In-Vehicle Display Icons and Other Information Elements: Preliminary Assessment of Visual Symbols

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FOREWORD

This is one of a series of reports produced as part of a contract to develop precise and detailed human factors design guidelines for in-vehicle display icons and other information elements. The contractual effort consists of three phases: analytical, empirical, and integrative.

This report is the second product of the analytical phase. It provides design guidance for the joint use of visual, auditory, and tactile information presentation and builds a foundation for future design tools that will assist designers in specifying icon design for in-vehicle information technologies, particularly as they relate to Advanced Traveler Information Systems (ATIS).

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Director, Office of Safety
Research and Development

NOTICE

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16. Abstract
This report describes the methods and results associated with *Task B: Preliminary Assessment of Visual Symbols*. The purpose of Task B is twofold: (1) it identifies credible procedures, heuristics, and principles for the joint use of visual, auditory, and tactile information to present in-vehicle messages, and (2) it defines message characteristics that should guide symbol design. Defining these characteristics and their interactions helps to identify design tradeoffs and provides the basis for future design guidelines and tools. The methodology employed to complete Task B included: refining a list of previously generated IVIS messages, conducting a review of the literature relevant to sensory modality, evaluating the IVIS messages using a sensory modality decision tool, defining messages according to their contextual characteristics and information processing elements (IPEs), clustering messages according to their contextual characteristics, grouping those clusters to identify general design categories, and examining the IPEs and design tradeoffs within each cluster and category.

Through the process of devising these design tools and decision aids and analyzing the list of relevant IVIS messages, we developed the following conclusions: (1) a review of existing literature regarding visual, auditory and tactile information presentation provided numerous general principles for modality selection, which was the basis for an effective sensory modality decision tool, (2) classifying IVIS messages according to ITS technologies and general functions is insufficient for providing effective design guidelines, (3) understanding the driving context under which IVIS messages are presented is critical for successful design guideline development, (4) the IPEs associated with an IVIS message can successfully be used to develop the design guidelines that consider the perceptual, memory, and motor control limits of the driver, (5) the cluster analysis technique provides a powerful tool to focus future analyses on a meaningful subset of possible combinations of contextual characteristics and IPEs, (6) the tools and decision aids developed as part of Task B have provided the project team with a solid analytical foundation to begin guideline development in Task C of this project, and (7) a key challenge associated with Task C will be to integrate the information provided in this report and develop clear, relevant, and easy-to-use design guidelines for in-vehicle icons.

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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 ACRONYMS

ABS . . . . Anti-Lock Brake System

ATIS . . . . Advanced Traveler Information Systems

CAS . . . . Collision Avoidance Systems

CVO . . . . Commercial Vehicle Operations

FHWA . . . . Federal Highway Administration

GPS . . . . Global Positioning System

HDD . . . . Head-Down Display

HUD . . . . Head-Up Display

IPE . . . . Information Processing Element

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

ITS . . . . Intelligent Transportation Systems

IVIS . . . . In-Vehicle Information System

MUTCD . . . . Manual of Uniform Traffic Control Devices

NHTSA . . . . National Highway Traffic Safety Administration

NTIS . . . . National Technical Information Service

EXECUTIVE SUMMARY

The overall goal of this project is to provide the designers of in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements. Due to the speed with which In-Vehicle Information System (IVIS) devices are entering the automotive marketplace, many of the research issues associated with the design of in-vehicle visual symbols and other information elements have not been adequately addressed. Specifically, research issues associated with auditory and tactile messages have not been addressed to the point where comprehensive design specifications for these systems can be confidently developed and communicated to the IVIS design community. For example, a key issue in future systems will be the need to integrate multiple sources of IVIS messages that are presented to drivers and to prioritize these sources to reduce driver overload and maintain public safety. Without the appropriate study and design guidance to aid and standardize their development, IVIS devices may present contradictory information to the driver, confuse the driver, overload or distract the driver, interfere with one another, violate driver expectations and responses, and lead to a decrease in driver safety. Therefore, it is critical that a comprehensive set of design guidelines for in-vehicle icon is developed and shared with industry.

This report (Task B: *Preliminary Assessment of Visual Symbols*) serves two purposes. First, it identifies credible procedures, heuristics, and principles for the joint use of visual, auditory, and tactile information to present in-vehicle messages. This report documents the underlying rationale for selection of display modality by reviewing the relevant literature and assessing the current state of knowledge. Second, this report defines message characteristics that should guide symbol design. Defining these characteristics and their interactions helps to identify design tradeoffs and provides the basis for future design guidelines and tools. In summary, this report provides design guidance for the joint use of visual, auditory, and tactile information presentation and builds a foundation for future design tools that will assist designers in specifying icon design for in-vehicle information technologies, particularly as they relate to Advanced Traveler Information Systems (ATIS).

The process used to identify design requirements of in-vehicle icons and IVIS messages included seven basic steps:

1. Generate a list of IVIS messages.
2. Conduct review of literature relevant to sensory modality.
3. Evaluate IVIS messages in order to determine sensory modality.
4. Define messages according to their contextual characteristics and information processing elements (IPEs).
5. Cluster messages according to contextual characteristics.
6. Group clusters to identify general design categories.
7. Examine IPEs and design tradeoffs within each cluster and category.

Figure 1 shows the order in which these steps were completed and their interrelationships. From this flow diagram we are able to see how the results of each step will be used to develop the final product design requirements and tradeoffs for categories of IVIS messages.

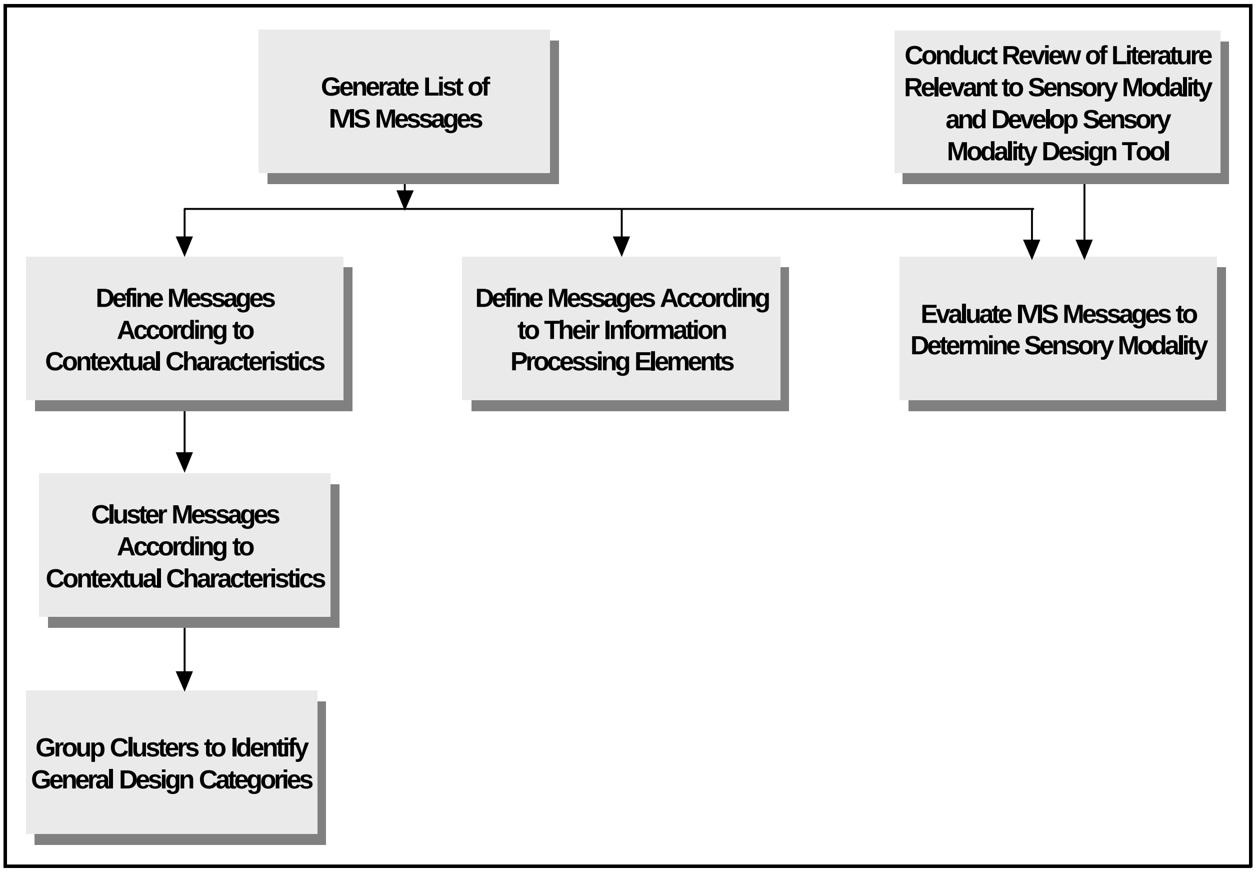


Figure 1. Relationships among Task B activities.

One of the first steps completed during this design process was to review literature for information related to development of rules for selecting display modes. An examination of these rules led us to the design of several decision aids that would assist designers in the selection of a sensory modality for displaying different pieces of in-vehicle information. Each decision aid was tested using several candidate information elements until a final viable approach could be determined. The final approach was then refined through additional informal testing and analysis. The final design tool can be seen in figure 2.

The results of applying the design tool suggest that: (1) the visual modality should be used to display more complex information that does not require the driver's immediate response and may need to be referred to at a later time, (2) the auditory modality should be used to present simple information that is extremely urgent or critical messages that require the driver's attention, (3) a combination of the auditory and visual modalities should be used to present information that is both complex and relatively urgent but is too complex to be presented via simple tone or verbal message, and (4) the tactile modality did not appear to be a viable option for presenting any of the IVIS messages we had identified.
.

Questions:		Very Low	Low	Medium	High	Very High	Visual	Auditory	Tactile
1. What is the degree of urgency of the message?	**Visual**	4	3	2	1	1	☐		
	Auditory	1	2	3	4	5		☐	
	Tactile	1	2	3	4	5			☐
2. To what degree might the message be referred to again later?	**Visual**	1	2	3	4	5	☐		
	Auditory	4	3	2	1	1		☐	
	Tactile	4	2	0	0	0			☐
3. What is the overall level of complexity of the message?	**Visual**	3	3	3	4	5	☐		
	Auditory	4	3	2	1	1		☐	
	Tactile	4	1	0	0	0			☐
4. To what degree does the message deal with a future action in time?	**Visual**	5	4	3	3	3	☐		
	Auditory	1	2	3	4	5		☐	
	Tactile	0	0	0	1	5			☐
5. To what degree does the message refer to locations in space?	**Visual**	3	3	3	4	5	☐		
	Auditory	5	4	3	2	1		☐	
	Tactile	5	1	0	0	0			☐
IVIS Message: ______							**sum** ☐ **Visual**	**sum** ☐ **Auditory**	**sum** ☐ **Tactile**
Other Relevant Factors: ______									

Figure 2. Sensory modality design tool.

The next step was to define the messages according to their contextual characteristics and the information processing elements they supported in order to provide a more solid basis for design. Once this was complete, a cluster analysis was completed that identified 12 unique clusters of IVIS messages. To organize these clusters for interpretation, a further analysis identified four groups of clusters based on the center of each of the 12 clusters. Table 1 summarizes each of the message groups and the design requirements that they support.

Table 1. Summary of general design principles: Group I-IV messages.

	Type of Message	General Design Principles
Group I	High-priority driving messages = relatively critical, high urgency messages that are tightly linked to the driving task.	! Highly salient and compelling ! Induce a fast response ! Distinguishable ! Place near the driver's center of attention
Group II	Medium-priority dependent messages = moderately urgent and critical messages that are presented either simultaneously or sequentially with other messages.	! Less salient, more subtle alerts ! An object display or map should be used to integrate the messages and promote comparisons and information integration
Group III	Non-driving independent message = no relation to the driving task and are unlikely to be presented either simultaneously or sequentially with other messages.	! Salient, compelling, and recognizable ! Easy to discriminate ! Support comparisons and relate status to norms or expectations ! Place outside the focus of driver's attention
Group IV	Low-priority messages = the most common type of message and are neither critical nor urgent.	! Easily discriminated ! Compelling, recognizable ! Highlight status changes and afford action ! Support comparisons and relate status to norms or expectations

Group I: High-priority driving messages are all relatively critical, high urgency messages that are tightly linked to the driving task. The nature of these messages has important design considerations. Specifically, these messages should be designed to be highly salient in order to ensure rapid processing and response to the messages.

The IPEs of *alert*, *identify*, and *decide* define this group of messages. These IPEs define every message in this group. The important design considerations associated with these IPEs include the need to design salient, compelling, recognizable messages that are easy to discriminate and that highlight status changes. For those messages that involve *alert*, the design should focus on salient messages that capture the driver's attention, at the cost of excluding detail that describes the situation.

Design tradeoffs associated with *Group I: High-priority driving messages* focus on attracting the driver's attention and conveying information quickly. These tradeoffs favor highly salient and compelling messages that induce a fast response rather than messages that are subtle and designed to avoid distracting the driver. The highly critical nature of some of the messages in this group, compared with many other lower priority measures, argues for design features that distinguish them even if it undermines the perceived priority of other messages. In general, the wide variation in criticality across the four groups argues for distinguishing highly critical messages.

The criticality and urgency of these messages, combined with their link to the driving task, suggests that they should be coupled to the driving task by placing them near the driver's center of attention. Linking these messages to the driving task will tend to minimize response time and enhance understanding, with the tradeoff being potential driver overload if too many messages are clustered in the focus of attention. Sample Group I messages are shown in table 2.

Table 2. Sample group I messages.

Sample Group I Messages
! Warning indicator (backing device) ! Interchange ahead ! School bus stopped ahead

Group II: Medium-priority dependent messages are moderately urgent and critical, and are presented either simultaneously or sequentially with other messages. There are several design considerations for messages that are highly dependent on other messages. Specifically, these messages can be co-located or share similar design features to aid in the detection and filtering of information.

The IPEs of *alert*, *identify*, *evaluate, plan, search, decide*, and *coordinate* define this group of messages. These IPEs define every message in this group. Some of the important design considerations associated with *evaluate, plan,* and *search* include designing messages that enable comparisons and that are readily interpretable. These messages should also provide sufficient detail to support a thorough evaluation of alternatives. In contrast, for those messages that involve *alert,* the message design should be salient so that it captures the driver's attention, in favor of a detailed message describing the situation.

Design tradeoffs associated with *Group II: Medium-priority dependent messages* focus on integrating information from several messages. The criticality and time urgency of these messages suggest less salient, more subtle alerts at the expense of slower response times. For the messages that are involved with planning and evaluation, the tight connection to other messages suggests that an object display or map should be used to integrate the messages and promote comparisons and information integration. The moderate urgency and criticality of messages in this group suggest that the strong visual or spatial links will not have a detrimental effect if they reduce the ability of the driver to discriminate between individual messages. The effectiveness of those messages that are highly linked to the driving tasks can be enhanced if they are displayed so that the driver can integrate them into the associated driving task. However, they should be placed so as not to compete with the higher priority driving-related messages, such as those described in Group I. Sample Group II messages are shown in table 3.

Table 3. Sample group II messages.

Sample Group II Messages
! Shortest route option ! Distance and time to turn ! System on and functioning (driver monitoring)

Group III: Non-driving independent messages have no relation to the driving task and are unlikely to be presented either simultaneously or sequentially with other messages. A general design consideration for this group is that they should not be placed in the focus of a driver's attention. Because these messages are unrelated to the driving task, they should not intrude on the information a driver processes while in transit.

The IPEs of *alert, identify, evaluate, control,* and *monitor* define this group of messages. These IPEs define every message in this group. The important design considerations associated with these IPEs include the need to design salient, compelling, recognizable messages that are easy to discriminate and that highlight status changes. In addition, these messages must support comparisons and relate status to norms or expectations.

Design tradeoffs associated with *Group III: Non-driving independent messages* focus on supporting the interpretation of messages that are not linked to the driving task or to other messages. Because these messages are relatively low priority, the design tradeoff can be made in favor of symbol designs that will aid interpretation at the cost of speed of recognition or salience. Specifically, this might include text labels or increased detail and representativeness of icons. Even for the *alert* messages the tradeoff should favor accuracy of interpretation over speed. Another important design tradeoff suggests these messages should be placed outside the focus of the driver's attention. The moderate level of priority and the lack of connection to the driving task argue for a slower response time rather than cluttering the driver's focus of attention with messages unrelated to the driving task. Sample Group III messages are shown in table 4.

Table 4. Sample group III messages.

Sample Group III Messages
! Inform driver of needed warranty services due ! System failure (all other CA systems) ! Message acknowledged/received

Group IV: Low-priority messages are the most common type of message and are neither critical nor urgent. Low priority messages should be designed in such a way that they do not distract the driver from safely operating the vehicle. They should be available for the driver to view when he/she feels comfortable doing so, but should not demand attention.

The IPEs of *identify, evaluate, coordinate, control,* and *monitor* define this group of messages. These IPEs define 140 of the 143 messages in this group. The important design considerations associated with these IPEs include the need to design messages that are easily discriminated, compelling, and recognizable, and that highlight status changes and afford action. In addition, these messages must support comparisons and relate status to norms or expectations.

Like *Group III: Non-driving independent messages*, design tradeoffs associated with *Group IV: Low-priority messages* focus on interpretation and understanding. However, because these messages vary in their relation to other messages and to the driving task, there are more alternatives to support interpretation. Because these messages are relatively low priority, the design tradeoff can be made in favor of symbol designs that will aid interpretation at the cost of speed of recognition or salience. However, the link with other messages can be exploited to enhance interpretation. For example, a common background or similar symbol characteristics can provide a context that will help drivers understand messages. This design tradeoff is in favor of increased understanding at the cost of increasing the potential for confusion with related messages. The *control* IPE introduces additional design requirements. In this context, *control* specifies invoking a function or choosing an option on a touch screen or menu structure of an IVIS. To support this IPE the message must afford action. Providing this information requires room on the icon and so a tradeoff is made in favor of identifying control opportunities at the cost of decreasing the symbol size. Sample Group IV messages are shown in table 5.

Table 5. Sample group IV messages.

Sample Group IV Messages
! Remaining balance in toll account ! Total time to complete travel (identify) ! Vacancy status of hotels along route

Through the process of devising these design tools and analyzing the current list of relevant IVIS messages, we have developed the following conclusions:

A review of existing literature regarding visual, auditory, and tactile information presentation provided numerous general principles for modality selection, which was the basis for an effective sensory modality design tool. A review of both general human factors research and more recent research directly related to ATIS and Collision Avoidance System (CAS) displays provided a number of general principles and heuristics regarding different display modes (visual, auditory, and tactile). Summarizing these rules and categorizing them according to the design decisions they supported allowed us to devise a design tool that would direct designers toward the most appropriate sensory modality choice.

Results of applying the sensory modality design tool indicated that the visual modality should be used for presenting complex messages that are less urgent and critical and that the driver may need to refer to at another point during the drive. Auditory messages were identified as those that have some type of alerting property. They provide the driver with urgent and critical information that is simple enough to be presented via an auditory tone or a brief verbal message. A combination of the visual and auditory modalities should be used for those messages that require the driver's attention but are too complicated to be presented by an auditory message or will be referred to again later in the drive. The tactile modality was not identified as appropriate for displaying any of the 273 candidate IVIS messages. However, it is important to note that there are a few instances where tactile displays have been shown to be useful (i.e., the shaker stick on an aircraft); therefore, they should not be ignored as a potential display modality.

Classifying IVIS messages according to ITS technologies and general functions is not sufficient for providing effective design guidelines. Classifying IVIS messages according to general IVIS capabilities and functions catalogs the range of messages, and shows similarities based on the IVIS capabilities they are meant to support. However, this approach to organizing IVIS messages does not reflect several important characteristics of the IVIS messages that can impact design guidelines. Effective design guidelines and design tools require a description of IVIS messages that reflects message characteristics that influence driver comprehension and response. Defining messages according to their driver-relevant characteristics provides a more solid basis for design.

Understanding the driving context under which IVIS messages are presented is critical for successful design guideline development. Successful presentation of IVIS messages using icons depends on creating a message appropriate to its driving context. This report defines the context of IVIS messages using four dimensions. These dimensions capture key elements of how context aids the interpretation of messages. Specifically, message urgency and criticality identify the consequences of not responding to a message in a timely manner. In contrast, dimensions such as the link to the driving task and the independence of the message identify opportunities to enhance the interpretation of a message by providing additional cues. Grouping the messages according to these four dimensions provides a first step in defining the requirements for integrating IVIS messages into a coherent set.

The IPEs associated with an IVIS message can successfully be used to develop the design guidelines that consider the perceptual, memory, and motor control limits of the driver. This report identifies nine different IPEs: alert, identify, search, evaluate, plan, decide, coordinate, control, and monitor. Together, these nine elements describe the range of information processing activities supported by IVIS messages. Each of these elements supports a different set of design requirements that complement those identified by contextual characteristics. Identifying the elements associated with each individual message informs the designer about design decisions and tradeoffs that will need to be made for several different design parameters.

The cluster analysis technique provides a powerful tool to focus future analyses on a meaningful subset of possible combinations of contextual characteristics and IPEs. The cluster analysis proved to be a very effective technique in the preliminary assessment of visual symbols. The original four contextual characteristics (with five levels within each), combined with the nine IPEs, yield 5,626 unique combinations. This presents designers with a dizzying array of tradeoffs to make when designing in-vehicle icons and other information elements. This approach uses a tradeoff analysis that serves to focus our future design guideline development efforts. Using statistical clustering techniques, the preliminary analysis identified four general message groups, which describe 12 message clusters. These groups and their corresponding clusters identify important combinations of contextual characteristics and IPEs that describe the range of IVIS messages. Preliminary consideration of these groups and clusters suggests that each cluster and group has unique design requirements for in-vehicle messages. The initial description of these design requirements and their associated tradeoffs provides the basis for more specific design guidelines and practical design tools.

The tools and decision aids developed as part of Task B have provided the project team with a solid analytical foundation to begin guideline development in Task C of this project. Combining the information obtained by identifying: (1) the contextual characteristics of a message, (2) the IPEs that the message supports, and (3) the results of applying the sensory modality decision tool provides the IVIS designer with a relatively comprehensive list of requirements and parameters that should be considered during the design of in-vehicle icons and other information elements. The initial description of these design requirements and associated tradeoffs provides the basis for more refined design guidelines to be developed as part of Task C of this project.

A key challenge associated with Task C will be to integrate the information provided in this report and develop clear, relevant, and easy-to-use design guidelines for in-vehicle icons. This report establishes some important relationships between IVIS messages, display modality, the driving context, and IPEs of the IVIS messages. Understanding these relationships is necessary, but not sufficient, to support the development of clear, relevant, and easy-to-use human factors design guidelines for in-vehicle icons and other information elements. During Task C, the project team will need to integrate the information presented in this report and the Task A report with specific design options for icon design such as background, symbol, border, symbol elements, and text labels.

INTRODUCTION

The introduction of Intelligent Transportation Systems (ITS), such as Advanced Traveler Information Systems (ATIS) and Collision Avoidance Systems (CAS), has brought with it an abundance of additional auditory, visual, and tactile information that the driver must not only recognize, but also comprehend and act upon in a timely manner. While the intent of this information is to increase driver safety, efficiency, and mobility by reducing accidents, collisions, and congestion, the potential exists for this information to do just the opposite. The amount and the complexity of information presented have the potential to overload and confuse drivers, putting an additional strain on their ability to safely drive the vehicle.

The overall goal of this project is to provide the designers of these in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements. Due to the speed with which In-Vehicle Information System (IVIS) devices are entering the automotive marketplace, many of the research issues associated with the design of in-vehicle visual symbols and other information elements have not been adequately addressed. Specifically, research issues associated with auditory and tactile messages have not been addressed to the point where comprehensive design specifications for these systems can be confidently developed and communicated to the IVIS design community. For example, a key issue in future systems will be the need to integrate multiple sources of IVIS messages that are presented to drivers and to prioritize these sources to reduce driver overload and maintain public safety. Without the appropriate study and design guidance to aid and standardize their development, IVIS devices may present contradictory information to the driver, confuse the driver, overload or distract the driver, interfere with one another, violate driver expectations and responses, and lead to a decrease in driver safety. Therefore, it is critical that a comprehensive set of design guidelines for in-vehicle icons is developed and shared with industry.

The product of this research effort will be a set of clear, concise, and user-centered human factors design guidelines. The guidelines will include issues such as the conspicuity, legibility, and comprehension associated with graphical and text-based icons and symbols. These guidelines will provide IVIS developers with key information regarding the use and integration of existing and new visual symbols. Specific objectives of this project are to:

- Design and perform experimentation to select appropriate symbols for in-vehicle use. Use the resulting data to write final guidelines for in-vehicle symbols usage encompassing both present and future symbols.

- Write both preliminary, as well as empirically based, final guidelines.

The flow of project activities is shown in figure 3. As seen in the figure, the project consists of a mix of analytical (Tasks A and B), empirical (Tasks D and E), and integrative (Tasks C and F) activities.

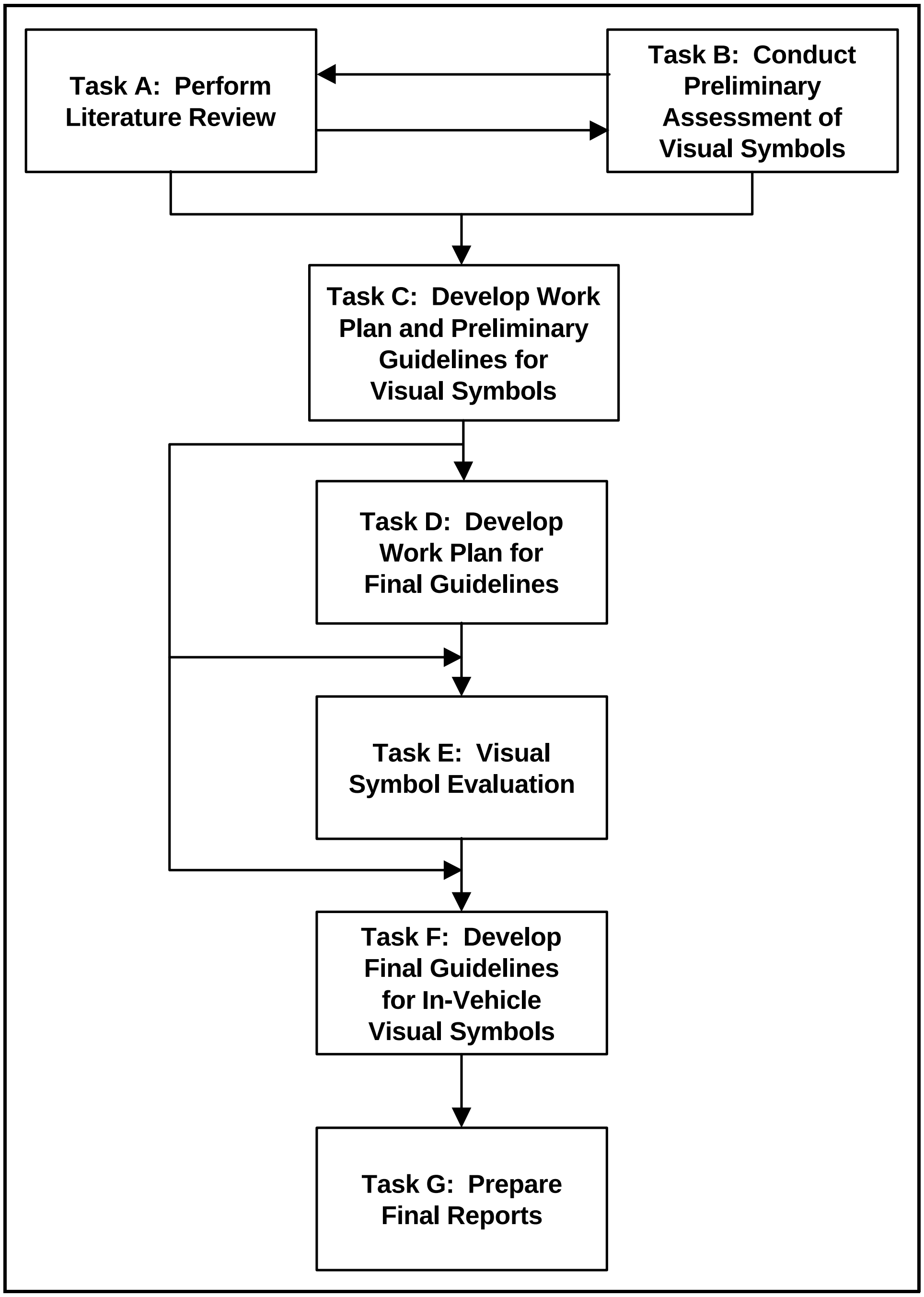


Figure 3. The flow of project activities.

This report (Task B: *Preliminary Assessment of Visual Symbols*) serves two purposes. First, it identifies credible procedures, heuristics, and principles for the joint use of visual, auditory, and tactile information to present in-vehicle messages. This report documents the underlying rationale for selection of display modality by reviewing the relevant literature and assessing the current state of knowledge. Second, this report defines message characteristics that should guide symbol design. Defining these characteristics and their interactions helps to identify design tradeoffs and provides the basis for future design guidelines and tools. In summary, this report provides design guidance for the joint use of visual, auditory, and tactile information presentation and builds a foundation for future design tools that will assist designers in specifying icon design for in-vehicle information technologies, particularly as they relate to ATIS.

THE ICON SELECTION AND DESIGN PROCESS

Our efforts in Task B began with the question, "How are icons selected and designed?" This is an important question, given that the results from Task B of this project must directly support the development of preliminary guidelines in Task C. Figure 4 summarizes a generic approach to the process of selecting and designing icons. Our analyses described in this report support this general process. Importantly, this generic process is described here solely for the purpose of providing a framework and context for this Task B analysis. It is not intended to represent all design efforts associated with icons, and our discussion below will not cover each aspect of the process in detail.

The process for determining the best method of presenting IVIS messages begins by identifying the most appropriate presentation mode (auditory, tactile, visual, or a combination of visual and other modes). Those messages that are determined to be best presented visually, or through a combination of visual and other modes, require the designer to make several other design decisions regarding the presentation format (text, complex graphic, icon, or icon and text). Text messages range from single words to complex phrases, even multiple sentences. For IVIS information, complex graphics are likely to be maps, but they may also include object displays that integrate multiple data elements (Carswell and Wickens, 1987; Vicente, Moray, Lee, Rasmussen, Jones, Brock, and Djemil, 1996). Icons are visual representations or images used to symbolize an object, action, or concept. They present information in a simple and condensed form. In some instances, an icon alone is insufficient for conveying its meaning and supplemental text is necessary. Text, complex graphics, icons, or icons with text are all viable options for presenting information, with the most appropriate option depending on the particular characteristics of the message.

After choosing to present information to the driver via icons or icons with associated text, the first step is to ask whether there is an existing icon or symbol that represents the message. If there is, it is necessary to evaluate it. Previous research has shown that even standard icons (i.e., those found in the Manual of Uniform Traffic Control Devices [MUTCD]) have comprehension levels that are extremely low, especially for older drivers (Dewar, 1994; Hawkins, Womack, and Mounce, 1993). If the icon scores high on ratings of comprehension, recognition, and appropriateness, and can be discriminated from other symbols within a set, then it is likely that it will be acceptable for use in an IVIS display.

If no icons exist for a particular message, or if existing icons are poorly understood, it may be necessary to design a new icon. IVIS designers must then define icon features such as border, background, symbol, text label (if any), and the elements that will make up the symbol. All of these basic features help to give the icon its meaning and make the difference between designing "good" icons and "bad" icons. This report defines message characteristics that can be used to develop design guidelines and design tradeoffs in icon development.

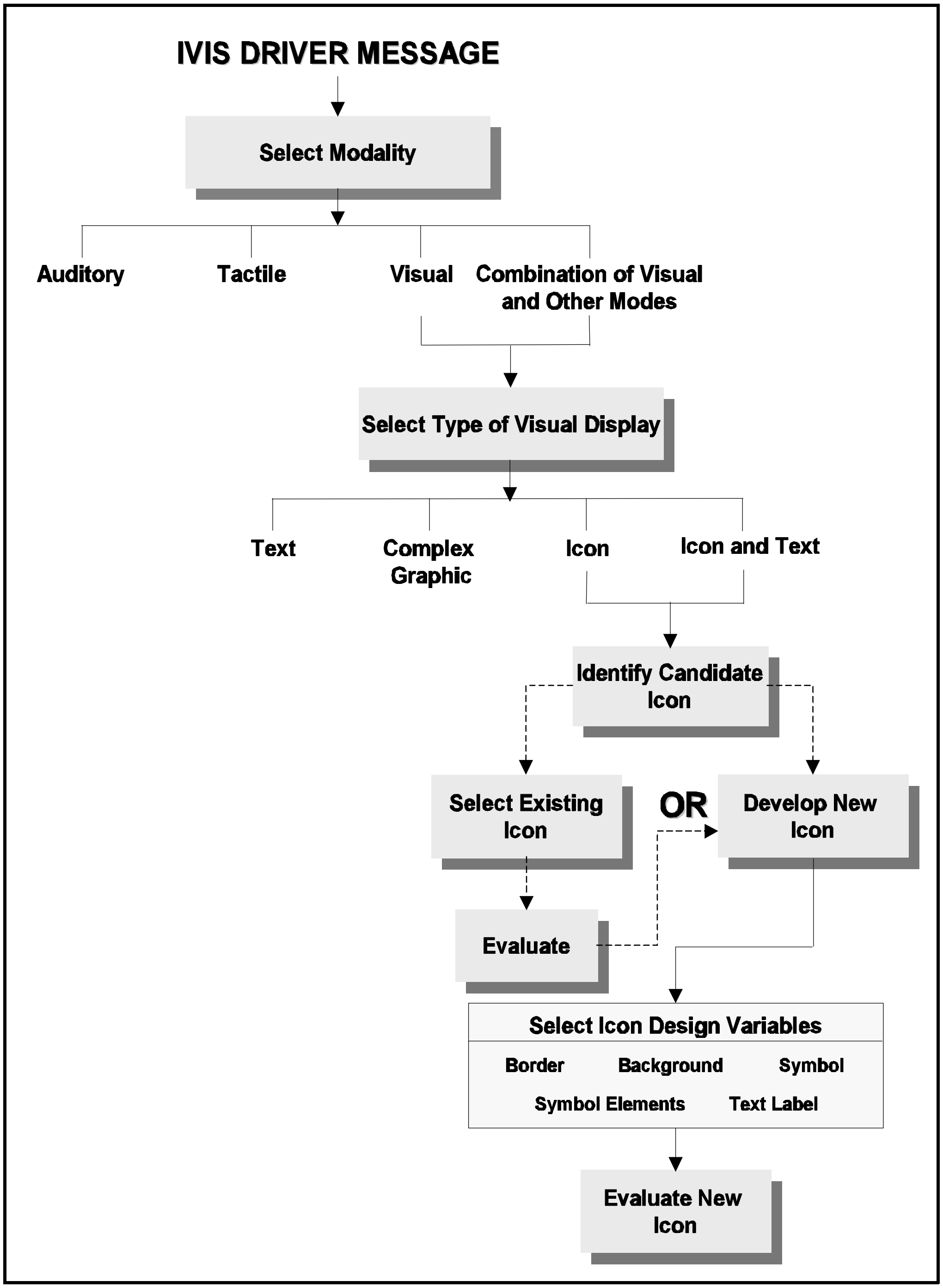


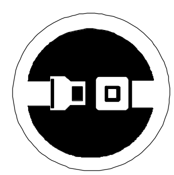
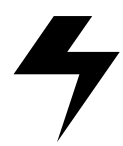
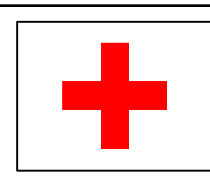
Figure 4. A generic icon selection and design process.

How Do Drivers Interpret Icons?

A theoretical understanding of how drivers interpret icons and messages can support effective design guidance for icons. Table 6 shows three elements that govern icon interpretation: driver knowledge, message context, and icon design (see also Carney, Campbell, and Mitchell, 1998). Some icons rely simply on their design for conveying their meaning. These icons are called image-related and are highly pictorial representations of the object or act they represent. For other icons, additional information regarding the context under which they are being seen is necessary for the correct meaning to be apparent. These icons are called concept-related and are based on an example or property of a real object or action. A third group of icons is called arbitrary. These icons do not resemble the object or action they represent and depend on context as well as knowledge to convey meaning.

Driver knowledge can dramatically enhance icon interpretation. In a study conducted by Wogalter and Sojourner (1997), a brief explanation of an icon's meaning greatly enhanced interpretation, even months after initial training was complete. The importance of message context reflects top-down interpretation that drives much of human information processing (Neisser, 1976). Context can also help to define the required response of the driver. A time-critical, safety-related message, such as a collision avoidance message, occurs in a context that demands an immediate response. Icon elements also contribute to interpretation, with their effect best understood in terms of the information processing that the icon is meant to support. Many times, information presented textually and pictorially will be informationally equivalent; however, one form of presenting the information makes it easier for the user to process and understand. Larkin and Simon (1987) argue that many problems can be expressed in both sentential and diagrammatic formats and that diagrams can often be superior for solving problems. Diagrams and icons allow information to be grouped in a way that facilitates understanding and reduces search time, making the information processing much more efficient. Although driver knowledge is an important contributor to icon interpretation, this report focuses on how context and icon features can combine to enhance drivers' interpretation of messages.

Table 6. Elements governing icon interpretation.

Icon Types	How Meaning is Derived	Example
Image-Related	Icon	 *Fasten Seat Belt*
Concept-Related	Icon + Context	 *Flash Function on a camera or High Voltage symbol in a power plant.*
Arbitrary	Icon + Context + Knowledge	 *Addition symbol, First Aid symbol, or International symbol for the Red Cross.*

Organization of This Report

To support the design process outlined in figure 3, this report analyzes potential IVIS messages and synthesizes this analysis into a design tool for identifying message modality and a basis for developing future design tools for visual symbols. The report begins with a description of IVIS functions, sub-functions, and associated messages. This description serves to partition the universe of IVIS messages into functional categories that are familiar to designers. To identify design requirements, the IVIS messages are then described in terms of their driver-relevant characteristics. These characteristics include the context of the message and the information processing that the message seeks to support. The driver-relevant message characteristics provide the basis for the two final sections: a design tool to identify appropriate message modality and a tradeoff analysis that provides the foundation for future design tools.

This report contains five main sections, including: (1) a description of the method used to analyze the IVIS messages, (2) IVIS messages and driver information requirements, (3) driver-relevant message characteristics, (4) joint use of visual, auditory, and tactile information presentation, and (5) tradeoff analysis for design of IVIS message format. References and appendices are also included.

METHOD

The process used to identify design requirements of in-vehicle icons and IVIS messages included seven basic steps:

1. Generate a list of IVIS messages.

2. Conduct review of literature relevant to sensory modality and develop sensory modality design tools.

3. Evaluate IVIS messages in order to determine sensory modality.

4. Define messages according to their contextual characteristics and information processing elements (IPEs).

5. Cluster messages according to contextual characteristics.

6. Group clusters to identify general design categories.

7. Examine IPEs and design tradeoffs within each cluster and category.

Figure 5 shows the order in which these steps were completed and the relationship between each of them. From this flow diagram we are able to see how the results of each step will be used in order to develop the final product design requirements and tradeoffs for categories of IVIS messages.

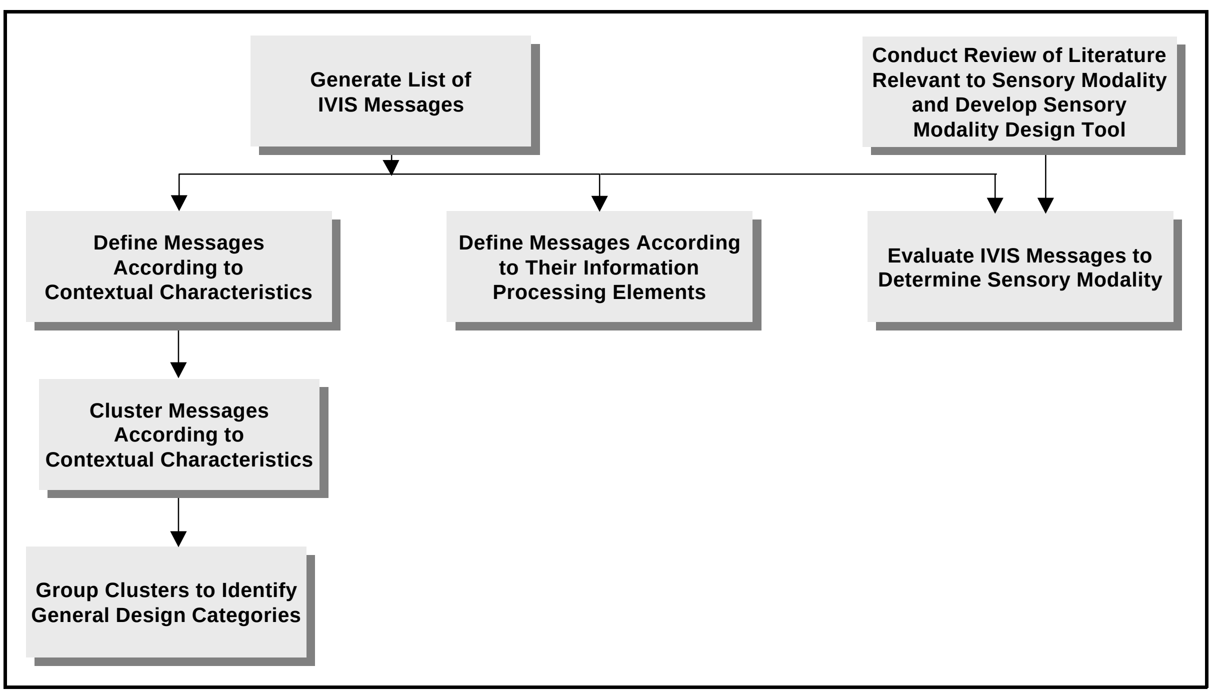


Figure 5. Relationships among Task B activities.

Generate a list of IVIS messages. A large list of driver information requirements, or candidate messages, were derived during Task A of this project. This list was developed by reviewing several existing reports (Campbell, Carney, and Kantowitz, 1997; Neale, Dingus, Schroeder, Zellers, and Reinach, 1997; Campbell, Carney, and Kantowitz, 1998; Campbell et al., 1996; Lee, Morgan, Wheeler, Hulse, and Dingus, 1997) and extracting those messages that were determined to be most relevant and helpful to drivers. Once the list was developed, the messages were partitioned into IVIS categories and functions (see appendix A) and mapped to candidate symbols. Several additions were made to this list when symbols were found that seemed relevant, but did not match any of the messages on the list. During Task B, the list of approximately 350 candidate messages was reviewed by members of a working group, which consisted of 15 human factors experts from both industry and research environments (see appendix B for a complete list of working group members, their affiliation, and contact information). Working group members made suggestions for both additions to and deletions from the list. After the review was complete, 273 messages remained to be used in subsequent steps in the design process.

Conduct review of literature relevant to sensory modality. A literature review was conducted that evaluated information concerning the choice of appropriate display modes (visual, auditory, or tactile) for the presentation of messages to the driver. The literature review included several sources, including government and industry standards, general design guides, texts, handbooks, general human factors literature, and relevant ATIS research. This review aided in the development of general design rules regarding display modality. Specific topics contained in this review included:

- The Key Knowledge Gap: Driver Capacity
- The Visual Demands of Driving
- Spare Capacity for Viewing a Map While Driving
- Attention, the Primary Task, and Information Overload
- General Rules for Modality Selection

Evaluate IVIS messages in order to determine sensory modality. A number of different decision tools were generated using the general design rules developed through the literature review process. Each of these decision tools were exercised using candidate messages and refined through informal testing and analysis until a final, viable approach was determined. The final design tool is shown in figure 6. Applying this design tool allows the designer to determine the most appropriate sensory modality (visual, auditory, tactile) for presenting each of the driver messages.

The design tool requires designers to respond to several different questions for which their response will range from “very high” to “very low.” Each response is associated with a point value for all three modalities. After all five of the questions have been answered, the point values are totaled for the three modalities. In cases where two modalities receive high scores (greater than 15), they should both be used to present the information (i.e., auditory **and** visual). In cases where two modalities receive identical scores or scores within only one point of one another (where scores are not greater than 15), the designer should choose one of the modalities (i.e., auditory **or** visual). In all other cases, the modality receiving the highest score is the suggested mode of presentation for that piece of information.

Questions:		Very Low	Low	Medium	High	Very High	**Visual**	**Auditory**	**Tactile**
1. What is the degree of urgency of the message?	**Visual**	4	3	2	1	1	☐		
	Auditory	1	2	3	4	5		☐	
	Tactile	1	2	3	4	5			☐
2. To what degree might the message be referred to again later?	**Visual**	1	2	3	4	5	☐		
	Auditory	4	3	2	1	1		☐	
	Tactile	4	2	0	0	0			☐
3. What is the overall level of complexity of the message?	**Visual**	3	3	3	4	5	☐		
	Auditory	4	3	2	1	1		☐	
	Tactile	4	1	0	0	0			☐
4. To what degree does the message deal with a future action in time?	**Visual**	5	4	3	3	3	☐		
	Auditory	1	2	3	4	5		☐	
	Tactile	0	0	0	1	5			☐
5. To what degree does the message refer to locations in space?	**Visual**	3	3	3	4	5	☐		
	Auditory	5	4	3	2	1		☐	
	Tactile	5	1	0	0	0			☐
							sum ☐ **Visual**	**sum** ☐ **Auditory**	**sum** ☐ **Tactile**

IVIS Message: ______________________________

____

Other Relevant Factors: ______________________________

____

Figure 6. Sensory modality design tool.

Define messages according to their contextual characteristics and IPEs. While determining the most appropriate modality for message presentation is crucial and helps the designer to make some basic design decisions, defining messages according to their driver-relevant characteristics (contextual characteristics and IPEs) provides a more solid basis for design. Assessing tradeoffs among contextual characteristics makes it possible to integrate IVIS icons with driving tasks to provide the driver with a coherent information source. In addition, IPEs help identify how a message should be designed so that it is compatible with the perceptual, decision making, and motor control limits of drivers.

The first step toward assessing these characteristics was to analyze each of the messages according to their contextual characteristics. Each message was rated according to its: time urgency, criticality, link to driving task, and independence of messages. Table 7 defines each of these contextual characteristics and shows the rating scale that was used to rate the messages. A key element of the rating process was developing definitions for each of the driver messages being rated. Three human factors professionals rated the list of candidate messages in a group discussion format in order to ensure a common understanding of each message. If there were any differences, they were discussed until a consensus was reached. Once the messages were defined, ratings for the contextual characteristics were developed.

Table 7. Summary of the four contextual characteristics that define IVIS messages.

Contextual Characteristics	Definition	Range
Time Urgency	Time available for the driver to respond to the message.	1 = Less than 3 seconds 2 = 3-10 seconds 3 = 10 seconds-2 minutes 4 = 2 minutes-10 minutes 5 = Greater than 10 minutes
Criticality	Consequence of not responding to the message in a timely manner.	1 = Likely death or injury 2 = Increased risk of accident 3 = Unsafe condition 4 = Delay or annoyance 5 = No driving related consequence
Link to Driving Tasks	Relationship of the message to vehicle control.	1 = Linked to safety critical drivingcontrol activities 2 = Linked to tactical driving decisions 3 = Linked to strategic driving decisions 4 = Linked to overall purpose of trip 5 = No relation to the driving task
Independence of Messages	The frequency with which a message is presented at the same time or sequentially with another message.	1 = Always 2 = Frequently 3 = Sometimes 4 = Rarely 5 = Never

The same three human factors professionals simultaneously defined the IPEs that supported each of the candidate IVIS messages. These IPEs include: alert, identify, search, evaluate, plan, decide, coordinate, control, or monitor (see table 8 for a definition of each). For each message, the raters defined the information processing that the messages would support by identifying likely input, the information processing that would occur, and the associated output. Identifying the correct input and output was crucial for clarifying the relevant IPEs that each message seeks to support.

Table 8. Summary of IPEs supported by IVIS messages.

IPE	Definition
Alert	Determine if a change has occurred that requires a response.
Identify	Associate a category or status with an event, location, time, type, region, or item.
Search	Look for a specific item from a set of alternatives.
Evaluate	Compare alternatives based on status or difference between alternatives.
Plan	Allocate resources and identify tasks to meet goal.
Decide	Choose a response to fit the situation.
Coordinate	Arrange timing of tasks to realize a plan.
Control	Enact a task with an action.
Monitor	Observe the system for deviations from intended behavior.

Cluster messages according to contextual characteristics. Once each message was defined according to the contextual characteristics and the IPEs, the messages were analyzed using a cluster analysis. The cluster analysis identifies clusters or groups of messages that share common contextual characteristics. The number of messages makes a hierarchical cluster analysis infeasible. As an alternative, the K-means cluster analysis technique was used. This technique identifies the messages that belong to each cluster and the distance each message is from the center of the cluster. This approach identifies a center for each cluster, where the center is defined by a unique combination of contextual characteristics that is most representative of the messages in the cluster. The cluster center can be thought of as the prototypical message for the cluster. All messages in a cluster will share some of the characteristics of the cluster center. The analysis also identifies the distance between cluster centers. The distance a message is from the cluster center defines how representative a message is of a cluster; the smaller the distance, the more representative the message. The distance to the cluster center increases with the number of characteristics of a message that differ with the characteristics that define the cluster center. A message would have no distance from a cluster center if its contextual characteristics exactly matched that of the center. The more the contextual characteristics differ for a message and a cluster center the greater the distance. The distance between cluster centers defines the uniqueness of each cluster. Ideally, messages would be grouped so that each message is close to the cluster center and each cluster center is well separated. The criterion for selecting the number of clusters was the ratio of the mean distance from the cluster center to the mean distance between cluster centers. This criterion was verified with a manual inspection of the resulting 12 clusters to ensure that it produced meaningful design distinctions.

Group clusters to identify general design categories. A second, standard cluster analysis was performed on the cluster centers of the initial cluster analysis. This identifies clusters of clusters, or general categories of message clusters. Using a “least-difference” approach to analyze differences between cluster centers, four distinct groups of clusters were identified. These categories provide an organizing framework for understanding the design distinctions between IVIS messages.

Examine IPEs and design tradeoffs within each cluster and category. The categories and clusters identify general categories of design considerations. These design considerations are augmented by an analysis of the IPEs associated with each cluster. The results of these analyses will be several groups of messages that have similar driver-relevant characteristics and, therefore, similar design issues associated with them. This will allow us to describe messages in a way that can support generally applicable design guidelines and provide the basis for design tradeoffs and guidance for IVIS designers.

Table 9 summarizes the analytical methods used to develop the final product design requirements and tradeoffs for categories of IVIS messages. It can also be thought of as a "roadmap" linking the methods to the results, directing the reader to the sections in the text that deal with specific issues, and pointing them to the appropriate appendices to obtain the actual results of applying our decision aids and design tools.

Table 9. Roadmap linking task methods, results, and appendices in this report.

Analytical Methods	Results	Relevant Appendix
1. Generate list of IVIS messages and define driver information requirements.	List of IVIS Messages and Driver Information Requirements (Pages 24-26).	Appendix A
2. Conduct review of literature relevant to sensory modality.	Joint Use of Visual, Auditory, and Tactile Information (Pages 26-47).	NA
3. Evaluate IVIS messages in order to determine sensory modality.	Application of the Sensory Modality Design Tool (Pages 47-53).	Appendices C and D
4. Define messages according to their contextual characteristics and IPEs.	Contextual Characteristics and Design Implications (Pages 53-57). IPEs and Design Implications (Pages 58-62).	Appendix E Appendix F
5. Cluster messages according to contextual characteristics.	Tradeoff analysis for IVIS Message Format and Visual Symbols (Pages 62-64).	Appendix G
6. Group clusters to identify general design categories.	Table 13. Contextual characteristics for groups and clusters of messages (Page 64).	NA
7. Examine information processing requirements and design tradeoffs within each cluster and category.	Tradeoff analysis for IVIS Message Format and Visual Symbols (Pages 64-69).	NA

RESULTS

OVERVIEW

Figure 7 shows the relationships between the methods and key findings in Task B. As noted earlier, this task represents the only project activity between the literature review (Task A) and the development of preliminary design guidelines (Task C). Therefore, it was important for this task to provide the necessary design principles and design tools on which to base the development of clear, relevant, and easy-to-use guidelines for icon design.

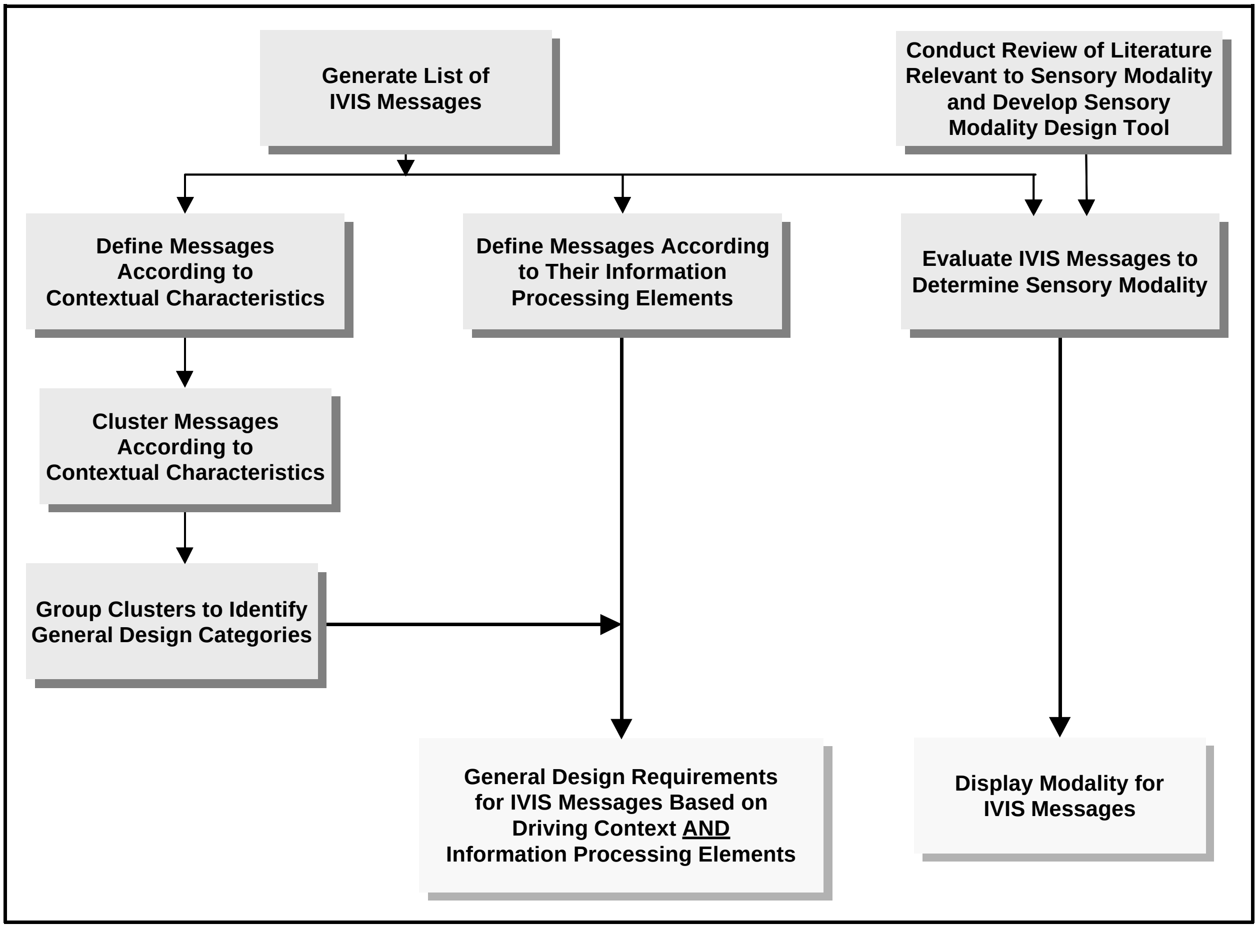


Figure 7. Relationships among Task B methods and results.

In particular, a key goal of this task was to develop a way to characterize IVIS messages according to a small number of key features, as a means of distilling the "universe" of IVIS messages (i.e., approximately 275) down to their most salient design-relevant dimensions.

As described below, this was accomplished by a series of analyses that: (1) identified design tradeoffs associated with display modalities, (2) rated characteristics of the driving context associated with IVIS messages, (3) classified messages according to their IPEs, and (4) used statistical clustering techniques to group related IVIS messages.

LIST OF IVIS MESSAGES AND DRIVER INFORMATION REQUIREMENTS

When the idea of advanced vehicle technologies was introduced a number of years ago, four major capabilities were proposed: (1) in-vehicle routing and navigation, (2) in-vehicle motorist services, (3) in-vehicle signing, and (4) in-vehicle safety and warning. A fifth capability dealt with technologies specific to Commercial Vehicle Operations (CVO). Today, IVIS has grown to encompass not only those capabilities, but also collision avoidance and Global Positioning System (GPS)-related information. A brief description of each of the current IVIS capabilities follows.

Routing and Navigation information provides drivers with information that would aid them in navigating from place to place on the roadway. In a passive configuration, one in which a system in a vehicle acts independently (e.g., without input from other sources such as real-time traffic flow), routing and navigation information is intended to help the driver plan a route to a destination and navigate to a destination. Passive systems operate based on: (1) stored route, address, and driver historical information, and (2) current vehicle position based on GPS, inertial, internal compass, wheel turn position, and other sensory data. Active systems work by receiving real-time information on traffic conditions. They provide information necessary for calculating alternative routes to bypass selected roadways or interchanges, and can re-calculate arrival times based on traffic conditions or re-routing.

Motorist Services information is like bringing the yellow pages into the vehicle. It allows the driver to access business databases such as restaurants, service stations, hotels, medical facilities, and all types of locations that are accessible by roadway.

Augmented Signage presents the driver with the non-commercial signs that you currently see on the side of the roadway (e.g., regulatory, notification, and guidance signs), inside the vehicle. It is believed that, in doing so, the information will be more salient and that drivers will be able to see the information and respond in a more timely manner (Dingus and Hulse, 1993).

Safety and Warning information may be provided to drivers regarding unsafe conditions or situations that are affecting the roadway ahead of the driver (Perez and Mast, 1992). This allows the driver to determine a course of action, which may include re-routing to avoid the hazard. According to Perez and Mast (1992), this capability does not include warnings of imminent danger that require immediate action (e.g., lane change/blind spot warning devices).

CVO-specific information reflects the needs of owners and operators. Much of the technology being proposed, or already in use, will help to increase the level of communication between owner and operator and reduce the amount of time spent on administrative tasks.

GPS-related information pertains to the status of GPS and will be particularly important to those drivers who are relying on an in-vehicle system for routing and navigation. Knowing the accuracy of the information received could influence the decision drivers would make regarding the route they are currently driving on or one they are contemplating switching to.

Collision Avoidance information would be presented to drivers in order to minimize the risk of collisions with objects in the driving environment and other vehicles in their vicinity. Warnings would be presented to drivers in cases where there was imminent danger that required the driver to take some kind of immediate action.

Within each of the IVIS capabilities described above, there are several different functions that a system could perform. These functions are based on driver information requirements, most of which were identified during previous work (Hulse et al., 1998, in progress) and revised just recently during one of the working group meetings conducted as part of this project. Table 10 summarizes functions associated with each of the IVIS capabilities and provides some examples of the types of messages that might be presented for each.

Table 10. Example messages associated with IVIS capabilities and functions.

IVIS Capabilities	Functions	Example Messages
ATIS—Routing and Navigation	Trip planning Multi-mode travel coordination and planning Predrive route and destination selection Route guidance Route navigation Automated toll collection	Display of lodging along set route Arrival time at destination Shortest route option Vehicle's current position Name of current street Cost of tolls along route
ATIS—Motorist Services	Broadcast services/attractions Services/attractions directory Destination coordination Message transfer	Lodging ahead Directory (index of yellow pages) Location of and distance to restaurant Incoming message
ATIS—Augmented Signage	Roadway guidance sign information Roadway notification sign information Roadway regulatory sign information	Route markers Sharp curve ahead Do not enter
ATIS—Safety/Warning	Immediate hazard warning Road condition information Automatic/manual aid request Vehicle condition monitoring	Emergency vehicle stopped ahead Traffic congestion ahead Inform driver aid has been requested Low oil pressure
ATIS—CVO	Trip planning Delivery related information Presentation of service directory information CVO-specific aid request information Cargo and vehicle monitoring information Augmented signage information Administrative information Post-trip summary	Approved fueling locations Scheduled pickup and delivery times Index of yellow pages Notify emergency services of haz mat Problem in trailer unit Low clearance Electronic permit application Miles traveled
GPS-related Information		Satellite signal strength
Collision Avoidance	Rear-end collision avoidance Road departure collision avoidance Lane change/merge collision avoidance Intersection collision avoidance Railroad crossing collision avoidance Driver monitoring devices Backing devices Automatic cruise control devices	System on and functioning System failure No danger indicator Advisory indicator Warning indicator Warning indicator Warning indicator Warning indicator

To identify IVIS capabilities that will be useful to the driver, it is important to understand the functions that the user might want the system to perform. More importantly, however, is knowing what information the driver is going to need to perform them. A complete list of the driver information requirements or in-vehicle messages associated with each IVIS function can be found in appendix A. In some instances, it was necessary to define the meaning or intent of a message before we could proceed any further with the tradeoff analyses discussed below. These message definitions can also be found in appendix A.

JOINT USE OF VISUAL, AUDITORY, AND TACTILE INFORMATION

The process for completing this section of the report involved reviewing the general human factors literature for information related to the development of rules for selecting display modes. This included industry and government standards, general design guides, texts, handbooks, and the general human factors literature. We also reviewed relevant ATIS research, in particular, the results of the research in which alternative display modes had been examined in controlled settings. Second, we developed general design rules regarding display modes based on the sources identified in the steps discussed above. Third, we developed a number of different design aids, exercised them with candidate information elements, and developed a final viable approach. Fourth, the selected approach was refined through more informal testing and analysis. Finally, the final design tool was used to evaluate a number of information elements and to develop a general scheme relating in-vehicle information elements to display modes.

Review of Relevant Literature

The Key Knowledge Gap: Driver Capacity

Within the context of the driving task, as it is performed in today's environment with today's technology, the fundamental question that must be asked regarding the introduction of additional driver information or displays for different modalities into the vehicle is: "What is safe and what is unsafe?" Unfortunately, there is not a sufficiently robust "model" for answering this question and much of the related research has been on very specific issues and questions, which makes generalizing to the larger question somewhat difficult (Dingus and Hulse, 1993). However, there is a body of research that sheds some light on the issues and, in particular, the capabilities of drivers to utilize information presented in different display modes within the vehicle. In particular, this research suggests that the spare visual capacities of drivers, particularly with reference to the use of head-down visual displays, can be quite limited.

On the surface it would appear that, in most circumstances, drivers have spare visual capacity while operating a vehicle. We look at signs, billboards, individuals in other vehicles, sometimes other passengers or objects in our own vehicles, all while driving. In all likelihood, we do these secondary activities only when we feel it is safe to do so, when, for example, our following headway is large or only when the demands of the primary task are low and we have the luxury of time. It is also probable that some drivers are good at "self-limiting their secondary tasks," such as looking for an item on the seat, while others are not (Mollenhauer, Hulse, Dingus, Jahns, and

Carney, 1997). However, despite the occasional or possibly even frequent instances in which the driver has spare capacity, there are clearly instances during driving when spare capacity is quite limited. In the case of navigating through an unfamiliar freeway interchange while using an electronic navigation system, for instance, a visual map display might place demands on spare capacity precisely at a time when there is little or none available. The display mode for various types of information must reflect these capacities and their varying nature over time.

In summary, while there are limits to the driver's capacity to perceive, process, and respond to stimuli in the driving environment, the precise boundaries of driver capacity are unclear. In particular, driver capacity, at any given point in time, is clearly dependent on a number of factors, including individual differences, driving conditions, the in-vehicle environment, and the driving task itself.

The Visual Demands of Driving

Most driver behavior is associated with: (1) lateral control of the vehicle through steering, and (2) longitudinal control through acceleration, deceleration, and braking (Shinar, 1978). Rockwell (1972) has developed convincing evidence that the vast majority of the time a driver maintains his or her eye gaze on or near the "focus of expansion," a point on or near the horizon directly in the forward path of the vehicle. Most eye movements are within an area that is less than 6 degrees of travel, and most eye fixations are between 100 and 350 ms in duration. Rockwell has found that 90 percent of all fixations fall within a surprisingly small region of ±4 degrees of the "focus of expansion." Shinar explains that, by looking at the focus of expansion, the driver gives himself or herself the maximum lead time for responding to the roadway and making latitudinal and longitudinal tracking inputs. Driver scan patterns have also been found to be greatly susceptible to variations in the task (Shinar, 1978). The introduction of road signs, a preceding car, and driving in familiar versus unfamiliar routes all greatly influence the scan patterns of the driver.

One of the simplest but perhaps most important studies of eye gaze and driver tracking performance was conducted by Zwahlen and DeBold (1986), who had subjects drive a vehicle on an unobstructed airport runway while closing their eyes. The trail of the vehicle was marked by draining a small tank of dye onto the pavement. The deviation from the course every 15 feet was recorded after each run of the car. Subjects also drove in a control condition in which they were able to view the runway/roadway. The results support the position that anything more than the briefest glance away from the roadway or forward field can result in a meaningful deviation from the intended track. Any display, the authors conclude, that requires anything more than a short glance should be reconsidered for use while driving. Furthermore, performance standards for evaluating the impact of displays and, for that matter, controls, should be developed.

Dingus, Antin, Hulse, and Wierwille (1988) conducted a study somewhat along the lines of that by Zwahlen and DeBold (1986). However, it focused on navigation systems as opposed to simply the effects of removing eye gaze from the road and examined visual time sharing demands associated with in-car navigation systems. Their work points to the many advantages of what is essentially an "eyes-off and hands-off" approach to in-vehicle navigation aiding systems. The demands of visual “turn-by-turn” navigation aids can be considerable, and, based on the work of Zwahlen and DeBold, may have a substantial impact on tracking performance.

Yet another “early” assessment of this topic was written by Rumar (1988), who concluded that spare visual resources could be allocated to an in-vehicle display, but often at the expense of other areas in the visual scene. There are, in essence, “side effects” associated with the introduction of any attention-demanding display into the vehicle, especially one that increases—rather than decreases—visual workload. If visual attention is directed away from the outside visual environment, then the side effect may be manifested in terms of performance on the primary driving task. Head-down displays (HDD) with high attentional demands may have costs that are proportional to these added attention demands.

Spare Capacity for Viewing a Map While Driving

Studies of navigating while driving have examined eye gaze, actual driver performance, and subjective measures of workload associated with different technologies and display modes. Burnett and Joyner (1993) conducted research assessing the differences between a driver navigating with a head-down visual display and a driver navigating with the assistance of a knowledgeable passenger. Differences between these two conditions were evaluated based on eye gaze and subjective workload. Although subjects felt that their workload was less while using the electronic visual display as opposed to being guided by the passenger, the eye gaze results suggested that it was higher. Eye gaze was directed off the road much of the time when the electronic display was in use, and it was concluded that the talking passenger “mode” was superior to the visual display mode.

In work that has become the basis for a number of estimates about “off the road” eye gaze duration and frequencies that might be detrimental to driving performance, French (1990) concluded that eye glances away from the roadway average around 1.28 seconds in normal driving conditions. Assuming that drivers self-limit and look away from the forward field of view only when they feel it is safe to do so and for a duration that is appropriate to the circumstances, this 1.28-second average off-road eye gaze duration provides a general basis for evaluating the potential impact of “demanding” visual displays. French concluded that glances of more than about 2 seconds should be avoided; that is, display systems should require eye gazes of no more than 2 seconds in duration. Mollenhauer et al. (1997) expanded on this recommendation by suggesting that the 2-second rule should be supplemented with a “four glance rule,” meaning that any unit of displayed information should take absolutely no more than four glances, each lasting no more than 2 seconds.

Attention, the Primary Task, and Information Overload

A change in the “display field” of an operator can bring about an orienting response, a redirection of attention away from the primary task. Even if this information is not particularly important, its presence may still have a detrimental impact by redirecting, if only momentarily, the operator’s attention (Shinar, 1978), especially if the secondary information is presented when the user is under a time constraint, such as when driving at high speed in traffic, performing a maneuver, or faced with a route decision point on a complex freeway interchange.

There have been a number of suggestions by researchers in the aviation display field that pilots' limits of attention may be being reached with the barrage of warnings, status displays, flight path displays, air traffic control data and links, weather information, navigation information, and communications involved in flight (Stokes and Wickens, 1988). There appear to be a growing number of aviation mishaps in which performance of the primary flying task has suffered, often with disastrous consequences, due to the attention given to secondary information in the cockpit (Wiener and Nagel, 1988). Much more attention, it has been said, must be given to examining the link between emerging technologies and information overload (Stokes and Wickens, 1988).

There are suggestions of similar impacts in the automotive transportation environment. Redelmeier (1997), for example, recently completed a fascinating epidemiological study based on the cellular telephone records of individuals involved in traffic accidents. The temporal relationship between in-vehicle cellular telephone use and crashes suggests that there is a four-fold increase in the risk of collision during their use, a level equal to driving under the influence of alcohol at common legal limits. The work has yet to be validated, but it gives cause for concern, especially in view of the many technologies and associated driver interfaces being considered for ITS.

Within this light, it has been suggested recently that in-transit display functions for ATIS systems should be limited to tasks that (Federal Highway Administration (FHWA), 1996):

- Do not interfere with the driving task.
- Have benefits that outweigh the costs.
- Will be used frequently.

General Rules for Modality Selection

Prior to discussing the advantages and disadvantages of different modes or the situations in which different modes should and should not be used, it is appropriate to review some of the general characteristics of vision and hearing—the two modalities employed most frequently for the display of information. Henneman (1952), in a very useful exercise, the product of which is still entirely applicable today, outlined the relative characteristics of vision and hearing. Table 11 summarizes these relative characteristics. Although they are generalizations and one could probably find exceptions to each rule, they are still very helpful for identifying the appropriate mode for various needs of the user and types of stimuli that might be available. Aural stimuli are presented essentially temporally (although they might be multidimensional, as in a musical chord); visual stimuli are essentially spatial. Aural stimuli arrive in sequence (except in the case of overlapping stimuli); visual stimuli arrive simultaneously (as in an entire scene that is comprehended as a whole at one point in time). A listener cannot easily refer back to an auditory stimulus, if at all; visual stimuli have good referability. Far more coding dimensions are available for visual stimuli than auditory stimuli. Our natural abilities for speech offer great flexibility in signal content; visual stimuli must be coded in advance, and text stimuli are essentially symbolic representations of speech. Auditory signals can be highly selective (as in “Turn right at the next intersection”); visual stimuli must often be filtered to find meaning (as in reading a map to locate the next waypoint). The transmission rate of speech is limited by the rate of speech; higher transmission rates are possible with vision. Lastly, aural signals can be attention-demanding, even if the user is fatigued; the receiver of a visual signal must be oriented toward the signal to receive it, and may often not perceive the signal if he or she is fatigued.

Table 11. The relative characteristics of hearing and vision (Henneman, 1952).

Characteristics of Hearing	Characteristics of Vision
Stimuli are essentially temporal	Stimuli are essentially spatial
Stimuli arrive sequentially	Stimuli arrive simultaneously
Stimuli have poor referability	Stimuli have good referability
Stimuli have fewer coding dimensions	Stimuli have many coding dimensions
Speech offers great flexibility	Stimuli must be coded in advance
Speech offers selectivity of messages	Stimuli must be filtered for meaning
Speech limited by talk rate	High transmission rates possible
Signals can be attention demanding	Receiver must orient toward stimuli

Principles for Selecting Visual vs. Auditory Modes

Much has been written on the selection of visual and auditory modes for various types of information and signals (Cushman and Rosenberg, 1991; Human Factors Section, Kodak, 1983; Dingus et al., 1996). Many authors have relied on the original work of Deatherage (1972), who laid out a series of useful rules for assisting designers in this task. Table 12 lists the original eight rules providing guidance for the selection of auditory and visual mode presentations. Auditory is best used when the message is simple; visual presentation is more appropriate when the message is complex. Auditory presentation is more appropriate when the message is short; longer messages are best presented visually. Auditory messages are inherently transient, so messages that need not be referred to later can be presented aurally; if referability is required, vision is best. Messages dealing with events in time, such as a countdown to an event (10, 9, 8, etc.) are best presented aurally; information dealing with locations in space is best presented visually. Immediate action requirements suggest the use of an aural display as opposed to visual. An auditory display should be used when the visual system is overburdened; a visual display can be used when the auditory channel is overburdened. Auditory signals can be best when the environment is not good for viewing visual displays, such as in limited visibility, high ambient light, etc.; visual presentation is usually best when an aural signal might not be heard in a noisy environment. Lastly, auditory signals are preferred when the user must move about; visual displays are appropriate when the user stays in one place.

Table 12. Rules for selecting auditory vs. visual display modes (Deatherage, 1972).

Use Auditory When…	Use Visual When…
The message is simple	The message is complex
The message is short	The message is long
The message will not be referred to later	The message will be referred to later
The message deals with events in time	The message deals with locations in space
The message calls for immediate action	The message does not call for immediate action
The visual system is overburdened	The auditory system is overburdened
The receiving location is too bright or dark	The receiving location is too noisy
The user must move about	The user can stay in one place

In addition to the above, Williges and Williges (1982) have pointed out another advantage of visual versus auditory presentation, an advantage that is similar to the benefit of referability, but not quite the same. They state that a displayed message can be referred to until it is understood and "encoded," not simply referred to again later to aid with memory; an auditory signal, in contrast, is heard once (typically), and if it is not comprehended at the time it is heard, there is not a second chance for encoding by the user.

Additional Criteria for Use of an Auditory Display

The general guidelines presented above address what are perhaps the most obvious reasons for using audio displays for the presentation of information. There are additional criteria, however, addressing topics ranging from customary signal coding to detecting signals in noise.

> Use an audio display to tell the user to look at something. Audio signals are commonly used to direct the user's attention to a visual display or to other important information. Audio signals are generally omnidirectional, and therefore appropriate for attracting the user's attention regardless of eye gaze or head position (Stokes and Wickens, 1988; Dingus and Hulse, 1993).
>
> Use an audio display when the signal must be detected independent of head position or eye gaze. This guideline is obviously related to the guideline listed above. In an automotive application, for example, an audio signal might be the most appropriate display mode for a warning when the eye gaze might be directed at any point within the entire field of view (Deatherage, 1972).
>
> Use an audio display when the signal must be distinguished from noise. Noise can be visual or auditory in nature. A generated audio signal can be designed for detection against background noise. Visual signals can be more difficult to detect against a backdrop of visual noise (Deatherage, 1972).
>
> Use an audio display when the signal must be detected under conditions of high "g" or anoxia (Deatherage, 1972). Although high g conditions might only be found in a race car,

and anoxia might only be found at unusually high driving altitudes, it is also possible that a driver impaired from drugs or alcohol might be more likely to detect an audio versus a visual, tactile, or other signal.

Use an audio display when the signal is acoustic in origin. A siren on an emergency vehicle contains information about its presence, its location, its distance, and sometimes the type of vehicle. This signal is acoustic in origin. Converting such a signal to another modality might not be necessary or desirable. Belz, Winters, Robinson, and Casali (1997) have conducted interesting work on auditory icons, sounds that convey meaning through the use of natural associations.

Use an audio signal when there is an expectancy for an audio signal. Using the above example, drivers have an expectancy regarding emergency vehicles and sirens. Changing the mode of the signal would likely lower the probability of detection—or at least the time to interpret the signal.

Use an audio signal to transmit directional information. Audio signals can provide directional information through natural directional cues, such as binaural intensity, the sound source reaching one ear before the other, or different sound quality to the ears (direct sound versus reverberant sound).

Use an audio signal when the message calls attention to immediate danger. Auditory signals are responded to slightly faster than visual signals. Auditory signals are naturally intrusive and attention demanding (Deatherage, 1972).

Perhaps the two most important principles regarding auditory displays are that they: (1) are highly effective for warnings, alerts, and conditions that demand the attention of the user regardless of orientation, and (2) can be effectively employed when the eyes are fully engaged.

The above principles can usually be applied only after the designer has studied and classified the desired actions of the user and then identified the auditory information that has the greatest probability of bringing about the desired response in the desired way. With reference to these “behaviors” and “signals,” Harris and Levine (1961) have put together a list of six very useful questions for sorting out the functional requirements of auditory signals. They are:

- Is the signal to be a warning call or instruction?

- Will the signal indicate an emergency or routine situation?

- How much time will be available to take action?

- Will the signal sound at regular intervals or infrequently?

- Must the signal function around other signals, and might it be confused?

! Will the signal be protecting life or valuable property?

The answers to these questions can help the designer apply the principles discussed above and make decisions regarding the application of speech or non-speech signals, as discussed below.

Speech vs. Non-Speech Auditory Signals

It is difficult, if not impossible, to discuss the issue of appropriate sensory modality (vision, audition, tactile, etc.) without discussing, at least to some degree, the type of presentation within a particular modality, especially the auditory modality. What can be achieved through speech is so fundamentally different from what can be achieved through non-speech sound that any discussion of auditory display options must touch upon these issues.

Some have argued that the use of speech output in products has not, for the most part, been well accepted (Cushman and Rosenberg, 1991). Speech output, it has been said, can be “gimmicky,” toy-like, and unnecessary, which is unquestionably true in certain circumstances. The more recent past may have seen a tapering-off of such “toy-like” applications in non-toy products, and more “appropriate” uses of speech technology in consumer-oriented products have appeared as the technology has matured. One such application, as discussed later, is in turn-by-turn route guidance systems.

The following pages summarize the most basic of recommendations for determining if a signal should be speech or non-speech. We start by discussing recommendations for the use of speech output, followed by the use of non-speech output.

> Use speech when a high degree of message flexibility is required. Auditory messages requiring sometimes complex or variable presentations lend themselves to speech (Cushman and Rosenberg, 1991).
>
> Use speech when a high degree of message detail is required (Cushman and Rosenberg, 1991). It is generally not possible for a simple, coded, non-speech sound to provide the level of detail required by some signals, especially if those signals address things such as instructions.
>
> Use speech when the listener has not been trained to interpret non-speech aural signals (Cushman and Rosenberg, 1991). There are relatively few auditory signals in the driving environment for which drivers have been trained. Examples might be a railroad crossing bell, a car horn, an emergency vehicle siren, or an in-vehicle chime to warn that the lights have been left on or the key left in the ignition. Regardless, training on these and other signals have probably been quite informal for most drivers. Employing speech will, in general, often be more appropriate than employing new non-speech sounds.
>
> Use speech when coded aural signals may be forgotten under stress (Edman, 1982; Stokes and Wickens, 1988). The meaning of coded non-speech signals, particularly when there are many in the operating environment, is far more likely to be forgotten under stress.

Use speech when it is necessary to identify the source of an auditory message (Woodson, 1981; Edman, 1982). Message sources can be stated in speech. Also, listeners can recognize different voices and points of origin for voices.

Use speech to present instructions or directions (when presented aurally) (Woodson, 1981; Edman, 1982). Although it has been argued by Hammerton (1974) that "instructions should be seen and not heard," there is little to support this generalization. Within the context of the above recommendation, there is no question that speech is a more effective means of communicating complex instructions and directions, especially in a driving environment.

Use speech when complex tonal signals are already in use (Woodson, 1981; Edman, 1982). As discussed above, speech offers infinitely more codes and these codes need not be put to memory in the same way as a non-speech code.

Use speech when there is a need for rapid two-way communication (Deatherage, 1972). Speech input and output is considerably faster (around 250 words per minute) than coded communication, such as Morse code (around 30 words per minute).

Use speech when the aural message deals with a future point in time for which there must be some preparation (Deatherage, 1972). Such a situation might be a countdown or, in an automotive setting, the time or distance to a route change.

Use speech when the aural message presents quantitative information. Like the interpretation rate for speech versus Morse code, presenting quantitative information with speech should be superior.

Use speech when the aural message deals with an event that must be responded to in the future (ISO/TC27SC13/WGG8N100, 1997). Signals can be classified into three temporal groups: Intermediate, short term, and long term. Speech is considered appropriate when the message must be dealt with over the long term, such as "Congestion ahead in 10 km." It is also considered suitable when the temporal classification is short term. Non-speech signals are typically more appropriate when the temporal requirement is immediate.

The following are guidelines for when to use non-speech:

Use non-speech signals when ambient noise can mask speech (Woodson, 1981). Background noise, especially within the ranges of common speech, is a major issue when considering speech signals and speech recognition and comprehension (Kryter, 1972).

Use non-speech signals when an immediate response is required (Woodson, 1981). This requirement applies as long as the user knows the signal code and meaning.

Use non-speech signals when the listener must be alerted that speech will follow (Woodson, 1981). There is some disagreement about this recommendation, and some research has been conducted that suggests that an alerting tone is not necessary or beneficial. The consensus, however, is that an alerting tone is generally helpful as long as it is not annoying.

Use non-speech signals when a spoken message might annoy the user (Woodson, 1981). As discussed later, there are situations in which spoken messages can annoy a user, especially if there is excessive use of voice or if the voice is loud or unpleasant.

Use non-speech signals when a spoken message might annoy other listeners (Woodson, 1981). The criteria listed above regarding the user, as opposed to the bystander (a front seat passenger, for example), apply here as well.

Use non-speech signals for a straightforward warning (Cushman and Rosenberg, 1991). Non-speech signals are most effective as a warning or alarm as long as the message is not complex and the code is well understood by all users.

Use a non-speech master signal when it is essential that the user orient toward a visual display providing specific information. Many systems employ a master signal when any of many sub-systems are out of limit. The F-15 fighter, for example, has a master audio warning directing the pilot's attention to visual displays (Stokes and Wickens, 1988). The consequences of redirecting the user's focus of visual attention should be assessed if this approach is employed.

Send warning signals via a different system from those being used for speech communication (Woodson, Tillman, and Tillman, 1992). In the case of, say, a voice-based turn-by-turn navigation system in a vehicle, this principle would suggest that any non-speech auditory warning should not—or at least sound like it is not—being broadcast over the same channel as the speech system.

<u>Caveats Regarding the Use of Speech as a Display</u>

Speech, especially with the recent development of inexpensive speech-generation technologies, has many potential applications, and some of these applications are in the driving environment. However, there are a number of cautions that should be taken with regard to the decision to use speech systems.

First, speech intelligibility can be influenced by the speech rate, length, content, complexity, background noise, pitch, and loudness (Kryter, 1972). Some in-vehicle, turn-by-turn route guidance speech display systems are, from the authors' subjective point of view, very intelligible in most vehicles—just as long as the windows are rolled up and the sound level is moderate. Many systems are simply not intelligible when vehicle windows are rolled down—even when volume is turned up.

Second, a volume control for speech systems is essential (Dingus and Hulse, 1993). Listening conditions vary, listeners have varying levels of hearing sensitivity, and perceptions of annoyance, which can reflect loudness, change over time. Annoyance thresholds also likely vary from one passenger to the next.

Third, there is a learning curve associated with listening to and understanding synthetic speech (Edman, 1982). Most users adapt quite quickly to synthetic speech systems (the learning curve is steep), but this factor has some relevance in settings such as a rental vehicle, which may be operated by many different users who have had no training with the speech generation display.

Fourth, Edman (1982) has made the point that speech intelligibility should not be confused with comprehensibility. A user may understand individual words produced by a synthetic speech system, but may have difficulty understanding the meaning of the entire message. This can reflect, of course, the meaning of words, the length of the utterance, or even the conditions in which the speech is generated.

Fifth, just as the display environment can become cluttered with visual displays (billboards, commercial signs, or roadway signs), the aural environment can become cluttered with excessive non-speech aural alarms. “Speech output has a tendency to clutter the auditory environment, which may easily lead to an overall degradation of user performance” (Edman, 1982). Stokes and Wickens (1988) have also noted the growth in aviation speech displays and warn that the aural environment is in danger of becoming as cluttered as the visual environment in the aviation realm.

Sixth, speech may be masked by background noise to a greater degree than is the case for non-speech aural signals (Moore, 1989; Stokes and Wickens, 1988). It is important to identify the background noise level and spectral characteristics of the listening environment and design the aural signal—be it speech or non-speech—so that necessary levels of intelligibility and comprehensibility are met.

Lastly, there is an interesting and potentially important issue raised by Noy (1990), and later by Perez and Mast (1992). They indicate that a verbal instruction—as opposed to a visually-presented instruction—may be more likely to generate unquestioning compliance. Drivers, according to Noy, tend to respond more instinctively to verbal information, especially when it is in the form of a command. For example, in the case of turn-by-turn route navigation, there are suggestions that the user of a voice guidance system (as opposed to a visual system) may be more likely to follow the generated instructions somewhat blindly, possibly failing to respond to the fact that the action violates a traffic regulation. A user might be more likely to follow directions that are incorrect when they are receiving verbal guidance as opposed to visual turn-by-turn route guidance. This is an issue that requires further research.

<u>Caveats Regarding the Use of Auditory Displays (All Types)</u>

There are four cautionary notes regarding the use or over-use of auditory displays. First, many or perhaps most auditory displays, especially non-speech alarms and warnings, are intrusive and distracting by nature (Stokes and Wickens, 1988). Auditory displays are typically more distracting than visual displays, and are often selected simply because of their intrusive and distracting qualities. The user is often forced to pay attention when an auditory alarm sounds.

The downside of this characteristic is that auditory displays have the potential of being too distracting and too intrusive. In a study of in-vehicle signage systems, Mollenhauer, Lee, Cho, Hulse, and Dingus (1994) found that, although a verbal display of road signage was superior to an in-dash visual display in terms of road sign recall, driver performance in the simulator was worse when the verbal system was in use. The authors concluded that the specific verbal display employed in their study was particularly intrusive, so much so that it actually degraded performance on the primary task. In light of some of the other research discussed later, this result is viewed as being a bit unusual, but it does illustrate the possible consequences of introducing an overly intrusive auditory display into the driving environment.

Second, Perez and Mast (1992) have raised the possibility that a particularly intrusive auditory signal has the potential of generating a panic or startle reaction, not necessarily just an orienting or "listening" response. In fact, evolving standards state that auditory signals should strive to elicit an orienting reaction by the listener, not a startle reflex (ISO/TC22/SC13/WG8N100, 1997).

Third, annoying auditory signals can become the physical targets of frustrated or annoyed users. There are many documented cases of users turning off or disabling auditory alarms that were felt to be too loud, frequent, or annoying. Sorkin (1988) recounts the story of a serious train accident in which the conductor had taped over an over-speed buzzer due to the high rate at which it sounded (due to the frequency with which the train was being driven over the specified speed).

Fourth, over-use of auditory displays can lead to auditory clutter, a condition in which there are so many auditory signals that the ability of the driver to elicit a reliable response comes into question. This problem also highlights the importance of keeping a holistic, systems approach to the use of all displays and the dangers of evaluating and adding individual display systems on a case-by-case basis.

Applicability of Non-Visual/Auditory Display Modes

In the 1960s and well into the 1970s there was considerable optimism among many researchers concerning the potential application of man-made displays employing modalities other than vision and hearing. Although there has been some success with tactile vision systems used in reading and navigation systems for the blind, as well as a few other applications of non-visual/auditory displays in various settings, the early promises for widespread use of non-visual/auditory displays have not panned out.

Many recent reviews, as well as some not-so-recent summaries, recognize these failings. For example, McCormick (1970) suggested that the tactile system might be well suited for only a very limited number of discrete stimuli, such as those used in warning, alerting, or vigilance tasks. As early as 1960, Hawkes took a very dim view of the prospects of widespread use of tactile displays to present anything other than the simplest of messages. The tactile system, Hawkes noted, is not designed to sense the small differences found in the visual and auditory systems, and, although some impressive coding schemes have been developed in which combinations of stimulation over various surfaces of the skin have been used to transmit text at impressive rates (Hawkes, 1960), the levels of training required for such systems make them entirely impractical for automotive applications. Complex schemes such as this are, in all probability, simply unnecessary and unworkable in the automotive setting. More recently, Mollenhauer et al. (1997) have also taken a dim view of the prospects of non-visual/auditory displays, concluding that tactile displays “cannot be viewed as a serious alternative to simple auditory warnings” with the current state of technology.

On the other hand, it should be noted that some non-visual/auditory display techniques have shown promise, although these applications are typically quite straightforward. The attention-demanding qualities of tactile signals, like the attention-demanding attributes of auditory alarms, suggest that they might find some areas of successful application. In fact, there are some automotive applications of tactile displays in widespread use today, as discussed below.

<u>A Review of Non-Visual/Auditory Channels</u>

Table 13 summarizes the characteristics and functions of the sensory channels other than vision and hearing. Descriptions of the cutaneous, kinesthetic, and vestibular systems and their potential for displaying information have been written by Howard (1986), Sherrick and Cholewiak (1986), and Clark and Horch (1986).

Table 13. Characteristics and functions of non-visual/auditory senses.

<table>
<tr><th>Sensory Channel</th><th>Characteristics</th><th>Function</th></tr>
<tr><td>Cutaneous</td><td>Responds to:
Mechanical energy
Electrical energy
Thermal energy</td><td>Sense of touch
Sense of temperature
Sense of pain</td></tr>
<tr><td>Kinesthetic</td><td>Responds to:
Tissue distortion arising from within.
A feedback loop for regulating</td><td rowspan="2">Proprioceptive sense
Sense of orientation of body and links
Body movement
Acceleration
Pain</td></tr>
<tr><td>Vestibular</td><td>Responds to:
Change in the position of the head relative to gravity</td></tr>
<tr><td>Olfactory</td><td>Responds to:
Chemical energy</td><td>Sense of smell</td></tr>
<tr><td>Gustatory</td><td>Responds to:
Chemical energy</td><td>Sense of taste</td></tr>
</table>

Cutaneous perception. Cutaneous perception occurs through mechanical, electrical, thermal, and chemical energy applied to the skin (Geldard, 1957). The system is highly specialized for sensing warm and cold, and especially configured for sensing pressure and changes in pressure. Cutaneous perception usually involves deformation of the skin. We adapt quickly to continuous pressure, and the thresholds of sensitivity therefore shift and sensitivity falls off as pressure is maintained over time.

Through the sense of touch and changes in pressure we sense not only continuous pressure, like that which occurs when sitting in a chair or grasping a handle, but changes in pressure through time and motion. The rate of deformation is very important for the perception of surface qualities such as roughness, smoothness, or softness (Deatherage, 1972). Extremes of temperature affect the tactile sense; sensitivity is degraded substantially by low temperatures.

Electrical stimulation of this system is possible, but from a practical point of view, the stimulus would have to fall between the boundaries of pain and painless pulses, something that might be quite difficult in real-world applications.

Conceptually, electrical stimulation could be coded by intensity, polarity, duration, interval, surface area, spacing, and location. Gilmor (in Hawkes, 1960) has discussed quite elaborate schemes for coding letters, symbols, and digits through electrical stimulation of the skin. Again, from a practical perspective, one must learn the code to put any of this into real-world use.

Mechanical or physical stimulation of the skin can be coded by location, frequency, intensity, and duration (McCormick, 1970). Alluisi (in Hawkes, 1960) found that tactile discrimination was limited to: (1) two or three levels of intensity, (2) two or three steps of change in intensity, (3) three or four steps of duration, and (4) six or seven positions on the chest. The receiver must learn the code, however. Tactile "vision" systems with arrays of mechanical or air-driven stimulators have, in some laboratory settings, been surprisingly effective (Corliss and Johnsen, 1968) at generating rough images that can be perceived by blind subjects.

Kinesthetic and vestibular perception. The kinesthetic and vestibular systems work jointly for the perception of the position and orientation of the body and limbs and the movement of the body. As discussed by Deatherage (1972), "For the most part, these stimuli provide information only that some change has occurred and visual cues then must be relied upon to determine the exact nature of the change."

The kinesthetic sense is somewhat unusual in that it originates entirely from "within," not from external stimulation as is the case with other sensory systems. We are not typically "aware" of kinesthetic stimulation or sensations, and kinesthetic sensations cannot easily be quantified in the same sense that we quantify visual or auditory stimuli (Deatherage, 1972). It is generally agreed that, although kinesthetic and vestibular feedback is obviously very important for the regulation of movement of the body and balance, the proprioceptive sense is quite insignificant in terms of its potential for use in man-made displays.

Olfactory and gustatory perception. The absolute thresholds for taste and, in particular, smell are astounding. In terms of equipment operation, we can smell burning insulation, oil or fuel, or a locked brake, all important activities. However, there is general agreement that the senses of taste and smell are "hardly reliable enough to use as a basis for design" (Deatherage, 1972), a design that might somehow create smells and tastes related to information presented by ATIS and related systems.

It is concluded that the only non-visual/auditory sense with any potential application to the ATIS display environment is the sense of touch.

Non-Visual/Auditory Mode Selection Principles

When viewed within the context of force feedback for controls, tactile perception (and to a certain degree, kinesthetic perception) plays a vital role in the sensing of "displayed" information. A well-designed manual clutch system, for example, provides cues about its operation through changes in effort over the course of travel. A steering wheel provides tactile and proprioceptive cues regarding the position of the wheel and the lateral track of the vehicle, but also possibly the quality of the road surface. Through force feedback, usually to the hand or foot, a control presents information about the status of the controlled element and its interaction with other elements directly to the human controller. Force feedback is a vital component of accurate human performance in manually controlled systems.

In the case of a shaker stick on an aircraft, which vibrates when a stall is about to occur, or the vibration and chatter on a brake pedal for an anti-lock brake system (ABS), which occurs when the system engages after sensing wheel slippage during braking, the control is used as a tactile feedback conduit to the operator. This is not "force feedback" in the classic sense of the term, but these approaches employ the use of somatosensory feedback to convey information related to the use of the control or, in the case of ABS, the automatic engagement of a system and the need for the operator to behave in a certain manner.

It is in the above context that the following principles for the selection of tactile mode displays were developed.

> Use dynamic tactile stimuli only when it is certain that the necessary body part (hand, foot, finger, etc.) will be in physical contact with the transducer at the time the feedback is to be transmitted. As an example, an accelerator pedal might be made to vibrate when the following headway is too short. However, if the driver's foot is not on the pedal, such as when a cruise control is engaged, then the signal will not be received. A "chatter" pedal on an ABS, in contrast, engages only when the control is being engaged (and the foot is clearly in contact with the control).
>
> Use dynamic tactile stimuli only when minimal or no training of the user will be required to understand the meaning of the feedback and the appropriate behavioral response. Markus (1997) recently summarized the status of ABS and their impact on crash frequencies. Despite the demonstrated improvements in stopping performance afforded by ABS, they have resulted in little or no reduction in crash frequency or severity. The U.S. National Highway Traffic Safety Administration (NHTSA), once contemplating an ABS mandate, dropped its plans in 1996. The problem is clearly a behavioral one, in which many drivers, even those aware of system operation and requirements, do not make the required response of pressing hard on the brake pedal when ABS is activated and the pedal "chatters." This result raises important concerns about drivers' abilities to override their natural habits based on experience and manual control expectancies, especially when

the required response must be rapid and purposeful. The substantial cost of ABS on a fleet-wide basis (over half of all cars now sold have ABS) has not been realized in terms of crash avoidance or reduction in severity due to this behavioral element.

Use dynamic tactile stimuli (with rapid square-wave onset) when a quick reaction time is required. Swink (1966), in an effort to demonstrate that dynamic tactile stimuli could produce significantly faster reaction times than visual or auditory stimuli, found that a square-wave electric pulse to the palm of the non-preferred hand (i.e., rapid onset and offset) produced responses that are faster than responses to visual or auditory stimuli.

Use dynamic tactile stimuli coupled with an auditory or visual signal when a very quick reaction time is required. In addition to finding that a tactile stimulus provides the most rapid reaction time, Swink (1966) found that a tactile stimulus was more facilitating than other stimuli when presented in combination with other stimuli. In general, he found that the greater the number of modes employed in a stimulus, the faster the reaction time.

Use dynamic tactile stimuli in situations that are compatible with the desired control input behavior and other related control input behaviors. The designer should be aware of situations in which the tactile stimulus might not illicit the desired behavior due to a startle response, negative transfer, or other factor. For example, Janssen and Nilsson (1990) have studied a “smart gas pedal” that vibrates as a collision warning when following headway is too short. The feedback “instructs” the driver to “lift off” the pedal to increase following headway or decelerate, and, in fact, the smart gas pedal was found to increase following headways, as hypothesized. However, consider a situation in which a vehicle has a “smart gas pedal” that vibrates when the driver is to lift off of the pedal, and the vehicle also has ABS in which the brake pedal vibrates when the system engages and the driver is to press down hard on the pedal. In one instance the vibration is telling the driver to lift up; in the other it is telling the driver to press down. Negative transfer—or confusion over which pedal is being actuated and the proper response, especially in an emergency situation—might be a distinct possibility with such a configuration.

Use dynamic tactile stimuli only in situations where perception of the stimulus will not be degraded by cold temperatures. Low-magnitude tactile displays, especially systems involving hands and feet, might not be perceived as anticipated when the driver has entered the car from a cold, outdoor environment.

Use dynamic tactile stimuli only in situations where perception of the stimulus will not be degraded by clothing, such as gloves or heavy shoes. Like the situation in which the stimulus must be of sufficient magnitude to be detected and identified in a cold environment, the stimulus must be of sufficient magnitude to be detected through clothing, especially heavy clothing.

Use dynamic tactile stimuli only when the stimulus will not startle the user. It is conceivable that a very infrequent tactile stimulus could startle a user, much like an infrequent and intrusive auditory stimulus.

Use a dynamic tactile display when the information is appropriately linked to the control through which the information is being presented. It seems appropriate that there be a natural link between the location of a tactile display and the desired response of the user, such as is the case with a "chattering" brake pedal when an ABS engages. Simply providing a tactile stimulus to the hands through the steering wheel would not be, it could be argued, a natural linkage unless the desired response had something to do with steering. A stall warning "shaker stick" on an aircraft control, for example, is linked to one of the behaviors that will alleviate the stall (pushing forward on the stick).

Modality Selection for Various ATIS Technologies

The previous research we have discussed provides general principles for the selection of display mode based on the entire arena of human factors research. Additionally, however, there is a body of research, much of it quite recent, that addresses issues pertaining to display mode in automotive applications. Much of this work is directly relevant to this discussion and the development of design aids for selecting the display mode for various ATIS components.

Display modes for navigation information. In addition to developing principles based on what has been shown to work or what is likely to work based on an analysis of the task, it is also possible to develop principles regarding appropriate display modes based on what apparently does not work or does not work well. It has become reasonably clear, based on the information on eye gaze durations and frequencies presented earlier, as well as research on in-vehicle navigation systems that are discussed later, that a vision-only, head-down map display is not the ideal mode for conveying route-following information to the driver when in transit.

One of the more convincing arguments for not relying on vision in a head-down format is provided by Dingus et al. (1988), who studied navigation during actual driving while using an early-generation ETAK system. Navigating with the electronic visual display clearly changed eye scan patterns ahead of the vehicle, resulting in a very significant reduction in the length of eye gazes forward of the car. Actual driver performance was not measured, but the eye scan data showed quite convincingly that a visually based electronic map display imposes significant time-sharing demands on the driver. A few years later, Antin, Dingus, Hulse, and Wierwille (1990), in support of the findings of Dingus et al. (1988), also concluded that a complex moving map places high attention demands on the driver when it is used for real-time navigation.

Independent of how the information is presented to the driver, it has become quite apparent that route following during navigation benefits from simple turn-by-turn instructions (Dingus et al., 1997a). A driver might receive this information from a list or, perhaps, a knowledgeable and skilled passenger who provides precise instructions at the correct time and place. An automated system could present this information visually in list or graphic form, with a voice, or both.

In addition to the finding that turn-by-turn information aids route-following, there is a considerable body of evidence that turn-by-turn instructions should be presented primarily through the aural mode and secondarily through the visual mode. As early as 1985, Streeter, Vitello, and Wonsiewicz concluded that audio presentation of route guidance information was better than visual presentation. This conclusion was later supported by the work of Verwey (1993), who concluded that verbal route guidance was clearly superior to a visual system involving a map and symbols, and by the research of Parks and Burnett (1993), who determined that audio turn-by-turn supported with visual information was best for route guidance and keeping the eye gaze on the road. Walker, Alicandri, Sedney, and Roberts (1990) also found that audio route guidance was best, even when the level of complexity of the information varied from low to high. Dingus et al. (1996), in a review of the literature, concluded that route navigation was easier with audio as opposed to visual display, and that driver workload was lower with audio presentation.

Three studies published in 1997 (Dingus et al., 1997b; Srinivasan and Jovanis; Zaidel and Noy) all demonstrate the benefits of voice for turn-by-turn route-following. Dingus et al. found that voice turn-by-turn drastically reduced eye fixations to the electronic map display, that voice guidance was of particular benefit to older drivers, and that redundant visual and auditory information was very helpful for older drivers. Srinivasan and Jovanis found clear superiority in terms of workload, speed, and navigation errors for a voice combined with an electronic map as compared with a head-up display (HUD)/electronic map condition and a paper map. These results were supported again by Zaidel and Noy, who found that verbal guidance instructions resulted in the best performance in an actual driving task.

Lastly, it has been determined that turn-by-turn audio messages should include only the essential information that is required for the maneuver, such as the direction of the turn, the turn street name, and the distance to the turn (Walker et al., 1990).

Therefore, a summary of the literature would suggest that for the presentation of navigation information, designers should use simple verbal audio guidance for turn-by-turn instructions during route-following, supplemented with highly simplified visual presentation for reference purposes.

Display modes for collision avoidance information. There are a number of types of potential collision warnings that could be presented to the driver, but the most frequently discussed are the frontal collision warning for following headway and a side collision warning for a lane change maneuver. Regardless of the type, a number of important issues should influence the type of display mode that might be selected for a collision warning.

First, relative to total driving time and the total number of opportunities, collisions and, in particular, rear-end collisions, are exceedingly rare on a per-driver basis (Janssen and Thomas, 1997). It is therefore quite conceivable that a highly accurate and reliable collision warning system in a vehicle might never generate a signal that would be perceived by the owner of the vehicle. This raises questions concerning training, startle responses, the creation of potentially superfluous or distracting information in the vehicle, and the criterion at which the signal (assuming, for example, an on/off signal) might be generated. Janssen and Thomas have stated that "...it is clear that the event a CAS should detect is so rare that serious doubts should be entertained regarding the possibility that detection of critical configurations could ever be performed flawlessly, let alone that it could be achieved without false alarms."

Second, it has been argued that a collision warning system should have nearly no false alarms; that is, instances in which the display generates a warning of a collision when a collision is not imminent. False alarms on an on/off type warning would be particularly detrimental to driving and to the driver's faith in the system (Dingus et al., 1997b). At the same time, it would be quite unacceptable to increase the miss rate, a case in which a collision is imminent and the system fails to detect and warn. These factors may play into the type of display that is appropriate (say, discrete or continuous) and, therefore, the display mode. A continuous display, one that presents continuous information on following headway as opposed to a discrete on/off alarm, for example, could not realistically be presented via an auditory signal.

Third, it is quite possible that adding a collision warning display to the driving environment may divert attention from the primary task and actually increase, not decrease, crashes (Dingus et al., 1997b). Given the very low crash incidence rate relative to all exposures, this is also a difficult topic to study through realistic experimentation. However, considering the very low frequency of rear-end collisions on a per-driver basis (once every 25 to 30 years of driving), a collision avoidance display having only the slightest negative impact on driver attention could cause more harm than good.

Fourth, presenting information regarding a dangerous condition or impending collision immediately prior to the event may have detrimental effects. Hirst and Graham (1997) have noted that "Whereas improved performance in vehicle control can be obtained by the provision of supplemental visual headway information, drivers engaged in highly time critical situations are unable to benefit from such information because they are reluctant to divert attention away from the primary visual source."

The above issues aside, there is evidence that some form of collision warning information might be quite helpful to many drivers, given human perceptual characteristics. Mortimer (1990) has analyzed rear-end collisions and pointed out the types of cues that are needed by drivers to make them better able to detect a dangerous headway. Although it is the change in the visual angle of the forward object (e.g., a car) that is the primary cue, changes in visual angle are not detected until the approaching vehicle is relatively close. In fact, a sizeable percentage of rear-end collisions occur when the front car is actually stopped or moving very slow. Dingus et al. (1997b) have also noted that closure rates are primarily perceived based on changes in visual angle, and that a display providing information on relative velocity might address this need. The consequences of this perceptual characteristic are compounded by the fact that perception-response time—the time between the detection of an obstacle and the lifting of the foot off of the accelerator—can be surprisingly long. Olson and Sivak (1986) note that the 95 percentile value is 1.6 seconds, and that most roadway design standards employ a value of 2.5 seconds in consideration of factors such as possible impairment, weather, and road conditions. In this light, a collision warning display might have considerable benefits.

Possibly the most relevant recent study on this topic was that conducted by Dingus et al. (1997b) in which they evaluated different headway displays and found that a perspective visual display providing information on relative headway was most beneficial in terms of reducing following headway. Unfortunately, there were no measures of lateral tracking performance, so it cannot be certain that other elements of the driving task were not impaired due to the presence of the headway display. Overall, this work suggests that a collision warning display that presents relative headway information visually would be superior to a discrete visual display or even a discrete auditory display.

It has also been suggested that an auditory alarm be employed as a collision warning. Tijerina and Hetrick (1997) have, based on computer simulations, investigated the impact of an alarm that sounds when an unsafe lane change is about to be made. The turn indicator must be active and a vehicle must be present in the destination lane for the alarm to sound. In view of concerns over false alarms, presentation of alarms when a driver might be least capable of taking evasive action, and providing discrete as opposed to continuous information for a collision warning, one has to wonder about the reasonableness of this concept.

There is some evidence that a combined visual display and auditory display might provide the best all around approach to the presentation of collision warning information. Dingus et al. (1997b) found that the combination of their perspective visual display and verbal warning (either “look ahead” or “brake”) was most effective at reducing problematical headways. Generally similar results were seen by Hirst and Graham (1997), who found that an abstract visual display combined with a speech warning resulted in earlier braking times. However, their subjects clearly preferred the non-speech warnings. Hirst and Graham also note that “...drivers do not knowingly approach a relatively slow moving vehicle and brake at the last possible moment to avoid a collision.” It would be entirely inappropriate to design a collision warning system that operated on this principle. Drivers apparently do benefit, however, from visual information concerning relative headways (ordinal or ratio information, as opposed to simply discrete or nominal information) and also verbal warnings, although the latter has the potential of being annoying.

In summary, tactile (the smart gas pedal), auditory (alarms and speech warnings), and visual displays have all been investigated as potential modes for collision warning displays. To one degree or another, each mode has been shown to be effective. However, the findings in their totality suggest that a visual display (not a simple discrete visual alarm) combined with a verbal warning might be most effective in addressing headway problems. A tactile display, such as the “smart gas pedal,” in combination with a continuous head-up visual display, might show promise as well, but the foot must be on the pedal in order for the tactile signal to be detected. Also, the ancillary consequences of placing a visual collision warning display in the driver’s field of view, as well as the impact of an auditory or tactile warning, have not been extensively researched.

Display modes for in-vehicle signing information. Akamatsu, Imacho, Daimon, and Kawashima (1997) have noted that road signs, street names, etc. “...should be displayed... in a manner that is compatible with their location in the real traffic environment,” a recommendation that seems quite prudent and reasonable. There must also be compatibility with the primary task, however, and it is apparent that frequent and prolonged eye gazes away from the forward field of view can have a profound impact on overall driver performance. Simply moving external signage into the vehicle, especially to a head-down visual display, might not be appropriate in consideration of the larger driving task.

Current technical issues appertaining to HUDs, and, in particular, concerns regarding cognitive capture and visual accommodation to HUD images and the real world (Roscoe, 1987a, 1987b, 1989), raise concerns regarding the display of signage with a HUD. These and related issues are in need of additional research before any conclusions can be made about their efficacy. It is also apparent, based on the overall view of auditory displays, that presenting extensive signing information, including road names, cross streets, alternate routes—all things that we perceive, filter, and selectively attend to in the natural visual world—cannot all be presented aurally without the risk of creating a highly annoying and intrusive situation.

Display modes for in-vehicle motorist services information. The activities involved in searching a complex data base, reviewing parameters and options, and making selections regarding the universe of motorist services are not—be they performed with a visual, auditory, or combined display system—generally compatible with the concurrent demands of driving a vehicle (Labiale, 1990). A driver should not be expected or, for that matter, allowed (through the design of the interface) to conduct such activities while in-transit. The recent work of Redelmeier (1997) on accidents associated with cellular telephone usage while in transit raises important concerns regarding the safety impact of secondary visual and possibly auditory tasks while driving.

Considering that such activities will be performed when the vehicle is stopped, display modes that are primarily visual in nature will be most appropriate for sorting, selecting, and reviewing motorist services. Work by Huiberts (1989) indicates that visual—as opposed to speech-based—display systems have the most promise in this regard. Similarly, Lee, Dingus, Mollenhauer, and Brown (1996) found that complex ATIS information was best presented visually, as opposed to aurally. While not much empirical data are available relevant to AutoPC systems, they would be considered one such type of motorist services information source. Motorists will soon be able to send and receive e-mail, obtain real-time traffic and weather reports, transfer data from their home or office computers, and obtain driving directions all from the front seat of their car. Systems such as JottoDesk and Norton Mobile Essentials have already been developed for these purposes (Orski, 1998).

Display modes for in-vehicle safety advisory and warning information. There are a number of potential and reasonable display configurations for safety and advisory warning systems. The most promising, however, are likely to be primarily auditory in nature, perhaps with a visual "backup." As researched by Folds and Fain (1997), traffic advisory messages can be displayed in text form on large signs in the driving environment. Messages are typically quite short and pertain only to the current or nearby linked roadways. Traffic radio announcements (of obviously varying degrees of usefulness) are used daily by millions of commuters in North America and elsewhere. In Germany, there exists the travel pilot system in which a non-audible signal is broadcast at the beginning and end of an audible traffic announcement. Any radio equipped with a special toggling feature will detect the signal, toggle the volume up for the duration of the broadcast, and toggle back down to an inaudible level at the conclusion of the traffic message. The system is quite popular, especially for travelers on the autobahn. Recent advancements include a storage function in which the car radio can store reports for the last 2 hours. At the outset of a trip a driver can call up the latest reports rather than having to wait for 20 or so minutes for the next broadcast.

One could argue, based on the popularity of audio traffic information systems, that requiring that verbal messages of all types be limited to two to five words may not be reasonable (ISO/TC22/SC13/WG8N100, 1997) for all applications, especially those involving verbal traffic advisories of a moderately complex nature. Many drivers routinely listen to the radio, talk radio, traffic radio, and all manner of auditory presentations while driving. Furthermore, many drivers are very familiar with routes and may be far more interested in learning of traffic problems and alternate route suggestions based on traffic conditions. Such verbal messages could be considerably longer than two to five words, given the type of information currently broadcast by radio and the travel pilot system in Germany.

If an ATIS-equipped driver were to identify a destination for a route-following or mapping system, traffic safety and advisory information pertaining to the primary route or related alternate routes could be provided to the motorist, along with suggestions regarding route changes. Given the desirability of eyes-off/hands-off operation of navigation and route-following hardware, the apparent benefits of verbal turn-by-turn guidance approaches, and the need for referability of information, it is likely that a "display involving the use of verbal information/instructions and visual backup for reference would be most promising, most beneficial, and least intrusive."

Specific Design Guidance

The purpose of this paper is to provide guidance on the selection of display modes. There is a large volume of literature on display design once the designer has selected the appropriate display mode. Useful references are provided by McCormick (1970), U.S. FDA HFDG (1997), VanCott and Kinkade (1972), MIL-STD-1472D (1989), and Woodson et al. (1992).

APPLICATION OF THE SENSORY MODALITY DESIGN TOOL

An examination of the general design rules led us to the design of several different decision aids that would assist designers in the selection of a sensory modality for displaying different pieces of in-vehicle information. Each decision aid was tested using several candidate information elements until a final viable approach could be determined. The final approach was then refined through more informal testing and analysis.

Differences Between the Current and Previous Modality Selection Design Tool

In previous work completed by Battelle (Campbell et al., 1998), a sensory modality design tool was used to help designers determine the most appropriate display modality for presenting each of the different driver information requirements for an ATIS. This tool required the designer to respond to a series of questions regarding a piece of information (i.e., Is the information complex or simple?). Their responses to the questions would then lead them down a specific path that would ultimately suggest the most appropriate display modality to use.

This tool was extremely helpful in that it provided designers with a simple-to-use method for determining display modality for ATIS information elements. However, for the purposes of the current effort, there are several limitations associated with the existing design tool. These include:

(1) no data sources later than 1992 were used to develop the design tool, (2) it overlooks the possible use of tactile or haptic displays, and (3) the format of the tool provides the means for making binary decisions about modality based on key decision criteria. These limitations are discussed briefly below.

The original design tool was based on older data sources. None of the data sources that were used as a basis for the original design tool were more recent than 1992. Importantly, there has been considerable research into questions about display modality for transportation applications since that time. This newer research could change design decisions regarding modality that might have been suggested by using the previous tool. As part of the current project, we have made every effort to obtain up-to-date information on display modality.

The original design tool overlooked the potential use of the tactile channel for the display of information. The initial optimism regarding the use of tactile displays for presenting driver information has dwindled and it is currently believed that this approach might be suited for only a very limited number of discrete stimuli. However, like auditory alarms, tactile signals do have some attention-demanding characteristics and might be useful in some situations. One example is that of the ABS in which the automatic engagement of the system reminds the driver of the appropriate action to take (stepping forcefully on the brake). Another is in the form of a "smart gas pedal" that pushes back on the driver's foot in order to indicate that the vehicle should slow down. Therefore, while the use of the tactile modality may be infrequent, it is worth considering as an option.

The original design tool was binary and unequivocal. As mentioned above, the decision tree format of the original design tool was extremely easy for designers to follow. Answering either "yes" or "no" to one question after another would lead them down a path to the appropriate sensory modality to use for displaying different pieces of information to the driver. The problem, however, was that for some of the questions the best response would have been "sometimes" or "slightly." Also, the order in which the questions were presented caused some of the design issues or criteria to outweigh the others and to have a greater impact on the outcome than was appropriate.

Therefore, the new design tool (see figure 8) asks designers to respond to several different questions independently. For each question their response will range from "very low" to "very high." Each response is associated with a point value for the three modalities (visual, auditory, and tactile). After all five of the questions have been answered, the point values are totaled for each of the modalities. The steps a designer must complete in order to use this design tool are summarized below and illustrated in figure 9.

Step 1: Identify and Define Driver Message
Step 2: Determine Appropriate Response to the Question and Circle Scores
Step 3: Transpose Scores to Visual, Auditory, Tactile Columns
Step 4: Complete Steps 2 & 3 for Questions 2 through 5
Step 5: Total Columns

Questions:		Very Low	Low	Medium	High	Very High	Visual	Auditory	Tactile
1. What is the degree of urgency of the message?	**Visual**	4	3	2	1	1			
	Auditory	1	2	3	4	5			
	Tactile	1	2	3	4	5			
2. To what degree might the message be referred to again later?	**Visual**	1	2	3	4	5			
	Auditory	4	3	2	1	1			
	Tactile	4	2	0	0	0			
3. What is the overall level of complexity of the message?	**Visual**	3	3	3	4	5			
	Auditory	4	3	2	1	1			
	Tactile	4	1	0	0	0			
4. To what degree does the message deal with a future action in time?	**Visual**	5	4	3	3	3			
	Auditory	1	2	3	4	5			
	Tactile	0	0	0	1	5			
5. To what degree does the message refer to locations in space?	**Visual**	3	3	3	4	5			
	Auditory	5	4	3	2	1			
	Tactile	5	1	0	0	0			
IVIS Message: ________________							**sum**	**sum**	**sum**
Other Relevant Factors: ________________							**Visual**	**Auditory**	**Tactile**

Figure 8. Sensory modality design tool.

The design tool was used to evaluate each of the 273 information elements listed in appendix A and to determine the most appropriate modality for presenting the different in-vehicle information elements. The results of applying this design tool can be found in appendix C. A summary of the overall scores for each of the modalities can be found for each of the messages in appendix D. Also given in appendix D is the modality choice that the scores support.

Importantly, these suggested modalities are preliminary and may be further revised during Task C. They reflect our understanding of the IVIS messages, as well as our consensus opinion regarding the answers to the questions presented in the sensory modality design tool. Moreover, the project working group will be evaluating the suggested modalities in the near future.

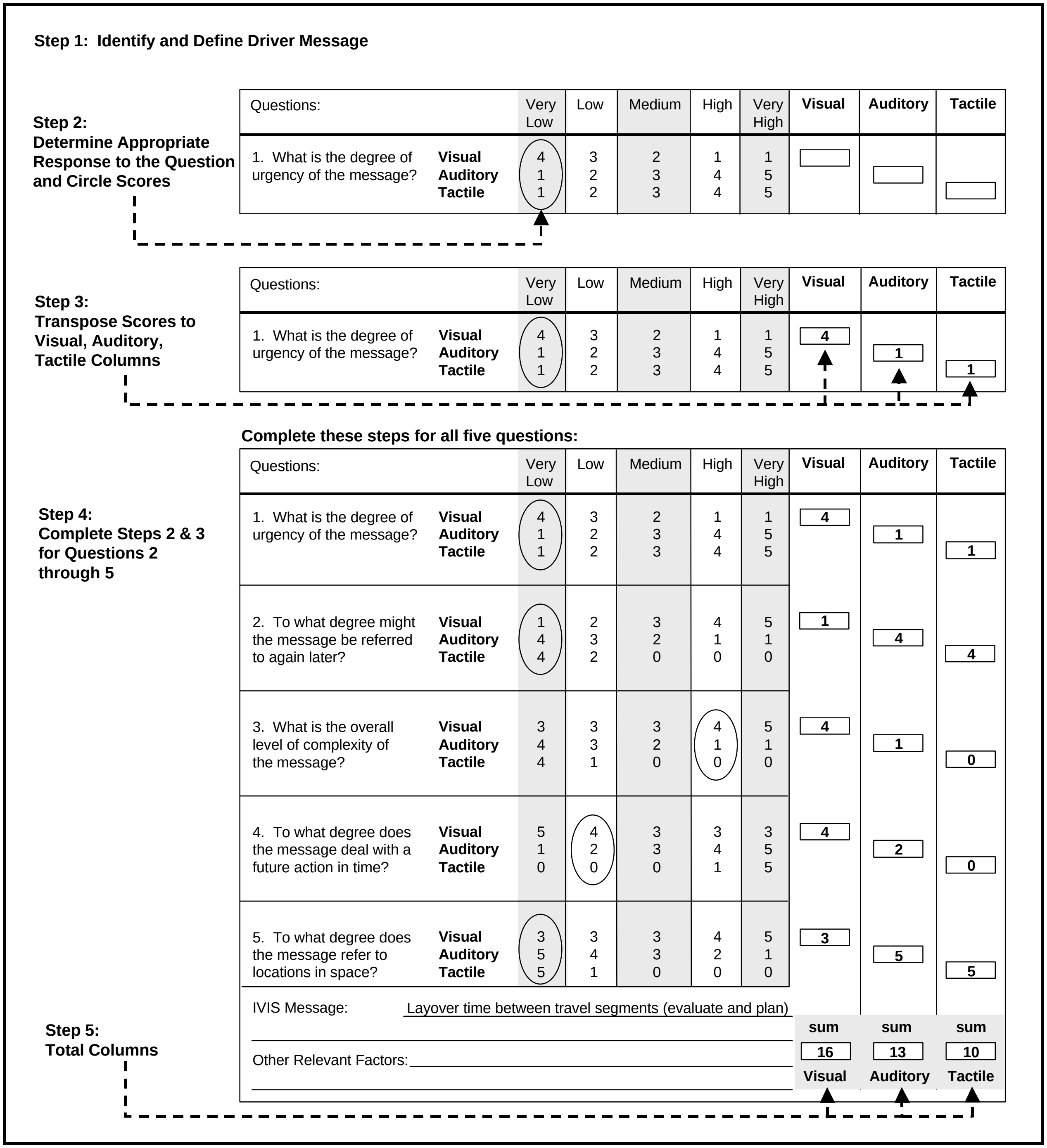


Figure 9. Steps for using the sensory modality design tool.

Determining the modality was not simply as easy as selecting the one with the highest point value. In cases where two modalities received high scores (15 or greater), it was suggested that the information be presented using some combination of the two. In doing so, it would reflect the fact that both modalities are necessary in order to adequately present the information. In cases where two modalities received the same score or they were only one point apart, it was suggested that the information be presented using either of the two modalities. In all other cases, the modality receiving the highest score is the suggested mode of presentation for that piece of information. Decisions regarding which one to use may be based on additional information regarding context or display constraints. If, however, two modalities received scores that were both higher than 15 *and* were only one point apart, it was determined that the fact that they both received scores greater than 15 was of greater significance (i.e., of higher priority). Therefore, the information would be presented by combining those two modalities instead of choosing between them. By prioritizing the rules, the designer will then know which one to use in cases where more than one is applicable. A summary of the rules for determining the most appropriate modality can be found in figure 10 below.

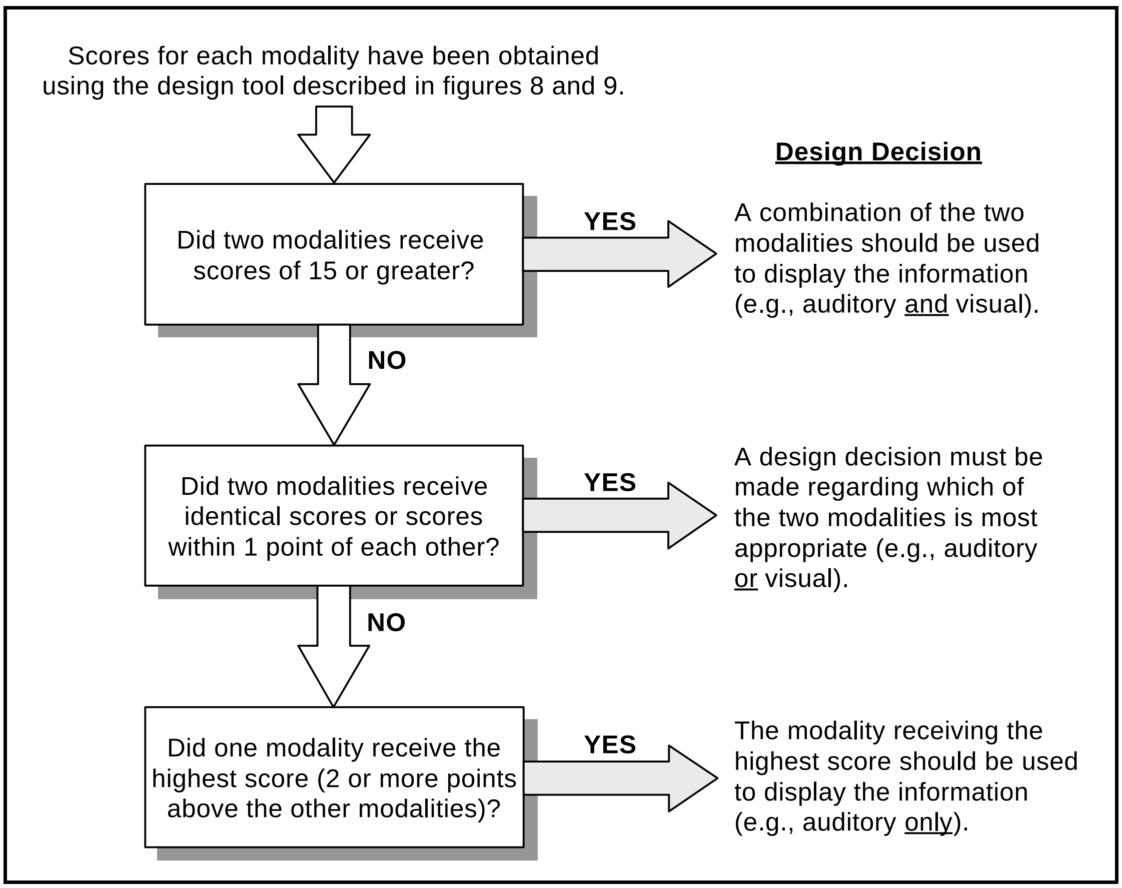


Figure 10. Rules for determining display modality.

In this flow diagram, the designer is asked to address each of the rules in the order of their priority. For example, if the auditory modality received a score of 17 and the visual score of 16, the first question a designer would ask is "Did the two modalities receive scores of 15 or greater?" Since the answer is "yes," the design decision states that "a combination of the two modalities should be used to display the information." However, if the auditory modality had received a score of 14 and the visual a score of 15, the answer to that first question would be "no." In this case, a designer would then proceed to the next question "Do the two modalities receive identical scores or scores within one point of each other?" Since the answer is "yes," the designer decision states that "a decision must be made regarding which of the two modalities is most appropriate." In the last case (i.e., the auditory modality receives a score of 12 and the visual a score of 15), the answer to both the first and the second question would be "no." Therefore, the designer would proceed to the third question and the subsequent design decision, which would be to present the modality that had received the highest score.

Messages that obtained high scores for the visual modality tended to be more complex (i.e., shortest route to a particular destination) and often required the display of diagrams, maps, or complex lists. Other messages that scored high in the visual domain were those that are relatively less critical or urgent (i.e., amenities at a gas station). These types of messages might be of interest to the driver, but by no means require the driver's immediate attention. Therefore, they can be placed on a display where the driver can obtain the information when he/she feels it is safe to do so. Other messages identified by the design tool as being best presented by the visual modality were those that would require the driver to refer to them repeatedly throughout the drive (i.e., vehicle's current position). There did not seem to be any trend linking visual messages to any particular driving task or level of message independence. The IPEs supported by the visual messages include: *identify, evaluate, plan, decide, or coordinate*. These messages provide the driver with enough information that he/she would be able to interpret it, evaluate it, and in some cases come up with a course of action.

The results of the design tool suggested that the auditory modality should be used for presenting extremely urgent or critical messages that would require the driver's immediate attention (i.e., notification that the driver is off-route). In the case of this particular message, the notification itself would be auditory. Any additional information regarding the driver's location with regard to the route or the necessary course corrections for returning to the route would require much more of the driver's resources and should be presented via the visual modality. The auditory modality was reserved for only those messages that were simple enough that they did not require additional information and for which a simple tone or short verbal message would provide the driver with all the information he or she would need. There did not seem to be any trend linking visual messages to any particular driving task or level of message independence. The IPE most often associated with the messages identified as auditory was *alert*. These messages warn the driver of some event (i.e., emergency vehicle approaching) or status (i.e., problem in tractor unit) that requires their attention.

Using a combination of the auditory and visual modalities was identified as optimal for presenting information that was complex and relatively urgent or critical (i.e., lanes blocked ahead). For these types of messages it is important for the driver to obtain the information quickly; however, the amount of information or the complexity of the information does not lend itself to the auditory modality. In many cases the auditory modality may simply act to direct the driver's attention toward the visual display. For example, alerting the driver of an upcoming turn using an auditory tone, and then providing details on the nature of the turn (direction, street name, via a visual message would reflect this joint use of the auditory and visual modalities). However, in other cases, the information may be presented aurally and the visual display may simply be there for the purpose of referability or clarification. There did not seem to be any trend linking visual messages to any particular driving task or level of message independence. The IPEs associated with combination visual/auditory messages were *alert* and *identify*. These messages use an auditory alert to direct the driver's attention to a visual display so that more complex information can be presented.

The sensory modality design tool was set up in such a way that a message that obtained the highest score possible for the tactile modality would receive an identical score for the auditory modality. Therefore, according to the criteria that were devised for scoring the results of the design tool, it would be up to the designer to decide whether the auditory or tactile modality was most appropriate. However, an evaluation of the messages revealed that none of the scores for the tactile modality made this design decision necessary. This result is supported by the review of the literature relevant to the non-visual/auditory modality, which concluded that the tactile modality might only be suited for very few messages, such as those used in warning, alerting, or vigilance tasks (McCormick, 1970). Mollenhauer et al. (1997) argue that "the tactile display cannot be viewed as a serious alternative to simple auditory warnings." Additionally, the current state of technology suggests that even the simplest of applications may not be realistic.

ANALYSIS OF DRIVING CONTEXT AND IPEs

Grouping IVIS messages according to general IVIS capabilities and functions catalogs the range of messages and shows similarities based on those capabilities they are meant to support. This organization is also useful because it is likely to be consistent with designers' model of IVIS and its components. Unfortunately, this organization does not reflect several important characteristics of IVIS messages. Specifically, effective design tools require a description of IVIS messages that reflects the message characteristics that influence driver comprehension and response. Defining messages according to their driver-relevant characteristics provides a more solid basis for design.

Driver-relevant message characteristics fall into two general categories. The first category defines the **context of the message**, which includes the link to the driving task and the link to other IVIS messages. These contextual characteristics make it possible to integrate IVIS icons with driving tasks to provide the driver with a coherent information source. The second category defines the **information processing elements** that the message seeks to support. The information processing elements of each message make it possible to identify how a message should be designed so that it is compatible with the perceptual, decision making, and motor control limits of drivers. The purpose of identifying the contextual characteristics and IPEs is to describe messages in a way that can support generally applicable design guidelines.

Contextual Characteristics and Design Implications

Grouping messages solely by their IVIS function (i.e., routing and navigation or safety/warning) does not provide designers with enough or the right kind of information for designing icons. Within the same IVIS function there might be messages that require a driver to respond immediately to a critical situation and there might be other messages that simply inform the driver of a situation they will need to be aware of at a later date. It makes sense that these two messages would be designed quite differently in order to make them more useful to the driver. The context of a message is, therefore, extremely important for several reasons; it can change the meaning of a message, it defines the salience of the message, and design tradeoffs may be made based on the context. Overall, the contextual characteristics define messages in a way that identifies design tradeoffs associated with integrating a message with other messages and with driving activities.

Context is also important because the meaning of an icon can change depending on the context under which it is being received. As an example, the international symbol for the Red Cross can have different meanings in different situations. For example, a red cross seen at a football game may be perceived as a first aid station whereas a red cross in a second grade classroom may be seen as a plus sign. Therefore, in order to understand the meaning of an icon we must know the context under which it is being viewed. The context of a message can also depend on the relationship of the message to the driving situation. Overall, we have identified four characteristics that define the context of an IVIS message:

- Time urgency.
- Criticality.
- Link to driving tasks.
- Independence of messages.

Time Urgency is defined in terms of the amount of time available for the driver to respond to a message. The amount of time to respond may vary from less than 3 seconds (average reaction time is around 2.5 seconds) to greater than 10 minutes. For example, when a driver receives collision avoidance information it is necessary that they take an immediate action, responding as quickly as they can in order to avoid an imminent threat. However, when a driver receives vehicle condition monitoring information regarding routine vehicle maintenance schedules (e.g., “oil change needed in 500 miles”), they may not need to address this message for several hours or several days depending on how far they are driving.

Criticality is defined as the consequence of not responding to the message in a timely manner. Ignoring messages presented by an IVIS can bring about consequences ranging from likely death or injury to no driving-related consequence at all. For example, the consequences of ignoring a collision avoidance warning could lead to a collision, which could end up being very severe and possibly life threatening. However, ignoring a motorist services message will probably produce no real consequences for the driver, especially if it was advertising a service that was not of interest to the driver.

Link to Driving Tasks is defined as the degree to which a message is related to the primary task of driving. The type of message a driver receives may range from those that are directly linked to driving control activities to those that have no relation to the driving task. For example, collision avoidance messages are directly related to the primary task of driving. On the opposite end of the spectrum, electronic messaging, which allows a driver to send and receive mail, has no direct link to the driving task. This type of information is not necessary for the driver to operate the vehicle and it could actually interfere with the driving task. Between these two extremes are tactical and strategic driving decisions. Tactical decisions are those that have to do with immediate maneuvers (i.e., turning at an intersection) while strategic decisions are those that have to do with the route as a whole (i.e., trip planning).

Independence of Messages is defined as the frequency with which a message is presented at the same time or sequentially with another message. Some messages will almost always be presented at the same time as, or directly before or after, other messages. Examples of these types of messages are trip planning and traffic congestion. Most often, when a driver is engaged in trip planning activities, he or she requires additional information in order to make a more educated decision regarding the route to take. Knowing the traffic conditions along several routes may help the driver to choose the one that will best fit the agenda for the trip. Other messages are stand-alone and will never need to be presented along with other messages. An example of one such message is a collision avoidance warning. The warning itself is all the information the driver needs, and probably all that he/she can handle at one time. Any additional information could cause the driver to become overloaded and actually impede the driver's ability to safely operate the vehicle.

Table 14 summarizes the definitions of each of the contextual characteristics discussed above. It also presents the rating scale that was used to help define the candidate messages according to their contextual characteristics.

Table 14. Summary of the four contextual characteristics that define IVIS messages.

Contextual Characteristics	Definition	Range
Time Urgency	Time available for the driver to respond to the message.	1 = Less than 3 seconds 2 = 3-10 seconds 3 = 10 seconds-2 minutes 4 = 2 minutes-10 minutes 5 = Greater than 10 minutes
Criticality	Consequence of not responding to the message in a timely manner.	1 = Likely death or injury 2 = Increased risk of accident 3 = Unsafe condition 4 = Delay or annoyance 5 = No driving-related consequence
Link to Driving Tasks	Relationship of the message to vehicle control.	1 = Linked to safety critical drivingcontrol activities 2 = Linked to tactical driving decisions 3 = Linked to strategic driving decisions 4 = Linked to overall purpose of trip 5 = No relation to the driving task
Independence of Messages	The frequency with which a message is presented at the same time or sequentially with another message.	1 = Always 2 = Frequently 3 = Sometimes 4 = Rarely 5 = Never

Each of the 273 candidate messages listed in appendix A was individually rated on all four contextual characteristics. Some examples of messages and their associated ratings can be seen in table 15. A summary of the results of this rating process for all messages can be found in appendix E.

Table 15. Examples of ratings given for selected messages.

IVIS Capability	Function	Message	Time Urgency	Criticality	Link to Driving Task	Independence of Messages
Collision Avoidance Information	Rear-End CA	Warning indicator (alert and identify)	1	1	1	1
Augmented Signage	Roadway Regulatory Sign Information	Yield sign	2	2	3	2
Safety/Warning Information	Vehicle Condition Monitoring	Low tire pressure	3	3	5	2
Routing and Navigation	Pre-drive Route and Destination Selection	Shortest route option	3	4	1	3
Routing and Navigation	Route Guidance	Final destination	4	4	3	3
Routing and Navigation	Trip Planning	Landmarks or topographical features	5	5	3	4
Motorist Services	Message Transfer	Alert driver message not sent and why	5	5	4	5

Each of the four contextual characteristics identifies design considerations for the display of IVIS information and the design of icons. It is important for the designer to consider the context under which these messages might be presented when they are designing them. An icon for a highly urgent message that is not directly linked to the driving task would be designed quite differently from a message that is critical but not urgent. Each of the four contextual characteristics identifies a separate set of design requirements.

Messages that have a high rating of time urgency should be presented in such a manner that they can be quickly identified and processed. They should demand the attention of the driver through the appropriate application of design principles such as color, size, changes in state (i.e., blinking), or modality. A good icon for presenting highly urgent information would also give clear cues as to the appropriate response a driver should make, thus reducing the amount of time required to retrieve displayed information and decide how to respond. For messages that have a lower rating of time urgency, it is more important that the information is presented in a less intrusive manner to avoid startling and distracting the driver.

It is important to convey the importance of highly critical messages. Using icons that stand out from the background through the use of size, color, or changes in state (i.e., blinking) can help draw attention to a message in a more timely manner, thus giving the driver more of a chance to respond. Also, adding the auditory modality to an icon that is critical may help to increase the perceived urgency of the message, thereby increasing driver compliance. Messages that are less critical should not distract the driver from the primary task of safely operating the vehicle. They should be presented in such a way that the driver could view them when they feel it is safe to do so.

Messages that are directly related to driving control activities should be integrated with the driving task so that the driver can obtain the information without looking away from the roadway. More generally, messages that are directly linked to the driving task should be presented near the driver's center of attention. Routine driving eye movement data suggest that the driver's focus of attention resides near the "point of expansion" (Rockwell, 1972). Messages can be placed near the center of attention by using a HUD or the auditory modality.

Those messages that are highly dependent on each other should be linked by presenting them simultaneously or sequentially. They could also be linked by being positioned together in space or by creating common features, such as background color or symbol style. Co-locating messages that are related to one another in some way might make it easier for the driver to integrate the information. Highly dependent messages should also have some of the same design characteristics (i.e., border or background) in order to show that the information is related in some way. We see examples of this on road signs currently presented outside the vehicle (e.g., motorist services signs are blue, recreational signs are brown, etc.). This helps the driver to both search for and filter information. For highly dependent messages it may also be useful to link them using complex graphics, such as object displays or maps.

Identifying the different contexts under which the driver is receiving the message can aid designers in their ability to design effective messages. Each contextual characteristic carries with it an implicit set of design criteria for best presenting the information. Table 16 summarizes the design implications associated with each of the contextual characteristics.

Table 16. Design implications associated with the different contextual characteristics.

Contextual Characteristics	Design Implications
Time Urgency	Design Requirements: Salient and compelling. *Design Tradeoff: Speed of response at the expense of potential for startle response.*
Criticality	Design Requirements: Convey priority and relative importance. *Design Tradeoff: Distinguishing high-priority messages at the expense of reducing the relative priority of others.*
Link to Driving Tasks	Design Requirements: Link driving-related messages to driving. *Design Tradeoff: Enhance understanding and response time at the expense of impeding drivers with too much information.*
Independence of Messages	Design Requirements: Provide context for understanding. *Design Tradeoff: Enhanced understanding at the expense of potential confusion with related messages.*

IPEs and Design Implications

The information processing perspective has long provided a useful tool to describe human-machine coordination (Broadbent and Gregory, 1963; Neisser, 1967; Rasmussen, 1986). Developed to identify guidelines for human-machine interfaces, Rasmussen's decision ladder provides one of the more detailed accounts of human-machine information processing. The decision ladder breaks the decision process into eight elements that describe the mental activities that link environmental cues to initiating actions. More recently Lee et al. (1997) adapted Rasmussen's decision ladder and Miller's (1971, 1974) information processing taxonomy to describe driver interaction with ATIS devices. This description helped identify the driver limits and capabilities that are relevant for particular ATIS functions. The current report builds on the work of Lee et al. (1997) to identify design requirements of IVIS messages.

Building on the previous information processing descriptions of human-machine coordination, the decision ladder has been adapted to address the specific issues associated with IVIS messages and visual symbol design. Figure 11 shows nine IPEs that define the information requirements of a driver interacting with an IVIS device. These elements comprise a decision cycle represented by the circle. Between each IPE, *phrases in italics* identify a knowledge state that acts as the input to one element and the output of the previous element. Together the nine elements describe the range of information processing activities supported by IVIS messages.

The decision cycle consists of four quadrants, with the IPEs within each quadrant serving a common purpose. The first quadrant, *Attention,* involves detecting disturbances and deviations and directing attention toward the disruption. The second quadrant, *Interpret*, builds upon this to classify and understand attended inputs. The third quadrant, *Selection*, uses this interpreted information to identify an appropriate course of action. The fourth quadrant, *Action,* carries out the course of action. Each quadrant helps identify general design requirements for supporting driver decisions and the IPEs within each quadrant identify specific requirements.

Just as in the decision ladder (Rasmussen, 1986), it is rare that any IVIS message will involve every IPE of the cycle. Some IVIS messages will simply *alert* drivers, while others might only *identify* the situation. Each IVIS message will involve a small number of IPEs, and many will only involve a single element. The IPEs define the information transformations and processing that IVIS messages are intended to support. This description is particularly useful for deriving design guidelines because it uses a common language to define IVIS messages *and* human information processing capabilities and limits. The following paragraphs describe these elements in more detail.

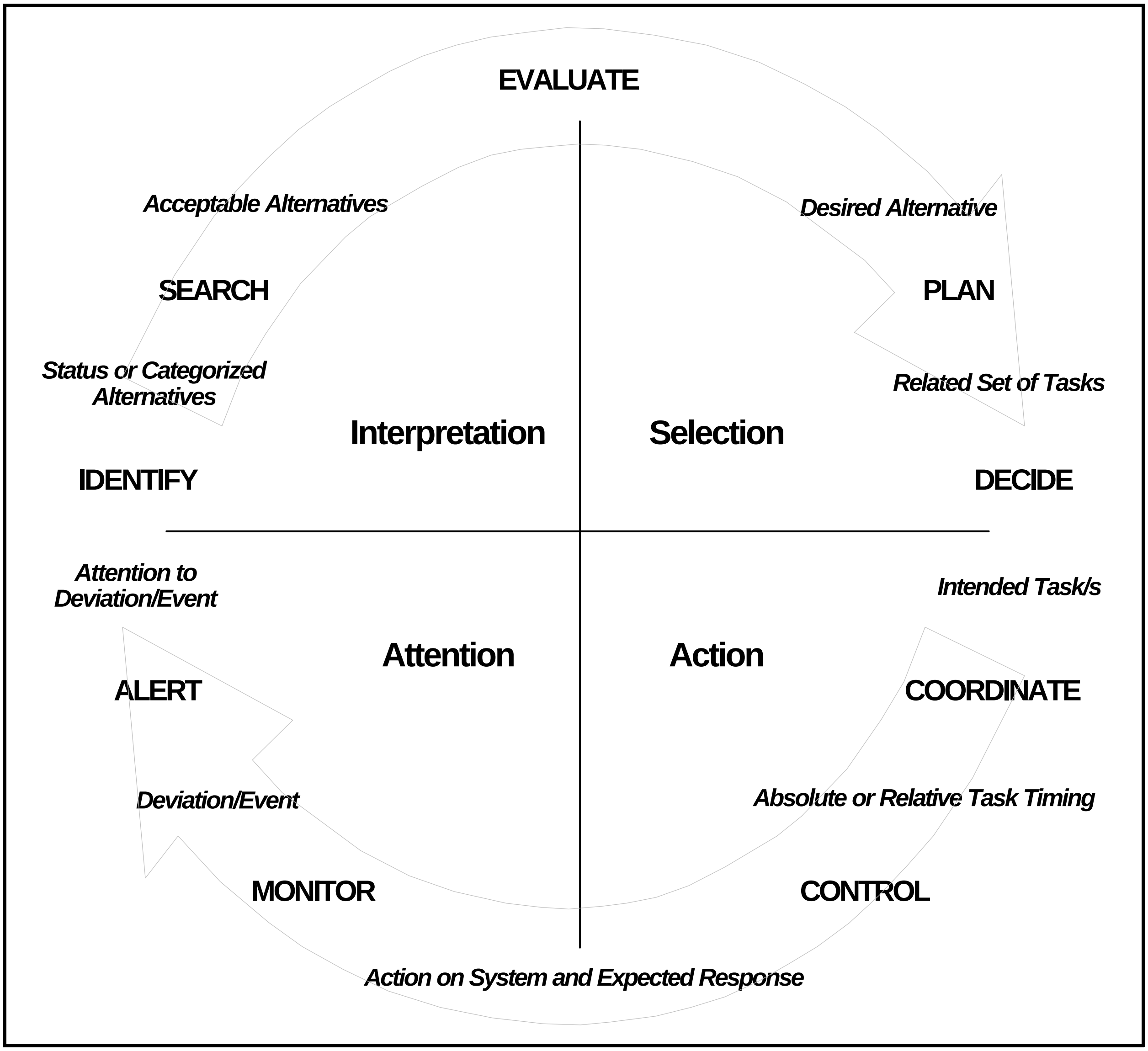


Figure 11. The IPEs supported by IVIS messages.

Alert represents the process of sensing the presence or absence of a cue that signals a need for a response from the driver. As such, *alert* involves discriminating relevant information from an unimportant background. This process includes only noticing changes in the environment and does not encompass the interpretation of these changes. Thus, *alert* only involves noticing changes in predefined signals. The output of this IPE consists of a recognition of a change in system status. A collision avoidance warning is a good example of a message that supports the *alert* IPE.

Identify involves assigning a status or category to an event, location, time, region, or item. This process involves matching characteristics of the item with a template and labeling the item based on a match. The output of this decision-making element is the identification of an item in terms of a familiar status or category. For example, visual symbols that distinguish different types of roads support the process of identifying the particular roads that are acceptable to the driver; the symbols *identify* which roads are particularly scenic or free of traffic.

Search involves scanning for alternatives that meet predefined parameters. Parameters may be physical characteristics or functional properties, and searching involves identifying those objects whose properties or characteristics meet the criteria that identify them as being of interest. The output of this information processing element includes a set of acceptable alternatives that match the search criteria. For example, icons in the services/attractions directory should support *searching* for restaurants of a particular type.

Evaluate shares some similarities with the processes of *identify* and *search*, but goes beyond labeling an item or situation and involves comparing alternatives based on the meaning of a set of cues. It goes beyond the data and involves making inferences about how the current situation, as defined by the cues, might influence the driver's overall goals. The output of this decision-making element is an understanding of the alternatives in the context of the goals of the driver. For example, icons in the services/attractions directory should support *evaluating* the relative costs of restaurants of a particular type. This contrasts with *identify*, which would involve recognizing familiar locations or well-learned routes. *Evaluate* occurs in novel situations, while *identify* occurs in familiar situations.

Plan involves matching resources to the current objectives. In addition, *plan* involves predicting future conditions associated with different actions. The output of this decision-making element is a coordinated set of actions that meet the goals of the driver within the constraints of the situation. In the context of driving, *plan* might involve selecting a time and route to arrive at work by 8:00 a.m. A more complex example might involve planning a cross-country trip, given constraints such as time, budget, and scenery.

Decide involves choosing the appropriate response for the situation. This process involves finding a satisfactory match between the driver's needs or goals and the available options. The output of this decision-making element is the choice of one alternative from several. In the context of driving, *decide* might be the choice of one route over another or the decision to adopt an option offered by a predrive route selection function.

Coordinate involves arranging the absolute or relative timing of tasks over time to avoid conflicts and ensure smooth performance. The input to this activity is a set of related tasks or activities and the output is a coordinated sequence of actions that achieve the objective. The output of this process is a set of tasks or activities arranged in time relative to each other or relative to some absolute time constraints. In the context of driving, *coordinate* might involve identifying the timing of an upcoming turn or the projected arrival time at a destination. For example, a driver must coordinate the timing of lane changes and turn signals to follow a set of route guidance directions.

Control refers to the execution of actions to achieve a plan. This process can be motor movements of the driver, such as acknowledging a warning signal by pressing a button. The output of this decision-making element is either the completion of a step (or sequence of steps) or the driver's response to a signal. Since many interactions with an ATIS/CVO system involve pressing keys and adjusting controls, this decision-making element is reserved to describe driver actions integral to the execution of a function.

Monitor involves observing an ongoing process to verify that it proceeds according to a predefined plan. This process involves a continuous comparison of the current state of the system to the expected state. The output of this decision-making element consists of identifying a deviation from the expected. For example, the in-vehicle routing and navigation system (IRANS) function of route guidance may monitor the path of the vehicle to ensure that it remains on the route defined at the start of the journey.

Table 17 summarizes the IPEs with a definition and the general design requirements associated with each IPE.

Table 17. Summary of IPEs supported by IVIS messages.

IPE	Definition and Design Requirements
Alert	Definition: Determine if a change has occurred that requires a response. *Design Requirements: Salient, recognizable, compelling, conveys priority.*
Identify	Definition: Associate a category or status with an event, location, time, type, region, or item.
Search	Definition: Look for a specific item from a set of alternatives. *Design Requirements: Legible, recognizable, easily discriminated, supports layered perception.*
Evaluate	Definition: Compare alternatives based on status or difference between alternatives. *Design Requirements: Interpretable, comparable.*
Plan	Definition: Allocate resources and identify tasks to meet goal. *Design Requirements: Comparable, compelling, reveals intent and process of planning.*
Decide	Definition: Choose a response to fit the situation. *Design Requirements: Salient, compelling, interpretable, potency-priority compatibility.*
Coordinate	Definition: Arrange timing of tasks to realize a plan. *Design Requirements: Linked to related tasks, conveys time duration and relationships.*
Control	Definition: Enact a task with an action. *Design Requirements: Affords action, compelling, shows consequences, shows response.*
Monitor	Definition: Observe the system for deviations from intended behavior. *Design Requirements: Easily discriminated, comparable, related to norms or expectations.*

Each of the 273 candidate messages listed in appendix A was defined by a set of IPEs. Some examples of messages and their associated IPEs can be found in table 18. A summary of the IPEs that define each of the messages can be found in appendix F.

Table 18. Examples of IPEs identified for selected messages.

IVIS Capability	Function	Message	IPE
Collision Avoidance Information	Backing Device	System failure	Alert
Augmented Signage	Roadway Notification Sign Information	Sharp curve ahead	Identify
Motorist Services	Destination Coordination	Locate nearest parking	Search
Motorist Services	Broadcast Services/ Attractions	Price range of food at restaurants	Evaluate
CVOs	Delivery-related Information	Optimize delivery schedules	Plan
Routing and Navigation	Route Navigation	Direction of turn	Decide
Routing and Navigation	Route Navigation	When a vehicle needs to get in the correct lane for turning or exiting	Coordinate
Motorist Services	Message Transfer	Send message	Control
Motorist Services	Destination Coordination	Confirmation of reservation	Monitor

The IPEs of each message identify design requirements that complement those identified by contextual characteristics. Specifically, the IPEs define design requirements that consider the perceptual, memory, and motor control limits of the driver.

Defining messages according to their contextual characteristics and IPEs helps to provide a more solid basis for design. The results of going through that process provide the designer with a list of specific design implications that are important for designing an effective icon to display a particular piece of information.

TRADEOFF ANALYSIS FOR IVIS MESSAGE FORMAT AND VISUAL SYMBOLS

Analysis of the contextual characteristics and IPEs[1] provides the basis for design guidance beyond the choice of message modality. This section presents a tradeoff analysis that reconciles the conflicting design requirements of messages by examining the contextual characteristics and IPEs of IVIS messages. By identifying messages that share similar design requirements, this tradeoff analysis generates a set of message clusters that provides a foundation for design guidelines and tools.

Clustering IVIS Messages According to the Driving Context

A statistical technique (K-means cluster analysis) was used to extract clusters of related messages from the pool of messages listed and described in appendix A. The contextual characteristics define these clusters, with messages in each cluster tending to share similar contextual characteristics. The cluster analysis identifies the center of each cluster, and the messages of a cluster tend to share various characteristics of the center. The cluster center is defined by a

[1]Results presented in appendices E and F, respectively.

unique combination of contextual characteristics that is most representative of the messages in the cluster. The cluster center can be thought of as the prototypical message for the cluster. All messages in a cluster will share some of the characteristics of the cluster center. The cluster analysis also identifies how far each message is from the center, indicating how representative the cluster center is of each message. The distance to the cluster center increases with the number of characteristics of a message that differ with the characteristics that define the cluster center. A message would have no distance from a cluster center if its contextual characteristics exactly matched that of the center. The more the contextual characteristics differ for a message and a cluster center the greater the distance. Larger distances indicate that the message is not well represented by the cluster. Table 19 shows the 12 clusters that represent the IVIS messages and example messages that belong to each cluster. Interestingly, the groups of messages based on the contextual characteristics of the driving task are very different from the groups of messages that are based on IVIS functions. For example, cluster 4 contains messages from many IVIS functions: Pre-drive Route and Destination Selection, Route Navigation, Destination Coordination, and CVO-specific Augmented Signage, just to name a few. While the messages in each cluster do not share the same IVIS function, they share the same design requirements. The cluster analysis uses the contextual characteristics to draw together messages that share similar design requirements, which may not be apparent in the functional description of IVIS messages.

Table 19. Example clusters and associated messages.

Cluster Number	Description	Example Messages (distance from cluster center)
Cluster 1	Extremely critical, highly urgent messages that are linked to safety-critical driving control activities and are almost always presented along with other messages.	Sharp curve ahead (0.673) Warning indicator for backing devices (.839) Speed limit in construction zones (1.038)
Cluster 2	These messages are both critical and urgent in that they are linked to tactical driving control activities. They are sometimes presented along with other messages.	Interchange ahead (0.557) Do not enter (0.988) Steep downgrade (1.282) Pedestrian crossing ahead (1.508)
Cluster 3	Messages that are moderately critical and urgent and are linked to tactical driving control activities. These messages are presented independently of other messages.	Uneven road ahead (0.439) Problem in the tractor unit (0.890) System failure - ACC (1.045) Merge (1.447)
Cluster 4	Non-critical, slightly urgent messages that are related to both tactical and strategic driving decisions and are always presented along with other messages.	Shortest route option (0.392) Name of street to turn on (0.613) Type of parking facility (0.613) Truck route (1.057)
Cluster 5	Moderately critical and urgent messages that are not related to the driving task at all and are always presented along with other messages.	System on and functioning - all other CA systems (0) System on and functioning - backing devices (0) System on and functioning- driver monitoring (0)
Cluster 6	Messages that are moderately critical but not urgent. These messages are not related to the driving task and are presented independently of other messages.	Inform driver of needed warranty services due (0)
Cluster 7	Urgent messages that are somewhat critical but not related to the driving task and independent of other messages.	Inform emergency services of cargo type (0) System failure - backing devices (0)

Cluster 8	Messages that are neither critical nor urgent. These messages are linked to the overall purpose of the trip and are independent of other messages.	Message acknowledged/received (0.825) Safety event recorder information (0.825) Dealers (1.217)
Cluster 9	Messages that are neither critical nor urgent. These messages are somewhat related to the purpose of the trip and are frequently linked with other messages.	Remaining balance in toll account (0.999) Optimize delivery schedules (1.020) Details about state and national parks (1.160) Reply to message (1.160)
Cluster 10	Messages that are somewhat critical but not urgent. They are linked to strategic driving decisions and are sometimes presented with other messages.	Total trip time - identify (0.537) Miles until truck is out of fuel (0.600) General weather forecast for specific area (0.927) No danger indicator - all other CA devices (1.680)
Cluster 11	Messages that are neither critical nor urgent and are linked to strategic driving decisions. These messages are almost always presented with other messages.	Price range of lodging along route (0.463) Fuel taxes - evaluate (0.809) Traffic congestion ahead (0.967) Distance and time to destination (1.433)
Cluster 12	Non-critical but somewhat urgent messages that are linked to either tactical or strategic driving decisions and are occasionally presented along with other messages.	Route markers (0.702) Recreational activities - identify (0.862) Cost of next toll along route (1.115) Vehicle's current position (1.222)

Grouping Clusters and Linking Them to the IPE

The cluster analysis identified 12 unique clusters of IVIS messages. To organize these clusters for interpretation, a further analysis identified four groups of clusters based on the center of each of the 12 clusters. Table 20 shows the output of this analysis. Each group of clusters represents a general category of messages, and the clusters within each category provide precise distinctions. The common elements of each group of clusters are highlighted to identify the distinctive elements of the four groups.

Table 20. Contextual characteristics for groups and clusters of messages.

Group Number	Cluster Number	Time Urgency	Criticality	Link to Driving Task	Independence of Messages
Group I	Cluster 1	**1.5**	**1.5**	**1**	1.5
	Cluster 2	**2.5**	**2.5**	**2**	3
	Cluster 3	**2.5**	**3**	**2**	4.5
Group II	Cluster 4	**3**	**4**	2.5	**1**
	Cluster 5	**3**	**3**	5	**1**
Group III	Cluster 6	5	3	**5**	**5**
	Cluster 7	2	3	**5**	**5**
	Cluster 8	5	5	**4**	**5**
Group IV	Cluster 9	**5**	**5**	4.5	2
	Cluster 10	**5**	**3.5**	3	3.5
	Cluster 11	**4.5**	**4**	3	1.5
	Cluster 12	**3.5**	**4.5**	2.5	3.5

TIME URGENCY: 1 = Less than 3 seconds; **2** = 3-10 seconds; **3** = 10 seconds - 2 minutes; **4** = 2 minutes - 10 minutes; **5** = Greater than 10 minutes. **CRITICALITY: 1** = Likely death or injury; **2** = Increased risk of accident; **3** = Unsafe condition; **4** = Delay or annoyance; **5** = No driving related consequence. **LINK TO DRIVING TASK: 1** = Linked to safety-critical driving control activities; **2** = Linked to tactical driving decisions; **3** = Linked to strategic driving decisions; **4** = Linked to overall purpose of trip; **5** = No relation to the driving task. **MESSAGE INDEPENDENCE: 1** = Always; **2** = Frequently; **3** = Sometimes; **4** = Rarely; **5** = Never.

A valuable outcome of the cluster analysis is that it identifies appropriate design tradeoffs for IVIS messages. The contextual characteristics and IPEs all identify design requirements, but the interactions between these design requirements make it difficult to identify specific tradeoffs for every combination of contextual characteristics and IPE. Specifically, five levels of each contextual characteristic and the nine IPEs generate 5,625 unique combinations of contextual characteristics and IPEs. The cluster analysis uses a representative sample of IVIS messages to identify which of the 5,625 combinations are likely to face designers. Appendix G shows that the 5,625 potential combinations can be distilled into 12 clusters, which can be further combined into four groups. The four groups and the associated 12 clusters have clear differences. These differences reflect design tradeoffs associated with the contextual characteristics.

Group I: High-priority driving messages are all relatively critical, high urgency messages that are tightly linked to the driving task. The clusters in this message group differ in their independence. One cluster is highly independent, one neutral, and one highly dependent. The criticality of the clusters ranges from moderate to high. The high priority, driving-related nature of these messages has important design considerations. Specifically, these messages should be designed to be highly salient in order to ensure rapid processing and response.

The IPEs of *alert*, *identify*, and *decide* define this group of messages. These IPEs define every message in this group. The important design considerations associated with these IPEs include the need to design salient, compelling, recognizable messages that are easy to discriminate and that highlight status changes. For those messages that involve *alert*, the design should focus on salient messages that capture the drivers' attention, at the cost of excluding detail that describes the situation.

Design tradeoffs associated with *Group I: High-priority driving messages* focus on attracting the drivers' attention and conveying information quickly. These tradeoffs favor highly salient and compelling messages that induce a fast response rather than messages that are subtle and designed to avoid distracting the driver. The highly critical nature of some of the messages in this group, compared with many other lower priority messages, argues for design features that distinguish them even if it undermines the perceived priority of other messages. In general, the wide variation in criticality across the four groups argues for distinguishing highly critical messages.

The criticality and urgency of these messages, combined with their link to the driving task, suggest that they should be coupled to the driving task by placing them near the driver's center of attention. Linking these messages to the driving task will tend to minimize response time and enhance understanding, with the tradeoff being potential driver overload if too many messages are clustered in the focus of attention.

Independence of messages varies for the clusters in the group. For messages that are highly dependent on other messages, the design tradeoff involves enhancing the understanding of messages by accentuating elements (such as a common background) shared with related messages, at the expense of making the messages less distinct and recognizable. This tradeoff cannot be reconciled for the messages as a group. This speed accuracy tradeoff must be considered for each message. For some messages the proper response may be similar for all related messages, and less distinct messages would not have negative consequences. For other messages the consequences of confusing the meaning of a message may be severe. The IPEs of a particular message can help reconcile this issue. For messages involving *alert,* the tradeoff should favor speed of processing by accentuating common elements shared with other messages. For messages involving *identify*, the tradeoff should favor accuracy, with message elements designed to be distinct and unique.

Table 21 summarizes the general design principles identified for presenting high-priority driving messages.

Table 21. Summary of general design principles: Group I messages.

	Type of Message	**General Design Principles**
Group I	High-priority driving messages = relatively critical, high urgency messages that are tightly linked to the driving task.	! Highly salient and compelling ! Induce a fast response ! Distinguishable ! Place near the driver's center of attention
	Examples of Group I Messages	
	! Warning indicator (backing device) ! Interchange ahead ! School bus stopped ahead	

Out of the 273 IVIS messages identified, 63 fell into Group I.

Group II: Medium-priority dependent messages are moderately urgent and critical, and are presented either simultaneously or sequentially with other messages. The clusters in this group differ in their connection to the driving task. One cluster is linked to both tactical and strategic driving decisions, while the other cluster is not related to the driving task. Several design considerations exist for messages that are highly dependent on other messages. Specifically, these messages can be co-located or share similar design features to aid in the detection and filtering of information.

The IPEs of *alert*, *identify*, *evaluate, plan*, *search*, *decide,* and *coordinate* define this group of messages. These IPEs define every message in this group. Some of the important design considerations associated with *evaluate*, *plan,* and *search* include designing messages that enable comparisons and are readily interpretable. These messages should also provide sufficient detail to support a thorough evaluation of alternatives. In contrast, for those messages that involve *alert,* the message design should be salient so that it captures the driver's attention, in favor of a detailed message describing the situation.

Table 22 summarizes the general design principles identified for presenting the 57 messages identified as medium-priority dependent messages.

Table 22. Summary of general design principles: Group II messages.

	Type of Message	General Design Principles
Group II	Medium-priority dependent messages = moderately urgent and critical messages that are presented either simultaneously or sequentially with other messages.	! less salient, more subtle alerts ! an object display or map should be used to integrate the messages and promote comparisons and information integration
	Examples of Group II Messages	
	! Shortest route option ! Distance and time to turn ! System on and functioning (driver monitoring)	

Design tradeoffs associated with *Group II: Medium-priority dependent messages* focus on integrating information from several messages. The criticality and time urgency of these messages suggest less salient, more subtle alerts at the expense of slower response times. For the messages that are involved with planning and evaluation, the tight connection to other messages suggests that an object display or map should be used to integrate the messages and promote comparisons and information integration. The moderate urgency and criticality of messages in this group suggest that the strong visual or spatial links will not have a detrimental effect if they reduce the ability of the driver to discriminate between individual messages. The effectiveness of those messages that are highly linked to the driving tasks can be enhanced if they are displayed so that the driver can integrate them into the associated driving task. However, they should be placed so as not to compete with the higher priority driving related messages, such as those described in Group I.

Group III: Non-driving independent messages have no relation to the driving task and are unlikely to be presented either simultaneously or sequentially with other messages. The clusters in this group differ in their criticality and urgency. Two clusters are moderately critical, resulting in unsafe conditions if the driver does not respond, whereas failing to respond to the third group has no driving-related consequence. One cluster of moderately critical messages is highly urgent while the other is not urgent. A general design consideration for this group is that they should not be placed in the focus of the driver's attention. Because these messages are unrelated to the driving task, they should not intrude on the information a driver processes while in-transit.

The IPEs of *alert*, *identify*, *evaluate*, *control*, and *monitor* define this group of messages. These IPEs define every message in this group. The important design considerations associated with these IPEs include the need to design salient, compelling, recognizable messages that are easy to discriminate and that highlight status changes. In addition, these messages must support comparisons and relate status to norms or expectations.

Design tradeoffs associated with *Group III: Non-driving independent messages* focus on supporting the interpretation of messages that are not linked to the driving task or to other messages. Because these messages are relatively low priority, the design tradeoff can be made in favor of symbol designs that will aid interpretation at the cost of speed of recognition or salience. Specifically, this might include text labels or increased detail and representativeness of icons.

Even for the *alert* messages the tradeoff should favor accuracy of interpretation over speed. Another important design tradeoff suggests these messages should be placed outside the focus of the driver's attention. The moderate level of priority and the lack of connection to the driving task argues for a slower response time rather than cluttering the driver's focus of attention with messages unrelated to the driving task.

Table 23 summarizes the general design principles identified for presenting non-driving independent messages.

Table 23. Summary of general design principles: Group III messages.

	Type of Message	General Design Principles
Group III	Non-driving independent messages = no relation to the driving task and are unlikely to be presented either simultaneously or sequentially with other messages.	! salient, compelling, and recognizable ! easy to discriminate ! support comparisons and relate status to norms or expectations ! place outside the focus of driver's attention
	Examples of Group III Messages	
	! Inform driver of needed warranty services due ! System failure (all other CA systems) ! Message acknowledged/received	

Ten of the 273 messages identified fell into Group III.

Group IV: Low-priority messages are the most common type of message and are neither critical nor urgent. They differ in their link to the driving task and message independence. Messages range from being linked to tactical driving to having no relation to the driving task. They also vary from being frequently paired with other messages to rarely being independent of other messages. Low priority messages should be designed in such a way that they do not distract the driver from safely operating the vehicle. They should be available for the driver to view when they feel comfortable doing so, but should not demand attention.

The IPEs of *identify, evaluate, coordinate, control,* and *monitor* define this group of messages. These IPEs define 140 of the 143 messages in this group. The important design considerations associated with these IPEs include the need to design messages that are easily discriminated, compelling, recognizable, and that highlight status changes and afford action. In addition, these messages must support comparisons and relate status to norms or expectations.

Table 24 summarizes the general design principles identified for presenting the 143 low-priority messages identified.

Table 24. Summary of general design principles: Group IV messages.

	Type of Message	General Design Principles
Group IV	Low-priority messages = the most common type of message and are neither critical nor urgent.	! easily discriminated ! compelling, recognizable ! highlight status changes and afford action ! support comparisons and relate status to norms or expectations
	Examples of Group IV Messages	
	! Remaining balance in toll account ! Total time to complete travel (identify) ! Vacancy status of hotels along route	

Like *Group III: Non-driving independent messages*, design tradeoffs associated with *Group IV: Low-priority messages* focus on interpretation and understanding. However, because these messages vary in their relation to other messages and to the driving task, there are more alternatives to support interpretation. Because these messages are relatively low priority, the design tradeoff can be made in favor of symbol designs that will aid interpretation at the cost of speed of recognition or salience. However, the link with other messages can be exploited to enhance interpretation. For example, a common background or similar symbol characteristics can provide a context that will help drivers understand messages. This design tradeoff is in favor of increased understanding at the cost of increasing the potential for confusion with related messages. The *control* IPE introduces additional design requirements. In this context, *control* specifies invoking a function or specifying option on a touch screen or menu structure of an IVIS. To support this IPE the message must afford action. Providing this information requires room on the icon and so a tradeoff is made in favor of identifying control opportunities at the cost of decreasing the symbol size.

This preliminary assessment of visual symbols is not intended to identify final design guidelines or tools. Instead, the initial tradeoff analysis serves to focus future development efforts. Using statistical clustering techniques, this preliminary analysis identified four general message groups, which describe 12 message clusters. These groups and their corresponding clusters identify important combinations of contextual characteristics and IPEs that describe the range of IVIS messages. Preliminary consideration of these groups and clusters suggests that each cluster and group has unique design requirements. The initial description of these design requirements and associated tradeoffs provides the basis for more refined design guidelines and practical design tools that address the messages that designers are likely to encounter.

CONCLUSIONS

The goal of Task B was to provide design guidance for the joint use of visual, auditory, and tactile information in order to build a foundation for future design principles and tools that will assist designers in specifying icon design for in-vehicle information technologies. Through the process of devising these design tools and analyzing the current list of relevant IVIS messages, we have developed the following conclusions:

- A review of existing literature regarding visual, auditory, and tactile information presentation provided numerous general principles for modality selection, which was the basis for an effective sensory modality design tool.

- Classifying IVIS messages according to ITS technologies and general functions is not sufficient for providing effective design guidelines.

- Understanding the driving context under which IVIS messages are presented is critical for successful design guideline development.

- The IPEs associated with an IVIS message can successfully be used to develop the design guidelines that consider the perceptual, memory, and motor control limits of the driver.

- The cluster analysis technique provides a powerful tool to focus future analyses on a meaningful subset of possible combinations of contextual characteristics and IPEs.

- The tools and decision aids developed as part of Task B have provided the project team with a solid analytical foundation to begin guideline development in Task C of this project.

- A key challenge associated with Task C will be to integrate the information provided in this report and develop clear, relevant, and easy-to-use design guidelines for in-vehicle icons.

Each of these conclusions is discussed below in more detail.

A review of existing literature regarding visual, auditory, and tactile information presentation provided numerous general principles for modality selection, which was the basis for an effective sensory modality decision tool. A review of both general human factors research and more recent research directly related to ATIS and CAS displays provided a number of general principles and heuristics regarding different display modes (visual, auditory, and tactile). Summarizing these rules and categorizing them according to the design decisions they supported allowed us to devise a design tool that would direct designers toward the most appropriate sensory modality choice.

Results of applying the sensory modality design tool indicated that the visual modality should be used for presenting complex messages that are less urgent and critical and that the driver may need to refer to at another point during the drive. Auditory messages were identified as those messages that had some type of alerting property. They provided the driver with urgent and critical information that was simple enough to be presented via an auditory tone or a brief verbal message. A combination of the visual and auditory modalities should be used for those messages that require the driver's attention but are too complicated to be presented by an auditory message or will be referred to again later in the drive. The tactile modality was not identified as appropriate for displaying any of the 273 candidate IVIS messages. However, it is important to note that there are a few instances where tactile displays have been shown to be useful (i.e., the shaker stick on an aircraft); therefore, they should not be ignored as a potential display modality.

Classifying IVIS messages according to ITS technologies and general functions is not sufficient for providing effective design guidelines. Classifying IVIS messages according to general IVIS capabilities and functions catalogs the range of messages and shows similarities based on the IVIS capabilities they are meant to support. However, this approach to organizing IVIS messages does not reflect several important characteristics of the IVIS messages that can impact design guidelines. Effective design guidelines and design tools require a description of IVIS messages that reflects message characteristics that influence driver comprehension and response. Defining messages according to their driver-relevant characteristics provides a more solid basis for design.

Understanding the driving context under which IVIS messages are presented is critical for successful design guideline development. Successful presentation of IVIS messages using icons depends on creating a message appropriate to its driving context. This report defines the context of IVIS messages using four dimensions. These dimensions captured key elements of how context aids the interpretation of messages. Specifically, message urgency and criticality identify the consequences of not responding to a message in a timely manner. In contrast, dimensions such as the link to the driving task and the independence of the message identified opportunities to enhance the interpretation of a message by providing additional cues. Grouping the messages according to these four dimensions provides a first step in defining the requirements for combining IVIS messages into a coherent set and incorporating IVIS messages into the driving task.

The IPEs associated with an IVIS message can successfully be used to develop the design guidelines that consider the perceptual, memory, and motor control limits of the driver. This report identified nine different IPEs: alert, identify, search, evaluate, plan, decide, coordinate, control, and monitor. Together, these nine elements describe the range of information processing activities supported by IVIS messages. Each of these elements supports a different set of design requirements that complement those identified by contextual characteristics. Identifying the elements associated with each individual message informs the designer about decisions and tradeoffs that will need to be made for several different design parameters.

The cluster analysis technique provides a powerful tool to focus future analyses on a meaningful subset of possible combinations of contextual characteristics and IPEs. The cluster analysis proved to be a very effective technique in the preliminary assessment of visual symbols. The original four contextual characteristics (with five levels within each), combined with the nine IPEs, yield 5,626 unique combinations. This presents designers with a dizzying array of tradeoffs to make when designing in-vehicle icons and other information elements. This approach uses a tradeoff analysis that serves to focus our future design guideline development efforts. Using statistical clustering techniques, the preliminary analysis identified four general message groups, which describe 12 message clusters. These groups and their corresponding clusters identify important combinations of contextual characteristics and IPEs that describe the range of IVIS messages. Preliminary consideration of these groups and clusters suggests that each cluster and group has unique design requirements for in-vehicle messages. The initial description of these design requirements and their associated tradeoffs provides the basis for more specific design guidelines and practical design tools.

The tools and decision aids developed as part of Task B have provided the project team with a solid analytical foundation to begin guideline development in Task C of this project. Combining the information obtained by identifying (1) the contextual characteristics of a message, (2) the IPEs that the message supports, and (3) the results of applying the sensory modality decision tool provides the IVIS designer with a relatively comprehensive list of requirements and parameters that should be considered during the design of in-vehicle icons and other information elements. The initial description of these design requirements and associated tradeoffs provides the basis for more refined design guidelines to be developed as part of Task C of this project.

A key challenge associated with Task C will be to integrate the information provided in this report and develop clear, relevant, and easy-to-use design guidelines for in-vehicle icons. This report establishes some important relationships between IVIS messages, display modality, the driving context, and IPEs of the IVIS messages. Understanding these relationships is necessary, but not sufficient, to support the development of clear, relevant, and easy-to-use human factors design guidelines for in-vehicle icons and other information elements. During Task C, the project team will need to integrate the information presented in this report and the Task A report with specific design options for icon design such as background, symbol, border, symbol elements, and text labels.

APPENDIX A: LIST OF IVIS MESSAGES AND THEIR DEFINITIONS

Message	Definition
ATIS—ROUTING AND NAVIGATION	
Trip Planning	
Display of lodging along set route	Location at waypoints or within a road segment with some additional detail
Price ranges of lodging along route	Dollar range or rating for lodging options
Vacancy status of hotels along route	Vacancy/No Vacancy
Locations of state and national parks	Locates parks within trip or trip segment
Details about state and national parks	Amenities (number of campsites, etc.)
Transit schedules in areas along route	Times and locations for transit modes
Total trip time (identify)	Trip times for selected route/travel plan
Total trip time (evaluate)	Compare trip times across travel alternatives
Time to each destination (identify)	Time to destination for selected route/travel plan
Time to each destination (evaluate and plan)	Compare time to destination across travel alternatives
Total trip mileage (identify)	Trip mileage for selected route/travel plan
Total trip mileage (evaluate)	Compare trip mileage across travel alternatives
Mileage to each destination (identify)	Mileage to destination for selected route/travel plan
Mileage to each destination (evaluate and plan)	Compare mileage to destination across travel alternatives
Total trip cost (identify)	Trip cost for selected route/travel plan
Total trip cost (evaluate)	Compare trip cost across travel alternatives
Number of tolls and cost of each toll (identify)	Number and cost of tolls on selected route
Number of tolls and cost of each toll (evaluate)	Compare number and cost of tolls across travel alternatives
Types of roads on route (identify)	Types of roads on selected route (distinguished by color or width)
Types of roads on route (evaluate)	Types of roads for comparing alternative routes (distinguished by color or width)
Summary of turns or roadway changes (identify)	Text listing of turn by turn info for selected route/travel plan

Message	Definition
Summary of turns or roadway changes (evaluate)	Text list of turn by turn info for comparing across travel alternatives
States, regions, communities, and districts along the route (identify)	States, etc., along selected route/travel plan
States, regions, communities, and districts along the route (evaluate)	Comparing states, etc., across travel alternatives
Landmarks or topographical features (identify)	Landmarks along selected route/travel plan
Landmarks or topographical features (evaluate)	Comparing landmarks across travel alternatives
Historical congestion information (identify)	Historical congestion information along selected route/travel plan
Historical congestion information (evaluate)	Comparing historical congestion information across travel alternatives
Magnify/minimize map view	Zoom feature
Shift to another region of the map	Moving up, down, left, or right
Multi-Mode Travel Coordination and Planning	
Start time required to catch other mode of transport (evaluate and plan)	Driver is considering multiple alternative routes/travel plans
Start time required to catch other mode of transport (coordinate)	Driver has already selected alternative and carrying out plan
Mode of travel to take for each segment of travel (evaluate and plan)	Driver is considering multiple alternative routes/travel plans
Mode of travel to take for each segment of travel (coordinate)	Driver has already selected alternative and carrying out plan
Arrival time at end of each segment of travel (evaluate and plan)	Driver is considering multiple alternative routes/travel plans
Arrival time at end of each segment of travel (coordinate)	Driver has already selected alternative and carrying out plan
Layover time between travel segments (evaluate and plan)	Driver is considering multiple alternative routes/travel plans
Layover time between travel segments (coordinate)	Driver has already selected alternative and carrying out plan
Arrival time at destination (evaluate and plan)	Driver is considering multiple alternative routes/travel plans
Arrival time at destination (coordinate)	Driver has already selected alternative and carrying out plan
Total time to complete travel (identify)	Time to complete travel on selected route

Message	Definition
Total time to complete travel (evaluate)	Comparing time to complete travel across alternatives
Pre-Drive Route and Destination Selection (Short or Commute Trip)	
Fastest route available	Planning aid to help trade off alternatives (presented individually)
Route avoiding tollways	Planning aid to help trade off alternatives (presented individually)
Most scenic route	Planning aid to help trade off alternatives (presented individually)
Route avoiding complex intersections	Planning aid to help trade off alternatives (presented individually)
Route option with least traffic	Planning aid to help trade off alternatives (presented individually)
Route that minimizes left turns	Planning aid to help trade off alternatives (presented individually)
Shortest route option	Planning aid to help trade off alternatives (presented individually)
Route option with least crime	Planning aid to help trade off alternatives (presented individually)
Route option with best road quality	Planning aid to help trade off alternatives (presented individually)
Route option with fewest number of traffic lights/stops	Planning aid to help trade off alternatives (presented individually)
Enter a specific street address	Inputting a destination so that the system can select a route that is not in the driver's list of common routes
Desired order of destinations	Planning aid to help trade off alternatives (presented individually)
Select from among destination alternatives	Selecting a destination from among a list of common routes (i.e., home, work, etc.)
Route Guidance	
Notification that the driver is off route	No immediate response required - an indication of vehicle status relative to planned route
Vehicle's current position	Driver only occasionally needs to know
Suggestion of alternative route	Unsolicited information if you are off route, or in response to driver request or congestion
Complete map of route (identify)	An already selected route is presented for information only
Complete map of route (evaluate)	Route presented for driver confirmation and acceptance
Next destination	Current location relative to future destination - no action required
Final destination	Current location relative to future destination - no action required
Re-route option with least traffic	Planning aid for trading off alternative routes
Shortest re-route option	Planning aid for trading off alternative routes
Road quality of re-route option	Planning aid for trading off alternative routes

Message	Definition
Information on road closures and restrictions	Information regarding the current route
Re-route option with fewest number of traffic lights/stop signs	Planning aid for trading off alternative routes
Suggested course of action for emergency vehicle stopped ahead	Some response is required by the driver (slowing, lane change)
Time and distance to bad road conditions (bumps, potholes, etc.)	Overlay on digital map
Time and distance to weather conditions	Overlay on digital map
Time and distance to traffic congested area	Overlay on digital map
Route Navigation	
Distance and time to destination	This information is not needed immediately
Distance and time to turn	This information is most helpful for making immediate decisions and maneuvers
Distance and time to exit	This information is most helpful for making immediate decisions and maneuvers
Name of street to turn on	
Lane suggestion for next turn	
Direction of turn	
Name of current street	
When the vehicle needs to get in a lane for turning or exiting	
Automated Toll Collection	
Location of and distance to next toll booth	This information is most helpful for making immediate decisions and maneuvers
Number of lanes in next toll booth	This information is most helpful for making immediate decisions and maneuvers
Cost of next toll	
Remaining balance in toll account	Toll collection is automated so that it is impossible for the driver to not have enough money
Notification of successful toll charge	

Message	Definition
ATIS—MOTORIST SERVICES	
Broadcast Services/Attractions	
Restaurant/food ahead	Driver requests this information en-route (left at next exit type information - immediate)
Restaurant type/style (e.g., Japanese, American, etc.) (search)	Only those pieces of information the driver has selected (from list of preferences) are presented to driver
Restaurant type/style (e.g., Japanese, American, etc.) (alert)	Driver has requested this specific information be presented
Restaurant type/style (e.g., Japanese, American, etc.) (identify)	All information is automatically broadcasted
Restaurant names (search)	Only those pieces of information the driver has selected (from list of preferences) are presented to driver
Restaurant names (alert)	Driver has requested this specific information be presented
Restaurant names (identify)	All information is automatically broadcasted
Price range of food at restaurants	Details regarding costs
Lodging ahead	Driver requests this information en-route (left at next exit type information - immediate)
Closest lodging with vacancy (search)	Only those pieces of information the driver has selected (from list of preferences) are presented to driver
Closest lodging with vacancy (alert)	Driver has requested this specific information be presented
Closest lodging with vacancy (identify)	All information is automatically broadcasted
Guest amenities (e.g., elevator, kennel, laundry, locker, parking, shower, restrooms, barber shop, hair salon)	Details regarding each alternative
Gas station ahead	Driver requests this information en-route (left at next exit type information - immediate)
Cost of gasoline	Details regarding costs
Hours of operation of the gas station	Details regarding hours
Amenities of gas station (e.g., restrooms, phone, food)	Details regarding each alternative
Restroom ahead	Driver requests this information en-route (left at next exit type information - immediate)
Telephone ahead	Driver requests this information en-route (left at next exit type information - immediate)

Message	Definition
Rest area ahead	Driver requests this information en-route (left at next exit type information - immediate)
Landmark information	Information regarding landmarks along the route
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (search)	Only those pieces of information the driver has selected (from list of preferences) are presented to driver
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (alert)	Driver has requested this specific information be presented
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (identify)	All information is automatically broadcasted
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (search)	Only those pieces of information the driver has selected (from list of preferences) are presented to driver
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (alert)	Driver has requested this specific information be presented
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (identify)	All information is automatically broadcasted
Services/Attractions Directory	
Directory (lodging, automotive, food, shopping, personal services, recreation, financial institutions, religious services, health care, emergency services, government facilities, and transportation)	The directory is like the yellow pages found in a telephone book
Destination Coordination	
Location of and distance to restaurant	Driver has identified a desired location
Location of and distance to lodging	Driver has identified a desired location
Location of and distance to gas station	Driver has identified a desired location
Location of and distance to nearest rest area	Driver has identified a desired location
Confirmation of reservation	Have sent reservation request and are waiting for a reply
Reservation details	
Locate nearest parking	Map with overlay of public parking
Type of parking facility	

Message	Definition
Diagram of parking facilities	
Real-time availability of parking	
Message Transfer (Assumes that Messages Are Non-CVO)	
Incoming message	
Message sent	
Send message	
Alert driver message was not sent and why not	
Write message	Typing out a message
Delete message	
Message acknowledged/received	
Access message	Read message
Save message	
Reply to a message	
Access the Internet	
ATIS—AUGMENTED SIGNAGE	
Roadway Guidance Sign Information	
Interchange ahead	These signs don't command you to do anything - just a marker
Route markers	These signs don't command you to do anything - just a marker
Mile posts	These signs don't command you to do anything - just a marker
Roadway Notification Sign Information	
Steep downgrade	Assumes it is warning the driver of a steep hill they will be traveling down
Percent of grade	Assumes that the percent grade is a warning presented for steep downgrades
Recommended speed as a function of grade	
Braking requirements for specific grades	
Tight ramp or intersection	
Railroad crossing	
Merge	This sign is telling the driver a specific action to take
Chevrons	

Message	Definition
Curve signs	
Sharp curve ahead	
Curve speed for specific vehicle sizes	
Maximum speed for negotiating the exit ramp safely	
Pedestrian crossing ahead	
Roadway Regulatory Sign Information	
Speed limit	
Speed limit in construction zones	
Vehicle is x mi/h over speed limit	
Stop	This sign is telling the driver a specific action to take
Yield	This sign is telling the driver a specific action to take
Do not enter	This sign is telling the driver a specific action to take
No right or left turn	This sign is telling the driver a specific action to take or not take
Left turn only/right turn only	This sign is telling the driver a specific action to take or not take
4-way stop	This is the little sign underneath the stop sign that identifies it as a 4-way stop
ATIS—SAFETY/WARNING	
Immediate Hazard Warning	
Emergency vehicle stopped ahead	
Emergency vehicle approaching	
Distance of approaching emergency vehicle	
Relative locations of emergency vehicles to you on a map	
School bus stopped ahead	
Road Condition Information	
Road work/construction ahead	
Uneven road ahead	
Fallen rock ahead	
Icy roads ahead	
Low shoulder	

Message	Definition
Snow ahead	
Rain ahead	
Fog ahead	
Squalls	
General weather forecast for a specific area	
Partly sunny weather conditions	Thought of as overlays on a map
Sunny conditions	Thought of as overlays on a map
Partly cloudy weather conditions	Thought of as overlays on a map
Traffic/congestion ahead	
Accident ahead	
Chemical spill ahead	
Lanes blocked ahead	
Lanes closed ahead	
General real-time traffic information	Real-time traffic information along the chosen route - not the whole area
How far/how long traffic is backed up	Shows driver how far/long traffic is backed up along the chosen route - not the whole area
Map showing areas of mild, moderate, and severe congestion	Map showing areas of congestion along the chosen route - not the whole area
Automatic/Manual Aid Request	
Inform driver that aid has been requested	
Inform driver of time until the emergency unit will arrive	
Vehicle Condition Monitoring	
Inform driver of current problem	
Inform driver of ways to correct problem	This could inform the driver of the correct action to take (i.e., pull over) or give them a route to the nearest service station
Provide more detailed information at the driver's request	Driver may ask for more explicit information regarding the corrective action
Inform the driver of needed warranty services due	
Low tire pressure	

Message	Definition
Low oil pressure	
Safety event recorder information	Only gives information after a drive has been completed
ATIS—COMMERCIAL VEHICLE OPERATIONS (CVO)	
Trip Planning	
Approved fueling locations (identify)	Fueling locations along selected route/travel plan
Approved fueling locations (evaluate)	Compare fueling locations across travel alternatives
Truck stops (identify)	Truck stops along selected route/travel plan
Truck stops (evaluate)	Compare truck stops across travel alternatives
Dealers (identify)	Dealers along selected route/travel plan
Dealers (evaluate)	Compare dealers across travel alternatives
Fuel costs (identify)	Fuel costs along selected route/travel plan
Fuel costs (evaluate)	Compare fuel costs across travel alternatives
Approved parking locations for types (identify)	Approved parking locations along selected route/travel plan
Approved parking locations for types (evaluate)	Compare parking locations across travel alternatives
Weight limits (identify)	Weight limits for selected route/travel plan
Weight limits (evaluate)	Compare weight limits across travel alternatives
Overhead restrictions (identify)	Overhead restrictions along selected route/travel plan
Overhead restrictions (evaluate)	Compare overhead restrictions across travel alternatives
Weigh stations (locations and whether they are open) (identify)	Weigh stations along selected route/travel plan
Weigh stations (locations and whether they are open) (evaluate)	Compare weigh stations across travel alternatives
Fuel taxes (identify)	Fuel taxes for selected route/travel plan
Fuel taxes (evaluate)	Compare fuel taxes across travel alternatives
Typical congestion of a route (identify)	Typical congestion along selected route/travel plan
Typical congestion of a route (evaluate)	Compare typical congestion across travel alternatives
Miles until truck is out of fuel	

Message	Definition
Delivery-Related Information	
Delivery location	
Scheduled pickup and delivery times	
Times of day or week that may affect delivery	Identifies times that are available or unavailable for delivery
Equipment types not allowed on roadway (identify)	Equipment types not allowed on roadway along selected route
Equipment types not allowed on roadway (evaluate)	Compare equipment types not allowed on roadway across travel alternatives
Optimize delivery schedules	
Customer's preferences (identify)	Related to those customer preferences related to location
Customer's preferences (coordinate)	Related to those customer preferences related to timing
Information from dispatcher regarding schedule changes and other pickup/delivery information	
Presentation of Service Directory Information	
Index of yellow pages and information from the Trucker's Atlas	Information that would normally be found in the yellow pages of a telephone book or the Trucker's Atlas
CVO-Specific Aid Request Information	
Inform emergency services of cargo type	This is especially important for those trucks carrying hazardous materials
Cargo and Vehicle Monitoring Information	
Problem in the trailer unit	
Problem in the tractor unit	An assumption was made that problems in the tractor would be more critical and urgent than those in the trailer
Precise information regarding vehicle performance (may be > 50 parameters)	
Augmented Signage Information	
Truck route	Indication of the direction of a truck route (i.e., a route that bypasses a city)
Truck speed limit	
Routing restrictions for specific vehicle cargo	
Weight limits	

Message	Definition
No hazardous materials allowed	
Low clearance	
Low overpasses on route	
Allowable vehicle length on roadway	
Allowable vehicle width on roadway	
Allowable vehicle height on roadway	
Administrative Information	
Allow driver to complete administrative paperwork electronically (i.e., taxes, licenses)	
Inform driver of regulatory administrative requirements	Driver is searching for applicable regulatory requirements from a list
Electronic permit application	
Pre-clearance	Time dependent clearance for traveling a particular road
Credential checking	Driver is submitting credentials to a regulatory agency
Driver-incentive and performance	Information presented to the driver that is similar to the post-trip summary
Post-Trip Summary (Assumes that this Primarily Applies to Long-Haul Truck Drivers with Continuous Trips)	
Elapsed time	Information used to monitor performance and efficiency of the vehicle after several trips
Miles traveled	Information used to monitor performance and efficiency of the vehicle after several trips
Fuel used	Information used to monitor performance and efficiency of the vehicle after several trips
Tools paid for driver logs	Information used to monitor performance and efficiency of the vehicle after several trips
Percent of time at idle	Information used to monitor performance and efficiency of the vehicle after several trips
GENERAL NAVIGATION SYSTEM INFORMATION	
Position of satellites in space; representation of which satellites are currently transmitting information	May help the driver to determine the cause of inaccurate vehicle positioning
Satellite signal strength	Supplement only to the navigation information, which is much more of an aid to the driver

Message	Definition
Current GPS position (latitude, longitude, altitude)	This information must be shown on a map to be of any help to the driver - shows driver the vehicle location based upon GPS
Number of available satellites	May help the driver to determine the cause of inaccurate vehicle positioning
COLLISION AVOIDANCE INFORMATION	
Rear-End Collision Avoidance	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive
Road Departure Collision Avoidance	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive
Lane Change/Merge Collision Avoidance	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working

Message	Definition
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive
Intersection Collision Avoidance	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive
Railroad Crossing Collision Avoidance	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem

Message	Definition
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive

Message	Definition
Driver Monitoring Devices (Drowsy Driver Detection)	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive
Backing Devices (Not a Parking Aid)	
System on and functioning	Indicates whether the system is on and functioning upon starting the vehicle
System failure	Assumes that the driver believes system is working
No danger indicator	Acts as a confirmation that you have taken the correct steps to avoid danger
Advisory indicator	Used in marginally unsafe conditions - cautionary, indicates the nature of the problem
Warning indicator (alert and identify)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - prescriptive
Warning indicator (alert, identify, and decide)	Used in unambiguously unsafe conditions - indicates the nature and severity of the problem and corrective action necessary - descriptive
Automated Cruise Control Devices (Engaged at Time Other Than Start-Up)	
System on and functioning	Indicates that the system has been turned on and is functioning
System failure	Assumes that the driver believes system is working

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APPENDIX C: RESULTS OF EVALUATING IVIS MESSAGES USING THE SENSORY MODALITY DESIGN TOOL

Key: V = Visual, A = Auditory, T = Tactile

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
ATIS—ROUTING AND NAVIGATION																		
Trip Planning																		
Display of lodging along set route	4	1	1	1	4	4	4	1	0	5	1	0	5	1	0	19	8	5
Price ranges of lodging along route	4	1	1	1	4	4	4	1	0	5	1	0	5	1	0	19	8	5
Vacancy status of hotels along route	4	1	1	1	4	4	4	1	0	5	1	0	5	1	0	19	8	5
Locations of state and national parks	4	1	1	1	4	4	4	1	0	5	1	0	5	1	0	19	8	5
Details about state and national parks	4	1	1	1	4	4	5	1	0	5	1	0	5	1	0	20	8	5
Transit schedules in areas along route	4	1	1	1	4	4	5	1	0	4	2	0	5	1	0	19	9	5
Total trip time (identify)	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Total trip time (evaluate)	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Time to each destination (identify)	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Time to each destination (evaluate and plan)	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10
Total trip mileage (identify)	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Total trip mileage (evaluate)	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Mileage to each destination (identify)	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Mileage to each destination (evaluate and plan)	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10
Total trip cost (identify)	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Total trip cost (evaluate)	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Number of tolls and cost of each toll (identify)	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Number of tolls and cost of each toll (evaluate)	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Types of roads on route (identify)	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
Types of roads on route (evaluate)	4	1	1	1	4	4	4	1	0	5	1	0	5	1	0	19	8	5
Summary of turns or roadway changes (identify)	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
Summary of turns or roadway changes (evaluate)	4	1	1	1	4	4	5	1	0	5	1	0	5	1	0	20	8	5
States, regions, communities, and districts along the route (identify)	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
States, regions, communities, and districts along the route (evaluate)	4	1	1	1	4	4	5	1	0	5	1	0	5	1	0	20	8	5
Landmarks or topographical features (identify)	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
Landmarks or topographical features (evaluate)	4	1	1	1	4	4	4	1	0	5	1	0	5	1	0	19	8	5
Historical congestion information (identify)	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
Historical congestion information (evaluate)	4	1	1	1	4	4	5	1	0	5	1	0	5	1	0	20	8	5
Magnify/minimize map view	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
Shift to another region of the map	4	1	1	1	4	4	3	2	0	5	1	0	5	1	0	18	9	5
Multi-mode Travel Coordination and Planning																		
Start time required to catch other mode of transport (evaluate and plan)	4	1	1	1	4	4	4	1	0	3	3	0	3	5	5	15	14	10
Start time required to catch other mode of transport (coordinate)	4	1	1	1	4	4	3	2	0	3	3	0	3	5	5	14	15	10
Mode of travel to take for each segment of travel (evaluate and plan)	4	1	1	1	4	4	4	1	0	4	2	0	3	5	5	16	13	10

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Mode of travel to take for each segment of travel (coordinate)	4	1	1	1	4	4	3	2	0	4	2	0	3	5	5	15	14	10
Arrival time at end of each segment of travel (evaluate and plan)	4	1	1	1	4	4	4	1	0	4	2	0	3	5	5	16	13	10
Arrival time at end of each segment of travel (coordinate)	4	1	1	1	4	4	3	2	0	4	2	0	3	5	5	15	14	10
Layover time between travel segments (evaluate and plan)	4	1	1	1	4	4	4	1	0	4	2	0	3	5	5	16	13	10
Layover time between travel segments (coordinate)	4	1	1	1	4	4	3	2	0	4	2	0	3	5	5	15	14	10
Arrival time at destination (evaluate and plan)	4	1	1	1	4	4	4	1	0	4	2	0	3	5	5	16	13	10
Arrival time at destination (coordinate)	4	1	1	1	4	4	3	2	0	4	2	0	3	5	5	15	14	10
Total time to complete travel (identify)	4	1	1	1	4	4	3	3	1	4	2	0	3	5	5	15	15	11
Total time to complete travel (evaluate)	4	1	1	1	4	4	3	2	0	4	2	0	3	5	5	15	14	10
Pre-drive Route and Destination Selection																		
Fastest route available	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Route avoiding tollways	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Most scenic route	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Route avoiding complex intersections	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Route option with least traffic	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Route that minimizes left turns	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Shortest route option	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Route option with least crime	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Route option with best road quality	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Route option with fewest number of traffic lights/stops	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Enter a specific street address	4	1	1	1	4	4	3	2	0	5	1	0	3	5	5	16	13	10
Desired order of destinations	4	1	1	1	4	4	4	1	0	5	1	0	4	2	0	18	9	5
Select from among destination alternatives	4	1	1	1	4	4	3	3	1	5	1	0	3	5	5	16	14	11
Route Guidance																		
Notification that the driver is off route	1	4	4	1	4	4	3	3	1	4	2	0	4	2	0	13	15	9
Vehicle's current position	3	2	2	5	1	0	3	4	4	5	1	0	5	1	0	21	9	6
Suggestion of alternative route	2	3	3	4	1	0	5	1	0	5	1	0	5	1	0	21	7	3
Complete map of route (identify)	3	2	2	5	1	0	5	1	0	5	1	0	5	1	0	23	6	2
Complete map of route (evaluate)	3	2	2	2	3	2	5	1	0	5	1	0	5	1	0	20	8	4
Next destination	3	2	2	5	1	0	4	1	0	5	1	0	5	1	0	22	6	2
Final destination	3	2	2	5	1	0	4	1	0	5	1	0	5	1	0	22	6	2
Re-route option with least traffic	3	2	2	4	1	0	5	1	0	5	1	0	5	1	0	22	6	2
Shortest re-route option	3	2	2	4	1	0	5	1	0	5	1	0	5	1	0	22	6	2
Road quality of re-route option	3	2	2	4	1	0	5	1	0	5	1	0	5	1	0	22	6	2
Information on road closures and restrictions	2	3	3	3	2	0	3	2	0	5	1	0	5	1	0	18	9	3
Re-route option with fewest number of traffic lights/stop signs	3	2	2	4	1	0	5	1	0	5	1	0	5	1	0	22	6	2
Suggested course of action for emergency vehicle stopped ahead	1	4	4	3	3	1	3	2	0	5	1	0	4	2	0	16	12	5

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Time and distance to bad road conditions (bumps, potholes, etc.)	2	3	3	2	3	2	3	2	0	4	2	0	5	1	0	16	11	5
Time and distance to weather conditions	2	3	3	2	3	2	3	2	0	4	2	0	5	1	0	16	11	5
Time and distance to traffic congested area	2	3	3	2	3	2	3	2	0	4	2	0	5	1	0	16	11	5
Route Navigation																		
Distance and time to destination	2	3	3	5	1	0	3	3	1	3	5	5	5	1	0	18	13	9
Distance and time to turn	1	4	4	5	1	0	3	3	1	3	5	5	5	1	0	17	14	10
Distance and time to exit	1	4	4	5	1	0	3	3	1	3	5	5	5	1	0	17	14	10
Name of street to turn on	1	4	4	4	1	0	3	3	1	4	2	0	5	1	0	17	11	5
Lane suggestion for next turn	1	4	4	4	1	0	3	3	1	4	2	0	5	1	0	17	11	5
Direction of turn	1	4	4	4	1	0	3	3	1	4	2	0	5	1	0	17	11	5
Name of current street	2	3	3	3	2	0	3	3	1	4	2	0	5	1	0	17	11	4
When the vehicle needs to get in a lane for turning or exiting	1	4	4	5	1	0	3	3	1	3	5	5	5	1	0	17	14	10
Automated Toll Collection																		
Location of and distance to next toll booth	3	2	2	2	3	2	3	2	0	4	2	0	5	1	0	17	10	4
Number of lanes in next toll booth	3	2	2	2	3	2	3	3	1	4	2	0	4	2	0	16	12	5
Cost of next toll	3	2	2	2	3	2	3	4	4	4	2	0	3	5	5	15	16	13
Remaining balance in toll account	3	2	2	2	3	2	3	4	4	4	2	0	3	5	5	15	16	13
Notification of successful toll charge	3	2	2	2	3	2	3	4	4	4	2	0	3	5	5	15	16	13
ATIS—MOTORIST SERVICES																		
Broadcast Services/Attractions																		

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Restaurant/food ahead	1	4	4	1	4	4	3	4	4	3	3	0	4	2	0	12	17	12
Restaurant type/style (search)	3	2	2	1	4	4	3	3	1	5	1	0	3	5	5	15	15	12
Restaurant type/style (alert)	1	4	4	1	4	4	3	3	1	5	1	0	3	5	5	13	17	14
Restaurant type/style (identify)	4	1	1	1	4	4	3	3	1	5	1	0	3	5	5	16	14	11
Restaurant names (search)	3	2	2	1	4	4	3	3	1	5	1	0	3	5	5	15	15	12
Restaurant names (alert)	1	4	4	1	4	4	3	3	1	5	1	0	3	5	5	13	17	14
Restaurant names (identify)	4	1	1	1	4	4	3	3	1	5	1	0	3	5	5	16	14	11
Price range of food at restaurants	3	2	2	2	3	2	3	3	1	5	1	0	3	5	5	16	14	10
Lodging ahead	1	4	4	1	4	4	3	4	4	3	3	0	4	2	0	12	17	12
Closest lodging with vacancy (search)	3	2	2	1	4	4	3	3	1	5	1	0	3	3	0	15	13	7
Closest lodging with vacancy (alert)	1	4	4	1	4	4	3	3	1	5	1	0	3	3	0	13	15	9
Closest lodging with vacancy (identify)	4	1	1	1	4	4	3	3	1	5	1	0	3	3	0	16	12	6
Guest amenities	3	2	2	2	3	2	3	3	1	5	1	0	3	5	5	16	14	10
Gas station ahead	1	4	4	1	4	4	3	4	4	3	3	0	4	2	0	12	17	12
Cost of gasoline	3	2	2	2	3	2	3	3	1	5	1	0	3	5	5	16	14	10
Hours of operation of the gas station	3	2	2	2	3	2	3	3	1	5	1	0	3	5	5	16	14	10
Amenities of gas station	3	2	2	2	3	2	3	3	1	5	1	0	3	5	5	16	14	10
Restroom ahead	1	4	4	1	4	4	3	4	4	3	3	0	4	2	0	12	17	12
Telephone ahead	1	4	4	1	4	4	3	4	4	3	3	0	4	2	0	12	17	12
Rest area ahead	1	4	4	1	4	4	3	4	4	3	3	0	4	2	0	12	17	12
Landmark information	4	1	1	2	3	2	3	3	1	5	1	0	4	2	0	18	10	4

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Specific destinations (search)	3	2	2	1	4	4	3	3	1	5	1	0	4	2	0	16	12	7
Specific destinations (alert)	1	4	4	1	4	4	3	3	1	5	1	0	4	2	0	14	14	9
Specific destinations (identify)	4	1	1	1	4	4	3	3	1	5	1	0	4	2	0	17	11	6
Recreational activities (search)	3	2	2	1	4	4	3	3	1	5	1	0	4	2	0	16	12	7
Recreational activities (alert)	1	4	4	1	4	4	3	3	1	5	1	0	4	2	0	14	14	9
Recreational activities (identify)	4	1	1	1	4	4	3	3	1	5	1	0	4	2	0	17	11	6
Services/Attractions Directory																		
Services/attractions directory	4	1	1	5	1	0	5	1	0	5	1	0	3	5	5	22	9	6
Destination Coordination																		
Location of and distance to restaurant	2	3	3	3	2	0	4	1	0	4	2	0	5	1	0	18	9	3
Location of and distance to lodging	2	3	3	3	2	0	4	1	0	4	2	0	5	1	0	18	9	3
Location of and distance to gas station	2	3	3	3	2	0	4	1	0	4	2	0	5	1	0	18	9	3
Location of and distance to nearest rest area	2	3	3	3	2	0	4	1	0	4	2	0	5	1	0	18	9	3
Confirmation of reservation	2	3	3	1	4	4	3	2	0	5	1	0	3	5	2	14	15	9
Reservation details	3	2	2	2	3	3	4	1	0	5	1	0	3	5	2	17	12	7
Locate nearest parking	2	3	3	3	2	0	4	1	0	5	1	0	5	1	0	19	8	3
Type of parking facility	3	2	2	2	3	3	3	2	0	5	1	0	3	3	0	16	11	5
Diagram of parking facilities	2	3	3	4	1	0	4	1	0	5	1	0	4	2	0	19	8	3
Real-time availability of parking	2	3	3	4	1	0	5	1	0	4	2	0	5	1	0	20	8	3
Message Transfer																		
Incoming message	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Message sent	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Send message	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Alert driver message was not sent and why not	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Write message	4	1	1	1	4	4	5	1	0	5	1	0	3	5	5	18	12	10
Delete message	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Message acknowledged/received	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Access message	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10
Save message	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Reply to message	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10
Access the Internet	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
ATIS—AUGMENTED SIGNAGE																		
Roadway Guidance Sign Information																		
Interchange ahead	2	3	3	3	2	0	3	3	1	3	3	0	4	2	0	15	13	4
Route markers	4	1	1	3	2	0	3	3	1	5	1	0	4	2	0	19	9	2
Mile posts	4	1	1	2	3	2	3	3	1	5	1	0	4	2	0	18	10	4
Roadway Notification Sign Information																		
Steep downgrade	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Percent of grade	3	2	2	1	4	4	3	3	1	3	3	0	3	5	5	13	17	12
Recommended speed as a function of grade	3	2	2	1	4	4	3	3	1	3	3	0	3	5	5	13	17	12
Braking requirements for specific grades	3	2	2	1	4	4	3	3	1	3	3	0	3	5	5	13	17	12
Tight ramp or intersection	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Railroad crossing	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Merge	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Chevrons	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Curve signs	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Sharp curve ahead	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Curve speed for specific vehicle sizes	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Maximum speed for negotiating the exit ramp safely	3	2	2	1	4	4	3	3	1	3	3	0	3	5	5	13	17	12
Pedestrian crossing ahead	3	2	2	1	4	4	3	3	1	3	3	0	3	3	0	13	15	7
Roadway Regulatory Sign Information																		
Speed limit	3	2	2	4	1	0	3	3	1	5	1	0	3	4	1	18	11	4

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Speed limit in construction zones	2	3	3	2	3	2	3	3	1	5	1	0	3	3	0	15	13	6
Vehicle is "x" mi/h over the speed limit	3	2	2	1	4	4	3	3	1	5	1	0	3	5	5	15	15	12
Stop	2	3	3	1	4	4	3	3	1	3	4	1	3	4	1	12	18	10
Yield	2	3	3	1	4	4	3	3	1	3	4	1	3	4	1	12	18	10
Do not enter	2	3	3	1	4	4	3	3	1	3	4	1	3	4	1	12	18	10
No right or left turn	2	3	3	1	4	4	3	3	1	3	4	1	3	4	1	12	18	10
Left turn only/right turn only	2	3	3	1	4	4	3	3	1	3	4	1	3	4	1	12	18	10
4-way stop	2	3	3	1	4	4	3	3	1	3	4	1	3	4	1	12	18	10
ATIS—SAFETY/WARNING																		
Immediate Hazard Warning																		
Emergency vehicle stopped ahead	2	3	3	1	4	4	3	3	1	4	2	0	4	2	0	14	14	8
Emergency vehicle approaching	1	4	4	1	4	4	3	3	1	4	2	0	4	2	0	13	15	9
Distance of approaching emergency vehicle	3	2	2	4	1	0	3	2	0	4	2	0	5	1	0	19	8	2
Relative locations of emergency vehicles to you on a map	3	2	2	4	1	0	5	1	0	5	1	0	5	1	0	22	6	2
School bus stopped ahead	2	3	3	1	4	4	3	3	1	4	2	0	4	2	0	14	14	8

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Road Condition Information																		
Road work/construction ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Uneven road ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Fallen rock ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Icy roads ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Low shoulder	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Snow ahead	3	2	2	1	4	4	3	2	0	4	2	0	4	2	0	15	12	6
Rain ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Fog ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Squalls	4	1	1	1	4	4	3	2	0	4	2	0	3	3	0	15	12	5
General weather forecast for a specific area	4	1	1	3	2	0	3	2	0	5	1	0	3	3	0	18	9	1
Partly sunny weather conditions	4	1	1	1	4	4	3	2	0	5	1	0	3	3	0	16	11	5
Sunny conditions	4	1	1	1	4	4	3	2	0	5	1	0	3	3	0	16	11	5
Partly cloudy weather conditions	4	1	1	1	4	4	3	2	0	5	1	0	3	3	0	16	11	5
Traffic congestion ahead	3	2	2	1	4	4	3	2	0	4	2	0	4	2	0	15	12	6
Accident ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Chemical spill ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Lanes blocked ahead	2	3	3	1	4	4	3	2	0	4	2	0	4	2	0	14	13	7
Lanes closed ahead	3	2	2	1	4	4	3	2	0	4	2	0	4	2	0	15	12	6
General real-time traffic information	3	2	2	5	1	0	5	1	0	5	1	0	4	2	0	22	7	2

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
How far/long traffic is backed up	3	2	2	5	1	0	4	1	0	5	1	0	4	2	0	21	7	2
Map showing areas of mild, moderate, and severe congestion	3	2	2	5	1	0	5	1	0	5	1	0	4	2	0	22	7	2
Automatic/Manual Aid Request																		
Inform driver that aid has been requested	4	1	1	1	4	4	3	4	4	5	1	0	3	5	5	16	15	14
Inform driver of time until emergency unit will arrive	4	1	1	3	2	0	3	3	1	5	1	0	3	4	1	18	11	3
Vehicle Condition Monitoring																		
Inform driver of current problem	2	3	3	4	1	0	3	2	0	5	1	0	3	5	5	17	12	8
Inform driver of ways to correct problem	3	2	2	5	1	0	4	1	0	5	1	0	3	5	5	20	10	7
Provide more detailed information at the driver's request	4	1	1	5	1	0	5	1	0	5	1	0	3	5	5	22	9	6
Inform the driver of needed warranty services due	4	1	1	4	1	0	4	1	0	5	1	0	3	5	5	20	9	6
Low tire pressure	2	3	3	2	3	2	3	4	4	5	1	0	3	5	5	15	16	14
Low oil pressure	2	3	3	2	3	2	3	4	4	5	1	0	3	5	5	15	16	14
Safety event recorder information	4	1	1	2	3	2	5	1	0	5	1	0	3	5	5	19	11	8
ATIS—COMMERCIAL VEHICLE OPERATIONS (CVO)																		
Trip Planning																		
Approved fueling locations (identify)	4	1	1	4	1	0	3	2	0	5	1	0	5	1	0	21	6	1
Approved fueling locations (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	5	1	0	22	5	1
Truck stops (identify)	4	1	1	4	1	0	3	2	0	5	1	0	4	1	0	20	6	1
Truck stops (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	4	1	0	21	5	1

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Dealers (identify)	4	1	1	4	1	0	3	2	0	5	1	0	4	1	0	20	6	1
Dealers (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	4	1	0	21	5	1
Fuel costs (identify)	4	1	1	4	1	0	3	2	0	5	1	0	3	4	1	19	9	2
Fuel costs (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	3	4	1	20	8	2
Approved parking locations for types (identify)	4	1	1	4	1	0	3	2	0	5	1	0	5	1	0	21	6	1
Approved parking locations for types (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	5	1	0	22	5	1
Weight limits (identify)	4	1	1	4	1	0	3	2	0	5	1	0	3	4	1	19	9	2
Weight limits (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	3	4	1	20	8	2
Overhead restrictions (identify)	4	1	1	4	1	0	3	2	0	5	1	0	3	4	1	19	9	2
Overhead restrictions (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	3	4	1	20	8	2
Weigh stations (locations and whether they are open) (identify)	4	1	1	4	1	0	3	2	0	5	1	0	5	1	0	21	6	1
Weigh stations (locations and whether they are open) (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	5	1	0	22	5	1
Fuel taxes (identify)	4	1	1	4	1	0	3	2	0	5	1	0	3	5	5	19	10	6
Fuel taxes (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	3	5	5	20	9	6
Typical congestion of a route (identify)	4	1	1	4	1	0	3	2	0	5	1	0	4	1	0	20	6	1
Typical congestion of a route (evaluate)	4	1	1	4	1	0	4	1	0	5	1	0	4	1	0	21	5	1
Miles until a truck is out of fuel	4	1	1	4	1	0	3	2	0	5	1	0	3	3	0	19	8	1
Delivery-Related Information																		
Delivery location	4	1	1	5	1	0	5	1	0	4	2	0	4	2	0	22	7	1

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Scheduled pickup and delivery times	4	1	1	5	1	0	4	1	0	3	3	0	3	4	1	19	10	2
Times of day or week that may affect delivery	4	1	1	5	1	0	4	1	0	3	3	0	3	4	1	19	10	2
Equipment types not allowed on roadway (identify)	4	1	1	5	1	0	3	3	1	5	1	0	3	5	5	20	11	7
Equipment types not allowed on roadway (evaluate)	4	1	1	5	1	0	4	1	0	5	1	0	3	5	5	21	9	6
Optimize delivery schedules	4	1	1	5	1	0	5	1	0	4	2	0	3	4	1	21	9	2
Customer's preferences (identify)	4	1	1	5	1	0	3	3	1	4	2	0	4	2	0	20	9	2
Customer's preferences (coordinate)	4	1	1	5	1	0	4	1	0	3	3	0	3	4	1	19	10	2
Information from dispatcher regarding schedule changes etc.	4	1	1	5	1	0	4	1	0	4	2	0	3	4	1	20	9	2
Presentation of Service Directory Information																		
Index of yellow pages and information from the Trucker's Atlas	4	1	1	5	1	0	5	1	0	4	2	0	3	4	1	21	9	2
CVO-specific aid request information																		
Inform emergency services of cargo type	1	4	4	2	3	2	3	3	1	5	1	0	3	5	5	14	16	12

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Cargo and Vehicle Monitoring Information																		
Problem in the trailer unit	2	3	3	2	3	2	3	2	0	4	2	0	3	4	1	14	14	6
Problem in the tractor unit	1	4	4	2	3	2	3	2	0	4	2	0	3	4	1	13	15	7
Precise information regarding vehicle performance	4	1	1	5	1	0	5	1	0	5	1	0	3	5	5	22	9	6
Augmented Signage Information																		
Truck route	3	2	2	2	3	2	3	3	1	5	1	0	4	2	0	17	11	5
Truck speed limit	2	3	3	4	1	0	3	3	1	4	2	0	3	4	1	16	13	5
Routing restrictions for specific vehicle cargo	3	2	2	3	2	0	3	2	0	5	1	0	4	2	0	18	9	2
Weight limits	3	2	2	2	3	2	3	3	1	5	1	0	3	4	1	16	13	6
No hazardous materials allowed	3	2	2	2	3	2	3	3	1	5	1	0	3	4	1	16	13	6
Low clearance	3	2	2	2	3	2	3	3	1	5	1	0	3	4	1	16	13	6
Low overpass on route	3	2	2	2	3	2	3	3	1	5	1	0	3	3	0	16	12	5
Allowable vehicle length on roadway	3	2	2	2	3	2	3	3	1	5	1	0	3	4	1	16	13	6
Allowable vehicle width on roadway	3	2	2	2	3	2	3	3	1	5	1	0	3	4	1	16	13	6
Allowable vehicle height on roadway	3	2	2	2	3	2	3	3	1	5	1	0	3	4	1	16	13	6
Administrative Information																		
Allow driver to complete administrative paperwork electronically	4	1	1	1	4	4	5	1	0	5	1	0	3	5	5	18	12	10
Inform driver of regulatory administrative requirements	4	1	1	1	4	4	5	1	0	5	1	0	3	5	5	18	12	10
Electronic permit application	4	1	1	1	4	4	5	1	0	5	1	0	3	5	5	18	12	10
Pre-clearance	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Credential checking	4	1	1	1	4	4	4	1	0	5	1	0	3	5	5	17	12	10
Driver incentive and performance	4	1	1	2	3	2	5	1	0	5	1	0	3	5	5	19	11	8
Post-Trip Summary																		
Elapsed time	4	1	1	5	1	0	3	2	0	5	1	0	3	5	5	20	10	6
Miles traveled	4	1	1	5	1	0	3	2	0	5	1	0	3	5	5	20	10	6
Fuel used	4	1	1	5	1	0	3	2	0	5	1	0	3	5	5	20	10	6
Tolls paid for driver logs	4	1	1	5	1	0	3	2	0	5	1	0	3	5	5	20	10	6
Percent of time at idle	4	1	1	5	1	0	3	2	0	5	1	0	3	5	5	20	10	6
GENERAL NAVIGATION SYSTEM INFORMATION																		
Position of satellites in space that are transmitting information	4	1	1	4	1	0	5	1	0	5	1	0	5	1	0	23	5	1
Satellite signal strength	4	1	1	4	1	0	5	1	0	5	1	0	5	1	0	23	5	1
Current GPS position (latitude, longitude, altitude)	4	1	1	4	1	0	5	1	0	5	1	0	5	1	0	23	5	1
Number of available satellites	4	1	1	4	1	0	4	1	0	5	1	0	3	4	1	20	8	2
COLLISION AVOIDANCE INFORMATION																		
Backing Devices																		
System on and functioning	2	3	3	2	3	2	3	4	4	5	1	0	3	5	5	15	16	14
System failure	1	4	4	3	2	0	3	3	1	5	1	0	3	5	5	15	15	10
No danger indicator	4	1	1	5	1	0	3	3	1	5	1	0	3	5	5	20	11	7
Advisory indicator	1	4	4	5	1	0	3	3	1	3	4	1	4	2	0	16	14	6
Warning indicator (alert and identify)	1	5	5	5	1	0	3	3	1	3	4	1	4	2	0	16	15	7

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Warning indicator (alert, identify, and decide)	1	5	5	5	1	0	3	3	1	3	4	1	4	2	0	16	15	7
Driver Monitoring Devices																		
System on and functioning	2	3	3	2	3	2	3	4	4	5	1	0	3	5	5	15	16	14
System failure	1	4	4	3	2	0	3	3	1	5	1	0	3	5	5	15	15	10
No danger indicator	4	1	1	5	1	0	3	3	1	5	1	0	3	5	5	20	11	7
Advisory indicator	2	3	3	5	1	0	3	3	1	4	2	0	3	5	5	17	14	9
Warning indicator (alert and identify)	1	5	5	5	1	0	3	3	1	4	2	0	3	5	5	16	16	11
Warning indicator (alert, identify, and decide)	1	5	5	5	1	0	3	3	1	4	2	0	3	5	5	16	16	11
All Other Collision Avoidance Devices																		
System on and functioning	2	3	3	2	3	2	3	4	4	5	1	0	3	5	5	15	16	14
System failure	1	4	4	3	2	0	3	3	1	5	1	0	3	5	5	15	15	10
No danger indicator	4	1	1	5	1	0	3	3	1	5	1	0	3	5	5	20	11	7
Advisory indicator	1	4	4	5	1	0	3	3	1	3	4	1	4	2	0	16	14	6
Warning indicator (alert and identify)	1	5	5	5	1	0	3	3	1	3	4	1	4	2	0	16	15	7
Warning indicator (alert, identify, and decide)	1	5	5	5	1	0	3	3	1	3	4	1	4	2	0	16	15	7

Message	Urgency			Repeated			Complexity			Time Dependent			Location Dependent			Overall Score		
	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T	V	A	T
Automated Cruise Control Devices																		
System on and functioning	1	4	4	2	3	2	3	4	4	5	1	0	3	5	5	14	17	15
System failure	1	4	4	3	2	0	3	3	1	5	1	0	3	5	5	15	15	10

APPENDIX D: PRELIMINARY MODALITY FOR PRESENTING IVIS MESSAGES

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
ATIS—ROUTING AND NAVIGATION				
Trip Planning				
Display of lodging along set route	19	8	5	Visual
Price ranges of lodging along route	19	8	5	Visual
Vacancy status of hotels along route	19	8	5	Visual
Locations of state and national parks	19	8	5	Visual
Details about state and national parks	20	8	5	Visual
Transit schedules in areas along route	19	9	5	Visual
Total trip time (identify)	16	15	14	Visual and Auditory
Total trip time (evaluate)	16	13	10	Visual
Time to each destination (identify)	16	13	10	Visual
Time to each destination (evaluate and plan)	17	12	10	Visual
Total trip mileage (identify)	16	15	14	Visual and Auditory
Total trip mileage (evaluate)	16	13	10	Visual
Mileage to each destination (identify)	16	13	10	Visual
Mileage to each destination (evaluate and plan)	17	12	10	Visual
Total trip cost (identify)	16	15	14	Visual and Auditory
Total trip cost (evaluate)	16	13	10	Visual
Number of tolls and cost of each toll (identify)	16	13	10	Visual
Number of tolls and cost of each toll (evaluate)	17	12	10	Visual
Types of roads on route (identify)	18	9	5	Visual
Types of roads on route (evaluate)	18	9	5	Visual
Summary of turns or roadway changes (identify)	18	9	5	Visual
Summary of turns or roadway changes (evaluate)	20	8	5	Visual
States, regions, communities, and districts along the route (identify)	18	9	5	Visual
States, regions, communities, and districts along the route (evaluate)	20	8	5	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Landmarks or topographical features (identify)	18	9	5	Visual
Landmarks or topographical features (evaluate)	19	8	5	Visual
Historical congestion information (identify)	18	9	5	Visual
Historical congestion information (evaluate)	20	8	5	Visual
Magnify/minimize map view	18	9	5	Visual
Shift to another region of the map	18	9	5	Visual
Multi-mode Travel Coordination and Planning				
Start time required to catch other mode of transport (evaluate and plan)	15	14	10	Visual or Auditory
Start time required to catch other mode of transport (coordinate)	14	15	10	Auditory or Visual
Mode of travel to take for each segment of travel (evaluate and plan)	16	13	10	Visual
Mode of travel to take for each segment of travel (coordinate)	15	14	10	Visual or Auditory
Arrival time at end of each segment of travel (evaluate and plan)	16	13	10	Visual
Arrival time at end of each segment of travel (coordinate)	15	14	10	Visual or Auditory
Layover time between travel segments (evaluate and plan)	16	13	10	Visual
Layover time between travel segments (coordinate)	15	14	10	Visual or Auditory
Arrival time at destination (evaluate and plan)	16	13	10	Visual
Arrival time at destination (coordinate)	15	14	10	Visual or Auditory
Total time to complete travel (identify)	15	14	10	Visual or Auditory
Total time to complete travel (evaluate)	15	14	10	Visual or Auditory
Pre-drive Route and Destination Selection				
Fastest route available	18	9	5	Visual
Route avoiding tollways	18	9	5	Visual
Most scenic route	18	9	5	Visual
Route avoiding complex intersections	18	9	5	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Route option with least traffic	18	9	5	Visual
Route that minimizes left turns	18	9	5	Visual
Shortest route option	18	9	5	Visual
Route option with least crime	18	9	5	Visual
Route option with best road quality	18	9	5	Visual
Route option with fewest number of traffic lights/stops	18	9	5	Visual
Enter a specific street address	16	13	10	Visual
Desired order of destinations	18	9	5	Visual
Select from among destination alternatives	16	14	11	Visual
Route Guidance				
Notification that the driver is off route	13	15	9	Auditory
Vehicle's current position	21	9	6	Visual
Suggestion of alternative route	21	7	3	Visual
Complete map of route (identify)	23	6	2	Visual
Complete map of route (evaluate)	20	8	4	Visual
Next destination	22	6	2	Visual
Final destination	22	6	2	Visual
Re-route option with least traffic	22	6	2	Visual
Shortest re-route option	22	6	2	Visual
Road quality of re-route option	22	6	2	Visual
Information on road closures and restrictions	18	9	3	Visual
Re-route option with fewest number of traffic lights/stop signs	22	6	2	Visual
Suggested course of action for emergency vehicle stopped ahead	16	12	5	Visual
Time and distance to bad road conditions (bumps, potholes, etc.)	16	11	5	Visual
Time and distance to weather conditions	16	11	5	Visual
Time and distance to traffic congested area	16	11	5	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Route Navigation				
Distance and time to destination	18	13	9	Visual
Distance and time to turn	17	14	10	Visual
Distance and time to exit	17	14	10	Visual
Name of street to turn on	17	11	5	Visual
Lane suggestion for next turn	17	11	5	Visual
Direction of turn	17	11	5	Visual
Name of current street	17	11	4	Visual
When the vehicle needs to get in a lane for turning or exiting	17	14	10	Visual
Automated Toll Collection				
Location of and distance to next toll booth	17	10	4	Visual
Number of lanes in next toll booth	16	12	5	Visual
Cost of next toll	15	16	13	Auditory and Visual
Remaining balance in toll account	15	16	13	Auditory and Visual
Notification of successful toll charge	15	16	13	Auditory and Visual
ATIS—MOTORIST SERVICES				
Broadcast Services/Attractions				
Restaurant/food ahead	12	17	12	Auditory
Restaurant type/style (search)	15	15	12	Visual and Auditory
Restaurant type/style (alert)	13	17	14	Auditory
Restaurant type/style (identify)	16	14	11	Visual
Restaurant names (search)	15	15	12	Visual and Auditory
Restaurant names (alert)	13	17	14	Auditory
Restaurant names (identify)	16	14	11	Visual
Price range of food at restaurants	16	14	10	Visual
Lodging ahead	12	17	12	Auditory
Closest lodging with vacancy (search)	15	13	7	Visual
Closest lodging with vacancy (alert)	13	15	9	Auditory

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Closest lodging with vacancy (identify)	16	12	6	Visual
Guest amenities	16	14	10	Visual
Gas station ahead	12	17	12	Auditory
Cost of gasoline	16	14	10	Visual
Hours of operation of the gas station	16	14	10	Visual
Amenities of gas station	16	14	10	Visual
Restroom ahead	12	17	12	Auditory
Telephone ahead	12	17	12	Auditory
Rest area ahead	12	17	12	Auditory
Landmark information	18	10	4	Visual
Specific destinations (search)	16	12	7	Visual
Specific destinations (alert)	14	14	9	Visual or Auditory
Specific destinations (identify)	17	11	6	Visual
Recreational activities (search)	16	12	7	Visual
Recreational activities (alert)	14	14	9	Visual or Auditory
Recreational activities (identify)	17	11	6	Visual
Services/Attractions Directory				
Services/attractions directory	22	9	6	Visual
Destination Coordination				
Location of and distance to restaurant	18	9	3	Visual
Location of and distance to lodging	18	9	3	Visual
Location of and distance to gas station	18	9	3	Visual
Location of and distance to nearest rest area	18	9	3	Visual
Confirmation of reservation	14	15	9	Auditory or Visual
Reservation details	17	12	7	Visual
Locate nearest parking	19	8	3	Visual
Type of parking facility	16	11	5	Visual
Diagram of parking facilities	19	8	3	Visual
Real-time availability of parking	20	8	3	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Message Transfer				
Incoming message	16	15	14	Visual and Auditory
Message sent	16	15	14	Visual and Auditory
Send message	16	15	14	Visual and Auditory
Alert driver message was not sent and why not	16	15	14	Visual and Auditory
Write message	18	12	10	Visual
Delete message	16	15	14	Visual and Auditory
Message acknowledged/received	16	15	14	Visual and Auditory
Access message	17	12	10	Visual
Save message	16	15	14	Visual and Auditory
Reply to message	17	12	10	Visual
Access the Internet	16	15	14	Visual and Auditory
ATIS—AUGMENTED SIGNAGE				
Roadway Guidance Sign Information				
Interchange ahead	15	13	4	Visual
Route markers	19	9	2	Visual
Mile posts	18	10	4	Visual
Roadway Notification Sign Information				
Steep downgrade	13	15	7	Auditory
Percent of grade	13	17	12	Auditory
Recommended speed as a function of grade	13	17	12	Auditory
Braking requirements for specific grades	13	17	12	Auditory
Tight ramp or intersection	13	15	7	Auditory
Railroad crossing	13	15	7	Auditory
Merge	13	15	7	Auditory
Chevrons	13	15	7	Auditory
Curve signs	13	15	7	Auditory
Sharp curve ahead	13	15	7	Auditory
Curve speed for specific vehicle sizes	13	15	7	Auditory

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Maximum speed for negotiating the exit ramp safely	13	17	12	Auditory
Pedestrian crossing ahead	13	15	7	Auditory
Roadway Regulatory Sign Information				
Speed limit	18	11	4	Visual
Speed limit in construction zones	15	13	6	Visual
Vehicle is "x" mi/h over the speed limit	15	15	12	Visual and Auditory
Stop	12	18	10	Auditory
Yield	12	18	10	Auditory
Do not enter	12	18	10	Auditory
No right or left turn	12	18	10	Auditory
Left turn only/right turn only	12	18	10	Auditory
4-way stop	12	18	10	Auditory
ATIS—SAFETY/WARNING				
Immediate Hazard Warning				
Emergency vehicle stopped ahead	14	14	8	Visual or Auditory
Emergency vehicle approaching	13	15	9	Auditory
Distance of approaching emergency vehicle	19	8	2	Visual
Relative locations of emergency vehicles to you on a map	22	6	2	Visual
School bus stopped ahead	14	14	8	Visual or Auditory
Road Condition Information				
Road work/construction ahead	14	13	7	Visual or Auditory
Uneven road ahead	14	13	7	Visual or Auditory
Fallen rock ahead	14	13	7	Visual or Auditory
Icy roads ahead	14	13	7	Visual or Auditory
Low shoulder	14	13	7	Visual or Auditory
Snow ahead	15	12	6	Visual
Rain ahead	14	13	7	Visual or Auditory
Fog ahead	14	13	7	Visual or Auditory

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Squalls	15	12	5	Visual
General weather forecast for a specific area	18	9	1	Visual
Partly sunny weather conditions	16	11	5	Visual
Sunny conditions	16	11	5	Visual
Partly cloudy weather conditions	16	11	5	Visual
Traffic congestion ahead	15	12	6	Visual
Accident ahead	14	13	7	Visual or Auditory
Chemical spill ahead	14	13	7	Visual or Auditory
Lanes blocked ahead	14	13	7	Visual or Auditory
Lanes closed ahead	15	12	6	Visual
General real-time traffic information	22	7	2	Visual
How far/long traffic is backed up	21	7	2	Visual
Map showing areas of mild, moderate, and severe congestion	22	7	2	Visual
Automatic/Manual Aid Request				
Inform driver that aid has been requested	16	15	14	Visual and Auditory
Inform driver of time until emergency unit will arrive	18	1	13	Visual
Vehicle Condition Monitoring				
Inform driver of current problem	17	12	8	Visual
Inform driver of ways to correct problem	20	10	7	Visual
Provide more detailed information at the driver's request	22	9	6	Visual
Inform the driver of needed warranty services due	20	9	6	Visual
Low tire pressure	15	16	14	Auditory and Visual
Low oil pressure	15	16	14	Auditory and Visual
Safety event recorder information	19	11	8	Visual
ATIS—COMMERCIAL VEHICLE OPERATIONS (CVO)				
Trip Planning				
Approved fueling locations (identify)	21	6	1	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Approved fueling locations (evaluate)	22	5	1	Visual
Truck stops (identify)	20	6	1	Visual
Truck stops (evaluate)	21	5	1	Visual
Dealers (identify)	20	6	1	Visual
Dealers (evaluate)	21	5	1	Visual
Fuel costs (identify)	19	9	2	Visual
Fuel costs (evaluate)	20	8	2	Visual
Approved parking locations for types (identify)	21	6	1	Visual
Approved parking locations for types (evaluate)	22	5	1	Visual
Weight limits (identify)	19	9	2	Visual
Weight limits (evaluate)	20	8	2	Visual
Overhead restrictions (identify)	19	9	2	Visual
Overhead restrictions (evaluate)	20	8	2	Visual
Weigh stations (locations and whether they are open) (identify)	21	6	1	Visual
Weigh stations (locations and whether they are open) (evaluate)	22	5	1	Visual
Fuel taxes (identify)	19	10	6	Visual
Fuel taxes (evaluate)	20	9	6	Visual
Typical congestion of a route (identify)	20	6	1	Visual
Typical congestion of a route (evaluate)	21	5	1	Visual
Miles until a truck is out of fuel	19	8	1	Visual
Delivery-Related Information				
Delivery location	22	7	1	Visual
Scheduled pickup and delivery times	19	10	2	Visual
Times of day or week that may affect delivery	19	10	2	Visual
Equipment types not allowed on roadway (identify)	20	11	7	Visual
Equipment types not allowed on roadway (evaluate)	21	9	6	Visual
Optimize delivery schedules	21	9	2	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Customer's preferences (identify)	20	9	2	Visual
Customer's preferences (coordinate)	19	10	2	Visual
Information from dispatcher regarding schedule changes etc.	20	9	2	Visual
Presentation of Service Directory Information				
Index of yellow pages and information from the Trucker's Atlas	21	9	2	Visual
CVO-Specific Aid Request Information				
Inform emergency services of cargo type	14	16	12	Auditory
Cargo and Vehicle Monitoring Information				
Problem in the trailer unit	14	14	6	Visual or Auditory
Problem in the tractor unit	13	15	7	Auditory
Precise information regarding vehicle performance	22	9	6	Visual
Augmented Signage Information				
Truck route	17	11	5	Visual
Truck speed limit	16	13	5	Visual
Routing restrictions for specific vehicle cargo	18	9	2	Visual
Weight limits	16	13	6	Visual
No hazardous materials allowed	16	13	6	Visual
Low clearance	16	13	6	Visual
Low overpass on route	16	12	5	Visual
Allowable vehicle length on roadway	16	13	6	Visual
Allowable vehicle width on roadway	16	13	6	Visual
Allowable vehicle height on roadway	16	13	6	Visual
Administrative Information				
Allow driver to complete administrative paperwork electronically	18	12	10	Visual
Inform driver of regulatory administrative requirements	18	12	10	Visual
Electronic permit application	18	12	10	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Pre-clearance	17	12	10	Visual
Credential checking	17	12	10	Visual
Driver incentive and performance	19	11	8	Visual
Post-Trip Summary				
Elapsed time	20	10	6	Visual
Miles traveled	20	10	6	Visual
Fuel used	20	10	6	Visual
Tolls paid for driver logs	20	10	6	Visual
Percent of time at idle	20	10	6	Visual
GENERAL NAVIGATION SYSTEM INFORMATION				
Position of satellites in space that are transmitting information	23	5	1	Visual
Satellite signal strength	23	5	1	Visual
Current GPS position (latitude, longitude, altitude)	23	5	1	Visual
Number of available satellites	20	8	2	Visual
COLLISION AVOIDANCE INFORMATION				
Backing Devices				
System on and functioning	15	16	14	Auditory and Visual
System failure	15	15	10	Auditory and Visual
No danger indicator	20	11	7	Visual
Advisory indicator	16	14	6	Visual
Warning indicator (alert and identify)	16	15	7	Visual and Auditory
Warning indicator (alert, identify, and decide)	16	15	7	Visual and Auditory
Driver Monitoring Devices				
System on and functioning	15	16	14	Auditory and Visual
System failure	15	15	10	Auditory and Visual
No danger indicator	20	11	7	Visual
Advisory indicator	17	14	9	Visual

Message	Overall Score			Preliminary Modality
	Visual	Auditory	Tactile	
Warning indicator (alert and identify)	16	16	11	Visual and Auditory
Warning indicator (alert, identify, and decide)	16	16	11	Visual and Auditory
All Other Collision Avoidance Devices				
System on and functioning	15	16	14	Auditory and Visual
System failure	15	15	10	Auditory and Visual
No danger indicator	20	11	7	Visual
Advisory indicator	16	14	6	Visual
Warning indicator (alert and identify)	16	15	7	Visual and Auditory
Warning indicator (alert, identify, and decide)	16	15	7	Visual and Auditory
Automated Cruise Control Devices				
System on and functioning	14	17	15	Auditory
System failure	15	15	10	Auditory and Visual

APPENDIX E: IVIS MESSAGES AND THEIR ASSOCIATED CONTEXTUAL CHARACTERISTICS

ATIS- Routing and Navigation

Trip Planning

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Display of lodging along set route with some accompanying details (cost, vacancy, chain)	5	4	1	3
Price ranges of lodging along route	5	4	1	3
Vacancy status of hotels along route	5	4	1	3
Locations of state and national parks	5	5	3	4
Details about state and national parks	5	5	3	4
Transit schedules in areas along route	5	4	3	3
Total trip time (identify)	5	4	4	3
Total trip time (evaluate)	5	4	4	3
Time to each destination (identify)	5	4	4	3
Time to each destination (evaluate)	5	4	4	3
Total trip mileage (identify)	5	4	4	3
Total trip mileage (evaluate)	5	4	4	3
Mileage to each destination (identify)	5	4	4	3
Mileage to each destination (evaluate)	5	4	4	3
Total trip cost (identify)	5	4	4	3
Total trip cost (evaluate)	5	4	4	3
Number of tolls and cost of each toll (identify)	5	4	4	3
Number of tolls and cost of each toll (evaluate)	5	4	4	3
Types of roads on route (identify)	5	3	3	3
Types of roads on route (evaluate)	5	3	3	3
Summary of turns or roadway changes (identify)	5	3	3	3

Trip Planning (Continued)

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Summary of turns or roadway changes (evaluate)	5	3	3	3
States, regions, communities and districts along the route (identify)	5	3	3	4
States, regions, communities and districts along the route (evaluate)	5	3	3	4
Landmarks or topographical features (identify)	5	5	3	4
Landmarks or topographical features (evaluate)	5	5	3	4
Historical congestion information (identify)	5	3	3	3
Historical congestion information (evaluate)	5	3	3	3
Magnify/minimize map view	5	5	3	5
Shift to another region of the map	5	5	3	5

Multi-mode travel coordination and planning

Start time required to catch other mode of transport (evaluate & plan)	5	4	4	3
Start time required to catch other mode of transport (coordinate)	4.5	4	4	3
Mode of travel to take for each segment of travel (evaluate & plan)	5	4	4	3
Mode of travel to take for each segment of travel (coordinate)	4.5	4	4	3
Arrival time at end of each segment of travel (evaluate & plan)	5	4	4	3
Arrival time at end of each segment of travel (coordinate)	4.5	4	4	3
Layover time between travel segments (evaluate & plan)	5	4	4	3
Layover time between travel segments (coordinate)	4.5	4	4	3
Arrival time at destination (evaluate & plan)	5	4	4	3
Arrival time at destination (coordinate)	4.5	4	4	3
Total time to complete travel (identify)	5	4	4	3
Total time to complete travel (evaluate)	5	4	4	3

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Predrive route and destination selection				
Fastest route available	3	4	1	3
Route avoiding tollways	3	4	1	3
Most scenic route	3	5	1	3
Route avoiding complex intersections	3	3	1	3
Route option with least traffic	3	3	1	3
Route that minimizes left turns	3	3	1	3
Shortest route option	3	4	1	3
Route option with the least crime	3	3	1	3
Route option with best road quality	3	3	1	3
Route option with fewest number of traffic lights/stops	3	3	1	3
Enter a specific street address	3	5	1	4
Select from among destination alternatives	3	5	1	4
Desired order of destinations	3	4	1	3
Route guidance				
Notification that the driver is off route	3	4	1	2
Vehicle's current position	4	4	3	2
Suggestion of alternative route	3	4	1	3
Complete map of route (identify)	5	4	1	3
Complete map of route (evaluate)	3	4	1	3
Next destination	3	4	3	3
Final destination	4	4	3	3

Route guidance (Continued)

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Re-route option with least traffic	3	3	1	3
Shortest re-route option	3	3	1	3
Re-route option with best road quality	3	3	1	3
Information on road closures and restrictions	5	3	3	3
Re-route option with fewest number of traffic lights/stop signs	3	3	1	3
Suggested course of action for emergency vehicle stopped ahead	3	2	4	2
Time and distance to bad road conditions	3	3	4	2
Time and distance to weather conditions	4	3	4	3
Time and distance to traffic congested area	4	3	3	3

Route navigation

Distance and time to destination	5	5	1	2
Distance and time to turn	3	3	1	2
Distance and time to exit	3	3	1	2
Name of street to turn on	3	4	1	2
Lane suggestion for next turn	3	3	1	2
Direction of turn	3	4	1	2
Name of current street	3	4	3	2
When the vehicle needs to get in a lane for turning or exiting	3	3	1	2

Automated toll collection

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Location of and distance to next toll booth	3	3	3	2
Number of lanes in next toll booth	3	5	3	2
Cost of next toll along route	3	5	3	2
Remaining balance in toll account	5	5	3	5
Notification of successful toll charge	5	5	3	5

ATIS- Motorist Services

Broadcast Services/Attractions	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Restaurant/food ahead	3	4	1	2
Restaurant type/style (e.g., Japanese, American, etc.) (search)	3	5	1	3
Restaurant type/style (e.g., Japanese, American, etc.) (alert)	3	4	1	2
Restaurant type/style (e.g., Japanese, American, etc.) (identify)	3	5	4	3
Restaurant names (search)	3	5	1	3
Restaurant names (alert)	3	4	1	2
Restaurant names (identify)	3	5	4	3
Price range of food at restaurants	3	5	1	3
Lodging ahead	3	4	1	2
Closest lodging with vacancy (search)	3	5	1	3
Closest lodging with vacancy (alert)	3	4	1	2
Closest lodging with vacancy (identify)	3	5	4	3
Guest amenities (e.g., elevator, kennel, laundry, locker, parking, shower, restrooms, barber shop, hair salon)	3	5	1	3
Gas station ahead	3	4	1	3
Cost of gasoline	3	5	1	3
Hours of operation of the gas station	3	5	1	3
Amenities of gas station (e.g., restrooms, phone, food)	3	5	1	3
Restroom ahead	3	4	1	2
Telephone ahead	3	4	1	2
Rest area ahead	3	4	1	2
Landmark information	3	4	4	3

Broadcast Services/Attractions (Continued)

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (search)	3	5	1	3
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (alert)	3	4	1	2
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (identify)	3	5	4	3
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (search)	3	5	1	3
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (alert)	3	4	1	2
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (identify)	3	5	4	3

Services/Attractions directory

Directory (lodging, automotive, food, shopping, personal services, recreation, financial institutions, religious services, health care, emergency services, government facilities, transportation)	5	5	1	4

Destination coordination

Location of and distance to restaurant	4	4	1	3
Location of and distance to lodging	4	4	1	3
Location of and distance to gas station	4	4	1	3
Location of and distance to nearest rest area	4	4	1	3
Confirmation of reservation	4	4	3	4
Reservation details	5	5	3	4
Locate nearest parking	3	4	1	2
Type of parking facility	3	4	1	2
Diagram of parking facilities	3	4	1	2
Real-time availability of parking	3	4	1	2

Message transfer

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Incoming message	5	5	3	5
Message sent	5	5	1	5
Send message	5	5	1	5
Alert driver message was not sent and why not	5	5	4	5
Write message	5	5	1	5
Delete message	5	5	1	5
Message acknowledged/received	5	5	5	5
Access message	5	5	1	5
Save message	5	5	1	5
Reply to a message	5	5	1	5
Access the internet	5	5	1	5

ATIS- Augmented Signage

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Roadway guidance sign information				
Interchange ahead	3	3	3	2
Route markers	3	4	4	3
Mile posts	3	4	5	3
Roadway notification sign information				
Steep downgrade	3	2	3	1
Percent of grade	3	2	3	1
Recommended speed as a function of grade	3	2	3	1
Braking requirements for specific grades	3	2	3	1
Tight ramp or intersection	2	2	2	1
Railroad crossing	2	4	5	1
Merge	2	2	5	1
Chevrons	1	2	2	1
Curve signs	2	3	2	1
Sharp curve ahead	2	2	2	1
Curve speed for specific vehicle sizes	2	2	2	1
Pedestrian crossing ahead	2	2	3	1
Maximum speed for negotiating the exit ramp safely	2	2	2	1

Roadway regulatory sign information

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Speed limit	2	3	5	2
Speed limit in construction zones	2	2	2	2
Vehicle is “x” mph over speed limit	2	3	5	1
Stop	2	2	3	2
Yield	2	2	3	2
Do not enter	2	2	3	2
No right or left turn	2	2	3	2
Left turn only/right turn only	2	2	3	2
4-way stop	2	4	1	2

ATIS- Safety/Warning

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Immediate hazard warning				
Emergency vehicle stopped ahead	3	3	4	2
Emergency vehicle approaching	2	3	4	2
Distance of approaching emergency vehicle	3	3	4	2
Relative locations of emergency vehicles to you on a map	4	4	5	3
School bus stopped ahead	3	3	5	2
Road condition information				
Road work/construction ahead	3	2	3	2
Uneven road ahead	3	3	5	2
Fallen rock ahead	3	3	5	2
Icy roads ahead	3	2	5	2
Low shoulder	3	3	5	2
Snow ahead	4	3	4	3
Rain ahead	4	3	5	2
Fog ahead	3	2	5	2
Squalls	5	4	3	3
General weather forecast for a specific area	5	3	3	3
Partly sunny weather conditions	5	5	3	4
Partly cloudy weather conditions	5	5	3	4
Sunny conditions	5	5	3	4

Road condition information (Continued)

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Traffic/congestion ahead	4	4	2	3
Accident ahead	3	2	3	2
Chemical spill ahead	3	2	3	2
Lanes blocked ahead	3	3	3	2
Lanes closed ahead	4	4	3	2
General real-time traffic information	4	4	2	3
How far/how long traffic is backed up	4	4	2	3
Map showing areas of mild, moderate and severe congestion	4	4	2	3

Automatic/Manual aid request

Inform driver that aid has been requested	5	5	3	5
Inform driver of time until the emergency unit will arrive	5	5	3	5

Vehicle condition monitoring

Inform driver of current problem	3	3	4	2
Inform driver of ways to correct problem	4	3	1	3
Provide more detailed information at the driver's request	5	5	1	5
Inform the driver of needed warranty services due	5	3	5	5
Low tire pressure	3	3	5	2
Low oil pressure	3	4	5	2
Safety event recorder information	5	5	5	5

ATIS- Commercial Vehicle Operations (CVO)

Trip Planning

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Approved fueling locations (identify)	5	4	1	3
Approved fueling locations (evaluate)	5	4	1	3
Truck stops (identify)	5	4	1	3
Truck stops (evaluate)	5	4	1	3
Dealers (identify)	5	5	5	3
Dealers (evaluate)	5	5	5	3
Fuel costs (identify)	5	4	1	3
Fuel costs (evaluate)	5	4	1	3
Approved parking locations for types (identify)	5	4	3	3
Approved parking locations for types (evaluate)	5	4	3	3
Weight limits (identify)	5	3	3	3
Weight limits (evaluate)	5	3	3	3
Overhead restrictions (identify)	5	3	3	3
Overhead restrictions (evaluate)	5	3	3	3
Weigh stations (locations and whether they are open) (identify)	5	4	3	3
Weigh stations (locations and whether they are open) (evaluate)	5	4	3	3
Fuel taxes (identify)	5	4	2	3
Fuel taxes (evaluate)	5	4	2	3
Typical congestion of a route (identify)	5	4	3	3
Typical congestion of a route (evaluate)	5	4	3	3
Miles until truck is out of fuel	5	4	3	3

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Delivery-related information				
Delivery location	5	4	2	4
Scheduled pickup and delivery times	5	4	2	4
Times of day or week that may affect delivery	5	4	2	3
Equipment types not allowed on roadway (identify)	5	4	4	3
Equipment types not allowed on roadway (evaluate)	5	4	4	3
Optimize delivery schedules	5	4	2	4
Customer's preferences (identify)	5	4	2	4
Customer's preferences (coordinate)	5	4	2	4
Information from dispatcher regarding schedule changes and other pickup/delivery information	5	4	2	4
Presentation of service directory information				
Index of yellow pages and information from the Trucker's Atlas	5	5	1	3
CVO-specific aid request information				
Inform emergency services of cargo type	2	3	5	5
Cargo and vehicle monitoring information				
Problem in the trailer unit	4	3	4	2
Problem in the tractor unit	3	3	4	2
Precise information regarding vehicle performance (may be > 50 parameters)	5	3	3	3

Augmented signage information	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Truck route	3	4	2	3
Truck speed limit	2	3	5	2
Routing restrictions for specific vehicle cargos	3	3	3	3
Weight limits	3	3	3	3
No hazardous materials allowed	3	3	3	3
Low clearance	3	3	3	3
Low overpasses on route	3	3	3	3
Allowable vehicle length on roadway	3	3	3	3
Allowable vehicle width on roadway	3	3	3	3
Allowable vehicle height on roadway	3	3	3	3

Administrative information

Allow driver to complete administrative paperwork electronically (i.e., taxes, licenses)	5	5	3	5
Inform driver of regulatory administrative requirements	5	4	3	5
Electronic permit application	5	4	3	5
Pre-clearance	5	4	3	5
Credential checking	5	4	3	5
Driver-incentive and performance	5	5	3	5

Post-trip summary	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Elapsed time	5	5	1	5
Miles traveled	5	5	1	5
Fuel used	5	5	1	5
Tools paid for driver logs	5	5	1	5
Percent of time at idle	5	5	1	5

General Navigation System Information

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Position of satellites in space; representation of which satellites are currently transmitting information	5	5	1	5
Satellite signal strength	5	5	1	5
Current GPS position (latitude, longitude, altitude)	5	5	1	5
Number of available satellites	5	5	1	5

Collision Avoidance Information

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Rear-end collision avoidance				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	2	2	1	2
Warning indicator (nature, etc.) (alert and identify)	1	1	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	1	1
Road departure collision avoidance				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	2	2	1	2
Warning indicator (nature, etc.) (alert and identify)	1	1	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	1	1
Lane change/merge collision avoidance				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	2	2	1	2
Warning indicator (nature, etc.) (alert and identify)	1	1	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	1	1

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Intersection collision avoidance				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	2	2	1	2
Warning indicator (nature, etc.) (alert and identify)	1	1	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	1	1
Railroad crossing collision avoidance				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	2	2	1	2
Warning indicator (nature, etc.) (alert and identify)	1	1	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	1	1
Driver monitoring devices				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	3	3	1	2
Warning indicator (nature, etc.) (alert and identify)	1	1	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	1	1

	Time Urgency	Criticality	Independence of Message	Link to Driving Tasks
Backing devices				
System on and functioning	3	3	1	5
System failure	2	3	5	5
No danger indicator	5	5	3	2
Advisory indicator (nature, etc.) (alert and identify)	2	2	1	2
Warning indicator (nature, etc.) (alert and identify)	1	2	1	1
Warning indicator (nature, etc.) (alert, identify, and decide)	1	2	1	1
Automated cruise control devices				
System on and functioning	2	4	5	1
System failure	2	3	5	1

APPENDIX F: IVIS MESSAGES AND THEIR ASSOCIATED INFORMATION PROCESSING ELEMENTS

ATIS- Routing and Navigation

Trip Planning	**A**	**I**	**S**	**E**	**P**	**D**	**CO**	**CN**	**M**
Display of lodging along set route	0	1	0	1	0	0	0	0	0
Price ranges of lodging along route	0	1	0	1	0	0	0	0	0
Vacancy status of hotels along route	0	1	0	1	0	0	0	0	0
Locations of state and national parks	0	1	0	0	0	0	0	0	0
Details about stateand national parks (amenities, # of campsites, etc.)	0	1	0	1	0	0	0	0	0
Transit schedules in areas along route	0	0	0	1	1	0	0	0	0
Total trip time (identify)	0	1	0	0	0	0	0	0	0
Total trip time (evaluate)	0	0	0	1	0	0	0	0	0
Time to each destination (identify)	0	1	0	0	0	0	0	0	0
Time to each destination (evaluate and plan)	0	0	0	1	1	0	0	0	0
Total trip mileage (identify)	0	1	0	0	0	0	0	0	0
Total trip mileage (evaluate)	0	0	0	1	0	0	0	0	0
Mileage to each destination (identify)	0	1	0	0	0	0	0	0	0
Mileage to each destination (evaluate and plan)	0	0	0	1	1	0	0	0	0
Total trip cost (identify)	0	1	0	0	0	0	0	0	0
Total trip cost (evaluate)	0	0	0	1	0	0	0	0	0
Number of tolls and cost of each toll (identify)	0	1	0	0	0	0	0	0	0
Number of tolls and cost of each toll (evaluate)	0	0	0	1	0	0	0	0	0

Trip Planning (Continued)	A	I	S	E	P	D	CO	CN	M
Types of roads on route (identify)	0	1	0	0	0	0	0	0	0
Types of roads on route (evaluate)	0	0	0	1	0	0	0	0	0
Summary of turns or roadway changes (identify)	0	1	0	0	0	0	0	0	0
Summary of turns or roadway changes (evaluate)	0	0	0	1	0	0	0	0	0
States, regions, communities and districts along the route (identify)	0	1	0	0	0	0	0	0	0
States, regions, communities and districts along the route (evaluate)	0	0	0	1	0	0	0	0	0
Landmarks or topographical features (identify)	0	1	0	0	0	0	0	0	0
Landmarks or topographical features (evaluate)	0	0	0	1	0	0	0	0	0
Historical congestion information (identify)	0	1	0	0	0	0	0	0	0
Historical congestion information (evaluate)	0	0	0	1	0	0	0	0	0
Magnify/minimize map view	0	0	0	0	0	0	0	1	0
Shift to another region of the map	0	0	0	0	0	0	0	1	0

Multi-mode travel coordination and planning	A	I	S	E	P	D	CO	CN	M
Start time required to catch other mode of transport (evaluate and plan)	0	0	0	1	1	0	0	0	0
Start time required to catch other mode of transport (coordinate)	0	0	0	0	0	0	1	0	0
Mode of travel to take for each segment of travel (evaluate and plan)	0	0	0	1	1	0	0	0	0
Mode of travel to take for each segment of travel (coordinate)	0	0	0	0	0	0	1	0	0
Arrival time at end of each segment of travel (evaluate and plan)	0	0	0	1	1	0	0	0	0
Arrival time at end of each segment of travel (coordinate)	0	0	0	0	0	0	1	0	0
Layover time between travel segments (evaluate and plan)	0	0	0	1	1	0	0	0	0
Layover time between travel segments (coordinate)	0	0	0	0	0	0	1	0	0
Arrival time at destination (evaluate and plan)	0	0	0	1	1	0	0	0	0
Arrival time at destination (coordinate)	0	0	0	0	0	0	1	0	0
Total time to complete travel (identify)	0	1	0	0	0	0	0	0	0
Total time to complete travel (evaluate)	0	0	0	1	0	0	0	0	0

Predrive route and destination selection	A	I	S	E	P	D	CO	CN	M
Fastest route available	0	0	0	0	1	0	0	0	0
Route avoiding tollways	0	0	0	0	1	0	0	0	0
Most scenic route	0	0	0	0	1	0	0	0	0
Route avoiding complex intersections	0	0	0	0	1	0	0	0	0
Route option with least traffic	0	0	0	0	1	0	0	0	0
Route that minimizes left turns	0	0	0	0	1	0	0	0	0
Shortest route option	0	0	0	0	1	0	0	0	0
Route option with least crime	0	0	0	0	1	0	0	0	0
Route option with best road quality	0	0	0	0	1	0	0	0	0
Route option with fewest number of traffic lights/stops	0	0	0	0	1	0	0	0	0
Enter a specific street address	0	0	0	0	1	0	0	0	0
Desired order of destinations	0	0	0	0	1	0	0	0	0
Select from among destination alternatives	0	0	1	0	1	0	0	0	0

Route guidance	A	I	S	E	P	D	CO	CN	M
Notification that the driver is off route	0	1	0	0	0	0	0	0	0
Vehicle’s current position	0	1	0	0	0	0	0	0	0
Suggestion of alternative route	0	0	0	0	1	0	0	0	0
Complete map of route (identify)	0	1	0	0	0	0	0	0	0
Complete map of route (evaluate)	0	0	0	1	0	0	0	0	0
Next destination	0	1	0	0	0	0	0	0	0
Final destination	0	1	0	0	0	0	0	0	0
Re-route option with least traffic	0	0	0	0	1	0	0	0	0
Shortest re-route option	0	0	0	0	1	0	0	0	0
Road quality of re-route option	0	0	0	0	1	0	0	0	0
Information on road closures and restrictions	0	1	0	0	0	0	0	0	0
Re-route option with fewest number of traffic lights/stop signs	0	0	0	0	1	0	0	0	0
Suggested course of action for emergency vehicle stopped ahead	1	0	0	0	0	1	0	0	0
Time and distance to bad road conditions	0	1	0	0	0	0	0	0	0
Time and distance to weather conditions	0	1	0	0	0	0	0	0	0
Time and distance to traffic congested area	0	1	0	0	0	0	0	0	0

Route navigation

	A	I	S	E	P	D	CO	CN	M
Distance and time to destination	0	1	0	0	0	0	0	0	0
Distance and time to turn	0	1	0	0	0	0	1	0	0
Distance and time to exit	0	1	0	0	0	0	1	0	0
Name of street to turn on	0	1	0	0	0	0	0	0	0
Lane suggestion for next turn	0	0	0	0	0	1	0	0	0
Direction of turn	0	0	0	0	0	1	0	0	0
Name of current street	0	1	0	0	0	0	0	0	0
When the vehicle needs to get in a lane for turning or exiting	0	0	0	0	0	0	1	0	0

Automated toll collection

Location of and distance to toll booths	0	1	0	0	0	0	1	0	0
Number of lanes in tolls	0	1	0	0	0	0	0	0	0
Cost of tolls along route	0	1	0	0	0	0	0	0	0
Remaining balance in toll account	0	1	0	0	0	0	0	0	0
Notification of successful toll charge	0	1	0	0	0	0	0	0	0

ATIS- Motorist Services

Broadcast Services/Attractions	A	I	S	E	P	D	CO	CN	M
Restaurant/food ahead	1	0	0	0	0	0	0	0	0
Restaurant type/style (e.g., Japanese, American, etc.) (search)	0	0	1	0	0	0	0	0	0
Restaurant type/style (e.g., Japanese, American, etc.) (alert)	1	0	0	0	0	0	0	0	0
Restaurant type/style (e.g., Japanese, American, etc.) (identify)	0	1	0	0	0	0	0	0	0
Restaurant names (search)	0	0	1	0	0	0	0	0	0
Restaurant names (alert)	1	0	0	0	0	0	0	0	0
Restaurant names (identify)	0	1	0	0	0	0	0	0	0
Price range of food at restaurants	0	0	0	1	0	0	0	0	0
Lodging ahead	1	0	0	0	0	0	0	0	0
Closest lodging with vacancy (search)	0	0	1	0	0	0	0	0	0
Closest lodging with vacancy (alert)	1	0	0	0	0	0	0	0	0
Closest lodging with vacancy (identify)	0	1	0	0	0	0	0	0	0
Guest amenities (e.g., elevator, kennel, laundry, locker, parking, shower, restrooms, barber shop, hair salon)	0	0	0	1	0	0	0	0	0
Gas station ahead	1	0	0	0	0	0	0	0	0
Cost of gasoline	0	0	0	1	0	0	0	0	0
Hours of operation of the gas station	0	0	0	1	0	0	0	0	0
Amenities of gas station (e.g., restrooms, phone, food)	0	0	0	1	0	0	0	0	0
Restroom ahead	1	0	0	0	0	0	0	0	0

Broadcast Services/Attractions (Continued)

	A	I	S	E	P	D	CO	CN	M
Telephone ahead	1	0	0	0	0	0	0	0	0
Rest area ahead	1	0	0	0	0	0	0	0	0
Landmark information	0	1	0	0	0	0	0	0	0
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (search)	0	0	1	0	0	0	0	0	0
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (alert)	1	0	0	0	0	0	0	0	0
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (identify)	0	1	0	0	0	0	0	0	0
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (search)	0	0	1	0	0	0	0	0	0
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (alert)	1	0	0	0	0	0	0	0	0
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (identify)	0	1	0	0	0	0	0	0	0

Services/Attractions directory

	A	I	S	E	P	D	CO	CN	M
Directory (lodging, automotive, food, shopping, personal services, recreation, financial institutions, religious services, health care, emergency services, government facilities, and transportation)	0	0	1	0	0	0	0	1	0

Destination coordination	A	I	S	E	P	D	CO	CN	M
Location of and distance to restaurant	0	1	0	0	0	0	1	0	0
Location of and distance to lodging	0	1	0	0	0	0	1	0	0
Location of and distance to gas station	0	1	0	0	0	0	1	0	0
Location of and distance to nearest rest area	0	1	0	0	0	0	1	0	0
Confirmation of reservation	0	0	0	0	0	0	0	0	1
Reservation details	0	1	0	0	0	0	0	0	0
Locate nearest parking	0	0	1	0	0	0	0	0	0
Type of parking facility	0	1	0	0	0	0	0	0	0
Diagram of parking facilities	0	1	0	0	1	0	0	0	0
Real-time availability of parking	0	1	0	0	0	0	0	0	0

Message transfer

	A	I	S	E	P	D	CO	CN	M
Incoming message	1	1	0	0	0	0	0	0	0
Message sent	0	0	0	0	0	0	0	0	1
Send message	0	0	0	0	0	0	0	1	0
Alert driver message was not sent and why not	1	1	0	0	0	0	0	0	0
Write message	0	0	0	0	0	0	0	1	0
Delete message	0	0	0	0	0	0	0	1	0
Message acknowledged/received	0	0	0	0	0	0	0	0	1
Access message	0	0	0	0	0	0	0	1	0
Save message	0	0	0	0	0	0	0	1	0
Reply to a message	0	0	0	0	0	0	0	1	0
Access the internet	0	0	0	0	0	0	0	1	0

ATIS- Augmented Signage

Roadway guidance sign information	A	I	S	E	P	D	CO	CN	M
Interchange ahead	0	1	0	0	0	0	0	0	0
Route markers	0	1	0	0	0	0	1	0	0
Mile posts	0	1	0	0	0	0	1	0	0

Roadway notification sign information

Steep downgrade	0	1	0	0	0	0	0	0	0
Percent of grade	0	1	0	0	0	0	0	0	0
Recommended speed as a function of grade	0	0	0	0	0	1	0	0	0
Braking requirements for specific grades	0	0	0	0	0	1	0	0	0
Tight ramp or intersection	0	1	0	0	0	0	0	0	0
Railroad crossing	0	1	0	0	0	0	0	0	0
Merge	0	1	0	0	0	1	0	0	0
Chevrons	0	1	0	0	0	0	0	0	0
Curve signs	0	1	0	0	0	0	0	0	0
Sharp curve ahead	0	1	0	0	0	0	0	0	0
Curve speed for specific vehicle sizes	0	0	0	0	0	1	0	0	0
Maximum speed for negotiating the exit ramp safely	0	1	0	0	0	0	0	0	0
Pedestrian crossing ahead	0	1	0	0	0	0	0	0	0

Roadway regulatory sign information	A	I	S	E	P	D	CO	CN	M
Speed limit	0	1	0	0	0	0	0	0	0
Speed limit in construction zones	0	1	0	0	0	0	0	0	0
Vehicle is “x” mph over speed limit	0	1	0	0	0	0	0	0	1
Stop	0	1	0	0	0	1	0	0	0
Yield	0	1	0	0	0	1	0	0	0
Do not enter	0	1	0	0	0	1	0	0	0
No right or left turn	0	1	0	0	0	1	0	0	0
Left turn only/right turn only	0	1	0	0	0	1	0	0	0
4-way stop	0	1	0	0	0	0	0	0	0

ATIS- Safety/Warning

Immediate hazard warning	A	I	S	E	P	D	CO	CN	M
Emergency vehicle stopped ahead	1	1	0	0	0	0	0	0	0
Emergency vehicle approaching	1	1	0	0	0	0	0	0	0
Distance of approaching emergency vehicle	0	1	0	0	0	0	1	0	0
Relative locations of emergency vehicles to you on a map	0	1	0	0	0	0	1	0	0
School bus stopped ahead	1	1	0	0	0	0	0	0	0
Road condition information									
Road work/construction ahead	1	1	0	0	0	0	0	0	0
Uneven road ahead	1	1	0	0	0	0	0	0	0
Fallen rock ahead	1	1	0	0	0	0	0	0	0
Icy roads ahead	1	1	0	0	0	0	0	0	0
Low shoulder	1	1	0	0	0	0	0	0	0
Snow ahead	1	1	0	0	0	0	0	0	0
Rain ahead	1	1	0	0	0	0	0	0	0
Fog ahead	1	1	0	0	0	0	0	0	0
Squalls	0	1	0	0	0	0	0	0	0
General weather forecast for a specific area	0	1	0	0	0	0	0	0	0
Partly sunny weather conditions	0	1	0	0	0	0	0	0	0

Road condition information (Continued)	A	I	S	E	P	D	CO	CN	M
Sunny conditions	0	1	0	0	0	0	0	0	0
Partly cloudy weather conditions	0	1	0	0	0	0	0	0	0
Traffic/congestion ahead	1	1	0	0	0	0	0	0	0
Accident ahead	1	1	0	0	0	0	0	0	0
Chemical spill ahead	1	1	0	0	0	0	0	0	0
Lanes blocked ahead	1	1	0	0	0	0	0	0	0
Lanes closed ahead	1	1	0	0	0	0	0	0	0
General real-time traffic information	0	1	0	0	0	0	0	0	0
How far/how long traffic is backed up	0	1	0	0	0	0	1	0	0
Map showing areas of mild, moderate and severe congestion	0	1	0	0	0	0	0	0	0
Automatic/Manual aid request									
Inform driver that aid has been requested	1	0	0	0	0	0	0	0	1
Inform driver of time until the emergency unit will arrive	1	0	0	0	0	0	1	0	0

Vehicle condition monitoring	**A**	**I**	**S**	**E**	**P**	**D**	**CO**	**CN**	**M**
Inform driver of current problem	1	0	0	0	0	0	0	0	1
Inform driver of ways to correct problem	0	0	0	0	1	1	0	0	0
Provide more detailed information at the driver’s request	0	0	0	0	0	0	0	1	0
Inform the driver of needed warranty services due	1	0	0	0	0	0	0	0	0
Low tire pressure	1	0	0	0	0	0	0	0	0
Low oil pressure	1	0	0	0	0	0	0	0	0
Safety event recorder information	0	1	0	0	0	0	0	0	0

ATIS- Commercial Vehicle Operations (CVO)

Trip Planning

	A	I	S	E	P	D	CO	CN	M
Approved fueling locations (identify)	0	1	0	0	0	0	0	0	0
Approved fueling locations (evaluate)	0	0	0	1	0	0	0	0	0
Truck stops (identify)	0	1	0	0	0	0	0	0	0
Truck stops (evaluate)	0	0	0	1	0	0	0	0	0
Dealers (identify)	0	1	0	0	0	0	0	0	0
Dealers (evaluate)	0	0	0	1	0	0	0	0	0
Fuel costs (identify)	0	1	0	0	0	0	0	0	0
Fuel costs (evaluate)	0	0	0	1	0	0	0	0	0
Approved parking locations for types (identify)	0	1	0	0	0	0	0	0	0
Approved parking locations for types (evaluate)	0	0	0	1	0	0	0	0	0
Weight limits (identify)	0	1	0	0	0	0	0	0	0
Weight limits (evaluate)	0	0	0	1	0	0	0	0	0
Overhead restrictions (identify)	0	1	0	0	0	0	0	0	0
Overhead restrictions (evaluate)	0	0	0	1	0	0	0	0	0
Weigh stations (locations and whether they are open) (identify)	0	1	0	0	0	0	0	0	0
Weigh stations (locations and whether they are open) (evaluate)	0	0	0	1	0	0	0	0	0
Fuel taxes (identify)	0	1	0	0	0	0	0	0	0
Fuel taxes (evaluate)	0	0	0	1	0	0	0	0	0

Trip Planning (Continued)

	A	I	S	E	P	D	CO	CN	M
Typical congestion of a route (identify)	0	1	0	0	0	0	0	0	0
Typical congestion of a route (evaluate)	0	0	0	1	0	0	0	0	0
Miles until truck is out of fuel	0	1	0	0	0	0	1	0	0

Delivery-related information

Delivery location	0	1	0	0	0	0	0	0	0
Scheduled pickup and delivery times	0	1	0	0	0	0	1	0	0
Times of day or week that may affect delivery	0	0	0	0	0	0	1	0	0
Equipment types not allowed on roadway (identify)	0	1	0	0	0	0	0	0	0
Equipment types not allowed on roadway (evaluate)	0	0	0	1	0	0	0	0	0
Optimize delivery schedules	0	0	0	0	1	0	0	0	0
Customer’s preferences (identify)	0	1	0	0	0	0	0	0	0
Customer’s preferences (coordinate)	0	0	0	0	0	0	1	0	0
Information from dispatcher regarding schedule changes and other pickup/delivery information	0	0	0	0	0	0	1	0	0

Presentation of service directory information

Index of yellow pages and information from the Trucker’s Atlas	0	0	1	0	0	0	0	1	0

CVO-specific aid request information

Inform emergency services of cargo type	0	0	0	0	0	0	0	1	0

Cargo and vehicle monitoring information	A	I	S	E	P	D	CO	CN	M
Problem in the trailer unit	1	0	0	0	0	0	0	0	1
Problem in the tractor unit	1	0	0	0	0	0	0	0	1
Precise information regarding vehicle performance (may be > 50 parameters)	0	1	0	0	0	0	0	0	1

Augmented signage information

Truck route	0	1	0	0	0	0	0	0	0
Truck speed limit	0	1	0	0	0	0	0	0	0
Routing restrictions for specific vehicle cargos	0	1	0	0	0	0	0	0	0
Weight limits	0	1	0	0	0	0	0	0	0
No hazardous materials allowed	0	1	0	0	0	0	0	0	0
Low clearance	0	1	0	0	0	0	0	0	0
Low overpasses on route	0	1	0	0	0	0	0	0	0
Allowable vehicle length on roadway	0	1	0	0	0	0	0	0	0
Allowable vehicle width on roadway	0	1	0	0	0	0	0	0	0
Allowable vehicle height on roadway	0	1	0	0	0	0	0	0	0

Administrative information	A	I	S	E	P	D	CO	CN	M
Allow driver to complete administrative paperwork electronically (i.e., taxes, licenses)	0	0	0	0	0	0	0	1	0
Inform driver of regulatory administrative requirements	0	1	1	0	0	0	0	0	0
Electronic permit application	0	0	0	0	0	0	0	1	0
Pre-clearance	0	0	0	0	0	0	1	1	0
Credential checking	0	0	0	0	0	0	0	1	0
Driver-incentive and performance	0	1	0	0	0	0	0	0	1

Post-trip summary

Elapsed time	0	1	0	0	0	0	0	0	1
Miles traveled	0	1	0	0	0	0	0	0	1
Fuel used	0	1	0	0	0	0	0	0	1
Tools paid for driver logs	0	1	0	0	0	0	0	0	1
Percent of time at idle	0	1	0	0	0	0	0	0	1

General Navigation System Information

	A	I	S	E	P	D	CO	CN	M
Position of satellites in space; representation of which satellites are currently transmitting information	0	1	0	0	0	0	0	0	0
Satellite signal strength	0	1	0	0	0	0	0	0	0
Current GPS position (latitude, longitude, altitude)	0	1	0	0	0	0	0	0	0
Number of available satellites	0	1	0	0	0	0	0	0	0

Collision Avoidance Information

Rear-end collision avoidance	A	I	S	E	P	D	CO	CN	M
System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0
Road departure collision avoidance									
System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0

Lane change/merge collision avoidance	A	I	S	E	P	D	CO	CN	M
System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0
Intersection collision avoidance									
System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0

Railroad crossing collision avoidance

	A	I	S	E	P	D	CO	CN	M
System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0

Driver monitoring devices

System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0

Backing devices	A	I	S	E	P	D	CO	CN	M
System on and functioning	0	1	0	0	0	0	0	0	0
System failure	1	0	0	0	0	0	0	0	0
No danger indicator	0	1	0	0	0	0	0	0	1
Advisory indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert and identify)	1	1	0	0	0	0	0	0	0
Warning indicator (nature, etc.) (alert, identify, and decide)	1	1	0	0	0	1	0	0	0
Automated cruise control devices									
System on and functioning	0	1	0	0	0	0	0	0	1
System failure	1	0	0	0	0	0	0	0	0

APPENDIX G: IVIS MESSAGES GROUPED BY CLUSTERS

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Tight ramp or intersection	I	1	0.67315	2	2	1	2	0	1	0	0	0	0	0	0	0
Sharp curve ahead	I	1	0.67315	2	2	1	2	0	1	0	0	0	0	0	0	0
Curve speed for specific vehicle sizes	I	1	0.67315	2	2	1	2	0	0	0	0	0	1	0	0	0
Maximum speed for negotiating the exit ramp safely	I	1	0.67315	2	2	1	2	0	1	0	0	0	0	0	0	0
Chevrons	I	1	0.76035	1	2	1	2	0	1	0	0	0	0	0	0	0
Warning indicator (backing devices) (alert and identify)	I	1	0.83853	1	2	1	1	1	1	0	0	0	0	0	0	0
Warning indicator (backing devices) (alert, identify, and decide)	I	1	0.83853	1	2	1	1	1	1	0	0	0	1	0	0	0
Speed limit in construction zones	I	1	1.03833	2	2	2	2	0	1	0	0	0	0	0	0	0
Advisory indicator (all other CA systems (alert and identify)	I	1	1.09687	2	2	2	1	1	1	0	0	0	0	0	0	0
Advisory indicator (backing devices) (alert and identify)	I	1	1.09687	2	2	2	1	1	1	0	0	0	0	0	0	0
Warning indicator (all other CA systems) (alert and identify)	I	1	1.15244	1	1	1	1	1	1	0	0	0	0	0	0	0
Warning indicator (all other CA systems) (alert, identify, and decide)	I	1	1.15244	1	1	1	1	1	1	0	0	0	1	0	0	0
Warning indicator (driver monitoring) (alert and identify)	I	1	1.15244	1	1	1	1	0	1	0	0	0	0	0	0	1
Warning indicator (driver monitoring) (alert, identify, and decide)	I	1	1.15244	1	1	1	1	1	0	0	0	0	0	0	0	0
Curve signs	I	1	1.35208	2	3	1	2	0	1	0	0	0	0	0	0	0
Location of and distance to next toll booth	I	2	0.55679	3	3	2	3	0	1	0	0	0	0	1	0	0
Interchange ahead	I	2	0.55679	3	3	2	3	0	1	0	0	0	0	0	0	0
Lanes blocked ahead	I	2	0.55679	3	3	2	3	1	1	0	0	0	0	0	0	0
Road work/construction ahead	I	2	0.58911	3	2	2	3	1	1	0	0	0	0	0	0	0
Accident ahead	I	2	0.58911	3	2	2	3	1	1	0	0	0	0	0	0	0
Chemical spill ahead	I	2	0.58911	3	2	2	3	1	1	0	0	0	0	0	0	0
Stop	I	2	0.98827	2	2	2	3	0	1	0	0	0	1	0	0	0
Yield	I	2	0.98827	2	2	2	3	0	1	0	0	0	1	0	0	0
Do not enter	I	2	0.98827	2	2	2	3	0	1	0	0	0	1	0	0	0
No right or left turn	I	2	0.98827	2	2	2	3	0	1	0	0	0	1	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Left turn only/right turn only	I	2	0.98827	2	2	2	3	0	1	0	0	0	1	0	0	0
Routing restrictions for specific vehicle cargos	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Weight limits	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
No hazardous materials allowed	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Low clearance	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Low overpasses on route	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Allowable vehicle length on roadway	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Allowable vehicle width on roadway	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Allowable vehicle height on roadway	I	2	1.00684	3	3	3	3	0	1	0	0	0	0	0	0	0
Suggested course of action for emergency vehicle stopped ahead	I	2	1.02506	3	2	2	4	1	0	0	0	0	1	0	0	0
Steep downgrade	I	2	1.28193	3	2	1	3	0	1	0	0	0	0	0	0	0
Percent of grade	I	2	1.28193	3	2	1	3	0	1	0	0	0	0	0	0	0
Recommended speed as a function of grade	I	2	1.28193	3	2	1	3	0	0	0	0	0	1	0	0	0
Braking requirements for specific grades	I	2	1.28193	3	2	1	3	0	0	0	0	0	1	0	0	0
Pedestrian crossing ahead	I	2	1.50764	2	2	1	3	0	1	0	0	0	0	0	0	0
Problem in the trailer unit	I	2	1.54405	4	3	2	4	1	0	0	0	0	0	0	0	1
School bus stopped ahead	I	3	0.43875	3	3	2	5	1	1	0	0	0	0	0	0	0
Uneven road ahead	I	3	0.43875	3	3	2	5	1	1	0	0	0	0	0	0	0
Fallen rock ahead	I	3	0.43875	3	3	2	5	1	1	0	0	0	0	0	0	0
Low shoulder	I	3	0.43875	3	3	2	5	1	1	0	0	0	0	0	0	0
Low tire pressure	I	3	0.43875	3	3	2	5	1	0	0	0	0	0	0	0	0
Speed limit	I	3	0.76974	2	3	2	5	0	1	0	0	0	0	0	0	0
Truck speed limit	I	3	0.76974	2	3	2	5	0	1	0	0	0	0	0	0	0
Time and distance to bad road conditions	I	3	0.89022	3	3	2	4	0	1	0	0	0	0	0	0	0
Emergency vehicle stopped ahead	I	3	0.89022	3	3	2	4	1	1	0	0	0	0	0	0	0
Distance of approaching emergency vehicle	I	3	0.89022	3	3	2	4	0	1	0	0	0	0	1	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Inform driver of current problem	I	3	0.89022	3	3	2	4	1	0	0	0	0	0	0	0	1
Problem in the tractor unit	I	3	0.89022	3	3	2	4	1	0	0	0	0	0	0	0	1
Vehicle is “x” mph over speed limit	I	3	1.04523	2	3	1	5	0	1	0	0	0	0	0	0	1
System failure (ACC)	I	3	1.04523	2	3	1	5	1	0	0	0	0	0	0	0	0
Emergency vehicle approaching	I	3	1.09202	2	3	2	4	1	1	0	0	0	0	0	0	0
Icy roads ahead	I	3	1.09202	3	2	2	5	1	1	0	0	0	0	0	0	0
Fog ahead	I	3	1.09202	3	2	2	5	1	1	0	0	0	0	0	0	0
Low oil pressure	I	3	1.09202	3	4	2	5	1	0	0	0	0	0	0	0	0
Rain ahead	I	3	1.33884	4	3	2	5	1	1	0	0	0	0	0	0	0
Railroad crossing	I	3	1.44655	2	4	1	5	0	1	0	0	0	0	0	0	0
Merge	I	3	1.44655	2	2	1	5	0	1	0	0	0	1	0	0	0
System on and functioning (ACC)	I	3	1.44655	2	4	1	5	0	1	0	0	0	0	0	0	0
Fastest route available	II	4	0.39153	3	4	3	1	0	0	0	0	1	0	0	0	0
Route avoiding tollways	II	4	0.39153	3	4	3	1	0	0	0	0	1	0	0	0	0
Shortest route option	II	4	0.39153	3	4	3	1	0	0	0	0	1	0	0	0	0
Desired order of destinations	II	4	0.39153	3	4	3	1	0	0	1	0	1	0	0	0	0
Suggestion of alternative route	II	4	0.39153	3	4	3	1	0	0	0	0	1	0	0	0	0
Complete map of route (evaluate)	II	4	0.39153	3	4	3	1	0	0	0	1	0	0	0	0	0
Gas station ahead	II	4	0.39153	3	4	3	1	1	0	0	0	0	0	0	0	0
Notification that the driver is off route	II	4	0.61279	3	4	2	1	0	1	0	0	0	0	0	0	0
Name of street to turn on	II	4	0.61279	3	4	2	1	0	1	0	0	0	0	0	0	0
Direction of turn	II	4	0.61279	3	4	2	1	0	0	0	0	0	1	0	0	0
Restaurant/food ahead	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Restaurant type/style (e.g., Japanese, American, etc.) (alert)	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Restaurant names (alert)	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Lodging ahead	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Closest lodging with vacancy (alert)	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Restroom ahead	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Telephone ahead	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Rest area ahead	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (alert)	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (alert)	II	4	0.61279	3	4	2	1	1	0	0	0	0	0	0	0	0
Locate nearest parking	II	4	0.61279	3	4	2	1	0	0	1	0	0	0	0	0	0
Type of parking facility	II	4	0.61279	3	4	2	1	0	1	0	0	0	0	0	0	0
Diagram of parking facilities	II	4	0.61279	3	4	2	1	0	1	0	0	1	0	0	0	0
Real-time availability of parking	II	4	0.61279	3	4	2	1	0	1	0	0	0	0	0	0	0
Route avoiding complex intersections	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Route option with least traffic	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Route that minimizes left turns	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Route option with the least crime	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Route option with best road quality	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Route option with fewest number of traffic lights/stops	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Re-route option with least traffic	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Shortest re-route option	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Re-route option with best road quality	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Re-route option with fewest number of traffic lights/stop signs	II	4	1.03885	3	3	3	1	0	0	0	0	1	0	0	0	0
Truck route	II	4	1.05653	3	4	3	2	0	1	0	0	0	0	0	0	0
Most scenic route	II	4	1.10787	3	5	3	1	0	0	0	0	1	0	0	0	0
Restaurant type/style (e.g., Japanese, American, etc.) (search)	II	4	1.10787	3	5	3	1	0	0	1	0	0	0	0	0	0
Restaurant names (search)	II	4	1.10787	3	5	3	1	0	0	1	0	0	0	0	0	0
Price range of food at restaurants	II	4	1.10787	3	5	3	1	0	0	0	1	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Closest lodging with vacancy (search)	II	4	1.10787	3	5	3	1	0	0	1	0	0	0	0	0	0
Guest amenities (e.g., elevator, kennel, laundry, locker, parking, shower, restrooms, barber shop, hair salon)	II	4	1.10787	3	5	3	1	0	0	0	1	0	0	0	0	0
Cost of gasoline	II	4	1.10787	3	5	3	1	0	0	0	1	0	0	0	0	0
Hours of operation of the gas station	II	4	1.10787	3	5	3	1	0	0	0	1	0	0	0	0	0
Amenities of gas station (e.g., restrooms, phone, food)	II	4	1.10787	3	5	3	1	0	0	0	1	0	0	0	0	0
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (search)	II	4	1.10787	3	5	3	1	0	0	1	0	0	0	0	0	0
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (search)	II	4	1.10787	3	5	3	1	0	0	1	0	0	0	0	0	0
Distance and time to turn	II	4	1.14081	3	3	2	1	0	1	0	0	0	0	1	0	0
Distance and time to exit	II	4	1.14081	3	3	2	1	0	1	0	0	0	0	1	0	0
Lane suggestion for next turn	II	4	1.14081	3	3	2	1	0	0	0	0	0	1	0	0	0
When the vehicle needs to get in a lane for turning or exiting	II	4	1.14081	3	3	2	1	0	0	0	0	0	0	1	0	0
Advisory indicator (driver monitoring) (alert and identify)	II	4	1.14081	3	3	2	1	1	1	0	0	0	1	0	0	0
4-way stop	II	4	1.15693	2	4	2	1	0	1	0	0	0	0	0	0	0
Enter a specific street address	II	4	1.73354	3	5	4	1	0	0	0	0	1	0	0	0	0
Select from among destination alternatives	II	4	1.73354	3	5	4	1	0	0	0	0	1	0	0	0	0
System on and functioning (all other CA systems)	II	5	0	3	3	5	1	0	1	0	0	0	0	0	0	0
System on and functioning (backing devices)	II	5	0	3	3	5	1	0	1	0	0	0	0	0	0	0
System on and functioning (driver monitoring)	II	5	0	3	3	5	1	0	1	0	0	0	0	0	0	1
Inform the driver of needed warranty services due	III	6	0	5	3	5	5	1	0	0	0	0	0	0	0	0
Inform emergency services of cargo type	III	7	0	2	3	5	5	0	0	0	0	0	0	0	1	0
System failure (all other CA systems)	III	7	0	2	3	5	5	1	0	0	0	0	0	0	0	0
System failure (backing devices)	III	7	0	2	3	5	5	1	0	0	0	0	0	0	0	0
System failure (driver monitoring)	III	7	0	2	3	5	5	1	1	0	0	0	0	0	0	0
Message acknowledged/received	III	8	0.82462	5	5	5	5	0	0	0	0	0	0	0	0	1
Safety event recorder information	III	8	0.82462	5	5	5	5	0	1	0	0	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Alert driver message was not sent and why not	III	8	1.13137	5	5	5	4	1	1	0	0	0	0	0	0	0
Dealers (identify)	III	8	1.21655	5	5	3	5	0	1	0	0	0	0	0	0	0
Dealers (evaluate)	III	8	1.21655	5	5	3	5	0	0	0	1	0	0	0	0	0
Magnify/minimize map view	IV	9	0.99882	5	5	5	3	0	0	0	0	0	0	0	1	0
Shift to another region of the map	IV	9	0.99882	5	5	5	3	0	0	0	0	0	0	0	1	0
Remaining balance in toll account	IV	9	0.99882	5	5	5	3	0	1	0	0	0	0	0	0	0
Notification of successful toll charge	IV	9	0.99882	5	5	5	3	0	1	0	0	0	0	0	0	0
Incoming message	IV	9	0.99882	5	5	5	3	1	1	0	0	0	0	0	0	0
Inform driver that aid has been requested	IV	9	0.99882	5	5	5	3	1	0	0	0	0	0	0	0	1
Inform driver of time until the emergency unit will arrive	IV	9	0.99882	5	5	5	3	1	0	0	0	0	0	1	0	0
Allow driver to complete administrative paperwork electronically (i.e., taxes, licenses)	IV	9	0.99882	5	5	5	3	0	0	0	0	0	0	0	1	0
Driver-incentive and performance	IV	9	0.99882	5	5	5	3	0	1	0	0	0	0	0	0	1
Delivery location	IV	9	1.02035	5	4	4	2	0	1	0	0	0	0	0	0	0
Scheduled pickup and delivery times	IV	9	1.02035	5	4	4	2	0	1	0	0	0	0	1	0	0
Optimize delivery schedules	IV	9	1.02035	5	4	4	2	0	0	0	0	1	0	0	0	0
Customer's preferences (identify)	IV	9	1.02035	5	4	4	2	0	1	0	0	0	0	0	0	0
Customer's preferences (coordinate)	IV	9	1.02035	5	4	4	2	0	0	0	0	0	0	1	0	0
Information from dispatcher regarding schedule changes and other pickup/delivery information	IV	9	1.02035	5	4	4	2	0	0	0	0	0	0	1	0	0
Locations of state and national parks	IV	9	1.15994	5	5	4	3	0	1	0	0	0	0	0	0	0
Details about state and national parks	IV	9	1.15994	5	5	4	3	0	1	0	1	0	0	0	0	0
Landmarks or topographical features (identify)	IV	9	1.15994	5	5	4	3	0	1	0	0	0	0	0	0	0
Landmarks or topographical features (evaluate)	IV	9	1.15994	5	5	4	3	0	0	0	1	0	0	0	0	0
Reservation details	IV	9	1.15994	5	5	4	3	0	1	0	0	0	0	0	0	0
Message sent	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	0	1
Send message	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Write message	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Delete message	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Access message	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Save message	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Reply to a message	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Access the internet	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Partly sunny weather conditions	IV	9	1.15994	5	5	4	3	0	1	0	0	0	0	0	0	0
Partly cloudy weather conditions	IV	9	1.15994	5	5	4	3	0	1	0	0	0	0	0	0	0
Sunny conditions	IV	9	1.15994	5	5	4	3	0	1	0	0	0	0	0	0	0
Provide more detailed information at the driver's request	IV	9	1.15994	5	5	5	1	0	0	0	0	0	0	0	1	0
Elapsed time	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	1
Miles traveled	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	1
Fuel used	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	1
Tools paid for driver logs	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	1
Percent of time at idle	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	1
Position of satellites in space; representation of which satellites are currently transmitting information	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	0
Satellite signal strength	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	0
Current GPS position (latitude, longitude, altitude)	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	0
Number of available satellites	IV	9	1.15994	5	5	5	1	0	1	0	0	0	0	0	0	0
Inform driver of regulatory administrative requirements	IV	9	1.23263	5	4	5	3	0	1	1	0	0	0	0	0	0
Electronic permit application	IV	9	1.23263	5	4	5	3	0	0	0	0	0	0	0	1	0
Pre-clearance	IV	9	1.23263	5	4	5	3	0	0	0	0	0	0	1	1	0
Credential checking	IV	9	1.23263	5	4	5	3	0	0	0	0	0	0	0	1	0
Directory (lodging, automotive, food, shopping, personal services, recreation, financial institutions, religious services, health care, emergency services, government facilities, transportation)	IV	9	1.30126	5	5	4	1	0	0	1	0	0	0	0	1	0
Total trip time (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Total trip time (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	0	0	0	0	0
Time to each destination (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Time to each destination (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Total trip mileage (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Total trip mileage (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	0	0	0	0	0
Mileage to each destination (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Mileage to each destination (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Total trip cost (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Total trip cost (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	0	0	0	0	0
Number of tolls and cost of each toll (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Number of tolls and cost of each toll (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	0	0	0	0	0
Start time required to catch other mode of transport (evaluate & plan)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Mode of travel to take for each segment of travel (evaluate & plan)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Arrival time at end of each segment of travel (evaluate & plan)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Layover time between travel segments (evaluate & plan)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Arrival time at destination (evaluate & plan)	IV	10	0.53668	5	4	3	4	0	0	0	1	1	0	0	0	0
Total time to complete travel (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Total time to complete travel (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	0	0	0	0	0
Equipment types not allowed on roadway (identify)	IV	10	0.53668	5	4	3	4	0	1	0	0	0	0	0	0	0
Equipment types not allowed on roadway (evaluate)	IV	10	0.53668	5	4	3	4	0	0	0	1	0	0	0	0	0
Transit schedules in areas along route	IV	10	0.59955	5	4	3	3	0	0	0	1	1	0	0	0	0
Squalls	IV	10	0.59955	5	4	3	3	0	1	0	0	0	0	0	0	0
Approved parking locations for types (identify)	IV	10	0.59955	5	4	3	3	0	1	0	0	0	0	0	0	0
Approved parking locations for types (evaluate)	IV	10	0.59955	5	4	3	3	0	0	0	1	0	0	0	0	0
Weigh stations (locations and whether they are open) (identify)	IV	10	0.59955	5	4	3	3	0	1	0	0	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
Weigh stations (locations and whether they are open) (evaluate)	IV	10	0.59955	5	4	3	3	0	0	0	1	0	0	0	0	0
Typical congestion of a route (identify)	IV	10	0.59955	5	4	3	3	0	1	0	0	0	0	0	0	0
Typical congestion of a route (evaluate)	IV	10	0.59955	5	4	3	3	0	0	0	1	0	0	0	0	0
Miles until truck is out of fuel	IV	10	0.59955	5	4	3	3	0	1	0	0	0	0	1	0	0
Start time required to catch other mode of transport (coordinate)	IV	10	0.66318	4.5	4	3	4	0	0	0	0	0	0	1	0	0
Mode of travel to take for each segment of travel (coordinate)	IV	10	0.66318	4.5	4	3	4	0	0	0	0	0	0	1	0	0
Arrival time at end of each segment of travel (coordinate)	IV	10	0.66318	4.5	4	3	4	0	0	0	0	0	0	1	0	0
Layover time between travel segments (coordinate)	IV	10	0.66318	4.5	4	3	4	0	0	0	0	0	0	1	0	0
Arrival time at destination (coordinate)	IV	10	0.66318	4.5	4	3	4	0	0	0	0	0	0	1	0	0
Types of roads on route (identify)	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
Types of roads on route (evaluate)	IV	10	0.92707	5	3	3	3	0	0	0	1	0	0	0	0	0
Summary of turns or roadway changes (identify)	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
Summary of turns or roadway changes (evaluate)	IV	10	0.92707	5	3	3	3	0	0	0	1	0	0	0	0	0
Historical congestion information (identify)	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
Historical congestion information (evaluate)	IV	10	0.92707	5	3	3	3	0	0	0	1	0	0	0	0	0
Information on road closures and restrictions	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
General weather forecast for a specific area	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
Weight limits (identify)	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
Weight limits (evaluate)	IV	10	0.92707	5	3	3	3	0	0	0	1	0	0	0	0	0
Overhead restrictions (identify)	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	0
Overhead restrictions (evaluate)	IV	10	0.92707	5	3	3	3	0	0	0	1	0	0	0	0	0
Precise information regarding vehicle performance (may be > 50 parameters)	IV	10	0.92707	5	3	3	3	0	1	0	0	0	0	0	0	1
Time and distance to weather conditions	IV	10	1.26159	4	3	3	4	0	1	0	0	0	0	0	0	0
Snow ahead	IV	10	1.26159	4	3	3	4	1	1	0	0	0	0	0	0	0
Time and distance to traffic congested area	IV	10	1.28958	4	3	3	3	0	1	0	0	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
States, regions, communities and districts along the route (identify)	IV	10	1.37665	5	3	4	3	0	1	0	0	0	0	0	0	0
States, regions, communities and districts along the route (evaluate)	IV	10	1.37665	5	3	4	3	0	0	0	1	0	0	0	0	0
Confirmation of reservation	IV	10	1.48282	4	4	4	3	0	0	0	0	0	0	0	0	1
No danger indicator (all other CA systems)	IV	10	1.6804	5	5	2	3	0	1	0	0	0	0	0	0	1
No danger indicator (backing devices)	IV	10	1.6804	5	5	2	3	0	1	0	0	0	0	0	0	1
No danger indicator (driver monitoring)	IV	10	1.6804	5	5	2	3	1	1	0	0	0	0	0	0	0
details (cost, vacancy, chain)	IV	11	0.46303	5	4	3	1	0	1	0	1	0	0	0	0	0
Price ranges of lodging along route	IV	11	0.46303	5	4	3	1	0	1	0	1	0	0	0	0	0
Vacancy status of hotels along route	IV	11	0.46303	5	4	3	1	0	1	0	1	0	0	0	0	0
Complete map of route (identify)	IV	11	0.46303	5	4	3	1	0	1	0	0	0	0	0	0	0
Approved fueling locations (identify)	IV	11	0.46303	5	4	3	1	0	1	0	0	0	0	0	0	0
Approved fueling locations (evaluate)	IV	11	0.46303	5	4	3	1	0	0	0	1	0	0	0	0	0
Truck stops (identify)	IV	11	0.46303	5	4	3	1	0	1	0	0	0	0	0	0	0
Truck stops (evaluate)	IV	11	0.46303	5	4	3	1	0	0	0	1	0	0	0	0	0
Fuel costs (identify)	IV	11	0.46303	5	4	3	1	0	1	0	0	0	0	0	0	0
Fuel costs (evaluate)	IV	11	0.46303	5	4	3	1	0	0	0	1	0	0	0	0	0
Location of and distance to restaurant	IV	11	0.70314	4	4	3	1	0	1	0	0	0	0	1	0	0
Location of and distance to lodging	IV	11	0.70314	4	4	3	1	0	1	0	0	0	0	1	0	0
Location of and distance to gas station	IV	11	0.70314	4	4	3	1	0	1	0	0	0	0	1	0	0
Location of and distance to nearest rest area	IV	11	0.70314	4	4	3	1	0	1	0	0	0	0	1	0	0
Fuel taxes (identify)	IV	11	0.80895	5	4	3	2	0	1	0	0	0	0	0	0	0
Fuel taxes (evaluate)	IV	11	0.80895	5	4	3	2	0	0	0	1	0	0	0	0	0
Times of day or week that may affect delivery	IV	11	0.80895	5	4	3	2	0	0	0	0	0	0	1	0	0
Traffic/congestion ahead	IV	11	0.96664	4	4	3	2	1	1	0	0	0	0	0	0	0
General real-time traffic information	IV	11	0.96664	4	4	3	2	0	1	0	0	0	0	0	0	0

Message	Group	Cluster	Distance	Time	Criticality	Link	Independence	A	I	S	E	P	D	CO	CN	M
How far/how long traffic is backed up	IV	11	0.96664	4	4	3	2	0	1	0	0	0	0	1	0	0
Map showing areas of mild, moderate and severe congestion	IV	11	0.96664	4	4	3	2	0	1	0	0	0	0	0	0	0
Index of yellow pages and information from the Trucker's Atlas	IV	11	1.02684	5	5	3	1	0	0	1	0	0	0	0	1	0
Inform driver of ways to correct problem	IV	11	1.28623	4	3	3	1	0	0	0	0	1	1	0	0	0
Distance and time to destination	IV	11	1.43332	5	5	2	1	0	1	0	0	0	0	0	0	0
Route markers	IV	12	0.70156	3	4	3	4	0	1	0	0	0	0	1	0	0
Next destination	IV	12	0.78561	3	4	3	3	0	1	0	0	0	0	0	0	0
Restaurant type/style (e.g., Japanese, American, etc.) (identify)	IV	12	0.8615	3	5	3	4	0	1	0	0	0	0	0	0	0
Restaurant names (identify)	IV	12	0.8615	3	5	3	4	0	1	0	0	0	0	0	0	0
Closest lodging with vacancy (identify)	IV	12	0.8615	3	5	3	4	0	1	0	0	0	0	0	0	0
Specific destinations (e.g., sports venue, nature attraction, coffee shop, post office, school, convenience store) (identify)	IV	12	0.8615	3	5	3	4	0	1	0	0	0	0	0	0	0
Recreational activities (e.g., hiking, bicycling, boat tours, fishing, sail boating, surfing, downhill skiing) (identify)	IV	12	0.8615	3	5	3	4	0	1	0	0	0	0	0	0	0
Name of current street	IV	12	0.99609	3	4	2	3	0	1	0	0	0	0	0	0	0
Final destination	IV	12	1.05697	4	4	3	3	0	1	0	0	0	0	0	0	0
Number of lanes in next toll booth	IV	12	1.11453	3	5	2	3	0	1	0	0	0	0	0	0	0
Cost of next toll along route	IV	12	1.11453	3	5	2	3	0	1	0	0	0	0	0	0	0
Vehicle's current position	IV	12	1.22155	4	4	2	3	0	1	0	0	0	0	0	0	0
Lanes closed ahead	IV	12	1.22155	4	4	2	3	1	1	0	0	0	0	0	0	0
Mile posts	IV	12	1.53857	3	4	3	5	0	1	0	0	0	0	1	0	0
Relative locations of emergency vehicles to you on a map	IV	12	1.69328	4	4	3	5	0	1	0	0	0	0	1	0	0
								51	153	10	39	29	16	25	17	19

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