In-Vehicle Display Icons and Other Information Elements

Volume II: Final Report

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U.S. Department of Transportation
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Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

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 a summary of the analytical, empirical, and integrative phases of the *In-Vehicle Display Icons and Other Information Elements* project. It is an overview of the process used to meet the primary goal of the project: to provide designers of in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements.

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Michael Trentecoste
Director
Office of Safety Research and Development
Federal Highway Administration

NOTICE

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16. Abstract:
Because of the speed with which IVIS devices are entering the automotive marketplace, many research issues associated with the design of in-vehicle visual symbols and other information elements have not been adequately addressed. The overall goal of the *In-Vehicle Display Icons and Other Information Elements* project has been to provide the designers of these in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements. Specific objectives of this project were to:

- Design and perform experimentation to select appropriate symbols for in-vehicle use, then analyze the resulting data to write final guidelines for in-vehicle symbols usage encompassing both current and future symbols.
- Write preliminary, as well as empirically based, final guidelines.

The key product of this project is a set of clear, concise, and user-centered human factors design guidelines for in-vehicle icon design. The guidelines address issues such as the legibility, recognition, interpretation, and evaluation of graphical and text-based icons and symbols. These guidelines provide IVIS developers with key information regarding the use and integration of existing and new visual symbols. In addition, the Icon IDEA software tool developed in this project has provided a real-time icon development and evaluation tool that, to-date, is receiving consistently positive reviews from the project's working group members. This tool is entirely functional and ready to use, and should prove to be an invaluable aid and resource for icon design.

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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 yard	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 degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	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 degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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 March 2003)

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LIST OF ACRONYMS

ASR .... Automatic Speech Recognition
ATIS .... Advanced Traveler Information Systems
CAS .... Collision Avoidance Systems
CVO .... Commercial Vehicle Operations
DOT .... Department of Transportation
FHWA .... Federal Highway Administration
HUD .... Head-Up Display
IPE .... Information Processing Elements
ISO .... International Organization for Standardization
ITS .... Intelligent Transportation Systems
IDEA .... Interactive Development and Evaluation Assistant
IVIS .... In-Vehicle Information System
MUTCD .... Manual on Uniform Traffic Control Devices
SAE .... Society of Automotive Engineers

EXECUTIVE SUMMARY

Recent and near-term development and deployment of Intelligent Transportation Systems (ITS) such as Advanced Traveler Information Systems (ATIS) and Collision Avoidance Systems (CAS) suggest that drivers will soon be faced with a host of new visual, auditory, and tactile information. In-Vehicle Information Systems (IVIS) technologies share the common goal of increasing public safety and reducing costs associated with accidents, collisions, and congestion. However, the distinctive and complex nature of IVIS devices suggests that these systems have the potential to further strain driver capabilities and that, if not carefully implemented, they may actually exacerbate existing traffic problems. Drivers have always had to time-share their attention between internal (e.g., speedometers) and external (e.g., traffic control devices) sources of information, but ITS technologies represent new frontiers for in-vehicle information systems.

The overall goal of the *"In-Vehicle Display Icons and Other Information Elements"* project has been to provide designers of these in-vehicle technologies with a set of design guidelines for these icons and other information elements. Specific objectives of this project were to:

- Design and perform experimentation to select appropriate symbols for in-vehicle use, then use the resulting data to write final guidelines for in-vehicle symbols usage encompassing both current and future symbols.
- Write preliminary, as well as empirically based, final guidelines.

IVIS devices are entering the automotive marketplace so quickly that many research issues associated with the design of in-vehicle visual symbols and other information elements have not been adequately addressed. Chief among these issues is 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. Also, 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. 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 these systems is developed and shared with industry.

The key product of this project is a set of clear, concise, and user-centered human factors design guidelines for in-vehicle icon design. The guidelines address issues such as the legibility, recognition, interpretation, and evaluation of graphical and text-based icons and symbols. These guidelines provide IVIS developers with key information regarding the use and integration of existing and new visual symbols.

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

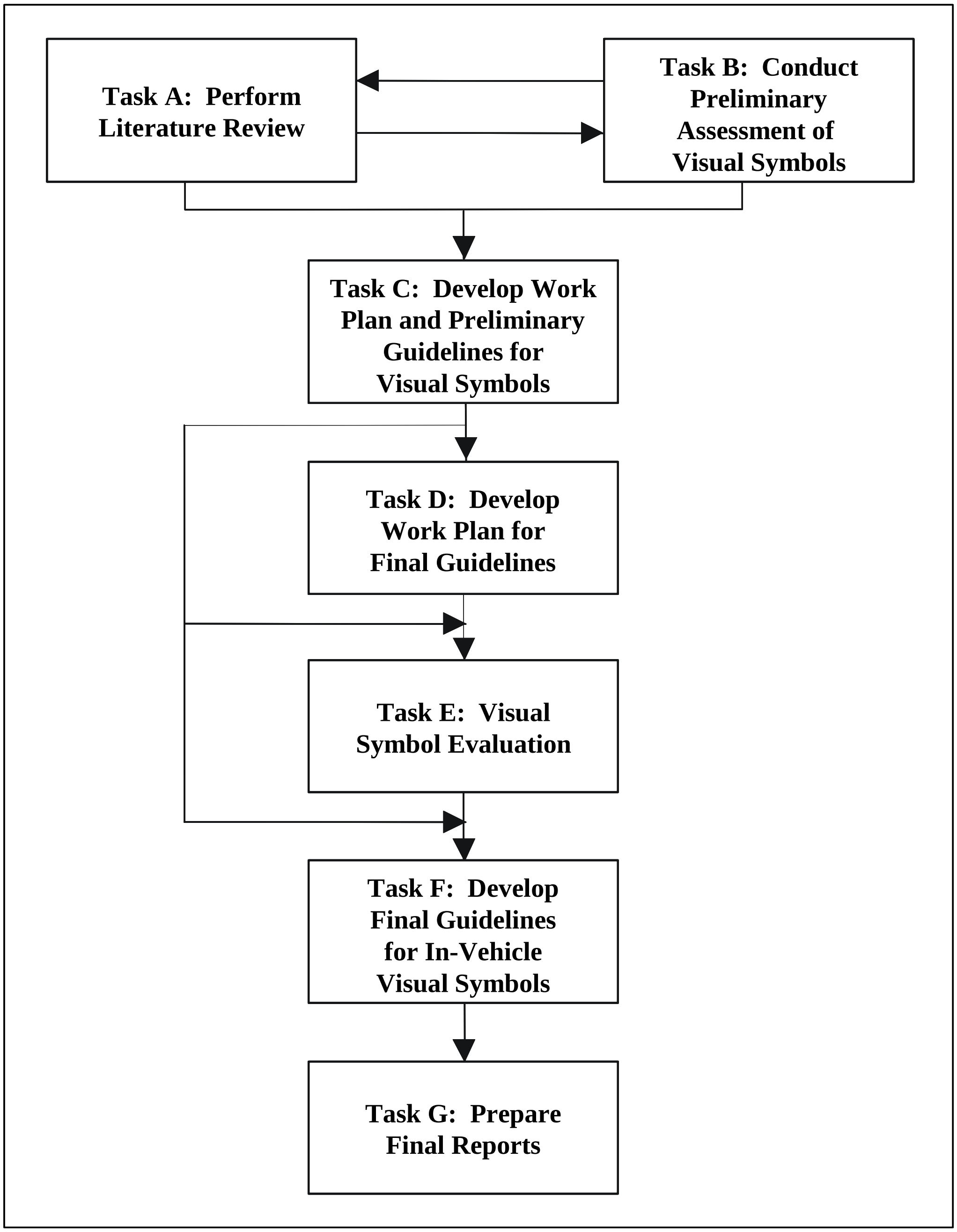

Figure 1. The Flow of Project Activities

As noted above, the overall goal of the *In-Vehicle Display Icons and Other Information Elements* project has been to provide the designers of in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements. The final design guidelines provided in Volume I of this project have clearly achieved this goal. These clear, relevant, and easy-to-use guidelines provide up-to-date information on a number of topics critical to icon development and evaluation.

Much of the impetus behind the initial conceptualization of this project can be summed up by going back to two of the conclusions from the project's task A report:

1. The lack of guidelines and standards for icons has resulted in design by consensus, a lack of scientific rigor in icon development, and multiple icons for the same messages.
2. Existing literature and standards provide little guidance for the design of new icons for IVIS devices.

In short, the transportation system design community—and, indeed, the larger electronics/computer industry—has not had the benefit of a single information source that provided clear, relevant, and useful guidance for icon design. The final guidelines produced in this project therefore fill a critical gap in the transportation human factors literature.

In addition, the Icon Interactive Development and Evaluation Assistant (Icon IDEA or IDEA) software tool developed in this project has provided a real-time icon development and evaluation tool that, to date, is receiving consistently positive reviews from the project's working group members. This tool is entirely functional and ready to use, and should prove to be an invaluable aid and resource for icon design. Also, the technical reports, conference papers, and conference presentations developed during this project provide a permanent record on a number of substantive issues related to icon design that may not yet be incorporated into either the final design guidelines or the IDEA software tool.

CHAPTER 1: INTRODUCTION

Recent and near-term development and deployment of Intelligent Transportation Systems (ITS) such as Advanced Traveler Information Systems (ATIS) and Collision Avoidance Systems (CAS) suggest that drivers will soon be faced with a host of new visual, auditory, and tactile information. In-Vehicle Information Systems (IVIS) technologies share the common goal of increasing public safety and reducing costs associated with accidents, collisions, and congestion. However, the distinctive and complex nature of IVIS devices suggests that these systems have the potential to further strain driver capabilities and that, if not carefully implemented, they may actually exacerbate existing traffic problems. Drivers have always had to time-share their attention between internal (e.g., speedometers) and external (e.g., traffic control devices) sources of information, but ITS technologies represent new frontiers for in-vehicle information systems.

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The flow of tasks in the project is shown in figure 2. As seen in the figure, the project consisted of a mix of analytical (tasks A and B), empirical (tasks D and E), and integrative (tasks C and F) activities.

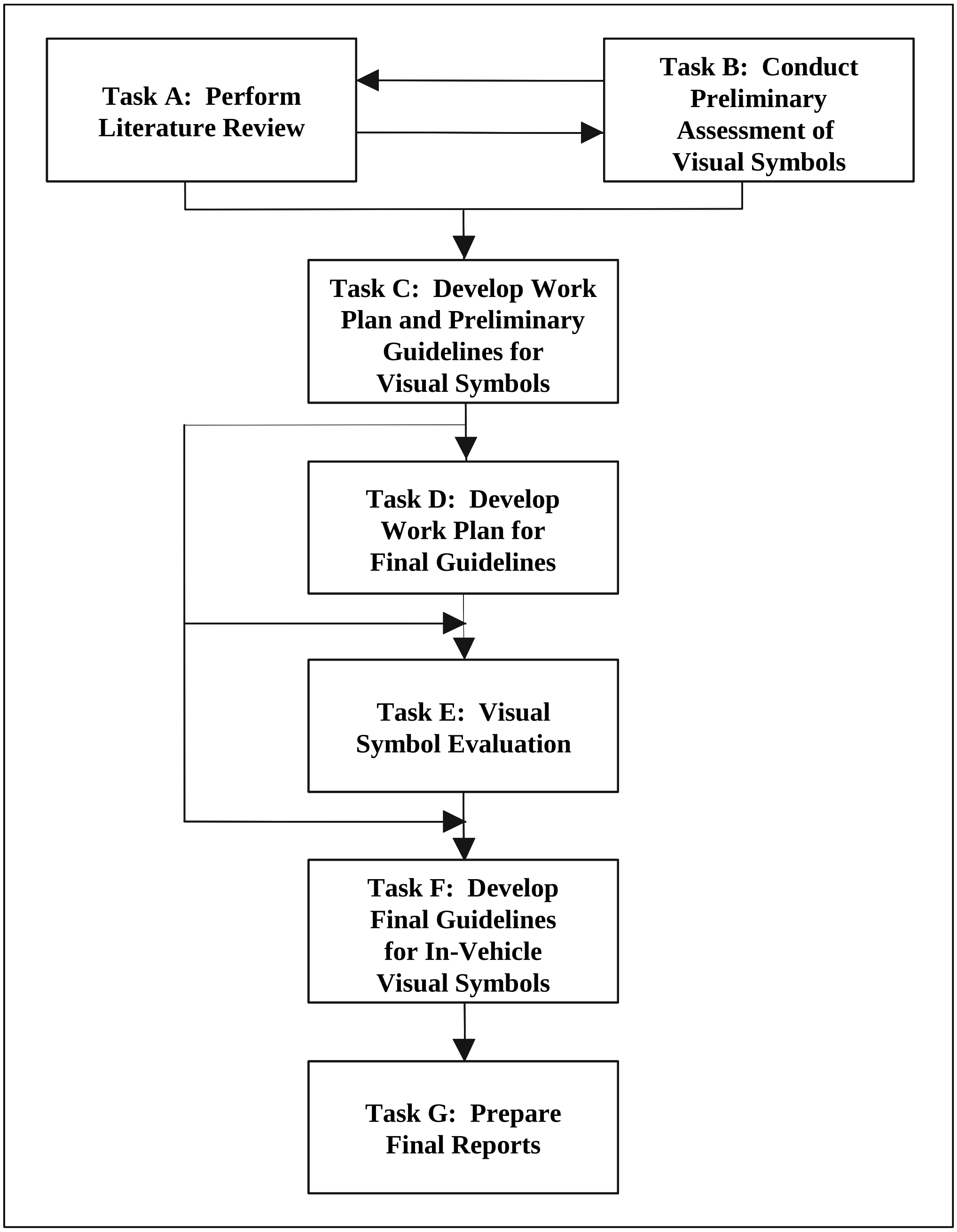


Figure 2. The Flow of Project Activities (as presented in figure 1)

In broad terms, the analytical activities (tasks A and B) provided a review of current in-vehicle icon use and designer needs for human factors information for in-vehicle icons; empirical activities (tasks D and E) consisted of experiments to address high-priority research gaps in the icon design literature; and integrative activities (tasks C and F) included the development of both preliminary and final human factors design guidelines for in-vehicle icons.

A key element of the project has been the participation of a project working group, consisting of transportation and computing professionals from automotive manufacturers, in-vehicle systems vendors, academia, software companies, and the ITS and human factors communities. A full list of the past and current working group for this project is provided in appendix A. The working group has helped to ensure that design guidelines resulting from this project conform to icon designers' specific needs with respect to content, organization, and format. Specific activities of the working group have been to:

- Participate in regular teleconferences to discuss project status, deliverables, and future plans.
- Review project reports and provide feedback.
- Provide relevant information and documents to the project team.
- Identify the needed content, organization, and format for the guidelines.
- Serve as reviewers for the in-progress guidelines.
- Provide more formal evaluation of the draft guidelines handbook.

This report provides one project deliverable associated with task G: "Prepare Final Reports." The purpose of task G is to provide final documentation of the objectives, methods, and results from this project. The remainder of this report is presented in two sections. The "Summary of Project Tasks" section describes the objectives, conduct, and results from tasks A–F of this project. The "Results and Conclusions Section" summarizes the project's key products and benefits.

CHAPTER 2: SUMMARY OF PROJECT TASKS

This section of this report summarizes the following project tasks:

- Task A: Perform Literature Review.
- Task B: Conduct Preliminary Assessment of Visual Symbols.
- Task C: Develop Workplan and Preliminary Guidelines for Visual Symbols.
- Task D: Develop Workplan for Final Guidelines.
- Task E: Evaluate Visual Symbols.
- Task F: Develop Final Guidelines for In-Vehicle Visual Symbols.

TASK A: PERFORM LITERATURE REVIEW

The purpose of task A was to conduct a review of relevant symbols and research, including the use of symbols by manufacturers and after-market vendors for existing and planned in-vehicle systems. The methodology employed included examining articles collected as part of the previous guideline development efforts, conducting extensive database searches, and accessing the Internet to gather information regarding the most current use of symbols in existing and future in-vehicle information systems. More than 200 articles, several books, and more than 100 Web sites were found via this methodology.

Once all of the literature was gathered, it was reviewed to determine its relevance to the current project. Specifically, attention was given to including information relevant to:

- The definition of an icon, design and evaluation of symbols, and models of symbol recognition and understanding.
- The effect of symbol mode (e.g., visual, auditory, tactile).
- The effects of symbol content and format.
- Driver information needs for in-vehicle messages (ATIS and CAS).
- Current use of symbols and icons by manufacturers and after-market vendors.
- Evaluation practices for icons and symbols.
- Existing standards and guidelines (e.g., Society of Automotive Engineers (SAE), International Organization for Standardization (ISO), and the *Manual on Uniform Traffic Control Devices* (MUTCD)).

The review comprehensively captured the status of icon/symbol research and applications and, most importantly, provided a solid foundation for subsequent tasks in this project. The following conclusions emerged from the review and analyses of the literature for icon and symbol research and current applications:

The lack of guidelines and standards for icons has resulted in design by consensus, a lack of scientific rigor in icon development, and multiple icons for the same messages. A number of sources for existing transportation symbols and icons were found during this literature review. They provided symbols and icons for numerous transportation applications (i.e., road signs, traveler information, warnings, etc.). However, during our investigation of these sources, it became clear that the process of developing and choosing icons is very subjective. Icons are frequently incorporated into system designs on the basis of consensus, opinions, and aesthetic preferences of the system development team. While such a process can result in an effective icon (as evidenced by the many effective icons in use in in-vehicle devices), it also runs the risk of producing unclear and ineffective icons.

Existing literature and standards provide little guidance for the design of new icons for IVIS devices. The majority of literature relevant to the design of icons can be placed into one of two categories: (1) a general discussion on the development of symbols (i.e., what they are, why they should be used, and how they work), or (2) proposed methods for the evaluation of symbols and demonstrations of these evaluations using existing symbols. Although the existing literature helps provide background information necessary to understand how we derive meaning from icons and symbols, it does little to aid in the development of design guidelines for new icons.

General design principles for icon design are sufficient to avoid development of a "bad" icon, but are not specific enough to support development of the "best" icon. The review and integration activities suggested that a number of general principles for icon design are available to IVIS developers. These include the structure, shape, and color of icons. However, for several reasons, these guidelines are not sufficient to support the development of optimum, or "best," icons. First, these principles, like many human factors guidelines materials, are not specific enough. For example, they identify how icon shape can affect comprehension. But how do designers select a shape to begin with? How does a designer start with "givens," such as a driving context and driver information needs, and identify a shape that matches these "givens?" Second, it is difficult for designers to know how to apply the principles in any given situation. For example, when is the structure of an icon more important than its shape? Are there times when the conspicuity of an icon (such as a collision avoidance warning) is more important than the details of its physical design? How do color and shape interact to impact the driver's interpretation of an icon or symbol? Third, existing principles do not provide adequate guidance on issues such as how to "match" an icon with its associated message. In this regard, available principles for icon design do not generally address the importance of information elements (the purpose of the icon, such as alert, inform, plan, and decide) to the driver's accurate interpretation and effective use of icons. Thus, there are still considerable gaps between the needs of icon developers and the availability of human factors design information.

Development of new icons and symbols for in-vehicle devices will require iterative testing and evaluation; existing test and evaluation methods provide sufficient scientific rigor for future evaluations of icons and symbols. The interpretation and ultimate utility of icons and symbols depend on the relationship, or "match," between the message and the graphic elements selected to convey the message. Unfortunately, there is no immediate or obvious method of determining this "match," given the variability associated with IVIS devices, IVIS messages, and drivers.

Therefore, good icon design requires development of a range of candidate icons and, equally important, iterative testing and evaluation of these candidate icons.

Despite industry concerns over the utility and relevance of human factors design guidelines, rigorous and proven methods for design guideline development exist and will be used in tasks C and F of this project. Designers of advanced automotive displays have criticized many existing human factors reference materials for being too wordy, too general, and too hard to understand, and have requested guidance that is concise, specific, and clear.[(1)] In particular, three challenges are associated with the development of human factors design guidelines for in-vehicle icons and symbols: (1) the lack of human factors design criteria; (2) the development of selection criteria for data sources used to produce guidelines; and (3) variability in the user population of human factors design guidelines.[(1,2)]

Despite these challenges, a number of successful design guidelines for ATIS, CAS, and other in-vehicle devices have been developed. [(3,4)] The general procedures used in these efforts were used to guide design guideline development activities in tasks C and F of the current project.

TASK B: CONDUCT PRELIMINARY ASSESSMENT OF VISUAL SYMBOLS

Task B in this project served two very useful purposes. First, it identified credible procedures, heuristics, and principles for the joint use of visual, auditory, and tactile information to present in-vehicle messages. The task B report documented the underlying rationale for selection of display modality by reviewing the relevant literature and assessing the current state of knowledge. Second, task B defined 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, task B provided design guidance for the joint use of visual, auditory, and tactile information presentation and provided a foundation for future design tools that could assist designers in specifying icon design for in-vehicle information technologies, particularly as they relate to ATIS.

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

1. Generate a list of IVIS messages.
2. Conduct review of literature relevant to sensory modality.
3. Evaluate IVIS messages 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 3 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 were used to develop the final product design requirements and tradeoffs for categories of IVIS messages.

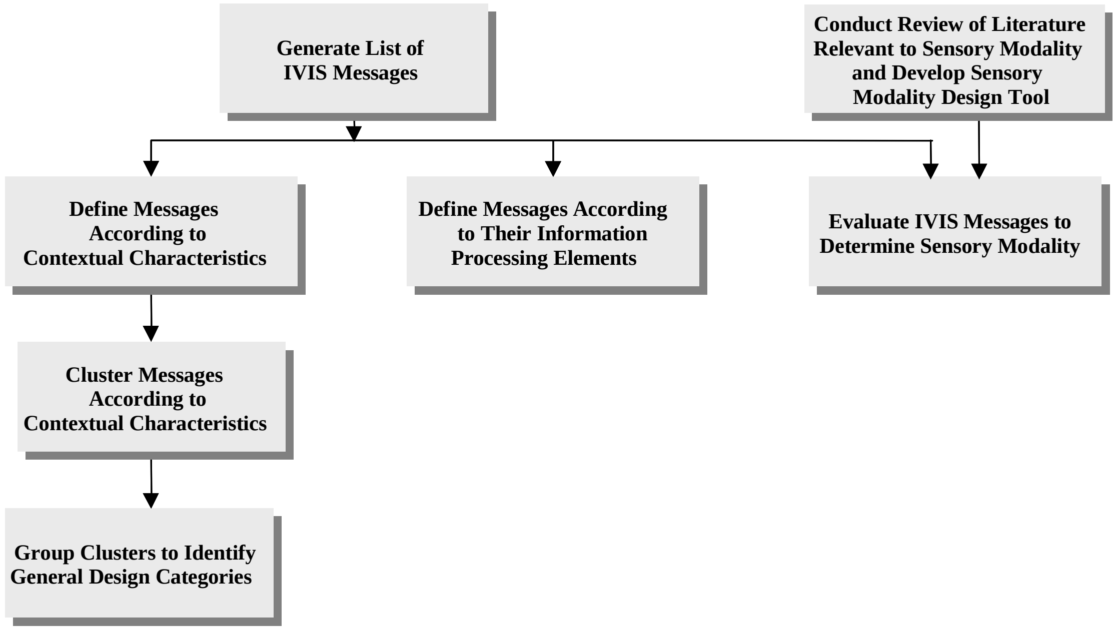


Figure 3. Flowchart of Task B Activities

One of the first steps completed during task B was to review the literature for information related to the development of rules for selecting display modes. An examination of these rules led 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 4.

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 IVIS messages that had been 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 4. Design Tool from Task B

The next step was to provide a more solid basis for design by defining the messages according to their contextual characteristics and the information processing elements they supported. Once this was complete, a cluster analysis was conducted; it identified 12 unique clusters of IVIS messages. To organize these clusters for interpretation, a further analysis identified 4 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	SAMPLE MESSAGES
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.	• Warning indicator (backing device). • Interchange ahead. • School bus stopped ahead.
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.	• Shortest route option. • Distance and time to turn. • System on and functioning (driver monitoring).
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.	• Inform driver of needed warranty services due. • System failure (all other Collision Avoidance systems). • Message acknowledged or received.
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.	• Remaining balance in toll account. • Total time to complete travel (identify). • Vacancy status of hotels along route.

Devising these design tools and analyzing the current list of relevant IVIS messages resulted in the following conclusions in task B:

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 led to 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 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 in a few instances 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 does catalog the range of messages and show similarities based on the IVIS capabilities they are meant to support. However, this organizing approach does not reflect several important characteristics of IVIS messages that can influence 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 that 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 Information Processing Elements (IPEs) associated with an IVIS message can be used successfully 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 element 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 4 contextual characteristics (with 5 levels within each), combined with the 9 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 future design guideline development efforts. Using statistical clustering techniques, the preliminary analysis identified four general message groups that 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 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.
3. The results of applying the sensory modality decision tool, which 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 provided the basis for more refined design guidelines developed as part of task C of this project.

A key challenge associated with task C would be to integrate the information provided in the task B report and develop clear, relevant, and easy-to-use design guidelines for in-vehicle icons. The task B report established some important relationships among 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 would 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.

TASK C: DEVELOP WORKPLAN AND PRELIMINARY GUIDELINES FOR VISUAL SYMBOLS

The overall goal of task C was to produce a set of preliminary human factors design guidelines for in-vehicle visual symbols. Toward this end, task C activities included three interrelated subtasks:

1. Developing a workplan for the preliminary guidelines.
2. Developing the preliminary guidelines.
3. Developing a working paper that explored information and symbology usage issues.

Each of these task C subtasks is discussed in more detail below.

Developing a workplan for the preliminary guidelines. The development of the *Human Factors Design Guidelines for In-Vehicle Symbols and Other Information Elements* was directed toward answering the following general question: What is the relationship between various symbol design parameters and a driver's ability to use automotive displays effectively and comfortably given variations in operating conditions, driving tasks, and driver demographics? In the human factors community, it is widely acknowledged that the majority of human factors/human performance research findings cannot be easily generalized to complex, real-world systems. This is often because such research is situation-specific (i.e., the results are highly dependent upon the environment, context, experimental task, subject demographics, etc. that identify a given study). Nonetheless, legitimate and much needed generalizations of the data are possible through careful and thoughtful integration of existing research findings.

Specifically, development of the guidelines was expected to include several essential elements: (1) a comprehensive database of existing information sources; (2) knowledge of the automotive display design environment, including tradeoffs and constraints; (3) analytical activities, including a clear definition of the criteria that will be used to determine the quality and applicability of data sources; (4) a willingness to apply experience and judgment to the development of human factors design guidelines; and (5) methods of presenting the design guidelines in a manner compatible with the user-community's needs and desires for the guidelines.

Figure 5 shows the overall design guideline development process presented in the task C workplan, while figure 6 shows the process for developing individual guidelines.

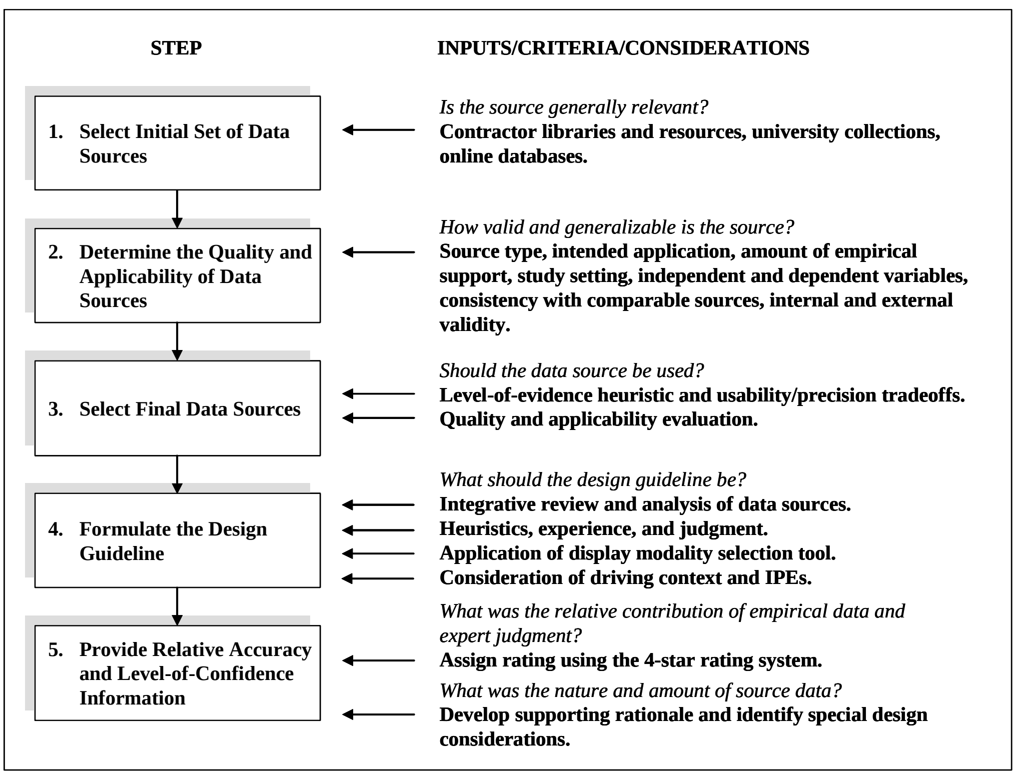


Figure 5. Flowchart of the Design Guidelines Development Process

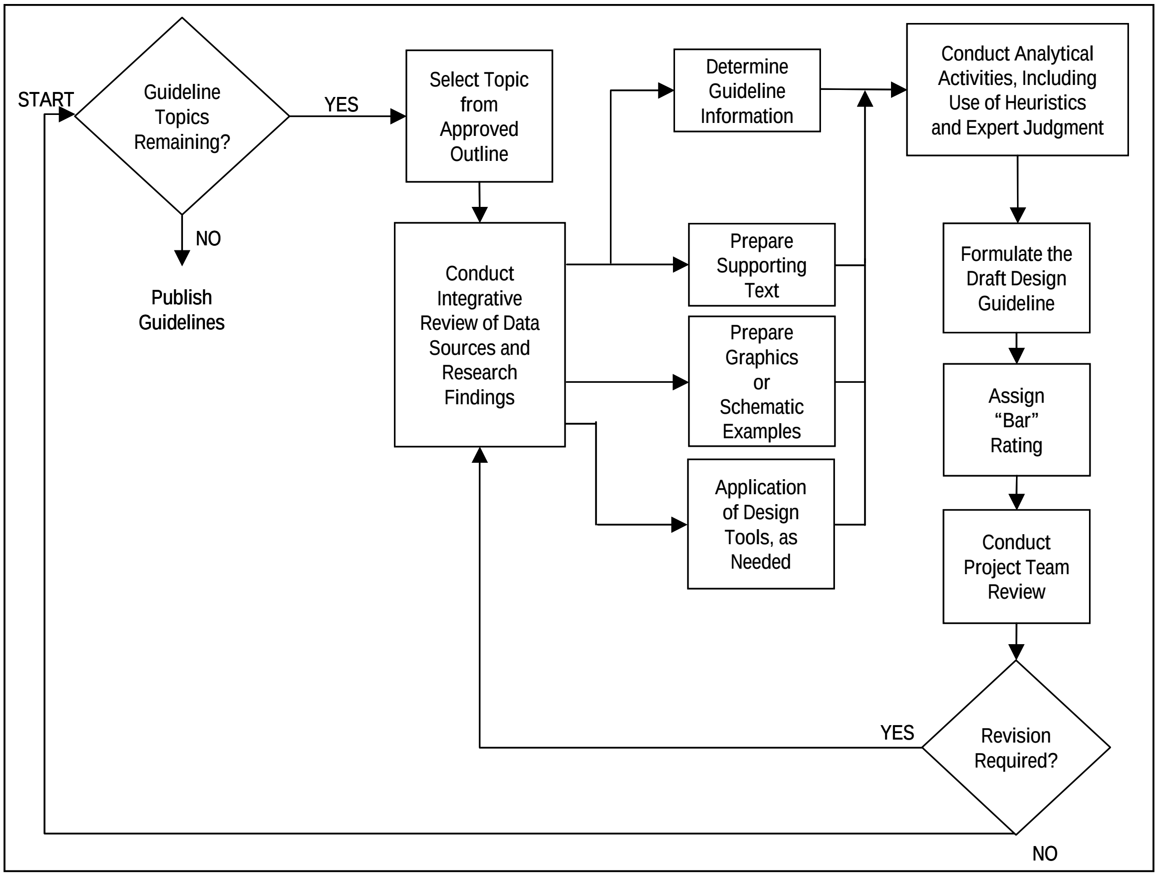


Figure 6. Developing Individual Guidelines

The preliminary design guidelines were expected to contain a similar content structure as that used in the Advanced Traveler Information Systems/Commercial Vehicle Operations (ATIS/CVO) design guidelines produced for the Federal Highway Administration (FHWA). The final content was expected to be determined after consultation with FHWA and the project working group members. Figure 7 summarizes the proposed table of contents for the preliminary guidelines.

For the preliminary design guidelines, a two-page presentation format was chosen to satisfy the conflicting requirements for having simple graphics versus more complex, detailed descriptions of "real world" design situations. A schematic example of the two-page format presented in the original workplan is shown in figure 8. The left-hand page presents the graphic data and simple supporting text, while the right-hand page provides the more detailed information that a human factors practitioner is likely to require in performing his or her design tasks.

Table of Contents for Preliminary Design Guidelines

Figure 7. Proposed Table of Contents for the Task C Preliminary Guidelines

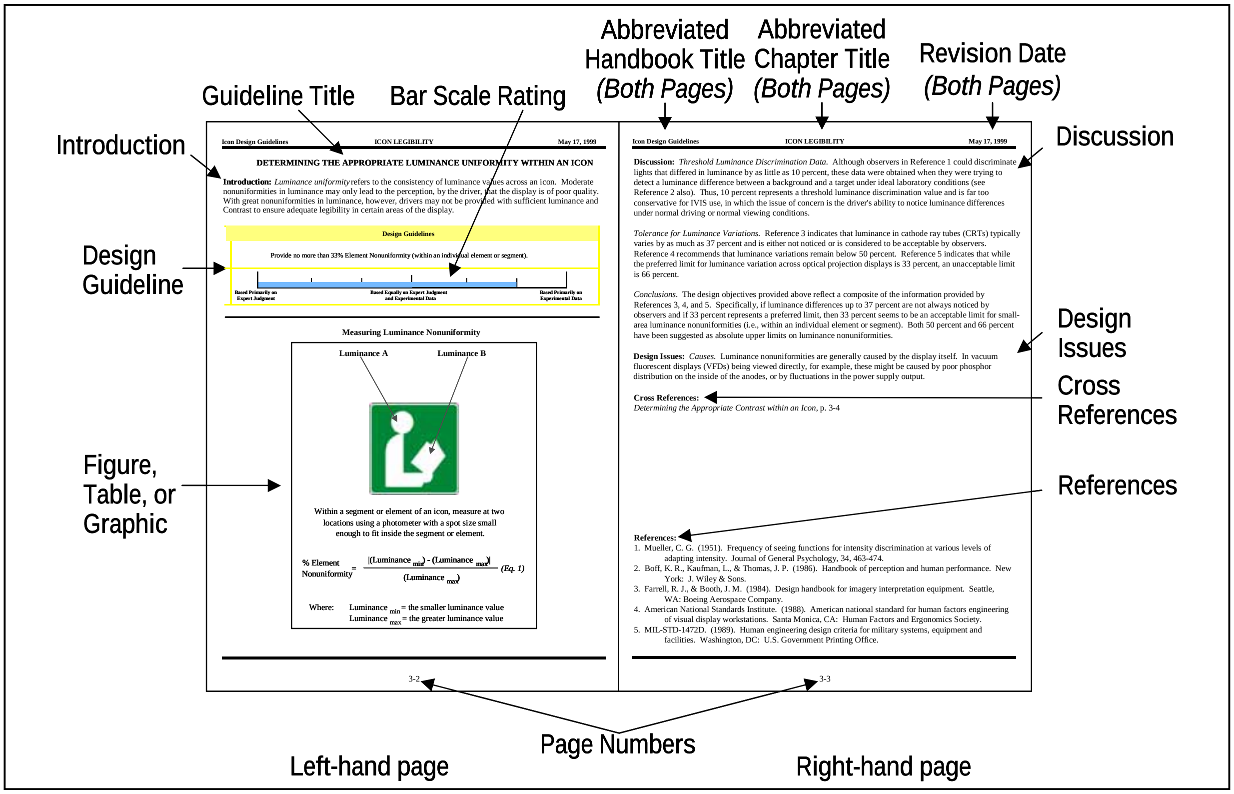


Figure 8. Sample of the Two-Page Format

The contractor's previous experience in developing human factors design guidelines provided us with a number of heuristics regarding "ideal" presentation formats. These heuristics included:

- The handbook should, as much as possible, present its information in graphic form.
- The preferred graphic is a figure, chart, or graph. Generally, representational figures are the most useful.
- Text information should also be included, but its primary functions should be to help explain the graphics.
- Text information should always be kept brief, perhaps limited to one- or two-line recommendations.
- Text information should be highly organized and tightly structured within each topic.
- When making design recommendations, references to original source material should be included.
- When possible, the implications of the design objective for human performance should be specified.
- When recommendations are made, they should be highly specific.
- Recommendations should not just be given in absolute terms, but should specify a range of acceptable values, if appropriate.

- The topics in the handbook should be arranged in such a way as to permit ready updating as new data are provided.

Developing the preliminary guidelines. The task C preliminary guidelines were subsequently developed according to the steps outlined in the workplan described above and distributed to both FHWA and the project working group members. The actual table of contents from these preliminary guidelines is shown below in figure 9.

TABLE OF CONTENTS **CHAPTER 1: HOW TO USE THE DESIGN GUIDELINES** INTRODUCTION TWO-PAGE FORMAT THE LEFT-HAND PAGE Introduction Design Guideline The Rating System Figure, Table, or Graphic THE RIGHT-HAND PAGE Discussion Design Issues Cross Reference References OTHER FEATURES	**CHAPTER 6: THE AUDITORY PRESENTATION OF IN-VEHICLE INFORMATION** Augmenting Icons with Auditory Information Determining the Appropriate Auditory Signal Design of Simple Tones Design of Earcons Design of Auditory Icons Design of Speech Messages Perceived Urgency of Auditory Signals General Design Guidelines for Automatic Speech Recognition Systems
CHAPTER 2: GENERAL ISSUES IN ICON DESIGN General Development Process for In-Vehicle Icons When to Use Icons Ways to Use Icons Types of Visual Icons Composition of an Icon Sequence of Icon Comprehension	**CHAPTER 7: EVALUATING IN-VEHICLE ICONS** Overview of Procedures for Evaluating In-Vehicle Icons Production Test Appropriateness Ranking Test Comprehension/Recognition Test Matching Test Additional Evaluation Approaches
CHAPTER 3: ICON LEGIBILITY Determining the Appropriate Luminance Uniformity within an Icon Determining the Appropriate Contrast within an Icon Determining the Appropriate Size of Icon Components Designing Effective Text Labels The Effects of Color on Icon Legibility	**CHAPTER 8: ICON COLLECTION** Routing and Navigation Information Motorist Services Information Augmented Signage Information Safety/Warning Information Commercial Vehicle Operations (CVO) Information General Navigation System Information Collision Avoidance Information Automated Cruise Control Devices
CHAPTER 4: ICON RECOGNITION Level of Realism Level of Detail Perceptual Principles of Icon Design Flash Rate Design of Prohibitive Symbols	**CHAPTER 9: TUTORIALS** Analysis of Rank Order Data **CHAPTER 10: DESIGN TOOL** Sensory Modality Design Tool **CHAPTER 11: EQUATIONS** **CHAPTER 12: GLOSSARY** **CHAPTER 13: LIST OF ABBREVIATIONS**
CHAPTER 5: ICON INTERPRETATION Enhancing Icon Interpretation with Text Labels Conveying the Effect of Actions with Icons Identifying Icons as Part of a Group Conveying System Status with Icons Enhancing Icon Interpretation with Color Conveying Urgency with Icons	**CHAPTER 14: REFERENCES** **CHAPTER 15: RELEVANT DOT, SAE, ISO DOCUMENTS** **LIST OF ICON WEB SITES** **SCOPE AND LIMITATIONS** **BACKGROUND** **CHAPTER 16: INDEX**

Figure 9. Contents from Preliminary Guidelines Handbook

Developing a working paper that explored information and symbology usage issues. The final task C activity was to develop and present an overview of key theoretical, development, empirical, or design issues associated with in-vehicle icons. This subtask provided an opportunity to consider the work that has been performed during previous project activities and to identify areas where additional analysis, empirical study, or guideline development was needed. In the task C5 report, ten key issues associated with in-vehicle visual symbols and information elements were identified and briefly discussed. These issues were:

1. The emergence of new and largely untested IVIS technologies.
2. Lack of empirical data for key icon design topics.
3. Lack of existing standards.
4. Selecting a symbolic metaphor for an IVIS message.
5. Designing by consensus.
6. Lack of design tools.
7. Device and/or technology dependencies.
8. Distributed versus centralized displays.
9. Amount of information displayed.
10. Auditory cues for attention-getting and localization.

TASK D: DEVELOP WORKPLAN FOR FINAL GUIDELINES

The purpose of task D was to build on the results of tasks B and C to create an updated workplan that would identify critical issues associated with icon design and specify empirical evaluations for symbol alternatives. Specifically, task D provided an opportunity to consider the work that had been performed during previous project activities and to identify specific experiments that are needed to address high-priority gaps in the preliminary guidelines developed in task C4.

The workplans developed during the conduct of task D were directed at key, high-priority human factors research issues for icon design and were identified during the six task D activities described below in figure 10.

The contractor made two recommendations to FHWA for the conduct of task E:

1. Conduct experiments 3 and 6 as described in option C.
2. Conduct experiment 2 (a low-cost, low-risk experiment) only as time and budget allowed, and as directed by FHWA.

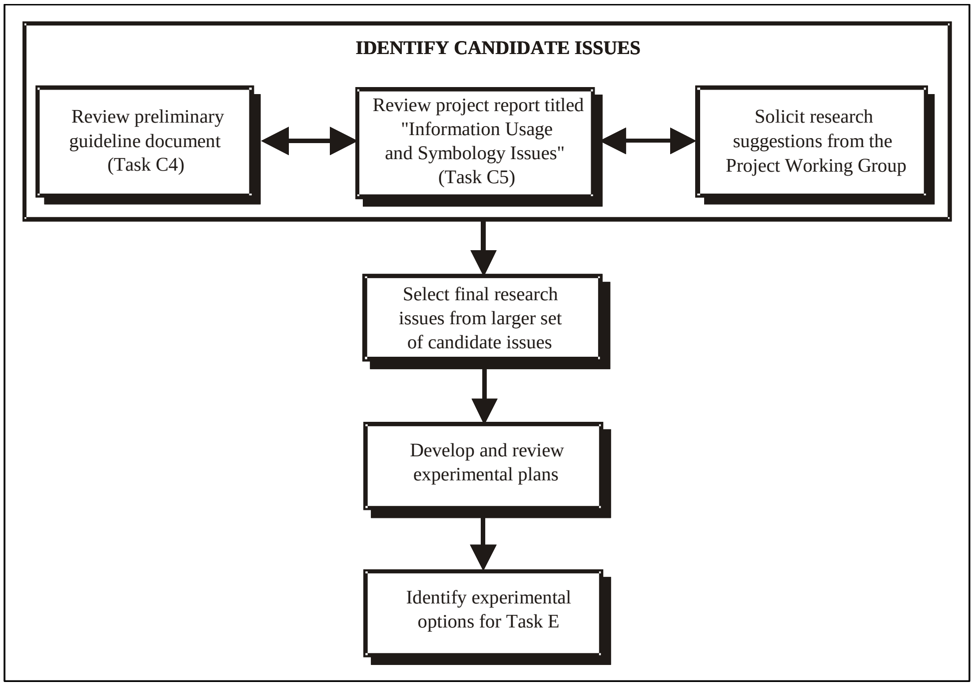


Figure 10. Flow of Task D Activities

In task D, project working group members were asked to solicit ideas for task E research topics. Between the working group members and the project team, 20 candidate research issues were identified. These candidate research issues, and their sources, are shown below in table 2.

Table 2. Candidate Research Issues Identified During the Early Phases of Task D

CANDIDATE RESEARCH ISSUE	SOURCE
• The effects of three different means of attracting driver attention (placement, auditory, flashing) on driver safety.	Preliminary Icon Design Guidelines (C4)
• The effects of flashing and animated icons on driver safety: Should they ever be used?	Preliminary Icon Design Guidelines (C4)
• The evaluation of several different types of collision warning symbols.	Preliminary Icon Design Guidelines (C4)
• How long should information be presented to the driver in order to ensure driver recognition and comprehension?	Preliminary Icon Design Guidelines (C4)
• How should information presentation be organized on a display—by priority or by subsystem?	Preliminary Icon Design Guidelines (C4)
• Can earcons be used effectively or are they equivalent to simple tones?	Preliminary Icon Design Guidelines (C4)
• Do auditory icons have any applications other than collision warning?	Preliminary Icon Design Guidelines (C4)
• How much information should be placed on the display at one time?	Information Usage and Symbology Issues (C5)
• Testing of previously untested IVIS technologies, such as collision warning systems.	Information Usage and Symbology Issues (C5)
• Effectiveness of Automatic Speech Recognition (ASR) systems for use in IVIS.	Information Usage and Symbology Issues (C5)
• Effectiveness of haptic displays for presenting in-vehicle information to drivers.	Information Usage and Symbology Issues (C5)
• Should information be centrally located on a display or distributed across displays for different subsystems?	Information Usage and Symbology Issues (C5)
• How resolution affects icon legibility, especially with respect to Head-Up Displays (HUDs).	Project Working Group
• Icons designed for use in non-color systems: Is color necessary for interpretation?	Project Working Group
• Complexity of interaction permissible with ASR systems.	Project Working Group
• How to identify earcons as part of a group.	Project Working Group
• Perceived annoyance of auditory signals.	Project Working Group
• When to use digitized versus synthetic speech.	Project Working Group
• Testing of a limited set of promising icons for particular applications (e.g., collision warning).	Project Working Group
• Timing of icon display relative to the auditory accompaniment.	Project Working Group

These 20 candidate research issues were reduced to six high-priority research issues through application of the following decision criteria to each of the 20 candidate issues:

- Is the issue directly relevant to the project?
- Can the experiment be performed within the project's budget and schedule constraints?
- Will the experiment yield high-quality human factors design guidelines for in-vehicle icons?

Application of these decision criteria yielded the six high-priority research issues shown below in table 3.[1]

Table 3. Research Issues Developed into Workplans

RESEARCH ISSUE
1. Evaluating the effects of three different means of diverting attention to in-vehicle information on driver safety.
2. An evaluation of collision warning symbols.
3. Auditory signals: Study of perceived urgency and perceived annoyance.
4. Integration of IVIS icons.
5. Interaction with an in-vehicle computer: Division of attention between an in-vehicle device and the roadway.
6. Generic vs. unique icons: Implications for driver understanding of IVIS messages.

For each of these six research issues, an experimental workplan was developed and then rated using a set of explicit decision criteria. Table 4 shows the table used for rating the key issues.[2]

[1] The titles of these issues are somewhat different from those listed in table 2 because some topics were combined and slightly modified.

[2] Raters used a 1-5 scale to indicate how true each of the statements was, with a rating of 5 used to indicate that the statement was entirely true and a rating of 1 used to indicate that the statement was entirely not true.

Table 4. Table for Rating Each of the Key Issues

	Decision Criteria							
Experiment Number and Title	**Relevant data currently lacking**	**Important for development of current systems**	**Important for development of future systems**	**Greatly impacts driver safety**	**Addresses a critical design need**	**Will generate general design guidelines for in-vehicle icons**	**Summed Score**	**Ranking**
Experiment 1— Evaluating the effects of three different means of diverting attention to in-vehicle information on driver safety								
Experiment 2—An evaluation of collision warning symbols								
Experiment 3—Auditory signals: Study of perceived urgency and perceived annoyance								
Experiment 4— Integration of IVIS icons								
Experiment 5— Interaction with an in-vehicle computer: Division of attention between an in-vehicle device and the roadway								
Experiment 6—Generic vs. unique icons: Implications for driver understanding of IVIS messages								

The results from this workplan evaluation process are shown below in table 5.

Table 5. Results of the Evaluations of the Six Workplans[3]

	Decision Criteria							
Experiment Number and Title	**Relevant data currently lacking**	**Important for development of current systems**	**Important for development of future systems**	**Greatly impacts driver safety**	**Addresses a critical design need**	**Will generate general design guidelines for in-vehicle icons**	**Summed Score**	**Ranking**
Experiment 1— Evaluating the effects of three different means of diverting attention to in-vehicle information on driver safety	3.00*	3.67	4.00	3.67	4.00	4.00	19.34	4.00
Experiment 2—An evaluation of collision warning symbols	3.67	4.33	4.00	4.67	3.67	1.67	22.01	5.00
Experiment 3—Auditory signals: Study of perceived urgency and perceived annoyance	3.67	3.33	3.33	3.00	3.33	3.00	19.66	6.00
Experiment 4— Integration of IVIS icons	4.67	3.00	5.00	3.33	3.33	4.33	23.66	3.00
Experiment 5— Interaction with an in-vehicle computer: Division of attention between an in-vehicle device and the roadway	4.00	4.33	5.00	4.33	3.67	3.00	24.33	1.00
Experiment 6—Generic vs. unique icons: Implications for driver understanding of IVIS messages	4.33	3.33	4.33	3.33	4.33	4.67	24.32	2.00

* mean value for all raters (5= true; 3= somewhat true; 1= not true)

[3] Only phase 1 of experiment 3 was rated.

Based on the results of the evaluations, several experimental options were developed, as shown below in table 6.

Table 6. Summary of Options A, B, C, and D

OPTIONS	COMBINED TECHNICAL PRIORITY	PREDICTED STRENGTH OF RESULTING GUIDELINES	OVERALL RISK (TECHNICAL, COST, SCHEDULE)
Option A: Experiment 4: *Integration of IVIS icons.* Experiment 6: *Generic vs. unique icons: Implications for driver understanding of IVIS messages.*	Medium	Medium	Low-Medium
Option B: Experiment 1: *Evaluating the effects of three different means of diverting attention to in-vehicle information on driver safety.* Experiment 2: *An evaluation of collision warning symbols.*	Low-Medium	Medium	Low-Medium
Option C: Experiment 3: *Auditory signals: Study of perceived urgency and perceived annoyance.* Experiment 6: *Generic vs. unique icons: Implications for driver understanding of IVIS messages.*	Medium	Medium	Low
Option D: Experiment 5: *Interaction with an in-vehicle computer: Division of attention between an in-vehicle device and the roadway.* Experiment 3: *Auditory signals: Study of perceived urgency and perceived annoyance.*	Medium	Medium	Medium-High

TASK E: EVALUATE VISUAL SYMBOLS

The objective of task E was to implement the experimental option selected by the FHWA in task D. As recommended in the task D report, FHWA indicated that option C should be implemented during the conduct of task E. The two sets of experiments conducted in task E, *Experiment 3: Urgency and Annoyance of Auditory Alerts*, and *Experiment 6: General versus Specific Icons: Implications for Driver Acceptance of IVIS Messages*, are discussed in more detail below.

Experiment 3: Urgency and Annoyance of Auditory Alerts

As in-vehicle information systems proliferate, the number of auditory alerts confronting the driver may increase dramatically. Auditory alerts alone or in combination with visual displays represent a promising approach to displaying information to drivers because they do not require drivers to look away from the roadway. Although promising, these systems must communicate their messages without distracting or annoying the driver. This study includes a series of five experiments focused on how sound parameters affect perceived annoyance, urgency, and appropriateness, and how these perceptions affect driving performance. This investigation had three specific objectives:

1. To determine the characteristics of sounds that affect perceived urgency and annoyance.
2. To determine whether the driving context affects perceived urgency and annoyance.
3. To determine whether perceived urgency and annoyance affect driving performance.

In the first four experiments, participants read a short description of a driving scenario and then rated and compared a series of sounds according to urgency, annoyance, and appropriateness. The short scenarios described the alert as a collision alert, a navigation alert, or an e-mail message notification. The fifth experiment used a driving simulator to investigate whether the sound parameters affecting urgency and annoyance also affected driving performance.

The experiments generated substantial support for the following findings:

- Like urgency, perceived annoyance is systematically related to auditory parameters.
- Auditory parameters do not uniformly affect perceived urgency and annoyance. This makes it possible to tailor sounds to maximize urgency and minimize annoyance. For example, to create a alert sound with a high urgency while minimizing annoyance, a high density, a slow speed and frequency series should be used.
- The principles of urgency mapping and annoyance tradeoff provide useful tools to maximize the appropriate pairing of sounds to messages and driving context.

Table 7 summarizes the effect of sound parameters on perceived annoyance and urgency.

Table 7. The Rank Ordered Means of Experiments 3 and 4 Ratings for Annoyance in the E-Mail Scenario

EXPERIMENT 3						EXPERIMENT 4					
	Onset	Offset	Burst Density	Mean	SD		Density	Speed	Type*	Mean	SD
Sound 8	slow	slow	3-pulse	51.06	22.57	Sound 6	low	fast	H/i/	41.25	17.99
Sound 7	slow	slow	4-pulse	54.19	25.34	Sound 4	low	slow	FS	43.56	24.12
Sound 6	slow	fast	3-pulse	54.69	24.46	Sound 2	low	fast	FS	44.88	23.23
Sound 5	slow	fast	4-pulse	57.25	26.91	Sound 8	low	slow	H/i/	48.38	24.54
Sound 3	fast	slow	4-pulse	57.44	25.76	Sound 3	high	slow	FS	58.06	28.31
Sound 4	fast	slow	3-pulse	57.88	23.25	Sound 1	high	fast	FS	66.56	20.58
Sound 2	fast	fast	3-pulse	61.00	25.97	Sound 7	high	slow	H/i/	79.19	13.38
Sound 1	fast	fast	4-pulse	64.88	25.64	Sound 5	high	fast	H/i/	80.38	11.95
Overall Mean				57.30		Overall Mean				57.78	
Standard Deviation				4.26		Standard Deviation				15.93	

* H/i/—high harmonic series; FS—frequency series

The experiments also identified the following trends that merit further investigation:

- The driving context affects how sound parameters affect urgency and annoyance.
- Urgency of alerts for a collision can affect driving performance, suggesting that considering urgency in alert designs can enhance driving safety.
- Urgency may be a relative judgment rather than an absolute and easily recognizable characteristic of auditory alerts; measuring urgency in some evaluation contexts thus can be problematic.
- Perceived annoyance is more highly correlated with subjective workload than is urgency; annoyance thus may affect driving performance as well as acceptance.
- The degree to which perceived appropriateness depends on urgency and annoyance depends on the driving scenario. The perceived appropriateness of highly critical messages depends on perceived urgency, and the appropriateness of less critical messages depends on perceived annoyance.

This research provides some useful design guidance, but several important research issues remain. These include identifying the most appropriate sound parameterization, investigating how perceptions change with exposure, investigating the efficacy of short sounds, and identifying the dependency on scenarios.

Experiment 6: General versus Specific Icons: Implications for Driver Acceptance of IVIS Messages

The experiment 6 study examined issues associated with using general vs. specific icons to present in-vehicle information to drivers. The set of experiments addressed the following empirical questions:

- Can general icons effectively convey IVIS information to drivers?
- Does the effectiveness of general icons vary as a function of the type of information conveyed (e.g., ATIS vs. vehicle status vs. collision avoidance)?
- Is driver age associated with these issues?

For the purposes of this research, *general icons* were defined as those that provide the driver with information about a broad driving situation or class of conditions without specifying detailed information about the situation or conditions. For example, a general icon for the message "crash warning" would indicate that a crash is imminent, but would not convey information regarding the precise nature of the projected crash (e.g., side, front, or rear crash). S*pecific icons* were defined as icons that do provide more detailed information about a driving situation or conditions. For example, a family of specific crash warning icons could be used, with each icon describing the specific nature of the projected crash (e.g., side, front, or rear crash). Figure 11 shows some examples of general and specific icons for key in-vehicle message categories.

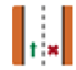
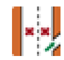
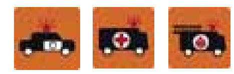
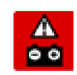
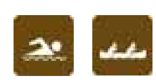
MESSAGE	GENERAL ICONS	SPECIFIC ICONS
Trip Navigation: Reduce Speed		
Trip Navigation: Lane Blocked		
Trip Navigation: Road Closed		
Trip Navigation: Emergency Vehicle		
Trip Navigation: Route Guidance		
Collision Avoidance System: Crash Warning		
Vehicle Condition Monitoring: Urgent Mechanical Problem		
Vehicle Condition Monitoring: Vehicle Maintenance Required		
ATIS (Motorist Services): Lodging		
ATIS (Motorist Services): Food		
ATIS (Motorist Services): Gas		
ATIS (Motorist Services): Water Recreation		

Figure 11. Examples of General and Specific Icons for Key In-Vehicle Message Categories

The study focused on driver comprehension and recognition of icons in a non-driving environment. The study had two phases. The objective of Phase 1 was to develop a set of icons for Phase 2 testing that met basic comprehension requirements. This was necessary because no icons have been standardized or commonly used for many future in-vehicle messages that may use icons. Before investigating the study objectives listed above, a set of specific and general icons for a range of IVIS functions meeting reasonable comprehension requirements was needed. In Phase 1, candidate general and specific icons were generated for a number of IVIS functions and driving scenarios. Then comprehension tests were conducted to identify how well these candidate icons conveyed their intended meanings. Phase 1 had two parts: Phase 1a consisted of initial comprehension testing of candidate general and specific icons; in Phase 1b, the Phase 1a icons not meeting basic comprehension levels (50 percent comprehension[4]) were redesigned and retested. Based on the results of the Phase 1a and 1b comprehension tests, a set of specific and general icons was identified for Phase 2 testing.

The objective of Phase 2 was to assess the degree to which general vs. specific icons matched subjects' understanding of a given driving situation and would be suitable for presentation on an IVIS. In Phase 2, all icons were presented within the context of a driving scenario. Phase 2 also had two parts: In Phase 2a, subjects were asked to rate how well a given icon described a particular driving scenario as well the icon's perceived effectiveness in helping them understand the situation and respond to it with the appropriate driving action. The results from Phase 2a were somewhat equivocal. Therefore, in Phase 2b, 69 younger and 78 older subjects were asked to select, from among four candidate icons, the most appropriate icon (only one icon could be selected) for depicting a given driving situation. In a separate question, they were also asked to indicate which of the four icons (they could select up to all four icons) would be acceptable for depicting the situation. A sample page from the Phase 2b response booklet is shown in figure 12 below.

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4 Fifty percent comprehension levels were chosen simply to ensure that icons tested in Phase 2 were not greatly different with respect to comprehensibility.

Driving scenario:

You are driving on the highway.
You are approaching a section of highway where some unusual activity is going on.
You may need to reduce your speed.

The In-Vehicle Information System in your car presents you with one of the icons shown below to inform you of the situation.

A

B

C

D

1) Please select **one icon** that <u>most accurately</u> conveys the driving scenario described above and circle the letter below which is associated with the selected icon.

A B C D

2) Which icon(s) above would be acceptable for this driving scenario? **You can select more than one icon**.

A B C D

Figure 12. A Sample Page from the Phase 2b Response Booklet

Experiment 6 Results

Effects of Driving Scenario Description Type. The effects of the *driving scenario description type* variable were associated with the strongest and most consistent effects in this Phase 2b study. When given a general scenario, subjects consistently chose a general icon as the most accurate for the situation. When given a specific scenario, subjects consistently chose a specific icon as the most accurate for the situation. Some exceptions were collision avoidance and water recreation; for these categories, specific icons were viewed as most accurate regardless of scenario description.

With respect to the acceptability of the icons, the driving scenario description (general or specific) had a slightly different effect. For the general scenarios, the general icons were always associated with acceptance levels above 80 percent. For the specific scenarios, the specific icons were always associated with acceptance levels above 80 percent. However, even with general scenarios, the specific icons were associated with at least 80 percent acceptance levels in 15 out of 23 message scenarios. With the specific scenarios, the general icons were associated with at least 80 percent acceptance levels in 20 out of 23 message scenarios. Overall, the subjects reactions to the icons were strongly influenced by their perception of the nature of the driving situation associated with an in-vehicle message.

Effects of Icon Type. As noted above, the effects of icon type (general vs. specific) were strongly mediated by the scenario descriptions given to subjects. General icons were selected as the most accurate when subjects were presented with a general scenario, and specific icons were selected as the most accurate when subjects were presented with a specific scenario. However, for two message categories—collision avoidance and water recreation—specific icons were selected as the most accurate icons regardless of the scenario description. For the collision avoidance icons at least, this suggests that specific icons are desired where safety is an issue, perhaps because drivers want to have as much information as is available.

These general findings however, should be considered in light of the question 2 (acceptability of icons) results. While the perceived accuracy of icons varied as a function of the scenario described to the subjects, high levels of acceptability were obtained for both the general and specific icons, regardless of scenario description. Specifically, the general icons resulted in 80 percent or higher levels of acceptance in 23 out of 23 messages in the general scenario description condition and in 20 out of 23 messages in the specific scenario description condition (exceptions were one of the three emergency vehicle messages and both vehicle maintenance messages). Therefore, it seems very clear that general icons can meet drivers' expectations and preferences for a broad range of IVIS messages.

Effects of Icon Message Category. These results have been discussed in the context of discussions for the other independent variables, but will be summarized again here. For both the collision avoidance and water recreation icon categories, specific icons were viewed as the most accurate regardless of scenario description. Unusual results were seen for the "emergency vehicle" messages. This is likely due to the generally low comprehension scores associated with these icons (especially the generic icon) from experiments 1a and 1b.

Effects of Distracter Icons. The only instance in which a distracter icon was selected as the most accurate was for the "vehicle maintenance required" message. The likely reason for this is that the distracter icon selected was a poor choice—it is the same as the generic icon used for "urgent mechanical problem."

Effects of Gender and Age. In both Phase 2a and Phase 2b, there were some scattered significant effects associated with gender and age. However, these effects were small, relatively few, and did not fall into any discernible pattern. For the "specific vs. general icon" question, age and gender seem to play, at most, a very minor role that should not influence icon design recommendations.

Overall, the task E, experiment 6 research resulted in the following design guidelines for icon developers:

- To minimize driver memory requirements and system complexity, general icons should be used as long as they do not negatively impact driver acceptance or driver performance. Well-designed general icons will be acceptable to most drivers under most driving circumstances.
- The strongest exception to this seems to be safety-related messages (e.g., collision avoidance icons). For safety-related messages, specific icons will provide higher levels of driver acceptance than general icons.

TASK F: DEVELOP FINAL GUIDELINES FOR IN-VEHICLE VISUAL SYMBOLS

The goal of task F was to develop final guidelines, based on the results and findings from previous project tasks. The same general guideline development procedures used in task C were to be used to produce the final guidelines.

In addition, in the fall of 2001, FHWA asked its contractor to develop another product from the Icon project. The preliminary guidelines from task C had included an "Icon Collection" of approximately 600 candidate icons organized by ITS functional areas, such as routing and navigation, motorist services, safety and warning information, collision avoidance, and commercial vehicle operations. With respect to this Icon Collection, a key issue of concern consistently voiced by the Icon Project Working Group was the lack of evaluative data included in the preliminary guidelines for these icons. Information regarding the degree to which these individual icons adhere to human factors design principles was not provided in the Icon Collection, nor were any suggestions made for improving individual icons. Working group members voiced concern that, without some information on the degree to which individual icons conform to human factors standards and principles, some users might inadvertently use unsuitable icons in their own in-vehicle applications. In response to this concern, FHWA asked the contractor to develop an interactive design tool for presenting individual candidate icons in the Icon Collection in a manner that also provided evaluative information about the icons.

Thus, task F included two parallel activities: (1) development of the final hardcopy human factors design guidelines, and (2) development of a database software tool. Each is discussed below.

Develop Final Guidelines

Development of the final design guidelines handbook included the following tasks:

- Review feedback from FHWA and the project working group.
- Revise table of contents for the final guidelines.
- Develop workplan for producing the final guidelines.
- Make editorial revisions to preliminary guidelines.
- Update preliminary guidelines with more recent data sources.
- Develop new guidelines based on more recent data sources.
- Develop new guidelines based on the task E experimental results.
- Add new chapter "Relevant USDOT, SAE, and ISO Documents."
- Update the Icon Collection.
- Add an index to the handbook.
- Update the "Tutorials," "Design Tool," "Equations," "Glossary," "Abbreviations," and "References" chapters to reflect all revisions to the handbook.

Figure 9 (shown earlier) illustrates the table of contents from the final design guidelines handbook.

Develop the Icon IDEA Software

As noted above, the goal of this effort was to develop an interactive design tool for presenting individual candidate icons in the Icon Collection in a manner that also provided evaluative information about the icons to icon developers. The database software tool (running under Microsoft® Access 1997 or 2000) developed in task F is called "Icon Interactive Development and Evaluation Assistant" or Icon IDEA. The preliminary version of Icon IDEA is complete; development included the following activities.

Develop Icon Database. Software specifications were developed for the icon database, defining the content and format requirements for storing icons to allow users access to the icons based on queries for vehicle function and message content. Identifying information associated with each icon includes the system function and subfunction, the intended message, the source of the icon, and the file name. Microsoft Access has been used for development of both the database and the user interface.

Develop Icon Evaluation Tool. Detailed icon evaluation procedures were developed and underwent lengthy internal testing and review. The evaluation focuses on physical, explicit icon features that have clear implications for user legibility, recognition, and interpretation. Each evaluation factor is well-supported by relevant research data. The tool consists of 28 questions that have been coded into Microsoft Access forms with active "buttons" to provide the appropriate sequencing of available user actions and input of data into the icon evaluation database. The 28 questions are organized into six categories: perceptual principles, level of detail, level of realism, use of color, prohibitive icons, and use of text. The tool allows for comparisons across raters for a given icon and supports the development of a "consensus" rater for developing final evaluation ratings.

Conduct Icon Evaluations. Using the icon evaluation tool, evaluations of the entire set of icons in the Icon Collection were conducted by multiple trained reviewers. Following the completion of these independent evaluations, a consensus process resulted in a final evaluation score for each icon.

Conduct Empirical Evaluations of Icon Comprehension. A separate set of comprehension evaluations was conducted for 100 of the icons in the Icon Collection. Comprehension tests were conducted using 160 paid test subjects who were representative of the driving population with respect to factors such as age, gender, and driving experience. Subjects were provided with a description of the context in which the icon would be used and then asked to describe the in-vehicle message that they believe was represented by the icon.

Develop User Interface. Interface development for Icon IDEA focused primarily upon user access to individual icons, evaluation results for the icons, the icon evaluation tool, and general design guidelines for icon development and evaluation. Buttons for major IDEA functions, supplemented by pull-down menus and dialog windows, provide the primary user interface. Users may search for icons by identification number or by icon type (i.e., function, subfunction, and category); output includes icons graphics only, graphics plus details, evaluation results, design recommendations, and (for a subset of the icons) comprehension study results.

The Icon IDEA software provides designers with the following basic functions and features:

- A searchable database of over 400 icons, organized and selectable by specific in-vehicle system functions and subfunctions.
- Access to evaluation scores for each of the icons in the database that reflect critical physical features of the icons such as: adherence to perceptual principles, level of detail, level of realism, use of color, design of prohibitive icons, and design of text labels.
- Recommendations for further refining the design of an icon following the consideration of the physical feature evaluation.
- Comprehension ratings from experimental subjects for a subset of the icons.
- The ability to add new icons into the database, to quickly evaluate critical physical features of the icons, and then immediately view the evaluation results and associated recommendations for design changes.
- The ability to add, modify, and delete information about icons, icon evaluations, and icon evaluators.
- The ability to print detailed, full-color reports of all icons and evaluation scores contained in the database.

- Embedded instructions for using Icon IDEA, context-specific help when conducting icon evaluations, ScreenTips linked to cursor position on the IDEA screen, and a detailed, on-line user manual in pdf format
- Clear and simple design guidelines for developing and evaluating in-vehicle icons in pdf format.

The figure below shows what Icon IDEA looks like when it is launched.

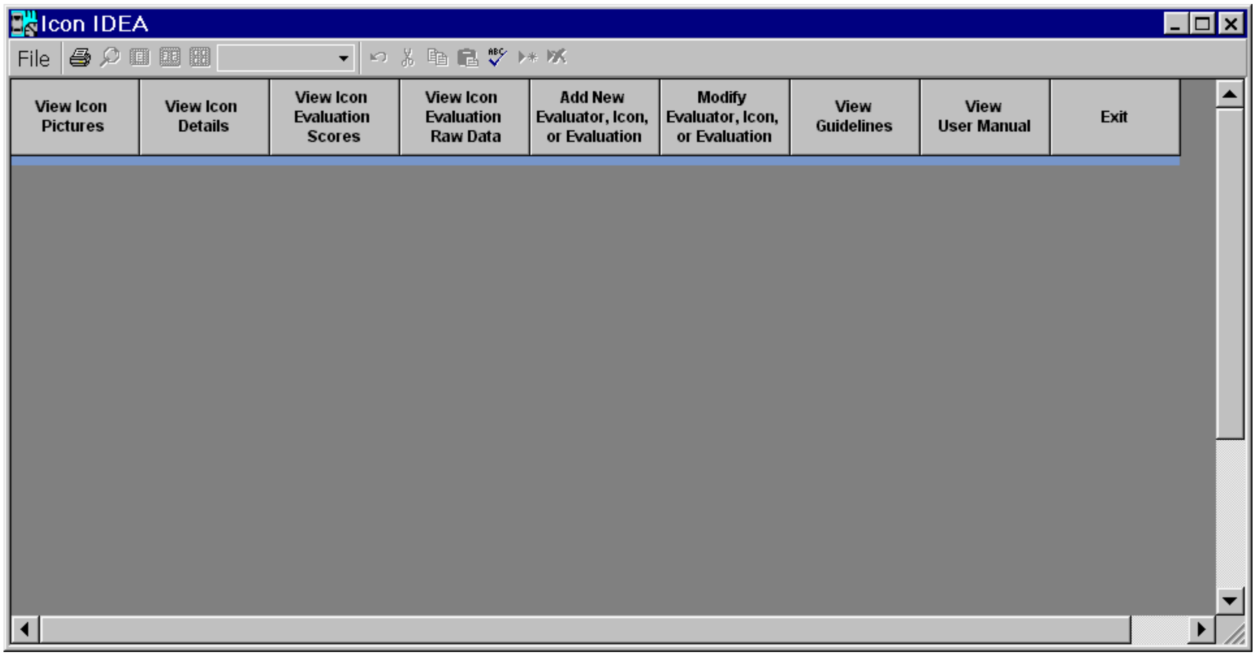

Figure 13. IDEA Start-Up Screen

The top bar, with "File" on the left, provides standard Microsoft Windows® options (Page Setup, Print, About Icon IDEA, and Exit), as well as the ability to compact the Icon IDEA database. Compacting the database is helpful when icons, evaluators, or evaluations have been modified, added to the database, or deleted from the database. Using this feature helps to optimize runtimes after changes have been made to the database.

A key feature of Icon IDEA is the ability to search for and to view available icons for a desired in-vehicle message. Figure 14 below shows the IDEA screen after such a search.

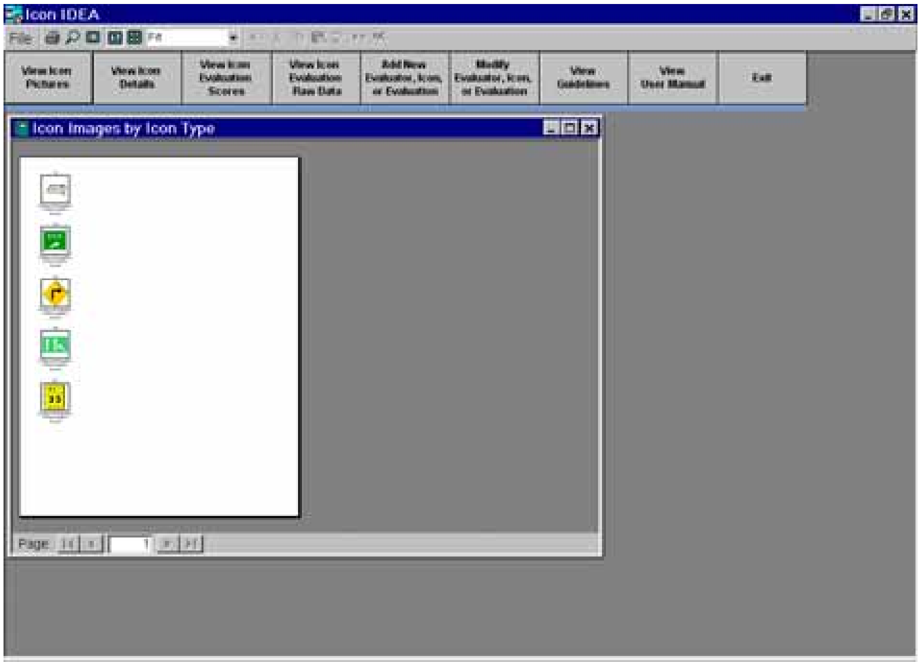

Figure 14. Results of the "View Icon Pictures" Function

Evaluation scores for individual icons can also be obtained. Figure 15 below shows the results of searching for certain icon types and then requesting the IDEA software to display evaluation scores for one of the icons identified during the search.

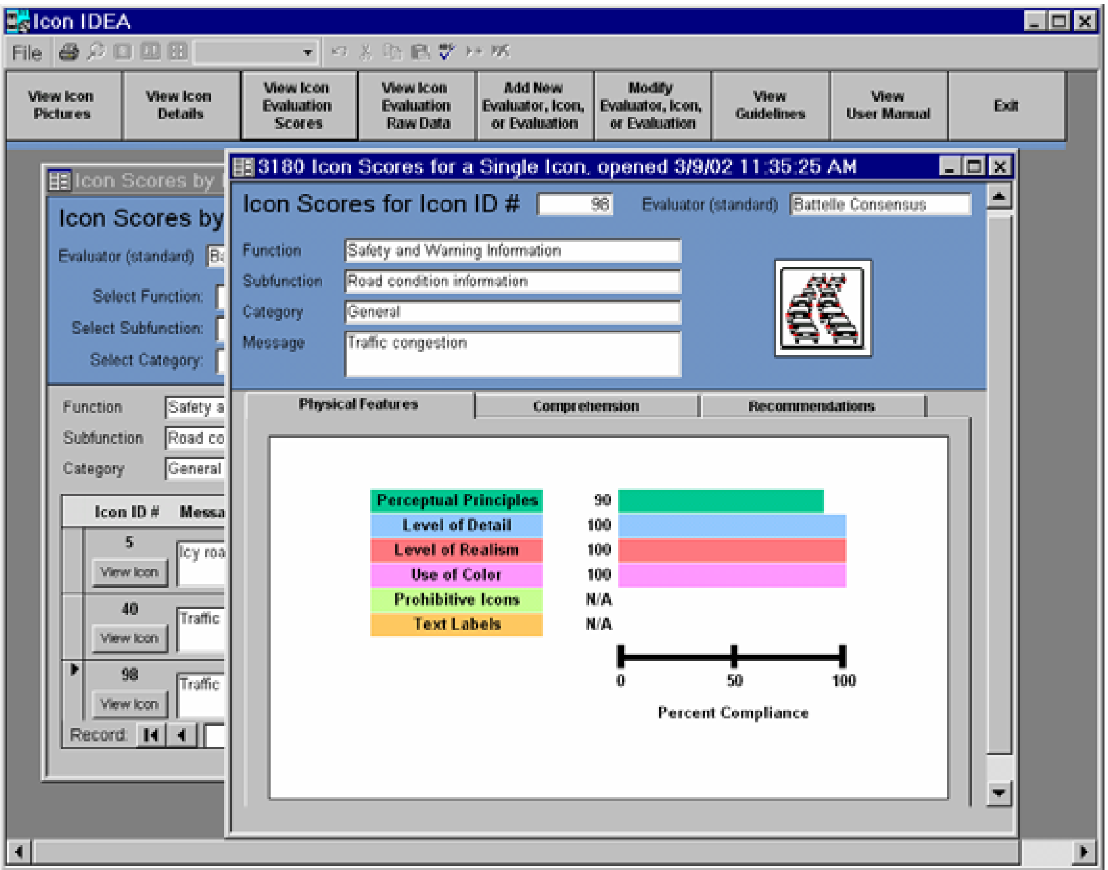

Figure 15. Evaluation Scores for "Physical Features" for the Traffic Congestion Icon

Figure 15 shows the first of three evaluation reports for the traffic congestion icon. The general procedures and specific steps associated with actually conducting a "Physical Features" evaluation are discussed in more detail in the IDEA User Manual and will not be reviewed here.[(5)]

As seen in figure 15, the "Physical Features" evaluation addresses six areas of icon design that are important for assuring that icons are legible and recognizable. These six design areas are:

- Perceptual Principles.
- Level of Detail.
- Level of Realism.
- Use of Color.
- Prohibitive Icons.
- Text Labels.

While these six areas do not capture all aspects of icon design that are important for legibility and recognizability, they do reflect icon design guidelines that: (1) are consistently identified as central to good icon design; (2) are well supported by numerous empirical studies contained in the icon design literature; and (3) can be assessed in a reasonable and consistent fashion with a tool such as Icon IDEA.

Figure 15 shows the degree to which the traffic congestion icon reflects good icon design practices within each of the six evaluation areas. As seen in the figure, the "Percent Compliance" for the "Perceptual Principles" design guidelines was 90 percent for this icon. The "Level of Detail," "Level of Realism," and "Use of Color" evaluation areas were all in 100 percent compliance with their associated design guidelines. Due to the nature of the traffic congestion icon, both the "Prohibition Icons" and "Text Labels" evaluation areas were not applicable (N/A).

Figure 16 below shows the second of three evaluation reports for the traffic congestion icon.

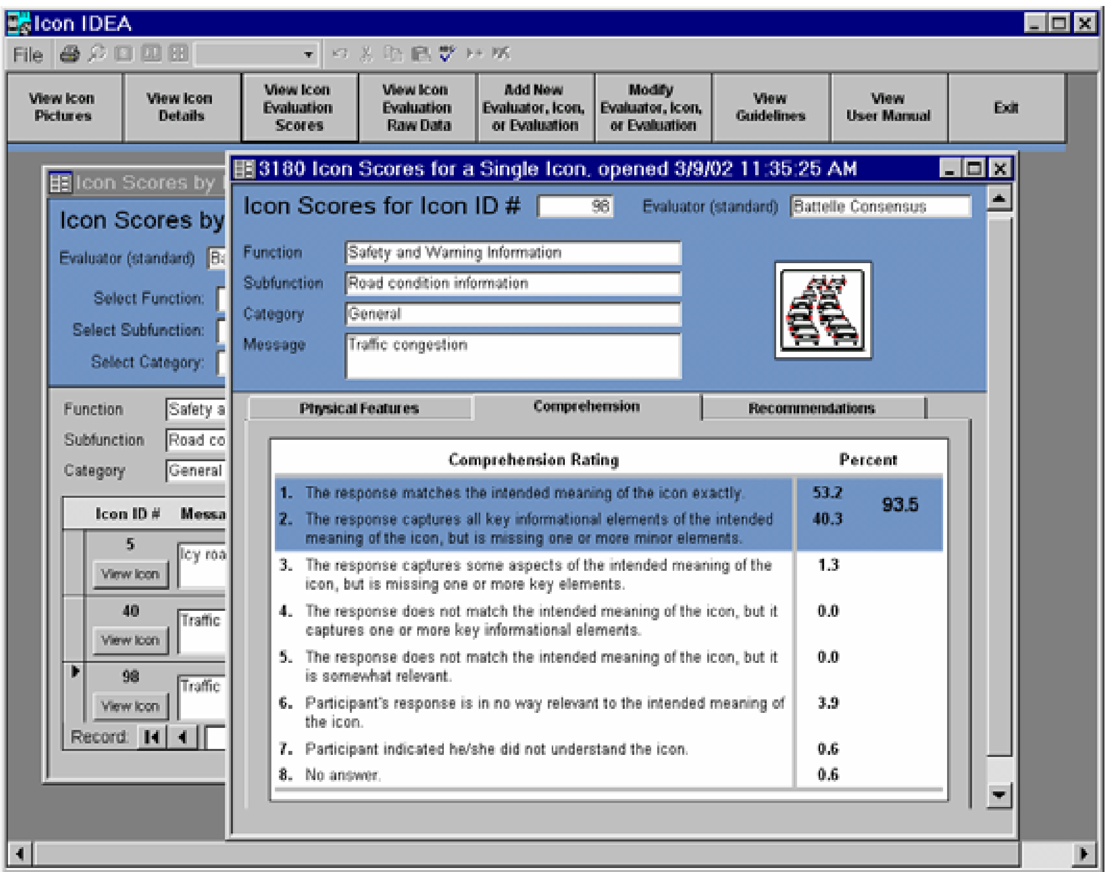

Figure 16. Comprehension Scores for the Traffic Congestion Icon

The comprehension scores shown in figure 16 reflect an empirical study involving 160 test subjects and 100 (from the more than 400 total) icons in the IDEA database.

The column on the left hand side of the icon scores report in figure 16 shows the eight possible categories that could be used to score the subjects' responses in the comprehension testing. The column on the right shows the percentage of subject responses falling into each of these eight categories. Acceptable levels of comprehension are usually considered to be associated with the first two categories of this 8-point scale (i.e., either "the response matches the intended meaning of the icon exactly" or "the response captures all key informational elements of the intended meaning of the icon, but is missing one or more minor elements").

Therefore, the total percent comprehension score for the traffic congestion icon represents the sum of the subject responses falling into categories 1 and 2 (53.2 percent plus 40.3 percent equals 93.5 percent). This is a very high comprehension rate: Acceptable comprehension rates for icons and symbols are usually considered to be 66 percent or, in certain cases, 85 percent. It should be noted that, at this time, the Icon IDEA software does not support adding in new comprehension scores for new or existing icons, or for modifying the existing comprehension scores.

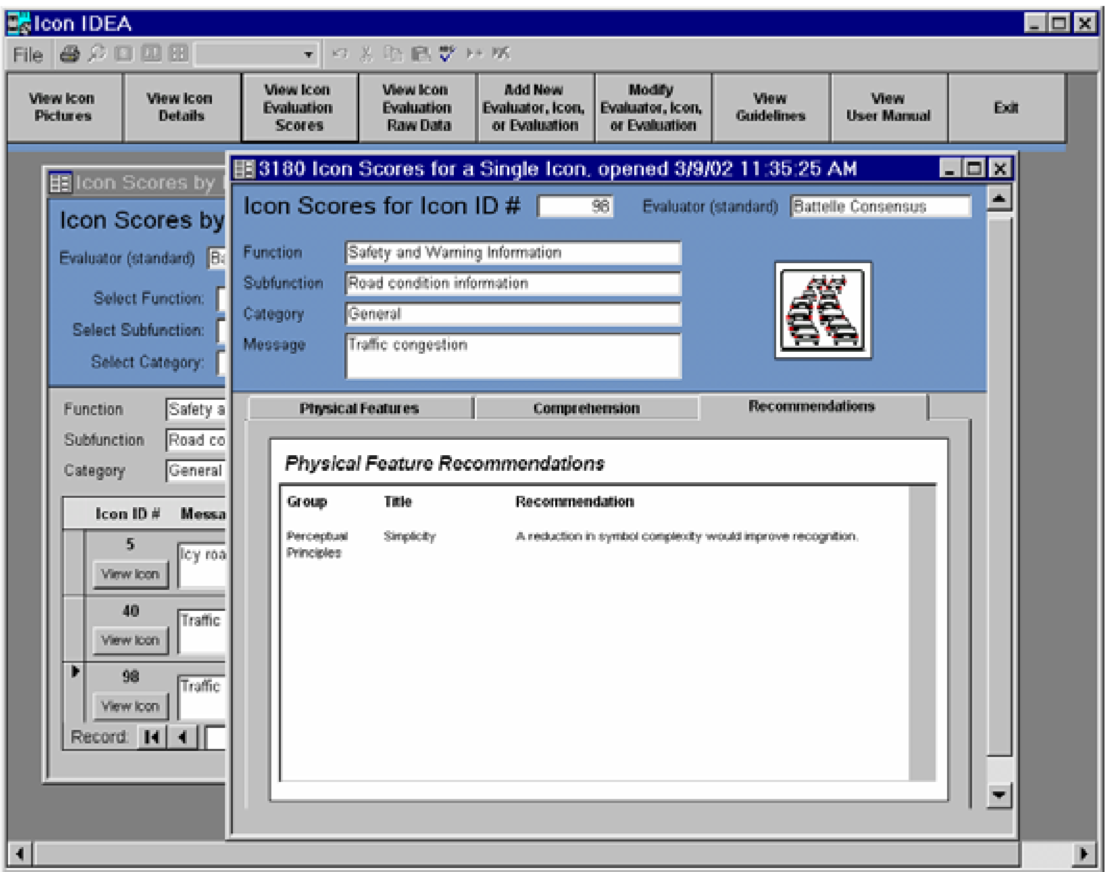

Figure 17. Design Recommendations for the Traffic Congestion Icon Reflecting the "Physical Features" Evaluation Results

Figure 17 shows the third of three evaluation reports for the traffic congestion icon; this report provides recommended design changes for the icon. The design recommendations for all icons in the IDEA database are based on possible design problems identified during the "Physical Features" evaluations. These recommendations directly reflect less-than-100 percent compliance with any of the design guidelines associated with the "Perceptual Principles," "Level of Detail," "Level of Realism," "Use of Color," "Prohibitive Icons," or "Text Labels" evaluation areas. Therefore, any time a physical feature score for an icon is less than 100 percent, design recommendations will be provided for the icon. For the traffic congestion icon, only one design recommendation is provided. Recall (from figure 15), that the percent compliance for the "Perceptual Principles" evaluation area was 90 percent. In figure 17, we see that the design recommendation provided—"a reduction in symbol complexity would improve recognition"—is associated with the "Perceptual Principles" evaluation area and a design guideline for icon simplicity.

CHAPTER 3: CONCLUSIONS

As noted above, the overall goal of the project has been to provide the designers of in-vehicle technologies with a set of design guidelines for in-vehicle display icons and other information elements. The final design guidelines provided in task F have clearly achieved this goal. These clear, relevant, and easy-to-use guidelines provide up-to-date information on a number of topics critical to icon development and evaluation.

Much of the impetus behind the initial conceptualization of this project can be summed up by going back to two of the conclusions from the final task A report:

- "The lack of guidelines and standards for icons has resulted in design by consensus, a lack of scientific rigor in icon development, and multiple icons for the same messages."
- "Existing literature and standards provide little guidance for the design of new icons for IVIS devices."

In short, the transportation system design community—and, indeed, the larger electronics/computer industry—has not had the benefit of a single information source that provided clear, relevant, and useful guidance for icon design. The final task F guidelines produced in this project therefore fill a critical gap in the transportation human factors literature.

In addition, the Icon IDEA software tool developed in this project has provided a real-time icon development and evaluation tool that, to date, is receiving consistently positive reviews from the project's working group members. This tool is entirely functional and ready to use, and should prove an invaluable aid and resource for icon design.

Moreover, the technical reports, conference papers, and conference presentations developed during this project provide a permanent record on a number of substantive issues related to icon design, yet perhaps not incorporated into either the final design guidelines or the IDEA software tool. Appendix B summarizes these products.

APPENDIX A: PROJECT WORKING GROUP[1]

Linda Angell, Ph.D.
General Motors Corporation

Mike Campbell
National Weather Service

Cher Carney
Battelle Human Factors Transportation Center

Peter Chin
Microsoft

Mark Cummings-Hill
Delphi Delco Electronics Systems

David G. Curry, Ph.D.
Packer Engineering, Inc.

Stuart DeSpain
Microsoft

James P. Foley, Ph.D.
Mitretek Systems, Inc.

Thomas M. Granda, Ph.D. (FHWA COTR)
Federal Highway Administration

Barry S. Grant
Ford Motor Company

Ronald B. Hoffman, Ph.D. (SAIC)
Federal Highway Administration

David Hoffmeister
Ford Motor Company

Maureen L. Hunter
Avia Technology

Steven K. Jahns, Ph.D.
PACCAR Technical Center

Barry H. Kantowitz, Ph.D.
University of Michigan Transportation Research Institute

Rick Karbowski
Ford Motor Company

Raymond J. Kiefer
General Motors Corporation

Chris Kirn
DaimlerChrysler Research and Technology

James A. Kleiss, Ph.D.
Johnson Controls, Inc.

Ken Kobetsky
American Association of State Highway and Transportation Officials

John D. Lee, Ph.D.
University of Iowa

Eddy Llaneras, Ph.D.
Westat, Inc.

Marvin McCallum, Ph.D. (Project Task Leader)
Battelle Human Factors Transportation Center

Christopher Monk (SAIC)
OHCR, National Highway Traffic Safety Administration

Mark Ohashi
Toyota Technical Center, USA

Colleen Page
Microsoft

[1] List includes both current and past working group members.

Joel Richman (Project Task Leader)
Battelle Human Factors Transportation Center

Gary L. Rupp, Ph.D.
Ford Motor Company

Tina Brunetti Sayer, Ph.D.
Visteon Corporation

Colleen Serafin
Johnson Controls, Inc.

Valerie K. Sims, Ph.D.
University of Central Florida

Marc Todd
Microsoft

Ben Truelove
Microsoft

Blaine Tsugawa
Office of the Federal Coordinator for Meteorology, National Oceanic Atmospheric Administration

Jonathan Upchurch, Ph.D., P.E.
University of Massachusetts - Amherst

Dave Wheatley
Motorola Laboratories

Peter Wolff
DaimlerChrysler Research and Technology

Steven Wreggit, Ph.D.
DaimlerChrysler Research and Technology

APPENDIX B: TECHNICAL REPORTS, PUBLICATIONS, AND PRESENTATIONS

Technical Reports

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Presentations

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