Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations: Identification of the Strengths and Weaknesses of Alternative Information Display Formats

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FOREWORD

This report is one of a series 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 integration. This report is a product of the analytic phase. Among the other analytic topics discussed in the series are ATIS and CVO system objectives and performance requirements, comparable systems analysis, ATIS/CVO functions, task analysis, alternate systems analysis, driver acceptance, identification and exploration, and definition and prioritization of research studies.

This report identifies information display format alternatives for in-vehicle devices for both private and CVO applications and presents a set of human factors design tools designers can use to develop safer and more effective ATIS displays. Also reported are research issues still requiring attention in order to further the goal of this project and to develop useful information format guidelines.

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Director, Office of Safety
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NOTICE

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16. Abstract

This report is one of a series 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 goals of the work covered in this report were to: (1) identify information format alternatives for ATIS devices for both private drivers and CVO applications, and (2) identify research issues that must be addressed in order to develop effective information format guidelines. To achieve these goals, and to make the greatest progress possible toward the ultimate project goal of guideline development, the project developed the strategy of turning the current state of knowledge into tools applicable to any ATIS design.

Four primary design-decision tools were developed. These tools are intended to help either professional or nonprofessional human factors designers make appropriate tradeoff decisions in designing effective ATIS displays. The four tools are: (1) Sensory Modality Allocation, (2) Trip Status Allocation, (3) Display Format Allocation, and (4) Display Location.

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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				
		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 TO 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)

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LIST OF ABBREVIATIONS

ATIS . . . . Advanced Traveler Information Systems

CB . . . . Citizens Band

CRT . . . . Cathode Ray Tube

CVO . . . . Commercial Vehicle Operations

FOV . . . . Field of View

HUD . . . . Head-up Display

HVAC . . . . Heating/Ventilation/Air Conditioning

IMSIS . . . . In-Vehicle Motorist Services Information Systems

IRANS . . . . In-Vehicle Routing and Navigation Systems

ISIS . . . . In-Vehicle Signing Information Systems

ITS . . . . Intelligent Transportation Systems

IVHS . . . . Intelligent Vehicle-Highway Systems

IVIS . . . . In-Vehicle information Systems

IVSAWS . . . . In-Vehicle Safety Advisory and Warning Systems

KTA . . . . Kepner-Tregoe Analysis

RP . . . . Route Map (pictorial)

EXECUTIVE SUMMARY

Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) incorporate functions that would enable drivers to access in-vehicle information that was previously unavailable, or was retrieved from domains outside the vehicle. When giving drivers access to such systems inside the vehicle, designers must not only consider safety (i.e., overloading the driver's limited information-processing resources), but also usability and driver acceptance. The primary concerns regarding ATIS are that it: will reduce safety instead of improving it, will not be usable by the driving public, or will not be widely accepted. Only careful, systematic design of ATIS/CVO information displays will provide systems that do not suffer from these consequences.

The goals of the work covered in this report were to: (1) identify information format alternatives for ATIS devices for both private drivers and CVO applications, and (2) identify research issues that must be addressed in order to develop effective information format guidelines. To achieve these goals and to progress toward the ultimate project goal of guideline development, the project developed the strategy of turning the current state of knowledge into tools applicable to any ATIS design.

As part of this task, four primary design tools were developed to help both professional and nonprofessional human factors designers make appropriate tradeoff decisions in designing effective ATIS displays. The four tools are:

(1) *Sensory Modality Allocation Design Tool.* This tool aids designers in identifying the sensory modality (e.g., auditory, visual, tactile) to which information requirements should be allocated. Sensory modality allocation can greatly affect both the safety and usability of an ATIS. For example, excessive visual information can overload the modality that already provides roughly 90 percent of a driver's information. Similarly, excessive auditory information can result in a system that is unusable, frustrating, and annoying.

(2) *Trip Status Allocation Design Tool*. This tool aids in the allocation of information to different parts of the trip, including: predrive (when the car is still in park, prior to the trip), zero speed, (when the vehicle is stopped during the trip, e.g., at a traffic signal), and in transit (when the vehicle is actually moving).

(3) *Display Format Allocation Trade Study Analyses.* These tools, in the form of trade study analyses, help designers determine which format (e.g., text, map, tone, voice) should be used to present the information. Display format can greatly affect a system's safety and usability. A moving map may be distracting and may become too information-dense to be legible. Alternatively, a list of textual directions may not provide all the information the driver needs.

(4) *Display Location Trade Study Analyses.* These tools, in the form of trade study analyses, aid in determining the location [e.g., head-up display (HUD), dashboard placement] of visual information displays. For example, a HUD may improve safety, but only when a

limited amount of information is presented and only when that information is reasonably legible.

In general, the tools were generated from principles gleaned from previous empirical research. Most of this research was based on reviews of the literature, with heavy reliance on previous task reports from this project. The guidelines extracted from those documents were applied with varying degrees of confidence to the problem of ATIS display design. Some of the guidelines, such as the limits of short-term memory, were taken from basic psychological research. Other guidelines were generated from analyses of comparable systems. Finally, a substantial portion of the guidelines were generated from existing intelligent transportation systems (ITS) and ATIS human factors research.

Utilizing the design tools, the project assessed more than 400 different ATIS/CVO driver information requirements. In general, the decisions suggested by the tools are reasonable. However, in many instances, the recommendations must be applied with care, particularly when an individual information requirement does not follow the general trend of similar requirements within a series of like functions. Caution is stressed, especially for trip status allocation. Therefore, the results section only highlights general trends in the data that could be used to create guidelines.

In general, variations in the quality and applicability of the research used to create the tools resulted in varying degrees of confidence in the resulting decisions. It is interesting to note that the highest level of guideline confidence was often not generated from ITS/ATIS research. In attempting to apply a number of similar ITS studies for an assessment of a given decision, we often found that the results were contradictory, the measures were difficult to apply directly, or the validity of the study was questionable. Still, this body of literature proved to be invaluable for many aspects of tool development.

This task was really the first project attempt to create a usable set of guidelines by applying existing data from multiple sources. Now that this has been accomplished for a major set of ATIS/CVO human factors issues, additional work is necessary to refine the tools developed. In addition, research is necessary to: (1) assess the validity of the process and the tools, and (2) use ATIS designers as subjects to assess the usability of the process and the tools.

Research is also needed to determine the effects of interactions between ATIS/CVO functions and subsystems. Now that more is known about what ATIS is likely to become, varying degrees of system functionality must be tested. Such research will be extremely useful, especially in comparison with studies that test only an isolated set of functions.

CHAPTER 1: BACKGROUND

INTRODUCTION

Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO) incorporate functions that enable drivers to access information that was previously unavailable, or was available only in domains outside the vehicle. ATIS/CVO information will encompass several in-vehicle information systems (IVIS), including routing and navigation, motorist services, signing, and safety warning systems. When giving drivers access to such systems inside the vehicle, designers must consider such things as safety and usability. It is possible that these systems, if not carefully designed, could overload the driver and reduce any safety benefits that could be gained from their use. The success of ATIS will also depend largely on the drivers' ability and desire to use the information provided. If ATIS are not easy for the majority of drivers to use, the overall effectiveness of such systems will suffer.

A primary issue in the development of safe and usable ATIS is the information display. Many decisions must be made regarding the type of information to present and when to present it. A designer must first determine the point at which certain pieces of information would be most useful to the driver: while the vehicle is still in park (predrive), while stopped at a traffic light (zero speed), or while in motion. Each of these presentation times has advantages and disadvantages that must be weighed by the designer. For example, during zero speed, the driver can allocate a substantial amount of information resources; however, the time available for retrieving that information is limited to the stop's duration.

Presenting information during different parts of the trip is only one of several information display issues that will directly affect the system's safety and usability. Additional areas to be considered are:

- The most appropriate sensory modality (e.g., auditory, visual, tactile) for presenting different information requirements. For example, excessive visual information can overload the modality that already provides roughly 90 percent of the information relevant to the driving task. Similarly, excessive auditory information can result in a system that is unusable, frustrating, and annoying.

- The best format (e.g., text, map, tone, voice) to use for presenting information. A moving map may be distracting, and may become too information-dense to be legible. Alternatively, a list of textual directions may not provide all of the information that the driver needs (e.g., an effective description of a maneuver at a complex intersection).

- The ideal location [e.g., head-up display (HUD), dashboard placement] for providing visual information. For example, a HUD may improve safety, but only if a limited amount of information is presented and only when that information is reasonably legible.

By systematically addressing each of these issues, designers should be able to develop displays that will have a positive impact on the safety and usability of ATIS/CVO systems.

This report presents several design tools and aids created to assist in the design and development of ATIS/CVO information displays, including:

- Information requirements and criticality assessment analysis (appendix A).
- Sensory modality allocation design tool and examples (appendix B).
- Trip status allocation design tool (appendix C).
- Display format trade study analyses (appendix D).
- Display location trade study analyses (appendix E).
- Modality, trip status, and display format recommendations (appendices F and G).

These design tools identify the strengths and weaknesses of certain display options. The analysis of these options will help us to create human factors guidelines for presenting different pieces of information and highlight those areas still in need of empirical research.

Project Goals

The first project goal was to assess the different formats, modalities, and locations for presenting ATIS/CVO information to drivers, and to use those assessments to develop widely generalizable tools for system designers. To construct these tools, we documented the analysis and decision-making process that a human factors professional would normally use to determine the feasible and optimum means of displaying information. This process was documented in a way that will provide a guide for human factors professionals, as well as for designers unfamiliar with human factors issues. Most of these tools appear in the form of flow charts and matrices. In the future, if this process can be refined and validated, it may be worthwhile to assess the value of a computer-based expert system. The work presented in this report will greatly influence the final guideline document and serve as a key reference for a large number of individual guidelines.

The second goal was to determine research issues that must be addressed in order to reach the ultimate project goal: a comprehensive set of information display guidelines. This goal was realized through the process of developing the information display tools. That is, there were occasions where decisions were unclear and available sources could not be confidently applied, leaving gaps in the decision making process. In those instances, the tools were left incomplete, and the need for additional research was highlighted.

CHAPTER 2: ATIS/CVO DISPLAY DESIGN TOOLS DEVELOPMENT

To provide designers with a comprehensive decision aid with which to design ATIS displays, a number of complementary tools needed to be developed. These tools, graphically depicted in figure 1, serve to provide guidance for key questions that arise during the design process. An overview of each tool and the design decisions it helps address is described in the following paragraphs.

In designing and assessing display options for information systems, it is necessary for the designer to understand the tasks that the driver must perform, as well as the information required to perform these tasks. Therefore, the first step in the process is to outline the potential information requirements for a given conceptual system [figure 1, block (1)]. This was done with considerable aid from the previous tasks performed for this project (Dingus et al., 1996; Lee, Morgan, Wheeler, Hulse, and Dingus, 1997; and Barfield et al., 1993), as well as through a review of the existing literature on ATIS. Other sources of information requirements were the survey results collected as part of this task and data from the task analysis completed as another part of this project (Wheeler et al., 1996).

Two separate assessments were then performed on the information requirements: 1) a functional grouping [figure 1, block (2a)], and 2) an assessment of information criticality while driving [figure 1, block (2b)]. The outcomes of each assessment led to the creation and use of additional design tools. The functional groupings provided input for the sensory modality allocation tool [figure 1, block (3a)], while the criticality assessment provided input for the trip status allocation tool [figure 1, block (3b)]. The results of the tools were then combined and used as input for the display format trade study analysis [figure 1, block (5)].

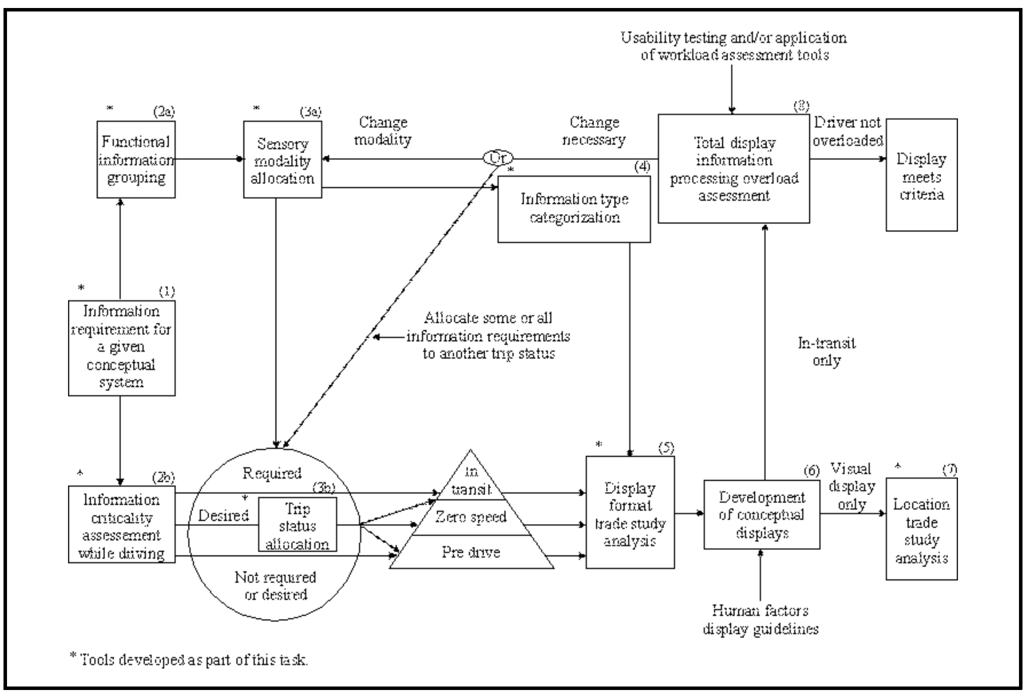

Figure 1. Design process for an ATIS information display.

The information requirements were sorted into six functional groups [table 1 and figure 1, block (2a)]. The groupings were devised by combining functions that provide similar types of information to the driver. Combining the information into functional groups greatly simplified the subsequent analyses.

Table 1. Information functional groupings.

Route Planning and Coordination
Trip planning Multimode travel coordination and planning Predrive route and destination selection CVO-specific (route scheduling) Destination coordination
Route Following
Dynamic route selection Route guidance Route navigation
Warning and Condition Monitoring
Immediate hazard warning Road condition information Vehicle condition monitoring CVO-specific (cargo and vehicle monitoring)
Signing
Roadway guidance sign information Roadway notification sign information Roadway regulatory information CVO-specific (road restriction information)
Communication and Aid Request
Message transfer Manual aid request Automatic aid request
Motorist Services
Automated toll collection Broadcast services/attractions Services/attractions directory

Next, feasible sensory modality alternatives for presenting the information were evaluated using the sensory modality allocation tool [figure 1, block (3a)]. Since the type of information within each functional group differed, separate categorizations based on an assessment of features inherent to the information for each group [figure, block (4)] resulted in six separate sensory modality decision aids. This categorization of information by type and decision tree approach optimized the usability of the design criteria selected. For example, the route planning and coordination sensory modality tool information is categorized by two features, information type and complexity. Two levels of each feature (e.g, type: locations, pathways, positions or status information, and complexity: simple or complex) create four pathways and endpoints. Appendix B contains the sensory modality allocation design tools and supporting examples for each functional group. In circumstances where the criteria used for a decision may not be clear to a user unfamiliar with human factors, examples of correct decisions are provided.

Concurrently, each information requirement was examined to determine its criticality [figure 1, block (2b) and appendix A], that is, whether it is “required” or “desired” by the driver while the vehicle is in motion. If the information is required, it is automatically allocated to an in-transit trip status (in transit refers to the period when the vehicle is in motion). If the information is neither required nor desired while in transit, the information requirement is allocated to predrive status (predrive refers to circumstances prior to the trip, or when the vehicle is in park). Those information requirements that are classified as desired but not required are subjected to a trip status allocation analysis on a case-by-case basis, using the trip status allocation tool (appendix C) in figure 1, block (3b). The trip status allocation design tool provides designers with guidelines for choosing the most appropriate trip status point (in transit, zero speed, or predrive) to display the information, based on information processing and manual control requirements. Note, the sensory modality allocation tool also provides input to the trip status tool.

A major difficulty in developing criteria to use in allocating a particular information requirement to one of the three trip status points, predrive, zero speed and in transit, was defining an acceptable zero speed duration. Zero speed, for the work covered by this report, is time when visual attention is not required for the driving task and the ATIS tasks are of relatively short duration (i.e., 10 s or less). This category is designed to allow the display of more complex information during the trip without compromising the guidelines for visual attention demands.

The multiple outcomes of the sensory modality and trip status allocation tools provide inputs to the display format tool for trade study analysis [figure 1, block (5)]. This tool consists of a series of trade studies that score feasible format options against a set of mutually exclusive human factors criteria. The criteria for the display format tool fit into three categories: safety, usability, and preference. Designers can use the scores to make relative comparisons of the display format options based on the human factors criteria selected. An individual display format matrix (appendix D) was created for each decision tree pathway produced by the sensory modality allocation tools.

By the time the display formats have been selected, the designers have received considerable guidance about the information requirements for a given conceptual system. They can use this guidance, along with the human factors display guidelines and any additional system-related constraints, to develop integrated conceptual display screens [figure 1, block (6)]. Because decisions about modality, trip status allocation, and display format will already have been made, the conceptual display design should proceed much more effectively.

For those conceptual displays that are visual, designers can use the visual display location tool (appendix E). This tool uses a trade study analysis [figure 1, block (7)] to weigh the tradeoffs between display locations. In addition, for information presented in transit, designers will have to assess a display's potential for driver overload. It is anticipated that this assessment will consist of usability testing, and workload and attention demand measurements in the laboratory [figure 1, block (8)]. If an information overload assessment reveals that an overload might occur, designers can alter the in-transit visual display by either reducing the amount of information allocated to the in-transit trip status, allocating the information to another trip status, or changing the presentation modality from visual to some other modality. Assessment of these changes can occur by reusing the sensory allocation and trip status allocation tools. Until these design tools are refined and validated, field evaluations of display alternatives should be conducted to ensure device safety.

CHAPTER 3: ATIS INFORMATION REQUIREMENTS

In the development of tools for designing in-vehicle information displays, a fundamental question is: What information will the driver need in order to accomplish the desired or required task? Thus, in designing any system, the designer's first step should be to develop a list of information requirements. Traditionally, this list is generated by human factors personnel through the use of a task analysis. However, many ATIS will be developed by smaller companies that cannot afford a human factors staff member. To help alleviate this problem, we have tried to provide a relatively comprehensive list of ATIS information requirements that should only require minor additions by designers, on a system-by-system basis.

To develop the information requirements list, we subjected each ATIS/CVO function to a detailed review. During this review, the functional characteristics of all subsystems, described in Lee et al. (1997), were studied to determine what the driver would require to operate the system. A task analysis was then completed, and a list of all information requirements was compiled. This list was then combined with the original CVO requirements list, contained in Barfield et al. (1993), and the resulting list was reexamined. Any additional information requirements that had previously been overlooked were added, and any information requirements that were not pertinent to the subsystem functions were removed. The list was then functionally grouped into six different categories of relevant ATIS/CVO information. Also, each information requirement was examined to determine its criticality with respect to the driving task (see appendix A).

SENSORY MODALITY AND TRIP STATUS ALLOCATION

Two of the most critical decisions associated with the display of ATIS information are: the sensory modality and the trip status point (predrive, zero speed, or in transit) during which the information is to be displayed. During the effort to construct decision aids for these two variables, it became apparent that they were critically linked; i.e., when constructing the trip status design tool, it was necessary to make assumptions about the sensory modality. For example, information provided aurally may be acceptable in certain in-transit circumstances, but information presented visually must be presented at zero speed or predrive. Likewise, in constructing the sensory modality design tool, assumptions about the trip status changed the desirability of modality options. To deal with this link, we determined that it was advantageous to conduct these analyses largely in parallel, with trip status decisions receiving input from the sensory modality tool. This approach allowed us to construct design tools that were easier to use and required fewer assumptions from the designer.

A difficulty discovered during the effort to establish decision criteria for sensory modality allocation was the fact that the applicable criteria will change in the decision aid, depending on the type of information being presented. For example, the criteria for establishing whether warning information should be aural are very different from the criteria affecting decisions regarding navigation or communication information. Our first approach to alleviating this problem was to create a separate tool based on the subfunction designation [i.e., In-Vehicle Routing and Navigation Systems (IRANS), In-Vehicle Motorist Services Information Systems (IMSIS), In-Vehicle Signing Information Systems (ISIS), In-Vehicle Safety Advisory and Warning Systems

(IVSAWS), and CVO-specific]. However, as was discovered when the functional descriptions were established as part of a previous task (Lee et al., 1997), the information within each subfunction varies widely. The strategy we eventually adopted involved categorizing the functions solely by the type of information they presented. This strategy resulted in the creation of six categories, summarized in table 1. This approach improved the clarity of each tool's decision points and reduced the number of decisions required to reach sensory modality allocation decisions. The simplified tools also resulted in more efficient use of the available research.

Sensory Modality Literature Review

Correctly choosing the sensory modality (auditory, visual, or tactile) for different in-vehicle displays is important to the overall effectiveness of ATIS. To make sound sensory mode decisions, designers must consider the user, the system, and the environment. The following paragraphs discuss research that is relevant to determining the advantages and disadvantages of using different sensory modes for different applications.

To help designers of all types of systems choose the best sensory mode of information presentation, Deatherage (1972) presented the following lists of accepted human factors guidelines. Use auditory presentation if:

- The message is simple.
- The message is short.
- The message will not be referred to later.
- The message deals with events in time.
- The message calls for immediate action.
- The visual system of the person is overburdened.
- The receiving location is too bright, or dark adaptation integrity is necessary.
- The person's job requires continual movement from place to place.

Use visual presentation if:

- The message is complex.
- The message is long.
- The message will be referred to later.
- The message deals with location in space.
- The message does not call for immediate action.
- The auditory system of the person is overburdened.
- The receiving location is too noisy.
- The person's job allows the person to remain in one place.

To achieve the objective of enhancing ATIS safety, visual attention demand must be minimized. Therefore, allocating supplemental tasks to the auditory modality (particularly in situations of high visual attention demand) might be the best alternative. One major advantage of auditory presentation in the driving environment is that information processing resources are allocated efficiently. Also, as Sorkin (1987) points out, the omnidirectional nature of auditory displays makes them the most desirable for alert and warning messages.

There is significant evidence to support the use of auditory displays in vehicles. Many authors have found that giving turn-by-turn directions via the auditory channel leads to quicker travel times, fewer wrong turns, and lower workload. Auditory displays also allow the driver to devote more attention to the primary task of driving, compared with route information being displayed on a visual map (Labiale, 1989, 1990; Parks, Ashby, and Fairclough, 1991; Streeter, Vitello, and Wonsiewicz, 1985; McKnight and McKnight, 1992). Additional evidence supports the notion that driving performance suffers when drivers are looking simultaneously at in-vehicle displays. Drivers tend either to fail to react to situations on the road (McKnight and McKnight, 1992), or to deviate from their course (Zwahlen and DeBald, 1986), or reduce their average driving speed (Walker, Alicandri, Sedney, and Roberts, 1991).

Additional research assessed the workload differences between information presented visually and information presented aurally (Labiale, 1990). The research showed that the workload was lower when navigation information was presented aurally than when it was presented visually, and that drivers preferred auditory information, stating that they felt it provided a safer system.

A study performed by Walker et al. (1991) gauged the safety of the drivers' performance while guidance devices that varied in complexity and mode of presentation were being used. The results showed that during high-load situations, subjects using auditory devices did not reduce their speeds as much as those using visual devices, and they also made fewer navigational errors than did subjects using visual devices. Also, the subjects using complex devices drove more slowly than those using simpler devices. This study indicates that, of the devices tested, the audio devices were somewhat safer to use than the visual devices, and moderate display complexity was generally preferable to higher display complexity.

On the other hand, there is also support for using visual displays in navigational tasks. Aretz (1991) makes the case that without a north-up map, drivers cannot construct an internal cognitive map of their routes. Therefore, a driver might arrive at a destination without having any navigational problems, yet have no idea of the destination's location relative to the driver's starting point or to other landmarks. Drivers prefer navigational systems that keep them informed of their current location (Streeter et al., 1985).

Dingus and Hulse (1993) cite some potentially negative aspects of using speech presentation in lieu of visual presentation for ATIS. These include: (1) improper prioritization and instinctive reaction to voice commands, even in cases where they conflict with regulatory information; (2) reduced intelligibility of low-cost speech synthesis devices; and (3) the inability of low-cost digitized speech devices to contain a vocabulary covering all desired information. In addition, the authors note that much of the information that will be provided by ATIS is too complex to be effectively displayed aurally.

Another consideration, according to Williges, Williges, and Elkerton (1987), and Robinson and Eberts (1987), is that for a spatial task such as navigating, performance is optimal when visual stimuli and manual responses are used. If the task is verbal, an auditory stimulus should be coupled with a verbal response from the person. These results suggest that for a navigation task, a visually displayed arrow indicating the direction of travel would be more beneficial than would verbal information (e.g., an auditory speech display).

Still another support of visual displays, especially in alert or warning situations, is the phenomenon of visual dominance. In a discussion of cross-modality attention, Wickens (1992) describes visual dominance as a human reaction that counteracts the automatic alerting tendencies of the auditory modality. It is a bias toward processing information in the visual channels when a person is concurrently being provided with auditory or proprioceptive information of the same importance. Behavior in these situations suggests that the subject responds appropriately to the visual information and disregards the cues provided by other modalities.

The safety implications associated with driver information systems are discussed in a paper by French (1990). The major concern of this research is the average glance time that is considered safe when the driver is looking at an in-vehicle display. It was found that a driver's average glance time is 1.28 s. Additionally, the guidelines included in French's paper indicate that glance times greater than 2 s are unsafe and unacceptable, while glance times between 1 and 2 s are considered marginally safe, and glance times under 1 s are considered safe. The information regarding glance time data was confirmed by Labiale (1989), who also found that the average glance times were 1.28 s, while 92.3 percent of all glances studied were less than 2 s.

One important measure of driver performance is the distance an automobile's path deviates from the center of the lane. In their study, Zwahlen, Adams, and DeBald (1987) examined the visual, safety, and performance aspects of operating a simulated cathode ray tube (CRT) touch panel display while driving at a constant speed along a straight path, a task that appears to be visually demanding. The conclusions of this research indicate that all visually demanding tasks can reduce driver performance.

Almost all of the literature reviewed indicated that operator performance could be improved by incorporating some combination of auditory and visual stimuli. Dingus and Hulse (1993) recommend that the auditory modality be utilized to: (1) provide an auditory prompt to look at a visual display for changing or upcoming information (thus lessening the need for the driver to scan the visual display constantly 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 either be checked or later referred to via the visual display). Labiale (1990) suggests that for driving safety, the optimal perceptual and cognitive solution seems to be a maximum seven- to nine-information-unit[1] aural message for road information, or an aural prompt to a simple map or other visual guidance presentation. Labiale (1990) also suggests that it would be useful if drivers could request a repeat of the aural message

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[1] Labiale (1990) defined a single information unit as a geographic entity name, a road type, a position or direction, an event cause or event consequence, a time or distance, or a proposed action. An example of an 8-unit message would be: traffic jam on I-80, speed limited to 45 mi/h.

if the information is complex. Robinson and Eberts (1987) suggest 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.

Wickens (1987) emphasizes the importance of coding display information redundantly in different modal formats. The redundant presentation of information in the auditory and visual modalities will accommodate transient shifts in noise in the processing environment (e.g., visual glare, background noise, verbal distractions) that may influence one format or another. Display format redundancy also accommodates the strengths of different ability groups in the population (e.g., high spatial ability versus high verbal ability).

The tactile channel is rarely used as the primary channel to transmit information; instead it is used as a redundant form of information presentation. The most common use of the tactile channel is the design of manual controls to provide feedback. Godthelp (1991) used an active gas pedal to provide feedback to the driver about automobile following distances. He concluded that a gas pedal that offers more resistance when the following distance is too short can increase following distances. This demonstrates that the tactile sensory channel is a viable method of providing selected information to drivers.

Unfortunately, no specific guidelines for tactile displays can be given. It can only be stated that an effort should be made to encode manual controls with tactile information. This will enhance feedback and enable drivers to manipulate controls without taking their eyes off the road. Therefore, designers of in-vehicle systems should seriously consider the use of tactile feedback displays. However, there is a great need for further research relevant to the use of tactile displays.

The majority of the research performed on in-vehicle systems has concentrated on the presentation of navigation and warning information. Many of the proposed functions of these types of systems could provide drivers with a wealth of useful information. As more applications are developed and integrated into working systems, researchers should continue to reevaluate the effects on driver performance.

Sensory Modality Criteria Development

Route Planning and Coordination

The route planning and coordination subfunction involves the coordination of long, multiple-segment trips. Coordination of these journeys may include identifying areas or points of interest, as well as accommodations, restaurants, and attractions. Because there is generally no need to plan this information after the trip has begun, designers can assume that most of these functions could be performed while the vehicle is stationary. Still, some of this information could be useful to the driver while traveling; therefore, dual-task attention requirements should be considered during the design stage.

The types of information that would be presented by this subfunction can be separated into two distinct groups. The first includes information about locations, pathways, or positions. Such information would enable the driver to preview a route or area and determine the relative positions of destinations, topographical features, or attractions. It could also include a global overview of a trip plan. In general, position information will usually result in the display of spatial location for different trip entities relative to each other.

The second group, discrete status information, includes costs, distances, times, and menu or scroll lists. These are discrete values or information items that may be presented alone or in combination, and in varying levels of complexity.

Complexity is a function of both the amount of information being provided and the difficulty involved in comprehending that information. Most of the functions included in the route planning and coordination category would be performed before the trip begins, while the vehicle is stationary. Complexity is not as important when the vehicle is stopped as when it is in motion. Therefore, 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 they can focus instead on standard human-computer interface issues. However, designers should still attempt to optimize display efficiency and ease of use, even when the information is to be presented while the vehicle is stationary.

Because of 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. However, care should be taken not to present more auditory information than the driver can retain in working memory. Miller (1956) estimated the working memory's capacity to be 7 ± 2 "chunks" of information. In a study that investigated the presentation of navigation information to drivers, Labiale (1990) also verified that for optimal performance, the maximum amount of information presented to drivers should be around seven to nine information units.

If the information on a display approaches the capacity limits of working memory, the system should include a method of recalling or representing the information at a later time. Displaying this information both visually and aurally would enable the driver to receive the information without adding to the visual attention load, and the information could be recalled at a later time if it is forgotten or misunderstood. There are areas within the route planning and coordination subfunction that require the display of complex information. This information can be most efficiently presented through the visual channel, because drivers can process detailed visual information more rapidly than they can process detailed auditory information (Deatherage, 1972).

Using the stated criteria, a sensory modality allocation design tool for route planning and coordination (appendix B, figure 3) was developed. As shown, the decision aid provides a step-by-step guide to the designer for the selection of appropriate sensory modalities for route planning and coordination information displays. An example associated with the sensory modality allocation design tool is also shown (appendix B, figure 4).

Route Following

The route following subfunction involves the presentation of information intended to guide the driver to a particular destination. Almost all of the information presented in this category would be displayed while the trip is in progress. Because of this, display designers must work to minimize the amount of driver attention and workload.

The types of information presented by the route following functions can be separated into two distinct groups. The first group includes information specific to the navigation task, such as spatial location or directional instructions (i.e., direction of next turn, or the vehicle's current position). The second group includes discrete status information (i.e., times, distances, and costs). It is necessary to distinguish between these two types of information, because the navigation displays will generally visually convey spatial information, and the status displays will generally utilize verbal information.

In the navigation function, two additional distinctions can be made. One is that the tool must be able to inform drivers of their current locations or positions. Drivers who have tested different in-vehicle navigation systems feel that it is very important to include position information, along with guidance for the next desired turn (Streeter et al., 1985). Another requirement is that the tool should guide the driver to a destination. Information should be presented in the form of instructions that help avoid driver confusion or navigational errors. The sensory modality that would best convey navigation or routing instruction information would vary with the level of complexity involved.

Position information can be simple or complex, depending on the level of detail being presented. If it is necessary to show the vehicle's position relative to multiple landmarks or routes, the display will be more complex. If the display is showing a distance and direction relative to a single landmark or route, it will probably be much simpler. Complex information can be presented most efficiently through the visual channel, because drivers can process detailed visual information more rapidly than detailed auditory information (Deatherage, 1972). However, information presented through the auditory channel requires no visual attention and is therefore generally less demanding for drivers while the vehicle is in motion.

Routing instructions would typically be presented to the driver before every required turn. Because the driver will be busy driving, the information should consume as little attention as possible. In the vast majority of cases, a complex display to present routing instructions is not required and should not be used. One of the few exceptions to this rule is the situation in which the driver is inadvertently off-route and requires additional information to navigate. Several authors (Labiale, 1990; Streeter et al., 1985; Parks et al., 1991) stressed the importance of limiting the amount of information presented to drivers while they are driving.

Vehicle status information consists of times, distances, costs, and associated lists. Time and distance values could be displayed either continuously or intermittently. For example, an effective continuous display would list the distance to the next turn at the top of the display screen and would increment the distance downward until the turn is reached. In contrast, a driver requesting an update of total time or distance remaining for the route would be best served by an intermittent display. A design consideration is that continuous information can decrease the salience of time-critical information and increase the required search and retrieval time. Additionally, continuous auditory information is likely to annoy the driver (Zaidel, 1991; Wierwille, 1993). Another design consideration is that in intermittent displays the driver needs to be alerted to the presence of new information, or the information might be missed.

The route following design tool is shown in figure 5 and an example appears in figure 6 (appendix B). During the development of this decision aid, the greatest difficulty involved interpreting and applying the current research on navigation applications. Much of the research concentrated on different performance measures. Some researchers determined a given display's effectiveness by measuring a driver's recall of instructions, while others determined this effectiveness by measuring navigation errors, completion time for a predefined navigation course, driver preferences, or lane deviations. All of these performance measures are important for evaluating the effectiveness of in-vehicle navigation systems. Yet, very few researchers have measured more than one or two of these variables, except when evaluating prototype systems. However, when prototypes are very different from each other, it is difficult to interpret the role that sensory allocation decisions have played in overall system effectiveness. Often, it is not clear whether the differences between systems resulted from sensory mode allocation or from strategic design differences. A possible goal for future research would be to develop a generic in-vehicle prototype system that would measure the effects of using different sensory modes (or combinations of modes) for different features, while keeping the base system constant. Such research could provide more definitive answers to sensory allocations questions.

Warning and Condition Monitoring

The warning and condition monitoring subfunction is intended to improve driving safety by providing information about roadway obstacles, advance warnings, and weather and road conditions. The creator of a warning information display must develop a design that will alert, but not startle, confuse, or annoy, the driver.

The priority of the information to be displayed will significantly affect the sensory mode selection. Higher priority warning messages should be presented in a manner that quickly commands the driver's attention and gives clear cues to the appropriate response. Generally, drivers must respond immediately to high-priority warning messages; therefore, presentation modes that reduce choice response times are favored. The choice response time is the time required to retrieve displayed information and decide on the response.

Medium-priority messages are used in situations that require a response at the earliest feasible opportunity. If a medium-priority message is not acted upon, there is a possibility for injury or equipment damage. Medium-priority messages are not as urgent as high-priority ones, so reaction time is not the most important factor. Drivers should be given as much relevant information as is advantageous, so that they can accurately assess the consequences of the situation. Information that is both thorough and clear is the essential consideration for medium-priority messages.

Low-priority messages are used to present advisory information that informs the driver of the existence of a potential hazard, even when danger is not imminent. This information should be presented in a manner that will not increase the accident potential by startling the driver or requiring too much attention. Since the message is not required immediately and does not notify the driver of imminent danger, the sensory mode used should minimize the display's intrusiveness and distraction potential, while still gaining the driver's attention in a timely manner.

The source of the warning should also influence that sensory mode selection. If designers know the source of a potentially dangerous situation, they can design the display to direct the driver's attention in a way that is most advantageous for resolving the situation. 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 somewhat more flexible. When they are presented on a CRT, they can direct attention inside the vehicle and provide a high level of detail. In contrast to the CRT, a HUD can provide information while maintaining the driver's visual attention on the forward external environment. Visual displays are not as effective as auditory displays at commanding a driver's attention, but when used in combination with an auditory alerting cue, they can provide fast response times and detailed information.

Tactile presentation modes might utilize partial or full manipulation of the vehicle controls, such as through an active steering wheel or brake pedal, or they might incorporate an alerting cue, such as a vibrating steering wheel. As an active control, tactile displays can provide salient information to the driver. Godthelp (1991) found that average headway was increased when drivers operated vehicles with accelerators requiring more force to accelerate when vehicle headway fell below a safe margin. This type of implementation proves that tactile/proprioceptive cues can be effective, but the amount and depth of information they can provide are generally limited.

Before the development of ATIS, warning message content only identified a problem. Now that more sophisticated information systems will be available in vehicles, designers should take advantage of the capability to present more useful information. Warning messages could describe in more detail the problem severity and the actions that drivers should take to resolve the problem. For the purposes of this report, this additional information is defined as context information. As an example, warning messages about a loss of oil pressure have traditionally been indicated by a lighted icon or a change on an analog dial. Future designs might use the same lighted icon and include a message about the actual pressure and the potential engine damage as a result of continued operation at that pressure. Additional detailed context messages could include the action to take to resolve the problem, such as "service engine as soon as possible," or "to prevent permanent damage, stop engine immediately."

The addition of contextual information to warning messages impacts the choice of sensory modality because of the increased amount and complexity of the information being provided. Using a traditional, dedicated, lighted icon to present a message about the wide variety of actions a driver may need to perform to resolve a situation would soon increase the number of icons beyond the limit of the driver's memory. Therefore, context information might better be displayed using a visual text or an auditory description.

Like all of the other ATIS portions discussed in this report, the display designs should be standardized system-wide, so that information can be displayed to drivers without confusion or ambiguity. This is especially important for the display of warning messages. For example, all messages of one categorization (priority, context required, etc.) could be displayed using the same sensory modality or combination of modes. Drivers would then have cues about the message category as they receive the message details.

The sensory modality allocation design tool for warning and condition monitoring and an example appear in figures 7 and 8, respectively (appendix B). The decision aid incorporates the aforementioned criteria into a decision tree format to increase usability for those designers not well-versed in human factors parameters.

Signing

Signing information in transit can be separated into two categories. The first includes the information a driver needs to operate the vehicle safely and legally. This information includes: speed limits, reduced-speed curves, and upcoming hazards. Information in the second category includes: roadway identification and navigation, destination distance, directions, and historical markers. Segregating these two groups distinguishes the relative importance of the information being presented. While most motorists would consider information in the second category to be important, it must be given a lower priority than information that aids drivers in their primary task of safely controlling the vehicle.

Complexity is a function of the amount of information being provided and the comprehension difficulty of that information. In determining the amount of information that can be effectively displayed at any given time, care should be taken not to present more information than drivers can retain in working memory. Wickens (1992) describes working memory as an attention-demanding store where people maintain information while evaluating, comparing, and examining different mental representations. To comprehend displayed information accurately, drivers must perform some or all of these functions. As previously described, the capacity of working memory has been estimated at approximately seven chunks of information by Miller (1956) and approximately seven to nine information units (e.g., roadway name) by Labiale (1990).

In many cases, displaying this information both visually and aurally would enable drivers to receive the information without adding to their visual attention load. In addition, the information could be recalled at a later time if it is forgotten or misunderstood. It is very important to minimize the complexity of displays in a signing system, because the system will be functioning almost entirely while the vehicle is in motion. Any unnecessary information would require driver attention and could create an unsafe condition.

If a signing system were to display every sign that currently exists in the roadway environment, the driver would become overwhelmed and frustrated by the quantity of information. In a normal driving situation, drivers employ natural selective attention when observing the roadway scene. MacDonald and Hoffman (1991) have theorized that, rather than completely processing all roadway signs, drivers initially give minimal attention to all signs and then process only those that have a higher importance in their situation. This ability allows drivers to naturally filter the information in the visual driving environment, and it acts as a safeguard against information overload. An in-vehicle signing system should also allow the driver to filter information selectively to the point where only critical information is being displayed. It is assumed that any information necessary for the safe operation of the vehicle would be important enough not to be filtered.

Whether or not the driver requests a piece of information should also influence the sensory mode chosen to display it. If information is to be presented automatically and is of lesser importance, it should be displayed visually, so the driver can review it when the attention demands of driving allow. The intrusive nature of auditory displays could quickly aggravate or overload a driver's auditory resources if too much unwanted or unnecessary information is presented automatically (Means, Carpenter, Szczublewski, Fleischman, Dingus, and Krage, 1992). If information has been requested, it should be displayed in the sensory mode that is appropriate for its complexity.

To date, little or no research has been performed to evaluate different methods of displaying sign information with an in-vehicle system. The resulting design tool and example shown in figures 9 and 10 (appendix B), respectively, are based on generally accepted human factors guidelines and principles and on existing research regarding the display of navigation information and sign comprehension. To assess system effectiveness and user preferences accurately, researchers should use prototypes of a signing system to clarify the decisions regarding the sensory mode to use for sign information display and the types of filtering that might be employed.

It should be noted that in developing the sensory allocation design tool for the signing function, no attempts were made to determine possible interactions with other ATIS components. It is possible that both the auditory and visual channels could become overloaded with messages from too many system components.

Communication and Aid Request

During the review of information requirements and the development of a matrix for sensory mode choices for communication and aid request system displays, it became apparent that two independent groups of information need to be displayed. The first group includes the contents of individual messages that are being sent or received, and the second group includes information about the function of the system itself. Examples of information in the first group might include the sender's name, time sent, time received, and the message itself. Message-system operation information might include a view of an electronic mailbox or a notification that a message has been received. These two groups provide different types of information: message content displays must be able to present long, detailed pieces of information, while message-system operation functions must be able to alert the driver to system activities, and provide the displays necessary for manipulating the system.

To choose the correct sensory modality for displaying communication and aid request information, the designer must also determine whether the message is critical or lower in priority. Critical messages should be displayed as soon as possible, while the display of lower priority messages could be delayed until it is convenient and safe to do so. Human factors guidelines defined by Deatherage (1972), Wickens (1992), and Simpson, McCauley, Roland, Ruth, and Williges (1987), recommend that longer complex messages be displayed visually for greater comprehension. A study that measured truck drivers' preferences of messaging system display formats currently used in Europe found that the users (both dispatchers and drivers) preferred a visual, text-based system over a speech-based system (Huiberts, 1989). The higher preference rating was based on four factors: the text-based system's ability to set up standardized messages and to integrate with other communications systems, its advantages for setting up an electronic mail system, and the higher comprehensibility of messages.

The visual presentation of detailed information does have some advantages with respect to comprehension and flexibility. Visual displays allow the driver to refer to information at a later time. Such displays can also present a larger quantity of data in a shorter period of time. However, because of the visual attention required by the driving task, any message that must be displayed 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 the use of an auditory speech display (Wickens, 1992).

The argument can be made that visual attention requirements should be minimized all the time by conveying 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 (Wickens, 1992; Stokes, Wickens, and Kyte, 1990; Wierwille, 1993). Speech displays are inherently intrusive and they tend to annoy the driver if they are used too frequently. In some applications of speech displays in aircraft, pilots have disabled the systems so they would not have to listen to the chatter of redundant or irrelevant messages. Because the current level of user acceptance for speech displays is so low (Wierwille, 1993), they should only be used when it is important not to increase a driver's visual workload. When speech displays are used, they should be accompanied by a visual representation of the message, which drivers could refer to at a later time to refresh their understanding of the details and to maximize comprehension (Wierwille, 1993; Wickens, 1992).

Message-system operation information can be categorized as either message system management or message event information. The message-system management category includes message accessing or storage, while the message event category includes messages sent or received notifications. Currently, no research exists to define the advantages and disadvantages of using auditory or visual displays to manage a message system in a motor vehicle. Research is needed to define the best way to display management function information.

Message event information can include set warnings or situation awareness messages of varying priority. Because of the similarities of message events and warning messages, previous research in the area of warning messages can help designers determine the optimal sensory mode allocation. Designers should consider the priority of the message event information. If a message is critical, the associated message-event notification should get the driver's attention, whether or not the display is actively being used to search for information (Huiberts, 1989).

Critical messages should be presented to the driver immediately. Examples of critical messages could include an ambulance dispatcher keeping the driver informed of emergency vehicle status, or a truck company dispatcher notifying a driver that the wrong cargo has been loaded and instructing the driver to return to base. Since the information is critical, an optimal solution would be to combine the omnidirectional and attention-demanding characteristics of an auditory display with the high comprehensibility of a visual display (Deatherage, 1972). Using a combination of display modes ensures that the driver's attention will be captured and that the message will be available for later reference. Another advantage of using a combination of display modes for critical messages is that if the vehicle is involved in an accident and one of the display systems is disabled, the chances are that the alternate system would still be functioning and the message could be displayed.

Display messages categorized as noncritical should notify the driver of a message event, but need not 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 such messages. In these cases, the driver merely needs to be reminded to check the messaging system when the next safe opportunity arises.

Very little research has addressed specific topics related to communication and aid request systems. Much of the literature reviewed for this section defined general human factors guidelines for display design. The sensory modality allocation design tool shown in figure 11 and the example shown in figure 12 (appendix B) reflect the results of existing research and the application of the theoretical determinations made in the literature.

It should be noted that when the sensory allocation design tool for the communication and aid request functions was developed, no attempts were made to determine possible interactions with other ATIS components. It is possible that either the auditory or visual channel could become overloaded with messages from too many system components.

<u>Motorist Services</u>

The motorist services subfunction is designed to provide the driver with information about services and attractions. 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 information service to find out about hotels, attractions, restaurants, and available services. The purpose of the motorist services subfunction 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-related information being displayed by other ATIS. Given this, the displays for this function should be designed such that they are less intrusive and can display information efficiently, to ensure availability for safety information display.

The motorist services information can be separated into two groups. The first group contains information such as the location of an attraction, which is given as an address or a global direction and distance. This information may be presented relative to either the vehicle or an intended destination. In general, position information presents spatial locations of attractions and services. The second group contains status, preference, and feature information, such as costs, availability, and hours of operation. These are discrete pieces of information that may be presented alone or in combinations of varying levels of complexity.

Motorist services information can be as simple or complex, based on the amount of information presented. Such information is complex if it contains more than seven to nine units or chunks (Labiale, 1990; Miller, 1956). By definition, individual information units include names of attractions or services, types of attractions, distances and times, costs, and individual features of attractions. As previously stated, complex information is displayed more effectively through the visual channel than through the auditory channel (Deatherage, 1972). However, because this information might be presented while the driver is busy driving, it might be necessary to simplify the messages into smaller units and display them through the auditory channel. This would prevent the messages from attracting attention away from the driving task, or from significantly increasing the driver's visual workload.

Status, feature, and preference information is composed of times, costs, and availability data for services and attractions. Times of operation and distances could be displayed either continuously or intermittently. For example, an effective continuous display would list the distance to an attraction at the top of a display screen and then have the distance increment downward as the vehicle approaches the attraction. An intermittent display could provide requested updates on the availability of accommodations at a particular destination. As previously discussed, whether a display is continuous or intermittent should influence the choice of the sensory mode. Information that is presented continuously through the auditory channel is likely to annoy the driver (Zaidel, 1991; Wierwille, 1993). When information is presented intermittently, drivers need to be alerted to its presence, especially when there is a chance that they will miss the display.

At this time, little or no research has addressed the issue of in-vehicle presentation of motorist service information. A large amount of information could be displayed by successfully providing this function. Research is needed to determine the types and amounts of information that can be displayed to drivers without interrupting the driving task. Additional research is needed to define the amount of information that drivers would prefer to have displayed at any given time. If the ability to advertise services and attractions through this system is fully developed, a method of filtering or limiting the amount of information being displayed would also be necessary; otherwise, drivers could soon be overloaded with in-vehicle commercial information. The sensory modality allocation design tool and corresponding example for motorist services information are shown in figures 13 and 14 (appendix B), respectively.

Trip Status Literature Review

Choosing the most appropriate trip status (predrive, zero speed, or in transit) for presenting information from the ATIS/CVO subfunctions is important to both the safety of the driver and the effectiveness of the system. To develop the trip status allocation design tool, a literature review of applicable issues was conducted. A number of articles and studies were consulted to obtain the foundation for the design tool. This section briefly reviews the objectives and major results of each article, and considers those results with respect to the development of a useful design tool.

The objective of the study by Dingus, Antin, Hulse, and Wierwille (1989) was to evaluate the attentional demand imposed by electronic navigation tasks. This study found that the driver's retrieval of complex information, such as cross street name, roadway distance, and roadway name, required a large number of relatively long glances at the display. However, even though the attentional demand associated with these complex tasks appeared to be high, the driving performance and behavioral measures did not strongly support the theory that driving performance would suffer while complex tasks were being performed. This led to the conclusion that, although greater visual attention may be required by some tasks, those tasks will not necessarily impair normal driving behavior.

Another study, conducted by French (1990), examined the safety implications associated with single glances to a driver information system. It was found that drivers' average glance time is 1.28 s. From the results of this study, French determined that glance times greater than 2 s were unsafe and unacceptable, glance times between 1 and 2 s were marginally safe, and glance times under 1 s were considered to be safe.

Labiale (1989) focused on the different methods of displaying road navigation maps and their influence on the cognitive performance of driving tasks. The results of this study indicated that whether or not the vehicle was in motion, maps displayed with written guidance produced a greater percentage of recall. The results also indicated that instructions were retained better if they were presented while the vehicle was stopped. Maps presented to the driver resulted in better performance if the maps contained the minimum amount of useful information. This was consistent with the drivers' preference for uncluttered maps. The study also found that the average glance time was 1.28 s (as with French, 1990), and that 92.3 percent of all the glances were less than 2 s. The major recommendation of this paper was that if map information is presented to the driver while the vehicle is moving, the map should be accompanied by auditory instructions. If the vehicle is stopped, the map should be accompanied by written instructions.

An additional study, conducted by Labiale (1990), attempted to determine ways to increase driving comfort and safety by decreasing the driver's mental workload and stress. This study indicated that driving safety was adversely affected when drivers were required to look away from the road. Also, long and complex information should be avoided, because it can cause mental overload if it appears at the wrong time. The study also found that drivers prefer auditory messages over visual ones, because they provide the driver with a greater feeling of safety.

A study conducted by Walker, Alicandri, Sedney, and Roberts (1990) discovered that the use of any onboard device adds to the demands of the driving task. This study examined how drivers' performance was affected by the use of several guidance devices, which varied in both complexity and mode of presentation. Of the devices tested, audio devices were somewhat safer to use than visual devices, and moderate display complexity was generally better than higher display complexity. The results also showed that compared with subjects who used visual devices, subjects who used auditory devices did not reduce their speeds as much during high-load situations and they made fewer navigational errors.

Wickens (1992) studied how people time-share when they must perform two or more activities in a short period of time. First, Wickens states that the ability to switch efficiently between activities is important. If given 10 minutes to perform two 5-minute tasks, an operator will achieve success if full use is made of the available time and no time is wasted in switching from one activity to the next. However, if given only 7 minutes to complete the two 5-minute tasks, an operator may be forced to process the tasks concurrently. If this is the case, three factors will influence the effectiveness of the multiple-task performance: confusion over the task elements, cooperation between task processes, and competition for task resources. Therefore, concurrent processing should be avoided while operating a vehicle. To ensure the safety of the driver, there must be ample time to complete both the driving task and any required or desired secondary task.

One important measure of driver performance is the amount by which an automobile's path deviates from the center of the lane. A study by Zwahlen et al. (1987) examined the visual, safety, and performance aspects of lateral lane position maintenance, while operating a simulated CRT touch panel display and driving at a constant speed along a straight path. Looking at and/or operating a CRT touch panel while driving a vehicle along a straight path appears to be visually demanding, if not dangerous, as demonstrated by the relatively high probabilities of lane deviation. The results of this study indicate that a driver's probability of exceeding a lane boundary while operating a simulated CRT touch panel are 3 percent and 15 percent for lane widths of 3.66 m and 3.05 m (12 ft and 10 ft), respectively. The authors conclude that in-vehicle CRT touch panel controls that require a number of consecutive eye fixations should be avoided. As investigated by this study, CRT touch panel controls and their sequential operation do not provide adequate driver safety performance.

A more general study by Zwahlen and DeBald (1986) investigated the safety aspects of simulated sophisticated in-vehicle information displays and controls, in terms of lateral lane position maintenance when driving along a straight path. Their results raise serious questions about the safety of introducing sophisticated in-vehicle displays and/or touch panels. According to the data compiled in this study, if a driver is driving 48.3 km/h (30 mi/h) on a highway with 3.66-m (12-ft) lanes and fixates on text within the vehicle for 2 s, there is approximately a 0.04 percent chance that the vehicle will deviate outside the lane. When the text reading time increases to 4 and 6 s, the chance of deviating from the lane increases to 1.10 percent and 8.69 percent, respectfully. The impact of lateral path deviations from the lane's center is much greater when a driver is driving on rural routes or on city streets with 3.05-m (10-ft) lanes. Based on these results, the authors recommend that sophisticated in-vehicle displays that require eye fixations of several seconds should be avoided.

Trip Status Criteria Development

An ATIS can provide a wealth of useful information to a driver. However, care must be taken to limit the amount of information displayed. Receiving complex, untimely, or distracting information could endanger drivers while they are operating a vehicle. Some drivers are good at self-limiting their secondary tasks (i.e., looking for a cassette or disciplining children in the back seat), while others are not. As examples, one look during a morning commute will reveal drivers swerving while combing their hair, talking on cellular phones, or cleaning up spilled coffee. Given that driving is an overlearned task that is highly automatic, drivers commonly overestimate the secondary-task workload they can handle and still safely operate the vehicle. In fact, the leading cause of accidents is driver inattention (National Highway Traffic Safety Administration, 1991). It is therefore necessary to limit the availability of some system functions to times when the risks associated with divided attention are lower. The trip status allocation tool (appendix C) was developed to aid in determining when during a trip information can be available to the driver.

As previously stated, the times when a driver must access information have been divided into three separate categories: predrive, zero speed, and in transit. Predrive information is presented only before the drive has started. At this time, the vehicle is stopped and in park, and the driver can direct full attention and manual control capability to the operation of the system, without concern for the driving environment.

The zero-speed category is similar to the predrive category in that the vehicle is stopped. However, the driver is in an active traffic situation and must devote some attention to the driving environment (e.g., while waiting at a stop light, some attention is required to monitor signal status) (Carpenter et al., 1991). In this situation, drivers are still able to devote nearly full attention to the system; however, the time available for the system is limited by the duration of the traffic control device or the cause of the zero speed condition. Therefore, operations available during a zero speed situation must typically take less time than those available during a predrive situation.

The in-transit condition occurs when the vehicle is in motion and the driver is handling the vehicle. All efforts must be made to limit the functionality of the in-transit mode to those tasks that: (1) do not significantly interfere with the driving task, (2) have convenience benefits that outweigh the cost (in terms of required driver resources), and (3) will be used relatively frequently.

The following paragraphs discuss the criteria used to create a design tool for the allocation of information requirements to the three trip status categories. Decisions are based on information value, information retrieval difficulty, manual control requirements, and the time sensitivity of the information.

All of the information that a well-designed ATIS presents can be considered useful; however, the system does not need to present all of that information to drivers while they are operating the vehicle. The value and cost (i.e., 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 full-trip planning functions, are complex and require more attention and are therefore high in cost. Such information should be displayed only when the vehicle is in park.

The value of some types of information may vary with context. To achieve the system goals, it may be necessary to display ATIS information that is not currently important (e.g., messages that are coming from a CVO message transfer system). Lower priority messages can usually be held until the vehicle is stopped or parked, and then presented. If the message has high priority (e.g., if it will change the path of the driver, or the sequence of deliveries), it might be necessary to display the message immediately. Therefore, the urgency of the information should be taken into account when determining the trip status mode for its presentation.

In other trip circumstances, the value of information may vary based upon individual needs, driver preferences, or individual trip requirements. In such circumstances, it may be practical to allow the driver to select the information to be displayed, or to ask the system to display information automatically on the basis of a set of criteria.

The effort required to retrieve information from a display should also influence the choice of trip status mode. For a visual display, valuable measures of effort are: the amount of glance time, and the combined number of glances required to retrieve the information. Some research has been performed to determine the amount of time that drivers can safely direct their attention away from the roadway. A visual display that requires frequent and lengthy glances might prevent the driver from adequately monitoring the driving environment. In fact, research has shown that deviation from the roadway lane center increases with longer eye-off-the-road time (Zwahlen and DeBald, 1986).

French (1990) determined that glances away from the roadway average around 1.28 s for normal drivers, and recommended that glances of more than 2 s be avoided. French’s recommendations agree with a study performed by Zwahlen et al. (1987) in which driver deviations from the centerline were measured while the drivers performed operations on a touch screen display. Based on this study, the authors state that it should not take more than four glances to completely retrieve information from a display. These values also agree with the average length and number of glances required for drivers to perform most standard in-car tasks, such as adjusting the fan (Wierwille, Antin, Dingus, and Hulse, 1988). Therefore, any display that requires more than four glances or requires glances longer than 2 s would require more visual attention than a driver could safely allocate, at least in some circumstances.

Another variable that should influence when the information is displayed is the need for manual inputs. Dingus, Antin, Hulse, and Wierwille (1988) found that the total required glance time more than doubled when one or more button presses were required to access information from a moving map navigation system. In one circumstance, subjects often had to perform one or more button presses to change the map zoom level to access the name of the next roadway along a route. Results showed that their average total display glance time was 12.1 s when button presses were required, compared with 4.6 s when the information was immediately available. Zwahlen et al. (1987) studied the effects of increased workload while making control inputs. They measured how much centerline deviation resulted when drivers performed an input operation on a CRT touch screen display. The results showed that the control inputs increased the amount of time that a driver's eyes were fixed inside the vehicle, and increased the chance of lane deviations large enough to cause an accident.

Recall that a zero speed situation exists when the vehicle is stopped during the normal drive. This category is designed to allow the display of more complex information without compromising the guidelines for visual attention demands. A major difficulty in developing the criteria for predrive, zero speed, and in transit allocations was the definition of an acceptable zero speed task duration. Some of the ATIS functions that drivers will desire or require during the drive will necessitate complex or detailed displays. Rather than reserving these functions for predrive situations, they could be made available to drivers during zero speed, when visual attention is not required for the driving task and the ATIS tasks are of relatively short duration (i.e., 10 s or less).

It is impossible to evaluate all of the zero speed conditions that exist in normal driving maneuvers. The vehicle may stop because of traffic congestion, or traffic lights, or simply because the driver has elected to pull over and stop. The most common cause of a zero speed event is a red light at a traffic signal. The average length of a red light is approximately 20 s; however, because vehicles may arrive after the light has changed to red, we cannot assume that all drivers will have the full 20 s. An estimate of the average stop duration at a red light is about 10 s. This number was used as a criterion for allocating information to the zero speed category, since it would result in successful retrieval in many circumstances. In addition, retrieval times that are significantly less than 10 s can be allocated to the in transit case (i.e., 4 glances maximum × 2 s per glance maximum = 8 s).

As discussed earlier, some of the information presented to a driver is time sensitive. To accomplish their functional goals, some ATIS components must present information while the vehicle is in motion. Navigation instructions, such as distance to the next turn and direction of the next turn, should be presented serially, giving the driver enough time to react correctly to each part of the instructions. It would not be feasible, for example, to wait until the vehicle is stopped to give the driver an instruction about an upcoming turn since a series of turns might be needed before the vehicle should be stopped. In addition, most warning messages should be presented immediately; waiting until the vehicle stops could have a negative impact on driver or vehicle safety.

Another possible future research topic is the difference in stopping/braking behavior drivers would exhibit when given the opportunity to gain access to zero speed information. For example, would a driver speed up to a stop light and brake quickly to allow more time retrieving zero speed information?

Another factor not addressed in the trip status allocation design tool is individual driver differences. Numerous studies have shown age-related differences in driver performance and ATIS performance. In addition, there are probably performance differences between commercial and private drivers, because of differences in training, age, and experience. However, the data are insufficient to establish criteria differences based on demographics. Even though some quantifiable performance differences do exist, several issues still remain regarding the safe allocation of information features, based on individual differences. These issues constitute a research gap that may need to be addressed in order to optimize the benefits of ATIS across a wide range of users.

DISPLAY FORMAT ALLOCATION

Literature Review

Directions are generally communicated from one person to another in one of two ways: a map or a list of instructions presented either verbally or in writing. Determining which display format option is better appears to depend on several different issues. The following is a discussion of the research relevant to these issues.

Bartram (1980) 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. In another study, Wetherell (1979) 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. Wetherell concluded that two factors could have caused these findings: (1) the spatial processing demands of driving, seeing, and orienting interfered with maintaining a mental map in working memory, and (2) subjects had a harder time maintaining a mental model of a map "learned" in a north-up orientation when they approached an intersection from any direction but north.

In a study conducted by Streeter et al. (1985), subjects who used a route list (a series of verbal directions) to drive a route through neighborhoods drove the route faster and more accurately than subjects who used a customized map with the route highlighted. In terms of attention required by a visual display, a well-designed turn-by-turn format requires less attention than a full-route format. A graphic turn-by-turn display presents only that information considered to be necessary; the turn direction, the distance to the turn, and the turn street name. This information is easy to display in a legible format that imposes a low attention demand.

McGranaghan, Mark, and Gould (1987) characterized route-following as a series of view-action pairs. The following is an example of a view-action pair. Information is required for an upcoming event (e.g., a turn), the event is executed, the information for the next event is displayed, the event is executed, etc. McGranaghan and his associates believe that for route-following, only the information for the next view-action pair should be displayed. In their opinion, any additional information is extraneous and potentially disruptive to the route-following task. There are advantages, however, to displaying an entire route. When the driving task requires relatively little attention, the driver can plan upcoming maneuvers. For complex routes, preplanning could alleviate much of the need for in transit preview (i.e., showing the map while the car is stopped and showing the turn-by-turn configuration when the car is in motion). Drivers may prefer to recall information and review it at their own pace.

A second advantage to in-vehicle route information involves maneuvers that happen one after another, such as two (or more) quick turns in succession. The information for the second turn may come up too soon for the driver to execute the second maneuver comfortably. If the route map is displayed, such an event can be planned in advance.

When selecting a turn-by-turn or route map visual display format, designers must ensure that the information is displayed in a usable and safe manner. If a route map is used, the designer must minimize the amount of information presented, so that the driver's attentional resources are not overloaded. Even when full-route map information is minimized, the literature is not clear whether driver resources will become overloaded during conditions that require a high level of driver attention.

These studies indicate that textual lists are easier to use than maps when drivers are navigating to unknown destinations. Note, however, that maps provide additional information (e.g., orientation information such as cross-streets) that textual lists do not. Therefore, the choice of a map or a list must depend on both the desired task and the required information. Depending on the system requirements, the inclusion of both display formats (displayed in different situations) may provide the most usable overall system.

A study performed by Mitchell (1993) investigated performance differences that resulted from using different types of displays to present navigation information. The results indicated that a pictorial route map (RP) was the worst way to present navigation information for in-car moving-map navigation systems. While using this map configuration, subject performance was consistently poor across all dependent measures. This poor performance could be due to a number of problems inherent to pictorial route maps. The presentation of entire route information may be overwhelming in actual driving situations, and should therefore be avoided when the vehicle is in motion. However, because pictorial full-route maps can offer drivers a valuable preview, they should be employed as a pretrip planning tool, made available only when the vehicle is stationary.

Mitchell (1993) found that subjects who used verbal maps tended to perform as well as those who used turn-by-turn maps and far better than those who used pictorial route maps. It was suggested that the lower performance of the pictorial route map usage might result from inconsistent information displays. Due to the limited amount of space available on the display, designers are likely to employ some type of algorithm for determining which information to display. Because route configurations are highly variant, the algorithm may be unable to display certain information items consistently. The findings also suggest that configurations that do not display full routes might prove more effective in terms of attention and information retrieval.

It is important to note that the current test and evaluation involved only static navigation screens. Several other factors must be considered if this study's findings are to be extended to real-world driving and navigation. For example, turn-by-turn configurations have certain disadvantages in dynamic systems. The dynamic system may not be able to present a series of close-proximity turns quickly enough for a driver to perceive, process, and react to the information effectively (Mitchell, 1993).

Results of Mitchell's study also indicate that the pictorial turn-by-turn map that displayed landmark information was most preferred overall. The other two pictorial turn-by-turn configurations with lane information presented separately from the intersection, or with just basic information about the intersection, were preferred over verbal maps and route maps (Mitchell, 1993).

Most of the results on navigation systems seem to support the recommendations outlined by Streeter (1985), which suggest that drivers should be presented with information that is most proximal to their location. Previous research also suggests that studying paper maps of a given route either substitutes for a cognitive map or aids in developing one. This cognitive map provides an orienting schema, which helps people organize information about an unfamiliar area (Antin, Dingus, Hulse, and Wierwille, 1990). Therefore, full-route information might aid drivers in the overall navigational task by helping them develop a cognitive map and survey knowledge of the area surrounding their route.

The auditory mode, if implemented effectively, has great potential for presenting complex information to the driver. Voice messages can elaborate on the information in the visual display, while allowing drivers to keep their eyes on the road. In addition, voice messages can indicate whether or not new visual information is available, so the driver need not glance frequently at the visual display to check for updates. Voice functions can be implemented as a supplement to visual displays, or as stand-alone systems.

General guidelines on when to use speech displays, has defined by Simpson et al. (1987), are:

- When warning signals are needed (because the auditory sense is omnidirectional).
- When there are too many visual displays.
- When information must be presented independently of head movement or body position.
- When darkness limits or precludes vision.
- Under conditions of anoxia (because visual acuity is more sensitive to anoxia than is auditory acuity).

Deatherage (1972) gives the following conditions for utilizing the benefits of speech displays:

- For identification of a message source.
- For listeners without special training in coded signals.
- When rapid, two-way information exchanges are required.
- When the message deals with a future time, requiring preparation.
- In stress situations, which might cause the operator to forget the meaning of coded signals.

The state of the art in selecting voice functions has not really progressed beyond this philosophical stage. Simpson (1983) and Williges and Williges (1982) independently added the following two items to the situations that would benefit from the use of speech displays:

- Spoken information should be highly reliable.
- Spoken information should be intended for use in the immediate future, because it is poorly retained in short-term memory.

To these we add a corollary to Deatherage's (1972) third reason for using speech:

- Use speech rather than nonspeech to eliminate the need to decode nonspeech signals, thereby minimizing the driver's information processing requirements.

According to Means et al. (1992), the precepts that can be applied to the design of an auditory interface to make it more palatable to a driver include:

- Minimize voice "chattering" and "nagging."
- Maximize voice intelligibility.
- Provide timely, useful information.
- Allow significant driver control of voice functions.

Drivers may not be receptive to the use of voice for a system warning unless the condition is urgent (i.e., they are about to collide with something). For example, to inform the driver of an open door, a nonverbal auditory signal or a telltale on the instrument panel is probably sufficient. A conservative approach should be taken for choosing the "personality" of an ATIS component. Anthropomorphism can be lessened by using voices that are more machine-like than human-like. Also, excessively long voice messages, or messages that exceed strict bounds of usefulness may be considered "chattering" or "nagging." Drivers are no more likely to take kindly to chattering and nagging cars than they do to passengers who exhibit the same characteristics. Also, drivers may want to suppress a voice system at times, and these wishes must be accommodated by giving the driver control over volume, as well as activation, of voice functions (Means et al., 1992). Auditory clutter, the term used by Stokes et al. (1990) to describe overuse of the auditory channel, can distract from the driving task. To minimize it, avoid using voice feedback to note correct maneuvers, driving speed, or system status (uses that are advocated by Davis, 1989).

The cognitive attention required to process auditory messages increases as intelligibility of the messages decreases. A number of factors influence intelligibility, including: speech rate, message length, message content, message complexity, background noise, pitch, and loudness (Van Cott and Kinkade, 1972; Marics and Williges, 1988). Many times, cost constraints will require the selection of synthesized speech, which is less intelligible than digitized speech. Although the quality of low-cost synthesized speech is constantly improving, factors such as tonal quality and inflection limit its relative effectiveness (Sanders and McCormick, 1987). Numerous researchers have tested various forms of synthesized speech; however, the state-of-the-art technology cannot yet deliver intelligibility/comprehensibility in all situations or environments.

Background noise, which affects both digitized and synthesized speech, is one intelligibility factor that is particularly important in an automobile. Noise in an automobile sometimes reaches 90 dB(A), making voice intelligibility impossible in some circumstances (Bailey, 1982). The noise in an automobile also comes from many sources, which have different masking properties (e.g., citizens band radios (CBs), cellular phones, stereo systems, conversation, and road noise), making it more difficult to alleviate the noise problem. Another consideration is that, while hearing is not a primary sensory mode for driving, there are situations when in-vehicle auditory displays could mask other important signals, such as railroad crossing bells or emergency vehicle sirens

(Lunenfeld, 1990). Designers therefore need to consider carefully the loudness, frequency components, and spectral content of the voice to be used.

In addressing some of the intelligibility concerns, Labiale (1990) recommends that when considering spoken messages, designers restrict the amount of information presented (seven to nine bits), or use the aural message as a prompt to a very simple visual guidance presentation. Labiale also recommends that the driver be able to repeat the aural message, especially if the information is complex.

An additional and potentially negative issue in the presentation of aural commands is that drivers may misinterpret the priority of the voice message. A study conducted by a Japanese automobile manufacturer indicated that drivers instinctively responded more strongly to verbal information than to visual information. This instinctive behavior was manifested in a tendency to follow the in-vehicle instructions, even if they conflicted with traffic regulatory information (e.g., turning the wrong way onto a one-way street) (Noy, 1991).

While voice presentation can alleviate the visual attention demand problems associated with navigation information, it has problems of its own. It is therefore recommended that the auditory modality be utilized to: (1) provide an auditory prompt to look at a visual display for changing or upcoming information (thus lessening the need for the driver to scan the visual display constantly in preparation for an upcoming event), or (2) accompany 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 solutions can reduce the visual attention demand of navigation systems without introducing the problems associated with sole reliance on voice messaging (Dingus and Hulse, 1993).

It should be emphasized that the driving task itself does not require a constant level of attention; some driving conditions require more attention than others (Mourant and Rockwell, 1970). For example, two-lane streets require more attention than do interstates; curved roads require more attention than do straight roads; and heavy traffic requires more attention than does light traffic (Hulse and Dingus, 1989). When the difficulty of the composite driving task exceeds the driver's attention capabilities, no amount of effort will keep performance constant. At this point, the performance of the navigation and/or driving tasks will begin to decline. To ensure that safety is maintained under all foreseeable driving circumstances, navigation information systems must require the least amount of attention possible.

Considerable research has been done regarding the use of nonverbal auditory warnings in aircraft cockpits (see Patterson, 1982, for a comprehensive discussion). Some of the knowledge accrued from aircraft research may pertain to passenger vehicles (e.g., appropriate volumes and temporal characteristics for auditory tones). However, principles guiding the use of auditory systems in aircraft must not be applied indiscriminately to passenger vehicles. It is important to bear in mind the essential differences between highly-trained cockpit personnel and automobile drivers, who range widely in age, driving ability, physical condition, etc. When ATIS become so commonplace as to be available to untrained drivers, the auditory signals used must be easily learned and must have minimal potential for confusion.

Parks et al. (1991) found that simple verbal instructions present the driver with the least distraction. Parks et al. conclude, "It is clear that maps are more difficult to use than simple text, symbol or speech instructions; even for the simple task of following a clearly highlighted route."

The TravTek ITS operational field test showed that about 74 percent of the time local drivers used a voice feature to supplement maps or icon displays, when given a choice. Rental drivers chose to use the voice function 90 percent of the time. TravTek featured five different navigation displays: (1) route map with voice, (2) route map without voice, (3) guidance with voice, (4) guidance without voice, and (5) voice only. Of the rental drivers surveyed, most preferred route map with voice and guidance with voice. Fewer preferred the route map without voice and guidance without voice, and the fewest preferred voice only (Fleischman, Thelen, and Dennard, 1993).

Tool Development

At this point in the design process the designer should know the trip status point sensory modality and functional grouping for presenting each piece of information relevant to the ATIS/CVO subfunctions. However, within one sensory modality there may be several different display formats for presenting information. For example, two global ways to present information visually are: (1) graphical or pictorial, and (2) text format that the user must read. Within these global classifications, categories that apply specifically to an information requirement (e.g., a graphical presentation of location information could be a full map with a lot of detail, a partial area map, a 3-D representation, or a simple arrow icon) can be described and assessed.

The display format design tool was developed using a trade study approach to provide a method for comparing feasible format alternatives for further consideration, rather than recommendations for the best way to present information within a category. The user of this tool should bear in mind that it was developed to work at a generic, categorical level; therefore, it sacrifices some decision-making resolution with respect to the presentation of specific information requirements. This design tool will suggest a format category that allows for a high degree of standardization across the functional groupings, based on specific characteristics of the information. However, results obtained from this tool may not match the standardization strategy that has been adopted by a designer; therefore, deviation from the suggested format may be necessary. Professional judgment should be used in applying the recommendations when the information requirement is specific and tends to be unique in comparison to its functional grouping.

Ideally, the designer should give further attention to determining the best design features within a category. Considerations such as different line weights, screen brightness, color, legibility, user preference, etc., should all be compared to find the best information presentation method. However, design tool development at this level of detail is beyond the scope of this project.

The display format allocation design tool is presented as a series of trade studies (appendix D). The tables contain the display alternatives for a given functional grouping and its associated sensory allocation pathways and the weighted decision criteria. The rankings and calculated weighted rankings are shown also. Appendix D contains the trade study tables. A short introduction to the trade study process is presented here.

Trade Study Process Overview

Due to constraints imposed by cost, techniques, etc., designers cannot always create designs that are optimal in every way. To meet one objective, they must often compromise another. Thus, throughout product development, designers must determine the combination of criteria that best satisfies the design objectives. A trade study analysis is a systematic approach used for identifying and prioritizing criteria to optimize a design. By using trade studies to evaluate alternative solutions, designers can avoid the tendency to go directly to a design based on their past experiences and can instead implement the product design that best satisfies the user's requirements. To ensure that evaluations are as rational and unbiased as possible, trade studies use a structured procedure as a framework (see figure 2).

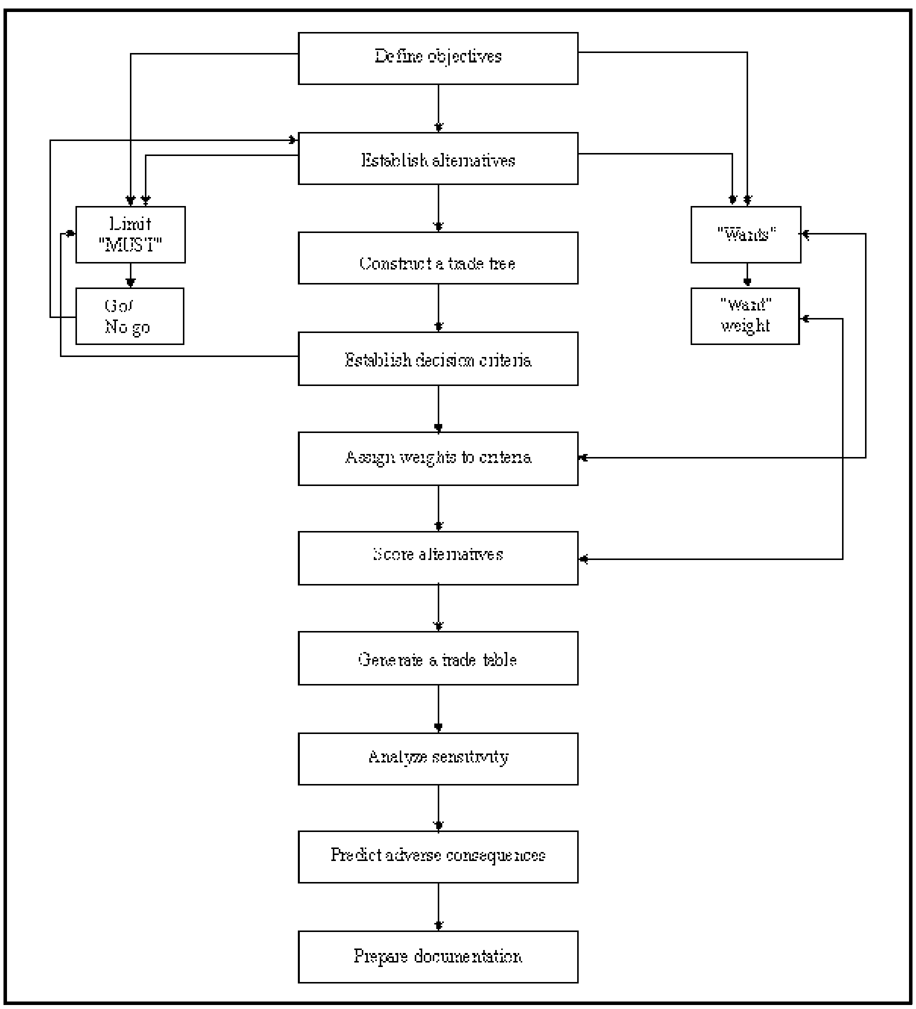


Figure 2. Trade study framework.

The steps presented in figure 2 are:

- *Define objectives*. Define the trade study's objectives in clear terms. This will provide a basis for selecting criteria.

- *Establish alternatives*. Consider all feasible approaches to achieving the design objectives.

- *Establish decision criteria*. The criteria provide a logical basis for selecting a solution. Typical criteria used in a trade study include: accuracy, lifetime, power output, low weight/low power, stability, sensitivity, bandwidth, reliability, cost, risk, user friendliness, and operational simplicity. For many systems, especially those that are relatively complex, there are many possible criteria. A design that is optimal for one criterion may not necessarily be optimal for another.

- *Assign weights to criteria*. Criteria weights, assigned *a priori*, range from 1 to 10, with larger numbers indicating the more important criteria. Weights must be assigned as objectively as possible, even though their assignment is a subjective process. To facilitate this process, it is often valuable to have multiple system experts independently weight the criteria and negotiate a final weighting.

- *Score the alternatives*. Two methods are commonly utilized to score alternatives. One method has one or more experts rate the design on a scale of 1 to 10 for each of the criteria. The second method has the experts rank the alternatives from highest (best) to lowest (worst). Particularly for complex analyses with large numbers of criteria and alternatives, the ranking method, performed either outright or via paired comparisons, appears to be as reliable as the scoring method and is easier to use. This is the most difficult and subjective aspect of the trade study process. Using multiple expert raters appears to provide the most reliable outcomes.

- *Generate a trade table*. A trade table helps calculate the weighted scores, which is obtained by multiplying the weight assigned to a criterion by the score for each alternative candidate. The candidates are then ranked by their total weighted scores across all criteria. As a rule of thumb, for a distinction in candidate scores to be meaningful, there should be at least a 10 percent difference in total score.

- *Analyze sensitivity*. In this step, the decision's sensitivity to changes in the values of attributes, weights, costs, and subjective estimates is determined. This analysis verifies that changes in the weights or scoring will reverse the decision and it assesses the sensitivity to changes in system requirements and technical capabilities. There are known cases where one or more of the following has occurred: (1) a trade decision was based on one alternative's narrow failure to meet requirements, or (2) a trade decision was based on cost, and the rejected alternative's cost was high only because of a minor change in capability. Such cases indicate the decision's sensitivity to requirements, and may not reflect the true objectives of the development. The impacts of relaxing the requirements are evaluated, and, where appropriate, recommendations are made for changes in the requirements.

! *Predict adverse consequences*. The adverse consequences of selecting the candidate solution are examined in this final step, to ensure that its selection will not adversely affect the overall design.

! *Prepare documentation*. Each trade study is documented in a report that shows the trade tree, describes the alternative candidates, and provides the justification for the selection. This report should also describe the changes in weights, scoring, or requirements that would revise the selection.

From these steps, designers can obtain the display configuration that best meets their criteria. A variation of this general approach, called the Kepner-Tregoe Analysis (KTA), is composed of the following steps:

(1) Identify alternative design solutions that meet all of your mandatory criteria.

(2) Identify secondary criteria that are important to the design.

(3) Weight the secondary criteria by importance (from 1 to 10).

(4) Score each alternative on each secondary criteria.

(5) Multiply each alternative's score on each criterion by the criterion's importance weighting.

(6) Sum the weighted scores for each alternative.

(7) Select the alternative with the highest score.

An example of the KTA method follows. Three design alternatives (A, B, and C) meet the mandatory requirements. A designer would obtain the result shown in table 2 by designating the weights and scores shown for the secondary criteria.

Table 2. Example of the KTA method.

Criteria (Want) \ Alternatives		A		B		C	
	WT	SC	WT*SC	SC	WT*SC	SC	WT*SC
Ease of use	10	05	50	06	60	10	100
Level of risk (low is best)	10	07	70	07	70	10	100
Reliability	10	04	40	02	20	10	100
Accuracy	09	08	72	10	90	10	90
Cost	06	05	30	05	30	10	60
Lifetime	06	09	54	09	54	10	60
Weight (low is best)	06	10	60	10	60	06	36
Minimum dimensions	08	08	64	10	80	05	40
Operational simplicity	10	07	70	05	50	10	100
Sensitivity	09	06	54	05	45	10	90
Total weighted score			564		559		**776**

WT: weight
SC: score
WT*SC: weighted score

In conclusion, the trade study analysis is a systematic and widely used tool for aiding designers in making complex design decisions. Both the standard and KTA methods are easy to use and have the following advantages:

- They provide an explicit decision model.
- They account for the varying importance of criteria.
- They provide a single score for each alternative.
- The KTA accounts for mandatory criteria, to eliminate alternatives.

However, the methods also have the following disadvantages:

- They rely on subjective data.
- The decision quality varies with the experience and biases of the system designers.

Trade study analyses can be accomplished using either the ranking or rating scoring method. The ranking method was used for each of the trade studies covered in this report. In cases where the number of alternatives being evaluated is high, ranking is generally used because of the difficulty in assigning meaningful rating magnitude difference estimates to a large number of alternatives. The subsequent sensitivity of the analyses can be affected by the choice between ranking or rating. This is overcome to some extent by the use of the weighted criteria. That is, since the ranked scores are multiplied by a weighting factor, sensitivity is regained in the product of the criteria weights and the ranks (with magnitude differences up to a factor of 10 for these analyses). The criteria weights are selected *a priori* in an attempt to provide a spread in the data that result in both sensitivity and meaningful difference. Based on our experience with similar analyses and comparison of selected results relative to known empirical data, we feel that the use of rankings produces valid results within the accuracy and resolution limits of the technique.

No matter what method a designer chooses, the trade study analysis, if properly executed, provides an objective and unbiased approach to alternative selection.

Criteria Development

The criteria used in the display format allocation design tool trade studies fit into three separate categories: safety, usability, and preference. These categories are broken down into specific elements that are operationally defined as being mutually exclusive from one another. The user of this trade study should keep in mind that the criteria were created to fit broad topic areas and not one particular display configuration. Therefore, the criteria only consider display advantages and disadvantages in the context of cognitive information processing aspects. It is not the intent of this trade study to distinguish the single best method of information presentation down to the level of font size, amount of information per screen, sound level, etc., all of which are sensory-related issues. To make comparisons at this level of detail requires direct evaluations of detailed design specification information. Instead, criteria have been developed to guide the designer to one or two format types that best fit the requirements of the given the situation. Operational definitions and corresponding weights of the format trade study criteria are as follows:

<u>Safety</u>

- *Distraction potential* (10). The potential that an information display will divert the driver's attention away from the primary task of driving.

- *Attentional demand* (10). The information processing resources required to retrieve the displayed information safely within the confines of the driving environment. Note: This is retrieval only, not the processing time needed to act on the information (which is covered under post-retrieval workload).

- *Post-retrieval workload* (8). The information-processing and decision-making resources required to respond to the displayed information.

<u>Usability</u>

- *Efficiency* (4). The time required to utilize the displayed information to perform the required task. This only includes the task completion times that are well below the threshold of unsafe conditions.

- *Error potential* (6). The potential of the displayed information to cause confusion and thereby increase the likelihood of errors. This includes the ease with which the information can be standardized and the expectancy of the inexperienced user.

Preference

- *Driver acceptance* (4). The relative partiality of a driver to a given format. This is operationally defined as any perceived positive aspects of a display format, excluding any annoyance aspects.

- *Annoyance potential* (6). The potential for a negative reaction toward the display, due to the frequency, reliability, or sensory characteristics of the information. Annoyance differs from attention distraction in that it refers to irritation or frustration rather than simply attention diversion.

The defined criteria were weighted based on their perceived importance to the human factors objectives of ATIS/CVO systems. The safety-related criteria tended to have the highest weightings, implying increased accident potential in circumstances of distraction or overload. In cases where the display presentation occurs during the predrive trip status, safety is no longer an issue, because both the time-critical and visual-overload elements of attentional demand are removed with the absence of the driving task.

Attention demand was given the highest weighting of 10 because this factor can interrupt visual scanning, which in turn creates the greatest accident potential.

Distraction potential and post-retrieval workload were weighted at 8 because they can still create accident potential. If a display were to cause significant peripheral view distraction (e.g., while using a moving map), it could divert driver attention away from the primary task of vehicle control and guidance. Distracting auditory displays may startle the driver, resulting in the same detrimental effect on driving performance. If the information presented to the driver is difficult to understand, or requires a high level of cognitive processing, the driver will have less, and possibly insufficient, resources to allocate to driving. Such distractions are less critical than visual distractions, but they still have the potential to affect the driving task, because there is a limit to the amount of information a driver can process. For example, a driver trying to choose between several suggested alternatives could become overloaded and could use poor judgment about following distance or gap acceptance.

Efficiency was weighted as a 4 because increasing the speed with which a driver can retrieve, process, and respond to displayed information makes the system more usable. Being able to navigate through the system quickly and efficiently will also increase the total number of tasks that can be performed in a given time period. This is different from post-retrieval workload and attention demand in that the time to process the information is not a safety issue. Take, for example, displays presented in predrive, where attention demand is not a safety issue because the car is not moving. The most efficient display format would win out in this trade study, based upon usability issues. The relatively low weighting of a 4 occurs because usability at this level does not have the higher costs associated with safety issues or other criteria that can lead to the system not being used.

Error potential was weighted as a 6 because a system that evokes a high error rate adversely affects the system's usability. Differences in the types or numbers of errors are likely to occur using one display presentation method over another. If the error rate is high, the user could become frustrated and might avoid using some functions in the future. Users tend to have preconceived notions about the way devices should work, so it is important that the information presentation match these notions. Closely related to this is the ability to standardize the presentation method across several system functions. Such uniformity will aid in error reduction.

Driver acceptance was weighted as a 4 because it only deals with the positive aspects of driver preference and is not really a performance issue. It is weighted low because it does not have safety or nonutilization effects on driver performance; however, it is still an important factor, because increased acceptance will lead to increased system use.

Annoyance potential, in contrast to driver acceptance, received a higher weighting of 6, due to the potential for the driver to ignore or disable the entire system if the information presentation is annoying. A system that annoys the driver to the point that the driver chooses to ignore it is equivalent to no system at all. Annoyance caused by only one element in a subsystem could cause the entire system to be deactivated. Care must be taken to account for user preferences that can cause such severe negative reactions.

Based on a review of pertinent literature, the different display formats within each functional grouping were rank-ordered from most desirable to least desirable. Most research performed to date compares a subset of all possible format options within a functional category. None of the research provides a complete, comprehensive review of all possible format options that are available, given the state of today's display technology. Because of this, the scores developed were based on general advantages and disadvantages evident across all published literature reviewed.

VISUAL DISPLAY LOCATIONS

Literature Review

A critical issue in the design of ATIS visual displays is the location of the displayed information. A poorly chosen location can hinder visual scanning and increase the required display glance time. In this section, we focus on the issue of optimizing display location. To accomplish this goal, consider not only location, but also a number of assumptions about basic display parameters, such as brightness and contrast. As will be discussed, these basic parameters drive other parameters, including display size and location.

Given the dynamic nature of required visual attention while driving, it is important to minimize the required glance time as much as possible. Research has shown that complicated information displays require relatively long glance times for drivers to extract information, especially older drivers (Pauzie, Martin-Lamellet, and Trauchessec, 1989; Dingus et al., 1989).

Dingus et al. (1988) found that while conducting most automotive secondary tasks, a driver's gaze switches about every 1.0 to 1.5 s. The farther the display location is from the roadway center field of view (FOV), the longer switching takes and the less time can be devoted to the roadway (Weintraub, Haines, and Randle, 1985) In addition, if the display is placed far away from the normal forward FOV, drivers cannot effectively use their peripheral vision to detect unexpected movement in front of the vehicle (Dingus and Hulse, 1993). Zwahlen and DeBald (1986) showed that deviation from the roadway lane center increases with longer eye-off-the-road time.

The position of visual displays was studied by Popp and Farber (1991). They found that when a display depicting relatively complex information was positioned directly in front of the driver, the driver performed better than when the same display was mounted in a peripheral location. However, when a sparse symbolic display format was used, the display position did not strongly influence driving performance.

Tarriere, Hartemann, Sfez, Chaput, and Petit-Poilvert (1988) suggested that a CRT display should be placed near the center of the dashboard and not too far below the horizontal gaze point. They stated that as a guide, the screen should be mounted at about 15 degrees below the horizontal, and for optimal driver comfort, should not exceed 30 degrees below the horizontal. A study by Hartemann and Favre (1990) also recommends that the display location should require no head movement and only minimal eye movement. Their suggested angles for vertical viewing were 15 to 30 degrees below the horizontal. In the horizontal plane, if the angle is less than 15 degrees, no head movement is required. If the angle is between 15 and 30 degrees, drivers will read more comfortably if they turn their heads. Finally, in nearly all cases, if the angle is greater than 30 degrees, drivers must move their heads. Helander (1987) agrees that for optimal driving and ATIS performance, in-vehicle displays should be located close to the front windshield, and he mentions that a tiltable screen or screen filter should be used to minimize screen reflections.

There is an abundance of research literature on HUDs. Though most of this literature concerns HUDs in the aerospace field (i.e., in cockpits), it might offer some guidance for in-vehicle visual displays. More recent research examining the effectiveness of HUDs in the driving environment has concentrated on the appropriate location for presenting the image, as well as on performance issues surrounding their use.

Campbell and Hershberger (1988) found that for both low and high levels of display complexity, steering variability was less for drivers using a HUD than for those using a traditional display panel. They also found that steering variability was minimized when the HUD's location was centered in the driver's horizontal FOV.

In their study, Liegeois and Twardowski (1988) found that there were two advantages to placing HUDs on the dashboard. First, this placement drastically decreases the time the driver takes to access the information, even when the display is peripheral to the driver's direct view axis. Second, it reduces the visual fatigue caused by numerous accommodations on the near dashboard. These researchers also had some suggestions about locating the holographic combiner; one combiner should be located at the periphery of the driver's FOV, and the other should be in the lower part of the windshield, centrally located between the driver and the passenger.

Wood and Thomas (1991) found that the windshield installation angle for the HUD should be 69 degrees, and the windshield curvature complexity should be a general third-order sphere. In their study, speed, fuel, temperature, turn-signal status, and warning symbols (brake, oil, seat belt, etc.) were chosen to be tested. The research found that there was a tradeoff between display FOV and head motion, with regard to a loss of display information. In addition, experience with the demonstration unit indicated that an instantaneous FOV of about 6 degrees vertically by 10 degrees horizontal provided a comfortably large FOV, and an exit aperture size of 10.2 cm by 10.2 cm (4" × 4") provides adequate head motion.

Greenland and Groves (1991) found that the best location for the HUD was centered in front of the driver and at a slight downward angle (within 15 degrees). This keeps it close to the driver's normal line of sight. HUDs may help older drivers who are farsighted, since the ideal HUD focus distance is considered to be a little more than 2 m from the driver. Because truck windshields are nearly vertical, the authors recommended using a separate combiner element as part of the HUD package, rather than the windshield. A separate combiner element would help prevent glare interference and low brightness. This design would also allow the HUD to be a completely self-contained unit, which in turn would allow the HUD to be placed in any convenient location in the vehicle .

Weintraub et al. (1984; 1985) compared the HUD at different optical distances with a traditional 10-degree downward instrument panel. They found that drivers using the HUD display had better decision times, reaction times, and eye reaccommodation than users of the 10-degree downward panel.

In their study, Sojourner and Antin (1990) compared speed monitoring, navigation, and salient cue detection for a HUD and a dashboard display. For salient cue detection, the subject response time was significantly less for the simulated HUD (mean = 0.57 s) than for the dashboard (mean = 1.01 s). However, the number of missed cues did not differ significantly between the two. Additional findings included a greater accuracy in the detection of speed violation; however, no differences were found with regard to navigation errors or perceived effectiveness. Also, several subjects suggested that the HUD be moved out of the direct line of sight, even though they had not used the HUD in any other location.

From the first part of the literature review, we can deduce the following general human factors guidelines for locating visual displays:

- For optimal driving performance, the in-vehicle displays should be located close to the FOV of the front windshield.

- A display positioned directly in the front of the driver will result in better driving performance than one mounted in a peripheral location.

- ! The CRT display should be near the dashboard's center and not too far below the horizontal. The optimal position for mounting the CRT screen is 15 degrees below the horizontal, and should not exceed 30 degrees.

- ! The vertical angles of comfort are between 15 and 30 degrees below the horizontal. The maximum horizontal comfort angle range is between 15 and 30 degrees left or right of the central viewing axis.

HUD Research Conclusions

- ! The HUD should be located in the center of the driver's horizontal FOV.

- ! The location of the holographic combiner can be located in one of two places: the periphery of the driver's FOV, or the lower part of the windshield in the middle between the driver and the passenger.

- ! An instantaneous field with dimensions of about 6 degrees vertical by 10 degrees horizontal provides a comfortably large FOV.

- ! An ideal HUD focus range is considered to be a little more than 2 m from the driver.

- ! Because truck windshields are nearly vertical, the HUD cannot be placed directly on them. Therefore, the combiner should be a separate part of the HUD package. This makes the HUD a completely self-contained unit that can be located in any usable and convenient position in the vehicle.

Tool Development

The amount and format of feasible information that a low-cost automotive HUD can successfully display is still being researched. It is conceivable that some circumstances will warrant both a HUD showing selected information, and an in-dash display showing more complex (e.g., predrive) information. It is also conceivable that despite its advantages, a HUD will not be feasible because of cost constraints. Because the current state of knowledge prevents accurate assessments of these issues, the trade study is constrained to a limited number of cases.

Three feasible and significantly different locations are available for a visual display in the automotive environment. These include a HUD, an integrated display in the forward instrument cluster, or a separate display at some distance from the forward FOV, usually to the right of the driver where radio and heating/ventilation/air conditioning (HVAC) controls are traditionally located. Based on the literature review, it is apparent that other display locations farther from the forward FOV have significant disadvantages and are therefore not considered.

HUDs project information into the driver's forward FOV. As previously discussed, a HUD allows drivers to keep their eyes forward so they can observe the information without taking their eyes off the road. A driver whose attention is focused on the roadway ahead can immediately detect potential hazards. Despite these advantages, there are a number of concerns about the use of HUDs in automobiles:

- Luminance may be a severely limiting factor, because of glare and cost restrictions. A HUD that is too dim and hard to read could be much worse than traditional dashboard displays.

- The information density and distraction potential must be carefully considered. For a driver the scenery is much more complex and detailed than for a pilot, raising automotive-specific concerns.

- Cognitive attention overload is an issue with HUDs. Just because a driver is looking ahead in this does not mean he is effectively processing roadway traffic information.

- An advantage of aircraft HUDs is that they are displayed at optical infinity, eliminating the requirement for accommodation. However, HUDs in cars are not at optical infinity; they are closer, eliminating some of this benefit. On the other hand, such benefits are not that great and may not even apply to automobile HUDs.

Additional research (Wickens, 1992) discusses the advantages of display integration. However, the variety of information types displayed in the automobile limits actual information integration. This limitation can be overcome by integrating the traditional dashboard information, by location and grouping, with ATIS information. A centrally located, integrated display follows the proximity and compatibility principle (Barnett and Wickens, 1988; Carswell and Wickens, 1987; Wickens and Andre, 1990), which states that, to the extent that information sources can be integrated, there will be an information processing benefit. That is, display proximity aids in information processing. Of course, an additional advantage of placing the display in the center of the FOV is the shortest scanning time from the roadway to the display.

It is clear that there are advantages and disadvantages to the three major location options. It is also apparent that in addition to the three primary options, a combination of a HUD and a dashboard display could prove beneficial, though expensive. So that we can rank the value of a combined display, we will include the options of a HUD plus integrated dashboard display and a HUD and separated dashboard display in the trade study analysis. Appendix E contains the display location trade study matrix.

Criteria Development

From the previous discussion, and from knowledge of the driving task, several criteria were deemed important for the selection of an appropriate display location. The definitions and corresponding weights of the criteria are as follows:

Legibility facilitation (10). The degree to which the display location facilitates information visibility. Visibility factors include contrast, brightness, glare, and signal-to-noise considerations.

Roadway/FOV compatibility (8). A measure of the feasibility of the driver being able to react to sudden external events if a significant portion of the peripheral FOV is still on the forward roadway while the driver is looking at a display.

Accommodation time (2). The time spent adjusting visually between the roadway and the display. If the location increases the driver's reaccommodation time, the driver will have less time to devote to the roadway.

Gaze shift distance (6). The shorter this distance, the less time spent in transition and the more time available to scan the roadway environment.

Display integration (6). Display integration reduces the number of gaze shifts required, thereby increasing available eye scanning time. Note that "display" in this case refers to the instrument panel and the roadway environment, since both require visual scanning.

Information availability to passenger (4). When present, a passenger can provide substantial support for ATIS-related functions. In addition, from a marketing point of view, passenger access to system functions may be desirable.

The stated criteria only include human factors considerations. Factors such as cost, space, the requirement for potential back-up systems in the case of HUDs, and other design constraints are also important, but are beyond the scope of this project. The weightings were assigned to each criterion based on its perceived importance to the human factors objectives of ATIS/CVO systems.

Display legibility was given the highest weighting of 10 because it is critical to both the safety and usability of the system. It should be noted that it is difficult to achieve good display legibility in the automotive environment. Therefore, any inherent display location features that can enhance this feature will be valuable.

Roadway/FOV compatibility was given a weighting of 8 because increasing the compatibility has the potential to impact safety.

Accommodation time was given a weighting of 2 because this time is quite short for shifts between in-dash displays and the roadway. However, an automotive HUD is not focused at infinity; therefore, some accommodation is still required.

Gaze shift distance was given a weighting of 6 because a system with a lower gaze shift distance requires less visual attention; therefore, safety may improve in some circumstances. However, the likely time savings will be moderate, even for complex tasks that require many shifts.

Display integration was given a weighting of 6 because greater integration improves information processing efficiency, thereby lessening the visual attention required. However, the degree to which the widely variant automotive information sources can be integrated, beyond proximity and functional grouping, is questionable. Still, moderate gains in efficiency can be expected.

Information availability to passengers was given a weighting of 4 because it has the potential to impact the safety and usability of the system. However, the system cannot be designed around the presence of a passenger. Passenger availability will probably increase system acceptance.

CHAPTER 4: DESIGN TOOLS APPLICATION RESULTS

SENSORY MODALITY AND TRIP STATUS RESULTS

The sensory allocation and trip status design tools were used to analyze each information requirement and determine acceptable presentation modes. Each information requirement was analyzed with the decision aid that matched its functional grouping. The results of such an analysis should tell the designer the optimal sensory mode for displaying any given information requirement (appendix F). While performing the analysis, it became clear that some of the decisions could take two different paths at a given decision point. In such cases, the designer must look closely at the decisions and ensure that both paths are investigated. Delving into the decision aid logic at a deeper level may reveal the more correct path for a given information requirement. For example, when a decision is based on complexity, the information requirement could feasibly be displayed with both high and low levels of complexity. An upcoming turn could be displayed as either a simple verbal instruction, such as "turn left on Dubuque Street," or a complex verbal instruction such as "turn left 152.5 m (500 ft) ahead at the stoplight, from Church Street to Dubuque Street." In such a case, the designer must choose the branch that would most effectively support the goals of the overall system. In this particular case, the information might be displayed in transit; therefore, a good general recommendation is to keep the presentation concise and meaningful.

There may also be points in the design tools at which the designer will want to follow both paths, noting any differences that are identified and the conditions under which they are valid. For example, a question on the signing function decision aid asks whether the information will be requested by the driver or will be displayed automatically. The information could be displayed either way, depending on the functional goals of the particular system. The designer should note the differences in the sensory mode that would be chosen, as well as the conditions that would make them valid. Later, when the display is actually being developed, the designer could make the proper sensory choice based on the result that is most applicable for the case being examined.

Some extraneous information requirements do not flow easily through the decision logic. An example is a display of the current filtering status for in-vehicle signing information. This status is relevant to the system, but it does not match the meaning of the other information requirements. Most of the requirements relate to sign information in the external environment. In addition, all of the decisions in the sensory allocation design tool are related to the sign information display, rather than to the system status. In this particular case, the designer can still answer the questions appropriately and come up with a usable sensory choice. However, some information requirements will need to be recategorized into other functional groupings that will more closely match the intended purpose of the information.

In general, the results of analyzing the information requirements with the sensory allocation tools show that using the auditory channel is desirable when the information is simple, or where there is some urgency associated with the message. The results also show that information requirements containing routing instructions should be displayed using either the auditory channel alone or a combination of the auditory and visual channels. The reason is that the driver can be presented with useful information without compromising the visual attention required for driving.

The visual channel is the best choice when information is complex or spatial. Combinations of the auditory and visual channel are effective for reducing post-retrieval processing time, reducing errors, and providing a more salient display that can command the driver's attention.

Following the analysis of the information requirements, there was some concern that the sensory allocation choices were not totally inclusive. For example, following one branch of the decision tree, the designer might end with a box that suggests auditory presentation when a successful system could be developed that does not use auditory presentation at all. The choices included were determined by examining the research that was available. The design tool is not designed to evaluate every possible display design, but rather to suggest one design or a combination of designs that have been determined to be effective.

DISPLAY FORMAT RESULTS

The recommended display formats are provided on an information-requirement by information-requirement basis by simply selecting the appropriate design tool and assessing the scores for each design option (appendix D). Because trip status was largely consistent within an information type category, the results of each trade study matrix only apply under the trip circumstances specified. That is, in order to avoid creating three times the number of matrices to account for just a few information requirement anomalies, only the trip status was considered.

For specific display modality recommendations, it would be best to consider the top two ranked displays, possibly even the top three, if the total scores are within about 10 percent of one another. The rankings, as well as the weightings are subjective, and the measurement tool has a relatively large degree of associated variance associated; therefore, close scores should not necessarily be seen as definitive differences.

The following paragraphs discuss the considerations and exceptions that were identified during construction of the matrices, as well as the general results of the trade study. The bolded headings correspond to the functional grouping headings in the trade study tables in appendix D.

Route Planning and Coordination

The information types included the route planning and coordination functions that are mostly intended to be performed in the predrive trip status. Because the driver would not be engaged in the driving task while using the system, safety criteria were not included in the design regarding an optimal display format.

For location, pathway, or position type information that is either complex or simple in format, 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 provide context to ease information transfer. In simple information situations, the use of speech improves the speed at which the supplemental information can be presented. Icon representations of complex information are ranked low, because of their inability to convey the needed information fully and efficiently.

For complex status-related information, text and icons with text were rated highest. Because spatial elements were no longer included, the information was often best presented with icon information that included a text description. Simple status information had three formats that were closely ranked: messages presented as speech, icon information with speech, and text with speech. In situations such as this with close ratings, standardization across the entire ATIS is a primary consideration.

In developing the ratings for the format alternatives for the route planning and coordination functions, it became clear that several areas require further research. Three-dimensional map displays have been mentioned in papers exploring alternative methods of displaying navigation information. Little empirical research is available to support judgments about the effectiveness of this type of display in meeting each of the criteria. Because of this, the rankings were based on the researchers' human factors judgment, given their knowledge of similar types of displays.

The sensory allocation decision aid suggested that the auditory channel could be used to display information in several routing and coordination situations. The use of simple tones for information presentation was not considered because tones do not offer the ability to provide the context or the complex message transmission capability that speech offers. In this functional grouping, even simple information cannot be effectively conveyed with tones or other nonspeech auditory options.

Route Following

Almost all route-following functions are performed during the in-transit trip status, so all of the criteria (including safety) were used for ranking the display format options. The navigation information typically displayed by the route-following function can be displayed on maps or graphic displays, through verbal instructions, or through combinations of visual and verbal instructions. If a hard copy was printed, it was assumed that the map or list was created during the predrive planning and that it would generally contain the same level of detail as the video display.

The route-following function offers a large number of feasible options, making the task of ranking the displays very difficult. Rank values were assigned by applying relevant results from previous research findings. No single study contained empirical results that covered the full range of display options. Therefore, extrapolations had to be made across differing experimental methods, creating a potential source for error in the rankings.

For complex navigation information that requires position information, partial-route video maps were generally chosen based on the criteria used. As the information complexity decreased, the trade study results pointed to simpler display formats that used icon representations of the information supplemented with speech or tones. For simple routing instructions, voice was ranked high with respect to safety, since the driver's attention focused on the driving task. The two top-ranked formats included voice, but they also required a visual element for referencing the information in more detail, or for preventing the voice message from having to be constantly repeated. Specifically, the presentation of simple routing instructions should include an icon with supplemental voice instructions. Visual text descriptions could also be used, if the information does not lend itself well to icon representation.

The format ratings for discrete status information highlights the elimination of the need for maps. Complex information of this type should use icon or graphical representations that include text descriptions. As the information becomes less complex, however, only icons or text are useful to convey the information; a combination of icons and text is not required.

For continuously displayed status information there was no clear winner. Text and icon combinations, icon or graphical representations, or text alone could probably all be used successfully, if properly implemented. It is assumed that continuously displayed information would be very simple, such as a count of accumulated travel time. Such information could be handled by a text display that only contained a few digits.

Warning and Condition Monitoring

Gradient levels of information priority fall into the warning and condition monitoring functional group. High, medium, and low levels of priority will often change the basic format of the display, based on the need to capture the driver's attention. This was taken into account for the ranking of the different display formats.

Tactile displays were deemed an option appropriate for this functional grouping. Tactile displays were grouped into vibration displays, such as shaking the gas pedal for a proximal incident warning display, and control-change displays. Control-change displays were operationally defined as tactile or proprioceptive displays that changed the resistance or feel of vehicle control. This definition was utilized because automatic controls do not really fall under the purview of ATIS. An example of a control-change display is an increase in resistance in the gas pedal pressure in a reduced-speed construction zone. Very little research tests vehicle systems that include control-change displays, simply because there aren't many systems available to test. Where context is not required, the results of the trade study show that control-change displays are rated fairly closely to audible warnings combined with an icon presentation as a desirable format option. However, a research study comparing the three options is required to validate this result.

Another area of unclear distinction is high-priority displays that required context information in order to be understood or acted upon. An auditory presentation was recommended. This modality has only one feasible option (speech), and combinations of options are available to provide context information. The rankings between the three suggested options for this case were very close. Therefore, for a given design situation, the differences between the displays may not be all that significant. Further empirical research is needed to distinguish between the different auditory methods of high-priority presentations in which context is required.

Signing

The display of signing information will likely be a dynamic process that has the potential to provide the driver with a very active in-vehicle display. It is anticipated that filtering the selected sign information will therefore be required. In addition, many of the more complex map displays were not considered as a presentation option for signing, due to the amount and complexity of such information. Partial maps could be used in some instances to provide integrated information.

When complex sign information is necessary for safe vehicle operation, an icon or graphical representation with supplemental voice is the preferred presentation method, based on the selected criteria. For the presentation of complex, requested informational messages, icon representation with a voice description was the clear winner over other presentation methods.

For less complex requested information related to safety, an icon presentation is rated high and equal to speech alone. Therefore, complex sign messages using icons/tones for more frequently occurring information and voice for more infrequent and important events should be considered the standard. As the sign information becomes less complex, use auditory information alone. A voice message with an alerting tone was the selected option.

Communication and Aid Request

Very little research addresses in-vehicle message transfer. The formats selected as options for this trade study were deemed to be feasible based on comparable systems and the known goals of this type of system. According to the results of the trade study, actual messages that contain critical information would best be presented with text on a video screen, with an alerting tone to let the driver know that the message is present. For lower priority messages, some standard information items could be relayed in the form of an icon, with a finer text description provided upon request.

For the message-system operation trade study analysis, the distinctions between format options became vague. This is an area that needs further research. The trade study found that for critical message events (e.g., “a message has been received”), text descriptions on a video screen should be considered, with the inclusion of voice or tone aids. This will alert drivers to specific events and allow them to read the message.

Motorist Services

There was a wide variety of display format options to consider in the motorist services functional group. Many different types of maps were considered, in addition to other visual display types. Combinations with audible displays were also considered. The recommended format can be highly situation-specific. In addition, due to the wide variety of information requirements within this functional grouping, the designer should take special care in applying these recommendations. Specific comparison trade studies at a finer sensory level may be necessary for motorist services information.

For complex, position-oriented motorist services information, three display methods should be considered: partial-route maps with a text description, partial maps alone, or some kind of icon presentation with a text description. The choice between the three options may be determined by the available screen size. However, this constraint was not considered by this trade study and may be a good topic for a comparison research study.

As the information becomes less complex, the addition of voice or tones to an icon or partial-route map may reduce the need to concentrate on the screen to receive the presentation. Once again, the choice of a display format may depend on the scale of the information being presented. If the information concerns the position of the vehicle relative to streets, cities, etc., then maps may be more useful than other options. Yet, in such cases, the information may be too complex for a display using icons.

Continuously displayed status information is best presented using text on a video screen, often as an alphanumeric display of low textual density. Intermittent complex information should be displayed as a graphic (when practical) with a textual explanation. As the intermittent information becomes less complex, the use of tones with icons, or even tones alone, should be considered.

VISUAL DISPLAY LOCATION RESULTS

As discussed in the previous section, the driving task requires constant visual environmental scans and potential responses to unexpected events. Therefore, a visual display must be placed such that it does not decrease the effectiveness and efficiency with which the driver can scan the environment.

From the display location literature review, we were able to generate several useful guidelines for display location. However, tradeoffs still exist between conventional and HUD technology, and between locations that are constrained by practical design considerations, such as cost, instrument panel availability, information requirements, etc.

The results of the trade study analysis (appendix E) show that the combination of a centrally integrated dashboard display and a HUD received the highest rating. The HUD alone and the centrally integrated display alone were also rated highly compared to the rest of the display location options with separate display components. It is clear from the location trade study that due to the visual processing inefficiencies inherent in separate displays located at some distance from the forward roadway FOV, other alternatives will likely be superior. Note, however, that all the other options require a significant redesign of the current automobile and will therefore be more costly.

CHAPTER 5: CONCLUSIONS

Four tools have been developed to help designers of ATIS/CVO displays make appropriate tradeoff decisions. The four tools are:

(1) *Sensory Modality Allocation*. This tool helps the designer determine which sensory modality or combination of modalities should be used to display the various kinds of information.

(2) *Trip Status Allocation*. This tool helps the designer decide what information can be displayed safely and effectively during the predrive, zero speed, and in-transit trip status classifications.

(3) *Display Format Allocation*. This tool helps the designer decide which display format should be used to display the information.

(4) *Display Location*. This tool helps the designer decide where to locate the different types of visual displays within the vehicle.

The tools are designed to be used together. Once the applicable determinations have been made, conceptual prototypes should be developed, and their information processing workload requirements should be assessed. The designer can then determine if the display is feasible, or if changes are required to maximize efficiency and safety.

TRIP STATUS, SENSORY MODALITY, AND DISPLAY FORMAT DISCUSSION

For each of the 400 information requirements, the specific trip status, sensory modality and display format results obtained using the procedures developed for this report are presented in appendix F. A general summary of the optimal choices, based on general information characteristics instead of detailed information requirements, can be found in appendix G.

During the predrive trip status, the sensory modality selected is either visual or a combination of visual and auditory. The complexity of the information being presented is the key decision point. Since the vehicle is not moving, safety is not a concern. The hazards of visual distraction and work overload have been removed; therefore, there is little reason to limit the use of visual-only information displays. In route planning situations, some spatial relationships between current location and desired destination are easier to show on a map than to explain in a verbal message. Plus, it is reasonable to plan a route before departure, and the need to interact with a vehicle is not a disadvantage if the vehicle is stationary.

It is interesting to note that the format of the visual component selected for route planning was not always a map. Text, on the contrary, is frequently used to describe locations, and a number of information requirements are too specific to be handled by a graphic alone. In addition, a written explanation often helps users who are not spatially adept to plan and execute routes.

As indicated by the information categories designated as in transit, once the destination has been determined and the driver begins the journey, the use of visual displays with no supplemental auditory information decreases. Because the driver must now devote visual attention to driving, as well as vehicle navigation and guidance, the use of visual-only displays must be curtailed. Note, however, that auditory displays alone are not necessarily what the driver requires. Results show that having a visual component to which the driver can safely refer will often prevent the audible message from requiring repetition. The use of icon representations of information with supplemental voice instructions for navigation will reduce the added visual attention typically required for maps. Another benefit of icon representation is that it reduces the distraction generated by peripheral motion from a moving route map.

Also, as shown, there are a few areas where auditory-only displays may be considered, namely message transfer situations and in-vehicle signing requests by the driver. Message transfer could be very visually distracting to a driver. Also, the length of a message plays a key role in the feasibility of visual presentation. A major problem with auditory presentation is the information overload and chatter that integrated ATIS are likely to generate. For example, according to these results, ISIS systems will make extensive use of the verbal channel. In addition, almost all of the information presentation for these systems will occur in transit. Given the amount of sign information currently in the environment, the overload and annoyance potential will be great, if these subsystems are not properly integrated.

The motorist services and information systems category covered the most diverse range of trip modes. Unlike the other categories, there was no single, clear trip status for this category. Much of the information provided by this function will be valuable while in transit. However, the inclusion of desired features requires that a global system perspective be used and that significant attention be paid to the possibility of overloading the driver. Several visual-only sensory presentations in the in-vehicle motorist services and information function are recommended, because the information is divided into small, discrete, noncritical units. This information can be safely displayed to the driver through graphic icons and simple maps or text. The danger comes not in the small informational units, but in the potential overload of too many small units. Many services could be displayed, and drivers could easily request more information than they should receive while driving. Some method of automatic filtering should be employed to prevent this potential hazard.

Warning and condition monitoring is the functional grouping that most often presents information to the driver while in transit. The optimal display formats tend to be auditory and tend to include more tones than do other functional areas, because of the simple nature of the information being presented. Often, the driver only needs to react to some discrete event that does not require context information to be understood. Because of this, tactile presentations are a viable method of information transfer in this functional grouping. While some research findings have shown the effectiveness of tactile warning displays, user preference is generally low. This is an area that requires research and advancements in technology before it can be viewed as a serious alternative to simple audible warnings.

Note that these recommendations must be applied with care, particularly when the trip status for an individual requirement differs from the general trend for other requirements in the same functional grouping. For example, in isolated instances, a route planning requirement specifies in-transit information presentation. In almost all other cases, route planning is performed during the predrive portion of the trip. As a result, the route planning decision aid developed for predrive cases only, does not consider the safety criteria associated with vehicle motion. Therefore, an informed adjustment in the decision aid (i.e., adding safety criteria) and in the resulting display format recommendation will be necessary if, contrary to the recommendations of this document, route-planning functions are to be performed while in transit.

VISUAL DISPLAY LOCATION DISCUSSION

The display location trade study results show that the combination of a HUD and a centrally located video dashboard display provides the optimal method of presenting visual ATIS information (appendix E). However, despite its advantages, this display option is the most expensive to include in the automotive environment. Where such costs are beyond the constraints of a given design, either a HUD or a centrally located dashboard display are attractive choices. Another issue with respect to these options is visual display format selection. A HUD must be analyzed for its compatibility with the display format chosen as well as the quantity of information to be provided. The current state of HUD technology does not allow the effective display of the amount of detailed information found on full-route maps. Information requirements that are simpler and require more frequent glances, such as icons and alphanumerics, are more suited to a HUD display. Information that requires more display resolution and possibly color coding should be allocated to a video screen display.

FUTURE ANALYSIS AND RESEARCH

As data were gathered from a number of similar studies to assess a given decision, it was often found that the results were contradictory, the measures were difficult to apply directly, or the study validity was questionable. In general, significant research is still required to understand fully the subtle tradeoffs of ATIS information display. Still, the existing body of literature proved invaluable for many aspects of the decision aid development.

Much of the ATIS/CVO research accomplished to date uses different performance measures. Researchers have determined a given display’s effectiveness by measuring a driver’s recall, navigation errors, predefined course, completion time, driver preferences, or lane deviations. Each of these performance measures has important implications for evaluating the effectiveness of in-vehicle ATIS. Unfortunately, very few of the researchers measured more than one or two of these variables. It is therefore recommended that future studies provide assessments of usability, safety, and preference/acceptance of multiple measures.

An issue that could not be effectively addressed by the trip status allocation decision aid is individual driver performance. It is well known that performance differences due to age and experience (e.g., commercial versus private drivers) will exist for ATIS. The following issues remain: (1) how best to quantify the differences operationally, and (2) how to allocate information features logistically, based on individual differences, while maintaining safety. The majority of research used to develop this report did not quantify the differences due to aging or driver experience levels and could therefore not be utilized to generate criteria for the design tools. This research gap may need to be addressed in order to optimize the benefits of ATIS across a wide range of users. Research is also required to determine the best way to counteract or alleviate the aging affects that reduce driver performance. Concentration on designing ATIS that enhance instead of degrade older drivers' mobility may prove useful.

Given the breadth of proposed ATIS, the likely market penetration, and the number of companies involved in ATIS design, system-wide standardization of information displays is somewhat critical. Standardization is especially important for the display of warning messages, to inform drivers without confusion or ambiguity. A major area of human factors ATIS research should therefore focus on the standardization of functions across many types of ATIS.

Additional research is needed to determine the effects of interactions between ATIS functions and subsystems. Now that more is known about what an ATIS is likely to become, varying degrees of ATIS functionality must be tested. Such research will be extremely useful compared with studies that test only an isolated set of functions.

Several research gaps were specifically identified as the ATIS design tools were built. In general, the tools were developed by applying principles generated from empirical research. Most of this research was based on literature reviews, with heavy reliance on the previous task reports completed for this project. The guidelines extracted from these documents were applied with varying degrees of confidence to the problem of ATIS display design. Some guidelines, such as the limits of short-term memory, were taken from basic psychological research. Other guidelines were generated from analyses of comparable systems. For example, much of the HUD research that led to the location trade study analysis described aircraft systems. Finally, a substantial portion of the IVHS and ATIS human factors research accomplished to date has addressed at least some aspect of information display.

One difficulty encountered in developing the criteria for the trip status design tool was the determination of an acceptable zero-speed task duration. This category is designed to allow for the display of more complex information without compromising the guidelines for visual attention demands. Some of the ATIS functions drivers will desire or require during the trip will necessitate complex or detailed displays. Rather than reserving these functions for predrive situations, the information could be made available to drivers during zero-speed time when visual attention is not required for the driving task, and the ATIS tasks are of relatively short duration (i.e., 10 s or less). The 10-s duration chosen for this decision aid was determined using what we currently know about the driving environment. The average stay at a red light is 20 s; therefore, one-half of this duration should create a useful environment for the majority of zero-speed situations. However, the actual amount of useful time that drivers will normally have available during zero-speed situations is a topic for further research

Another possible future research topic is the difference in stopping/braking behavior drivers would exhibit when given the opportunity to gain access to zero-speed information. For example, would a driver speed up to a stop light and brake quickly to allow more time for zero-speed information retrieval?

To date, little or no research has evaluated different methods of displaying sign information with an in-vehicle system. To assess system effectiveness and user preferences accurately, researchers should use prototypes of signing systems to clarify the decisions about: (1) sensory modalities and formats for sign information display, and (2) the filtering types that might be employed.

Similarly, very little research has addressed specific topics related to in-vehicle communications and aid request systems. Much of the communications literature discussed in this report was intended to define general human factors guidelines for display design. The applicability and transferability of these findings to an automotive environment and population requires further assessment.

Presently, little research has addressed the presentation of motorist service information. To provide this function successfully, it may be necessary to display a large amount of information. Research is needed for this function in order to define the amount of information that drivers would prefer to have displayed and are capable of processing 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 would also be necessary; otherwise, drivers could soon be overloaded with in-vehicle commercial information.

In the assessment of the routing and coordination functions, it became clear that several areas require further research to provide definitive answers to format selection questions. Three-dimensional map displays have been mentioned in research that explores alternative methods of providing navigation information. However, little empirical research is available to support judgments about the effectiveness of this type of display. The route-following function had the largest body of literature and also the largest number of feasible modality/format options from which to choose. No single study contains empirical results that cover the full range of display options. Therefore, a global metastudy, utilizing all feasible options, may prove useful in refining and validating the design tools for route following.

CONCLUDING THOUGHTS

In general, we feel that the development of design tools holds great promise in helping to achieve the ultimate project goal of useful and usable human factors guidelines. At the beginning of this process, we anticipated that a greater number and breadth of gaps would be present in the final product. The primary reason that these gaps were not as pronounced as expected was a willingness to: (1) apply research and guidelines from comparable systems and circumstances, and (2) rely on the human factors judgment of multiple experts in making some of the more difficult decisions. We feel that the result is a significant step in the right direction, but one that requires additional expert scrutiny, validation research, and “gap-filling” empirical research to complete the process.

APPENDIX A: INFORMATION REQUIREMENTS AND CRITICALITY ASSESSMENT ANALYSIS

Table 3. Criticality assessment while driving, for IRANS.

IRANS	
Information Requirement	**Criticality Assessment**
Trip Planning	
Current criteria for automated trip planning	neither required nor desired
Time to get to each destination from previous destination	desired
Cost of each toll along the route	desired
Total toll charges along the route	desired
Total time for trip	desired
Estimates of mileage	desired
Locations of attractions and points of interest	desired
Forecast weather information	desired
Historical traffic information	desired
Street or roadway names on the route	required
States, regions, communities, and districts along the route	neither required nor desired
Landmarks or topographical features along the route	desired
Number of turns or roadway changes required	neither required nor desired
Types of roads used on the route (interstate, highway, etc.)	desired
Distance to each destination from previous destination	desired
Distance to specific attractions	desired
Trip Planning CVO-Specific	
Scheduled pickup and delivery time	desired
Time of day restrictions	desired
Day of the week restrictions	desired
Restrictions related to size	desired
Restrictions related to weight	desired
Restrictions related to height	desired
Restrictions related to equipment type	desired
Restrictions related to cargo	desired

Table 3. Cont'd.

IRANS	
Information Requirement	**Criticality Assessment**
Multimode Travel Coordination and Planning	
Bus, train, airline, ferry, and trolley schedules	neither required nor desired
Real-time schedule updates for alternate transport modes	required
Location of park and ride facilities	neither required nor desired
Park and ride parking facilities	neither required nor desired
Combined travel mode schedules	neither required nor desired
Start time required to catch other mode of transport	neither required nor desired
Arrival time at destination	desired
Arrival time at end of each segment of travel	desired
Layover time between travel segments	desired
Mode of travel to take for each segment of travel	desired
Current constraint or optimization criteria mode	neither required nor desired
Total time to complete travel	neither required nor desired
Car pool instructions	neither required nor desired
Car pool requests/inquiries	neither required nor desired
Car pool member and address information	neither required nor desired
Car pool member community and district information	neither required nor desired
Minimum layover required to make next connection	desired
Notification of plan change to arrive at destination on time	desired
Interesting things to do during layover	neither required nor desired
Alternate mode ticket purchase enroute to destination	desired
Schedule of segment arrival and departure times	desired
Order of trip segments	neither required nor desired
States, regions, communities, and districts on the route	neither required nor desired
Segments by type of transport mode	neither required nor desired
Park and ride costs	neither required nor desired
Diagrams of alternate transport mode facilities	neither required nor desired

Table 3. Cont'd.

IRANS	
Information Requirement	**Criticality Assessment**
Parking instructions for using different travel modes	neither required nor desired
Location of next segment of travel	neither required nor desired
Area view of all segments of travel	neither required nor desired
Notification of unanticipated delays	desired
Alternate mode of transport ticket availability	desired
Multimode Travel Coordination and Planning CVO-Specific	
Schedule for transport of cargo	neither required nor desired
Transfer of information between alternate mode carriers	desired
Present location of modes of transport	desired
Regulations regarding mode of transport changes	neither required nor desired
Alternate mode of transport schedules	neither required nor desired
Real-time updates to alternate modes of transport schedules	required
Availability of alternate mode shipping space	neither required nor desired
Reservation of alternate mode shipping space	neither required nor desired
Size and weight constraints for alternate modes of transport	neither required nor desired
Facilities diagram for alternate modes of transport	neither required nor desired
Alternate mode of transport cargo tracking	desired
Alternate mode of transport status updates	desired
Costs of cargo transfer	desired
Costs of shipping on alternate mode of transport segment	desired
Total cost of transport using alternate route	desired
Predrive Route and Destination Selection	
Listing of routes and roadway names	required
Listing of available route optimization routines	neither required nor desired
Routing constraints (cost, time, etc.)	neither required nor desired
Distance to destination	desired
Time to get to destination	desired

Table 3. Cont'd.

IRANS	
Information Requirement	**Criticality Assessment**
Cost of completing route	neither required nor desired
Notification of a more optimal alternative route	desired
Preview of proposed alternative route	neither required nor desired
Historical congestion information	desired
Real-time congestion information	desired
Location of tolls	desired
Weather forecast information	desired
Regions, communities, and districts the route will traverse	neither required nor desired
Landmarks along route	desired
Predrive Route and Destination Selection CVO-Specific	
Notification of regulatory boundaries	neither required nor desired
Time of day restrictions	required
Day of the week restrictions	required
Restrictions related to size	required
Restrictions related to weight	required
Restrictions related to height	required
Restrictions related to equipment type	required
Restrictions related to cargo	required
Dynamic Route Selection	
Updated traffic information that might affect the route	required
Updated weather information that might affect the route	desired
Notification that driver is off route	required
Suggested procedure for getting back on route	required
Vehicle's current position	required
Weather forecast	desired
Cost comparisons between current and alternative routes	desired
Type of road (interstate, two lane, controlled access, etc.)	desired

Table 3. Cont'd.

IRANS	
Information Requirement	**Criticality Assessment**
Time to complete current route versus proposed route	desired
Directional heading information (North, South, East, West)	desired
Real-time road surface condition information	desired
Dynamic Route Selection CVO-Specific	
Time of day restrictions	required
Day of the week restrictions	required
Restrictions related to size	required
Restrictions related to weight	required
Restrictions related to height	required
Restrictions related to equipment type	required
Restrictions related to cargo	required
Route Guidance	
Distance to next turn	required
Name of street or route to turn on	required
Lane suggestion for setup of next turn	desired
Direction to turn	required
Name of current street	required
Indication that the driver is off route	required
Total distance remaining to destination	desired
Time to next turn at current speed	desired
Distance to toll booth	desired
Cost of toll	desired
Type of road (interstate, two lane, controlled access, etc.)	desired
Diagram of next intersection	desired
Max speed to negotiate exit ramp safely	desired
Directional heading (North, South, East, West)	desired
Total estimated time to reach destination	desired

Table 3. Cont'd.

IRANS	
Information Requirement	**Criticality Assessment**
Location of major landmarks (to aid in identifying turns)	desired
Route Guidance CVO-Specific	
When the vehicle needs to get in lane for turning	required
Sharp-turn indicator for larger vehicles	required
Route Navigation	
Distance to get to destination	desired
Time to get to destination	desired
Cost to get to destination	desired
Indication when a driver gets off route	required
Streets or roadways that make up the new route	required
States, regions, communities, and districts on the route	desired
Landmarks or topographical features along the route	desired
Number of turns or roadway changes required	desired
Notification of incidents along the route	required
Areas that the new route will traverse	desired
Description of incidents along the route	desired
Notification of accidents along the route	required
Updated weather information for the route	desired
Type of road surface (dirt, gravel, etc.)	desired
Type of road (interstate, two lane, controlled access, etc.)	desired
Current elevation	desired
Degree of curvature in the road	desired
Road construction along the route	required
Types of roadways and streets the new route will use	desired
Presentation of reroute options	desired
Indication that a faster route exists	desired

Table 3. Cont'd.

IRANS	
Information Requirement	**Criticality Assessment**
Automated Toll Collection	
Current toll cost	desired
Remaining balance in toll account	desired
Number of tolls left to be paid along the planned route	desired
Notification of successful toll charge	required
Interface to buy more credits	desired
Automated Toll Collection CVO-Specific	
Vehicle type	desired
Vehicle length	desired
Vehicle weight	desired
Time of day	desired
Route Scheduling CVO-Specific	
Optimize delivery schedules	neither required nor desired
Customer's preferences	neither required nor desired
Driver preferences	neither required nor desired
Most efficient manner to load/unload cargo	neither required nor desired
Weather forecast	desired
Historical traffic information	desired
Scheduled pickup and delivery time	desired
Time of day restrictions	desired
Day of the week restrictions	required
Restrictions related to size	required
Restrictions related to weight	required
Restrictions related to height	required
Restrictions related to equipment type	required
Restrictions related to cargo	required
Destination attractions, services	desired
Destination accommodations	desired

Table 4. Criticality assessment while driving, for IMSIS.

IMSIS	
Information Requirement	**Criticality Assessment**
Broadcast Services/Attractions	
Listing of drivers interests and preferences	desired
Indication of IMSIS system status (on, off, etc.)	required
Preferences mode for which service is to be broadcast	desired
Restaurant locations and costs	desired
Restaurant reservation availability	desired
Restaurant reservation establishment	desired
Services information (fuel prices and availability)	desired
Distance to attraction, restaurant, accommodation, service	desired
Attraction location	desired
Attraction description and costs	desired
Attraction hours of operation	desired
Attraction ticket availability	desired
Accommodation location	required
Accommodation description and costs	desired
Accommodation reservation availability	desired
Services/Attractions Directory	
Directory (index of yellow pages)	desired
Description of type of service/attraction provided	desired
List of services that are open	desired
Closest service	desired
Closest, open service	desired
View currently selected preferences	desired
Address of service/attraction	required
Phone number of service/attraction	required
List of alternate related services	desired
Restaurant locations and costs	desired

Table 4. Cont'd.

IMSIS	
Information Requirement	**Criticality Assessment**
Restaurant reservation availability	desired
Restaurant reservation establishment	desired
Services information (fuel prices and availability)	desired
Attraction description and costs	desired
Attraction hours of operation	desired
Attraction restrictions	desired
Attraction ticket availability	desired
Attraction ticket purchase	desired
Accommodation location	desired
Accommodation description and costs	desired
Accommodation reservation availability	desired
Accommodation reservation establishment	desired
Services/Attractions Directory CVO-Specific	
Vehicle restrictions	required
Information from truckers' atlas	neither required nor desired
Destination Coordination (Assumes Destination was Determined using Service/Attractions)	
Cost of parking nearest to destination	desired
Transportation availability from parking to destination	desired
Routing from destination to parking	required
Directions from parking destination	neither required nor desired
Payment methods supported	desired
Reservation details (number in party, time of arrival)	desired
Real-time time of arrival updates	required
Diagram of parking facility	neither required nor desired
Parking hours of operation	desired
Other transportation available from parking to destination	desired
Notification of transport arrival	desired

Table 4. Cont'd.

IMSIS	
Information Requirement	**Criticality Assessment**
Destination Coordination CVO-Specific	
Schedule changes from both dispatch and customer	required
Message Transfer	
Instructions for sending preset messages to other drivers	neither required nor desired
Select to whom the message will be sent	desired
Review received message	desired
Alert driver that a message is being sent	desired
Alert driver that a message has been sent	required
Alert driver that a message has been received	required
Retrieve saved messages	desired
Delete messages	desired
Recipient name for sent message	required
Name and access numbers	desired
Message response notification	desired
Notify driver that a response to message is required	desired
System operations mode (on/off)	desired

Table 5. Criticality assessment while driving, for ISIS.

ISIS	
Information Requirement	**Criticality Assessment**
Roadway Sign Guidance Information	
Sign information (street signs, regulatory signs, interchange graphics, route markers, and mile posts)	required
Sign information associated with driving to the destination	desired
Filter status information (status mode)	desired
Roadway Sign Guidance Information CVO-Specific	
Specific sign guidance (truck routes)	required
Delivery location (e.g., unload cargo in Bay #3)	required
Roadway Sign Notification Information	
Inform driver of potential hazards	required
Inform driver of changes in the roadway (merge signs, etc.)	required
Inform driver of temporary or dynamic changes in roadway (road closures, etc.)	required
Inform driver of distance to a notification point in question	required
Filter status information (status mode)	desired
Roadway Sign Notification Information CVO-Specific	
Road change information (steep grade, etc.)	required
Roadway Sign Regulatory Information	
Inform driver of regulatory information (stop signs, speed limits, yield signs, turn prohibitions, and lane use control)	required
Roadway Sign Regulatory Information CVO-Specific	
Specific regulatory information for CVO (truck speed limits, etc.)	required

Table 6. Criticality assessment while driving, for IVSAWS.

IVSAWS	
Information Requirement	**Criticality Assessment**
Immediate Hazard Warning	
Inform driver of the location of the hazard	required
Inform driver of the distance to the hazard	required
Inform driver if a route is available to avoid the hazard	desired
Inform driver of the type of hazard	desired
Inform driver of the approach of emergency vehicles	required
Warn driver of accident immediately ahead	required
Warn driver of a stopped hazard immediately ahead	required
Inform driver of the location of specific localized incidents	desired
Location of the vehicle	desired
Status of the hazard	desired
Inform the driver of action required to get out of the way of an emergency vehicle	required
Road Condition Information	
Inform the driver of road traction, visibility, congestion, construction activity, or weather conditions	required
Distance to congestion or construction activity	required
Route to avoid the congestion or construction activity	required
Suggestions for driving in low visibility or weather conditions	desired
Inform driver of relevant information regarding bridges	desired
Inform driver of strong crosswinds	desired
Type of road surface (dirt, gravel, etc.)	desired
Inform driver if water is flowing over the road	required
Automatic Aid Request	
Location information	neither required nor desired
Inform driver of time until emergency unit will arrive	neither required nor desired
Inform driver that aid has been requested	neither required nor desired
Inform emergency services of hazardous materials	neither required nor desired

Table 6. Cont'd.

IVSAWS	
Information Requirement	**Criticality Assessment**
Inform emergency services of cargo type	neither required nor desired
Manual Aid Request	
Location information	neither required nor desired
Inform driver of time and distance until emergency unit will arrive	neither required nor desired
Phone number of fire, ambulance, police, towing	neither required nor desired
Inform driver that phone will automatically dial requested aid if desired	neither required nor desired
Display messages from the emergency response center	neither required nor desired
Update real-time information from emergency response center	neither required nor desired
Vehicle Condition Monitoring	
Inform driver of current problems	required
Inform driver of ways to correct the problem	neither required nor desired
Inform driver of action to take until problem can be corrected	desired
Provide more detailed information at driver's request	desired
Inform driver of potential problems	required
Inform driver of needed warranty services due	neither required nor desired
Inform driver of any immediate danger after an accident	required
Coordination information with a service center	desired
Vehicle Condition Monitoring CVO-Specific	
Inform driver of the condition of the cargo (temperature, vibration, humidity, etc.)	required
Inform driver of the condition of the trailer	required
Inform driver of regulatory services due	neither required nor desired
Cargo and Vehicle Monitoring CVO-Specific	
Cargo data (restrictions, type, etc.)	required
Condition of the cargo (temperature, humidity, etc.)	required
Precise indication of vehicle performance (engine, brake, etc.)	desired
Location information for aid request	required

Table 7. Criticality assessment while driving, for CVO-specific functions.

CVO-SPECIFIC	
Information Requirement	**Criticality Assessment**
Fleet Resource Management	
Fleet resource management information is intended to be used by the dispatcher and does not include an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.	N/A
Dispatch	
Dispatch information is intended to be used by the dispatcher and does not include an in-vehicle display.	N/A
Regulatory Administration	
Regulatory administration requirements (taxes, license, and coordinating the transport of hazardous material)	neither required nor desired
Vehicle identification tag	neither required nor desired
Regulatory Enforcement	
Regulatory enforcement information is intended to be used by the dispatcher and does not involve an in-vehicle display.	N/A
Shipping Element	
Shipping element information is intended to be used by the dispatcher and does not involve an in-vehicle display.	N/A
Trucking Element	
Pickup and delivery schedules	desired
Height restriction of bridges, underpasses, or tunnels	required
Weight restriction of bridges and road surfaces	required
Width restriction of underpasses, bridges, and tunnels	required
Other restrictions established by departments of transportation	desired
Detailed descriptions of topological features (hills, etc.)	desired
Log information	desired
Communication information between driver and dispatcher	required
Regulating Element	
Regulating element information is intended to be used by the regulatory personnel and would probably not be an in-vehicle display.	N/A

Table 7. Cont'd.

CVO-SPECIFIC	
Information Requirement	**Criticality Assessment**
Receiving Element	
Expected date and time that the load will arrive at the receiving facility	neither required nor desired
Characteristics of the load	neither required nor desired
Industry Support Element	
Support element information is intended to be used by the dispatcher and does not involve an in-vehicle display.	N/A
Dispatch Element for Taxi and Other Personal Delivery Operations	
Dispatch information is intended to be used by the dispatcher and does not involve an in-vehicle display	N/A
Taxi Element	
Passenger pickup point	required
Plan of route to the pickup point or destination (see the information requirements for IRANS)	required
Estimated times if making the trip by alternate routes	desired
Likely conditions that will be encountered	desired
Traffic and other obstructions information	desired
Dispatch Element of Local Bus Operations (Fixed Route and Schedule)	
This information is intended to be used by the dispatcher and does not involve an in-vehicle display.	N/A
Bus Operations Element of Local Bus Operations (Fixed Route and Schedule)	
Communication between driver and dispatcher	required
Dispatch Element of Local Bus Operations (Paratransit)	
This information is intended to be used by the dispatcher and does not involve an in-vehicle display.	N/A
Bus Operations Element of Local Bus Operations (Paratransit)	
Communications information (see other CVO)	required
Navigation information (see IRANS)	required
Vehicle operation	required
Location of the passengers to be picked up	required

Table 7. Cont'd.

CVO-SPECIFIC	
Information Requirement	**Criticality Assessment**
Destination to which the passengers need to go	required
Most efficient route for passenger pickup and dropoff	required
Condition of safety-critical systems on the vehicle	required
Existence of hazardous road or traffic conditions	required
Location of traffic delays and alternate routes	required
Dispatch Element of Emergency Response Operations	
This information is intended to be used by the dispatcher and does not involve an in-vehicle display	N/A
Vehicle Operations Element of Emergency Response Operations	
Call receipt	required
Route planning	required
Navigation information (see IRANS)	required
Communications with hospital	required
Location of the emergency	required
Best route to take to get to the emergency	required
Nature of the emergency	required
Traffic conditions along the route	desired
Hazardous conditions along the route	required
Condition of vehicle safety-critical systems	required

APPENDIX B: SENSORY MODALITY ALLOCATION DESIGN TOOLS AND EXAMPLES

The sensory modality allocation design tools can be found on the following pages. These tools act as decision aids to guide the designer in selecting the appropriate sensory modality for displaying each of the information item requirements. A sensory modality allocation design tool was developed for each of the six functional information groups. This allows use of criteria for the decision process that are appropriate to that function group.

Examples of applications of each tool can be found by associating the asterisks in the design tool with the asterisks in the corresponding example. This will become clearer as you read through the design tools and their corresponding examples.

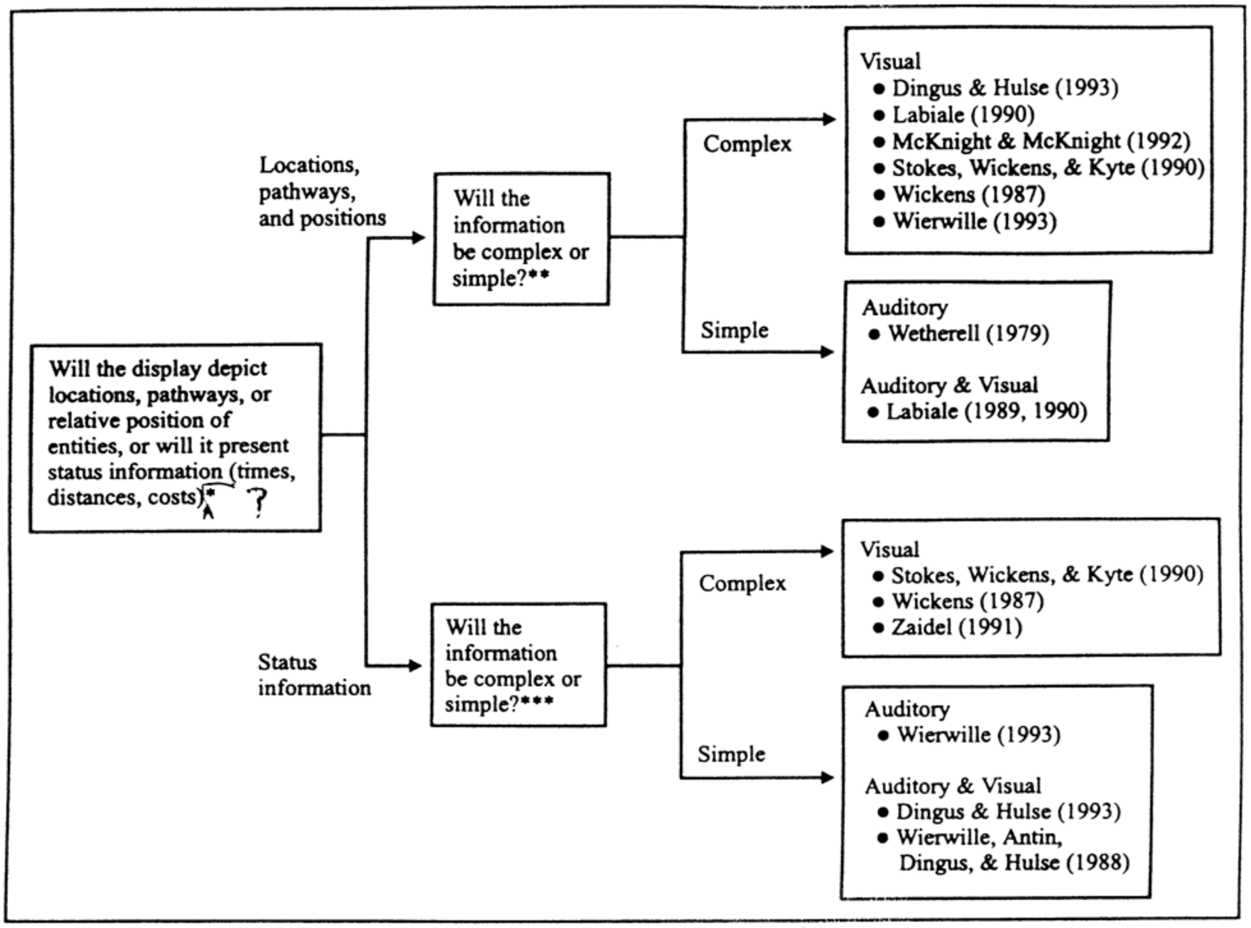


Figure 3. Sensory modality allocation design tool for route planning and coordination.

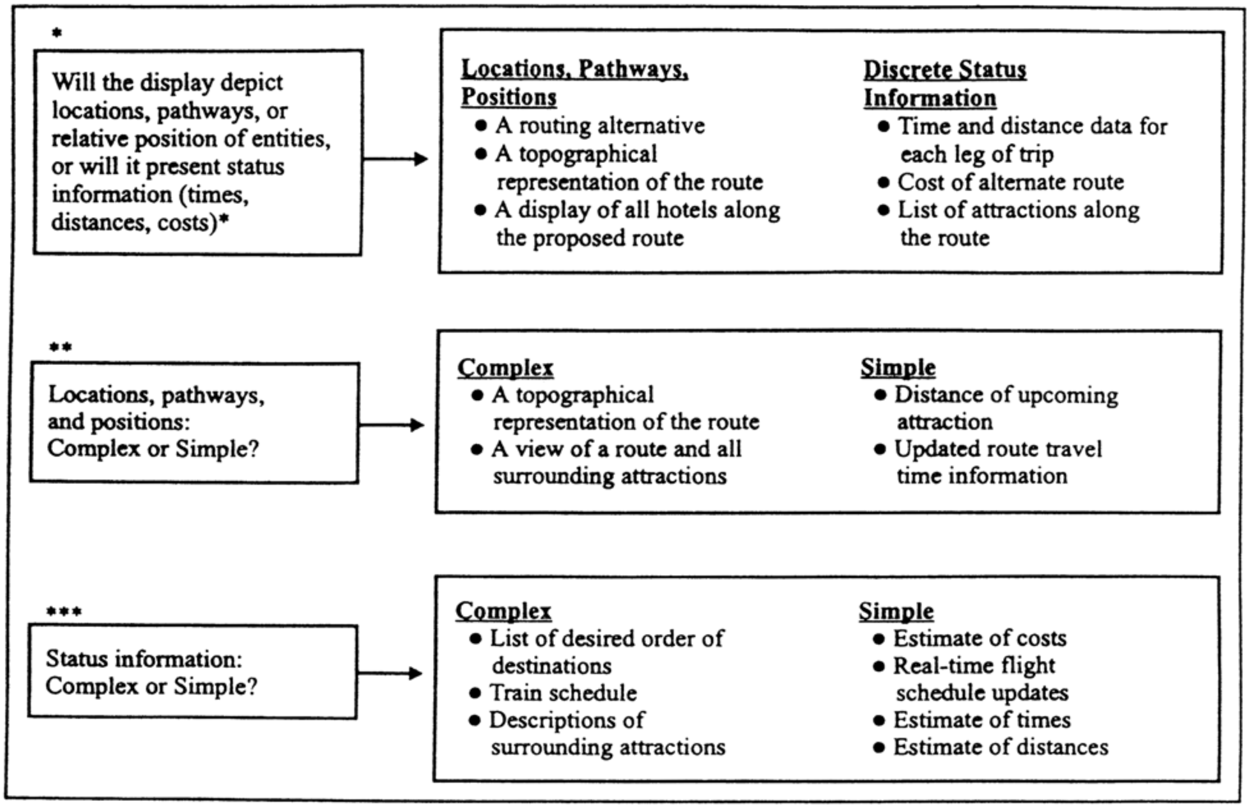


Figure 4. Sensory modality allocation design tool for route planning and coordination example.

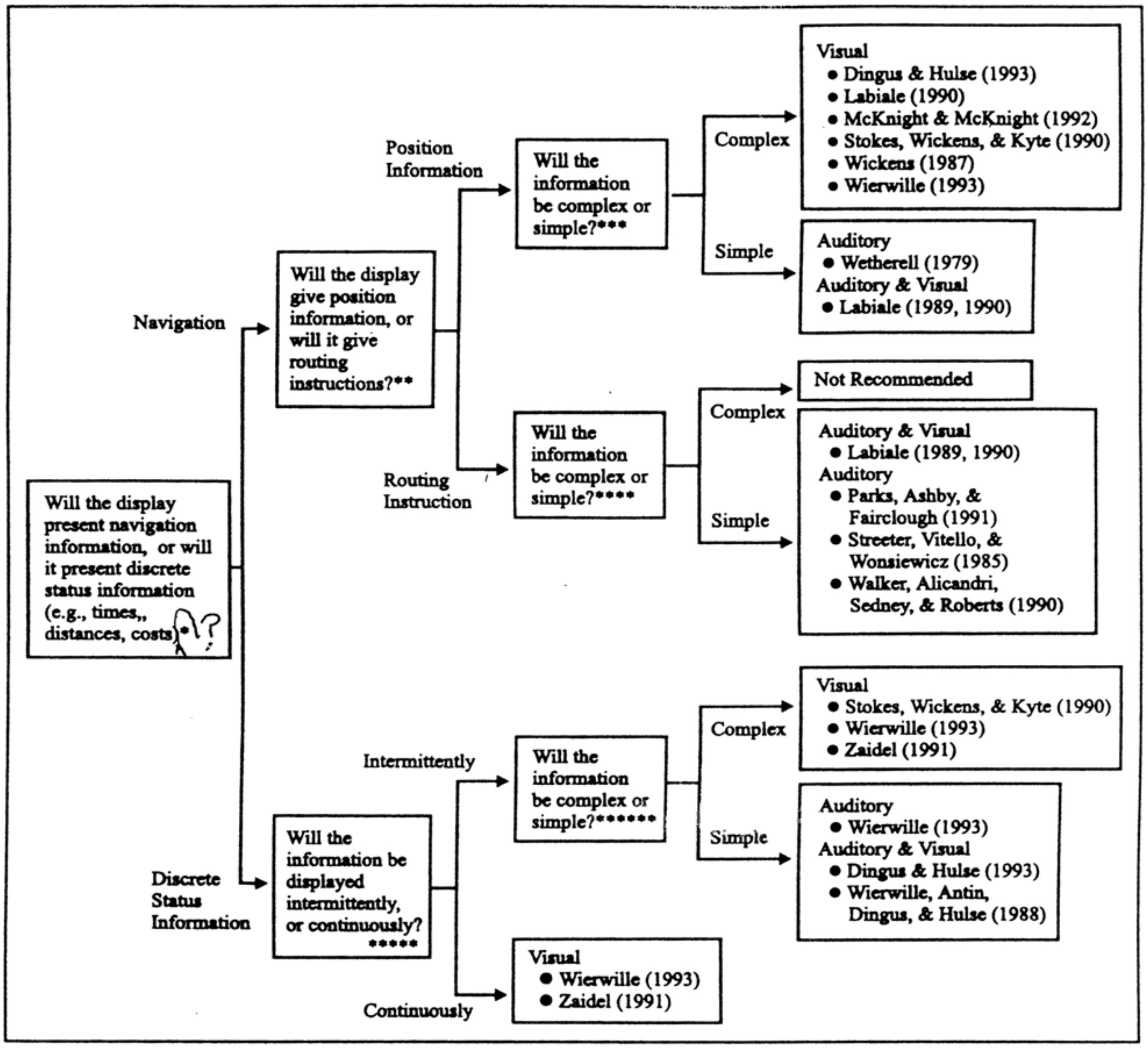


Figure 5. Sensory modality allocation design tool for route following.

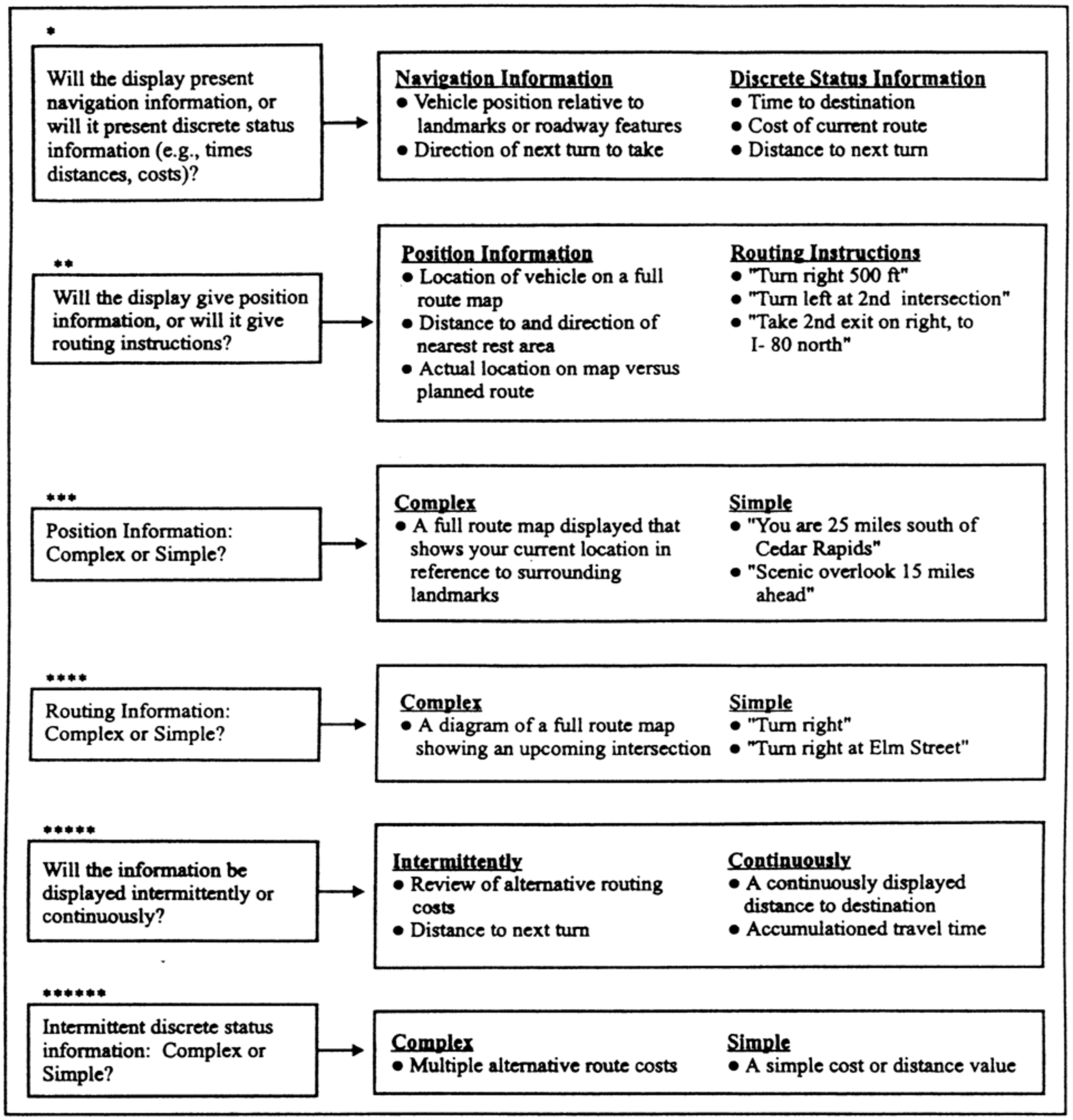


Figure 6. Sensory modality allocation design tool for route following example.

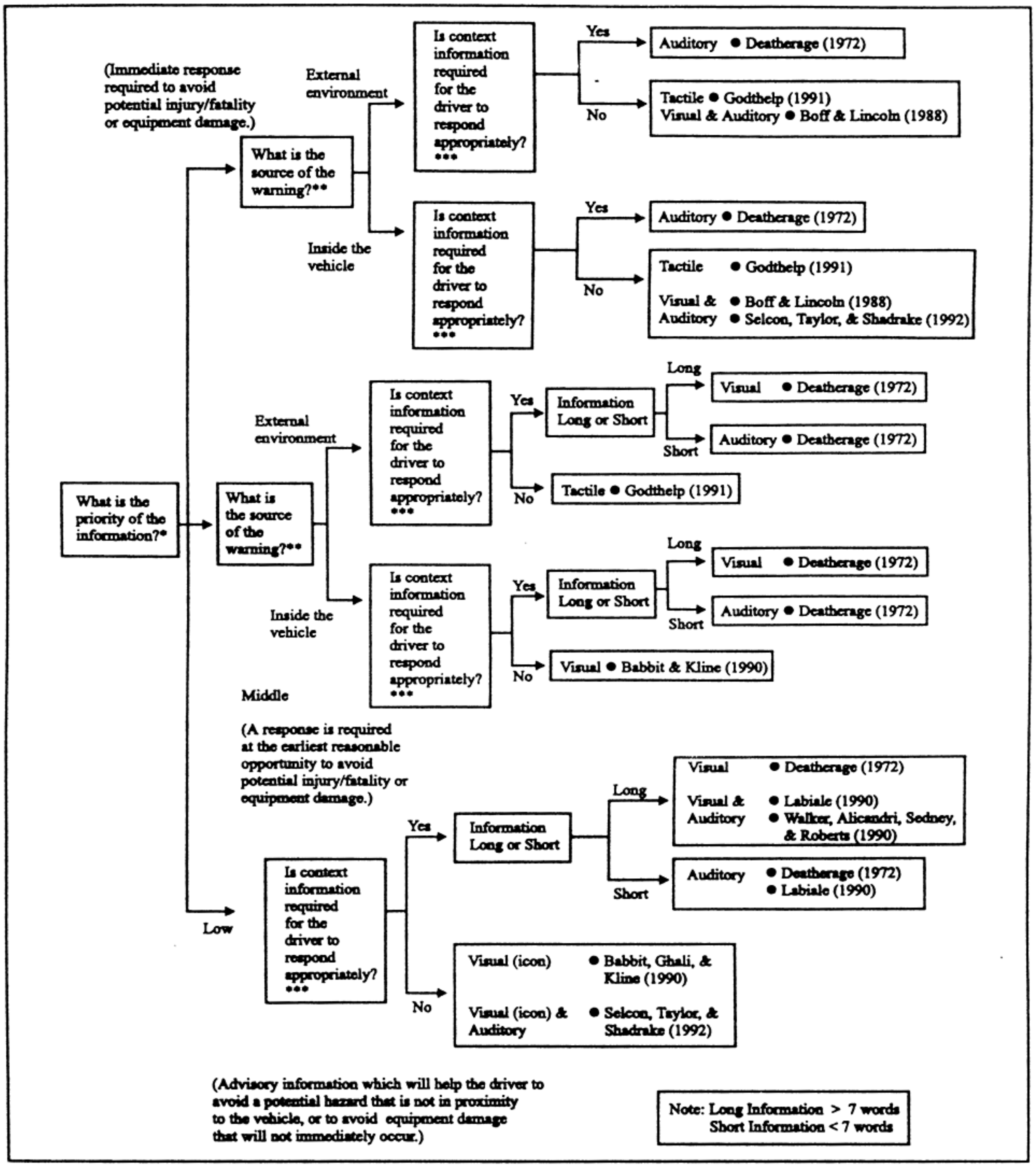


Figure 7. Sensory modality allocation design tool for warning and condition monitoring.

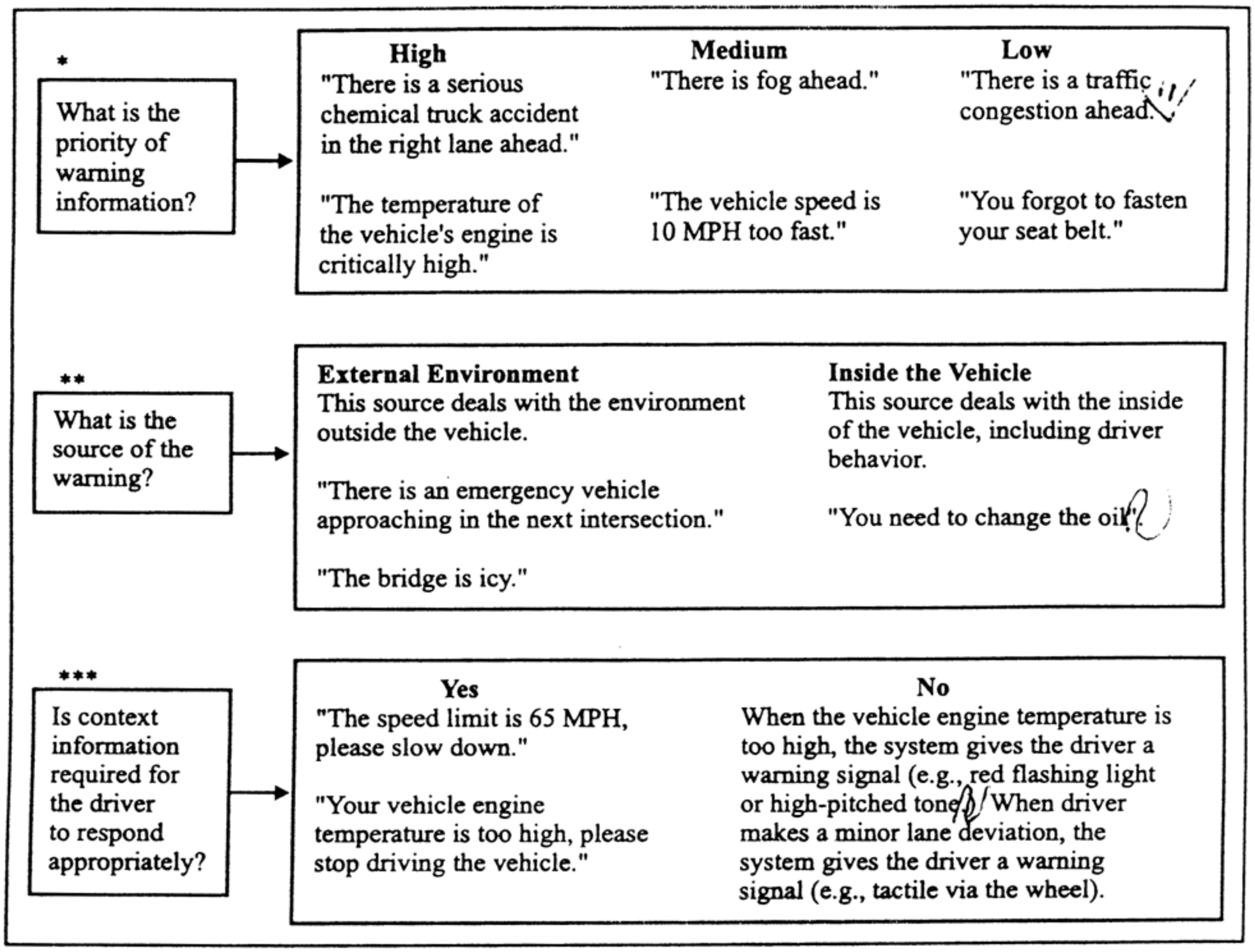


Figure 8. Sensory modality allocation design tool for warning and condition monitoring example.

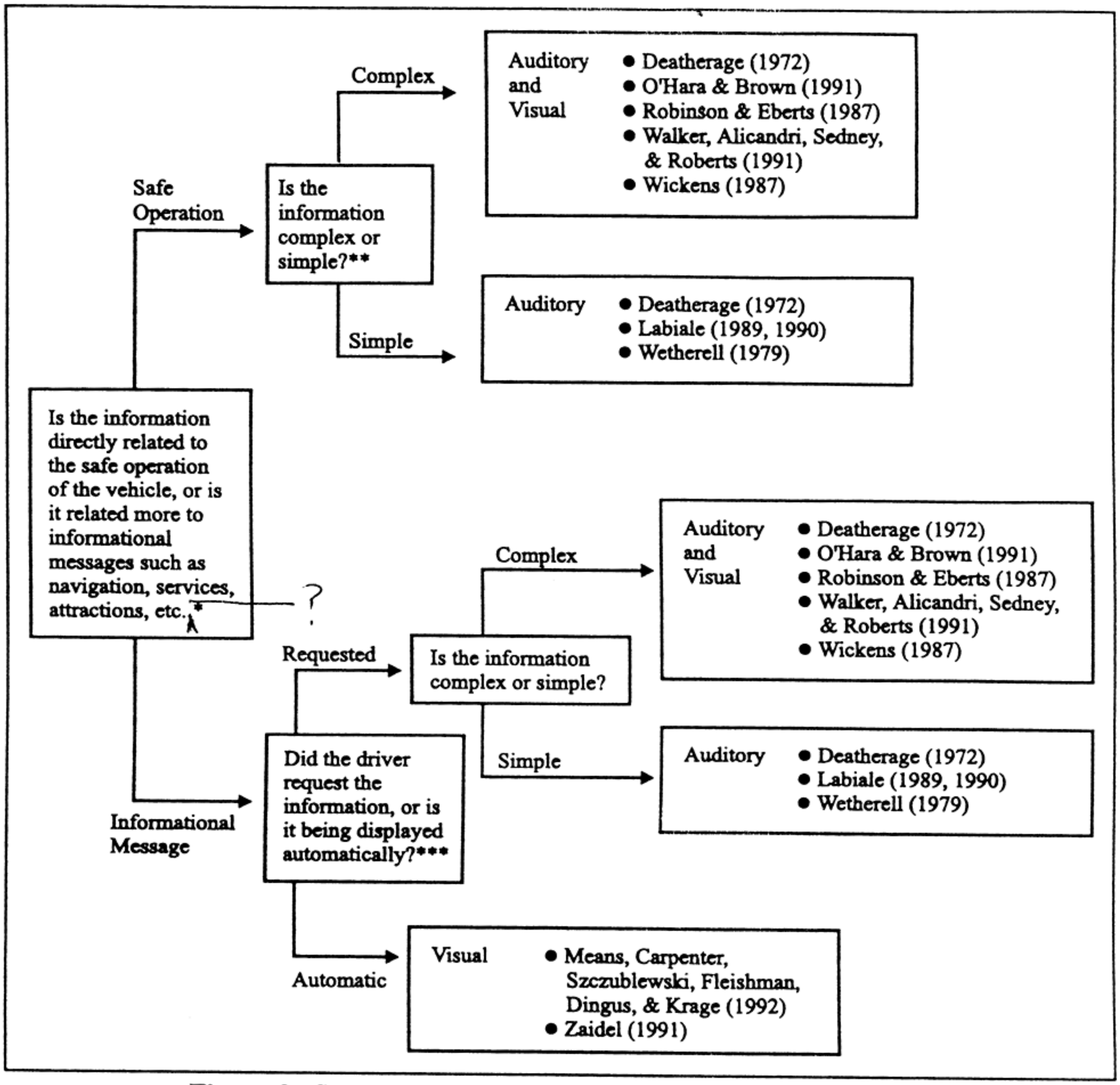


Figure 9. Sensory modality allocation design tool for signing.

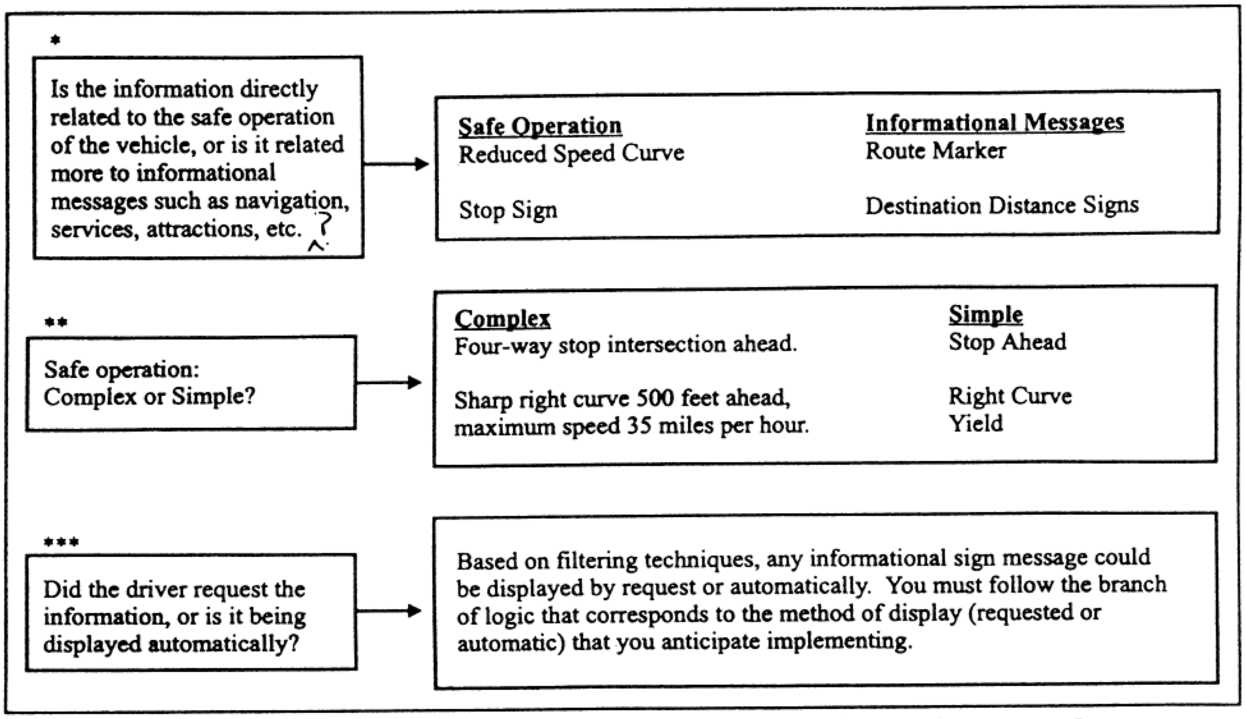


Figure 10. Sensory modality allocation design tool for signing example.

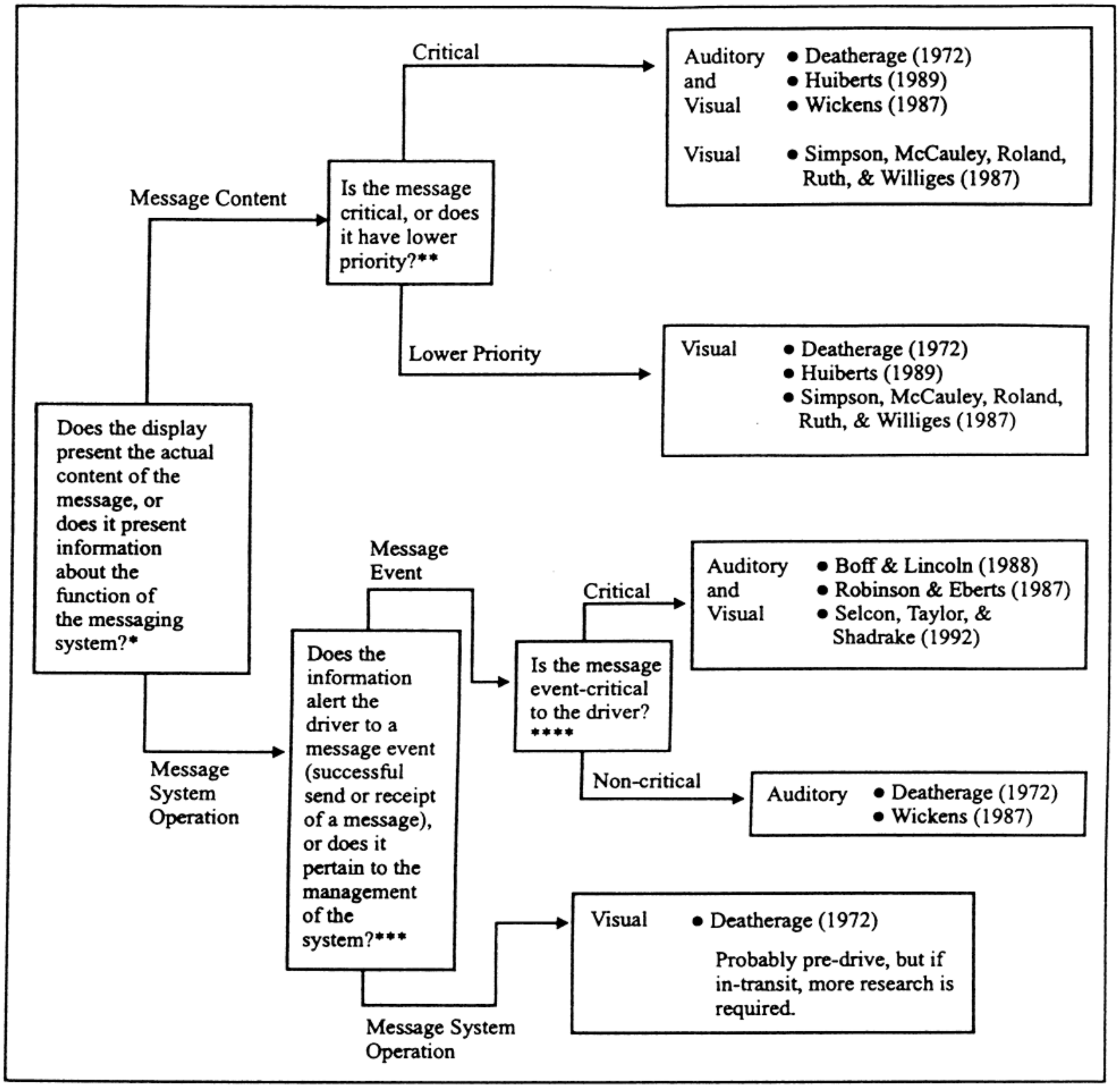


Figure 11. Sensory modality allocation design tool for communication and tool request.

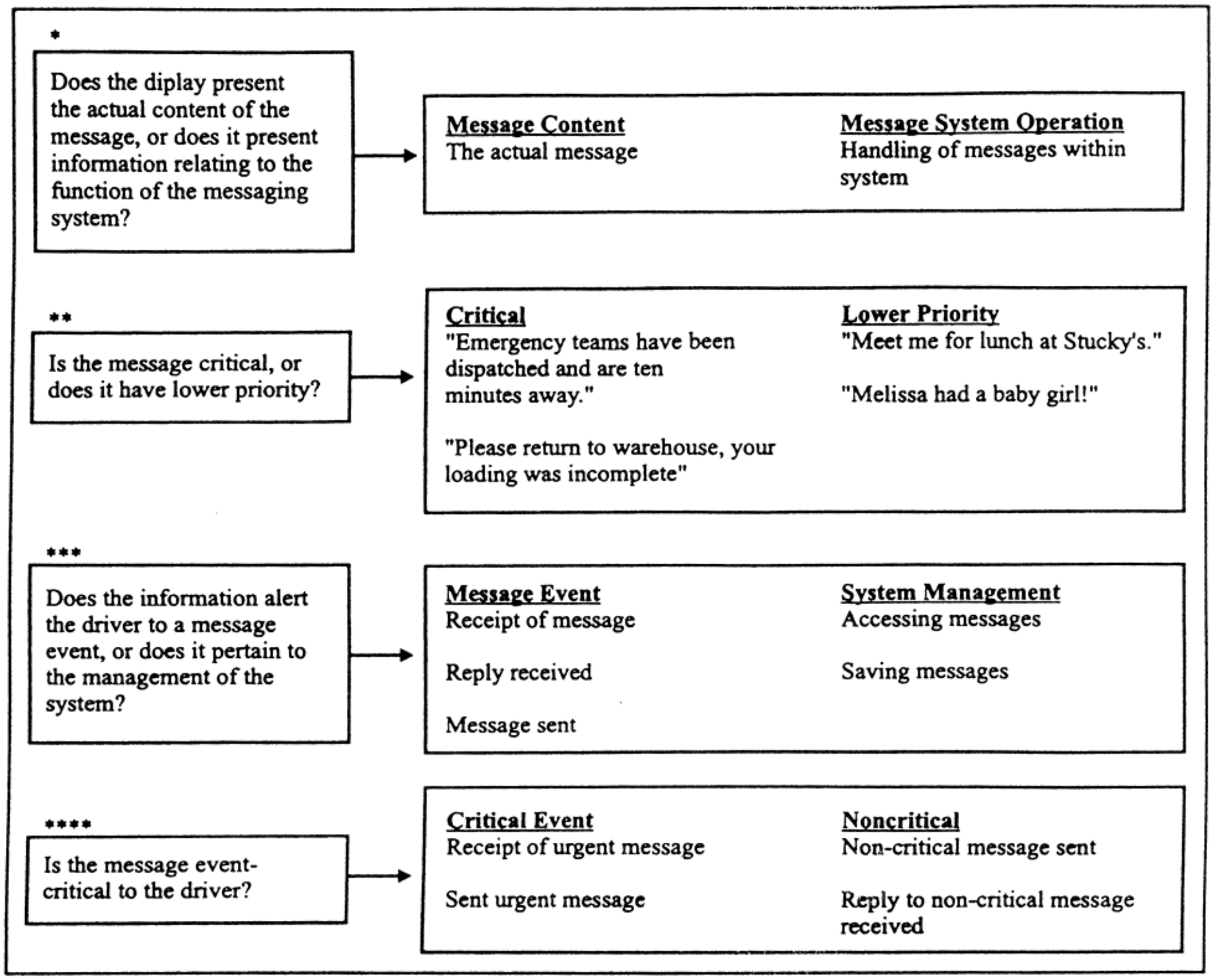


Figure 12. Sensory modality allocation design tool for communication and tool request example.

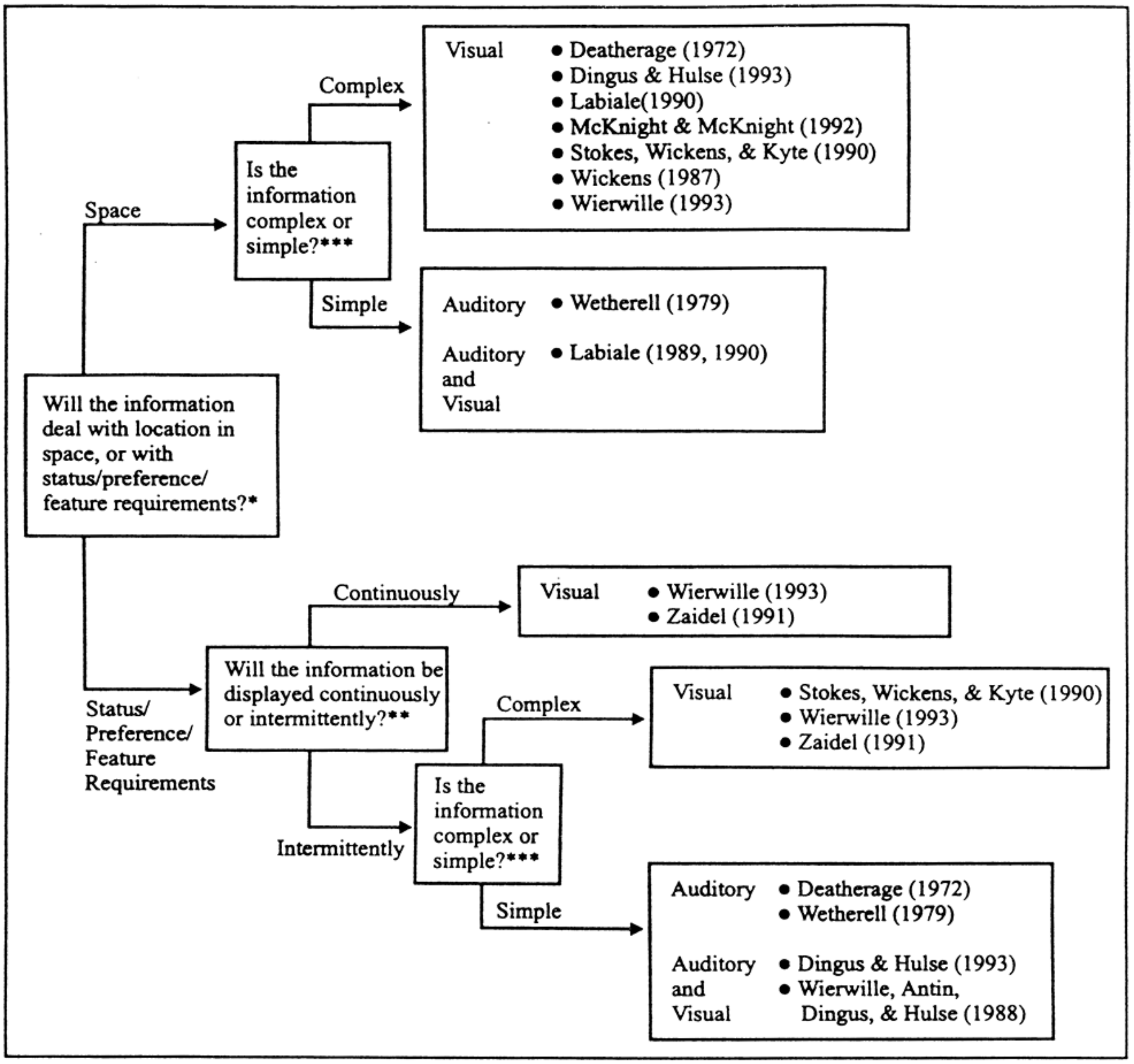


Figure 13. Sensory modality allocation design tool for motorist services.

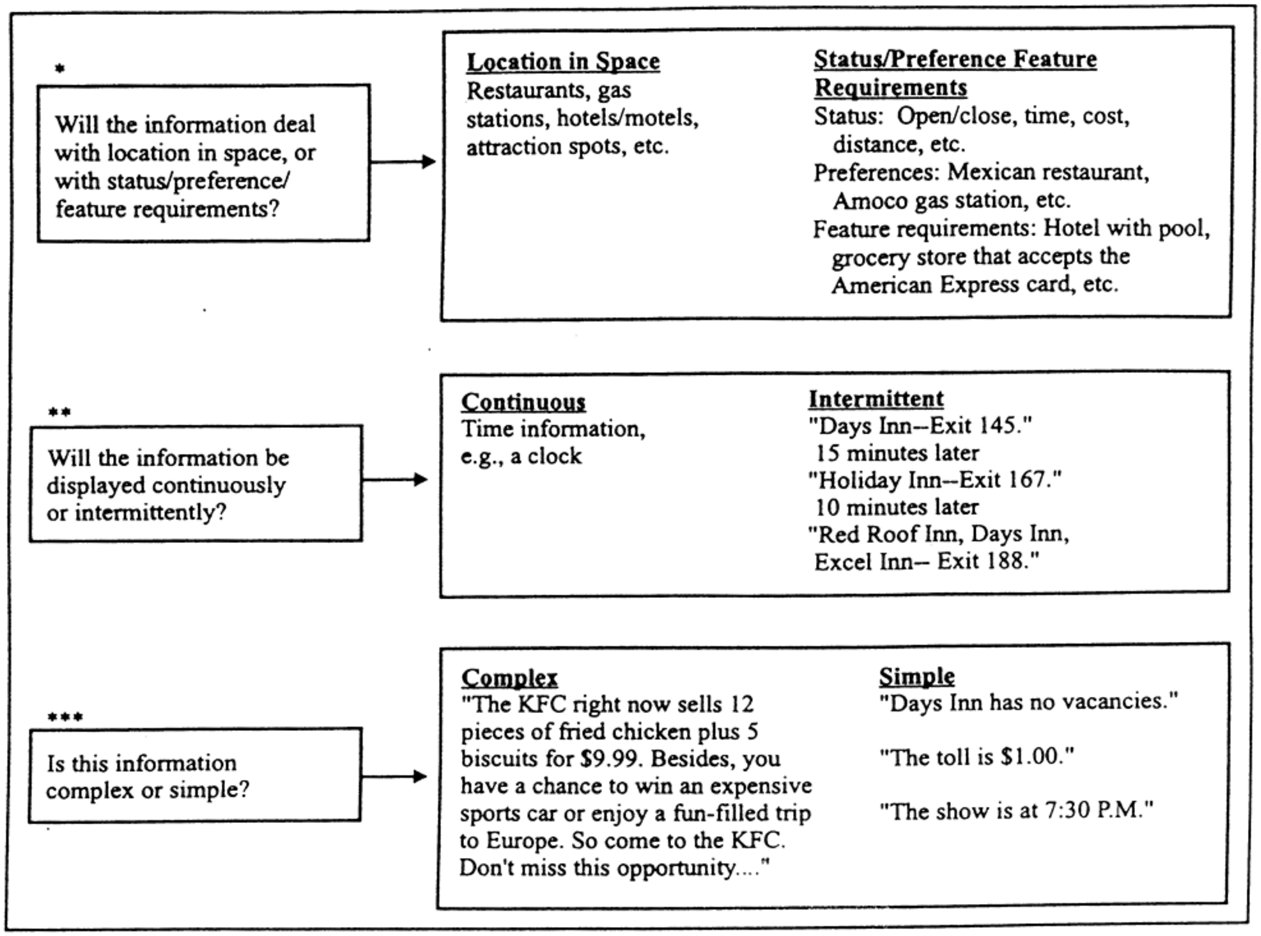
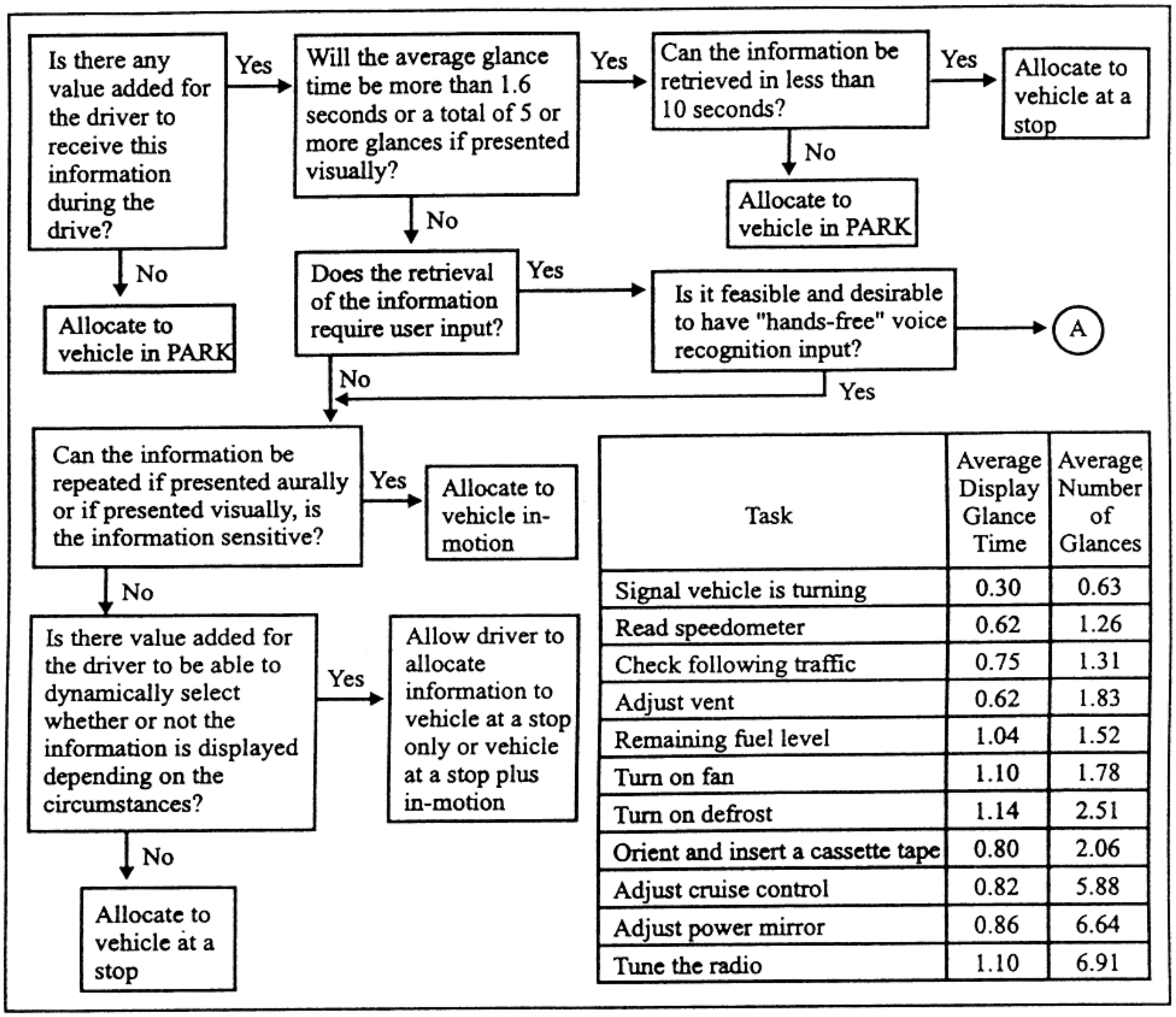


Figure 14. Sensory modality allocation design tool for motorist services example.

APPENDIX C: TRIP STATUS ALLOCATION DESIGN TOOL



Task	Average Display Glance Time	Average Number of Glances
Signal vehicle is turning	0.30	0.63
Read speedometer	0.62	1.26
Check following traffic	0.75	1.31
Adjust vent	0.62	1.83
Remaining fuel level	1.04	1.52
Turn on fan	1.10	1.78
Turn on defrost	1.14	2.51
Orient and insert a cassette tape	0.80	2.06
Adjust cruise control	0.82	5.88
Adjust power mirror	0.86	6.64
Tune the radio	1.10	6.91

Figure 15. Trip status allocation design tool.

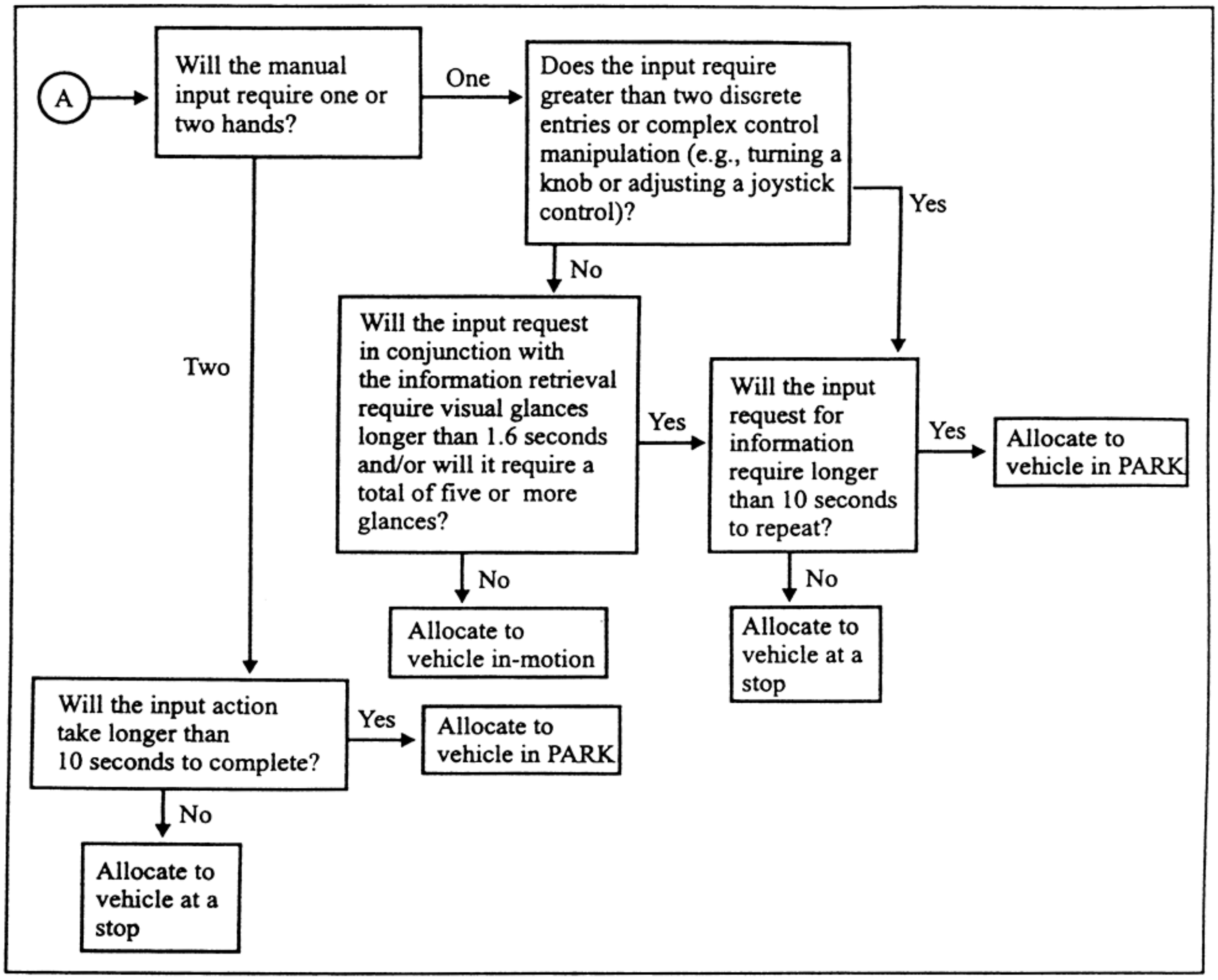


Figure 15. Trip status allocation design tool. (Cont'd.)

APPENDIX D: DISPLAY FORMAT TRADE STUDY ANALYSIS

The display format design tool consists of a series of trade studies, with feasible format options and criteria derived from the information format, sensory modality, and trip status design tools. Each of the trade studies can be found on the following pages. A trade study decision matrix was created for each pathway be the sensory modality allocation and function grouping tools.

Table 8. Route planning and coordination: Location pathways or positions, complex information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Full route video map display		**0.0**		**0.0**		**0.0**	13.0	**52.0**	9.5	**57.0**	11.0	**44.0**	12.5	**75.0**	**228.0**	1
	Partial route video map display		**0.0**		**0.0**		**0.0**	12.0	**48.0**	9.5	**57.0**	10.0	**40.0**	10.5	**63.0**	**208.0**	4
	Full printed map		**0.0**		**0.0**		**0.0**	11.0	**44.0**	7.5	**45.0**	6.5	**26.0**	7.5	**45.0**	**160.0**	6
	Partial printed map		**0.0**		**0.0**		**0.0**	10.0	**40.0**	7.5	**45.0**	6.5	**26.0**	5.0	**30.0**	**141.0**	7
	3-D map display (full or partial)		**0.0**		**0.0**		**0.0**	6.0	**24.0**	3.0	**18.0**	3.0	**12.0**	3.0	**18.0**	**72.0**	11
	Icon or graphic representation		**0.0**		**0.0**		**0.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	1.0	**6.0**	**20.0**	13
Text presentation (visual, verbal)	Description printed out (hardcopy)		**0.0**		**0.0**		**0.0**	3.5	**14.0**	5.5	**33.0**	5.0	**20.0**	75.	**45.0**	**112.0**	9
	Description on video screen		**0.0**		**0.0**		**0.0**	3.5	**14.0**	5.5	**33.0**	9.0	**36.0**	7.5	**45.0**	**128.0**	8
Text combined with graphical presentation (visual, spatial & verbal)	Full-route video map display with text description		**0.0**		**0.0**		**0.0**	4.0	**16.0**	12.5	**75.0**	13.0	**52.0**	12.5	**75.0**	**218.0**	2.5
	Partial-route video map display with text description		**0.0**		**0.0**		**0.0**	8.0	**32.0**	12.5	**75.0**	12.0	**48.0**	10.5	**63.0**	**218.0**	2.5
	Printed map with text description		**0.0**		**0.0**		**0.0**	7.0	**28.0**	11.0	**66.0**	8.0	**32.0**	7.5	**45.0**	**171.0**	5
	3-D video map display with text description		**0.0**		**0.0**		**0.0**	5.0	**20.0**	4.0	**24.0**	4.0	**16.0**	4.0	**24.0**	**84.0**	10
	Icon or graphic representation with text description		**0.0**		**0.0**		**0.0**	2.0	**8.0**	2.0	**12.0**	2.0	**8.0**	2.0	**12.0**	**40.0**	12

Table 9. Route planning and coordination: Location pathways or positions, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)		**0.0**		**0.0**		**0.0**	2.0	**8.0**	4.0	**24.0**	1.0	**4.0**	2.5	**15.0**	**51.0**	7
Speech combined with graphical presentation (auditory, visual)	Full route video map display with voice		**0.0**		**0.0**		**0.0**	8.0	**32.0**	6.0	**36.0**	7.5	**30.0**	6.0	**36.0**	**134.0**	1
	Partial-route video map display with voice		**0.0**		**0.0**		**0.0**	6.0	**24.0**	7.0	**42.0**	7.5	**30.0**	6.0	**36.0**	**132.0**	2
	Printed map with voice		**0.0**		**0.0**		**0.0**	6.0	**24.0**	5.0	**30.0**	5.0	**20.0**	4.0	**24.0**	**98.0**	3
	3-D voice map display with voice		**0.0**		**0.0**		**0.0**	6.0	**24.0**	3.0	**18.0**	3.5	**14.0**	6.0	**36.0**	**92.0**	4
	Icon or graphic representation plus voice		**0.0**		**0.0**		**0.0**	4.0	**16.0**	1.0	**6.0**	3.5	**14.0**	3.0	**18.0**	**54.0**	6
Speech combined with text presentation (auditory, visual)	Description printed out (hardcopy) with voice		**0.0**		**0.0**		**0.0**	1.0	**4.0**	2.0	**12.0**	2.0	**8.0**	1.0	**6.0**	**30.0**	8
	Description on video screen with voice		**0.0**		**0.0**		**0.0**	3.0	**12.0**	5.0	**30.0**	6.0	**24.0**	2.5	**15.0**	**81.0**	5

Table 10. Route planning and coordination: Status information, complex format.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Icon or graphic representation		**0.0**		**0.0**		**0.0**	1.0	**4.0**	1.0	**2.0**	2.0	**2.0**	2.0	**12.0**	**20.0**	4
Text presentation (visual, verbal)	Description printed out (hardcopy)		**0.0**		**0.0**		**0.0**	2.0	**8.0**	2.0	**12.0**	1.0	**4.0**	2.0	**12.0**	**36.0**	3
	Description on video screen		**0.0**		**0.0**		**0.0**	3.5	**14.0**	4.0	**24.0**	3.5	**14.0**	2.0	**12.0**	**64.0**	1
Text with graphical presentation (visual, spatial, and verbal)	Icon or graphic representation with text description		**0.0**		**0.0**		**0.0**	3.5	**14.0**	3.0	**18.0**	3.5	**14.0**	2.0	**12.0**	**58.0**	2

Table 11. Route planning and coordination: Status information, simple format.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)		**0.0**		**0.0**		**0.0**	2.0	**8.0**	2.0	**12.0**	2.0	**8.0**	4.0	**24.0**	**52.0**	2.5
Speech and graphical representation (auditory, visual)	Icon or graphic representation plus voice		**0.0**		**0.0**		**0.0**	4.0	**16.0**	1.0	**6.0**	3.0	**12.0**	3.0	**18.0**	**52.0**	2.5
Speech combined with text presentation (auditory, visual)	Description printed out (hardcopy) with voice		**0.0**		**0.0**		**0.0**	1.0	**4.0**	3.5	**21.0**	1.0	**4.0**	1.5	**9.0**	**38.0**	4
	Description on video screen with voice		**0.0**		**0.0**		**0.0**	3.0	**12.0**	3.5	**21.0**	4.0	**16.0**	1.5	**9.0**	**58.0**	1

Table 12. Route following: Navigation, position, complex information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Full route video map display with icon info.	7.0	**56.0**	9.5	**95.0**	8.0	**0.0**	10.0	**40.0**	6.5	**39.0**	10.0	**40.0**	12.0	**72.0**	**342.0**	7
	Partial route video map display with icon info.	9.0	**72.0**	11.5	**115.0**	10.0	**80.0**	11.0	**44.0**	8.5	**51.0**	11.0	**44.0**	13.0	**78.0**	**484.0**	1
	Full printed map with icon info.	1.0	**8.0**	9.5	**95.0**	7.0	**56.0**	7.0	**28.0**	6.5	**39.0**	8.0	**32.0**	11.0	**66.0**	**324.0**	9
	Partial printed map with icon info.	2.0	**16.0**	11.5	**115.0**	9.0	**72.0**	8.0	**32.0**	8.5	**51.0**	7.0	**28.0**	10.0	**60.0**	**374.0**	3
	3-D map display (full or partial) with icon info.	6.0	**48.0**	5.0	**50.0**	4.0	**32.0**	4.0	**16.0**	2.0	**12.0**	5.0	**20.0**	9.0	**54.0**	**232.0**	11
	Icon or graphic representation	13.0	**104.0**	13.0	**130.0**	6.0	**48.0**	3.0	**12.0**	1.0	**6.0**	3.0	**12.0**	7.0	**42.0**	**354.0**	4
Text presentation (visual, verbal)	Description printed out (hardcopy)	4.0	**32.0**	6.0	**60.0**	1.0	**8.0**	1.0	**4.0**	4.5	**27.0**	1.0	**4.0**	3.0	**18.0**	**153.0**	13
	Description on video screen	11.0	**88.0**	7.0	**70.0**	2.0	**16.0**	2.0	**8.0**	4.5	**27.0**	2.0	**8.0**	4.0	**24.0**	**241.0**	10
Text combined with graphical presentation (visual, spatial, verbal)	Full-route video map display with text description	8.0	**64.0**	2.0	**20.0**	12.0	**96.0**	12.0	**48.0**	11.0	**66.0**	12.5	**50.0**	1.5	**9.0**	**353.0**	5
	Partial-route video map display with text description	10.0	**80.0**	4.0	**40.0**	13.0	**104.0**	13.0	**52.0**	12.5	**75.0**	12.5	**50.0**	1.5	**9.0**	**410.0**	2
	Printed map with text description	3.0	**24.0**	3.0	**30.0**	11.0	**88.0**	9.0	**36.0**	12.5	**75.0**	9.0	**36.0**	6.0	**36.0**	**325.0**	8
	3-D video map display with text description	5.0	**40.0**	1.0	**10.0**	5.0	**40.0**	6.0	**24.0**	3.0	**18.0**	6.0	**24.0**	5.0	**30.0**	**186.0**	12
	Icon or graphic representation with text description	12.0	**96.0**	8.0	**80.0**	3.0	**24.0**	5.0	**20.0**	10.0	**60.0**	4.0	**16.0**	8.0	**48.0**	**344.0**	6

Table 13. Route following: Navigation, position, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Auditory presentation (visual, spatial)	Message presented as speech (digital or synthesized)	8.0	**64.0**	13.0	**130.0**	8.0	**64.0**	14.0	**56.0**	2.0	**12.0**	8.0	**32.0**	4.0	**24.0**	**382.0**	8
	Alerting tones, chimes, etc.	16.0	**128.0**	16.0	**160.0**	1.0	**8.0**	9.0	**36.0**	1.0	**6.0**	1.0	**4.0**	1.0	**6.0**	**348.0**	12
Speech combined with graphical presentation (auditory, visual)	Full route video map display with voice	3.5	**28.0**	7.0	**70.0**	14.5	**116.0**	11.0	**44.0**	15.5	**93.0**	15.5	**62.0**	10.0	**60.0**	**473.0**	4
	Partial route video map display with voice	3.5	**28.0**	8.0	**80.0**	14.5	**116.0**	13.0	**52.0**	15.5	**93.0**	15.5	**62.0**	9.0	**54.0**	**485.0**	3
	Printed map with voice	1.0	**8.0**	5.5	**55.0**	13.0	**104.0**	2.5	**10.0**	14.0	**84.0**	5.0	**20.0**	15.0	**90.0**	**371.0**	9
	3-D map display with voice	2.0	**16.0**	5.5	**55.0**	10.0	**80.0**	6.0	**24.0**	7.5	**45.0**	10.0	**40.0**	16.0	**96.0**	**356.0**	11
	Icon or graphic representation plus voice	5.0	**40.0**	14.0	**140.0**	16.0	**128.0**	15.5	**62.0**	10.0	**60.0**	12.0	**48.0**	8.0	**48.0**	**526.0**	1
Speech combined with text (visual, verbal)	Description printed out (hardcopy) with voice	6.5	**52.0**	1.0	**10.0**	11.5	**92.0**	2.5	**10.0**	5.0	**30.0**	4.0	**16.0**	14.0	**84.0**	**294.0**	14.5
	Description on video screen with voice	6.5	**52.0**	2.0	**20.0**	11.5	**92.0**	7.0	**28.0**	6.0	**36.0**	6.0	**24.0**	3.0	**18.0**	**270.0**	16
Tones combined with graphical presentation (auditory, visual)	Full-route video map display with text description	11.5	**92.0**	11.0	**110.0**	3.5	**28.0**	10.0	**40.0**	12.5	**75.0**	13.5	**54.0**	7.0	**42.0**	**441.0**	6
	Partial-route video map display with text description	11.5	**92.0**	12.0	**120.0**	3.5	**28.0**	12.0	**48.0**	12.5	**75.0**	13.5	**54.0**	6.0	**36.0**	**453.0**	5
	Printed map with text description	9.0	**72.0**	9.5	**95.0**	9.0	**72.0**	2.5	**10.0**	11.0	**66.0**	1.0	**4.0**	13.0	**78.0**	**397.0**	7
	3-D video map display with text description	10.0	**80.0**	9.5	**95.0**	2.0	**16.0**	5.0	**20.0**	7.5	**45.0**	9.0	**36.0**	11.0	**66.0**	**358.0**	10
	Icon or graphic representation with text description	14.5	**116.0**	15.0	**150.0**	5.0	**40.0**	15.5	**62.0**	9.0	**54.0**	11.0	**44.0**	5.0	**30.0**	**496.0**	2
Tones combined with text (auditory, visual)	Description printed out (hardcopy) with tones	13.0	**104.0**	3.0	**30.0**	6.5	**52.0**	2.5	**10.0**	3.0	**18.0**	2.0	**8.0**	12.0	**72.0**	**294.0**	14.5
	Description on video screen with tones	14.5	**116.0**	4.0	**40.0**	6.5	**52.0**	8.0	**32.0**	4.0	**24.0**	7.0	**28.0**	2.0	**12.0**	**304.0**	13

Table 14. Route following: Navigation, routing instructions, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Auditory presentation (visual, spatial)	Message presented as speech (digital or synthesized)	8.0	**64.0**	15.0	**150.0**	2.0	**16.0**	16.0	**64.0**	2.0	**12.0**	16.0	**64.0**	2.0	**12.0**	**382.0**	10
	Alerting tones, chimes, etc.	15.0	**120.0**	16.0	**160.0**	1.0	**8.0**	9.0	**36.0**	1.0	**6.0**	1.0	**4.0**	1.0	**6.0**	**340.0**	11
Speech combined with graphical presentation (auditory, visual)	Full route video map display with voice	3.5	**28.0**	3.0	**30.0**	6.0	**48.0**	11.0	**44.0**	7.0	**42.0**	12.0	**48.0**	11.0	**66.0**	**306.0**	13.5
	Partial route video map display with voice	3.5	**28.0**	12.0	**120.0**	8.5	**68.0**	7.5	**30.0**	11.5	**69.0**	14.5	**58.0**	12.0	**72.0**	**445.0**	6
	Printed map with voice	2.0	**16.0**	11.0	**110.0**	8.5	**68.0**	7.5	**30.0**	11.5	**69.0**	14.5	**58.0**	14.0	**84.0**	**435.0**	7
	3-D map display with voice	1.0	**8.0**	1.0	**10.0**	4.0	**32.0**	6.0	**24.0**	4.0	**24.0**	3.0	**12.0**	6.0	**36.0**	**146.0**	16
	Icon or graphic representation plus voice	7.0	**56.0**	14.0	**140.0**	12.0	**96.0**	15.0	**60.0**	10.0	**60.0**	13.0	**52.0**	14.0	**84.0**	**548.0**	1
Speech combined with text (visual, verbal)	Description printed out (hardcopy) with voice	5.0	**40.0**	7.5	**75.0**	15.5	**124.0**	13.5	**54.0**	14.0	**84.0**	10.5	**42.0**	8.0	**48.0**	**467.0**	5
	Description on video screen with voice	6.0	**48.0**	7.5	**75.0**	15.5	**124.0**	13.5	**54.0**	16.0	**96.0**	10.5	**42.0**	16.0	**96.0**	**535.0**	2
Tones combined with graphical presentation (auditory, visual)	Full-route video map display with text description	11.5	**92.0**	4.0	**40.0**	5.0	**40.0**	2.0	**8.0**	6.0	**36.0**	9.0	**36.0**	9.0	**54.0**	**306.0**	13.5
	Partial-route video map display with text description	11.5	**92.0**	10.0	**100.0**	7.0	**56.0**	3.5	**14.0**	8.5	**51.0**	8.0	**32.0**	10.0	**60.0**	**405.0**	9
	Printed map with text description	9.0	**72.0**	9.0	**90.0**	10.0	**80.0**	3.5	**14.0**	8.5	**51.0**	2.0	**8.0**	3.0	**18.0**	**333.0**	12
	3-D video map display with text description	10.0	**80.0**	2.0	**20.0**	3.0	**24.0**	1.0	**4.0**	3.0	**18.0**	4.0	**16.0**	5.0	**30.0**	**192.0**	15
	Icon or graphic representation with text description	14.0	**112.0**	13.0	**130.0**	11.0	**88.0**	5.0	**20.0**	5.0	**30.0**	6.0	**24.0**	13.0	**78.0**	**482.0**	4
Tones combined with text (auditory, visual)	Description printed out (hardcopy) with tones	12.0	**96.0**	5.0	**50.0**	13.5	**108.0**	10.0	**40.0**	13.0	**78.0**	5.0	**20.0**	7.0	**42.0**	**434.0**	8
	Description on video screen with tones	13.0	**104.0**	6.0	**60.0**	13.5	**108.0**	12.0	**48.0**	15.0	**90.0**	7.0	**28.0**	15.0	**90.0**	**528.0**	3

Table 15. Route following: Discrete, intermittently displayed, complex information.

R R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		**10**		**8**		**4**		**6**		**4**		**6**			
		Distraction Potential		**Attention Demand**		**Post-Retrieval Workload**		**Efficiency**		**Error Potential**		**Driver Acceptance**		**Annoyance Potential**			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Icon or graphic representation	4.0	**32.0**	3.0	**30.0**	1.0	**8.0**	2.5	**10.0**	1.0	**6.0**	3.0	**12.0**	2.0	**12.0**	**110.0**	3
Text presentation (visual, verbal)	Description printed out (hardcopy)	1.0	**8.0**	1.5	**15.0**	3.5	**28.0**	1.0	**4.0**	2.5	**15.0**	1.0	**4.0**	1.0	**6.0**	**80.0**	4
	Description on video screen	2.5	**20.0**	1.5	**15.0**	3.5	**28.0**	2.5	**10.0**	2.5	**15.0**	2.0	**8.0**	3.5	**21.0**	**117.0**	2
Text combined with graphical presentation (visual, verbal)	Icon or graphic representation with text description	2.5	**20.0**	4.0	**40.0**	2.0	**16.0**	4.0	**16.0**	4.0	**24.0**	4.0	**16.0**	3.5	**21.0**	**153.0**	1

Table 16. Route following: Discrete, intermittently displayed, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	4.5	**36.0**	5.0	**50.0**	2.0	**16.0**	4.5	**18.0**	2.0	**12.0**	6.0	**24.0**	3.0	**18.0**	**174.0**	7
	Alerting tones, chimes, etc.	4.5	**36.0**	8.0	**80.0**	1.0	**8.0**	4.5	**18.0**	1.0	**6.0**	3.0	**12.0**	7.0	**42.0**	**202.0**	4
Speech combined with graphical presentation (auditory, visual)	Icon or graphic representation plus voice	2.5	**20.0**	6.0	**60.0**	6.0	**48.0**	7.0	**28.0**	4.0	**24.0**	7.0	**28.0**	4.0	**24.0**	**232.0**	3
Speech combined with text presentation (auditory, visual)	Description printed out (hardcopy) with voice	1.0	**8.0**	1.0	**10.0**	7.5	**60.0**	2.0	**8.0**	5.0	**30.0**	2.0	**8.0**	1.0	**6.0**	**130.0**	8
	Description on video screen with voice	2.5	**20.0**	2.0	**20.0**	7.5	**60.0**	3.0	**12.0**	7.0	**42.0**	5.0	**20.0**	2.0	**12.0**	**186.0**	6
Tones combined with graphical presentation (auditory, visual)	Icon or graphic representation with simple tones, chimes, etc.	7.0	**56.0**	7.0	**70.0**	3.0	**24.0**	8.0	**32.0**	3.0	**18.0**	8.0	**32.0**	8.0	**48.0**	**280.0**	1
Tones combined with text (auditory, visual)	Description printed out (hardcopy) with tones	6.0	**48.0**	4.0	**40.0**	4.5	**36.0**	1.0	**4.0**	6.0	**36.0**	1.0	**4.0**	5.0	**30.0**	**198.0**	5
	Description on video screen with tones	8.0	**64.0**	3.0	**30.0**	4.5	**36.0**	6.0	**24.0**	8.0	**48.0**	4.0	**16.0**	6.0	**36.0**	**254.0**	2

Table 17. Route following: Discrete, continuously displayed information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Icon or graphic representation	2.5	**20.0**	3.0	**30.0**	1.0	**8.0**	1.5	**6.0**	1.0	**6.0**	2.0	**8.0**	1.5	**9.0**	**87.0**	3
Text presentation (visual, verbal)	Description on video screen	2.5	**20.0**	1.0	**10.0**	2.0	**16.0**	3.0	**12.0**	2.0	**12.0**	1.0	**4.0**	3.0	**18.0**	**92.0**	2
Text combined with graphical presentation (visual, verbal)	Icon or graphic representation with text description	1.0	**8.0**	2.0	**20.0**	3.0	**24.0**	1.5	**6.0**	3.0	**18.0**	3.0	**12.0**	1.5	**9.0**	**97.0**	1

Table 18. Warning modality: High priority, external environment, context required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	2.0	**20.0**	2.5	**20.0**	2.0	**8.0**	2.0	**12.0**	2.5	**10.0**	2.0	**12.0**	**94.0**	1.5
	Alerting tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	3.0	**18.0**	**94.0**	1.5
	Alerting tone, then voice	1.5	**12.0**	1.0	**10.0**	2.5	**20.0**	3.0	**12.0**	3.0	**18.0**	2.5	**10.0**	1.0	**6.0**	**88.0**	3

Table 19. Warning modality: High priority, external environment, context not required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Tactile presentation (tactile)	Automatic control manipulation or change in tactile feedback	6.0	**48.0**	5.0	**50.0**	2.0	**16.0**	4.0	**16.0**	2.0	**12.0**	4.0	**16.0**	2.0	**12.0**	**170.0**	3
	Vibration of controls alerting driver	5.0	**40.0**	6.0	**60.0**	1.0	**8.0**	2.0	**8.0**	1.0	**6.0**	3.0	**12.0**	3.0	**18.0**	**152.0**	4
Speech combined with graphical presentation (auditory, visual)	Icon or graphic representation plus voice	3.0	**24.0**	2.0	**20.0**	6.0	**48.0**	6.0	**24.0**	5.5	**33.0**	6.0	**24.0**	1.5	**9.0**	**182.0**	2
Speech combined with text presentation (auditory, visual)	Description on video screen with voice	1.0	**8.0**	1.0	**10.0**	5.0	**40.0**	5.0	**20.0**	5.5	**33.0**	1.0	**4.0**	1.5	**9.0**	**124.0**	6
Tones combined with graphical presentation (auditory, visual)	Icon or graphic representation with simple tones, chimes, etc.	4.0	**32.0**	4.0	**40.0**	4.0	**32.0**	3.0	**12.0**	4.0	**24.0**	5.0	**20.0**	5.5	**33.0**	**193.0**	1
Tones combined with text presentation	Description on video screen with tones	2.0	**16.0**	3.0	**30.0**	3.0	**24.0**	1.0	**4.0**	3.0	**18.0**	2.0	**8.0**	5.5	**33.0**	**133.0**	5

Table 20. Warning modality: High priority, inside the vehicle, context required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.0	**10.0**	2.5	**20.0**	3.0	**12.0**	2.0	**12.0**	2.5	**10.0**	2.0	**12.0**	**88.0**	2
	Alerting tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	3.0	**18.0**	**94.0**	1.5
	Alerting tone, then speech	1.5	**12.0**	2.0	**20.0**	2.5	**20.0**	2.0	**8.0**	3.0	**18.0**	2.5	**10.0**	1.0	**6.0**	**94.0**	1.5

Table 21. Warning modality: High priority, inside the vehicle, context not required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		**10**		**8**		**4**		**6**		**4**		**6**			
		Distraction Potential		**Attention Demand**		**Post-Retrieval Workload**		**Efficiency**		**Error Potential**		**Driver Acceptance**		**Annoyance Potential**			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Tactile presentation (tactile)	Vibration of controls alerting driver	1.0	**8.0**	9.0	**90.0**	1.0	**8.0**	1.0	**4.0**	1.5	**9.0**	1.0	**4.0**	1.5	**9.0**	**132.0**	9
Speech combined with graphical presentation (auditory, visual)	Dedicated lights with voice	4.0	**32.0**	3.0	**30.0**	5.0	**40.0**	7.0	**28.0**	7.0	**42.0**	4.0	**16.0**	4.5	**27.0**	**215.0**	7
	Icon or graphic representation plus voice	3.0	**24.0**	1.0	**10.0**	9.0	**72.0**	7.0	**28.0**	9.0	**54.0**	5.0	**20.0**	4.5	**27.0**	**235.0**	5
Speech combined with text presentation (auditory, visual)	Description on video screen with voice	2.0	**16.0**	2.0	**20.0**	8.0	**64.0**	7.0	**28.0**	5.0	**30.0**	3.0	**12.0**	3.0	**18.0**	**188.0**	8
Tones combined with graphical presentation (auditory, visual)	Dedicated lights with tones	7.0	**56.0**	7.0	**70.0**	3.0	**24.0**	3.0	**12.0**	6.0	**36.0**	8.0	**32.0**	8.0	**48.0**	**278.0**	2
	Icon or graphic representation with simple tones, chimes, etc.	6.0	**48.0**	5.0	**50.0**	6.0	**48.0**	4.0	**16.0**	8.0	**48.0**	9.0	**36.0**	8.0	**48.0**	**294.0**	1
Tones with text presentation	Description on video screen with tones	5.0	**40.0**	6.0	**60.0**	4.0	**32.0**	7.0	**28.0**	4.0	**24.0**	7.0	**28.0**	8.0	**48.0**	**260.0**	3
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	8.0	**64.0**	4.0	**40.0**	7.0	**56.0**	7.0	**28.0**	3.0	**18.0**	2.0	**8.0**	1.5	**9.0**	**223.0**	6
	Alerting tones, chimes, etc.	9.0	**72.0**	8.0	**80.0**	2.0	**16.0**	2.0	**8.0**	1.5	**9.0**	6.0	**24.0**	6.0	**36.0**	**245.0**	4

Table 22. Warning modality: Medium priority, external environment, context required, long.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		**10**		**8**		**4**		**6**		**4**		**6**			
		Distraction Potential		**Attention Demand**		**Post-Retrieval Workload**		**Efficiency**		**Error Potential**		**Driver Acceptance**		**Annoyance Potential**			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Partial-route video map display with icon info	2.0	**16.0**	3.0	**30.0**	2.0	**16.0**	1.5	**6.0**	5.0	**30.0**	4.5	**18.0**	4.0	**24.0**	**140.0**	3
	Icon or graphic representation	5.0	**40.0**	5.0	**50.0**	3.5	**28.0**	4.0	**16.0**	1.0	**6.0**	2.5	**10.0**	1.0	**6.0**	**156.0**	2
Text presentation (visual, verbal)	Description on video screen	3.0	**24.0**	4.0	**40.0**	3.5	**28.0**	3.0	**12.0**	3.0	**18.0**	1.0	**4.0**	2.0	**12.0**	**138.0**	4
Text combined with graphical presentation (visual, spatial, verbal)	Partial-route video map display with text description	1.0	**8.0**	1.0	**10.0**	1.0	**8.0**	1.5	**6.0**	4.0	**24.0**	4.5	**18.0**	4.0	**24.0**	**98.0**	5
	Icon or graphic representation with text description	4.0	**32.0**	2.0	**20.0**	5.0	**40.0**	5.0	**20.0**	2.0	**12.0**	2.5	**10.0**	4.0	**24.0**	**158.0**	1

Table 23. Warning modality: Medium priority, external environment, context required, short.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.0	**10.0**	2.0	**16.0**	2.0	**8.0**	2.0	**12.0**	2.0	**8.0**	2.5	**15.0**	**81.0**	3
	Alerting tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	1.0	**6.0**	**82.0**	2
	Alerting tone, then speech	1.5	**12.0**	2.0	**20.0**	3.0	**24.0**	3.0	**12.0**	3.0	**18.0**	3.0	**12.0**	2.5	**15.0**	**113.0**	1

Table 24. Warning modality: Medium priority, external environment, context not required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Tactile presentation (tactile)	Automatic control manipulation, or change in tactile feedback	2.0	**16.0**	1.0	**10.0**	1.5	**12.0**	2.0	**8.0**	2.0	**12.0**	2.0	**8.0**	2.0	**12.0**	**78.0**	1
	Vibration of controls alerting driver	1.0	**8.0**	2.0	**20.0**	1.5	**12.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	1.0	**6.0**	**60.0**	2

Table 25. Warning modality: Medium priority, inside the vehicle, context required, long.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Dedicated light with icon label	4.0	**32.0**	4.0	**40.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	3.0	**12.0**	5.0	**30.0**	**132.0**	4
	Icon or graphic representation	4.0	**32.0**	5.0	**50.0**	3.0	**24.0**	2.0	**8.0**	2.0	**12.0**	4.0	**16.0**	4.0	**24.0**	**166.0**	1
Text presentation (visual, verbal)	Description on video screen	4.0	**32.0**	3.0	**30.0**	2.0	**16.0**	3.5	**14.0**	4.0	**24.0**	1.0	**4.0**	3.0	**18.0**	**138.0**	3
Text combined with graphical presentation (visual, spatial, verbal)	Dedicated light with text description	1.5	**12.0**	1.0	**10.0**	4.0	**32.0**	3.5	**14.0**	4.0	**24.0**	2.0	**8.0**	1.5	**9.0**	**109.0**	5
	Icon or graphic representation with text description	1.5	**12.0**	2.0	**20.0**	5.0	**40.0**	5.0	**20.0**	4.0	**24.0**	5.0	**20.0**	1.5	**9.0**	**145.0**	2

Table 26. Warning modality: Medium priority, inside the vehicle, context required, short.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.0	**10.0**	2.0	**16.0**	2.0	**8.0**	1.5	**9.0**	2.5	**10.0**	2.0	**12.0**	**77.0**	3
	Alerting tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.5	**9.0**	1.0	**4.0**	2.0	**12.0**	**91.0**	2
	Alerting tone followed by speech message	1.5	**12.0**	2.0	**20.0**	3.0	**24.0**	3.0	**12.0**	3.0	**18.0**	2.5	**10.0**	2.0	**12.0**	**108.0**	1

Table 27. Warning modality: Medium priority, inside the vehicle, context not required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Dedicated light	4.0	**32.0**	5.0	**50.0**	3.5	**28.0**	3.5	**14.0**	1.0	**6.0**	1.5	**6.0**	4.0	**24.0**	**160.0**	2
	Icon or graphic representation	4.0	**32.0**	4.0	**40.0**	5.0	**40.0**	5.0	**20.0**	4.0	**24.0**	4.5	**18.0**	4.0	**24.0**	**198.0**	1
Text presentation (visual, verbal)	Description on video screen	4.0	**32.0**	3.0	**30.0**	3.5	**28.0**	3.5	**14.0**	2.5	**15.0**	1.5	**6.0**	4.0	**24.0**	**149.0**	3
Text combined with graphical presentation (visual, spatial, verbal)	Dedicated light and text	1.5	**12.0**	1.5	**15.0**	1.5	**12.0**	1.0	**4.0**	2.5	**15.0**	3.0	**12.0**	1.5	**9.0**	**79.0**	5
	Icon or graphic representation with text description	1.5	**12.0**	1.5	**15.0**	1.5	**12.0**	2.0	**8.0**	5.0	**30.0**	4.5	**18.0**	1.5	**9.0**	**104.0**	4

Table 28. Warning modality: Low priority, context required, long.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Partial-route video map display with icon info	8.5	**68**	5.0	**50**	6.5	**52**	4.0	**16**	2.5	**15**	6.0	**24**	9.0	**54**	**279.0**	10
	Icon or graphic representation	11.5	**92**	6.0	**60**	6.5	**52**	5.0	**20**	2.5	**15**	11.5	**46**	12.5	**75**	**360.0**	4
Text presentation (visual, verbal)	Description on video screen	11.5	**92**	2.5	**25**	2.5	**20**	3.0	**12**	6.0	**36**	3.0	**12**	10.0	**60**	**257.0**	11
Speech combined with graphical presentation (auditory, visual)	Partial-route video map display with voice	1.0	**8**	7.5	**75**	12.5	**100**	11.5	**46**	10.0	**60**	6.0	**24**	1.5	**9**	**322.0**	6
	Dedicated light with voice	3.0	**24**	11.5	**115**	2.5	**20**	1.5	**6**	8.0	**48**	1.5	**6**	3.5	**21**	**240.0**	13
	Icon or graphic representation plus voice	3.0	**24**	11.5	**115**	12.5	**100**	13.0	**52**	10.0	**60**	11.5	**46**	3.5	**21**	**418.0**	1
Speech and text presentation (auditory, visual)	Description on video screen with voice	3.0	**24**	9.0	**90**	5.0	**40**	11.5	**46**	12.5	**75**	9.0	**36**	1.5	**9**	**320.0**	7
Tones combined with graphical presentation (auditory, visual)	Partial-route video map display with tones	5.0	**40**	7.5	**75**	8.5	**68**	9.0	**36**	2.5	**15**	6.0	**24**	5.5	**33**	**291.0**	8
	Icon or graphic representation with simple tones, chimes, etc.	6.5	**52**	13.0	**130**	8.5	**68**	10.0	**40.0**	2.5	**15**	11.5	**46**	7.0	**42**	**393.0**	3
Tones with text presentation	Description on video screen with tones	6.5	**52**	10.0	**100**	2.5	**20**	6.0	**24**	6.0	**36**	6.0	**24**	5.5	**33**	**289.0**	9
Text combined with graphical presentation (visual, spatial, verbal)	Partial-route video map display with text description	8.5	**68**	4.0	**40**	10.5	**84**	7.0	**28**	10.0	**60**	6.0	**24**	8.0	**48**	**352.0**	5
	Dedicated light with text description	11.5	**92**	2.5	**25**	2.5	**20**	1.5	**6**	6.0	**36**	1.5	**6**	11.0	**66**	**251.0**	12
	Icon or graphic representation with text description	11.5	**92**	1.0	**10**	10.5	**84**	8.0	**32**	12.5	**75**	11.5	**46**	12.5	**75**	**414.0**	2

Table 29. Warning modality: Low priority, context required, short.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.0	**10.0**	2.0	**16.0**	2.0	**8.0**	2.0	**12.0**	1.0	**4.0**	2.0	**12.0**	**74.0**	3
	Alerting tones, chimes, etc.	3.0	**24.0**	2.0	**20.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	3.0	**12.0**	3.0	**18.0**	**92.0**	2
	Alerting tone, then speech	1.5	**12.0**	3.0	**30.0**	3.0	**24.0**	3.0	**12.0**	3.0	**18.0**	2.0	**8.0**	1.0	**6.0**	**110.0**	1

Table 30. Warning modality: Low priority, context not required.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Dedicated light	6.0	**48.0**	5.5	**55.0**	1.0	**8.0**	1.5	**6.0**	1.0	**6.0**	2.5	**10.0**	5.0	**30.0**	**163.0**	3
	Icon or graphic representation	5.0	**40.0**	5.5	**55.0**	4.0	**32.0**	3.5	**14.0**	6.0	**36.0**	5.0	**20.0**	6.0	**36.0**	**233.0**	1
Speech combined with graphical presentation (auditory, visual)	Dedicated light with voice	2.0	**16.0**	1.5	**15.0**	3.0	**24.0**	3.5	**14.0**	3.0	**18.0**	2.5	**10.0**	1.5	**9.0**	**106.0**	6
	Icon or graphic representation plus voice	1.0	**8.0**	1.5	**15.0**	6.0	**48.0**	6.0	**24.0**	4.5	**27.0**	2.5	**10.0**	1.5	**9.0**	**141.0**	4
Tones combined with graphical presentation (visual, spatial, verbal)	Dedicated light display with tones	4.0	**32.0**	3.5	**35.0**	2.0	**16.0**	1.5	**6.0**	2.0	**12.0**	2.5	**10.0**	3.0	**18.0**	**129.0**	5
	Icon or graphic representation with simple tones, chimes, etc.	3.0	**24.0**	3.5	**35.0**	5.0	**40.0**	5.0	**20.0**	4.5	**27.0**	6.0	**24.0**	4.0	**24.0**	**194.0**	2

Table 31. Signing: Vehicle operations, complex information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Speech combined with graphical presentation (auditory, visual)	Partial-route video map display with voice	1.0	**8.0**	2.0	**20.0**	1.5	**12.0**	3.0	**12.0**	2.0	**12.0**	1.5	**6.0**	4.0	**24.0**	**94.0**	5
	Icon or graphic representation plus voice	2.5	**20.0**	5.0	**50.0**	5.5	**44.0**	6.0	**24.0**	4.0	**24.0**	5.5	**22.0**	4.0	**24.0**	**208.0**	1
Speech combined with text (auditory, visual)	Description on video screen with voice	2.5	**20.0**	4.0	**40.0**	5.5	**44.0**	4.5	**18.0**	6.0	**36.0**	3.5	**14.0**	4.0	**24.0**	**196.0**	2.5
Tones combined with graphical presentation (auditory, visual)	Partial-route video map display with tones	4.0	**32.0**	1.0	**10.0**	1.5	**12.0**	1.5	**6.0**	2.0	**12.0**	1.5	**6.0**	2.0	**12.0**	**90.0**	6
	Icon or graphic representation with simple tones, chimes, etc.	5.5	**44.0**	6.0	**60.0**	3.5	**28.0**	4.5	**18.0**	2.0	**12.0**	5.5	**22.0**	2.0	**12.0**	**196.0**	2.5
Tones with text (auditory, visual)	Description on video screen with tones	5.5	**44.0**	3.0	**30.0**	3.5	**28.0**	1.5	**6.0**	5.0	**30.0**	3.5	**14.0**	2.0	**12.0**	**164.0**	4

Table 32. Signing: Vehicle operations, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.5	**15.0**	2.5	**20.0**	3.0	**12.0**	2.0	**12.0**	3.0	**12.0**	2.0	**12.0**	**95.0**	2
	Alerting tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	1.0	**6.0**	**82.0**	3
	Alerting tone, then speech	1.5	**12.0**	1.5	**15.0**	2.5	**20.0**	2.0	**8.0**	3.0	**18.0**	2.0	**8.0**	3.0	**18.0**	**99.0**	1

Table 33. Signing: Informational message, requested, complex information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Speech combined with graphical presentation (auditory, visual)	Partial-route video map display with voice	6.0	**48.0**	4.0	**40.0**	5.0	**40.0**	3.5	**14.0**	4.0	**24.0**	4.0	**16.0**	1.0	**6.0**	**188.0**	3
	Icon or graphic representation plus voice	5.0	**40.0**	5.0	**50.0**	6.0	**48.0**	5.5	**22.0**	5.0	**30.0**	6.0	**24.0**	3.0	**18.0**	**232.0**	1
Speech with text (auditory, visual)	Description on video screen with voice	4.0	**32.0**	6.0	**60.0**	3.5	**28.0**	1.0	**4.0**	6.0	**36.0**	5.0	**20.0**	2.0	**12.0**	**192.0**	2
Tones combined with graphical presentation (auditory, visual)	Partial-route video map display with tones	2.0	**16.0**	1.5	**15.0**	1.0	**8.0**	3.5	**14.0**	2.0	**12.0**	1.0	**4.0**	4.0	**24.0**	**93.0**	6
	Icon or graphic representation with simple tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	2.0	**16.0**	5.5	**22.0**	3.0	**18.0**	3.0	**12.0**	6.0	**36.0**	**158.0**	4
Tones combined with text (auditory, visual)	Description on video screen with tones	1.0	**8.0**	1.5	**15.0**	3.5	**28.0**	2.0	**8.0**	1.0	**6.0**	2.0	**8.0**	5.0	**30.0**	**103.0**	5

Table 34. Signing: Informational message, requested, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.5	**15.0**	2.5	**20.0**	3.0	**12.0**	2.0	**12.0**	3.0	**12.0**	1.5	**9.0**	**92.0**	2
	Alerting tones, chimes, etc.	3.0	**24.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	3.0	**18.0**	**94.0**	1
	Alerting tone, then speech	1.5	**12.0**	1.5	**15.0**	2.5	**20.0**	2.0	**8.0**	3.0	**18.0**	2.0	**8.0**	1.5	**9.0**	**90.0**	3

Table 35. Signing: Informational message, automatically presented information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Partial-route video map display with icon information	2.0	**16.0**	2.0	**20.0**	1.0	**8.0**	2.5	**10.0**	1.0	**6.0**	2.0	**8.0**	1.0	**6.0**	**74.0**	5
	Icon or graphic representation	5.0	**40.0**	5.0	**50.0**	2.0	**16.0**	2.5	**10.0**	3.0	**18.0**	5.0	**20.0**	5.0	**30.0**	**184.0**	1
Text presentation (visual, verbal)	Description on video screen	4.0	**32.0**	1.0	**10.0**	3.0	**24.0**	1.0	**4.0**	4.0	**24.0**	1.0	**4.0**	2.0	**12.0**	**110.0**	4
Text combined with graphical presentation (visual, verbal)	Partial-route video map display with text description	1.0	**8.0**	4.0	**40.0**	4.0	**32.0**	4.5	**18.0**	2.0	**12.0**	3.0	**12.0**	3.0	**18.0**	**140.0**	3
	Icon or graphic representation with text description	3.0	**24.0**	3.0	**30.0**	5.0	**40.0**	4.5	**18.0**	5.0	**30.0**	4.0	**16.0**	4.0	**24.0**	**182.0**	2

Table 36. Communications and aid request: Message content, critical information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Video map display (full or partial) with icon information	7.5	**60.0**	2.5	**25.0**	1.5	**12.0**	2.5	**10.0**	2.0	**12.0**	5.0	**20.0**	7.0	**42.0**	**181.0**	9
	Icon or graphic representation	9.5	**76.0**	11.0	**110.0**	3.5	**28.0**	2.5	**10.0**	4.5	**27.0**	1.0	**4.0**	10.5	**63.0**	**318.0**	3
Text presentation (visual, verbal)	Description on video screen	11.0	**88.0**	8.0	**8.0**	8.0	**64.0**	10.0	**40**	6.0	**36**	11.0	**44.0**	10.5	**63.0**	**415.0**	1
Speech combined with graphical presentation (auditory, visual)	Video map display with voice	1.0	**8.0**	5.0	**50.0**	5.5	**44.0**	5.0	**20.0**	2.0	**12.0**	5.0	**20.0**	1.0	**6.0**	**160.0**	10
	Icon or graphic representation plus voice	3.0	**24.0**	9.0	**90.0**	5.5	**44.0**	10.0	**40.0**	10.0	**60.0**	5.0	**20.0**	2.5	**15.0**	**293.0**	5
Speech and text presentation (auditory, visual)	Description on video screen with voice	2.0	**16.0**	5.0	**50.0**	10.0	**80.0**	10.0	**40.0**	10.0	**60.0**	10.0	**40.0**	2.5	**15.0**	**301.0**	4
Tones combined with graphical presentation (auditory, visual)	Video map display with tones	4.0	**32.0**	2.5	**25.0**	1.5	**12.0**	2.5	**10.0**	2.0	**12.0**	5.0	**20.0**	4.0	**24.0**	**135.0**	11
	Icon or graphic representation with simple tones, chimes, etc.	6.0	**48.0**	10.0	**100.0**	3.5	**28.0**	8.0	**32.0**	4.5	**27.0**	5.0	**20.0**	6.0	**36.0**	**291.0**	6
Tones and text presentation (auditory, visual)	Description on video screen with tones	5.0	**40.0**	5.0	**50.0**	7.0	**56.0**	6.0	**24.0**	8.0	**48.0**	2.0	**8.0**	5.0	**30.0**	**256.0**	8
Text combined with graphical presentation (visual, spatial, verbal)	Video map display with text description	7.5	**60**	1.0	**10.0**	10.0	**80.0**	2.5	**10.0**	7.0	**42.0**	8.0	**32.0**	8.5	**51.0**	**285.0**	7
	Icon or graphic representation with text description	9.5	**76.0**	7.0	**70.0**	10.0	**80.0**	7.0	**28.0**	10.0	**60.0**	9.0	**36.0**	8.5	**51.0**	**401.0**	2

Table 37. Communications and aid request: Message content, low-priority information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Map display (full or partial) with icon information	1.5	**12.0**	1.0	**10.0**	2.5	**20.0**	1.5	**6.0**	1.5	**9.0**	2.5	**10.0**	2.0	**12.0**	**79.0**	6
	Icon or graphic representation	4.5	**36.0**	5.5	**55.0**	5.0	**40.0**	3.5	**14.0**	3.5	**21.0**	5.0	**20.0**	5.0	**30.0**	**216.0**	2
Text presentation (visual, verbal)	Description printed out (hardcopy)	3.0	**24.0**	3.0	**30.0**	2.5	**20.0**	1.5	**6.0**	5.5	**33.0**	1.0	**4.0**	1.0	**6.0**	**123.0**	4
	Description on video screen	6.0	**48.0**	4.0	**40.0**	2.5	**20.0**	4.0	**16.0**	5.5	**33.0**	5.0	**20.0**	5.0	**30.0**	**207.0**	3
Text combined with graphical presentation (visual, spatial, verbal)	3-D video map display with text description	1.5	**12.0**	2.0	**20.0**	2.5	**20.0**	3.0	**12.0**	1.5	**9.0**	2.5	**10.0**	3.0	**18.0**	**101.0**	5
	Icon or graphic representation with text description	4.5	**36.0**	5.5	**55.0**	6.0	**48.0**	5.5	**22.0**	3.5	**21.0**	5.0	**20.0**	5.0	**30.0**	**232.0**	1

Table 38. Communications and aid request: Message-system operation, message event, critical information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Speech combined with graphical presentation (auditory, visual)	Dedicated light	5.5	**44.0**	2.5	**25.0**	3.5	**28.0**	2.0	**8.0**	1.5	**9.0**	1.0	**4.0**	1.0	**6.0**	**124.0**	6
	Icon or graphic representation plus voice	5.5	**44.0**	1.0	**10.0**	5.5	**44.0**	6.0	**24.0**	3.0	**18.0**	4.0	**16.0**	2.5	**15.0**	**171.0**	3
Speech combined with text presentation (auditory, visual)	Description on video screen with voice	4.0	**32.0**	2.5	**25.0**	5.5	**44.0**	5.0	**20.0**	6.0	**36.0**	3.0	**12.0**	2.5	**15.0**	**184.0**	1
Tones combined with graphical presentation (auditory, visual)	Dedicated light	3.0	**24.0**	5.5	**55.0**	1.0	**8.0**	1.0	**4.0**	1.5	**9.0**	2.0	**8.0**	3.0	**18.0**	**126.0**	5
	Icon or graphic representation with simple tones, chimes, etc.	1.5	**12.0**	4.0	**40.0**	2.0	**16.0**	4.0	**16.0**	5.0	**30.0**	6.0	**24.0**	4.5	**27.0**	**165.0**	4
Tones combined with text (auditory, visual)	Description on video screen with tones	1.5	**12.0**	5.5	**55.0**	3.5	**28.0**	3.0	**12.0**	4.0	**24.0**	5.0	**20.0**	4.5	**27.0**	**178.0**	2

Table 39. Communications and aid request: Message-system operation, message event, noncritical information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	1.5	**12.0**	1.0	**10.0**	2.0	**16.0**	1.5	**6.0**	2.0	**12.0**	2.0	**8.0**	2.0	**12.0**	**76.0**	3
	Alerting tones, chimes, etc.	3.0	**24.0**	2.0	**20.0**	1.0	**8.0**	1.5	**6.0**	1.0	**6.0**	2.0	**8.0**	3.0	**18.0**	**90.0**	2
	Speech with alerting tone	1.5	**12.0**	3.0	**30.0**	3.0	**24.0**	3.0	**12.0**	3.0	**18.0**	2.0	**8.0**	1.0	**6.0**	**110.0**	1

Table 40. Communications and aid request: Message-system operation, message system management.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Message presented as speech (digital or synthesized)	2.0	**16.0**	3.0	**30.0**	2.0	**16.0**	2.0	**8.0**	1.0	**6.0**	2.5	**10.0**	2.0	**12.0**	**98.0**	1
Text presentation (visual, verbal)	Alerting tones, chimes, etc.	2.0	**16.0**	2.0	**20.0**	1.0	**8.0**	1.0	**4.0**	2.0	**12.0**	1.0	**4.0**	3.0	**18.0**	**82.0**	3
Text with graphical presentation (visual, spatial, verbal)	Speech with alerting tone	2.0	**16.0**	1.0	**10.0**	3.0	**24.0**	3.0	**12.0**	3.0	**18.0**	2.5	**10.0**	1.0	**6.0**	**96.0**	2

Table 41. Motorist services: Position-oriented, complex information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**R**	**RxW**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Full-route video map display with icon information	9.0	**72.0**	10.0	**100.0**	8.5	**0.0**	9.5	**38.0**	4.0	**24.0**	9.5	**38.0**	10.5	**63.0**	**335.0**	6
	Partial-route video map display with icon information	10.0	**80.0**	11.0	**110.0**	8.5	**68.0**	9.5	**38.0**	6.0	**36.0**	10.5	**42.0**	12.5	**75.0**	**449.0**	2
	Full printed map with icon information	8.0	**64.0**	5.0	**50.0**	8.5	**68.0**	4.5	**18.0**	3.0	**18.0**	1.5	**6.0**	2.0	**12.0**	**236.0**	9
	Partial printed map with icon information	6.0	**48.0**	5.0	**50.0**	8.5	**68.0**	4.5	**18.0**	5.0	**30.0**	1.5	**6.0**	2.0	**12.0**	**232.0**	11
	3-D map display (full or partial) with icon information	5.0	**40.0**	3.0	**30.0**	1.5	**12.0**	2.0	**8.0**	2.0	**12.0**	6.5	**26.0**	5.0	**30.0**	**158.0**	12
	Icon or graphic representation	13.0	**104.0**	13.0	**130.0**	3.5	**28.0**	1.0	**4.0**	1.0	**6.0**	5.0	**20.0**	7.0	**42.0**	**334.0**	7
Text presentation (visual, verbal)	Description printed out (hardcopy)	7.0	**56.0**	1.0	**10.0**	5.5	**44.0**	7.5	**30.0**	8.0	**48.0**	4.0	**16.0**	5.0	**30.0**	**234.0**	10
	Description on video screen	11.0	**88.0**	7.0	**70.0**	5.5	**44.0**	7.5	**30.0**	9.0	**54.0**	6.0	**24.0**	8.0	**48.0**	**358.0**	5
Text combined with graphical presentation (visual, spatial, verbal)	Full-route video map display with text description	2.5	**20.0**	8.0	**80.0**	12.0	**96.0**	12.5	**50.0**	11.5	**69.0**	9.5	**38.0**	10.5	**63.0**	**416.0**	4
	Partial-route video map display with text description	2.5	**20.0**	9.0	**90.0**	12.0	**96.0**	12.5	**50.0**	13.0	**78.0**	10.5	**42.0**	12.5	**75.0**	**451.0**	1
	Printed map with text description	4.0	**32.0**	5.0	**50.0**	12.0	**96.0**	6.0	**24.0**	11.5	**69.0**	3.0	**12.0**	2.0	**12.0**	**295.0**	8
	3-D video map display with text description	1.0	**8.0**	2.0	**20.0**	1.5	**12.0**	3.0	**12.0**	7.0	**42.0**	6.5	**26.0**	5.0	**30.0**	**150.0**	13
	Icon or graphic representation with text description	12.0	**96.0**	12.0	**120.0**	3.5	**28.0**	11.0	**44.0**	10.0	**60.0**	8.0	**32.0**	9.0	**54**	**434.0**	3

Table 42. Motorist services: Position-oriented, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	4.0	**32.0**	3.5	**35.0**	2.0	**16.0**	4.0	**16.0**	4.0	**24.0**	3.0	**12.0**	2.0	**12.0**	**147.0**	7
	Alerting tones, chimes, etc.	7.0	**56.0**	3.5	**35.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.0	**4.0**	7.0.	**42.0**	**155.0**	6
Speech with graphical presentation (auditory, visual)	Partial-route video map display with voice	1.0	**8.0**	6.5	**65.0**	5.5	**44.0**	6.0	**24.0**	7.0	**42.0**	4.0	**16.0**	4.0	**24.0**	**223.0**	2
	Icon or graphic representation plus voice	2.0	**16.0**	6.5	**65.0**	7.0	**56.0**	7.0	**28.0**	2.0	**12.0**	6.0	**24.0**	2.0	**12.0**	**213.0**	3
Speech with text (auditory, visual)	Description on video screen with voice	3.0	**24.0**	2.0	**20.0**	5.5	**44.0**	2.5	**10.0**	6.0	**36.0**	5.0	**20.0**	2.0	**12.0**	**166.0**	4
Tones combined with graphical presentation (auditory, visual)	Icon or graphic representation with simple tones, chimes, etc.	5.5	**44.0**	5.0	**50.0**	4.0	**32.0**	5.0	**20.0**	3.0	**18.0**	7.0	**28.0**	5.5	**33.0**	**225.0**	1
Presentation (auditory, visual)	Description on video screen with tones	5.5	**44.0**	1.0	**10.0**	3.0	**24.0**	2.5	**10.0**	5.0	**30.0**	2.0	**8.0**	5.5	**33.0**	**159.0**	5

Table 43. Motorist services: Status, continuous information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Icon or graphic representation	2.5	**20.0**	3.0	**30.0**	1.0	**8.0**	2.0	**8.0**	1.0	**6.0**	2.5	**10.0**	1.5	**9.0**	**91.0**	2
Text presentation (visual, verbal)	Description on video screen	2.5	**20.0**	2.0	**20.0**	2.0	**16.0**	3.0	**12.0**	2.0	**12.0**	2.5	**10.0**	3.0	**18.0**	**108.0**	1
Text with graphical presentation (visual, spatial, verbal)	Icon or graphic representation with text description	1.0	**8.0**	1.0	**10.0**	3.0	**24.0**	1.0	**4.0**	3.0	**18.0**	1.0	**4.0**	1.5	**9.0**	**77.0**	3

Table 44. Motorist services: Status, intermittent display, complex information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		**10**		**8**		**4**		**6**		**4**		**6**			
		Distraction Potential		**Attention Demand**		**Post-Retrieval Workload**		**Efficiency**		**Error Potential**		**Driver Acceptance**		**Annoyance Potential**			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Graphical presentation (visual, spatial)	Icon or graphic representation	2.5	**20.0**	3.0	**30.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	1.5	**6.0**	1.0	**6.0**	**80.0**	2
Text presentation (visual, verbal)	Description on video screen	2.5	**20.0**	1.0	**10.0**	2.0	**16.0**	2.0	**8.0**	2.0	**12.0**	1.5	**6.0**	2.5	**15.0**	**87.0**	3
Text with graphical presentation (visual, spatial, verbal)	Icon or graphic representation with text description	1.0	**8.0**	2.0	**20.0**	3.0	**24.0**	3.0	**12.0**	3.0	**18.0**	3.0	**12.0**	2.5	**15.0**	**109.0**	1

Table 45. Motorist Services: Status, intermittent display, simple information.

R = Ranking of display
RxW = Ranking times assigned weight

		Assigned Weights															
		8		10		8		4		6		4		6			
		Distraction Potential		Attention Demand		Post-Retrieval Workload		Efficiency		Error Potential		Driver Acceptance		Annoyance Potential			
Display Mode	**General Display Description**	**R**	**Rx W**	**R**	**Rx W**	**R**	**RxW**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**R**	**Rx W**	**Total**	**Rank**
Auditory presentation (auditory)	Message presented as speech (digital or synthesized)	5.0	**40.0**	4.0	**40.0**	2.0	**16.0**	4.5	**18.0**	3.0	**18.0**	2.0	**8.0**	1.0	**6.0**	**146.0**	5
	Alerting tones, chimes, etc.	6.0	**48.0**	5.0	**50.0**	1.0	**8.0**	1.0	**4.0**	1.0	**6.0**	4.0	**16.0**	6.0	**36.0**	**168.0**	2
Speech combined with graphical presentation (auditory, visual)	Icon or graphic representation plus voice	1.5	**12.0**	2.0	**20.0**	6.0	**48.0**	6.0	**24.0**	4.0	**24.0**	3.0	**12.0**	3.0	**18.0**	**158.0**	4
Speech combined with text (auditory, visual)	Description on video screen with voice	1.5	**12.0**	1.0	**10.0**	5.0	**40.0**	3.0	**12.0**	6.0	**36.0**	1.0	**4.0**	2.0	**12.0**	**126.0**	6
Tones combined with graphical presentation (auditory, visual)	Icon or graphic representation with alerting tones, chimes, etc.	3.5	**28.0**	6.0	**60.0**	4.0	**32.0**	4.5	**18.0**	2.0	**12.0**	6.0	**24.0**	5.0	**30.0**	**204.0**	1
Tones combined with text (auditory, visual)	Description on video screen with tones	3.5	**28.0**	3.0	**30.0**	3.0	**24.0**	2.0	**8.0**	5.0	**30.0**	5.0	**20.0**	4.0	**24.0**	**164.0**	3

APPENDIX E: DISPLAY LOCATION TRADE ANALYSIS

Table 46. Display location trade study.

Criterion	**Legibility Facilitation**		**Roadway Field-of-View Compatibility**		**Accommodation Time**		**Distance of Gaze Shift**		**Degree of Display Integration**		**Availability of Information to the Passenger**		
WT =	10		8		1		6		6		4		
Alternative	SC	WT*SC	SC	WT*SC	SC	WT*SC	SC	WT*SC	SC	WT*SC	SC	WT*SC	**Total Score**
Head-up display	1	10	5	40	5	5	5	30	4	24	1	4	113
Centrally integrated dashboard display	5	50	2	16	2	2	2	12	3	18	4	16	114
Separate dashboard display on left or right side	4	40	1	8	1	1	1	6	1	6	5	20	81
Head-up display plus centrally integrated dashboard display	3	30	4	32	4	4	4	24	5	30	2	8	128
Head-up display plus separated dashboard display on left or right side	2	20	3	24	3	3	3	18	2	12	3	12	89

APPENDIX F: SENSORY MODALITY, TRIP STATUS, AND DISPLAY FORMAT ALLOCATION FOR EACH INFORMATION REQUIREMENT

The following pages contain the results of applying the sensory modality allocation and trip status allocation design tools together with the display format trade study.

Table 47. Sensory modality, trip status, and display format allocation for each information requirement for IRANS.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Trip Planning			
Current criteria for automated trip planning	visual	predrive	Text description on video screen Icon or graphic representation with text description
Time to get to each destination from previous destination	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Cost of each toll along the route	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Total toll charges along the route	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Total time for trip	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Total distance for trip	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Locations of attractions and points of interest	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Forecast weather information	visual	predrive	Text description on video screen Icon or graphic representation with text description
Historical traffic information	visual	predrive	Text description on video screen Icon or graphic representation with text description
Street or roadway names on the route	visual	predrive	Text description on video screen Icon or graphic representation with text description
States, regions, communities, and districts along the route	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Landmarks or topographical features along the route	visual	predrive	Full-route video map display Full- or partial-route map display with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Number of turns or roadway changes required	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Types of roads used on route (interstate, highway, two-lane street, etc.)	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Distance to each destination from previous destination	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Distance to specific attractions	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Trip Planning CVO-Specific ***Note: Restrictions for trip planning cover entire trip.***			
Scheduled pickup and delivery time	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Time of day restrictions	visual	predrive	Text description on video screen Icon or graphic representation with text description
Day of the week restrictions	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to size	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to weight	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to height	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to equipment type	visual	predrive	Text description on video screen Icon or graphic representation with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Restrictions related to cargo	visual	predrive	Text description on video screen Icon or graphic representation with text description
Multimode Travel Coordination and Planning Information Requirement			
Bus, train, airline, ferry, and trolley schedules	visual	predrive	Text description on video screen Icon or graphic representation with text description
Location of park and ride facilities	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Park and ride parking facilities	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Combined travel mode schedules	visual	predrive	Text description on video screen Icon or graphic representation with text description
Start time required to catch other mode of transport	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Arrival time at destination	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Arrival time at end of each segment of travel	visual	predrive	Text description on video screen Icon or graphic representation with text description
Layover time between travel segments	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Mode of travel to take for each segment of travel	visual	predrive	Text description on video screen Icon or graphic representation with text description
Current constraint or optimization criteria mode	visual	predrive	Text description on video screen Icon or graphic representation with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Total time to complete travel	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Car pool instructions	visual	predrive	Text description on video screen Icon or graphic representation with text description
Car pool requests/inquiries	visual	predrive	Text description on video screen Icon or graphic representation with text description
Car pool member and address information	visual	predrive	Text description on video screen Icon or graphic representation with text description
Car pool member community and district information	visual	predrive	Text description on video screen Icon or graphic representation with text description
Minimum layover required to make next connection	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Real-time schedule updates for alternate modes of transport	visual	predrive	Text description on video screen Icon or graphic representation with text description
Notification of plan change to arrive at destination on time	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Interesting things to do during layover	visual	predrive	Text description on video screen Icon or graphic representation with text description
Alternate mode ticket purchase enroute to destination	visual	predrive	Text description on video screen Icon or graphic representation with text description
Schedule of segment arrival and departure times	visual	predrive	Text description on video screen Icon or graphic representation with text description
Order of trip segments	visual	predrive	Text description on video screen Icon or graphic representation with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
States, regions, communities, and districts on the route	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Segments by type of transport mode	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Park and ride costs	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Diagrams of alternate transport mode facilities	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Parking instructions for using different travel modes	visual	predrive	Text description on video screen Icon or graphic representation with text description
Location of next segment of travel	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Area view of all segments of travel	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Notification of unanticipated delays	auditory and visual, auditory	predrive	Full-route video map display Full- or partial-route map display with text description
Alternate mode of transport ticket availability	visual	predrive	Text description on video screen Icon or graphic representation with text description
Multimode Travel Coordination and Planning CVO-Specific			
Schedule for transport of cargo	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Transfer of information between alternate mode carriers	visual	predrive	Text description on video screen Icon or graphic representation with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Present location of modes of transport	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Regulations regarding mode of transport changes	visual	predrive	Text description on video screen Icon or graphic representation with text description
Alternate mode of transport schedules	visual	predrive	Text description on video screen Icon or graphic representation with text description
Real-time updates to alternate modes of transport schedules	visual	predrive	Text description on video screen Icon or graphic representation with text description
Availability of alternate mode shipping space	visual	predrive	Text description on video screen Icon or graphic representation with text description
Reservation of alternate mode shipping space	visual	predrive	Text description on video screen Icon or graphic representation with text description
Size and weight constraints for alternate modes of transport	visual	predrive	Text description on video screen Icon or graphic representation with text description
Facilities diagram for alternate modes of transport	visual	predrive	Text description on video screen Icon or graphic representation with text description
Alternate mode of transport cargo tracking	visual	predrive	Text description on video screen Icon or graphic representation with text description
Costs of cargo transfer	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Costs of shipping on alternate mode of transport segment	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Total cost of transport using alternate modes	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Landmarks along route	visual		Full-route video map display Full- or partial-route map display with text description
Predrive Route and Destination Selection			
Listing of routes and roadway names	visual	predrive	Text description on video screen Icon or graphic representation with text description
Listing of route available optimizations routines	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Routing constraints (cost, time, etc.)	visual	predrive	Text description on video screen Icon or graphic representation with text description
Distance to destination	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Time to get to destination	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Cost of completing route	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Notification of a more optimal alternative route	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Preview of proposed alternative route	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Historical congestion information	visual	predrive	Text description on video screen Icon or graphic representation with text description
Real-time congestion information	visual	predrive	Full-route video map display Full- or partial-route map display with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Location of tolls	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Weather forecast information	visual	predrive	Text description on video screen Icon or graphic representation with text description
Regions, communities, and districts the route will traverse	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Type of road (interstate, two lane, controlled access, one-way, etc.)	auditory and visual, auditory	predrive	Text description on video screen with voice Message presented as speech with or without icons
Predrive Route and Destination Selection CVO-Specific			
Notification of regulatory boundaries	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Time of day restrictions	visual	predrive	Text description on video screen Icon or graphic representation with text description
Day of the week restrictions	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to size	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to weight	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to height	visual	predrive	Text description on video screen Icon or graphic representation with text description
Restrictions related to equipment type	visual	predrive	Text description on video screen Icon or graphic representation with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Restrictions related to cargo	visual	predrive	Text description on video screen Icon or graphic representation with text description
Dynamic Route Selection			
Updated traffic information that might affect the route	auditory and visual, auditory	in transit	Icon or graphic representation with voice Icon or graphic representation with tones, chimes, etc.
Updated weather information that might affect the route	auditory and visual, auditory	in transit	Icon or graphic representation with voice Icon or graphic representation with tones, chimes, etc.
Notification that driver is off route	auditory and visual, auditory	in transit	Icon or graphic representation with voice Icon or graphic representation with tones, chimes, etc.
Suggested procedure for getting back on route	visual	in transit	Partial-route video map Partial-route video map with text description
Vehicle's current position	visual	in transit	Partial-route video map Partial-route video map with text description
Weather forecast	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Cost comparisons between current and alternative routes	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Type of road (interstate, two lane, controlled access, etc.)	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Time to complete current route versus proposed route	auditory and visual, auditory	zero speed	Icon or graphic representation with tones Text description on video screen with tones
Directional heading information (North, South, East, West)	auditory and visual, auditory	in transit	Icon or graphic representation with voice Icon or graphic representation with tones, chimes, etc.

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Real-time road surface condition information	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Dynamic Route Selection CVO-Specific			
Time of day restrictions	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Day of the week restriction	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Restrictions related to size	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Restrictions related to weight	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Restrictions related to height	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Restrictions related to equipment type	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Restrictions related to cargo	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Route Guidance			
Name of street or route to turn on	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Lane suggestion for setup of next turn	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Distance to next turn	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Direction to turn	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Name of current street	auditory and visual, auditory	in transit	Icon or graphic representation with text description Text description on video screen
Indication that the driver is off route	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Total distance remaining to destination	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Time to next turn at current speed	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Distance to toll booth	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Cost of toll	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Type of road (interstate, two lane, controlled access, etc.)	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Diagram of next intersection	visual	in transit	Partial-route video map Partial-route video map with text description
Max speed to negotiate exit ramp safely	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Directional heading (North, South, East, West)	auditory and visual, auditory	in transit	Icon or graphic representation plus voice Message presented as speech (digital or synthesized)
Total estimated time to reach destination	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Location of major landmarks (to aid in identifying turns)	visual	in transit	Partial-route video map Partial-route video map with text description
Route Guidance CVO-Specific			
When the vehicle needs to get in lane for turning	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Sharp turn indicator for larger vehicles	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Route Navigation			
Distance to get to destination	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Time to get to destination	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Cost to get to destination	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Indicate when a driver gets off route	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Streets or roadways that make up the new route	visual	predrive	Icon or graphic representation with text description Text description on video screen
States, regions, communities, and districts on the route	visual	predrive	Icon or graphic representation with text description Text description on video screen
Landmarks or topographical features along the route	visual	predrive	Icon or graphic representation with text description Text description on video screen
Number of turns or roadway changes required	auditory and visual, auditory	predrive	Icon or graphic representation with voice Text description on video screen with voice

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Areas that the new route will traverse	visual	predrive	Icon or graphic representation with text description Text description on video screen
Notification of incidents	auditory and visual, auditory	predrive	Icon or graphic representation with voice Text description on video screen with voice
Description of incidents	visual	predrive	Icon or graphic representation with text description Text description on video screen
Notification of accidents	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Updated weather information for the route	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Type of road surface (dirt, gravel, etc.)	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Type of road (interstate, two lane, controlled access, etc.)	auditory and visual, auditory	in transit	Icon or graphic representation with voice Text description on video screen with voice
Current elevation	auditory and visual, auditory	in transit	Icon or graphic representation with voice Icon or graphic representation with tones, chimes, etc.
Degree of curvature in the road	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Road construction along the route	auditory and visual, auditory	in transit	Icon or graphic representation with voice Icon or graphic representation with tones, chimes, etc.
Types of roadways and streets the new route will use	visual	predrive	Partial-route video map Partial-route video map with text description
Presentation of reroute options	visual	predrive	Partial-route video map Partial-route video map with text description

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Indicate that a faster route exists	auditory and visual, auditory	in transit	Icon or graphic representation with tones Text description on video screen with tones
Automated Toll Collection			
Current toll cost	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Remaining balance in toll account	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Number of tolls left to be paid along the planned route	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Notification of successful toll charge	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Interface to buy more credits	visual	zero speed	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Automated Toll Collection CVO-Specific			
Vehicle type	auditory and visual, auditory	zero speed	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Vehicle length	auditory and visual, auditory	zero speed	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Vehicle weight	auditory and visual, auditory	zero speed	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Time of day	auditory and visual, auditory	zero speed	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Route Scheduling CVO-Specific			
Optimize delivery schedules	visual	predrive	Partial-route video map Partial-route video map with text description
Customer's preferences	visual	predrive	Partial-route video map Partial-route video map with text description
Driver preferences	visual	predrive	Partial-route video map Partial-route video map with text description
Most efficient manner to load/unload cargo	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Weather forecast	auditory and visual, auditory	predrive	Icon or graphic representation with text description Text description on video screen
Historical traffic information	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Scheduled pickup and delivery time	auditory and visual, auditory	predrive	Icon or graphic representation with text description Text description on video screen
Time of day restrictions	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Day of the week restrictions	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Restrictions related to size	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Restrictions related to weight	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice

Table 47. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Restrictions related to height	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Restrictions related to equipment type	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Restrictions related to cargo	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Destination attractions, services	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice
Destination accommodations	visual	predrive	Icon or graphic representation with voice Text description on video screen with voice

Table 48. Sensory modality, trip status, and display format allocation for each information requirement for IMSIS.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Broadcast Services/Attractions			
Listing of drivers interests and preferences	visual	predrive	Icon or graphic representation with text description Text description on video screen
Indication of IMSIS system status (on, off, etc.)	visual	in transit	Text description on video screen Icon or graphic representation
Preference mode for which service is to be broadcast	auditory and visual, auditory	predrive	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Restaurant locations and costs	visual	zero speed	Partial-route video map display with text description Partial-route video map display with icons
Restaurant reservation availability	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Restaurant reservation establishment	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Services information (fuel prices and availability)	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Distance to attraction, restaurant, accommodation, service	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Partial-route video map with voice
Attraction location	visual	in transit	Partial-route video map display with text description Partial-route video map display with icons
Attraction description and costs	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Attraction ticket availability	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Accommodation location	visual	in transit	Partial-route video map display with text description Partial-route video map display with icons

Table 48. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Accommodation description and costs	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Accommodation reservation availability	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Services/Attractions Directory			
Directory (index of yellow pages)	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Description of type of service/attraction provided	visual	zero speed	Icon or graphic representation with text description Text description on video screen
List of services that are open	visual	predrive	Icon or graphic representation with text description Text description on video screen
Closest service	visual	in transit	Partial-route video map display with text description Partial-route video map display with icons
Closest open service	visual	in transit	Partial-route video map display with text description Partial-route video map display with icons
View currently selected preferences	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Address of service/attraction	visual	in transit	Icon or graphic representation with text description Text description on video screen
Phone number of service/attraction	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
List of alternate related services	visual	predrive	Icon or graphic representation with text description Text description on video screen

Table 48. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Restaurant locations and costs	visual	zero speed	Partial-route video map display with text description Partial-route video map display with icons
Restaurant reservation availability	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Restaurant reservation establishment	auditory and visual, auditory	zero speed	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Services information (fuel prices and availability)	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Attraction description and costs	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Attraction hours of operation	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Attraction restrictions	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Attraction ticket availability	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Attraction ticket purchase	visual	in transit	Icon or graphic representation with text description Text description on video screen
Accommodation location	visual	in transit	Partial-route video map display with text description Partial-route video map display with icons
Accommodation description and costs	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Accommodation reservation availability	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.

Table 48. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Accommodation reservation establishment	visual	zero speed	Icon or graphic representation with text description Text description on video screen
Services/Attractions Directory CVO-Specific			
Vehicle restrictions	auditory and visual, auditory	in transit	Icon or graphic representation with tones, chimes Alerting tones, chimes, etc.
Information from truckers' atlas	visual	predrive	Icon or graphic representation with text description Text description on video screen
Destination Coordination (Assumes Destination was Determined using Service/Attractions)			
Confirmation of reservations	auditory and visual	in transit	Text description on video screen with voice Message presented as speech with our without icons
List other times available, if time wanted is not available	visual	in transit	Icon or graphic representation with text description Text description on video screen
Locate the nearest parking to destination	auditory and visual, auditory	in transit	Full-route video map with voice Partial-route video map with voice
Type of parking facility	auditory and visual, auditory	in transit	Text description on video screen with voice Message presented as speech with our without icons
Cost of parking nearest to destination	auditory and visual, auditory	in transit	Text description on video screen with voice Message presented as speech with our without icons
Transportation availability from parking to destination	auditory and visual, auditory	in transit	Text description on video screen with voice Message presented as speech with our without icons
Routing from destination to parking	visual	in transit	Full-route video map display Full- or partial-route map display with text description

Table 48. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Directions from parking to destination	visual	predrive	Full- or partial-route video map display Full- or partial-route video map display with text description
Payment methods supported	auditory and visual	in transit	Text description on video screen with voice Message presented as speech with our without icons
Reservation details (number in party, time of arrival)	auditory and visual	zero speed	Text description on video screen with voice Message presented as speech with our without icons
Real-time, time of arrival updates	auditory and visual	in transit	Text description on video screen with voice Message presented as speech with our without icons
Diagram of parking facility	visual	predrive	Full-route video map display Full- or partial-route map display with text description
Parking hours of operation	auditory and visual	in transit	Text description on video screen with voice Message presented as speech with our without icons
Other transportation available from parking to destination	visual	predrive	Text description on video screen Icon or graphic representation with text description
Notification of transport arrival	auditory and visual	in transit	Text description on video screen with voice Message presented as speech with our without icons
Destination Coordination CVO-Specific			
Information from both dispatch and customer schedule change	visual	in transit	Text description on video screen Icon or graphic representation with text description
Message Transfer			
Instructions for sending preset messages to other drivers	visual	predrive	Icon or graphic representation Icon or graphic representation with text description

Table 48. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Selecting to whom the message will be sent	visual	zero speed	Icon or graphic representation Icon or graphic representation with text description
Reviewing received message	visual	zero speed	Icon or graphic representation with text description Icon or graphic representation Description on video screen
Alerting driver that a message has been sent	auditory	in transit	Speech with alerting tone
Alerting driver that the message typed was not sent and reason for not being sent	auditory	in transit	Speech with alerting tone
Alerting driver that a message has been received	auditory	in transit	Speech with alerting tone
Retrieving saved messages	auditory	in transit	Icon or graphic representation Icon or graphic representation with text description
Deleting messages	visual	zero speed	Icon or graphic representation Icon or graphic representation with text description
Recipient name	visual	in transit	Icon or graphic representation Icon or graphic representation with text description
Name and access numbers	visual	zero speed	Icon or graphic representation Icon or graphic representation with text description
Responding to a message	auditory	in transit	Speech with alerting tone
Notify driver that a response to message is required	auditory and visual	in transit	Text description on video screen with voice Text description on video screen with tones
System operations mode (on/off)	visual	in transit	Icon or graphic representation Icon or graphic representation with text description

Table 49. Sensory modality, trip status, and display format allocation for each information requirement for ISIS.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Roadway Sign Guidance Information			
Sign information (e.g., street signs, regulatory signs, interchange graphics, route markers, and mile posts)	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized)
Sign information associated with driving to the destination	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized)
Filter status information (status mode)	visual	in transit	Icon or graphic representation with text description
Roadway Sign Guidance Information CVO-Specific			
Specific sign guidance (truck routes)	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized)
Delivery location (e.g., unload the cargo in Bay #3)	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized)
Roadway Sign Notification Information			
Inform driver of potential hazards	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized
Inform driver of changes in the roadway (merge signs, speed limits, etc.)	auditory	in transit	Icon representation with speech Text on video screen with voice
Inform driver of temporary or dynamic changes in roadway (road closures, etc.)	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized
Inform driver of distance to a notification point in question	auditory	in transit	Alerting tone, then speech Message presented as speech (digital or synthesized
Filter status information (status mode)	auditory	in transit	Icon or graphic representation with text description

Table 49. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Roadway Sign Notification Information CVO-Specific			
Inform driver of special restriction information for weight, length, height, etc.	auditory and visual	in transit	Icon or graphic representation plus voice
Road change information (e.g., prepare for steep grade, sharp curve, etc.)	visual	in transit	Icon or graphic representation with text description
Roadway Sign Regulatory Information			
Inform driver of regulatory information (e.g., stop signs, speed limits, yield signs, turn prohibitions, lane use control, etc.)	auditory	in transit	Alerting tones, chimes, etc. Message presented as speech (digital or synthesized) Alerting tone, then speech
Roadway Sign Regulatory Information CVO-Specific			
Specific regulatory information for CVO (e.g., truck speed limits, etc.)	visual	in transit	Icon or graphic representation with text description

Table 50. Sensory modality, trip status, and display format allocation for each information requirement for IVSAWS.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Immediate Hazard Warning			
Inform driver of the location of the hazard	visual	in transit	Icon or graphic representation with text description Icon or graphic representation only
Inform driver of the distance to the hazard	auditory	in transit	Alerting tone, then speech
Inform driver if a route is available to avoid the hazard	visual	zero speed	Icon or graphic representation with text description Icon or graphic representation only
Inform driver of the type of hazard	auditory	in transit	Icon or graphic representation
Inform driver of the approach of emergency vehicles	auditory	in transit	Message presented as speech Alerting tone, then speech
Warn driver of accident immediately ahead	auditory and visual, tactile	in transit	Icon or graphical representation with tones, chimes Automated control manipulation or change in tactile feedback
Warn driver of a stopped hazard immediately ahead	visual	in transit	Automatic control manipulation or change in tactile feedback
Inform driver of the location of specific localized incidents	auditory and visual	in transit	Icon or graphic representation plus voice Icon or graphic representation with text description
Location of the vehicle	auditory and visual	in transit	Icon or graphic representation plus voice Icon or graphic representation with text description
Status of the hazard	auditory	in transit	Alerting tone, then speech
Inform driver of action required to get out of the way of an emergency vehicle	auditory	in transit	Message presented as speech Alerting tone, then speech

Table 50. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Road Condition Information			
Inform driver of road traction, visibility, congestion, construction activity, or weather conditions	visual	in transit	Icon or graphic representation with text description Icon or graphic representation only
Distance to congestion or construction activity	auditory	in transit	Alerting tone, then speech
Suggestions for driving in visibility or weather conditions	auditory and visual	in transit	Icon or graphic representation plus voice Icon or graphic representation with text description
Inform driver of any relevant information regarding bridges (e.g., one-lane bridge, possible ice on bridges, etc.)	auditory	in transit	Alerting tone, then speech
Inform driver of strong crosswinds	auditory	in transit	Alerting tone, then speech
Type of road surface (dirt, gravel, etc.)	auditory	in transit	Alerting tone, then speech
Inform driver if water is flowing over the road	auditory	in transit	Alerting tone, then speech
Road surface type information	auditory	in transit	Alerting tone, then speech
Automatic Aid Request			
Location information	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen
Inform driver of time until emergency unit will arrive	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen
Inform driver that aid has been requested	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen

Table 50. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Automatic Aid Request CVO-Specific			
Inform emergency services of hazardous materials	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen
Inform emergency services of cargo type	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen
Manual Aid Request			
Location information	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen
Inform driver of time and distance until emergency unit will arrive	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen
Phone number of fire, ambulance, police, towing	visual	predrive	Icon or graphic representation with text description Text description on video screen
Inform driver that phone will automatically dial requested aid if desired	visual	predrive	Icon or graphic representation with text description Text description on video screen
Display messages from the emergency response center	visual	predrive	Icon or graphic representation with text description Text description on video screen
Update real-time information from the emergency center	auditory and visual, visual	predrive	Icon or graphic representation with text description Text description on video screen

Table 50. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Vehicle Condition Monitoring			
Inform driver of current problems	visual	in transit	Icon or graphic representation
Inform driver of ways to correct the problem	visual	predrive	Icon or graphic representation
Inform driver of action to take until problem can be corrected	auditory	zero speed	Alerting tone, then speech
Provide more detailed information at driver's request	auditory and visual, visual	predrive	Icon or graphic representation plus speech Icon or graphic representation with text description
Inform the driver of potential problems	visual (icon), visual (icon) and auditory	in transit	Icon or graphic representation
Inform the driver of needed warranty services due	auditory	predrive	Alerting tone, then speech
Inform the driver of any immediate danger after an accident	auditory and visual, tactile	in transit	Icon or graphic representation with tones, chimes Dedicated lights with tones Text description on screen with tones
Coordination information with a service center	auditory	predrive	Alerting tone, then speech
Vehicle Condition Monitoring CVO-Specific			
Inform driver of the condition of the cargo (temperature, vibration, humidity, etc.)	auditory	in transit	Alerting tone, then speech
Inform the driver of the condition of the trailer	auditory	in transit	Alerting tone, then speech
Inform driver of regulatory services due	auditory and visual, visual	predrive	Icon or graphic representation plus speech Icon or graphic representation with text description

Table 50. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Cargo and Vehicle Monitoring CVO-Specific			
Cargo data (restrictions, type, etc.)	auditory and visual, visual	in transit	Icon or graphic representation plus speech Icon or graphic representation with text description
Condition of the cargo (temperature, humidity, etc.)	auditory	in transit	Alerting tone, then speech
Precise indication of vehicle performance (engine, brake, etc.)	auditory and visual, visual	predrive	Icon or graphic representation plus speech Icon or graphic representation with text description
Location information for aid request	auditory	in transit	Icon or graphic representation plus speech Icon or graphic representation with text description

Table 51. Sensory modality, trip status, and display format allocation for each CVO-specific information requirement.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Fleet Resource Management			
Fleet resource management information is intended to be used by the dispatcher and does not include an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A
Dispatch			
Dispatch information is intended to be used by the dispatcher and does not include an in-vehicle display.			N/A
Regulatory Administration			
Regulatory administration requirements (taxes, license, and coordinating the transport of hazardous material)		predrive	
Vehicle identification tag		predrive	
Regulatory Enforcement			
Regulatory enforcement information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A

Table 51. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Shipping Element			
Shipping element information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A
Trucking Element			
Pickup and delivery schedules		predrive	
Height restriction of bridges, underpasses, or tunnels		predrive	
Weight restriction of bridges, and road surfaces		predrive	
Width restriction of underpasses, bridges, or tunnels		predrive	
Other restrictions established by departments of transportation and local authorities		predrive	
Detailed descriptions of topological features (hills, etc.)		predrive	
Navigation information (see the information requirements for IRANS)		predrive	
Information deals with temporary problems (see the information requirements for the IVSAWS)		predrive	
Knowing how to get to a specific loading dock or location in a shipping yard		predrive	

Table 51. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Condition of the vehicle he is driving and the load that he is carrying		predrive	
Condition and the operation of equipment in the trailer		predrive	
Log information of recording periods that the vehicle is in motion		predrive	
Communication information between the driver and the dispatcher on the progress of the shipment, and on the delivery and the next pickup		predrive	
Regulating Element			
Regulating element information is intended to be used by the regulatory personnel and would probably not be an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A
Receiving Element			
Expected date and time that the load will arrive at the receiving facility		predrive	
Characteristics of the load		predrive	
Industry Support Element			
Support element information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A

Table 51. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Dispatch Element for Taxi and Other Personal Delivery Operations			
Dispatch information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A
Taxi Element			
Passenger pickup point		in transit	
Planning a route to the pickup point or destination (see the information requirements for IRANS)		predrive	
Estimated times if making the trip by alternate routes		predrive	
Likely conditions that will be encountered		predrive	
Traffic and other obstructions information		predrive	
Dispatch Element of Local Bus Operations (Fixed Route and Schedule)			
This information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays only.			N/A

Table 51. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Bus Operations Element of Local Bus Operations (Fixed Route and Schedule)			
Communication between driver and dispatcher. Information on the condition of the vehicle systems (see the information requirements for IVSAWS). Road conditions along the reroute (see the information requirements for ISIS and IVSAWS).			
Dispatch Element of Local Bus Operations (Paratransit)			
This information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays.			N/A
Bus Operations Element of Local Bus Operations (Paratransit)			
Communications		in transit	
Navigation		in transit	
Vehicle operation		in transit	
Location of the passengers to be picked up		in transit	
Destination to which the passengers need to go		in transit	
Most efficient route for passenger pickup and dropoff		in transit	
Condition of safety-critical systems on the vehicle		in transit	

Table 51. Cont'd.

Information Requirement	Sensory Allocation	Trip Status	Optimal Display Format Allocation
Existence of hazardous road or traffic conditions		in transit	
Location of traffic delays and alternate routes		in transit	
Dispatch Element of Emergency Response Operations			
This information is intended to be used by the dispatcher and does not involve an in-vehicle display. This aid is designed to be used for the development of in-vehicle displays.			N/A
Vehicle Operations Element of Emergency Response Operations			
Call receipt		in transit	
Route planning		in transit	
Navigation		in transit	
Communications		in transit	
Location of the emergency		in transit	
Best route to take to get to the emergency		in transit	
Nature of the emergency		in transit	
Traffic conditions along the route		in transit	
Hazardous conditions along the route		in transit	
Condition of vehicle safety critical systems		in transit	

APPENDIX G: TRIP STATUS, SENSORY MODALITY, AND DISPLAY FORMAT RECOMMENDATIONS SUMMARY

Table 52. Trip status, sensory modality, and display format recommendations summary.

Information Type	Trip Status	Display Modality and Format
Route Planning and Coordination		
Location of pathways or positions, complex information	predrive	Full-route video map display
Location of pathways or positions, simple information	predrive	Full-route video map display with speech
Status information, complex format	predrive	Text description on video screen
Status information, simple format	predrive	Text description on video screen with speech
Route Following		
Navigation, position, complex information	in transit	Partial-route video map display with Icon information
Navigation, position, simple information	in transit	Icon or graphic representation plus speech
Navigation, routing instructions, simple information	in transit	Icon or graphic representation plus speech
Discrete, intermittently displayed, complex information	in transit	Icon or graphic representation with text description
Discrete, intermittently displayed, simple information	in transit	Icon or graphic representation with simple tones, chimes, etc.
Discrete, continuously displayed information	in transit	Icon or graphic representation with text description
Warning and Condition Monitoring		
High priority, external environment, context required	in transit	Message presented as speech (digital or synthesized) Alerting tone, then speech
High priority, external environment, context not required	in transit	Icon or graphic representation with simple tones, chimes, etc.
High priority, inside the vehicle, context required	in transit	Alerting tone, chimes, etc. Alerting tone, then speech

Table 52. Cont'd.

Information Type	Trip Status	Display Modality and Format
High priority, inside the vehicle, context not required	in transit	Icon or graphic representation with simple tones, chimes, etc.
Medium priority, external environment, context required, long	in transit	Icon or graphic representation with text description
Medium priority, external environment, context required, short	in transit	Alerting tone, then speech
Medium priority, external environment, context not required	in transit	Automatic control manipulation or change in tactile feedback
Medium priority, inside the vehicle, context required, long	in transit	Icon or graphic representation
Medium priority, inside the vehicle, context required, short	in transit	Alerting tone then speech
Medium priority, inside the vehicle, context not required	in transit	Icon or graphic representation
Low priority, context required, long	in transit	Icon or graphic representation plus speech
Low priority, context required, short	in transit	Alerting tone, then speech
Low priority, context not required	in transit	Icon or graphic representation
Signing		
Vehicle operation, complex information	in transit	Icon or graphic representation plus speech
Vehicle operation, simple information	in transit	Alerting tone then speech
Informational message, requested, complex information	in transit	Icon or graphic representation plus speech
Informational message, requested, simple information	in transit	Alerting tone, chimes, etc.
Informational message, automatically presented	in transit	Icon or graphic representation
Communications and Aid Request		
Message content, critical information	in transit	Text description on video screen
Message content, low-priority information	in transit	Icon or graphic representation with text description

Table 52. Cont'd.

Information Type	Trip Status	Display Modality and Format
Message system operation, message event, critical information	in transit	Text description on video screen with speech
Message system operation, message event, noncritical information	in transit	Speech with alerting tone
Message system operation, message system management	in transit	Icon or graphic representation
Motorist Services		
Position oriented, complex information	in transit, zero speed, or predrive	Partial-route video map display with text description
Position oriented, simple information	in transit zero speed, or predrive	Icon or graphic representation with simple tones, chimes, etc.
Status, continuous information	in transit zero speed, or predrive	Text description on video screen
Status, intermittent display, complex	in transit zero speed, or predrive	Icon or graphic representation with text description
Status, intermittent display, simple information	in transit zero speed, or predrive	Icon or graphic representation with simple tones, chimes, etc.

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