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Development of Design and Engineering Recommendations
for In-Vehicle Alphanumeric Messages

RATIONALE

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1. SCOPE

This Information Report provides recommendations for alphanumeric messages that are supplied to the vehicle by external (e.g., RDS, satellite radio) or internal (e.g., infotainment system) sources *while the vehicle is in-motion*. Information/design recommendations contained in this report apply to OEM (embedded) and aftermarket systems.

Ergonomic issues with regard to display characteristics (e.g., viewing angle, brightness, contrast, font design, etc.) should review ISO 15008.

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ISO/TS 16951 (2004). Road vehicles - Ergonomic aspects of transport information and control systems (TICS) - Procedures for determining priority of on-board messages presented to drivers (15 March, 2004).

ISO/FDS 15006 (2011). Road vehicles - Ergonomic aspects of transport information and control systems - Specifications for in-vehicle auditory presentation

3. IN-VEHICLE INFORMATION SYSTEM (IVIS) INFORMATION SOURCES

A wide range of information and the potential for a great volume of messages suggests that it is important to systematically examine and categorize messages a driver may receive. As described in Figure 1, this Information Report identifies six different in-vehicle information system sources. Coordinating information sources so that the driver receives the most important messages in a pronounced, timely, and salient manner is one of the challenges of integrating diverse sources of data (e.g., message priority is relative). Such an approach begins with an analysis of the types of information that are likely to confront drivers. This analysis helps define the technology and products, but not the characteristics that are most relevant to driver interaction with the messages. This requires an analysis of the display relevant message characteristics. These characteristics are separate from the particular product or in-vehicle technology, but define the messages in terms of what they communicate to the driver, such as a high urgency message or long complex message.

Once an alphanumeric message is assigned to an information source category, the designer must identify the communication requirements of in-vehicle information system functions. After the communication functions are identified, these requirements can then define display format and flow parameters. This approach is detailed in the next section.

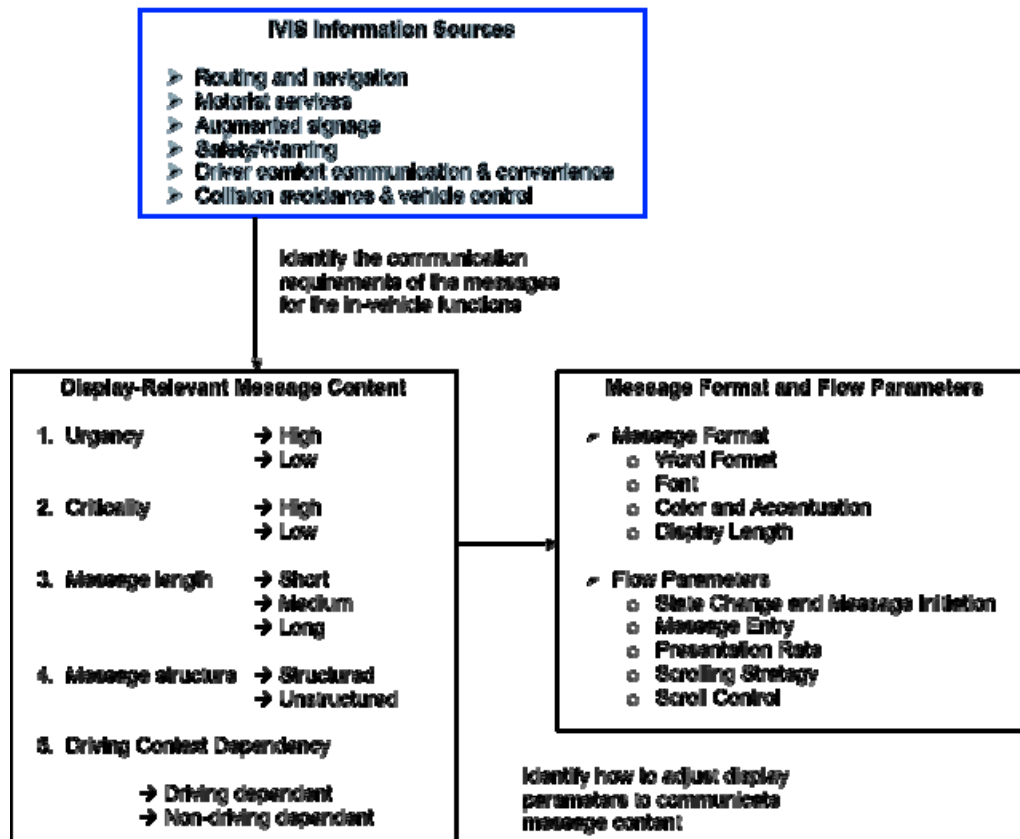


FIGURE 3-1 - FRAMEWORK GUIDING THE DESIGN RECOMMENDATIONS (ADAPTED FROM LEE ET AL., 1999)

3.1 IVIS Information Sources

By understanding the scope of the issues associated with the type of data being displayed, a more efficiently design alphanumeric-based message can be designed. For instance, the content of messages are divided into six different categories:

- Routing and Navigation
- Motorist Services
- Augmented Signage
- Safety/Warning
- Driver Comfort, Communication, and Convenience
- Collision Avoidance and Vehicle Control

Dividing these message types by content, a prioritization method can be developed to reduce driver overload when important messages must be interpreted and acted on. Each of these categories of information can be further decomposed by assessing the urgency, criticality and driving context of the message (see also SAE J2395; ISO CD 16951). Using this method, a comprehensive set of recommendations can be developed that answer immediate design questions. A critical step in the design of in-vehicle alphanumeric messaging display is to identify the type of information to be presented to the driver (Hoffman et al., 2005). Carney et al. (1998) reviewed several reports and extracted an extensive set of driver information requirements. Their list of driver information requirements with regards to IVIS capabilities was further expanded by Lee & Kantowitz (2005) and is described in Table 3-1. This list will change as messaging is a dynamic field.

TABLE 1 - EXAMPLES OF TYPES OF DRIVER INFORMATION REQUIREMENTS FOR KEY IVIS MESSAGE SOURCES

IVIS MESSAGE SOURCES	INFORMATION TYPES/FUNCTIONS
Routing and Navigation	Trip planning Pre-drive route and destination selection Off-route recalculation Route guidance Route navigation Automated toll collection Route scheduling Post-trip summary
Motorist Services	Broadcast services/attractions Services/attractions directory Destination coordination Delivery related information
Augmented Signage	Guidance sign information Notification sign information Regulatory sign information
Safety/Warning	Immediate hazard warning Road condition information Automatic aid request Manual aid request Vehicle condition monitoring Driver monitoring devices Sensory augmentation
Collision Avoidance and Vehicle Control	Forward collision avoidance Road departure collision avoidance Lane change and merge collision avoidance Intersection collision avoidance Railroad crossing collision avoidance Backing aid Advanced cruise control
Driver Comfort, Communication, and Convenience	Real-time communication (e.g., electronic road signs) Asynchronous communications Contact search and history Entertainment and general information Interactive entertainment Heating, ventilation, air conditioning, and noise Automatic system configuration

Identifying these driver information sources does not necessarily dictate how the information should be displayed. However, it does influence how the message will be structured and what its content will be. As a result, the message content will influence how the information should be displayed. For instance, safety and warning information and augmented signage are generally yoked to the context of the drive. These messages will require more urgent attention than the other categories and will consequently consist of short and structured messages. Other information sources such as infotainment may be less context critical and thus have longer and less structured messages.

It should be noted that collision avoidance and vehicle control are not part of the scope of this Information Report that focuses on alphanumeric-based messages. They have been included because there are some elements that could be relevant in terms of sensitivity settings or post warning/event messages. More specifically, elements such as adaptive cruise control and railroad crossing warnings could fit into an alphanumeric warning structure. In general, imminent collision warnings should not be solely visual in nature (SAE J2400).

3.2 Basic Driver Performance Limits

The information sources dictate the content and structure of messages to be displayed which, in turn, determine the most effective display characteristics. The combination of these factors influences the drivers' visual sampling strategy, the primary factor guiding how information is extracted inside and outside of the vehicle. Simply put, the more eyes-off-road time, the less time the driver has to respond to changing roadway conditions. Senders, Kristofferson, Levison, Dietrich, and Ward (1967) were the first to quantify this, and found that on a closed section of new highway, a vehicle could be driven with only intermittent visual sampling. Using a helmet with a visor that periodically occluded the forward view they found:

- A driver can maintain vehicle control with periodic samples of the roadway.
- Between samples, the driver becomes increasingly uncertain about the state of the vehicle relative to the roadway.
- When the uncertainty exceeds a threshold, the driver samples the forward view.
- Drivers' are generally well-calibrated regarding the buildup of uncertainty relative to the vehicle dynamics and roadway characteristics.

To complement this early work, Wierwille (1993) described a conceptual sampling model that begins when the driver initiates an in-vehicle task by glancing to a location of interest—in this case the alphanumeric message display. Information extraction begins and time elapses. If drivers can chunk information at about 1 s or less, they will return their glance to the forward scene. However, if chunking takes longer, drivers will continue to glance at the display. If this occurs, uncertainty will build as the eyes remain off the road and drivers will quickly feel pressured to return their eyes to the forward scene. If the glance to the in-vehicle location exceeds approximately 1.5 s and the information cannot be obtained (or chunked), drivers will return their eyes to the forward scene and try again later. If chunked information can be obtained within approximately 1.5 s, drivers will extract the information and return to the forward scene. Additional samples are handled in the same way, until all required information is obtained (see Figure 3-2).

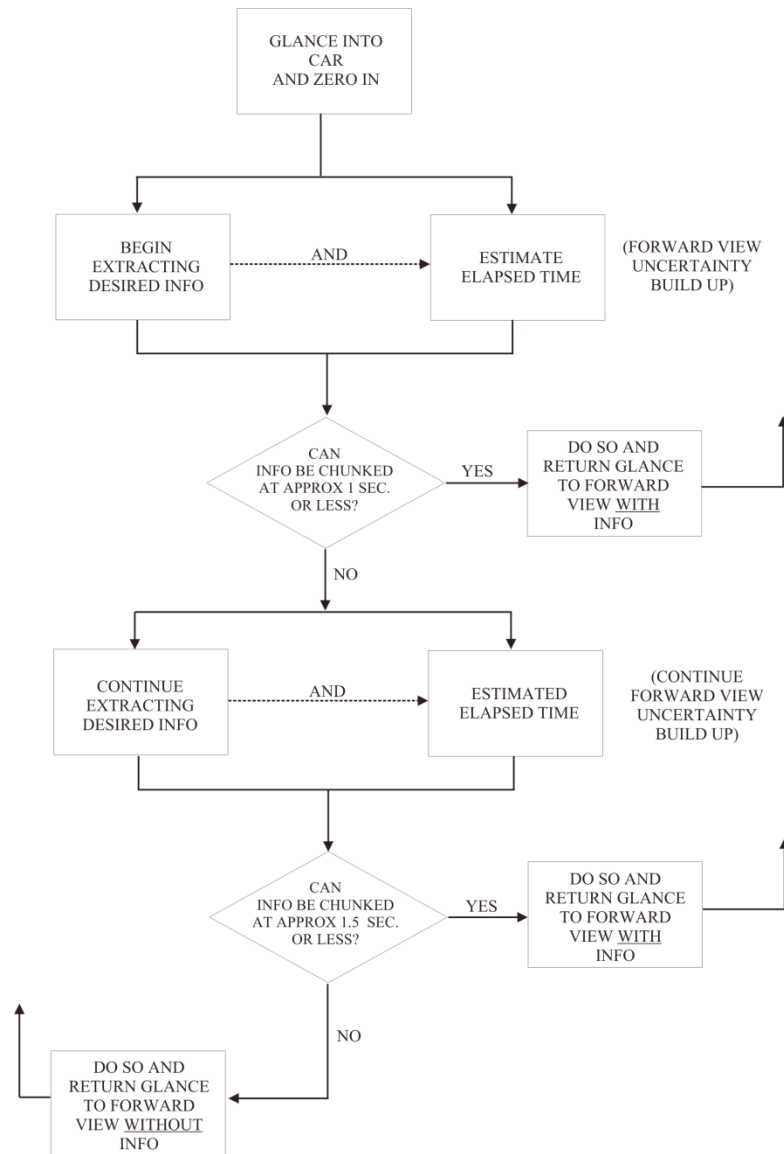


FIGURE 3-2 - WIERWILLE'S (1993) MODEL OF VISUAL SAMPLING FOR IN-VEHICLE TASKS

Additionally, as drivers enter curves and encounter uncertain roadway situations such as traffic, more closely spaced samples become necessary. A byproduct of the early Senders et al. work is Time-to-Line Crossing (TLC), a measure developed by Godthelp, Milgram, and Blaauw (1984). TLC specifically examines uncertainty buildup related to the amount of time it would take for the vehicle to cross the center line or shoulder line assuming the steering wheel is held constant. Godthelp et al. showed that in-vehicle devices must be designed so that the driver can get enough samples per unit time of the forward view to ensure efficient lane position maintenance. In other words, the acceptable length and number of samples to an in-vehicle device is quite limited, but the duration and timing rather than the total number of glances may have a greater impact on driving performance.

Rockwell (1988) examined in-car glance durations and number of glances for radio and mirror tasks on the open road—in traffic. He found that individual glance times into the car clustered around 1.27 to 1.42 s and that for radio tasks such as tuning, four or five glances were required. Rockwell concluded that drivers develop a fairly consistent time-sharing strategy for performing instrument panel tasks while driving, that individual glance length is relatively consistent, and that for complex tasks, more glances are required. Gellatly & Kleiss (2000) also found that drivers completed a range of in-vehicle tasks using a series of 1 to 1.5 s glances to the in-vehicle display/control system and that total task time depended on the number of glances and not the mean duration of glances. Likewise, Bhise, Forbes, and Farber (1986) found that single glance times to the instrument panel vary relatively little with the type of task, but that number of glances varies greatly with the type of task.

3.3 The Life of a Message

To apply these findings and models of visual sampling models to alphanumeric message design, the life of a message has been decomposed. This decomposition reveals that there is more to an alphanumeric message than just reading; drivers must manage the timing and display of the message (see Figure 3-3). Although the number of characters, words, and information units in a message has a strong effect on the drivers sampling behavior, the display characteristics that influence how a driver manages the message display may also influence visual sampling. By using this basic model to check each aspect of the alphanumeric message design, overly demanding designs can be identified and mitigated.

The first phase following a nominal state (e.g., blank screen) is the initial state change signifying the arrival of a new message. Initiation of the display of a message may be controlled manually by the driver or automatically by the system. Message initiation and display play a critical role in visual sampling because they can influence whether drivers defer reading a message until after demanding roadway situations have passed. The display of the message begins with the process of message entry. Messages can either appear simply by ‘turning on’ or enter dynamically (e.g., either by sliding in horizontally or vertically). Understanding the factors influencing when the message is initiated is particularly important because the timing of the demands of reading a message relative to the roadway demands may be more important than the absolute demands of reading the message itself. The ability of the driver to appropriately manage the message reading task relative to negotiating turns and intersections may be critically dependent on alphanumeric message system design.

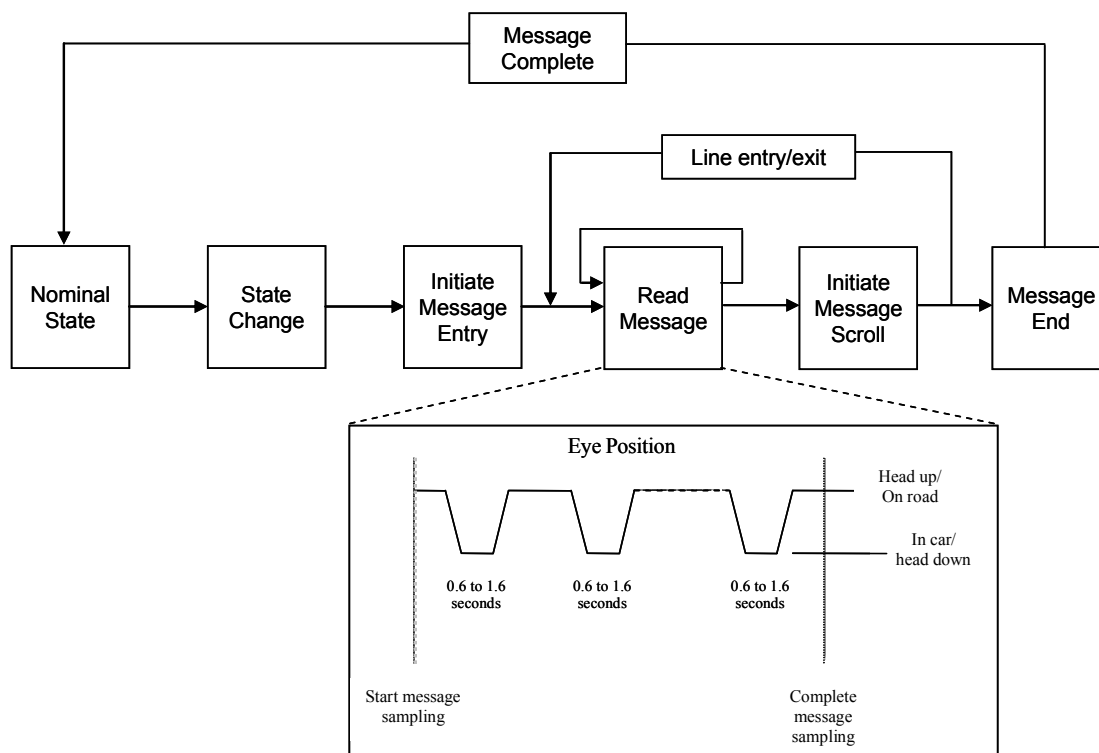


FIGURE 3-3 - THE LIFE OF A MESSAGE

Once the message has entered or is turned on, the reading phase begins. This is where visual demands can begin to build, depending on the complexity of the message. The driver samples the message, returns his/her vision to the forward roadway, samples the message again, and returns to the roadway, until the displayed portion of the message has been completely sampled. Importantly, before drivers begin extracting information, they may need to orient themselves within the message. This may be particularly important in displays that have many lines of text. Wierwille (1993) found that these samples range from 0.6 to 1.6 s. If the message is too long or complex, it may require the driver to look away from the forward roadway more often and for greater periods in order to chunk the information (Figure 2). Figure 3 shows how this sampling pattern might represent the driver's visual sampling during the reading phase of the message.

After the displayed portion of the message has been read, the message content may need to be scrolled, and the reading phase reinitiated. In other words, a message that is four to five lines long might be presented in three instances, each divided by the need to scroll to the next. The overall visual demands associated with reading a message on a multi-line display compared to scrolling through a message on a display containing fewer lines of text has not been empirically investigated or analytically modeled.

4. DESIGN RECOMMENDATIONS FORMAT

From the literature review, a set of recommendations that follow the same process that was discussed in Figure 3-1 are provided. Subsequent sections of the Information Report will provide specific design recommendations and rationale for the conceptualization, development, design, testing, or evaluation of in-vehicle alphanumeric displays. Specific designs for such systems are not provided. The most important fundamentals of such information display types are provided.

4.1 Display-Relevant Message Content

First, the content of display-relevant messages should be considered to functionally group driver information requirements. The second box in Figure 3-1 describes a number of factors related to message content: urgency; criticality; length; structure; information processing elements; driving context dependency; and message structure. According to Lee et al. (1999), within the same IVIS function there might be messages that either requires a driver to respond immediately to a critical situation or simply informs the driver of a situation they will need to be aware of later. It makes sense that these two messages would be designed quite differently in order to make them more useful to the driver. The context of a message is, therefore, extremely important for several reasons: it can change the meaning of a message, it defines the salience of the message, and design tradeoffs may be made based on the context. Overall the context characteristics define messages in a way that identifies design tradeoffs associated with integrating a message with other messages and driving activities.

From Lee et al. (1999), five characteristics that define the context of an IVIS message, which can be seen in Table 4-1 are adapted.

TABLE 4-1 - SUMMARY OF URGENCY, CRITICALITY, CONTEXT, MESSAGE LENGTH AND STRUCTURE (ADAPTED FROM LEE ET. AL, 1999)

MESSAGE CHARACTERISTICS	DEFINITION	RANGE
Time Urgency	Time available for driver to respond to message	Emergency: 0-3 s Immediate: 3-10 s Near Term: 10-20 s Preparatory: 20-120 s Discretionary: >120 s
Criticality	Consequence for not responding	Low = Delay or annoyance High = Increase risk of danger to occupant or vehicle
Driving Context Dependency	Relationship to driving context	Related = linked to driver control Unrelated = No relation to driving context
Message length	Length of message	Short message: ≤ 3 information units Medium message: 4-6 information units Long message: ≥ 7 information units
Message Structure	How a message is structured in terms of succinctness	Structured or unstructured

Time Urgency is defined in terms of the amount of time available for the driver to respond to a message. Greater than 10 s for low urgency and less than 10 s for high urgency was chosen. Lee's analyses include greater resolution because their analyses included true imminent alerts that must be responded to immediately (e.g., less than 3 s). They also used 3 to 10 s; 10 s to 2 min; 2 to 10 min; greater than 10 min. The 10 s threshold was chosen for two reasons: first because it is the midpoint of Lee et al.; and second, 10 s represents about 1000 ft of driving at freeway speeds (65 mph). For alphanumeric messages in general, there should not be any imminent messages, so the context of urgent information should concentrate more on driver maneuvers related to the roadway environment. Many navigation systems utilize the 900 to 1000 ft decision times for final navigation-based alerts.

While there are a variety of levels of high and low urgency, there are also very low urgency messages. For example, when a driver receives vehicle condition monitoring information regarding routine vehicle maintenance schedules (e.g., "oil change needed in 500 miles"), they may not need to address this message for several hours or several days depending on how far they are driving. Urgency should also be considered relative to imminent safety. So messages that might involve more infotainment and other non-safety related information should always be relegated to low urgency. Designers may want to consider that some information is only presented during engine start - such as lower priority maintenance issues like oil change reminders. More imminent engine-related issues (timing belt, low oil pressure/level, alternator) should be displayed in real-time, however.

Criticality is the consequence of not responding to the message in a timely manner. Ignoring messages can bring about consequences ranging from a crash to no driving-related consequence at all. For example, the consequences of ignoring a 'Road Closed' message could end up being very severe and possibly life threatening. However, ignoring a motorist services message will probably produce no real consequences for the driver - other than an inconvenience. Since alphanumeric message displays should not be used for time-critical information (e.g., imminent), the criticality has been limited to two levels: low (delay or annoyance) and high (increase risk of crash). It should be noted that for simplicity, the number levels suggested by Lee et al. have been limited (1999).

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

Message Length is defined for our purposes as short, medium or long. A short message is one that can be displayed in a set of minimal information units that can be chunked in a single glance. Information units to distinguish the different levels were chosen. As per table two, short messages are those that are less than or equal to three information units; medium messages are those that are 4 to 6 information units; and long messages are those that are greater than or equal to seven units. The implication for this rationale is that the Medium length messages may require more than one glance, but are not on multiple pages (i.e., two lines); Long messages are those that are more complex and require multiple glances and paging. For instance, warning and signage messages can be conveyed in brief, short messages, while motorist services and other entertainment messages will require longer messages. It is possible that some driver information categories may be made up of short, medium and long messages. See also recommendations on message length.

Message Structure refers to whether messages are intentionally structured for highly specific information for efficient extraction through brief glances or are more free-flowing and casual. For example, basic warning principles suggest that a message should employ a signal word, a description of the hazard, a description of the consequences, and instructions on actions to be taken (Sanders and McCormick, 1997). Generalizing this framework to a message format for an in-vehicle display: the signal word would convey the reason for the message, i.e. "weather" or "traffic"; the hazard would relay the event that had occurred, i.e., "crash ahead"; the consequences would describe the results of the event, i.e., "road closed"; the instructions would direct the driver to take action, i.e., "exit 2 miles". While this is related to message length, there can also be structured medium and long messages. In these instances, language style can be used to present more information in a concise manner, such as an entire route to be navigated in turn-by-turn directions. In general, the distinction is most relevant in the design of more succinct messages, relative to longer less important messages.

4.2 Message Format

Once a message is categorized and defined in terms of relevance, it must be appropriately depicted and annunciated. The final box from Figure 4-1 identifies parameters to communicate message content. Message format refers to the graphical characteristics of displaying a message. In terms of the message format itself, there are four general areas to consider:

Word format refers to the manner in which individual words are displayed, either in their entirety or an abbreviated form. Simple rules for abbreviation strategies will be presented in the recommendations. For instance, a common abbreviation rule for changeable/dynamic message signs is to retain only the first letter and syllable of a word while vowels are eliminated with only key consonants being retained.

Font refers to the geometrical characteristics or style of symbology. The design goal for fonts is to avoid extensive flourishes and embellishments of the symbols—so that Alphanumeric messages are easily and quickly read (see also ISO 15008).

Color and Accentuation refers to the use of color and contrasts to display messages in a manner which is easy to read and identifies the most salient information to the driver.

Display Length refers to the total amount of information that is able to be displayed at any given instant. In the context of this report, display length is characterized by the number of lines displayed of an understood length.

4.3 Flow Parameters

Flow Parameters refer to the life of a message relative to how it initiates and enters the display and how subsequent information is presented and/or paged. More specifically, flow parameters are made up of state changes and message initiation, message entry types and the display of subsequent information, and how control of flow is allocated.

State Change and Message Initiation refers to how a new message is enunciated and activated. For instance, under nominal conditions, displays will be blank. Upon receipt of new information, the system must inform the driver of a new 'state', indicating that new information has arrived for viewing. Examples of state change indication are auditory icons or flashing displays. On the contrary, state changes may go unidentified, whereby information simply appears. Following a state change, messages are initiated either manually by the driver or automatically displayed by the system.

Message Entry describes the phase where a message enters or appears on the display. Messages can simply appear, or fade in. Entry can be activated by the driver or the system and describes both the entry and exit of the text relative to the field. Alphanumeric information can simply appear in its entirety, as in 'normal page alphanumeric presentation.

4.3.1 Key References

ISO 15008 (2009). Road vehicles - Ergonomic aspects of transport information and control systems - Specifications and test procedures for in-vehicle visual presentation (15 February, 2009).

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