly under conditions in which the more critical design parameters (i.e., character height, contrast, or luminance) do not meet the specified guidelines. Symbol width-to-height ratio may also increase in importance when such issues as the criticality of the displayed information, the availability of alternate cues to legibility, and the nature of the information (e.g., dynamic vs. static) are taken into account.

**Cross References:**
*Symbol Strokewidth-to-Height Ratio, p. 3-12*
*Symbol Spacing, p. 3-14*

**Notes:**

**Key References:**
1. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.
2. Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design (5th ed.).* New York: McGraw-Hill.
3. Farrell, R. J., & Booth, J. M. (1984). *Design handbook for imagery interpretation equipment.* Seattle, WA: Boeing Aerospace Company.

# SYMBOL STROKEWIDTH-TO-HEIGHT RATIO

**Introduction:** *Symbol strokewidth-to-height ratio* refers to the ratio of the symbol stroke thickness to symbol height.

Design Goals:

(1) Provide adequate symbol strokewidth-to-height ratios so that 95 percent of drivers can comfortably and quickly read the ATIS symbology 95 percent of the time.

(2) To the extent possible, provide a lower ratio (down to a 1:6 ratio) as the criticality of the display information increases (e.g., hazard warnings are more critical than street names).

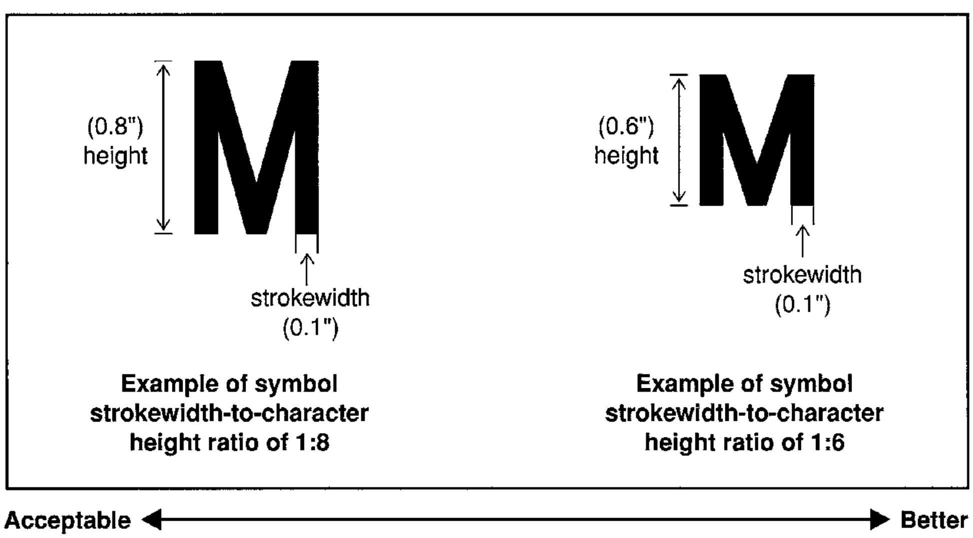
(3) To the extent possible, provide a lower ratio (down to a 1:6 ratio) as the number of alternate cues to legibility (e.g., consistent position, color) decreases.

(4) To the extent possible, provide a lower ratio (down to a 1:6 ratio) for dynamic symbology (e.g., next turn) than for static symbology (e.g., legends).

## Design Guidelines***

1:8 – 1:6 (strokewidth:height)

### Examples of Recommended Symbol Strokewidth-to-Height Ratios



**Supporting Rationale:** These design objectives are consistent with the legibility requirements suggested by the standard human factors reference sources (e.g., see References 1, 2, and 3).

**Special Design Considerations:** *Relative Importance of Strokewidth-to-Height Ratio on Legibility.* The standard human factors reference sources do not discuss strokewidth-to-height ratio in great detail and do not reference empirical data sources associated with this symbol variable. Reference 1 indicates that the symbol strokewidth-to-height ratio is not an important determinant of legibility as long as symbol height, contrast, and luminance are adequate. Nonetheless, it can have an impact on ATIS legibility, particularly under conditions in which the more critical design parameters (i.e., character height, contrast, or luminance) do not meet the specified objectives. Symbol strokewidth-to-height ratio may also become more critical when such issues as the criticality of the displayed information, the availability of alternate cues to legibility, and the nature of the information (e.g., dynamic vs. static) are taken into account.

In general, optimum ratios for black symbols on a white background are lower than those for white symbols on a black background, due to a phenomenon called "irradiation." Irradiation occurs when white features appear to "spread" into adjacent black areas, but not the reverse (Reference 4). Reference 4 also notes that highly illuminated displays and/or dark adaptation of the observer accentuate the irradiation effect. Reference 4 recommends strokewidth-to-height ratios for black on white symbols of 1:6 - 1:8 and ratios for white on black symbols of 1:8 – 1:10.

**Cross References:**
*Symbol Width-to-Height Ratio, p. 3-10*
*Symbol Spacing, p. 3-14*

**Notes:**

**Key References:**
1. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
2. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.
3. Woodson, D. E., & Conover, D. W. (1964). *Human engineering guide for equipment designers.* Berkeley, CA: University of California Press.
4. Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design (5th ed.)* New York: McGraw-Hill.

# SYMBOL SPACING

**Introduction:** *Symbol spacing* refers to the horizontal space between adjacent characters on a display. Symbol spacing is often expressed as the ratio of space-between-characters to symbol-height (space-to-symbol-height ratio).

Design Goals for Symbol Spacing:

(1) Provide adequate symbol space-to-height ratios so that 95 percent of drivers can comfortably and quickly read the ATIS symbology 95 percent of the time.

(2) To the extent possible, provide wider spacing (up to a 0.25:1 ratio) as the criticality of the display information increases (e.g., hazard warnings).

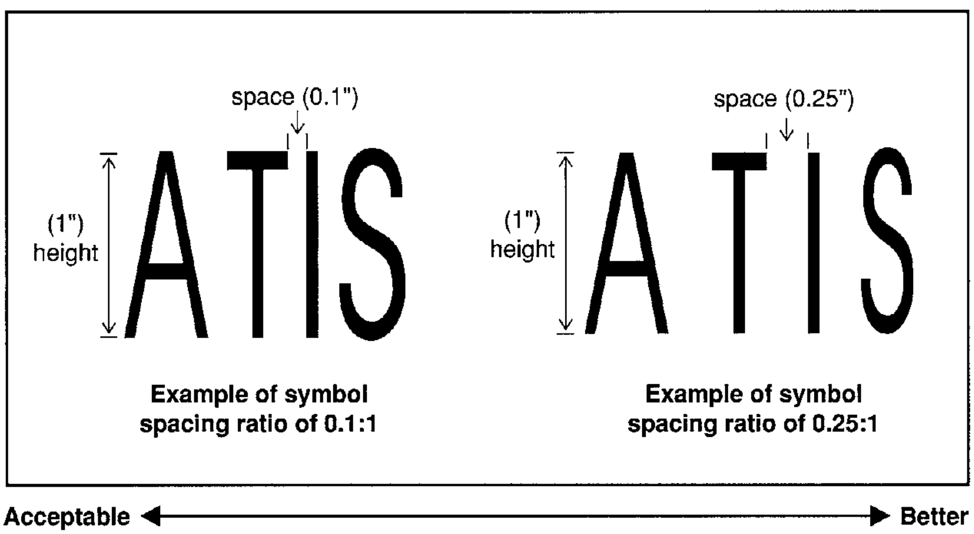
(3) To the extent possible, provide wider spacing (up to a 0.25:1 ratio) as the number of alternate cues to legibility (e.g., consistent position, color) decreases.

(4) To the extent possible, provide wider spacing (up to a 0.25:1 ratio) for dynamic symbology (e.g., next turn) than for static symbology (e.g., legends).

**Design Guidelines*****

0.1:1 – 0.25:1 (space:height)

### Examples of Recommended Symbol Spacing



**Supporting Rationale:** The legibility data described in Reference 1 indicates that space-to-symbol-height ratios of 0.1:1 are adequate for direct viewing of most displays. Recommendations for larger spacing (up to 0.25:1) reflect data obtained under "suboptimal" conditions (see also References 2 and 3); such conditions might be representative of reduced contrast conditions or of older drivers with reduced visual acuity.

**Special Design Considerations:** *Relative Importance of Symbol Spacing.* The standard human factors reference sources do not discuss symbol spacing in great detail and do not reference empirical data sources associated with this symbol variable. Compared to character height, contrast, and luminance, symbol space-to-height ratio will generally be a less critical ATIS design parameter. Nonetheless, it can have an impact on ATIS legibility, particularly under conditions in which the more critical design parameters (i.e., character height, contrast, or luminance) do not meet the specified guidelines. Symbol spacing may also increase in importance when such issues as the criticality of the displayed information, the availability of alternate cues to legibility, and the nature of the information (e.g., dynamic vs. static) are taken into account.

**Cross References:**
*Symbol Width-to-Height Ratio, p. 3-10*
*Symbol Strokewidth-to-Height Ratio, p. 3-12*

**Notes:**

**Key References:**
1. Crook, M. N., Hanson, J. A., & Weisz, A. (1954). *Legibility of type as determined by the combined effects of typographical variables and reflectance of background* (Report No. WADC T-53-0440). Wright-Patterson Air Force Base, OH: Wright Air Development Center (DTIC No. AD-043309).
2. Meister, D. (1984). *Human engineering data base for design and selection of cathode ray tube and other display systems* (NPRDC TR 84-51). San Diego, CA: Navy Personnel Research and Development Center (DTIC No. AD-A145704).
3. Boff, K. R., & Lincoln, J. E. (Eds.). (1988). *Engineering data compendium: Human perception and performance.* Wright-Patterson Air Force Base, OH: Armstrong Aerospace Medical Research Laboratory.

## SYMBOL COLOR

**Introduction:** Our perception of *color* is derived from variations in the wavelength or spectral composition of light. Color perception can be described in terms of three psychological dimensions: hue, saturation, and brightness. Hue is related to the dominant wavelength of the stimulus, saturation is somewhat more loosely related to the spectral bandwidth of the stimulus, and brightness is related to the luminance of the stimulus.

### Design Guidelines**

- Any reasonably visible color may be used for ATIS symbols, as long as recommendations for symbol height, contrast, and luminance are adhered to.
- Highly saturated blue (i.e., approximately 450 nanometers) should be avoided.
- When used as a coding device, population stereotypes for color should be adhered to; i.e., use green for "O.K." conditions, yellow for "caution" conditions, and red for "hazard" conditions.
- If colored lines are shown against a colored background, the color contrast between the elements should be a minimum of 100 E (CIE Yu'v') distances.

### Examples of Standard Uses of Color

| Green is often used for information such as: | Yellow is often used for information such as: | Red is often used for information such as: |
|---|---|---|
| O.K. | caution | cancel |
| accept | wait | hazard |
| proceed | | stop |
| | | delete |



As seen in the examples above, legibility of symbol colors depends on background color. For example, on a white background, yellow symbols may be illegible, and on a black background, blue symbols may be illegible. Legibility is a function of both the symbol and its background.

**Supporting Rationale:** Despite well-established differences in visual sensitivity as a function of color (wavelength), there is no consistent, empirical evidence that color has a meaningful effect on legibility (References 1, 2, and 3), and, in principle, any reasonably visible color may be used, as long as recommendations for symbol height and contrast are adhered to. It is recommended that a highly saturated blue be avoided because the central fovea is relatively insensitive to highly saturated blue (References 4 and 5); highly saturated blue has also been associated with "disruptions in accommodation" (Reference 6).

**Special Design Considerations:** *Typical Use of Color.* Most human factors reference sources discuss color as a coding device (e.g., green = "O.K."; yellow = "caution"; red = "hazard"). This use of color is not applicable to the issue of the color's effect on symbol legibility for ATIS devices.

**Cross References:**

*Symbol Contrast, p. 3-2*
*Symbol Height, p. 3-4*
*Symbol Luminance Uniformity, p. 3-6*
*Selection of Colors for Coding Visual Displays, p. 3-18*
*Use of Color Coding, p. 3-20*
*Color Contrast, p. 3-22*
*Color Coding of Traffic Flow Information, p. 5-6*

**Notes:**

**Key References:**

1. Reynolds, H. N. (1971). The visual effects of exposure to electroluminescent lighting. *Human Factors,* 13(1), pp. 29-40.
2. Post, D. L. (1985). Effects of color on CRT symbol legibility. *Society for Information Display 1985 Digest*, pp. 196-199.
3. Christ, R. E. (1975). Review and analysis of color coding research for visual displays. *Human Factors,* 17(6), pp. 542-570.
4. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
5. Murch, G. M. (1987). Visual perception basics. *Society for Information Display Seminar Lecture Notes, 1,* pp. 2-1 - 2-36.
6. Donohoo, D. T., & Snyder, H. L. (1985). Accommodation during color contrast. *Digest of the Society for Information Display,* pp. 200-203.

# SELECTION OF COLORS FOR CODING VISUAL DISPLAYS

**Introduction:** *Selection of colors for coding visual displays* refers to the use of different colors either to bring information to the attention of a driver, or to aid the driver in distinguishing between items on a display. Color coding may be used to make absolute or relative discriminations, and should be used in a way that is redundant with other coding dimensions (e.g., shape, size, brightness).

## Design Guidelines***

When either absolute or relative discriminations are required, the following Commission Internationale de l'Eclairage (CIE) color set should be used to achieve maximum discrimination.

### Recommended CIE Color Set for Maximum Discrimination

| | SATURATED SET | | DESATURATED SET | |
|---|---|---|---|---|
| COLOR NAME | U' | V' | U' | V' |
| RED | 0.4161 | 0.5285 | 0.3819 | 0.5112 |
| GREEN | 0.1206 | 0.5613 | 0.1462 | 0.5546 |
| BLUE | 0.1724 | 0.1681 | 0.1594 | 0.2679 |
| ORANGE | 0.3347 | 0.5119 | 0.2794 | 0.4998 |
| YELLOW | 0.2023 | 0.5204 | 0.2023 | 0.5204 |
| LIGHT BLUE | 0.1590 | 0.3052 | 0.1600 | 0.3800 |
| PINK | 0.2595 | 0.3079 | 0.2500 | 0.3700 |
| WHITE | 0.1978 | 0.4684 | 0.1978 | 0.4684 |

**Supporting Rationale:** A set of seven colors (plus white) that are maximally discriminable has been identified (Reference 1). Reference 1 also identified a more subdued set of colors that are highly discriminable. The names of the colors and the CIE 1976 Uniform Chromaticity-Scale (UCS) units for both the saturated and desaturated color sets are given above. Either of these color sets is suitable for use in situations where absolute or relative discriminations are required. Research has shown that color coding reduces both the time required to make discriminations and the number of errors, particularly on dense displays (Reference 2). Analysis of an in-vehicle navigation system showed that differences in traffic congestion were more easily discriminated when color coded than when coded using varying line widths (Reference 3). Reference 3 also found that color coding of the recommended route was considered helpful by drivers when using other, comparable systems. Additionally, they report that color coding is useful to distinguish between portions of a route already completed and the portion remaining to the destination.

**Special Design Considerations:** (1) Approximately 8 percent of the population, mostly males, does not have normal color vision, and color deficient vision does not disqualify an individual from driving. Therefore, when critical information must be presented to drivers, color coding should be redundant with other coding (e.g., shape coding). (2) The ability to perceive and distinguish colors is mediated by the cones in the retina. Therefore, the ability to discriminate colors is reduced in twilight and full nighttime conditions compared to daytime conditions. In the guidelines above, both saturated and desaturated color sets are provided, to reflect different approaches that ATIS designers might take regarding the use of color.

**Cross References:**
*Symbol Color, p. 3-16*
*Use of Color Coding, p. 3-20*
*Color Contrast, p. 3-22*
*Color Coding of Traffic Flow Information, p. 5-6*

**Notes:**

**Key References:**
1. Boff, K. R., & Lincoln, J. E. (Eds.). (1988). *Engineering data compendium: Human perception and performance.* Wright-Patterson Air Force Base, OH: Armstrong Aerospace Medical Research Laboratory.
2. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).
3. Hennessy, R. T., Hutchins, C. W., & Cicinelli, J. G. (1990). *Color requirements for the E-2C enhanced main display unit (EMDU)* (Final Report No. N00019-89-C-0174). Washington, DC: Naval Air Systems Command.

# USE OF COLOR CODING

**Introduction:** *Color coding* refers to the use of chromaticity to differentially identify items in a display systematically. The categories used to color code objects on a display depend upon the tasks required of the operators.

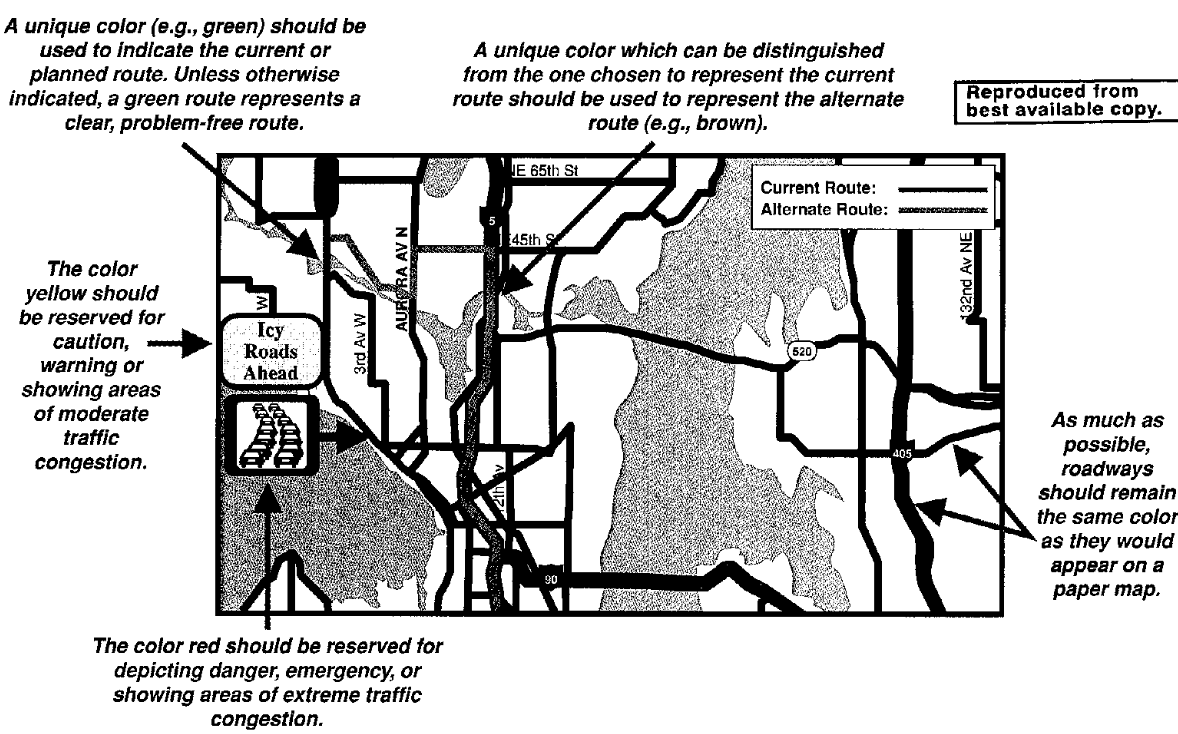
## Design Guidelines****

Design Guidelines for the use of color include:

- The number of colors used to code information should be kept to a minimum, not to exceed 4 colors for casual users and 7 colors for experienced, long term ATIS/CVO users.
- Do not violate population expectations regarding use of color. Several examples of population stereotypes are:
  - Red: indicates Stop, Warning, System Operating Out of Tolerance
  - Yellow: indicates Caution
  - Green: indicates Go Ahead, System Operating Within Tolerance
- Color codes should be applied consistently throughout the system; colors should have the same meaning on each screen that the system can display.
- As the number of colors used is increased, the size of color coded objects should be increased.
- Use compatible color combinations when colors are presented simultaneously. Avoid red/green, blue/yellow, green/blue, and red/blue pairs unless an attempt is being made to make different parts of the screen appear in different planes.

### Schematic Example of the Use of Color Coding






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** These guidelines represent a collection of guidelines from the human factors literature as presented in References 1-4.

**Special Design Considerations:** (1) Approximately 8 percent of the population, mostly males, does not have normal color vision, and color deficient vision does not disqualify an individual from driving. The most common deficiency is an inability to distinguish between red and green. Therefore, when critical information must be presented to drivers, color coding should be redundant with other coding (e.g., shape coding). (2) The ability to discriminate colors is reduced in twilight and full nighttime conditions compared to daytime conditions.

**Cross References:**

*Symbol Color, p. 3-16*
*Selection of Colors for Coding Visual Displays, p. 3-18*
*Color Contrast, p. 3-22*
*Color Coding of Traffic Flow Information, p. 5-6*

**Notes:**

**Key References:**

1. Durrett, H. J. (1987). *Color and the computer.* San Diego, CA: Academic Press.
2. Hennessy, R. T., Hutchins, C. W., & Cicinelli, J. G. (1990). *Color requirements for the E-2C enhanced main display unit (EMDU)* (Final Report, Contract No. N00019-89-C-0174). Washington, DC: Naval Air Systems Command.
3. Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design (5th ed.).* New York: McGraw-Hill.
4. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.

## COLOR CONTRAST

**Introduction:** *Color contrast* refers to the relationship between symbol and background associated with chromatic differences such as hue and saturation. Determining the amount of contrast provided to the driver becomes a more complex problem when the symbology and/or the background are colored.

**Design Guidelines*****

Colored symbols should differ from their colored backgrounds by a minimum of 100 ΔE (CIE Yu'v') distances.

---

### Equation for Determining Color Contrast

$$\Delta E(\text{CIE Yu' v'}) = \left[\left(155\left(\frac{\Delta Y}{Ym}\right)\right)^2 + (367\ \Delta u')^2 + (167\ \Delta v')^2\right]^{0.5} \qquad \textit{(Eq. 7)}$$

where

ΔE (CIE Yu' v') = the color contrast metric

ΔY = difference in luminance between text (symbology) and background

Ym = the maximum luminance of text (symbology) or background

Δu' = difference between u' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below)

Δv' = difference between v' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below)

NOTE: The constants 155, 367, and 167 in equation 7 are empirically derived weights (Reference 1).

NOTE: Reference 1 states, *"The discriminability of pairs of colors depends on their differences in chrominance and luminance. While an entirely satisfactory metric does not exist which combines these attributes into a single assessment of total color difference, an estimate can be derived by calculating the weighted difference between the locations of the colors in the 1976 CIE UCS (CIE UCS L*u*v*)."*

> *"Note that this estimate should be used only to ensure discriminability of colors of relatively high luminance. Severe nonlinearities in the UCS limit the usefulness of this metric for colors having small luminance differences. In addition, the specification of small color differences should be treated with caution due to the inherent lack of color uniformity on most* CRTs."

**Supporting Rationale:** The interested reader is referred to Reference 2 or Reference 1 for a review of both color contrast issues and the research that has been done in this area (see also References 3 and 4). In brief, color contrast research has been aimed at developing a measure of color contrast that can be related to human visual functioning. Such research has attempted to develop a UCS (i.e., one in which equal distances on a color diagram correspond to equal perceptions regarding color differences, where the color difference within a UCS is used to indicate the magnitude of color contrast). The measure of color contrast (or difference) is then correlated with human performance (Reference 2). Reference 1 has provided a metric for determining symbol colors to maximize legibility for symbols of relatively high luminance. This metric, ΔE (CIE Yu'v'), which is shown in the figure, is derived from the 1976 CIE UCS color diagram (CIE UCS). Although the metric does not combine the different attributes of color into a single assessment of total color difference, it provides a useful estimate of color contrast.

Reference 1 indicates that for legibility of colored symbols on a colored background (with relatively high luminance conditions), the colors should differ by a minimum of 100ΔE (CIE Yu'v') distances. If the formula is applied to figures and background that differ negligibly in u' and v', this value corresponds to approximately 80 percent luminance contrast, which is rather high in comparison with traditional contrast recommendations. Specific applications may be able to use less than 100ΔE (CIE Yu'v') distances.

**Special Design Considerations:** Although ΔE (CIE Yu'v') provides a seemingly adequate measure of color contrast, it is clear that much more research is needed in this area before specific recommendations regarding color contrast can be made for automotive applications. Reference 2 notes that different experimental tasks as well as different response measures need to be investigated.

Color contrast is a sufficiently difficult concept when applied to fixed-color, fixed-background displays; it becomes more complex when applied to displays such as automotive HUDs. With HUDs, the background for the symbology is dynamic and can be almost any color; background luminance can range from a fraction of a footlambert to 6,000 or more footlamberts, depending on conditions. In addition, the symbology is translucent, which means that both the background color and luminance combine with the symbology's color and luminance in an additive fashion. Color contrast, therefore, is not a very meaningful parameter when applied to head-up displays.

**Cross References:**

*Symbol Color, p. 3-16*
*Selection of Colors for Coding Visual Displays, p. 3-18*
*Use of Color Coding, p. 3-20*
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*Color Coding of Traffic Flow Information, p. 5-6*

**Key References:**

1. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
2. Decker, J. J., Pigion, R. D., & Snyder, H. L. (1987). *A literature review and experimental plan for research on the display of information on matrix-addressable displays.* Blacksburg, VA: Human Engineering Laboratory, VPI & SU.
3. Post, D. L., Costanza, E. B., & Lippert, T. M. (1982). Expressions of color contrast as equivalent achromatic contrast. *Proceedings of the Human Factors and Ergonomics Society 26th Annual Meeting,* (pp. 581-585). Santa Monica, CA: Human Factors and Ergonomics Society.
4. Post, D. L., & Snyder, H. L. (1986). *Color contrast metrics for complex images.* Blacksburg, VA: Human Factors Laboratory, VPI & SU (DTIC No. AD-A174960).

## SENSORY MODALITY FOR PRESENTING ATIS/CVO MESSAGES

**Introduction:** *Sensory modality for presenting ATIS/CVO messages* refers to the display modality most appropriate for presenting in-vehicle information to the driver. Almost all the literature on this topic suggests that operator performance can be improved by combining auditory and visual messages. These channels should be used together to provide either redundant or complimentary cues to the driver whenever possible. However, it is also important to know the advantages and disadvantages of using each of these modalities independent of one another, so that when designers are faced with a choice, they can choose the modality that facilitates driver decision making and performance.

### Design Guidelines***

| Information Characteristic | Sensory Modality |
|---|---|
| High Complexity | Visual |
| Low Complexity | Auditory |
| High Priority | Auditory |
| Low Priority | Visual |
| Intermittent Display | Auditory |
| Continuous Display | Visual |
| Requested Presentation | Auditory (Unless complex, then visual) |
| Automatic Presentation | Visual (Unless high priority, then auditory) |

### Heuristics for Assessing Complexity and Priority

**Complexity** is a function of how much information is being provided and how difficult it is to process. The phrase "information units" is used to describe the amount of information presented, in terms of key nouns and adjectives contained within a message. The design guideline entitled "Auditory Message Length" on page 3-26 provides a tool for determining the number of information units.

| High Complexity | Low Complexity |
|---|---|
| > 9 information units | 3-5 information units |
| Processing time > 5 s | Processing time < 5 s |
| Examples: topographical representations of a route, or full route maps, or schedules for alternate modes of transportation | Examples: directions of turns, or estimates of travel costs |

**Priority** is a function of the urgency of a response and the consequences of failing to make a response.

| High Priority | Low Priority |
|---|---|
| Fast response needed (0-5 minutes) | No response needed (5 min +) |
| Serious consequences (death or injury) | No immediate consequences |
| Examples: notification of serious traffic conditions which may affect the safety of the driver, or mechanical problems which could impact the safety of the driver or the condition of the vehicle | Examples: vehicle maintenance schedules, or weather information |

**Supporting Rationale:** Reference 1 found that drivers can process complex information faster through the visual channel than through the auditory channel, especially when pictures can be used instead of words. When presenting information aurally, an attempt should be made to make it simple so that it does not exceed the capabilities of working memory—7 to 9 information units (see also Reference 2).

Information to be presented continuously is best presented visually so that it does not become a nuisance to the driver. Continuous auditory information could very well be perceived as chattering and nagging, or could overwhelm the driver with too much information. On the other hand, information presented intermittently is best presented aurally so that the driver is made aware of its presentation.

According to Reference 3, when information is requested, it should be presented through the modality that is most appropriate for its complexity so that the driver can most easily understand and utilize the information. However, when information is presented automatically to the driver, the information should be presented visually unless it is of an urgent nature. In cases such as this, the information should be presented aurally so that it is sure to capture the attention of the driver regardless of where the driver is looking.

Similarly, information that is considered high priority or that requires a very quick response from the driver should be presented through the modality which commands the drivers attention the fastest—the auditory mode. Any other information that can be considered advisory or purely informative (without being requested) can best be presented in the visual mode, which will not distract the driver from the main task of driving.

**Special Design Considerations:** Reference 3 suggests that these are general guidelines to be followed. However, each information element should be considered individually in order to ensure the most appropriate sensory modality for presentation. Another very important issue to consider is whether or not the driver needs the information while the vehicle is in-transit, or if receiving the information predrive would be sufficient. Knowing this could cause the designer to come to a very different conclusion regarding the most appropriate display modality.

In Reference 4, a driving simulator was used to study the benefits of multimodal displays (both auditory and visual). The multimodal displays were associated with better driving performance than auditory-only or visual-only displays, as well as better performance on a navigation task. Both the multimodal and auditory-only displays were associated with better emergency responses than the visual-only display.

**Cross References:**

*Auditory Message Length, p. 3-26*
*Complexity of ATIS Information, p. 3-28*
*Modality of ATIS Information for CVO, p. 9-30*

**Key References:**

1. Deatherage, B. H. (1972). Auditory and other sensory forms of information presentation. In H. Van Cott & R. Kinkade (Eds.), *Human engineering guide to equipment design* (Rev. ed.), (pp. 123-160). Washington, DC: U.S. Government Printing Office.
2. Labiale, G. (1990). In-car road information: Comparison of auditory and visual presentation. *Proceedings of the Human Factors and Ergonomics Society 34th Annual Meeting,* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
3. Mollenhauer, M. A., Dingus, T. A., & Hulse, M. C. (1995). Recommendations for sensory mode selection for ATIS displays. *Proceedings of the Institute of Transportation Engineers 65th Annual Meeting: A Compendium of Technical Papers.* Washington, DC: Institute of Transportation Engineers.
4. Liu, Y., & Dingus, T. A. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Human factors evaluation of the effectiveness of multi-modality displays in advanced traveler information systems.* Washington, DC: Federal Highway Administration (FHWA-RD-150).

## AUDITORY MESSAGE LENGTH

**Introduction:** *Auditory message length* refers to the number of syllables, words, or sentences necessary for presenting auditory information to the driver. Depending on the type of information being presented, different message lengths are acceptable.

### Design Guidelines***

- Messages that require an urgent action should be a single word or a short sentence with the fewest number of syllables possible. Drivers should be able to understand the message immediately.
- Messages that are not urgent or for which a response may be delayed can be a maximum of 7 units of information in the fewest number of words possible. If the information cannot be presented in a short sentence, the most important information should be presented at the beginning and/or the end of the message.
- Navigation instructions should be limited to 3 or 4 information units.

### Determining the Number of Information Units

| | |
|---|---|
| **4 units** | Road Construction Ahead at Jaspertown |
| **8 units** | Road Construction on Interstate 5 for next 10 miles<br>Take Highway 99 |
| **11 units** | Interstate 80 closed for construction between Iowa City and Cedar Rapids<br>Exit at West Liberty and drive north on Highway 16 |
| **16 units** | Accident Ahead<br>Exit #215 closed to Dover<br>Traffic detoured to Exit #216<br>Follow Highway 46 to Chester and turn east onto Inglenook Road |

### Examples of Auditory Messages

| Suggested | Not Suggested |
|---|---|
| "Accident ahead, merge right." | "Accident ahead in the left lane, merge right as soon as possible." |
| "Oil change needed by July 1, 1997." | "Vehicle maintenance log shows that vehicle oil change is due and should be completed by July 1, 1997." |
| "Turn right in 1/2 mile." | "At the next stoplight, turn right onto Stark Lane in 1/2 mile." |

**Supporting Rationale:** The longer the message, the more processing time required by the driver. Therefore, messages that require the driver to make an immediate response should be as short as possible. One-word messages informing the driver of the appropriate action to take might work best in situations such as these. As the response required by the driver becomes less and less urgent, the messages can become more detailed. However, an effort should still be made to make the messages as concise as possible.

**Special Design Considerations:** When presenting messages that do not require immediate action, Reference 1 suggests several things for helping the driver use the information: (1) Present the information in the order of importance or relevance to the driver; (2) Present the most important information at either the beginning or the end of the message because it is easiest to recall; (3) Highlight the most important parts of the message; (4) Provide a means for repeating the message—this is especially helpful for older drivers; and (5) Provide a redundant visual presentation of the information—this is also helpful for older drivers.

**Cross References:**

*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*ATIS Design for Special Populations, p. 3-38*

**Notes:**

**Key References:**

1. Ross, T., Midtland, K., Fuchs, M., Pauzie, A., Engert, A., Duncan, B., Vaughan, G., Vernet, M., Peters, H., Burnett, G., & May, A. (1996). *HARDIE design guidelines handbook: Human factors guidelines for information presentation by ATT systems* (DRIVE II Project V2008).

# COMPLEXITY OF ATIS INFORMATION

**Introduction:** The *complexity of ATIS information* refers to the number of information units being presented during written or textual in-vehicle road messages. In this context, an information unit can describe geography (e.g., city), type of roadway (e.g., highway), event causes (e.g., stalled vehicle), event consequences (e.g., traffic jam), time and distances, and proposed actions. Therefore, information units can be described as the relevant words in a message.

## Design Guidelines****

- Text messages presented when the vehicle is in motion should be no longer than 4 information units, in order to minimize the eyes-off-road time.
- Many text messages are best presented while the vehicle is stationary. In these cases, 6-8 information units are optimal.

### Determining the Number of Information Units

| | |
|---|---|
| **4 units** | Road Construction Ahead at Jaspertown |
| **8 units** | Road Construction on Interstate 5 for next 10 miles<br>Take Highway 99 |
| **11 units** | Interstate 80 closed for construction between Iowa City and Cedar Rapids<br>Exit at West Liberty and drive north on Highway 16 |
| **16 units** | Accident Ahead<br>Exit #215 closed to Dover<br>Traffic detoured to Exit #216<br>Follow Highway 46 to Chester and turn east onto Inglenook Road |

### The Effects of Information Complexity (from Reference 2).

| Length of Message | 3-4 units | 6-8 units | 10-12 units | 14-18 units |
|---|---|---|---|---|
| Duration of Glance | 1.08 s | 1.18 s | 1.20 s | 1.35 s |
| Number of Glances | 3.8 | 6.9 | 9.6 | 15.5 |
| Memory Recall | 100% | 97.5% | 75.4% | 52.4% |

**Supporting Rationale:** Reference 1 analyzed the number of lane deviations that occurred while operating a CRT touch screen. The results suggest that the number of glances away from the roadway be limited to 3 and that glance durations which exceeded 2 seconds in duration are unacceptable. Reference 1 examined the amount/complexity of information necessary for evoking these unsafe glance frequencies and durations. The results of this on-road study suggest that although the duration of glances does not increase dramatically as the number of information units increase, the number of glances does. Therefore, the shortest information message (3-4 units) would be the most appropriate for keeping drivers' attention on the forward roadway. The driver's ability to recall information was also examined in Reference 2. Only 75 percent of a 10-12 unit message could be recalled, in comparison to 100 percent of a 3-4 unit message and 98 percent of a 6-8 unit message. This finding is consistent with Reference 3, which proposed that the maximum capacity of working memory is "seven, plus or minus two" chunks of information. Again, this finding suggests that keeping the message short, 3-8 information units, would increase the likelihood that it will be recalled by the driver.

**Special Design Considerations:** According to Reference 4, both glance durations and glance frequencies increase with age, due to the deterioration of vision and slowing of cognitive processes. Older people also experience many more problems associated with retention, as studies have shown that increasing the difficulty of memory-related tasks will affect the performance of older subjects more than younger subjects (see Reference 5). Therefore, making messages shorter and simpler will help to improve performance, particularly for older drivers. Reference 6 suggests increasing the display time of messages or providing a "repeat last message" function so that drivers could pace themselves. In this way, older drivers would be able to call up information at the rate that they are comfortable receiving it, thus reducing excessive glances to the screen.

**Cross References:**

*Auditory Message Length, p. 3-26*
*ATIS Design for Special Populations, p. 3-38*
*Presentation of General Trip Planning Information, p. 5-10*
*Presentation of Roadway Information, p. 5-12*
*Presentation of Point of Interest Information, p. 5-14*
*Presentation of Travel Coordination Information, p. 5-18*
*Presentation of Route and Destination Selection Information, p. 5-22*
*Presentation of Dynamic Route Selection Information, p. 5-24*

**Key References:**

1. Zwhalen, H. T., Adams, C. C., Jr., & DeBald, D. P. (1988). Safety aspects of CRT touch panel controls in automobiles. In A. G. Gale et al. (Eds.), *Vision in vehicles, 2,* (pp. 335-344). Amsterdam: Elsevier Science.
2. Labiale, G. (1996). Complexity of in-car visual messages and driver's performance. In A. G. Gale et al. (Eds.), *Vision in vehicles, 5,* (pp. 187-194). Bron Cedex, France: INRETS.
3. Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review,* 63, 81-97.
4. Wierwille, W. W., Hulse, M. C., Fischer, T. J., & Dingus, T. A. (1988). Strategic use of visual resources by the driver while navigating with an in-car navigation display system. *XXII FISITA Congress Technical Papers: Automotive Systems Technology: The Future, 2,* (pp. 2.661-2.675). Warrendale, PA: Society of Automotive Engineers.
5. Salthouse, T. A. (1982). *Adult cognition: An experimental psychology of human aging.* New York: Springer- Verlag.
6. Graham, R., & Mitchell, V. A. (1997). An evaluation of the ability of drivers to assimilate and retain in-vehicle traffic messages. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 185-201). Mahwah, NJ: Lawrence Erlbaum Associates.

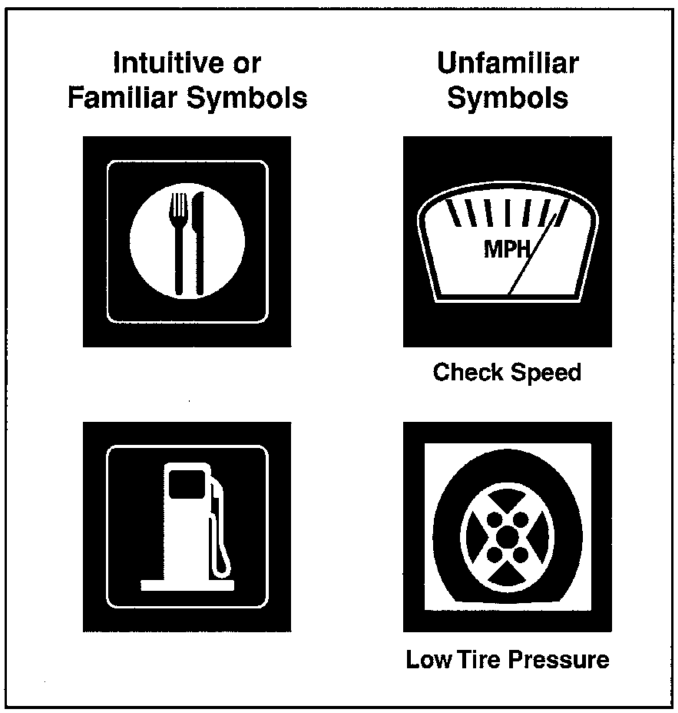
## SYMBOL VERSUS TEXT PRESENTATION OF ATIS/CVO MESSAGES

**Introduction:** *Symbol versus text presentation of ATIS/CVO messages* refers to the style and format of in-vehicle visual messages. A key ATIS/CVO design issue is presenting information to the driver so that it is not distracting and is easily understood. Symbols or icons are increasingly used in the design of electronic devices under the assumption that they are preferable to text (e.g., "a picture is worth a thousand words"). However, if drivers are unfamiliar with the symbol or if the symbol is not intuitive, it may be less effective than a corresponding text message when used in an ATIS/CVO device.

### Design Guidelines**

- Symbols that are familiar or intuitive can be used without accompanying text labels.
- Unfamiliar or nonintuitive symbols should be accompanied by a text label.

**Two Examples of Intuitive or Familiar Symbols (Without Text Label), Two Examples of Symbols That Should Have a Text Label**



**Supporting Rationale:** Reference 1 investigated drivers' memory for traffic and traveler-related messages presented on an ATIS using a medium fidelity driving simulator. A range of messages from the Augmented Signage, Motorist Services, and Safety/Warning functions of ATIS were presented to subjects, using both symbol and text presentation modes. Both low and high comprehension symbols, as well as long and short text messages, were examined. (Lists of the symbols used in the study are included in Reference 1.) Reaction time to the messages and message comprehension were measured. Except for very low comprehension symbols (i.e., unfamiliar or nonintuitive), performance was similar for symbol and text message formats; these data confirmed research conducted in Reference 2.

The empirical data regarding the use of symbols versus text are mixed, reflecting different empirical approaches, different types of messages, and the specific types of symbols used across empirical studies. For example, while Reference 2 found similar performance for symbols and text, Reference 3, an on-the-road study, found that drivers react faster to symbols than to text, particularly under visually degraded conditions.

**Special Design Considerations:** ATIS designers should choose symbols that are easily comprehended by both younger and older drivers. Older drivers tend to have lower comprehension levels than younger drivers for automotive symbols, perhaps due to their greater experience, familiarity, and level of comfort with text-based messages.

Familiarity and intuitiveness are key attributes associated with comprehension levels for symbols. Driver familiarity with a symbol is based on usage and experience and cannot be provided (directly) by the ATIS designer. However, designers can influence the intuitiveness of a symbol by selecting symbols that are clear and have a direct, obvious link with their associated system operation. For example, a symbol of a trash can that is used to erase or discard files is a highly intuitive symbol used in computer systems. In ATIS/CVO design, however, driver operations or system messages are often highly complex, and developing an "intuitive" symbol is not straightforward. In general, new symbols should be tested and evaluated prior to their introduction into ATIS/CVO devices, in order to maximize driver comprehension.

**Cross References:** None.

**Notes:**

**Key References:**

1. Kantowitz, B. H., Hanowski, R. J., Kantowitz, S. C., & Garness, S. A. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Display channels.* Washington, DC: Federal Highway Administration (FHWA-RD-96-148).
2. Hawkins, H. E., Womack, K. N., & Mounce, J. M. (1993). *Driver comprehension of warning signs.* Paper presented at the 72nd Annual Meeting of the Transportation Research Board. Washington, DC.
3. Ellis, J., & Dewar, T. (1979). Rapid comprehension of verbal and symbolic traffic sign messages. *Human Factors,* 21, pp. 161-168.

# MESSAGE STYLES

**Introduction:** *Message style* refers to the way in which information is given to the driver. The information can be presented in an advisory manner ("command style") or in more of a descriptive manner ("notification style"). *Command style messages* inform drivers of a situation and suggest a particular action to take in response to a situation. *Notification style messages* simply inform drivers and allow them to determine the appropriate action on their own.

## Design Guidelines****

- Command style messages promote compliance and should therefore be used for presenting safety-critical information that requires an immediate response.
- Command style messages should be used infrequently, because they may cause drivers to over-rely on information given to them in-vehicle and to become complacent about searching the outside environment for out-of-vehicle information.
- Notification style messages should be used for presenting low criticality information.

### Decision Aid for Determining When to Use Each Message Style

**Is the situation critical?**

| Is an immediate control action necessary? | No | Yes |
|---|---|---|
| No | Notification Style Message | Notification Style Message |
| Yes | Notification Style Message | Command Style Message |

"Immediate" is defied as an incident or condition which occures within "X" meters of the vehicle's current position, where:

$$X = (\text{Speed (in km/h)} \times 1.637) + 14.799 \quad \textit{(Eq. 8)}$$

### Examples of Each of the Different Message Styles

| | |
|---|---|
| **Command Style** | "Slow Down"<br>"Move into the Right Lane" |
| **Notification Style** | "Vehicle Ahead"<br>"Accident Ahead, 1/2 mile" |

**Supporting Rationale:** In Reference 1, message style was investigated in order to determine its effect on driver compliance with warnings and driver safety. Results of the study indicate that the importance of the message should determine the message style to be used. For highly critical messages, command style should be used in order to increase the level of compliance. For less critical messages, notification style should be used, to ensure that the driver remains actively involved in the driving task. The urgency associated with making some type of control action should also be considered when determining the message style to be used. If the need for a control action is immediate and critical to the safety of the driver, then a command style message should be given. If, however, the need is not immediate or the control action is not necessary for the safety of the driver, then a notification style message would be more appropriate. In these cases, an "immediate" control action is defined as one which would occur after the preferred minimum distance for presenting information.

Reference 2 investigated the findings of Reference 1 in an on-the-road study. Again, high compliance was found for the command messages as compared to the notification messages.

**Special Design Considerations:** A study conducted in Reference 3 determined that including a combination of descriptive and advisory components in messages promotes the driver's situation awareness and decreases the amount of time necessary for making decisions. According to this study, increasing the amount of time necessary for reading the combined message was compensated by a decrease in the decision making time.

Reference 1 found that providing drivers with only roadside information does not generate very high driver compliance, while providing drivers with only ATIS information increases driver compliance but decreases safety. However, providing ATIS as well as roadside information was found to generate high driver compliance without the decrease in safety. Therefore, it is suggested that ATIS as well as redundant roadside information be given whenever possible.

Beyond the guidelines presented on the preceding page, developing ATIS messages is a process that should involve careful consideration of the message content, complexity, priority, and the consequences of a missed or misunderstood message.

**Cross References:**

*Timing of Auditory Navigation Information, p. 5-4*

**Notes:**

**Key References:**

1. Lee, J. D., Stone, S. R., Gore, B. F., Colton, C., Macauley, J., Kinghorn, R. A., Campbell, J. L., Finch, M., & Jamieson, G. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Design alternatives for in-vehicle information displays: Message style, modality and location.* Washington, DC: Federal Highway Administration (FHWA-RD-96-147).
2. Kantowitz, B. H., Hooey, B. L., & Simsek, O. (1998). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: On road evaluation of ATIS messages* Washington, DC: Federal Highway Administration (FHWA-RD-99-132).
3. Fain, W. B. (1995). Analysis of the influence of traffic information messages on route selection. *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting,* (pp. 1082-1086). Santa Monica, CA: Human Factors and Ergonomics Society.

## DESIGN OF HEAD-UP DISPLAYS FOR ATIS

Introduction: The automotive HUD is an electro-optical device that presents both static and dynamic symbology and/or graphics in the driver's forward FOV. Presenting navigation information to drivers through HUDs is possible due to recent developments in automotive design, electronic instrumentation, and optics.

HUDs have the potential to improve driving performance and driver safety in a variety of ways. First, since the HUD is close to the driver's nominal line of sight (LOS), it allows the driver to sample both vehicle and driving information without the same accommodative shift required by conventional instrument clusters or head-down displays (HDDs). Second, it has the potential to reduce eyes-off-the-road time, by presenting relevant driving information at or near the forward LOS. However, since the initial development of prototype automotive HUDs, there has been a concern that the presence of the HUD image may interfere with the driving task and negatively impact driving performance. These concerns have developed from four main sources: (1) analogies to military HUD environments; (2) speculative common-sense notions that any image in the driver's forward LOS may affect visual performance and vehicle control judgments; (3) the subjective experience of some individuals indicating that the HUD image compels high visual attention on initial exposure to the display; and (4) suggestions that the HUD might represent a glare source that may decrease forward preview distance during very low ambient luminance nighttime driving.

Recent research into the question of safety with automotive HUDs has produced mixed results (see Reference 1). A recent study, however, that investigated the safety and applicability of using HUDs for ATIS applications did not indicate any distraction effects associated with an automotive HUD (Reference 2).

**Design Guidelines****

| Design Element | Guideline |
|---|---|
| Image Viewing Distance | • Locate the HUD image 2.35 to 2.80 meters from the design-eye-position of the HUD. |
| Image Distortion | • No HUD element should vary from its intended size by more than +/- 10%.<br>• No point on the HUD display should be displaced by more than 5% of the total image width or height (horizontal or vertical FOV). |
| Luminance Adjustment Control<br>(see equation below) | • A luminance adjustment control for the HUD image should be provided.<br>• A continuous rotary knob, slide, or a thumbwheel should be the type of control provided for this adjustment.<br>• Luminance values, as a function of control position, should be derived from a power function (see equation below). |

### The Luminance Control Function for an Automotive HUD

$$\text{Footlambert} = [(P \times L_{max}^{0.33}) + ((1-P) \times (L_{min}^{0.33}))]^{(1 \div 0.33)} \quad (Eq. 9)$$

where: P = the proportion of total control movement
$L_{max}$ = maximum luminance provided
$L_{min}$ = minimum luminance provided

**Supporting Rationale:** *Image Distance.* Typical fixation distances while driving are 25 meters (Reference 3), or about 0.04 diopters (D) accommodation. Average depth-of-focus values, for representative stimuli and visual conditions, are 0.63 diopters (Reference 4). Therefore, for normal eyes during most driving situations, little or no change in accommodation is required from 2.8 meters to optical infinity [0.04 +/- (0.63/2) = -0.275D (far focus) and + 0.355D (near focus); 1 â 0.355 = 2.8D]. For the purpose of reducing or eliminating accommodation requirements, the image distance of the HUD should be 2.8 meters or beyond. Depending on the visual angle between the HUD symbology and objects of interest in the visual scene, and on assumptions about driving scene fixation distances, image distance values representing tolerable binocular lateral disparity range from approximately 2.35 meters to 8.03 meters (References 5 and 6). These values represent estimates of tolerable disparity when an observer attempts to fixate on both the HUD and the external driving scene at the same time. Since drivers should not need to fixate on both the HUD and the external driving scene at the same time, these values are very conservative (i.e., less-conservative assumptions would allow the HUD to be closer to the driver).

*Image Distortion.* References 7 and 8 indicate that CRT symbols that are intended to be the same size should not vary in size by more than +/- 10 percent in either the vertical or horizontal dimension. Reference 9 also indicates that no point on a display should be displaced with respect to orientation or position by more than 5 percent of total image width or height. The design guidelines provided above reflect these standard human factors design guidelines.

*Luminance Adjustment Control.* Expected variations in HUD background luminances, as well as differences among drivers in terms of preferences and visual capabilities, suggest that drivers should be able to make minimal adjustments to the HUD luminance. Since continuous control of luminance over discrete luminance ranges is required, either a continuous rotary control, slide, or a thumbwheel type of control should be used (References 9 and 10). Although of less importance during daytime conditions, drivers will be able to avoid display-produced glare at night more easily if the luminance gain function follows the power function originally described in Reference 11. The luminance control functions depicted above will lead to the perception, by the driver, of approximate linearity between display brightness and the position of the luminance control.

**Cross References:**
*Color Contrast, p. 3-22*

**Key References:**

1. Gish, K. W., & Staplin, L. (1995). *Human factors aspects of using head-up displays in automobiles: A review of the literature.* Washington, DC: National Highway Traffic Safety Administration (DOT HS 808 320).
2. Hooey, B. L., & Gore, B. F. (1998). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Head-up displays and driver attention for navigation information.* Washington, DC: Federal Highway Administration (FHWA-RD-96-153).
3. Mourant, R. R., & Rockwell, T. H. (1970). Mapping eye-movement patterns to the visual scene in driving: An exploratory study. *Human Factors,* 12, pp. 81-87.
4. Ogle, K. N., & Schwartz, J. T. (1959). Depth of focus of the human eye. *Journal of the Optical Society of America, 49,* pp. 273- 280.
5. Bell, H. H., & Ciuffreda, K. J. (1985). *Advanced simulator for pilot training: Effects of collimation on accommodation and convergence* (AD-A159 545/3). Brooks Air Force Base, TX: Air Force Human Resources Laboratory.
6. Ogle, K. N. (1972). *Researches in binocular vision.* New York: Hafner.
7. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.
8. Meister, D. (1984). *Human engineering data base for design and selection of cathode ray tube and other display systems* (NPRDC TR 84-51). San Diego, CA: Navy Personnel Research and Development Center (DTIC No. AD-A145704).
9. MIL-STD-1472D. (1989). *Human engineering criteria for military systems, equipment, and facilities.* Washington, DC: U.S. Government Printing Office.
10. Chapanis, A., & Kincade, R. G. (1972). Design of controls. In H. P. Van Cott & R.G. Kincade (Eds.), *Human engineering guide to equipment design* (rev. ed.) (pp. 345-370). Washington, DC: U.S. Government Printing Office.
11. Stevens, S. S. (1957). On the psychophysical law. *Psychological Review, 64,* pp. 153-181.

# TAILORING OF ATIS INFORMATION TO INDIVIDUAL PREFERENCES

**Introduction:** *The tailoring of ATIS information to individual preferences* refers to a driver's ability to personalize or to adjust ATIS design parameters to suit their individual driving habits, needs, and preferences.

## Design Guidelines***

Drivers should be able to tailor the presentation of ATIS information to their own preferences and driving requirements, particularly for information requiring immediate compliance.

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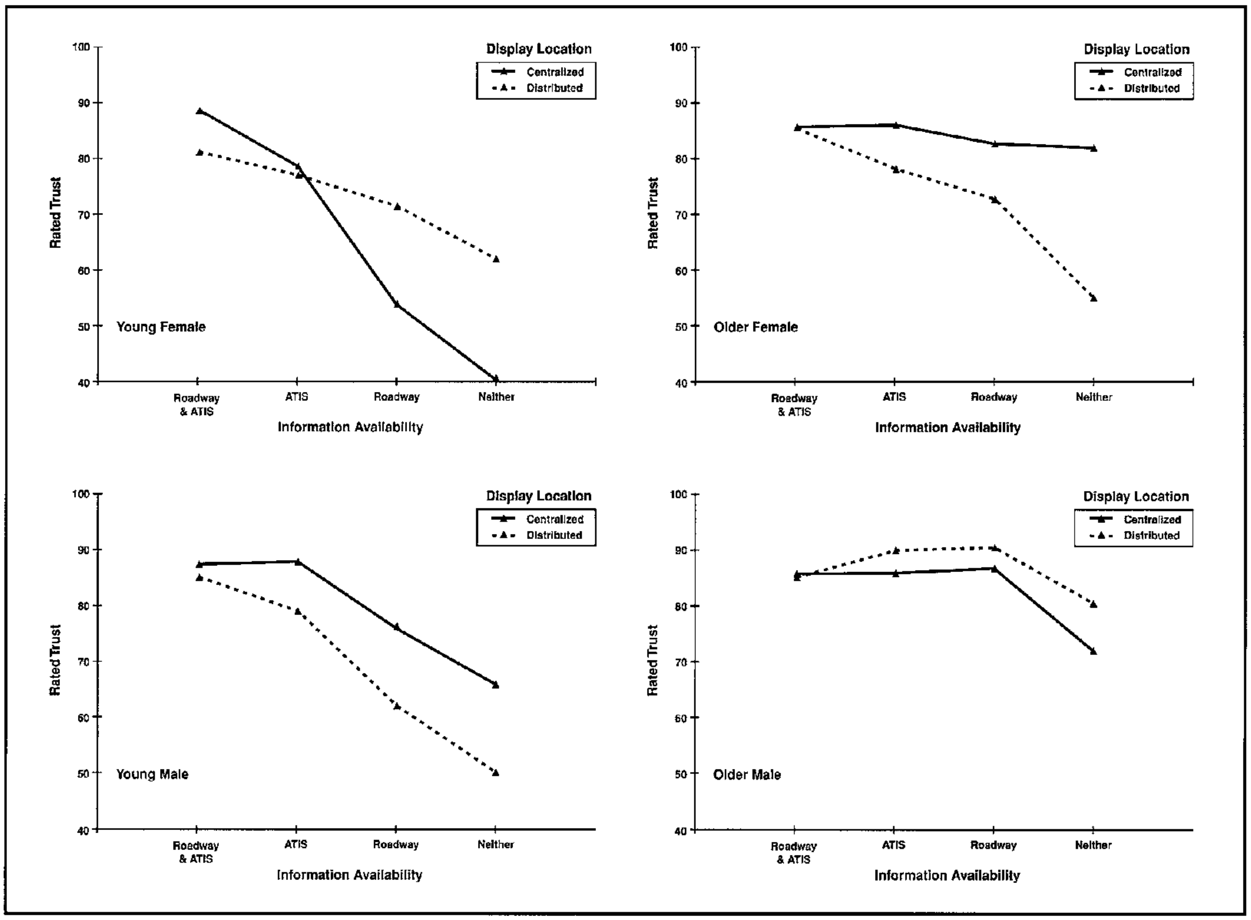
### The Effect of Information Availability, Age, Gender, and Display Location on Trust



**Supporting Rationale:** References 1 and 2 describe the strong influence that trust can play in users' reaction to, and performance with, a complex system. In particular, levels of trust can affect sampling strategies, as well as the ultimate use of the system. In Reference 3, ATIS warning messages were presented to drivers using a driving simulator equipped with a reconfigurable ATIS. The visual scene was controlled to present drivers with roadway information in a form similar to the changeable message signs found on highways. ATIS information was presented in either a centralized location (a single, center-mounted CRT screen) or in distributed locations (CRT, head-down instrument panel, head-up display). Information availability refers to the medium by which sign information was made available to the drivers. Four options were investigated: (1) ATIS presentation only, (2) roadway sign only, (3) ATIS presentation and roadway signs, and (4) neither ATIS presentation nor roadway signs. In the study, driver trust and confidence in the presented information was assessed using a variety of subjective indices. The results (the figure on the opposing page and the table below provide an example) showed wide variability in trust and self-confidence as a function of age and gender. This general finding was repeated across a range of experimental conditions (message style, information availability, information modality) and relevant subjective measures (rated self-confidence, situational awareness, and mental effort).

**Specific Effects of Age and Gender on ATIS Devices.**

| Gender | Younger | Older |
|---|---|---|
| **Female** | A crossover interaction indicates that the trust of young females drops more with centralized displays. | The trust of older females drops more with distributed displays, remaining almost unaffected with the centralized displays. |
| **Male** | The trust of young males drops more with the distributed displays. | The trust of older males remains relatively constant for both the centralized and distributed displays and only declines slightly when ATIS and roadway information were not present. |

**Special Design Considerations:** The precise ATIS design parameters that should be adjustable by individual drivers have not been extensively studied. Moreover, without additional empirical data, it is difficult to know how such "personalization" of an ATIS device should be accomplished. In general, issues that must be addressed include decrements in visual acuity associated with older drivers (e.g., requirements for larger fonts), and an over-reliance on ATIS information associated with younger subjects.

**Cross References:**
*ATIS Design for Special Populations, p. 3-38*

**Notes:**

**Key References:**
1. Lee, J. D., & Moray, N. (1992). Trust and the allocation of function in the control of automatic systems. *Ergonomics, 35*, pp. 1243-1270.
2. Lee, J. D., & Moray, N. (1994). Trust, self-confidence, and operators' adaptation to automation. *International Journal of Human-Computer Studies, 40*, pp. 153-184.
3. Lee, J. D., Stone, S. R., Gore, B. F., Colton, C., Macauley, J., Kinghorn, R. A., Campbell, J. L., Finch, M., & Jamieson, G. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Design alternatives for in-vehicle information displays: Message style, modality and location.* Washington, DC: Federal Highway Administration (FHWA-RD-96-147).

# ATIS DESIGN FOR SPECIAL POPULATIONS

**Introduction:** *ATIS design for special populations* refers to design criteria aimed specifically at drivers with either sensory or cognitive disabilities that might affect their ability to effectively use the system. One such population is the older drivers, those over the age of 60. There is a considerable body of research showing that the older population has numerous cognitive and sensory deficits. Other special populations include handicapped or disabled drivers as well as those people with minor cognitive impairments. In many cases, the suggestions made for improving ATIS design for these populations would increase its usability for the general population as well.

## Design Guidelines**

- Use only simple, 3 or 4 information unit messages. (The phrase "information units" is used to describe the amount of information presented in terms of key nouns and adjectives contained within a message. The design guideline entitled "Auditory Message Length" on page 3-26 provides a tool for determining the number of information units.)
- Warnings should be available in alternative forms (i.e., visual, auditory, or tactile), allowing both visual and hearing impaired persons to adapt the signal to their perceptual characteristics.
- Drivers should be able to have the system repeat messages.
- Systems should provide the means for attaining larger displays or enlarging images in order to adapt the visual output to the users needs. For the same reasons, the volume of auditory systems should also be adjustable.
- Allow drivers to select multiple, redundant modalities for message presentation (i.e., both visual and auditory).

### Potential Benefits of ATI Subsystems for Special Populations

| System | Potential Benefits/Problems Addressed |
|---|---|
| **Route Guidance** | Could be helpful for older drivers suffering from the mild memory deficits typical of normal aging or for those suffering from the early stages of Alzheimer's. The route guidance subsystem would help drivers to remember routes and road names. |
| **Trip Planning** | Might be helpful for older drivers, whose ability to process information has slowed. The trip planning subsystem would help reduce the cognitive load placed on the driver, lowering the crash potential while in-transit. |
| **Mayday/Aid Request** | Could be especially helpful for elderly or disabled drivers, who might be limited in their ability to move or respond in an emergency situation. The mayday/aid request subsystem could automatically contact the correct emergency personnel and transmit all of the necessary location information. |
| **In-Vehicle Signage** | Might be helpful for older drivers, especially during night driving. It has been reported that the visual acuity of older drivers can drop dramatically (20/140) when they are subjected to decreased illumination. The in-vehicle signage subsystem would present on-road traffic signs inside the vehicle in order to enhance visibility. |

**Supporting Rationale:** Reference 1 presents several recommendations for improving ATIS devices to be used by older drivers. Suggestions are made for reducing message complexity by eliminating unnecessary information or words in a message. Three- or four-element messages were found to be most satisfactory in terms of safety, usefulness, and driver acceptability. A simulator study summarized in Reference 2 found that the differences in performance between young and older drivers increase as a function of information complexity. It also recommends breaking complex pieces of information down into several smaller information units.

Reference 1 also found that increasing the amount of time that information is displayed and allowing drivers to repeat messages if necessary were beneficial for older drivers whose cognitive speeds are slightly slower. Short breaks in between messages were also found to be helpful for older drivers, in that it gave them the time they needed to reorient themselves to the roadway ahead and reduced the number of glances away from the forward roadway. The study completed in Reference 1 found that older subjects were open to the idea of an ATIS device but encountered problems when it came to reading, encoding, and retaining complex messages. The results suggested that the visual problems could be overcome by allowing the driver to adjust controls for brightness, contrast, and saturation of the screen to their own personal preference.

**Special Design Considerations:** Reference 3 suggests that allowing the system to be flexible so that it can be set to match a drivers preference is very important, and states that "uniform settings would be at best unhelpful, at worst dangerous." An on-road study completed in Reference 4 suggests that allowing drivers to select the type of message they would like to receive and to decide whether or not it would be redundant might help the older driver. In this way, the drivers are allowed to make the message seem as urgent as they feel is necessary. Older drivers may perceive being off-route as being more urgent than younger drivers.

Reference 5 examined latency and recall for auditory messages (earcons, verbal messages, and complex tones) for older and younger subjects. Older subjects were unable to achieve adequate recognition performance for the sounds during training. Thus, older drivers may have difficulties recalling the meaning of auditory messages under real-world driving conditions.

**Cross References:**

*Auditory Message Length, p. 3-26*
*Complexity of ATIS Information, p. 3-28*
*Tailoring of ATIS Information to Individual Preferences, p. 3-36*

**Key References:**

1. Graham, R., & Mitchell, V. A. (1997). An evaluation of the ability of drivers to assimilate and retain in-vehicle traffic messages. Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 185-201). Mahwah, NJ: Lawrence Erlbaum Associates.
2. Marin-Lamellet, C., & Dejeammes, M. (1995). The processing of complex guidance symbols by elderly drivers: A simulator based study and an evaluation of the CARMINAT guidance system by the European Community DRIVE-EDDIT Project. *Proceedings of the 6th Vehicle Navigation and Information Systems Conference* (pp. 10-117). Piscataway, NJ: IEEE.
3. Oxley, P. (1996). Elderly drivers and safety when using IT systems. *IATSS Research, 20(*1), (pp. 102-110). Berkeley, CA: University of California at Berkeley.
4. Hanowski, R. J., Gallagher, J. P., Kieliszewski, C. A., Dingus, T. A., Biever, W., & Neale, V. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Driver response to unexpected situations when using an in-vehicle information system.* Washington, DC: Federal Highway Administration (FHWA-RD-99-131).
5. Kantowitz, B. H., Hanowski, R. J., Kantowitz, S. C., & Garness, S. A. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Display channels.* Washington, DC: Federal Highway Administration (FHWA-RD-96-148).

# DESIGN OF ATIS SUBSYSTEM INTERFACES

**Introduction:** *Design of ATIS subsystem interfaces* refers to the consistency of the "look and feel" associated with the ATIS driver-vehicle interface (DVI), across various functions within the ATIS. For example, a single ATIS device could include trip planning, route guidance, travel coordination, and message transfer functions, much as modern computer systems include word processing, graphics, and e-mail applications. The degree of integration or consistency refers to the color schemes, fonts, layouts, and control operations associated with these different functions. A fully integrated system would have a common user interface, with the same colors, formats, and control operations; in a non-integrated system, these features could vary from function to function.

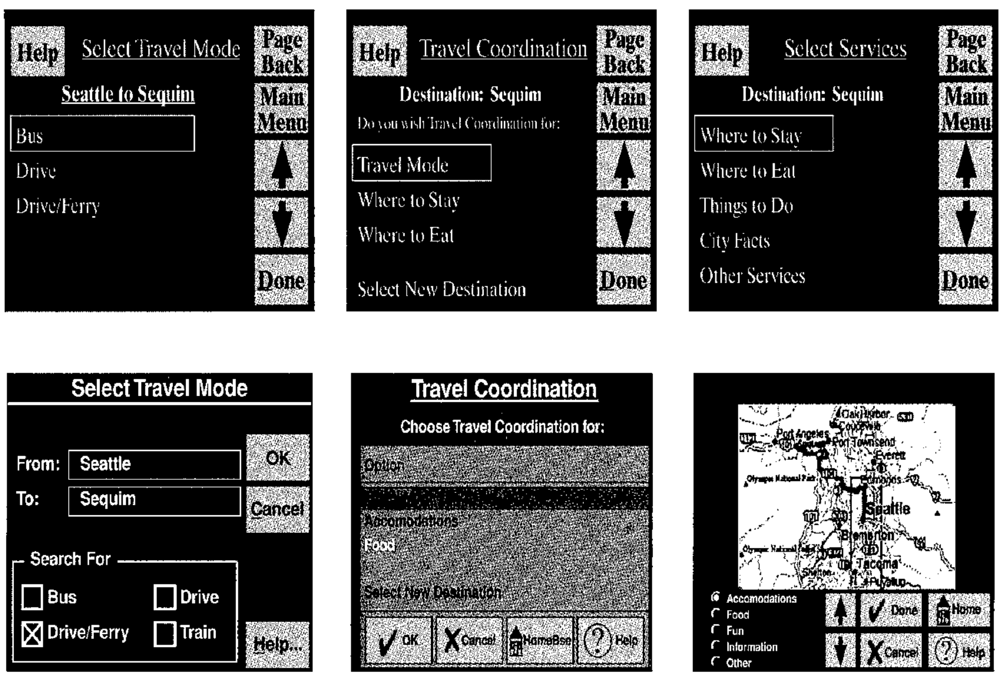
## Design Guidelines***

- When the vehicle is in PARK, a nonintegrated ATIS device will result in acceptable performance.
- A nonintegrated ATIS interface can also be used for non-in-vehicle ATIS applications such as Internet, hotel, portable and kiosk devices.

### Examples of Both Integrated and Nonintegrated ATIS DVIs from Comparable ATIS Functions

**Examples of an integrated ATIS DVI**

**Examples of a nonintegrated ATIS DVI**




**Travel Mode Function** | **Travel Coordination Function** | **Services Directory Function**

**Supporting Rationale:** In Reference 1, user performance and cognitive demands were investigated in a study that included both integrated and nonintegrated ATIS interfaces. In various predrive scenarios, subjects were asked to plan trips, select routes, select modes of travel, make reservations, and respond to messages during a PC-based ATIS simulation. For the predrive scenarios investigated, no differences were found between the integrated and non-integrated systems in terms of performance (time to plan the trip, number of errors, requests for system help) or cognitive demands (understanding of the system, difficulties in navigating across system functions). Since out-of-vehicle ATIS applications such as Internet, hotel, portable and kiosk devices are, by definition, "predrive," nonintegrated ATIS functions can also be used in these applications.

**Special Design Considerations:** Although Reference 1 has determined that nonintegrated ATIS devices can be used without decrements in performance or increases in cognitive demands, user acceptance concerns may favor a more integrated approach to the design of the ATIS interface. For example, computer users have come to expect a certain consistency across the user interface as they move from application (e.g., word processing) to application (e.g., spreadsheets) on their computer. Thus, different applications may use the same keystrokes to perform similar functions, such as the standardized use of Ctrl+C for copy and Ctrl+V for paste. Similarly, for aesthetic and user acceptance reasons, ATIS designers should use a common "look and feel" across ATIS functions whenever feasible.

**Cross References:** None.

**Notes:**

**Key References:**

1. Campbell, J. L., Hanowski, R. J., Hooey, B. L., Gore, B. F., & Kantowitz, B. H. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: ATIS function transitions.* Washington, DC: Federal Highway Administration (FHWA-RD-96-146).

## GENERAL GUIDELINES FOR USER INTERFACE DESIGN

**Introduction:** *User interface design* refers to the system design characteristics of a computer-based system that includes the screen layout and format, selection of icons, use of borders and windows, control selection and placement, and the procedures and "rules" that define transactions between the system and the user.

### Design Guidelines **

| General Guideline (adapted from References 1 and 2) | Possible ATIS/CVO Application |
|---|---|
| Make objects, actions, and options visible to the user. | Choices for transit mode (e.g., train, bus, or ferry) should all be identified and selectable to the user on a single screen or an obviously linked set of screens. |
| Provide error messages in plain language, and indicate the precise problem. | If a driver enters an address (for trip planning purposes) that does not exist, rather than a message such as "Error in Input," use "That Address Does not Exist." |
| Users should not have to remember information across dialogs. | For interactions involving more than one related screen organized in a hierarchical fashion, such as restaurant selections, key information or user-entered information should be carried from screen to screen. |
| Conduct frequent testing of the user interface, recognize that system designers are not representative users of the final system. | Even small changes (e.g., changes in screen layout, color, or menu hierarchy) can have a significant effect on user acceptance and performance. Conduct testing with representative users at critical design stages and when key design elements are changed. |
| Provide undo and redo functions that support corrections to user input as well as recovery from errors. | When complicated inputs are made, such as entering destinations or selecting travel modes, provide "Back," "Delete," or "Undo" buttons, or functions that allow the user to recover from errors and re-enter information. |
| Objects on the screen that look the same should act the same. | Do not use the same symbol (e.g., a fuel pump) for both a descriptive display icon and a control button that prompts the system to perform some action. |
| Every user action should result in a reaction from the system. | Provide understandable visual or auditory feedback in response to user inputs in the form of: changes to data fields, changes to another screen within the menu hierarchy, or a dialogue message. |
| If an item on the display must be remembered, flag or display it in a salient and meaningful manner. | Key roadway features such as construction zones and congested roadways (or destinations for the CVO driver) should be highlighted with unique colors and/or icons. |

**Supporting Rationale:** In Reference 1, human-computer interaction (HCI) designers were surveyed to identify maxims that they found to be useful during their user interface design activities. A final list of 34 maxims was then sent to members of the American National Standards Institute (ANSI) committee and other HCI designers, who were asked to rate each maxim on its impact on the usability of computer systems. Some of the guidelines above represent the maxims that were rated as the most implementable and having the greatest impact on usability.

Other guidelines listed above were adapted from a larger set of broad user interface design principles provided in Reference 2, which summarizes principles from cognitive psychology and applies these principles to problems of user interface design in office systems.

**Special Design Considerations:** These guidelines are very general and should be implemented in a careful and purposeful manner. Application to specific design issues should reflect the goals, requirements, and constraints of individual design efforts.

**Cross References:**
*Number of Control Actions for Commercial Driver ATIS Tasks, p. 9-2*

**Notes:**

**Key References:**
1. Lund, A. M. (1997). Expert ratings of usability maxims. *Ergonomics in Design, 5(3)*, pp. 15-20.
2. Marshall, C., Nelson, C., & Gardiner, M. M. (1987). Design guidelines. In M. M. Gardiner & B. Christie (Eds.), *Applying cognitive psychology to user-interface design* (pp. 221-278). New York: J. Wiley & Sons.

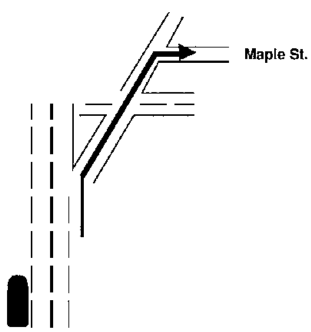
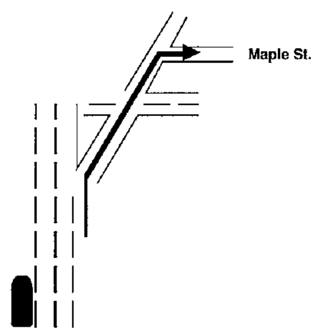
## GENERAL GUIDELINES FOR ATIS MESSAGES

**Introduction:** *ATIS messages* refer broadly to information items that are presented to the driver through an ATIS device. They include information relevant to navigation, motorist services, congestion, safety, augmented signage, weather, or caution/alert messages.

### Design Guidelines**

- Avoid using text-only display formats, except when presenting information such as directions for navigation and restaurant options, departure times, and other nongraphic information.
- When presenting information about an upcoming event, such as a turn, a desired exit, or a construction zone, present the information in terms of both time to the event and one other relevant parameter such as number of preceding intersections or miles to the event. Do not present the event information only in terms of time to the event.
- When presenting information about an upcoming event, such as a turn, use 2-3 warning messages to the driver regarding the need for a turn. Do not use only one warning message.

### Example of ATIS Message Options Evaluated in Reference 1

| | | | |
|---|---|---|---|
| |  | Exit right lane 2 miles.<br>Continue straight through first intersection.<br>Turn right on Maple St. |  Exit right lane 2 miles.<br>Continue straight through first intersection.<br>Turn right on Maple St. |
| What is your preference for this display? | mean ranking = 2.43 | mean ranking = 2.46 | mean ranking = 1.10 |

**CVO drivers were asked to rank these three displays in order of their preferences. They were asked to assign a "1" to the most preferred display, a "2" to the second most preferred display, and a "3" to the least preferred display. As seen above, the combined text/graphic display had the best rating, with a mean rating of 1.10.**

**Supporting Rationale:** In Reference 1, both a survey and a user clinic were conducted to evaluate display formats for several types of ATIS displays in order to identify driver population stereotypes and preferences. The survey was a paper-and-pencil questionnaire that obtained information from rural, urban, and commercial drivers on priorities, preferences, and suggested formats for ATIS information. Information elements included in the survey included motorist services, time/distance to destination, guide signs, road construction, navigation, congestion, emergency vehicle notification, and regulatory information. The user clinic was a computer simulation designed to determine presentation comprehension and driver preferences in a dynamic driving scenario. Information elements included in the user clinic included yellow pages, restaurant description and costs, alternative route displays, and alerts for accidents, congestion, and weather. The guidelines above reflect the key results from the survey and user clinic.

**Special Design Considerations:** The guidelines presented here are preliminary and general, and should be implemented in a careful and purposeful manner. Application to specific design issues should reflect the goals, requirements, and constraints of individual design efforts.

**Cross References:**
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*Symbol Versus text Presentation of ATIS/CVO Messages, p. 3-30*
*Timing of Navigation Information, p. 5-4*

**Notes:**

**Key References:**
1. Neale, V. L., Dingus, T. A., Schroeder, A. D., Zellers, S., & Reinach, S. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Investigation of user stereotypes and preferences.* Washington, DC: Federal Highway Administration (FHWA-RD-96-149).

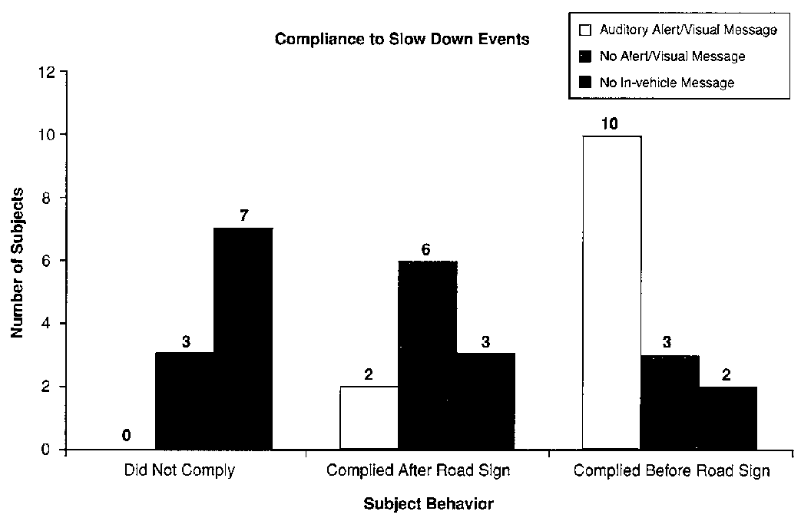
# USE OF ALERTS FOR ATIS MESSAGES

**Introduction:** *Alerts for ATIS messages* refers to information presented to drivers prior to, or concurrent with, the presentation of an ATIS message. Alerts are typically used to notify drivers of high-priority ATIS messages associated with safety (e.g., immediate hazard, emergency vehicle approaching), vehicle status (e.g., vehicle condition warning), or augmented signage information (e.g., guidance, notification, or regulatory signs).

## Design Guidelines***

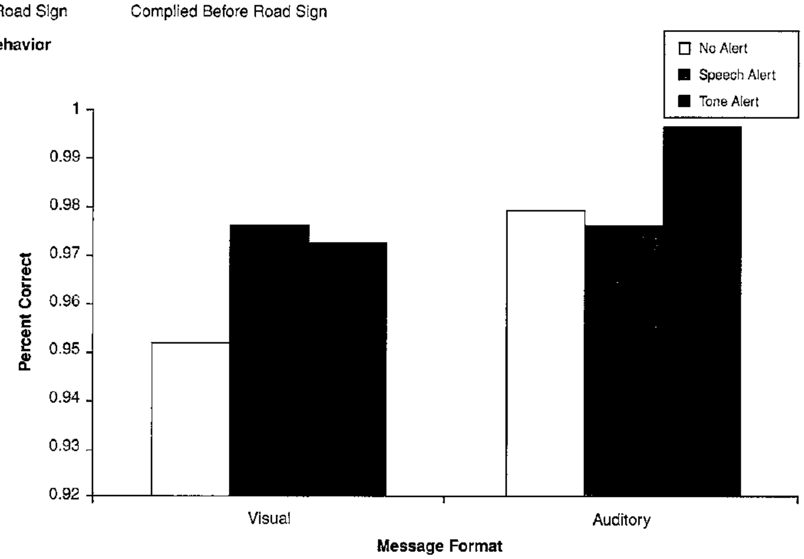
- High-priority information presented on an ATIS visual display should be preceded by an auditory alerting tone.
- The alerting tone should immediately precede, or be presented at the same time as, the high-priority visual information.
- If no alerting tone can be provided, the high-priority visual information should be supplemented by redundant auditory information (e.g., speech).

## Selected Results From Key References




***From Reference 1—a visual ATIS message, preceded by an auditory alerting tone, was associated with higher compliance levels than a visual message alone.***

***From Reference 2—auditory alerts were associated with better performance than no alerts. If no alert can be provided and the message is high priority, an auditory message should be used.***



**Supporting Rationale:** In Reference 1, a simulator study was performed in which drivers were informed of upcoming speed zones (i.e., construction zone and school zone) approximately 7.1 seconds before reaching a corresponding roadway sign. The advanced warning was given to the driver in one of two ways, either a text message on an in-vehicle display or a text message preceded by an auditory tone. The results of this study indicated that 9 of the 12 drivers who received only a visual warning either never slowed to the goal speed or slowed only after they had passed the sign located on the roadway. In contrast, 10 of the 12 drivers who received the combination visual and auditory warning were able to slow to the goal speed well in advance of the roadway sign. Therefore, these results suggest that for the presentation of notification sign information which advises drivers to make changes in their current speed of travel, the combination of an auditory alerting tone and ATIS textual information may lead to faster and more reliable compliance.

In Reference 2, subjects were trained to recall six complex sounds (earcons) and six visual icons that were part of an experiment investigating ATIS devices. These earcons and icons, along with speech and textual messages, were then presented to subjects while they navigated through a simulated driving environment in a fixed-base driving simulator. Twelve of the subjects received a speech alert before all message presentations, 12 of the subjects received a tone alert, and 12 of the subjects received no alert at all. Performance measures included: response times to a recognition question on the message, accuracy in recognizing the meaning of a message, and confidence in their answers. Results suggested that subjects in the no alert group were significantly less accurate, slower, and less confident with the visual messages than they were with the auditory messages. Performance in the speech alert and tone alert groups did not differ. These findings suggest that alerts of some type will improve accuracy, latency, and confidence associated with visual messages.

**Special Design Considerations:** The guidelines presented here are preliminary and general, and should be implemented in a careful and purposeful manner. Application to specific design issues should reflect the goals, requirements, and constraints of individual design efforts.

**Cross References:**

*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*General Guidelines for ATIS Messages, p. 3-44*
*Timing of Navigation Information, p. 5-4*
*General Guidelines for Augmented Signage Information, p. 8-10*

**Notes:**

**Key References:**

1. Kantowitz, B. H., Simsek, O., & Carney, C. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: ATIS function transitions* (Contract No. DTFH61-92-C-00102). Seattle, WA: Battelle Human Factors Transportation Center.
2. Kantowitz, B. H., Hanowski, R. J., Kantowitz, S. C., & Garness, S. A. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Display channels.* Washington, DC: Federal Highway Administration (FHWA-RD-96-148).

# CHAPTER 4: GENERAL GUIDELINES FOR ADVANCED TRAVELER INFORMATION SYSTEM (ATIS) CONTROLS

This chapter provides human factors design guidelines relevant to the controls associated with ATIS devices. ATIS controls represent the primary means by which the driver interacts with the system and, therefore, their design is critical to successful use of ATIS devices. The following design topics are included in this chapter:

## ■ MANUAL CONTROLS



## ■ OTHER

# SELECTION OF CONTROL TYPE

**Introduction:** *Selection of control type* refers to the apparatus by which the driver makes control inputs (i.e., push- buttons, push-pull knobs, rotary knobs (discrete and continuous), levers, slides, thumbwheels, toggle switches, or rocker switches). Selection of appropriate control types is important to decisions regarding control location, because some control types are more suited to particular locations, and, conversely, particular locations are ideal for certain types of controls.

## Design Guidelines***

The tables below provides a summary of the suggested control types with respect to various design and human-computer interface characteristics. Recommendations for control selections from the various human factors sources are in good agreement (see References 1, 2, 3, and 4).

| Control Function | Suggested Control Type |
|---|---|
| Selection between two alternatives or discrete positions; e.g., on/off. | Toggle switch, two-position stalk, push-pull knob, push-button, or rocker switch. |
| Selection among three or more alternatives or discrete positions; e.g., modes of operation for climate controls. | Slide, multipurpose stalk, discrete rotary knob, three-position toggle or rocker switch, push-buttons (for three alternatives only), key pad, or touch screen. |
| Precise adjustment; e.g., radio volume. | Continuous rotary knob or thumbwheel. |
| Gross adjustment; e.g., intermittent windshield wiper. | Continuous rotary knob, lever, or touch screen. |
| Large force application; e.g., column tilt. | Lever. |

| Expected Control Location | Suggested Control Type |
|---|---|
| Panel | Toggle switch, rotary knob, push-pull knob, thumbwheel, slide, push-button, rocker switch, touch screen, or key pad. |
| Stalk | Rotary on end or in middle of stalk, push-button on end of stalk, or small slide. |
| Pod | Push-button or thumbwheel. |
| Steering wheel, side | Stalk or lever. |
| Steering wheel, front | Push-button. |

| Control Task Requirement | Suggested Control Type |
|---|---|
| Blind operation | Toggle switch, rocker switch, discrete rotary knob, or key pad. |
| Tactile feedback | Toggle switch, rocker switch, push-to-lock push-button, slide with detents, discrete rotary knob, or key pad. |
| Visual identification of control position | Toggle switch, rotary, slide, or lever. |
| Easy check reading in an array of controls | Toggle switch, rotary, slide, or lever. |
| Fast actuation | Toggle switch, two-position stalk, rocker switch, or push-button. |

**Supporting Rationale:** Controls vary not only in terms of their functions, applications, and methods of operations, but also with respect to such characteristics as their relative space requirements, the likelihood of accidental activation, and the ease with which the position of the control can be identified. These characteristics should be considered when determining the method of operation and control type for secondary automotive controls.

**Special Design Considerations:** Selection of a control type is an iterative process, involving trade-offs between a variety of competing design concerns. In particular, control selection requires an analysis of the following driver-vehicle system considerations (adapted from Reference 1): (1) the function of the control, (2) the desired location of the control, (3) the requirement of the control task, (4) the vehicle environment, and (5) the consequence of driver error.

**Cross References:**

*Control Movement Compatibility, p. 4-4*
*Control Coding, p. 4-6*

**Notes:**

**Key References:**

1. Chapanis, A., & Kinkade, R. G. (1972). Design of controls. In H. P. Van Cott & R. G. Kinkade (Eds.), *Human engineering guide to equipment design* (rev. ed.) (pp. 345-379). Washington, DC: U.S. Government Printing Office.
2. Boff, K. R., & Lincoln, J. E. (Eds.). (1988). *Engineering data compendium: Human perception and performance.* Wright-Patterson Air Force Base, OH: Armstrong Aerospace Medical Research Laboratory.
3. Woodson, D. E., & Conover, D. W. (1964). *Human engineering guide for equipment designers.* Berkeley, CA: University of California Press.
4. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.

# CONTROL MOVEMENT COMPATIBILITY

**Introduction:** *Control movement compatibility* refers to the expected relationships between control actuation movements and the corresponding movements or changes in the system being controlled. Making control movements consistent with the driver's expectations can decrease reaction times, learning times, and control errors, and increase driver satisfaction with the vehicle's controls.

## Design Guidelines***

- Control movements should correspond to the expectations of the user. See table below for recommended control-movement-to-system-function relationships.
- Expectations for up-to-increase are probably stronger than those for clockwise-to-increase.

### Recommended Control Movement-to-System Function Relationship

| System Function | Control Movement |
|---|---|
| On | Up, right, forward, pull |
| Off | Down, left, rearward, push |
| Right | Clockwise, right |
| Left | Counterclockwise, left |
| Up | Up, rearward |
| Down | Down, forward |
| Increase | Up, right, forward, clockwise |
| Decrease | Down, left, rearward, counterclockwise |

**Supporting Rationale:** The control-movement-to-system-function relationships are recommended based on a review of several different human factors sources (see References 1 and 2). The optimum direction of movement for a given control depends on a number of factors, including: (1) the position of the operator relative to the control, (2) the position and direction of movement of any associated display, (3) the change resulting from the control movement, and (4) the control-movement-to-system-function relationships for other controls that the driver uses.

**Special Design Considerations:** According to Reference 3, it may be necessary to violate one compatibility relationship in order to take advantage of another one in the design of a system. An example of this is the rotary stalk control. In order to increase some parameter using the left-hand stalk, the control must be rotated up or counterclockwise. Although up is the correct movement for increasing a system function, counterclockwise is not. Therefore, the designer must determine which of the driver's expectations is stronger or which can be violated without affecting the driver's ability to effectively use the system.

**Cross References:**

*Selection of Control Type, p. 4-2*
*Control Coding, p. 4-6*

**Notes:**

**Key References:**

1. Chapanis, A., & Kinkade, R. G. (1972). Design of controls. In H. P. Van Cott & R. G. Kinkade (Eds.), *Human engineering guide to equipment design* (rev. ed.) (pp. 345-379). Washington, DC: U.S. Government Printing Office.
2. Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design* (5th ed.) New York: McGraw-Hill.
3. Rogers, S. P., & Campbell, J. L. (1991). *Guidelines for automobile hand control locations and actuations based upon driver expectancies and ergonomic principles* (TR 947-1). Santa Barbara, CA: Anacapa Sciences, Inc.

# CONTROL CODING

**Introduction:** *Control coding* refers to the design characteristics of controls that serve to identify the control or to identify the relationship between the control and the function to be controlled. Proper coding of controls will increase the probability that the controls will be quickly and accurately located by drivers, thus reducing the eyes-off-road time.

## Design Guidelines***

Use one or more of the following design characteristics to identify controls:

- Location Coding: In order to ensure discriminable and unique control locations, controls must be separated by distances that are sufficient to avoid confusion among positions (see table below entitled "Recommended Minimum Control Separation Distances").
- Shape Coding: This is most effective when used in combination with location coding. Errors in the driver's hand position are indicated by the feel of the control.
- Size Coding: This is most effective when used in combination with location coding. As many as two or three sizes can be used to discriminate controls. In general, size coding is most effective if the diameter of the outermost control is _" (1.27 cm) larger than the next-closest control on the stalk.

### Recommended Minimum Control Separation[1] Distances

| Control | Push-Buttons (No Array) | Push-Button Arrays | Rocker Switches | Toggle Switches | Thumb-Wheels | Discrete Rotary Controls | Continuous Rotary Controls |
|---|---|---|---|---|---|---|---|
| Push-Buttons (No Array) | 1.27 cm (0.5 in) | 5.08 cm (2.0 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) |
| Push-Button Arrays | 5.08 cm (2.0 in) | 5.08 cm (2.0 in) | 3.81 cm (1.5 in) | 3.81 cm (1.5 in) | 3.81 cm (1.5 in) | 5.08 cm (2.0 in) | 5.08 cm (2.0 in) |
| Rocker Switches | 1.27 cm (0.5 in) | 3.81 cm (1.5 in) | 1.27 cm (0.5 in) | 1.91 cm (0.75 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) |
| Toggle Switches | 1.27 cm (0.5 in) | 3.81 cm (1.5 in) | 1.91 cm (0.75 in) | 1.91 cm (0.75 in) | 1.27 cm (0.5 in) | 1.91 cm (0.75 in) | 1.91 cm (0.75 in) |
| Thumb-Wheels | 1.27 cm (0.5 in) | 3.81 cm (1.5 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) | 1.27 cm (0.5 in) | 1.91 cm (0.75 in) | 1.91 cm (0.75 in) |
| Discrete Rotary Controls | 1.27 cm (0.5 in) | 5.08 cm (2.0 in) | 1.27 cm (0.5 in) | 1.91 cm (0.75 in) | 1.91 cm (0.75 in) | 2.54 cm (1.0 in) | 2.54 cm (1.0 in) |
| Continuous Rotary Controls | 1.27 cm (0.5 in) | 5.08 cm (2.0 in) | 1.27 cm (0.5 in) | 1.91 cm (0.75 in) | 1.91 cm (0.75 in) | 2.54 cm (1.0 in) | 2.54 cm (1.0 in) |

[1]Separation is measured between the outermost adjacent edges.

**Supporting Rationale:** Several sources (see Reference 1 and 2) have provided recommendations for minimum distances between controls. Most of these recommendations have been developed for application in environments other than automobiles. However, they provide helpful information regarding location coding and avoidance of inadvertent activation of adjacent controls.

Shape coding is an effective way to increase the identifiability of controls and is most often used on rotary knobs. Most standard human factors references provide graphics showing knob shapes that are rarely confused with one another. See Reference 3 for some of these knob designs.

Size coding is most appropriate when ganged controls are used (i.e., two or more knobs mounted on concentric shafts). Different knob diameters must be used if the ganged controls are to be discriminable from one another. In automobiles, for example, volume and tone controls on the radio system are often ganged. Suggestions for different knob dimensions can be found in References 2 and 4.

There are three methods of texture coding that are rarely confused with one another: smooth, fluted (horizontal lines), and knurled (crisscross pattern). However, different methods and amounts of either fluting or knurling may be confused with each other.

**Special Design Considerations:** Because drivers are most often operating in-vehicle controls without taking their eyes off the roadway, it is important that they be as easy to locate and activate as possible. Coding can be extremely helpful for accomplishing this. However, in situations where gloves are used, redundant coding using colors and labels may become necessary.

**Cross References:**
*Selection of Control Type, p. 4-2*
*Control Movement Compatibility, p. 4-4*

**Notes:**

**Key References:**
1. Nuclear Regulatory Commission. (1981). *Guidelines for control room design reviews* (NUREG-0700). Washington, DC: U.S. Government Printing Office.
2. Boff, K. R., & Lincoln, J. E. (Eds.). (1988). *Engineering data compendium: Human perception and performance.* Wright-Patterson Air Force Base, OH: Armstrong Aerospace Medical Research Laboratory.
3. Hunt, D. P. (1953). *The coding of aircraft controls* (Technical Report 53-221). Wright-Patterson Air Force Base, OH: Wright Air Development Center.
4. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment, and facilities.* Washington, DC: U.S. Government Printing Office.

# SELECTION OF KEYBOARDS FOR ATIS DEVICES

**Introduction:** *Selection of keyboards for ATIS devices* refers to trade-offs and heuristics associated with fixed-function vs. variable-function keyboards. As discussed in Reference 1, examples of a fixed-function keyboard include cash register terminals and hand-held calculators; examples of a variable-function keyboard include keyboards for video games with different controls for different games, shifted keys of computer keyboards, and, in general, "soft" keys that can be changed via software control.

## Design Guidelines** (From Reference 1)

**Use fixed-function keyboards when:**

- One set of functions is frequently employed
- Functions must be executed quickly
- Correct function selection is critical

**Use variable-function keyboards when:**

- Several subsets of functions are frequently used
- Pacing of entries is not forced
- Sophisticated prompting and feedback are available

### Advantages and Disadvantages of Fixed- and Variable-Function Keyboards (from Reference 1)

| | **Fixed-Function Keyboards** | **Variable-Function Keyboards** |
|---|---|---|
| **Advantages** | Simplicity of operation | Fewer keys |
| | Function is evident from key | Less visual search |
| | Minimal software support | Less arm/hand movement |
| | Logical key grouping | Can be modified by software changes |
| **Disadvantages** | Numerous functions require numerous keys | Increased function selection time |
| | Frequent visual search | Decreased clarity of key labeling |
| | Frequent arm/hand movement | Increased prompting and feedback requirements |
| | Changes require hardware modification | Increased training requirements |

**Supporting Rationale:** The guidelines provided above reflect a review and analysis of fixed- vs. variable-function keyboards reported in Reference 1. They reflect common usage of both fixed- and variable-function keyboards, as well as general heuristics for their selection.

**Special Design Considerations:** It may be desirable to design ATIS devices so that they include both fixed- and variable-function keyboard elements. Functions that are common across ATIS tasks such as "Enter" or "Back" or "On/Off" might best be accomplished by using dedicated, fixed-function (or "hard") controls. Functions that involve selecting from among alternatives that vary from task to task (selection of: system functions, map scale, travel mode, etc.) might be best accomplished by using nondedicated, variable-function (or "soft") controls.

Also, while many devices can provide the driver with the ability to communicate with an ATIS (e.g., touch screens, speech controls, trackballs, push-buttons), keyboards are best for tasks that involve great amounts of text input, such as entering addresses for Routing and Navigation applications or entering preferences and services selection information for Motorist Services applications.

**Cross References:**
*Selection of Control Type, p. 4-2*

**Notes:**

**Key References:**
1. Greenstein, J. S., & Arnaut, L. Y. (1987). Chapter 11.4: Human factors aspects of manual computer input devices. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 1450-1489). New York: J. Wiley & Sons, Inc.

# DESIGN OF SPEECH-BASED CONTROLS

**Introduction:** *Design of speech-based controls* refers to systems that recognize human speech and treat speech commands as inputs to the ATIS system. As discussed in Reference 1, automatic speech recognition (ASR) systems may be characterized with respect to three sets of design characteristics. First, speaker-dependent systems recognize speech from only one speaker that has been calibrated to the system; speaker-independent systems can recognize speech from many speakers. Second, isolated word recognition systems require that speakers provide a pause or gap between words in a message; continuous speech recognition systems do not require any pause between words. Third, ASR systems vary with respect to the size of the vocabulary that they recognize.

## Design Guidelines**

- Speech controls should be used to aid complex tasks that involve high cognitive, visual, and/or manual requirements.
- Vocabulary sets for ASR systems should be familiar to drivers and should avoid using similar-sounding words or phrases.
- Drivers should be provided with immediate feedback of the recognition results or the system's response to the speech input.

### Issues to Consider When Designing ASR Systems

| Task-Related Issues | Environment-Related Issues | Operator-Related Issues |
|---|---|---|
| • Single versus Dual Task<br>• Workload<br>• Head Movement Requirements<br>• Driving Situation (e.g., effects of stress)<br>• Requirements for Feedback<br>• Vocabulary Requirements | • External Noise (e.g., traffic, road noise)<br>• Internal Noise (e.g., entertainment system, conversation)<br>• Vibration<br>• Acceleration/Deceleration G-forces | • Age<br>• Articulation<br>• Regional Accents<br>• Level of Training<br>• Gender |

**Supporting Rationale:** Reference 2 provides considerable discussion of issues and research related to speech controls; the guidelines presented above have been adapted from design principles presented in Reference 2 and, to a lesser extent, Reference 1. The guidelines presented above reflect limited experience in the use of speech as a control device from two technical domains: (1) military information systems and flight control, and (2) the telecommunications field. Case studies and anecdotal results from several applications of speech controls can be found in References 1 and 2. Although various commercial speech recognition systems have been developed for automotive applications, published empirical results are few and have not always provided consistent design guidance.

**Special Design Considerations:** As noted in Reference 2, key issues in the design and implementation of ASR systems include:

- Recognition accuracy: Lower accuracies will reduce system performance and user acceptance.
- Background noise: Ambient noise (traffic, radio, speech displays) can interfere with ASR system performance.
- Speech variability: Human speech varies considerably with respect to volume, frequency, pitch, and tone under different conditions. Speech variability can contribute to reduced recognition of speech.
- Task selection: Selection of tasks for which speech should be used must reflect task characteristics and a clear understanding of the trade-offs associated with using speech controls vs. manual controls.

**Cross References:**
*ATIS Design for Special Populations, p. 3-38*

**Notes:**

**Key References:**
1. McMillan, G. R., Eggleston, R. G., & Anderson, T. R. (1997). Nonconventional controls. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (pp. 729- 771). New York: J. Wiley & Sons.
2. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.

# PROVIDING DESTINATION PREVIEW CAPABILITY

**Introduction:** *Providing destination preview capability* refers to providing the user with the capability to recenter (slew) the map and to change the range scale (magnification) to enable full preview of route details. The user of an electronic map displaying route information may desire to preview the origin, destination, or any segment of the route. The system design should, however, distinguish clearly between a recentered map mode (i.e., vehicle in center of display) and the normal display mode (i.e., vehicle moves relative to stationary map) showing current position of the user/vehicle.\Failure to clearly distinguish between these two modes can result in confusion about current location.

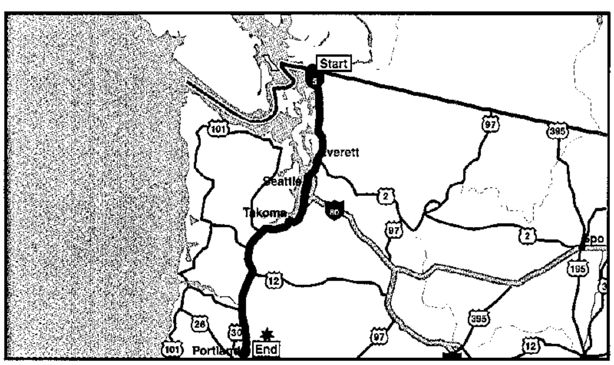
## Design Guidelines**

Allow ATIS users to preview a detailed depiction of the destination or other key nodes or segments of a planned route. This capability can be provided by the combination of a map recentering (slew) function and a map scale (magnification) function.

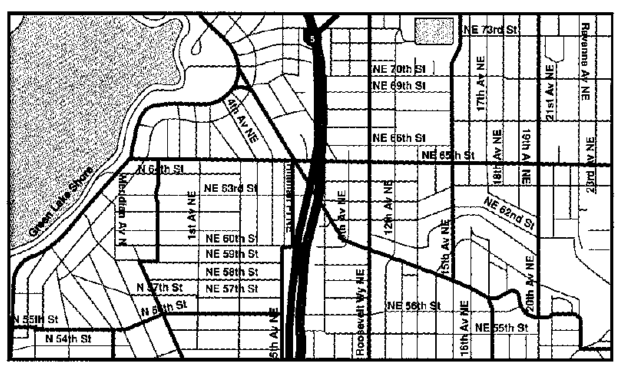
| Function | Description | Example Implementation |
|---|---|---|
| Map Slew/Recenter | Car in Center of Display, Geographic Definition, Definition of Map Segment | Touchscreen, or Joystick, or Trackball |
| Map Scale Control | Control of X, Y Scaling in Miles/Kilometers | Multistage Toggle Button or Knob, Up and Down Arrows |
| Map Mode Status Indicator or Lock-Out | Caution When Not Vehicle-Centered | Indicator Light, Recenter Button or Function Available Only When Stopped |

### Grand View of Long Route; Detailed View of One Node Recentered






Trip-Level Destination View




Preview of Route Segment Details

**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** As described in Reference 1, the utility of electronic maps is multiplied by incorporating the combination of a map scale control and recenter function. The combination of scale control and a recentering function enables the user to preview any area of the map in greater detail. The user can have a "high level" overview of a long route or a closer look at more detailed features pertinent to turns, areas of potential navigation errors, the destination, or other areas of interest.\With the magnified view, the map must be recentered to achieve a detailed view of a more distant map location.

**Special Design Considerations:** In-vehicle navigation displays typically depict the vehicle near the center of the display screen. When the user recenters the map, the vehicle symbol will no longer be in the normal location relative to the screen. This can lead to user confusion about current vehicle location, particularly if the user's attention is turned elsewhere after recentering. The benefits derived from empowering users to recenter the map must be weighed against the potential for misinterpretations of current location. Protection against this type of error can be designed into the system by displaying a caution indicator or by locking out the recenter function when the vehicle is in motion. If users are allowed to slew or recenter the map while in motion, a simple one-button return to the normal, user-vehicle-centered mode is recommended. A mode that allows the vehicle to always remain in the center of the screen may also be provided.

**Cross References:**

*Selection of Control Type, p. 4-2*
*Control Movement Compatibility, p. 4-4*

**Notes:**

**Key References:**

1. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).

# CHAPTER 5: ROUTING AND NAVIGATION GUIDELINES

This chapter provides human factors design guidelines relevant to Routing and Navigation Functions of ATIS devices. Routing and Navigation Functions provide drivers with information about how to get from one place to another. When integrated with an Advanced Traffic Management System (ATMS), Routing and Navigation provides information on recurrent and nonrecurrent traffic congestion and is capable of calculating, selecting, and displaying optimum routes based on real-time traffic data.

The following design topics are included in this chapter:

## ■ GENERAL GUIDELINES



## ■ SPECIFIC ROUTING & NAVIGATION MESSAGES

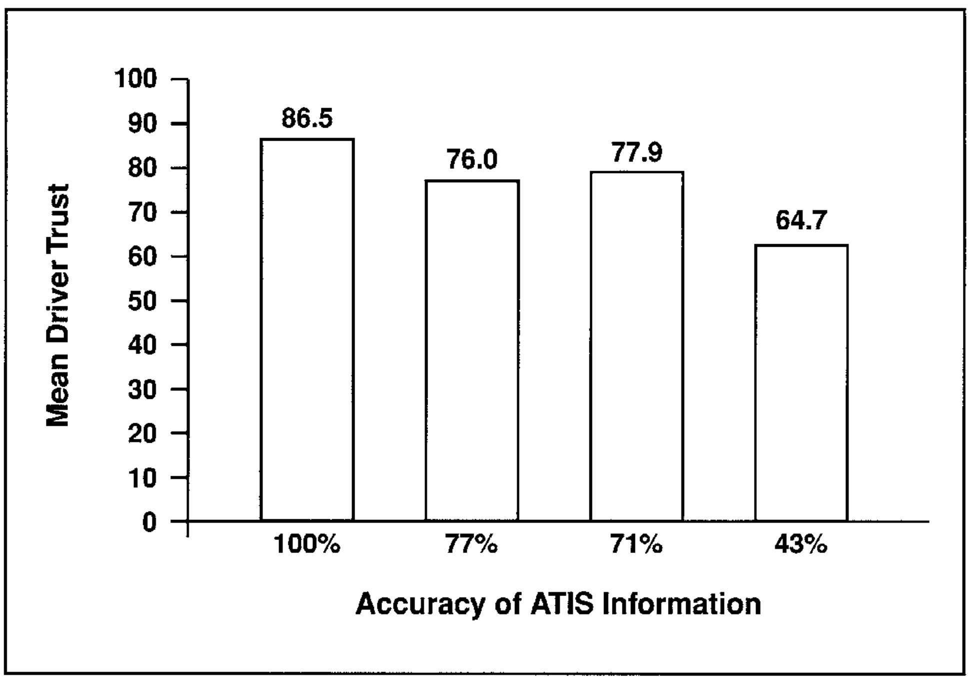
# ACCURACY OF ROUTING INFORMATION

**Introduction:** The *accuracy of routing information* refers to the correctness, usually expressed as a percentage, of traffic information presented to motorists. In this context, accuracy is considered to be a binary concept; i.e., the information is either accurate or inaccurate. Although accuracy is most often discussed with respect to congestion levels associated with various routing options, it may also refer to total travel time estimates, estimates of time delays due to congestion, and presentation of accident information.

## Design Guidelines****

- Across a typical trip, traffic information, such as congestion levels, should be at least 70% accurate.
- Higher accuracy levels may be required by drivers in a familiar setting (e.g., residents of a city) than in an unfamiliar setting (e.g., rental car drivers).

**Driver Trust in an ATIS at Different Levels of Information Accuracy**



**Supporting Rationale:** In Reference 1, a study was conducted which measured driver's trust in a simulated ATIS at different levels of system accuracy. Results showed that while 100 percent accurate information yields the best driver performance and subjective opinion, information that is 71 percent accurate remains acceptable and useful. Drivers are willing to tolerate some error in simulated ATIS. However, when information accuracy drops to 43 percent, driver performance and opinion suffer. Thus, information accuracy below 71 percent is not recommended to system designers. Future research is needed to evaluate information accuracy between 44 and 70 percent. It was also found that giving a driver inaccurate information in a familiar setting was more harmful than giving inaccurate information in an unfamiliar setting.

**Special Design Considerations:** One thing to consider when presenting route information to a driver is that there may be special design trade-offs between the accuracy of presented information and the timeliness of such information. For example, information accuracy may be increased by using multiple, independent sources of raw traffic data to derive estimates of congestion levels. However, such increases in accuracy may increase the time between the onset or occurrence of a traffic situation or condition, and the presentation of this information on an ATIS device. Another thing to consider is that drivers have greater self-confidence in familiar settings; they are more critical of ATIS and hold to a higher standard of user acceptability when they know the area geography. Thus, to achieve user acceptance, in-vehicle systems intended for purchase by a driver in a private passenger vehicle will likely have to meet higher standards than systems intended for commercial use.

**Cross References:**
*Color Coding of Traffic Flow Information, p. 5-6*
*Vehicle Location Accuracy, p. 5-20*
*Presentation of Route and Destination Selection Information, p. 5-22*
*Presentation of Dynamic Route Selection Information, p. 5-24*
*Presentation of Route Guidance Information, p. 5-26*
*Presentation of Route Information Involving Incidents, p. 5-32*

**Notes:**

**Key References:**
1. Kantowitz, B. H., Hanowski, R. J., & Kantowitz, S. C. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: The effects of inaccurate traffic information on driver acceptance of in-vehicle information systems.* Washington, DC: Federal Highway Administration (FHWA-RD-96-145).

## TIMING OF AUDITORY NAVIGATION INFORMATION

**Introduction:** The *timing of auditory navigation information* refers to the time or distance at which the ATIS should present an auditory instruction to the driver before an approaching navigation maneuver (e.g., a required turn).

### Design Guidelines**

- For maneuvers defined as leaving the current route (i.e., turning onto a side road), the timing of the auditory guidance instruction can be based on the equations provided below.
- It may be advisable to implement the equation for "preferred maximum distance." An instruction given slightly too early is preferable to one given too late.
- When the distance between two subsequent maneuvers is less than the minimum preferred distance for that speed, the instructions are "stacked" (given during a single message).

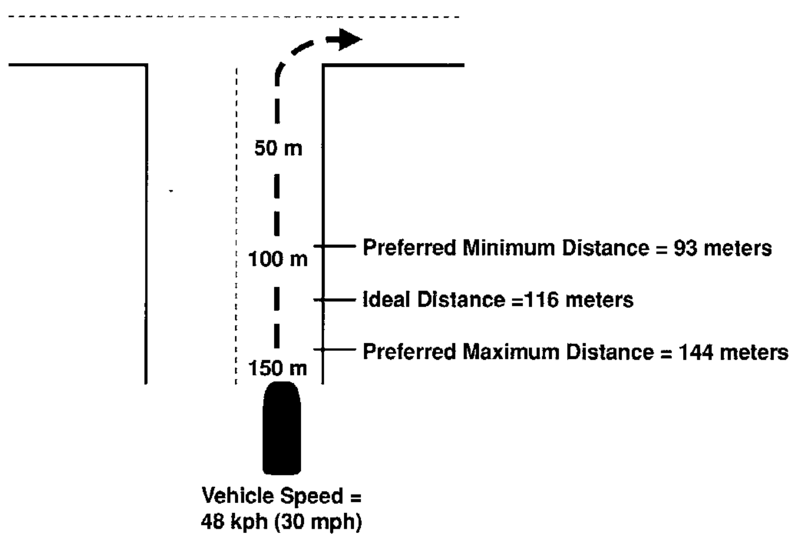
---

### Equations for Determining the Appropriate Timing of an Instruction

| Equations[1] | | |
|---|---|---|
| Preferred Minimum Distance | = (Speed x 1.637) + 14.799 | *(Eq. 10)* |
| Ideal Distance | = (Speed x 1.973) + 21.307 | *(Eq. 11)* |
| Preferred Maximum Distance | = (Speed x 2.222) + 37.144 | *(Eq. 12)* |

[1] where speed is in km/h and distances are in meters

### Example of the Suggested Timing for Navigational Information



**Supporting Rationale:** In Reference 1, subjects were asked to give a subjective rating of the timeliness of auditory navigation instructions (1 = much too early to 6 = much too late). From the subjects ratings, regression lines were plotted. Three separate equations were developed for calculating the distance at which navigation information should be given regarding an approaching turn onto a side road, while traveling at different speeds.

Reference 2 conducted a similar study aimed at determining the last possible moment at which a subject would feel comfortable hearing an auditory navigational instruction. The results of this study indicated that, traveling at speeds of 40 mph, the recommended distance for giving navigational instructions before a turn is 450 feet. However, it is necessary to make adjustments for other speeds (15 feet for each mile per hour); age of driver (up to 119 feet); the direction of turn, left or right (left turns require more warning distance); and gender of the driver. The results of this study are similar to those found in Reference 1 but were determined to be more difficult to apply to the general driver population.

**Special Design Considerations:** The applicability of these guidelines to visual guidance messages is uncertain. Since visual information (with no accompanying auditory alert) is likely to be perceived later than auditory messages, the distances recommended above may have to be increased somewhat to account for this delay. Turning off the current route is only one type of maneuver. There are many other types (i.e., turning at a T-intersection, or an existing freeway) which should be studied separately to determine the factors which will affect them. The results of these studies could then be combined with the above guidelines to determine the appropriate timings for any possible type of combination of maneuvers.

In Reference 3, it was recommended that if two maneuvers are less than 10 seconds apart, the two instructions should be given together, prior to the first maneuver. This is referred to as "stacking" the messages. Reference 1 gave a similar recommendation, stating that when the distance between two subsequent maneuvers is less than the minimum preferred distance for that speed, the instructions should be stacked.

**Cross References:**

*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*Auditory Message Length, p. 3-26*
*Message Styles, p. 3-32*

**Notes:**

**Key References:**

1. Ross, T., Vaughan, G., & Nicolle, C. (1997). Design guidelines for route guidance systems: Development process and an empirical example for timing of guidance instructions. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 139-152). Mahwah, NJ: Lawrence Erlbaum Associates.
2. Green, P., & George, K. (1995). When should auditory guidance systems tell drivers to turn? *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting,* (pp. 1072-1076). Santa Monica, CA: Human Factors and Ergonomics Society.
3. Verwey, W. B., Alm, H., Groeger, J. A., Janssen, W. H., Kuiken, M. J., Schraagen, J. M., Schumann, J., van Winsum, W., &Wontorra, H. (1993). GIDS functions. In J. A. Michon (Ed.), *Generic intelligent driver support: A comprehensive report on GIDS* (pp. 113-144). London: Taylor & Francis.

## COLOR CODING OF TRAFFIC FLOW INFORMATION

**Introduction:** *Color coding of traffic flow* information refers to the use of colors to represent the mean speed of traffic flows on different road segments along a particular route. This type of information might help drivers make more informed decisions regarding alternate routes, departure times, or modes of transportation, if necessary.

### Design Guidelines***

- Road segments should be color coded (green, yellow, red) to indicate the mean speed of the traffic flow.
- Do not present more than three or four levels of traffic information. The three distinguishable levels of congestion are low (roughly equivalent to level-of-service A and B), moderate (roughly equivalent to level-of-service C and D), and high (roughly equivalent to level-of-service E). A fourth, "stop-and-go" or "blocked lanes," may be added if necessary (roughly equivalent to level-of-service F).

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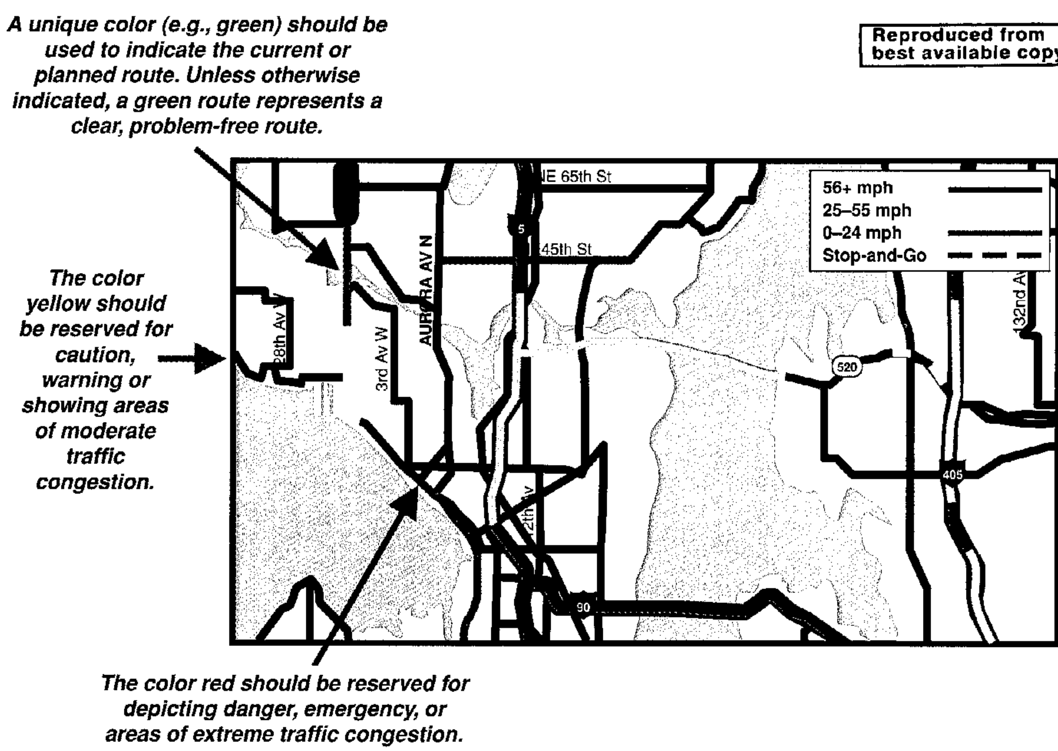
### Examples of Color Coding for Four Levels of Traffic Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** The results of usability tests reported in Reference 1 confirmed that there is an intuitive link between traffic light colors and traffic speed. Drivers consistently used the colors on the freeway lanes as well as a color key to correctly identify traffic speeds and make decisions regarding alternate routes. Reference 2 agrees with the color choices and states that it is not conflicting to use red, which normally means danger (International Standards Organization (ISO) 2575), to indicate heavy traffic, as heavier traffic does represent a more dangerous situation for the driver. Also, the color red is already used to indicate traffic congestion in some other countries (i.e., France).

Reference 3 provides definitions and descriptions for the various levels of service used to describe traffic conditions in terms of factors such as speed, travel time, safety, and freedom to maneuver.

**Special Design Considerations:** Choosing the best background color for the display is important. Colors that are generally good (i.e., yellow) may be poor choices for such a complex color map. Reference 1 conducted a usability study to determine the background color which would be easiest on the driver's eyes while displaying the information in the most effective manner. The results showed that most people preferred a gray background, found it easier to read, and thought that the other features of the map stood out the best with a gray background.

Roadway lines need to be thick enough so that the colors of roadways indicating the traffic conditions can be easily and quickly identified by the driver. A study conducted in Reference 4 used color coded lines that were 2 mm wide. Although line width was not an independent variable of interest in this study, lesser widths were found to be problematic. This would especially be true for older drivers. It should also be noted that, in order to enhance contrast, the background color used for this display was gray.

**Cross References:**
*Symbol Color, p. 3-16*
*Use of Color Coding, p. 3-20*

**Notes:**

**Key References:**
1. Miller, C., Spyridakis, J., & Haselkorn, M. (1994). A development tool for advanced traveler information systems screen designs. *IVHS review: An in-print forum for opinion and analysis,* Summer: pp. 75-97.
2. Ross, T., Midtland, K., Fuchs, M., Pauzie, A., Engert, A., Duncan, B., Vaughan, G., Vernet, M., Peters, H., Burnett, G., & May, A. (1996). *HARDIE design guidelines handbook: Human factors guidelines for information presentation by ATT systems* (DRIVE II Project V2008).
3. Transportation Research Board. (1992). *Highway capacity manual: Special report 209* (2nd ed. rev.). Washington, DC: Transportation Research Board, National Research Council.
4. Paelke, G., & Green, P. (1993). *Development and testing of a traffic information system driver interface* (Technical Report UMTRI 93-20). Ann Arbor, MI: The University of Michigan Transportation Research Institute.

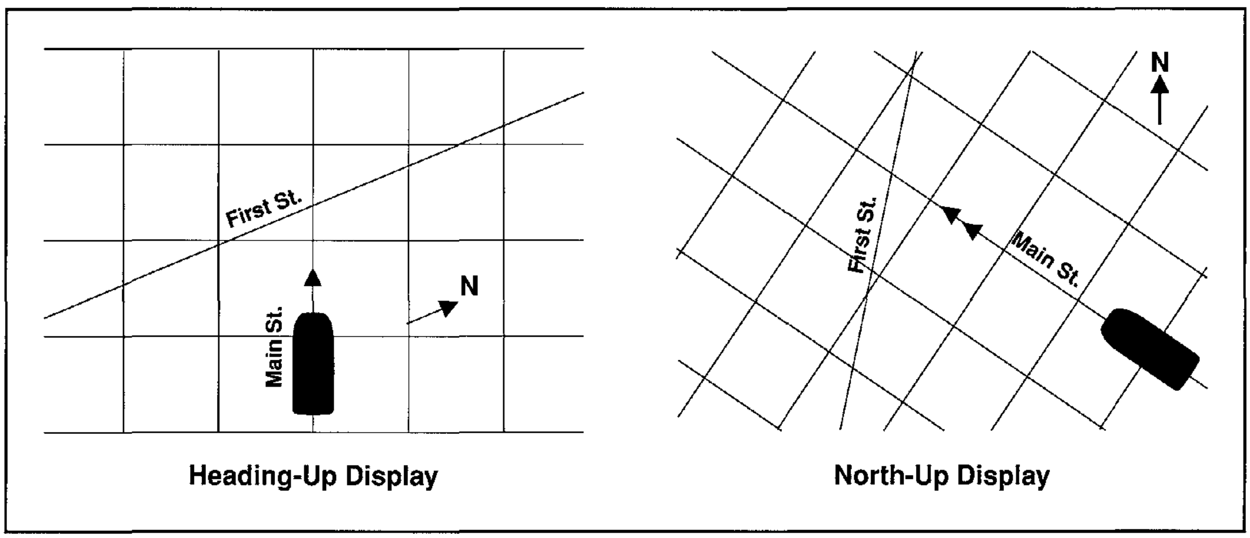
# ORIENTATION OF MOVING MAP DISPLAYS

**Introduction:** The *orientation of a moving map display* refers to the angle that the map is rotated relative to the electronic display surface. Moving map displays may be oriented in a number of ways. The most common orientations are north-up and heading-up (sometimes referred to as track-up). Paper maps used by motorists are typically drawn north-up, following traditional cartographic convention, that is, with true north being towards the top of the page. With a north-up moving map, the orientation of the symbol of the vehicle on the screen changes as the vehicle turns left and right; the symbol points towards the top of the map display only when the vehicle is pointing north. In contrast, with a heading-up map the vehicle symbol remains pointed towards the top of the screen regardless of the vehicle's heading. As the vehicle turns left and right, the map display rotates clockwise and counterclockwise, respectively, so that the symbol remains pointed towards the top of the screen. Variations of these two orientations are possible.

## Design Guidelines****

- The user of an in-vehicle navigation system should be able to select a heading-up or a north-up moving map display.
- In a route planning mode, the default should be north-up. When the system is in guidance mode, the default should be heading-up.

### Schematic Example of Heading-Up and North-Up Displays



**Supporting Rationale:** Reference 1 found that geographic orientation and map interpretation were considerably better when the map and the map user are oriented in the same direction. These data argue for aligning maps with the direction the driver is facing; i.e., a heading-up orientation. Experience with advanced aviation tactical and mission planning displays (Reference 2) has shown that users commonly select north-up mode when planning a route and heading-up mode when flying, when there are no constraints on mode selection.

**Special Design Considerations:** If multiple display orientations are possible, the user should be able to select between any of those modes for route planning or for route guidance modes of operations. Reference 3 describes a heading separated map orientation scheme which is an alternative to the north- and heading-up modes commonly used. Allowing experienced users to specify the default map orientations may be considered.

**Cross References:**
*Selection of Control Type, p. 4-2*

**Notes:**

**Key References:**

1. Adeyemi, E. O. (1992). The effect of map orientation on human spatial performance. *The Cartographic Journal, 19*(1), pp. 28-33.
2. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).
3. Prabhu, G. V., Shalin, V. L., Drury, C. G., & Helander, M. (1996). Task-map coherence for the display of in-vehicle navigation displays. *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting,* (pp. 822-886). Santa Monica, CA: Human Factors and Ergonomics Society.

## PRESENTATION OF GENERAL TRIP PLANNING INFORMATION

**Introduction:** *General trip planning information* refers to information which would assist drivers in the coordination of long and/or multiple-destination journeys. Coordination of these journeys may involve identifying scenic routes and historical sites. However, the general purpose of this information is to provide the driver with an estimate of journey time, mileage, and costs.

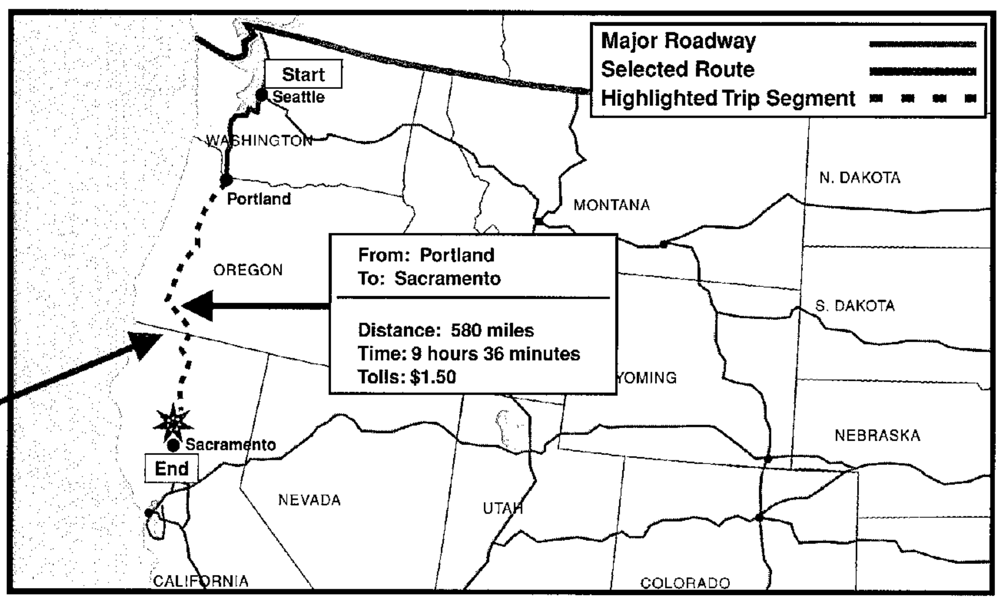
**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Total trip time | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Time to each destination or Auditory | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Total trip mileage | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Mileage to each destination | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Total trip cost | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Number of tolls and cost of each toll per segment | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |

### Schematic Example of Presenting General Trip Planning Information



***Allow drivers to select individual trip segments and call up trip information (i.e., mileage, time, and cost) for each of the segments.***




**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying general trip planning information. It was determined that, due to the amount of attention potentially required by an ATIS visual display, it might be necessary to display some part of a complex message through the auditory channel. Also, the presentation of information regarding an entire route may be overwhelming in actual driving situations and should therefore be avoided. An alternative might be to break the trip down into succinct "chunks" associated with salient waypoints within the total trip. Because this information may be complex and require time and driver attention to assimilate, this type of information should be employed as a pretrip planning tool, available only when the vehicle is stationary.

**Special Design Considerations:** Activities performed before the trip has begun are not constrained by many of the safety considerations that apply to in-transit displays. This means that designers can place less emphasis on reducing visual and mental attention, and that they should focus their display considerations on standard HCI issues.

**Cross References:** None.

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

## PRESENTATION OF ROADWAY INFORMATION

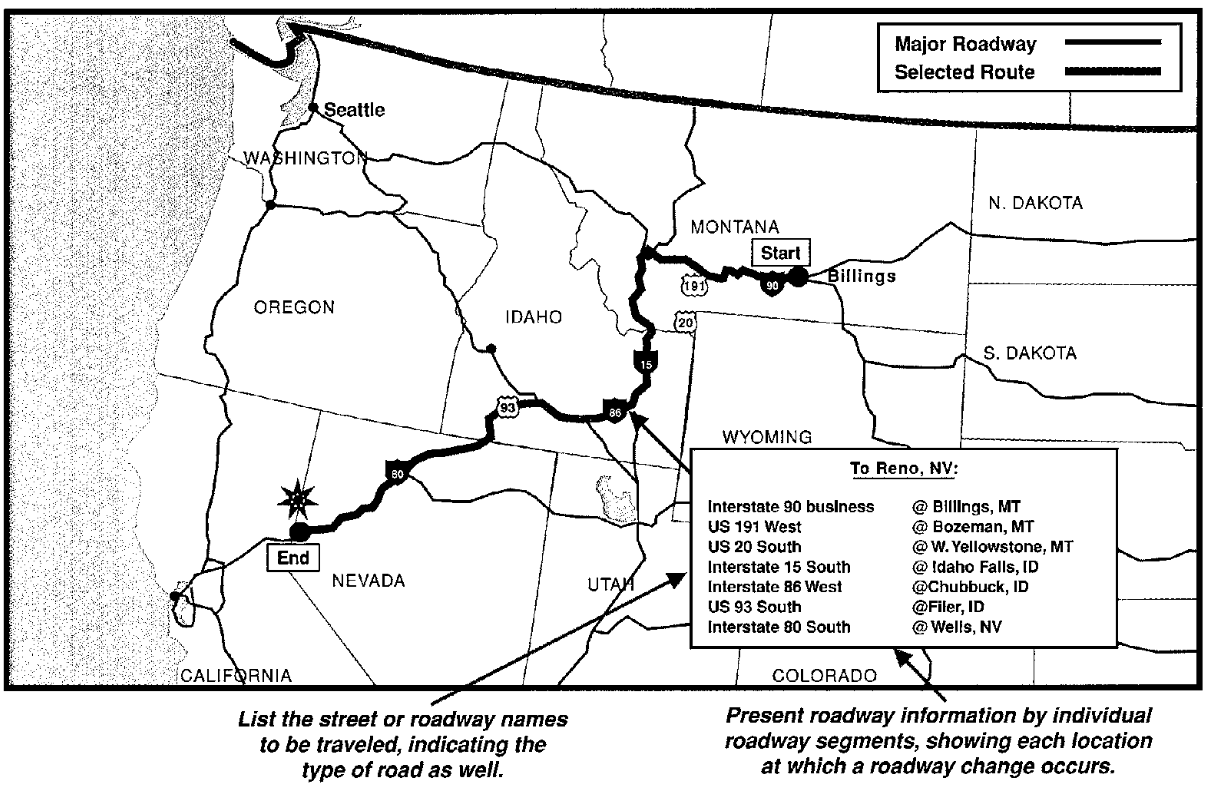
**Introduction:** *Roadway information* refers to information presented to a driver during trip planning. It may include the street or roadway names, the types of roads used, and the number of turns or roadway changes required along the route. This information will give the driver a general overview of the trip he/she is about to take, as well as familiarize them with the overall route.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Street or roadway names on route | Visual | Vehicle in PARK | Full or partial route map with or without text |
| Types of roads used on route (interstates, highways, 2-lane streets) | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Number of turns or roadway changes required | Visual | Vehicle in PARK | Text description with voice or iconic or graphic representation with text |

### Schematic Example of Presenting Roadway Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying roadway information. It was determined that when providing the driver with location, pathway, or position type information that is in either a simple or complex format, it is most desirable to use a full or partial route map. However, adding text can be beneficial in complex situations where the information might not be fully understood with just a picture. It was also determined that the presentation of roadway information for the entire route could be overwhelming in actual driving situations and should therefore be avoided. However, because pictorial full-route maps can offer drivers a valuable preview, they should be employed as a pretrip planning tool but made available only when the vehicle is stationary.

**Special Design Considerations:** Reference 2 discusses a study which tested subjects' ability to plan a bus route using either a list or a map. The subjects who used a map made their decisions more quickly than those who used a list. However, Reference 3 found that subjects who studied a map of a driving route made more errors when actually driving the route than did subjects who studied a textual list of turns. The above studies indicate that textual lists are easier to use than maps, but that maps provide additional information that textual lists do not. Therefore, the choice of a map or a list must depend on the desired task and required information. Depending on the requirements of the system under design, the inclusion of both display formats may provide the most useful overall system for drivers.

**Cross References:**

*Presentation of Point of Interest Information, p. 5-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Bartram, D. J. (1980). Comprehending spatial information: The relative efficiency of different methods of presenting information about bus routes. *Journal of Applied Psychology,* 65, pp. 103-110.
3. Wetherell, A. (1979). Short term memory for verbal graphic route information. *Proceedings of the Human Factors and Ergonomics Society 23rd Annual Meeting,* (pp. 464-468). Santa Monica, CA: Human Factors and Ergonomics Society.

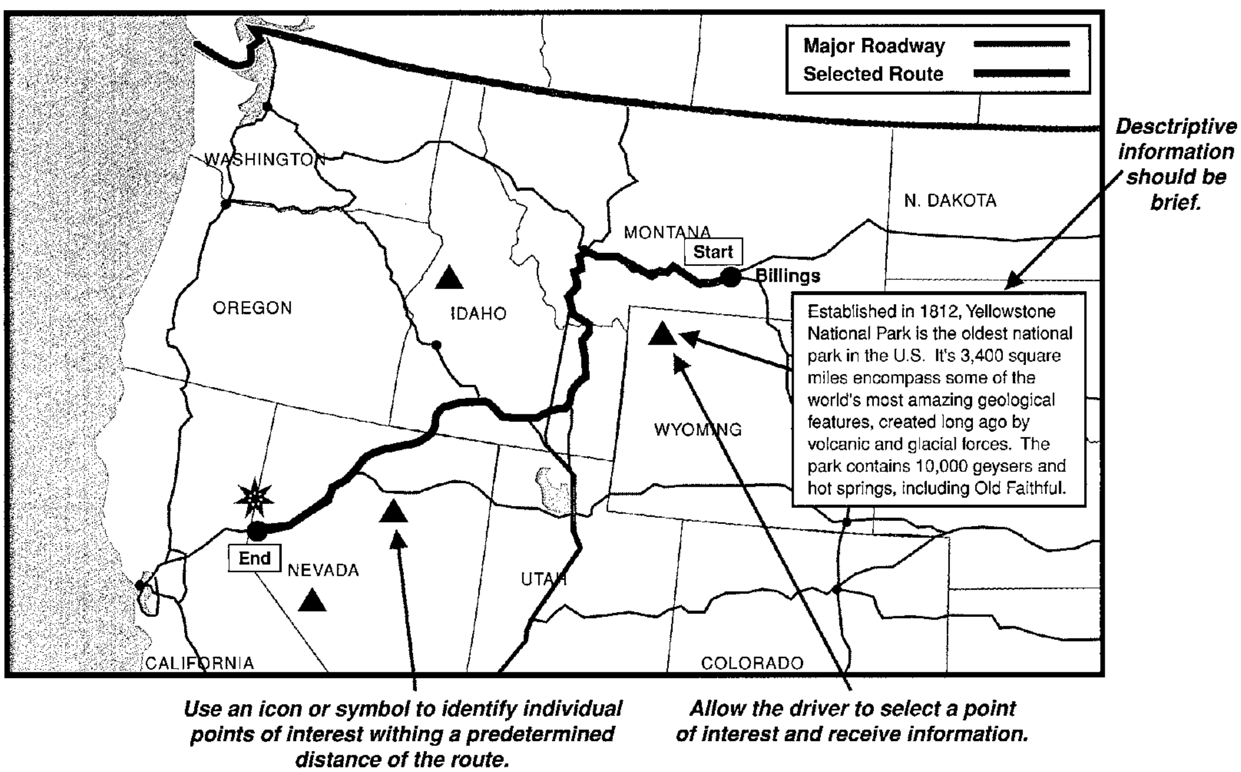
## PRESENTATION OF POINT OF INTEREST INFORMATION

**Introduction:** *Point of interest information* refers to information presented to the driver that identifies scenic routes, historical sites, national parks, and recreational areas within a predetermined radius surrounding the route. Having this information will allow drivers to choose whether or not they wish to adjust their route and travel plans to include a specific point of interest. Other information that might be presented includes states, regions, communities, and districts along the route.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Location of attractions and points of interest | Visual | Vehicle in PARK | Full map or full or partial route map with text |
| Landmarks or topographical features | Visual | Vehicle in PARK | Full map or full or partial route map with text |
| States, regions, communities and districts along the route | Visual | Vehicle in PARK | Full map or full or partial route map with text |

### Schematic Example of Presenting Point of Interest Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying point of interest information. While it was determined that any information a well-designed ATIS can present will be considered useful, the system does not need to present all of it to drivers while they are operating the vehicle. The value and cost (in terms of information processing and control requirements) of providing the information during any given trip mode must be determined. Some types of information, such as guidance instructions, should be presented in-transit, because they have a high value while driving. Other types of information, such as many trip planning functions, are complex, require more attention, and are therefore high cost to driver attention. Such information should be displayed only when the vehicle is stationary.

**Special Design Considerations:** Allowing the driver to enter information regarding the trip goals (i.e., personal interests, cost constraints, distance willing to divert, etc.) would allow the computer to search a database and identify relevant travel information. This information could then be presented to the driver so that he/she could make a selection from among the possible alternatives.

**Cross References:**
*Presentation of Roadway Information, p. 5-12*

**Notes:**

**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

# CLEAR DEPICTION OF ROUTE ON ELECTRONIC MAPS

**Introduction:** Route information displayed on an electronic map must be clearly distinguishable from normal map features in both route planning and guidance modes. In paper maps, a planned route can be clearly indicated by highlighting it with a colored marker. Similarly, on electronic maps, the user must be able to immediately discriminate the route from the variety of line shapes, sizes, and colors that may be used on the electronic map to depict local streets, arterials, highways, interstates, rivers, and other features.

## Design Guidelines**

- The user of an in-vehicle navigation system should be able to clearly distinguish a recommended, planned, or selected route from all other map features.
- A transparent color overlay in a unique color, such as green, is recommended to indicate the route.
- Other possible methods for highlighting the route are thicker or bolder street/highway lines. Thicker lines should be 1.5–2 times wider than the standard line.
- If colored lines are shown against a colored background, the color contrast between the elements should be a minimum of 100ΔE (CIE Yu'v') distances.

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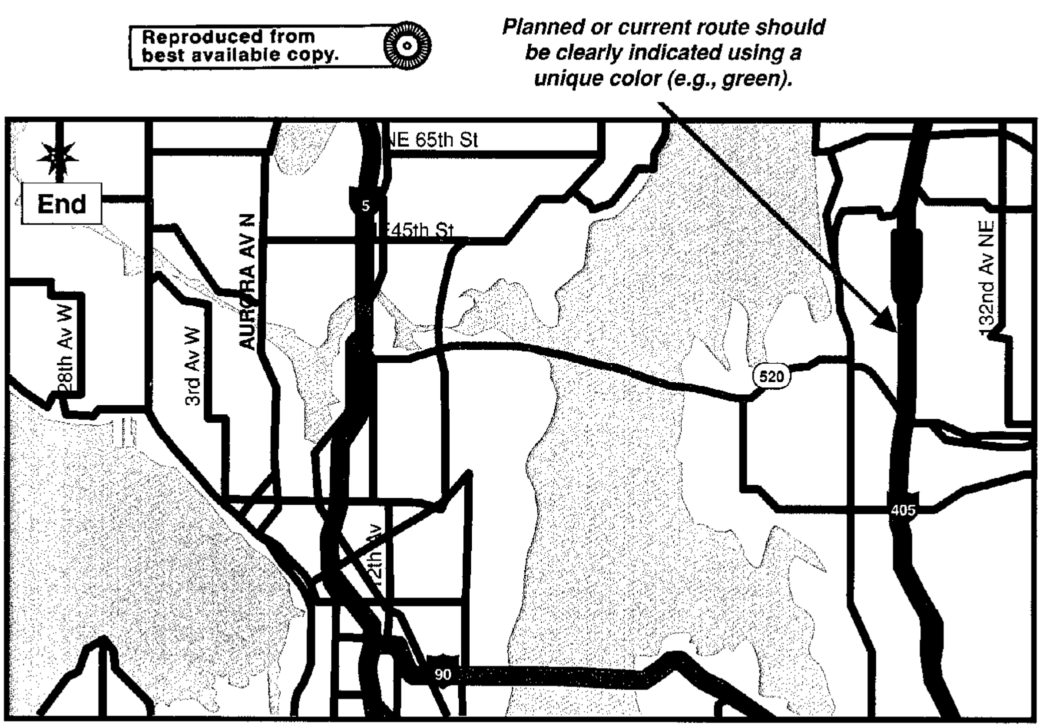
### Schematic Example of Map Showing Color Coded Route






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** As described in Reference 1, route guidance on an electronic map is beneficial only if the user can easily identify the indicated route. The user, often the driver, may not have time available to search the map display. Highlighting the route will reduce this search time. Inadequate highlighting of the recommended route increases driver workload and leads to increased time with eyes on the display rather than on the road.

Reference 2 recommends that colored symbols should differ from their colored background by a minimum of 100Δ(CI Yu'v') distances (see also the design guideline entitled "Color Contrast" in Chapter 3 of this document).

**Special Design Considerations:** The method chosen to highlight the route must not detract from other information depicted on the map. The route highlighting also must have the same dynamic characteristics as all other map features, i.e., it must move correctly in both north-up and heading-up modes. The route highlighting must be robust over a wide range of ambient lighting, from night to direct sunlight. Redundant coding techniques, e.g., color codes in addition to bolder, thicker route lines, may also improve comprehension.

**Cross References:**
*Selection of Colors for Coding Visual Displays, p. 3-18*
*Use of Color for Coding, p. 3-20*
*Color Contrast, p. 3-22*

**Notes:**

**Key References:**

1. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).
2. American National Standards Institute. (1988). *American national standard for human factors engineering of visual display workstations.* Santa Monica, CA: Human Factors and Ergonomics Society.

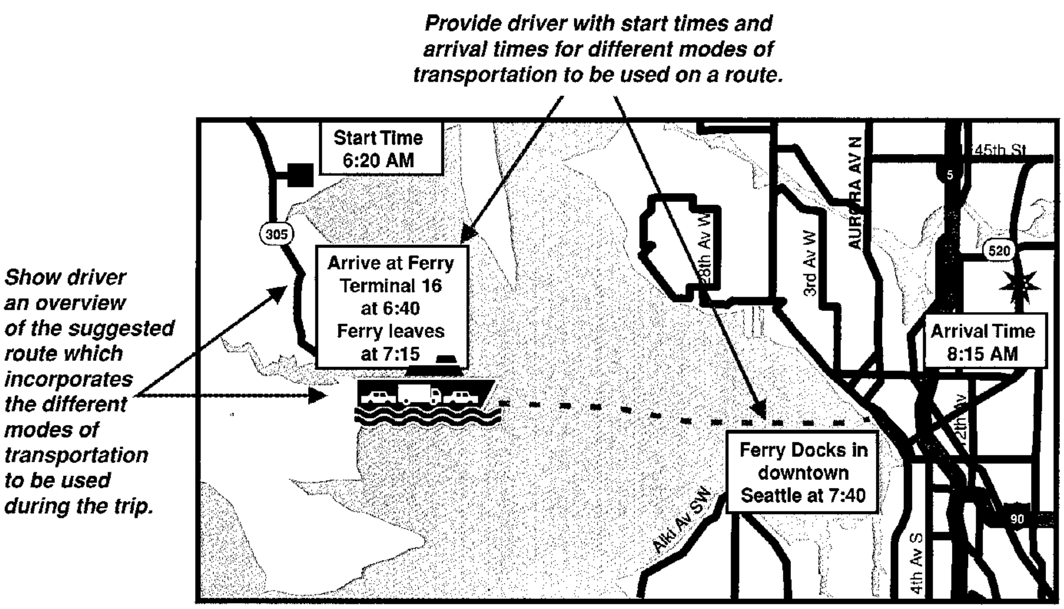
# PRESENTATION OF TRAVEL COORDINATION INFORMATION

**Introduction:** *Travel coordination information* refers to information regarding different modes of transportation (e.g., buses, trains, and subways), that may be used in conjunction with driving a vehicle. This information might include real-time updates of actual bus arrival times and anticipated travel times, and would allow coordination of multimode trips.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Start time required to catch other mode of transport | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Mode of travel to take for each segment of travel | Visual | Vehicle in PARK | Text description or iconic or graphic representation with text |
| Arrival time at end of each segment of travel | Visual | Vehicle in PARK | Text description or iconic or graphic representation with text |
| Layover time between travel segments | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Arrival time at destination | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Total time to complete travel | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |

## Schematic Example of Presenting Travel Coordination Information




**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying travel coordination information. It was determined that due to both the amount of information being presented and the complexity of that information, the system should present travel coordination information to the driver while the vehicle is stationary. Activities performed before the trip has begun are not constrained by many of the safety considerations that apply to in-transit displays. This means that designers can place less emphasis on reducing visual and mental attention, and that they should instead focus their display considerations on standard human-computer interface issues, such as optimizing display efficiency and ease of use.

**Special Design Considerations:** According to Reference 2, the main human constraint with this subsystem will be entering the information into the computer system. The drivers' ability to operate the system will depend upon their familiarity with computers and their ability to navigate complex menu systems. The driver may also be constrained by his or her perceptions of system reliability. If the computer supplies erroneous information, or information is presented in a confusing way, the advice might not be followed. A study reported in Reference 3 found that information which is less than 70 percent reliable will reduce the driver's trust in the system. Also, Reference 4 suggests that traffic information, such as estimated arrival times, be updated at least every 15 minutes.

**Cross References:**
*Accuracy of Routing Information, p. 5-2*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats*. Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Lee, J. D., Morgan, J., Wheeler, W. A., Hulse, M. C., & Dingus, T. A. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicles: ATIS and CVO functional description*. Washington, DC: Federal Highway Administration (FHWA-RD-95-201).
3. Kantowitz, B. H., Hanowski, R. J., & Kantowitz, S. C. (1997). Driver reliability demands for traffic advisory information. In Y. I. Noy (Ed.), *Ergonomics and safety of intelligent driver interfaces* (pp. 1-22). Mahwah, NJ: Lawrence Erlbaum Associates.
4. Dingus, T. A., & Hulse, M. C. (1993). Some human factors design issues and recommendations for automobile navigation information systems. *Transportation Research, 1C*(2), pp. 119-131.

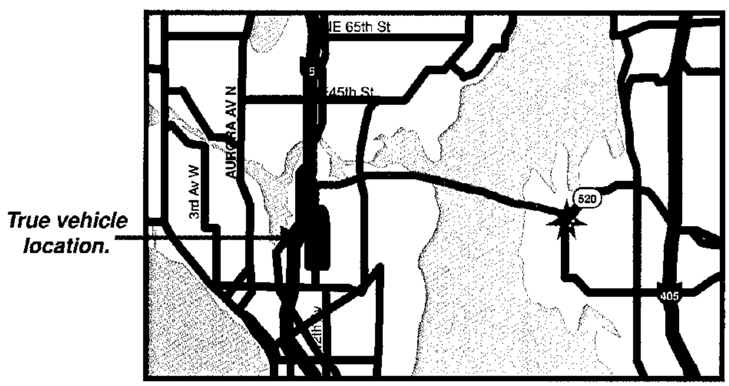
# VEHICLE LOCATION ACCURACY

**Introduction:** *Vehicle location accuracy* refers to the difference between the actual position of the vehicle and the position of the vehicle as presented by an ATIS or CVO device. Accuracy is a function of both the variability inherent to the method of determining the vehicle's position (e.g., differential GPS provides a more accurate position estimate than does raw GPS) and, in the case of a moving vehicle, the latency in determining the position. Error attributable to the position sensing system is often described as the ellipse (or circle) that contains the true position of the vehicle a known percentage of time. Typically, 95 percent or 99 percent is used as the criterion for the error envelope. The root mean square (RMS) error is an alternative method commonly used to describe the position error. Position error due to latency is a function of the update rate and the velocity of the vehicle. Assuming that the system is able to determine the position of the vehicle perfectly, a 1 second delay in updating the position of a vehicle traveling 100 kph (62 mph) results in an error of 27.8 m (91 ft).

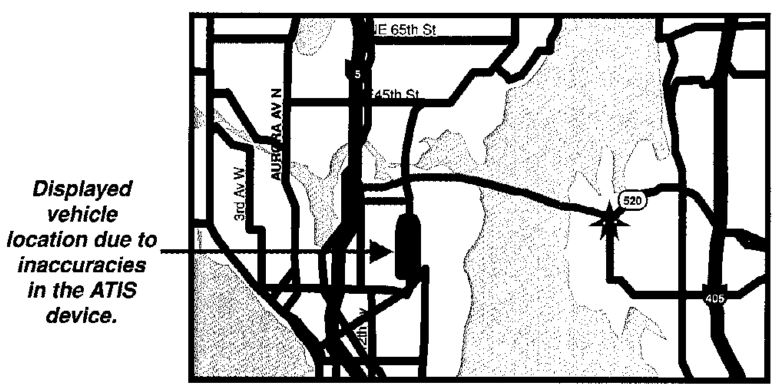
## Design Guidelines*

The maximum error for navigation and guidance systems should not exceed 27.8 m (91 ft), and in no case should cause the system to assume that the vehicle is on a parallel road.

## Schematic Example of Presenting Accurate and Inaccurate Vehicle Location Information




*Recommended route based on accurate vehicle position.*




*Recommended route based on inaccurate vehicle position.*

**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** As summarized in Reference 1, inaccurate vehicle position information can result in a misleading route selection. The top figure on the left-hand page shows a recommended route generated by a system that has accurately determined the position of the vehicle on the road network. The bottom figure on the left-hand page shows a route that would be generated if the position error is so large that the assumed position of the vehicle is on a road parallel to the correct road. The route shown in the bottom figure, and guidance commands based on that route, would be misleading to the driver.

Inaccurate information also adversely impacts the usability of a route guidance system (Reference 1). Consider a route guidance system that has a large lag. In this case, the vehicle would be closer than desirable to the point that the system should signal that a turn is upcoming. The magnitude of the error will be a function of vehicle speed.

**Special Design Considerations:** Anecdotal evidence suggests that there are certain situations in which even accuracy to within 91 feet may not be sufficient. For example, surface streets are frequently located near, or even directly beneath, freeways or highways above the surface streets. Thus, the ATIS may confuse roadways at different surface levels that are adjacent to one another. Under such conditions, location accuracies may need to be within 10 meters or 30 feet.

This is especially critical in applications where drivers must be provided advance notice of maneuvers. For systems in which contact analog symbology is displayed, vehicle position errors in alignment between symbology and the external scene must be reduced to a level that is acceptable to system users. If vehicle position information becomes degraded, or there is uncertainty about the level of accuracy, the interface should clearly provide the driver and dispatcher a message to indicate the state of the system. In cases where position error is questionable, the driver and others relying on accurate representation of the vehicle's position (e.g., a dispatcher) should be presented with a clear message that the location of the vehicle is questionable. As soon as the problem is corrected, the system should update the route information and indicate that the system is performing at the normal level of accuracy.

Designers of CVO systems should be aware that the acceptability of navigation systems is strongly influenced by perceived errors in the system. As drivers and fleet managers expressed in interviews conducted in Reference 1, the trust placed in the system is critical to the frequency of use and reliance on the system.

**Cross References:**
*Accuracy of Routing Information, p. 5-2*

**Notes:**

**Key References:**
1. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).

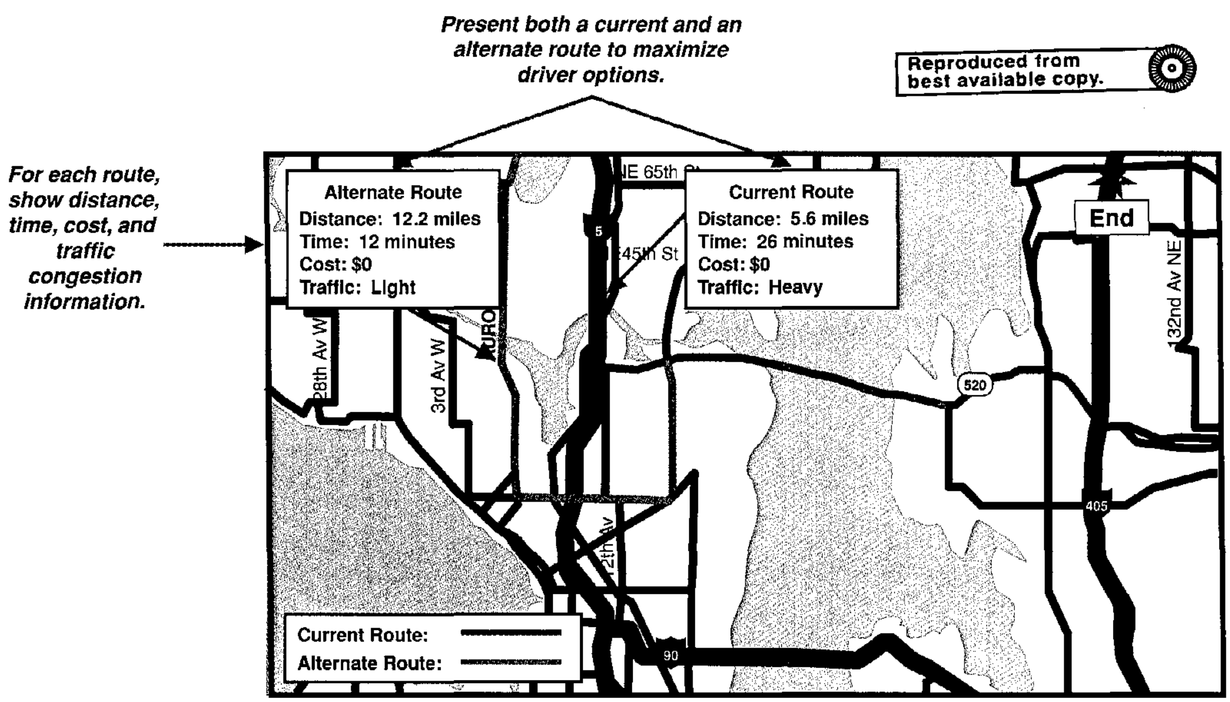
## PRESENTATION OF ROUTE AND DESTINATION SELECTION INFORMATION

**Introduction:** *Route and destination selection information* refers to destination and route selection choices that the driver engages in when the vehicle is in park and when driving to one destination. The information provided by the system might include real-time or historical congestion information, estimated travel time, and routes that optimize travel on a variety of parameters.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Preview of proposed alternative route | Visual | Vehicle in PARK | Text description with voice |
| Distance to destination | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Time to destination | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Cost of completing route | Auditory and Visual or Auditory | Vehicle in PARK | Text description with voice or as speech with or without icons |
| Historical congestion information | Visual | Vehicle in PARK | Text description or iconic or graphic representation with text |

### Schematic Example of Presenting Route and Destination Selection Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying route and destination selection information. For location, pathway, or position type information, the full or partial route video maps are clearly the most desirable. Adding text is beneficial in complex situations where the information might not be fully understood with just a picture. The redundant or supplemental use of text will help to provide context to ease in information transfer. The amount of attention required for attending to this type of information might make it necessary to display some part of the message through the auditory channel.

**Special Design Considerations:** Reference 2 analyzed the impact of traffic information on commuters' behavior and found that pretrip information is more valuable to commuters than enroute information. Having traffic information before drivers begin their trips allows them to make the necessary decision regarding departure time and route choices. Almost 16 percent of the people surveyed indicated that they had more than one route that they used to drive to work; i.e., different on-ramps or off-ramps, different freeways or surface streets. However, a PC-based simulation study, conducted in Reference 3, discovered a "route bias" which revealed that drivers are more likely to follow advice to take the freeway than they are to take the side roads or surface streets. Thus, implementation of an ATIS system that provides route information would make even more drivers aware of potential alternate routes.

**Cross References:**
*Color Coding of Traffic Flow Information, p. 5-6*

**Notes:**

**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Abdel-Aty, M. A., Vaughn, K. M., Jovanis, P. P., Kitamura, R., & Mannering, F. L. (1994). Impact of traffic information on commuters' behavior: Empirical results from southern California and their implications for ATIS. *Moving Towards Deployment: Proceedings of the IVHS America 1994 Annual Meeting, 2,* (pp. 823- 830). Atlanta, GA: IVHS America.
3. Vaughn, K. M., Abdel-Aty, M. A., Kitamura, R., & Jovanis, P. P. (1993). Analysis of sequential route choice under ATIS. Computing in civil and building engineering. *Proceedings of the Fifth International Conference (V- ICCCBE),* (pp. 825-832). New York: American Society of Civil Engineers.

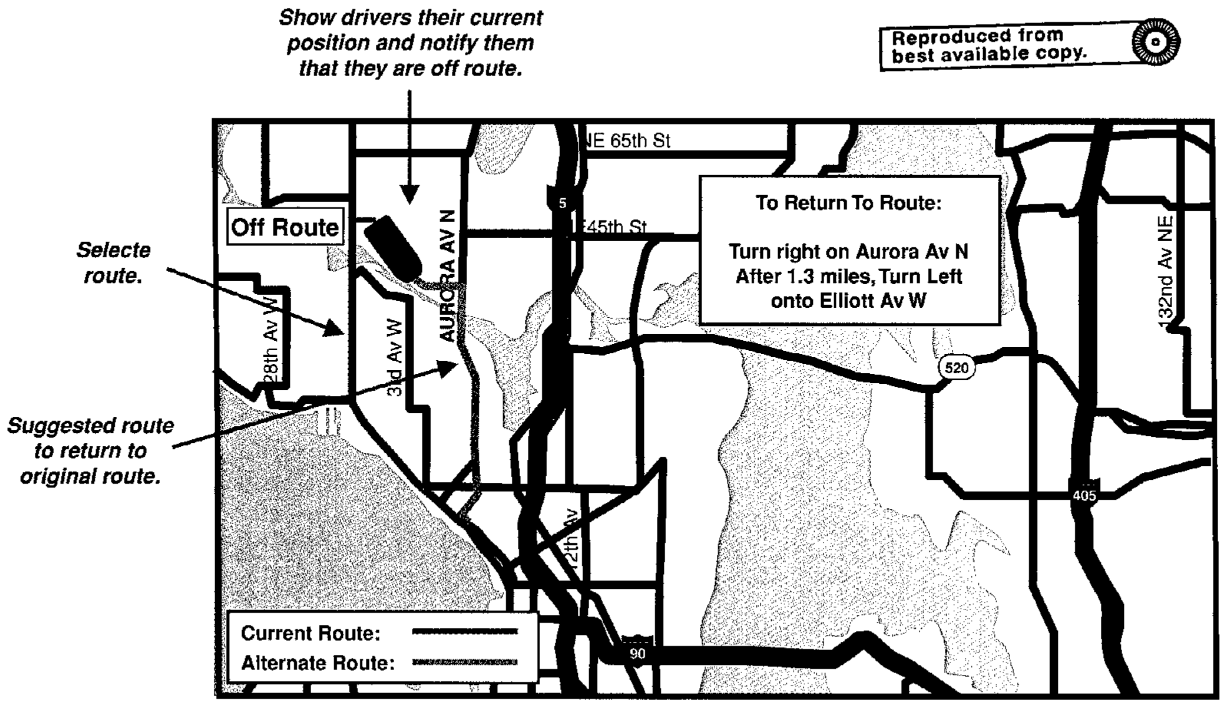
# PRESENTATION OF DYNAMIC ROUTE SELECTION INFORMATION

**Introduction:** *Dynamic route selection information* refers to any route selection function which is performed during the drive. The purpose of this ATIS function is to provide the driver with a mechanism for recovering once they have left or wandered from the intended route. When a driver makes a wrong turn and leaves the intended route, the dynamic route selection function can generate a new route which will accommodate the driver's current position.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Notification that the driver is off-route | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with voice, tones, or chimes |
| Vehicle's current position | Visual | Vehicle in Motion | Partial route map with or without text |
| Suggested procedure for getting back on route | Visual | Vehicle Stopped or in PARK | Partial route map with or without text |

### Schematic Example of Presenting Dynamic Route Selection Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying dynamic route information. Because almost all of the information presented will be displayed while the trip is in progress, display designers must minimize the amount of additional driver attention and workload. According to Reference 2, when guiding the driver to a destination, it is more helpful for the system to present the information to the driver in the form of instructions. The sensory modality that would best convey routing instruction information would vary, depending on the level of complexity that is involved. Complex information can be presented most efficiently through the visual channel, because drivers can process detailed visual information more rapidly than they can process detailed auditory information (Reference 3).

**Special Design Considerations:** There are a number of ways that an ATIS could deal with situations in which the driver has left a selected route, including recalculating a new route based on the current position or providing instructions on how to return to the original route. Another issue for designers to consider is whether or not the driver should have the option to reject the suggested route given by the computer. Perhaps the driver does not believe the suggested route would save them any time, or perhaps the suggested route would take the driver through a section of the city that the driver wishes to avoid for some reason. In these instances, the driver might want to be able to reject the route and select a different one. However, the amount of attention required for performing this task while driving could be substantially more than can be allocated safely. Therefore, the design effort needs to concentrate on the user interface and on making as much of the function automatic as possible.

If the procedure for getting back on route is relatively simple (e.g., a single turn), then an auditory message might be used.

Reference 2 states that drivers prefer systems that keep them informed of their current position. Therefore, throughout this guideline document, the current position of the vehicle is displayed to the driver using a small car icon.

**Cross References:**
*Color Coding of Traffic Flow Information, p. 5-6*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Streeter, L. A., Vitello, D., & Wonsiewicz, S. A. (1985). How to tell people where to go: Comparing navigational aids. *International Journal of Man-Machine Studies,* 22, pp. 549-562.
3. Deatherage, B. H. (1972). Auditory and other sensory forms of information presentation. In H. Van Cott & R. Kinkade (Eds.), *Human engineering guide to equipment design* (rev. ed.) (pp. 123-160). Washington, DC: U.S. Government Printing Office.

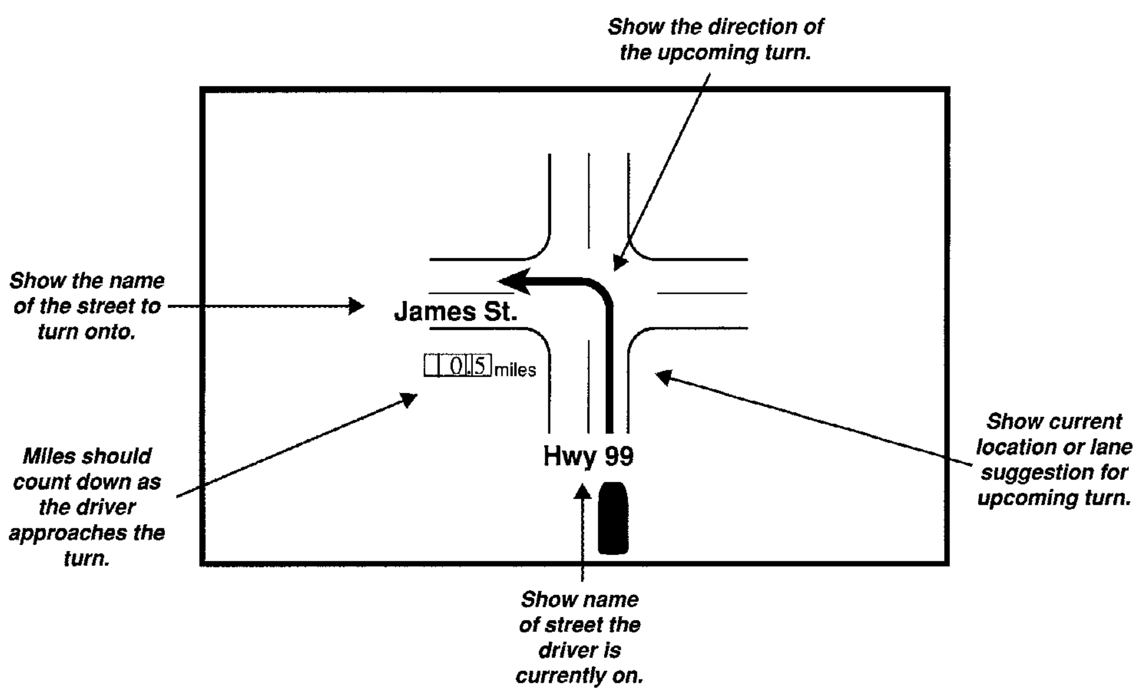
# PRESENTATION OF ROUTE GUIDANCE INFORMATION

**Introduction:** Given a destination and current location, *route guidance information* refers to navigation directions in a turn-by-turn format. Route guidance provides information such as: distance to the next turn, the name of the street to turn onto, what lane to be in to make the turn, and the direction of the upcoming turn.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Distance to next turn | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones or text description with tones |
| Name of street to turn on | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones or text description with tones |
| Lane suggestion for next turn | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones or text description with tones |
| Direction of turn | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones or text description with tones |
| Name of current street | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones or text description with tones |

**Schematic Example of Presenting Route Guidance Information**




**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying route guidance information. It was determined that almost all of the information presented during this ATIS function would be displayed while the trip was in progress and that the information should be presented in the form of turn-by-turn instructions to help avoid driver confusion or navigational errors. The sensory modality that would best convey navigation or routing instruction information will vary with the level of complexity that is involved. Complex information can be presented most efficiently through the visual channel, because drivers can process detailed visual information more rapidly than they can process detailed auditory information (Reference 2). However, simple information presented through the auditory channel may be easier for drivers to attend to.

**Special Design Considerations:** Several authors (see References 3, 4, and 5) have stressed the importance of limiting the amount of information presented to the drivers when they are driving. Reference 6 argues that the display should be limited to only the necessary information, including: the next turn, how far away the turn is, what street to turn on, and which direction to turn on a prespecified route. It also suggests that people who are familiar with an area prefer to be given cross streets of the next turn, whereas people who are unfamiliar with an area prefer to be given distance information. Distance values could be displayed continuously or intermittently (e.g., every 0.1 or 0.2 miles). An example of an effectively used continuous display would be one that lists the distance to the next turn at the top of the display screen and increments the distance downward until the turn is reached. A driver requesting an update to total distance remaining for the route would be served best by an intermittent display. Whether information is going to be displayed continuously or intermittently should influence a designer's choice of sensory modality, since continuous information can decrease the salience of time-critical information and increase required search and retrieval time. Additionally, continuous auditory information is likely to annoy the driver (Reference 7 and 8). An important factor in intermittent displays is that the driver needs to be alerted to the presence of new information, or the information might be missed. Also, research conducted in Reference 9 suggests that views of intersections should be plan views (directly overhead) or aerial views (as from a flying plane), but not perspective views (from the driver's eye view). This is in accordance with a laboratory study which found that 87 percent of drivers tested preferred the plan view (Reference 10).

**Cross References:**
*Auditory Message Length, p. 3-26; Timing of Auditory Navigation Information, p. 5-4*

**Key References:**

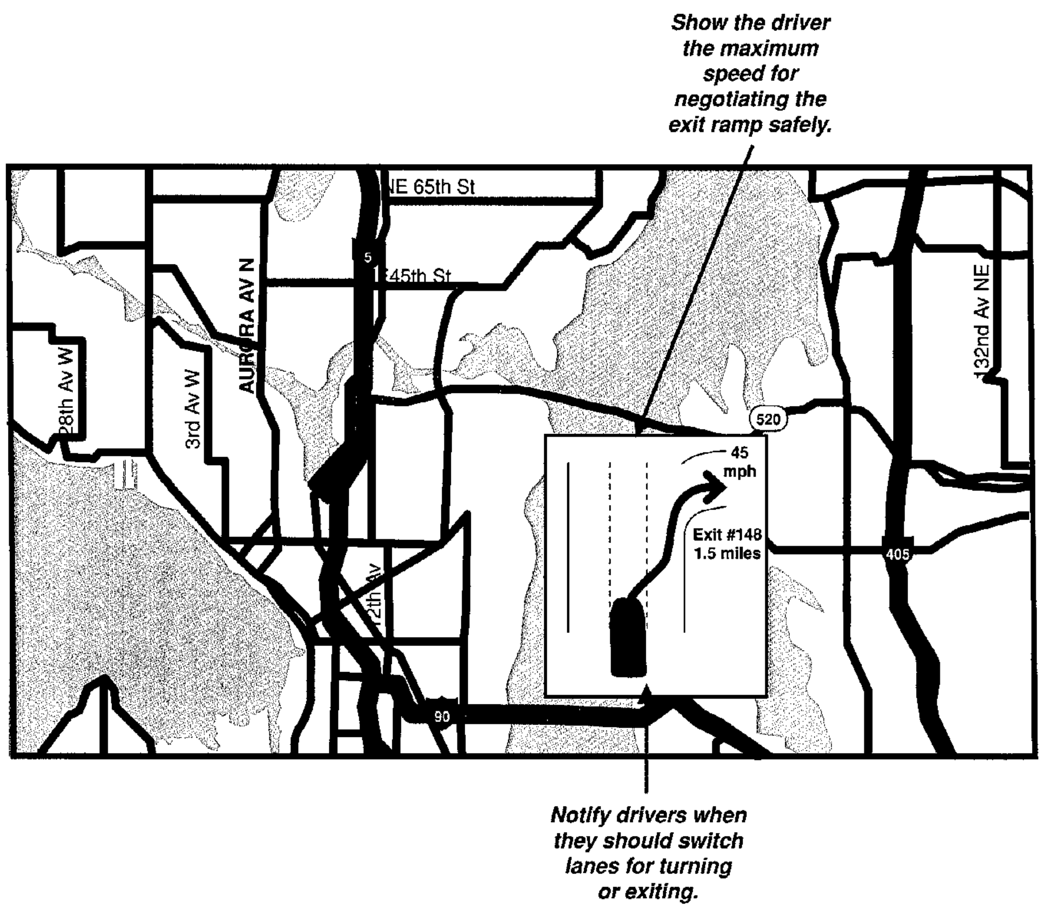
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Deatherage, B. H. (1972). Auditory and other sensory forms of information presentation. In H. Van Cott & R. Kinkade (Eds.), *Human engineering guide to equipment design* (rev. ed.) (pp. 123-160). Washington, DC: U.S. Government Printing Office.
3. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors and Ergonomics Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
4. Streeter, L. A., Vitello, D., & Wonsiewicz, S. A. (1985). How to tell people where to go: Comparing navigational aids. *International Journal of Man-Machine Studies, 22,* pp. 549-562.
5. Parks, A. M., Ashby, M. C., & Fairclough, S. H. (1991). The effect of different in-vehicle route information displays on driver behavior. *Vehicle Navigation and Information Systems Conference Proceedings,* (pp. 61-70). Warrendale, PA: Society of Automotive Engineers.
6. Streeter, L. A. (1985). Interface considerations in the design of an electronic navigator. *Auto Carta.*
7. Zaidel, D. M. (1991). *Specification of a methodology for investigating the human factors of advanced driver information systems.* Ontario, Canada: Transport Canada.
8. Wierwille, W. W. (1993). Visual and manual demands of in-car controls and displays. In B. Peacock & W. Karwowski (Eds.), *Automotive ergonomics* (pp. 229-320). London: Taylor & Francis.
9. Green, P., & Williams, M. (1992). Perspective in orientation/navigation displays: A human factors test. *Proceedings of the In-Vehicle Navigation and Information Systems Conference* (pp. 231-237). Warrendale, PA: Society of Automotive Engineers.
10. Peters, R. D., James, C., Wochinger, K., & Alicandri, E. (1995). Advanced traveler information systems (ATIS): Human factors staff research at the Federal Highway Administration. *Proceedings of the Institute of Transportation Engineers 65th Meeting* (pp. 677-680). Washington, DC: Institute of Transportation Engineers.

## PRESENTATION OF LANE POSITION INFORMATION

**Introduction:** *Lane position information* refers to information presented for the purpose of helping drivers avoid last minute lane changes. Providing the driver with a little extra lead time to make a lane change might be beneficial when driving an unfamiliar route or in circumstances where traffic is heavy and lane maneuvers may be difficult.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| When the vehicle needs to get in a lane for turning or exiting | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with voice or text description with voice |
| Maximum speed for negotiating the exit ramp safely | Visual | Vehicle in Motion | Iconic or graphic representation |

### Schematic Example of Presenting Lane Position Information




**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying lane position information. It was determined that this type of information would be most useful to the driver if displayed while in transit and that the convenience benefits would outweigh the costs (in terms of required driver resources to process this information). Reference 2 confirmed the ability of drivers to look at messages on an ATIS without affecting their lane-keeping abilities.

**Special Design Considerations:** In Reference 3, it is argued that the display should show two turns in a row when the turns are in close proximity (in succession). This would allow drivers to execute the first maneuver in such a way as to be prepared for the second maneuver. While there has not been empirical work done to determine what constitutes "close proximity," a reasonable working definition was determined to be 0.1 miles (0.06 kilometers), since that is the accuracy of all displayed information. When multiple messages are being presented, they should be presented in the order in which the driver must respond to them. For example, the message that should be attended to and responded to first should be presented first.

Presenting lane position information would be very beneficial for commercial drivers. Many commercial vehicles require substantially more time than private vehicles to make any kind of maneuver or lane change. Thus, it may be important to take vehicle size into consideration when determining the timing necessary for presenting lane position information.

**Cross References:**

*Auditory Message Length, p. 3-26*
*Complexity of ATIS Information, p. 3-28*
*Timing of Auditory Navigation Information, p. 5-4*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Kantowitz, B. H., Hanowski, R. J., Kantowitz, S. C., & Garness, S. A. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Display channels.* Washington, DC: Federal Highway Administration (FHWA-RD-96-148).
3. Rothery, R. W., Thompson, R. R., & von Buseck, C. R. (1968). *A design for an experimental route guidance system. Volume III: Driver display experimental evaluation* (Technical Report No. GMR-815-III). Warren, MI: General Motors Research Laboratories.

# PRESENTATION OF TOLL COLLECTION INFORMATION

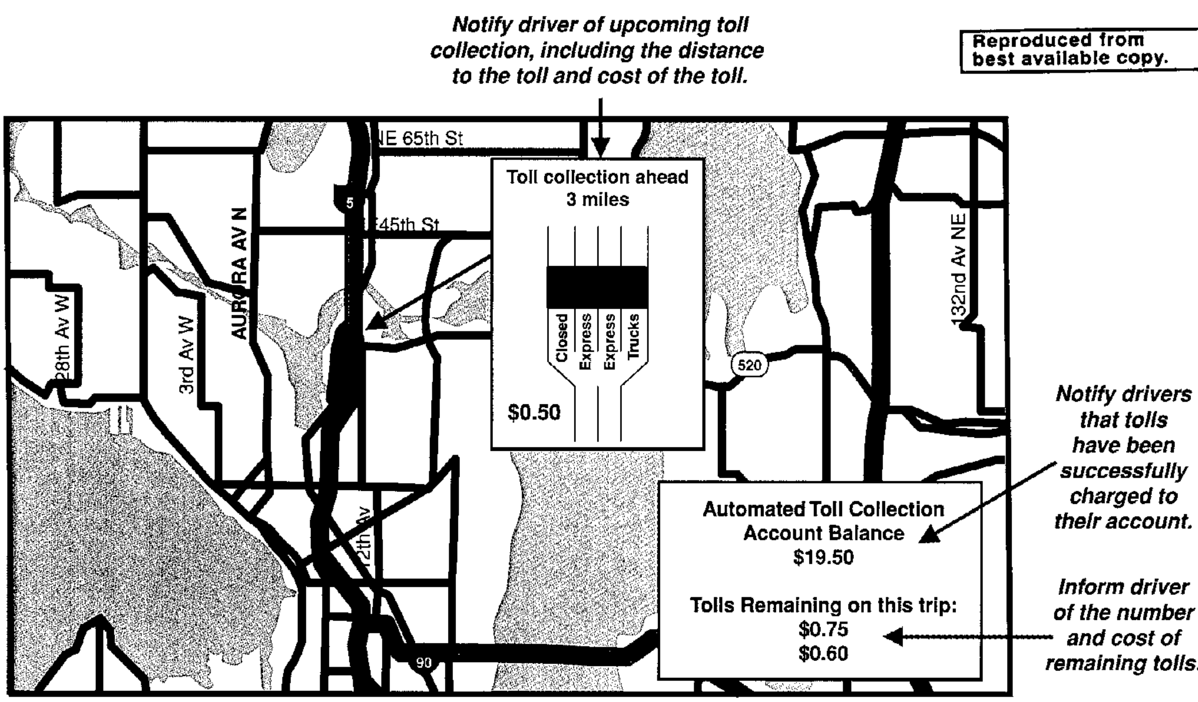
**Introduction:** *Automated toll collection* refers to allowing a vehicle to travel through a toll roadway without stopping to pay tolls. Instead, tolls would be automatically deducted from the driver's account as they drive past toll collection areas. This would enable tolls to be adjusted to balance traffic flows (higher toll rate during peak rush hour). Also, automated toll collection would provide drivers information regarding toll credits and the current toll costs.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Distance to toll booth | Visual | Vehicle in Motion | Iconic or graphic representation |
| Cost of toll | Visual | Vehicle in Motion | Iconic or graphic representation |
| Remaining balance in toll account | Visual | Vehicle in Motion | Iconic or graphic representation |
| Number of tolls to be paid along the route | Visual | Vehicle in Motion | Iconic or graphic representation |
| Notification of successful toll charge | Visual | Vehicle in Motion | Iconic or graphic representation |

## Schematic Example of Presenting Toll Collection Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying automated toll collection information. It was determined that this type of information would be most useful to the driver if displayed while in transit and that the convenience benefits would outweigh the costs (in terms of required driver resources). Also, because presentation of this type of information would be relatively infrequent and not extremely important with regard to aiding in navigation or driver safety, the visual modality was chosen as the primary method for presenting this type of information.

**Special Design Considerations:** The driver currently learns of the cost of the toll by reading a sign posted before the toll. ATIS can supply the driver with this information, as well as the vehicle's toll credit. The primary factor influencing the success of this function lies in driver acceptance of the technology. Thus, driver attitudes will govern the success of this system. If drivers believe that the system assesses tolls incorrectly or invades their privacy, they may prefer manual toll collection. By providing drivers with estimated costs of a trip, automated toll collection facilitates trip planning and predrive route and destination selection. Rapid communication of congestion pricing toll changes would facilitate multimode travel coordination and planning by aiding drivers in the comparison of private vehicle versus mass transit options.

**Cross References:**

*Complexity of ATIS Information, p. 3-28*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

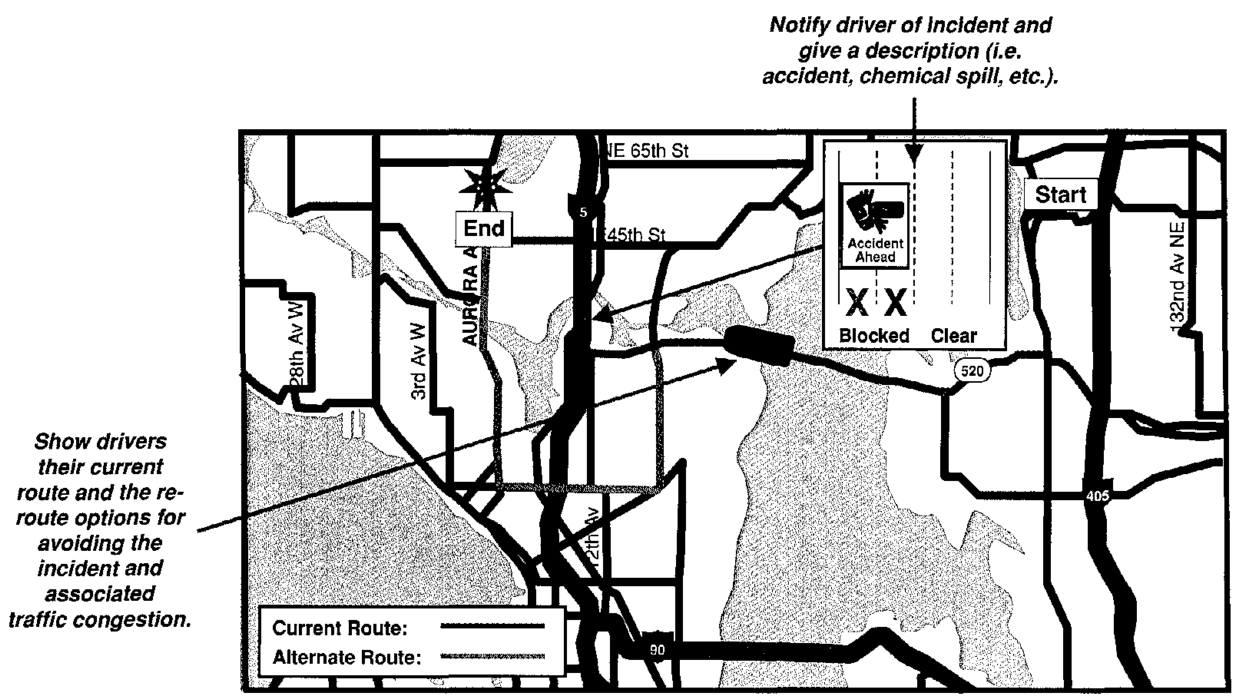
## PRESENTATION OF ROUTE INCIDENT INFORMATION

**Introduction:** *Route incident information* refers to the data necessary for helping a driver travel to a selected destination when incidents are detected along the route.

**Design Guidelines***

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Notification of incidents | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with voice or text description |
| Description of incidents | Visual | Vehicle in in Motion | Iconic or graphic representation or text description |
| Presentation of re-route options | Visual | Vehicle Stopped or in PARK | Partial route map with or without text |

### Schematic Example of Presenting Route Navigation Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format for route incident information. Due to the nature of route incident information, it was determined that this type of information would be most useful to the driver if displayed while in transit and that the convenience benefits would outweigh the costs, in terms of required driver resources. It was also recommended that the auditory modality be used to: (1) provide an auditory prompt to look at the visual display for changing or upcoming information (thus lessening the need for the driver to constantly scan the visual display in preparation for an upcoming event), or (2) have some type of simple visual information presentation to supplement the auditory message (so that a message that is not fully understood or remembered can be checked, or later referred to, via the visual display). These uses of the auditory modality can reduce the visual attention demand of navigation systems, without the problems caused by sole reliance on voice messaging (Reference 2).

**Special Design Considerations:** It has been suggested that merely telling drivers the effect on traffic associated with an incident is insufficient (Reference 3). Instead, drivers should be told the cause of the congestion (e.g., accident, construction, etc.). Also, the driver might be given information about which lanes are open (e.g., green arrows for open and red Xs for blocked). Lane numbers are not desired. If the term "lane blocked" is used, the assumption is that the blockage is temporary, often due to an accident. The term "lane blocked" is preferred over "lane condition." "Closed" implies a long-term problem.

If re-route options are simple (e.g., one turn), then the instructions may be safely presented to the driver while the vehicle is in motion.

**Cross References:**
*Color Coding of Traffic Flow Information, p. 5-6*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Dingus, T. A., & Hulse, M. C. (1993). Some human factors design issues and recommendations for automobile navigation information systems. *Transportation Research,* 1C(2), pp. 119-131.
3. Dudek, C. L., Huchingson, R. D., Stockton, W. R., Koppa, R. J., Richards, S. H., & Mast, T. M. (1978). *Human factors requirements for real-time motorist information displays, Volume 1-Design guide.* Washington, DC: Federal Highway Administration (FHWA-RD-78-5).

# CHAPTER 6: MOTORIST SERVICES GUIDELINES

This chapter provides human factors design guidelines relevant to Motorist Services Functions of ATIS devices. Motorist Services Functions provide motorists with commercial logos and signing for motels, eating facilities, service stations, and other signing displayed inside the vehicle to direct motorists to recreational areas, historical sites, etc. Motorist Services Functions provide routing information for local destinations.

The following design topics are included in this chapter:

# PRESENTATION OF SERVICES/ATTRACTION INFORMATION

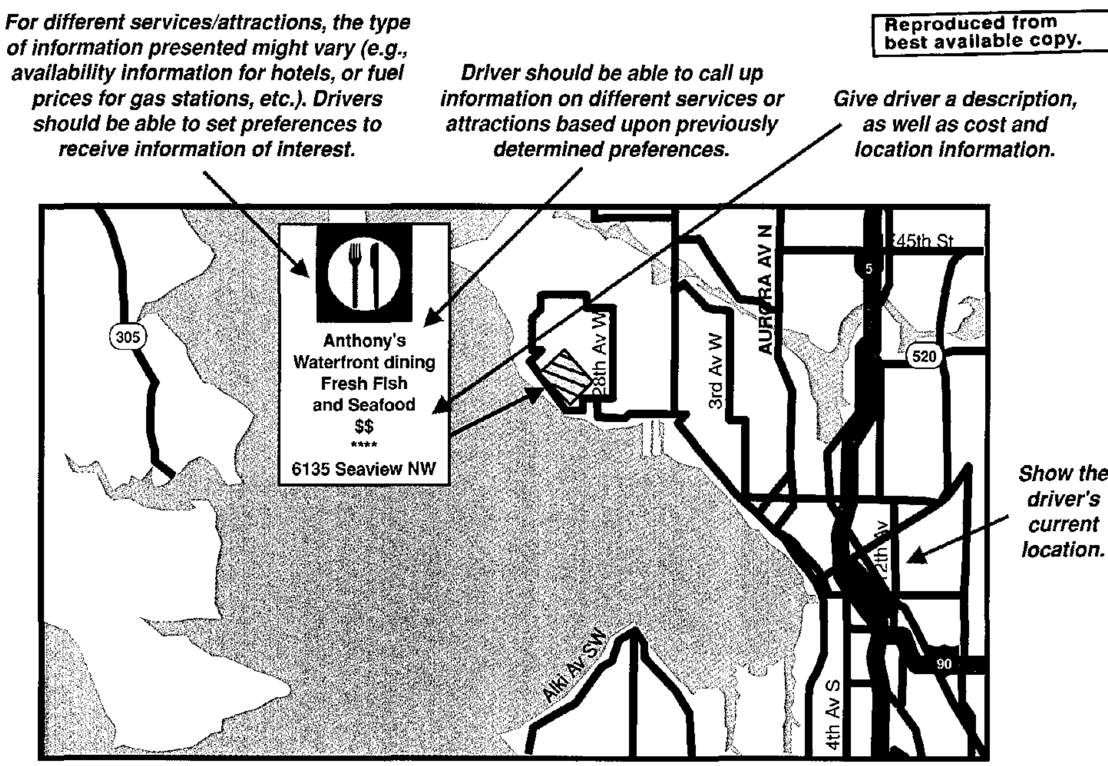
**Introduction:** *Services/attraction information* refers to information provided to travelers which is normally found on commercial road signs or in the yellow pages of a phone book. This information should not be provided unless specifically requested from the driver. However, the information presented can be filtered to present only those services/attractions which meet a certain profile of the driver's interests.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Description and costs of services/attraction | Visual | Vehicle at a Stop | Iconic or graphic representation with text |
| Location of services/attraction | Auditory and Visual or Visual | Vehicle in Motion | Tone to indicate arrival, partial route map with text or icons, or sortable text list |
| Availability of services/attraction | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones |
| Distance from present location to services/attraction | Auditory and Visual or Auditory | Vehicle in Motion | Iconic or graphic representation with tones or partial route map with voice |

## Schematic Example of Presenting Services/Attraction Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying services/attraction information. It was determined that complex information would be displayed more effectively through the visual channel than through the auditory channel (Reference 2). However, because this information might be presented while the driver is engaged in the driving task, it might be necessary to simplify the messages into smaller units and display them through the auditory channel as well. This would prevent the messages from detracting attention from the driving task or from significantly increasing the driver's workload. It was also determined that this type of information would be more valuable to the driver if given in transit; the benefit of having this type of information would outweigh the costs, in terms of information processing and control requirements.

**Special Design Considerations:** Using current technology, the driver would need to consult the yellow pages of a phone book, see information on a road sign, or use a telephone to get information about hotels, attractions, restaurants, and available services. The purpose of this function is to consolidate all of these sources into one information system. While this information is useful to the driver, it is neither as urgent nor as important as safety information from other ATIS subsystems. Given this, the displays for this function will need to be designed so that they are less intrusive and can display information efficiently to ensure the ability to display safety information.

Additional research for this function is needed to define the amount of information that drivers would prefer to have displayed to them at any given time. If the capability to advertise services and attractions through this system is fully developed, a method of filtering or limiting the amount of information being displayed will be necessary to avoid overloading drivers with in-vehicle commercial information. Efficient display of motorist service information might include the use of integrated or grouped information elements. For example, information such as the description, location, and distance of travel for motorist services might be grouped and accessible to the driver by a single information request.

Guidelines for services/attraction information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Presentation of Preference and Directory Information, p. 6-4*
*Presentation of Destination Coordination Information, p. 6-6*
*The Message Transfer Function, p. 6-8*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

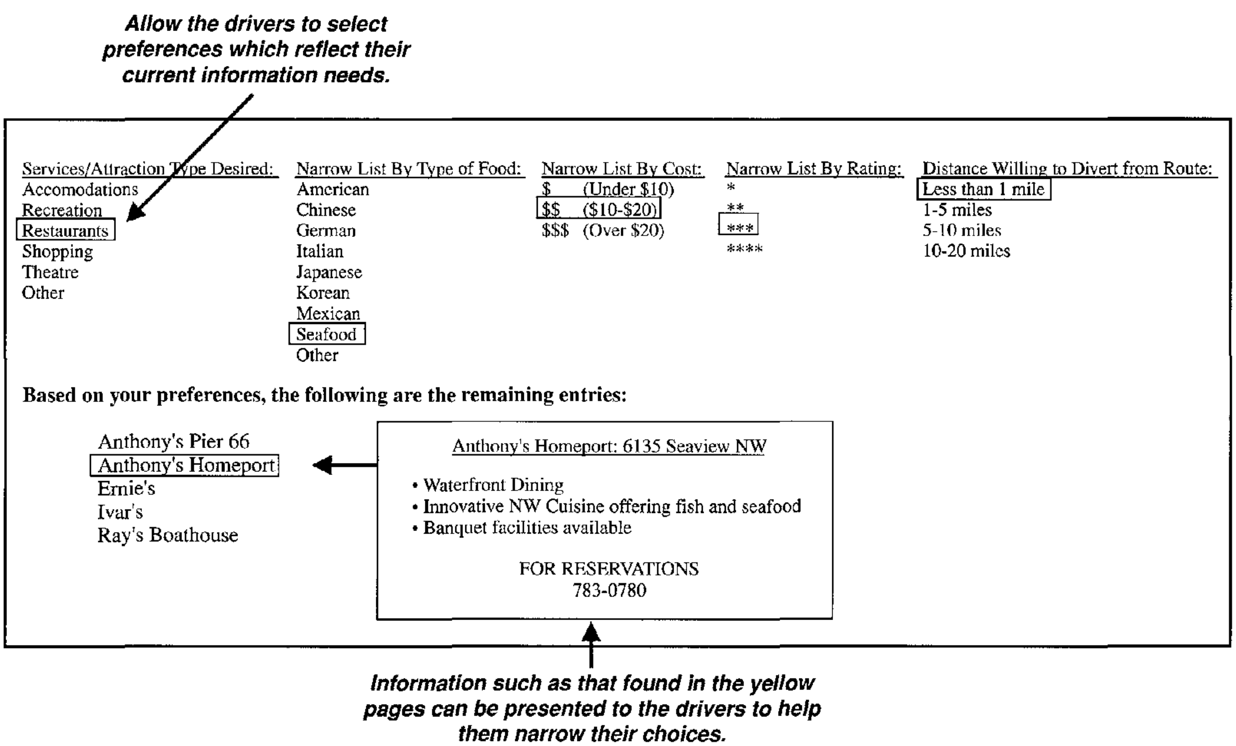
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO): Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Deatherage, B. H. (1972). Auditory and other sensory forms of information presentation. In H. Van Cott & R. Kinkade (Eds.), *Human engineering guide to equipment design,* (rev. ed.) (pp. 123-160). Washington, DC: U.S. Government Printing Office.

## PRESENTATION OF PREFERENCE AND DIRECTORY INFORMATION

**Introduction:** *Preference and directory information* refers to information similar to that found in the yellow pages. However, unlike a yellow pages directory, the services/attractions directory has the flexibility of a computer database and would facilitate a wide variety of search methods. For instance, in searching for a shopping center, one parameter might be its physical location, which might be specified using an electronic map and touch screen. Providing the system with preference information allows it to assess information concerning businesses or attractions that satisfy the driver's current need.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Directory (index of yellow pages) | Visual | Vehicle at a Stop | Iconic or graphic representation with text or text description |
| View currently selected preferences | Visual | Vehicle at a Stop | Iconic or graphic representation with text or text description |

### Schematic Example of Presenting Preference and Directory Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying preferences and directory information. It was determined that this information would be best presented while the vehicle was stopped briefly during the normal drive (zero speed). In this situation, drivers are able to devote nearly full attention to the system, but the time available for work with the system is limited by the duration of the traffic control device or any other cause of the zero-speed condition. Therefore, operations during a zero-speed situation must typically take less time than those available during a predrive situation. An estimate of the average stop duration at a red light is about 10 seconds. Therefore, this number is used as a criterion for allocating information to the zero-speed category.

It was also determined that the information should be presented visually due to the amount of information being displayed on the screen and the number of display interactions necessary for selecting preferences. Any time there are more than 7 to 9 units of related pieces of information, the information is considered to be complex (Reference 2 and 3). Complex information is displayed more effectively through the visual channel.

**Special Design Considerations:** A primary factor limiting a traveler's use of the system would be the driver's attitudes and knowledge regarding the system. The driver must know how to use the system (although it should be designed to be self-explanatory), and the traveler must have confidence that the system can deliver valuable information. Therefore, designers should concentrate more on HCI issues such as how the driver will input their preferences and how that information will be displayed.

Since drivers must specify complicated information concerning their needs, the system may include a touch screen menu system or a remote keypad. Reference 4 examined the visual, safety and performance aspects of operating a simulated CRT touch panel display while driving at a constant speed along a straight path, with respect to lateral lane position maintenance. Looking at and/or operating a CRT touch panel while driving a vehicle along a straight path appears to be a visually demanding, if not dangerous task, as demonstrated by the relatively high probabilities of lane deviations. Therefore, presenting this information during zero speed, as suggested in the above guideline, appears to be the best option.

Guidelines for preference and directory information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Presentation of Services/Attractions Information, p. 6-2*
*Presentation of Destination Coordination Information, p. 6-6*
*The Message Transfer Function, p. 6-8*
*Trip Status Allocation Design Tool, p. 10-14*

**Key References:**

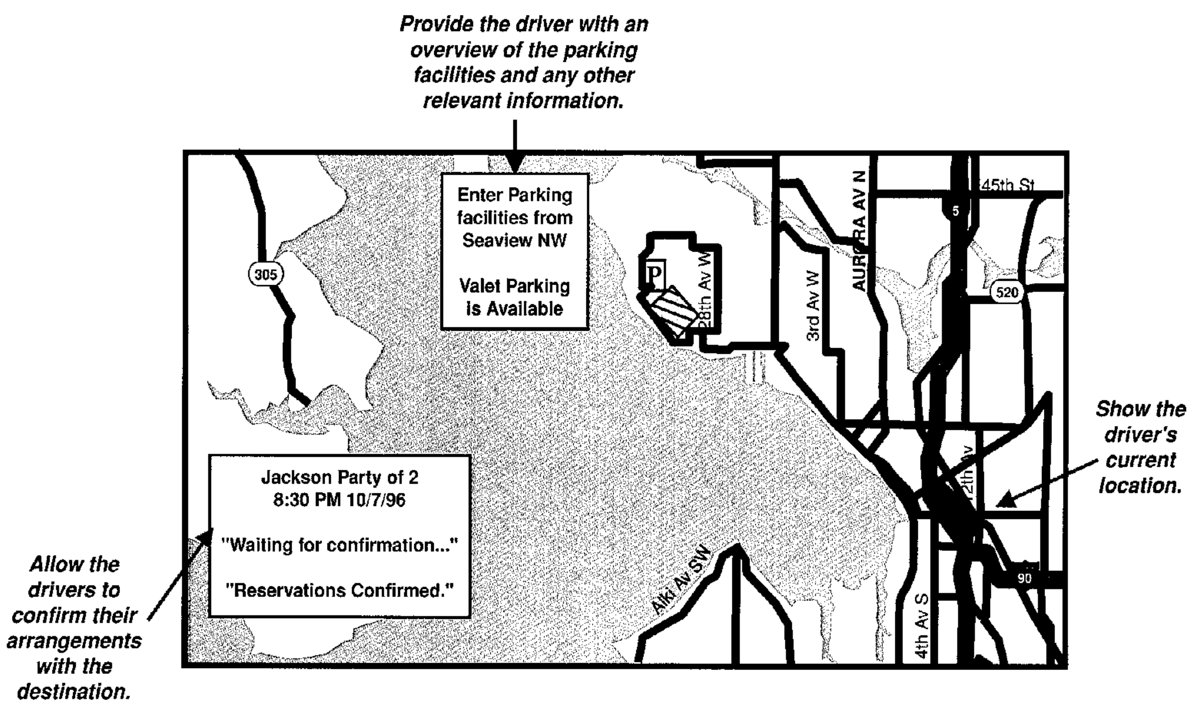
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO): Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Labiale G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting,* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
3. Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review,* 63, pp. 81-97.
4. Zwahlen, H. T., Adams, C. C., & DeBald, D. P. (1987). Safety aspects of CRT touch panel controls in automobiles. *Proceedings of the Second International Conference on Vision in Vehicles* (pp. 1-10). England: University of Nottingham.

# PRESENTATION OF DESTINATION COORDINATION INFORMATION

**Introduction:** *Destination coordination information* refers to information which enables the driver to communicate and make arrangements with the final destination. This function may include making restaurant and hotel reservations. In addition, it may include ascertaining information about parking availability and location.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Confirmation of reservation | Auditory and Visual | Vehicle in Motion | Text description with voice or speech with or without icons |
| Locate nearest parking | Auditory and Visual | Vehicle in Motion | Full or partial route map with voice |
| Type of parking facility | Auditory and Visual | Vehicle in Motion | Text description with voice or speech with or without icons |
| Reservation details | Auditory and Visual | Vehicle at a Stop | Text description with voice or speech with or without icons |
| Diagram of parking facilities | Visual | Vehicle in PARK | Full or partial route map with voice |

**Schematic Example of Presenting Destination Coordination Information**




**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying destination coordination information. It was determined that operator performance could be improved by incorporating some combination of auditory and visual stimuli. Reference 2 recommends that: (1) the auditory modality be utilized to provide an auditory prompt to look at a visual display for changing or upcoming information (thus lessening the need for the driver to constantly scan the visual display in preparation for an upcoming event), or (2) simple visual information should supplement the auditory message (so that a message that is not fully understood or remembered can be checked, or later referred to, via the visual display).

As the amount of effort required to retrieve information from a display increases due to greater levels of complexity, the trip status selected will change from presenting it while the vehicle is in motion, while it is stopped, and finally, to while it is parked. Any display that requires more than four glances (Reference 3) or requires glances longer than two seconds (Reference 4 would require significantly more visual attention than should be given while in transit and therefore should be allocated to one of the other trip statuses. In order to be completely presented during zero speed (while the vehicle is stopped during the normal drive) the information cannot take longer than the zero-speed event itself, which is a stop light in most cases. The average stop duration at a red light is about ten seconds. Information given to the driver during predrive can be complex and attention demanding, as there are no safety issues associated with overloading the driver at this point.

**Special Design Considerations:** Some people may prefer direct communication with the destination, and the transitory nature of parking availability may limit the predictive accuracy of the system. Therefore, usability and acceptance issues will be among the most important for designers of this subsystem. It will be very important to consider the human-computer interface issues which will make this a more effective system.

Guidelines for destination and coordination information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Presentation of Services/Attractions Information, p. 6-2*
*Presentation of Preference and Directory Information, p. 6-4*
*The Message Transfer Function, p. 6-8*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

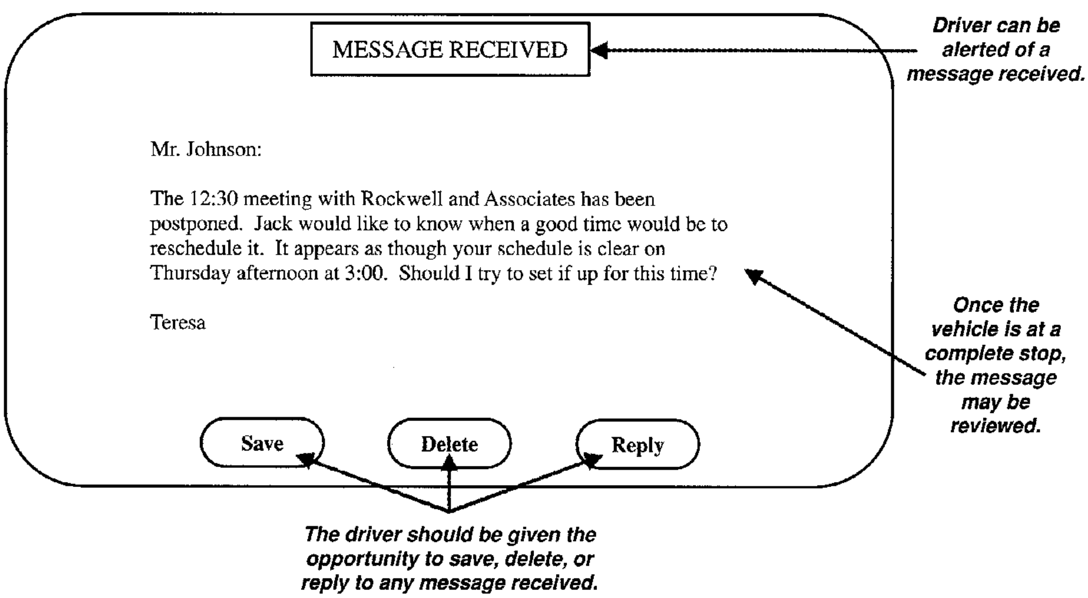
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO): Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Dingus, T. A., & Hulse, M. C. (1993). Some human factors design issues and recommendations for automobile navigation information systems. *Transportation Research,* 1C(2), pp. 119-131.
3. Zwahlen, H. T., Adams, C. C., & DeBald, D. P. (1987). Safety aspects of CRT touch panel controls in automobiles. *Proceedings of the Second International Conference on Vision in Vehicles* (pp. 1-10). England: University of Nottingham.
4. French, R. L. (1990). In-vehicle navigation-status and safety impacts. *Technical Papers from ITE's 1990, 1989, and 1988 Conferences* (pp. 226-235). Washington, DC: Institute of Transportation Engineers.

# THE MESSAGE TRANSFER FUNCTION

**Introduction:** The *message transfer function* refers to the capability for drivers to communicate with others. Currently this function is accommodated with cellular phones and Citizen's Band (CB) radios; however, future ATIS systems may improve upon this technology. This function might include text and voice messages; however, it does not include the transmission of mayday calls. Likewise, this function is separate from the computer-aided dispatch function, but may be used with it.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Alert driver of message received | Auditory | Vehicle in Motion | Speech with alerting tone |
| Review received message | Visual or Auditory | Vehicle at a Stop, or in Motion if speech is used | Iconic or graphic representation with or without text or speech |
| Reply to a message | Auditory | Vehicle in Motion | Speech |
| Alert driver message was sent | Auditory | Vehicle in Motion | Speech with alerting tone |
| Alert driver message was not sent and why not | Auditory | Vehicle in Motion | Speech with alerting tone |
| Delete message | Visual | Vehicle at a Stop | Iconic or graphic representation with or without text |
| Save message | Visual | Vehicle at a Stop | Iconic or graphic representation with or without text |

## Schematic Example of Presenting Message Transfer Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying message transfer information. It was determined that visual presentation of detailed information does have some advantages in comprehension and flexibility. Visual displays allow the driver to refer to information at a later time, and such displays are able to present a larger quantity of data in a shorter period of time. However, because of the level of visual attention that is required by the driving task, any message that must be displayed to a driver immediately, such as a critical priority message, should be presented in a manner that would not add to the visual attention load. Currently, the best way to present detailed information without compromising visual attention is by using an auditory speech display (Reference 2). An argument might be made for minimizing visual attention requirements all of the time by displaying all messages through a speech display, but research on user acceptance of speech displays indicates that they should be used sparingly. Like the visual channel, the auditory channel can quickly become cluttered or overloaded with stimuli (References 2, 3, and 4).

**Special Design Considerations:** The most relevant human constraint that influences how well drivers could use this function involves the driver's understanding of the ATIS menu structure and the capabilities of the system. Specifically, identifying the message recipient in a database containing several access numbers might be a difficult task for some people. Therefore, designers should concentrate their efforts in the area of human-computer interaction to ensure an easy and effective system design. Driver attitude is another factor that may play an important role in whether or not people will use this function. For instance, entering a message and specifying its destination may be cumbersome to some drivers who might prefer to convey the information directly over the phone or in person. Similarly, some users may not trust the computer's ability to deliver the message in an accurate and timely fashion.

Messages that are noncritical should incorporate a display that can signal the driver of a message event but does not need to convey a sense of urgency or importance. Noncritical messages are more routine or general and the driver is not endangered or penalized by waiting until a later time to review the message. If a sender indicates that a message is critical, the associated message event notification should be able to get the driver's attention, whether or not the display is actively being searched for information (Reference 5). Critical messages should be presented to the driver as soon as the vehicle is at a stop.

Guidelines for message transfer information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Auditory Message Length, p. 3-26*
*Presentation of Services/Attractions Information, p. 6-2*
*Presentation of Preference and Directory Information, p. 6-4*
*Presentation of Destination Coordination Information, p. 6-6*
*Trip Status Allocation Design Tool, p. 10-14*

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO): Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Wickens, C. D. (1992). *Engineering psychology and human performance.* New York: Harper-Collins.
3. Stokes, A., Wickens, C., & Kite, K. (1990). *Display technology: Human factors concepts.* Warrendale, PA: Society of Automotive Engineers.
4. Wierwille, W. W. (1993). Visual and manual demands of in-car controls and displays. In B. Peacock & W. Karwowski (Eds.), *Automotive ergonomics* (pp. 229-320). London: Taylor & Francis.
5. Huiberts, S. J. C. (1989). How important is mobile communication for a truck company? *IEEE,* CH2789- 6/89/0000-0361 (pp. 361-364). Piscataway, NJ: IEEE.

# CHAPTER 7: SAFETY/WARNING GUIDELINES

This chapter provides human factors design relevant to Safety/Warning Functions of ATIS devices. Safety/Warning Functions provide warnings of unsafe conditions and situations affecting the driver on the roadway ahead. Safety/Warning Functions provide sufficient advance warning to permit the driver to take remedial action. Safety/Warning Functions provide messages related to relatively transient conditions, requiring modifications to the messages at irregular intervals. It should also be noted that mayday systems have been subsumed under Safety/Warning Functions for the purposes of the present discussion. Safety/Warning Functions do not encompass in-vehicle warnings of imminent danger requiring immediate action (e.g., collision avoidance devices).

The following design topics are included in this chapter:

## PRESENTATION OF ROAD CONDITION INFORMATION

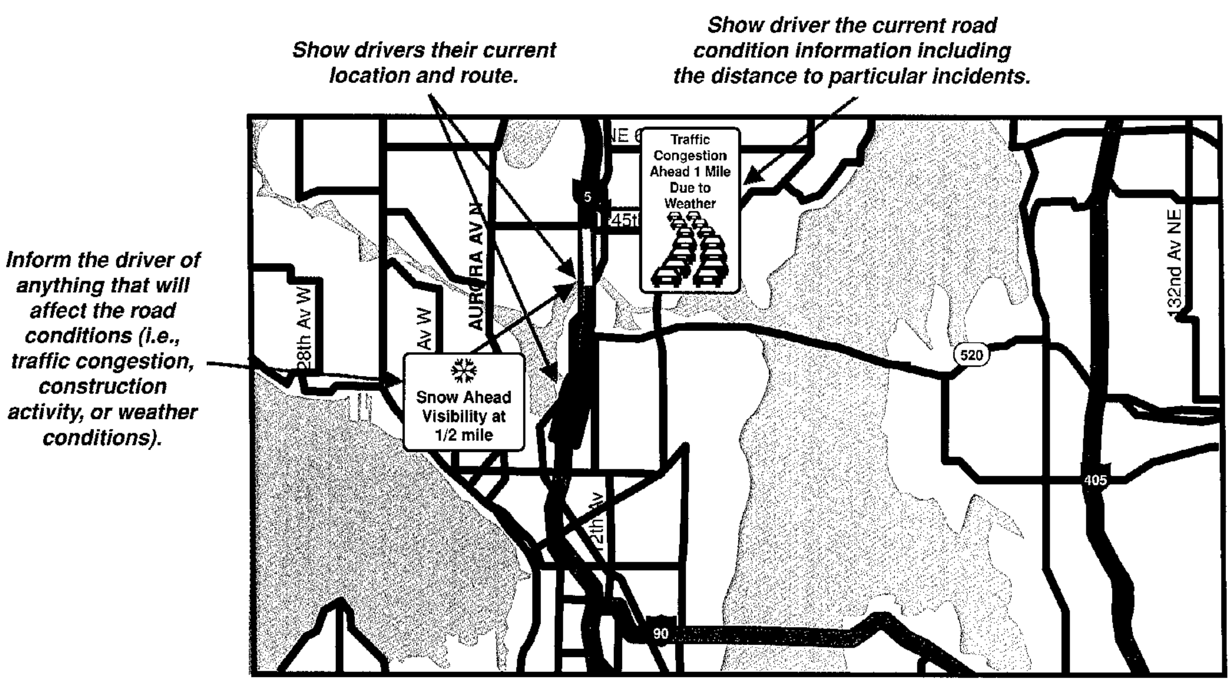
**Introduction:** *Road condition information* refers to information relevant within some predefined proximity to the vehicle or its route. This information may include traction, visibility, congestion, construction activity, or weather conditions. Compared to the information conveyed by the immediate hazard information system, this function provides general information that could cover a wider geographic area and a longer time span.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Inform driver of road traction, visibility, congestion, construction activity, or weather conditions | Visual | Vehicle in Motion | Iconic or graphic representation with or without text |
| Distance to congestion or construction activity | Auditory | Vehicle in Motion | Alerting tone, then speech |

### Schematic Example of Presenting Road Condition Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying road condition information. This type of information will most likely be presented to the driver under stressful driving conditions, such as congestion or bad weather. Therefore, it was determined that using an auditory alert (such as a tone or short speech message) to indicate that more detailed warning information was available would allow the drivers to access the information when they felt it was safe to do so.

**Special Design Considerations:** The reliability of the information presented will affect drivers' attitudes regarding this subfunction and will directly impact trust in the system. Reference 2 examined the effect of unreliable navigation information on drivers' trust of the system and suggested that information presented to the driver which is less than 71 percent reliable will reduce the amount of trust drivers place in the system. It is not known whether or not the results would be similar for information other than navigation (i.e., road conditions). However, due to the impact that road condition information might have on driver safety, it is believed that similar results would be found.

**Cross References:**

*Use of Color Coding, p. 3-20*
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Kantowitz, B. H., Hanowski, R. J., & Kantowitz, S. C. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: The effects of inaccurate traffic information on driver acceptance of in-vehicle information systems.* Washington, DC: Federal Highway Administration (FHWA-RD-96-145).

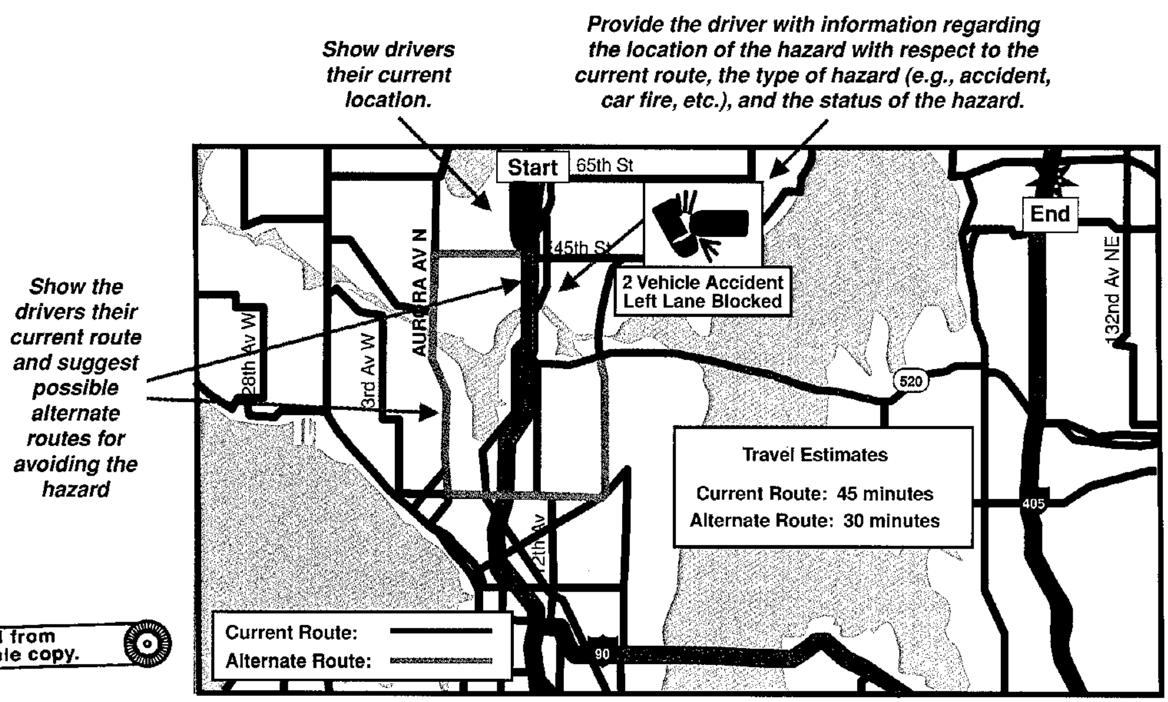
# PRESENTATION OF IMMEDIATE HAZARD WARNING INFORMATION

**Introduction:** *Immediate hazard warning information* refers to information regarding the relative location of a hazard and the type of hazard. This information may include warning the driver of an accident immediately ahead or a stopped school bus. Thus, this information focuses on the location of specific localized incidents.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Inform driver of incident/hazard | Auditory and Visual | Vehicle in Motion | Iconic or graphic representation with voice or text |
| Indication of the type of hazard | Auditory and Visual | Vehicle in Motion | Iconic or graphic representation |
| Distance to hazard | Auditory | Vehicle in Motion | Alerting tone, then speech |
| Status of hazard | Auditory | Vehicle in Motion | Alerting tone, then speech |
| Alternate route | Visual | Vehicle at a Stop | Iconic or graphic representation with or without text |

## Schematic Example of Presenting Hazard Warning Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying immediate hazard warning information. It was determined that a combination of alerting tones, speech messages, and icons would best present hazard warning information. The auditory modality offers an advantage for displays that are concerned with the external environment, because they can get the driver's attention regardless of where the driver is looking. Visual displays are not as effective at commanding a driver's attention. However, when used in combination with an auditory alerting cue, they can provide fast response times and detailed information. Having the information presented in a visual format allows the drivers to refer to it at their convenience and when they feel it is safe to do so.

**Special Design Considerations:** Reference 2 suggests that merely telling drivers about immediate hazards is insufficient. Instead, drivers should be told the nature of the hazard ahead (e.g., accident or traffic congestion). These information elements may be consolidated into one element. For example, placing a visual icon that depicts the nature of the incident at the location of the incident would be an efficient method of integrating these pieces of information. Also, whenever possible, drivers should be given information about which lanes are open (e.g., green arrows for open and red Xs for blocked). If the term "lane blocked" is used, the assumption is that the blockage is temporary, while using the term "closed" implies a long-term problem. In addition to location, type and distance to the hazard, other pieces of information which might be of interest to a driver using this function include: location where speed decreases, travel speed through problem area, and the length or area of congestion. While these pieces of information may be of interest to the drivers and may help them to decide whether or not to take an alternate route, care must be taken to present the information so that it does not distract the driver from the primary task of driving.

**Cross References:**
*Color Contrast, p. 3-22*
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*

**Notes:**

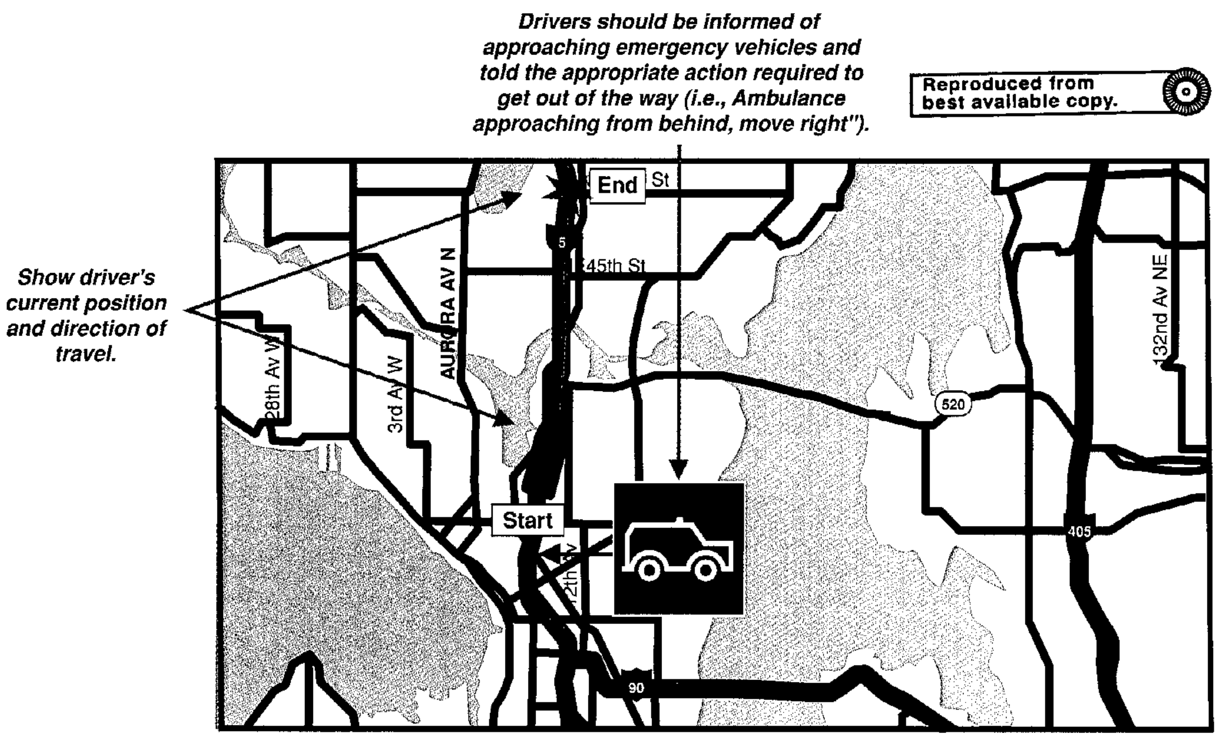
**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Dudek, C. L., Huchingson, R. D., Stockton, W. R., Koppa, R. J., Richards, S. H., & Mast, T. M. (1978). *Human factors requirements for real-time motorist information displays, Volume 1-Design guide.* Washington, DC: Federal Highway Administration (FHWA-RD-78-5).

## PRESENTATION OF APPROACHING EMERGENCY VEHICLE INFORMATION

**Introduction:** *Emergency vehicle information* refers to warning drivers of approaching emergency vehicles (i.e., police cars, fire trucks, ambulances). If the ATIS possesses reliable data on surrounding traffic and conditions, this function may also include telling the driver the appropriate action necessary to move out of the way.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Inform the driver of the approaching emergency vehicle | Auditory or Auditory and Visual | Vehicle in Motion | Speech, or alerting tone then speech |
| Inform the driver of the action required to move out of the way of the emergency vehicle | Auditory or Auditory and Visual | Vehicle in Motion | Speech, or alerting tone then speech |
| Location of approaching vehicle | Auditory or Auditory and Visual | Vehicle in Motion | Speech, or alerting tone then speech |

### Schematic Example of Presenting Emergency Vehicle Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying approaching emergency vehicle information. It was determined that presenting an auditory tone would work best for alerting the drivers without distracting, confusing, or annoying them. Reference 2 states that the omnidirectional nature of auditory displays makes them most desirable for alert and warning messages. Verbal instructions as well as a visual display were used to supplement the alert, giving the driver any additional information which might be helpful. Reference 3 suggests that optimal display design would combine desirable features from speech displays, such as warning or alerting capability, with the spatial orientation provided by visual displays. This is supported by guidelines in Reference 4 which state that, because safety/warning messages are likely to occur with some frequency, they should be presented visually. However, they should be accompanied by an auditory alert, such as a tone, to draw attention quickly.

**Special Design Considerations:** According to Reference 4, the location of the hazard (e.g., approaching emergency vehicle) should always be given to the driver using words such as: ahead, behind, left, right, ahead to left, and ahead to right. It was determined that reading the text associated with the location of the hazard took less time than if drivers were to search their environment for the location of the hazard. Reference 5 found that people had the most difficult time localizing emergency vehicles which were approaching them from the front. Adding both auditory and visual cues in such situations might aid in reducing the amount of search time necessary.

**Cross References:**
*Color Contrast, p. 3-22*
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*

**Notes:**

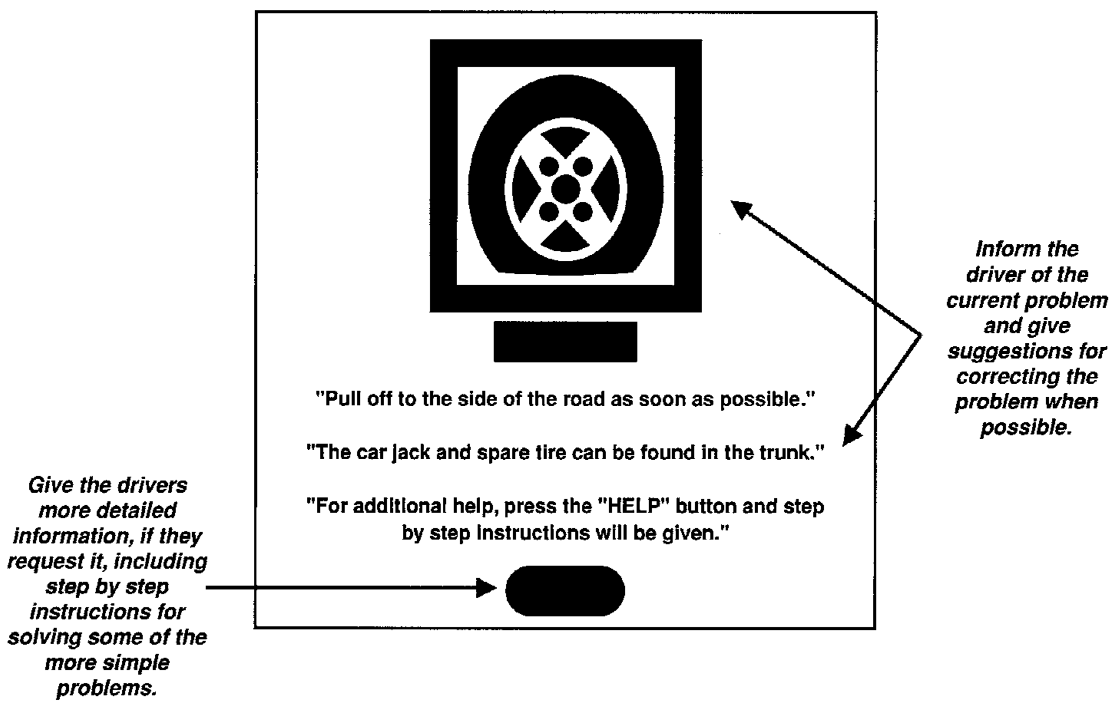
**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Sorkin, R. D. (1987). Design of auditory and tactile displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
3. Robinson, C. P., & Eberts, R. E. (1987). Comparison of speech and pictorial displays in a cockpit environment. *Human Factors, 29*(1), pp. 31-44.
4. Green, P., Levison, W., Paelke, G., & Serafin, C. (1995). *Preliminary human factors design guidelines for driver information systems.* Washington, DC: Federal Highway Administration (FHWA-RD-94-087).
5. Caelli, T., & Porter, D. (1980). On difficulties in localizing ambulance sirens. *Human Factors, 22,* pp. 719-724.

## PRESENTATION OF VEHICLE CONDITION MONITORING INFORMATION

**Introduction:** *Vehicle condition monitoring* refers to the tracking of the overall condition of the vehicle to inform the driver of current problems as well as potential problems. Vehicular monitoring could range from reminding the driver to perform certain services (e.g., oil change) to warning the driver about current problems (e.g., engine overheating or flat tire). This system could also be interactive, allowing the driver to interrogate the system regarding the problem and possible solutions.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Inform driver of current problem | Visual | Vehicle in Motion | Iconic or graphic representation |
| Inform driver of ways to correct problem | Visual | Vehicle in PARK | Iconic or graphic representation |
| Provide more detailed informationat the driver's request | Auditory and Visual or Auditory | Vehicle in PARK | Iconic or graphic representation with speech or text |
| Inform the driver of needed warranty services due | Visual | Vehicle in PARK | Iconic, graphic, or text presentation |

### Schematic Example of Vehicle Condition Monitoring Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying vehicle condition monitoring information. It was determined that, although the driver should be warned of problems that arise while driving, more detailed information should be given once the vehicle has been stopped. The sensory modality for presenting vehicle condition information should be based on the severity of the problem. Higher priority warning messages should be presented in a way that gets the attention of the driver very quickly and gives clear cues as to the appropriate response to the problem. Medium priority messages are not as urgent and therefore do not require as fast a response time. Presenting thorough and clear information is the most important consideration for presenting this level of information. Low priority messages give the driver advisory information. Since the message is not required immediately and does not notify the driver of imminent danger, it should be presented in a manner which will not startle the driver or require too much attention.

Requirements for repeating this information are uncertain. At a minimum, such messages should be available at vehicle start-up. Drivers might also be given the option of suppressing messages, if they desire.

**Special Design Considerations:** Traditionally, vehicle condition information has been presented to the driver by dedicated, lighted icons. However, new ATIS functions could make it possible to present such a wide variety of information to the driver that the number of icons drivers would need to remember would be beyond the limit of their memory. Not only will the ATIS identify problems, as is currently done, but it will be able to describe the problem severity in detail and give the driver possible solutions. Text or auditory speech description can be used to present more detailed, complex vehicle condition information.

**Cross References:**

*Color Contrast, p. 3-22*

*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*

**Notes:**

**Key References:**

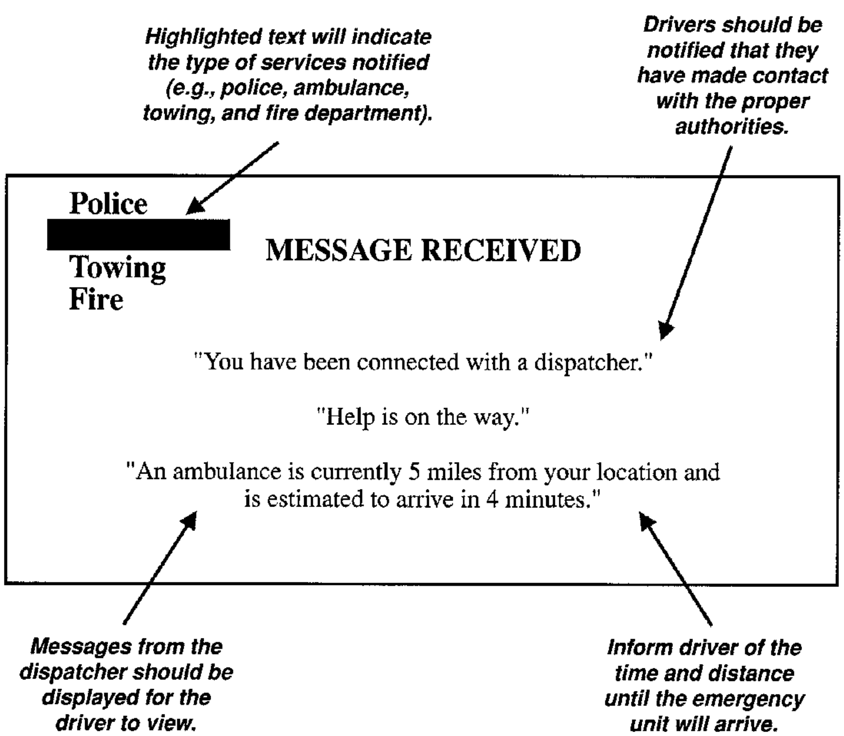
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

# PRESENTATION OF AUTOMATIC/MANUAL AID REQUEST INFORMATION

**Introduction:** *Automatic/manual aid request information* refers to a function that allows the driver to request emergency services without leaving the vehicle. This function would provide drivers with immediate access to a wide variety of roadside assistance (e.g., police, ambulance, towing, and fire department) without the need to locate a phone, know the appropriate phone number, or even know their current location. In circumstances where a manual aid request is not feasible and where immediate response is essential, this function would activate automatically.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Inform driver that aid has been requested | Auditory and Visual or Visual | Vehicle in PARK | Tone with text description or iconic or graphic representation with text |
| Inform driver of time until emergency unit will arrive | Auditory and Visual or Visual | Vehicle in PARK | Tone with text description or iconic or graphic representation with text |
| Display messages from the emergency response center | Visual | Vehicle in PARK | Iconic or graphic representation with or without text |
| Update real-time information from the emergency center | Auditory and Visual or Visual | Vehicle in PARK | Tone with text description or iconic or graphic representation with text |

### Schematic Example of Presenting Manual Aid Request Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying automatic and manual aid request information. An assumption was made that requests for aid would come as the result of either vehicle problems, an accident, or offering roadside assistance. Therefore, this function would operate primarily while the vehicle was stationary. It was also determined that using a combination of both visual and auditory display modes might help to ensure that a message would be displayed if the vehicle were in an accident. In this case, even if one of the systems were disabled, there would be a chance that the other system would be able to display the message to the driver.

**Special Design Considerations:** According to Reference 2, critical messages, such as those from an ambulance dispatcher, should be presented to the driver immediately and should be able to get the driver's attention whether or not the display is actively being searched for information. Communication between the vehicle or the driver and the emergency dispatcher is essential for the effective use of this function. In the case of automatic aid requests, the vehicle will need the ability to detect, analyze, and report emergencies to the correct authorities. However, in the case of manual aid requests, the driver will be responsible for entering data concerning the specific services needed and the relative urgency of the request. In both cases, it is extremely important that the dispatcher be able to inform the drivers that their request for aid has been received and that a response is in progress.

**Cross References:**
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*Presentation of CVO-Specific Aid Request Information, p. 9-16*

**Notes:**

**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Huiberts, S. J. C. (1989). How important is mobile communication for a truck company? *IEEE*, CH2789-6/89/0000-0361, (pp. 361-364). Piscataway, NJ: IEEE.

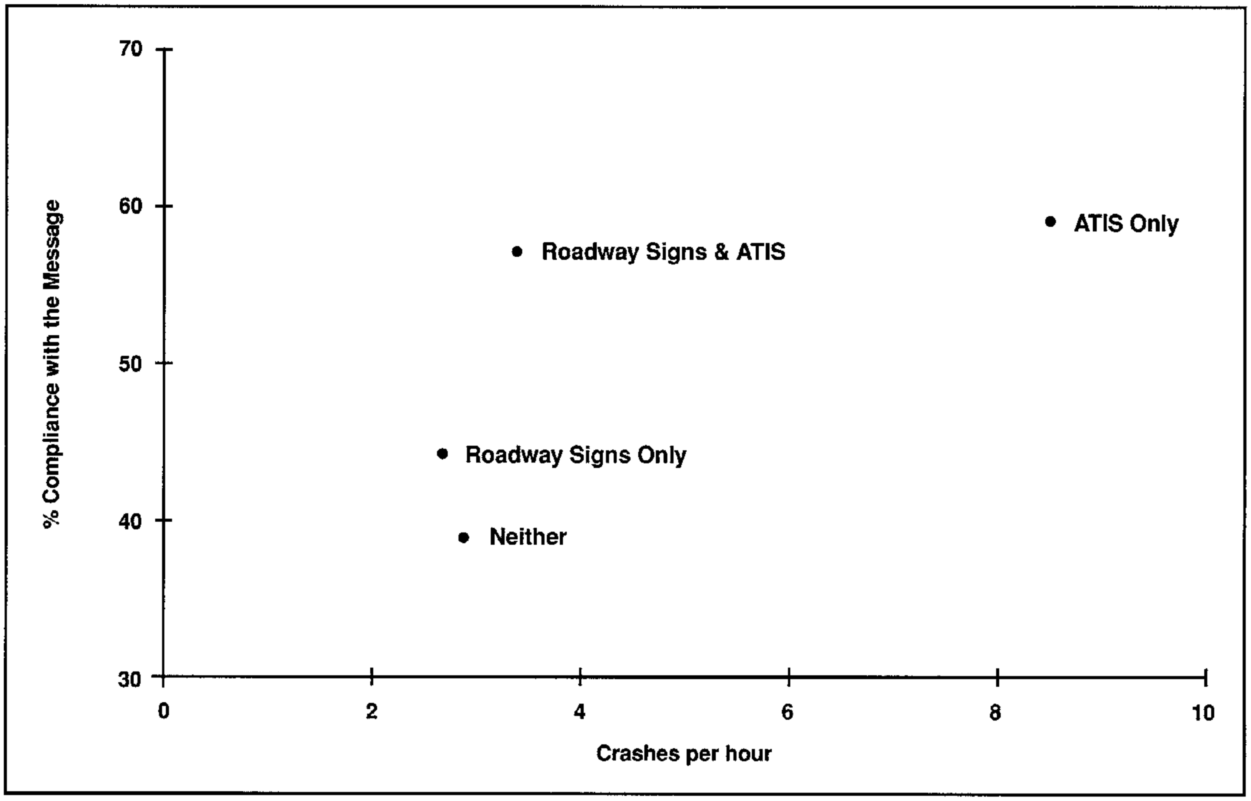
# RELATIONSHIP BETWEEN ATIS INFORMATION AND ROADWAY SIGNS

**Introduction:** The relationship between *ATIS information and roadway signs* refers to the correspondence or consistency between these two forms of presenting safety/warning information. Safety/Warning information might be presented on roadway signs alone, on the ATIS alone, or on both display mediums. *Notification style* messages simply inform the drivers and allow them to determine the appropriate action on their own. *Command style* messages inform the driver of a situation and suggest a particular action to take in response to that situation.

## Design Guidelines***

Notification messages presented on an ATIS should be paired with redundant roadway sign information.

### Driver Compliance and Performance with Different Combinations of ATIS and Roadway Information



**Supporting Rationale:** In Reference 1, ATIS warning messages were presented to drivers using a driving simulator equipped with a reconfigurable ATIS. The visual scene was controlled to present drivers with roadway information in a form similar to the changeable message signs found on highways. In the study, driver safety and compliance to the presented information was assessed using a variety of objective (driver performance, response to the message) and subjective (rated self-confidence and trust) indices. ATIS messages, corresponding to events such as roadway curves, the presence of crosswalks, icy roadway, road construction, accidents in the lane ahead, and an upcoming high occupancy vehicle (HOV) lane, were presented to subjects. To assess the effects of the source of ATIS information, the information was made available to drivers only on the ATIS, only on the roadway, via both the ATIS and the roadway, and on neither the ATIS nor the roadway, depending on the driving trial. As seen in the figure on the opposing page, the best combination of few crashes and high rates of compliance with the messages was associated with driving trials in which the ATIS information was redundant with information presented via roadway signs.

**Special Design Considerations:** This design guideline is most appropriate when applied to notification (as opposed to command) messages; see also the design guideline on Message Style. Although command style messages were associated with high levels of driver compliance, they were also associated with more crashes than were notification style messages.

**Cross References:**
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*
*Message Styles, p. 3-32*

**Notes:**

**Key References:**

1. Lee, J. D., Stone, S. R., Gore, B. F., Colton, C., Macauley, J., Kinghorn, R. A., Campbell, J. L., Finch, M., & Jamieson, G. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Design alternatives for in-vehicle information displays: Message style, modality and location.* Washington, DC: Federal Highway Administration (FHWA-RD-96-147).

# CHAPTER 8: AUGMENTED SIGNAGE INFORMATION GUIDELINES

This chapter provides human factors design relevant to Augmented Signage Information Functions of ATIS devices. Augmented Signage Information Functions provide noncommercial routing, warning, regulatory, and advisory information that is currently depicted on external roadway signs inside the vehicle. Augmented Signage Information Functions are distinguished from Safety/Warning Functions on the basis of the relative permanence of the information displayed by this system.

The following design topics are included in this chapter:

## ■ TYPES OF AUGMENTED SIGNAGE



## ■ GENERAL

# PRESENTATION OF FILTERING SIGN INFORMATION

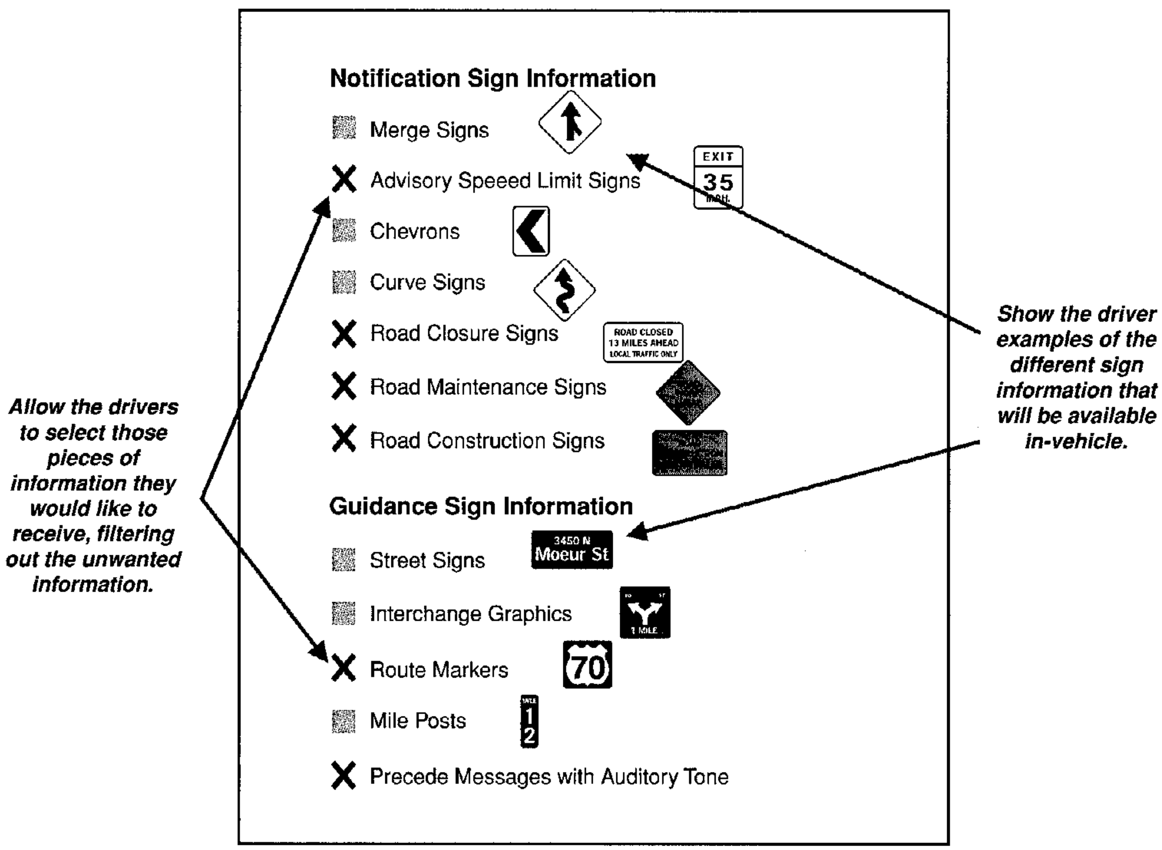
**Introduction:** *Filtering sign information* refers to allowing the drivers to select the on-road signage they would like to receive in-vehicle. The driver will be able to filter both notification and guidance sign information. However, due to the importance of regulatory sign information, it will be presented to the driver regardless of preference.

| Design Guidelines** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Filtering status | Visual | Vehicle in PARK | Iconic or graphic representation with text |

- Drivers should also be able to select whether or not they want In-Vehicle Information System (IVIS) messages to be preceded by an alerting tone.

## Schematic Examples of Filtering Sign Information

***X's indicate information the driver wants to receive***




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying sign filtering information. It was determined that, due to the complexity of the information, it should be presented to the driver visually; however, the amount of information being displayed may become distracting. Therefore, the drivers should be able to change the amount of information presented by selecting or deselecting pieces of information they would like to receive.

**Special Design Considerations:** Since augmented signage information, as currently conceptualized, is redundant with roadside signs, designers must be careful not to overload the driver. Such information will be most useful when: (1) the driver cannot see the roadside signs, such as in bad weather, (2) the driver needs the information but cannot attend to the roadside sign, or (3) the driver might benefit from redundant information. The critical task for designers is to provide the information when it is needed, and avoid distracting the driver when it is not.

It has been theorized that rather than completely processing all of the signs along the roadway, drivers selectively attend to those which are most applicable to their current driving situation. Therefore, it might be worthwhile to allow drivers to selectively filter the sign information which will be presented to them in-vehicle as well. The ability to do this will protect drivers from the possibility of information overload.

It is important to note that very little research has been performed to evaluate different methods of displaying sign information with an in-vehicle system. The design guidelines given are based solely on generally accepted human factors guidelines and principles. To accurately assess the system effectiveness and user preferences, designers should use prototypes of a signing system to clarify the decisions about which sensory mode to use for sign information display and the types of filtering that might be employed. Also, timing requirements for augmented signage information are uncertain.

Guidelines for filtering sign information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*General Guidelines for Augmented Signage Information, p. 8-10*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

## PRESENTATION OF GUIDANCE SIGN INFORMATION

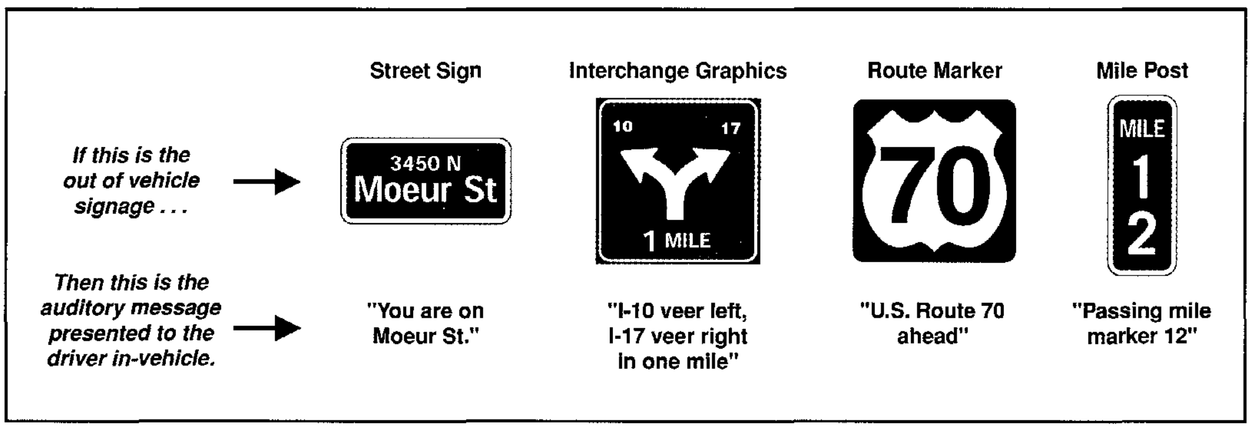
**Introduction:** *Guidance sign information* refers to information which helps to guide a driver to a particular destination. This information is normally found in the out-of-vehicle environment (e.g., street signs, interchange graphics, route markers, and mile posts). However, with augmented signage information, this information is brought into the vehicle and displayed to the driver.

**Design Guidelines****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Sign information (e.g., street signs, interchange graphics, route markers, and mile posts) | Auditory or Visual | Vehicle in in Motion | Alerting tone then speech, or speech or alerting tone, then icon |
| Sign information associated with driving to the destination | Auditory or Visual | Vehicle in Motion | Alerting tone then speech, or speech or alerting tone, then icon |

### Schematic Examples of Guidance Sign Information

*Each of the roadway guidance sign examples shown below could be presented to the driver in the form of a brief auditory message. An example of such an auditory message is shown as well.*




**Timing requirements for Signage Information are uncertain. See also the guideline on "Timing of Navigation Information," for more information on timing.**

**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying guidance sign information. The nature of this information precludes it from being presented at any time other than in transit. Information complexity is the main factor in determining the sensory modality most appropriate for presenting the information. When presenting complex sign information relating to vehicle safety, an iconic or graphical representation supplemented with voice is the preferred presentation. The potential complexity of this information precludes an auditory format. However, when the information is not safety related, icons with tones are preferred. Therefore, voice is preferred for presenting information related to more infrequent and important events, such as guidance sign information. As the information presented becomes simple, information should be presented through the auditory channel alone. Care should be taken, however, not to present too much unwanted or unnecessary information, as this could quickly aggravate or overload the driver's auditory resources.

**Special Design Considerations:** It has been theorized that rather than completely processing all of the signs along the roadway, drivers selectively attend to those which are most applicable to their current driving situation. Certain information, such as the current street, might become annoying to drivers if presented too frequently. Therefore, it might be worthwhile to allow drivers to selectively filter the sign information which will be presented to them in-vehicle as well. This ability will protect drivers from the possibility of information overload and annoyance.

Research done to date regarding the presentation of auditory messages indicates that aural messages should be comprised of a minimum of four syllables to provide sufficient linguistic context for comprehension (Reference 2), but limited to 7 to 9 units (Reference 3). Also, for increased intelligibility, Reference 4 suggests that sentences be used instead of isolated words.

Selection of the auditory versus visual mode for this information should reflect consideration of priority, complexity, and the consequences of a missed message.

Guidelines for guidance sign information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*Relationship Between ATIS Information and Roadway Signs, p. 7-12*
*Presentation of Filtering Sign Information, p. 8-2*
*General Guidelines for Augmented Signage Information, p. 8-10*
*Trip Status Allocation Design Tool, p. 10-14*

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
3. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
4. Sorkin, R. D., & Kantowitz, B. H. (1987). Speech communication. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 294-309). New York: J. Wiley & Sons.

## PRESENTATION OF NOTIFICATION SIGN INFORMATION

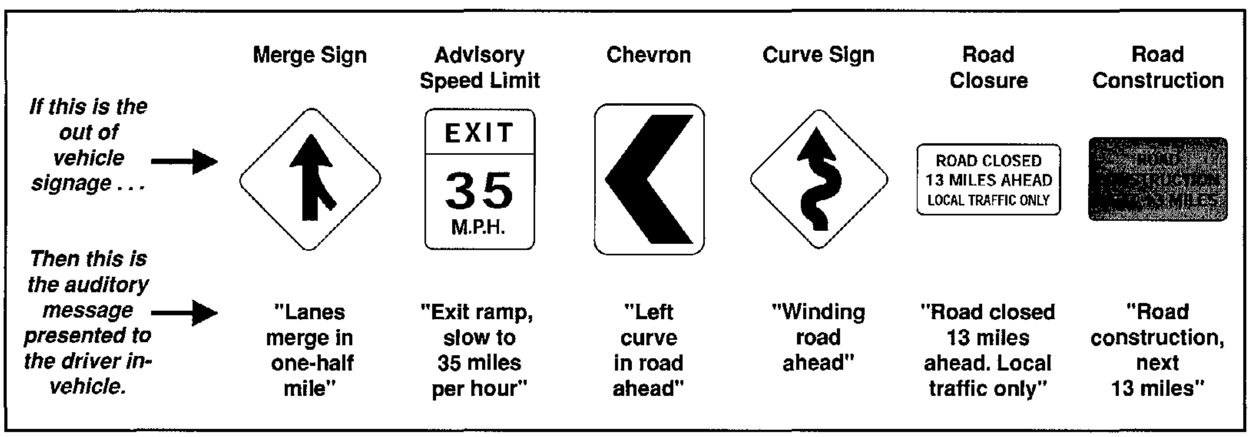
**Introduction:** *Notification sign information* refers to information which notifies drivers of potential hazards or changes in the roadway. This information will be presented to the driver in-vehicle. Examples of this information will include: merge signs, advisory speed limits, chevrons, and curve arrows. In addition, notification information may include temporary or dynamic information such as road closures, road maintenance, or road construction. Other supplementary information such as the distance to a notification point may also be provided.

**Design Guidelines*****

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Inform driver of changes in the roadway (e.g., merge signs, advisory speed limits, chevrons, curve arrows) | Auditory and Visual | Vehicle in Motion | Auditory alerting tone followed by icon or text message |
| Inform driver of temporary or dynamic information (e.g., road closures, road maintenance or road construction) | Auditory or Visual | Vehicle in Motion | Alerting tone then speech, or speech or alerting tone, then icon |
| Inform driver of distance to a particular notification point | Auditory | Vehicle in in Motion | Speech, or alerting tone, then speech |

### Schematic Examples of Notification Sign Information

*Each of the roadway notification sign examples shown below could be presented to the driver in the form of a brief auditory message. An example of such an auditory message is shown as well.*




**Timing requirements for Signage Information are uncertain. See also the guideline on "Timing of Navigation Information," for more information on timing.**

**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying notification sign information. The nature of this information precludes it from being presented at any time other than in transit. Information complexity is the main factor in determining the sensory modality most appropriate for presenting the information.

In Reference 2, a simulator study was performed in which drivers were informed of upcoming speed zones (i.e., construction zone and school zone) approximately 7.1 seconds before reaching a corresponding roadway sign. The advanced warning was given to the driver in one of two ways, either a text message on an in-vehicle display or a text message preceded by an auditory tone. The results of this study indicated that 15 of the 18 drivers who received only a visual warning either never slowed to the goal speed or slowed only after they had passed the sign located on the roadway. In contrast, 12 of the 18 drivers who received the combination visual and auditory warning were able to slow to the goal speed well in advance of the roadway sign. Therefore, these results suggest that for the presentation of notification sign information which advises drivers to make changes in their current speed of travel, the combination of an auditory alerting tone and ATIS textual information may lead to faster and more reliable compliance.

**Special Design Considerations:** It has been theorized that rather than completely processing all of the signs along the roadway, drivers selectively attend to those which are most applicable to their current driving situation. Therefore, it might be worthwhile to allow drivers to selectively filter the sign information which will be presented in-vehicle as well. The ability to do this will protect drivers from the possibility of information overload.

Research done to date, regarding the presentation of auditory messages indicates that aural messages should be comprised of a minimum of four syllables to provide sufficient linguistic context for comprehension (Reference 3), but limited to 7 to 9 units (Reference 4). Also, for increased intelligibility, Reference 5 suggests that sentences be used instead of isolated words. Guidelines for notification sign information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*Relationship Between ATIS Information and Roadway Signs, p. 7-12*
*Presentation of Filtering Sign Information, p. 8-2*
*General Guidelines for Augmented Signage Information, p. 8-10*
*Trip Status Allocation Design Tool, p. 10-14*

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Kantowitz, B. H., Simsek, O., & Carney, C. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: ATIS function transitions* (Contract No. DTFH61-92-C-00102). Seattle, WA: Battelle Human Factors Transportation Center.
3. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
4. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
5. Sorkin, R. D., & Kantowitz, B. H. (1987). Speech communication. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 294-309). New York: J. Wiley & Sons.

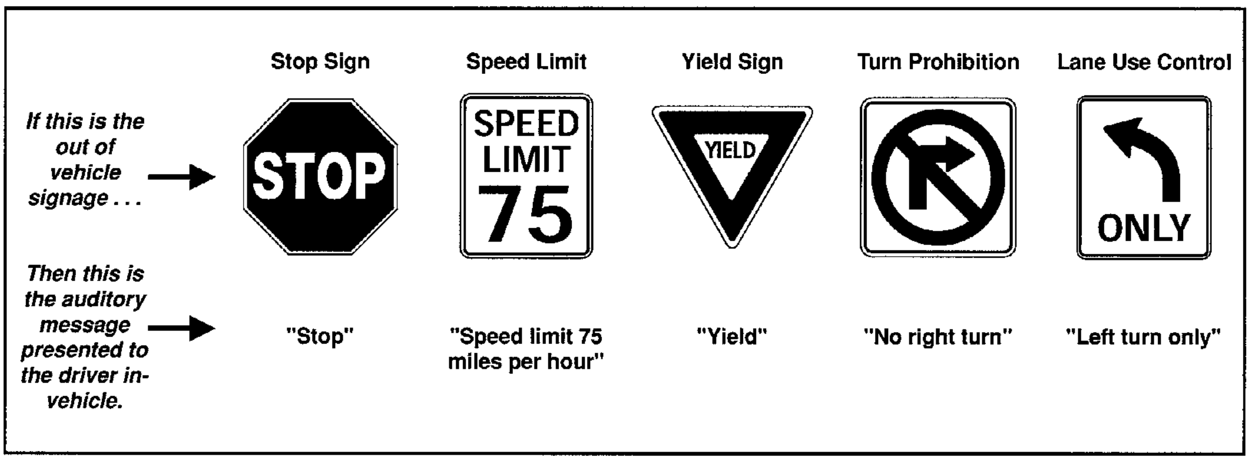
## PRESENTATION OF REGULATORY SIGN INFORMATION

**Introduction:** *Regulatory sign information* refers to information found on out-of-vehicle signage which helps to regulate traffic and displays the rules of the road. This information can also be presented to the driver in-vehicle. Examples of this information include: speed limit signs, stop signs, yield signs, turn prohibitions, and lane use control (e.g., left turn only).

| Design Guidelines*** | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Inform driver of regulatory information (e.g., stop signs, speed limits, yield signs, turn prohibitions, and lane use controls) | Auditory and Visual | Vehicle in Motion | Alerting tone then speech, or speech or alerting tone, then icon |

### Schematic Examples of Regulatory Sign Information

*Each of the regulatory sign examples shown below could be presented to the driver in the form of a brief auditory message. An example of such an auditory message is shown as well.*




**Timing requirements for Signage Information are uncertain. See also the guideline on "Timing of Navigation Information," for more information on timing.**

**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying regulatory sign information. The nature of this information precludes it from being presented at any time other than in transit. Information complexity is the main factor in determining the sensory modality most appropriate for presenting the information.

In Reference 2, a simulator study was performed in which drivers were informed of upcoming speed zones (i.e., construction zone and school zone) approximately 7.1 seconds before reaching a corresponding roadway sign. The advanced warning was given to the driver in one of two ways, either a text message on an in-vehicle display or a text message preceded by an auditory tone. The results of this study indicated that 15 of the 18 drivers who received only a visual warning either never slowed to the goal speed or slowed only after they had passed the sign located on the roadway. In contrast, 12 of the 18 drivers who received the combination visual and auditory warning were able to slow to the goal speed well in advance of the roadway sign. Therefore, these results suggest that for the presentation of regulatory sign information which advises drivers to make changes in their current speed of travel, the combination of an auditory alerting tone and ATIS textual information may lead to faster and more reliable compliance.

**Special Design Considerations:** When displaying sign information in-vehicle, allow a driver to selectively filter the information to protect drivers from the possibility of information overload. However, regulatory sign information is important for the safe and legal operation of the driver's vehicle, and filtering this information could lead to traffic citations or even accidents. Therefore, the filtering option given for both the notification and guidance sign information is not suggested for the regulatory sign information.

Research done to date regarding the presentation of auditory messages indicates that aural messages should be comprised of a minimum of four syllables to provide sufficient linguistic context for comprehension (Reference 3), but limited to 7 to 9 units (Reference 4). Also, for increased intelligibility, Reference 5 suggests that sentences be used instead of isolated words. Guidelines for regulatory sign information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*Relationship Between ATIS Information and Roadway Signs, p. 7-12*
*Presentation of Filtering Sign Information, p. 8-2*
*General Guidelines for Augmented Signage Information, p. 8-10*
*Trip Status Allocation Design Tool, p. 10-14*

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Kantowitz, B. H., Simsek, O., & Carney, C. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: ATIS function transitions* (Contract No. DTFH61-92-C-00102). Seattle, WA: Battelle Human Factors Transportation Center.
3. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
4. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
5. Sorkin, R. D., & Kantowitz, B. H. (1987). Speech communication. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 294-309). New York: J. Wiley & Sons.

# GENERAL GUIDELINES FOR AUGMENTED SIGNAGE INFORMATION

**Introduction:** *Augmentation signage information* refers to transportation technologies that use in-vehicle displays to present the driver with noncommercial routing, warning, regulatory, and advisory information that is currently presented on external roadway signs (Reference 1).

## Design Guidelines***

- Augmented signage information should be presented in the manner that allows drivers sufficient time to interpret the message, determine an appropriate response, and to make that response. [In Reference 2, in-vehicle messages were presented 3-5 seconds before the external road sign (or a relevant roadway condition) was visible.]
- If an auditory warning or attention signal is used to precede the visual presentation of the in-vehicle signage, the volume of the signal should be adjustable by the driver.
- Drivers should be able to adjust the content of the information that is presented through the in-vehicle signage system; i.e., to suppress the presentation of information considered unimportant or distracting.

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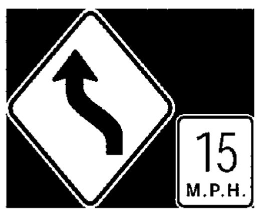
### Augmented Signage Information Evaluated in Reference 2

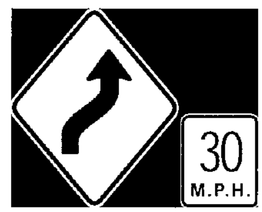

Stop Ahead

Stop



15 MPH Reverse Turn

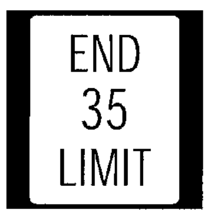
30 MPH Winding Road



30 MPH Reverse Curve

Speed Limit 35 MPH

25 MPH One Lane Tunnel



End 35 MPH Speed

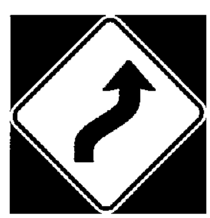
25 MPH "Y" Curve

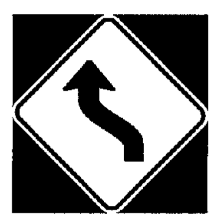
Yield


Curve


Winding Road

One Lane Bridge


Reverse Curve


Reverse Curve

**Supporting Rationale:** In Reference 2, a field experiment was conducted to investigate the benefits of in-vehicle signing information under conditions where external factors reduce or eliminate the driver's ability to see external road signs. The study included both day and night driving conditions, rain and clear weather conditions, and younger and older drivers. All conditions were tested both with and without (i.e., just the standard external signs) the in-vehicle signage information. Three measures of driver performance were collected, as well as subjective data to determine driver preferences and acceptance associated with the in-vehicle displays. The results indicated that the in-vehicle signage information was associated with more appropriate speeds and greater reaction distance for all drivers, increased awareness of road sign information, and a high acceptance rate. No adverse effects associated with driver performance or vehicle control were found. However, some subjects (particularly younger drivers) found the auditory attention signal that preceded the visual in-vehicle signage information to be somewhat distracting and annoying.

In reference 3, a simulation study was conducted to compare driver performance with in-vehicle versus roadside traffic signing under both foggy and clear ambient conditions. As in Reference 2, the in-vehicle signing condition led to faster driver responses (due to an earlier presentation to the driver), particularly for older drivers under foggy conditions. The study was not conclusive, yet (as with Reference 2) suggested some potential benefits of in-vehicle signing.

**Special Design Considerations:** Relatively little research has been conducted to investigate the driver performance implications of various design approaches to augmented signage systems. For example, the effects of information modality (auditory vs. visual), different locations within the vehicle for visual displays, and message timing relative to the location of external signs remain to be addressed by the research community. Timing is a particularly important issue that has not received sufficient empirical attention. In studies conducted to date, in-vehicle signage has been presented to drivers well before the corresponding roadway signs were legible. In these studies, faster driver responses to the in-vehicle versus roadway signs have been interpreted as a benefit of in-vehicle signage. However, this may not always be the case; in many driving situations, for example, premature braking responses can lead to crashes or other incidents. Thus, messages should be presented so that they allow sufficient time for a driver response, yet not presented so early that drivers respond in a premature or inappropriate manner.

The guidelines presented here are preliminary, general, and should be implemented in a careful and purposeful manner. Application to specific design issues should reflect the goals, requirements, and constraints of individual design efforts.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Presentation of Filtering Sign Information, p. 8-2*
*Presentation of Guidance Sign Information, p. 8-4*
*Presentation of Notification Sign Information, p. 8-6*
*Presentation of Regulatory Sign information, p. 8-8*

**Key References:**

1. Perez, W. A., & Mast, T.M. (1992). Human factors and advanced traveler information systems (ATIS). *Proceedings of the Human Factors and Ergonomics Society 36th Annual Meeting* (pp. 1073-1077). Santa Monica, CA: Human Factors and Ergonomics Society.
2. Collins, D.J., Biever, W.J., Dingus, T.A., & Neale, V.L. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Driver performance and behavior interaction with ISIS under reduced visibility conditions.* Washington, DC: Federal Highway Administration (FHWA-RD-99-130).
3. Marshall, R., & Mahach, K. (1996). The effects of an in-vehicle information system (IVIS) signing component on driver response to stop signs and traffic signals on a simulated rural highway. *Proceedings of the Third Annual ITS World Congress.* Orlando, FL: ITS America.

# CHAPTER 9: COMMERCIAL VEHICLE OPERATIONS GUIDELINES

This chapter provides human factors design relevant to Commercial Vehicle Operations Functions of ATIS devices. CVO systems cover a broad spectrum of capabilities that have been identified to meet specific operational requirements. The scope of the present review has excluded crash avoidance systems, such as automatic clearance sensing.

The following design topics are included in this chapter:

## ■ GENERAL GUIDELINES



## ■ CVO-SPECIFIC INFORMATION

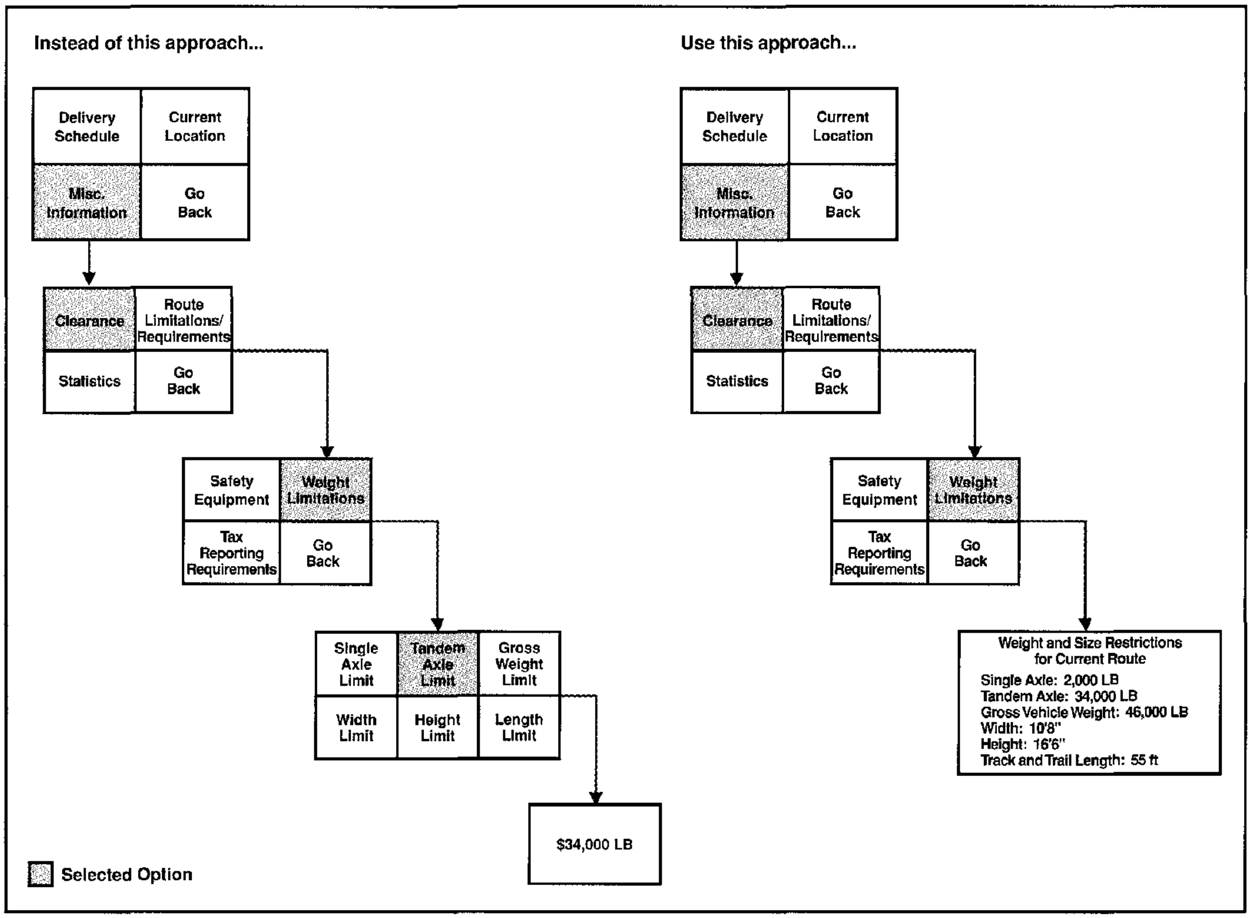
# NUMBER OF CONTROL ACTIONS FOR COMMERCIAL DRIVER ATIS TASKS

**Introduction:** The *number of control actions for commercial driver ATIS tasks* refers to the number of control actions, such as button presses, required to complete a specific information retrieval task during ATIS operations while the vehicle is in motion.

## Design Guidelines****

Completion of critical individual CVO tasks while the vehicle is in motion should not require more than three control actions, such as button presses.

### Redesign Tasks to Minimize Required Control Actions



**Supporting Rationale:** In Reference 1, the effects of display modality, level of interaction, and the amount of information on commercial driver performance and system operation were investigated in a simulation study. In the study, a prototype ATIS was used to present routing, vehicle monitoring, and record-keeping information to the driver. Drivers used the system to perform tasks consistent with driving scenarios developed for the study. Tasks requiring greater than three control actions (button presses) were associated with significant increases in task response time and decrements on driver performance. These findings confirmed the general results presented in Reference 2 in which driving performance declined as the number of required manual tasks increased. Reference 1 also found that the number of control actions had a greater effect on driver performance than did the amount of information presented on the display. While display clutter should be minimized, these findings suggest that commercial drivers are skilled at regulating their attention between display monitoring and driving the vehicle.

**Special Design Considerations:** As described in Reference 1, the design guideline above was derived using fairly simple tasks in which the driver made a series of selections from among several displayed alternatives until a particular task goal was reached. If the time to complete the task is not critical and if (for a particular task) drivers are able to re-direct their attention to the driving scene in-between individual control actions, then a greater number of control actions may not have a negative impact on driver performance or workload. Alternatively, for time-critical operations that require additional visual search of the ATIS display, such as clicking on icons or route segments using a cursor function, even three control actions may be too many for some commercial drivers.

**Cross References:**

*Selection of Control Type, p. 4-2*
*Control Movement Compatibility, p. 4-4*
*Control Coding, p. 4-6*

**Key References:**

1. Mollenhauer, M. A., Dingus, T. A., Hankey, J. M., Carney, C., & Neale, V. L. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Display formats and CVO driver workload.* Washington, DC: Federal Highway Administration (FHWA-RD-96-152).
2. Noy, Y. I. (1989). Intelligent route guidance: Will the new horse be as good as the old? *Proceedings of the Vehicle Navigation and Information Systems Conference* (pp. 49-55). Warrendale, PA: Society of Automotive Engineers.

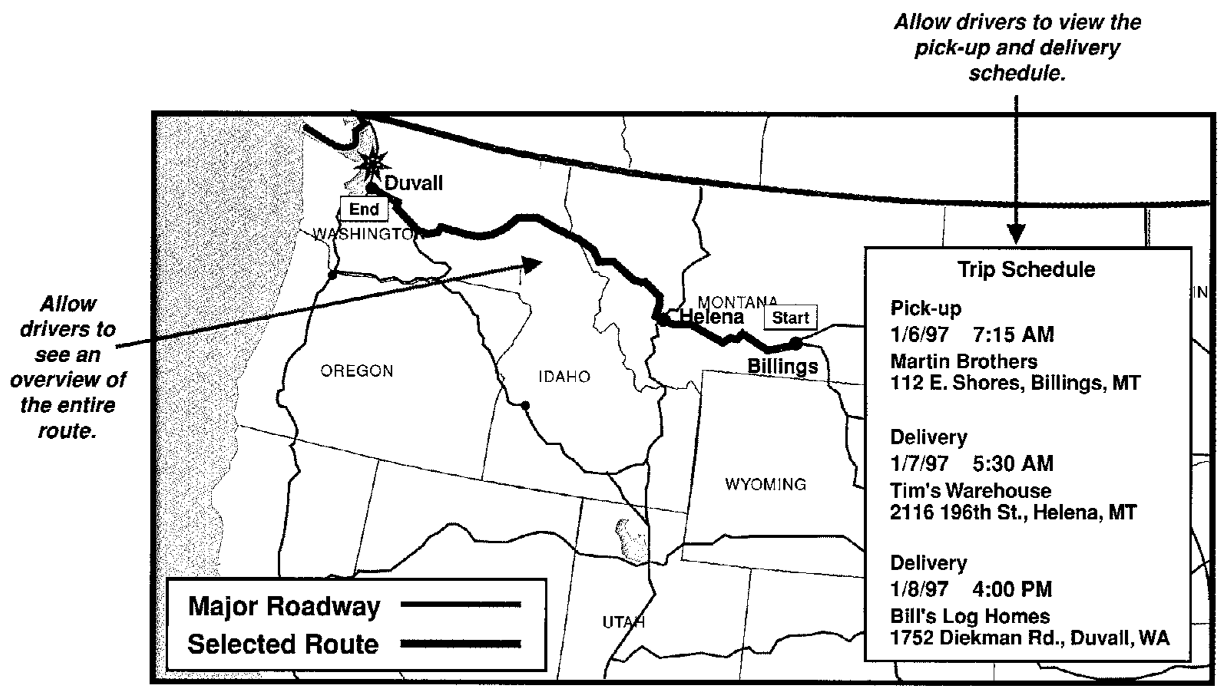
## PRESENTATION OF TRIP SCHEDULING INFORMATION

**Introduction:** *Trip scheduling information* refers to information regarding each of the pick-up and delivery points along a pre-determined route. This information will aid in the coordination of long, multiple-stop journeys and allow drivers to double-check that the current route will optimize their delivery schedule.

**Design Guidelines***

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Scheduled pick-up and delivery times | Visual or Visual and Auditory | Vehicle in PARK | Text description with voice, as needed |

### Schematic Example of Presenting CVO-Specific Trip Scheduling Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific trip schedule information. It was determined that, due to the amount of information being presented to the driver, it would be necessary to present this information while the vehicle was in park. The complexity of the information also made it advisable to present that information visually so that specific information could be referred to, as necessary. It was also determined that providing the drivers with an overview of the trip on a route map would help them to better see and evaluate their overall schedule.

**Special Design Considerations:** Trip scheduling information will be important for long-distance commercial drivers, especially those traveling unfamiliar routes. Their main interest is in finding the quickest possible route available for accomplishing their job. Currently, drivers have access to a wide variety of information sources, including dispatchers with complex routing and scheduling systems, other drivers, and well-established routes from years of personal experience. This subfunction will work to incorporate all of these sources, presenting the driver with the optimal route and overlaying the trip schedule for the driver to evaluate.

Because this information will be presented while the vehicle is in PARK, it is not necessary to concentrate on the safety-related issues such as reducing visual and mental workload. Instead, the emphasis should be placed on HCI issues which would help to optimize the display efficiency and ease of use.

Guidelines for trip scheduling information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**
*Selection of Colors for Coding Visual Displays, p. 3-18*
*Presentation of Destination Preview, p. 4-12*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

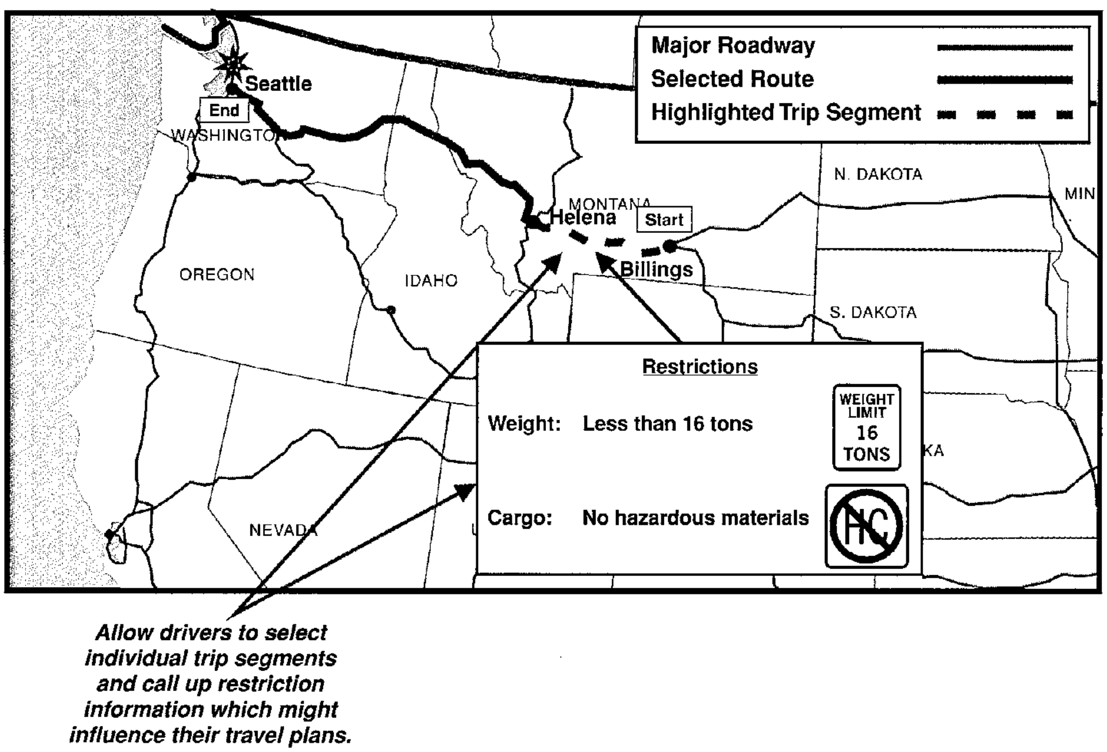
# PRESENTATION OF RESTRICTION INFORMATION

**Introduction:** *Restriction information* refers to weight, size, and cargo constraints, which might not concern private drivers, but could impact the travel plans of commercial drivers, perhaps even forcing them to choose an alternate route.

| Design Guidelines* | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Restrictions: Time of day, day of week, size, weight, height, equipment type, cargo | Visual | Vehicle in PARK | Text description or iconic or graphic representation with text |

## Schematic Example of Presenting CVO-Specific Restriction Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific restriction information. It was determined that this type of information would be most useful to the driver during the predrive trip planning stage, due to the fact that some of the information might cause the driver to change his/her travel plans. Also, due to the complexity and the amount of information being presented, it was determined that the information should be presented visually.

**Special Design Considerations:** CVO drivers are concerned with things such as: road restrictions for carrying certain cargo, restrictions against using certain road types, and restrictions based on bridge height and vehicle weight. Taking all of these things into consideration can make planning a route very difficult, especially when the intent is to find the fastest route possible. Allowing the driver to view any restriction information automatically, once a route has been entered, should make this job much easier. However, the presentation of roadway restrictions over the entire route may be too much information to give at one time. The drivers should be allowed to break the trip down into succinct chunks associated with waypoints within the total trip. In this way, they will be able to see which parts of the route, if any, need to be replanned, and which parts are acceptable.

Activities performed before the trip has begun are not constrained by many of the safety considerations that are placed on in-transit displays. Therefore, designers can place less emphasis on reducing visual and mental attention, and instead focus their display considerations on standard HCI issues, optimizing display efficiency and ease of use.

**Cross References:**

*Selection of Colors for Coding Visual Displays, p. 3-18*
*Presentation of Destination Preview, p. 4-12*

**Notes:**

**Key References:**

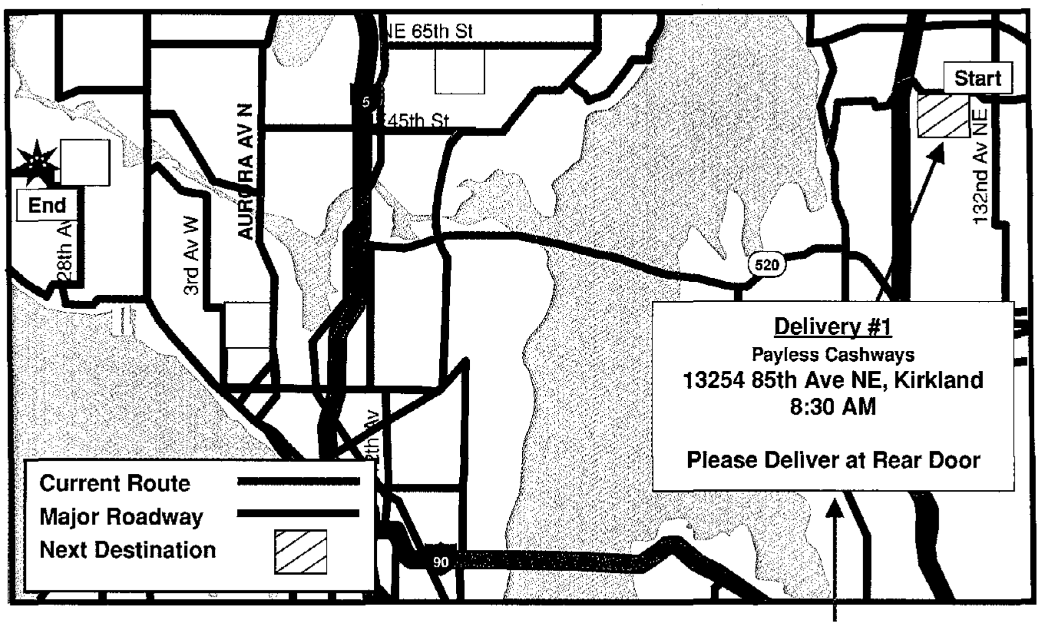
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

## PRESENTATION OF ROUTE SCHEDULING INFORMATION

**Introduction:** *Route scheduling information* concerns the coordination of short, multiple-destination routes to minimize travel time or to minimize lateness on deliveries. Therefore, this function would take the driver's destination as input and provide an optimal routing for traveling between destinations.

| Design Guidelines* | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Optimize delivery schedules | Visual | Vehicle in PARK | Partial route map with or without text |
| Customer's preferences | Visual | Vehicle in PARK | Partial route map with or without text |

### Schematic Example of Presenting CVO-Specific Route Scheduling Information




***Allow drivers to select different pick-up or delivery points and get more detailed information, including customer preferences.***



**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific route scheduling information. It was determined that this type of information would be presented while the vehicle was still in PARK. Giving the drivers this information would enable them to review a route or area and to determine the relative positions of destinations. The information could also include a global overview of a trip plan. Complex, spatial information such as this would be best presented to the driver visually.

**Special Design Considerations:** Route scheduling is a CVO-specific function that concerns the coordination of numerous destinations to minimize travel time or to minimize lateness on deliveries. Therefore, this function would take the driver's destinations as input and provide an optimal order for traveling between destinations. The main constraint of a system such as this will be the ability of the user to interact effectively with a computer terminal. This ability depends on computer familiarity and the ability to navigate complex menu structures. This suggests that designers should focus their display considerations on standard HCI issues, optimizing display efficiency and ease of use.

**Cross References:**

*Selection of Colors for Coding Visual Displays, p. 3-18*
*Presentation of Destination Preview, p. 4-12*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

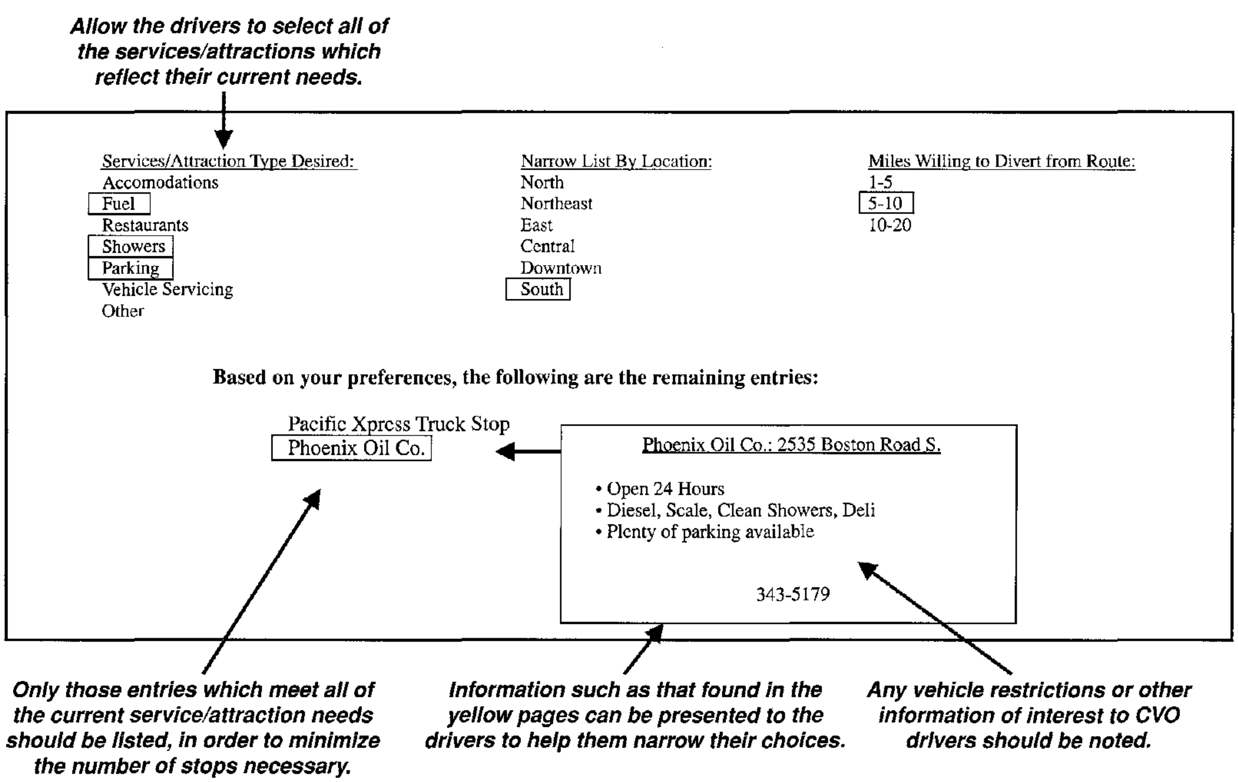
## PRESENTATION OF SERVICE DIRECTORY INFORMATION

**Introduction:** *Service directory information* refers to information similar to that found in the yellow pages or a Trucker's Atlas. However, the attraction/services directory has the flexibility of a computer database and would facilitate a wide variety of search methods, allowing CVO drivers to satisfy their current needs in the fewest number of stops.

**Design Guidelines***

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Directory (index of yellow pages and information from Trucker's Atlas) | Visual | Vehicle at a Stop | Iconic or graphic representation with text or text description |
| View currently selected preferences | Visual | Vehicle at a Stop | Iconic or graphic representation with text or text description |
| Vehicle restrictions (e.g., weight, cargo) | Auditory and Visual or Auditory | Vehicle in Motion | Alerting tones, chimes, etc., or iconic or graphic representation with tones, chimes |

### Schematic Example of Presenting Service Directory Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying service directory information. It was determined that this information would be best presented while the vehicle was stopped briefly during the normal drive (zero speed). In this situation, drivers are able to devote nearly full attention to the system, but the time available for work with the system is limited by the duration of the traffic control device or any other cause of the zero-speed condition. Therefore, operations during a zero-speed situation must typically take less time than those available during a predrive situation. An estimate of the average stop duration at a red light is about 10 seconds. Therefore, this number is used as a criterion for allocating information to the zero-speed category.

It was also determined that the information should be presented visually, due to the amount of information being displayed on the screen and the number of display interactions necessary for selecting preferences. Any time there are more than 7 to 9 units of information, the information is considered to be complex (Reference 2 and 3). Complex information is displayed more effectively through the visual channel.

**Special Design Considerations:** A primary factor limiting a driver's use of the system would be the driver's attitudes and knowledge regarding the system. The driver must know how to use the system (although it should be designed to be self-explanatory) and must have confidence that the system can deliver valuable information. Therefore, designers should concentrate more on human-computer interface issues, such as how the drivers will input their preferences and how that information will be displayed.

Implementing this function for commercial vehicles will require a database tailored to the needs of truck drivers. Commercial vehicle operators are interested in finding the services they need as close to one location as possible, so that the number of stops they need to make is minimized. Allowing CVO drivers to select more than one service at a time will help to reduce the number of remaining entries to those that are located within a designated distance from one another. Also, any restrictions that different services/attractions have that would influence a CVO driver should be indicated, including size and weight limitations. Since drivers must specify complicated information concerning their needs, the system will likely include a touchscreen menu system or a remote keypad. Reference 4 examined the visual, safety, and performance aspects of operating a simulated CRT touch panel display while driving at a constant speed along a straight path with respect to lateral lane position maintenance. Looking at and/or operating a CRT touch panel while driving a vehicle along a straight path appears to be a visually demanding, if not dangerous task, as demonstrated by the relatively high probabilities of lane deviations. Therefore, presenting this information during zero speed, as suggested in the above guideline, appears to be the best option.

**Cross References:** None.

**Key References:**

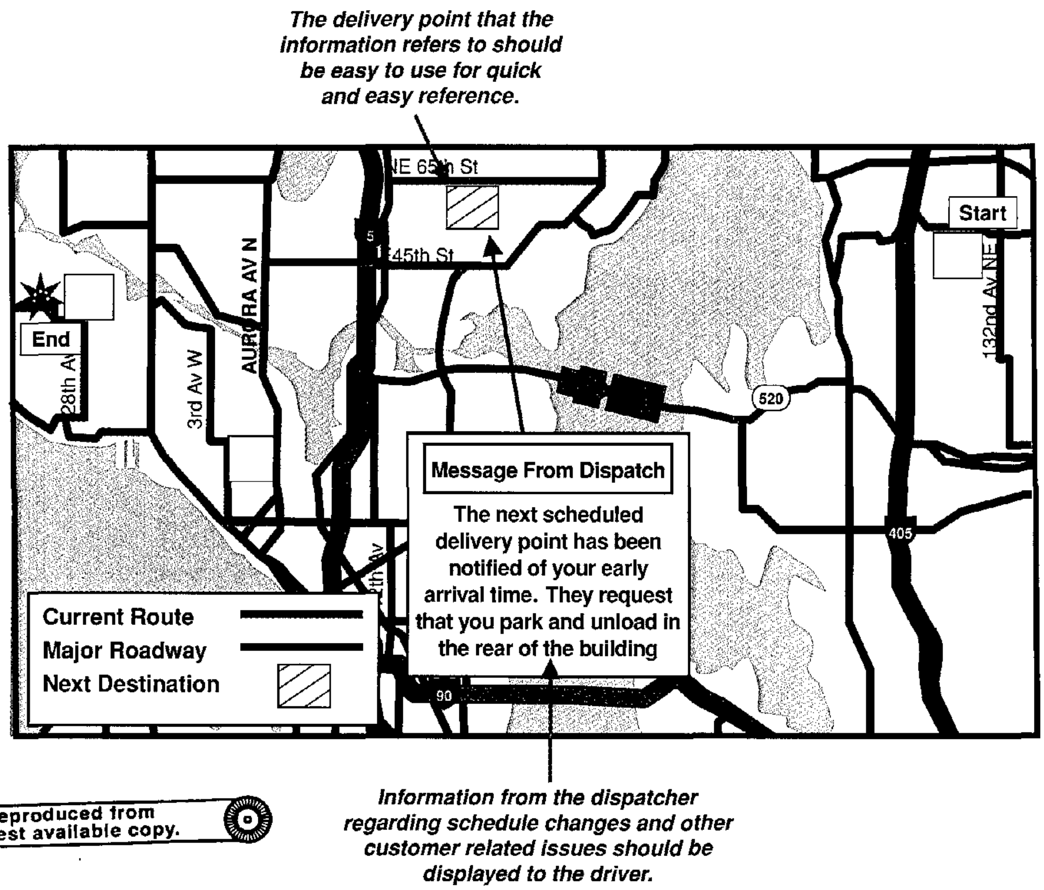
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
3. Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. Psychological Review, 63, pp. 81-97.
4. Zwahlen, H. T., Adams, C. C., & DeBald, D. P. (1987). Safety aspects of CRT touch panel controls in automobiles. *Proceedings of the Second International Conference on Vision in Vehicles* (pp. 1-10). England: University of Nottingham.

# PRESENTATION OF DESTINATION COORDINATION INFORMATION

**Introduction:** *Destination coordination information* refers to coordinating shipments with customers. This might involve making arrangements for loading and unloading shipments and catering to changes in scheduled pick-up and delivery times.

| Design Guidelines* | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Information from dispatcher regarding schedule changes and other pick-up/delivery information | Visual | Vehicle in Motion | Text description or iconic or graphic representation with text |

## Schematic Example of Presenting CVO-Specific Destination Coordination Information






**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** In Reference 1, a literature review, an analysis, and the results of applying a research-based design tool were used to identify the most appropriate display type, trip status, and display format to use when displaying destination coordination information. It was determined that this type of information would be most useful to the driver if presented while in transit. Displaying messages from dispatch should be done both visually and aurally. This will enable the driver to receive the information without adding to the additional visual attention load, allowing the information to be recalled at a later time if it is forgotten or misunderstood. However, a route map locating the delivery points and the suggested route should be presented visually. Showing a vehicle's position relative to multiple landmarks or routes is considered to be complex information which can be presented most efficiently through the visual channel. According to Reference 2, drivers can process detailed visual information more rapidly than they can process detailed auditory information.

**Special Design Considerations:** This function allows dispatch to provide the drivers with information relevant to their schedule, including communication with the different delivery points, whenever requested. However, future systems may even have the capability to provide this information directly to the driver. When implementing this function, a dedicated "status line" may be included on some portion of the display.

**Cross References:**

*Selection of Colors for Coding Visual Displays, p. 3-18*
*Presentation of Destination Preview, p. 4-12*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Deatherage, B. H. (1972). Auditory and other sensory forms of information presentation. In H. Van Cott & R. Kinkade (Eds.), *Human engineering guide to equipment design* (rev. ed.) (pp. 123-160). Washington, DC: U.S. Government Printing Office.

## COMMUNICATION ACKNOWLEDGMENT FOR CVO IN-VEHICLE SYSTEMS

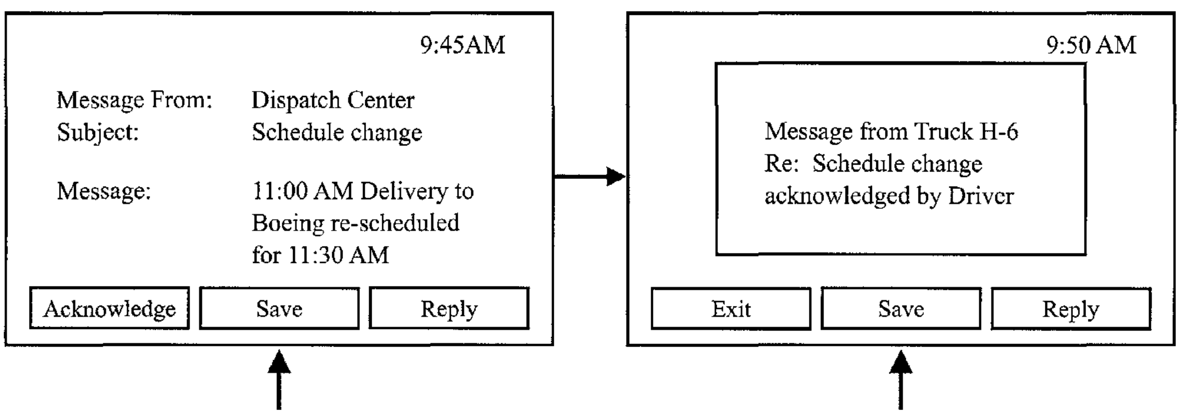
**Introduction:** *Communication acknowledgment* refers to the capability of a CVO in-vehicle communication or messaging system to provide the sender of a message (i.e., a driver or a dispatcher) confirmation that a message was transmitted and received by the system hardware, and to provide information as to whether or not a message has been accessed or "opened" by the recipient.

Acknowledgment is inherent in systems requiring concurrent participation of both sender and receiver in the communication. Telephones and two-way radios are common examples of systems that inherently provide acknowledgment. Acknowledgment is not inherent in systems that allow messages to be sent and received without immediate involvement of both parties (or all parties, in the case of messages broadcast to multiple recipients). Systems that store messages for later access, electronic mail, and telephone answering machines, for example, often do not acknowledge receipt of a message by the hardware, nor access of the message by the recipient.

### Design Guidelines*

- CVO in-vehicle communication systems that do not require direct, real-time interaction between drivers and dispatchers should provide the sender an acknowledgment that a message has been sent and received or, alternatively, a means to determine the status of each message.
- An acknowledgment should provide the sender feedback regarding the transmission and receipt of messages by the hardware components of the communication system, and also should provide acknowledgment that a message was actually "opened," or otherwise accessed, by the recipient.
- Communication acknowledgments should be restricted to when the vehicle is stopped or in PARK.

### Schematic Example of Implementing a Communication Acknowledgment Function for CVO




***Schematic example of message screen seen by the driver***

***Schematic example of message screen seen by the dispatch center***

**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** CVO applications require frequent communications between drivers and dispatchers (Reference 1). CVO drivers are responsible for communicating with dispatchers regarding cargo loading and unloading updates, delivery schedules, customer information and updates, and vehicle conditions. Dispatchers receive messages from many fleet vehicles and, in return, send specific instructions and requests for information. The link between these two parties is essential for the productivity of a fleet. Providing a positive indication that a message has been sent and received will eliminate uncertainties that can cause multiple copies of a message to be needlessly transmitted. Eliminating redundant messages frees the communication network for other message traffic.

**Special Design Considerations:** When a message is opened by the recipient, the system should either automatically send confirmation that the message was received or require the recipient to make a simple input into the system (e.g., a single key press) that transmits confirmation to the sender that the message was read. A positive acknowledgment is required; the absence of an indication is not sufficient to show that the system is operating normally, or that a message has been accessed.

The party sending a message should be advised if a message is purged from the communication system prior to being accessed by the recipient.

Guidelines for the communication acknowledgment information for ATIS reflect certain assumptions regarding the priority, length, and complexity of messages. These assumptions may not apply to all design situations.

**Cross References:**
*The Message Transfer Function, p. 6-8*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**
1. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).

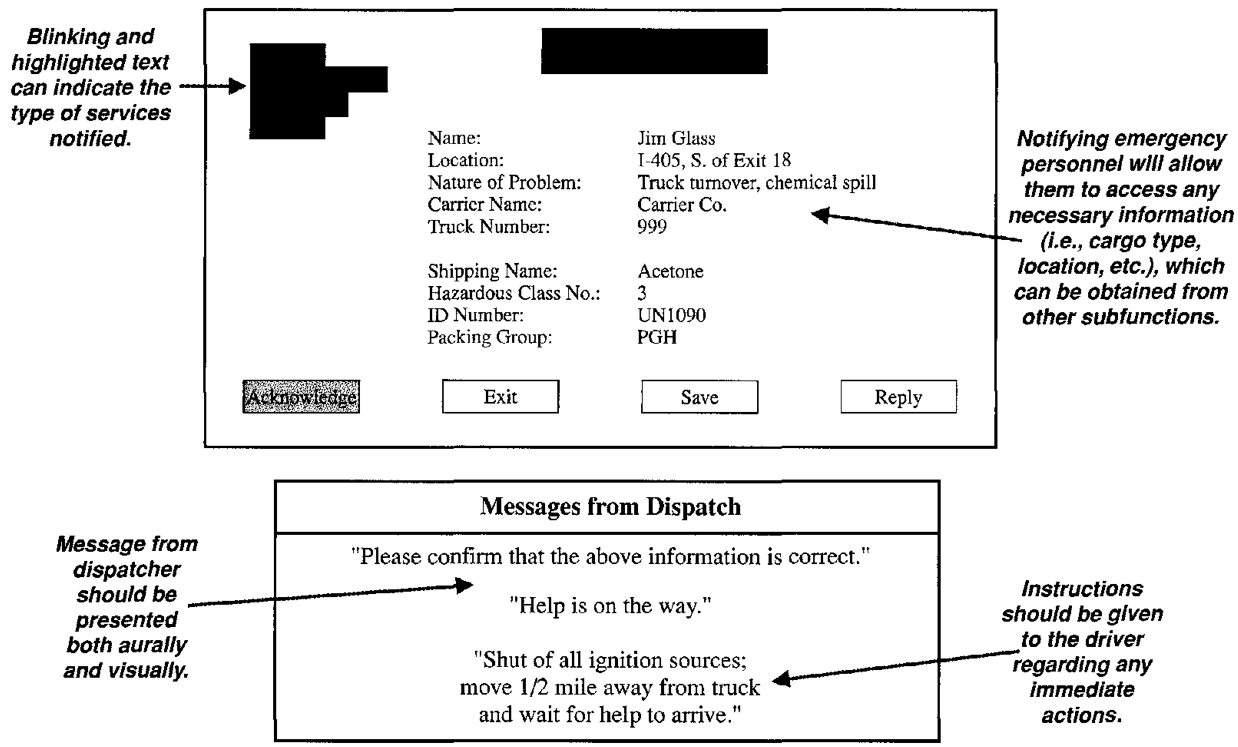
# PRESENTATION OF CVO-SPECIFIC AID REQUEST INFORMATION

**Introduction:** *CVO-specific aid request information* refers to the ability to notify emergency personnel (e.g., police, ambulance, towing, fire) of the need for aid. It may also include the ability to provide the driver with feedback regarding the status of emergency services. In the case of commercial vehicles, it may be especially important for emergency personnel to know specific information regarding the type of truck and the cargo it is carrying.

**Design Guidelines***

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Notify emergency services of hazardous material | Auditory and Visual or Visual | Vehicle in PARK or Zero Speed | Iconic or graphic representation with text or text description |
| Inform emergency services of cargo type | Auditory and Visual or Visual | Vehicle in PARK or Zero Speed | Iconic or graphic representation with text or text description |

## Schematic Example of Presenting CVO-Specific Aid Request Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific aid request information. An assumption was made that requests for aid would come as the result of either vehicle problems, an accident, or offering roadside assistance. Therefore, this function would operate primarily while the vehicle was in PARK. Using a combination of both visual and auditory display modes might help to ensure that a message would be displayed if the vehicle were in an accident. Even if one of the systems were disabled, there would be a chance that the other system would be able to display the message to the driver.

**Special Design Considerations:** According to Reference 2, critical messages, such as those from an ambulance dispatcher, should be presented to the driver immediately and should be able to get the driver's attention whether or not the display is actively being searched for information. Communication between the vehicle or the driver and the emergency dispatcher is essential for the effective use of this function. In the case of automatic aid requests, the vehicle will need the ability to detect, analyze, and report emergencies to the correct authorities. However, in the case of manual aid requests, the driver will be responsible for entering data concerning the specific services needed and the relative urgency of the request. In both cases, it is important that the dispatcher be able to inform the drivers that their request for aid has been heard and is being responded to.

In the case of commercial vehicles which might be carrying hazardous materials, it is extremely important that emergency personnel be notified in advance so that precautionary measures may be taken and the correct emergency personnel can be sent.

**Cross References:**

*Presentation of Automatic/Manual Aid Request Information, p. 7-10*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Huiberts, S. J. C. (1989). How important is mobile communication for a truck company? *IEEE,* CH2789- 6/89/0000-0361, (pp. 361-364). Piscataway, NJ: IEEE.

## PRESENTATION OF CVO-SPECIFIC GUIDANCE SIGN INFORMATION

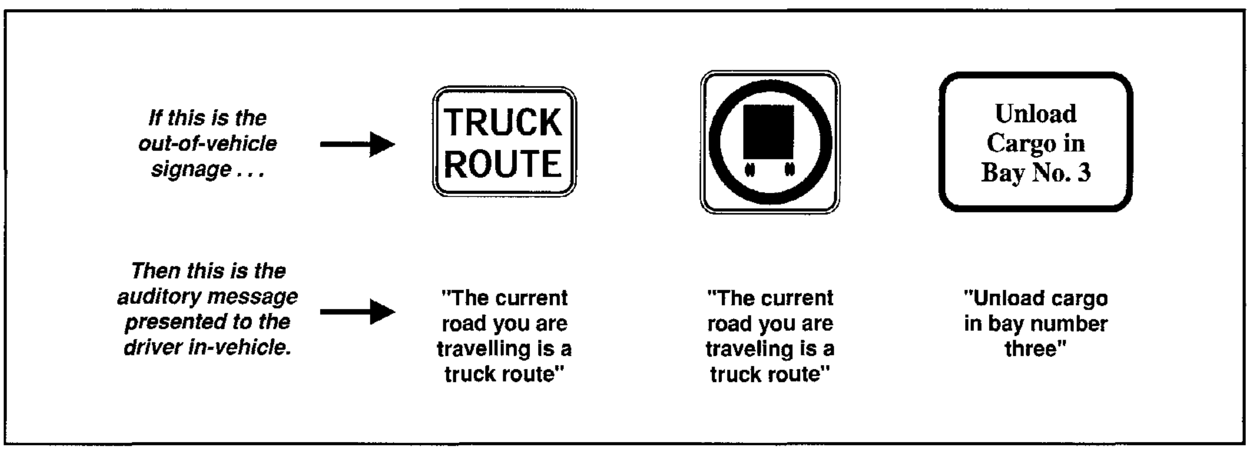
**Introduction:** *CVO-specific guidance sign information* refers to sign information which might be helpful for guiding commercial vehicle operators to a particular destination. Such information is currently found on out-of-the-vehicle signage (e.g., truck route signs). However, this subfunction would allow this information to be presented to the commercial driver aurally, in the vehicle.

**Design Guidelines***

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Specific sign guidance (e.g., truck route) | Auditory | Vehicle in Motion | Alerting tone, then speech, or entire message presented as speech or alerting tone, then icon |
| Delivery location | Auditory | Vehicle in Motion | Alerting tone, then speech, or entire message presented as speech or alerting tone, then icon |

### Schematic Example of Presenting CVO-Specific Guidance Sign Information

***In addition to visual on-road guidance signs (i.e., street signs, interchange graphics, route markers and mile posts), in-vehicle signage specific to the guidance of commercial vehicles may be presented to the driver in the form of a brief auditory message. An example of such an auditory message is shown.***



**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying guidance sign information. It was determined that the nature of the information precludes it from being presented at any other time than in transit. The criticality of the information will determine which format will be used to display it. Although the information will always be presented through the auditory channel, information which is deemed to be more critical or unique (e.g., requiring immediate response) will be preceded by an alerting tone. Otherwise, the information will be given solely as a voice message. In this way, the distraction potential associated with these types of messages should be reduced.

**Special Design Considerations:** Research done to date regarding the presentation of auditory messages indicates that aural messages should be comprised of a minimum of 4 syllables to provide sufficient linguistic context for comprehension (Reference 2), but limited to 7 to 9 units (Reference 3). Also, for increased intelligibility, Reference 4 suggests that whole sentences be used instead of isolated words.

Rather than completely processing all of the signs along the roadway, CVO drivers selectively attend to those which are most applicable to their current driving situation. It might be worthwhile to allow a driver to selectively filter the sign information which will be presented to them in-vehicle, in order to protect drivers from the possibility of information overload.

It is important to note that very little research has been performed to evaluate different methods of displaying sign information with an in-vehicle system. The design guidelines given are based solely on generally accepted human factors guidelines and principles. To accurately assess the system effectiveness and user preferences, researchers should use prototypes of a signing system to clarify the decisions about which sensory mode to use for sign information display and the types of filtering that might be employed.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*Presentation of Filtering Sign Information, p. 8-2*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
3. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
4. Sorkin, R. D., & Kantowitz, B. H. (1987). Speech communication. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 294-309). New York: J. Wiley & Sons.

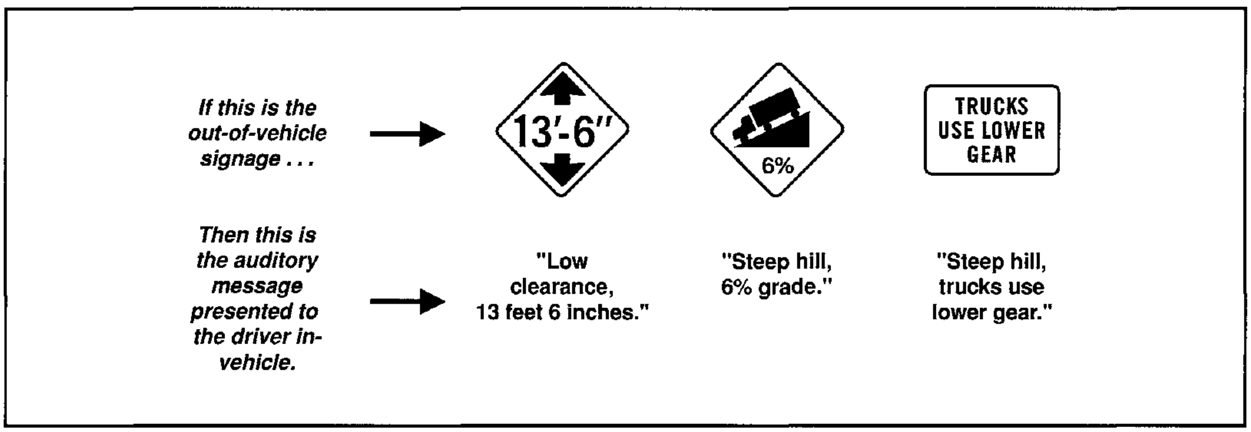
# PRESENTATION OF CVO-SPECIFIC NOTIFICATION SIGN INFORMATION

**Introduction:** *CVO-specific notification sign information* refers to information regarding potential hazards and road changes. Particularly in the case of large trucks, additional time to plan or prepare for long/steep grades, sharp curves, exits, and lane changes may be valuable. Also, presenting this information in-vehicle may allow for it to be more detailed and timely.

| Design Guidelines* | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Road change information i.e., steep grade, sharp curve, or exit) | Auditory | Vehicle in Motion | Alerting tone, then speech, or entire message presented as speech, or alerting tone, then icon |

## Schematic Example of Presenting CVO-Specific Notification Sign Information

***In addition to visual on-road notification signs (i.e., merge signs, advisory speed limits, chevrons, curve arrows, and road closure, maintenance, or construction signs), in-vehicle signage specific to the special notification needs of commercial vehicles will be presented to the driver in the form of a brief auditory message. An example of such an auditory message is shown.***



**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying notification sign information. It was determined that the nature of the information precludes it from being presented at any other time than in transit. Simple notification information should be presented through the auditory channel to avoid distracting the driver unnecessarily. More critical or unique notification messages (e.g., those requiring an immediate response) should be preceded by an auditory alert, in order to get the attention of the driver more quickly.

**Special Design Considerations:** Research done to date regarding the presentation of auditory messages indicates that aural messages should be comprised of a minimum of 4 syllables to provide sufficient linguistic context for comprehension (Reference 2), but limited to 7 to 9 unrelated informational items (Reference 3). Also, for increased intelligibility, Reference 4 suggests that sentences be used instead of isolated words.

Rather than completely processing all of the signs along the roadway, CVO drivers selectively attend to those which are most applicable to their current driving situation. Therefore, it might be worthwhile to allow drivers to selectively filter the sign information which will be presented to them in-vehicle. The ability to filter sign information will help to protect drivers from the possibility of information overload.

It is important to note that very little research has been performed to evaluate different methods of displaying sign information with an in-vehicle system. The design guidelines given are based solely on generally accepted human factors guidelines and principles. To accurately assess the system effectiveness and user preferences, researchers should use prototypes of a signing system to clarify the decisions about which sensory mode to use for sign information display.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*Presentation of Filtering Sign Information, p. 8-2*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
3. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
4. Sorkin, R. D., & Kantowitz, B. H. (1987). Speech communication. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 294-309). New York: J. Wiley & Sons.

## PRESENTATION OF CVO-SPECIFIC REGULATORY SIGN INFORMATION

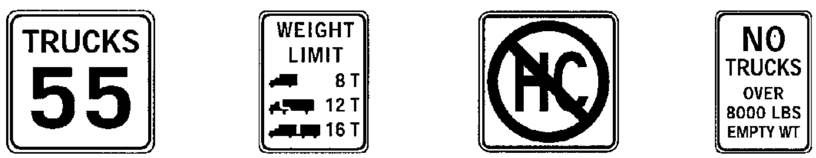
**Introduction:** *CVO-specific regulatory sign information* refers to information regarding size and weight limits, truck speed limits, and any road restrictions.

| Design Guidelines* | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Specific regulatory information for CVO's (e.g., truck speed limits, weight limits, etc.) | Auditory or Visual | Vehicle in Transit | Alerting tone, then speech or entire message presented as speech or alerting tone, then icon |

### Schematic Example of Presenting CVO-Specific Regulatory Sign Information

***In addition to visual on-road regulatory signs (i.e., stop signs, speed limits, yield signs, turn prohibitions, and lane use control), signage necessary for regulating commercial vehicles will be presented to the driver in the form of a brief auditory message. An example of such an auditory message is shown.***

*If this is the out-of-vehicle signage . . .* →




*Then this is the auditory message presented to the driver in-vehicle.* →

| | | | |
|---|---|---|---|
| **"Truck speed limit is 55 miles per hour."** | **"Weight limits: 2 axles equals 8 tons 3 axles equals 16 tons 4 axles equals 24 tons."** | **"Hazardous cargo prohibited on this route."** | **"No trucks over 8,000 pounds, empty weight."** |

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific regulatory sign information. It was determined that the nature of the information precludes it from being presented at any other time than in transit. Professional drivers engage in trip planning activities which familiarize them with the regulations associated with different segments of their route. The goal is to remind the drivers without distracting them unnecessarily from the driving task. Therefore, this information will be presented to the driver aurally.

**Special Design Considerations:** Research done to date regarding the presentation of auditory messages indicates that aural messages should be comprised of a minimum of 4 syllables to provide sufficient linguistic context for comprehension (Reference 2), but limited to 7 to 9 units (Reference 3). Also, for increased intelligibility, Reference 4 suggests that sentences be used instead of isolated words.

Rather than completely processing all of the signs along the roadway, CVO drivers selectively attend to those which are most applicable to their current driving situation. Therefore, it might be worthwhile to allow a driver to selectively filter the sign information which will be presented to them in-vehicle. The ability to filter sign information might help to protect drivers, especially CVO, from the possibility of information overload.

**Cross References:**

*Use of Alerts for ATIS Messages, p. 3-46*
*Timing of Auditory Navigation Information, p. 5-4*
*Presentation of Filtering Sign Information, p. 8-2*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats*. Washington, DC: Federal Highway Administration (FHWA-RD-96-142).
2. Simpson, C. A., McCauley, M. E., Roland, E. F., Ruth, J. C., & Williges, B. H. (1987). Speech controls and displays. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 549-574). New York: J. Wiley & Sons.
3. Labiale, G. (1990). In-car road information: Comparisons of auditory and visual presentation. *Proceedings of the Human Factors Society 34th Annual Meeting* (pp. 623-627). Santa Monica, CA: Human Factors and Ergonomics Society.
4. Sorkin, R. D., & Kantowitz, B. H. (1987). Speech communication. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 294-309). New York: J. Wiley & Sons.

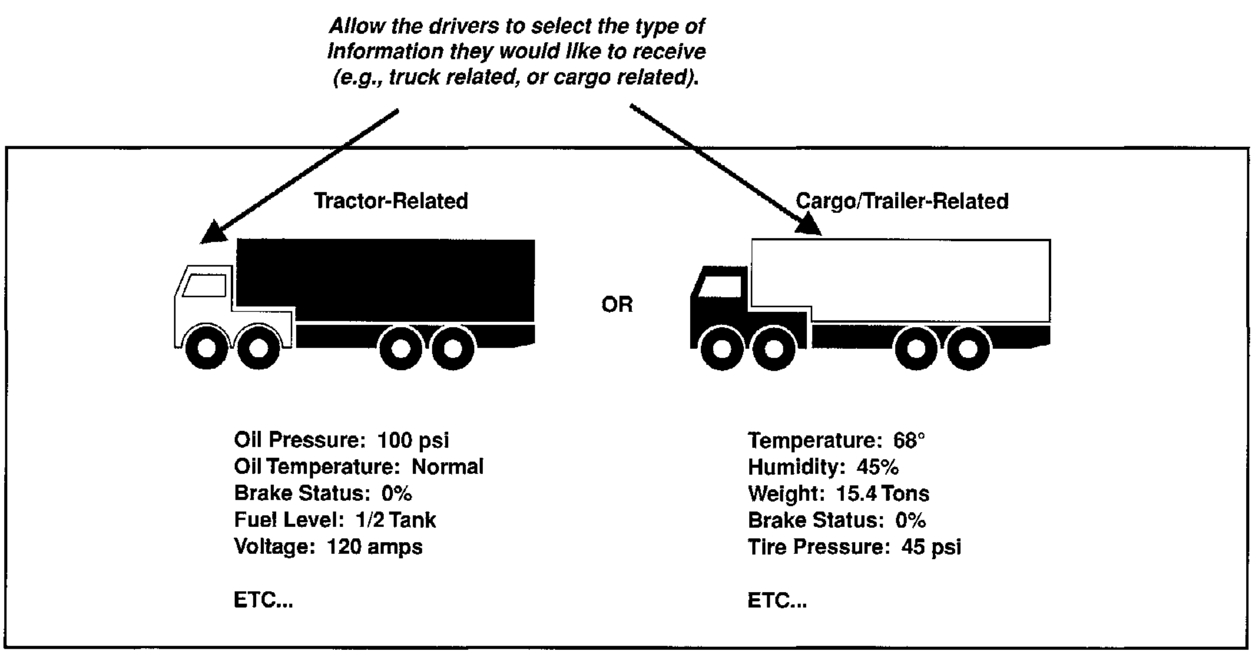
## PRESENTATION OF CVO-SPECIFIC CARGO AND VEHICLE MONITORING INFORMATION

**Introduction:** *CVO-specific cargo and vehicle monitoring information* refers to more detailed and diverse information than that presented to private drivers. It may include a more precise indication of engine performance. In addition, many commercial vehicles carry sensitive cargo, which require careful monitoring of things like temperature, humidity, and vibration.

**Design Guidelines***

| Information Element | Display Type | Trip Status | Display Format |
|---|---|---|---|
| Condition of the cargo | Visual or Visual and Auditory | Vehicle in Motion | Text description with or without voice |
| Condition of the trailer | Visual or Visual and Auditory | Vehicle in Motion | Text description with or without voice |
| Precise information regarding vehicle performance | Visual or Visual and Auditory | Vehicle in Motion | Text description with or without voice |

### Schematic Example of Presenting Cargo and Vehicle Monitoring Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific cargo and vehicle monitoring information. It was determined that cargo and vehicle monitoring should be done in transit to allow drivers to monitor for changes which might affect their ability to successfully complete the route or make a scheduled delivery. When determining the appropriate sensory modality, it was determined that visual displays are somewhat more flexible and give the driver greater detail, but lack the ability to grab the attention of a driver. However, when used in combination with an auditory alert or message, visual displays can provide fast response times and detailed information that can be referred to visually when the driver feels it is safe to do so. An auditory message might be used to augment visual information unless, for example, abnormal conditions are present.

**Special Design Considerations:** Cargo and vehicle monitoring information could be useful for dispatchers and company managers if it is used as an aid in coordinating maintenance and ensuring the timely delivery of undamaged goods. The dispatcher could use this information to arrange for repair services, note recurring problems with specific vehicles, or select alternate routes. However, it is conceivable that drivers may resent the dispatcher's ability to monitor their performance so closely. Unless these systems are introduced while considering the broader issues of driver acceptance, drivers' behavior and use of the system may reduce its potential.

**Cross References:**
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**
1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

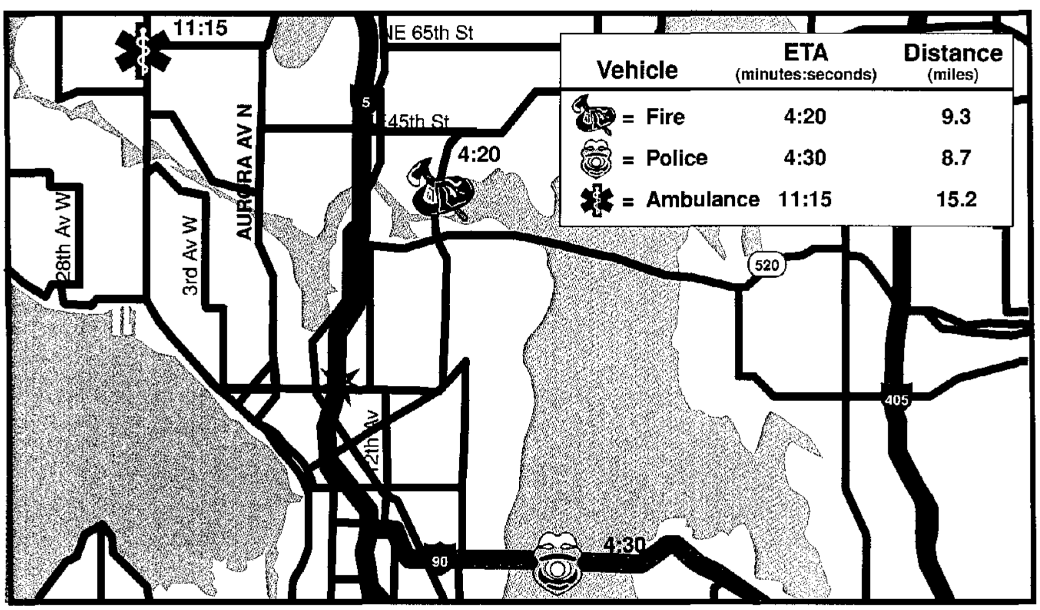
# ESTIMATED TIME OF ARRIVAL FOR EMERGENCY VEHICLES

**Introduction:** *Estimated time of arrival (ETA)* refers to the ability of a system to estimate the time remaining until a vehicle reaches the destination. In this context, ETA is simply the length of the route remaining to be negotiated divided by the average speed expected over the remaining route (e.g., ETA is 3 minutes, 15 seconds). It is common in some domains to add ETA to the current time to express estimated arrival time in clock time (e.g., a commercial aircraft might express their ETA as 7:30 p.m.). Accurate ETA information is critical to the effective deployment of emergency response vehicle fleets.

## Design Guidelines**

- ETA for all vehicles responding to a location should be available continuously to emergency vehicle dispatchers.
- These ETAs should be updated in near real time, and displayed in a format that supports dispatcher decision making.
- Display update rates for alphanumerics should be slow enough to allow reading of the individual characters; updates should not be made at a rate faster than 1 Hz.
- The user should be provided a means to "freeze" the values to allow simultaneous comparison of ETAs for different vehicles.

### Schematic Example of Presenting Estimated Time of Arrival for Emergency Vehicles




**Important Note:** The map display depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

**Supporting Rationale:** Display update rates for alphanumerics should be slow enough to allow reading of the individual characters; updates should not be made at a rate faster than 1 Hz, as recommended in Reference 2. The ability to get emergency response vehicles on-site as quickly as possible is critical to saving lives and property. It is common, therefore, for dispatchers to initially direct multiple vehicles to respond to the same destination. Later, as the sequence of arrivals becomes apparent to the dispatcher, all but the earliest arriver(s) is (are) redirected or recalled. Until being redirected, unnecessary vehicles are not available to respond to other emergencies. Determining order of arrival requires the dispatcher to estimate distances and expected speeds, taking traffic into account, for each emergency vehicle. This is a difficult and error prone task when performed manually.

As described in Reference 1, the use of navigation and guidance systems coupled with real-time traffic information promises both improved estimation of arrival times and reduced workload placed on dispatchers. Providing ETA information to dispatchers will reduce the use of redundant vehicles in responding to emergency situations. This improvement may be manifest as a reduction in the number of vehicles initially dispatched, or in terms of reassigning or recalling dispatched vehicles earlier than can be done when ETA is estimated manually. Improvements in dispatching emergency vehicles are expected to translate into improvements in overall efficiency of emergency services.

**Special Design Considerations:** The user should be provided a means to "freeze" the values to allow simultaneous comparison of ETAs for different vehicles. Clearly, ETA should be as accurate as possible. In order to accurately estimate arrival times, the computations for emergency response vehicles must take the differences in the operating pattern between these vehicles and those of nonemergency vehicles into account. For example, the ability of emergency vehicles to "run" red lights and stop signs, and to travel the wrong way on one-way streets and divided roads, will result in faster transit times and earlier ETAs than nonemergency vehicles. (The ability to drive the "wrong" way and to drive off-road [e.g., through a park] also have implications for navigation and guidance systems tailored to emergency vehicles.) Additionally, ETA computations should not necessarily assume that the speed of traffic along the route (e.g., "probe" vehicles) is a good estimator of the speed the emergency vehicle will be traveling. Even in heavy urban stop-and-go traffic, an emergency vehicle may be able to travel more rapidly than nonemergency vehicles.

**Cross References:**

*Symbol Versus Text Presentation of ATIS/CVO Messages, p. 3-30*

**Notes:**

**Key References:**

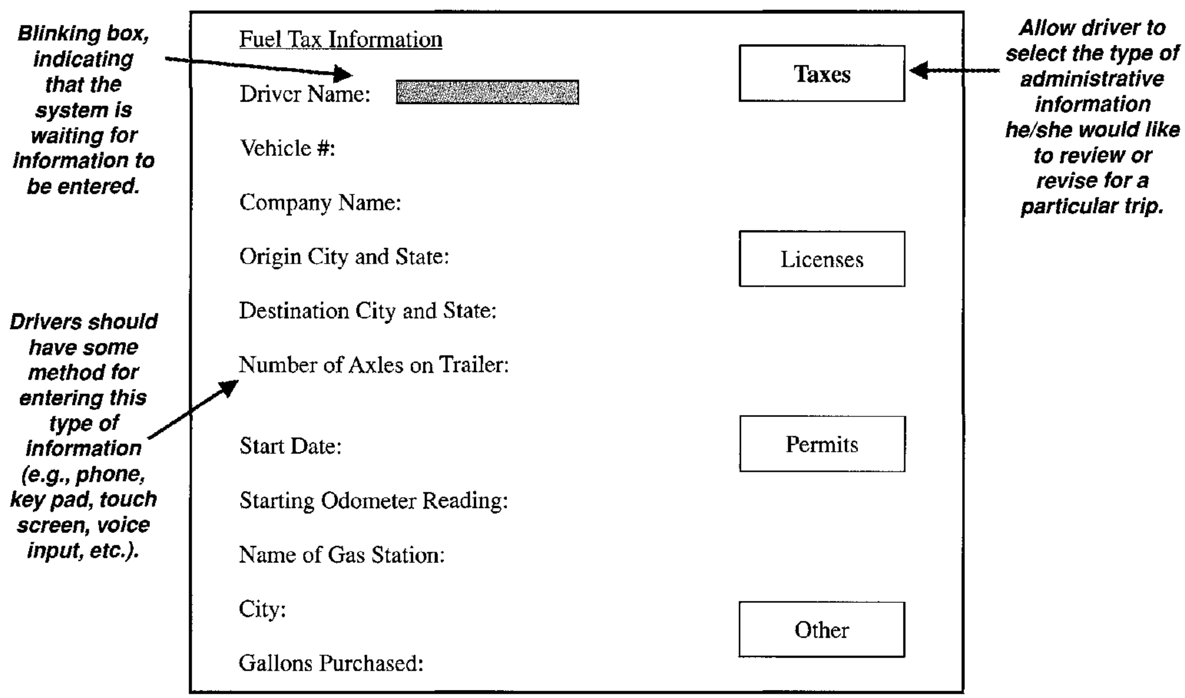
1. Clarke, D. L., McCauley, M. E., Sharkey, T. J., Dingus, T. A., & Lee, J. D. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Comparable systems analysis.* Washington, DC: Federal Highway Administration (FHWA-RD-95-197).
2. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.

## PRESENTATION OF CVO-SPECIFIC REGULATORY ADMINISTRATIVE INFORMATION

**Introduction:** *CVO-specific regulatory administrative information* refers to various regulatory administrative requirements, including taxes, licensing, permits, and coordination of the transport of hazardous materials. This function may also be involved with checking the required training programs and other administrative functions required of a CVO company by law.

| Design Guidelines* | | | |
|---|---|---|---|
| **Information Element** | **Display Type** | **Trip Status** | **Display Format** |
| Allow driver to complete administrative paperwork electronically | Visual | Vehicle in PARK | Text description |
| Inform driver of regulatory administrative requirements | Visual | Vehicle in PARK | Text description |

### Schematic Example of Presenting CVO-Specific Regulatory Administrative Information




**Important Note:** The graphic depicted above is provided solely to augment this Design Guideline by illustrating general design principles. It may not be suitable for your immediate application without modification.

* Primary expert judgment
** Expert judgment with supporting empirical data
Empirical data with supporting expert judgment ***
Primarily empirical data ****

**Supporting Rationale:** Reference 1 used a literature review, an analysis, and the results of applying a research-based design tool to identify the most appropriate display type, trip status, and display format to use when displaying CVO-specific regulatory administrative information. This information should be entered into the system before a trip is begun so that it can be transmitted to the appropriate check stations as the drivers travel the route. Due to the complexity and the amount of information to be entered into the system, it was determined that visual text would be the best display format to use.

**Special Design Considerations:** Currently, regulatory administration relies on the physical inspection of vehicle, driver, and/or shipment paperwork at the ports of entry and other locations. With ATIS, this would be done electronically using a comparison of information originally provided by the carrier, weight sensors on the roadway, and identification tags on the vehicle. This would remove the necessity for a vehicle to stop at the port of entry to have paperwork examined. The success of this function will depend on the ability of designers to make the system efficient and easy to use. Marketing will also play an important part in the success of this type of system. It will be important for the drivers to view this system as an aid, designed to make their job easier, rather than a way for management or government to check up on them.

**Cross References:**

*Presentation of Filtering Sign Information, p. 8-2*
*Trip Status Allocation Design Tool, p. 10-14*

**Notes:**

**Key References:**

1. Hulse, M. C., Dingus, T. A., Mollenhauer, M. A., Liu, Y., Jahns, S. K., Brown, T., & McKinney, B. (1997). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: Identify strengths and weaknesses of alternative information display formats.* Washington, DC: Federal Highway Administration (FHWA-RD-96-142).

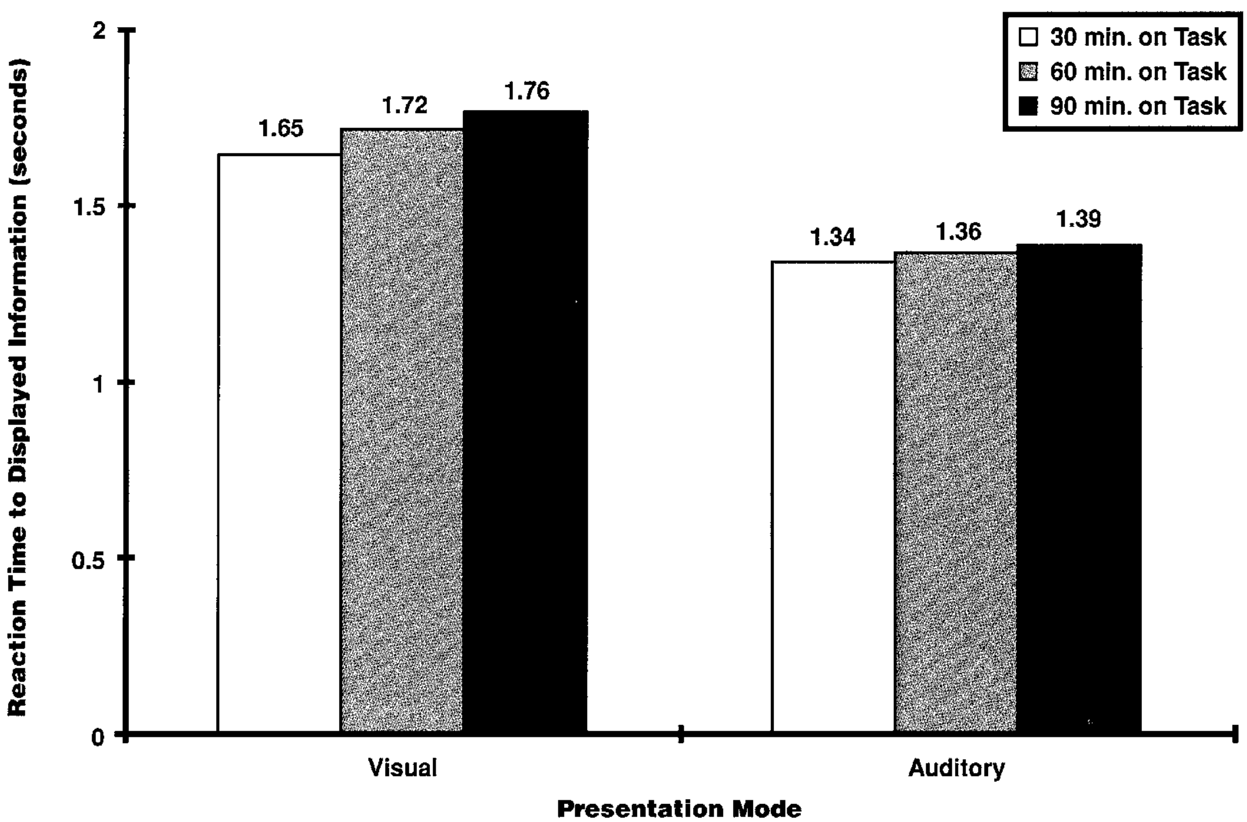
# MODALITY OF ATIS INFORMATION FOR CVO

**Introduction:** The *modality of ATIS information for CVO* refers to the use of auditory and/or visual presentation modalities.

## Design Guidelines***

Use an auditory presentation mode instead of a visual mode, particularly for simple information under conditions in which the driver must make a rapid response to the information.

### Effects of ATIS Information Modality on Driver Response Time



**Supporting Rationale:** In Reference 1, a low-fidelity, fixed-base driving simulator was used to study the effects of different approaches to ATIS design and levels of driver fatigue on driver performance. ATIS information provided in the study included on-road signage and route guidance information. Both visual and auditory modalities were used to present ATIS information and, in both modes, different levels of information complexity were assessed. Fatigue was manipulated by using both sleep-deprived and non-sleep-deprived experimental subjects. Reaction time was consistently faster to ATIS information presented via the auditory mode than via the visual mode.

**Special Design Considerations:** In Reference 1, there was a small increase in reaction time in the auditory mode when information complexity increased from medium (speed limit, current speed, engine condition, road signing, navigation map indicating distance to the next intersection) to high (medium condition + current and upcoming street names). There was no such increase in the visual mode. This suggests that the advantages associated with the auditory modality decrease as the complexity of the ATIS information increases.

**Cross References:**
*Sensory Modality for Presenting ATIS/CVO Messages, p. 3-24*

**Notes:**

**Key References:**
1. Lee, J. D., Dingus, T. A., Mollenhauer, M. A., & Brown, T. (1996). *Development of human factors guidelines for advanced traveler information systems and commercial vehicle operations: CVO driver fatigue and complex in-vehicle systems.* Washington, DC: Federal Highway Administration (FHWA-RD-96-151).

# CHAPTER 10: DESIGN TOOLS

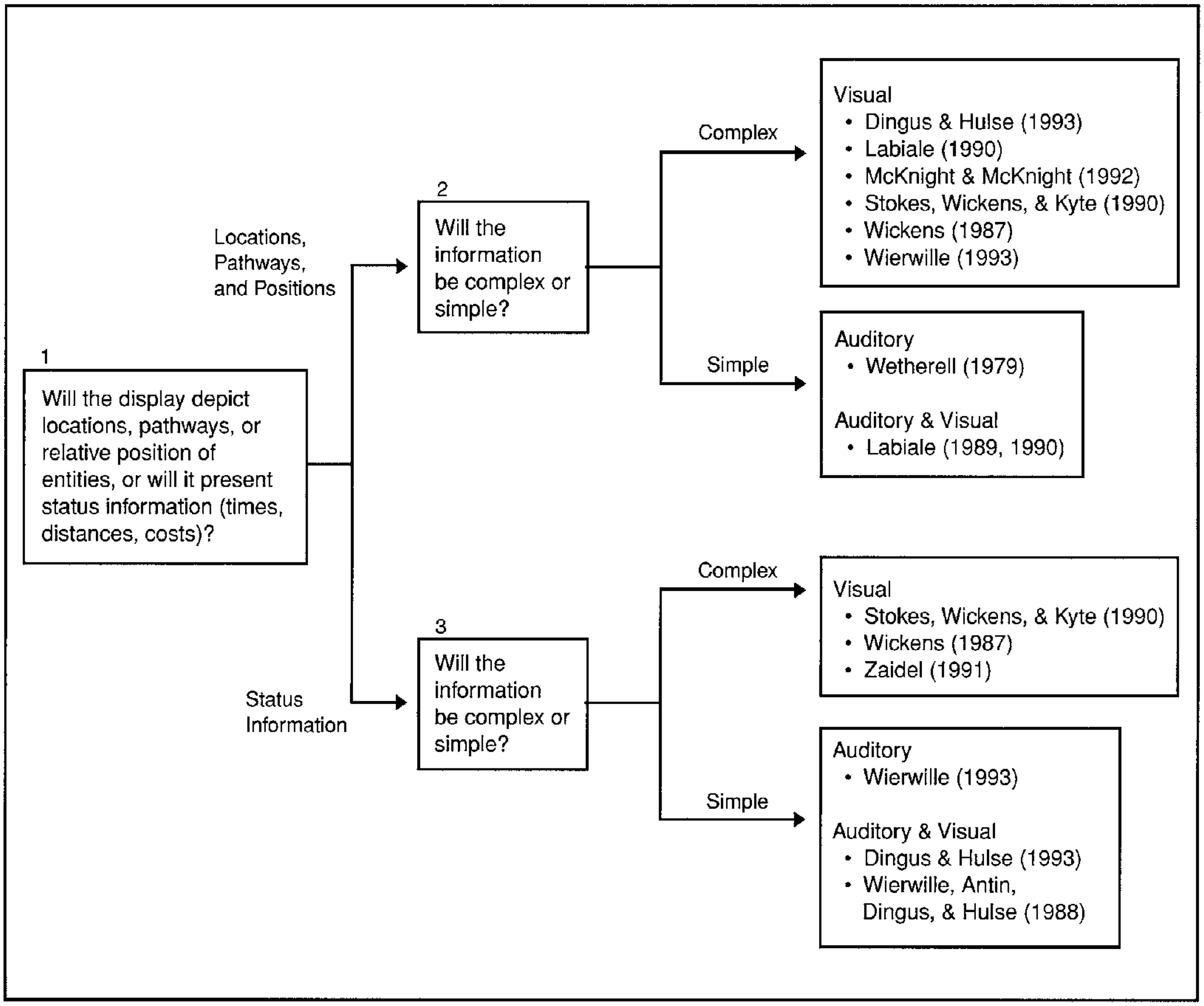
This section of the human factors design guidelines handbook provides ATIS/CVO developers with an integrated set of eight tools that can be used to address a wide range of design issues associated with the development of ATIS/CVO. These tools were originally developed as part of the analytical phase of this project and are described in more detail in Hulse et al. (1997). The tools were generated from human factors principles based on empirical research. Importantly, there is still a relatively small database of studies that are directly relevant to ATIS design. Therefore, while some of the data sources used in the development of these design tools are directly relevant to ITS and ATIS/CVO, others, such as those dealing with perception and memory, were obtained from the basic psychological research literature, while others were generated from analyses of comparable systems.

The design tools provide the ATIS/CVO developer with a series of step-by-step aids for making specific decisions for numerous ATIS/CVO design parameters that are critical to driver performance and driver acceptance. Many deal with the use of auditory vs. visual presentations of ATIS information, some guide the designer through decisions regarding *when* to allow drivers to access certain types of information during a trip, others address the need to extablish criteria for assessing the criticality of in-vehicle information. The basic format of each design tool is the same, and uses a dicision-tree structure. Within a broad category of ATIS information (e.g., route planning, warning information, signing design), users work through 2-6 simple numbered questions regarding the nature, complexity, source, or criticality of the information to be presented to the user of an ATIS/CVO device. The question number appears in the upper left-hand corner outside of the box. Each "answer" leads to a different "branch" of the dicision tree, which eventually provides design guidance, as well as a set of empirical references supporting the design principle being illustrated. Inorder to help ATIS/CVO designers use the tools and to answer the questions contained within them, examples (see right-hand pages) using relevant ATIS/CVO design issues are also provided. So that the user may better understand the relationship between the individual design tools and their corresponding examples, key questions within the design tools are numbered. The same questions within the example have been assigned the same numbers.

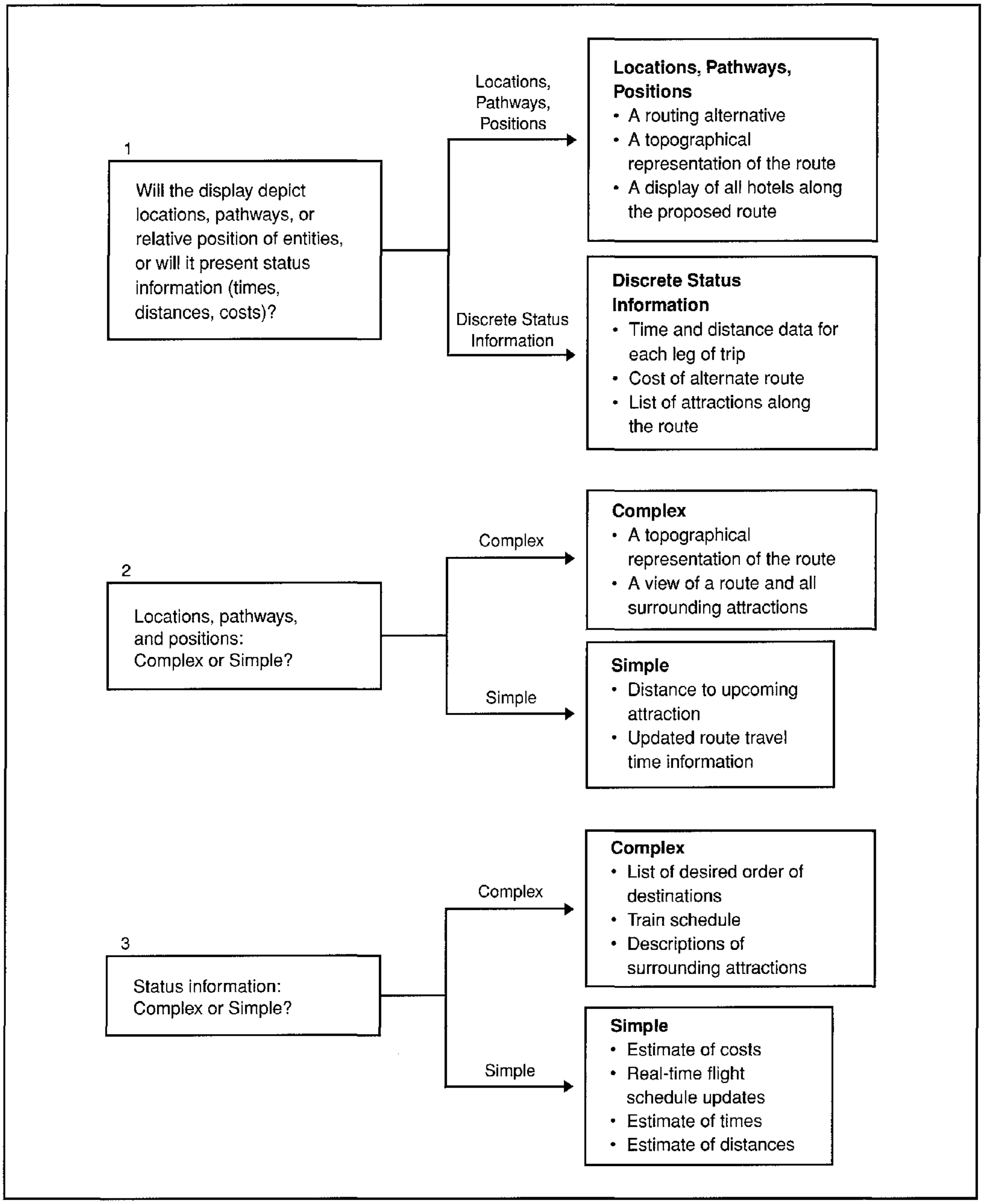
## ROUTE PLANNING AND COORDINATION SENSORY ALLOCATION DESIGN TOOL

### Discussion

A design tool for “Route planning and coordination sensory allocation” is presented below. An example is presented on the opposing page.



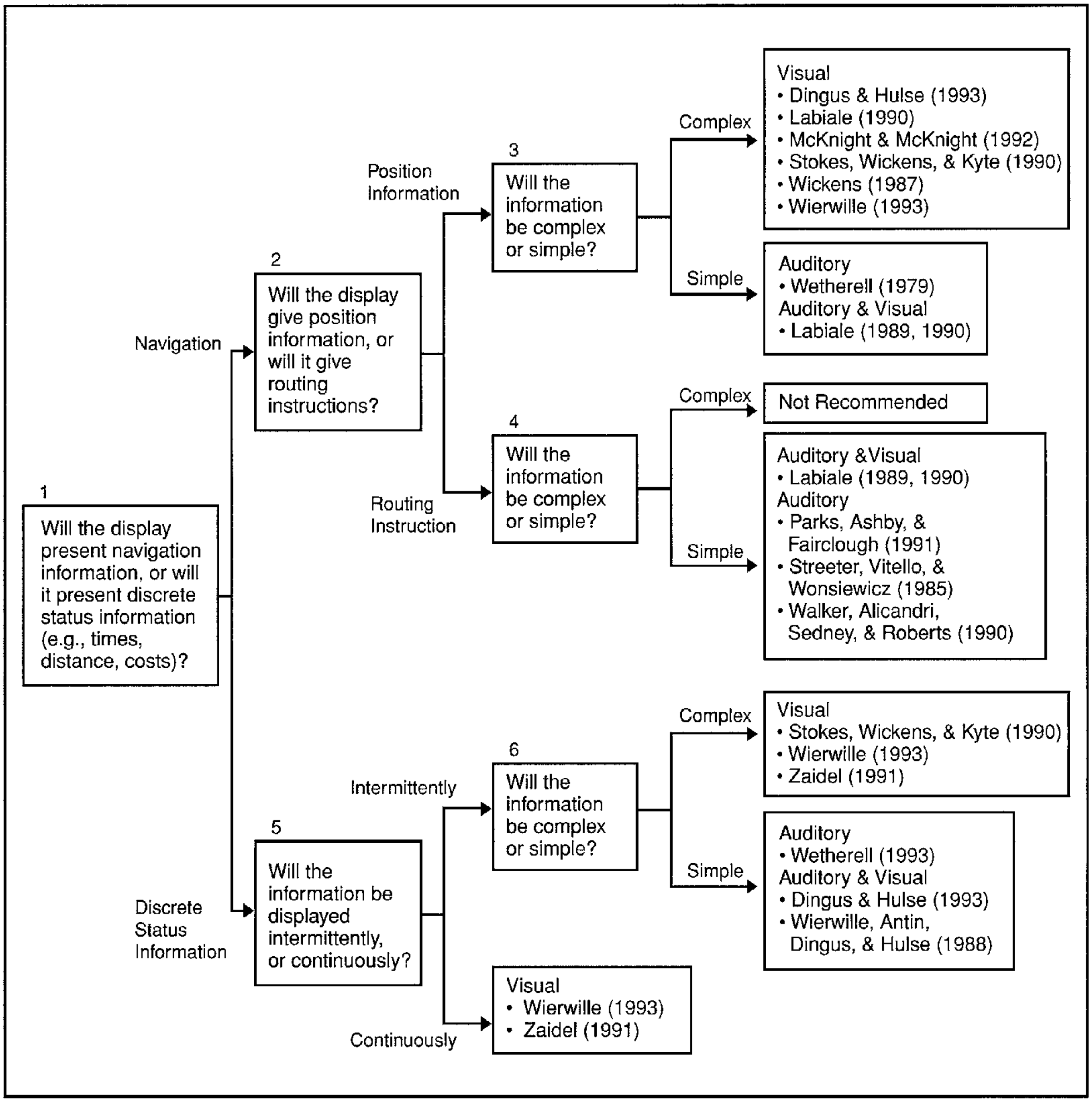
# ROUTE PLANNING AND COORDINATION SENSORY ALLOCATION DESIGN TOOL EXAMPLE



# ROUTE FOLLOWING SENSORY ALLOCATION DESIGN TOOL

## Discussion

A design tool for "Route following sensory allocation" is presented below. An example is presented on the opposing page.



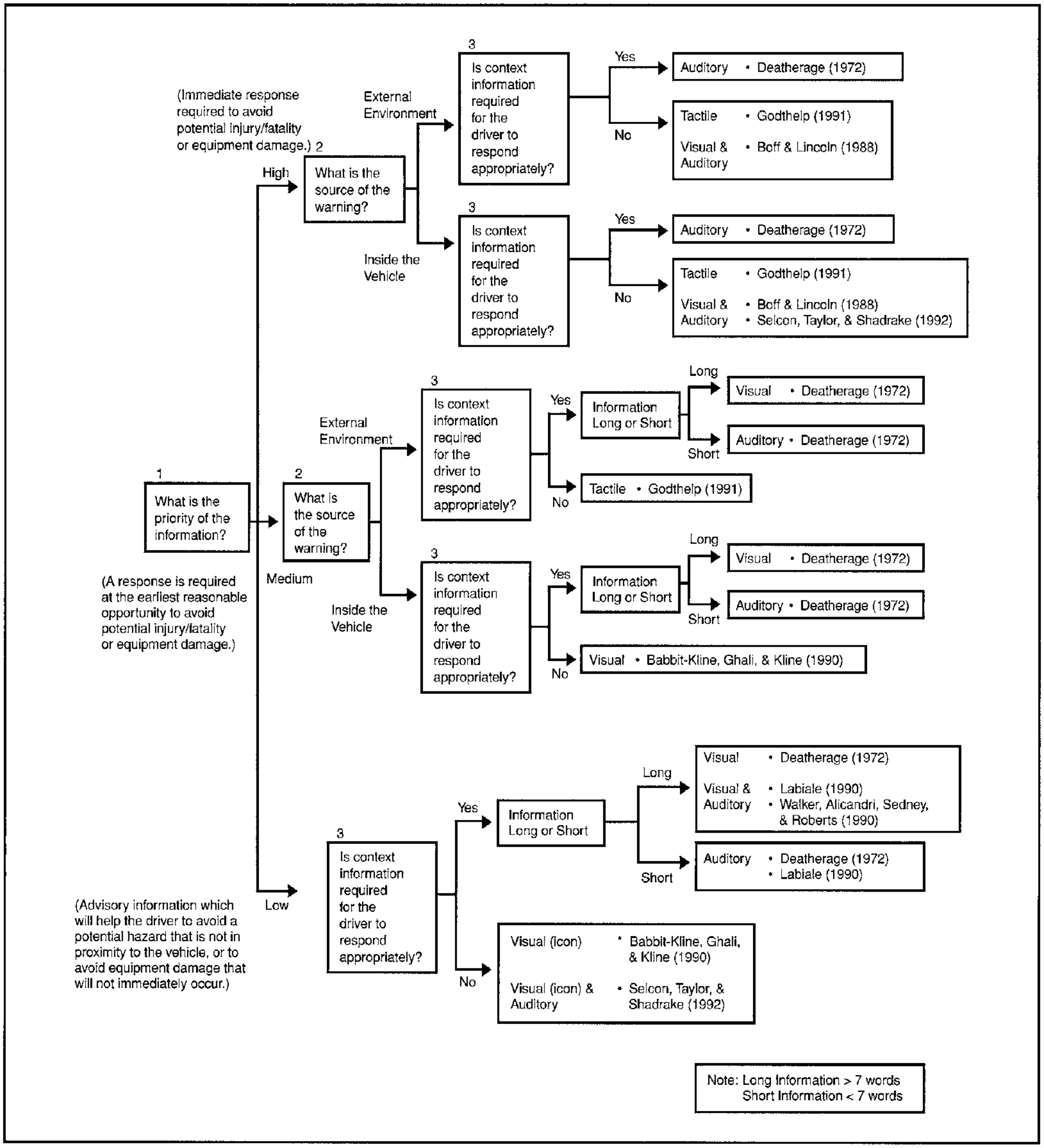
# ROUTE FOLLOWING SENSORY ALLOCATION DESIGN TOOL EXAMPLE

| | | |
|---|---|---|
| 1<br>Will the display present navigation information, or will it present discrete status information (e.g., times, distance, costs)? → | **Navigation Information**<br>• Vehicle position relative to landmarks or roadway features<br>• Direction of next turn to take | **Discrete Status Information**<br>• Time to destination<br>• Cost of current route<br>• Distance to next turn |
| 2<br>Will the display give position information, or will it give routing instructions? → | **Position Information**<br>• Location of vehicle on a full route map<br>• Distance to and direction of nearest rest area<br>• Actual location on map versus planned route | **Routing Instructions**<br>• "Turn right 500 ft"<br>• "Turn left at 2nd intersection"<br>• "Take 2nd exit on right, to I-80 north" |
| 3<br>Position information: Complex or Simple? → | **Complex**<br>• A full route map that shows current location in reference to surrounding landmarks | **Simple**<br>• "You are 25 miles south of Cedar Rapids"<br>• "Scenic overlook 15 miles ahead" |
| 4<br>Routing information: Complex or Simple? → | **Complex**<br>• A diagram of a full route map showing an upcoming intersection | **Simple**<br>• "Turn right"<br>• "Turn right at Elm Street" |
| 5<br>Will the information be displayed intermittently or continuously? → | **Intermittently**<br>• Review of alternative routing costs<br>• Distance to next turn | **Continuously**<br>• A continuously displayed distance to destination<br>• Accumulated travel time |
| 6<br>Intermittent discrete status information: Complex or Simple? → | **Complex**<br>• Multiple alternative route costs | **Simple**<br>• A simple cost or distance value |

## WARNING AND CONDITION MONITORING SENSORY ALLOCATION DESIGN TOOL

### Discussion

A design tool for "Warning and condition monitoring sensory allocation" is presented below. An example is presented on the opposing page.



# WARNING AND CONDITION MONITORING SENSORY ALLOCATION DESIGN TOOL EXAMPLE

1

What is the priority of the warning information?

| High | Medium | Low |
|---|---|---|
| *(Immediate response required to avoid potential injury/fatality or equipment damage.)* | *(A response is required at the earliest reasonable opportunity to avoid potential injury/fatality or equipment damage.)* | *(Advisory information which will help the driver to avoid a potential hazard that is not in proximity to the vehicle, or to avoid equipment damage that will not immediately occur.)* |
| "There is a serious chemical truck accident in the right lane ahead." | "There is fog ahead." | "There is traffic congestion ahead." |
| "The temperature of the vehicle's engine is critically high." | "The vehicle speed is 10 MPH too fast." | "You forgot to fasten your seat belt." |

2

What is the source of the warning?

| External Environment | Inside the Vehicle |
|---|---|
| This source deals with the environment outside the vehicle. | This source deals with the inside of the vehicle, including driver behavior. |
| "There is an emergency vehicle approaching the next intersection." | "You need to change the oil." |
| "The bridge is icy." | |

3

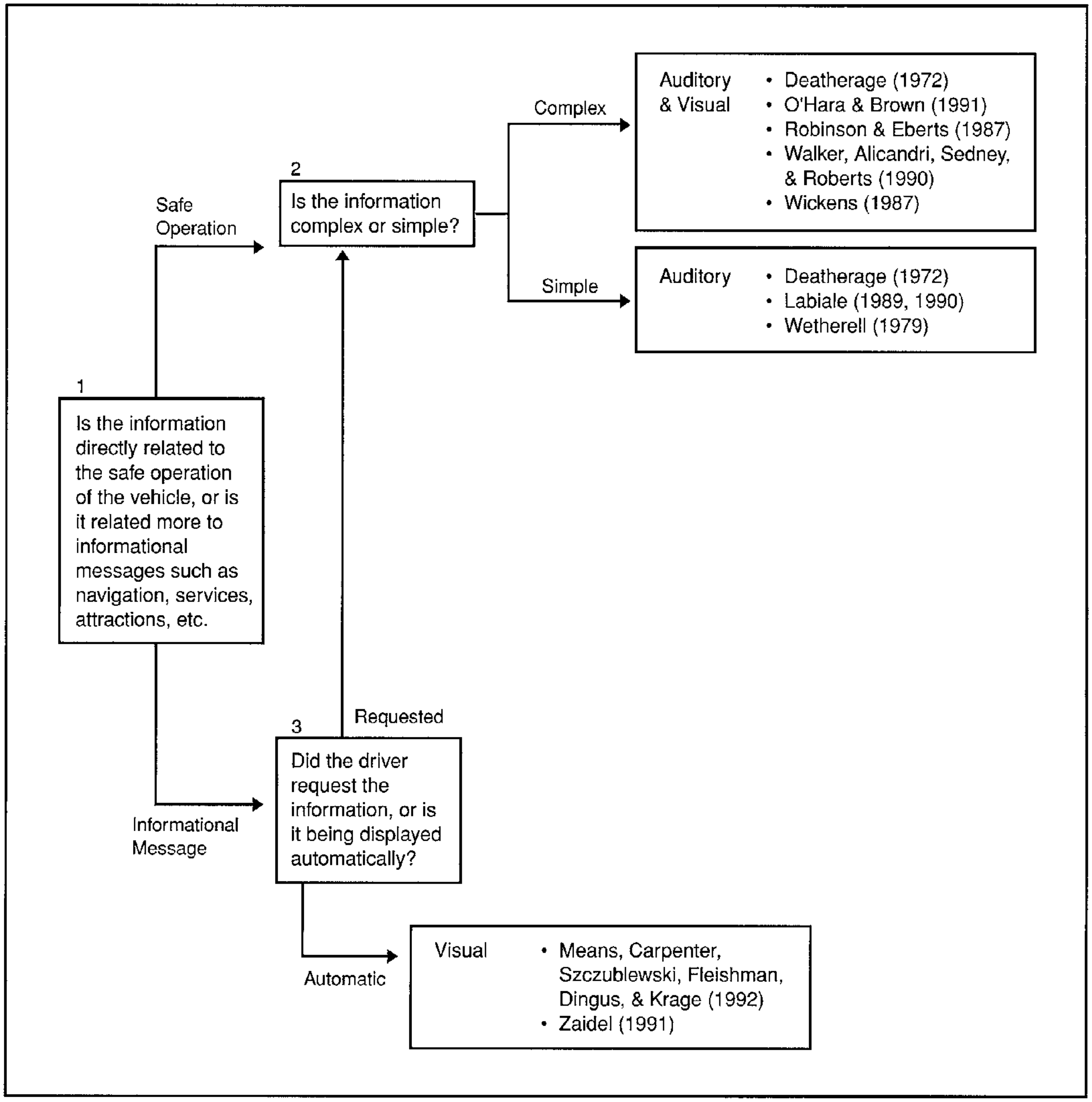
Is context information required for the driver to respond appropriately?

| Yes | No |
|---|---|
| "The speed limit is 65 MPH, please slow down." | When the vehicle engine temperature is too high, the system gives the driver a warning signal (e.g., red flashing light or high-pitched tone). When driver makes a minor lane deviation, the system gives the driver a warning signal (e.g., tactile via the wheel). |
| "Your vehicle engine temperature is too high, please stop driving the vehicle." | |

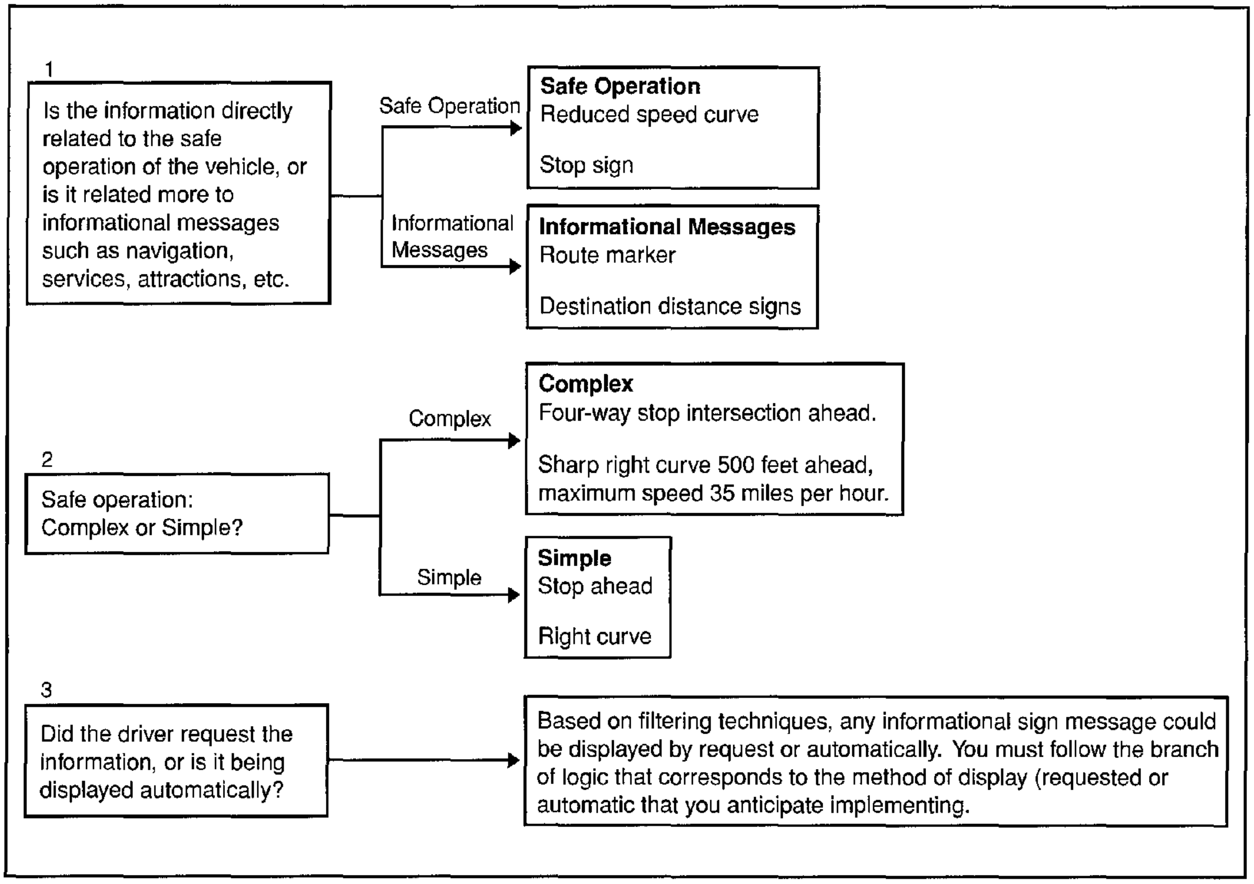
## SIGNING SENSORY ALLOCATION DESIGN TOOL

### Discussion

A design tool for "Signing sensory allocation" is presented below. An example is presented on the opposing page.



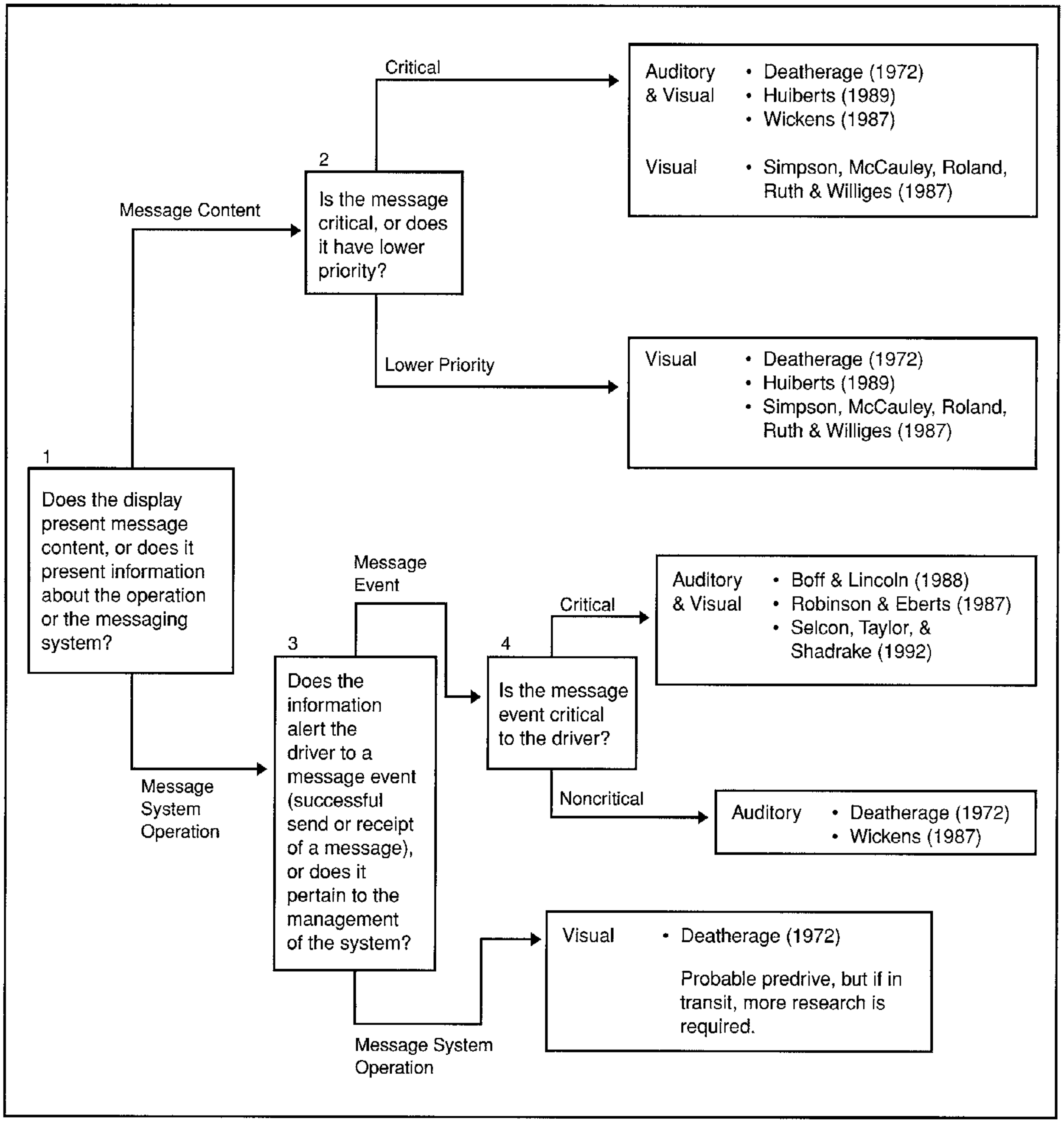
## SIGNING SENSORY ALLOCATION DESIGN TOOL EXAMPLE



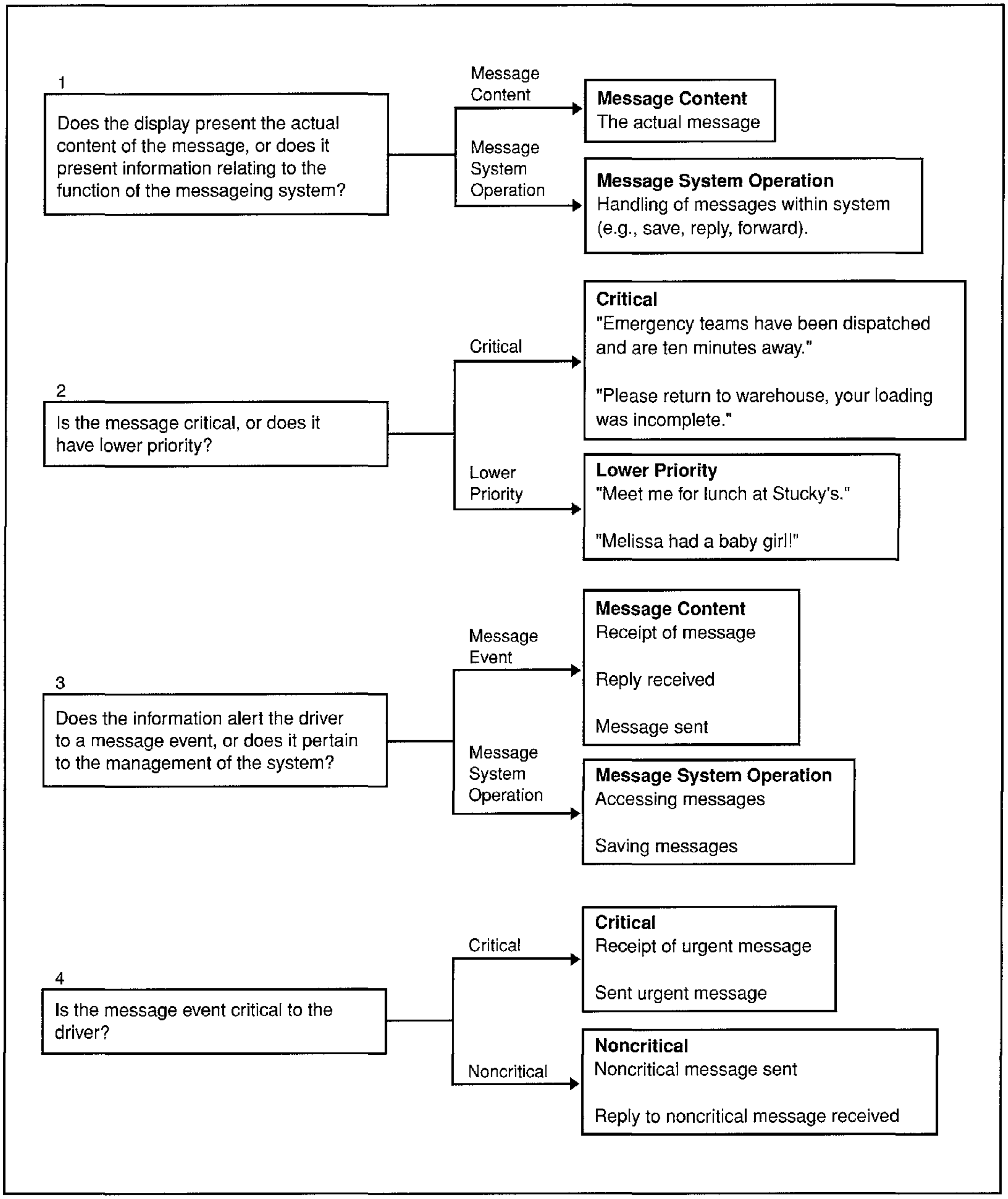
## COMMUNICATION AND AID REQUEST SENSORY ALLOCATION DESIGN TOOL

### Discussion

A design tool for "Communication and aid request sensory allocation" is presented below. An example is presented on the opposing page.



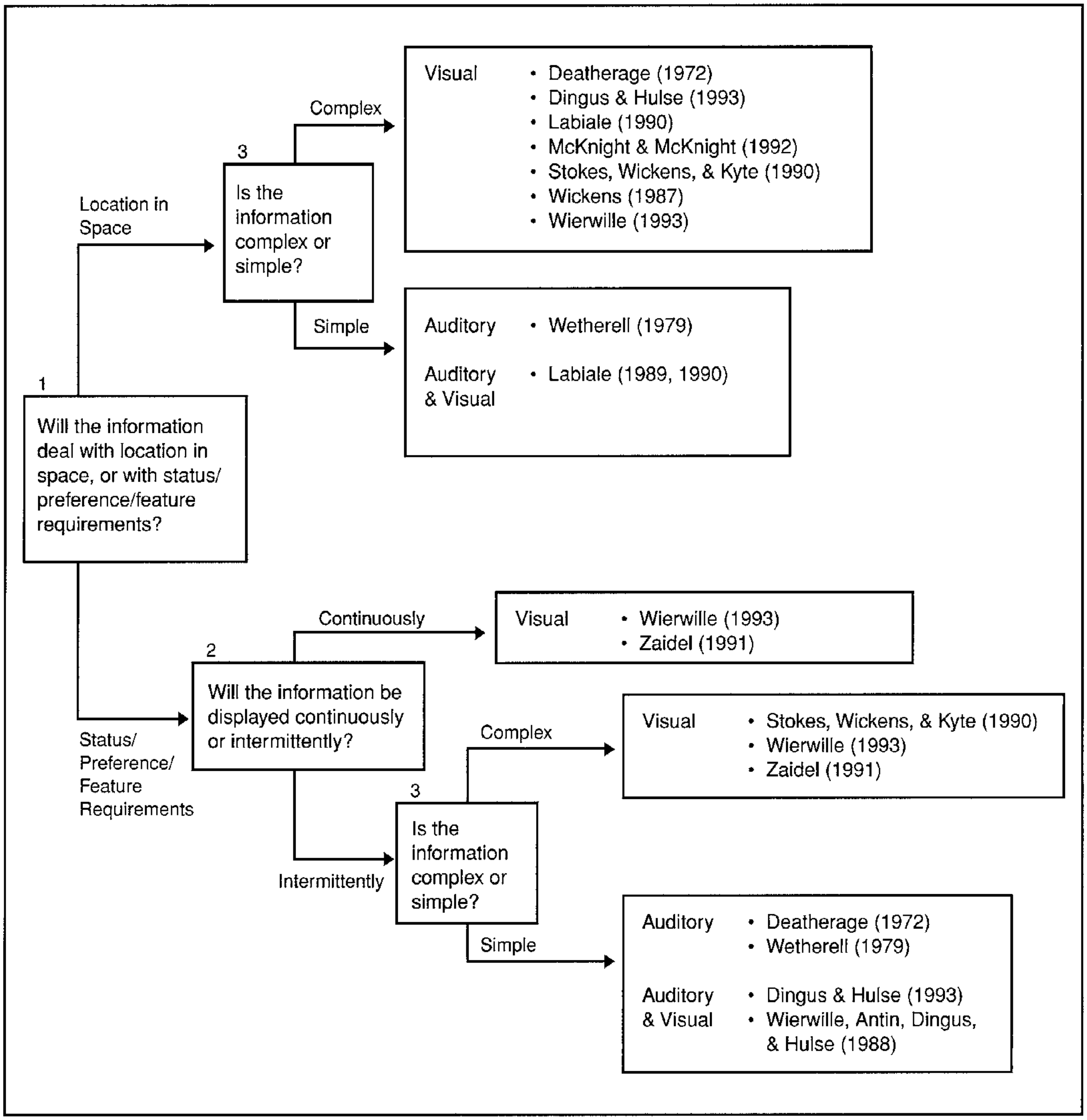
# COMMUNICATION AND AID REQUEST SENSORY ALLOCATION DESIGN TOOL EXAMPLE



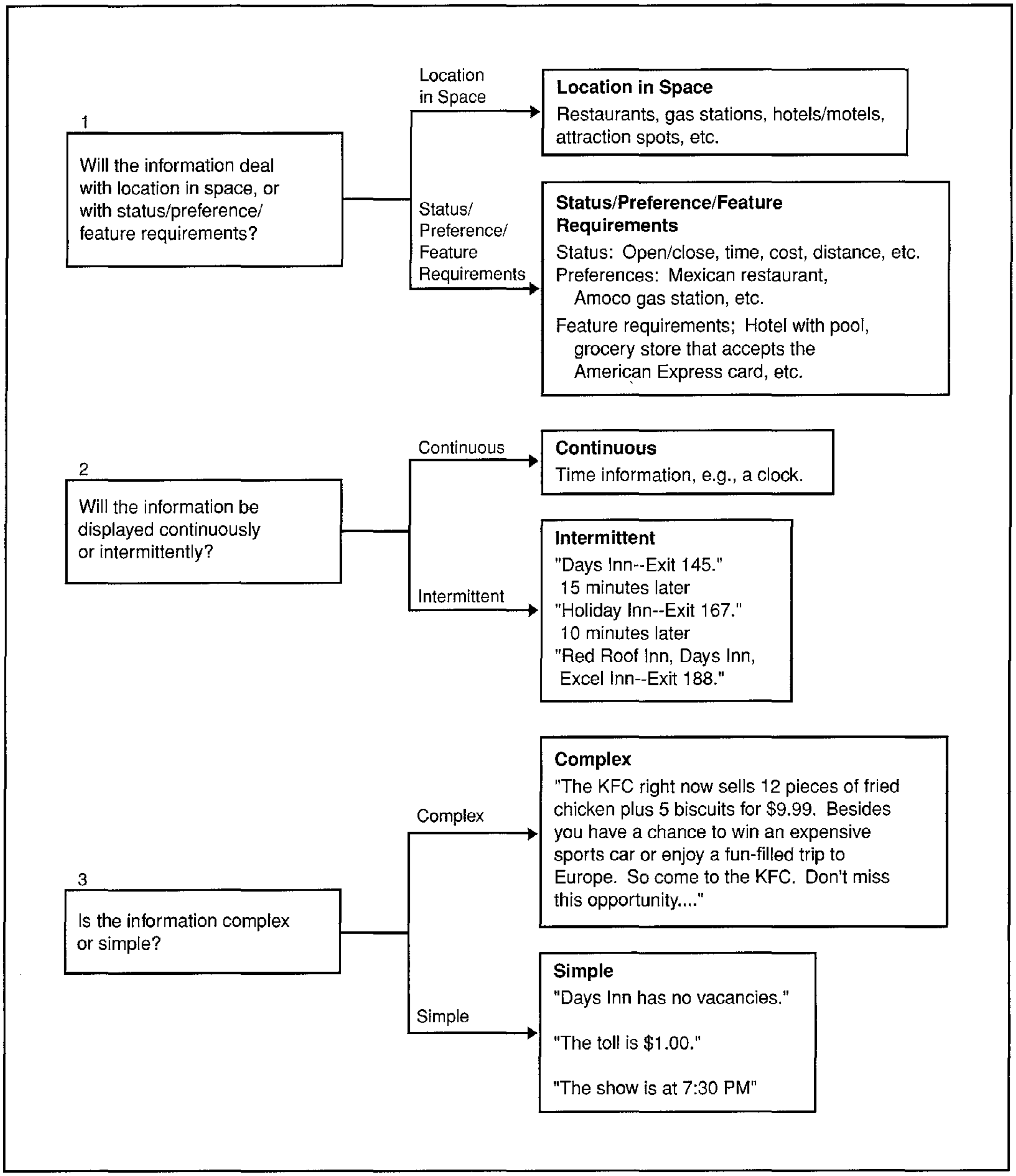
## MOTORIST SERVICES SENSORY ALLOCATION DESIGN TOOL

### Discussion

A design tool for "Motorist services sensory allocation" is presented below. An example is presented on the opposing page.



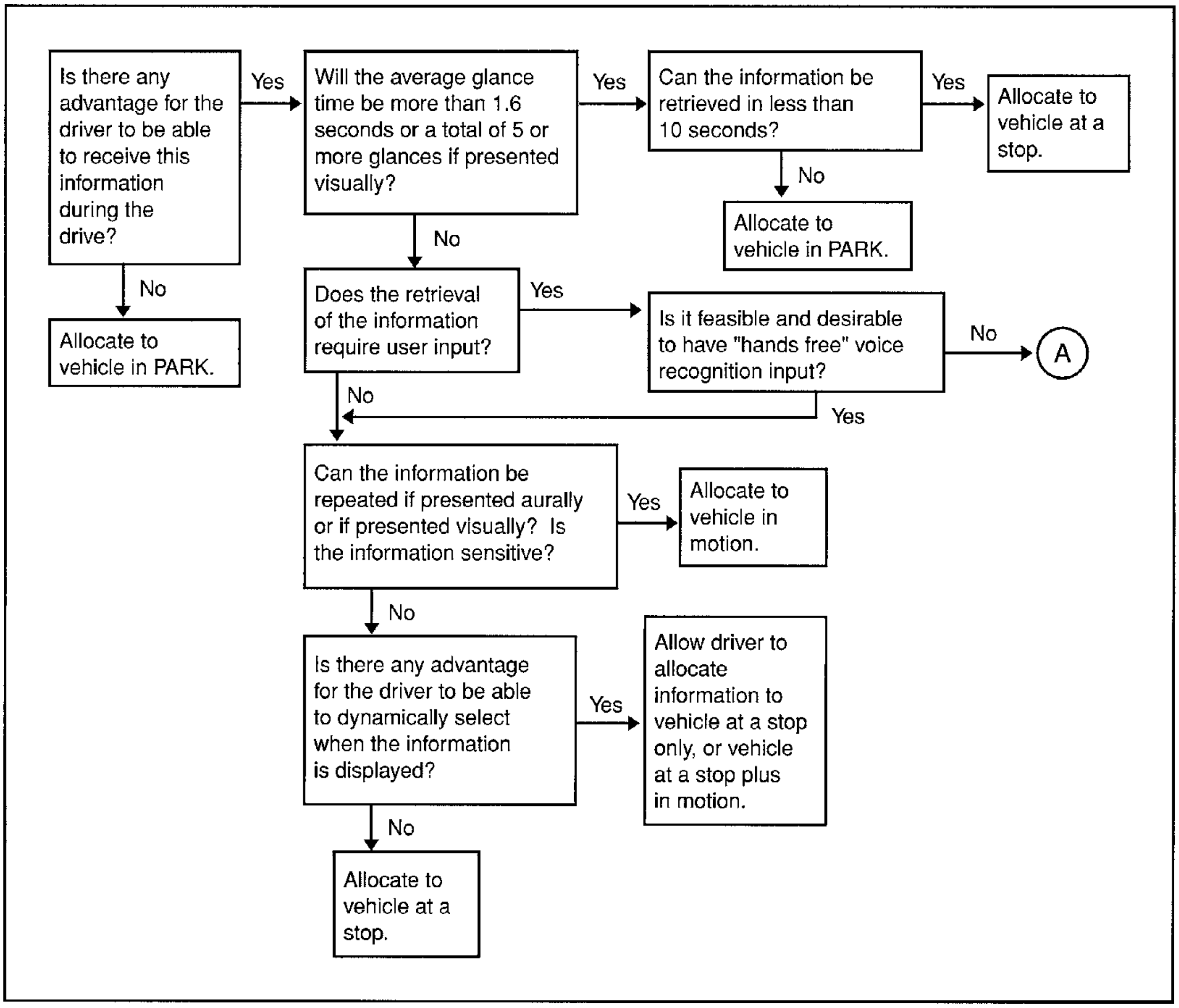
## MOTORIST SERVICES SENSORY ALLOCATION DESIGN TOOL EXAMPLE



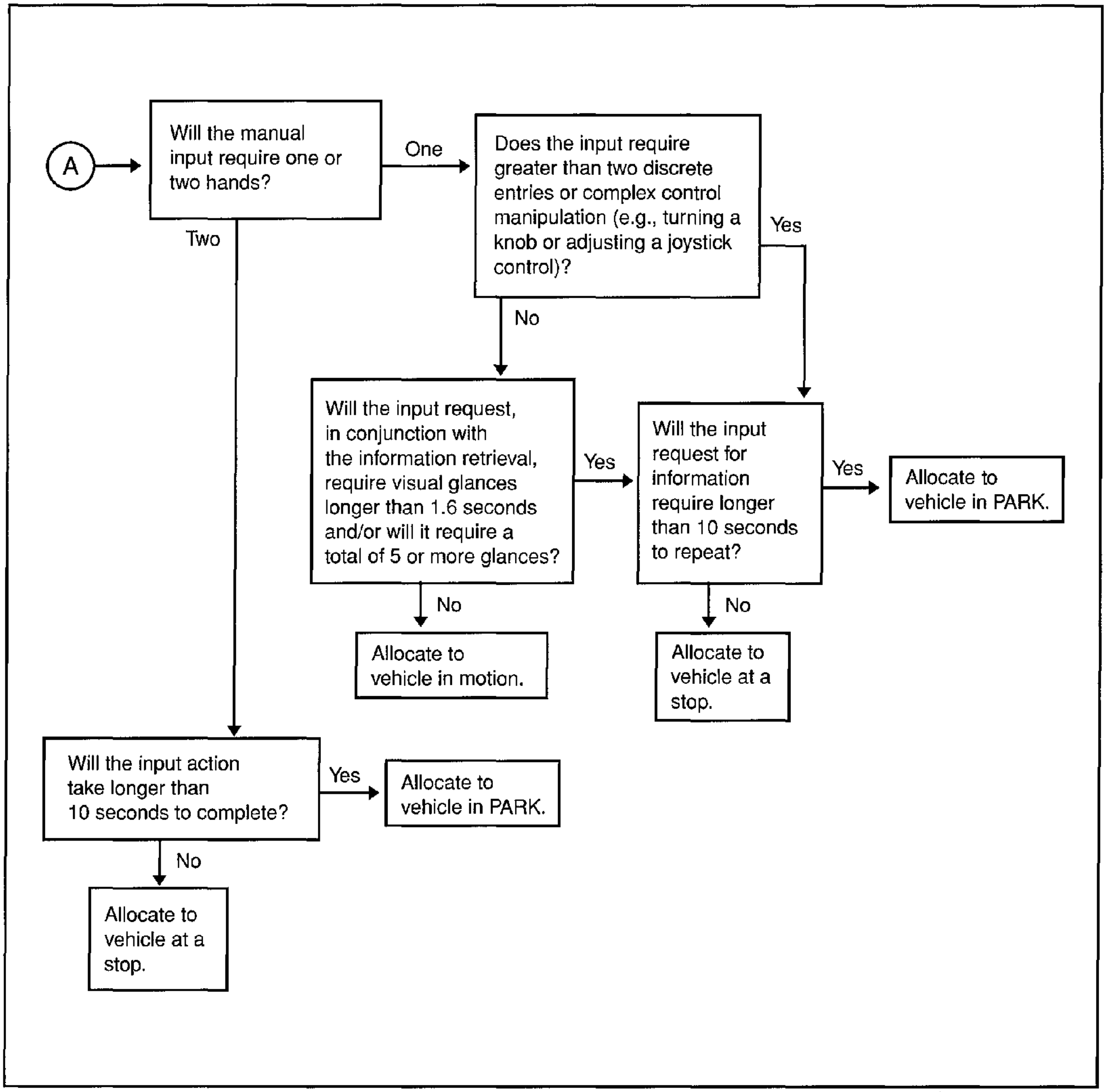
## TRIP STATUS ALLOCATION DESIGN TOOL

### Discussion

A design tool for "Trip status allocation" is presented below. An example is presented on the opposing page.



## TRIP STATUS ALLOCATION DESIGN TOOL (CONTINUED)



# CHAPTER 11: EQUATIONS

## SYMBOL CONTRAST

**Introduction:** *Symbol contrast* refers to the relationship between the luminance of a symbol and the luminance of the symbol's background. Contrast requirements have not been empirically studied under a wide range of representative driving situations and conditions, and there are few empirical data that can be directly used to specify design guidelines for the symbol contrast of automotive ATIS displays.

*(Equation 1)* p. 3-2

Here, we define contrast as a ratio between maximum and minimum luminance values or:

$$\text{Contrast ratio} = \frac{\text{Luminance}_{max}}{\text{Luminance}_{min}}$$

where:

$\text{Luminance}_{max}$ = luminance emitted by the area or element of greatest intensity
$\text{Luminance}_{min}$ = luminance emitted by the area or element of least intensity

## SYMBOL HEIGHT

**Introduction:** *Symbol height* refers to the vertical distance between the top and bottom edges of an unaccented letter or number. Since ATIS devices can be used at a broad range of display distances, symbol height is best defined and specified as the *visual angle* subtended by the symbology (at the driver's eye), in minutes of arc.

*(Equations 2, 3, and 4)* p. 3-4

| If Known | Use These Formulas for Calculating These Unknowns | | |
|---|---|---|---|
| | **Visual Angle** | **Symbol Height** | **Distance** |
| **Distance and Symbol Height** | $\text{Arc Tan}\left(\frac{\text{Symbol Height}}{\text{Distance}}\right)$ | — | — |
| **Distance and Visual Angle** | — | Distance x (Tangent (Visual Angle)) | — |
| **Visual Angle and Symbol Height** | — | — | $\frac{\text{Symbol Height}}{\text{Tangent (Visual Angle)}}$ |

where:

Symbol Height = the height of the symbology
Distance = distance from viewers eyepoint to the display
Visual Angle = angle in degrees
Height and Distance use the same unit of measure

# SYMBOL LUMINANCE UNIFORMITY

**Introduction:** *Symbol luminance uniformity* refers to the consistency of luminance values across a display.

*(Equation 5)* p. 3-6

**Measuring segment of element uniformity**

Within a segment or element of the ATIS display, measure at two locations using a photometer with a spot size small enough to fit inside the segment or element.

$$\textbf{\% Element Uniformity} = \frac{|(\text{Luminance}_{min}) - (\text{Luminance}_{max})|}{(\text{Luminance}_{max})}$$

*(Equation 6)* p. 3-6

**Measuring whole display uniformity**

Within two areas of the ATIS display, measure at two locations using a photometer.

$$\textbf{\% Display Uniformity} = \frac{|(\text{Luminance}_{min}) - (\text{Luminance}_{max})|}{(\text{Luminance}_{max})}$$

where:

$\text{Luminance}_{min}$ = the smaller luminance value
$\text{Luminance}_{max}$ = the greater luminance value

## COLOR CONTRAST

**Introduction:** *Color contrast* refers to the relationship between symbol and background associated with chromatic differences such as hue and saturation. Determining the amount of contrast provided to the driver becomes a more complex problem when the symbology and/or the background are colored.

*(Equation 7)* p. 3-22

$$\Delta E(\text{CIE Yu' v'}) = \left[\left(155\left(\frac{\Delta Y}{Ym}\right)\right)^2 + (367\ \Delta u')^2 + (167\ \Delta v')^2\right]^{0.5}$$

where

| | |
|---|---|
| ΔE (CIE Yu' v') | = the color contrast metric |
| ΔY | = difference in luminance between text (symbology) and background |
| Ym | = the maximum luminance of text (symbology) or background |
| Δu' | = difference between u' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below) |
| Δv' | = difference between v' coordinates of text (symbology) and background (per the 1976 CIE UCS; see note below) |

NOTE: The constants 155, 367, and 167 in equation 7 are empirically drived weights (Reference 1).

## MESSAGE STYLES

**Introduction:** *Message style* refers to the way in which information is given to the driver. The information can be presented in an advisory manner ("command style") or in more of a descriptive manner ("notification style"). *Command style messages* inform drivers of a situation and suggest a particular action to take in response to that situation. *Notification style messages* simply inform drivers and allow them to determine the appropriate action on their own. Message style should be selected based on an evaluation of the criticality of the situation and the need to make a control action immediately.

*(Equation 8)* p. 3-32

"Immediate" is defined as an incident or condition which occurs within "X" meters of the vehicle's current position, where:

**X = (Speed (in km/h) x 1.637) + 14.799**

## DESIGN OF HEAD-UP DISPLAYS FOR ATIS

**Introduction:** The automotive HUD is an electro-optical device that presents both static and dynamic symbology and/or graphics in the driver's forward FOV. Presenting navigation information to drivers through HUDs is possible due to recent developments in automotive design, electronic instrumentation, and optics.

*(Equation 9)* p. 3-34

**The Luminance Control Function for an automotive HUD**

$$\text{Footlambert} = [(P \times L_{max}{}^{0.33}) + ((1\text{-}P) \times (L_{min}{}^{0.33}))]^{(1 \div 0.33)}$$

where: P = the proportion of total control movement
$L_{max}$ = maximum luminance provided
$L_{min}$ = minimum luminance provided

## TIMING OF AUDITORY NAVIGATION INFORMATION

**Introduction:** The *timing of auditory navigation information* refers to the time or distance at which ATIS should present an auditory instruction to the driver before an approaching navigation maneuver (e.g., a required turn).

*(Equations 10, 11, and 12)* p. 5-4

**Equations[1]**

| | |
|---|---|
| **Preferred Minimum Distance** | **= (Speed x 1.637) + 14.799** |
| **Ideal Distance** | **= (Speed x 1.973) + 21.307** |
| **Preferred Maximum Distance** | **= (Speed x 2.222) + 37.144** |

[1]where speed is in km/h and distances are in meters

# CHAPTER 12: GLOSSARY

**Accuracy of routing information**
Refers to the correctness, usually expressed as a percentage, of traffic information presented to motorists. In this context, accuracy is considered to be a binary concept; i.e., the information is either accurate or inaccurate. Although accuracy is most often discussed with respect to congestion levels associated with various routing options, it may also refer to total travel time estimates, estimates of time delays due to congestion, and presentation of accident information.

**Advanced fleet management**
Uses advanced vehicle routing algorithms that collect real-time congestion information to balance routes and loads, and predict travel times.

**Alerts for ATIS messages**
Refers to information presented to drivers prior to, or concurrent with, the presentation of an ATIS message. Alerts are typically used to notify drivers of high-priority ATIS messages associated with safety (e.g., immediate hazard, emergency vehicle approaching), vehicle status (e.g., vehicle condition warning), or augmented signage information (e.g., guidance, notification, or regulatory signs).

**ASR**
*Automatic Speech Recognition*

**ATIS**
*Advanced Traveler Information Systems*

**ATIS design for special populations**
Refers to design criteria aimed specifically at drivers with either sensory or cognitive disabilities that might affect their ability to effectively use the system. One such population is the older driver, over the age of sixty. There is a considerable body of research showing that the older population has numerous cognitive and sensory deficits. Other special populations include handicapped or disabled drivers, as well as those people with minor cognitive impairments. In many cases, the suggestions made for improving ATIS design for these populations would increase its usability for the general population as well.

**ATMS**
*Advanced Traffic Management Systems*

**Auditory message length** Refers to the number of syllables, words, or sentences necessary for presenting auditory information to the driver. Depending on the type of information being presented, different message lengths are acceptable.

**Augmented signage functions** Refers to transportation technologies that provide the user/driver with noncommercial routing, warning, regulatory, and advisory information that is currently presented on external roadway signs.

**Automated toll collection** Refers to allowing a vehicle to travel through a toll roadway without stopping to pay tolls. Instead, tolls would be automatically deducted from the drivers accounts as they drive past toll collection areas. This would enable tolls to be adjusted to balance traffic flows (higher toll rate during peak rush hour). Also, automated toll collection would provide drivers with information regarding toll credits and the current toll costs.

**Automated vehicle location** Employs GPS, or other triangulation technologies, to provide real-time information regarding the location and status of vehicles.

**Automatic/manual aid request information** Refers to a function that allows the driver to request emergency services without leaving the vehicle. This function would provide drivers with immediate access to a wide variety of roadside assistance (e.g., police, ambulance, towing, and fire department) without the need to locate a phone, know the appropriate phone number, or even know their current location. In circumstances where a manual aid request is not feasible and where immediate response is essential, this function would activate automatically.

**Automatic vehicle classification (AVC)** EC technology to provide a readable, electronic record of vehicle type and contents.

**Automatic vehicle classification/automatic vehicle identification (AVC/AVI)** Would allow uninterrupted movement of the vehicle through inspection or weighing stations.

**AVL** *Automated Vehicle Location*

**CAS** — *Collision Avoidance System*

**CIE** — *Commission Internationale de l'Eclairage*

**CB Radio** — *Citizen's Band Radio*

**Clear depiction of route on electronic maps** — Route information displayed on an electronic map must be clearly distinguishable from normal map features, in both route planning and guidance modes. In paper maps, a planned route can be clearly indicated by highlighting it with a colored marker. Similarly, on electronic maps, the user must be able to immediately discriminate the route from the variety of line shapes, sizes, and colors that may be used on the electronic map to depict local streets, arterials, highways, interstates, rivers and other features.

**Color coding** — Refers to the use of chromaticity to differentially identify items in a display systematically. The categories used to color code objects on a display depend upon the tasks required of the operators.

**Color coding of traffic flow information** — Refers to the use of colors to represent the mean speed of traffic flows on different road segments along a particular route. This type of information might help drivers make more informed decisions regarding alternate routes, departure times, or modes of transportation, if necessary.

**Color contrast** — Refers to the relationship between symbol and background associated with chromatic differences such as hue and saturation. Determining the amount of contrast provided to the driver becomes a more complex problem when the symbology and/or background are colored.

**Command style messages** — Refers to a message style that informs the driver of a situation and suggests a particular action to take in response to that situation.

**Communication acknowledgment** — Refers to the capability of a CVO in-vehicle communication or messaging system to provide the sender of a message (i.e., a driver or a dispatcher) confirmation that a message was transmitted and received by the system hardware, and to provide information as to whether or not a message has been accessed or "opened" by the recipient.

**Complexity of ATIS information** — Refers to the number of information units being presented during written or textual in-vehicle road messages. In this context, an information unit can describe geography (e.g., city), type of roadway (e.g., highway), event causes (e.g., stalled vehicle), event consequences (e.g., traffic jam), time and distances, and proposed actions. Therefore, information units can be described as the relevant words in a message.

**Control coding** — Refers to the design characteristics of controls that serve to identify the control or to identify the relationship between the control and the function to be controlled. Proper coding of controls will increase the probability that the controls will be quickly and accurately located by drivers, thus reducing the eyes-off-road time.

**Control movement compatibility** — Refers to the expected relationships between control actuation movements, and the corresponding movements or change in the system being controlled. Making control movements consistent with the driver's expectations can decrease reaction and learning times, control errors, and can increase driver satisfaction with the vehicle's controls.

**CRT** — *Cathode Ray Tube*

**CSRDF** — *Crew Station Research and Development Facility*

**CVO** — *Commercial Vehicle Operations*

**CVO-specific aid request information** — Refers to the ability to notify emergency personnel (e.g., police, ambulance, towing, fire) of the need for aid. It may also include the ability to provide the driver with feedback regarding the status of emergency services. In the case of commercial vehicles, it may be especially important for emergency personnel to know specific information regarding the type of truck and the cargo it is carrying.

**CVO-specific cargo and vehicle monitoring information** — Refers to more detailed and diverse information than that presented to private drivers. It may include a more precise indication of engine performance. In addition, many commercial vehicles carry sensitive cargo, which require careful monitoring of things like temperature, humidity, and vibration.

**CVO-specific guidance sign information**

Refers to sign information which might be helpful for guiding commercial vehicle operators to a particular destination. Such information is currently found on out-of-the-vehicle signage (e.g., truck route signs); however, this subfunction would allow this information to be presented to the commercial driver aurally, in the vehicle.

**CVO-specific notification sign information**

Refers to information regarding potential hazards and road changes. Particularly in the case of large trucks, additional time to plan or prepare for long/steep grades, sharp curves, exits, and lane changes may be valuable. Also, presenting this information in-vehicle may allow for it to be more detailed and timely.

**CVO-specific regulatory administrative information**

Refers to various regulatory administrative requirements, including taxes, licensing, permits, and coordination of the transport of hazardous materials. This function may also be involved with checking the required training programs and other administrative functions required of a CVO company by law.

**CVO-specific regulatory sign information**

Refers to information regarding size and weight limits, truck speed limits, and any road restrictions.

**Design of ATIS subsystem interfaces**

Refers to the consistency of the "look and feel" associated with ATIS driver-vehicle interface (DVI), across various functions within the ATIS. For example, a single ATIS device could include trip planning, route guidance, travel coordination, and message transfer functions, much as modern computer systems include word processing, graphics, and e-mail applications. The degree of integration or consistency refers to the color schemes, fonts, layouts, and control operations associated with these different functions. A fully integrated system would have a common user interface, with the same colors, formats, and control operations; in a nonintegrated system, these features could vary from function to function.

**Design of head-up displays for ATIS**

Refers to an electro-optical device that presents both static and dynamic symbology and/or graphics in the driver's forward FOV. Presenting navigation information to drivers through HUDs is possible due to recent developments in automotive design, electronic instrumentation, and optics.

**Design of speech-based controls**

Refers to systems that recognize human speech and treat speech commands as inputs to the ATIS system. Automatic speech recognition (ASR) systems may be characterized with respect to three sets of design characteristics. First, speaker-dependent systems recognize speech from only one speaker that has been calibrated to the system; speaker- independent systems can recognize speech from many speakers. Second, isolated word recognition systems require that speakers provide a pause or gap between words in a message; continuous speech recognition systems do not require any pause between words. Third, ASR systems vary with respect to the size of the vocabulary that they recognize.

**Destination coordination information [CVO]**

Refers to coordinating shipments with customers. This might involve making arrangements for loading and unloading shipments and catering to changes in scheduled pick-up and delivery times.

**Destination coordination information**

Refers to information which enables the driver to communicate make arrangements with the final destination. This function may include making restaurant and hotel reservations. In addition, it may include ascertaining information about parking availability and location.

**Destination preview**

Refers to providing the user with the capability to recenter (slew) the map and to change the range scale (magnification) to enable full preview of route details. The user of an electronic map displaying route information may desire to preview the origin, destination, or any segment of the route. The system design should, however, distinguish clearly between a recentered map mode and the normal display mode showing current position of the user/vehicle. Failure to clearly distinguish between these two modes can result in confusion about current location.

**DOT**

*Department of Transportation*

**Driver/vehicle real-time safety monitoring**

Could include records of duty logs, medical qualifications data, and commercial driver's license information. Vehicle-related elements could include operational data and conditional information (such as status of brakes, lights, tires, and steering).

**Dynamic route selection information**

Refers to any route selection function which is performed during the drive. The purpose of this ATIS function is to provide the driver with a mechanism for recovering once they have left or wandered from the intended route. When a driver makes a wrong turn and leaves the intended route, the dynamic route selection function can generate a new route which will accommodate the driver's current position.

**DVI**

*Driver-Vehicle Interface*

**EC**

*Electronic Credentials*

**Electronic credentials**

Would enable a motor carrier to electronically file for, obtain, and pay for all required licenses, registrations, and permits. An electronic record of the credential could be sent to the motor carrier's headquarters or other desired location.

**Electronic log book**

Could replace the manual trip log typically prepared by the motor carrier. The fuel tax rates for each state and the number of vehicle miles traveled within each state could be recorded electronically if electronic beacons were provided at all site boundaries.

**Emergency vehicle information**

Refers to warning drivers of approaching emergency vehicles (i.e., police cars, fire trucks, ambulances). If the ATIS possesses reliable data on surrounding traffic and conditions, this function may also include telling the driver the appropriate action necessary to move out of the way.

**Estimated time of arrival**

Refers to the ability of a system to estimate the time remaining until a vehicle reaches the destination. In this context, ETA is simply the length of the route remaining to be negotiated divided by the average speed expected over the remaining route (e.g., ETA is 3 minutes, 15 seconds). It is common in some domains to add ETA to the current time to express estimated arrival time in clock time (e.g., a commercial aircraft might express their ETA as 7:30 p.m.). Accurate ETA information is critical to the effective deployment of emergency response vehicle fleets.

**ETA**

*Estimated Time of Arrival*

**FHWA**

*Federal Highway Administration*

**Filtering sign information** — Refers to allowing the driver to select the on-road signage they would like to receive in-vehicle. The driver will be able to filter both notification and guidance sign information. However, due to the importance of regulatory sign information, it will be presented to the driver regardless of preference.

**Font segments** — Refers to electronic displays in which characters are formed by illuminating discrete segments within a basic symbol pattern. The majority of electronic displays using this technique employ 7-segment patterns to generate numerals (e.g., digital speedometers and clocks); however, 14-segment and 16-segment patterns are also available for the generation of complete alphanumeric sets.

**FMVSS** — *Federal Motor Vehicle Safety Standards*

**FOV** — *Field-of-View*

**Ganged controls** — Refers to two or more knobs mounted on concentric shafts.

**General trip planning information** — Refers to information which assists drivers in the coordination of long and/or multiple-destination journeys. Coordination of these journeys may involve identifying scenic routes and historical sites. However, the general purpose of this information is to provide the driver with an estimate of journey time, mileage, and costs.

**GPS** — *Global Positioning System*

**Guidance sign information** — Refers to information which helps to guide a driver to a particular destination. This information is normally found in the out-of-vehicle environment (e.g., street signs, interchange graphics, route markers, and mile posts). However, with augmented signage messages, this information will be brought into the vehicle and displayed to the driver.

**Hazardous material information systems** — Could provide enforcement and incident management response teams with timely, accurate information on cargo contents, enabling them to react properly in emergency situations.

**HCI** — *Human-Computer Interaction*

**HDD** — *Head-Down Display*

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| **HOV** | *High Occupancy Vehicles* |
| **HUD** | *Head-Up Display* |
| **Immediate hazard warning information** | Refers to information regarding the relative location of a hazard and the type of hazard. This information may include warning the driver of an accident immediately ahead or a stopped school bus. Thus, this information focuses on the location of specific localized incidents. |
| **IMSIS** | *In-Vehicle Motorist Services Information Systems* |
| **Information units** | This phrase is used to describe the amount of information presented in terms of key nouns and adjectives contained within a message. |
| **IRANS** | *In-Vehicle Routing and Navigation Systems* |
| **ISIS** | *In-Vehicle Signing and Information Systems* |
| **ISO** | *International Standards Organization* |
| **ITS** | *Intelligent Transportation Systems* |
| **IVIS** | *In-Vehicle Information System* |
| **IVSAWS** | *In-Vehicle Safety and Warning Systems* |
| **Lane position information** | Refers to information presented for the purpose of helping drivers avoid last minute lane changes. Providing the driver with a little extra lead time to make a lane change might be beneficial when driving an unfamiliar route or in circumstances where traffic is heavy and lane maneuvers may be difficult. |
| **Level-of-service** | A qualitative measure describing operational conditions within a traffic stream; generally described in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety. |
| **LOS** | *Line-of-Sight* |

**Message transfer function**

Refers to the capability for drivers to communicate with others. Currently this function is accommodated with cellular phones and Citizen's Band (CB) radios; however, future ATIS systems may improve upon this technology. This function might include text and voice messages, however, it does not include the transmission of mayday calls. Likewise, this function is separate from the computer-aided dispatch function, but may be used with it.

**Modality of ATIS information for CVO**

Refers to the use of auditory and/or visual presentation modalities.

**Motorist services functions**

Refers to transportation technologies that provide the user/driver with commercial logos and signing for motels, eating facilities, service stations, and other signing displayed inside the vehicle to direct motorists to recreational areas, historical sites, etc. Can also provide routing information for local destinations.

**Notification sign information**

Refers to information which notifies drivers of potential hazards or changes in the roadway. This information will be presented to the driver in-vehicle. Examples of this information will include: merge signs, advisory speed limits, chevrons, and curve arrows. In addition, notification information may include temporary or dynamic information such as road closures, road maintenance, or road construction. Other supplementary information, such as the distance to a notification point, may also be provided.

**Notification style messages**

Refers to a message style that simply informs drivers and allows them to determine the appropriate action on their own.

**Number of control actions for commercial driver ATIS tasks**

Refers to the number of control actions, such as button presses, required to complete a specific information retrieval task during ATIS operations while the vehicle is in motion.

**Orientation of moving map displays**

Refers to the angle that the map is rotated relative to the electronic display surface. Moving map displays may be oriented in a number of ways. The most common orientations are north-up and heading-up (sometimes referred to as track-up). Paper maps used by motorists are typically drawn north-up following traditional cartographic convention; that is, with true north being towards the top of the page. With a north-up moving map, the orientation of the symbol of the vehicle on the screen changes as the vehicle turns left and right; the symbol points toward the top of the map display only when the vehicle is pointing north. In contrast, with a heading-up map the vehicle symbol remains pointed towards the top of the screen regardless of the vehicle's heading. As the vehicle turns left and right, the map display rotates clockwise and counterclockwise, respectively, so that the symbol remains pointed towards the top of the screen. Variations of these two orientations are possible.

**Pathway information**

Refers to full or partial route information given to a driver.

**Point of interest information**

Refers to information presented to the driver that identifies scenic routes, historical sites, national parks, and recreational areas within a predetermined radius surrounding the route. Having this information will allow drivers to choose whether or not they wish to adjust their route and travel plans to include a specific point of interest. Other information that might be presented includes: states, regions, communities, and districts along the route.

**Preference and directory information**

Refers to information similar to that found in the yellow pages. However, unlike a yellow pages directory, the services/attractions directory has the flexibility of a computer database and would facilitate a wide variety of search methods. For instance, in searching for a shopping center, one parameter might be its physical location, which might be specified using an electronic map and touch screen. Providing the system with preference information allows it to assess information concerning businesses or attractions that satisfy the driver's current need.

**Regulatory sign information**

Refers to information found on out-of-vehicle signage which helps to regulate traffic and displays the rules of the road. This information will be presented to the driver in-vehicle. Examples of this information include: speed limit signs, stop signs, yield signs, turn prohibitions, and lane use control (e.g., left turn only).

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| **Relationship between ATIS information and roadway signs** | Refers to the correspondence or consistency between these two forms of presenting safety/warning information. Safety/warning information might be presented on roadway signs alone, on the ATIS alone, or on both display mediums. |
| **R&D** | *Research & Development* |
| **Restriction information** | Refers to weight, size, and cargo constraints, which might not concern private drivers, but could impact the travel plans of a commercial driver, perhaps even forcing them to choose an alternate route. |
| **RGS** | *Route Guidance Simulator* |
| **RMS** | *Root Mean Square* |
| **Road condition information** | Refers to information relevant within some predefined proximity to the vehicle or its route. This information may include traction, visibility, congestion, construction activity, or weather conditions. Compared to the information conveyed by the immediate hazard information system, this function provides general information that could cover a wider geographic area and a longer time span. |
| **Roadway information** | Refers to information presented to a driver during trip planning. It may include the street or roadway names, the types of roads used, and the number of turns or roadway changes required along the route. This information will give drivers a general overview of the trip they are about to take, as well as familiarize them with the overall route. |
| **Route and destination selection information** | Refers to destination and route selection choices that the driver engages in when the vehicle is in park and when driving to one destination. The information provided by the system might include real-time or historical congestion information, estimated travel time, and routes that optimize travel on a variety of parameters. |
| **Route guidance information** | Refers to navigation directions in a turn-by-turn format. Route guidance provides information such as: distance to the next turn, the name of the street to turn onto, what lane to be in to make the turn, and the direction of the upcoming turn. |

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| **Route incident information** | Refers to the data necessary for helping a driver travel to a selected destination when incidents are detected along the route. |
| **Route scheduling information** | Concerns the coordination of short, multiple-destination routes to minimize travel time or to minimize lateness on deliveries. Therefore, this function would take the driver's destination as input and provide an optimal order for traveling between destinations. |
| **Routing and navigation functions** | Refers to transportation technologies that provide the user/driver with information about how to get from one place to another. When integrated with an Advanced Traffic Management System (ATMS), Routing and Navigation provides information on recurrent and non-recurrent traffic congestion and is capable of calculating, selecting, and displaying optimum routes based on real-time traffic conditions. |
| **SAE** | *Society of Automotive Engineers* |
| **Safety/warning functions** | Refers to transportation technologies that provide the user/driver with warnings of unsafe conditions and situations affecting the driver on the roadway ahead. Can also provide sufficient advanced warning to permit the driver to take remedial action, and provide messages related to relatively transient conditions, requiring modifications to the messages at irregular intervals. |
| **Selection of colors for coding visual displays** | Refers to the use of different colors either to bring information to the attention of a driver, or to aid the driver in distinguishing between items on a display. Color coding may be used to make absolute or relative discriminations, and should be used in a way that is redundant with other coding dimensions (e.g., shape, size, brightness). |
| **Selection of control type** | Refers to the apparatus by which the driver makes control inputs [i.e., push-buttons, push-pull knobs, rotary knobs (discrete and continuous), levers, slides, thumbwheels, toggle switches, or rocker switches]. Selection of appropriate control types is important to decisions regarding control location, because some control types are more suited to particular locations, and, conversely, particular locations are ideal for certain types of controls. |

**Selection of keyboards for ATIS devices**

Refers to trade-offs and heuristics associated with fixed-function vs. variable-function keyboards. Examples of a fixed-function keyboard include cash register terminals and hand-held calculators; examples of a variable-function keyboard include keyboards for video games with different controls for different games, shifted keys of computer keyboards, and, in general, "soft" keys that can be changed via software control.

**Sensory modality for presenting ATIS/CVO messages**

Refers to the display modality most appropriate for presenting in-vehicle information to the driver. Almost all the literature on this topic suggests that operator performance can be improved by combining auditory and visual messages. These channels should be used together to provide either redundant or complimentary cues to the driver whenever possible. However, it is also important to know the advantages and disadvantages of using each of these modalities independent of one another so that when designers are faced with a choice, they can choose the modality that facilitates driver decision making and performance.

**Services/attraction information**

Refers to information provided to travelers which is normally found on commercial road signs or yellow pages. This information should not be provided unless specifically requested from the driver. However, the information presented can be filtered to present only those services/attractions which meet a certain profile of the driver's interests.

**Service directory information**

Refers to information similar to that found in the yellow pages or a Trucker's Atlas. However, the attraction/services directory has the flexibility of a computer database and would facilitate a wide variety of search methods, allowing CVO drivers to satisfy their current needs in the fewest number of stops.

**Stacking messages**

Refers to a practice in which, if two maneuvers are less than 10 seconds apart, the two instructions should be given together, prior to the first maneuver.

**Symbol color**

Color perception is derived from variations in the wavelength or spectral composition of light. Color perception can be described in terms of three psychological dimensions: hue, saturation, and brightness. Hue is related to the dominant wavelength of the stimulus, saturation is somewhat more loosely related to the spectral bandwidth of the stimulus, and brightness is related to the luminance of the stimulus.

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| **Symbol contrast** | Refers to the relationship between the luminance of a symbol and the luminance of the symbol's background. |
| **Symbol font** | Refers to the geometrical characteristics or style of symbology. Design goals for symbol font are to avoid extensive flourishes and embellishments of the symbols. |
| **Symbol height** | Refers to the vertical distance between the top and bottom edges of an unaccented letter or number. Since ATIS devices can be used at a broad range of display distances, symbol height is best defined and specified as the visual angle subtended by the symbology (at the driver's eye), in minutes of arc. |
| **Symbol luminance uniformity** | Refers to the consistency of luminance values across a display. |
| **Symbol spacing** | Refers to the horizontal space between adjacent characters on a display. Symbol spacing is often expressed as the ratio of space-between-characters to symbol-height (space-to-symbol-height ratio). |
| **Symbol strokewidth-to-height ratio** | Refers to the ratio of the symbol stroke thickness to symbol height. |
| **Symbol versus text presentation of ATIS/CVO messages** | Refers to the style and format of in-vehicle visual messages. A key ATIS/CVO design issue is the presentation of information to the driver so that it is not distracting and is easily understood. Symbols or icons are increasingly used in the design of electronic devices under the assumption that they are preferable to text (e.g., "a picture is worth a thousand words"). However, if drivers are unfamiliar with the symbol or if the symbol is not intuitive, it may be less effective than a corresponding text message when used in an ATIS/CVO device. |
| **Symbol width-to-height ratio** | Refers to the ratio of the width to the height of the symbology. |
| **Tailoring of ATIS information to individual preferences** | Refers to drivers' ability to personalize or to adjust ATIS design parameters to suit their individual driving habits, needs, and preferences. |
| **Timing of auditory navigation information** | Refers to the time or distance at which ATIS should present an auditory instruction to the driver before an approaching navigation maneuver (e.g., a required turn). |

**Travel coordination information** Refers to information regarding different modes of transportation (e.g., buses, trains, and subways) that may be used in conjunction with driving a vehicle. This information might include real-time updates of actual bus arrival times and anticipated travel times, and would allow coordination of multimode trips.

**Trip scheduling information** Refers to information regarding each of the pick-up and delivery points along a predetermined route. This information aids in the coordination of long, multiple-stop journeys and allows drivers to double-check that the current route will optimize their delivery schedule.

**Two-way real-time communications** Would provide ATIS and ATMS information to drivers or dispatchers concerning congestion, incidents, and optimum routing.

**TWC** *Two-Way Real-Time Communications*

**UCS** *Uniform Chromaticity-Scale*

**UMTRI** *University of Michigan Transportation Research Institute*

**User interface design** Refers to the system design characteristics of a computer-based system that includes the screen layout and format, selection of icons, use of borders and windows, control selection and placement, and the procedures and "rules" that define transactions between the system and the user.

**VDT** *Visual Display Terminal*

**Vehicle condition monitoring** Refers to the tracking of the overall condition of the vehicle to inform the driver of current problems as well as potential problems. Vehicular monitoring could range from reminding the driver to perform certain services (e.g., oil change) to warning the driver about current problems (e.g., engine overheating or flat tire). This system could also be interactive, allowing the driver to interrogate the system regarding the problem and possible solutions.

**Vehicle location accuracy**

Refers to the difference between the actual position of the vehicle and the position of the vehicle as presented by an ATIS or CVO device. Accuracy is a function of both the variability inherent to the method of determining the vehicle's position (e.g., differential GPS provides a more accurate position estimate than does raw GPS) and, in the case of a moving vehicle, the latency in determining the position. Error attributable to the position sensing system is often described as the ellipse (or circle) that contains the true position of the vehicle a known percentage of time. Typically, 95 percent or 99 percent is used as the criterion for the error envelope. The root mean square (RMS) error is an alternative method commonly used to describe the position error. Position error due to latency is a function of the update rate and the velocity of the vehicle. Assuming that the system is able to determine the position of the vehicle perfectly, a 1 second delay in updating the position of a vehicle traveling 100 kph (62 mph) results in an error of 27.8 meters (91 ft).

**VFD**

*Vacuum Fluorescent Displays*

**Weigh in motion**

Allows motor carriers equipped with special transponders to proceed on the highway at normal speeds through instrumented weigh stations as their weight is electronically inspected by in-pavement scales and readers.

**WIM**

*Weigh in Motion*

# CHAPTER 13: LIST OF ABBREVIATIONS

ANSI ........ American National Standards Institute

ASR ........ Automatic Speech Recognition

ATIS ........ Advanced Traveler Information Systems

ATMS ........ Advanced Traffic Management System

AVC ........ Automatic Vehicle Classification

AVC/AVI ........ Automatic Vehicle Classification/Automatic Vehicle Identification

AVL ........ Automated Vehicle Location

CAS ........ Collision Avoidance System

CB Radio ........ Citizen's Band Radio

CIE ........ Commission Internationale de l'Eclairage

CRT ........ Cathode Ray Tube

CSRDF ........ Crew Station Research and Development Facility

CVO ........ Commercial Vehicle Operations

DOT ........ Department of Transportation

DVI ........ Driver-Vehicle Interface

EC ........ Electronic Credentials

ETA ........ Estimated Time of Arrival

FHWA ........ Federal Highway Administration

FMVSS ........ Federal Motor Vehicle Safety Standards

FOV ........ Field of View

GPS ........ Global Positioning System

HCI ........ Human-Computer Interaction

HDD ........ Head-Down Display

HOV ........ High Occupancy Vehicles

HUD ........ Head-Up Display

IMSIS ........ In-Vehicle Motorist Services Information Systems

IRANS ........ In-Vehicle Routing and Navigation Systems

## LIST OF ABBREVIATIONS (Cont'd)

ISIS ........ In-Vehicle Signing Information Systems

ISO ........ International Standards Organization

ITS ........ Intelligent Transportation Systems

IVIS ........ In-Vehicle Information System

IVSAWS ........ In-Vehicle Safety Advisory and Warning Systems

LOS ........ Line of Sight

R&D ........ Research & Development

RGS ........ Route Guidance Simulator

RMS ........ Root Mean Square

SAE ........ Society of Automotive Engineers

TWC ........ Two-Way Real-Time Communications

UCS ........ Uniform Chromaticity-Scale

UMTRI ........ University of Michigan Transportation Research Institute

VDT ........ Visual Display Terminal

VFD ........ Vacuum Fluorescent Displays

WIM ........ Weigh in Motion

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**Human Factors ITS Contract Research Program**
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**Traffic and Driver Information Systems Division**

## Assessment of Effect of In-Vehicle Display Systems on Driver Performance

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### Relevant FMVSS Documents

A number of Federal Motor Vehicle Safety Standards (FMVSS) that may be relevant to the design of ATIS/CVO devices appear in Section 49 of the Code of Federal Regulations, Part 571. Relevant FMVSS documents include:

- Standard Number 101: Controls and Displays
- Standard Number 107: Reflecting Metal Surfaces (Glare)
- Standard Number 125: Warning Devices

### Relevant SAE Documents

The Society of Automotive Engineers also publishes standards, recommended practices, and information reports. Relevant SAE documents include:

- J1050a: Describing and Measuring the Driver's Field of View
- J1052 May87: Motor Vehicle Driver and Passenger Head Position
- J1138: Design Criteria — Driver Hand Controls Location for Passenger Cars, Multi-Purpose Vehicles, and Trucks (10000 GVW and Under)
- J1139 Apr94: Direction-of-Motion Stereotypes for Automotive Hand Controls
- J2119 Jun93: Manual Controls for Mature Drivers

# CHAPTER 18: SCOPE AND LIMITATIONS OF THESE DESIGN GUIDELINES

The human factors design guidelines presented here are applicable to the design of ATIS devices. In-vehicle ATIS devices have been the primary focus of the ATIS research community, and much of the empirical work that has been used to form the basis of these guidelines has been generated in the context of an in-vehicle ATIS. Kiosk, hotel, portable, and Internet-based ATIS devices and applications have become widespread in recent years. To the extent possible, these guidelines have been developed for use during the development of each of these ATIS applications.

Furthermore, these guidelines are applicable to the broad range of information that might be conveyed to private and commercial drivers through an ATIS. Such information includes, of course, routing and guidance information; but it also includes signing, safety and warning information, as well as motorist services.

As discussed in many of the individual design guidelines contained in this handbook, there are relatively few empirical data that are directly relevant and applicable to the design of ATIS devices. Thus, these preliminary design guidelines have been formulated through reviews and analyses of the best available data, including empirical research conducted as part of the guidelines development process. However, the content and organization of the document as a whole, as well as specific guidelines themselves, will undoubtedly be modified as additional empirical data become available. In that sense, this document should be considered a "living document"—in process and subject to future revisions.

# CHAPTER 19: BACKGROUND OF THESE HUMAN FACTORS DESIGN GUIDELINES FOR ATIS/CVO

Significant advances in electronics and microcomputing during the past few decades have led to the feasibility of a functionally powerful, computer-based ATIS as part of the automotive environment. Although these systems range in functionality, they all have the goal of acquiring, analyzing, communicating, and presenting information to assist travelers in moving from a starting location to a desired destination. While systems under development or in production promise to improve travel safety, efficiency, and comfort, they represent a new frontier in ground transportation. This handbook is intended to address a growing information gap between the advanced and diverse status of automotive technologies such as ATIS devices, and the availability of human factors design criteria that can be used during the system design process. Specifically, the relationship between various ATIS design parameters and the driver's ability to effectively and comfortably use an ATIS—given variations in operating conditions, driving tasks, and driver demographics—has not been extensively studied. Most design guidelines for automotive displays have been derived from display design guidelines developed for military applications (e.g., MIL-STD-1472D). Such guidelines are often inappropriate when applied to automotive design situations, due to differences in user populations, user expectations, operator tasks, design constraints, design trade-offs, and user capabilities and limitations.

For example, the older driver presents a unique concern with regard to the design of automotive display systems. As individuals live longer and drive longer, a larger proportion of the driving population is age 65 or older. Experimental data indicate considerable differences between older and younger drivers with respect to sensory, cognitive, and psychomotor abilities. For instance, in the visual domain, older drivers are characterized by decreased accommodative ability, decreased acuity, decreased contrast sensitivity, increased glare sensitivity, and increased luminance requirements. Older drivers are at a particular disadvantage when attempting to use many modern display systems: their own abilities to use the systems have decreased, while the visual, information processing, and motor demands placed on them have increased. Wherever possible, design guidelines specifically aimed at the older driver have been included.

In summary, there is an urgent need for a clear, relevant, and well-referenced set of human factors design guidelines, for ATIS devices. This document summarizes human engineering data, guidelines, and principles, for use by creative designers, engineers and human factors practitioners during the ATIS design process. These summaries take the form of design guidelines for 75 distinct ATIS design parameters. These design guidelines are intended to: (1) be concise, (2) be unambiguous, (3) be traceable to specific references, where applicable, and (4) highlight implications for driver performance, where appropriate.

## HOW THE DESIGN GUIDELINES WERE DEVELOPED

The Battelle Human Factors Transportation Center developed these design guidelines through a 5-year study conducted for the U.S. Federal Highway Administration. ATIS/CVO devices are intended to provide a wealth of real-time information to the driver, including route guidance to avoid congestion and minimize travel time, safety and warning notices, and identification of desired motorist services, such as how to get to the nearest service station. While ATIS and CVO systems offer great potential benefits, their effectiveness depends on driver acceptance of the new technology, the ability of the systems to integrate the information with other driving tasks, and the extent to which the systems conform to driver physical and cognitive limitations and capabilities.

There were three technical phases associated with this project: (1) an analytical phase, (2) an empirical phase, and (3) an integrative phase. Below, we summarize results from the completed analytical phase of the project, present results from the empirical phase, and discuss guideline development activities associated with the integrative phase.

**Analytical Activities**

During the analytical phase, seven tasks were performed.

**Tasks Completed During the Analytical Phase.**

| Summary of Tasks |
|---|
| Literature Review |
| ATIS and CVO Development Objectives and Performance Requirements |
| ATIS and CVO Functional Description |
| Comparable System Analysis |
| Task Analysis of ATIS/CVO Functions |
| User Information Requirements |
| Development of Decision-Aiding Tools for System Design |

The purpose of these tasks was to summarize the state of knowledge about human factors issues associated with ATIS/CVO systems and to lay the foundation for the empirical and integrative activities yet to come. Of the seven analytical tasks performed, four aided substantially in achieving the specific project goal of guideline development:

- A literature review of human factors-related articles associated with ATIS and ATIS- related CVO systems.
- A functional description of ATIS/CVO systems.
- A comparable systems analysis of existing highway transportation and related non- highway transportation systems.
- The development of decision-aiding tools for the designing of alternate systems.

The Literature Review

The main goal of the literature review was to identify the research gaps which needed to be filled in order to establish useful human factors guidelines and to assess existing guidelines to determine their applicability to ATIS systems. In order to gather the necessary literature, a mass mailing was performed to solicit articles, reports, and information from public and private sector organizations and individuals, numerous database searches were conducted, and advertisements were placed in the *Human Factors Bulletin*. In all, over 1,000 data sources were obtained and summarized with respect to a range of key topics relevant to the design of ATIS/CVO. In general, the information gathered during the literature review was instrumental in:

- Providing a listing of human factors principles used to structure the development of preliminary guidelines.
- Providing the necessary references used as "Key References" in the final guideline document.

The Functional Description

The goal of the functional description was to analyze the various functions that technology might perform in ATIS/CVO systems and to discuss whether or not the integration of some of the features would enhance or hinder drivers' abilities. In order to do this, five subsystems were determined which represent broad categories of ATIS/CVO functions. These subsystems include:

- In-Vehicle Routing and Navigation Systems (IRANS).
- In-Vehicle Motorist Services Information Systems (IMSIS).
- In-Vehicle Safety Advisory and Warning Systems (IVSAWS).
- In-Vehicle Signing Information Systems (ISIS).
- CVO-specific functions.

After identifying the relationship between these subsystems, it was possible to indicate the potential conflicts and dependencies between them which might affect the ability of the ATIS/CVO system to achieve the ITS objectives of safety, efficiency, and enhanced mobility. Then, a more detailed analysis of the functional characteristics of each subsystem was done to show how they would combine to achieve the ITS goals and performance requirements. Other important applications of the functional description were: (1) identifying the information flows and decision-making processes implied by ATIS functions; (2) identifying the relative importance of different cognitive characteristics, to focus empirical data collection efforts; (3) identifying functional similarities of comparable systems; (4) cataloging human limits associated with similar technology; and (5) providing a possible framework for translating research findings into design guidelines which could easily be used by designers. Together, these applications of a functional description will facilitate the development of useful and usable ATIS/CVO systems.

The Comparable Systems Analysis

The goal of the comparable systems analysis was to analyze existing highway transportation and related nonhighway transportation systems to obtain lessons learned for the design and implementation of ATIS/CVO systems. A preliminary list of candidate systems was compiled from several sources and seven were selected based on several criteria, including: relevance to ATIS/CVO concepts, user time-sharing characteristics, technology level, system complexity, dynamics of information flow, level of implementation, and accessibility. Four of the systems selected (TravTek, University of Michigan Transportation Research Institute (UMTRI), Navmate, and Seattle Fire Department) were highway transportation systems, one (OmniTRACS) was a CVO system, one (Crew Station Research and Development Facility (CSRDF)) included advanced navigation technology for army aviation, and the seventh (Sikorsky) was an expert system for cognitive decision-aiding in helicopter mission replanning. An in-depth analysis was performed on each of the systems and the information obtained was compiled into a set of human factors "lessons learned." These lessons learned were then translated into 66 human factors design principles relevant to 13 different design issues. The table below gives some examples of specific design issues and an associated human factors design principle.

**Examples of Design Issues and Associated Human Factors Design Principles.**

| Design Issue | Human Factors Design Principle |
|---|---|
| In-Vehicle Display Design | Digital maps should be available to depict the user's current location, destination, and a recommended route, but such maps are not the preferred method for depicting route guidance. |
| User-System Interface | The driver should be given the option to reject a recommended route (for any reason, such as recent knowledge of road closure) and the system should calculate an alternate. |
| Driver Attention/Workload/Safety | While the vehicle is in motion, the interface design should reduce driver workload through restricted access to control functions, guidance screens rather than maps, and supplementary use of voice output with the visual display. |

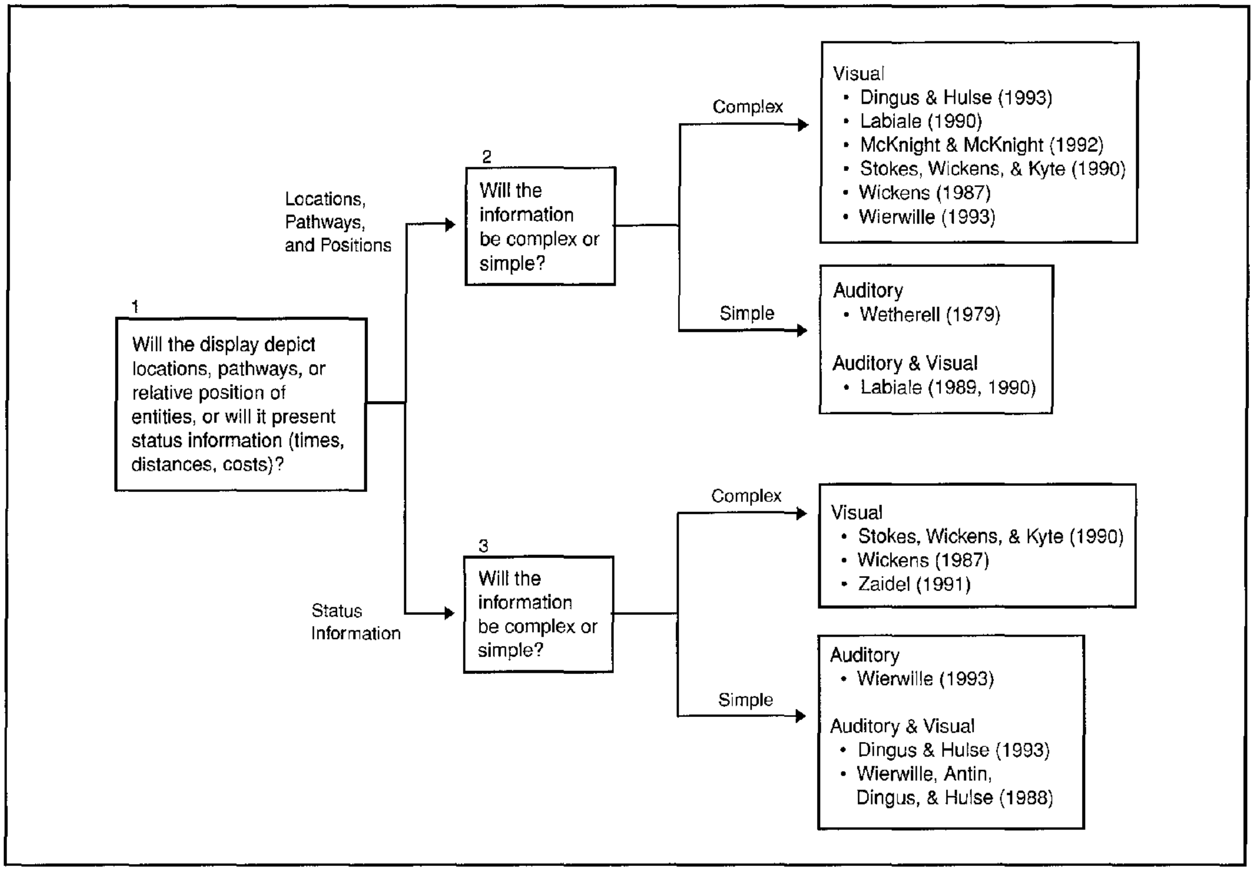
Development of Decision-Aiding Tools for System Design

The goals of this task were: (1) to identify format alternatives for the presentation of information relating to applications of ATIS, and (2) to identify research issues which must be addressed in order to develop effective guidelines. To achieve these goals, the strategy of turning the current state of knowledge into tools applicable for ATIS design was developed. Among the tools initially developed were:

- Trip status allocation (e.g., predrive, zero speed, or in transit).
- Display format allocation (e.g., text, icon, graphics, or route map).
- Display location (e.g., head-up or head-down).
- Sensory modality allocation (e.g., visual, auditory, or visual and auditory).

The tools were generated by examining the existing empirical research and performing several different task analyses, function allocations, criticality assessments, and trade studies. The tools are in the form of flow diagrams and act as a guide to designers, suggesting trip status, display format, display location, and sensory modality for the presentation of each ATIS/CVO driver information requirement.

Part of the sensory modality design tool is shown in the figure below. As can be seen in the diagram, answering certain questions regarding the type of information to be presented leads you to a suggested method of presentation. In addition, each of the final design decisions is supported by empirical research.




**Design Tool for Determining the Sensory Modality for Presenting Different Pieces of Information**

Each of the design tools is laid out in the same manner, to make it easy for designers, engineers and human factors professionals alike to make quick design decisions that are based on the most current and applicable empirical data available.

Summary of the Analytical Phase

Each of the tasks performed during the analytical portion of this research contributed directly to the development of useful design guidelines for ATIS/CVO. The literature review provided a large number of high quality references for each guideline. The functional description indicated critical interactions between subsystems and their functions which might interfere with the ITS objectives. And, the comparable system analysis and decision-aiding tools provided enough information to actually create numerous guidelines.

## Empirical Activities

The first year of this research produced several working papers that suggested over 300 viable topics for human factors empirical research. By eliminating topics requiring more resources than available, candidate topics were reduced to a set of 91 candidate issues, which were organized into the following 11 categories:

- Coordination of multiple ATIS functions.
- Driver function and information requirements.
- Reliability, timing, and priority of information.
- Interface form and modality.
- Timesharing, attention, and workload.
- Effect of ATIS on driving performance.
- Driver acceptance.
- Navigation and route selection strategies.
- Training and education.
- Design and presentation of human factors design guidelines.
- Research strategies and methods.

Eight human factors experts were asked to rate all issues on several criteria. The table below lists rating criteria drawn from three broad categories. The first set of criteria includes five categories used in the IVHS American Strategic Plan.

**Rating Criteria.**

| IVHS America | Other | Methodology |
|---|---|---|
| • Congestion<br>• Safety<br>• Mobility<br>• Environment<br>• Economic | • Existing Data<br>• Guidelines<br>• Older Drivers<br>• Younger Drivers | • Cost<br>• Time<br>• Practicality<br>• Generality<br>• Suitability |

The human factors experts, highly familiar with IVHS and ground transportation, provided the raw data. Six raters were drawn from key authors of the working papers (Dingus/University of Iowa; Kantowitz/Battelle; Landau/GM Hughes; Lee/Battelle; McCauley/Monterey Technologies; Wheeler/Battelle). In addition, two distinguished university faculty also completed the lengthy questionnaire (Professors Moray/University of Illinois and Triggs/Monas University). Since they did not participate in writing the working papers, it was hoped that their ratings would not reflect any possible biases potentially acquired by Battelle team members during the course of their intense collaboration on this project.

Each rating form contained 2,184 cells (91 issues ( 24 criteria). Since the eight raters completed all cells, there are a total of 17,472 rating entries in the data set. A 5-point scale was used for ratings. Completing the rating form took approximately 8 hours. Raters were self-paced.

After the ratings were scored, raters were given three new lists of candidate issues to evaluate. List A contained the highest rated 16 issues for the entire data set, weighted as described later in this paper. List B contained the highest rated 16 issues based only on the data for the individual rater but using the same weighting scheme. Thus, eight unique List B forms were generated, one for each rater. List C contained a stratified random sample of 16 candidate issues with four issues drawn from each quartile, again with the same weighting scheme. Raters were told to treat each list independently and were not informed how the lists were created. For each list, raters were instructed to delete as many issues as they wished, if they believed a particular issue was either not important or not practical given resource limits of the project. They could also add one issue to each list.

A linear psychometric model was used to combine ratings into a single score for each rater. A sensitivity analysis was conducted to determine how different ratings for the criteria altered the relative performance of the research issues. The final weighted scale was successfully validated.

Those research issues considered to be most vital, and subsequently studied, include:

- Driver acceptance.
- The effect of inaccurate traffic information.
- The ability to transition between ATIS functions.
- Information display formats for ISIS and IVSAWS.
- Commercial vehicle driver fatigue.
- Commercial vehicle driver workload.
- Driver response during unexpected situations.
- The benefits of multimodal displays.
- The use of HUDs for ATIS applications.
- Driver performance under reduced visibility conditions when using ATIS.
- The effects of ISIS and IVSAWS on driver behavior.

Driver Acceptance

While ATIS and CVO systems are intended to provide a wealth of real-time information to the driver, their effectiveness depends on driver acceptance of the new technology. Three separate but related experiments assessed both private and commercial drivers' acceptance of these technologies. In these studies, private and commercial drivers were introduced to an ATIS device through written and verbal descriptions, videotape, and Battelle's Route Guidance Simulator (RGS). Questionnaires, interviews, and performance measures revealed the following conclusions about driver acceptance of ATIS and CVO systems:

- Private vehicle drivers use and benefit from accurate traffic information. Even information that is less than 100 percent accurate can be useful; however, inaccurate information that causes commuting delays may negatively affect drivers' trust in the ATIS.
- Both local and long-haul commercial drivers place considerable value on ATIS functions that increase driver safety (i.e., hazard warning, road condition information, and automatic emergency aid requests). These functions should be included in any CVO system. Unwanted or even neutral features (i.e., on-line service directory) unnecessarily increase system complexity and reduce driver acceptance.

The Effect of Inaccurate Traffic Information

This research examines two important issues related to driver behavior and acceptance of this new technology: (1) What effect does route familiarity have on ATIS use and acceptance, and (2) how accurate does the presented information need to be for an ATIS to be accepted and considered useful? In order to examine these issues, a study conducted using the RGS looked at the effect of three levels of information accuracy (100 percent, 71 percent and 43 percent accurate) in both familiar and unfamiliar driving environments. Results showed the following:

- Drivers have greater self-confidence when driving in familiar settings and will therefore be more critical of the ATIS advice, holding it to a higher standard of user acceptability. Commercial success for ATIS devices will be easier to accomplish in unfamiliar settings (e.g., for use in rental cars for visitors).
- Though a system that was 100 percent accurate yielded the best driver performance and preference, systems that were only 71 percent accurate were still accepted and used. And, systems that were 43 percent accurate produced powerful decrements in performance and opinion.

The Ability to Transition Between ATIS Functions

The goal of this experiment was to examine the cognitive demands placed on the driver by the need to transition across ATIS functions. It was believed that interactions between the functions might sometimes inhibit and sometimes facilitate performance on associated cognitive tasks. In order to examine this hypothesis, transitions across six ATIS predrive functions were investigated. In half of the cases, the subsystem functions had a similar user interface and screen format. For the other half, the user interfaces and screen formats were different across subsystems. Results of the study indicated that:

- Subjects experienced very little difficulty in using and transitioning across the various ATIS functions.
- In terms of recognizing screens or, perhaps, maintaining an accurate mental model of the ATIS screens, there was an advantage (in terms of both speed and accuracy) to designing each ATIS function with a unique "look and feel."

Information Display Formats for ISIS and IVSAWS

A critical issue facing both ATIS designers and highway engineers is the concern that warning messages may go unheeded. The goal of this study was to examine a wide range of display design parameters (i.e., display modality, message style, and display location) on driver compliance with warnings and driving safety. The results indicated that:

- ATIS warnings can generate a greater compliance compared to road signs; however, they may undermine driver performance by fostering an over-reliance on ATIS information.

The results also suggested that message style had more of an impact on driving safety than did the display modality used. An associated result indicated that:

- Command messages (i.e., Slow Down) promote greater compliance, but they reduce safety and should therefore be reserved for situations where an immediate and rapid response is required to preserve driver safety. Otherwise a notification message style may be more appropriate (i.e., Speed Limit 25 mph).

CVO Driver Fatigue

The major objective of this study was to determine how fatigue impacts a CVO driver's ability to interact with complex in-vehicle systems. The two possibilities are that: (1) an ATIS might enhance driving performance by increasing arousal and reducing fatigue, or (2) an ATIS might decrease performance by overloading the driver under circumstances of fatigue. Results of a study addressing this issue found the former to be true:

- Fatigue effects can be mitigated to some extent when drivers interact with an ATIS. Therefore, drivers should not be discouraged from ATIS interaction under fatiguing conditions.

Other interesting results of the study suggest that:

- Increasing ATIS complexity can increase mental workload, thus decreasing driving performance. However, commercial drivers were able to operate an ATIS of moderate complexity with no apparent degradation in performance.
- ATIS information that is relatively simple and is time-sensitive should be presented via the auditory modality; complex messages should be presented via the visual modality or through both visual and auditory modalities.

CVO Driver Workload

The intent of an ATIS/CVO system is to automate some of the tasks performed by the CVO driver (communicating with dispatch, checking gauges, documentation), thus reducing the overall workload level. However, the addition of these features and functions, which are to be completed while the driver is in transit, may actually increase the level of workload to dangerous levels. A study was conducted to examine these driver workload issues using both commercial truck and taxi drivers. The results of the study showed that, for truck drivers:

- Minimize the level of interaction required by the system while driving by keeping the number of control manipulations to a minimum (less than four). The number of control activations has a greater effect on driver performance than the amount of information presented on the display.
- Navigation and vehicle condition information was most useful.

For taxi drivers:

- Minimize the amount of interaction required by an ATIS if the interaction is time- dependent. Drivers should be allowed to delay making control activations until they feel it is safe to do so.
- Navigation and general communication information was most useful.

Driver Response During Unexpected Situations

A field experiment was conducted to investigate the benefits and detriments of using an IVIS when the driver is confronted with unexpected situations. The IVIS used in the present study included three in-vehicle subsystems: ISIS, IRANS, and IVSAWS. This research focused on five primary areas: (1) the inclusion of unexpected situations (specifically, external events and vehicle status warnings), (2) driver notification of these events and warnings via an IVSAWS, (3) situation awareness of the driver when confronted with unexpected situations, (4) the impact of IVIS display density on driver response to unexpected situations, and (5) older driver use of an IVIS when confronted with unexpected situations.

Three research questions were posed and investigated, each involving the use of an IVIS and response to unexpected situations: (1) Are there benefits for IVIS that incorporate ISIS, IRANS, and IVSAWS, (2) what impact does IVIS information density have on driver's behavior and performance, and (3) what impact does driver age have on system use and measures related to driver behavior and performance?

The following conclusions and recommendations were made from this field study:

- Results indicated a clear benefit for drivers responding to external events and vehicle status warnings when using an IVIS.
- Drivers are capable of safely switching attention from an IVIS to the forward roadway, while responding to an external event.
- The grouping and layout of information is an important consideration for IVIS design; guidelines provided in other domains (e.g., HCI) are a useful supplement to ATIS/CVO guidelines.
- Older drivers behave more cautiously when using an IVIS and responding to unexpected situations.
- Limitations associated with older driver performance, such as longer response latency and more frequent navigation errors, may be reduced through the use of an optimally designed IVIS.
- Auditory cues for alerts should allow user control of intensity.
- Drivers should be allowed to select “low urgency” messages and alerting cues from a bank of options that cross modalities.

Benefits of Multimodal Displays

There were two objectives for this research. First, to what degree, and under which circumstances, are multimodal displays beneficial? Second, for circumstances where multimodal displays are not beneficial, which single modality results in best performance? These questions were addressed in two separate steps. In the first step, the optimum candidate information items for a multimodal display were analytically determined, and designs of the multimodal displays for presenting the information were conceived. In the second step, the effectiveness of multimodal displays was tested in a driving simulator experiment and compared to single-modality displays—auditory or visual—for the information identified.

Four primary findings were determined:

- For emergency response displays, the multimodal and the auditory displays resulted in faster reaction times than the visual display for detecting warning information, while information presented on the multimodal display resulted in fewer errors than the auditory display.
- For navigation tasks, the multimodal display resulted in the best performance for both total correct turns and number of navigation-related errors.
- For driving performance, the multimodal display generally resulted in better performance for both speed maintenance and safe driving behavior.
- For subjective workload and preference ratings, the multimodal display and the auditory display received more preferable ratings than did the visual display.

Use of HUDs for ATIS Applications

To date, HUDs have been used primarily as secondary displays to provide drivers with status information such as speed, gauge information, and turn signal status. Such information is generally redundant with other HDD information and is considered to be noncritical; i.e., information that does not have direct or immediate safety implications. However, future applications of automotive HUDs may include collision avoidance system (CAS) warnings, night vision information, and navigation devices (Kaptein, 1994; Weintraub & Ensing, 1992). Thus, the HUD may be used as a primary display for the presentation of critical information requiring an immediate response by the driver.

The overall objective of this study was to investigate the use of a HUD for an ATIS device. Of particular importance are how display location and drivers' age interact to influence driver behavior. The Battelle High Fidelity Driving Simulator was used to conduct the study. Two navigation aids, a HDD and a HUD, were used to present messages to the subjects across three driving scenarios. Results from the study indicated that:

- Older drivers committed more navigation errors than younger drivers.
- There were no differences between the HUD and the HDD conditions with respect to navigation errors, collisions with external objects such as cars and balls bouncing in the street, or driver performance.

Driver Performance Under Reduced Visibility Conditions When Using ATIS
Recent technological innovations and the need for increased safety on the world's roads have led to the introduction of IVIS. These systems will provide navigation and advisory information to drivers while they are driving. One aspect of these systems, ISIS, would provide the warning, regulatory, and advisory information that is currently found on road signs. These systems may be of particular benefit when external elements, such as rain, snow, or night driving, reduce or eliminate the opportunity for drivers to detect road signs. This study attempts to determine what benefits, if any, are realized by drivers using this system.

In this study, 58 drivers operated an instrumented Oldsmobile Aurora under eight conditions. The eight conditions consisted of: a daylight-clear weather-ISIS condition, daylight-clear weather-no ISIS condition, a daylight-rain-ISIS condition, a daylight-rain-no ISIS condition, a night-clear weather-ISIS condition, a night-clear weather-no ISIS condition, a night-rain-ISIS condition, and a night-rain-no ISIS-condition. Younger drivers (18-30 years old) and older drivers (65 years or older) took part in this study.

The results indicated that:

- Use of the ISIS display led to reduced speeds and greater reaction distances for all drivers.
- Evidence was found that seems to indicate that older drivers may receive a greater benefit in complex, unfamiliar, or low visibility situations.
- Evidence was also found that indicates that all drivers may receive a greater benefit at night for the complex or unfamiliar situations.
- Subjectively, the majority of the drivers indicated that the ISIS display made them more aware of road sign information.

Effects of ISIS and IVSAWS on Driver Behavior
This study was designed to answer three research questions intended to provide information for the development of ATIS design guidelines. The three questions were: (1) Does message potency affect compliance rates to navigation, augmented signage, and safety and warning messages, (2) are advance notification messages that warn drivers of upcoming route guidance instructions helpful, and (3) do traffic density and roadway demands affect a driver's ability to utilize ATIS information? Participants drove an instrumented 1994 Saturn Station Wagon that was equipped with a prototype ATIS. A "Wizard of Oz" methodology was used whereby ATIS messages presented to the driver were controlled by an experimenter in the back seat. Four video cameras and an eye tracker were used to record driver behavior.

The results indicated that:

- Latency did not differ as a function of information density. It was expected that presenting multiple messages within one minute might exceed drivers' ability to process information, and this may manifest in longer button press latencies. Contrary to our hypothesis, presenting two or even three messages within one minute did not appear to be too many, at least to the extent that it affected their "state of readiness" to receive a new message.

- The number of large steering reversals in the "before message" window did not differ significantly from those recorded in the "during message" window. This suggests that the presentation of ATIS messages did not increase attentional or workload demands, at least to the extent that can be seen in an increase in large steering reversals.
- As expected, drivers who received advanced notification of a turn were prepared to turn sooner (indicated by turn signal activation) after the onset of the actual navigation message (3.6 seconds) than those who did not receive advance notification (5.4 seconds). This suggests that the advance notification messages were used by drivers to help them prepare for upcoming turns.
- In summary, compliance was higher to auditory/command messages than visual/notification messages. It is clear that urgent messages where a response from the driver is critical should be presented using the auditory/command format.

Summary of the Empirical Phase

In this subsection we have described the empirical phase of this project to develop a relevant and useful set of human factors design guidelines for ATIS/CVO. While ATIS and CVO systems offer great potential benefits to the driving public, their effectiveness depends on driver acceptance of the new technology, the ability of the system to integrate with other driving tasks, and the extent to which the systems conform to driver physical and cognitive limitations and capabilities. The findings from these studies will ensure that the ATIS and CVO systems conform to human limitations and capabilities, enhance driver acceptance, and promote highway safety.

**Integrative Activities**

The integrative phase of this project has included activities intended to address a number of critical issues in human factors design guideline development, such as: variability in the ATIS/CVO design community with respect to background and design tasks, variability in the amount of empirical data across design topics, and a lack of objective criteria for data source selection.

The User Requirements Analysis

In order to develop guidelines that are clear, relevant, and easy to use for the widest range of ATIS designers, a *User Requirements Analysis* was conducted to identify the ATIS design community's needs and desires for human factors guidelines information on ATIS/CVO. In this analysis, 30 members of the ATIS design community were interviewed by Battelle staff to identify their unique needs and preferences for ATIS human factors design guidelines. Participants in the User Requirements Analysis were obtained from some of the leading developers of ATIS devices in the United States, and included a range of designers with different educational backgrounds, technical expertise, and ATIS/CVO design responsibilities.

Topics that were covered during the 2-hour in-person interviews included:

- Educational and technical background information on the interview participants.
- Overview of their organization's design approach to ATIS/CVO devices.
- Opportunities for human factors input into the ATIS design process.

- Current human factors methodologies used by ATIS designers.
- Present difficulties in applying human factors information to the design of ATIS.
- Suggested solutions to these difficulties. Recommendations for desired ATIS/CVO human factors design topics.
- Evaluations of alternative design guideline formats for ATIS/CVO topics.

With respect to areas of training and technical expertise, 25 percent of the interview participants were human factors researchers or practitioners, while 75 percent of the participants were electrical, industrial, mechanical, software, and system engineers with little or no human factors training.

All of the participants had some responsibility for the content and layout of ATIS/CVO devices, 86 percent of the participants were involved in conceptual and/or detailed design of ATIS/CVO devices, and 75 percent were involved in the test and evaluation of ATIS/CVO devices.

While 100 percent of the participants reported an urgent need for human factors design guidance in their ATIS/CVO design activities, only 45 percent of the participants reported that there was any human factors input to their current ATIS/CVO design efforts. This lack of human factors input to their design process was attributed to: (1) the absence of empirical human factors data on ATIS/CVO, (2) difficulties in understanding human factors data sources and in making cost-benefit trade-offs with human factors data, and (3) difficulties in obtaining human factors data in a timely fashion.

The results from the User Requirements Analysis have been used to determine the content, organization, and formats associated with this handbook. With respect to the content of this handbook, the consensus among ATIS/CVO designers was to: (1) include all ATIS functions but to focus on Routing and Navigation, (2) include guidelines on the selection and legibility of symbols or icons, as well as on the legibility of letters and numbers, and (3) limit the inclusion of design tools and human factors tutorials in the handbook.

Designers recommended that the handbook be organized: (1) by ATIS design topics, not by human factors engineering issues, (2) in a manner that facilitates rapid search and find activities of individual design guidelines, and (3) in a manner that supports future updates, revisions, and additions.

As for the format, i.e., the "look and feel" of individual design guidelines, ATIS/CVO designers expressed consistent preferences for guideline formats that: (1) are graphic based, with color and supporting text, (2) provide explicit design guidance, (3) include guidelines that are highlighted and prominent, (4) include text information that is brief, highly organized and tightly structured, (5) include a brief rationale for the guideline, as well as references used to develop the guideline, and (6) include a rating to indicate the relative contribution of empirical data and expert judgement to the development of the final guideline.

In addition, the ATIS/CVO designers made numerous comments that reflected their frustrations with using traditional human factors reference sources. They also provided suggestions for addressing these concerns and maximizing the utility and relevance of human factors design guidelines for ATIS/CVO.

Examples of such comments included:

- "Think about how people are going to use the information for formulating a solution."
- "Transfer the data into something more applicable."
- "Recommendations need to be more specific to our problems."
- "It would be nice to see the information applied."
- "A good summary of the findings is important; for example, what is the best way to show a turn is required, voice or graphically?"
- "Guidelines need to be more applicable to a large number of situations."
- "We are now designing systems within systems—very complex."

Comments such as these clearly reflect a desire for human factors design guidelines that can be directly applied to the day-to-day decisions that designers face, and they highlight two recurring problems with standard human factors reference sources, discussed below.

The first recurring problem with human factors reference sources is that most such materials are organized around human factors topics and not the system design topics that are particularly relevant to nonhuman factors professionals within the larger ATIS/CVO design community. For example, the chapters or sections within human factors reference sources frequently contain titles such as: Perception & Attention, Population Characteristics, Human Error, Cognitive Constraints, Workspace Design, and User-Computer Dialogues. In order to increase the utility of our guidelines, particularly for the ATIS designer without a degree or background in human factors, we have organized the guidelines in this handbook around ATIS/CVO-specific topics such as: Trip Planning, Dynamic Route Selection, Route Guidance, Immediate Hazard Warning, Road Condition Information, and CVO Functions.

The second problem is that most human factors reference sources consistently present individual design guidelines as isolated, independent design parameters. Thus, in making day-to-day design decisions when using traditional handbooks, designers are frequently forced to look up, cross reference, and then integrate a host of individual design principles in order to address a specific design question. This handbook has organized groups of related human factors information into integrated guideline clusters. For example, for a given design guideline topic such as "Presentation of Route Guidance Information," the guideline addresses an integrated set of specific design issues such as: What information elements should be presented, should an auditory or a visual display be used, when should the information be presented to the driver, and what should the display look like? Such an approach provides a number of distinct advantages to users, including: reducing search and retrieval times, reducing cross-referencing requirements, increasing awareness of related design topics, increasing relevance of individual guidelines, and increasing the overall utility of this handbook.

Development of Individual Guidelines

To a great extent, the process of formulating the design guidelines was topic-specific. This was because the wide variety of ATIS parameters covered, as well as the nonuniformity of data sources relevant to each topic, precluded any precise and invariant design guideline development process.

For the most part, however, the data sources considered relevant to a particular design guideline were subjected to an integrative review and analysis in order to arrive at the final design guideline. In general, an integrative review summarizes previous research by aggregating the results of a number of similar studies. With respect to individual ATIS design parameters, this means that the results or recommendations from this project's findings, as well as other selected data sources, were compared, contrasted, and perhaps combined. In particular, judgments regarding the quality (i.e., rigor and validity) and applicability (i.e., the extent to which a data source could be generalized to the automotive display design environment) of the data sources were made at this time. If the goals and research methods associated with different data sources were similar, relatively consistent results or recommendations provided strong direction for the formulation of the design guidelines. However, with inconsistent methods and/or results, the goals, theoretical orientations, methods, and results of data sources were given more detailed consideration.

Analytical activities in the design guideline formulation process included categorizing, ordering, manipulating, and summarizing. Inputs to these activities included not only the results of the integrative review described above, but also considerations such as: (1) the limitations and constraints associated with each design guideline, (2) the automotive environment and typically encountered driving conditions, and (3) trade-offs between the usefulness and precision of the design guidelines. The analytical component of the design guideline development process, then, was the method by which the more "objective" inputs (integrative review, quality, applicability) were combined with more "subjective" inputs (parameter-specific considerations, expert judgment) to formulate the final design guideline. Some of the analysis and reasoning associated with these activities is explained in the Supporting Rationale section of each design guideline.

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