In-Vehicle Display Icons and Other Information Elements: Literature Review

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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 the first product of the analytical phase. It provides a literature review of research associated with in-vehicle icons and symbols, and describes current test and evaluation practices for icons. It also summarizes driver information requirements for in-vehicle messages and the current use of icons and symbols by manufacturers and after-market vendors.

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Michael F. Trentacoste
Director, Office of Safety
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NOTICE

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16. Abstract
This report describes the objectives, methods, and findings associated with *Task A: Perform Literature Review*. The purpose of Task A is 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 to complete Task A included: examining articles collected as part of Battelle=s 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 websites were found via this methodology.

On the basis of our review and analyses of the literature for icon and symbol research and current applications, we developed the following conclusions: (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 in-vehicle information system (IVIS) devices; (3) general design principles for icon design are sufficient to avoid development of a Abad@ icon, but are not specific enough to support development of the Abest@ icon; (4) 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; and (5) 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.

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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

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

APPROXIMATE CONVERSIONS TO SI UNITS

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

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

(Revised September 1993)

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LIST OF ABBREVIATIONS

ATIS	Advanced Traveler Information System
BES	Best Evidence Synthesis
CAS	Collision Avoidance System
CVO	Commercial Vehicle Operations
DOT	Department of Transportation
FHWA	Federal Highway Administration
FMVSS	Federal Motor Vehicle Safety Standards
HVAC	Heating, Ventilation, Air-Conditioning
ISO	International Standards Organization
ITS	Intelligent Transportation System
IVIS	In-Vehicle Information System
MUTCD	Manual of Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
SAE	Society of Automotive Engineers
UWIN	University of Washington Information Navigator

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Finally, we would like to thank our colleague, Dr. John Lee, for his constructive comments and insightful suggestions on an earlier draft of this report.

EXECUTIVE SUMMARY

The overall goal of this project is to provide designers of in-vehicle technologies with a set of human factors 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 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 the driver and to prioritize these sources to reduce driver overload and maintain public safety. Without appropriate study and design guidance to aid and standardize icon and symbol 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 icon/symbol design is developed and shared with industry.

This report describes the objectives, methods, and findings associated with Task A: *Perform Literature Review*. The purpose of Task A is 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 to complete Task A included: examining articles collected as part of Battelle's 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 websites were found via this methodology.

Once all of the literature was gathered, it was reviewed in order to determine its relevance to the current project. Specifically, we concentrated on 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 (Advanced Traveler Information System [ATIS] and Collision Avoidance System [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 Standards Organization [ISO], and Manual of Uniform Traffic Control Devices [MUTCD]).

This review has comprehensively captured the status of icon/symbol research and applications and, most importantly, provided a solid foundation for subsequent tasks in this project. On the basis of our review and analyses of the literature for icon and symbol research and current applications, we have developed the following conclusions:

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. Our review and integration activities suggest that a number of general principles for icon design are available to IVIS developers. These include 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 (Campbell, Rogers, & Spiker, 1990). In particular, there are three challenges 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 (Campbell, 1995; 1996).

Despite these challenges, a number of successful design guidelines for ATIS, CAS, and other in-vehicle devices have been developed (Campbell, 1989; Campbell et al., 1990; Rogers & Campbell, 1991; Campbell & Walls, 1992; Campbell et al., 1996; Campbell, Carney, & Kantowitz, 1998). The general procedures used in these efforts will be used to guide our design guideline development activities in the current project.

INTRODUCTION

Recent and near-term development and deployment of Intelligent Transportation Systems (ITS) such as ATIS and CAS suggest that drivers will soon be faced with a host of new visual, auditory, and tactile information. 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 they may, if not carefully implemented, actually exacerbate existing traffic problems. Although drivers have always had to time-share their attention between internal (e.g., speedometers) and external (e.g., traffic control devices) sources of information, ITS technologies represent new frontiers for in-vehicle information systems.

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. Because of the speed with which 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, 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. 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. 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 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 preliminary, as well as empirically based, final guidelines.

The flow of project activities is shown in figure 1. 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.

This report describes the objectives, methods, and findings associated with Task A: *Perform Literature Review*. The purpose of Task A is 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. This review represents an integral component of the entire project. Because of the short period of time available to formally prepare the draft guidelines in Task C, the results of this literature review have been organized and documented in a form that will readily and directly support Task B activities and, by extension, the development of the preliminary guidelines in Task C.

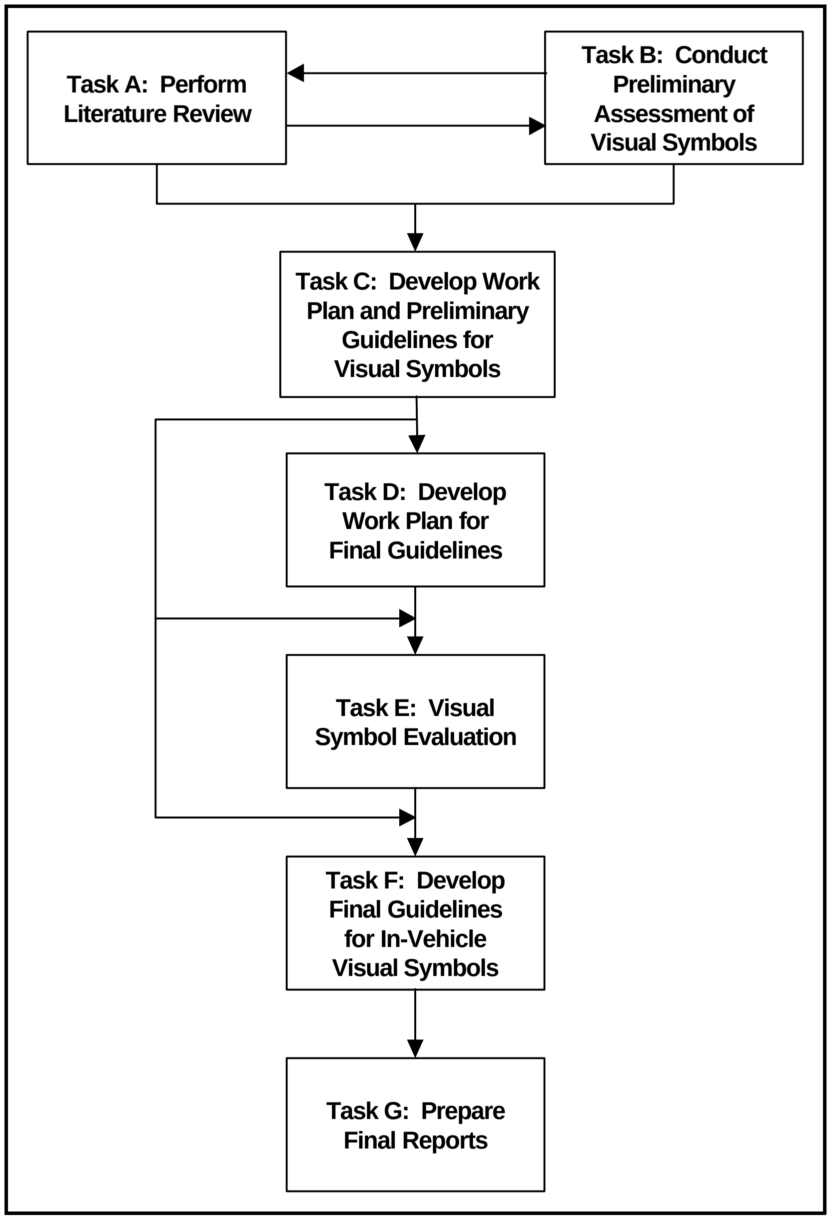


Figure 1. The flow of project activities.

METHOD

The first step toward the development of human factors design guidelines for in-vehicle icons and symbols was a review of the existing literature relevant to icons, visual symbols, and other information elements. The methodology employed to complete this review included: examining articles collected as part of Battelle's 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 websites were found via this methodology.

Hundreds of articles from previous literature review efforts completed by the Battelle team were examined in order to determine their applicability to the current project. One of the literature reviews concentrated on human factors-related issues associated with ATIS and Commercial Vehicle Operations (CVO) devices, including the use of symbols and icons (Campbell et al., 1998; Dingus & Hulse, 1993). The other review was completed in order to support research and guideline development for CAS devices (Campbell et al., 1997; Campbell et al., 1996).

In addition, more than 200 candidate data sources were identified during a series of comprehensive database searches. Most of these articles were found during key word searches performed using the University of Washington Information Navigator (UWIN), an on-line search engine for performing extensive literature searches. Other articles were found by Battelle Seattle Library and Information Services while performing on-line searches of several databases (i.e., PSYCH INFO, NEXIS, DIALOG, or the World Wide Web).

The Internet was also found to be a useful resource for gathering information. Hundreds of websites were visited and found to be especially helpful for locating many icon and symbol sources, as well as for determining the most current use of icons by manufacturers. Several websites contained signs, symbols, and icons specifically relevant to the presentation of automotive and traffic information. Other websites included more general travel icons for restaurants, hotels, phones, etc. A list of these websites is provided in appendix A.

Once all of the literature was gathered, it was reviewed in order to determine its relevance to the current project. Specifically, we concentrated on 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., SAE, ISO, and MUTCD).

It should be noted that several different disciplines were represented by the information sources included in this review, including human factors and ergonomics, graphic arts, advertising, psychology, computer science, linguistics, and history.

Literature that was determined to be relevant was then subjected to a second, more thorough review using an established literature review methodology, *Best Evidence Synthesis* (BES) (Slavin, 1986, 1987). The BES approach is designed to guide the systematic analysis of technical literature in which only the best evidence in a given knowledge domain is included in the review. Importantly, the characteristics that define this "best evidence" vary with the domain. For example, when applied to issues associated with driver responses to warnings, the best evidence might consist of well-controlled, randomized experiments in some areas but only quasi-experimental field tests in others. Therefore, the BES approach emphasizes the use of domain-specific review criteria to derive a set of data sources meeting minimum standards of quality and applicability. Summaries of the key reference material used in this literature review can be found in appendix B.

The literature that survived this second review was then separated into several categories representing specific areas or topics of interest. These areas of interest represent the different sections found in the results of this literature review.

- Empirical Studies of Icons and Their Effectiveness

- Models of Symbol Recognition and Understanding

- Basic Design Principles for Icon Design

- ISO Evaluation Procedures for Icons

- Additional Icon Evaluation Techniques

- Driver Information Requirements for IVIS Messages

- Existing Symbols and Icons

- Existing Standards and Guidelines

- Challenges to the Development of Human Factors Design Guidelines for Icons and Symbols

RESULTS

BACKGROUND

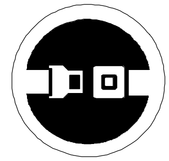
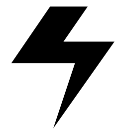
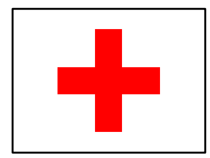
Icons are visual representations or images used to symbolize an object, action, or concept. Several authors have classified icons into three different types: image-related (pictorial), concept-related (analogy), and arbitrary (Lodding, 1983; Rogers, 1989; Modley, 1976; Beardon, 1992; Bliss, 1965). Image-related icons are highly pictorial representations of the object or act they represent. For these types of icons, meaning can be derived directly from the icon itself. For example, a seat belt icon usually appears whenever the ignition is started in a vehicle. This simply alerts drivers to the fact that they should be wearing their seat belt. This type of icon refers directly to the object it resembles and is therefore the easiest for people to remember and takes almost no effort to learn.

Concept-related icons are based on an example or a property of a real object or action. In most instances, the meaning of these types of icons will change depending upon the context that it is presented in. For instance, a lightning bolt symbol that is shown on a camera usually represents the flash function. However, when the lightening bolt symbol is seen in a different context, perhaps while touring an electrical plant, it might be indicating a high voltage area. Because of these icons' ability to change their meaning depending on the context they are viewed under, they are slightly more difficult for people to learn.

Arbitrary icons do not resemble the object or action they represent, but become meaningful only through convention and education. A good example of an arbitrary icon is the Red Cross symbol, which generally refers to the concept of emergency first aid. To someone from another culture, however, it may have an entirely different meaning or it may have no meaning at all. For example, if you are not aware of this symbol's link to medicine or emergency first aid, you may simply see it as a symbol for addition or perhaps as a religious cross. However, if you are aware of this link, you may recognize it as the international symbol for the Red Cross. Therefore, it is necessary, in most cases, to have a particular knowledge base before being able to derive the correct meaning from these types of icons. This makes them the most difficult for people to learn and to remember.

These distinctions between icon types are important because they can allow us to make predictions about an icon's interpretation and overall utility. Interpretation of an image-related icon may be high if the icon is a clear, straightforward representation of the message it represents. Interpretation of context-related icons may be high if the user understands the situation and condition associated with presentation of the icon. Interpretation of arbitrary icons requires both context and knowledge, yet they are very powerful and flexible. For example, both our alphabet and numeric systems are arbitrary, yet useful in a wide variety of situations. In table 1 below, we have described each of these icon types.

Table 1. Description of icon types.

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.*

An icon can consist of several parts: a border, a background, a symbol (which is made up of elements), and a text label (see figure 2). While an icon must contain a symbol, it is not necessary for it to have all of the other parts listed above. However, each part can add meaning to an icon in its own way. Borders can make icons appear more consistent, but they can also limit their size. The use of a background can help to group icons; however, as with borders, they can compete with the overall symbol or specific elements. Labeling icons with text can be a good idea for icons that are not readily apparent, but they can also take up precious space that might be better used to increase the size and understandability of an icon. A more complete discussion of the advantages and disadvantages associated with each of these parts can be found in the "Basic Design Principles for Icon Design" section of this literature review.

The use of icons or symbols is among the oldest forms of communication, dating back to the days of cave dwellers (Horton, 1994). During this time, pictures were used to record history and tell stories. As time went on, the visual symbols began to represent sounds instead of ideas and the alphabet was created. The alphabet has evolved and replaced iconic languages in most cultures. However, if we look around us, we can still see the influence of these ancient graphic symbols (for example, in art, on traveler information signs, and now even in computer programs).

There are many reasons to use icons for presenting information. Horton (1994) suggests that well-designed icons can help people to work more quickly and possibly improve productivity and reliability because they will eliminate the need for people to read, analyze, ponder, or translate them. He also suggests that there are several professions (i.e., engineers, scientists, designers) in which people work and think in visual images; therefore, it makes sense to present information to them in ways that make it easier for them to do their jobs.

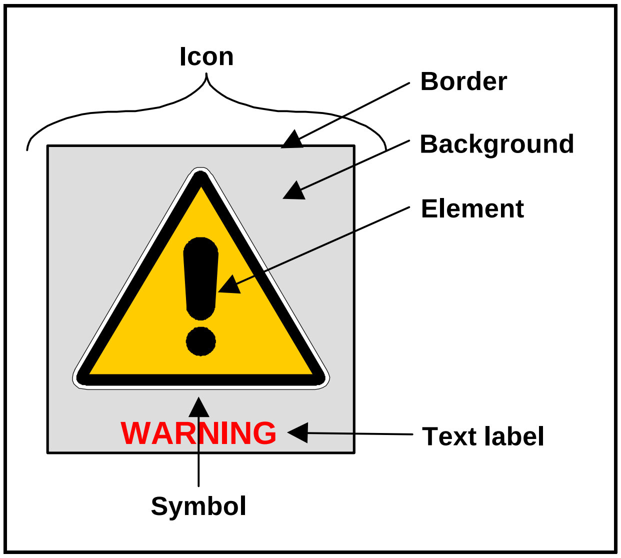


Figure 2. Composition of an icon.

The human visual and perceptual systems have a powerful ability to recognize and identify icons. In a study conducted by Standing (1973), 2,500 slides were shown to subjects for 10 seconds. Subjects were then shown pairs of slides and asked which of the two they had already seen. They were able to recognize 85 to 95 percent of the slides correctly even when the new slide was shown for only a second or when it was a mirror image of the original.

Well-designed symbols are recognized more accurately and quickly than similarly worded signs (Edworthy & Adams, 1996). Research performed by King (1971) compared subjects' ability to interpret the meaning of symbol and word highway signs. Subjects were asked to match a test sign to one of nine they were shown on a following film segment. The results of this research showed that overall, people were able to more accurately match symbol signs than they were word signs. Also, 65 percent of subjects reported that the symbol signs were easier to match. Another study conducted by Walker, Nicolay, and Stearns (1965) found similar results. They investigated subjects' ability to correctly identify word and symbol signs and found that subjects were able to more accurately identify the symbol signs. Horton (1994) gives three reasons for this: (1) icons are more visually distinct than words; (2) visual symbols have names that we remember along with them, thus they are stored as both visual and verbal memories whereas text labels are stored only verbally; and (3) visual images are stored in several forms and tightly linked to one another and to other forms.

Another reason to use icons is the increase in the number of commercial products that are used by people of different languages and cultures. The global market increases the need for more universal designs. The use of icons is one way of moving toward this goal. Icons, signs, and symbols have been used for centuries to inform weary travelers of the services and attractions available to them in strange and foreign lands (i.e., a horseshoe hanging above the door of a blacksmith shop). From this standpoint, icons are already a well-established means for conveying messages across cultures (Rogers, 1989). Even those who are unable to read the language (i.e., foreign speakers and children) are able to comprehend the meaning behind many symbols and icons.

Icons can also be presented in a more spatially condensed form (Zwaga & Boersema, 1983; Rohr & Keppel, 1984; Hemenway, 1982) than can most text-based messages. This is especially important to consider when designing computer interfaces where the amount of room available on a display is extremely limited. Road signs also have a limited amount of space for presenting information and must take advantage of the fact that more information can be presented to the driver via icons and symbols than can be presented textually (see figure 3 below). Research in this domain has shown that symbols can be recognized more rapidly and are legible at greater distances and smaller sizes than information presented in other formats (Ells & Dewar, 1979; Walker et al., 1965; Jacobs, Johnston, & Cole, 1975).

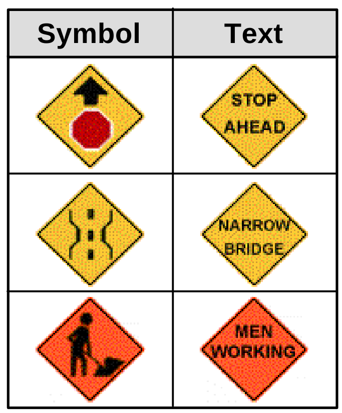


Figure 3. Examples of symbolic vs. textual road signs.

Empirical Studies of Icons and Their Effectiveness

Most empirical investigations related to icons and symbols fall into two categories: (1) studies that have evaluated the efficacy of icons over other visual information, such as text messages, and (2) studies that have sought to identify the "best" icon(s), usually in terms of preference, reaction time, or comprehension from among a set of candidate icons. As discussed in more detail below, past evaluations of in-vehicle symbols have frequently resulted in findings that cannot support the development of clear, definitive guidelines. This issue is discussed in more detail in Hanowski and Kantowitz (1997). In addition, many studies investigating in-vehicle symbol usage and design have not been able to provide design guidance for the development of *new* symbols—a key requirement in the current project. These studies are summarized in the following paragraphs.

As stated above, there has been considerable research as to whether or not symbolic messages may be a better means for presenting information to drivers than textual messages. King and Tierney (1970) compared the glance legibility of symbolic and worded highway signs. Subjects were shown film segments of both symbol and word traffic signs that were either 1/3, 1/6, 1/9, or

1/18 second in duration. Afterward, each subject was shown a film segment with nine signs on it and asked to match one of them to the test sign they had just viewed. Results of the study indicated that symbol signs were recognized much more accurately and that their meaning was easier to interpret.

In a study completed by Ells and Dewar (1979), subjects listened to a traffic message that was read aloud by the experimenter. Shortly thereafter, they were shown a slide of a traffic sign and asked to respond with a "yes" or "no" regarding whether the auditory traffic message they had heard previously and the visual traffic sign they had just seen were the same. Accuracy and response time were the key independent variables recorded. Results of this study showed that incorrect responses were very infrequent, occurring on less than 5 percent of the trials for all subjects, regardless of the format of the sign (symbol or text). However, subjects responded quicker to symbolic signs than they did to textual signs for both "yes" and "no" responses. The authors concluded that the meaning of existing symbolic traffic signs is generally understood more quickly than a corresponding textual sign.

In a study conducted by Dewar, Ells, and Mundy (1976), subjects were presented slides of traffic signs and asked to identify aloud the message that was on the sign. Results showed that the subjects' reaction times to textual sign messages were significantly shorter than to symbolic message signs. However, the authors hypothesized that these shorter reaction times for verbal messages may have been a result of the verbal identification task that the subjects were asked to perform rather than from more efficient processing of the meaning of verbal messages. Several other studies have confirmed that verbal responses seem to be more compatible with textual message signs (Mergler & Zandi, 1983; Shoptaugh & Whitaker, 1984; Whitaker & Stacey, 1981).

A more recent study conducted by Hanowski and Kantowitz (1997) failed to find an advantage for icons over text messages when information was presented to subjects in-vehicle. Using a medium fidelity driving simulator, they investigated drivers' memory for traffic and traveler related messages presented on an ATIS display. A range of messages, including in-vehicle signing, traffic management, and hazard warnings, were presented to subjects using both symbol and text presentation modes. Both low and high comprehension symbols, as well as long and short text messages were examined. Reaction time to the messages and message comprehension were measured. Except for very low comprehension symbols (i.e., unfamiliar or nonintuitive), performance was similar for symbol and text message formats.

Additional symbol research has concentrated on comparing the visibility and legibility of symbolic and textual messages. Jacobs et al. (1975) examined the visibility of alphabetic and symbolic forms of 16 different traffic sign messages for observers with normal vision. Fifty percent threshold legibility distances were defined as the distance at which subjects could correctly recognize the sign, and were determined for each of the 10 subjects who participated. Results showed that the 50 percent threshold legibility distance for the alphabetic signs was almost twice that which was found for the symbolic signs (142 m and 270 m, respectively).

A study conducted by Kline et al. (1990) found similar results. Sixteen subjects ranging in age from 16 to 72 years were shown a sign (either text or iconic) that was initially too small to be recognized. The size of the sign was slowly increased until the subjects reported they could see it. At this time, they were asked to indicate what the sign meant. The results indicated that visibility distances for icons were generally much greater than those for text signs for subjects of all ages, giving them almost twice as much time to respond.

Kline and Fuchs (1993) expanded upon this research by comparing not only text and symbolic signs, but also by adding a condition in which the subject was presented with an improved symbolic sign. The improved symbolic sign had altered contour size and increased contour separation in an attempt to avoid higher spatial frequencies, thus increasing visibility, particularly for the older driver. The results again showed that the average distance at which a symbolic sign could be identified was about twice that of textual signs. In addition, visibility distances of the improved symbolic signs were three times those of their corresponding text signs and 50 percent greater than the standard symbolic signs.

The advantage associated with using the improved symbolic sign over the standard symbolic sign all but disappeared, however, in a study conducted by Long and Kearns (1996). They examined 64 subjects' ability to recognize the same three types of traffic signs (text, icon, and modified or improved icon) under either stationary, low-velocity, or high-velocity conditions. Consistent with what has been found in all of the previous research, iconic versions of traffic signs exhibited significantly lower threshold sizes than did standard textual message signs when subjects were stationary. However, under dynamic viewing conditions this was not always the case. Under the low-velocity conditions the modified icon did improve visibility significantly. However, under the high-velocity condition, visibility was not improved.

There is also some research that has attempted to evaluate existing symbols or icons used to present automotive information to the driver. Its goal is primarily to identify those icons that are successful and those that should be re-designed. Green and Pew (1978) asked 50 university students to evaluate 19 different symbols for labeling automotive controls and displays. Each subject was asked to complete five different experimental tasks:

(1) A familiarity task to determine whether the subject had any previous experience with the test symbols.

(2) An association task during which subjects were read a short paragraph describing a scenario in which they would be required to use a particular control or display on the instrument panel; subjects were required to point to the symbol for the particular item that had been described.

(3) A rating task, during which the subjects were asked to rate how well each symbol communicated its name or function.

(4) A paired-associative learning task to evaluate how difficult it was to learn the test symbols.

(5) A reaction time task where the experimenter would read the label of one of the 19 symbols. Three-quarters of a second later a slide of one of the test symbols was shown. Subjects were asked to respond by pressing one of two buttons, either to indicate that the label and the symbol had been the same or that they were different.

In general, results of this study showed that symbol performance was variable, depending on which task had been performed. Overall, the most interesting results came from examining the confusion matrix. Several of the symbols were repeatedly confused with one another. It is not surprising that these icons were ones that were either similar in appearance (i.e., headlights, fog lights, low beam and high beam, and parking light symbols) or icons that seemed to the subject to serve similar functions (i.e., windshield washer, windshield wiper). From these results, one might conclude that symbols should be designed to be easily discriminable from one another. However, if that is not possible, text labels should be considered as an option.

A study completed by Zwaga and Boersema (1983) evaluated 29 graphic symbols that were to be used for public information signs in railway stations. A sheet with the 29 different symbols on it was shown to 11,600 railway passengers. They were given a referent (i.e., telephone) for the target symbol and were then asked to select the symbol they would follow to find the specified referent. According to Zwaga and Boersema, confusion most often occurs when two symbols have the same elements or two symbols have been designed so that the image content of one icon appears to be the same as the image content of another. Making sure that icons are distinct enough from one another, especially when the referent they are describing is similar, is extremely important for effective design.

Hawkins, Womack, and Mounce (1993) surveyed 1,745 drivers in order to assess their comprehension of 46 different traffic control devices found in the MUTCD. The survey included 13 questions on regulatory signs, 18 questions on warning signs, and 7 questions on pavement markings. Results of the survey were interpreted individually for each of the signs. For example, the results presented for the "Speed Zone Ahead" sign showed that only 55 percent of subjects correctly answered that this sign meant that the speed limit would be lowered ahead. Furthermore, people who misunderstood the sign and chose one of the other four possible responses tended to be non-anglo drivers, drivers with less than a high school education, and drivers who drive less often and have fewer years of driving experience.

Green (1981) asked subjects to rate the meaningfulness of 216 symbols that had been proposed for 26 different automotive display functions. These symbols were gathered from several different sources; about 150 were generated by participants of a previous phase of this research study, while others were obtained from ISO Standard 2575, SAE Standard J1048, Federal Motor Vehicle Safety Standards (FMVSS) 101, Heard (1974), and the researchers themselves. Subjects were asked to rate the meaningfulness of each candidate symbol. Results of this study were a ranking of the symbols, ordered by their ratings from best to worst.

The effects of driver age have also been important to the general issue of icon design. Dewar, Kline, and Swanson (1994) investigated symbolic traffic sign comprehension as a function of age for 85 of the symbols in the MUTCD. Their results indicated that older drivers had a poorer understanding than did younger drivers on 39 percent of the symbols examined. There were no age differences with the remaining 61 percent of the symbols.

Similarly, Saunby, Farber, and DeMello (1988) assessed the understandability and recognition of 25 automotive ISO symbols by U.S. drivers. Common automobile symbols were assessed such as those for horn, battery, fan, oil, and windshield wipers. Two evaluation methods were used. Part one tested a driver's ability to understand a symbol by having participants write the meaning of each symbol next to its icon. Older drivers (over 50 years) scored only 37 percent correct versus 56 percent correct for younger subjects (under 30 years). Part two tested a driver's ability to recognize a symbol by having participants match the 25 symbols with 25 stated functions. Here, older drivers scored 61 percent correct versus 82 percent correct for younger drivers. In both of these studies, it is unclear why older drivers had more difficulty recognizing symbols than younger drivers.

Allen, Parseghian, and van Valkenburgh (1980) have suggested a possible reason. Their subjects drove an interactive simulator and responded to symbol signs presented along a route. Signs remained visible until the driver depressed a foot switch indicating recognition. Seventy-two symbols were randomly presented, each from one of the following categories: regulatory, warning-permanent, construction, and information. After drivers were tested for initial symbol knowledge, symbol training was provided. After a one to two-week interval, subjects were re-tested for symbol retention. Results showed that, for older drivers, initial symbol knowledge was poor, but that these older drivers learned the symbols easily when trained, and adequately recalled the symbols after the designated time interval. Allen et al. concluded that any age-related effects seen in previous studies may have been the result of generational differences, which should be considered when interpreting age-related results. As the population ages, research is needed to further investigate this issue and determine what aspects of visual symbols can be easily identified and recognized by older drivers.

In summary, a number of empirical studies have investigated the overall utility and design of icons and symbols. They have, for the most part, demonstrated that icons and symbols can provide a distinct advantage over text messages. They have explored several different techniques that may be useful for the evaluation of symbols and icons. And, they have also established that certain icons are "good," while others are "bad." Unfortunately, they have done so without telling us very much about the characteristics of icons that distinguish the "good" from the "bad."

Taken as a whole, these studies provide little guidance for the design of future symbols. They lack a systematic explanation of how features of the symbols taken both individually and collectively affect meaningfulness, comprehension, and acceptance. The existing studies do not generally consider the key features of candidate symbols or how these features are parametrically related to measures of understandability or meaningfulness.

Another approach, used successfully to evaluate candidate in-vehicle messages for CAS (Campbell & Hanowski, 1996; Jovanis & Campbell, 1996) and ATIS devices (Lee et al., 1997), may be more useful. This approach explicitly evaluates the effect of key design dimensions of in-vehicle messages on understandability and utility. In the past, these design dimensions have included message features such as command versus notification characteristics of ATIS messages (Lee et al., 1997), or general CAS alerts versus CAS alerts that provide the driver with information on the nature of a crash situation (Campbell & Hanowski, 1996; Jovanis & Campbell, 1996).

These studies have found that such distinctions account for a great deal more response variance than do standard distinctions between, for example, symbolic versus text presentation of messages. In this regard, evaluations of candidate display information will frequently focus on "surface" differences between displays, such as symbols versus text (Hawkins, Womack, & Mounce, 1993) or symbolic versus auditory presentations (Ells & Dewar, 1979). However, as reported in Hanowski and Kantowitz (1997), inconsistent findings frequently result from such studies. Such inconsistencies can reflect semantic features of the messages that are not typically considered in human factors studies. An IVIS study that explicitly considered key design dimensions was reported by Jovanis and Campbell (1996), who evaluated approximately 50 candidate CAS alerts using a rapid prototyping and focus group approach. Alerts were rated, using Likert-scales, on several response dimensions, such as the degree to which the alert got the subjects' attention, the degree of urgency conveyed by the alert, and the effectiveness of the alerts in conveying where a collision might take place. Analyses of the resulting data that focused on broad differences between classes of alerts (e.g., symbols versus verbal versus tones versus earcons) provided little in the way of design guidance—little variance was accounted for by the modality of the alert. However, an analysis that cut across modalities and examined semantic features of the alerts yielded rich information that was used to guide subsequent research and system design.

A Conceptual Framework for Icon Design

Developing effective design guidelines for the development of icons and symbols requires a conceptual approach that applies a theoretical understanding of driver perception and performance (Kantowitz, 1997). Past research has demonstrated that, if they are designed appropriately, visual symbols and icons can be a very effective way to communicate information to the driver. Less definitive information is available on *how* to design effective icons and symbols.

As shown in figure 4, there seem to be three stages associated with icon comprehension and use. The first stage, legibility, reflects the relationship between the driver, the icon, and the environment. It includes basic issues such as whether or not the driver can see the icon, given the normal range of lighting and viewing conditions associated with driving. Legibility will depend on icon design issues such as size, brightness, color, stroke width, and contrast.

The second stage, recognition, reflects the relationship between the driver, the icon, and *other* icons or visual display elements. It includes issues such as whether the driver can identify the icon, especially in the context of other symbols and icons. For example, the standard icon for fuel depicts a gas pump. Accurate recognition of this icon would mean that the driver recognizes it as a gas pump. Recognition will depend on design issues such as the shape of the icon, figure/ground relationships, level of detail, use of overlapping elements, orientation, and discriminability from other symbols.

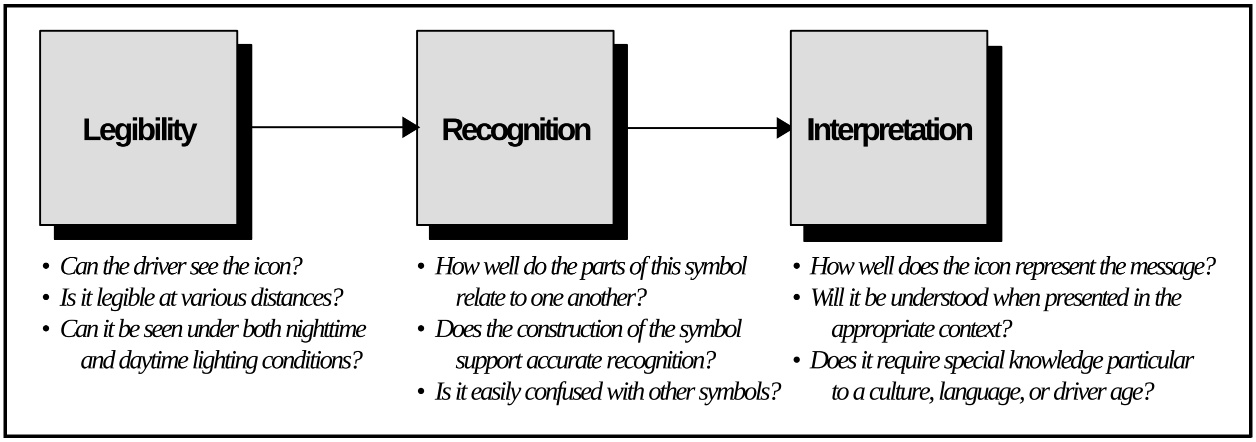


Figure 4. Sequence of icon comprehension and use.

The third stage, interpretation, reflects the relationship between the driver, the icon, and the referent or message associated with the icon. It incudes issues such as whether the driver comprehends the meaning, intent, or purpose of the icon. For example, using the “gas pump” icon described above as an example, successful interpretation would mean that the driver understands what the icon’s message is—the vehicle is low on fuel. Interpretation will depend on design issues such as the “match” between the icon and its associated message and the context in which the icon is presented.

Figure 4 is helpful, but not sufficient to allow us to select appropriate icons/symbols from a large universe of possible alternatives. The key challenge of the present project is to find a scientifically valid way to create useful symbology for IVIS message sets, taking into account driver capabilities and limitations. Studying individual icons and determining which have the highest memory scores or fastest response times is not a sufficient solution. This simple approach ignores interactions between sets of icons and will not yield a useful methodology for integrating symbols, especially when different message sets (e.g., navigation versus crash avoidance) must be displayed. A possible solution is to use theory to map symbols to the in-vehicle messages. Symbols are effective only to the extent that they convey messages that drivers need and can effectively use.

Figure 5 shows a theoretical structure, adapted from Rasmussen (1986), that allows us to determine key features, called *information elements*, of the IVIS message sets. The concept of information elements has been used in the past to examine critical human factors concerns with ATIS/CVO functions and messages (Lee et al., 1996). Each box in figure 5 represents an information element, each of which defines a different way IVIS messages can convey information to drivers. The boxes (or stages) in figure 5 are at different conceptual levels. For example, a message that *alerts* the driver is conceptually less complex than a message that *informs* the driver: an *alert* merely signals some abnormal situation, like the master caution light in airplanes and in some vehicles, whereas an *inform* localizes a discrepancy between an actual and a desired system status, like an airplane or vehicle warning that fuel is insufficient to reach the desired destination. The cognitive load placed on the driver by these two kinds of messages is very different. The theoretical structure in figure 5 is an analytic tool that helps us to quickly and systematically evaluate symbols by identifying the semantic content of the message (or message set) that the symbol (or set of symbols) must convey.

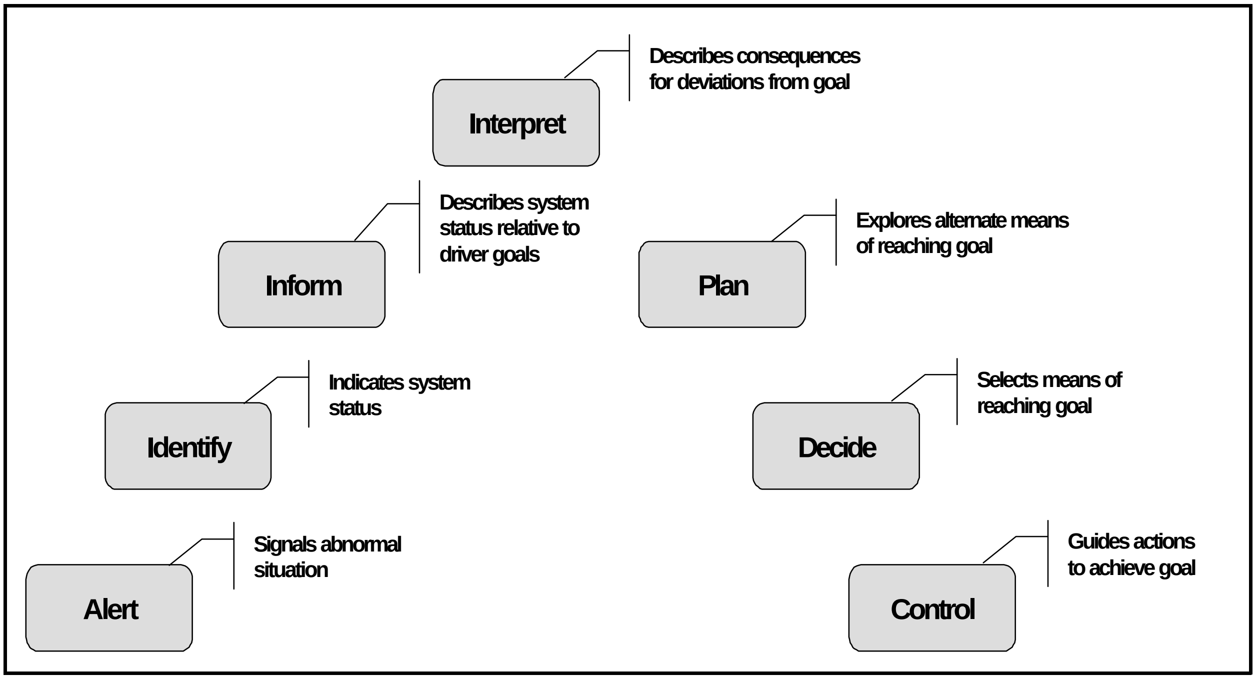


Figure 5. Preliminary conceptual framework that identifies the information content of messages and the requirements of candidate symbology.

ICON DESIGN

Models of Symbol Recognition and Understanding

A discussion of symbol recognition and understanding would not be complete without first reviewing the basics of visual processing. It is important to understand that the first step toward true comprehension of a symbol is the ability to perceive it and process it. Humans process language and visual information in different hemispheres of the brain. The left hemisphere of the brain generally processes language, while the right hemisphere generally processes visual/spatial information. The way in which these two types of information are processed also differs considerably. The left hemisphere processes information serially, one piece at a time, while the right hemisphere functions in a parallel mode, taking in chunks of information all at once. Therefore, when we first perceive an image or symbol, it is captured as a whole, processed in a parallel manner, and its semantics or meaning are entered into long-term memory. This transfer of visual information to long-term memory may occur straight from sensory memory or it may occur via a short-term visual memory similar to that of verbal memory. It appears as though there is no upper bound to visual memory (Lodding, 1983).

While there are many unanswered questions about how visual information is recalled, studies have shown that most people can recognize previously viewed images with almost perfect accuracy (Paivio, 1971; Haber, 1970). Fleming and Levie (1977) also found that, given a certain number of items, people are able to recognize pictorial material faster than textual material. So what is it about pictorial information that helps us to recognize it? Cody and Madigan (1982) studied recognition by comparing performance with black and white drawings, black and white detail and shaded drawings, black and white photographs, and color photographs. Results showed no differences in subjects' ability to recognize pictorial information from these different sources. This indicates that the details that come from using color or shading or real photographs are not the most important factors affecting recognition. Instead, it is the type of features in the visual stimulus that are encoded and stored for later recall.

<u>Basic Feature Analysis</u>

While feature encoding may be important for the subsequent recognition of symbols that we have just learned, feature decoding or analysis can help us to recall or comprehend those symbols that we have difficulty remembering or have never seen before. Feature analysis is the process of breaking down a visual image (such as a symbol or icon) into simpler and simpler graphic objects until we can recognize the separate pieces and then combine their meanings to arrive at an understanding of the whole.

There are a number of alternative cues that are frequently used to enhance the understandability of an icon or symbol. These cues may include things such as: context, experiences of the user, redundant coding, and repetition of graphic elements. Context refers to the situation in which we view the icon and all of the pieces of information available in our environment that might lead us to interpret it in one way or another. According to Horton (1994), this can include: adjacent icons; related labels or other text; previous windows, displays, or screens; or the overall task we are trying to accomplish. Horton gives several examples of how changing the context in which a symbol is presented can change the perceived meaning. One such example is presented in table 2.

Table 2. Example of how context can affect meaning (Horton, 1994).

	in this context...	**means this.**
The color red...	Traffic light	STOP
	Weather map	Severe or Hot
	Flower	Love
	Security	Danger

Past experiences of the user can also trigger mental processes that lead to recall and understanding:

- Our *perceptions* can help us filter out irrelevant information, giving us only that which seems important or meaningful.

- *Interest* and *curiosity* guide our attention and help us notice specific things that might aid in determining meaning.

- *Memories* and *knowledge* help us fill in the blanks and edit images so that they make sense to us.

- Through *reasoning* we can infer meaning, even when we are not given all of the necessary information.

- *Emotion* motivates us to find meaning, even when it may be very difficult.

Redundant coding (i.e., presentation of the same message two different ways in the same icon) can also help enhance meaningfulness. For example, a stop sign is red, octagonal, and has the word "STOP" on it. All of these things together help give it its meaning. However, if someone is color blind, the sign can still have meaning to them because of the redundant coding of the shape of the sign and the text message presented on it. Without these redundant cues, a person might have a very difficult time determining any kind of meaning.

Repetition of graphic elements within a set of icons can also make it easier for a user to identify the icon and retain its meaning. According to Hemenway (1982), icons that share graphical elements are easier to learn because users are able to apply what they have learned from the decoding of one icon to the next icon that they see. She also states that repeating a graphic element can make it easier to identify and more memorable, simply because users see it more often than they would if it weren't repeated. However, the repetition of graphic elements could also have the negative effect of leading to confusion between icons. Therefore, care should be taken to ensure that those icons that are close together, either in location or in meaning, should be easy to discriminate between.

Gestalt Thinking

Many of the perceptual theories about how we decode and comprehend symbols have come from the ideas and experiments that were completed by the Gestalt psychologists like Kohler, Wertheimer, and Koffka. They were the first to discover that the determinants of shape and form are the *figures* in the visual field, which in turn are characterized by their *contour* (i.e., outline or boundary). They called this delineation of one part of the visual field from another the "figure/ground" phenomenon. They also derived many of the principles that make up the concept of "figural goodness," whereby the perceptual process of decoding any incoming stimuli is enhanced by the inherent clarity and stability of the form (Easterby, 1967).

Easterby (1967, 1969, 1970) has done a lot of work examining the figural aspects of symbols and using the principles of figural goodness to determine how they affect perception, recognition, understanding, and learning. He argues that the structural properties of a symbol are important determinates of its perceptibility and that they provide the contextual cues which define the meaning of a symbol (Barnard & Marcel, 1978). These structural properties include such things as continuity, closure, symmetry, simplicity, and unity (Easterby, 1970).

! *Continuity*—Icons that have a smooth, continuous outline are easier to perceive.

! *Closure*—Icons that are closed figures are preferred.

! *Symmetry*—Icons that are symmetric are easier to organize into the visual perception process.

! *Simplicity*—Icons should be as simple as possible. The inclusion of fine details makes icons ambiguous and more difficult to interpret.

! *Unity*—Icons should be as unified as possible. This can be achieved by consistent use of size and positioning for icons that are repeated and by enclosing solid and line figures when they occur together.

Using these structural properties can help create optimal conditions for recognition and comprehension by guiding the eye to the true subject or feature of importance in an icon. Easterby would argue that if an icon possesses these five general characteristics, it can be called a "good" icon.

Basic Design Principles

In order to gain the greatest benefits from the use of icons, they must be designed in a careful and thoughtful manner. Green and Pew (1978) argue that providing well-designed symbols can actually increase comprehension. However, determining what a "well-designed symbol" actually is can be a harder task than one might imagine. A well-designed symbol has been defined as one that is legible (Sanders & McCormick, 1993), understandable (Dewar, 1994), comprehensible (Ringseis & Caird, 1995), and meaningful (Greene, 1979). While these definitions make sense, they do not give much direction as to how to go about designing a good icon while avoiding the mistakes that can lead to the design of a bad icon.

Specifically, what distinguishes a good icon from a bad icon? Why does the meaning of some icons seem immediately clear to most users while others only lead to confusion, frustration, and errors? Specific guidelines for icon design will be developed in Task C of this project. Below, we summarize general principles for icon design.

<u>General Suggestions for Icon Design</u>

Some very general suggestions for improving icon design have appeared in the literature several times (Aurelio & Cist, 1990; Easterby, 1970; Welford, 1984). These general suggestions include the following:

! Icons should be designed with the appropriate level of realism. Any unnecessary picture elements should be deleted from the design. Include only those details that will add to the meaning of the symbol and delete those parts that will distract from the true goals of recognition and understanding. Horton (1994) discusses the five different levels of detail and realism that can be used: photograph, drawing, caricature, outline, and silhouette (see figure 6 for an example of each). Each of these styles has its place, where one may work better than another for conveying particular types of information.

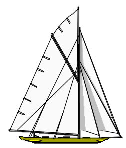
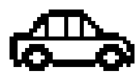
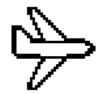
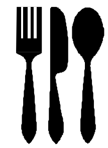
Photograph	Drawing	Caricature	Outline	Silhouette
				

Figure 6. Examples of the five levels of realism for icon design (icons from Horton, 1994, and Corel*DRAW!* 6.0).

! Maximize the amount of resemblance to actual objects through the use of image or concept-related icons. According to Horton (1994), objects can be made even more recognizable through the use of certain techniques, such as changing the viewpoint, exaggeration of crucial concepts, or the use of depth cues or shadows. Figure 7 gives some examples of these techniques. If at all possible, avoid using arbitrary objects such as symbols (Gittins, 1986). Although it is possible for people to learn to associate the concept with an arbitrary symbol, it can take a lot of time and/or money to accomplish.

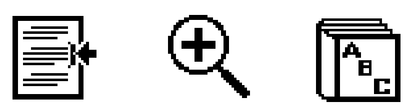
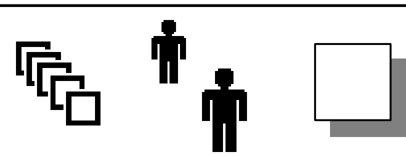
Changing Viewpoint	
Exaggerating Crucial Concepts (i.e., point to object, frame object, enlarge object)	
Use of Depth Cues (i.e., overlap, scale, shadow)	

Figure 7. Techniques for improving icon recognizability (icons from Horton, 1994).

! Symbols should identify an object and show the "effect" or action that will occur when the control is actuated. When a symbol conveys action, it is important that the resultant action of the mechanism is what is displayed (Dreyfuss, 1966). Horton (1994) gives several examples of how we can best show action or motion (see figure 8). He suggests using arrows, speed lines, and sequencing of images to accomplish this task.

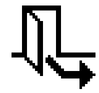
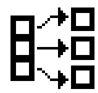
Arrows	
Speed Lines	
Sequencing of Images	

Figure 8. Examples of how to best show action or motion (icons from Horton, 1994).

! Use symbols that the user already associates with the object or idea. Many times there are icons that already exist and that have become acceptable through use over time. Also, take advantage of population stereotypes whenever possible. There is no need to invent another symbol if one already exists that will adequately present the information. Examples include a trash can icon to delete files or an airplane icon to designate the location of an airport.

While each of these general suggestions gives us some useful information, it is not clear how or when to apply them. In the case of designing with the appropriate level of realism, how does a designer know whether a simple outline will convey the meaning of a particular referent or whether a drawing will be necessary? In many cases, the literature is not helpful for making these kinds of determinations. Slightly more specific, and therefore more useful, information was found in the literature that discussed the issues surrounding symbol structure, shape, color, and modality.

Symbol Structure

Icons can consist of simply a graphical image, or they can contain a border, a background, a text label, or a combination of any of these elements. It is important to understand how incorporating any one of these elements into the design of an icon can affect its appearance and understandability.

Borders show the extent of an icon (i.e., where it begins and where it ends). This can be important to interactive systems that use icons as control buttons. In such instances, a border might help the user determine exactly where to click or point in order to select an icon. They also make icons appear orderly, consistent, and uniform. Borders can also help to clarify the icon’s meaning if they resemble a familiar object (i.e., a book or an engine symbol). However, there are some drawbacks associated with using borders. They can make icons less distinctive, compete with the image, and limit the size of the image that can be used (Horton, 1994).

The use of a background is not always seen as being an important part of icon design. However, when used appropriately, backgrounds can help emphasize the image, group or classify icons, or show the state of an icon (see figure 9).

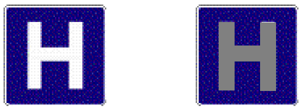
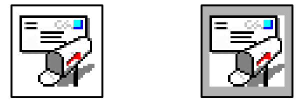
Emphasize Image	Group Icons	Show Icon Status
 *The lack of contrast for the icon on the right causes it to disappear into the background.*	 *Icons that belong in the same category can be grouped by their background (e.g., all recreational and cultural interest signs have the same brown background).*	 *Varying the background of an icon can show its status or condition.*

Figure 9. The use of background in icon design (icons from MUTCD and SUNY at Geneseo College).

Horton (1994) gives several suggestions for successfully using backgrounds to enhance an icon:

- Don't cover more than half the available area with objects.
- Avoid patterns in the background.
- Put the image clearly in front of the background.
- Place objects in the center and the background around the periphery.
- Use unsaturated, cool colors for the background and saturated, warm colors for the foreground image.
- Keep the background static; if anything blinks or moves, the viewer perceives it as a foreground image.
- Make the background image a simple rendition of a recognizable, concrete object.

As with borders, however, backgrounds can compete with and overwhelm the central image in the icon. Backgrounds must be used in a manner that complements the image and increases icon comprehension.

Horton (1994) suggests that presenting text labels in addition to an icon is a good idea when the icon is not obvious or if it is being presented for the first time. Research has shown that presenting the two together can increase comprehension and therefore overall effectiveness. For example, a study performed by Edigo and Patterson (1988) compared people's ability to navigate through a database using either pictorial icons, text labels, or a combination of the two. The results showed that subjects were able to reach the target object much quicker and with fewer steps in the icon plus text condition. Another study conducted by Muter and Mayson (1986) found similar results when they examined the role of graphics in the selection of items from a menu. Specifically, they found that text plus graphics greatly reduced the number of errors in the selection of the correct item.

However, the use of text labels in icon design may lead to other problems. First, text labels must be brief, no more than one or two words, and not all icon concepts may be amenable to such a succinct label. If not carefully chosen, a text label may mislead the user and reduce comprehension. Second, text labels reduce the universal nature of icons, as they must reflect a specific language and/or culture. Third, text labels require additional display space. Such space might be better used to increase the size and understandability of the icon.

<u>Symbol Shape</u>

One important factor in icon design is the actual visual characteristic or shape of the icon. Shapes can help people discriminate between icons in a set. A study conducted by Arend, Muthig, and Wandmacher (1987) compared the selection and response times for three different sets of icons: a set in which the icons differed by their global features (i.e., shape, size, color), a set in which the icons differed by their local features (i.e., lines and structures within an icon), and a word set. The results of the study indicated that the global features of an icon are responded to faster than local features. This phenomenon has been called the "global superiority effect" (Pomerantz, 1983; Wandmacher & Arend, 1985). One explanation for this effect is that global features can be scanned in parallel while local features must be scanned sequentially. Another explanation, however, is that scanning global features requires one to pay attention to less detail and therefore can be done more rapidly.

Shapes are also important for icon design because they can infer meaning. This is particularly true of traffic signs. According to the MUTCD, "STOP" signs are octagonal in shape, "YIELD" signs are equilateral triangles pointing downward, other regulatory signs are rectangular in shape with the longer dimension vertical, and warning signs are generally diamond-shaped (see figure 10). Having certain shapes designated for specific types of signs can help reduce both recognition and response times.

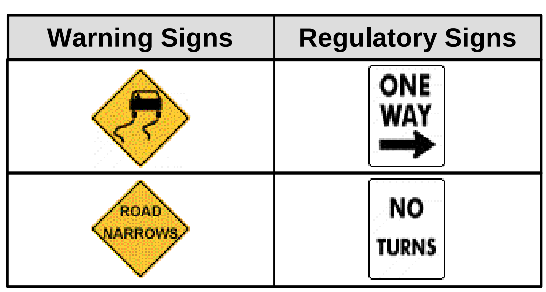


Figure 10. Examples of the designated shapes for particular types of traffic signs.

Horton (1994) suggests that certain shapes project certain meanings:

- Straight-edged shapes most frequently occur in man-made objects and suggest a mechanical or rigid quality.

- Rounded shapes occur in nature and living organisms and we associate them with organic, fluid concepts.

- Regular shapes can represent abstract concepts better than irregular shapes, which tend to draw attention to their irregularity.

- Irregular shapes tend to draw attention to themselves and may best be used to represent unique objects.

- Concave shapes draw the viewer's eye to the enclosed space, causing the viewer to focus attention on whatever is there.

- Convex shapes push the viewer's attention outward.

While the effect of shape is more subtle, it can be an important tool for adding meaning to an icon.

Symbol Color

The idea of using color in symbol design must be approached very carefully. Some research has shown that it does nothing to improve the discriminability of symbols. Biederman and Ju (1988) compared subjects' ability to recognize color photographs with their ability to recognize simple line drawings of common objects. They found no difference in either the amount of time it took subjects to recognize the object or the number of errors made. Rogers (1989) does not recommend using color to fill in images. She states that searching for an icon from a whole set of filled-in icons can be a more difficult task than if the icons were simply black and white.

Others argue, however, that, when used correctly, color can be a useful tool for conveying meaning. The most common and consistent use of color for conveying meaning is in traffic control devices. The use of green as permissive, amber or yellow for warning, and red for restrictive is almost universal. Another example where the use of color has come to hold some particular meaning is in the use of red for hot and blue for cold. These are two examples of very strong "population stereotypes" or expectations. When designing icons, it is important to understand population stereotypes and to try not to violate these expectations (Campbell et al., 1998).

Color can also be used effectively as a coding mechanism, making it easier for people to distinguish between those icons that are related to each other. Davidoff (1988) performed an extensive literature review on the use of color for a range of different tasks and found that color may be most useful for dividing icons into related subgroups. It may also help facilitate rapid identification. One must be careful, however, not to use too many colors, as this will only increase search time.

The combination of colors is also critical to good symbol design. Page (1993) conducted an analysis of prior research on color combinations in order to reduce the number of combinations he would have to include in his study. A summary of the results of this analysis can be seen below.

- According to a study performed by Helander (1989), blue text on red or red text on blue can cause chromostereopsis, which is a false indication of depth.

- Red text on green and red text on blue caused 10 percent poorer performance on selection tasks in a study completed by Matthews and Mertins (1989).

- Taylor and Murch (1986) found that magenta and green received the lowest scores in preference tests of computer colors, while black, blue, and red received the highest.

- Nearly 10 percent of the Caucasian male population and 4 percent of the non-Caucasian male population suffer from either color deficiencies or color blindness. The following color combinations should be avoided for these individuals: cyan and gray, yellow and light green, green and brown, red and black (Travis, 1990; Thorell & Smith, 1990).

In summary, while color can be an effective cue for both the legibility and comprehension of icons, it must be used in a careful and deliberate manner. Issues such as color contrast, color combinations, and the overall number of colors used to develop an icon set can have a serious impact on the perception and utility of icons.

Symbol Modality

Presentation of ATIS and CAS information is usually done through the visual modality, the auditory modality, or some combination of the two (Campbell et al., 1998; Campbell et al., 1997). Within the driving environment, each of these modes is associated with some advantages and disadvantages. Presenting information visually is less intrusive than presenting information through the auditory channel. However, the visual channel is the more traditional mode for presenting information to the driver, and is associated with relatively higher information rates (Sorkin, 1987) than the auditory channel. Also, driving requires a great deal of visual scanning just to maintain proper lane position and situational awareness of surrounding traffic conditions. Using a visual display to present information to the driver introduces yet another visual task, which could end up overloading the driver and lead to unsafe driving conditions. For these reasons, many manufacturers of ATIS and CAS devices are looking into the possibility of using auditory tones or sounds for the presentation of in-vehicle messages.

Auditory icons or “earcons” represent a special subset of auditory displays. Earcons allow people to monitor and identify sources of information from all directions, not just the direction that the head is pointed, as is the case with visual sources of information. This allows for much more flexibility and enables the user’s attention to be captured even while performing a separate task.

This would provide drivers with access to useful information without having to take their eyes off of the roadway.

Brewster, Wright, and Edwards (1993) list several other advantages to the use of earcons. First, they can be used to supplement the visual system by either increasing the amount of information presented, or reducing the amount of information that will have to be perceived out of the visual channel. Second, they can act as a redundant cue. If someone cannot remember what an icon looks like, they might remember what it sounds like. Third, they make graphical user interfaces more accessible to those users who are visually disabled.

The use of auditory icons for in-vehicle display devices, particularly CAS, has received quite a bit of attention. It is believed that drivers might be better able to interpret the meaning of auditory icons and respond to them in an a more appropriate and timely manner than traditional auditory verbal messages or simple tones (Graham, Hirst, & Carter, 1995). However, a recent study by Graham et al. (1995) found mixed results. When examining the response times to either a simple tone, a one-word voice message, or two auditory icons (i.e., skidding tires and a car horn), results showed faster reaction times for the auditory icons. But the results also showed more frequent inappropriate braking responses with the auditory icons. It appears as though drivers always perceived the auditory icon as requiring an immediate response.

Another issue to be considered when designing earcons for use in an in-vehicle system is volume. It is difficult to determine exactly what volume level is necessary and appropriate. Auditory alerts that are too loud may be switched off and not turned back on again, especially if false alarm rates are high (Rood, Chillery, & Collister, 1985; Thorning & Ablett, 1985). A second concern is that loud warnings may actually divert drivers' attention away from a potentially critical situation while they attend to an alert. And lastly, loud alarms can startle drivers, causing them to become confused and disoriented, again making it difficult for them to attend to the situation that they are being warned about. Therefore, setting the auditory icons to activate at the appropriate levels is extremely important if they are to be at all effective in the way they were intended.

Another thing to consider during the design of earcons is people's ability to learn and remember them. Edworthy (1994) states that warnings and their meanings can be easily learned as long as people are not expected to learn too many and can discriminate between the two. Patterson (1982) suggests using no more than six distinct auditory alerts. However, making all six of them different enough to distinguish and remember as separate earcons can be difficult. Meredith and Edworthy (1994) have found that auditory warnings of the same tone or those with the same on/off ratio can easily be confused.

These considerations are especially important when designing earcons that will be used by the aging population. In a study conducted by Kantowitz et al. (1997), 18 subjects (12 between ages 18 and 30, and 6 over age 65) were played 21 unique naturalistic sounds or complex tones and asked to write down what each one meant. While scores for the younger subjects for pretest one, two, and three were 98.75, 99.6, and 100 percent, respectively, older subjects were unable, even in four pretest trials, to recognize all 21 messages. Kantowitz et al. (1997) suggest that their failure was due to an inability to distinguish the 300 m bursts of sounds rather than an inability to remember 21 different earcons.

Although the selection of auditory vs. visual forms of information display depends on a number of situation-specific variables, Deatherage (1972) has provided general guidelines for selecting auditory vs. visual display modalities. These guidelines are presented in table 3.

Table 3. General guidelines for the selection of auditory vs. visual forms of information presentation (from Deatherage, 1972).

Use Auditory Presentation If:	Use Visual Presentation If:
1. The message is simple	1. The message is complex
2. The message is short	2. The message is long
3. The message will not be referred to later	3. The message will be referred to later
4. The message deals with events in time	4. The message deals with location in space
5. The message calls for immediate action	5. The message does not call for immediate action
6. The visual system of the person is overburdened	6. The auditory system of the person is overburdened
7. The receiving location is too bright or dark-adaptation integrity is necessary	7. The receiving location is too noisy
8. The person's job requires him to move about continually	8. The person's job allows him to remain in one position

Task B of this project will further address some of the issues surrounding symbol modality. The discussion presented above is intended to introduce the possibility of alternative presentation modes and to discuss some of the important considerations that must be made when selecting display modality. A summary of these design considerations can be found in table 4.

Table 4. Summary of design considerations.

Visual	Auditory
Size	Volume
Brightness	Duration
Shape	Frequency
Contrast	Spatial location
Color	Format (voice, naturalistic sound, simple tone, complex tone)
Location	Number of presentations
Structure	

EVALUATION OF ICONS

The only way to ensure good icon design is through iterative testing and evaluation. By this we mean testing and revising and then testing again. Several iterations of testing and revising are typically required to produce icons that are reliable and efficient. The International Committee for Breaking the Language Barrier proposes several useful criteria for the primary evaluation of icons (Kato, 1972). Designers should ask themselves these questions as a way to ensure that the most important design issues have been considered before they move ahead toward any additional testing:

! Is it easy to associate the symbol with the message?

! Is the symbol equally appropriate for all of the cultures and situations in which it will be used?

! Will the symbol be appropriate in the future?

! Is the symbol pleasing and noncontroversial?

! Is the symbol in accordance with existing international standard symbols?

! Can the symbol or its elements be applied systematically for a variety of interrelated concepts?

! Is the symbol easy to reproduce in a variety of environments and situations?

! Is the symbol distinguishable from other symbols?

Once designers have considered each of these issues and feel confident that the icons they have developed meet the necessary criteria, it is important that evaluation be taken to the next level—testing with actual subjects who represent the user population.

ISO Evaluation Procedures

A four-stage method for icon development and evaluation was proposed in 1973 by Technical Committee 145, which was formed by the ISO. This method involves four individual test procedures. The first three tests—the production test, appropriateness ranking test, and comprehension/recognition test—are all important for limiting the number of candidate symbols. The final test, the matching test, is used to ensure comprehension and recognition, and that there is no confusion between symbols within a set (Easterby & Zwaga, 1978). Each of these tests is summarized below.

Production Test

The production test is used to generate a broad range of candidate symbols for a concept or referent under consideration. In this test, subjects are asked to draw symbols that they think represent a particular referent. The outcome is a number of symbolic representations of a referent that are considered comprehensible by individual subjects. The overall goal of the production test is to create as many different candidate symbols for the next stage of evaluation as possible.

Appropriateness Ranking Test

The purpose of the appropriateness ranking test is to screen the candidate symbols and select the best for further testing. This can be done by showing the subject a set of cards, one for each of the symbols, and asking them to rank order them according to their appropriateness. Then, using Torgerson's (1965) categorical scaling model, the designer can calculate scale values. This allows the designer to obtain not only a general rank order, but also some indication as to how much the candidate symbols differ along the scale. Once data have been gathered regarding the appropriateness of each of the symbol candidates, the three candidate symbols with the highest ranking are typically selected for further testing.

Comprehension/Recognition Test

From the comprehension/recognition test we can determine which of the screened candidate symbols for a concept is best understood by a sample of subjects who represent the user population. During this test, a symbol is presented to a subject, the context of use of the symbol is specified, and the subject is asked to name the object, location, or activity the symbol stands for. It should be noted that previous studies have indicated that significant differences exist between younger people and older people in their ability to comprehend symbols (Dewar et al., 1994; Saunby et al., 1988). Therefore, subjects should be representative of the user population (e.g., half between the ages of 18 and 40 years and the other half over 55 years).

Matching Test

Once the best or most appropriate design for a particular symbol has been determined, it is important to examine how well that symbol will work within a set and whether the many symbols within the set can be discriminated from one another without confusion. In order to do this, a matching test is performed. Subjects are shown a sheet with all of the symbols from a set on it, arranged in a matrix. The subject is then told the context under which they would use these symbols. Next, subjects are given a referent name and asked to indicate on the matrix which one of the symbols stands for that particular referent. The outcome of the matching test is two measures of symbol effectiveness: the number of correct choices of a particular symbol and the degree of confusion between symbols.

Additional Evaluation Techniques

In addition to the ISO procedure described above, there have been several other efforts aimed at the systematic evaluation of symbols, summarized in table 5. Green and Pew (1978) studied 19 candidate symbols for use in automobile displays and controls. They examined whether subjects understood how the symbol was used, how well the symbol conveyed its message, how difficult it was to learn and remember the symbol, and the amount of time required to determine whether or not a symbol fit a particular referent. Dewar and Ells examined some of the same symbols using several other measures. These measures included: legibility distance, reaction time, glance legibility, semantic differential ratings, and preference (Dewar & Ells, 1974; Dewar et al., 1976; Ells & Dewar, 1979). Another set of experiments was carried out by Roberts, Lareau, and Welch (1977), who examined both printed and symbolic versions of 19 traffic signs. They used five more measures for determining symbol effectiveness: understanding time, accuracy of comprehension, certainty, preference, and identification time.

Table 5. Summary of additional symbol evaluation techniques.

Source	Evaluation Technique
Green and Pew (1978)	• Familiarity task • Association task • Rating task • Paired-Associative learning task • Reaction time task
Dewar and Ells (1974) Dewar, Ells, and Mundy (1976) Ells and Dewar (1979)	• Legibility distance • Reaction time • Glance legibility • Semantic differential rating • Preference
Roberts, Lareau, and Welch (1977)	• Understanding time • Accuracy of comprehension • Certainty • Preference • Identification time

Determining which of the measures to use to evaluate the effectiveness of your candidate symbols can become very confusing. According to Mackett-Stout and Dewar (1981), the importance of using specific measures depends upon the purpose of the symbol and where it will be used. Using some measure of comprehension is essential to evaluate any candidate symbol. Measures of legibility distance may be important if you are evaluating symbols on a road sign, but less important if the symbol is on a road map. Additionally, results from the study conducted by Green and Pew (1978) indicate that preference is a worthwhile measure to include in symbol evaluation. Other measures, such as reaction time or glance legibility, might also be included if symbols will require a rapid response or if there is a short exposure duration.

It should be noted that, while the design of any new symbol warrants evaluation before it should be used, evaluation of existing symbols should also be considered. Many of the source books

(Dreyfuss, 1972; Modley, 1976) contain symbols which, for the most part, have not adequately been evaluated. It would be erroneous to assume that just because a symbol is in use, it must be adequate. A good example of this can be found in some fairly recent research that was conducted by Dewar et al. (1994) and Hawkins et al. (1993). Both studies examined the comprehension of symbols found in the MUTCD. This document contains the principles that govern the design and application of traffic control devices to date. Results of both studies showed that comprehension levels for many of the signs were extremely low, especially for older drivers.

It is also important to remember that icons are not displayed in isolation. They are most often displayed along with a group of related icons, as part of a set. Therefore, evaluations should examine groups of related or concurrently displayed icons and consider all of the potential confusions and ambiguities that might occur. These confusions could take place because two or more icons have similar characteristics, making it difficult to determine which one represents a particular message. For example, in a study conducted by Green and Pew (1978), the choke symbol was often confused with the symbol for the ventilating fan. This confusion most likely occurred because the two symbols had similar characteristics, in that they both contained an element that could be perceived as a fan blade. Confusions can also occur because two or more messages are equally likely to be paired with a particular icon. A study conducted by Saunby et al. (1988) discovered that the windshield washer and windshield wiper messages were both more likely to be paired with a single symbol containing elements (wiper blade and washer spray) important to both messages. Therefore, since the meaning of icons can be ambiguous, icons must, to the extent possible, reflect the best possible surrogate for a particular message. That is, the message or referent associated with the icon must be the predominant message associated with the icon.

When evaluating icons, it is important to examine not only those icons that the subjects correctly recognize and understand, but to identify the errors or misidentifications that can occur as well. Identifying the confusions between symbols and determining why they occur can be extremely important to the development of a good set of icons. It is especially helpful when subjects are able to identify the exact element(s) in the symbol that are causing the confusion. This makes it much easier and quicker for the designers to make the necessary revisions before testing begins again.

DRIVER INFORMATION REQUIREMENTS

The first step toward designing a set of icons or symbols for ATIS or CAS devices is to determine the type of information that the driver is going to need. A list of driver information requirements was created by reviewing several existing reports (Campbell et al., 1997; Neale et al., 1997; Campbell, et al., 1998; Cambell et al., 1996) and extracting those information requirements that were determined to be most relevant and helpful to drivers (see appendix C for a complete list).

The driver information requirements that were identified were separated into several different categories: *ATIS—Routing and Navigation, ATIS—Motorist Services, ATIS—Augmented Signage, ATIS—Safety/Warning, ATIS—Commercial Vehicle Operations (CVO), GPS-Related*

Information, and Collision Avoidance. A brief description of the types of information requirements that can be found in each category is given in table 6.

Table 6. Types of driver information requirements found within each category.

Categories	Information Types
ATIS—Routing and Navigation	Trip planning Multi-mode travel coordination and planning Pre-drive route and destination selection Route guidance Route navigation Automated toll collection
ATIS—Motorist Services	Broadcast services/attractions Services/attractions directory Destination coordination Message transfer
ATIS—Augmented Signage	Roadway guidance sign information Roadway notification sign information Roadway regulatory sign information
ATIS—Safety/Warning	Immediate hazard warning Road condition information Automatic/manual aid request Vehicle condition monitoring
ATIS—Commercial Vehicle Operations (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
GPS-Related Information	
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

EXISTING SYMBOLS AND ICONS

Once the comprehensive list of driver information requirements was developed, we attempted to match existing symbols and icons to each of those requirements. Existing symbols were gathered from four different sources: standards documents, icon websites, systems currently available or under development, and relevant research.

- ***Standardized icons accepted by government institutions for conveying information to drivers.*** These are standard icons that can be found in the MUTCD and Department of Motor Vehicle manuals from various States. Appendix D shows those standardized icons that match up with the driver information requirements previously identified. It should be noted that standardized symbols or icons could not be found for many of the information requirements we identified. This was particularly true for ATIS routing and navigation and collision avoidance information for which no standardized icons could be found.

- ***Non-standardized icons that could be used to convey information to drivers.*** These icons were found by searching numerous websites (see appendix A for a complete list of home pages). Appendix E shows those non-standardized icons that match up with the driver information requirements previously identified. Notice that for some of the information requirements there are several candidate symbols or icons to choose from, while for others none could be identified. This was particularly true for certain categories of ATIS routing and navigation and collision avoidance information for which no candidate symbols or icons could be found.

- ***Icons currently being used by manufacturers and after-market vendors of ATIS and CAS systems.*** These icons were found by searching companies' web pages and contacting company representatives via phone and e-mail to obtain information about existing systems. Several companies presented either a description or a demonstration of their system, including examples of screens which may be seen by the user. These screens contained icons currently being used by these systems for representing many different driver information requirements. Appendix F provides a figure (or screen) that contains the symbol or icon currently being used by a particular manufacturer or after-market vendor to represent that driver information requirement. It should be noted that this information is not yet complete, as we are still waiting for sample screens from Clarion, Alpine, Siemens, and General Motors. These will be added as soon as they become available and included in our Task B activities.

- ***Icons used in previous research efforts related to ATIS and CAS systems.*** These icons were found by reviewing several completed reports that have examined issues related to in-vehicle navigation and information systems (Campbell et al., 1997; Neale et al., 1997; Campbell et al., 1998; Campbell et al., 1996). Appendix G provides a figure (or graphic) containing the symbol or icon that was used in one of the research projects mentioned above to represent a particular driver information requirement.

While we were able to identify a wide variety of symbols/icons for representing a large number of driver information requirements, it is important to remember that most have never been systematically evaluated to determine how well they would be recognized or understood by the people who would use them. Several studies have assessed the comprehension rates of those symbols and icons that are considered standard and have found comprehension to be rather low

(Hawkins et al., 1993; Dewar et al., 1994; Saunby et al., 1988). If this is the case for standard icons, what kind of comprehension rates can we expect from those icons or symbols that are not considered standard?

The research has indicated that current standards for determining minimum acceptable comprehension rates are inconsistent and may not apply to a broad range of IVIS driver messages. For example, Heard (1974) recommends a 75 percent recognition rate and a maximum of 5 percent confusions. Most of the literature, however, adheres to the ISO recommendation of a 67 percent comprehension rate for acceptance. In addition, existing literature does not address the possibility of having different minimum acceptable comprehension rates to reflect differences in the priority or urgency of IVIS messages (e.g., restaurant information vs. collision warnings). We plan to address these issues during our guideline development in task C. We will also have to address the issue of having two icons with similar comprehension rates representing the same message. In cases such as this, we will have to determine the point at which one icon is better than another. For example, is an icon that has a comprehension rate of 86 percent really better than one that has a comprehension rate of 84 percent?

It appears as though the process of developing and choosing icons is a very subjective one and that a set of standards or guidelines would be extremely helpful to designers. Existing standards leave much to be desired in the way of aiding the design of symbols and icons to be used in more advanced IVIS devices. A discussion of the state of current standards and guidelines follows.

EXISTING STANDARDS AND GUIDELINES

Several different standards are in place for regulating the design and production of automotive displays. Most of these standards come from the United States Government and are issued by the National Highway Traffic and Safety Administration (NHTSA). These standards are called the Federal Motor Vehicle Safety Standards (FMVSS) and Regulations. Additional regulations are published by the ISO and the SAE. Standards have also been developed for the presentation of additional information elements that one would normally see presented on the outside of the vehicle (i.e., road signs, signals, markings, and devices). These standards can be found in the MUTCD.

This section provides a brief review of those automotive standards that seem to apply to our effort of producing a guideline document for the design of in-vehicle display icons and other information elements.

ISO Standards

The ISO consists of a number of national standards bodies worldwide. The process of preparing international standards takes place through technical committees. Any member interested in participating in a particular committee has the option to do so. International organizations, governmental and nongovernmental, in liaison with the ISO, also take part in the work.

A review of the ISO standards relevant to graphic symbols and their design for use in automotive displays and controls led us to ISO 2575: 1995 and ISO 3461-1: 1988. A brief description of what is contained in these standards can be found in the following paragraphs.

<u>ISO 2575</u>
Road Vehicles—Symbols for controls, indicators, and tell-tales.

This international standard establishes the symbols that should be used on indicators and tell-tales of automobiles to ensure identification and facilitation of use (i.e., high beam or hazard warning). Where appropriate, it also states the color that should be used for best informing the driver of either correct operation or malfunctions.

<u>ISO 3461-1</u>
General principles for the creation of graphical symbols- Part 1: Graphical symbols for use on equipment.

This part of ISO 3461 establishes the basis for creating graphic symbols for use on equipment. It contains the basic design principles for constructing graphic symbols, including their size, shape, orientation, and instructions for application.

Relevant SAE Standards

The SAE is made up of 75,000 members from more than 97 countries worldwide who share an interest in advancing mobility technology. Standards are written through technical committees consisting of those persons who have an interest or expertise in a particular area. SAE technical committees write more new aerospace and automotive engineering standards than any other standards-writing organization in the world.

A review of the SAE standards relevant to graphic symbols and their design for use in automotive displays and controls led us to SAE J1048. A brief description of what is contained in this standard follows.

<u>SAE J1048</u>
Symbols for motor vehicle controls, indicators, and tell-tales.

This standard specifies the graphic symbols that should be located on certain controls, indicators, or tell-tales in order to ensure their identification and facilitate their use (i.e., upper beam or hazard warning). This standard also gives any additional specifications that may be necessary, such as colors for indicating both correct operation and malfunction of the controls.

Federal Motor Vehicle Safety Standards (FMVSS)

FMVSS regulations come from the United States Government and are issued by the NHTSA, an agency within the Department of Transportation (DOT). A review of the standards that apply to graphic symbols and their design for use in automotive displays and controls led us to MVSS 101/80. A brief description of what is contained in this standard follows.

MVSS 101/80

The goal of this standard is to ensure the accessibility and visibility of motor vehicle controls and displays and to facilitate their selection in order to reduce the safety hazards caused by attention being diverted away from roadway and the chance of making a mistake during control selection. This standard contains requirements for the location, identification, and illumination of motor vehicle controls and displays (i.e., master lighting switch, hazard warning signal).

Manual of Uniform Traffic Control Devices

Since 1971, the Federal Highway Administration (FHWA) has been responsible for publishing the MUTCD, which contains all of the standards for the design, application, and proper placement of traffic control devices. In general, these standards have come about through the result of extensive research, experimentation, and practical experience. They are constantly under review to ensure that advances in technology are taken into account and that the manual is updated when necessary.

The MUTCD contains information regarding standard sign shapes and their meanings, standard sign colors, and standard sign typefaces. It also lists all of the traffic signs used in the United States by their type (regulatory, warning, maker, guide) and sub-type (R1, R2, etc.). It should be noted that all traffic signs are required to conform to the MUTCD; no exceptions are made.

Overall, there are relatively few standards that can be used to specify design guidelines for advanced IVIS devices. While the existing standards identify current "best practices" for the use of icons, they have several limitations with respect to the current project. First, they often reflect common usage of icons, as opposed to icons that have been tested and validated through some scientifically rigorous process. Thus, they often reflect the familiar—as opposed to the "best"—in suggested use of icons. Second, they are limited to standard and traditional in-vehicle messages; no standards are available for most ATIS and CAS messages. Third, they do not address a central question in this project, "What makes a good icon?" They provide little guidance for the design of new icons. Below, we discuss several challenges to the development of human factors design guidelines for in-vehicle symbols and icons.

CHALLENGES TO THE DEVELOPMENT OF HUMAN FACTORS DESIGN GUIDELINES FOR ICONS AND SYMBOLS

Both industry and government have initiated a number of recent efforts to develop human factors design guidelines for IVIS. The impetus behind many of these efforts has been a growing information gap between the advanced and diverse status of human-machine systems, and the availability of human factors design criteria that can be used during the system design process. The increasing complexity of in-vehicle transportation devices has underscored the importance of providing system developers with user-centered, human factors guidance early in the design process.

However, there is considerable uncertainty and concern regarding the nature and utility of human factors handbooks and guidelines materials. For example, it is well established that human factors guidelines following traditional formats for presenting information are not useful and are often ignored by designers (Meister & Farr, 1967; Rouse & Cody, 1988; Rogers, Spiker, & Campbell, 1989; Burns & Vicente, 1994). In this regard, 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 (Campbell et al., 1990).

There are three critical challenges 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. These challenges have been discussed previously by Campbell (1995, 1996) and are summarized below.

Challenge 1: Lack of Human Factors Design Criteria

A key issue in the development of human factors design guidelines for IVIS has been the availability of relevant findings from the research literature. Considerable discussion within the human factors community has focused upon the lack of human factors criteria available on which to base the design of many complex, human-machine systems. Meister (1984, 1989) suggested that basic research has been of little value to human factors practitioners because the precise meaning of data, when applied to situations that are different from the one in which the data were collected, is often obscure and imprecise. Smith (1987) made a similar claim in his assertion that most human factors research is directed at a specific design problem and, thus, most results are not generalizable to other problems. Simon (1973, 1987), while readily admitting that most human factors data are situation specific and cannot quantitatively predict performance under operational situations, cited methodological inadequacies as the primary cause. Rouse and Cody (1988) interviewed 35 designers of man-machine systems to determine how they allocated their time and how they used available design information. Their results indicated that designers found much of the research literature difficult to understand, that few data were generalizable to specific issues of concern, and that designers were often interested in “null results” (i.e., variables that do not affect a design concern), but that such results were seldom published. More recently, Burns and Vicente (1994) asked designers to rate the value and cost of obtaining human factors reference information using information drawn from the Engineering Data Compendium (Boff & Lincoln, 1988)—one of the most comprehensive and up-to-date human factors reference sources available. They found that while the information was rated as very costly to obtain, its perceived value was low and that designers would only expend small amounts of effort to obtain the information.

In response to these concerns with existing sources, Rouse (1985) has proposed that intermediaries are needed to translate and transform research results into design information that is readily usable by design practitioners. Rouse (1987) also suggested that the real issue is not one of a lack of data; rather, it is the unwillingness of many human factors practitioners to extrapolate from existing data to specific design problems. In Rouse’s view, practitioners must "go beyond the data," and be willing to use their experience, intuition, and common sense to analyze and synthesize research data in a manner that is consistent with the information needs and design constraints of system developers. Boff (1988), while acknowledging that much useless experimental data exist, asserted that *"usability also depends on the basic skills and inclinations of practitioners, limitations in the available support environment, and constraints imposed by the system design and acquisition processes."* Boff persuasively argued that successful system design, in the absence of situation-specific data, involves a subjective integration of available information, design constraints, and personal experience; "leaping the gap" between the question at hand and the available research data involves a risk that depends upon both the reliability of the data and the consequences associated with an incorrect decision.

To address this challenge, we plan to develop human factors design guidelines that are clear, relevant, and useful. Final guidelines will always represent an integration of user requirements, design constraints, available research data, and expert judgment. Campbell (1996) argues that the development of human factors design guidelines that are clear, relevant, and useful requires a judicious mix of science and art. That is, while a number of empirical and systematic methods are available for the development of guidelines, the final guidelines will always represent an integration of user requirements, design constraints, available information, and expert judgment. Campbell (1995) also has summarized a set of procedures and heuristics associated with both the science and art components of human factors design guideline development. These procedures have been successfully used in a number of previous guideline development efforts for IVIS (e.g., Campbell, 1989; Campbell et al., 1990; Rogers & Campbell, 1991; Campbell & Walls, 1992; Campbell et al., 1996; Campbell et al., 1998), and will be used to guide the current project.

Challenge 2: Developing Selection Criteria for Data Sources Used to Produce Guidelines

A second issue in producing human factors design guidelines for IVIS has been to develop criteria and a rationale describing how individual data sources will be selected and used. This is an important issue because design guidelines are typically based on theoretical discussions, analytical models, and empirical findings, all of which must be extracted from the open literature, reviewed, and integrated into a final handbook of design guidelines.

Although systematically reviewing existing research and topic areas is a fundamental activity within the behavioral sciences, the goals, methods, and conceptual framework of individual reviews vary considerably. Literature reviews are generally aimed at cumulating knowledge in an area (Feldman, 1971); however, some reviews are directed at theory development, some synthesize knowledge in an area, and some make generalizations about specific issues from relevant materials (Jackson, 1980). The type of review associated with IVIS human factors design guidelines has been an integrative research review. An integrative research review summarizes past research by drawing overall conclusions from many separate studies that are believed to address related or identical issues (Cooper, 1989).

Within the behavioral sciences, literature reviews are often conducted without formulating a clear rationale for selecting data sources (Slavin, 1986). The lack of clearly defined selection criteria for data sources will, at the very least, prevent the design guidelines developer from determining how representative the data sources selected for inclusion in the literature review are, compared with the human factors field as a whole. Even more serious problems would ensue from having poorly specified selection criteria. For example, the lack of explicit selection criteria may lead to biased accounts of a given technical area since it implies that: (1) lower quality work has equal weight as higher quality studies; (2) older studies conducted with outmoded technology (i.e., less applicable) are weighted the same as more recent work with more advanced technologies; and (3) study results based on, for example, performance measures and evaluation criteria of only peripheral interest are just as important as those from the central domains of interest. In addition, future researchers of IVIS design issues (or any IVIS-related handbook development) would not be able to replicate the data source selection process, an essential element of any scientific methodology.

A number of approaches to developing selection criteria for integrative literature reviews are available (Campbell et al., 1990). For example, a traditional and frequently used approach to literature reviews (Light & Pillemer, 1984) is to stratify candidate data sources by key characteristics of studies. Another approach is represented by the development of meta-analysis techniques (Glass, 1976). These techniques were developed because traditional reviews were believed to do a poor job of justifying their selection of relevant study characteristics, and because the reviewer's biases influenced the inclusion decisions in an inappropriate manner. Meta-analytic techniques are based on the "exhaustive inclusion" principle, in which all studies are included that satisfy broad standards for the appropriateness of their independent and dependent variables (Cooper, 1989).

To address this challenge, we plan to use an established literature review methodology, BES, (Slavin, 1986, 1987) in constructing and applying data source selection criteria. During design guideline development projects (e.g., Campbell & Walls, 1992; Campbell et al., 1997; Campbell et al., 1998) very similar to the one envisioned for the current study, we have employed the BES approach successfully. Derived from the legal principle of best evidence, BES is designed to guide the systematic analysis of technical literature in which only the best evidence in a given knowledge domain is included in the review. Importantly, the characteristics that define this "best evidence" will vary with the domain. For example, when applied to issues associated with driver responses to warnings, the best evidence might consist of well-controlled randomized experiments in some areas but only quasi-experimental field tests in others. The context-dependent nature of evidence quality will be especially important to the design of IVIS devices, reflecting variations in the goals and methods used in the many industrial design and human factors information sources that are expected to be included in the review activities. The pragmatic basis of BES emphasizes the use of domain-specific review criteria to derive a set of data sources meeting minimum standards of quality and applicability.

Challenge 3: Variability in the User Population of Human Factors Design Guidelines

IVIS designers and developers come from a variety of backgrounds and design disciplines. They possess varying amounts of human factors knowledge, and they use human factors handbooks/ guidelines to obtain different types of information (Rogers et al., 1989). This variability implies that, to the extent possible, design guidelines handbook for in-vehicle icons and symbols should present information in a range of formats representative of the range of user sophistication and user information needs. For example, relatively unsophisticated users, or those with "quick and dirty" information needs (e.g., those information elements or IVIS messages that are most useful for older drivers), should be able to access needed information quickly, yet should also be able to access the more detailed human factors information that is available in the handbook. More sophisticated users should be provided with more detailed and involved discussions of, for example, complex human factors issues in which two or more opposing viewpoints are equally supported by empirical data or theoretical considerations (e.g., decision-making in complex and dynamic environments).

A related issue is that all IVIS devices are designed and developed in the context of a particular design process. The specific design process is, of course, unique to a given organization that is developing the IVIS device. Nonetheless, human factors design guidelines must, to the extent possible, be consistent with the general design process in which they are used. There are a number of ways in which design guidelines can be "mismatched" to a given design process. For example, the guidelines may be inconsistent with organizational or technical constraints, they may not reflect starting points or "givens" within the design effort, they may not be presented in a manner consistent with key steps within the design process, and they may not contain those human factors design topics deemed to be most important to a given design effort.

To address this challenge, we plan to use an approach similar to that used during the development of our ATIS/CVO human factors design guidelines (Campbell et al., 1998). A key element of this successful approach is to conduct a User Requirements Analysis in order to determine the appropriate content, format, and organization for the guidelines. Although a formal User Requirements Analysis was not called out as a requirement for this project, we will (as part of Tasks C and F) develop a brief structured response booklet and survey individual members of the project working group over the telephone to identify appropriate content, format, and organization for the preliminary guidelines. Key issues in the effort will include the design process associated with IVIS display development (especially icons and symbols), current sources for design information on visual symbols, information needs from among candidate guideline topics, and preferences among candidate presentation formats for individual guidelines.

In summary, the goal of human factors design guidelines efforts is typically to summarize human engineering data, recommendations, and principles for use by designers, engineers, human factors practitioners, and others. Guidelines may be used during a number of phases within the design process, including conceptual, functional, and detailed design phases, as well as during evaluations of completed designs. Regardless of the precise manner in which guidelines are used, human factors guidelines must always be an organized, readable collection of specific design guidance that should be achieved during the system design process. In general, human factors design guidelines, according to Campbell et al. (1990), must:

! Be concise.

! Be directive.

- Be unambiguous.

- Be verifiable through observation, measurement, or some other scientifically approved process.

- Have some implication for human performance.

CONCLUSIONS

The goal of Task A has been to conduct a review of relevant symbols and research, including the use of symbols by manufacturers and after-market vendors. Overall, the review has comprehensively captured the status of icon/symbol research and applications and, most importantly, provided a solid foundation for subsequent tasks in this project.

On the basis of our review and analyses of the literature for icon and symbol research and current applications, we have developed the following conclusions:

- 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.

- General design principles for icon design are sufficient to avoid the development of a "bad" icon, but are not specific enough to support the development of the "best" icon.

- 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.

- 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.

Each of these conclusions is discussed in more detail below.

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.

The available research suggests that the meaning of many of the icons used in current systems and contained in existing guidelines are not understood by drivers. Also, it was discovered that multiple sources often do not use the same symbols for a single referent. In other words, an object, action, or idea is frequently represented by one symbol in one source and a different symbol in another. Similarly, certain icons are used to present very different information, depending on the system and the context in which they are used. In addition, our review of current use of icons in IVIS devices suggests that few evaluations of icons/symbols are performed to determine whether drivers can recognize or understand them.

These problems, of course, represent all of the reasons why the current project has been initiated. In part, they may reflect the lack of a broader framework for icon comprehension, use, and development. In this regard, the conceptual framework presented earlier in this report may prove useful for providing a foundation for subsequent tasks in this project.

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. While this type of literature is helpful for providing the background information necessary for understanding how we derive meaning from icons and symbols, it does little to aid in the development of guidelines for the design of new icons.

It was also extremely difficult to find literature directly relevant to icon usage for more advanced IVIS devices. Most of the research to date has evaluated either those symbols that would be placed on traffic/public information signs or standard icons used on instrument panels (Frank, Koenig, & Lendholt, 1973; Lendholt, 1974; Baber & Wankling, 1992; Green & Pew, 1978; Jack, 1972; Heard, 1974; Zwaga & Boersema, 1983; Mackett-Stout & Dewar, 1981; Easterby & Zwaga, 1978; Greene, 1979; Green, 1981).

The ISO and SAE standards, as well as standards found in the FMVSS and MUTCD documents that we reviewed, also addressed only those standard icons seen on the instrument panel (i.e., headlight symbols, fuel lights, etc.). None of the documents that we were able to locate have addressed the issue of standardizing symbols and icons to be used in more advanced IVIS devices.

However, a key requirement of the current project is to develop design guidelines that will aid IVIS developers to produce *new* in-vehicle icons and symbols. Challenges for Tasks B and C will be to integrate existing research and knowledge about icons with theories of visual perception, information processing, and driver behavior in a manner that produces rigorous and useful design tools and guidelines.

General design principles for icon design are sufficient to avoid the development of a "bad" icon, but are not specific enough to support the development of the "best" icon. Our review and integration activities in Task A suggest that a number of general principles for icon design are available to IVIS developers. These include guidelines related to structure, shape, and color for icons. Also available are general heuristics related to the importance of designing icons that are understandable to drivers, as are robust models of symbol recognition and understanding. These guidelines, heuristics, and models are all well supported by research findings. If applied in a consistent and proper manner, these principles would result, overall, in IVIS icons that are better than many that are currently used. Use of these principles would likely help designers avoid many of the illegible, unrecognizable, and misunderstood icons that characterize current in-vehicle devices.

However, for several reasons, they 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 when it is used 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 much 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* (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 under consideration 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.

Numerous data sources provide clear and useful guidance for the evaluation of in-vehicle icons and symbols. These range from standards such as ISO3461-1, to studies conducted by Green and Pew (1978) and the many studies conducted by Dewar. We are confident that careful application of some of these methods can be used in Tasks D and E of this project as we develop and evaluate new icons and symbols. In addition, we will use methods for evaluating icons that we have used in similar efforts (e.g., Jovanis & Campbell, 1996) that explicitly incorporate the information elements associated with icons into the evaluation process. These methods can also be translated into design guidelines for the development and evaluation of icons during Task C of this project.

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 (Campbell et al., 1990). In particular, there are three challenges 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 (Campbell, 1995, 1996).

These challenges are real and need to be addressed. Even in the absence of design guidelines, human factors-related design decisions must be made in order to support near-term development of in-vehicle icons and symbols. Without human factors guidelines tailored to the IVIS design environment, IVIS planners and designers may: (1) make false assumptions regarding driver needs for, and use of, in-vehicle display icons; (2) consult existing human factors guidelines that are inapplicable to IVIS design (e.g., military human factors standards for icon design that do not reflect the decision-making behavior of older drivers); (3) develop their own "human factors" guidelines based on their individual experiences and biases; or (4) simply ignore human factors considerations altogether.

Despite these challenges, we have developed a number of successful design guidelines for ATIS, CAS, and other in-vehicle devices (Campbell, 1989; Campbell et al., 1990; Rogers & Campbell, 1991; Campbell & Walls, 1992; Campbell et al., 1996; Campbell et al., 1998). The general procedures used in these efforts will be used to guide our design guideline development activities in the current project.

APPENDIX A: WEBSITES CONTAINING ICON AND SYMBOL SOURCES

WEBSITES WITH TRAFFIC SIGN/VEHICLE INFORMATION

http://www.iconbazaar.com/road_signs

This website contains road signs separated into categories such as: warning signs, information signs, recreational signs.

http://www.ips.be/_wbm/home.htm

This website contains common traffic signs found around the world such as "men at work" and "pedestrian crossing."

http://www.iut-orsay.fr/~guet/Pietons_

This website contains French, Spanish, and Portuguese traffic signs.

http://www.qmark.com/qm_web/road_sig.html

This website contains common European road signs and a multiple-choice quiz regarding these signs.

http://www.is.titech.ac.jp/labs/makimotolab/fujimoto/RTA/Rsign.html

This website contains Japanese traffic signs.

http://www.infomal.com.my/general/signlogo.htm

This website contains Malaysian traffic signs.

http://members.aol.com/rcmoeur/signman.html

This website contains icons from the Manual of Uniform Traffic Control Devices.

http://www.travlang.com/signs

This website contains traffic signs from European countries.

http://members.aol.com/intlsigns/index.htm

This website contains a main index to many links such as "Signs of the World."

http://www.dps.state.ak.us/dmv/DLMANUAL/signshm.htm

This website contains traffic signs from the Alaska Department of Motor Vehicles.

http://www.hardhatusa.com/cat160.html

This website contains turn, curve, and merge signs.

http://www.hardhatusa.com/cat161.html

This website contains various icons such as fallen rock ahead, rest area, pedestrian crossing, slippery road ahead.

http://www.hardhatusa.com/cat089.html

This website contains icons of cars, car parts, and gasoline icons.

http://www.dhp.n1/traffic/english.html_

This website contains information about Dutch traffic signs.

http://ftp1.rad.kumc.edu/icons/icons.htm

This website contains a main index to sites with icons in categories such as: business/office, food, fun, home/family, mail/E-mail, sports, transportation, signs.

MORE GENERAL ICON SITES (INCLUDING RESTAURANT/ HOTEL/ PHONE/ GENERAL TRAVEL/ COMPUTER-RELATED ICONS)

http://www.sct.gu.edu.au/~anthony/icons/desc/Icons.html
This website contains an index to a wide range of icons sorted by size and color including world wide web/computer icons, food, furniture, and animal icons.

http://www.geneseo.edu/icons/symbols/index.html
This website contains an index including links to pages with book, medical, music, entertainment, and world-wide web icons)

http://www.hardhatusa.com/cat162.html
This website contains airport, barbershop, hair salon, nightlife, transportation, and money icons.

http://www.hardhatusa.com/cat163.html
This website contains food, money, and elevator icons.

http://www.hardhatusa.com/cat164.html
This website contains medical, transportation, information, handicapped, and lodging icons.

http://www.hardhatusa.com/cat166.html
This website contains phone, food, and transportation icons.

http://www.hardhatusa.com/cat167.html
This website contains transportation and restroom icons.

http://www.hardhatusa.com/cat139.html
This website contains train and bus icons.

WEBSITES CONTAINING WEATHER SYMBOLS/ICONS

http://www.hardhatusa.com/cat142.html
This website contains cloud, rain, snow, and sun icons.

http://www.intellicast.com/weather/atl/
http://www.intellicast.com/weather/dlh/
http://www.intellicast.com/weather/pir/
http://www.intellicast.com/weather/mgm/
http://www.intellicast.com/weather/ilm/
http://www.intellicast.com/weather/phx/
These intellicast websites are from various parts of the country such as Atlanta, Duluth, and Phoenix. Each site contains a complete four-day forecast with various weather icons.

WEBSITES FOR SYMBOLS/ICONS FOUND IN EXISTING SYSTEMS

http://bluemarblegeo.com/apptrac.htm
This website contains links to BlueMarble Geo sample screens.

http://www.etak.com/Automotive/slide1.html
This website contains an introduction to the EtakGuide slide show.

http://www.etak.com/skymap/tour/testdrive.html
This website is the home page for a product tour of the Skymap system.

http://www.fastline.com

This website is the Fastline main index.

http://www.carin.com/prod3.htm

This website contains links to Carin 520 features, including sample screens.

http://www.tecmobility.it/English/display_ing.shtml

This website contains sample screens of the Tecmobility route planner.

http://www.teletype.com/gps/

This website contains an index to the TeleType GPS system.

http://www.xanavi.co.jp/en/nav/index.html

This website contains an index to Xanavi Birdview system.

http://www.delco.com/delco/wp_collision.html

This website contains icons used in the Delco Forewarn system.

http://www.conquestinc.com/specs.htm

This website contains graphics used in the Eyemax system.

http://www.eaton.com/VORAD/sysdes.html

This website contains an index of the VORAD system including links to VORAD interface graphics.

APPENDIX B: KEY REFERENCE MATERIAL

Citation: Arend, A., Muthig, K., & Wandmacher, J. (1987). Evidence for global superiority in menu selection by icons. *Behaviour & Information Technology, 6*, 411-426.

Relevance to this Project: A search-and-select paradigm was adopted to investigate which visual characteristics of icons are relevant for menu selection. Two icons sets (abstract icons, representational icons) were compared with a word command set. For abstract icons, global features were used in order to maximize their visual distinctiveness. For representational icons, local features were used in order to ensure a high degree of representativeness and a small "articulatory distance." Results revealed that abstract icons were searched and selected much faster than both word commands and representational icons. In addition, response time functions indicated that abstract icons can be searched in parallel, whereas word commands and representational icons have to be searched sequentially.

Citation: Barnard, P., & Marcel, T. (1978). Representation and understanding in the use of symbols and pictograms. In R. Easterby & H. Zwaga (Eds.), *Information Design: The Design and Evaluation of Signs and Printed Material.* New York: John Wiley & Sons.

Relevance to this Project: The objective of this paper is to focus, from a psychological standpoint, on some of the communicative and representational issues involved in creating and understanding pictorial representations of information. Included in this book chapter is a more general discussion of communication and the ways in which pictorial information can be represented; an overview of the research relevant to the perception; recognition, understanding, and learning of icons; and the implications of these research findings in the overall design of an icon.

Citation: Brewster, S. A., Wright, P. C., & Edwards, A. D. (1993). An evaluation of earcons for use in auditory human-computer interfaces. *INTERCHI 1993*, 222-227.

Relevance to this Project: An evaluation of earcons was carried out to see whether they are an effective means of communicating information in sound. An initial experiment showed that earcons were better than unstructured bursts of sound and that musical timbres were more effective than simple tones. A second experiment was then carried out that improved upon some of the weaknesses shown in experiment 1 to give a significant improvement in recognition. From the results of these experiments, some guidelines were drawn up for use in the creation of earcons. Earcons have been shown to be an effective method for communicating information in human-computer interface.

Citation: Davidoff, J. (1988). The role of color in visual displays. In D. J. Osborne (Ed.), *International Reviews of Ergonomics* (pp. 21-42). London: Taylor & Francis.

Relevance to this Project: The nature of the task to be performed with a visual display is critical for decisions concerning the use of color. For most detection and search tasks, segmentation of a display by color is useful, perhaps essential. Recommendations for the design of visual displays are given.

Citation: Dewar, R. E., Ells, J. G., & Mundy, G. (1976). Reaction time as an index of traffic sign perception. *Human Factors, 18*, 381-392.

Relevance to this Project: Verbal reaction times to identify and to classify 20 traffic sign messages were measured under three conditions—sign alone, sign plus visual loading task, and sign plus visual loading task plus visual distraction. Similar trends were found in the three experiments: reaction times were smaller for the classification task than for the identification task, smaller for warning than for regulatory signs, and smaller for verbal than for symbolic messages. Comparison of these reaction time data with on-the-road measures of legibility distance revealed significant correlations.

Citation: Dewar, R. E., Kline, D. W., & Swanson, A. H. (1994). Age differences in comprehension of traffic sign symbols. *Transportation Research Record 1456*, 1-10.

Relevance to this Project: Previous research has shown that drivers, particularly elderly ones, do not understand many of the symbolic traffic signs on U.S. highways. Phase I of this research examined comprehension levels of virtually all (85) of the symbols in the U.S. Manual on Uniform Traffic Control Devices for Streets and Highways as a function of age. Of the 85 standard symbols, 16 were understood by more than 95 percent of the drivers; however, 10 were understood by less than 40 percent. Older drivers had poorer understanding than younger ones of 39 percent of the symbols examined. In Phase II, modifications and redesigns to selected symbols resulted in better understanding of three messages and poorer understanding of four messages. Comprehension of the novel symbols was close to that of the modified and redesigned ones. Again, older drivers had poorer understanding, but there was no systematic relationship between age and changes in comprehension level following revision of the symbols.

Citation: Dreyfuss, H. (1966). Case study: Symbols for industrial use. In G. Kepes (Ed.), *Sign, Image, Symbol*. New York: Braziller.

Relevance to this Project: The step-by-step process used by a large manufacturer to develop symbols for industrial use is described. Through the process of completing this symbol development, several basic conclusions were drawn that might be helpful for designers in the future. These conclusions were stated as guidelines and relevant examples were given.

Citation: Dreyfuss, H. (1972). *Symbol Sourcebook*. New York: McGraw-Hill.

Relevance to this Project: This book is a collection of symbols from several different disciplines. Some that were more relevant to this project include: accommodations and travel, geography, meteorology, recreation, safety, traffic, and vehicle controls. There were also separate chapters that discussed the design of basic symbols, graphic forms, and colors.

Citation: Easterby, R. S. (1967). Perceptual organization in static displays for man-machine systems. *Ergonomics*, *10*, 193-205.

Relevance to this Project: Topics covered in this paper include: perceptual organization aspects of display design, system display requirements, language attributes in displays, perceptual theories in display design, and meaning in display design, or the use of structure (both internal and external), in order to convey meaning.

Citation: Easterby, R. S. (1970). The perception of symbols for machine displays. *Ergonomics*, *13*, 149-158.

Relevance to this Project: The role of pattern perception theory based on the Gestalt view of perception is discussed in relation to the practical design of symbols for machine displays. Experimental studies of discrimination and apprehension of meaning of symbols are reviewed, and some recommended perceptual principles important to symbol design are summarized.

Citation: Easterby, R., & Zwaga, H. (Eds.). (1978). Developing effective symbols for public information. *Information Design: The Design and Evaluation of Signs and Printed Material* (pp. 277-297). New York: John Wiley & Sons.

Relevance to this Project: An overabundance of symbols led to the need for standardization. In 1973, the International Organization for Standardization (ISO) set up Technical Committee 145 to work on the development of an international standard for public information symbols. The committee decided that no symbol should be standardized; instead, each proposed symbol should be tested with a reliable evaluation procedure. This paper discusses the ISO technique for evaluating symbols that has been developed: production test, appropriateness ranking test, comprehension/recognition test, and the matching test.

Citation: Edworthy, J., & Adams, A. (1996). *Warning Design: A Research Perspective*. Bristol, PA: Taylor & Francis.

Relevance to this Project: A wide range of behavioral research on warnings is reviewed. Relevant research with both auditory and visual warnings is presented and discussed. In the realm of visual warnings, the issue of design and evaluation of warnings using words and also of those using symbols is covered in detail.

Citation: Ells, J. G., & Dewar, R. E. (1979). Rapid comprehension of verbal and symbolic traffic sign messages. *Human Factors, 21*, 161-168.

Relevance to this Project: A "same"- "different" reaction time procedure was used in two experiments to measure the times required to comprehend the meanings of projected slides of traffic signs. The results indicated that signs with symbolic messages could be understood more quickly than those with verbal messages. Visually degrading the signs resulted in a greater decrement in performance for verbal than for symbolic signs.

Citation: Gittins, D. (1986). Icon-based human computer interaction. *International Journal of Man-Machine Studies, 24*, 519-543.

Relevance to this Project: This paper is concerned with the use of icons in human-computer interaction (HCI). The author attempts to provide a more systematic treatment of icon interfaces than has hitherto been made, and to create a classification that it is hoped will be of use to the dialogue designer. The characteristics, advantages, and disadvantages of icon-based dialogues are described. Metaphors, design alternatives, display structures, and implementation factors are discussed, and there is a summary of some icon design guidelines drawn from a variety of sources. Some mention is also made of attempts by researchers to measure the effectiveness of icon designs empirically.

Citation: Graham, R., Hirst, S., & Carter, C. (1995). *Auditory Icons for Collision Avoidance Warnings*. Paper presented at the ITS America Annual Conference, Washington, DC.

Relevance to this Project: The auditory modality has particular advantages over the visual or haptic for collision avoidance warnings, including increased reaction times and eyes-free use. It has been argued that "auditory icons," conveying information about system events by analogy with everyday events, can further improve these benefits. To test these assumptions, an experiment was carried out to compare the effects of conventional auditory collision warnings with auditory icon warnings in terms of reaction times and driver preferences. Results of this experiment showed that auditory icon warnings produced significantly faster reaction times than the traditional warnings, but suffered from an increase in inappropriate behaviors (reacting with a brake press to a non-collision situation). It is argued that an optimal warning might be achieved with an auditory icon sound, but certain sound parameters could be changed to reduce any startle effects caused by highly urgent warnings.

Citation: Green, P. (1981). Displays for automotive instrument panels: Production and rating of symbols. *HSRI Research Review, July-August*, 1-12.

Relevance to this Project: An experiment was conducted to produce pictographic symbols for identifying gauges and/or warning lights on instrument panels of motor vehicles. Students in a Michigan psychology class drew pictures to symbolize seven vehicle systems (brake, coolant, etc.), four properties of these systems (fluid level, temperature, pressure, filter), and 26 combinations (brake fluid level, coolant temperature, etc.). In a second experiment, the students rated the meaningfulness of 216 symbols proposed for 26 different display functions. The proposed symbols, assembled from several sources, included those the students had produced. The rating experiment identified promising candidates for further investigation.

Citation: Green, P., & Pew, R. (1978). Evaluating pictographic symbols: An automotive application. *Human Factors, 20*, 103-114.

Relevance to this Project: Fifty university students participated in a laboratory experiment that examined 19 pictographic symbols previously used or proposed for labeling automobile controls and displays. Association norms, measures of familiarity, and magnitude estimates of the symbols' communicativeness were collected. Twenty of these subjects also participated in a paired-associative learning task and a two-alternative, forced-choice reaction-time task in which they made same-different judgments in response to verbally presented symbol labels followed by visually presented pictograms. It was found that, in general, the relative order of merit for the individual symbols was not consistent across tasks. Specifically, ratings of communicativeness were found to be well correlated with associative strength and to a lesser extent with reaction time, but associative strength was only weakly correlated with reaction time.

Citation: Greene, P. (1979). *Development of Pictographic Symbols for Vehicle Controls and Displays*. SAE Technical Paper Series (No. 790383), Warrendale, PA: Society of Automotive Engineers.

Relevance to this Project: Two experiments were conducted to develop symbols for seven automobile controls and displays (heater, air conditioner, fresh air vent, radio volume, radio tuning, exterior lamp failure, and tire pressure). In the first, 43 drivers drew pictures they thought should be used as symbols for the items in question. Based on their suggestions, the author designed several candidate symbols for each function. In the second experiment, 62 drivers rated how well each candidate's intended meaning was understood. For many functions a "best" symbol was found, often one that differed from that currently used by the automobile manufacturers.

Citation: Hawkins, G. H., Jr., Womack, K. N., & Mounce, J. M. (1993). Driver comprehension of regulatory signs, warning signs, and pavement markings. *Transportation Research Record 1403*, 67-82.

Relevance to this Project: A survey of 1,745 Texas drivers was conducted to assess their comprehension of selected traffic control devices. The survey consisted of a 17-minute videotape presentation of 46 devices, of which 38 were regulatory signs, warning signs, or pavement markings. For each question, the survey participant was exposed to an in-context and close-up view of the device. The questions were asked verbally, and the participants selected their answers from a list of four multiple choice responses, of which one was always "not sure." Response rates ranged from 15.5 to 93.2 percent correct.

Citation: Hemenway, K. (1982). Psychological issues in the use of icons in command menus. *Proceedings of the CHI 1988 Conference on Human Factors in Computing Systems*. Washington, DC: ACM (New York).

Relevance to this Project: Their commercial and technical advantages aside, to a large extent the effects of icons on users' performance with a system are unknown. This study is an initial attempt to understand how commands are represented graphically, to identify the characteristics of icons that make them easy or difficult to comprehend, and to identify the characteristics that lead to retention of the icon-command correspondences. More generally, it is an initial attempt to identify how the user's ability to learn and understand a system is affected by the way in which the commands are represented.

Citation: Horton, W. K. (1994). *The Icon Book: Visual Symbols for Computer Systems and Documentation*. New York: John Wiley & Sons.

Relevance to this Project: This book contains heavily illustrated, research-based accounts on every aspect of the icon design process—from initial planning to refining and testing techniques. It presents strategies and methods for encoding meaning in icons, developing iconic languages and a consistent design style, and using color and other design tools. Suggestions are also given for representing complex concepts, helping the designer to determine when using an icon is not appropriate. This book also contains a comprehensive icon glossary.

Citation: Jacobs, R. J., Johnston, A. W., & Cole, B. L. (1975). The visibility of alphabetic and symbolic traffic signs. *Australian Road Research*, *5*(7), 68-86.

Relevance to this Project: Sixteen familiar road sign messages (regulatory and warning) were examined in both alphabetic and symbolic form for observers with visual acuities from normal to as low as 6/21. Threshold legibility distances were calculated with probit analysis for individual signs and groups of signs. The main result of interest for this project was that the average 50 percent threshold legibility distance for symbolic signs is about twice that for alphabetic signs for all levels of visual acuity.

Citation: Kline, D. W., & Fuchs, P. (1993). The visibility of symbolic highway signs can be increased among drivers of all ages. *Human Factors, 35*, 25-34.

Relevance to this Project: Visibility and comprehension of standard text, standard symbolic, and improved highway signs were compared among young, middle-aged, and elderly observers. The average distance at which standard symbolic signs could be identified was about two times that of text signs for all three age groups. The visibility distances of the improved symbolic signs, which were designed using an optical blur (i.e., low-pass) approach in order to avoid higher spatial frequencies, exceeded those of both text and standard symbolic signs. Visibility distance was decreased significantly among older drivers on some signs but not others. There were no significant age differences in the comprehension of symbolic signs. Acuity, a good predictor of visibility distance of both text and standard symbolic signs, was only weakly related to the visibility distance of the improved symbolic signs. These findings demonstrate that low-pass symbolic signs have significant advantages in visibility over their text counterparts for all drivers.

Citation: Kline, T. J., Ghali, L. M., Kline, D. W., & Brown, S. (1990). Visibility distance of highway signs among young, middle-aged, and older observers: Icons are better than text. *Human Factors, 32*, 609-619

Relevance to this Project: The visibility distances for young, middle-aged, and elderly observers of text and icon versions of four different highway signs were compared under day and dusk lighting conditions. No age differences were observed. Icon signs, however, were visible at much greater distances than were text signs for all three age groups, a difference that was more pronounced under dusk conditions. There were no age differences in the comprehension of icon signs, but there was considerable variability from one icon sign to another in the degree to which they were comprehended. Acuity was found to be a better predictor of the visibility distance of text signs in both day and dusk conditions than it was of icon signs. To the degree that they are comprehended, icon signs appear to offer drivers of all ages almost twice as much time in which to respond to them.

Citation: Lodding, K. N. (1983). Iconic interfacing. *IEEE Computer Graphics and Applications, 24*, 11-20.

Relevance to this Project: The use of icons is seen as an opportunity to capitalize on the new ability of graphic displays, reduce the learning curve in both time and effort, and facilitate user performance while reducing errors. This paper discusses human processing of images and its effect on the design of a man-machine interface. Several different design styles for icons are discussed and advantages and disadvantages are given for using each. Also, there is some discussion regarding the processes for both design and testing of icons.

Citation: Long, G. M., & Kearns, D. F. (1996). Visibility of text and icon highway signs under dynamic viewing conditions. *Human Factors, 38*, 690-701.

Relevance to this Project: Threshold sizes for accurate identification were determined for three different types of highway signs (text, icon, and modified icon) under two conditions of horizontal target motion (60 degrees and 120 degrees per second). The two iconic versions were superior to the text version in nearly all cases, and this benefit of the pictorial format was even more pronounced in the higher-velocity condition. The advantage of the modified icon signs over the standard icon signs that had been determined in previous work was replicated here under the low-velocity condition but essentially disappeared under the higher-velocity condition. Sign-reading performance was found to be related to dynamic visual acuity (with Landolt-C targets) under the two velocity conditions. Results are discussed in terms of the "low-pass format" for sign design suggested by previous researchers and in terms of the potential utility of dynamic acuity for the driving setting.

Citation: Mackett-Stout, J., & Dewar, R. (1981). Evaluation of symbolic public information signs. *Human Factors, 23*(2), 139-151.

Relevance to this Project: In a series of four experiments, symbolic representations of eight public information messages were evaluated in an attempt to identify the relative adequacy of each symbol. Four versions of each message were examined using measures of legibility distance, comprehension, preference, and glance legibility. Significant positive correlations were found among the first three measures. An efficiency index was employed as an overall measure of the effectiveness of individual symbols, and recommendations were made concerning their future use.

Citation: Modley, R. (1976). *Handbook of Pictorial Symbols*. New York: Dover Press.

Relevance to this Project: This book is arranged into two separate parts. Part one deals with pictorial symbols, showing more than 1,300 examples. You will find symbols representing almost every facet of human existence. Part two contains an extensive survey of public symbols. The selection of public symbols in this book comes largely from a 1974 study called Symbol Signs prepared by the American Institute of Graphic Arts for the U.S. DOT. In this section you will find symbols arranged according to service (i.e., telephones, restrooms, coffee shops) or facility (i.e., airports, railroads, worlds fairs).

Citation: Pomerantz, J. R. (1983). Global and local precedence: Selective attention in form and motion perceptions. *Journal of Experimental Psychology: General, 112*, 516-540.

Relevance to this Project: Five experiments traced the causes of the discrepancy in research that showed both local and global precedence in selective attention tasks. Results showed that instances of both local and global precedence could be demonstrated for certain types of stimuli. Cases of both local and global precedence have been amply documented but no general theory can explain why or when these effects will appear until a better understanding is gained of the nature of the perceptual processes that are trapped by different measures of selective attention.

Citation: Roberts, K. M., Lareau, E. W., & Welch, D. (1977). *Perceptual Factors and Meanings of Symbolic Information Elements. Vol. II.* Washington, DC: Federal Highway Administration (FHWA-RD-77-65).

Relevance to this Project: A laboratory evaluation of 108 symbolized and printed message traffic signs was conducted. Sign efficiency was measured utilizing five dependent variables. An efficiency index was calculated for each sign based on the summed values of the five variables for that sign. This index permitted a relative comparison of the performance of signs within each message group. The investigation also attempted to assess the effects of subject learning on improvements in performance for the measures employed. In addition, the empirical findings of the study suggested some crude but usable principles for future symbol design and usage.

Citation: Rogers, Y. (1989). Icon design for the user interface. *International Reviews of Ergonomics, 2*, 129-154.

Relevance to this Project: This paper sets out to outline the major issues surrounding the suitability and design of icons to be used in user interfaces. In particular, it focuses on the merits and disadvantages of this type of communication and compares it with the use of verbal language. A number of pertinent design characteristics are also discussed. These include considerations such as shape, size, color, discriminability with a set of icons, and the use of textual labels with icons. Finally, some future trends are suggested.

Citation: Saunby, C. S., Farber, E. I., & DeMello, J. (1988). *Driver Understanding and Recognition of Automotive ISO Symbols*. SAE Technical Paper Series (No. 880056). Warrendale, PA: Society of Automotive Engineers.

Relevance to this Project: This study assesses the understanding and recognition, by U.S. drivers, of the 25 automotive ISO symbols specified in SAE standard J1048. A two-part survey was administered to 505 volunteers at the Secretary of State's office located in a Detroit suburb. Percentage results for symbol understanding indicated low levels of understanding for many symbols; percentage results for symbol recognition were generally much higher for all symbols. The effects of gender, age, and education level on the percentage results were summarized.

Citation: Taylor, J. M., & Murch, G. M. (1986). The effective use of color in computer graphics applications. *Computer Graphics 1986 Conference Proceedings*, 515-521.

Relevance to this Project: General guidelines that should be followed and basic principles that should be understood in order to create effective color displays for graphic applications are reviewed. The fundamentals of color use in text and symbolics as well as alphanumeric displays are discussed in terms of the perceptual, physiological, and cognitive principles applicable to the human interface.

Citation: Travis, D. S. (1990). Applying visual psychophysics to user interface design. *Behaviour and Information Technology, 9*(5), 425-438.

Relevance to this Project: This article reviews recent research bearing on the areas of perception relevant to users of electronic displays. Areas of visual ability, space attributes, and color elements are considered. Considerations of time focus on the relationship between flicker rate and luminance. From the viewpoint of current display technology, the most important attribute is vision. To design effective visual displays, the designer needs to match the attributes of the final image to the spatial, temporal, and chromatic abilities of the visual system.

Citation: Wandmacher, J., & Arend, U. (1985). Superiority of global features in classification and matching. *Psychological Research, 47*, 143-151.

Relevance to this Project: Global superiority was investigated with 88 undergraduates in six experiments that used noncompound stimuli. The first four experiments investigated a postperceptual or attentional explanation of global superiority; in the fifth and sixth experiments, the perceptual explanation that global features are extracted faster and become available sooner than local features was tested. Results show that global superiority was consistently observed in several of the matching and classification tasks, suggesting, together with previous findings, that global superiority is a pervasive phenomenon.

Citation: Zwaga, H. J., & Boersema, T. (1983). Evaluation of a set of graphic symbols. *Applied Ergonomics, 14,* 43-54.

Relevance to this Project: To evaluate the efficiency of a coherent set of graphic symbols for public information in railway stations, a matching procedure was used, in which a referent was specified to respondents, and they were asked to select the appropriate symbol for the complete set of symbols shown to them. A total of 29 symbols were evaluated using 11,600 railway passengers as respondents. Results showed that only half of the symbols meet a criterion of 67 percent correct responses. Both increasing age and low level of travel experience have a deteriorating effect on the understanding of the symbols. In addition to the percentage correct responses, analysis of the confusions between referents and symbols allows a more detailed assessment of the causes of a low efficiency of a symbol or a group of symbols. It is demonstrated that, based mainly on the measured confusions between symbols, proposals for the redesign of symbols can be formulated.

APPENDIX C: DRIVER INFORMATION REQUIREMENTS—CANDIDATE IN-VEHICLE MESSAGES

ROUTING AND NAVIGATION INFORMATION

Trip Planning

- display of lodging along set route
- price ranges of lodging along route
- vacancy status of hotels along route
- locations of state and national parks
- transit schedules in areas along route
- total trip time
- time to each destination
- total trip mileage
- mileage to each destination
- total trip cost
- number of tolls and cost of each toll per segment
- type of roads on route
- number of turns or roadway changes required
- states, regions, communities, and districts along the route
- landmarks or topographical features

Multi-Mode Travel Coordination and Planning

- start time required to catch other mode of transport
- mode of travel to take for each segment of travel
- arrival time at end of each segment of travel
- layover time between travel segments
- arrival time at destination
- total time to complete travel

Pre-Drive Route and Destination Selection

- fastest route available
- route avoiding tollways
- most scenic route
- route avoiding complex intersections
- route option with least traffic
- route that minimizes left turns
- shortest route option
- crime ratings of route options
- road quality of route option
- number of traffic lights/stops of route options

Route Guidance

- notification that the driver is off route
- vehicle’s current position

- suggestion of alternative route
- complete map of route
- desired order of destinations
- next destination
- final destination
- reroute option with least traffic
- shortest reroute option
- crime ratings of reroute options
- road quality of reroute options
- information on road closures and restrictions
- number of traffic lights/stop signs of reroute options
- suggested course of action for emergency vehicle stopped ahead
- recommended course of action for approaching emergency vehicle scenario
- time and distance to bad road conditions
- recommended course of action for bad road conditions
- time and distance to weather conditions
- time and distance to traffic congested area
- historical congestion information

Route Navigation

- distance and time to destination
- distance and time to turn
- distance and time to exit
- 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
- maximum speed for negotiating the exit ramp safely

Automated Toll Collection

- location of and distance to toll booths
- number of lanes in tolls
- cost of tolls along route
- remaining balance in toll account
- notification of tolls to be paid along route
- notification of successful toll charge

MOTORIST SERVICES INFORMATION

Broadcast Services/Attractions

- restaurant/food ahead
- restaurant type/style (e.g. Japanese, American, Mexican, etc.)
- restaurant names
- price range of food at restaurants

- lodging ahead
- closest lodging with vacancy
- guest amenities:
    - elevator
    - kennel
    - laundry
    - locker
    - parking
    - shower
    - restrooms
    - barber shop
    - hair salon
- gas station ahead
- cost of gasoline
- hours of operation of gas station
- amenities of gas station:
    - restrooms
    - phone
    - food
- restroom ahead
- telephone ahead
- rest area ahead
- landmark information
- sports venue
- nature attraction
- arts and culture venue
- RV park
- airport
- shopping center
- night life attraction
- hospital
- ice cream shop
- coffee shop
- pharmacy
- courthouse
- music venue
- movie theater
- car mechanic
- football stadium
- post office
- library
- school
- convenience store
- aquarium
- zoo

- bank
- theater (drama)
- car rental agency
- college
- golf course
- personal landmark
- ATM
- casino
- city hall/government building
- commuter rail station
- train station
- bus station
- convention center/exhibit hall
- ferry terminal
- grocery store
- park and ride
- parking lot
- information
- amusement park
- wildlife preserve
- camping
- picnic area
- hiking
- general winter recreation
- general water recreation
- amphitheater
- climbing
- rock climbing
- hunting
- playground
- rock collecting
- spelunking
- stable
- bicycle trail
- horse trail
- interpretive automobile trail
- interpretive trail
- off-road vehicle trail
- trail bike trail
- tramway
- all-terrain vehicle trail
- boat tours
- canoeing
- diving
- scuba diving

- fishing
- marina
- motor boating
- boat launching
- rowboating
- sailboating
- waterskiing
- surfing
- swimming
- wading
- ice skating
- ski jumping
- ski bobbing
- cross-country skiing
- downhill skiing
- sledding
- snowmobiling
- snowshoeing

Services/Attractions Directory
- directory (index of yellow pages)
- view currently selected preferences

Destination Coordination
- location of and distance to restaurant
- location of and distance to lodging
- location of and distance to gas station
- distance to and direction of nearest rest area
- confirmation of reservation
- reservation details
- locate nearest parking
- type of parking facility
- diagram of parking facilities
- real-time availability of parking

Message Transfer
- incoming message
- message sent/send message
- alert driver message was not sent and why not
- write message
- delete message
- message acknowledged/received
- access message
- save message
- review received message

- reply to a message
- access the Internet

AUGMENTED SIGNAGE INFORMATION

Roadway Guidance Sign Information

- interchange ahead
- route markers
- mile posts

Roadway Notification Sign Information

- steep downgrade
- percent of grade
- recommended speed as a function of grade
- braking requirements for specific grades
- tight ramp or intersection
- railroad crossing
- merge
- chevrons
- curve signs
- sharp curve ahead
- curve speed for specific vehicle sizes
- pedestrian crossing ahead

Roadway Regulatory Sign Information

- speed limit
- speed limit in construction zones
- vehicle is “x” mi/h over speed limit
- stop
- yield
- do not enter
- no right or left turn
- left turn only/right turn only
- 4-way stop

SAFETY/WARNING INFORMATION

Immediate Hazard Warning

- emergency vehicle stopped ahead
- 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
- frost damage ahead
- icy roads ahead
- low shoulder
- general weather forecast for a specific area
- snow ahead
- partly sunny weather conditions
- partly cloudy weather conditions
- sunny conditions
- rain ahead
- squalls
- fog
- traffic/congestion ahead
- general real-time traffic information
- how far/how long traffic is backed up
- map showing areas of mild, moderate, and severe congestion
- accident ahead
- chemical spill ahead
- lanes blocked ahead
- lanes closed ahead

Automatic/Manual Aid Request

- inform driver that aid has been requested
- inform driver of time until emergency unit will arrive
- display messages from the emergency response center
- update real-time information from the emergency center

Vehicle Condition Monitoring

- inform driver of current problem
- inform driver of ways to correct problem
- provide more detailed information at the driver's request
- inform the driver of needed warranty services due
- low tire pressure
- low oil pressure
- safety event recorder information

COMMERCIAL VEHICLE OPERATIONS (CVO) INFORMATION

Trip Planning

- approved fueling locations
- truck stops
- dealers

- fuel costs
- approved parking locations for types
- weight limits
- overhead restrictions
- weigh stations (locations and whether or not they are open)
- fuel taxes
- typical congestion of route
- miles until truck is out of fuel

Delivery-Related Information
- delivery location
- scheduled pickup and delivery times
- times of day or week that may affect delivery
- equipment types not allowed on roadway
- optimize delivery schedules
- customer's preferences
- information from dispatcher regarding schedule changes and other pickup/delivery information

Presentation of Service Directory Information
- index of yellow pages and information from Trucker's Atlas

CVO-Specific Aid Request Information
- notify emergency services of hazardous material (CVO)
- inform emergency services of cargo type (CVO)

Cargo and Vehicle Monitoring Information
- problem in the trailer unit
- problem in the tractor unit
- precise information regarding vehicle performance (may be >50 parameters)

Augmented Signage Information
- truck route
- truck speed limit
- routing restrictions for specific vehicle cargos
- weight limits
- 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
- electronic permit application
- pre-clearance
- credential checking
- driver-incentive and performance

Post-Trip Summary
- elapsed time
- miles traveled
- fuel used
- tools paid for driver logs
- percent of time at idle

GPS-RELATED INFORMATION

- position of satellites in space; representation of which satellites are currently transmitting information
- satellite signal strength
- current GPS position (latitude, longitude, altitude)
- magnify/minimize map view
- shift to another region of the map
- shift to another region of the world
- look for a specific street address

COLLISION AVOIDANCE INFORMATION

Rear-End Collision Avoidance
- system on and functioning
- system failure
- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

Road-Departure Collision Avoidance
- system on and functioning
- system failure
- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

Lane Change/Merge Collision Avoidance
- system on and functioning
- system failure

- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

Intersection Collision Avoidance
- system on and functioning
- system failure
- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

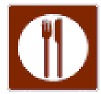
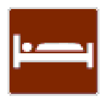
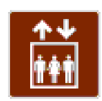
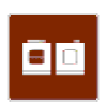
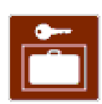
Railroad Crossing Collision Avoidance
- system on and functioning
- system failure
- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

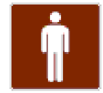
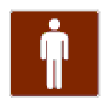
Driver Monitoring Devices
- system on and functioning
- system failure
- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

Backing Devices
- system on and functioning
- system failure
- no danger indicator
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

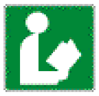
Automatic Cruise Control Devices
- system on and functioning
- system failure
- headway selection
- mode selection
- advisory indicator (also nature, severity, corrective action required)
- warning indicator (also nature, severity, corrective action required)

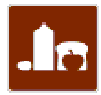
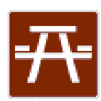
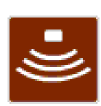
APPENDIX D: STANDARDIZED ICONS ACCEPTED BY GOVERNMENT INSTITUTIONS FOR CONVEYING INFORMATION TO DRIVERS

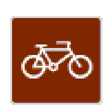
MOTORIST SERVICES INFORMATION		
Function	**Message**	**Candidate Symbols**
Broadcast services/ attractions	restaurant/food ahead	http://members.aol.com/rcmoeur/rm.html 
	restaurant type/style (e.g., Japanese, American, Mexican, etc.)	
	restaurant names	
	price range of food at restaurants	
	lodging ahead	http://members.aol.com/rcmoeur/rm.html 
	closest lodging with vacancy	
	guest amenities:	http://members.aol.com/rcmoeur/ra.html
	elevator	
	kennel	
	laundry	
	locker	
	parking	

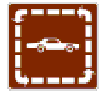
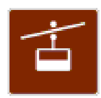
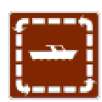
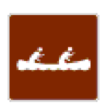
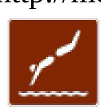
Function	Message	Candidate Symbols
	shower	
	restrooms	  
	barber shop	
	hair salon	
	gas station ahead	http://members.aol.com/rcmoeur/rm.html 
	cost of gasoline	
	hours of operation of gas station	
	amenities of gas station:	
	restrooms	http://members.aol.com/rcmoeur/rm.html; ra.html   
	phone	
	food	
	restroom ahead	see above
	telephone ahead	http://members.aol.com/rcmoeur/rm.html 
	rest area ahead	http://www.dps.state.ak.us/dmv/DLMANUAL/pg44e.htm 

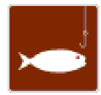
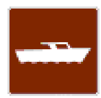
Function	Message	Candidate Symbols
	landmark information	
	sports venue	
	nature attraction	
	arts and culture venue	
	RV park	
	airport	http://members.aol.com/rcmoeur/ra.html 
	shopping center	
	night life attraction	
	hospital	http://www.dps.state.ak.us/dmv/DLMANUAL/signs.htm; http://members.aol.com/rcmoeur/rm.html  
	ice cream shop	
	coffee shop	
	pharmacy	
	courthouse	
	music venue	
	movie theater	
	car mechanic	http://members.aol.com/rcmoeur/rm.html 
	football stadium	

Function	Message	Candidate Symbols
	post office	http://members.aol.com/rcmoeur/rm.html 
	library	http://members.aol.com/rcmoeur/i.html 
	school	
	convenience store	
	aquarium	
	zoo	
	bank	
	theater (drama)	
	car rental agency	
	college	
	golf course	
	personal landmark	
	ATM	
	casino	
	city hall/government building	
	commuter rail station	
	train station	
	bus station	
	convention center/exhibition hall	

Function	Message	Candidate Symbols
	ferry terminal	http://members.aol.com/rcmoeur/rm.html 
	grocery store	http://members.aol.com/rcmoeur/rm.html 
	park and ride	
	parking lot	
	information	
	amusement park	
	wildlife preserve	
	camping	http://members.aol.com/rcmoeur/rm.html 
	picnic area	http://members.aol.com/rcmoeur/rm.html 
	hiking	http://members.aol.com/rcmoeur/rl.html 
	general winter recreation	http://members.aol.com/rcmoeur/rs.html 
	general water recreation	
	amphitheater	http://members.aol.com/rcmoeur/rl.html 

Function	Message	Candidate Symbols
	climbing	http://members.aol.com/rcmoeur/rl.html 
	rock climbing	http://members.aol.com/rcmoeur/rl.html 
	hunting	http://members.aol.com/rcmoeur/rl.html 
	playground	http://members.aol.com/rcmoeur/rl.html 
	rock collecting	http://members.aol.com/rcmoeur/rl.html 
	spelunking	http://members.aol.com/rcmoeur/rl.html 
	stable	http://members.aol.com/rcmoeur/rl.html 
	bicycle trail	http://members.aol.com/rcmoeur/rl.html 
	horse trail	http://members.aol.com/rcmoeur/rl.html 

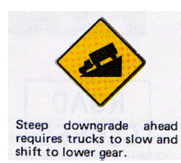
Function	**Message**	**Candidate Symbols**
	interpretive automobile trail	http://members.aol.com/rcmoeur/rl.html 
	interpretive trail	http://members.aol.com/rcmoeur/rl.html 
	off-road vehicle trail	http://members.aol.com/rcmoeur/rl.html 
	trail bike trail	http://members.aol.com/rcmoeur/rl.html 
	tramway	http://members.aol.com/rcmoeur/rl.html 
	all-terrain vehicle trail	http://members.aol.com/rcmoeur/rl.html 
	boat tours	http://members.aol.com/rcmoeur/rw.html 
	canoeing	http://members.aol.com/rcmoeur/rw.html 
	diving	http://members.aol.com/rcmoeur/rw.html 

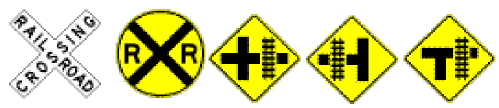
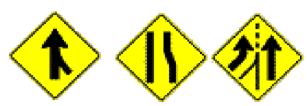
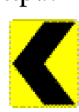
Function	Message	Candidate Symbols
	scuba diving	http://members.aol.com/rcmoeur/rw.html 
	fishing	http://members.aol.com/rcmoeur/rw.html 
	marina	http://members.aol.com/rcmoeur/rw.html 
	motor boating	http://members.aol.com/rcmoeur/rw.html 
	boat launching	http://members.aol.com/rcmoeur/rw.html 
	rowboating	http://members.aol.com/rcmoeur/rw.html 
	sailboating	http://members.aol.com/rcmoeur/rw.html 
	waterskiing	http://members.aol.com/rcmoeur/rw.html 
	surfing	http://members.aol.com/rcmoeur/rw.html 

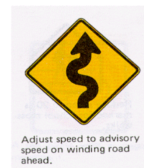
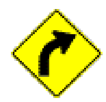
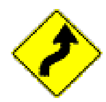
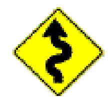
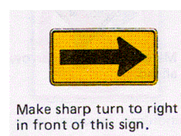
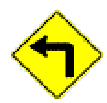
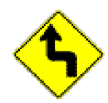
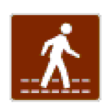
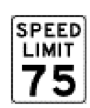
Function	Message	Candidate Symbols
	swimming	http://members.aol.com/rcmoeur/rw.html 
	wading	http://members.aol.com/rcmoeur/rw.html 
	ice skating	http://members.aol.com/rcmoeur/rs.html 
	ski jumping	http://members.aol.com/rcmoeur/rs.html 
	ski bobbing	http://members.aol.com/rcmoeur/rs.html 
	cross-country skiing	http://members.aol.com/rcmoeur/rs.html 
	downhill skiing	http://members.aol.com/rcmoeur/rs.html 
	sledding	http://members.aol.com/rcmoeur/rs.html 
	snowmobiling	http://members.aol.com/rcmoeur/rs.html 

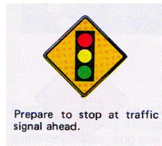
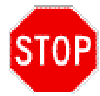
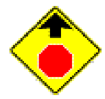
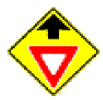
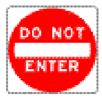
Function	Message	Candidate Symbols
	snowshoeing	http://members.aol.com/rcmoeur/rs.html 
Services/attractions directory	directory (index of yellow pages)	
	view currently selected preferences	
Destination coordination	location of and distance to restaurant	
	location of and distance to lodging	
	location of and distance to gas station	
	distance to and direction of nearest rest area	
	confirmation of reservation	
	reservation details	
	locate nearest parking	
	type of parking facility	
	diagram of parking facilities	

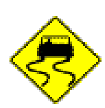
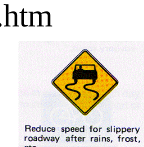
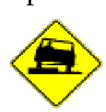
Function	Message	Candidate Symbols
	real-time availability of parking	
Message transfer	incoming message	
	message sent/send message	
	alert driver message was not sent and why not	
	write message	
	delete message	
	message acknowledged/received	
	access message	
	save message	
	review received message	
	reply to a message	
	access the Internet	

AUGMENTED SIGNAGE INFORMATION		
Function	**Message**	**Candidate Symbols**
Roadway guidance sign information	interchange ahead	
	route markers	
	mile posts	
Roadway notification sign information	steep downgrade	http://www.dps.state.ak.us/dmv/DLMANUAL/pg43k.htm http://members.aol.com/rcmoeur/w7.html  

Function	Message	Candidate Symbols
	percent of grade	
	recommended speed as a function of grade	
	braking requirements for specific grades	
	tight ramp or intersection	http://members.aol.com/rcmoeur/w1.html 
	railroad crossing	http://www.members.aol.com/rcmoeur/rrsign.html 
	merge	http://members.aol.com/rcmoeur/w4.html http://www.dps.state.ak.us/dmv/DLMANUAL/pg43a.htm http://www.dps.state.ak.us/dmv/DLMANUAL/pg43j.htm   
	chevrons	http://members.aol.com/rcmoeur/w1.html 

Function	**Message**	**Candidate Symbols**
	curve signs	http://www.dps.state.ak.us/dmv/DLMANUAL/pg44a.htm http://www.dps.state.ak.us/dmv/DLMANUAL/pg44b.htm http://members.aol.com/rcmoeur/w1.html     
	sharp curve ahead	http://members.aol.com/rcmoeur/w1.html http://www.dps.state.ak.us/dmv/DLMANUAL/pg44c.htm   
	curve speed for specific vehicle sizes	
	pedestrian crossing ahead	http://members.aol.com/rcmoeur/rg.html 
Roadway regulatory sign information	speed limit	http://www.dps.state.ak.us/dmv/DLMANUAL/pg429.htm http://members.aol.com/rcmoeur/r2.html http://www.dps.state.ak.us/dmv/DLMANUAL/signs.htm   
	speed limit in construction zones	

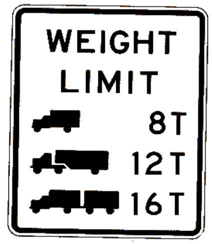
Function	Message	Candidate Symbols
	vehicle is x mi/h over speed limit	
	stop	http://www.dps.state.ak.us/dmv/DLMANUAL/pg43i.htm http://members.aol.com/rcmoeur/r1.html http://members.aol.com/rcmoeur/w3.html   
	yield	http://members.aol.com/rcmoeur/r1.html http://members.aol.com/rcmoeur/w3.html  
	do not enter	http://members.aol.com/rcmoeur/r5.html 
	no right or left turn	http://members.aol.com/rcmoeur/r3.html  
	left turn only/right turn only	
	4-way stop	http://members.aol.com/rcmoeur/r1.html 

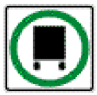
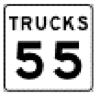
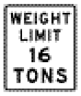
SAFETY/WARNING INFORMATION		
Function	**Message**	**Candidate Symbols**
Immediate hazard warning	emergency vehicle stopped ahead	
	distance of approaching emergency vehicle	
	relative locations of emergency vehicles to you on a map	
	school bus stopped ahead	
Road condition information	road work/construction ahead	http://members.aol.com/rcmoeur/w20.html http://members.aol.com/rcmoeur/w21.html http://www.dps.state.ak.us/dmv/DLMANUAL/pg44h.htm   
	uneven road ahead	
	fallen rock ahead	http://members.aol.com/rcmoeur/rg.html 
	frost damage ahead	
	icy roads ahead	http://members.aol.com/rcmoeur/w8.html; http://www.dps.state.ak.us/dmv/DLMANUAL/pg43f.htm  
	low shoulder	http://members.aol.com/rcmoeur/w8.html 

Function	**Message**	**Candidate Symbols**
	general weather forecast for a specific area	
	snow ahead	
	partly sunny weather conditions	
	partly cloudy weather conditions	
	sunny conditions	
	rain ahead	
	squalls	
	fog	
	traffic/congestion ahead	
	general real-time traffic information	
	how far/how long traffic is backed up	
	map showing areas of mild, moderate and severe congestion	
	accident ahead	
	chemical spill ahead	
	lanes blocked ahead	
	lanes closed ahead	http://members.aol.com/rcmoeur/w20.html 
Automatic/manual aid request	inform driver that aid had been requested	
	inform driver of time until emergency unit will arrive	

Function	Message	Candidate Symbols
	display messages from the emergency response center	
	update real-time information from the emergency center	
Vehicle condition monitoring	inform driver of current problem	
	inform driver of ways to correct problem	
	provide more detailed information at the driver's request	
	inform the driver of needed warranty services due	
	low tire pressure	
	low oil pressure	
	safety event recorder information	

COMMERCIAL VEHICLE OPERATIONS (CVO) INFORMATION		
Function	**Message**	**Candidate Symbols**
Trip planning	approved fueling locations	
	truck stops	
	dealers	
	fuel costs	
	approved parking locations for types	

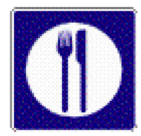
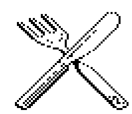
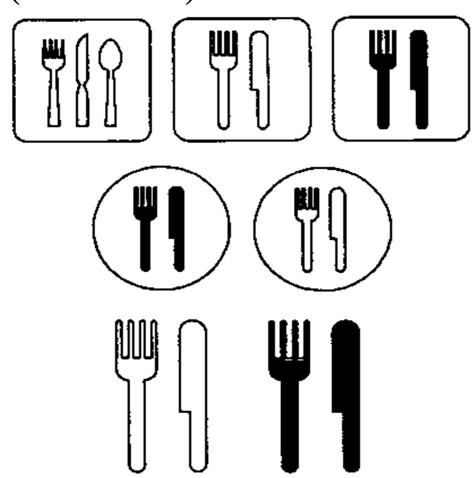
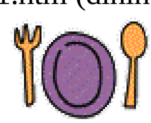
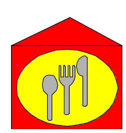
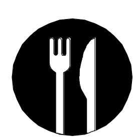
Function	Message	Candidate Symbols
	weight limits	
	overhead restrictions	
	weigh stations (locations and whether or not they are open)	
	fuel taxes	
	typical congestion of route	
	miles until truck is out of fuel	
Delivery-related information	delivery location	
	scheduled pickup and delivery times	
	times of day or week that may affect delivery	
	equipment types not allowed on roadway	
	optimize delivery schedules	
	customer's preferences	
	information from dispatcher regarding schedule changes and other pickup/delivery information	
Presentation of service directory information	index of yellow pages and information from Trucker's Atlas	

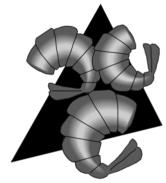
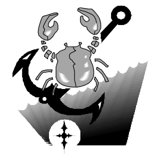
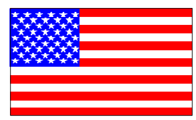
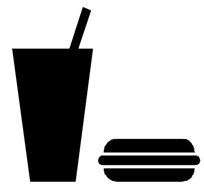
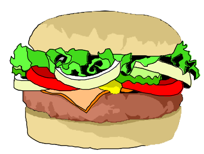
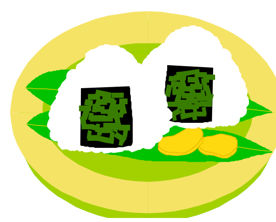
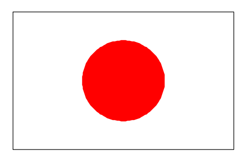
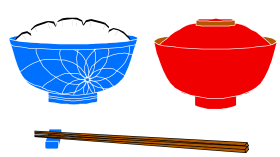
Function	Message	Candidate Symbols
CVO-specific aid request information	notify emergency services of hazardous material	
	inform emergency services of cargo type	
Cargo and vehicle monitoring information	problem in the trailer unit	
	problem in the tractor unit	
	precise information regarding vehicle performance	
Augmented signage information	truck route	http://members.aol.com/rcmoeur/r14.html 
	truck speed limit	http://members.aol.com/rcmoeur/r2.html 
	routing restrictions for specific vehicle cargoes	
	weight limits	http://members.aol.com/rcmoeur/r12.html 
	no hazardous materials allowed	http://members.aol.com/rcmoeur/r14.html 
	low clearance	

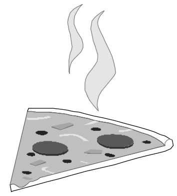
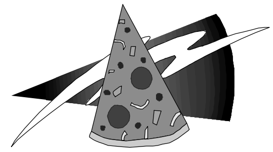
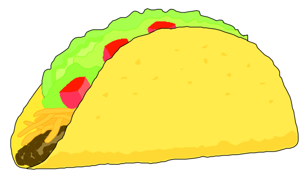
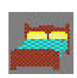
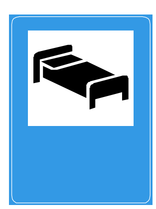
Function	Message	Candidate Symbols
	low overpasses on route	http://www.dps.state.ak.us/dmv/DLMANUAL/pg43l.htm 
	allowable vehicle length on roadway	
	allowable vehicle width on roadway	
	allowable vehicle height on roadway	http://www.dps.state.ak.us/dmv/DLMANUAL/pg43l.htm 
Administrative information	allow driver to complete administrative paperwork electronically (i.e., taxes, licenses)	
	inform driver of regulatory administrative requirements	
	electronic permit application	
	pre-clearance	
	credential checking	
	driver-incentive and performance	
Post-trip summary	elapsed time	
	miles traveled	
	fuel used	
	tools paid for driver logs	
	percent of time at idle	

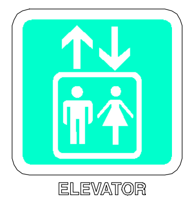
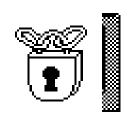
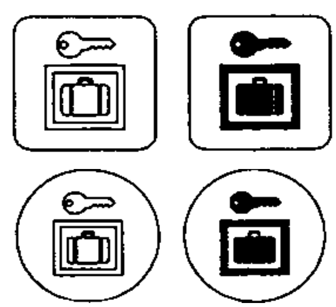
GPS-RELATED INFORMATION		
Function	**Message**	**Candidate Symbols**
	position of satellites in space; representation of which satellites are currently transmitting information	
	satellite signal strength	
	current GPS position (latitude, longitude, altitude)	
	magnify/minimize map view	
Function	**Message**	**Candidate Symbols**
	shift to another region of the map	
	shift to another region of the world	
	look for a specific street address	

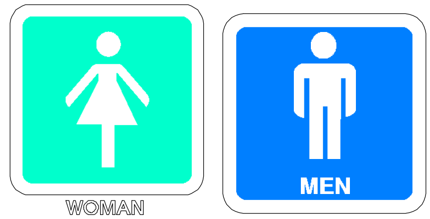
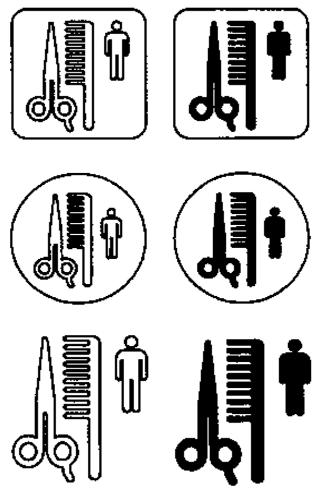
APPENDIX E: NON-STANDARDIZED ICONS THAT COULD BE USED TO CONVEY INFORMATION TO DRIVERS

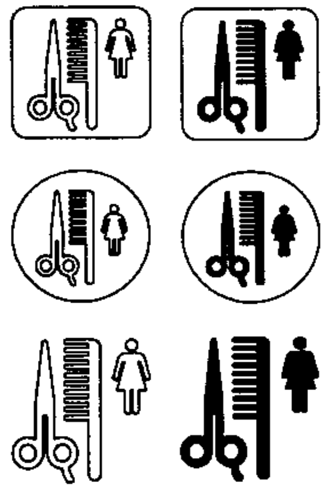
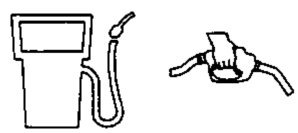
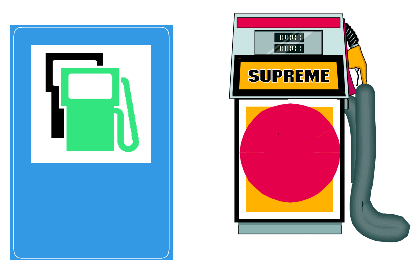
MOTORIST SERVICES INFORMATION		
Function	**Message**	**Candidate Symbols**
Broadcast services/ attractions	restaurant/food ahead	http://www.iconbazaar.com/road_signs/blue/  http://www.sct.gu.edu.au/~anthony/icons/desc/bw- 64/knife.fork.xbm  http://www.hardhatusa.com/cat166.html (ILL 279-285)  http://ftp1.rad.kumc.edu/icons/food/food01.htm (dining.gif; godine.gif)   Corel 6.0 Clipart “restaur”, “symb248"  

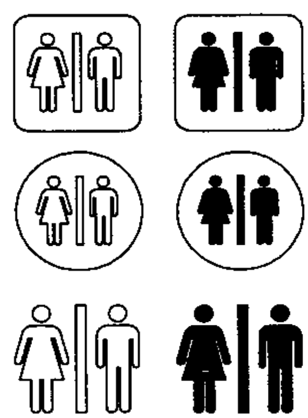
Function	**Message**	**Candidate Symbols**
	restaurant type/style (e.g., seafood, American, Japanese, Chinese, pizza, Mexican)	Corel Clip Art 6.0 “seafood”, “shrimp”   Corel Clip Art 6.0 “hamburgd”, “usac”, “symb249"    Corel Clip Art 6.0 “japanc”, “omusubi”   http://www.sct.gu.edu.au/~anthony/icons/desc/bw-misc/fortune.xbm  Corel Clip Art 6.0 “gohan1" “chinac”  

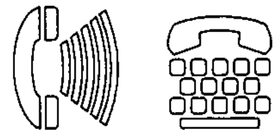
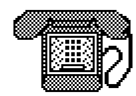
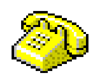
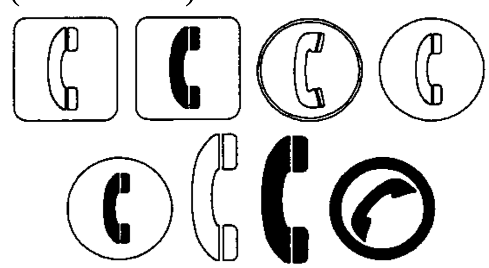
Function	Message	Candidate Symbols
		Corel Clip Art 6.0 “pizza”, “pizzazz”   Corel Clip Art 6.0 “taco” 
	restaurant names	KFC: http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/colonel.xbm 
	price range of food at restaurants	
	lodging ahead	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Furniture/bed.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Furniture/bed2.bmp  Corel Clip Art 6.0 “365px” 

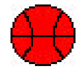
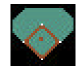
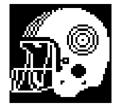
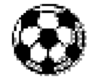
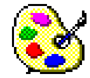
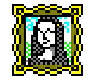
Function	Message	Candidate Symbols
	closest lodging with vacancy	vacancy icon: http://members.aol.com/rmoeuradot/200x200/guide/reccult/RM-090.gif 
	guest amenities:	
	elevator	Corel Clipart 6.0 “s12" 
	kennel	
	laundry	
	locker	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/lock.xbm and lock2.xbm  http://www.hardhatusa.com/cat162.html (ILL 33-36) 
	parking	
	shower	

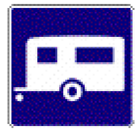
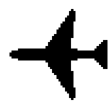
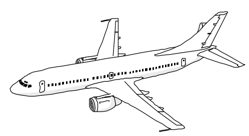
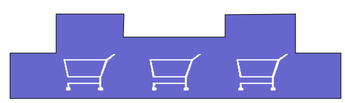
Function	Message	Candidate Symbols
	restrooms	Corel Clipart 6.0 “s11", “sign01" 
	barber shop	http://www.hardhatusa.com/cat162.html (ILL 21-26)  http://ftp1.rad.kumc.edu/icons/Signs/Signs01.htm (barber.gif) 

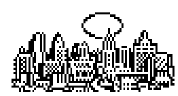
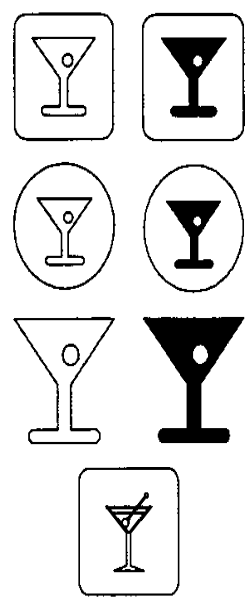
Function	**Message**	**Candidate Symbols**
	hair salon	http://www.hardhatusa.com/cat162.html (ILL 27-32) 
	gas station ahead	http://www.iconbazaar/road_signs/blue/  http://www.hardhatusa.com/cat089.html (#57, 58)  Corel Clipart 6.0 "357px", "gasoline" 
	cost of gasoline	
	hours of operation of gas station	

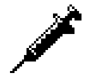
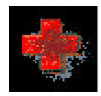
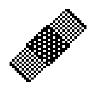
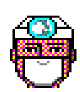
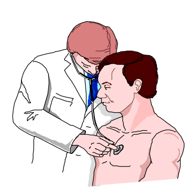
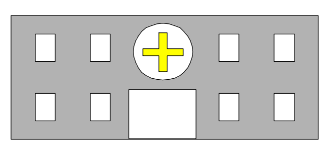
Function	Message	Candidate Symbols
	amenities of gas station:	
	restrooms	see below
	phone	see below
	food	see above
	restroom ahead	http://www.hku.hk/lib/gif/gificon2.html  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Furniture/toilet.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Furniture/toilet2.bmp  http://www.hardhatusa.com/cat167.html (ILL 335-340) 

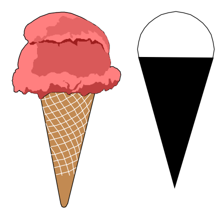
Function	**Message**	**Candidate Symbols**
	telephone ahead	http://www.hardhatusa.com/cat161.html (#54, 55)  http://www.sct.gu.edu.au/~anthony/icons/desc/std/phone.xbm  http://www.hku.hk/lib/gif/gificon2.html  http://www.hardhatusa.com/cat166.html (ILL 257-264)  Corel Clipart 6.0 “phonec”, “symb379" 
	rest area ahead	
	landmark information	

Function	Message	Candidate Symbols
	sports venue	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/ball.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/ball_b~1.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/baseball.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/gridiron.xbm  http://www.geneseo.edu/icons/symbols/five.html (soccer.gif) 
	nature attraction	
	arts and culture venue	http://www.geneseo.edu/icons/symbols/index.html (art.gif)  http://www.geneseo.edu/icons/symbols/five.html (palette.gif)  http://www.geneseo.edu/icons/symbols/five.html (picture.gif) 

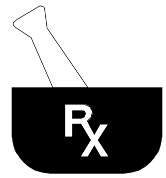
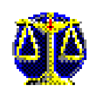
Function	Message	Candidate Symbols
	RV park	http://www.iconbazaar.com/road_signs/blue/ 
	airport	http://www.iconbazaar.com/road_signs/green/  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/airport.xbm  Corel Clipart 6.0 “737per” 
	shopping center	Corel Clipart 6.0 “shopmall” 

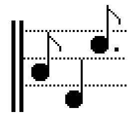
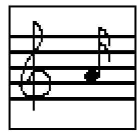
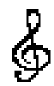
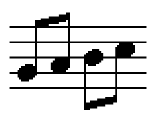
Function	Message	Candidate Symbols
	night life attraction	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/martini.xbm  http://www.wins.uva.nl/~bobd/beer.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-misc/champagne.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-64/city.xbm  http://www.hardhastusa.com/cat162.html (LL14-20) 

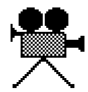
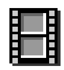
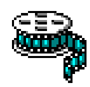
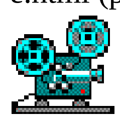
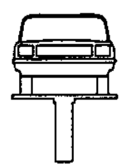
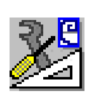
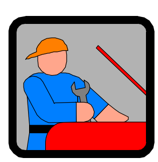
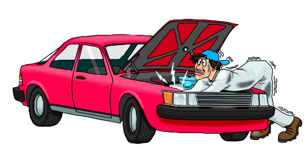
Function	Message	Candidate Symbols
	hospital	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/sringe.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-48/redcross.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/bandaid.xbm  http://www.iconbazaar.com/blue/ (a couple)   http://www.geneseo.edu/icons/symbols/index.html (cadeuc.gif)  http://www.geneseo.edu/icons/symbols/four.html (mddoc.gif)  Corel Clipart 6.0 “doctor1", “hospital”  

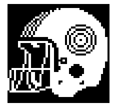
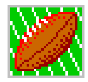
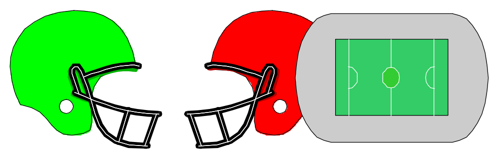
Function	**Message**	**Candidate Symbols**
	ice cream shop	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/icecream.xbm  http://ftp1.rad.kumc.edu/icons/food/food02.htm (icecream.gif)  Corel Clipart 6.0 “icecone”, “icecream” 

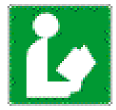
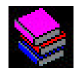
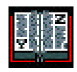
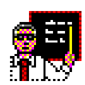
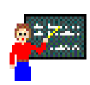
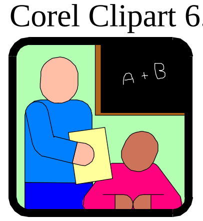
Function	Message	Candidate Symbols
	coffee shop	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-misc/coffee.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/cup.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/cup2.xbm  http://www.geneseo.edu/icons/symbols/five.html (icon3.gif)  http://www.hardhatusa.com/cat163.html (ILL 73-76)  http://ftp1.rad.kumc.edu/icons/food/food02.htm (cup99.gif)  Corel Clipart 6.0 “symcoff” 

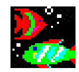
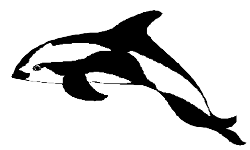
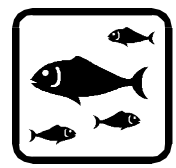
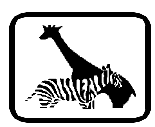
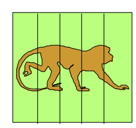
Function	**Message**	**Candidate Symbols**
	pharmacy	Corel Clipart 6.0 “symb426", “pills3"  
	courthouse	http://www.hardhatusa.com/cat161.html (42 and 43)   http://www.geneseo.edu/icons/symbols/four.html (justice.gif)  Corel Clipart 6.0 “189px” 

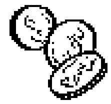
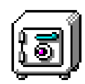
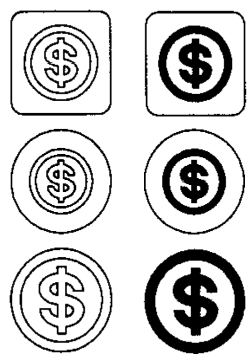
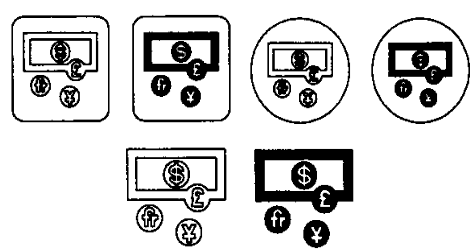
Function	Message	Candidate Symbols
	music venue	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-64/music.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-64/music2.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/clef.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/audio.xbm  http://www.geneseo.edu/icons/symbols/four.html (mus05.gif) 

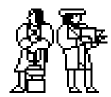
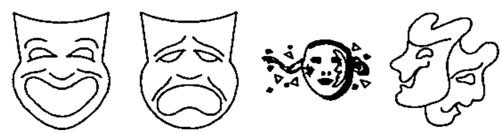
Function	**Message**	**Candidate Symbols**
	movie theater	http://www.sct.gu.edu.au/~anthony/icons/desc/std/ movie.xbm  http://www.hypernews.org/HyperNews/get/ hypernews/future/68/1/1/1/1.html (movie.gif)  http://www.geneseo.edu/icons/symbols/three.html (film01.gif)  http://www.geneseo.edu/icons/symbols/five.html (projectr.gif) 
	car mechanic	http://www.hardhatusa.com/cat089.html (#56)  http://www.geneseo.edu/icons/symbols/six.html (tools.gif)  Corel Clipart 6.0 “mechanc”, “mechanic”  

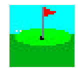
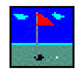
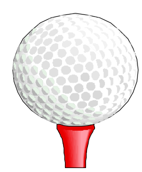
Function	**Message**	**Candidate Symbols**
	football stadium	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/gridiron.xbm  http://ftp1.rad.kumc.edu/icons/Sports/sports01.htm (football.gif)  Corel Clipart 6.0 “helmets”, “stadium” 
	post office	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/mailbox2.bmp  Corel Clipart 6.0 “usps1" 

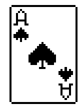
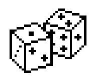
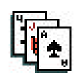
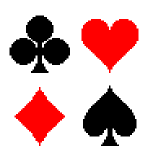
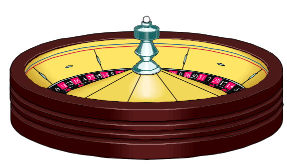
Function	Message	Candidate Symbols
	library	http://members.aol.com/rcmoeur/i.html  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Books/stack.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Books/end.bmp 
	school	http://www.hardhatusa.com/cat161.html (#45)  http://www.geneseo.edu/icons/symbols/six.html (teacher.gif)  http://ftp1.rad.kumc.edu/icons/business/busine01.htm (teacher2.gif)  Corel Clipart 6.0 “teacher3" 
	convenience store	

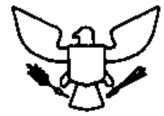
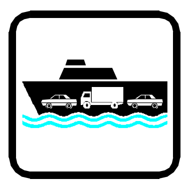
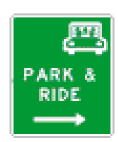
Function	Message	Candidate Symbols
	aquarium	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Animals/fish7.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Animals/fish3.bmp  Corel Clipart 6.0 “dolphin1", “200px”  
	zoo	http://www.geneseo.edu/icons/symbols/five.html (panda.gif)  Corel Clipart 6.0 “zoo”, “199px”  

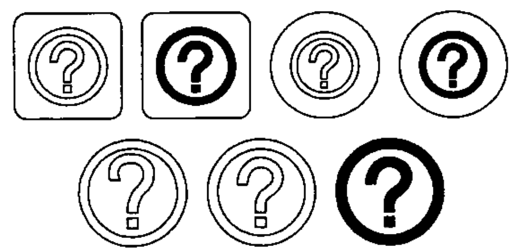
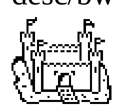
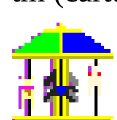
Function	Message	Candidate Symbols
	bank	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/coins.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/money.xbm  http://www.geneseo.edu/icons/symbols/five.html (safe.gif)  http://www.hardhatusa.com/cat162 (ILL 59-64)  http://www.hardhatusa.com/cat163 (ILL 77-82) 

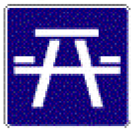
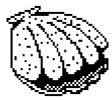
Function	Message	Candidate Symbols
	theater (drama)	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-misc/drama.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/mensetmanus.xbm  http://www.hardhatusa.com/cat161.html (#33, 34,35,36) 
	car rental agency	
	college	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/graduate.xbm  http://www.geneseo.edu/icons/symbols/four.html (mbord02.gif) 

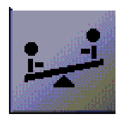
Function	Message	Candidate Symbols
	golf course	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/golf.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/golf2.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/golf3.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/golf4.bmp  Corel Clipart 6.0  
	personal landmark	
	ATM	Corel Clipart 6.0 

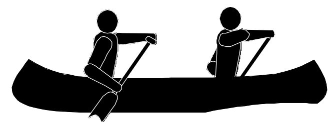
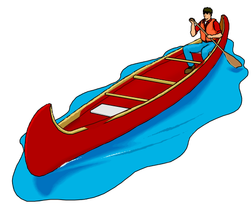
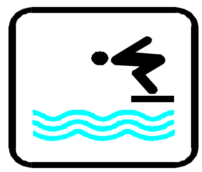
Function	Message	Candidate Symbols
	casino	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/cards.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/dice.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/cards.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/ace_in_hole.bmp  http://ftp1.rad.kumc.edu/icons/fun/fun01.htm (suitf.gif)  Corel Clipart 6.0 “roulette” 

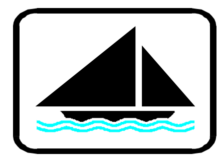
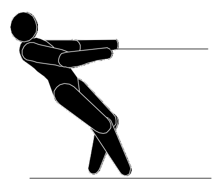
Function	Message	Candidate Symbols
	city hall/government building	http://www.hardhatusa.com/cat161.html (#43)  Corel Clipart 6.0 “201px” 
	commuter rail station	
	train station	
	bus station	
	convention center/exhibition hall	
	ferry terminal	Corel Clipart 6.0 “120px” 
	grocery store	
	park and ride	http://www.iconbazaar.com/road_signs/green/ 
	parking lot	

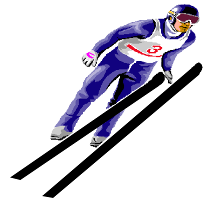
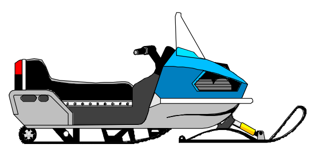
Function	Message	Candidate Symbols
	information	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-64/question.xbm  http://www.iconbazaar.com/blue/  http://www.hardhatusa.com/cat164.html (ILL 181-187) 
	amusement park	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/castle.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Games/tetris.bmp  http://ftp1.rad.kumc.edu/icons/fun/fun01.htm (carturn.gif) 
	wildlife preserve	

Function	Message	Candidate Symbols
	camping	http://www.iconbazaar.com/blue/ 
	picnic area	http://www.iconbazaar.com/blue/ 
	hiking	
	general winter recreation	http://www.iconbazaar.com/road_signs/green/ 
	general water recreation	http://www.sct.gu.edu.au/~anthony/icons/desc/std/ shell.xbm 
	amphitheater	

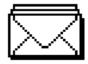
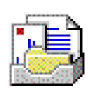
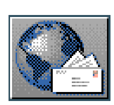
Function	**Message**	**Candidate Symbols**
	climbing	Corel Clipart 6.0 “mntclimb”, “208px”  
	rock climbing	
	hunting	
	playground	http://ftp1.rad.kumc.edu/icons/home_family/family02.htm (anisaw.gif) 
	rock collecting	
	spelunking	Corel Clipart 6.0 “205px” 
	stable	
	bicycle trail	
	horse trail	
	interpretive automobile trail	
	interpretive trail	
	off-road vehicle trail	
	trail bike trail	
	tramway	
	all-terrain vehicle trail	

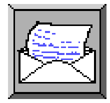
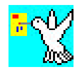
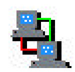
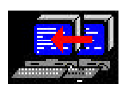
Function	Message	Candidate Symbols
	boat tours	
	canoeing	Corel Clipart 6.0 “str_cano”, “canoe”  
	diving	Corel Clipart 6.0 “219px” 
	scuba diving	Corel Clipart 6.0 “scuba” 
	fishing	Corel Clipart 6.0 “fishrman” 
	marina	
	motor boating	
	boat launching	

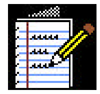
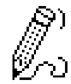
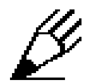
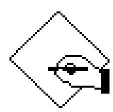
Function	**Message**	**Candidate Symbols**
	rowboating	Corel Clipart 6.0 “rowing” 
	sailboating	Corel Clipart 6.0 “sailboat”  
	waterskiing	Corel Clipart 6.0 “str_watr”, “waterski1"  
	surfing	Corel Clipart 6.0 “surfing” 
	swimming	Corel Clipart 6.0 “swimming” 
	wading	
	ice skating	

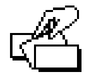
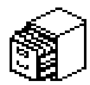
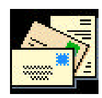
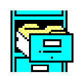
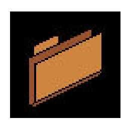
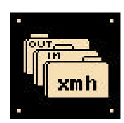
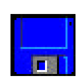
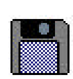
Function	Message	Candidate Symbols
	ski jumping	Corel Clipart 6.0 “sjump”, “longjump”  
	ski bobbing	
	cross-country skiing	Corel Clipart 6.0 “xcntrysk” 
	downhill skiing	Corel Clipart 6.0 “dwnhlsk”, “228px”  
	sledding	
	snowmobiling	Corel Clipart 6.0 “snomble2", “snowmobl”  
	snowshoeing	

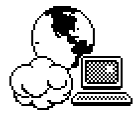
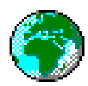
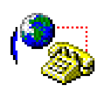
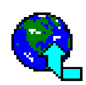
Function	**Message**	**Candidate Symbols**
Services/attractions directory	directory (index of yellow pages)	
	view currently selected preferences	
Destination coordination	location of and distance to restaurant	
	location of and distance to lodging	
	location of and distance to gas station	
	distance to and direction of nearest rest area	
	confirmation of reservation	
	reservation details	
	locate nearest parking	
	type of parking facility	
	diagram of parking facilities	
	real-time availability of parking	

Function	**Message**	**Candidate Symbols**
Message transfer	incoming message	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/mail.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-64x38/xmail_~1.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-64x38/mailbox.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/mail_zap.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/mailslot.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/news.bmp  http://www.geneseo.edu/icons/symbols/two.html (email1.gif)  http://ftp1.rad.kumc.edu/icons/mail/mail02.htm (but004.gif) 

Function	Message	Candidate Symbols
	message sent/send message	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/letter_edit.xpm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/mail_p~1.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/ cl-32/Network/rlogin.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-64x38/mail-new.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-64x38/pc_ftp.bmp  http://www.geneseo.edu/icons/symbols/two.html (email3.gif) 
	alert driver message was not sent and why not	

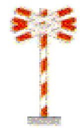
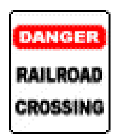
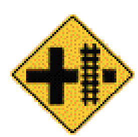
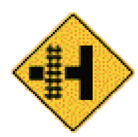
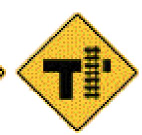
Function	**Message**	**Candidate Symbols**
	write message	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-48/notebook.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/pencil.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/pencil2.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/pencil3.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-48/application.xbm 
	delete message	
	message acknowledged/received	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/gopher_page.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/letter.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Network/nfs.bmp 

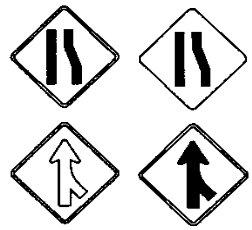
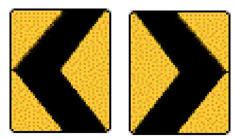
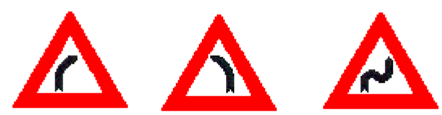
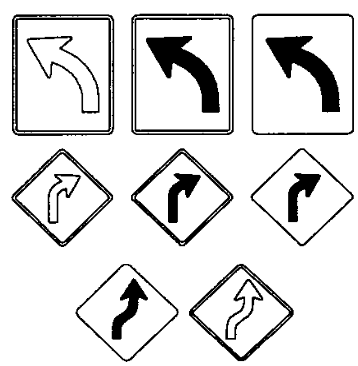
Function	Message	Candidate Symbols
	access message	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/sorting.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/ bw-32/filing_open.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-48/mail.bmp  http://ftp1.rad.kumc.edu/icons/business/busine01.htm (filecab2.gif) 
	save message	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-64/file.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-64/xmh.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Disks/3D_blue.bmp  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-32/Disks/grey_b~1.bmp 

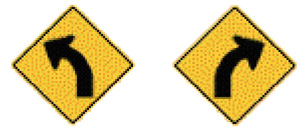
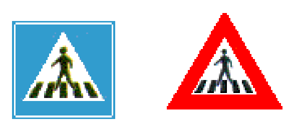
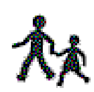
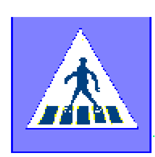
Function	**Message**	**Candidate Symbols**
	review received message	
	reply to a message	
	access the Internet	http://www.sct.gu.edu.au/~anthony/icons/desc/std/network.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/cl-48/www.bmp  http://www.geneseo.edu/icons/symbols/three.html (globe01.gif)  http://www.geneseo.edu/icons/symbols/six.html (www1, 2, 3.gif)  

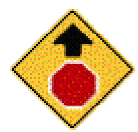
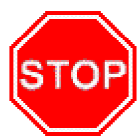
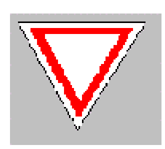
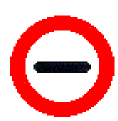
AUGMENTED SIGNAGE INFORMATION		
Function	**Message**	**Candidate Symbols**
Roadway guidance sign information	interchange ahead	
	route markers	
	mile posts	http://www.iconbazaar.com/road_signs/green/ 

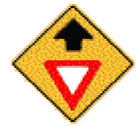
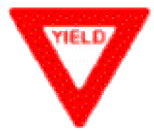
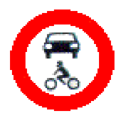
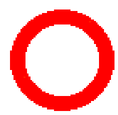
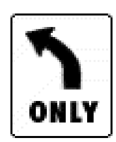
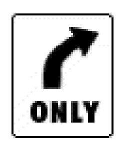
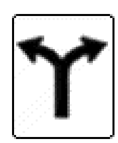
Function	Message	Candidate Symbols
Roadway notification sign information	steep downgrade	http://www.iconbazaar.com/road_signs/yellow/ (a couple)  
	percent of grade	
	recommended speed as a function of grade	
	braking requirements for specific grades	
	tight ramp or intersection	

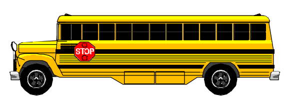
Function	Message	Candidate Symbols
	railroad crossing	http://www.dhp.nl/traffic/english.html  http://www.infomal.com.my/general/signlogo.htm   http://www.iconbazaar.com/road_signs/red/  http://www.iconbazaar.com/road_signs/yellow/     http://www.is.titech.ac.jp/labs/makimotolab/fujimoto/RTA/Rsign.html 

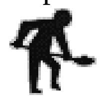
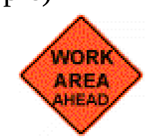
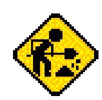
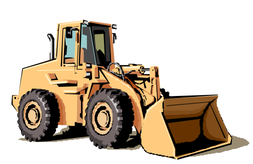
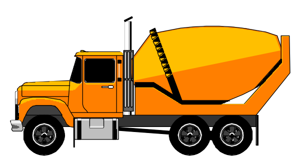
Function	Message	Candidate Symbols
	merge	http://www.hardhatusa.com/cat160.html (#41, 42, 22, 23) 
	chevrons	http://www.iconbazaar.com/road_signs/yellow 
	curve signs	http://www.dhp.nl/traffic/english.html (left, right, both)  http://www.hardhatusa.com/cat160.html (4,5,6, 28, 29, 30, 31, 33) 

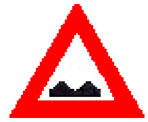
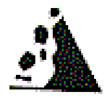
Function	Message	Candidate Symbols
	sharp curve ahead	http://www.iconbazaar/road_signs/yellow/ (a couple)  http://www.hardhatusa.com/cat160.html (25, 26, 27) 
	curve speed for specific vehicle sizes	
	pedestrian crossing ahead	http://www.iconbazaar.com/road_signs/yellow/  http://www.dhp.nl/traffic/english.html  http://www.ips.be/_wbm/home.htm  http://www.travlang.com/signs/various.html 

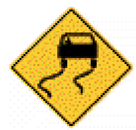
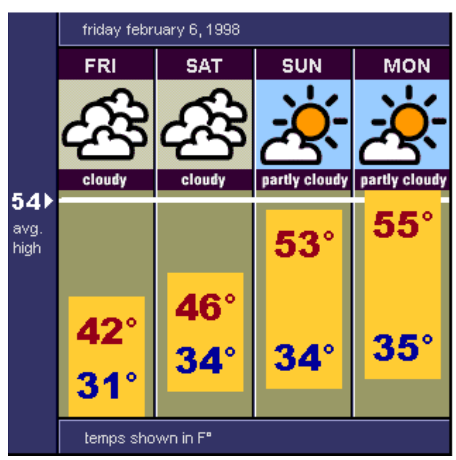
Function	Message	Candidate Symbols
Roadway regulatory sign information	speed limit	http://www.dhp.nl.traffic/english.html 
	speed limit in construction zones	
	vehicle is x mi/h over speed limit	
	stop	http://www.iconbazaar.com/road_signs/yellow/   http://www.iconbazaar.com/road_signs/red/  http://www.travlang.com/signs/regulate.html  http://www.dhp.nl/traffic/english.html 

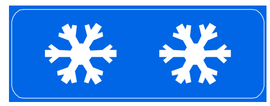
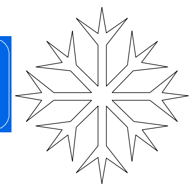
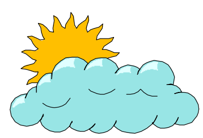
Function	Message	Candidate Symbols
	yield	http://www.iconbazaar.com/road_signs/yellow/   http://www.iconbazaar.com/road_signs/red/ 
	do not enter	http://www.dhp.nl/traffic/english.html   http://www.iconbazaar.com/road_signs/red/ 
	no right or left turn	http://www.iconbazaar.com/road_signs/red/  
	left turn only/right turn only	http://www.iconbazaar.com/road_signs/white    
	4-way stop	http://www.iconbazaar.com/road_signs/red/ 

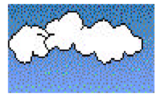
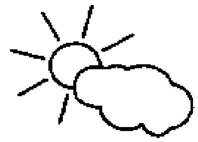
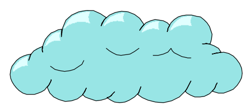
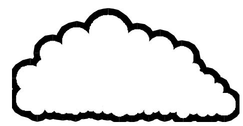
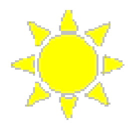
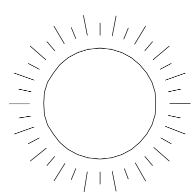
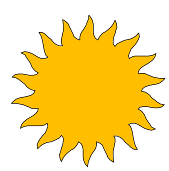
SAFETY/WARNING INFORMATION		
Function	**Message**	**Candidate Symbols**
Immediate hazard warning	emergency vehicle stopped ahead	Corel Clipart 6.0 “firelogo”, “firepump”, “police”, “amb2"    
	distance of approaching emergency vehicle	
	relative locations of emergency vehicles to you on a map	
	school bus stopped ahead	school bus icon: http://www.hardhatusa.com/cat139.html (TTL032)  Corel Clipart 6.0 “skoolbus” 

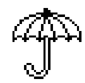
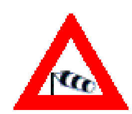
Function	**Message**	**Candidate Symbols**
Road condition information	road work/construction ahead	http://www.dhp.nl/traffic/english.html  http://www.ips.be/_wbm/home.htm  http://www.hardhatusa.com/cat161.html (#6)  http://www.iconbazaar.com/road_signs/orange (a couple)  http://www.geneseo.edu/icons/symbols/six.html (uconstr1, 2, 3)  Corel Clipart 6.0 “bull2", “mixer” 

Function	Message	Candidate Symbols
	uneven road ahead	http://www.dhp.nl/traffic/english.html 
	fallen rock ahead	http://www.dhp.nl/traffic/english.html (loose stones)  http://www.ips.be/_wbm/home.htm  http://www.infomal.com.my/general/sognlogo.htm  http://www.hardhatusa.com/cat161.html 
	frost damage ahead	http://www.travlang.com/signs/others.html 

Function	Message	Candidate Symbols
	icy roads ahead	http://www.dhp.nl/traffic/english.html  http://www.iconbazaar.com/road_signs/yellow/  http://www.infomal.com.my/general/signlogo.htm 
	low shoulder	
	general weather forecast for a specific area	go to various intellicast sites for the following weather info and/or a general forecast. Switch around to different regions for different types of weather: http://www.intellicast.com/weather/atl/ 

Function	**Message**	**Candidate Symbols**
	snow ahead	http://www.hardhatusa.com/cat142.html (WTL 11)  Corel Clipart 6.0 “pe_36", “snow025"  
	partly sunny weather conditions	http://www.hardhatusa.com/cat142.html (WTL 23)  Corel Clipart 6.0 “symb571" 

Function	Message	Candidate Symbols
	partly cloudy weather conditions	http://www.sct.gu.edu.au/~anthony/icons/desc/cl-misc/environ1_clouds.bmp  http://www.hardhatusa.com/cat142.html (WTL 18)  Corel Clipart 6.0 “cloud”, “symb568"  
	sunny conditions	http://www.geneseo.edu/icons/symbols/six.html (sun03.gif)  http://www.hardhatusa.com/cat142.html (WTL 24)  Corel Clipart 6.0 “symb556", “symb567"  

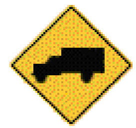
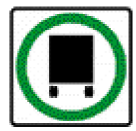
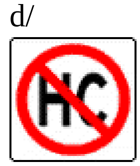
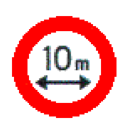
Function	Message	Candidate Symbols
	rain ahead	http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/umbrella.xbm  http://www.sct.gu.edu.au/~anthony/icons/desc/bw-32/umbrella2.xbm  http://www.hardhatusa.com/cat142.html (WTL 9, 10, 26)  Corel Clipart 6.0 "symb573", "symb569" 
	squalls	http://www.dhp.nl/traffic/english.html 
	fog	
	traffic/congestion ahead	
	general real-time traffic information	
	how far/how long traffic is backed up	
	map showing areas of mild, moderate and severe congestion	
Function	**Message**	**Candidate Symbols**

	accident ahead	http://www.infomal.com.my/general/signlog2.htm  http://www.iconbazaar.com/road_signs/yellow/ 
	chemical spill ahead	
	lanes blocked ahead	
	lanes closed ahead	
Automatic/manual aid request	inform driver that aid had been requested	
	inform driver of time until emergency unit will arrive	
	display messages from the emergency response center	
	update real-time information from the emergency center	
Vehicle condition monitoring	inform driver of current problem	
	inform driver of ways to correct problem	
	provide more detailed information at the driver's request	

Function	Message	Candidate Symbols
	inform the driver of needed warranty services due	
	low tire pressure	
	low oil pressure	
	safety event recorder information	

COMMERCIAL VEHICLE OPERATIONS (CVO) INFORMATION		
Function	**Message**	**Candidate Symbols**
Trip planning	approved fueling locations	
	truck stops	
	dealers	
	fuel costs	
	approved parking locations for types	
	weight limits	
	overhead restrictions	
	weigh stations (locations and whether or not they are open)	
	fuel taxes	
	typical congestion of route	
	miles until truck is out of fuel	
Delivery-related information	delivery location	
	scheduled pickup and delivery times	

Function	Message	Candidate Symbols
	times of day or week that may affect delivery	
	equipment types not allowed on roadway	
	optimize delivery schedules	
	customer’s preferences	
	information from dispatcher regarding schedule changes and other pickup/delivery information	
Presentation of service directory information	index of yellow pages and information from Trucker’s Atlas	
CVO-specific aid request information	notify emergency services of hazardous material	
	inform emergency services of cargo type	
Cargo and vehicle monitoring information	problem in the trailer unit	
	problem in the tractor unit	
	precise information regarding vehicle performance	

Function	Message	Candidate Symbols
Augmented signage information	truck route	http://www.iconbazaar.com/road_signs/yellow/  http://www.iconbazaar.com/road_signs/green/ 
	truck speed limit	
	routing restrictions for specific vehicle cargoes	
	weight limits	http://www.dhp.nl/traffic/english.html 
	no hazardous materials allowed	http://www.iconbazaar.com/road_signs/red/ 
	low clearance	
	low overpasses on route	
	allowable vehicle length on roadway	http://www.dhp.nl/traffic/english.html 
	allowable vehicle width on roadway	http://www.dhp.nl/traffic/english.html 

Function	Message	Candidate Symbols
	allowable vehicle height on roadway	
Administrative information	allow driver to complete administrative paperwork electronically (i.e., taxes, licenses)	
	inform driver of regulatory administrative requirements	
	electronic permit applications	
	pre-clearance	
	credential checking	
	driver-incentive and performance	
Post-trip summary	elapsed time	
	miles traveled	
	fuel used	
	tools paid for driver logs	
	percent of time at idle	

GPS-RELATED INFORMATION		
Function	**Message**	**Candidate Symbols**
	position of satellites in space; representation of which satellites are currently transmitting information	
	satellite signal strength	

Function	**Message**	**Candidate Symbols**
	current GPS position (latitude, longitude, altitude)	
	magnify/minimize map view	
	shift to another region of the map	
	shift to another region of the world	
	look for a specific street address	

APPENDIX F: ICONS CURRENTLY BEING USED BY MANUFACTURERS AND AFTER-MARKET VENDORS OF ATIS AND CAS SYSTEMS

ROUTING AND NAVIGATION INFORMATION (Material from existing in-vehicle navigation products)		
Function	**Message**	**Candidate Symbols**
Trip planning	display of lodging along set route	
	price ranges of lodging along route	
	vacancy status of hotels along route	
	locations of state and national parks	
	transit schedules in areas along route	
	total trip time	
	time to each destination	
	total trip mileage	
	mileage to each destination	
	total trip cost	
	number of tolls and cost of each toll per segment	
	type of roads on route	
	number of turns or roadway changes required	
	states, regions, communities and districts along the route	
	landmarks or topographical features	
Multi-mode travel coordination and planning	start time required to catch other mode of transport	
	mode of travel to take for each segment of travel	
	arrival time at end of each segment of travel	
	layover time between travel segments	
	arrival time at destination	
	total time to complete travel	

Function	**Message**	**Candidate Symbols**
Pre-drive route and destination selection	fastest route available	
	route avoiding tollways	
	most scenic route	Figures 11, 12
	route avoiding tollways	
	route avoiding complex intersections	
	route that minimizes left turns	
	route option with least traffic	
	shortest route option	
	crime ratings of route options	
	road quality of route options	
	number of traffic lights/stops of route options	
Route guidance	notification that the driver is off route	Figures 13, 14
	vehicle’s current position	
	suggestion of alternative route	Figures 15, 16
	complete map of route	Figures 17, 18, 19, 20, 21, 22, 23, 24, 25
	desired order of destinations	
	next destination	
	final destination	Figures 20, 21
	reroute option with least traffic	
	shortest reroute option	
	crime ratings of reroute options	
	road quality of reroute options	
	information on road closures and restrictions	
	number of traffic lights/stop signs of reroute options	

Function	Message	Candidate Symbols
	suggested course of action for emergency vehicle stopped ahead	
	recommended course of action for approaching emergency vehicle scenario	
	time and distance to bad road conditions	
	recommended course of action for bad road conditions	
	time and distance to weather conditions	
	time and distance to traffic congested area	
	historical congestion information	
Route navigation	distance and time to destination	
	distance and time to turn	Figures 26, 27, 28, 29, 30
	distance and time to exit	
	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	
	maximum speed for negotiating the exit ramp safely	
Automated toll collection	location of and distance to toll booths	
	number of lanes in tolls	
	cost of tolls along route	
	remaining balance in toll account	
	notification of tolls to be paid along route	
	notification of successful toll charge	

MOTORIST SERVICES INFORMATION (Material from products being currently used)		
Function	**Message**	**Candidate Symbols**
Broadcast services/ attractions	restaurant/food ahead	Figures 31, 32
	restaurant type/style (e.g. Japanese, American, Mexican, etc.)	Figure 33
	restaurant names	
	price range of food at restaurants	Figure 34
	review ratings of restaurants	Figure 34
	lodging ahead	
	closest lodging with vacancy	
	guest amenities:	
	elevator	
	kennel	
	laundry	
	locker	
	parking	
	shower	
	restrooms	
	barber shop	
	hair salon	
	gas station ahead	Figure 33
	cost of gasoline	
	hours of operation of gas station	

Function	Message	Candidate Symbols
	amenities of gas station:	
	restrooms	
	phone	
	food	
	restroom ahead	
	telephone ahead	
	rest area ahead	
	landmark information	
	sports venue	Figure 35
	nature attraction	Figure 35
	arts and culture venue	Figure 35
	RV park	Figure 35
	airport	Figures 17, 35, 36, 37, 38
	shopping center	Figure 35
	night life attraction	Figure 35
	hospital	Figure 35
	ice cream shop	Figure 33
	coffee shop	Figure 33
	pharmacy	Figure 33
	courthouse	Figure 33
	music venue	Figure 33
	movie theater	Figure 33
	car mechanic	Figure 33
	football stadium	Figure 33
	post office	
	library	

Function	**Message**	**Candidate Symbols**
	school	
	convenience store	Figure 33
	aquarium	
	zoo	Figure 33
	bank	Figure 33
	theater (drama)	Figure 33
	car rental agency	Figure 33
	college	Figure 33
	golf course	Figure 32
	personal landmark	Figures 20, 15, 16
	ATM	
	casino	
	city hall/government building	
	commuter rail station	Figure 15
	train station	Figure 39
	bus station	Figure 39
	convention center/exhibition hall	
	ferry terminal	
	grocery store	
	park and ride	
	parking lot	
	information	Figure 40
	amusement park	Figure 11
	wildlife preserve	Figure 12
	camping	

Function	Message	Candidate Symbols
	picnic area	
	hiking	
	general winter recreation	
	general water recreation	
	amphitheater	
	climbing	
	rock climbing	
	hunting	
	playground	
	rock collecting	
	spelunking	
	stable	
	bicycle trail	
	horse trail	
	interpretive automobile trail	
	interpretive trail	
	off-road vehicle trail	
	trail bike trail	
	tramway	
	all-terrain vehicle trail	
	boat tours	
	canoeing	
	diving	
	scuba diving	
	fishing	

Function	**Message**	**Candidate Symbols**
	marina	
	motor boating	
	boat launching	
	rowboating	
	sailboating	
	waterskiing	
	surfing	
	swimming	
	wading	
	ice skating	
	ski jumping	
	ski bobbing	
	cross-country skiing	
	downhill skiing	
	sledding	
	snowmobiling	
	snowshoeing	
Services/attractions directory	directory (index of yellow pages)	
	view currently selected preferences	
Destination coordination	location of and distance to restaurant	
	location of and distance to lodging	
	location of and distance to gas station	

Function	Message	Candidate Symbols
	distance to and direction of nearest rest area	
	confirmation of reservation	
	reservation details	
	locate nearest parking	
	type of parking facility	
	diagram of parking facilities	
	real-time availability of parking	
Message transfer	incoming message	
	message sent/send message	
	alert driver message was not sent and why not	
	write message	
	delete message	
	message acknowledged/received	
	access message	
	save message	
	review received message	
	reply to a message	
	access the Internet	

AUGMENTED SIGNAGE INFORMATION		
Function	**Message**	**Candidate Symbols**
Roadway guidance sign information	interchange ahead	
	route markers	
	mile posts	
Roadway notification sign information	steep downgrade	
	percent of grade	
	recommended speed as a function of grade	
	braking requirements for specific grades	
	tight ramp or intersection	
	railroad crossing	
	merge	
	chevrons	
	curve signs	
	sharp curve ahead	
	curve speed for specific vehicle sizes	
	pedestrian crossing ahead	
Roadway regulatory sign information	speed limit	
	speed limit in construction zones	
	vehicle is x mi/h over speed limit	
	stop	

Function	Message	Candidate Symbols
	yield	
	do not enter	
	no right or left turn	
	left turn only/right turn only	
	4-way stop	

SAFETY/WARNING INFORMATION		
Function	**Message**	**Candidate Symbols**
Immediate hazard warning	emergency vehicle stopped ahead	
	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	Figure 41
	uneven road ahead	
	fallen rock ahead	
	frost damage ahead	
	icy roads ahead	
	low shoulder	
	general weather forecast for a specific area	
	snow ahead	
Function	**Message**	**Candidate Symbols**

	partly sunny weather conditions	
	partly cloudy weather conditions	
	sunny conditions	
	rain ahead	
	squalls	
	fog	
	traffic/congestion ahead	Figure 37
	general real-time traffic information	
	how far/how long traffic is backed up	
	map showing areas of mild, moderate and severe congestion	
	accident ahead	Figure 41
	chemical spill ahead	
	lanes blocked ahead	
	lanes closed ahead	
Automatic/manual aid request	inform driver that aid had been requested	
	inform driver of time until emergency unit will arrive	
	display messages from the emergency response center	
	update real time information from the emergency center	
Function	**Message**	**Candidate Symbols**

Vehicle condition monitoring	inform driver of current problem	
	inform driver of ways to correct problem	
	provide more detailed information at the driver’s request	
	inform the driver of needed warranty services due	
	low tire pressure	
	low oil pressure	
	safety event recorder information	

COMMERCIAL VEHICLE OPERATIONS (CVO) INFORMATION		
Function	**Message**	**Candidate Symbols**
Trip planning	approved fueling locations	
	truck stops	
	dealers	
	fuel costs	
	approved parking locations for types	
	weight limits	
	overhead restrictions	
	weigh stations (locations and whether or not they are open)	
	fuel taxes	

Function	**Message**	**Candidate Symbols**
	typical congestion of route	
	miles until truck is out of fuel	
Delivery-related information	delivery location	
	scheduled pickup and delivery times	
	times of day or week that may affect delivery	
	equipment types not allowed on roadway	
	optimize delivery schedules	
	customer’s preferences	
	information from dispatcher regarding schedule changes and other pickup/delivery information	
Presentation of service directory information	index of yellow pages and information from Trucker’s Atlas	
CVO-specific aid request information	notify emergency services of hazardous material	
	inform emergency services of cargo type	
Cargo and vehicle monitoring information	problem in the trailer unit	
	problem in the tractor unit	

Function	Message	Candidate Symbols
	precise information regarding vehicle performance	
Augmented signage information	truck route	
	truck speed limit	
	routing restrictions for specific vehicle cargoes	
	weight limits	
	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	
	electronic permit application	
	pre-clearance	

Function	Message	Candidate Symbols
	credential checking	
	driver-incentive and performance	
Post-trip summary	elapsed time	
	miles traveled	
	fuel used	
	tools paid for driver logs	
	percent of time at idle	

GPS-RELATED INFORMATION		
Function	**Message**	**Candidate Symbols**
	position of satellites in space; representation of which satellites are currently transmitting information	Figures 42, 43
	satellite signal strength	Figures 42, 43
	current GPS position (latitude, longitude, altitude)	Figures 44, 45
	magnify/minimize map view	Figure 20
	shift to another region of the map	Figure 20
	shift to another region of the world	Figure 20
	look for a specific street address	Figures 20, 46

COLLISION AVOIDANCE INFORMATION (Material from existing collision avoidance systems)		
Function	**Message**	**Candidate Symbols**
Rear-end collision avoidance	system on and functioning	
	system failure	
	no danger indicator	Figures 47, 48, 49
	advisory indicator (also nature, severity, corrective action required)	Figures 47, 48, 49
	warning indicator (also nature, severity, corrective action required)	Figures 47, 48, 49
Road-departure collision avoidance	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Lane change/merge collision avoidance	system on and functioning	
	system failure	
	no danger indicator	Figure 50
	advisory indicator (also nature, severity, corrective action required)	Figure 50
	warning indicator (also nature, severity, corrective action required)	Figure 50
Intersection collision avoidance	system on and functioning	

Function	**Message**	**Candidate Symbols**
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Railroad crossing collision avoidance	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Driver monitoring devices	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Backing devices	system on and functioning	
	system failure	
	no danger indicator	

Function	**Message**	**Candidate Symbols**
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Automatic cruise control devices	system on and functioning	
	system failure	
	headway selection	
	mode selection	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	

Figure 11. ATIS-Routing and Navigation (System by Etak-screen 1).

Figure 12. ATIS-Routing and Navigation (System by Etak-screen 2).

Figure 13. ATIS-Routing and Navigation (System by Xanavi-screen 1).

Figure 14. ATIS-Routing and Navigation (System by Xanavi-screen 2).

Figure 15. ATIS-Routing and Navigation (System by Fastline-screen 1).

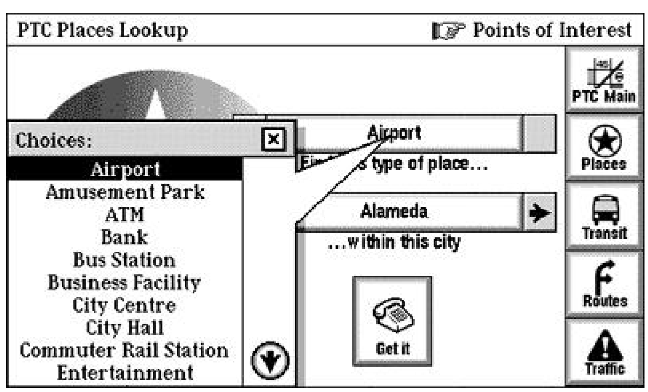


Figure 16. ATIS-Routing and Navigation (System by Fastline-screen 2).

Figure 17. ATIS-Routing and Navigation (System by Xanavi-screen 3).

Figure 18. ATIS-Routing and Navigation (System by Philips-screen 1).

Figure 19. ATIS-Routing and Navigation (System by Philips-screen 2).

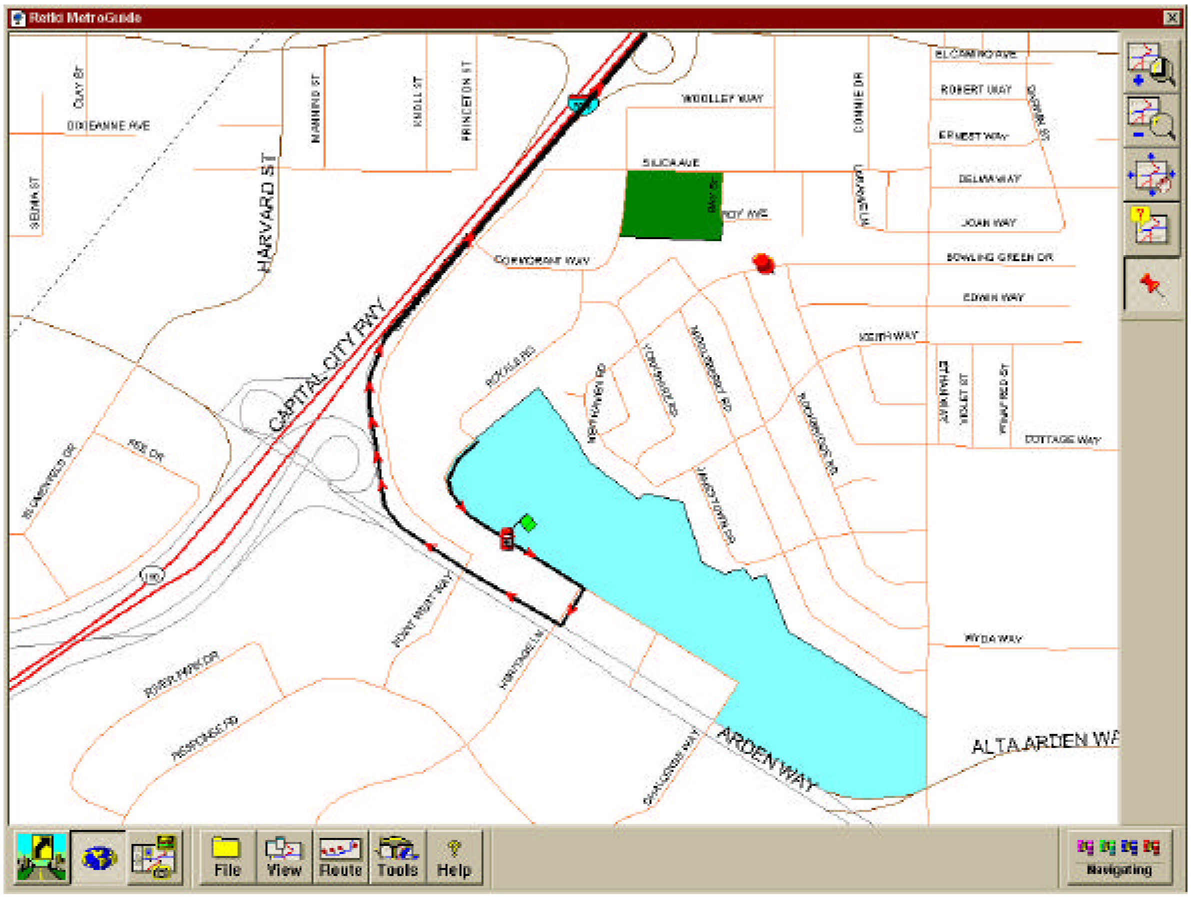


Figure 20. ATIS-Routing and Navigation (System by Retki-screen 1).

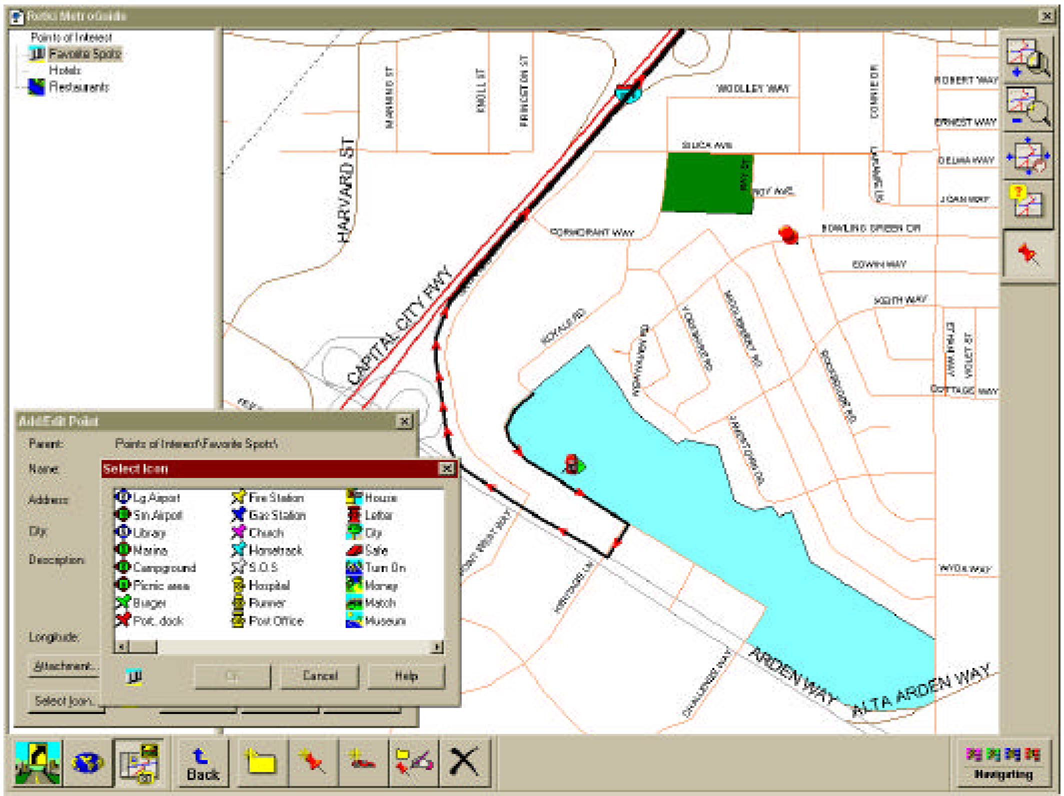


Figure 21. ATIS-Routing and Navigation (System by Retki-screen 2).

Figure 22. ATIS-Routing and Navigation (System by Tecmobility-screen 1).

Figure 23. ATIS-Routing and Navigation (System by Tecmobility-screen 2).

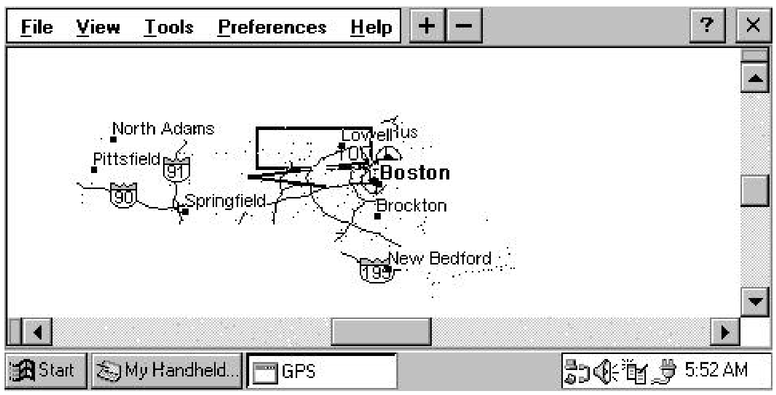


Figure 24. ATIS-Routing and Navigation (System by TeleType-screen 1).

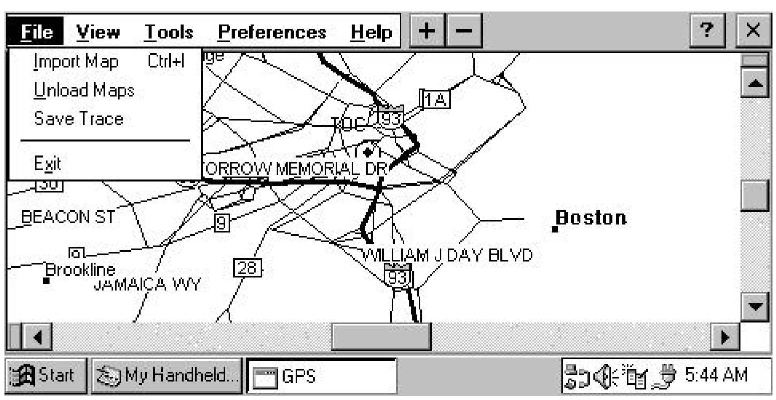


Figure 25. ATIS-Routing and Navigation (System by TeleType-screen 2).

Figure 26. ATIS-Routing and Navigation (System by Philips-screen 3).

Figure 27. ATIS-Routing and Navigation (System by Zexel-screen 1).

Figure 28. ATIS-Routing and Navigation (System by Zexel-screen 2).

Figure 29. ATIS-Routing and Navigation (System by Zexel-screen 3).

Figure 30. ATIS-Routing and Navigation (System by Zexel-screen 4).

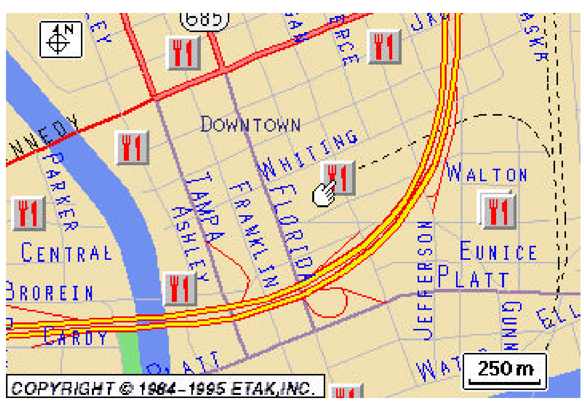


Figure 31. ATIS-Motorist Services (System by Etak-screen 3).

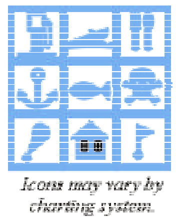


Figure 32. ATIS-Motorist Services (System by C Map USA).

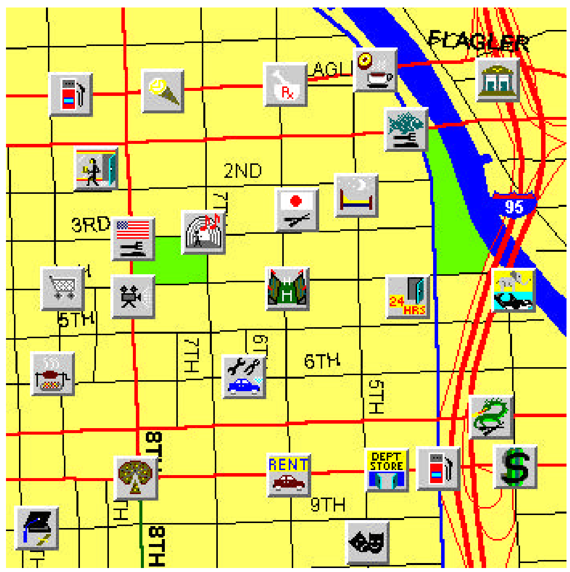


Figure 33. ATIS-Motorist Services (System by Etak-screen 4).

Figure 34. ATIS-Motorist Services (System by Etak-screen 5).

Figure 35. ATIS-Motorist Services (System by Etak-screen 6).

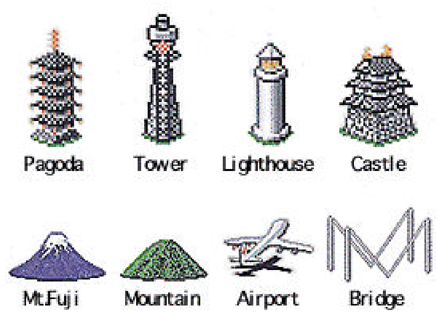


Figure 36. ATIS-Motorist Services (System by Xanavi-screen 4).

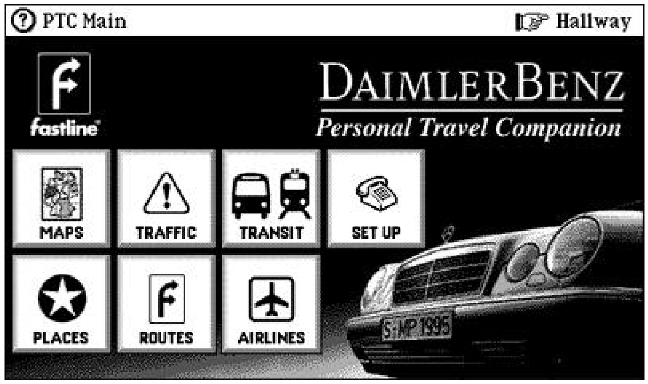


Figure 37. ATIS-Motorist Services (System by Fastline-screen 3).

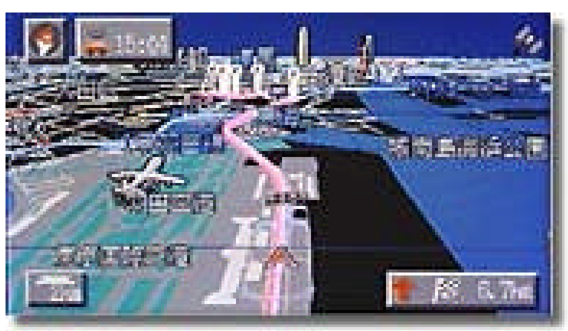


Figure 38. ATIS-Motorist Services (System by Xanavi-screen 5).

Figure 39. ATIS-Motorist Services (System by Fastline-screen 4).

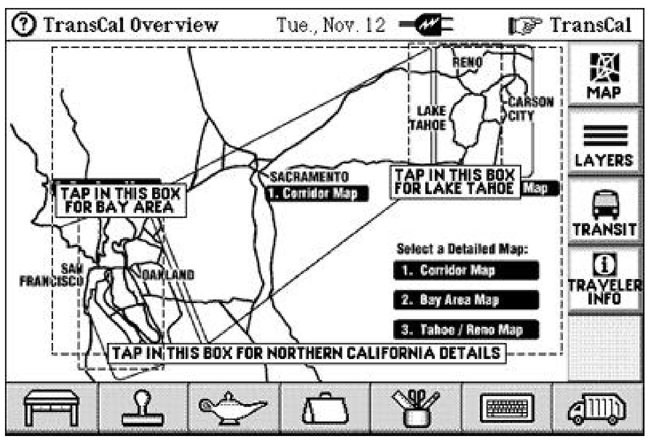


Figure 40. ATIS-Motorist Services (System by Fastline-screen 5).

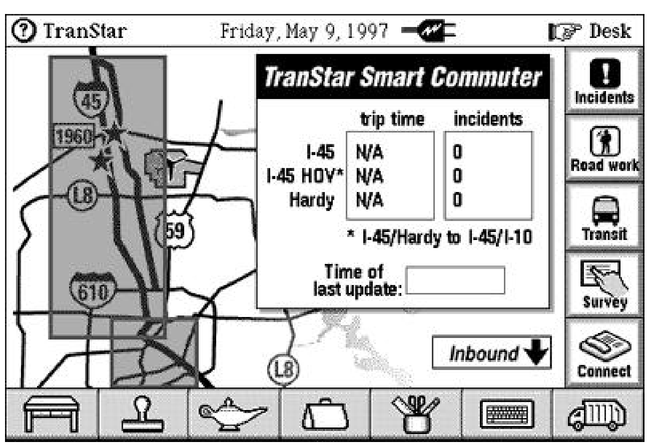


Figure 41. ATIS-Safety/Warning (System by Fastline-screen 6).

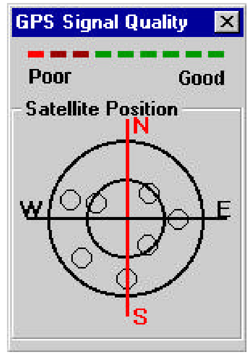


Figure 42. ATIS-GPS-related (System by Etak-screen 7).

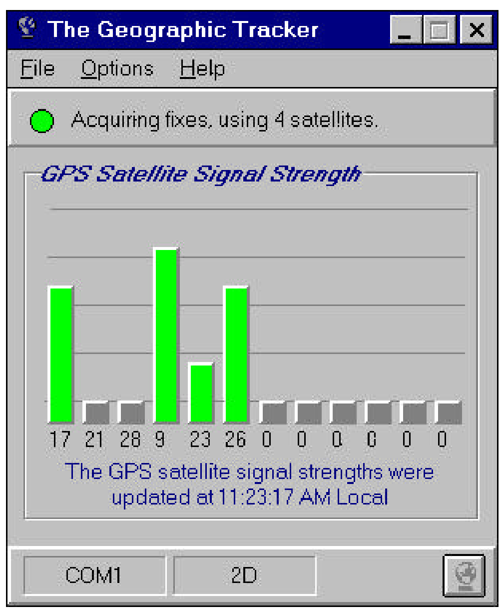


Figure 43. ATIS-GPS-related (System by Bluemarble Geo).

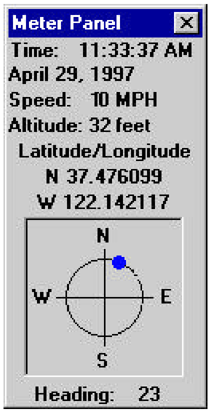


Figure 44. ATIS-GPS-related (System by Etak-screen 8).

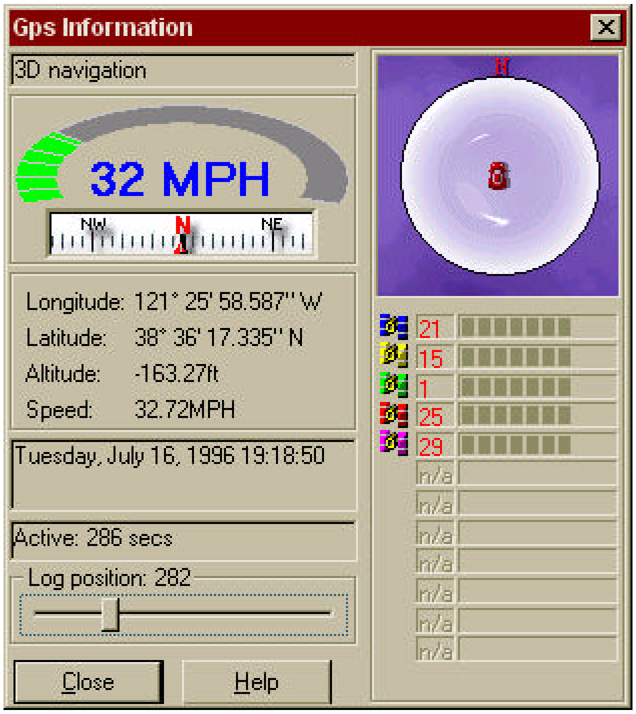


Figure 45. ATIS-GPS-related (System by Retki-screen 3).

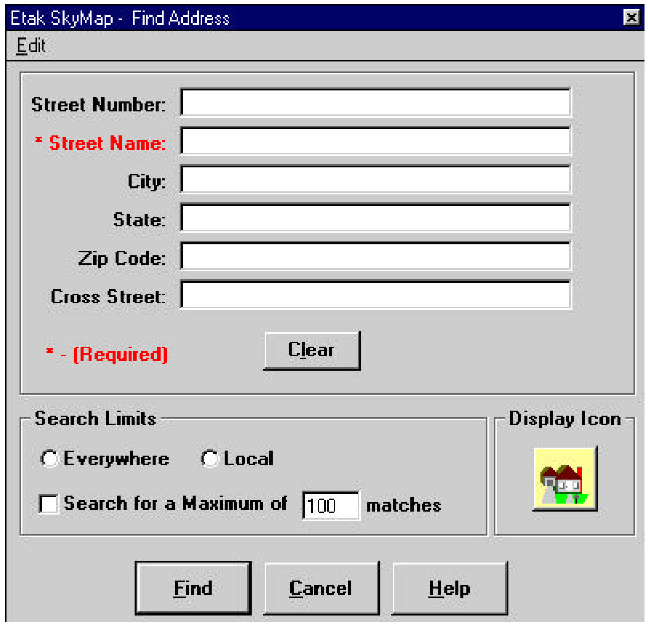


Figure 46. ATIS-GPS-related (System by Etak-screen 9).

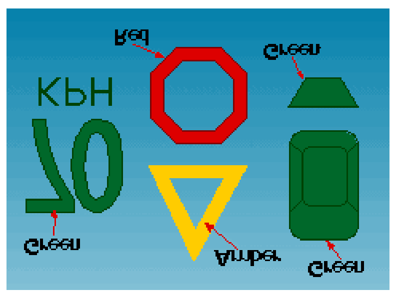


Figure 47. Collision Avoidance (System by Delco).

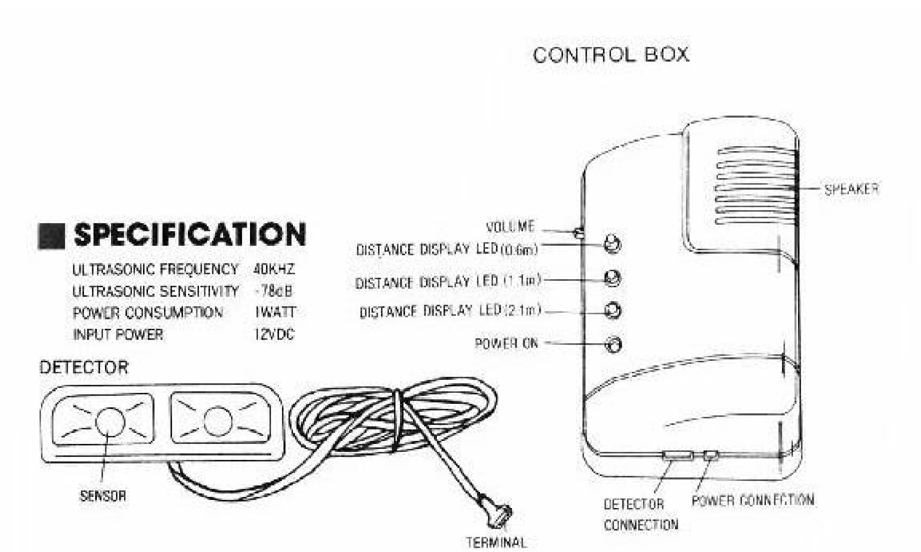


Figure 48. Collision Avoidance (System by Eyemax).

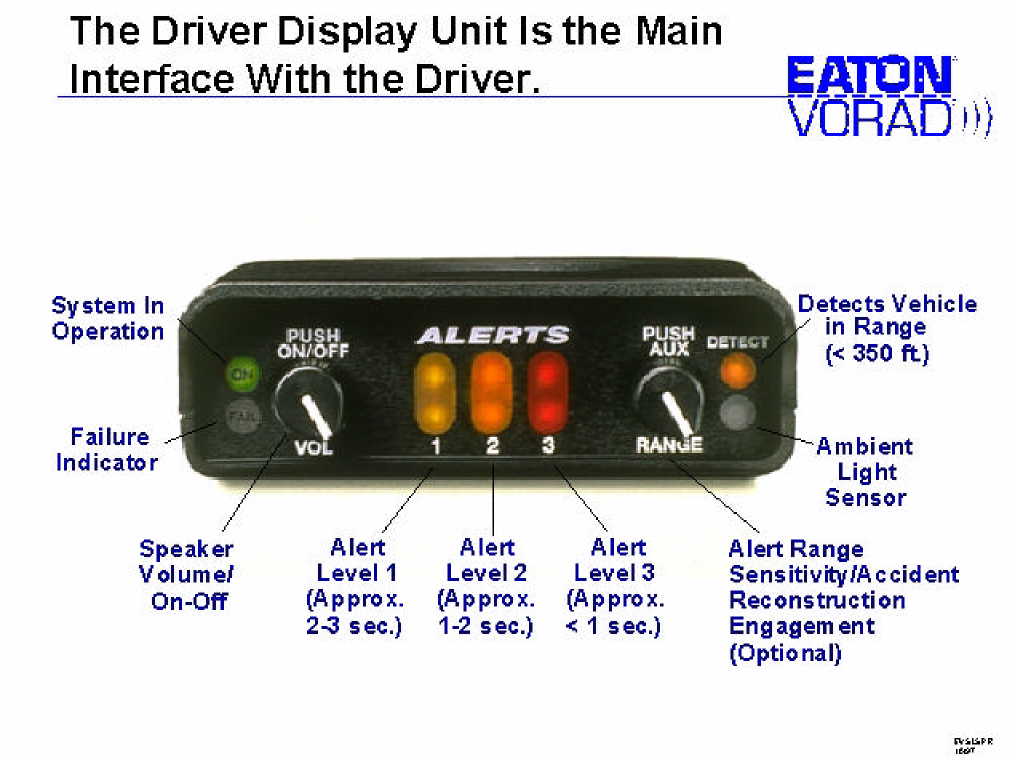


Figure 49. Collision Avoidance (System by Eaton Vorad-screen 1).

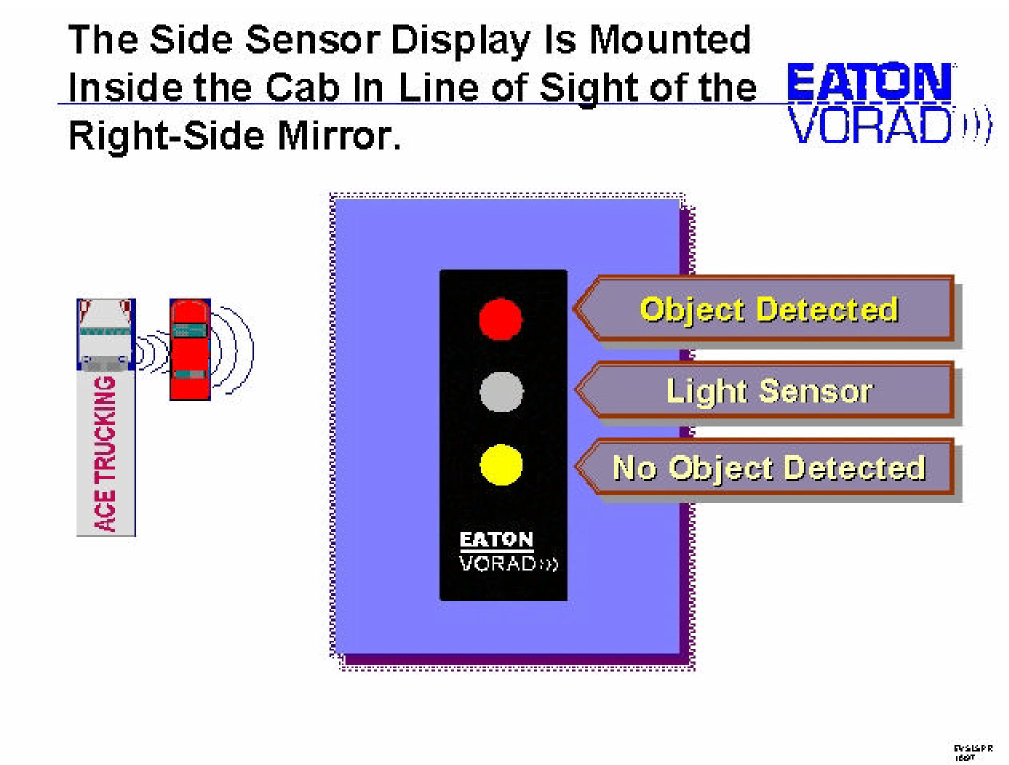


Figure 50. Collision Avoidance (System by Eaton Vorad-screen 2).

APPENDIX G: ICONS USED IN PREVIOUS RESEARCH EFFORTS RELATED TO ATIS AND CAS SYSTEMS

ROUTING AND NAVIGATION INFORMATION (Material from experimental studies)		
Function	**Message**	**Candidate Symbols**
Trip planning	display of lodging along set route	
	price ranges of lodging along route	
	vacancy status of hotels along route	
	locations of state and national parks	
	transit schedules in areas along route	
	total trip time	
	time to each destination	
	total trip mileage	
	mileage to each destination	
	total trip cost	
	number of tolls and cost of each toll per segment	
	type of roads on route	
	number of turns or roadway changes required	
	states, regions, communities, and districts along the route	
	landmarks or topographical features	
Multi-mode travel coordination and planning	start time required to catch other mode of transport	Figure 51
	mode of travel to take for each segment of travel	Figure 51
	arrival time at end of each segment of travel	Figure 51
	layover time between travel segments	
	arrival time at destination	Figure 51
	total time to complete travel	

Function	**Message**	**Candidate Symbols**
Pre-drive route and destination selection	fastest route available	
	route avoiding tollways	
	most scenic route	
	route avoiding tollways	Figure 52
	route avoiding complex intersections	
	route option with least traffic	Figure 53
	route that minimizes left turns	
	shortest route option	
	crime ratings of route options	
	road quality of route options	
	number of traffic lights/stops of route options	
Route guidance	notification that the driver is off route	Figures 54, 55
	vehicle's current position	
	suggestion of alternative route	Figures 56, 57
	complete map of route	Figures 58, 59
	desired order of destinations	Figures 60, 61
	next destination	Figures 60, 61
	final destination	Figures 60, 61
	reroute option with least traffic	Figure 53
	shortest reroute option	
	crime ratings of reroute options	
	road quality of reroute options	
	information on road closures and restrictions	
	number of traffic lights/stop signs of reroute options	

Function	Message	Candidate Symbols
	suggested course of action for emergency vehicle stopped ahead	
	recommended course of action for approaching emergency vehicle scenario	
	time and distance to bad road conditions	
	recommended course of action for bad road conditions	
	time and distance to weather conditions	
	time and distance to traffic congested area	
	historical congestion information	
Route navigation	distance and time to destination	Figure 62
	distance and time to turn	Figure 63
	distance and time to exit	Figures 64, 65
	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	
	maximum speed for negotiating the exit ramp safely	
Automated toll collection	location of and distance to toll booths	Figure 52
	number of lanes in tolls	Figure 52
	cost of tolls along route	
	remaining balance in toll account	
	notification of tolls to be paid along route	
	notification of successful toll charge	

MOTORIST SERVICES INFORMATION (Experimental)		
Function	**Message**	**Candidate Symbols**
Broadcast services/ attractions	restaurant/food ahead	Figure 66
	restaurant type/style (e.g. Japanese, American, Mexican, etc.)	
	restaurant names	Figure 67
	price range of food at restaurants	
	review ratings of restaurants	
	lodging ahead	
	closest lodging with vacancy	
	guest amenities:	
	elevator	
	kennel	
	laundry	
	locker	
	parking	
	shower	
	restrooms	
	barber shop	
	hair salon	
	gas station ahead	
	cost of gasoline	
	hours of operation of gas station	

Function	Message	Candidate Symbols
	amenities of gas station:	
	restrooms	
	phone	
	food	
	restroom ahead	
	telephone ahead	
	rest area ahead	
	landmark information	Figure 68
	sports venue	
	nature attraction	
	arts and culture venue	
	RV park	
	airport	
	shopping center	
	night life attraction	
	hospital	
	ice cream shop	
	coffee shop	
	pharmacy	
	courthouse	
	music venue	
	movie theater	
	car mechanic	
	football stadium	
	post office	
	library	

Function	Message	Candidate Symbols
	school	
	convenience store	
	aquarium	
	zoo	
	bank	
	theater (drama)	
	car rental agency	
	college	
	golf course	
	personal landmark	
	ATM	
	casino	
	city hall/government building	
	commuter rail station	
	train station	
	bus station	
	convention center/exhibition hall	
	ferry terminal	
	grocery store	
	park and ride	
	parking lot	
	information	
	amusement park	
	wildlife preserve	
	camping	

Function	Message	Candidate Symbols
	picnic area	
	hiking	
	general winter recreation	
	general water recreation	
	amphitheater	
	climbing	
	rock climbing	
	hunting	
	playground	
	rock collecting	
	spelunking	
	stable	
	bicycle trail	
	horse trail	
	interpretive automobile trail	
	interpretive trail	
	off-road vehicle trail	
	trail bike trail	
	tramway	
	all-terrain vehicle trail	
	boat tours	
	canoeing	
	diving	
	scuba diving	
	fishing	

Function	**Message**	**Candidate Symbols**
	marina	
	motor boating	
	boat launching	
	rowboating	
	sailboating	
	waterskiing	
	surfing	
	swimming	
	wading	
	ice skating	
	ski jumping	
	ski bobbing	
	cross-country skiing	
	downhill skiing	
	sledding	
	snowmobiling	
	snowshoeing	
Services/attractions directory	directory (index of yellow pages)	
	view currently selected preferences	
Destination coordination	location of and distance to restaurant	
	location of and distance to lodging	
	location of and distance to gas station	Figure 66

Function	**Message**	**Candidate Symbols**
	distance to and direction of nearest rest area	
	confirmation of reservation	
	reservation details	
	locate nearest parking	
	type of parking facility	
	diagram of parking facilities	Figure 69
	real-time availability of parking	
Message transfer	incoming message	
	message sent/send message	
	alert driver message was not sent and why not	
	write message	
	delete message	
	message acknowledged/received	
	access message	
	save message	
	review received message	
	reply to a message	
	access the Internet	

AUGMENTED SIGNAGE INFORMATION		
Function	**Message**	**Candidate Symbols**
Roadway guidance sign information	interchange ahead	Figure 70
	route markers	Figure 70
	mile posts	Figure 70
Roadway notification sign information	steep downgrade	Figure 71
	percent of grade	
	recommended speed as a function of grade	
	braking requirements for specific grades	
	tight ramp or intersection	
	railroad crossing	
	merge	Figure 72
	chevrons	Figure 72
	curve signs	Figure 72
	sharp curve ahead	
	curve speed for specific vehicle sizes	
	pedestrian crossing ahead	
Roadway regulatory sign information	speed limit	Figure 73
	speed limit in construction zones	
	vehicle is x mi/h over speed limit	
	stop	Figure 73

Function	Message	Candidate Symbols
	yield	Figure 73
	do not enter	
	no right or left turn	Figure 73
	left turn only/right turn only	Figure 73
	4-way stop	

SAFETY/WARNING INFORMATION		
Function	**Message**	**Candidate Symbols**
Immediate hazard warning	emergency vehicle stopped ahead	Figure 74
	distance of approaching emergency vehicle	Figure 75
	relative locations of emergency vehicles to you on a map	Figure 76
	school bus stopped ahead	
Road condition information	road work/construction ahead	
	uneven road ahead	
	fallen rock ahead	
	frost damage ahead	
	icy roads ahead	
	low shoulder	
	general weather forecast for a specific area	
	snow ahead	Figure 77

Function	Message	Candidate Symbols
	partly sunny weather conditions	
	partly cloudy weather conditions	
	sunny conditions	
	rain ahead	
	squalls	
	fog	
	traffic/congestion ahead	Figure 78
	general real-time traffic information	
	how far/how long traffic is backed up	
	map showing areas of mild, moderate and severe congestion	Figures 53, 79
	accident ahead	Figures 80, 81
	chemical spill ahead	
	lanes blocked ahead	Figure 82
	lanes closed ahead	
Automatic/manual aid request	inform driver that aid had been requested	
	inform driver of time until emergency unit will arrive	
	display messages from the emergency response center	
	update real-time information from the emergency center	

Function	Message	Candidate Symbols
Vehicle condition monitoring	inform driver of current problem	
	inform driver of ways to correct problem	
	provide more detailed information at the driver's request	
	inform the driver of needed warranty services due	
	low tire pressure	
	low oil pressure	
	safety event recorder information	

COMMERCIAL VEHICLE OPERATIONS (CVO) INFORMATION		
Function	**Message**	**Candidate Symbols**
Trip planning	approved fueling locations	
	truck stops	
	dealers	
	fuel costs	
	approved parking locations for types	
	weight limits	
	overhead restrictions	
	weigh stations (locations and whether or not they are open)	
	fuel taxes	

Function	**Message**	**Candidate Symbols**
	typical congestion of route	
	miles until truck is out of fuel	
Delivery-related information	delivery location	
	scheduled pickup and delivery times	
	times of day or week that may affect delivery	
	equipment types not allowed on roadway	
	optimize delivery schedules	
	customer's preferences	
	information from dispatcher regarding schedule changes and other pickup/delivery information	
Presentation of service directory information	index of yellow pages and information from Trucker's Atlas	
CVO-specific aid request information	notify emergency services of hazardous material	
	inform emergency services of cargo type	
Cargo and vehicle monitoring information	problem in the trailer unit	Figure 83
	problem in the tractor unit	Figure 83

Function	Message	Candidate Symbols
	precise information regarding vehicle performance	
Augmented signage information	truck route	Figure 84
	truck speed limit	
	routing restrictions for specific vehicle cargoes	Figure 85
	weight limits	Figure 85
	no hazardous materials allowed	Figure 85
	low clearance	Figure 71
	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	
	electronic permit application	
	pre-clearance	
Function	**Message**	**Candidate Symbols**

	credential checking	
	driver-incentive and performance	
Post-trip summary	elapsed time	
	miles traveled	
	fuel used	
	tools paid for driver logs	
	percent of time at idle	

GPS-RELATED INFORMATION		
Function	**Message**	**Candidate Symbols**
	position of satellites in space; representation of which satellites are currently transmitting information	
	satellite signal strength	
	current GPS position (latitude, longitude, altitude)	
	magnify/minimize map view	
	shift to another region of the map	
	shift to another region of the world	
	look for a specific street address	

COLLISION AVOIDANCE INFORMATION (Material from experimental studies)		
Function	**Message**	**Candidate symbols**
Rear-end collision avoidance	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Road-departure collision avoidance	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Lane change/merge collision avoidance	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	Table 7

Function	Message	Candidate Symbols
Intersection collision avoidance	system on and functioning	
	system failure	
	no danger indicator	Figure 86
	advisory indicator (also nature, severity, corrective action required)	Figure 87
	warning indicator (also nature, severity, corrective action required)	Figure 88
Railroad crossing collision avoidance	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Driver monitoring devices	system on and functioning	
	system failure	
	no danger indicator	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Backing devices	system on and functioning	
	system failure	
	no danger indicator	

Function	**Message**	**Candidate Symbols**
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	
Automatic cruise control devices	system on and functioning	
	system failure	
	headway selection	
	mode selection	
	advisory indicator (also nature, severity, corrective action required)	
	warning indicator (also nature, severity, corrective action required)	

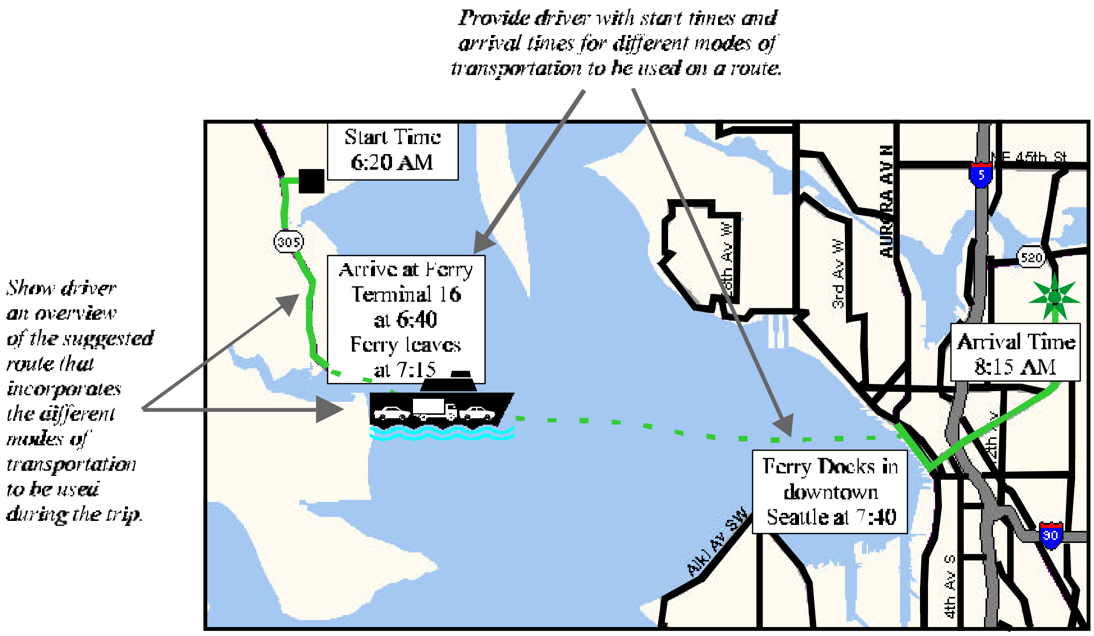


Figure 51. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 1).

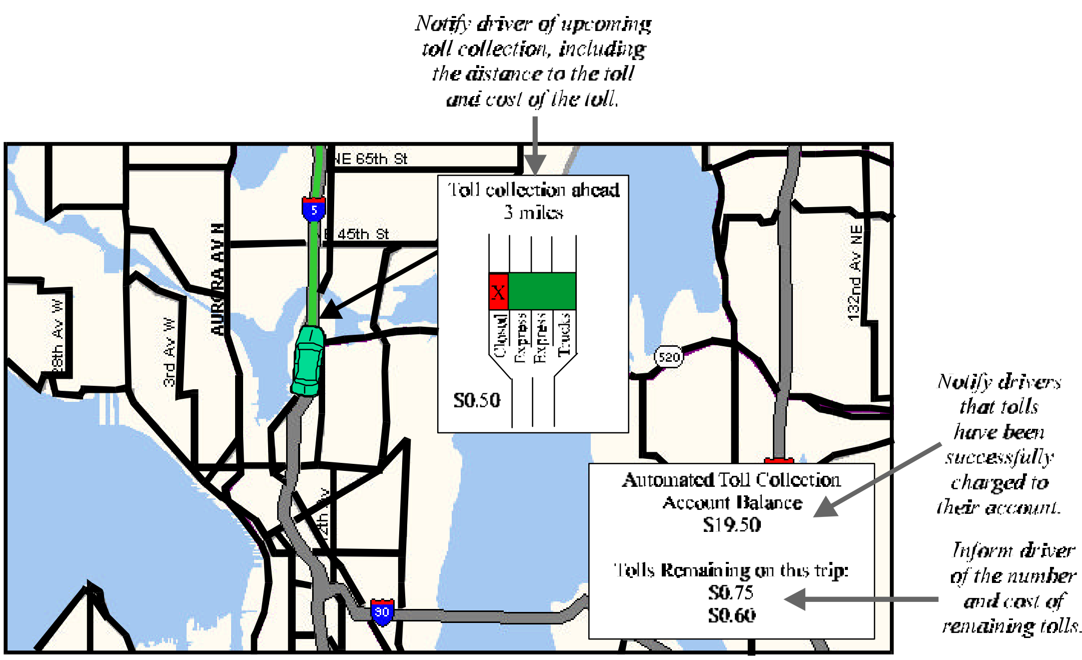


Figure 52. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 2).

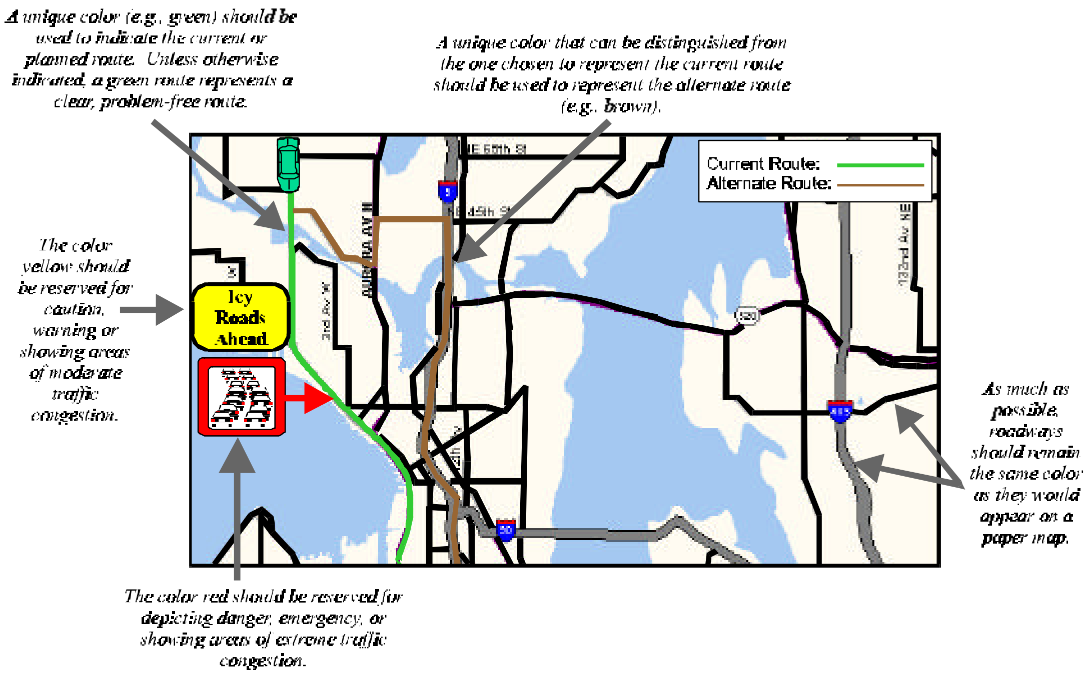


Figure 53. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 3).

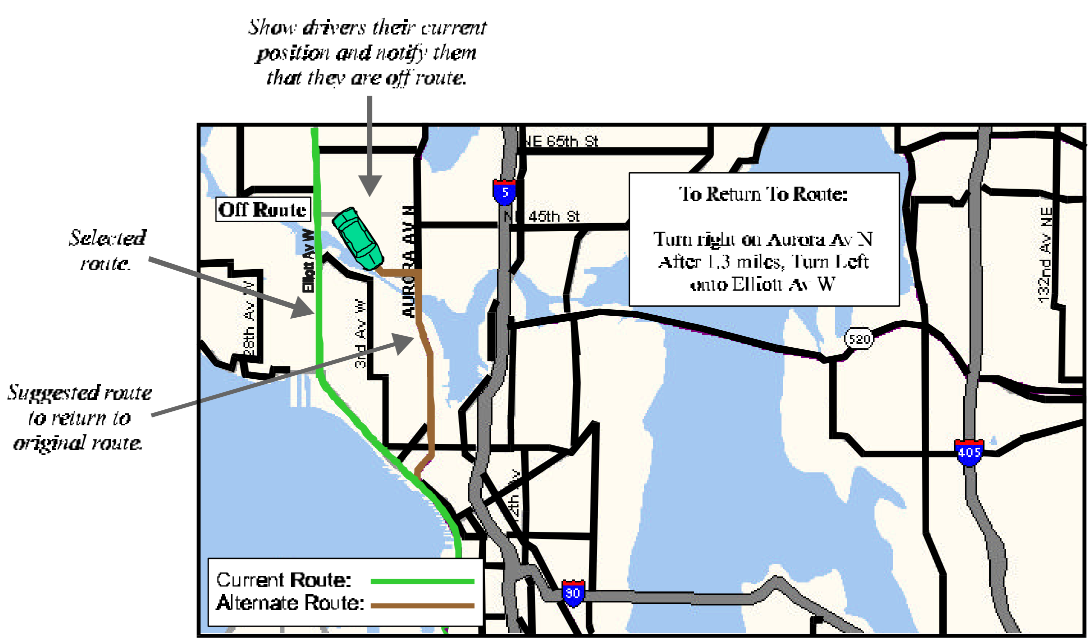


Figure 54. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 4).

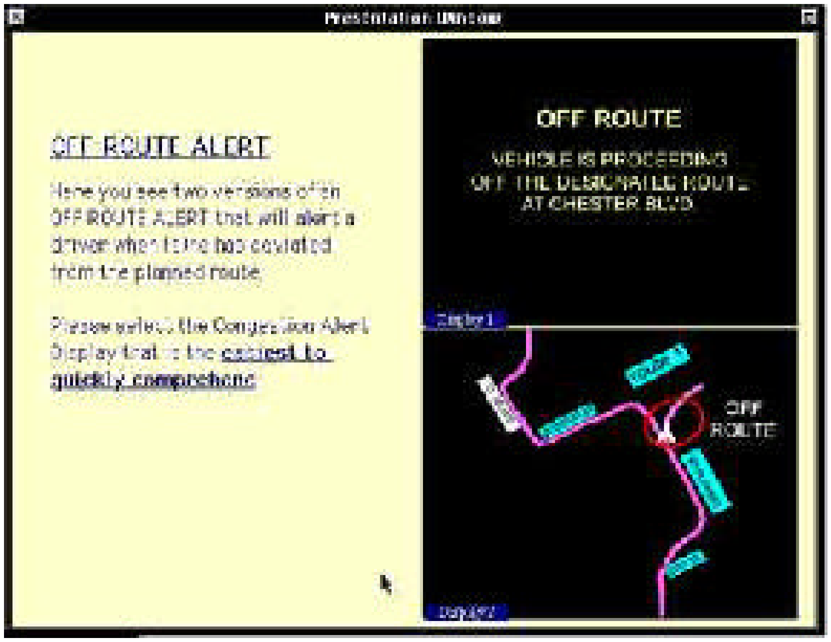


Figure 55. ATIS-Routing and Navigation (from Neale et al., 1997-graphic 1).

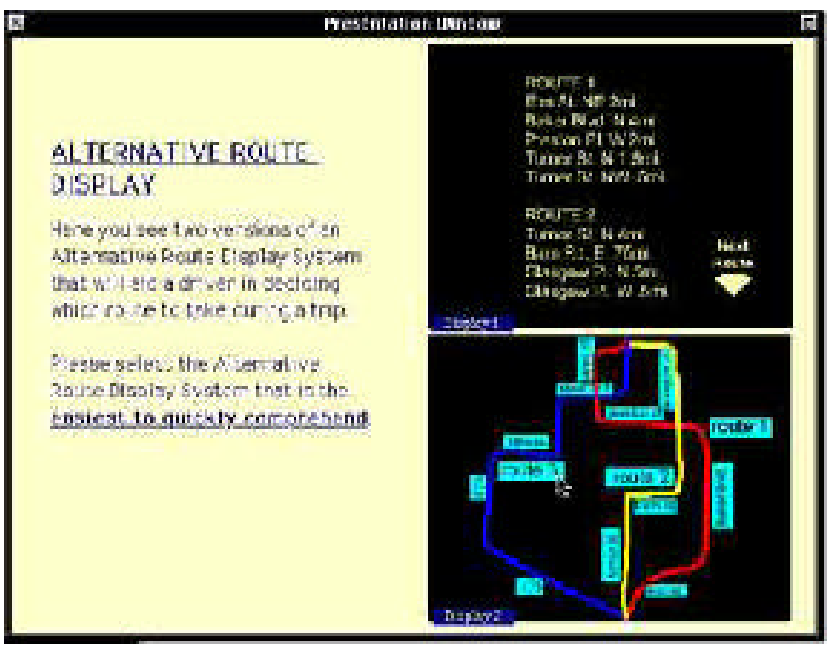


Figure 56. ATIS-Routing and Navigation (from Neale et al., 1997-graphic 2).

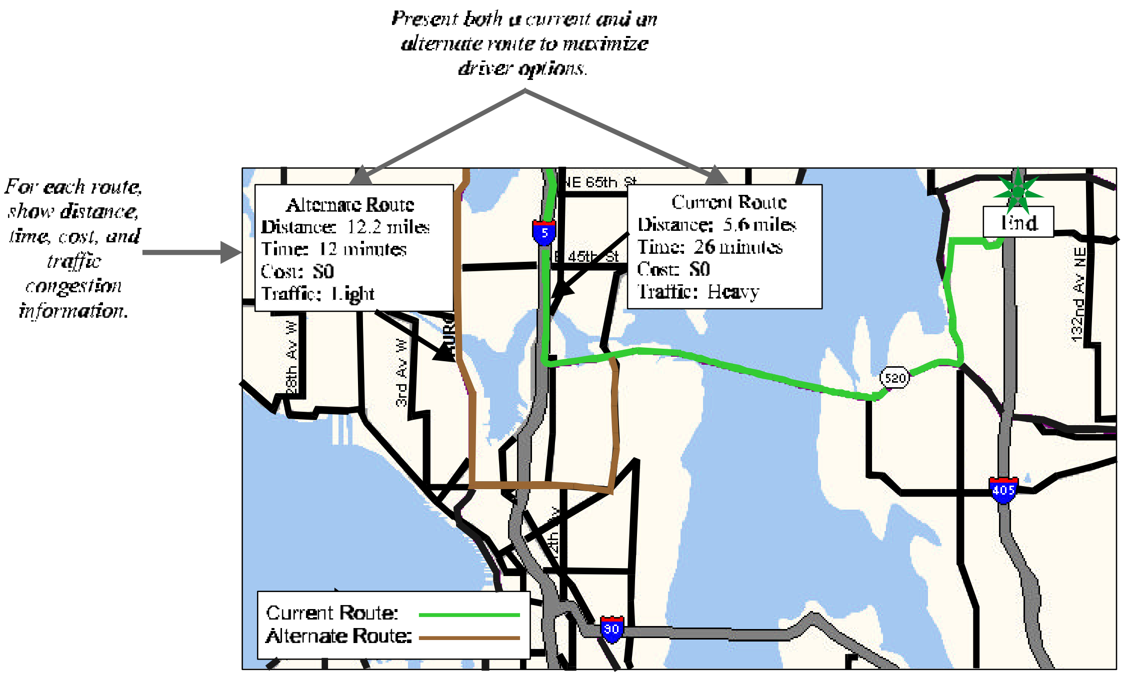


Figure 57. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 5).

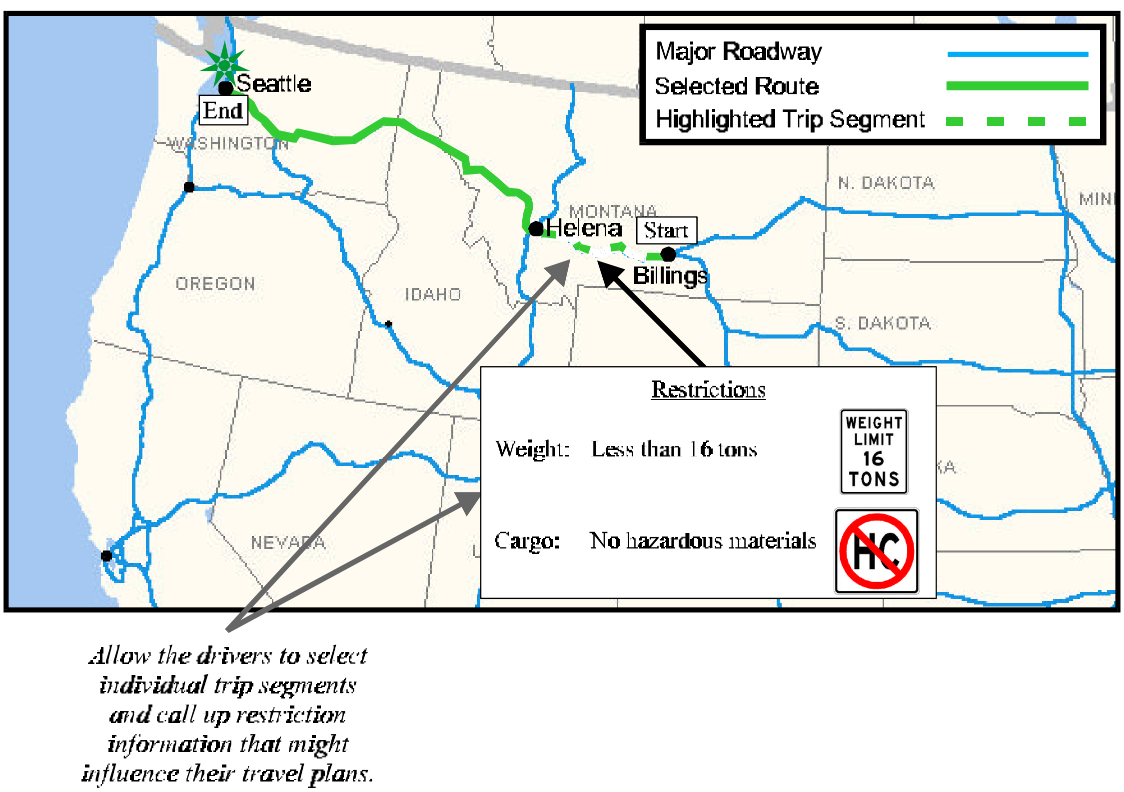


Figure 58. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 6).

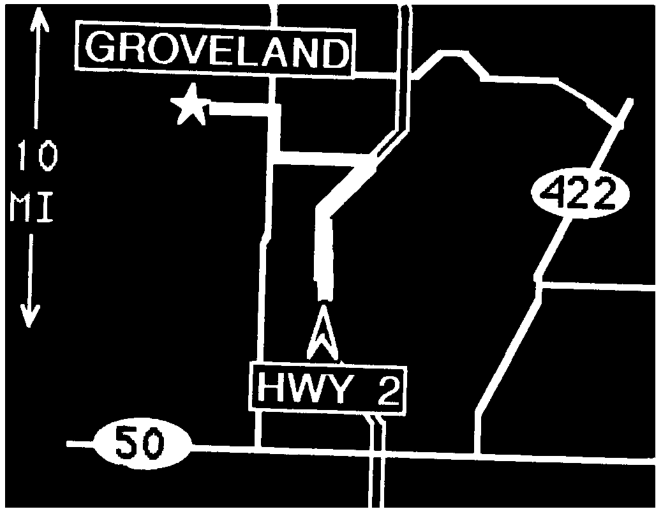


Figure 59. ATIS-Routing and Navigation (from Neale et al., 1997-graphic 3).

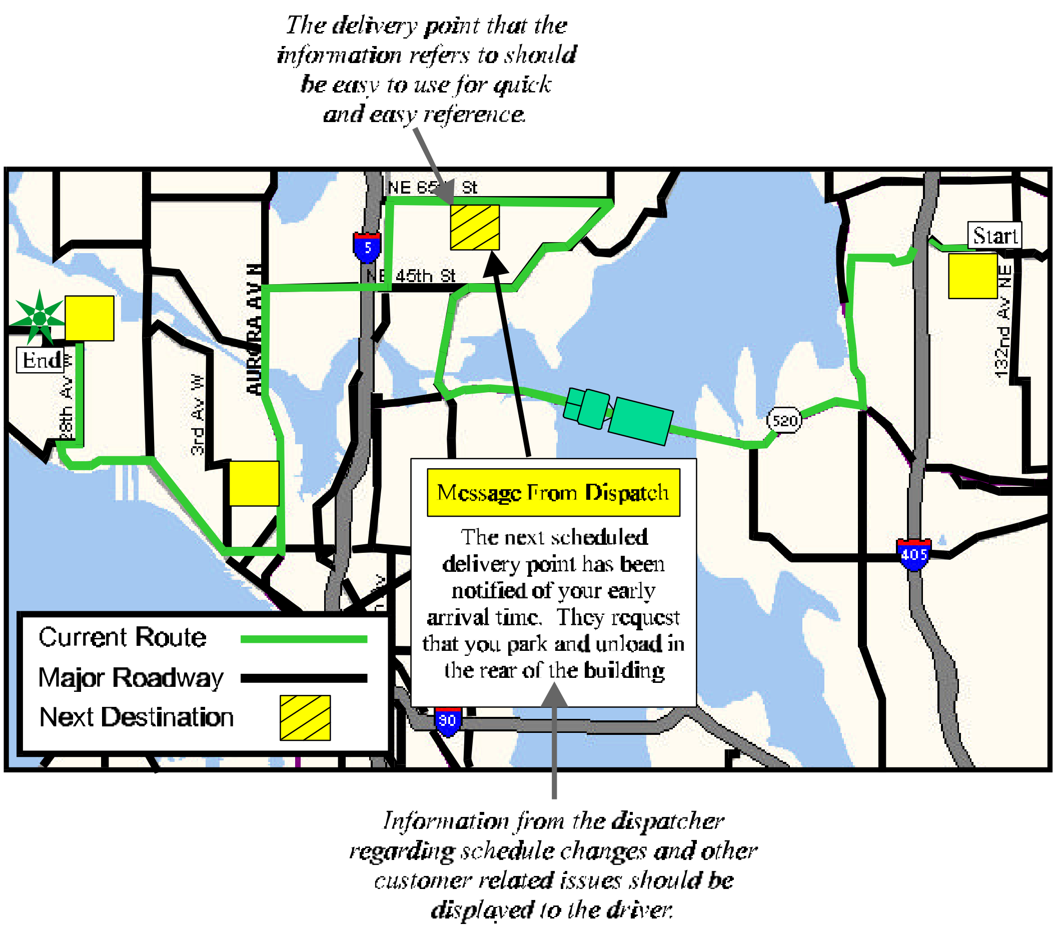


Figure 60. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 7).

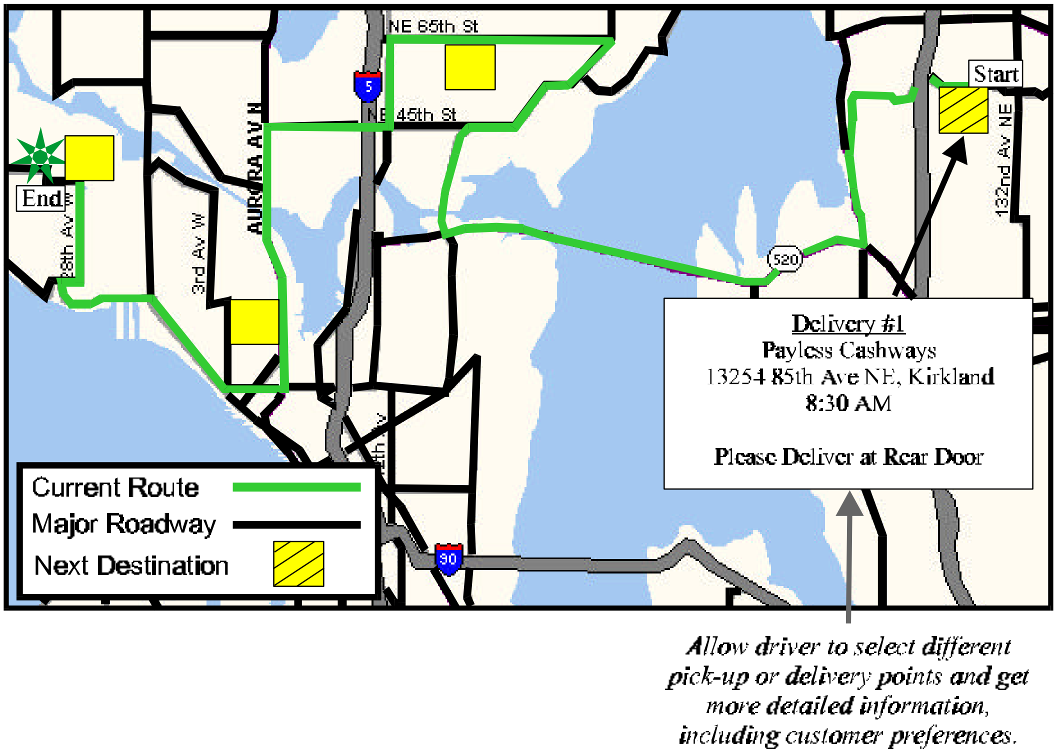


Figure 61. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 8).

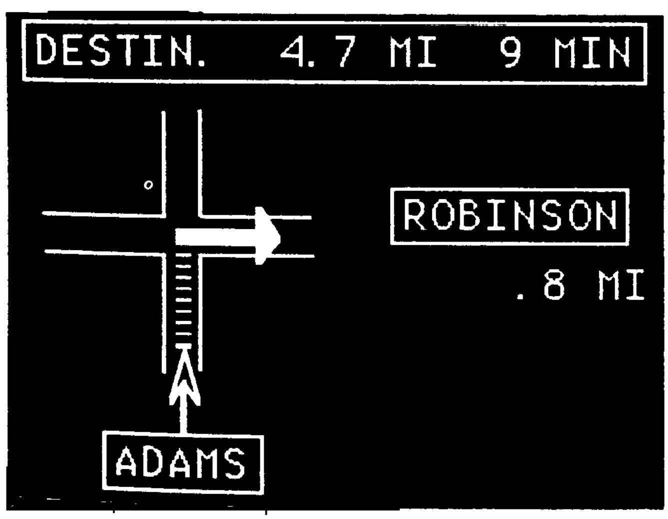


Figure 62. ATIS-Routing and Navigation (from Neale et al., 1997-graphic 4)

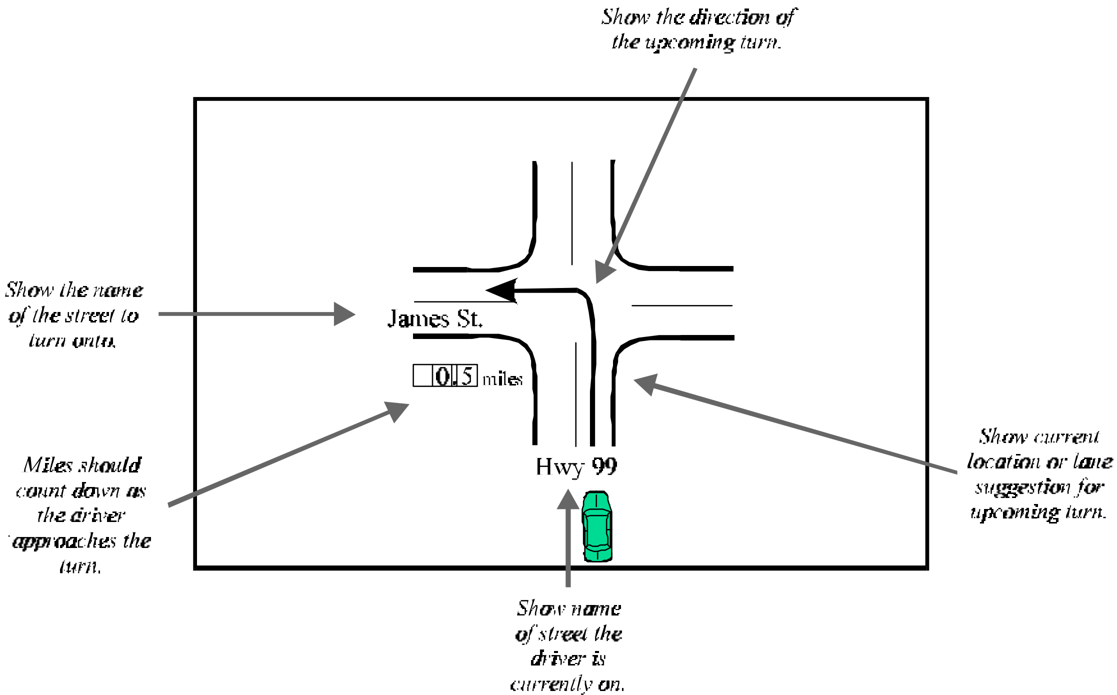


Figure 63. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 9)

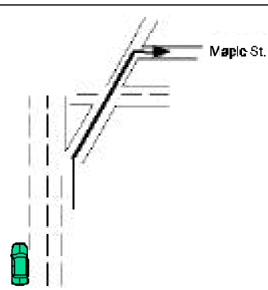
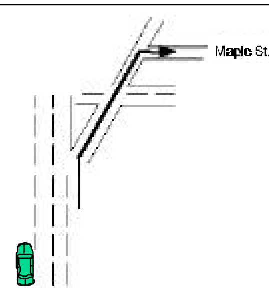
	 	Exit right lane 2 miles. Continue straight through first intersection. Turn right on Maple St.	 Exit right lane 2 miles. Continue straight through first intersection. Turn right on Maple St.
What is your preference for this display?	mean ranking = 2.43	mean ranking = 2.46	mean ranking = 1.10

Figure 64. ATIS-Routing and Navigation (from Neale et al., 1997-graphic 5).

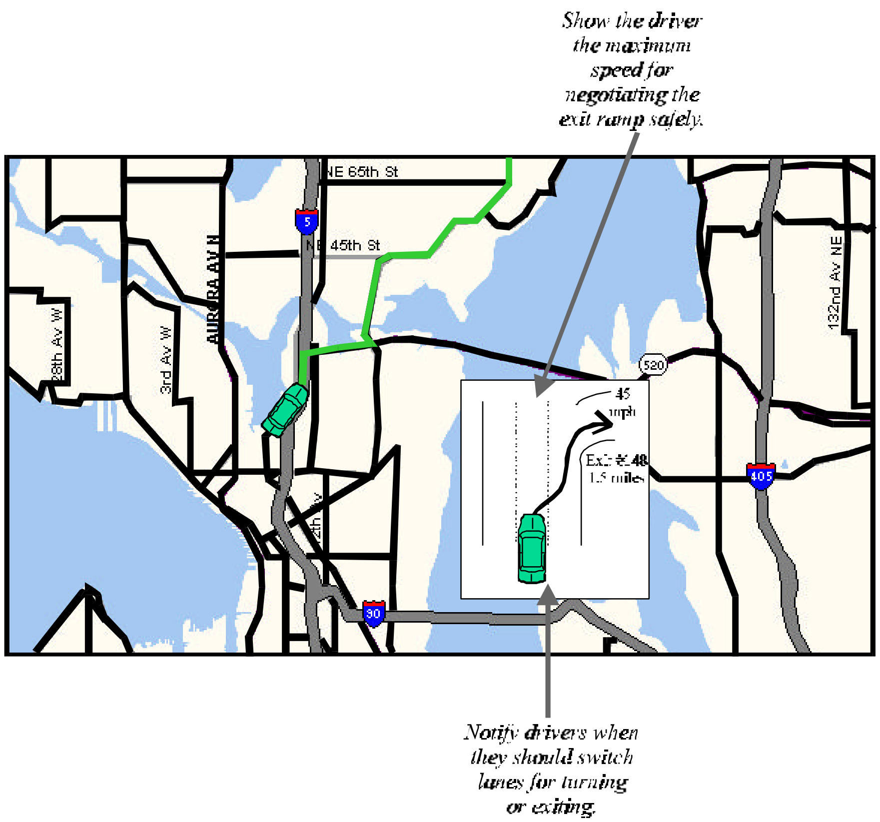


Figure 65. ATIS-Routing and Navigation (from Campbell et al., 1998-graphic 10).

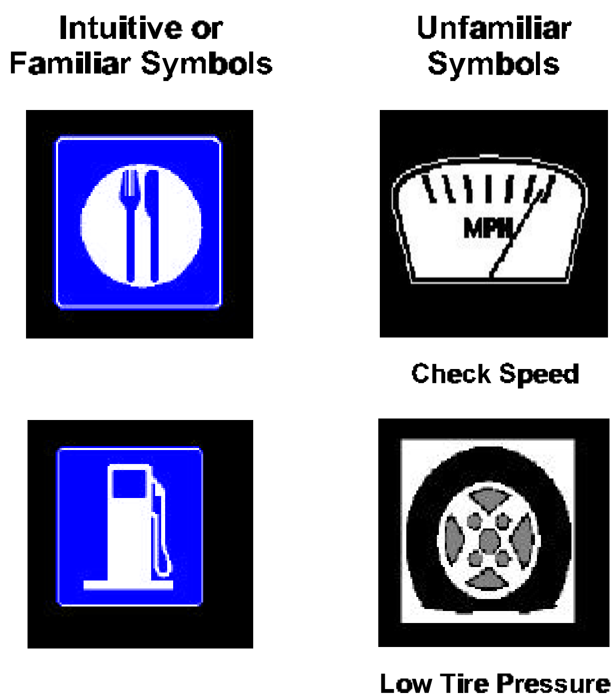


Figure 66. ATIS-Motorist Services (from Campbell et al., 1998-graphic 11).

Figure 67. ATIS-Motorist Services (from Neale et al., 1997-graphic 6).

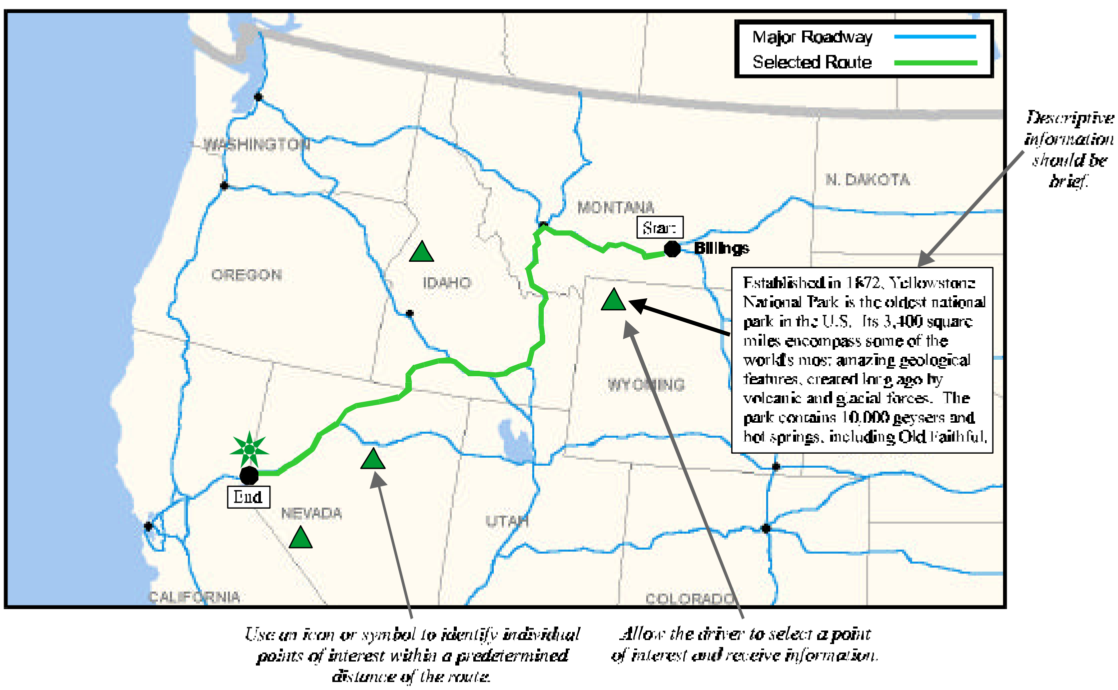
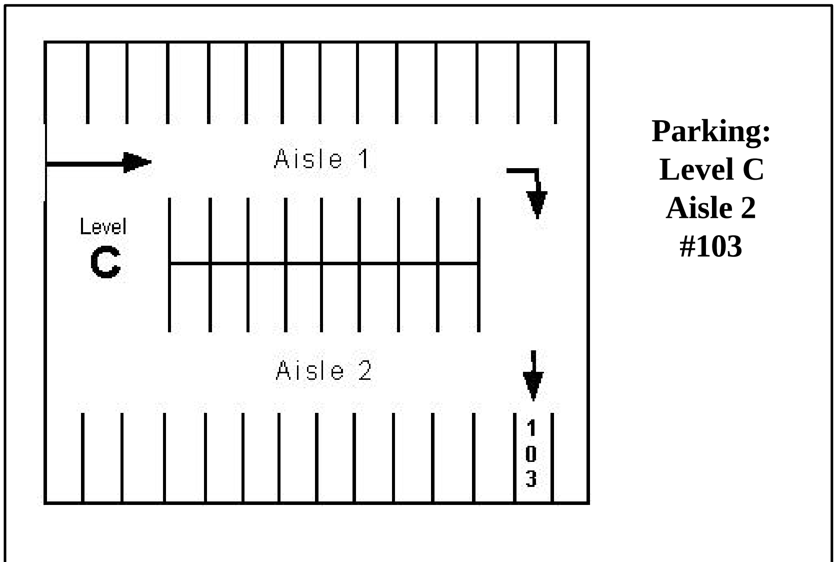


Figure 68. ATIS-Motorist Services (from Campbell et al., 1998-graphic 12).



What is your preference for each display?	

Figure 69. ATIS-Motorist Services (from Neale et al., 1997-graphic 7).

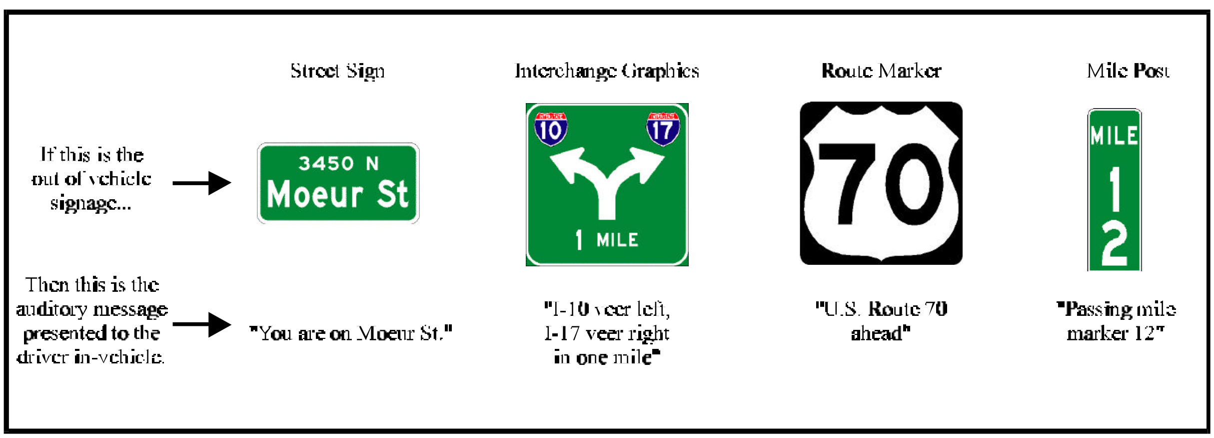


Figure 70. ATIS-Augmented Signage (from Campbell et al., 1998-graphic 13).

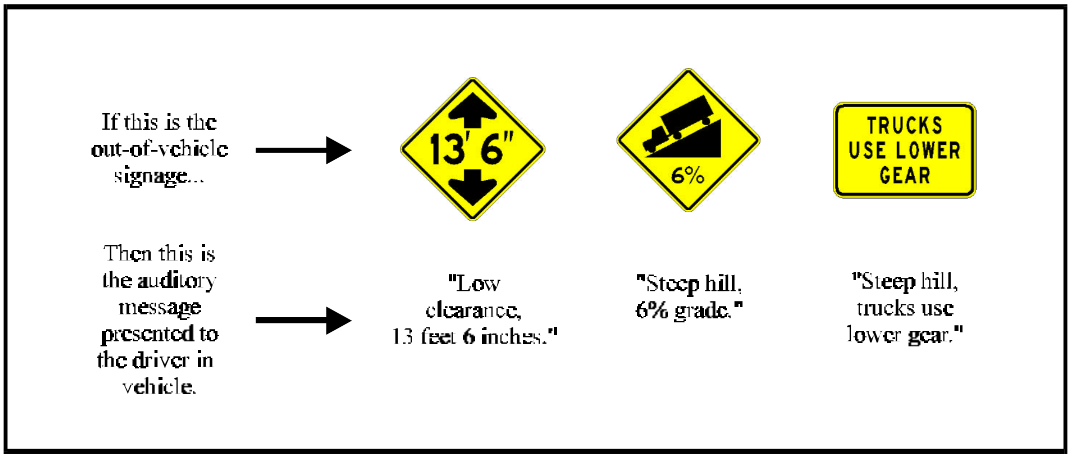


Figure 71. ATIS-Augmented Signage (from Campbell et al., 1998-graphic 14).

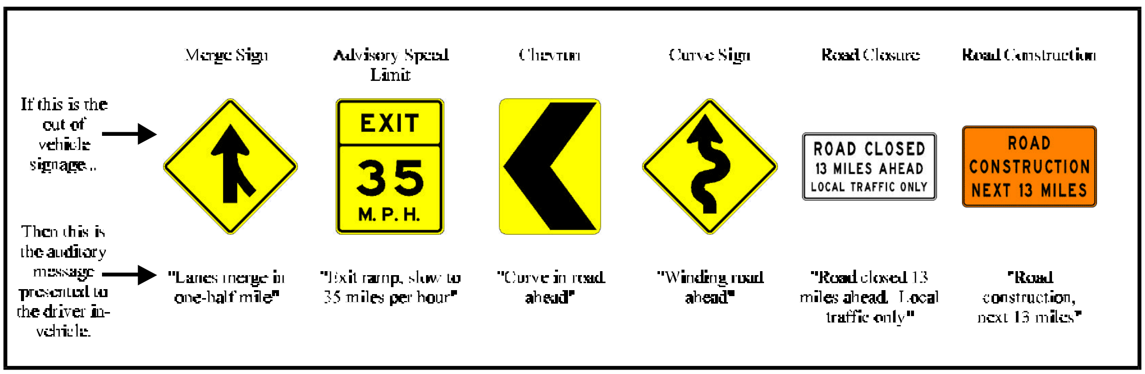


Figure 72. ATIS-Augmented Signage (from Campbell et al., 1998-graphic 15).

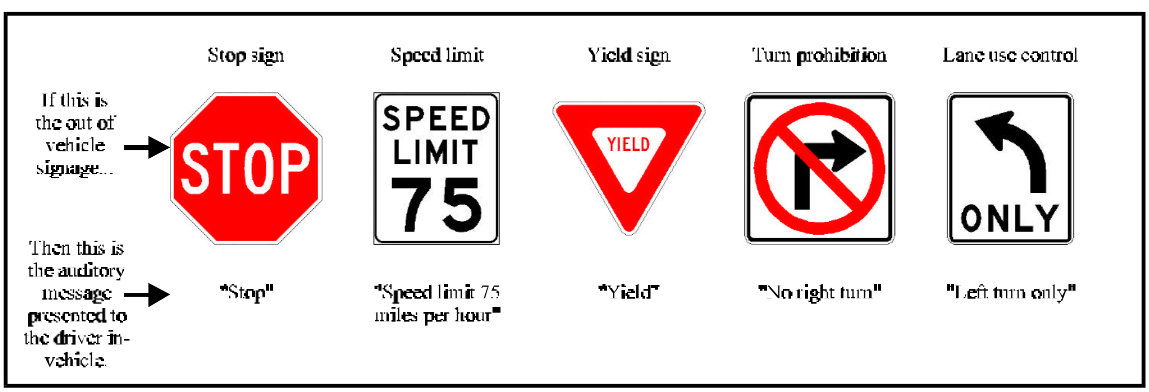


Figure 73. ATIS-Augmented Signage (from Campbell et al., 1998-graphic 16).

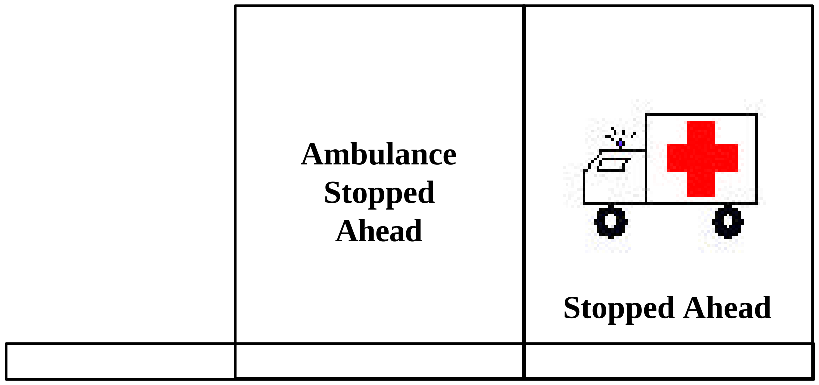


Figure 74. ATIS-Safety/Warning (from Neale et al., 1997-graphic 8).

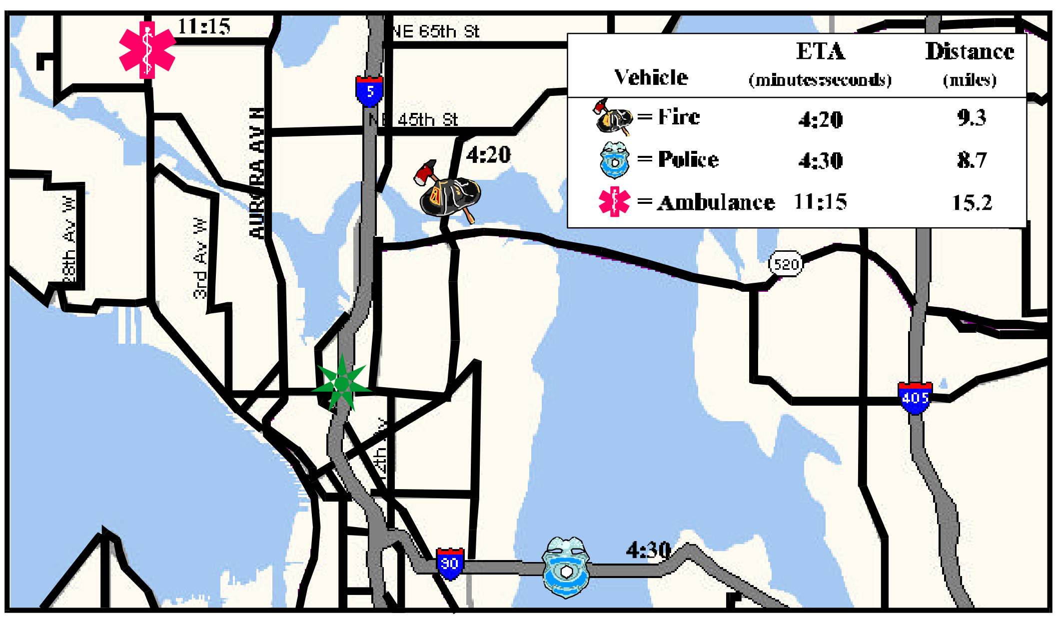


Figure 75. ATIS-Safety/Warning (from Campbell et al., 1998-graphic 17).

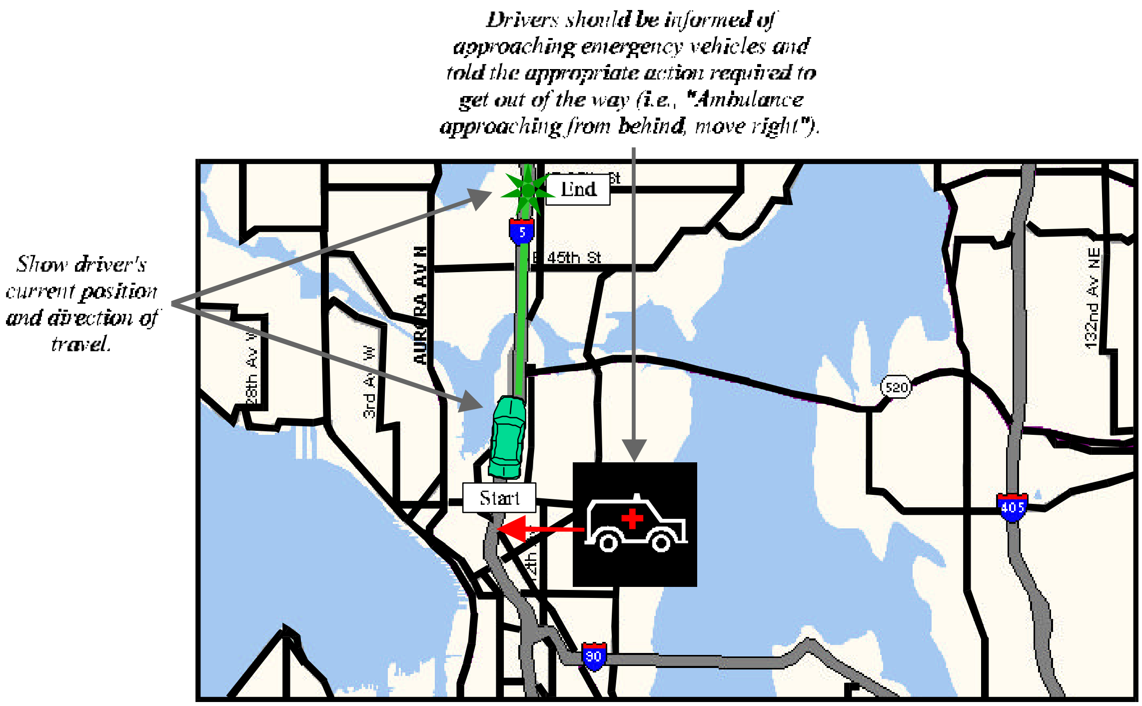


Figure 76. ATIS-Safety/Warning (from Campbell et al., 1998-graphic 18).

Figure 77. ATIS-Safety/Warning (from Neale et al., 1997-graphic 9).

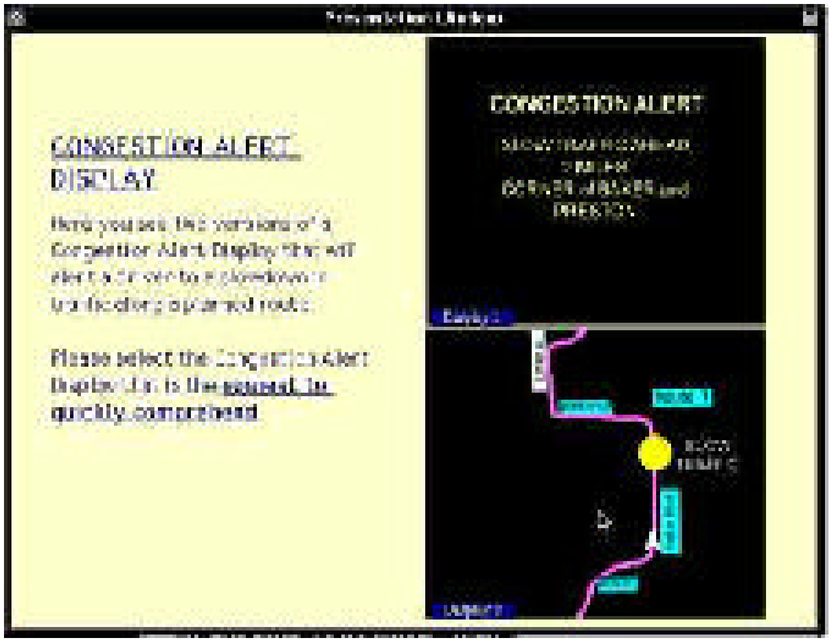


Figure 78. ATIS-Safety/Warning (from Neale et al., 1997-graphic 10).

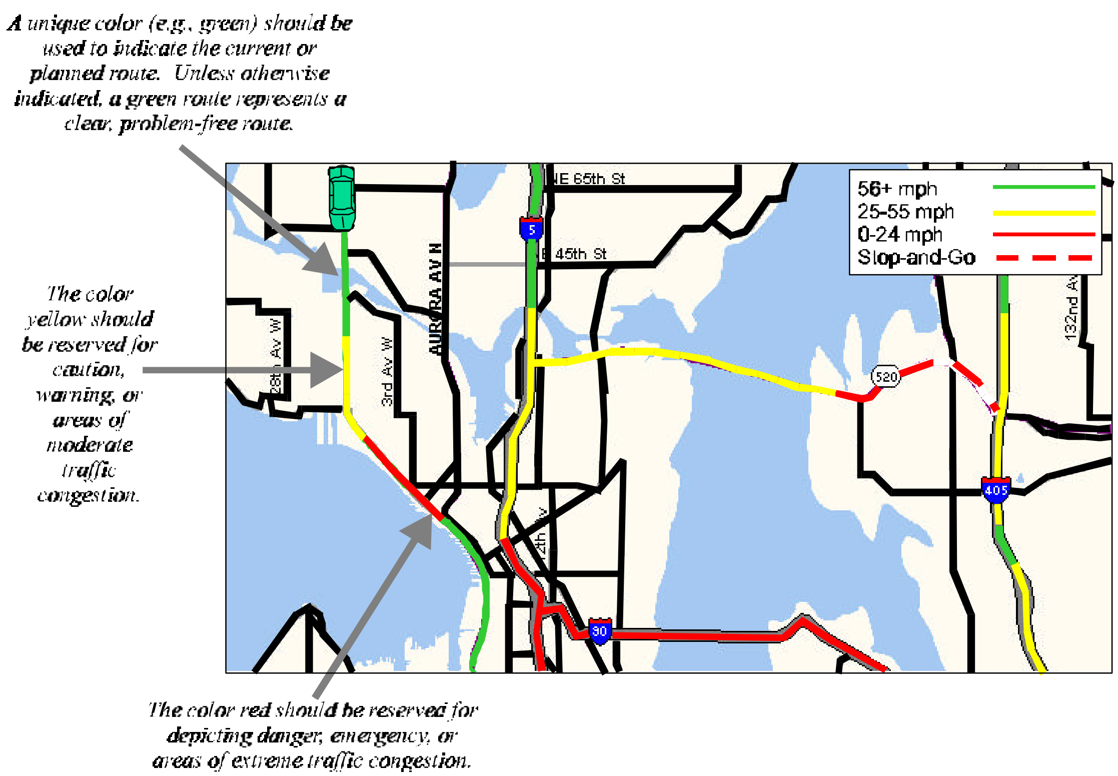


Figure 79. ATIS-Safety/Warning (from Campbell et al., 1998-graphic 19).

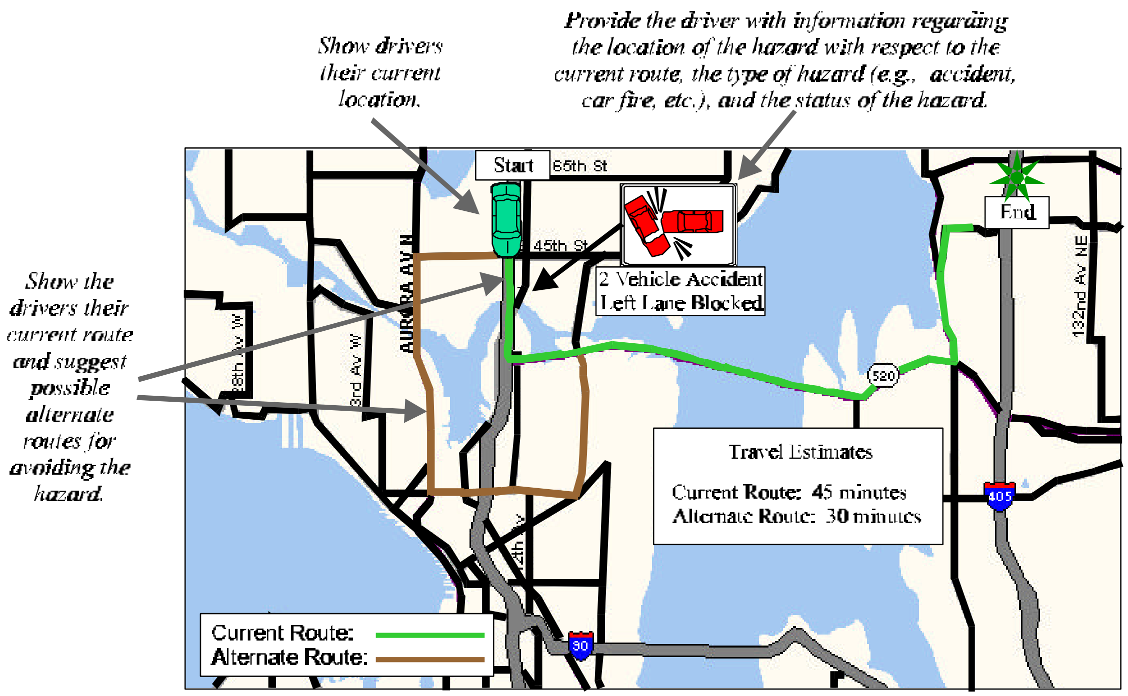


Figure 80. ATIS-Safety/Warning (from Campbell et al., 1998-graphic 20).

Figure 81. ATIS-Safety/Warning (from Neale et al., 1997-graphic 11).

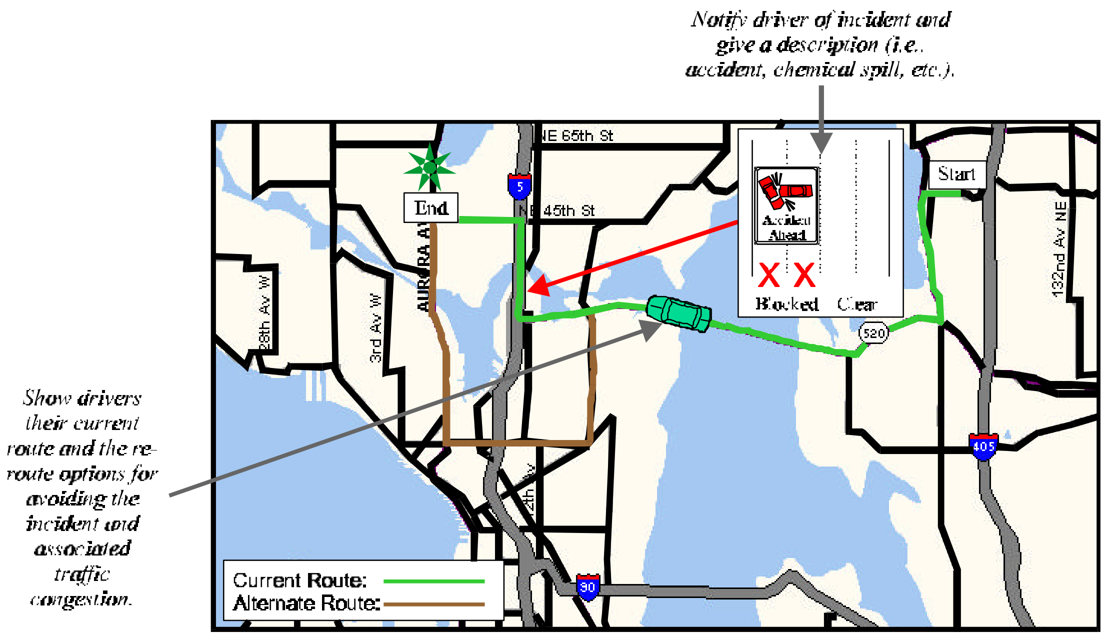


Figure 82. ATIS-Safety/Warning (from Campbell et al., 1998-graphic 21).

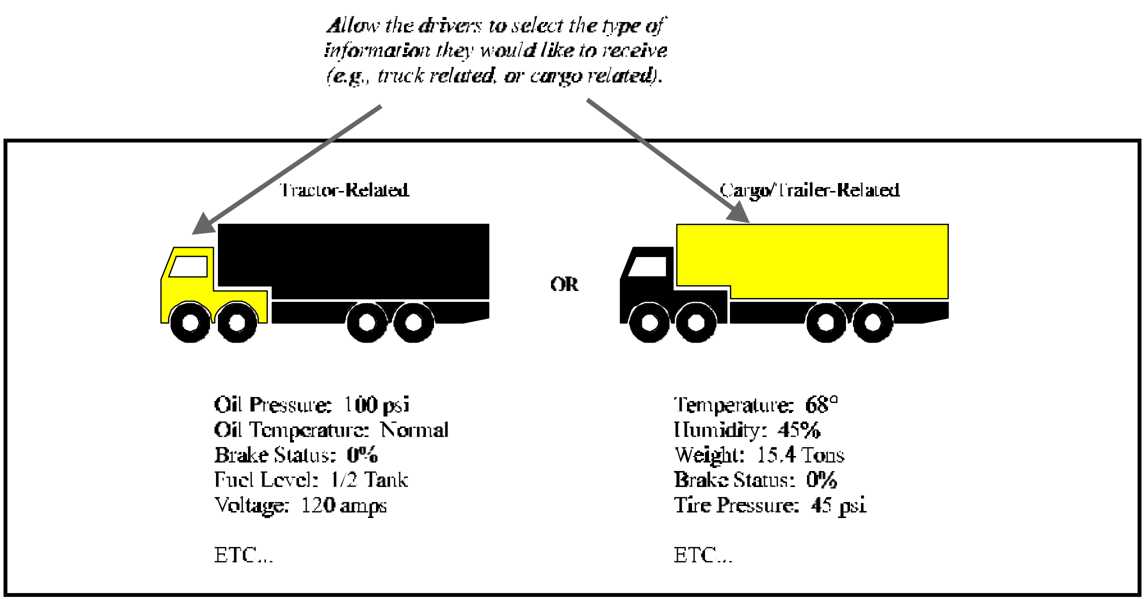


Figure 83. ATIS-CVO (from Campbell et al., 1998-graphic 22).

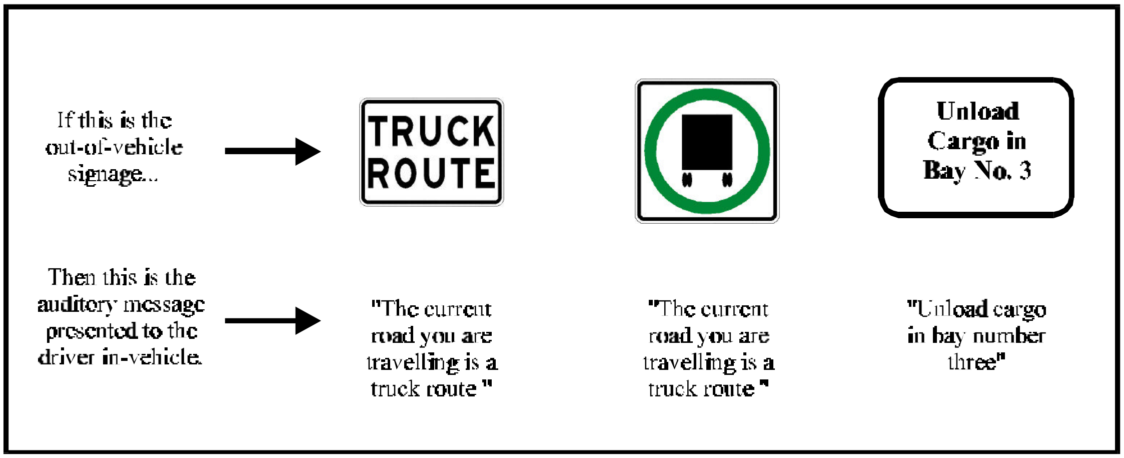


Figure 84. ATIS-CVO (from Campbell et al., 1998-graphic 23).

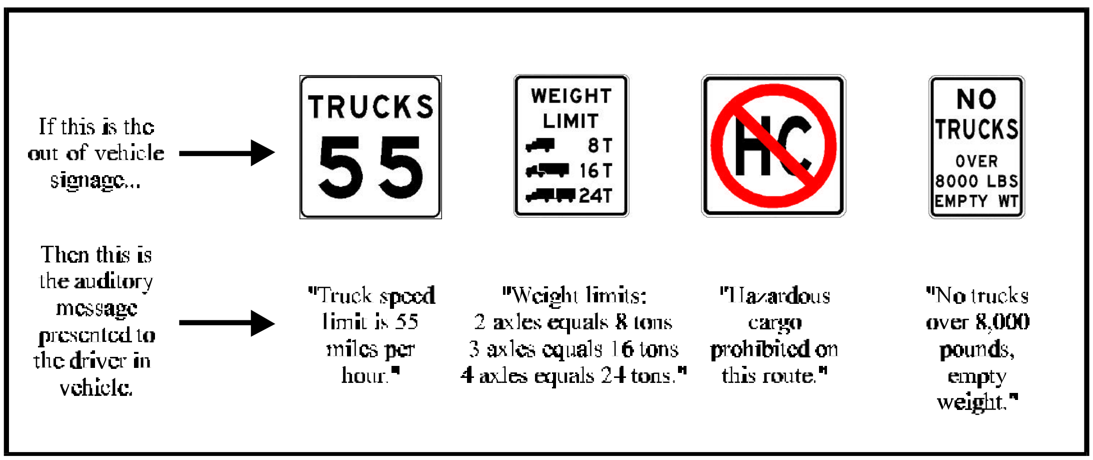


Figure 85. ATIS-CVO (from Campbell et al., 1998-graphic 24).

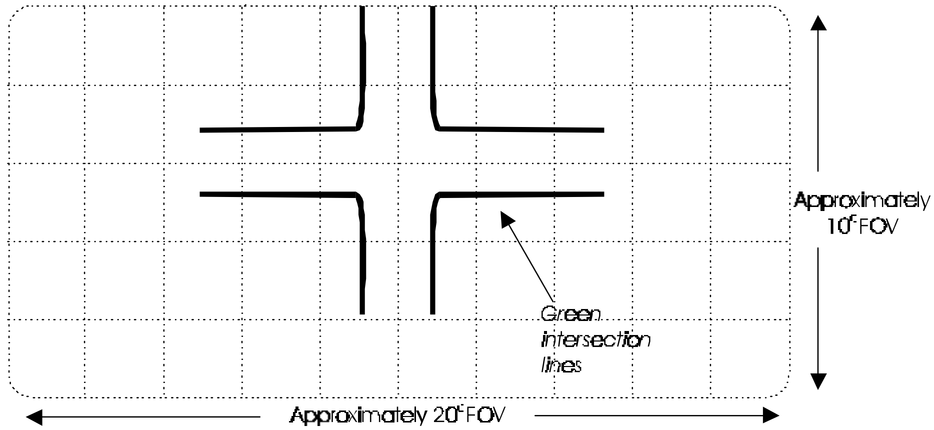


Figure 86. Collision Avoidance (from Campbell et al., 1997-graphic 1).

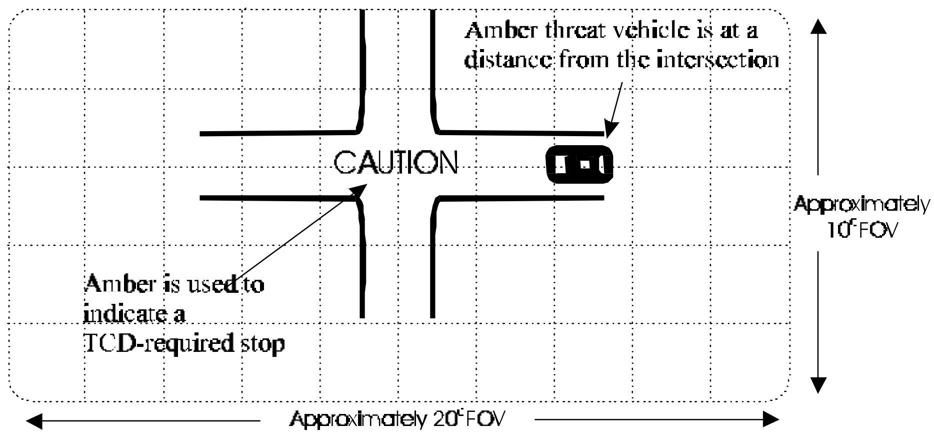


Figure 87. Collision Avoidance (from Campbell et al., 1997-graphic 2).

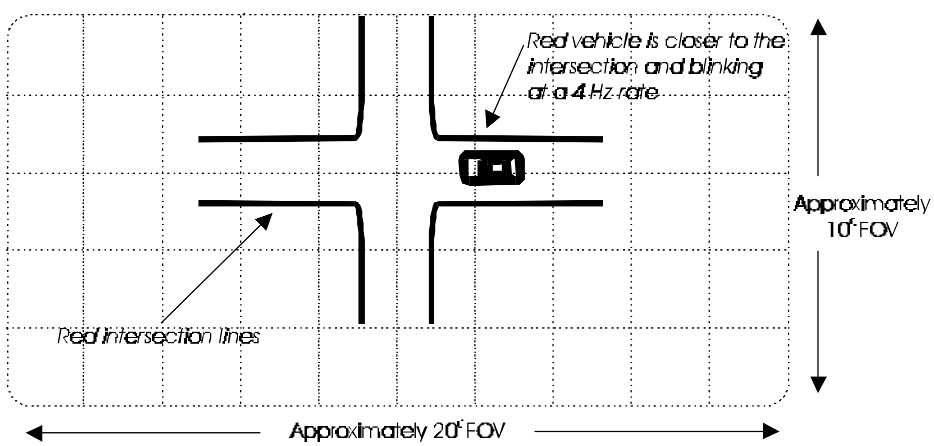


Figure 88. Collision Avoidance (from Campbell et al., 1997-graphic 3).

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