# Driver Use of En Route Real-Time Travel Time Information

# Final Report

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**Task Order 28**

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## Executive Summary

Travel time is an important piece of information that can be given to motorists. Communications and display technologies now permit the provision of key travel information to drivers in real time, using changeable message signs. Travel time information has the potential to improve driver decision making, with benefits to the individual traveler and roadway system performance. Real-time travel time displays are increasingly used in the United States, and more extensive use and innovative displays are seen in other countries. Guidance does not currently exist on how to effectively provide this information, which must be useful, understandable, timely, credible, and safely used and should result in predictable effects on route choice and route diversion.

The purpose of this project was to conduct human factors research to establish a basis for more effective provision of real-time travel time information. Such real-time travel time systems will only work well if they are designed with consideration of driver information needs and an understanding of the perceptual and cognitive aspects of motorist use of the signs. The project addressed these issues through various analytical and empirical activities. These included:

- Review of literature on travel time information and driver behavior.
- Identification of current practices and their rationale.
- Focus groups with drivers who commute along corridors with real-time travel time displays, in three cities with different signing practices and traffic system characteristics (Atlanta, Milwaukee, Seattle).
- Trip logs kept by commuters in the same three cities, documenting the driver's experience with travel time displays and with influences on route choice, confidence in decisions, and other driver perceptions and beliefs.
- A laboratory study of the comprehension and interpretation of travel time displays. The experiment systematically manipulated numerous features of the travel time displays and measured the effects in terms of how long it took to extract the relevant information from the sign, the ease of processing the information, confidence in one's knowledge of the best route, and degree of willingness to change to a different route.

In Study 1, commuters in three urban areas who see travel time signs on their daily commutes were recruited to participate in a two-part research study. Participants first attended a focus group where they discussed their commuting habits, use of travel time signs, and preferences for travel time sign design. Following the focus group, participants filled out a driver log about their commuting experience and use of travel time information after every commuting trip for a period of two weeks.

In Study 2, commuters along a freeway corridor in the Washington, DC area were recruited to participate in a laboratory-based experiment that used static displays to compare alternatives in terms of how well the viewer is able to comprehend the message and use the information to reach a decision about route choice. Travel time signs are not used in the region, so participants were unfamiliar with travel time signs in general. Signs included a broad range of formatting and content alternatives, and included some signs with diagrammatic elements.

Taken together, the results of the various project activities provided a number of findings regarding how drivers perceive and use travel time displays and the effects of various display features. A few of the findings are highlighted here:

- Drivers (regular commuters in particular) like having travel time displays and consider them useful and reasonably accurate. The displays help set expectations for the trip and are felt to reduce frustration.
- Despite the positive attitudes toward travel time displays, it is difficult to find substantial effects of these displays on actual route decisions. Part of the reason for this may be that because the signs are typically located on freeways, drivers often feel committed to their initial choice and (for many commutes) do not see viable options, except under extreme conditions. There is some indication that travel time displays on the *approach* to freeways might result in greater route diversion, but this practice is quite limited in the U.S. and data on its effectiveness are lacking.
- Travel time to a destination is the primary information drivers want and is what is typically provided in current practice. Alternative or additional types of information do not appear necessary or particularly helpful and may even increase the demands on the driver in processing the sign information. Such information includes average speed, distance to the destination, time estimate ranges, time stamps, time trend indicators, and color coding to indicate congestion level.
- Simple diagrammatic signs, with linear depiction of the roadway and travel times to two or three destinations, appear acceptable. More complex diagrammatic signs appear difficult to readily interpret (although familiarization or training may mitigate this).
- An effective layout is to left justify the destination and right justify the travel time. A header message (TRAVEL TIME TO) may be centered and although it is typically used, it may not be necessary.
- Travel time displays may place undesirable demands on drivers if they exceed three lines of text or six information units.

Recommendations for the design and use of en route real-time travel time displays were derived from the research findings.

# Introduction

This project addressed the impact of en route, real-time travel time, and related information, on driver comprehension and behavior. There are many human factors issues related to defining the most effective way to provide this information. This project determined the key issues to address, conducted research to evaluate alternatives, and provided preliminary guidance to practitioners.

## *Background*

The provision of real-time travel time information to en route motorists using changeable message signs (CMS) has become increasingly viable as sign technology and information resources become more available and affordable. These technologies are included under the rubric of Advanced Traveler Information Systems (ATIS). If drivers are presented with timely information about roadway status, including travel time or related information (e.g., speed, congestion), they can make more rational decisions about route choice. Roadway operators could potentially use real-time information displays to influence the degree of route diversion on a given facility and improve the efficiency of the roadway network. Such systems will only work well if they are designed with consideration of driver information needs and an understanding of the driver decision process. The information provided must be useful, understandable, credible, timely, and safely used. The situation is complex because the ideal approach may depend on the characteristics of the particular driver, trip, roadway, and roadway network. While these issues have been addressed somewhat in prior research, there is a lack of understanding of the human factors requirements for effective en route real-time travel time information.

In the United States, travel time estimates and other ATIS information have typically been presented in alphanumeric form on matrix CMS displays. Some examples are shown in Figure 1. A recent FHWA scanning study of ITS in Europe and Japan (Njord et al., 2006) observed that the provision of travel time information to motorists using CMS is more extensive in other parts of the world. A team of U.S. experts visited sites in Germany, France, and Japan. They observed the use of overhead CMS to "manage traffic flow, reduce congestion, and communicate incidents and other information." Among the specific recommendations in the report is "Promote the further use of changeable/dynamic graphical signs."

CMS products also now offer affordable options for the use of graphics, color, and animation. A review of these capabilities (Lerner, Singer, & Huey, 2004) found that other countries were making use of such displays for real-time travel time information, even though use in the U.S. was minimal. Some examples from the report are shown in Figure 2. These examples come from Australia, the Netherlands, and Japan. Note that to varying degrees they use words, numbers, graphics (schematic roadway), and color coding. These examples illustrate some of the alternative types of displays and information content that might be considered, and there are obvious human factors questions regarding how drivers will interpret and use the information. It is not known how well these alternative types of displays work in general and for the United States in particular.


**Figure 1. Travel time signs in the United States**
**(clockwise from top left: Atlanta, GA; Los Angeles, CA; Chicago, IL; Milwaukee, WI)**


**Figure 2. Diagrammatic travel time signs**
**(from left to right: Australia, Netherlands (prototype), and Japan)**

Obviously, there are many alternatives regarding what information to provide, how to convey it, the type of display to use, the location of the display, and so forth. Not only is there the question of what works well, but also concerns about inconsistent practice and potential motorist confusion. A recent survey (Dudek, 2008) reported a wide range of practice and a diversity of opinion among agencies regarding best practices and perceived benefits of travel time information.

### *Objective and Scope*

The purpose of this project was to conduct human factors research to establish a basis for effective provision of real-time travel time information. Such systems will only work well if they are designed with consideration of driver information needs and an understanding of the driver decision process. The human factors issues are broad, with many related factors and considerable complexity. The purpose of this project was to identify the key issues, prioritize the areas where the most promising gains could be made, and conduct research to provide useful knowledge and guidance. The specifically stated objectives of the project were to:

- Assess impacts of en route real-time travel time/delay/speed information on drivers.
- Define the most effective way to provide en route real-time travel time information.
- Develop preliminary guidance to practitioners for delivering en route travel time information.

The focus of this project was on the presentation of estimated travel time, or related information such as travel speed, delay, or congestion level, in real time to motorists via on-road CMS. This project only addressed travel times for limited access highways such as freeways and expressways; travel time systems have not been implemented on minor roads or arterials in the United States, and these road types have unique considerations that are outside the scope of this project.

## Review of Literature and Practice

### *Method*

Keyword searches and scans of relevant journals and reports were used to identify available literature relating to the human factors aspects of real-time provision of travel time information. Two major FHWA research programs provided substantive literature reviews in the late 1990s: *Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO)* (Campbell, Carney, & Kantowitz, 1998) and *Analysis of Travelers' Preferences for Routing: Final Report (*Lerner, Llaneras, & Huey, 2000). The present review used those reviews as a starting point and focused its search activities primarily on literature from the past ten years. More than 130 documents were acquired and reviewed for relevant information.

The project also sought information on current practices and rationale regarding the use and display of travel time information in the United States. This was accomplished though Internet searches and formal requests for information. While the resulting summary is not completely comprehensive, project staff identified a broad range of jurisdictions that provide travel time information using a variety of different practices.

The request for information on current practices was distributed to States participating in the Pooled Fund Study (PFS) program, and to the Transportation Research Board (technical committees AND20 User Information Systems, AHB15 Intelligent Transport Systems, AHB20 Freeway Operations), Institute of Transportation Engineers (Management and Operations/ITS Council), and American Association of State Highway and Transportation Officials (Standing Committee on Highways). The request briefly described the project and its interests and specifically indicated interest in the following information:

- Research or evaluation on this topic, including unpublished or informal studies;
- Examples of implementation of real-time travel time systems;
- Practices and policies on what to display and how to display it;
- Available guidance or standards on the topic;
- People or agencies that may be especially knowledgeable or have unique information; and
- Issues to consider in the course of conducting this information search.

This review was conducted concurrently with a separate *NCHRP Synthesis* project titled *Changeable Message Sign Displays During Non-Incident, Non-Roadwork Periods* that included a survey to identify the prevalence and practices of en route travel time in the United States (Dudek, 2008). The current project's review of practice was more focused on the details of travel time displays, while the Synthesis project was broader in its consideration of various types of messages on changeable message signs, and more systematic as a survey of State practices. Survey results address a wide range of issues, including reasons for use or nonuse of travel time, prevalence of various display features and formats, public response, lessons learned, concerns and challenges, and implementation costs. The *NCHRP Synthesis* report, which is available through the Transportation Research Board Web site, is a useful complement to the present review of literature and current practice.

## Findings

The review identified few studies that directly assess the effects of display characteristics of travel time, though a number of studies more generally addressed information requirements for CMS messages. A summary of review findings is presented below, and the complete review, including example display images and references, is presented in Appendix A. The findings in Appendix A are organized under headings representing major human factors issues in travel time reporting. Below each heading are questions relevant to the topic and findings related to each question in the form of research results, guidelines, current practice, and expert opinion and experience. In some cases, no findings were identified for particular questions.

Summary findings for key topics are presented below; Appendix A provides reference citations and more extensive treatment.

**Audience for Travel Time Information**: Most agencies tailor their travel time information for commuters who are familiar with the area because travel time information is considered to be most useful during peak commuting hours when roads are most likely to be congested. Common commuting destinations or landmarks such as "downtown" are often shown on signs. Some areas attempt to accommodate less familiar drivers by choosing easily identifiable destinations such as Interstates or by showing the distances to destinations in addition to travel times.

**Driver Assumptions about Travel Time System**: Drivers generally understand that travel times are estimates rather than precise predictions, and that their actual travel time may vary. Few drivers know how travel times are calculated.

**Perceived Value of Travel Time Information**: Most drivers like to have travel time information because it keeps them informed of conditions ahead and helps them set expectations for their trip. Few drivers, however, actually change their route or other driving behaviors in response to travel times. Some drivers have unfavorable opinions of travel time because they perceive the information to be inaccurate, unreliable, or irrelevant to their route.

**Message Content / Information Elements**: Nearly all travel time signs in the United States show travel time in minutes. One jurisdiction shows average freeway speed on some arterial signs, but uses travel time on all freeway signs. Drivers prefer travel time to delay time or speed information, but also like to receive incident information (e.g., presence, location, lane closures, congestion, detours). Drivers generally prefer descriptive rather than prescriptive information. Drivers prefer to make their own route choices, and there is a higher standard for accuracy for prescriptive routing information.

**Message Design and Layout**: The vast majority of travel time signs in the United States use amber, all-caps, alphanumeric characters on three-line CMSs. Characters are typically 18 inches tall to provide sufficient viewing time at freeway speeds. Most signs are located directly above the roadway, while some are located on the roadside. Messages are generally displayed fully justified or centered, with the nearest destination at the top of the sign. Some agencies use banner text (e.g., "travel time to:") while others do not because they feel that it is unnecessary and that the space is better utilized by presenting more traffic-relevant information. Few travel time CMSs provide two phases of information or show alternate route information.

**Travel Time Reporting**: Some jurisdictions show a single travel time estimate while others show a range of two to five minutes. Operators sometimes prefer to show a range of times because it emphasizes that the estimate is not exact and increases the likelihood that the drivers' actual travel times will be within the estimated range. In most locations, travel times are updated every one to three minutes, though one goes as long as 10 minutes between updates. The same jurisdiction also shows the time of the most recent update.

**CMS Locations and Destinations for Travel Time Display**: Most jurisdictions select heavily used exits as destinations on travel time signs. Destinations are usually limited to a range of 10 to 20 miles ahead because it is more difficult o accurately estimate travel times on long stretches of road. A few jurisdictions do not report travel times above some maximum threshold, and instead show a message such as "over 30 min" or "30+ min." HOV lane travel times are shown in some areas, but others have opted not to show this information because of a concern that it might encourage illegal use of HOV lanes.

**Route Choice / Diversion**: Drivers tend not to divert unless they are confident that the alternate route will save a significant amount of time. Drivers are less likely to divert onto roads with unpredictable travel times, many traffic control devices, and numerous navigational maneuvers. In some jurisdictions, certain travel time CMSs are used to show travel times to a destination via different routes. Though times are shown, these signs do not recommend a "best" route. Even where alternate route information is not provided, many jurisdictions report installing travel time signs in advance of alternate route options to give drivers the opportunity to divert.

**Phasing / Staggering of Travel Time Information**: The *Manual on Uniform Traffic Control Devices* specifies that a CMS should show no more than two phases of information, with each phase conveying a separate thought. There is no consensus in the United States, however, regarding whether two-phase signs are advisable. Some agencies use two-phase signs to present travel times to additional destinations or to supplement travel times with incident information. Adverse effects such as drivers slowing down to read the signs have been reported in some locations, but not others. Two-phase signs should only be used in locations where driver demand is low and where sufficient reading time is available at highway speeds.

**Use of Color, Graphics, Symbols, and Dynamic Elements**: While monochrome, alphanumeric travel time signs are the norm in the United States, some signs in other countries use color, graphics, and symbols to express travel time information. A common feature on these types of signs is color coding to indicate traffic conditions. Color is most often used on diagrammatic signs that visually represent the roadway ahead either as a straight line or as a simplified map. Segments of roadway are color-coded to indicate traffic conditions. Worldwide, green, yellow, and red are used to express low, medium, and heavy congestion. Diagrammatic map signs may show multiple routes to a common destination or different destinations. Colors may be supplemented with numerical travel time information.

**Relationship between Travel Time CMS and Static Signs**: Static signage is rarely used to supplement travel time information. The placement of travel time signs and other signs should be considered to ensure that driver demands are minimized.

**Message Prioritization, Hours of Use, and Failure Modes**: Travel time information is generally considered to be lower priority than information about incidents, work zones, adverse weather, hazardous road conditions, and missing child AMBER Alerts. Travel time messages will be superseded by these other messages. The Federal Highway Administration recommends that on signs where travel times are shown, travel time should be shown at all times as long as it is not superseded by a higher-priority message. While some areas display travel times 24 hours a day, others only show travel times during daytime hours or just during peak driving periods. Those that only display travel times at certain times typically do so because they consider travel times to have little value when traffic is free flowing, while those that show travel times at all times typically do so because they do not want to leave CMSs blank.

**System Reliability and Accuracy**: The Federal Highway Administration recommends that travel time signs achieve at least 90 percent accuracy, and never less than 80 percent, though some lab studies suggest that drivers may still find information useful with accuracy as low as 70 percent. Research also suggests that perceptions of information accuracy have a significant effect on compliance with route guidance information.

**Mitigating Undesirable Results of Travel Time Information**: There are numerous, mostly anecdotal, reports of drivers slowing to read travel time signs, causing congestion and possibly rear-end collisions. These problems may lessen as drivers become familiar with the messages and they tend not to slow down any more, unless a novel message is displayed. To minimize driver slowing and collision risk, travel time signs should be placed in areas where drivers have relatively few demands on their attention and where there is sufficient viewing distance available. Problems may also be reduced by initiating a public information campaign about travel times before they are implemented. One jurisdiction placed the message “Travel times coming soon to this sign” on the sign for a week before initiating travel time display.

**Presentation of Travel Time Information on Portable CMS**: Portable CMSs are rarely used to present travel times because of insufficient space for messages and insufficient visibility, though one demonstration project used a three-phase message on a portable CMS to report expected delays at a downstream work zone.

**Presentation of Travel Time Information on Non-Freeway Locations**: A small number of jurisdictions display freeway travel times on some arterial roads en route to freeway entrances. This informs drivers of traffic conditions before entering the freeway, and perhaps allows them to choose a different route. These signs are generally smaller than the large overhead CMS on freeways, and some use two phases to display all relevant information.

## Overview of Studies

The review of literature and practice identified a wide range of unanswered questions related to the design and use of real-time travel time CMS displays. While this project cannot address all of them in detail, it addressed many of the major issues through two distinct studies using different methods. The two studies were:

- Study 1: Actual driver experience and decision making with real-time travel time displays
- Study 2: Driver comprehension and interpretation of display alternatives

Study 1 used driver log and focus group techniques, while Study 2 used laboratory-based methods. Taken together, these two studies addressed a wide range of key questions using different approaches. The combined findings of these studies were used as a primary resource for the development of a set of recommended practices.

## Study 1: Driver Experience with Real Time Travel Time Displays

Many of the key questions about driver use of real-time travel time information are not readily addressed through laboratory experiments. Instead, Study 1 used a combination of driver trip logs and focus groups to explore driver use of travel time information in their decisions, what problems or limitations they encounter, the benefits they perceive, and various other issues. Study participants were regular users of routes where real-time travel time information is provided, in three regions of the country where real-time travel time practices differ from one another. The focus groups also presented these drivers with examples of real-time travel time display types from other regions and countries, to see what differences may be deemed helpful, how decisions may be influenced by alternative formats, and so forth.

Study 1 addressed those issues best answered by exploring the behaviors and beliefs of actual experienced users of en route real-time travel time information. The study collected both objective (driver log) and subjective (focus group) data. Specific issues included:

- How do drivers actually use real-time travel time information in their decision making?
- What effect does it have on their route choice?
- What triggers a route change?
- What is the perceived credibility of the information and what influences that?
- What are the perceived benefits and overall value of real-time travel time information?
- What behaviors are seen when the information displayed indicates a significant delay?
    - Their own behavior and what they observe in traffic
    - Unintended consequences, if any (conflicts, abrupt lane changes, more cell phone use, etc.)
- What limits the usefulness of real-time travel time displays?
- Are there confusions or ambiguities about the meaning of the displays?
- How helpful are the destinations used and the placement of the real-time travel time signs? What could be improved?
- Supplementary information that might be useful and how it might be displayed.

- Discussion of alternate formats used in other regions and discussion of preferences and strengths/weaknesses.

In addition to directly addressing these issues, Study 1 provided a basis for decisions about what scenarios, messages, and displays to include in the subsequent phase (Study 2) of this research.

## *Method*

The study used two distinct methods: driver logs and focus groups. Both methods focus on the actual experiences of drivers who routinely encounter en route real-time travel time information, rather than "what if" questions. The questions focused on those particular issues where information is best provided through focus group techniques, as opposed to the laboratory methods used in the subsequent study. Visual aids depicting various messages, formats, and communication strategies were used to assist the discussion and make the examples concrete. After discussing their experiences and the displays used in their region, participants were shown examples from other regions and discussed features that they found interesting about them.

The individual driver log data collection took place after the focus groups. Participants were instructed on the procedure and given the log forms at the end of the focus groups. Participants completed a log form following each trip to or from work that they made as a driver, for a period of two weeks. The log forms provided information on how the travel time displays influenced driver thinking, decisions, and performance, in close to real time. At the end of the two weeks, participants also completed a final questionnaire addressing more general reactions travel time.

### Design

Region of the country (and the associated type of travel time display) was the only formally manipulated variable in this study. Although a number of factors were approximately balanced in the groups (e.g., age, gender, commute characteristics), the focus group method does not allow formal statistical analysis for these factors. However, the driver log portion of the study allowed data to be associated with individual participants. Age group categories were determined post hoc based on the participant pool.

### Study Locations

Three different urban areas were selected as sites for this study: Atlanta, GA; Milwaukee, WI; and Seattle, WA. These areas were selected because they have reasonably extensive programs of en route real-time travel time information that have existed for a number of years, they are in different regions of the country, and they differ in their approaches to provision of travel time information.

### Participants

Study participants were paid volunteers who regularly commute along a route that provides en route real-time travel time information via CMS. All participants lived in suburban areas and regularly commuted to downtown areas during morning rush hour and returned home during evening rush hours. Equal numbers of participants were recruited at each of the three study locations. Recruiting methods included ads in local newspapers and Craigslist, recruitment through regional rideshare coordination offices, and through community organizations. The recruitment ads did not refer to travel time displays, but simply sought regular commuters along a given corridor. All ad respondents were screened via telephone to ensure that they met the study criteria. Criteria included the daily commute characteristics, including distance, origin, and destination, and exposure to real-time travel time displays. Fifteen people participated in the focus groups in each location, for a total of 45 focus group participants. The same individuals completed the driver log portion of the study, however, complete driver logs were only received from 42 participants.

## Procedure

At each of the three study locations, two focus groups were conducted. In a given location, both focus groups followed the same discussion path and included participants with similar demographic and commuting characteristics. Study sessions were conducted on Saturday mornings and afternoons to accommodate participants' work schedules. Each focus group was about 90 minutes in duration. Focus groups were video-recorded for later analysis.

The focus groups followed a structured question path to assure that all of the key points were addressed in a logical sequence. Focus groups were accompanied by slides projected on a large screen showing examples of travel time signs to stimulate discussion. The focus group path was customized to each study location, using local travel time examples as topics for discussion and to compare against alternative display designs. The focus group slides for Seattle are shown in Appendix B. Focus groups addressed the following major topics:

1. Commuting habits and route choice factors
2. Discussion of local travel time displays
3. Use and benefits of travel time displays
4. Features of travel time displays (likes and dislikes, credibility, confusions, locations, destinations)
5. Effects on behavior (interpretation, route choice, reactions to long travel time estimates, dangerous behaviors observed)
6. Alternative travel time displays (alternative information and formats, diagrammatic signs)
7. Direct comparisons of local signs with alternative versions
8. Design of ideal travel time signs
9. Value of travel time and suggestions for improvements

The driver log portion of the study required participants to complete a short questionnaire after each trip to or from the workplace, for a period of two weeks. The questionnaire collected basic trip information (e.g., start time, end time, route, weather), traffic information sources, traffic conditions, and a variety of questions about the usefulness and effects of travel time information. An example log form from Seattle is shown in Appendix C. Participants were asked to complete each questionnaire immediately after the drive to ensure that their memories were accurate. After two weeks of data collection, participants completed a final questionnaire that addressed their use or nonuse of the travel time information, limitations and problems, safety or operational concerns, suggested improvements, and so forth. The final questionnaire is shown in Appendix D. Participants mailed completed forms to the researchers using pre-addressed, postage-paid envelopes.

## *Results*

## Focus Groups

The focus groups revealed areas of agreement and disagreement between participants, as well as how different roadway system and traffic characteristics may influence how travel time information should be delivered to commuters. Findings are summarized below. Findings from all three regions (Atlanta, Milwaukee, Seattle) are treated together, with local differences noted where relevant.

**Commute Habits**

- Most drivers reported that they do not have viable alternate routes to and from work. Most drivers felt that other routes, which are usually arterials, are slower roads, and even when traffic is bad on their primary route, the alternates are often even worse. Drivers tended to consider congestion an unavoidable part of their commute, and were accustomed to some delays. If congestion was severe, drivers were more willing to use alternate routes, though some preferred to wait at home or work for traffic to subside, or make a stop to do errands.
- Many drivers sought traffic information on television or radio before leaving home or work. Only a few sought traffic information by visiting a web site or calling 511, and very few did so on a regular basis.

**Credibility of Travel Time Signs**

- There was no consensus across groups regarding the credibility and accuracy of travel time signs. All groups acknowledged that the signs were not always correct, but some participants felt that the signs were generally accurate while others felt that they were inaccurate too often to be trusted. When the travel times were inaccurate, participants overwhelmingly said that reported travel times were underestimated. Participants in Atlanta disliked when travel time signs reported open-ended travel times (e.g., 40+ MIN).
- Some participants noted that travel times are often underestimated at predicable times, such as the early morning commute when congestion is increasing. As a solution, some participants recommended adding a trend indication to let drivers know whether travel times are increasing or decreasing. Concepts included up or down arrows, or plus/minus signs.
- In general, Seattle drivers thought the signs were very accurate. Milwaukee participants' opinions were more mixed. Atlanta drivers had the least confidence in travel time sign accuracy, but some drivers believed the estimates were generally accurate for shorter trips and times.

**Usefulness of Travel Time Signs**

- Many drivers believed that travel time signs set commute expectations and reduce frustration. Knowing how long it will take to get to a destination, whether the time is good or bad, removes uncertainty.
- Several drivers only used the signs for incident/emergency information (e.g., crashes, lane closures, amber alerts).
- A minority of drivers report seeing increased driver aggressiveness in the vicinity of travel time signs, especially if a long travel time is reported.

- Many drivers considered the HOV lane information useless because they do not or cannot carpool, and felt that it was frustrating to see that using the HOV lane could save time, though it was noted that transportation agencies might want to show HOV time savings to encourage more drivers to carpool. Some thought that showing HOV travel time would tempt drivers to use the HOV lane illegally.
- A few drivers said they used travel time signs to decide whether they should switch to an alternate route. Drivers noted that this is particularly true on the weekends when there is a choice whether to proceed with the trip or not, or in the evenings when arrival time is less critical and one can take a chance with an alternate route. Travel time signs were considered less useful for routing decisions during the morning commute when one has little choice about destination and arrival time.
- As experienced commuters, many participants reported that they develop an awareness of typical travel times that they expect on their routes. In this sense, travel time functions as a relative measure of congestion as well as an absolute measure of time.

**Amount of Information**

- Participants generally reported that they could easily and safely read more information than was presently shown on signs. Participants felt that two-phase signs and signs with travel times to three destinations would pose no difficulties. One Atlanta participant noted that signs could provide more information when congestion is heavy because traffic will be moving more slowly, allowing drivers more time to read the signs.
- Some participants noted that as regular commuters, they experience the same signs on a daily basis and become adept at selectively reading the information that is important to them and tuning out the rest.

**Timestamps**

- Several drivers in all cities felt that timestamps would be helpful. None of the focus group participants knew how often travel times were updated, though most assumed it was updated at least every ten or 15 minutes. Most participants liked the presence of "time of last update" information on the signs, but some acknowledged that if travel time signs were updated at least every five or ten minutes, and they were aware of this, that the time of most recent update information would not be necessary on the sign. When given the choice between adding a timestamp or an additional destination to travel time signs, most participants preferred the additional destination. One participant suggested that a static sign could be attached to a CMS that states how often travel times are updated.

**Alternative Information Elements**

- *Range of time.* Drivers largely preferred a single travel time estimate rather than a range of time. Drivers were aware that travel times were estimated and accepted small variations in actual travel time. Ranges were generally seen as unnecessary information.
- *Destination identifier*. Participants generally preferred street name to alternatives such as town name, exit number, or landmark. Town names were seen as too general, especially for short trips, though some participants thought that town names could be used for distant destinations while street names could be used for closer destinations. Participants in all three study locations were usually unaware of exit numbers and only attended to street names. Landmarks such as "downtown" were considered to be somewhat useful,

though participants acknowledged that it might not be clear what exit the sign is referring to. Nonetheless, participants in Milwaukee, where “downtown” is used as a destination, understood the general area that the sign refers to and found it helpful.

- *Distance to destination*. Most drivers considered this unnecessary because regular commuters already know the approximate distances, though some noted that it might be useful for drivers who are unfamiliar with the destinations and might want to know how far away they are to understand the travel times.
- *Alternative measures*. Drivers overwhelmingly preferred travel time to delay time and average speed. Delay time was seen as lacking a baseline (delay compared to what?) and average speed was seen as potentially confusing because actual speed can vary significantly over the course of many miles.
- *Banner*. Participants generally considered banner information (e.g., “travel time to:”) unnecessary because travel time signs are easily identified and understood. Participants preferred to replace the banner with more useful information such as an additional destination.
- *Incident information*. Many drivers liked to receive incident information warning of crashes, lane closures, and other incidents ahead that might influence traffic conditions. Some drivers wanted to see alternate route information in the case of an incident, but others noted that in such cases, the alternate route would probably become congested as well.

### Diagrammatic Travel Time Signs

- Diagrammatic travel time signs were received positively by most participants. Participants typically preferred signs that gave travel times in addition to color coding. The diagrammatic nature of the signs was seen as especially useful for identifying problem locations and planning routes around them. A few participants noted that it would be helpful to specifically show incident locations on the diagrammatic signs. Several participants raised the point that diagrams are most useful in downtown settings where there are multiple route options.

### Color Coding of Travel Time Signs

- Many drivers felt that three colors was a maximum, though some thought that four would be more discriminative. There was broad consensus on relative speeds and colors—red for congested or slow traffic, yellow for moderate traffic, and green for traffic at or just below the speed limit. There was no clear agreement, however, on what exact speeds colors should represent. One driver suggested using colors to indicate relative speeds (i.e., whether traffic was moving faster or slower than the norm for a stretch of road rather than absolute speeds.

## Driver Logs

Forty-two participants completed the driver log procedure for a two-week period. This provides 84 person-weeks, or about 1.6 person-years, of driving exposure. A total of 842 complete driver logs were received. Of these, 232 were not from weekday rush hour commutes or were trips where the driver did not report encountering travel time signs, leaving a total of 610 driver logs that were used for the majority of analyses.

Question 11 of the driver log collected feedback about the usefulness of the travel time signs experienced on each trip. The question included nine agree/disagree items that participants rated on a scale of 1 to 5, where 1 meant “strongly disagree” and 5 meant “strongly agree.” Figure 3 shows the percentage of driver logs in which the participant agreed with each statement (rating of 4 or 5), broken out by study location. Overall, the figure shows that participants had positive reactions to the travel time information they received. Sizable majorities agreed that travel times were accurate, that destinations were relevant to their trips, that travel time signs helped them predict their arrival times, that they made the best decisions about their routes, and that they liked having travel times. For fewer than half of the trips, participants reported that travel time signs influenced their route choices, largely because drivers opted to stay on their initial route. Similarly, on a minority of trips participants reported that travel time signs helped to save them time. Very few participants reported that travel time signs caused drivers to slow down or drive dangerously, or that the signs included too much information for them to read. The figure does show some variability between participants in different study locations. Atlanta participants had less positive reactions than other participants to most items. This presumably reflects opinions revealed in the focus groups, where Atlanta participants reported frequent traffic congestion, unreliable travel time estimates in congested conditions, and a lack of viable alternate routes. Given the small sample sizes for each city, however, differences should be interpreted with caution.

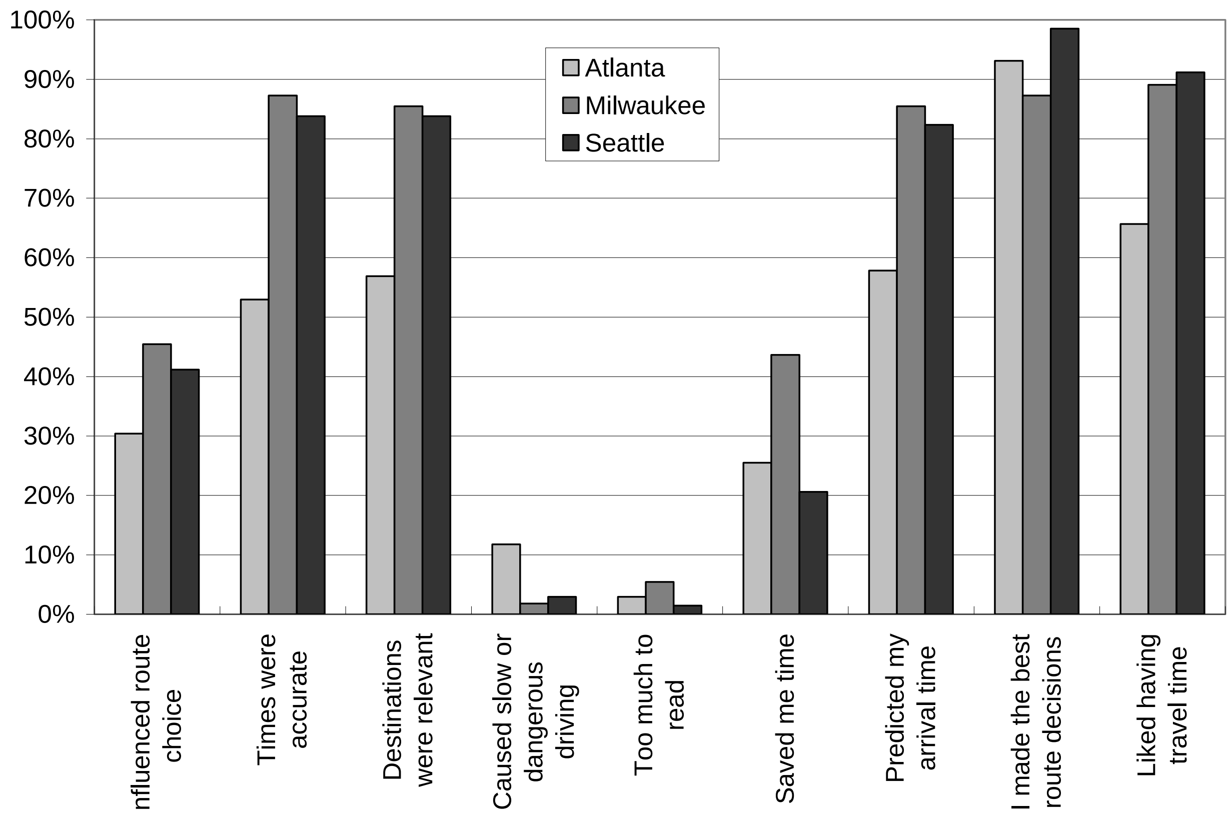



**Figure 3. Percentage of trip logs indicating agreement with statements about travel time signs, by study location**

Drivers overwhelmingly liked seeing travel times and felt that they made the best decisions about their trips. Drivers reported not liking travel time information or not making the best trip decisions on only 3 percent of trips (one participant accounted for nearly half of these instances).

For 20 percent of trips, drivers stated that travel time information did not save them time. Nonetheless, for these trips drivers still reported that they liked having travel times (mean = 4.36) and that they made the best decisions about their route (mean = 4.53).

Diversions from the planned route were rare, occurring in less than 6 percent of all trips. Overwhelmingly, diversions occurred when traffic congestion was far worse than usual or when an incident was reported ahead. About 56 percent of drivers who diverted reported that travel time information made them confident that an alternate route would be faster or about the same as the current route. More than one-third were not confident which route would be faster. Many drivers diverted before encountering congestion because they were aware that there would be congestion ahead.

In a small number of cases (11), drivers reported choosing not to take their usual freeway route at all, opting for an alternate route. In most cases, this decision was due to pre-trip congestion or incident information, while a few others experienced major backups attempting to reach the freeway or saw arterial travel time signs that indicated freeway congestion.

The participants' responses to the sub-items of Question 11 were also broken out by traffic condition and are shown in Figure 4. The ratings for each item were made on a five-point scale, where 1 means strongly disagree, 5 means strongly agree, and 3 is the neutral point. The figure shows the mean ratings as deviations from the neutral value. In this figure, data are presented separately for "better" and "worse" traffic conditions. Question 7b of the driver log asked "How did the level of congestion on the freeway compare to your typical commuting experience on this route?" The "better" traffic cases are those trips where the driver indicated congestion was "slightly" or "much" better than usual. The "worse" traffic cases were those trips where the driver indicated congestion was "slightly" or "much" worse than usual. Traffic condition affected driver ratings of the accuracy of the travel times and how well they allowed the driver to predict arrival time. Although during worse conditions the drivers felt accuracy and predicted arrival were somewhat degraded, there was relatively little effect on how well they liked having travel time information on the particular trip. Drivers remained confident in their routing decisions when traffic was worse, but not to the extent of their confidence under better traffic conditions. There was very little effect of traffic congestion on the mean ratings of whether the travel time display influenced route choice or saved the driver time on this trip. While this is somewhat surprising, it is consistent with the discussion in the focus groups, which indicated that while drivers liked travel time displays, they seldom seem to result in a change of planned route.

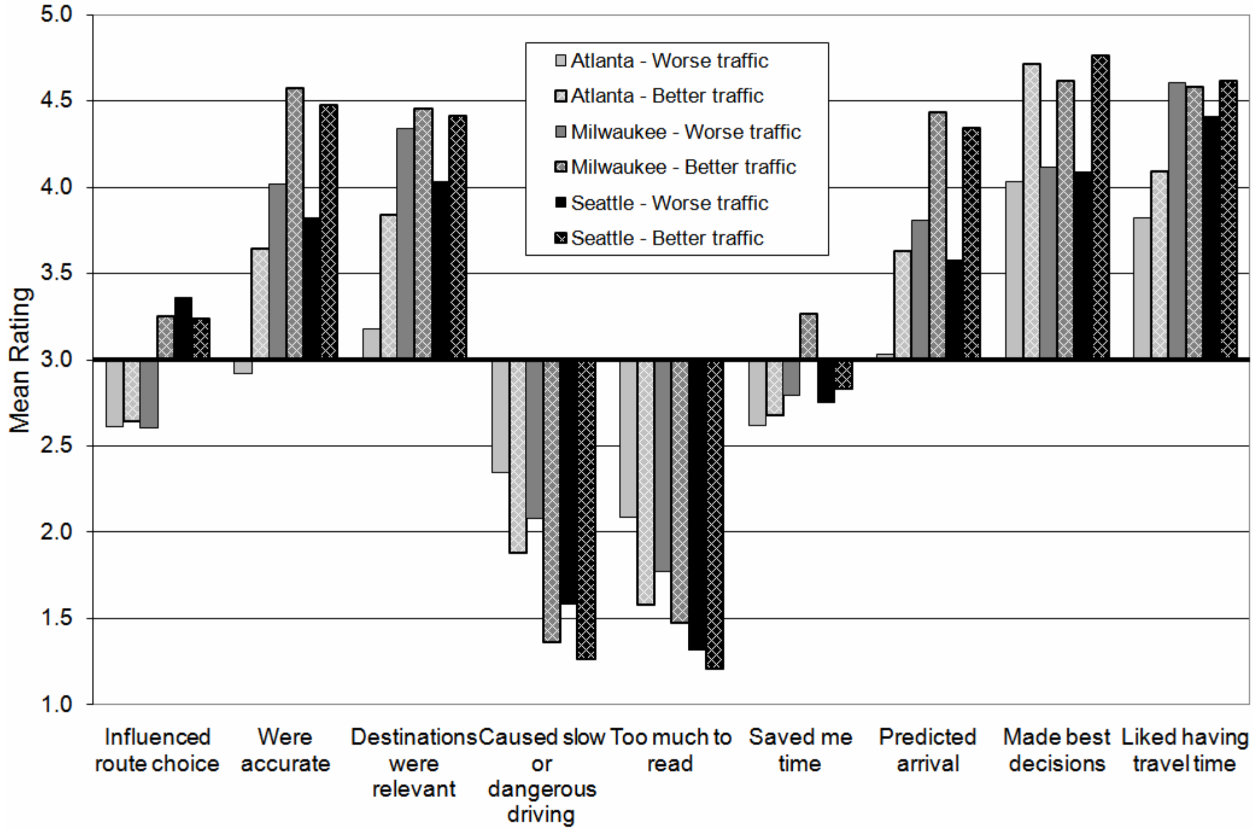



**Figure 4. Mean ratings by location and self-reported traffic conditions (worse than usual versus better than usual)**

## Final Questionnaire

The final questionnaire, shown in Appendix D, gave participants the opportunity to provide overall feedback about their experiences with travel time signs, rather than the trip-specific information provided in the driver logs. In the final questionnaire, participants provided their level of agreement or disagreement with 13 statements, where 1 means strongly disagree and 5 means strongly agree. The mean responses, distributed by study location, are shown in Figure 5. The figure shows ratings as variations from a rating of 3, which is the neutral point on the scale, so bars above the axis indicate agreement and bars below the axis indicate disagreement. The final questionnaire included a number of items that were on the driver logs, and the findings from these questions are very similar, indicating that the driver trip log findings tend to reflect participants' overall reactions to the travel time displays.

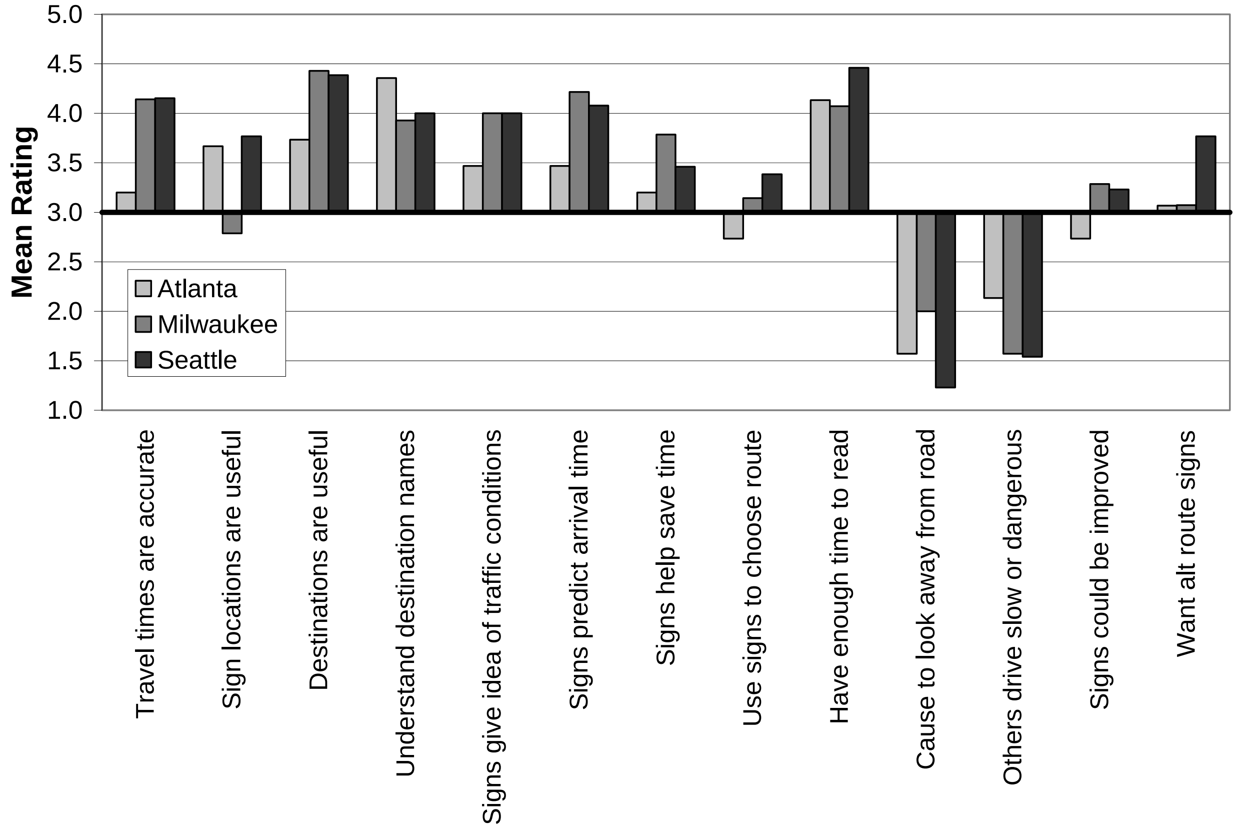



**Figure 5. Mean ratings of final questionnaire questions, by study location**

# Study 2: Comprehension and Interpretation of Alternative Displays

Study 2 was a laboratory-based experiment that used static displays to compare alternatives in terms of how well the viewer is able to comprehend the message and use the information to reach a decision about route choice. The "comprehension" measures included both the speed and ease of processing the display. The "decision" measures included the subjective likelihood of diverting to another route and the degree of confidence in route choice. The method used a combination of objective performance measures and subjective rating items, which expand and clarify the empirical data. The method allowed efficient inclusion of a wide range of alternative messages, formats, and scenarios. The study encompassed a wide range of alternatives in terms of format, message content, message structure, coding conventions, and destination factors. The findings indicate the strengths and weaknesses of various approaches.

## *Method*

### Participants

Forty-nine paid volunteers participated in this study. Participants were daily commuters who traveled during peak hours from the Maryland suburbs of Washington, DC southbound on I-270 to the Capitol Beltway (I-495) that encircles Washington. Participants were recruited through ads in Craigslist and a regional newspaper. Ads stated that daily commuters were needed for a highway research study, but did not state the study focus on travel time signs. All participants were between the ages of 20 and 60 and the sample was approximately balanced between age decades and genders.

## Design

The experimental design included the within-subjects variables of display and scenario. Trials were arranged in blocks. Each block began with the introduction of a commute scenario. Scenario variables included time of day (morning southbound versus evening northbound commute), congestion (moderate versus heavy), and familiarity (I-270 versus I-75 in the Atlanta area). Participants then viewed a series of signs that provided travel time or other information in the context of the aforementioned scenario. Signs included a variety of alphanumeric CMS signs, diagrammatic color-coded signs, and other prototype designs used in the United States or abroad, or that emerged as promising concepts in the preceding focus groups.

The basic logic of the experiment was to define a “baseline” sign and trip scenario. Then various aspects of the travel time sign or the trip were systematically varied, so that the effects of each factor could be evaluated versus the baseline condition. The baseline scenario was a morning commute along the participant’s usual route (I-270), with moderate traffic (average speed of about 30 mph). There were two baseline signs, one text and one diagrammatic (see Figure 6). The baseline text sign included the most common content and layout features of travel time signs in the U.S. The baseline diagrammatic sign was designed to have parallel information to the text sign and drew on examples taken from Australia, The Netherlands, and the U.S. Nineteen different features of travel time signs were manipulated, as were three trip scenario features. So for example, a travel time display factor, such as a “timestamp” to show when the travel time was last updated, would be added to the baseline text sign in the baseline trip scenario. Responses to the sign without the timestamp (base sign) could then be compared directly to responses to the sign with the time stamp. Likewise, to see the effects of a scenario factor such as route familiarity, the same sign would be presented in a scenario that differed only in showing unfamiliar (Atlanta) destinations rather than the participant’s familiar route.


**Figure 6. Baseline signs: Text (left) and diagrammatic (right)**

In addition to the baseline and comparison travel time signs, six “benchmark” signs were presented to participants. Benchmark signs were static signs designed according to the specifications of post-interchange Distance signs, as described in Section 2E.36 of the *MUTCD*.

This particular sign type was chosen because its appearance and format are somewhat similar to those of text travel time signs. The *MUTCD* indicates that “two or three interchanges” should be shown on these signs. It further states that if more than three interchanges are to be identified, a different sort of sign (NEXT EXITS sign) may be used. Thus this set of signs provide a “benchmark” for this experiment in that it include both signs that are acceptable according to the *MUTCD* (Benchmarks 1-4) and signs that have more information than acceptable (Benchmarks 5, 6). These signs were included so that the experimental signs developed for this study could be compared against accepted, standard freeway signs and signs that follow accepted design principles, except that they include more information than is acceptable. The inclusion of standard highway signs provides an indication of the ease and speed of comprehension for these signs, against which the experimental signs can be compared.

In total, the experiment included 75 sign/scenario combinations. The full set is shown in Appendix E. Sign and scenario features were not fully crossed; most experimental trials were based on the baseline scenario (familiar morning commute in moderately heavy traffic). The specific factors manipulated in the scenarios and signs are indicated below.

The three factors in the trip scenarios were:

- *Familiarity with the route*. The familiar route for these participants was I-270 and I-495 in Montgomery County, Maryland. The unfamiliar route was along I-75 in Atlanta.
- *Traffic speed and congestion*. The baseline condition shows heavy but flowing traffic in the video clip, with an approximate speed of 30 mph. The travel time displays were based on a 30 mph assumption. The heavy traffic condition showed congested, slow-moving traffic, with an assumed speed of about 20 mph.
- *Direction of commute*. The morning commute was southbound and the evening commute was northbound. Travel time destinations and times shown in the experiment were appropriate to the direction of travel in the scenario.

The sign characteristics manipulated in the study were:

- Number of destinations (2, 3, 4) shown in a single phase
- Number of phases (1, 2 for 4-destination displays)
- Timestamp (timestamp, none)
- Time range (none, 3 min, 5 min, open-ended)
- Travel time trend arrow (none, individual destinations up and down, overall, words)
- Alternative route (none, alternative route not given, alternative route time)
- Layout (right, left, left and right)
- Diagram (text, diagrammatic sign)
- Traffic information (none, traffic density information)
- Destination type (exit number, street name, route number, landmark, town)
- Distance information (none, distance to destination)
- Speed information (none, speed at destination given instead of traffic time)
- Delay information (none, delay information)
- Color-coded text (none, destination times color coded)
- HOV savings information (none, HOV savings information)
- Header (none, “travel time to”)
- Time unit (none, time unit in “min”)

- Fixed header (variable header, static header)
- Fixed background (standard changeable message sign, static sign with changeable destination times)

The key dependent variables in this study were the following:

- Reading time (self-paced viewing time for sign)
- Ease of assimilating information (rating)
- Willingness to change routes (rating)
- Confidence in route choice (rating)

Destinations shown on each sign were selected from among the exits along the corridor used by study participants. The destinations were varied to ensure that the destination(s) shown on each sign would not be predictable.

## Procedure

Participants were tested in a computer laboratory in groups of 7 to 13, each person at their own computer console for display and response. Each session was up to two hours in duration. Upon arrival, participants were assigned a seat, and read and completed a consent form. The experimenter then explained the experimental task and presented a short practice block consisting of 3 trials based in Atlanta (a standard 2 destination text sign, a standard 2 phase text sign, and a simple diagrammatic sign). Participants viewed static displays for a period of up to 5 seconds and made several responses to each. The general sequence of events is this:

- On their individual computer monitors, participants were presented with the text trip scenario and then shown a brief video clip of rush hour on I-270 to illustrate the roadway and traffic conditions (see Figure 7). Participants were not told a specific work destination, but rather were told that they are headed to their normal work destination.
- A real-time travel time display was shown on the screen. Participants clicked the left mouse button as soon as they felt they had acquired the relevant information (there was a lockout to prevent pushing the key too quickly or multiple times). The sign display terminated when the button was clicked, or when the maximum display period of five seconds had timed out (6 seconds for two phase signs with 3 seconds per phase). This provided a measure of comprehension time for each display.
- A question regarding the information content or format was presented and the participants selected a response from a list of four options (see Figure 8). The purpose of the question was to ensure that the participant was paying attention to the sign and not just clicking the mouse as quickly as possible. Answers were not scored, though participants were not told this.


**Figure 7. Text trip scenario description (left) and screen capture from road condition video clip (right)**

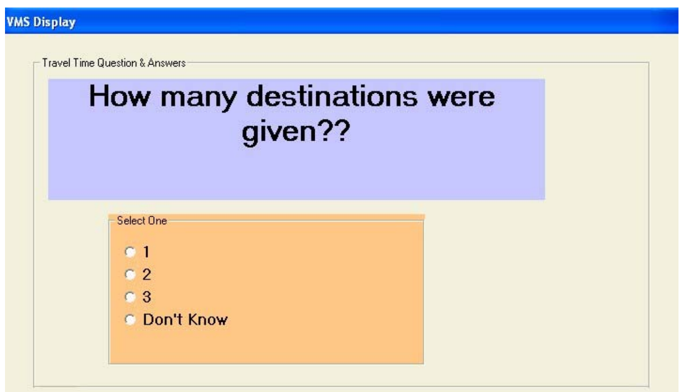



**Figure 8. Example verification question**

- Participants made three ratings using a 10-point scale (see Figure 9):
  - How easy was it for you to get the information you need from the sign?
  - How willing are you to change to a different route?
  - How confident are you that you know the best route right now?

Each scenario introduction was followed by a block of approximately 5 to 14 trials (unique sign displays) that were associated with that scenario. When all the participants in the group finished a block, the next block began. There were 8 experimental blocks. Base scenarios (moderate congestion and morning commute clips on the familiar road) contained from 12 to 14 trials for each block. Alternative blocks (heavy traffic, heavy evening traffic, and unfamiliar roads) contained 5 or 6 trials per block. The first block was a standard block and then was followed by a shorter alternative block. These blocks alternated until all 8 were presented. Participants were given a 15-minute break following the fifth block. The final block contained all diagrammatic signs (no diagrammatic signs were presented earlier in the experimental task). All standard blocks included at least one benchmark sign and one two-phase sign. Also, there were two orders presented—the first semi-random order was presented in reverse (although the diagrammatic block was still the final set of items presented).

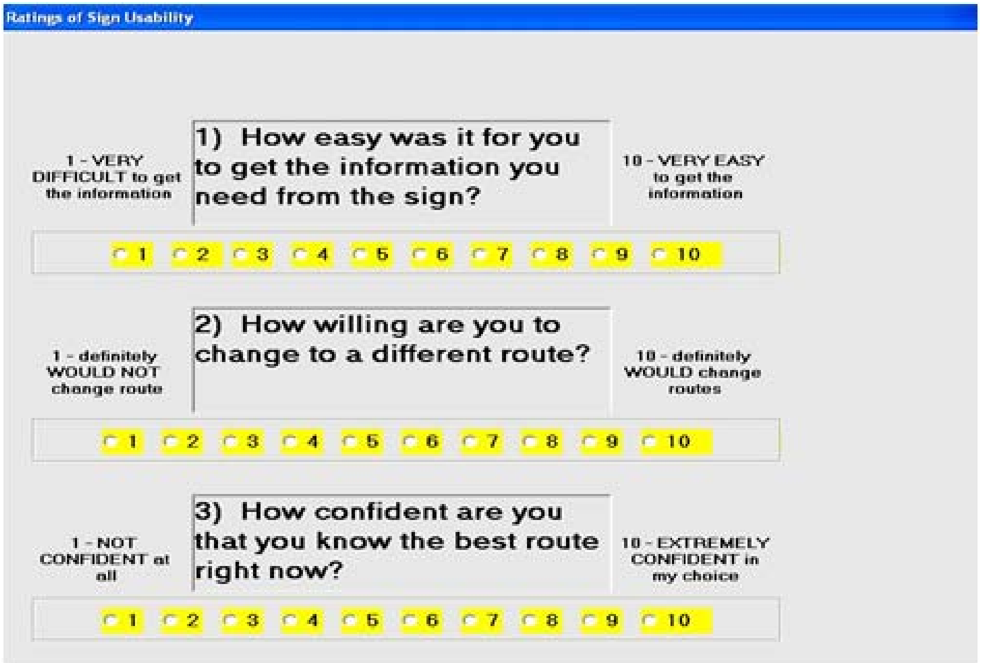



**Figure 9. Rating screen**

## *Results*

### ANOVAs for Sign Features and Conditions

Table 1 summarizes the results of a series of analyses of variance, conducted on subsets of the data. The rows of the table indicate the sign feature or condition being analyzed. The center columns show the dependent measures. The final column indicates the set of signs included in the particular analysis. The sign numbers refer to the labeling of the examples in Appendix E.

**Table 1. Significance of sign dimensions by latency and ratings on processing ease, diversion likelihood, and confidence**

| Factor | Latency | Ease of Processing | Diversion likelihood | Confidence | Signs |
|---|---|---|---|---|---|
| Number of destinations | + | + | | + | Base1/19, 2, 3 |
| Number of phases | N/A | + | | | Base1/19, 36 |
| Time stamp | + | | | | Base1/19, 5, 6, 7 |
| Time range | | | + | | Base1/19, 8, 9, 10 |
| Trend arrow | + | + | | + | Base1/19, 11, 12, 13, 37 |
| Alt route | + | | + | + | Base1/19, 16, 17 |
| Layout | | + | | | Base1/19, 20, 21 |
| Benchmarks | + | + | | | Benchmarks 1-6 |
| Diagrammatic (a) | | + | | + | Base1, Base2, Sign19 |
| Diagrammatic (b) | + | + | | + | Base2, Diagram 1-9 |
| Traffic info | + | + | + | | Base1/19, 22, 23, 34 |
| Destination type | + | + | | + | Base1/19, 24, 25, 26, 27 |
| Distance info | + | | | | Base1/19, 28 |
| Speed | + | + | | + | Base1/19, 29 |
| Delay info | | | | | Base1/19, 30 |
| Color-coded text | + | | | + | Base1/19, 31 |
| HOV savings info | + | + | | + | Base1/19, 15, 32 |
| Header | | | | | Base1/19, 39 |
| Time unit | + | + | | + | Base1/19, 38 |
| Fixed header | | + | | | Base1/19, 33 |
| Fixed background | | + | | | Base1/19, 35 |
| Congestion level | | | | | Base1, Hmorning1-6, Signs2,17,19,20,21, 32,40,43,44 |
| Time of day | | | | | Heavymorning1-5 Heavyevening1-5 |
| Familiarity | | * | | + | Base1, Unfamiliar1-5, Signs2,17,19,20,21, 32,40,43,44 |

Note: + = $p < .05$; * = $p < .10$

SAS PROC MIXED was used to analyze latency, subjective ease of processing, ratings of diversion likelihood, and confidence ratings for each of the sign dimensions. Each sign dimension was represented by one or more signs that were constructed a priori. This dimension was compared to a set of base signs which were comparable except for the characteristic being varied. Participant and Sign were included as random effects while the specific dimension was entered into the model as a fixed effect. The “Latency” column shows the significance for the time it took a participant to register a mouse click when completing sign viewing. The column entitled “Ease of Processing” gives the significance for self-reported ease of processing ratings on a scale from 1 to 10, with 1 being “extremely difficult” and 10 being “extremely easy”. Similarly, the remaining two columns give the significance for self-report ratings of the likelihood to divert on a 10-point scale and confidence in the choice of diverting. For specific mean values, refer to Appendix F. The following discussion follows the order of dimensions in the table above.

*Destinations*. Signs with four destinations (Sign 3) took longer to process than signs with three destinations (Sign 2), which in turn took longer to process than signs with two destinations (Base1 and Sign 19). This relative ordering also held for Ease of Processing and Confidence.

Base1


Sign 19


Sign 2


Sign 3


*Phases.* Participants found it easier to process one- phase signs. Ratings of diversion and confidence were not significant. Latency was not analyzed because of the two-phase presentation of the information.

Base1


Sign 19


Sign 36 (two phases)


*Timestamp*. Participants took longer to read the sign when there was a timestamp. No version of a timestamp influenced ease of processing or predicted a significant increase in drivers' confidence in their ability to determine the best route alternative.

| | |
|---|---|
| Base1<br> | Sign 19<br> |
| Sign 5<br> | Sign 6<br> |
| Sign 7<br> | |

*Time range*. There was no overall model difference in latency, but there were small differences between specific signs. Sign 9 took longer to process than the standard signs (Base1 and Sign 19) and the open-ended time range (Sign 10). Similarly, the subjective ease of processing ratings did not yield a significant difference, but the open-ended sign (Sign 10) was rated as easier to process than the 3 min range sign (Sign 8) and the 5 min range sign (Sign 9). There was a significant effect of diversion likelihood ratings, with drivers more likely to divert for the open-ended sign (Sign 10). It is possible that the open-ended range (denote by a "+") implies serious congestion or possibly a major traffic disruption that should be avoided.

| | |
|---|---|
| Base1<br> | Sign 19<br> |
| Sign 8<br> | Sign 9<br> |
| Sign 10<br> | |

*Trend arrow*. Signs 11, 12, and 37 took longer to process than the baseline signs (Base1 and Sign 19). Also, signs without a trend arrow were rated as easier to process. There was a difference in confidence, with drivers being more confident without at a trend arrow. Also, drivers were more confident in their choice for signs that have individual destination trend arrows (Signs 11 and 12) than with trend words (Sign 37).

<table>
<tr><td>Base1<br>
</td><td>Sign 19<br>
</td></tr>
<tr><td>Sign 11<br>
</td><td>Sign 12<br>
</td></tr>
<tr><td>Sign 37<br>
</td><td></td></tr>
</table>

*Alternate route information*. The latency difference was driven by longer processing times for signs with alternate information given, which is expected. Drivers were more likely to choose to divert if given general alternate route warnings (Sign 16) or specific alternate routes (Sign 17). Also, drivers were more confident without alternate route information given, and were least confident when an alternative warning was given with no route information (Sign 17).

<table>
<tr><td>Base1<br>
</td><td>Sign 19<br>
</td></tr>
<tr><td>Sign 16<br>
</td><td>Sign 17<br>
</td></tr>
</table>

*Layout*. Only ease of processing ratings showed significant differences for the type of layout. Sign 20 was rated as easiest, although it was very close to the base signs. Sign 21 was considered the most difficult to process.

Base1

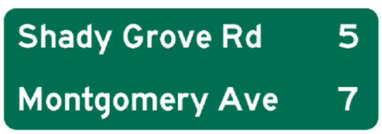

Sign 19


Sign 20


Sign 21

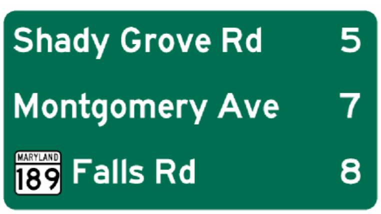

*Benchmarks.* Response latency and rated ease of processing generally increased with the number of destinations shown on the sign. A notable deviation, however, was the ease of processing rating for Benchmark 6, which was unexpectedly high. Upon review, this appears to be an artifact related to the particular follow-up question used for this trial.

Bench 1



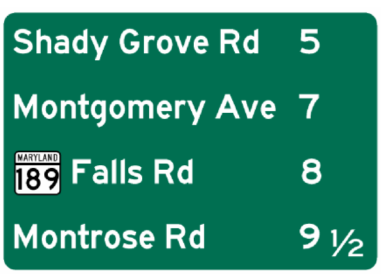

Bench 2


Bench 3




Bench 4


Bench 5




Bench 6

*Diagrammatic*. There are two analyses done to investigate the role of diagrammatic representations in traffic signs:

a) The base diagrammatic sign (Base2) was compared to two text signs with similar content (Base1, Sign 19). There was no difference in the time it took to process either type of sign or in the likelihood to divert. Drivers had more confidence in text signs and rated them as easier to process.

b) Diagrammatic signs were compared to one another. Participants took longer to process the more complex diagrammatic signs (Diagram 5-9) than simpler diagrammatic signs (e.g., Base2, Diagram 1, 2, 3). Similarly, simpler diagrammatic signs were also rated easier to process than complex signs. Drivers were more confident with simple diagrammatic signs and were less confident with complex diagrammatic signs. There was no difference in likelihood to divert ratings.

Base1


Sign 19


Base 2

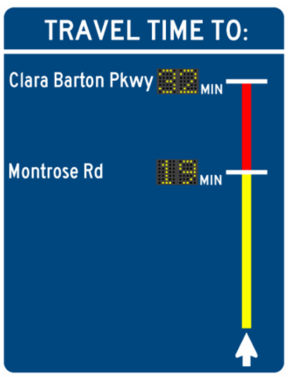



Diagram 1


Diagram 2

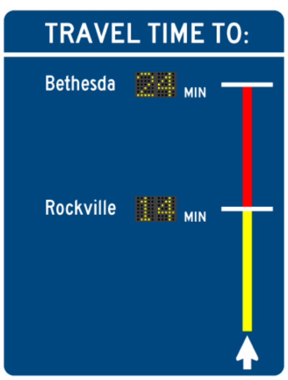



Diagram 3

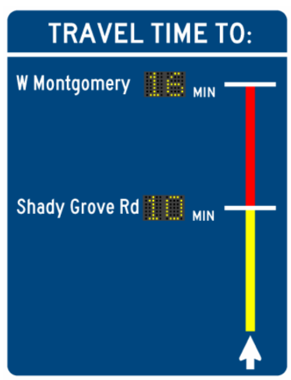


Diagram 4

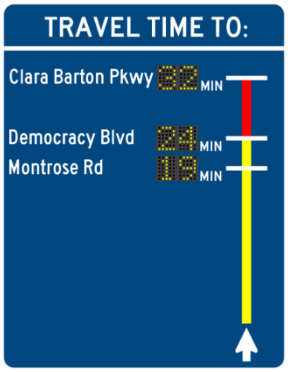



Diagram 5


Diagram 6


Diagram 7

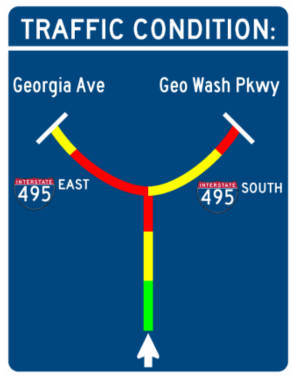



Diagram 8

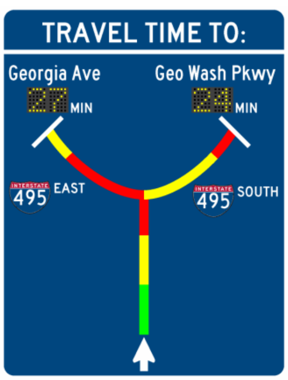
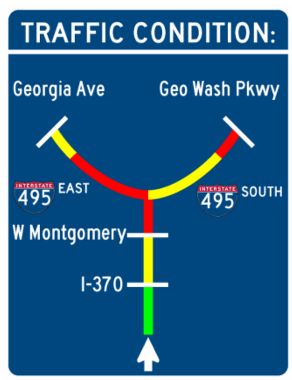



Diagram 9



*Traffic information*. Participants processed base signs faster than Signs 22 and 23, but not 34. Sign 34 was also processed faster than Sign 22. As for self-reported ease of processing, the effect is driven by Sign 34 being rated higher than the other signs. Drivers gave higher likelihood of diversion ratings for signs 23 and 34.

<table>
<tr>
<td>Base1<br>
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<td>Sign 19<br>
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<td>Sign 22<br>
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<td>Sign 23<br>
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<tr>
<td>Sign 34<br>
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</table>

*Destination type*. Drivers processed the base signs (Base1 and Sign 19) and Sign 27 (town labels) the fastest. Base signs (Base1 and Sign 19) and Sign 27 were rated as easier to process than either Sign 24 or Sign 26. Also, drivers were more confident with the base signs (Base1 and Sign 19) than Sign 24 and Sign 26.

<table>
<tr>
<td>Base1<br>
</td>
<td>Sign 19<br>
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<tr>
<td>Sign 24<br>
</td>
<td>Sign 25<br>
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<tr>
<td>Sign 26<br>
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<td>Sign 27<br>
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</table>

*Distance information*. Drivers took longer to process the sign with distance-to-destination information (Sign 28). There were no other significant differences compared to the base signs.

| | |
|---|---|
| Base1<br><br> | Sign 19<br><br> |
| Sign 28<br><br> | |

*Speed*. Drivers took longer to process the sign that showed speed instead of travel time to exits (Sign 29 versus Base1 and Sign 19). Drivers also reported that the signs with speed at destinations were harder to process and resulted in less confidence.

| | |
|---|---|
| Base1<br><br> | Sign 19<br><br> |
| Sign 29<br><br> | |

*Delay information*. There were no significant differences between signs on the latency measure or any of the self-report ratings.

| | |
|---|---|
| Base1<br><br> | Sign 19<br><br> |
| Sign 30<br><br> | |

*Color-coded text*. Drivers took longer to process the sign with color-coded text. Also, the color-coded text sign was reported to be slightly more difficult to process, although this difference was not significant. Finally, drivers were less confident with the color-coded text sign.

<table>
<tr><td>Base1<br></td><td>Sign 19<br></td></tr>
<tr><td>Sign 31<br></td><td></td></tr>
</table>

*HOV savings information*. Among this group of signs, Sign 15 took the longest to process, was rated as the most difficult to process, and made drivers least confident in making decisions.

<table>
<tr><td>Base1<br></td><td>Sign 19<br></td></tr>
<tr><td>Sign 15<br></td><td>Sign 32<br></td></tr>
</table>

*Header*. There were no significant differences between the signs across measures, though there was a small, insignificant increase in confidence when a sign included a header.

<table>
<tr><td>Base1<br></td><td>Sign 19<br></td></tr>
<tr><td>Sign 39<br></td><td></td></tr>
</table>

*Fixed header*. Drivers rated the sign with a fixed header more difficult to process. There were no other significant differences between the signs.

| | |
|---|---|
| Base1<br> | Sign 19<br> |
| Sign 33<br> | |

*Time unit*. Drivers took longer to process the sign without time units provided (Sign 38). Also, drivers rated the lack of time unit as more difficult to process and they had less confidence in decisions based on the sign without time units.

| | |
|---|---|
| Base1<br> | Sign 19<br> |
| Sign 38<br> | |

*Fixed background*. Drivers rated the sign with a fixed background (Sign 35 )as easier to process. Also, although not significant, there was a slight trend in the direction of fixed signs yielding slightly higher likelihood of diversion ratings, and slightly higher confidence in decisions based on fixed signs.

| | |
|---|---|
| Base1<br> | Sign 19<br> |
| Sign 35<br> | |

*Congestion level*. Congestion level did not affect latency to process the signs, subjective ease of processing ratings, likelihood to divert, or confidence. The signs were constructed to be paired between both groups (Hmorning 1 is comparable to Base1 and Sign 19, etc.). There are a few differences to note: a) when given alternate route time information in heavy traffic (Hmorning 3), participants are more likely to increase their likelihood to divert than during normal traffic (Sign 17), b) when given "HOV Saves" information during heavy traffic, participants are more willing to divert than in normal traffic (Hmorning 4 versus Sign 32, respectively). Note that there was no difference in diversion likelihood when given alternate route information only (without time) in a two-phase sign (Sign 44 versus Hmorning 5).

Base1


Hmorning 1

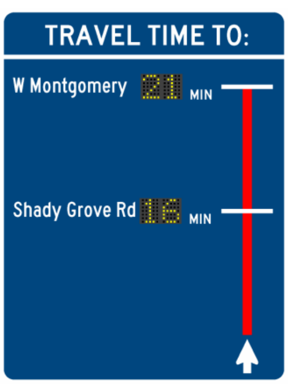

Hmorning 2


Hmorning 3


Hmorning 4


Hmorning 5 (two phase)


Hmorning 6




Sign 2


Sign 17


Sign 19

<table>
<tr><td>Sign 20<br><br></td><td>Sign 21<br><br></td></tr>
<tr><td>Sign 32<br><br></td><td>Sign 40<br><br></td></tr>
<tr><td>Sign 43 (two phase)<br><br></td><td>Sign 44 (two phase)<br><br></td></tr>
</table>

*Time of day*. Time of day did not affect latency to process the signs, subjective ease of processing ratings, likelihood to divert, or confidence. The signs were constructed to be paired between both groups (Hmorning 1 is comparable to Hevening 1, etc.). Direct comparisons of comparable signs did not yield any meaningful differences.

<table>
<tr><td>Hmorning 1<br><br></td><td>Hmorning 2<br><br></td></tr>
<tr><td>Hmorning 3<br><br></td><td>Hmorning 4<br><br></td></tr>
<tr><td>Hmorning 5 (two phase)<br><br></td><td>Hevening 1<br><br></td></tr>
</table>

Hevening 2


Hevening 3


Hevening 4


Hevening 5 (two phase)


*Familiarity*. Familiarity did not affect latency to process the signs, subjective ease of processing ratings (although there was a trend toward familiar signs being easier to process), and likelihood to divert. Drivers were more confident with the familiar signs than with the unfamiliar signs, though there was no effect when alternate route information was provided (Sign 17 versus Unfamiliar 3). The signs were constructed to be paired between both groups (Unfamiliar 1 is comparable to Base1 and Sign 19, etc.). Within these pairs, there was one difference to note: there were slightly higher ease of processing ratings for the familiar two phase signs (Signs 43 and 40 versus Unfamiliar 5).

Base1


Unfamiliar 1


Unfamiliar 2


Unfamiliar 3


Unfamiliar 4


Unfamiliar 5 (two phase)

Sign 2


Sign 17


Sign 19


Sign 20


Sign 21


Sign 32


Sign 40


Sign 43


Sign 44 (two phase)



## Relationships among Measures

Figure 10 shows a scatterplots of latency versus ease of processing ratings for each sign. Two-phase signs have been excluded because they had a fixed presentation of 6 seconds total for both phases, so latency data were not meaningful. There is a significant and strong negative correlation between latency and ease of processing ratings, where a higher rating (i.e., easier to process) also meant a shorter processing time. Diagrammatic signs have a stronger negative relation between these two variables than text signs ($r = -.80$ and $r = -.41$, respectively). Separate regression lines are shown for text signs and diagrammatic signs to show these relationships. There was also a strong positive correlation between ease of processing rating and confidence in route choice (.91). A scatterplot showing the relationship of these variables is presented in Figure 11. Signs that were given higher confidence ratings were also considered easier to process.

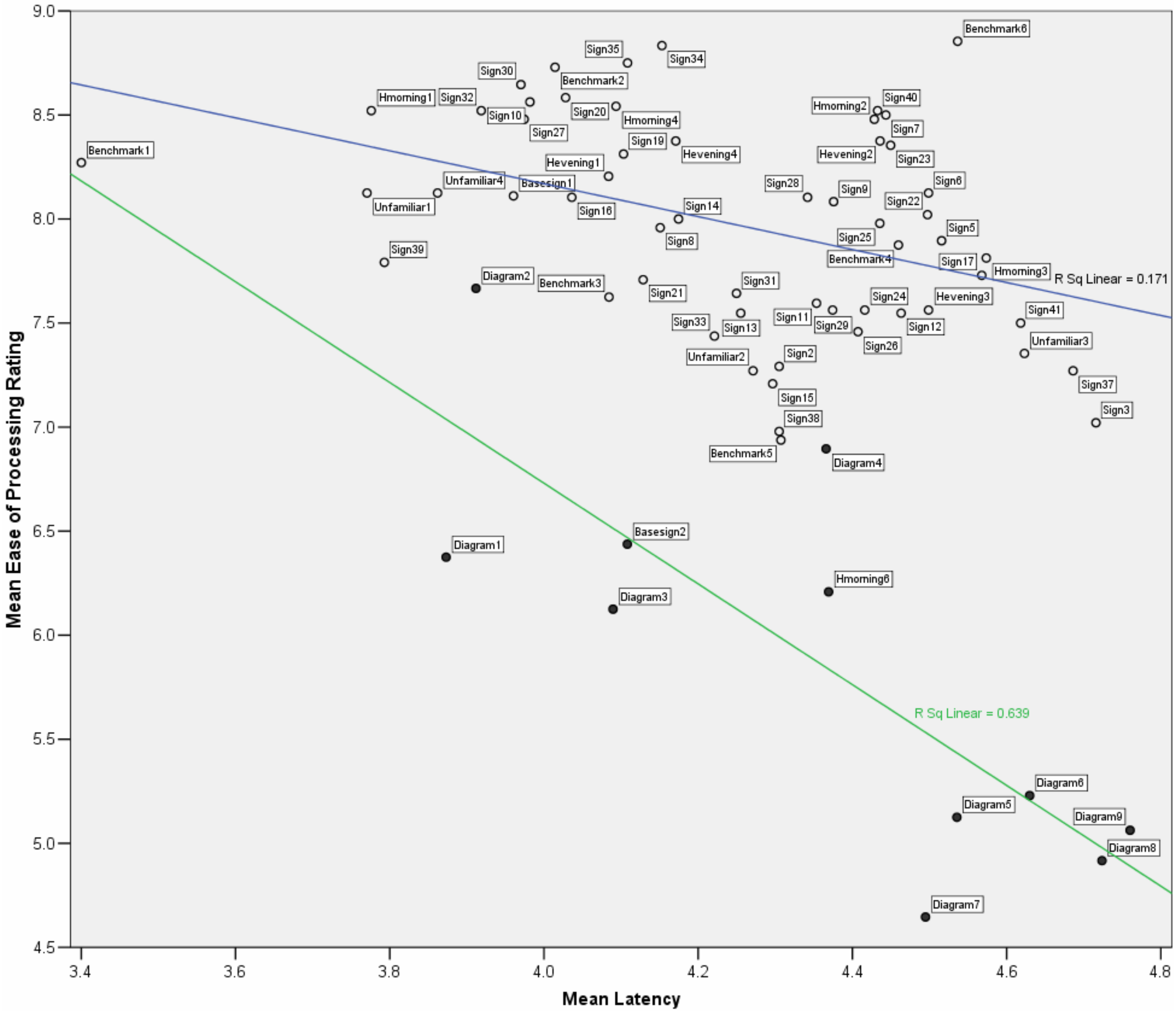



**Figure 10. Scatterplot of mean latency versus mean ease of processing rating for each sign**

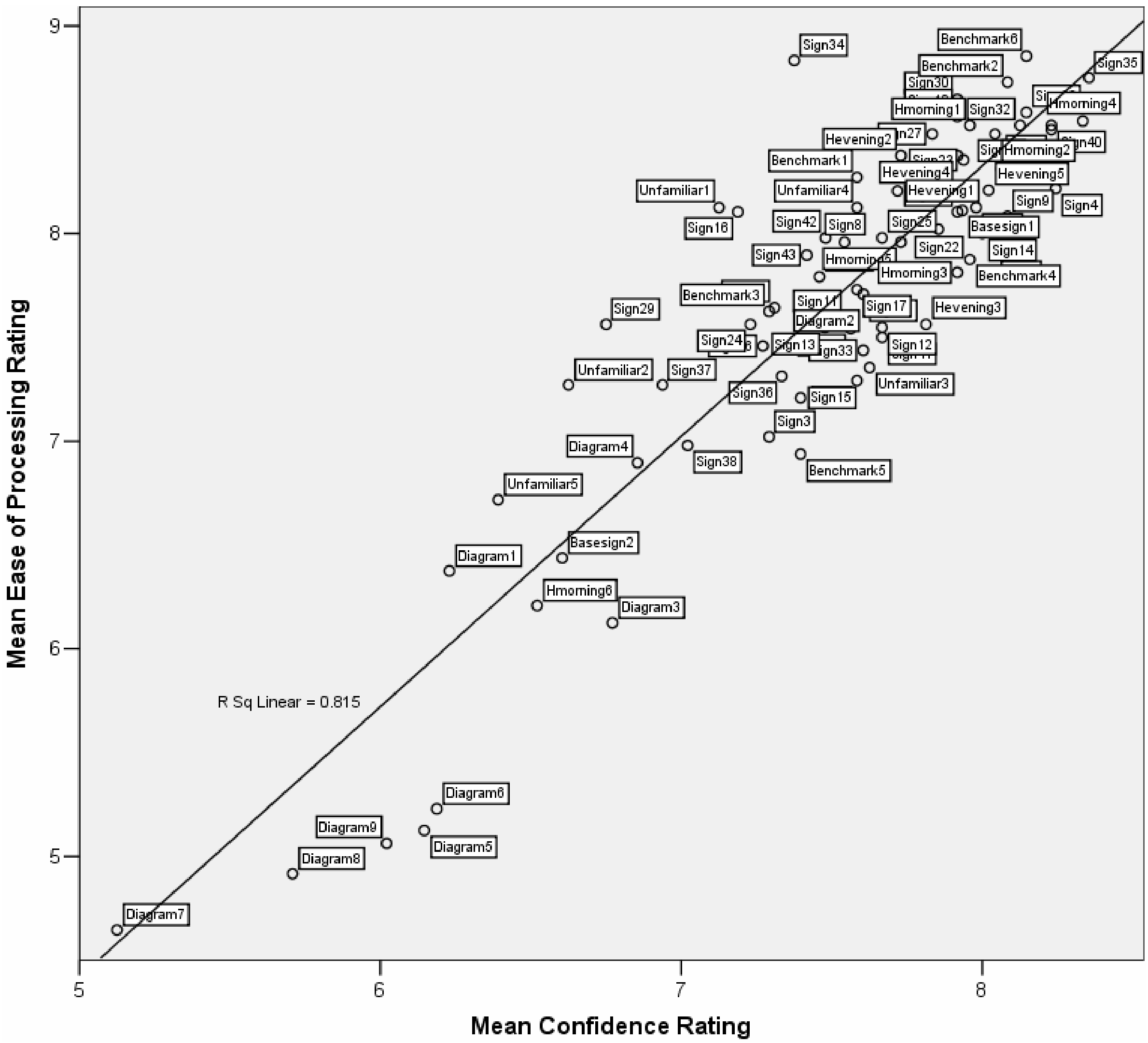



**Figure 11. Scatterplot of mean confidence rating versus mean ease of processing rating for each sign**

*Relationship of information units and benchmark signs to latency*. The various signs used in the study can be categorized based on the amount of information in the sign. To accomplish this, we used the method suggested by Ullman, Ullman, Dudek, and Williams (2007) where an information unit is defined as the answer to a question. So for example, the sign at right has seven information units: one travel time header (What is this sign showing?), three destinations (What is the destination?), and three travel times (How long will it take?).


Figure 12 is a scatterplot of latency by information units in the sign. Since the determination of information is somewhat ambiguous for diagrammatic signs, and since latency and ease of processing data were quite different between text and diagrammatic signs, the analysis of information units was confined to text signs only. There is a substantial linear relationship (r = .65), with an approximate increase of about 0.15 seconds of viewing time required for each additional information unit. As the figure indicates, although the number of information units in the sign is an important determinant of how much time is required to deal with the travel time display, it is not the only factor. There is considerable variability around the trend line.

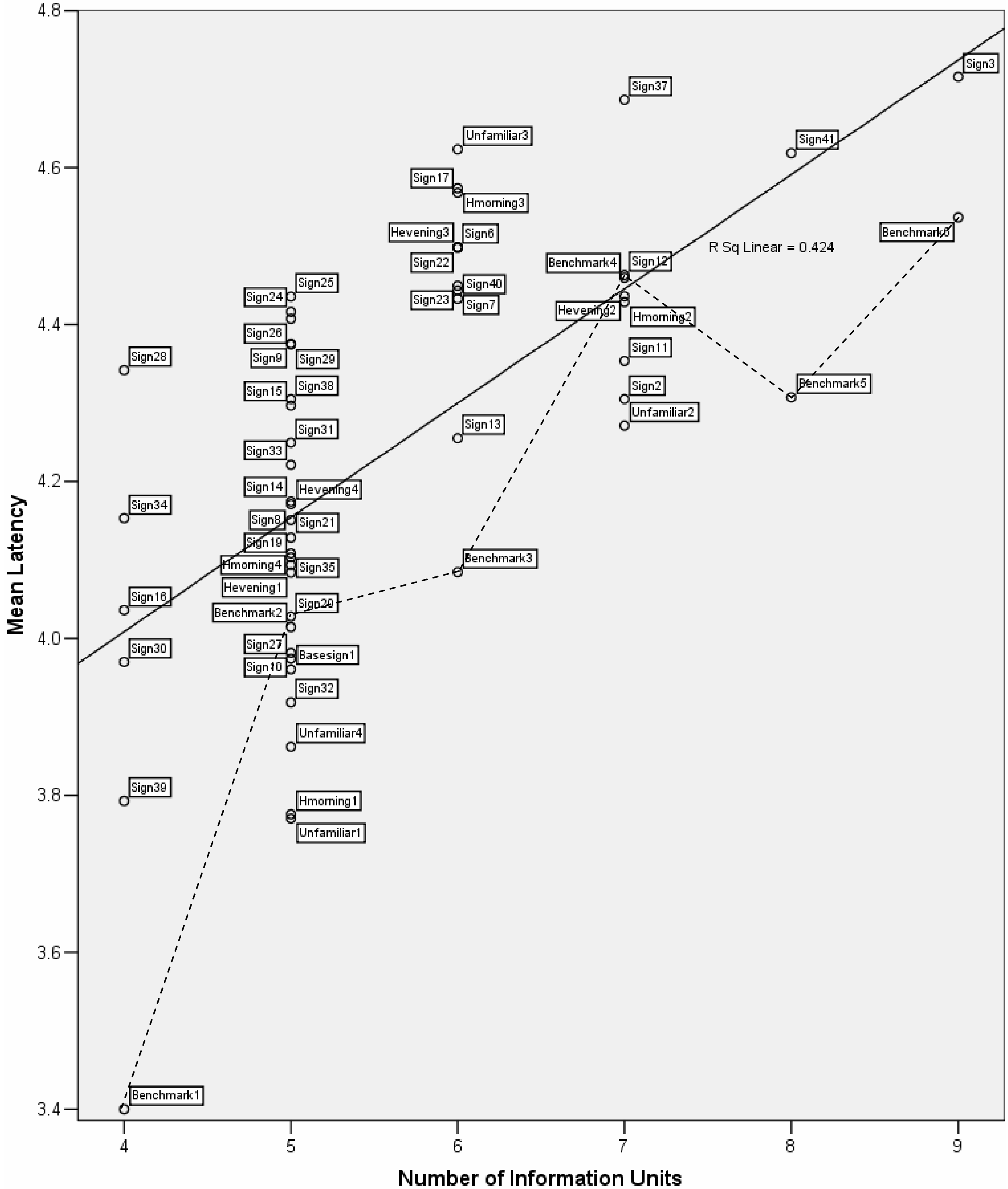



**Figure 12. Scatterplot of number of information units versus mean processing latency for each sign**

The set of six benchmark signs is included in Figure 12 and the data points for these are shown connected by the dashed line. One may argue that travel time displays that take as long or longer to process than static signs not permitted by the MUTCD may be too demanding of driver attention. Using this logic, those travel time displays with mean latencies 4.0 seconds or less are acceptable. Those with latencies of 4.4 seconds or greater are unacceptable. The range between 4.0 and 4.4 seconds is somewhat ambiguous, but based on Benchmark 5, those above approximately 4.25 seconds are questionable.

# Summary and Recommendations

## *Summary of Key Findings*

Based on the results of the driver logs, focus groups, and laboratory study, a number of findings emerge. Drivers generally have positive attitudes toward CMS-based real time travel time displays. They like having this information, generally feel it to be reasonably accurate, and do not feel there are notable problems with available time to read the signs, distraction, or negative effects on traffic (e.g., slowing, aggression). At the same time, however, it is difficult to find substantial effects of freeway-based travel time displays on actual route decisions. Drivers in the focus group/log study did not self-report much influence and the laboratory study found few cases where a change of route was reported as likely. People appear to like travel time displays because they help set expectations for the trip and reduce frustration. In many cases, commuters did not feel that there was a good viable option for an alternative route, except under extreme conditions.

Drivers in the focus group/log study generally got information on travel time or congestion from the CMS displays and from radio and television traffic reports. Drivers often reported that radio and television traffic reports had more of an effect on trip decisions because these sources could be used before starting a trip or before committing to a freeway route. There was not much reported use of traffic web sites or other resources. This circumstance could change with changes in technology or greater familiarity with information sources, but generally the commuters in this study did not seek out addition pre-trip information or use other en route sources.

Commuters understand that the travel time displays are estimates and generally do not feel that it is necessary to show a time range. In the laboratory study, providing a time range, rather than a single time estimate, did not influence ratings of confidence and only influenced diversion likelihood for the special case where there was an open-ended interval due to serious congestion (e.g., 30+ MIN). However, commuters do not have a good sense of how frequently travel times are updated. Consequently, they have questions about the accuracy or reliability of the information. There was not good consensus regarding how accurate travel times are. In the laboratory study, time stamps did not influence the participants' confidence ratings in their knowledge of the best route to take. It should also be noted that participants tend to feel quite confident in their route choice decisions, so there may be something of a ceiling effect. In the driver log results, about 90% of the trip logs indicated moderate or strong agreement with the statement "I am confident that I made the best decisions about my route." For trips where traffic conditions were good, the mean rating of agreement with the statement was about 4.7 on the 5-point scale. Even for trips where traffic was worse than usual, the mean ratings exceeded 4.0. Likewise in the laboratory study, ratings of confidence in knowing the best route to take were quite high (between 7 and 9 on the 10-point scale, excluding the diagrammatic displays). Thus commuters appear to feel quite confident in their decisions.

The focus group participants expressed particular concern about the accuracy of travel time estimates during periods when congestion was increasing during peak periods. One recommendation was to provide some indication of the current trend (e.g., upward arrow if travel times are increasing). Versions of such a sign did not show any benefit in the laboratory testing (in fact, drivers rated more confidence in their route choice when there was no trend indicator). However, ratings may have been influenced by the unfamiliarity of the trend displays and the concept may merit further investigation.

The ability to rapidly process the information in a travel time display is related to the amount of information in the sign. Current practice limits most travel time CMS displays to three lines of text and commuters report little difficulty in dealing with typical displays. In the lab study, experimental four-line displays frequently required more time to process than benchmark signs, based on MUTCD-acceptable signs. Even among displays limited to three lines of text, there was considerable variability in how much time was required to view the signs. Based upon the benchmark signs, travel time displays that require no more than 4.0 seconds of viewing time (under the conditions of the experiment) should cause little difficulty, while those requiring at least 4.4 seconds of viewing time clearly exceed benchmark levels. While simple diagrammatic signs in the experiment met viewing time criteria, the more complex diagrammatic signs typically exceeded the 4.4 second criterion. Of the text signs that exceeded the criterion, they generally were those with four lines of text. This is the case even where one of the text lines was only a header (e.g., TRAVEL TIME TO). While participants in the focus groups expressed the belief that they could handle more information, these data suggest that the three text-line format is a reasonable limit. Emerging technology (e.g., full matrix sign displays) may make other formats more feasible, but adding more information may not be warranted. Expressed in terms of units of information, the findings of the lab experiment suggest that viewing times become questionable where there are approximately six units of information in the display.

This project’s initial review of national practice found a variety of practices in terms of how travel time information is laid out on the display (e.g., centering versus left justification) and in terms of any supplemental or alternative information that may be included (e.g., distance, speed). Several layouts were included in the laboratory study. Layout did not influence the time required to process the sign, but one version (right justification) was rated as more difficult to process. Focus group discussion suggested that people favor a layout where the destination is left justified and the travel time is right justified, which is in fact common in practice. Focus group participants expressed a preference for travel time over speed data and the laboratory study supported this in finding that a version showing speed instead of time took longer to process, was rated as more difficult to process, and resulted in lower confidence. Including distance to the destination did not influence any of the ratings, though it did require more time to process. Distance information was not seen as valuable in the focus groups, either. Removing the header (TRAVEL TIME TO) from the display did not have any effect on processing time or any of the ratings. This suggests it may be possible to eliminate the header in favor of an additional destination or other information without adverse effects. The presence of the time unit (MIN) did have an effect. Even though the header implies that the numeric display is of travel time, when MIN was eliminated, the sign took longer to process and participants rated it as more difficult and it resulted in lower confidence. Color coding the travel time in the text displays (red for heavier congestion) was not beneficial. The color version took longer to process and participants rated lower confidence. All of this (together with the earlier discussion of time stamps and trend indications) suggests that a reasonable travel time CMS display provides a left-justified destination, a right-justified travel time with minutes indicated, but not speed, distance, time range, time stamp, trend, or color coding. However, it should be noted that there may be effects of novelty or familiarity in the laboratory experiment, since participants did not have pre-exposure to the set of displays, or prior experience with actual travel time displays. There was no intent to "teach" the viewers about each display, since part of the interest was in how immediately understandable each design was. It is possible that some of these features might have benefits if the public becomes familiar with them.

Diagrammatic signs may hold some promise for travel time applications if they are graphically simple. The focus group discussants liked certain features of these signs, such as being able to determine the location or extent of congestion, compare alternative paths, or detect congestion levels at a glance through color coding. However, they expressed concern about reading and interpreting more complex examples while driving. The lab study found that simple diagrammatic signs, with linear depictions of the current route, were comparable to text signs in terms of the time required and diversion likelihood, although they were rated as more difficult to process. More complex diagrammatic signs, showing schematic roadways, were among the signs that took longest to process and were rated by far the most difficult to process.

Certain features of signs or situations were associated with a greater willingness to divert to another route. The laboratory experiment had limitations in this regard, since not all signs were evaluated at identical locations. However, features associated with a greater tendency toward diversion may still be noted. They were in general what might be expected. These included: specification of an alternate route; specific statements regarding heavy congestion; an open-ended time estimate (30+ MIN); and scenarios that were based on heavy congestion. The highest ratings for diversion were for four-line displays that specifically stated "USE ALT RTE" and also indicated that route and its travel time (VIA RT 355 12 MIN).

## *Recommendations*

Recommendations for the design of en route real-time travel time displays follow, based on the project findings. Because the extent of data on any particular feature is limited, the recommendations should be treated as preliminary. Also, these general recommendations may not be consistent with some local signing practices and so may have to be adapted. It may also be noted that in contrast to some foreign applications, travel time displays in the United States are typically provided via CMSs that are not specifically dedicated to travel time messages. Travel time information may be the default when other, higher-priority messages are not warranted (e.g., incidents, adverse weather, AMBER Alerts). This may preclude the use of fixed sign elements that simplify the sign and allow additional sorts or amounts of information. The recommendations below are based on normal U.S. practice and the available findings.

- Provide travel times to destinations, rather than travel speeds or descriptions of congestion. Indicate the time units (MIN).
- Left justify the destinations and right justify the travel times.
- Normally describe destinations as street names or towns, assuming the display is intended primarily for regular commuters. Exit numbers are not recommended.

- There does not appear to be a benefit to including distance to destinations, time stamps, travel time trend indicators, or color coding of text. Since trend indicators and color coding are novel, there may be potential benefits if the public becomes familiar with these concepts, but in the absence of data on this, they are not recommended.
- Limit displays to three lines of text and no more than six information units.
- Simple fixed diagrammatic signs, with a linear depiction of the roadway and including a dynamic display of travel time, are acceptable. More complex map diagrams and/or diagrams with more than three destinations appear to be too difficult to readily interpret under driving conditions.
- Route diversion appears difficult to encourage with freeway-based travel time displays. Drivers frequently feel committed to their original decision or feel that there is no good alternative route at that point. There is some indication that travel time information may have more influence on route diversion if it is provided prior to a freeway entrance (on the surface street approach to the freeway). There is some limited use of arterially-located travel time displays in the United States, but no formal assessment. Exploration of travel time displays on approaches to freeways is suggested, but specific recommendations for their use cannot be provided.
- To maximize route diversion in response to a freeway-based travel time display, the following display features should be considered:
    - Specifically recommend using an alternate route (USE ALT RTE)
    - Indicate a specific alternate route (VIA RT 355)
    - Indicate major delay or incident (MAJOR DELAY)
    - Provide an open-ended travel time estimate (30+ MIN)
    - Show travel times for both current and alternate route
- Convey to the public that travel times are updated frequently, but do not use the changeable message display for this purpose. Consider a fixed sign component (e.g., UPDATED EVERY 3 MINTUES) and/or a public education campaign.

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# Appendix A: Real-Time Travel Time Summary of Literature and Practice

# Audience for Travel Time Information

1. Who is the audience for travel time information?
    - Portland identified 4 classes of driver: local commuter, local non-commuter, non-local commuter, non-local non-commuter. Officials decided that local commuters would be the primary audience for travel time information and designed system accordingly (Oregon Department of Transportation, 2005).
    - Forth Worth designs travel time signs to accommodate local drivers because 90% of traffic on roads during rush hours is local (Connell, pc).
    - San Antonio designs its travel time signs primarily to accommodate local commuters (Fariello, pc).
    - Missouri designs its travel time signs primarily to accommodate local commuters (Sommerhauser, pc).
    - A statewide survey in Florida found that drivers aged 18-49 were most likely to drive during rush hour while older drivers were most likely to drive midday between rush hours (Executive Board Workshop Briefing Regarding Customer Satisfaction Survey)
2. What are the best practices to accommodate drivers who are *familiar* with an area (e.g., residents, commuters) versus those who are *unfamiliar* with an area (e.g., tourists, business visitors)?
    - Drivers who are familiar with an area have higher expectations for information accuracy than unfamiliar drivers (Campbell et al., 1998).
    - FHWA suggests that travel time signs might display distance to destinations rather than, or in addition to, destination name because drivers unfamiliar with an area might not know how to interpret a travel time to a destination of unknown distance (Meehan, 2005a). Travel time CMS in Atlanta, Nashville, Missouri, and Baton Rouge include distance to destination.
    - Orlando showed delay time rather than travel time until June, 2007 when they changed software providers. The switch to travel time was made to ensure consistency with Florida's 511 practices and to comply with the federal grant that provides funding for the travel time system (Heller, pc).
    - Wisconsin recommends targeting messages to commuters during rush hours and to general traffic during other hours. Wisconsin emphasizes use of landmarks (e.g., downtown, stadium) as travel time destinations during rush hours. Outside of rush hour, Wisconsin primarily uses destinations that are used on static signs or that are easily located on maps. For example, freeway interchanges should be identified by cross street identifier rather than interchange name (e.g., Zoo) for general traffic, or distances should be used rather than landmarks (Wisconsin Department of Transportation, 2006).
    - San Antonio often uses interstates as destinations because they are useful and relatively familiar landmarks for all drivers, familiar and unfamiliar (Strain, 2005).
    - Idaho plans to use common names for destinations (e.g., Boise Airport, City Center) that will be meaningful to drivers unfamiliar with the area (Koeberlein, pc).
    - Delay time can be good for familiar drivers like commuters, but others will have little sense of what it means (Dembowski, pc).

- o Utah's current system is only especially useful to drivers with a high degree of local knowledge, but the upgraded system will add distance to destination to CMS and use landmarks in place of some road names (especially for distance destinations) (Clayton, pc).
- o Although Missouri considers local drivers and commuters to be the primary audience for travel times, distance to destination was added to CMS as a compromise to accommodate drivers unfamiliar with the area (Sommerhauser, pc).

3. What are the particular information needs and preferences of commercial vehicle drivers and emergency vehicle drivers?
   - o Commercial drivers often work on tight schedules and may find travel time especially useful to plan around delays (Clayton, pc).

## Driver Assumptions about Travel Time System

4. How do drivers believe that travel time is calculated and how does this affect their trust and behavior? How precise do they expect travel time estimates to be?
   - o A lab study found that people inherently understand that travel time is an estimate and the time on the board doesn't represent a precise prediction; however, drivers can use their knowledge of local traffic patterns to predict how travel time has changed since the last measurement, so the authors recommend adding time of most recent measurement (Dudek, Trout, et al., 2000). Only Houston appears to include time of most recent measurement on travel time CMS.
5. Do drivers attribute erroneous travel time reports to outdated data, generally poor system functionality, or an occasional system failure?
   - o
6. How do drivers interpret the presence of non-travel time message on CMS that normally displays travel time? Do drivers understand that travel time is the default message and that other messages are considered higher priority? Do drivers understand that (in most jurisdictions) travel time is only displayed during certain hours of the day?
   - o
7. How do drivers use travel time CMS in conjunction with other traffic information sources (e.g., radio traffic reports, 511, pre-trip information)?
   - o In the Bay Area, the travel time data used for CMS display is also the basis for 511 travel time reporting, private traffic reporting companies, and news organizations. The consistency between various sources reinforces the validity of the information (Lively, pc).

## Perceived Value of Travel Time Information

8. How does the public feel about travel time information?
   - o In San Antonio, people initially considered travel time a nice-to-have feature, but now that it's been implemented people view it as a necessity (Strain, 2005).
   - o According to a survey conducted in the United Kingdom, people who liked travel time information did so mostly because it keeps them informed; relatively few thought that it minimizes delays, gives advance warning of conditions ahead, or allows better trip/route

planning. Of the few (12%) who didn't like travel time or were uncertain, it was mainly because they believed the information was inaccurate, that the information was irrelevant because there was no alternative to the route, or that travel time would encourage speeding or driver distraction (Edwards, 2006).

- In a 2004 survey, 82% of Houston respondents had a positive opinion of travel time CMS (Texas Department of Transportation, 2005).
- United Kingdom drivers strongly preferred travel time over general information/safety messages (Edwards, 2006).
- United Kingdom drivers thought both travel time (82%) and delay time (91%) were useful (delay time may have rated higher than travel time because travel time is only used when conditions are normal) (Edwards, 2006).
- Travel time information allows drivers to phone ahead and let others know they'll be late in advance (Hoops & Gallegos, 2006).

9. What outreach can be conducted to increase the value that drivers receive from travel time displays?
    - Public feedback can help to identify popular locations to use as travel time destinations (Meehan, 2005b).
    - Jurisdictions can provide notification of planned travel time displays to the public. For instance, San Antonio posted the message "TRAVEL TIMES ARE COMING IN XX DAYS" on CMS (Meehan, 2005b).
    - Public outreach campaigns can help to mitigate driver confusion and slowing following travel time implementation (Meehan, 2005b).

## Message Content / Information Elements

10. What type of information can be provided to drivers regarding traffic conditions?
    - Travel time
    - Average speed of traffic
    - Delay time (time in excess of free-flowing travel time or "normal" travel time)
    - Speed as percentage of free-flowing (e.g., 80%) (Lerner & Llaneras, 2000)
    - Traffic information should be quantitative rather than qualitative (Lerner & Llaneras, 2000).
11. What information do drivers want on CMS?
    - A survey of Houston drivers found that 93% wanted incident reports and 82% wanted travel time. Many drivers though that incident reports were important, but that they need travel time in addition to decide how an incident affects their trips (ITS for Traveler Information).
    - For advanced traveler information systems (ATIS), the most desired/effective information includes incident location, type, and estimated delays associated with incidents, length of backup, suggested alternate routes, and alternate route directions. Traffic maps with incident locations and segment travel times were considered highly desirable (Llaneras et al., 1999; cited in Lerner et al., 2000).
    - Drivers generally want both descriptive information (reason for delay) and temporal information (extent of delay). Descriptive information provides the context for the temporal information (Lerner et al., 1998a).

- Given the scenario of a traffic incident ahead, the information that most drivers want is the location of the incident and the current delay (Lerner et al., 1998a).
- Drivers generally prefer traffic information in terms of time (travel time, delay time) rather than traffic speed (Lerner et al., 1998a).
- Drivers prefer quantitative descriptions of delay rather than qualitative descriptions (Lerner et al., 1998b).
- In a survey, nearly 75% of drivers in the United Kingdom suggested improvements to existing travel time signs. These included (in rank order): information about the reason for delay*, alternate route information, improved accuracy/timeliness of information, improved CMS locations, add more CMS, and include travel speed (Edwards, 2006). *If delay is incident/roadwork related, it is more likely that there is a distinct endpoint to the delay than if delay is just congestion-related.
- A survey of in-vehicle travel time information recipients found that drivers most wanted the exact location of congestion. Following this, backup length, lane closure information, type of problem, and average speed through the area were rated similarly (Minnesota Department of Transportation, 1998).
- An online survey of drivers in response to a work zone speed advisory system (which provided the average speed of traffic through the work zone) found that 51% of drivers wanted CMS to display average speed while 69% wanted CMS to display delay time (Pesti et al., n.d.)

12. What information do transportation agencies include on travel time CMS?
    - In California, delay time was considered good for drivers familiar with an area, but not for unfamiliar drivers who might not know how to interpret it. Travel time was used instead because many areas of California have a significant amount of non local traffic (Jenkinson, pc).
    - Forth Worth specifically uses travel times to major intersections (rather than landmarks or distances) because 90% of the traffic that could use the signs is local traffic (Connell, pc).
    - In San Antonio, distance to destination is not included because there is not enough room on CMS (Fariello, pc).
    - The Transportation Service Center manager for Illinois Department of Transportation believes that drivers' use of travel time CMS varies widely and that it is more meaningful to drivers than congestion information (Galas, pc).
    - A lead ITS engineer for Texas Department of Transportation believes that commuters who drive a route daily develop travel time expectations and can calculate their own delay time based on the difference from normal CMS travel time. Therefore, travel time provides more useful information to commuters than delay time (Fariello, pc).
    - Utah is considering adding distance to destination to travel time CMS because travel times don't mean much unless drivers have a good sense of how far away the destinations are (Clayton, pc).
    - When Utah upgrades its travel time system, distant destinations will be more general and well-known (e.g., Salt Lake City), whereas closer destinations will be more specific, such as landmarks or road names. Although Utah currently only uses road names as destinations, Clayton believes that road names are too specific to mean much to drivers who are a long distance away, and may not have a sense of how far they are from the road. (Clayton, pc).

- Orlando includes travel time, distance, and destination name on CMS. This limits CMS to showing one destination per phase, so two phases are used to show second a second destination (Heller, pc).
- Missouri primarily uses street names that are also listed as exits on static signage as destinations. "Downtown" is used as a destination because it applies to a broad section of drivers whereas relatively few drivers may be familiar with specific exits on the city's Interstate loop. Some drivers have complained that downtown is too vague and they are unsure where downtown begins (Sommerhauser, pc).
- Missouri shows distance to destination because drivers can easily compare distance versus travel time to determine how well traffic is moving (Sommerhauser, pc).
- Missouri opted not to show delay time because they considered it to be confusing to drivers. Travel time is more concrete and meaningful to drivers and implies greater accuracy of calculations (Sommerhauser, pc).

13. Should travel time information be descriptive and/or prescriptive?
    - Descriptive (i.e., state the conditions) is more neutral because it makes no judgment and suggests no action) and allows drivers to interpret the information themselves. Prescriptive (i.e., suggest an action) may require a higher threshold of accuracy (e.g., if you tell people what to do, you'd better be confident that it's the best option). Prescriptive information may have greater influence on driver behavior, which could be positive in the viewpoint of traffic management centers (Lappin & Bottom, 2001).
    - Prescriptive information (e.g., suggested rerouting) is more likely to be used by people knowledgeable about area roads (Lappin & Bottom, 2001).
    - Driver compliance is highest for messages that combine information with prescription, followed by information only, and finally prescription only (Lappin & Bottom, 2001).
    - Drivers generally preferred descriptive information (men in particular) on an in-vehicle ATIS, but might be more willing to use route guidance and rerouting information if they had more control over type of routing (e.g., use favored alternates, use local streets) (Mehndiratta et al., 1999).
14. If a destination road has multiple names (e.g., name and number), how should it be identified on CMS? What about destinations with names too long for CMS? For numbered roads, are the letters necessary (e.g., I-95 vs. 95, SR-76 vs. 76)? Should road names include their "surname" (e.g., RD, AVE, BLVD)?
    - In practice, agencies tend to use major numbered highways and interstates as destinations on CMS. Minor roads, boulevards, etc., tend not to be used. For major roads, the standard abbreviated highway designator is included in the name. Space is rarely an issue because numbered roads occupy 3 characters at most. If space is limited, names are sometimes abbreviated (e.g., DWNTWN instead of downtown, ATL instead of Atlanta).
    - Lab study found that route number prefix (e.g., **RTE** 28, **I**-95) should be included on sign because only 75% of people correctly identify number alone as route number (17% think it's the exit number). This problem might be greatest among drivers who are unfamiliar with the area (Dudek, Trout, et al., 2000).
15. If delay time is reported rather than travel time, how should "normal" travel time be defined to estimate delay time? How slow must traffic be to be considered delayed?
    - Delay time is harder for drivers to "disprove" than travel time, so delay time may be advantageous in maintaining system credibility if time algorithms are error-prone (Neudorff et al., 2003). Utah originally showed delay time for this reason, but switched to travel time when data quality was improved.

16. If average speed or travel time reflects traffic in excess of speed limit, what information should be provided?
    - Bay Area established a minimum travel time, which is the lowest travel time that the sign will display, regardless of actual traffic speed. This is defined as the time taken to drive the segment at the posted speed limit. A maximum travel time is also shown; it is equivalent to 10 times the minimum travel time or 99 minutes, whichever is less. If the measured travel time exceeds the programmed maximum, the line on the CMS is blanked out (though Margulici, 2006 suggests that excessive travel time will be displayed as OVER XX MIN). Implementers plan to select more realistic maximum travel times when more drive time data is available (Caltrans, 2005b).
    - Chicago sets its minimum travel time for a route to the time it would take to drive the route at the speed limit (Webb, 2004).
17. How should travel time destinations be defined?
    - Destinations can be exit names (best for locals) or exit numbers (best for out-of-towners) (Lerner & Llaneras, 2000).
    - Landmarks (e.g., downtown) can be useful as destinations because they are understandable to both familiar and unfamiliar drivers, and they also often are vague destinations that support the idea that travel times are only estimates (Margulici et al., 2006).
    - Washington state tends to use town names rather than specific interchanges because these destinations are more general and allow for some imprecision in travel time calculation (Jacobson, pc).
    - San Antonio was unsure what to call a complicated interchange and ended up creating a new name for the destination (410 South Cutoff). Drivers began to associate the name with the interchange and news agencies began to use the name in their reports (Fariello, pc).
    - Chicago uses either major intersections or well-known landmarks as destinations. The choice of which type to use depends on which is best known to commuters. In the case of Chicago, landmarks must be more specific than “downtown” because downtown is 7 miles long, which is too broad to be used as a destination identifier. Destinations were selected by Illinois Department of Transportation without public input, but Illinois Department of Transportation considers public feedback with regard to destination names. However, the travel time system is old and difficult to change (Galas, pc).
    - CA rejected adding distance to destination to travel time signs because it seemed to be too much information (Lively, pc).
    - Portland recommends selecting destinations that are known to a majority of drivers (Oregon Department of Transportation, 2005).
    - Orlando primarily uses road names that are major exits from the freeway, but occasionally uses major landmarks such as a bridge (Heller, pc).
    - Wisconsin recommends that freeways be called by their numerical designation rather than local name, though there can be exceptions where name is more familiar (Wisconsin Department of Transportation, 2006). Destinations should be identified by crossroad because this is consistent with static signage and allows drivers to cross reference information between CMS and static signage (Dembowski, pc).
    - Wisconsin specifies that CMS should not use landmarks such as DOWNTOWN or AIRPORT (Wisconsin Department of Transportation, 2006), though this may be

done infrequently when landmark or interchange name is more meaningful to drivers than official designations (Dembowski, pc).

- Wisconsin changes its destinations on travel time signs depending on time of day. CMS show destinations relevant to commuters during rush hours and more general destinations for a broader audience outside of rush hours (Meehan, 2005a; Dembowski, pc).
- California must be careful about which exits are selected as destinations, especially when travel times are shown for long distances between towns/cities, to avoid political ramifications of which towns get named and which do not. This is a good reason not to provide travel times over very long ranges on CMS, though 511 and web sites can be used for this purpose (Lively, pc).

18. How can travel time information be provided between two locations if the start point is *not* at the location of the travel time CMS?
    - 
19. If delays begin somewhere between the CMS and a destination, how can drivers be made aware of where delays begin? A similar information need may exist if delays end before the destination reported on the CMS.
    - A two phase message may be used to display both travel time and congestion information. This is done in a few jurisdictions, including San Antonio (see photo below, from Strain, 2005):
    - 

    - Graphical route CMS allow drivers to see travel times or congestion levels for multiple segments of the roadway and can determine where congestion or delays exist (see Question 43 for examples).
    - Delay time (rather than travel time) CMS might be advantageous because they can report the delay between any two points (e.g., Edwards, 2006).
20. Is there a way to inform the driver whether delays are improving or worsening? What value would this have?
    - A few traffic web sites provide this information, but no CMS do in the U.S.
    - Drivers who are familiar with traffic patterns in an area (e.g., commuters) may have a sense of how traffic patterns develop over time. For example, congestion may tend to worsen early in the morning commute (e.g., 7 am to 8 am) and then improve late in the morning commute (e.g., 9 am to 10 am). Drivers familiar with these patterns may expect their actual drive time to be somewhat better or worse than reported conditions.
21. How much information can be presented on a travel time CMS before driver and system performance begin to suffer?
    - In a Bay Area survey, 84% of respondents said three destinations on a trael time CMS does not provide too much information, despite Caltrans concerns to the contrary (Bay Area was using some three-destination signs at the time of the survey) (Margulici, 2006).

# Message Design and Layout

22. How should messages be constructed?

- It is important to standardize order of words, order of message information units, and application of messages (Neudorff et al., 2003).
- FHWA recommends no qualifiers on travel time (e.g., approximately, estimated) because drivers understand that it's not exact (Meehan, 2005a).
- FHWA recommends using general destination information (e.g., downtown) rather than specific exits for travel time CMS where the destination is more than 10 miles away (Meehan, 2005a).
- Wisconsin recommends that all traveler information messages be limited to 8 words (Wisconsin Department of Transportation, 2006).
- Wisconsin uses all caps, with only one font and one font size (Wisconsin Department of Transportation, 2006).
- Wisconsin recommends proportional spacing rather than fixed spacing where possible (Wisconsin Department of Transportation, 2006).
- Wisconsin recommends justified format for travel time, but centered is used for all other information (Wisconsin Department of Transportation, 2006).
- Portland appears to list destinations in reverse order (farthest destination is on top line of CMS), but it is unclear if this is standard practice (Oregon Department of Transportation, 2005).

23. Is a sign header necessary (e.g., TRAVEL TIME TO:)? What should be used as a header?
    - Kansas City (KC Scout) determined that header information was not necessary because people recognize travel time signs and eliminating header info frees up significant space that can be used for message content (Webb, 2004). Baton Rouge and Nashville also do not use headers.
    - Utah plans to eliminate "travel time" header because it does not help drivers and replace it with distance to destination when the system is overhauled soon (Clayton, pc).
    - FHWA says that header text such as "Travel time to:" is good but not necessary because people understand the message when only destination and travel time are provided (Meehan, 2005a).
    - California conducted focus group testing to determine the best header text. The public wanted full sentences, but final text was a compromise due to limited space (Jenkinson, pc).
    - Caltrans District 8 (Inland Empire) uses "MINUTES TO" as a header (http://www.dot.ca.gov/dist8/tmc/webmap.htm)
    - Chicago uses "TRAVEL TIMES TO" as a header when there are 2 destinations, but excludes headers when there are 3 destinations (Illinois Department of Transportation, 2005).
24. What are the best practices for abbreviations? How do they affect driver comprehension?
    - San Antonio did not test abbreviations with the public, but drivers figured out what they meant (Fariello, pc).
    - Durkop & Dudek (2003) investigated driver comprehension of abbreviations on CMS. Although most abbreviations were not directly relevant to CMS, percentages of participants who correctly comprehended abbreviations ranged from about 80% to nearly 100%.
25. How should messages be formatted / laid out?
    - The Manual on Uniform Traffic Control Devices (MUTCD) (Federal Highway Administration, 2003) states that:

- "Changeable message signs should be capital letters and have a desirable letter size of 450 mm (18 in) or a minimum letter size of 265 mm (10.6 in). Signs should be limited to not more than 3 lines with not more than 20 characters per line."
-

- Table reproduced from report by Enterprise (2004, p 34-35):

| State | Display Details |
|---|---|
| **Arizona** | 18" Character Height, 3 lines |
| **California** | Full Matrix,12" to 60" Character Height (18" during typical operation) |
| **Georgia** | 18" Character Height, 1000' Minimum visibility |
| **Iowa** | Full Matrix, 18" Character Height |
| **Missouri** | 18" Character Height |
| **Nebraska** | 1100' Minimum Visibility |
| **New Mexico** | Full Matrix, 12" Character Height |
| **North Carolina** | 18" Character Height |
| **Ohio** | 12" or 18" Character Height, Capital Letters Only |
| **Oregon** | 18" Character Height |
| **Pennsylvania** | 10 ½" Character Height (Absolute Minimum),<br>18" Character Height (Typical) |
| **Utah** | Full Matrix, 12" Character Height on Surface Street VMS,<br>18" Character Height on Freeway VMS |
| **Virginia** | Full Matrix, 18" Character Height, 3 Lines, 21 Characters per Line |
| **Washington** | 18" Character Height |

- San Antonio's CMSs are primarily 3x18 character matrixes.
- Wisconsin's CMSs are 3x21.
- Kansas City's are 3x21 (Webb, 2004).
- Caltrans has minimum spec of 3x16, formatted as shown below (Caltrans, n.d.):

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Line 1 | | T | R | A | V | E | L | | T | I | M | E | | T | O | |
| Line 2 | X | X | X | X | X | X | X | X | | T | T | T | | M | I | N |
| Line 3 | Y | Y | Y | Y | Y | Y | Y | Y | | T | T | T | | M | I | N |

8 character target name — 3 character time

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 Target Example | | T | R | A | V | E | L | | T | I | M | E | | T | O | |
| | B | E | A | C | H | | B | L | | | 1 | 1 | | M | I | N |
| | 2 | 2 | | F | W | Y | | | | | 1 | 9 | | M | I | N |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Target Example | | T | R | A | V | E | L | | T | I | M | E | | T | O | |
| | L | A | X | | | | | | | | 2 | 0 | | M | I | N |
| | | | | | | | | | | | | | | | | |

- Travel time sign in Los Angeles County (photo courtesy of Jeff Aragaki)


- 
- Travel time sign in Ventura County, CA (Caltrans District 7) (Hoops & Gallegos, 2006):

o 


o Nashville travel time sign (top) and replica (bottom) (Tennessee Department of Transportation, 2005):

o 


o 


o Atlanta travel time format (ITS Engineers, 2004):

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | I | - | 2 | 0 | / | E | X | I | T | | 2 | 4 | 7 | | | | | |
| | | | | | 1 | 0 | | M | I | | A | H | E | A | D | | | | | | |
| T | R | A | V | E | L | | T | I | M | E | : | | 1 | 2 | - | 1 | 4 | | M | I | N |

o Atlanta travel time sign (Meehan & Rupert, 2004):

- 

- Atlanta travel time sign replicas (not in true color) (Rupert, 2005):
- 

- 

- Baton Rouge travel time sign (Louisiana Department of Transportation and Development, 2007):
- 

- Portland travel time sign format (Oregon Department of Transportation, 2005):

- TRAVEL TIME TO
  I-405 12-15 MIN
  HWY 26 10-12 MIN
- Seattle area travel time sign:
- 

- Chicago area uses a variety of formats for travel time signs, including two-phase signs (see last two examples). The images from gcmtravel.com below reflect content, but not actual layout:
- 5 MIN TO MONTROSE
  16 MIN TO O'HARE
- 36 MINUTES TO
  CIRCLE
  VIA KENNEDY
- Phase 1: Phase 2:
- 10 MINUTES TO
  MONTROSE
  VIA KENNEDY

  25 MINUTES TO
  O'HARE
  VIA KENNEDY
- Phase 1: Phase 2:
- CERMAK TOLL 20 MIN
  DNTWN VIA 290 32 MIN
  DNTWN VIA 90 52 MIN

  TRUCKS
  USE
  2 RIGHT LANES
- Bay Area travel time signs (Margulici, 2006). The top photo shows proper procedure; it's unclear why the bottom photo shows destinations in reverse order:

o 


o 


o Formatting examples of Bay Area's three travel time sign configurations. Two-destination (left) is most common. Three-destination replaces the banner text with the nearest destination (center). One-destination (right) may have one or two phases (two-stage is shown) and may be on smaller arterial CMS which necessitate shorter messages (Travel times on changeable message signs in District 4: Field elements and system configuration, 2006):

o

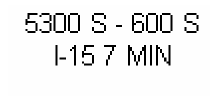
| Two-destination | | Three-destination | | One-destination |
|---|---|---|---|---|
| | | | | TIME TO<br>RTE 92<br>XXX MIN |
| TRAVEL TIME TO | | SF DWNTWN | XX MIN | TIME TO |
| RTE 92 | XX MIN | SFO ARPT | XX MIN | RTE 280 |
| SFO ARPT | XX MIN | OAK ARPT | XX MIN | XXX MIN |

o Utah travel time sign replica:

o 


o Examples of unformatted Utah travel time text (http://www.utahcommuterlink.com/):

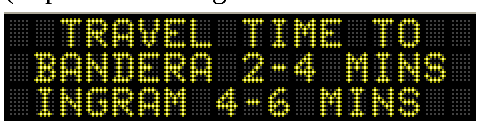
- 



- Utah previously used delay time rather than travel time because of a lack of confidence in travel time data. The display format was like this (Webb, 2004):
- **CONGESTION**<br>**400 S-BECK ST**<br>**20 MIN DELAY**

  **CONGESTION**<br>**I-15 AT 400S**<br>**30 MIN DELAY**
- San Antonio travel time sign (top) and replica of a two-phase travel time message (bottom) (Strain, 2005):
- 

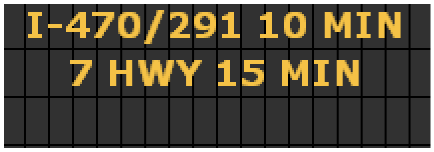
- 

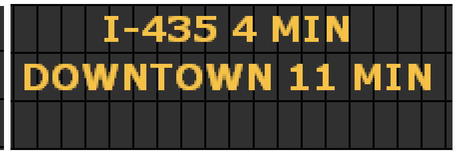
- Although most travel time CMS in San Antonio report short travel times as UNDER 5 MINS, a sign observed on June 6, 2007 appeared like this, possibly because there was not enough space for UNDER 5 MINS (http://www.transguide.dot.state.tx.us/TravelTimes/signs.php):
- 

- In Houston, travel time signs include time of most recent reading (see replica below) because probe data can result in latency of up to about 10 minutes (this way drivers know how outdated the info might be) (Texas Department of Transportation, 2005):
- 

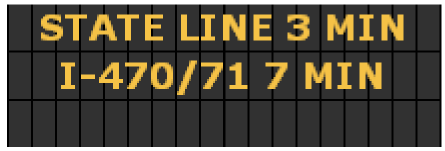
- Kansas City, MO travel time signs showing single-destination sign (top) and three-destination sign (bottom) (KC Scout web site):
- 

-
- Electronic replicas of Kansas City travel time signs (KC Scout web site):

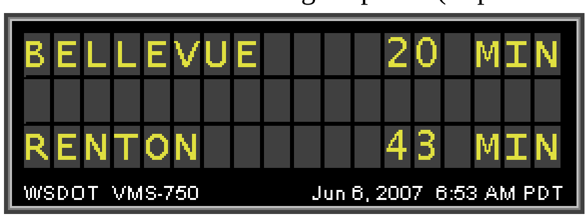
- 

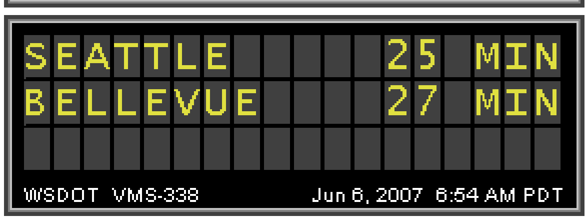


- 



- Wisconsin travel time sign (Langer, 2005):
- 

- Seattle area travel time sign replicas (http://www.wsdot.wa.gov/traffic/seattle/vms/):
- 

- 

- 

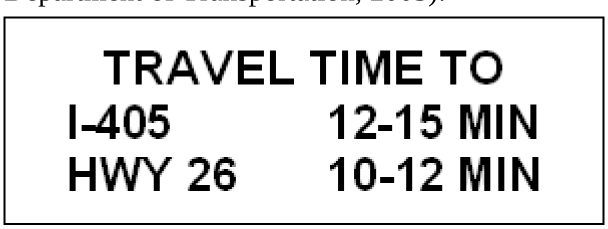
- A portable work zone system used on I-95 in NC provided three levels of message: general message (no delay), minor delay, and major delay (which was phased as follows: TRAFFIC STOPPED AHEAD / 20 MINUTE DELAY / USE EXIT 141 AS ALT) (Bushman & Berthelot, 2005).

- CMS in the United Kingdom use travel time when conditions are normal and delay time when there is a major incident (see example replicas below) (Edwards, 2006):


- 


- United Kingdom journey time “link” sign to provide travel time on a road other than the current one (Highways Agency, 2003):
- 


26. If travel times to multiple locations are presented, how should travel times be ordered?
    - Most show nearest destination on top, but Chicago appears to order destinations both ways (see below) (Illinois Department of Transportation, 2005):
    - 


    - Travel time CMS in Portland also appear to place the farthest destination on top (Oregon Department of Transportation, 2005):
    - 

# Travel Time Reporting

27. How should travel times be shown?
    - FHWA recommends time range of 2-3 minutes (Meehan, 2005a).
    - Tennessee uses 2-3 minute range (Texas Department of Transportation, 2005).
    - Atlanta uses a 3 minute range for most destinations, but may use a 2 minute range for especially short trips or a 4 minute range for especially long trips. The purpose of showing a range rather than an exact number is to help ensure that the estimate is accurate for most drivers (Meehan, 2005b).
    - Wisconsin Department of Transportation rounds up to the nearest minute (Langer, 2005).
    - Kansas City rounds up to nearest minute (KC Scout website). Webb (2004) reports that the initial plan was to round to the nearest minute as the low range estimate, then add 20% as the high range estimate. It's unclear whether this was ever done.
    - San Antonio shows a range of 3 minutes so that people understand that travel time is not exact, but their own time will usually be within the range. The actual calculated time is rounded down to the nearest minute to establish the bottom of the range, and two minutes are added to establish the top of the range (e.g., 5.5 min calculated time will show as 5-7 min).
    - Orlando rounds up to the nearest minute, but travel time CMS on a privately owned toll road in Orlando show a range of minutes. Florida Department of Transportation and the private company do not coordinate travel time reporting procedures (Heller, pc).
    - Caltrans has a scaled estimation regime: recommends rounding up to the nearest X minutes, where X may be progressively larger as travel time increases (e.g., 17 minutes rounds to nearest 5 minutes (i.e., 20 min); 44 min rounds to nearest 10 minutes (e.g., 50 min) (Caltrans, n.d.).
    - California displays a time range because travel times are based on data from prior vehicles and is therefore outdated rather than predictive (Jenkinson, pc).
    - Oregon Department of Transportation presents travel times in range of +/- 1 minute during most times, but uses a range of up to 4 minutes (+/- 2 minutes) for periods of congestion. This is because travel time is less predictable during congestion (Oregon Department of Transportation, 2005).
    - In Wausau, Wisconsin, a portable CMS displays real-time traffic speed through rural work zone (Vik, pc). Measurement is imprecise and reported speeds are rounded to nearest 10 mph (e.g., 55, 45, 35) or stopped traffic ahead. Purpose is not to indicate travel time so much as to warn drivers to expect slowing or stopped traffic (Dembowski, pc).
    - Travel time information should be supplemented with an indication of travel time variability or typical range (Lerner & Llaneras, 2000).
    - Washington rounds to the nearest minute. Even though measurement is not precise to that level of accuracy, the public accepts it (Jacobson, pc).
28. What information can be provided to let drivers know whether current travel times are good or bad (or better or worse than usual)?
    - Signs could report average travel time (or speed), but this information is probably excessive on roadways (Lerner & Llaneras, 2000). In fact, Caltrans considered showing average or normal travel times on roadside static signage, but opted not to do this (Lively, pc).

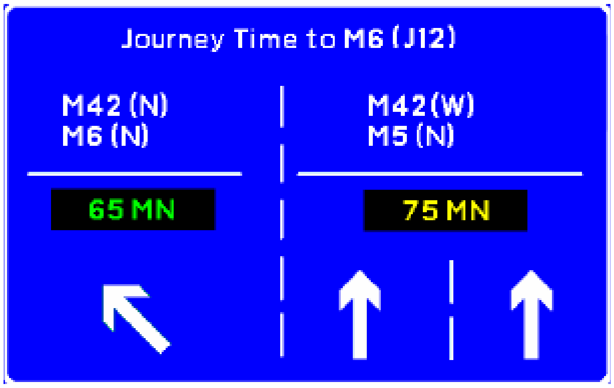
- Milwaukee's online travel time site shows actual travel time and time in excess of normal drive (i.e., delay time). Routes where travel time is at least 20% greater than normal are shown in bold.

29. If traffic is free-flowing for all sign destinations, would a "no delays" type of message have more meaning to drivers than travel time?
    - 
30. If travel time is fairly consistent from day to day, or if travel times are presented at times when congestion very rarely occurs, will drivers begin to tune out travel time messages? If so, what can be done to draw attention when conditions differ from the norm?
    - In Wisconsin, where travel times are displayed 24/7, Department of Transportation staff believe that drivers become familiar with travel time signs and can tell with a very quick glance if the travel times differ from normal (Dembowski, pc).
    - In Forth Worth, travel time implementer believes that that once drivers are familiar with travel times, they only look at numbers, not text (Connell, pc).
    - Some drivers in Utah have complained that they begin to tune out travel time signs because they show the same information all the time, so when important information is presented, they tune it out as well (Clayton, pc).
31. How often should travel time estimates be updated?
    - Wisconsin Department of Transportation updates every 60 seconds because it's a reasonable time for viewers to see updates and during congested times, travel times are highly variable (Langer, 2005).
    - Caltrans District 7 updates travel times every 3 minutes, though the system can accommodate spans of 1 to 5 minutes (Caltrans travel time information project summary).
    - Caltrans District 4 proposed (as of Feb 2005) that the system update travel time when any one route's predicted time is at least 2 minutes different than the calculated time, or consistently off by 1 minute for 3 consecutive minutes. Updates are made every 15 minutes no matter what other conditions exist. Also, if data are unavailable for 10 minutes, the destination is blanked out from the CMS (Margulici et al., 2006).
    - Houston updates travel times every 10 minutes; a few locations are updated more frequently. Houston's best practices say that travel time information should not be older than 15 minutes, though most jurisdictions update travel times much more frequently (Texas Department of Tranportation, 2005).
    - Utah updates travel times every minute (Utah Commuterlink website).

## CMS Locations and Destinations for Travel Time Display

32. For what road segments should travel times be displayed?
    - FHWA recommends reporting for heavily used segments and choosing heavily used exits as destinations (Meehan, 2005a).
    - Oregon Department of Transportation guidelines say that at least 50% of drivers who see a travel time CMS should reach the destination shown on the CMS. In other words, CMS shouldn't show a destination that most driver will exit prior to (unless diverting due to congestion) (Oregon Department of Transportation, 2005).
    - Oregon Department of Transportation guidelines say that travel time destinations should be "well known to a majority of drivers" (Oregon Department of Transportation, 2005).

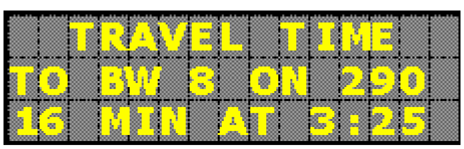
33. What are appropriate maximum and minimum segment lengths (in miles or travel times) for travel time reporting?
    - The longer the road segment, the more likely it is that that travel times will be inaccurate. However, longer travel times may be acceptable if there is a long distance between exits, if the majority of drivers are on the road for a long distance, if the road is not prone to major delays, and if the travel time calculation is relatively precise or predictive (Lively, pc).
    - San Antonio posts travel times below 5 min as “UNDER 5 MINS” and over 30 min as “OVER 30 MINS” because travel times over 30 minutes are too great to be accurate (Fariello, pc).
    - In the Atlanta area, travel times over 30 minutes are displayed as “30+ MINUTES” (Meehan, 2005b).
    - Bay Area tries to keep destinations between 4 and 20 miles from travel time sign because more than 20 miles is too hard to predict and less than 4 doesn’t provide useful information to most drivers. A rule of thumb is that at least 50% of drivers who see a given destination should be going to or beyond the destination (unless congestion causes rerouting) (Margulici, 2006).
    - Utah has some CMS that display travel times as small as 3 minutes, but these provide little value to drivers, especially since distance to destination is not provided (e.g., 3 minutes is very good for a destination 3 miles away, but very poor for a destination 1 mile away) (Clayton, pc).
    - Portland suggests reporting travel time to destinations between 3 and 15 miles from the CMS because travel times are difficult to predict for distances greater than 15 miles (Oregon Department of Transportation, 2005).
    - Wisconsin Department of Transportation aims for travel times between 6 and 20 minutes. 6 minutes is so short that it’s hardly worth posting; more than 20 minutes can be inaccurate and drivers can forget what information they saw on a CMS many miles back (Langer, 2005).
    - Oregon Department of Transportation recommends that destinations be 3 to 15 miles beyond the CMS because travel times are too hard to predict for longer distances) (Oregon Department of Transportation, 2005).
    - In the Bay Area, most travel times are for destinations 5 to 15 miles away.
    - In San Antonio, most travel times are for destinations 5 to 10 miles away.
    - In the Atlanta area, travel time destinations usually range from 5 to 15 miles away (Meehan, 2005b)
34. How can travel time displays be implemented on special use lanes or separated lanes (e.g., HOV lanes, HOT lanes, local/express lanes)?
    - Chicago calculates travel times for express lanes and local lanes separately. They are displayed on separate CMS (Galas, pc).
    - California does not display travel times for HOT/HOV lanes, but does try to display mainline travel times prior to HOT lane decision points. Some HOT lanes are managed by private companies (Jenkinson, pc).
    - Georgia Department of Transportation provides travel times for HOV lanes (http://www.georgia-navigator.com/about).
    - Seattle reports travel times for mainline and HOV separately on its web site, but not on CMS.

- California has considered adding travel time CMS for HOV, but is concerned that shorter reported travel times on HOV will lead to increased violations and increased delays. HOV travel times will require coordination with enforcement if it is to be successful (Lively, pc).
- Forth Worth is considering displaying travel time for HOT lanes, but specific plans are uncertain because HOT lanes will be under different jurisdiction than mainline CMS (Connell, pc).
- A prototype "lane choice panel" in the United Kingdom using both static and dynamic elements might be one model reporting travel times on separated roads (Highways Agency, 2003):
- 


## Route Choice / Diversion

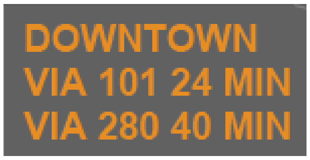
35. What information can be provided about alternate routes or travel times on roads other than the one that drivers are currently on?
    - San Antonio provides occasional travel times to a major destination via two different routes, but does not provide explicit routing guidance. This is because the CMS do not provide enough space and because the target audience for travel time (commuters) will generally know the best alternate routes and can decide for themselves whether they should divert (Fariello, pc).
    - Wisconsin recommends travel time on alternate routes be displayed like this (Wisconsin Department of Transportation, 2006):

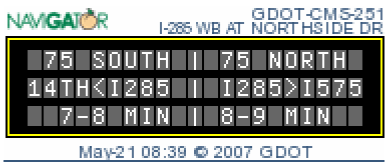
      FREEWAY TIME TO AIRPORT
      VIA I-894 15 MIN
      VIA I-94 18 MIN

    - Houston can show travel time on an alternate route like this (Transtar website):
    - 

    - Seattle area can show travel time via alternative routes like this (Washington State Department of Transportation travel time web site):

- 

- In the Bay Area, travel time on alternate routes is shown like this (Margulici, 2006):
- 

- Atlanta area has at least one sign that shows travel times on multiple routes, though this sign appears to be designed for two separate audiences (those taking 75 South and those taking 75 North) rather than showing alternative routes for a single audience (Georgia Navigator website):
- 

- Atlanta also has a sign that shows current speeds in different directions of the same road (like the sign shown above, it is designed for two separate directions of travel) (Georgia Navigator website):
- 

- In Barcelona, alternate route travel times are shown like this (Rupert et al., 2003):
- 

- Given the choice between the two, drivers prefer travel time/delay information rather than diversion information. Drivers can make their own routing decisions if they have appropriate information (Lerner & Llaneras, 2000).
- Orlando shows travel time for the current road and an alternative route (toll road, which is privately owned) on separate phases of a CMS and allows drivers to choose their own route based on the information (Heller, pc).

36. What are the best practices for route diversion?
    - Expected trip time should be the primary factor for route selection/diversion (Lerner & Llaneras, 2000).
    - If an alternate route is suggested, most drivers want to know the travel time for that route (Lerner et al., 1998).
    - Potential time savings from diversion must be balanced against the travel time variability, lower functional class, more complex paths (especially for unfamiliar drivers), and potential for diversion to increase delays on alternate route (Lerner & Llaneras, 2000).
    - If diversion is recommended, travel time for the alternate route should be provided (Lerner & Llaneras, 2000).
    - If transportation agency wants to encourage drivers to use an alternate route, a clear time savings should be shown for the alternate route. If minimal diversion is desired, messages should confirm minimal time differences and minimize certainty about the delay on the primary route (Lerner et al., 1998b).
    - If only minimal information can be presented, drivers prefer descriptive information to route suggestions (Lerner et al., 1998b).
    - The language that indicates level of certainty in route recommendations can be manipulated to influence the percentage of drivers who divert (Lerner & Llaneras, 2000).
    - If an incident is responsible for the recommendation to divert, the CMS should specify where the incident is so drivers can return to original route beyond the incident (Lerner & Llaneras, 2000).
    - Ideally, alternate routes should be freeways, have few turns and signals, require minimal navigation, and immediately result in less traffic density (Lerner & Llaneras, 2000).
    - For commuters, route diversion should only be recommended if the time savings is at least 20% (Lerner & Llaneras, 2000).
    - Chicago recommends that CMS be located upstream of decision points where drivers can divert (Illinois Department of Transportation, 2005).
    - Wisconsin ‘passively’ encourages diversion by locating CMS before choice points, but they are limited in the ability to suggest alternate routes because if alternate routes are under another agency’s jurisdiction, the agency may be upset by the manipulation of traffic on its roads and might feel that the freeway agency is impinging on its jurisdiction (Dembowski, pc).
    - California locates travel time CMS before major decision points to allow drivers to make informed route choices. Explicit alternate route information practices vary by district and are generally at the discretion of TMC staff. If there are multiple route options, CMS may state “USE ALTERNATE ROUTE.” If there is only one acceptable alternative, the CMS will state the route to take (Jenkinson, pc).
37. What factors influence whether drivers choose to divert (e.g., length of delay, cause of delay, trip purpose, peak vs. off-peak hours, personal characteristics/driving style, familiarity with area/alternates, availability of alternate route, expectations of travel time on alternate route,

availability of information about alternates, stress/uncertainty caused by diverting, degree of expected time savings required to make diversion worthwhile)?

- Drivers are much less likely to follow a route recommendation if it requires diverting from their original route (Mahmassani et al., 1998; cited in Lerner et al., 2000).
- Drivers who are concerned with minimizing travel time uncertainty (such as commuters who do not have flexible work arrival times) are more likely to seek travel time information and reroute if they face delays on the primary route (Abdel-Aty et al., 1997a; cited in Lerner et al., 2000).
- Commuters who regularly drive different routes to work are not more likely to reroute around a traffic incident than driver who use a constant route (Abdel-Aty et al., 1997a; cited in Lerner et al., 2000).
- Young, higher income drivers with long commutes are most likely to divert to another route. Females and people concerned with driving through unsafe neighborhoods are least likely to divert (Abdel-Aty et al., 1997a; cited in Lerner et al., 2000).
- Drivers who receive en-route traffic information are more likely to reroute around delays and then return to the primary route beyond the congested area. Although en-route information may increase diversions, the diversions may be of shorter average length if drivers return to the primary route beyond the congested area (Abdel-Aty et al., 1997a; cited in Lerner et al., 2000).
- Drivers are interested in minimizing travel time *variability*, not just travel time itself, so drivers may opt take the route with a more predictable travel time even if the alternative is likely to have a shorter travel time, on average (Abdel-Aty et al., 1997b; cited in Lerner et al., 2000).
- Drivers prefer routes with fewer navigational maneuvers, segments, and traffic signals, even if the preferred route may be slightly longer to drive (Abdel-Aty et al., 1997b; cited in Lerner et al., 2000).
- In a simulated ATIS, a graphical representation of congestion ahead significantly increased driver propensity to reroute, especially if the congestion began immediately after a convenient rerouting decision point (Mahmassani, H., & Srinivasan, K., 1998; cited in Lerner et al., 2000). This may have implications for graphical travel time/congestion maps posted as freeway signs.
- On average, commuters tolerate arrival at work between 10 minutes early and 5 minutes late. They are more likely to reroute if predicted arrival is more than 5 minutes late (Mahmassani, H., & Srinivasan, K., 1998; cited in Lerner et al., 2000).
- In a study of an ATIS, drivers were more likely to comply with routing advice on a freeway than on an arterial and when the suggested route involves few turns (Chen & Jovanis, 1779; cited in Lerner et al., 2000).
- Positive perceptions of traffic information accuracy has a significant effect on whether drivers choose to comply with route guidance information (Chen & Jovanis, 1779; cited in Lerner et al., 2000).
- Commuters are more likely to reroute if arrival time predictions exceed their preferred arrival time (Mahmassani & Liu, 1997; cited in Lerner et al., 2000).
- Given complete and accurate information in an ATIS, drivers, on average, will generally require a time savings of 22% for the remainder of their trip before they decide to reroute, but the overall time savings must be greater than 4 minutes (Mahmassani, H., & Srinivasan, K., 1998; cited in Lerner et al., 2000).

- Commuters are more apt to reroute to a faster route if they are running late to work than if they are running early (Mahmassani & Liu, 1997; cited in Lerner et al., 2000).
- Travel time information is most likely to be used effectively on roads with high variability of travel time and among drivers familiar with the area (Chorus, Molin, & van Wee, 2007).
- A survey of online travel time information found that 68% of users in Pittsburgh and 86% in Philadelphia who checked travel times online before leaving home changed their routes based on the information. 47% in Pittsburgh and 66% in Philadelphia adjusted the time that they left home based on expected travel time (ITS for Traveler Information).
- A 2004 survey found that 85% of respondents changed route in response to travel time information; 66% felt that this reduced their travel time, 29% were unsure (Texas Department of Transportation, 2005).
- A survey in the Los Angeles area found that drivers generally would not divert based on travel time info, but like to have the information (Caltrans, n.d.).
- A survey found that 15% of drivers who received travel time information rerouted (the summary does not clarify whether this is for a given trip or in driver's entire experience) (Caltrans, 2005a).
- A lab study in the Netherlands found that drivers prefer routes with predictable travel times over routes with unpredictable travel times, even if the predictable route has a slightly longer travel time, on average. Drivers will reuse a route that took unusually long the day before if the travel time prediction was accurate, but will pick a different route if the travel time prediction was inaccurate (Bogers et al., 2006).

## Phasing / Staggering of Travel Time Information

38. Can travel time messages and other messages be shown in multiple phases?
    - Section 2E.21 of the MUTCD (Federal Highway Administration, 2003) states that:
        - "No more than two displays should be used within any message cycle."
        - "Each display should convey a single thought."
        - "The entire message cycle should be readable at least twice by drivers traveling at the posted speed, the off-peak 85th-percentile speed, or the operating speed."
    - Orlando always shows two-phase travel time messages (one destination per phase). Anecdotal reports do not suggest that the signs are causing distraction or slowing (Heller, pc).
    - Missouri strongly prefers single-phase messages because two-phase messages were reportedly causing traffic to slow on freeways (Webb, 2004). However, Missouri has begun using two-phase messages to alternate incident information and travel time. Two-phase CMS have received positive anecdotal feedback. Traffic had slowed when the signs went into use, but a public information campaign returned the flow to normal. The destination shown for an incident message is usually selected in order to give drivers an accurate idea of where the delay will end and what the travel time will be to the destination. Travel time and incident information support one another and help give drivers a complete picture of the situation and its effects (Sommerhauser, pc).
    - Houston uses single-phase messages because survey results indicate that's what drivers prefer, though they occasionally use two-phase messages if there is important information that can only be conveyed in that format (Texas Department of Transportation, 2005).

- Idaho plans to show messages in just one stage because two-stage messages have caused slowdowns in the past (Koeberlein, pc).
- Wisconsin has not experienced traffic problems or distraction as a result of 2-phase messages. It's important to put CMS in location where driver cognitive demand is low and it is visible for a long distance. When people get accustomed to seeing info on a sign, it interferes with them less – they can pull the information they need more quickly and have expectations about sign contents.
- The "TRAVEL TIME TO" banner can remain and the destinations can be phased to show additional destinations, but this is uncommon in practice. Although his findings are not directly relevant to travel time information, Dudek (2005) found that alternating one line of a three-line CMS did not adversely affect message recall, but did significantly increase reading time.
- Oregon Department of Transportation only uses single phase messages to minimize driver distraction (Oregon Department of Transportation, 2005).
- San Antonio sometimes alternates travel time and incident/congestion messages (Strain, 2005):


- Wisconsin also sometimes alternates travel time and incident/congestion messages.

39. Can CMS be located longitudinally to present relatively large amounts of information (whether related to each another or independent) without overloading drivers (e.g., travel time information on first CMS, rerouting information on next)?
    - 

## Use of Color, Graphics, Symbols, and Dynamic Elements

40. How can color be used on travel time displays?
    - The Manual on Uniform Traffic Control Devices (MUTCD) states that CMS… "that display a warning or regulatory message may use a black background with a white, yellow, orange, red, or fluorescent yellow-green legend as appropriate, except where specifically restricted…." (Federal Highway Administration, 2003)
    - Wisconsin forbids use of color (Wisconsin Department of Transportation, 2006).
    - A series of studies in the Netherlands on full color information panel signs found that color intensity is not a good way to indicate flow or a preferred route. Colors should always be functional (i.e., only use color to represent meaningful information). Red should only be used to represent blocked roads (note: this is inconsistent with broad practice in the U.S., where red often represents heavy congestion) (Roskam et al., 2002).
    - For ATIS, road segments should be color coded green, yellow, and red to represent mean speed of traffic flow. No more than three levels of traffic should be coded. A fourth level for stop-and-go or blocked lanes may be added if necessary (Campbell et al, 1998).
    - Drivers make an intuitive connection between traffic light colors and green/yellow/red traffic coding (Miller et al., 1994; cited in Campbell et al., 1998).

- There is no conflict in using red (which typically represents danger) as a color code for slow traffic in ATIS because slowing traffic may constitute a dangerous situation (Ross et al., 1996; cited in Campbell et al., 1998).

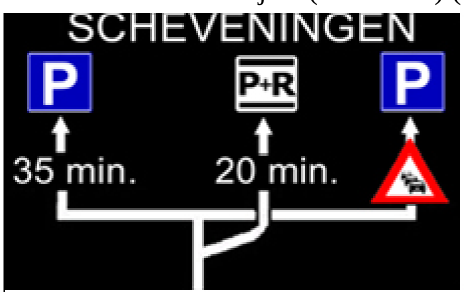
41. How can animation be used on travel time displays?
    - The MUTCD (Federal Highway Administration, 2003) states that:
        - "The display format *shall not* include animation, rapid flashing, or other dynamic elements that are characteristic of sports scoreboards or advertising displays."
        - "Techniques of message display such as fading, exploding, dissolving, or moving messages shall not be used."
    - Wisconsin forbids use of animation on CMS (Wisconsin Department of Transportation, 2006).
42. How can symbols be used on travel time displays?
    - In Japan, incidents are identified on graphical CMS using a red 'X' (Lerner et al., 2004):
    - 

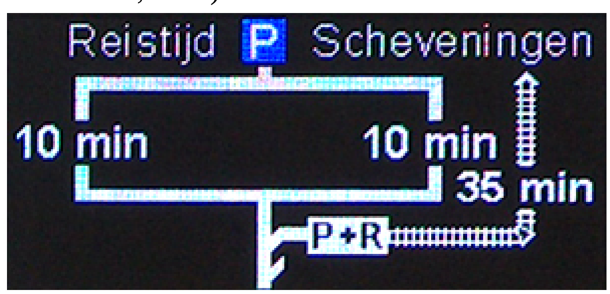
    - Japan also uses a different symbol for congestion, as seen at the left of the CMS below (Highways Agency, 2003):
    - 

43. Can graphical/map signs be used in place of text-only signs?
    - VicRoads' Travel Time System (Victoria, Australia) shows travel time to destinations (bottom-to-top) and color codes traffic for each leg as green (light), yellow (medium), or red (heavy) (see below). Other signs are posted on arterials prior to freeways and code traffic to major destinations (e.g., downtown) using color coded text stating light,

medium, or heavy. A survey found 70-90% public acceptance and 57% of respondents reported that, based on color coding, the traffic they encountered was as expected, with about even numbers reporting it to be more and less than expected (Lerner et al., 2004).

- 

- Dutch/German project at AVV Transport Research Centre in Delft developed prototype full color information panels (FCIP) for freeway directional guidance within TRAVELGUIDE Project (see below) (Lerner et al., 2004).
- 



- Another sign from AVV (Lerner et al., 2004):

- 

- In Japan, a travel time CMS (top) and an incident/congestion graphical CMS showing alternate routes (bottom) (Lerner et al., 2004):
- 

- 

- Japanese GRIP (left) and congestion information panel (right) (Highways Agency, 2003):



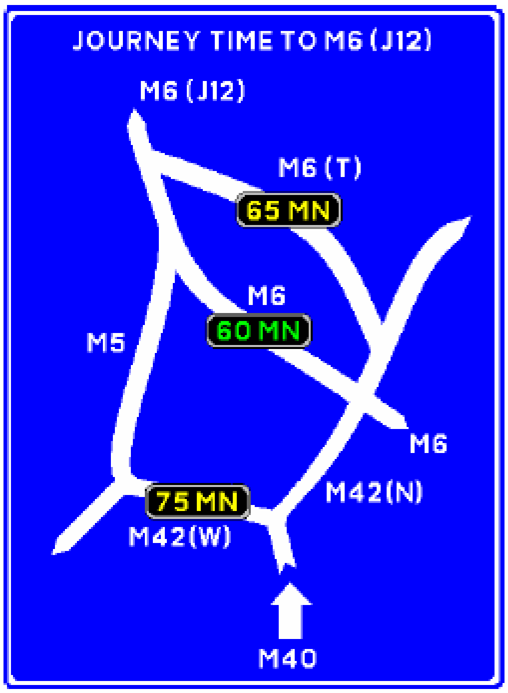
- German GRIP that began operating in Munich area in 2003, with dimensions shown (Highways Agency, 2003):


| | |
|---|---|
| 'X ' height | 210 mm |
| Sign Face Width | 8000 mm |
| Sign Face Height | 6200 mm |
| Route Width | 240 mm |

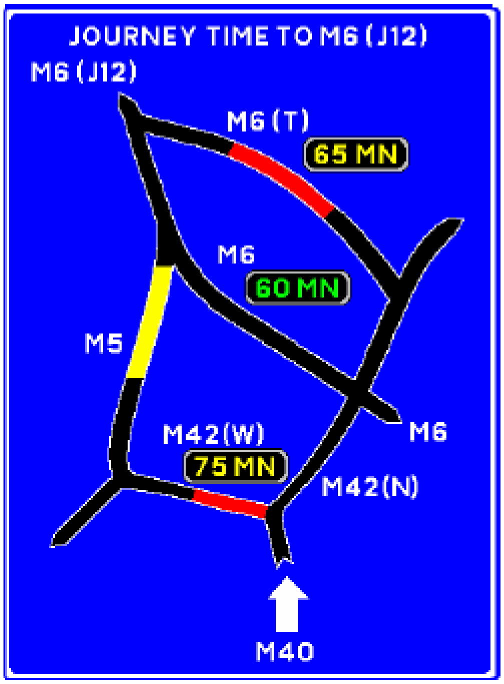
- French GRIP prototype (Highways Agency, 2003):


- Spanish GRIP used in Madrid area, with travel times (Highways Agency, 2003):

- 

- Proposed GRIP journey time panels in UK (two alternative prototypes), with dimensions (Highways Agency, 2003):
- 


| Panel Size using Medium Font | |
|---|---|
| 'x'– height' | 300 mm |
| Sign Face Width | 9475 mm |
| Sign Face Height | 13560 mm |
| Area | 128.45 $m^2$ |
| Route Width | 450 mm |

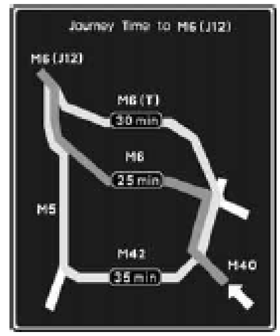
o 


| Panel Size using Motorway Font for route numbers | |
|---|---|
| 'x'– height' | 300 mm |
| Sign Face Width | 10385 mm |
| Sign Face Height | 15930 mm |
| Area | 165.46 $m^2$ |
| Route Width | 600 mm |

44. If a graphical route map sign is used, should all road sections be color coded, or should color only be used where congestion exists?
    - Drivers may interpret blank (unlit sections) as meaning that the section of road is closed (McCabe & Valera, 2003) or that speed/travel time data is unavailable.
45. Is there any value to flashing full messages or parts of messages?
    - Dudek (2004) identifies this as a top-tier research issue, but finds that reading time may increase. None of the jurisdictions that have travel time CMS flash messages.
    - Dudek (2005) recommends language added to the MUTCD to limit or forbid flashing message elements based on research that shows show degradation of reading time/comprehension and no meaningful benefits.
46. How does driver comprehension differ between various graphical and text travel time displays?
    - Simulator study in UK by Richards et al. (2005) compared the signs shown in the two figures reproduced below. Participants viewed signs in simulated environment, then answered questions such was "what was the journey time to XX road?" and "which route was the fasted to XX town?" Signs 4 and 11 (both text-only) had the highest comprehension and recall rates. Participants also reported having the fewest problems understanding these signs. Signs 8 and 9 were considered easiest to understand, though only by a small margin.

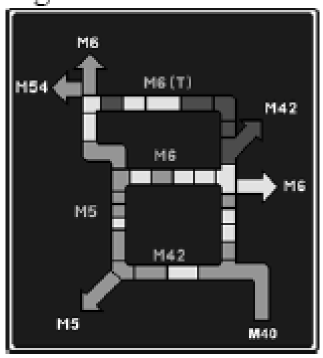

Sign 1 (existing sign)


Sign 2

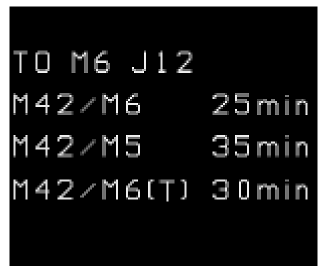



Sign 3 (& 17)

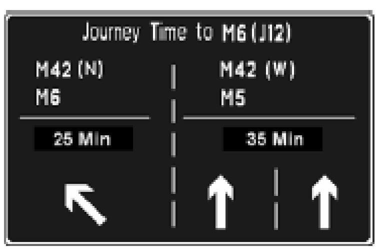

Sign 4




Sign 5 (& 12)

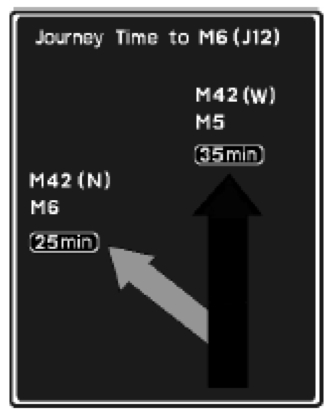



Sign 6




Sign 8


Sign 9

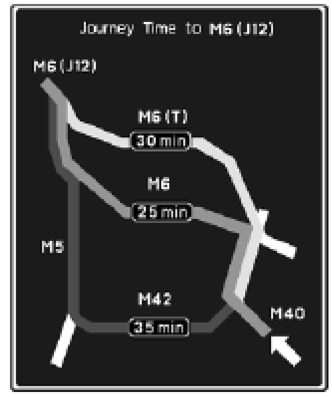



Sign 10

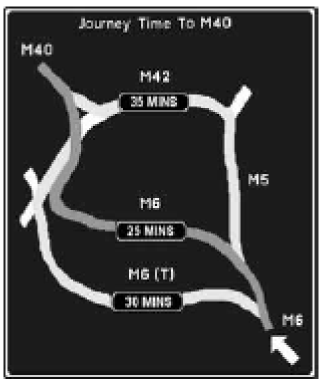
*Figure 2a. Sign Designs Used in the Research Used in the Research. 17 and 12 are flashing versions of 3 and 5 respectively. Yellow and green routings are used in Sign 3and 10, while a yellow green and red scheme is used in Sign 5.*


Sign 11


Sign 13

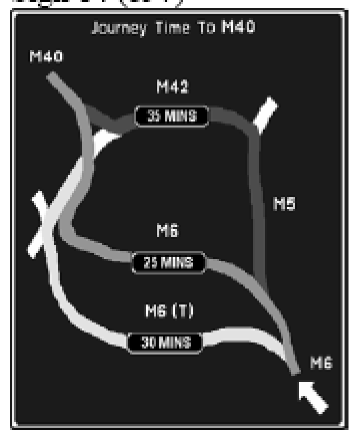



Sign 14 (& 7)

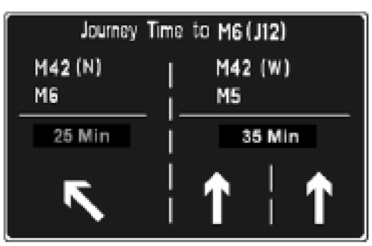



Sign 15

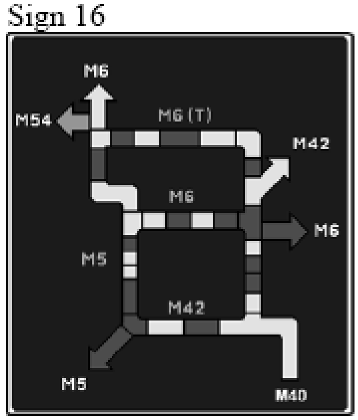

Sign 16




Sign 18




Sign 19

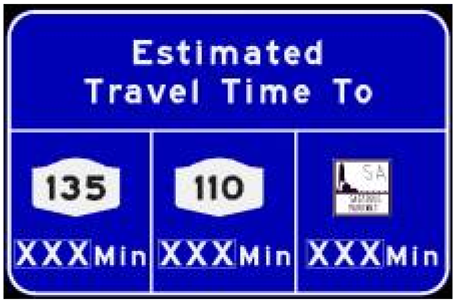


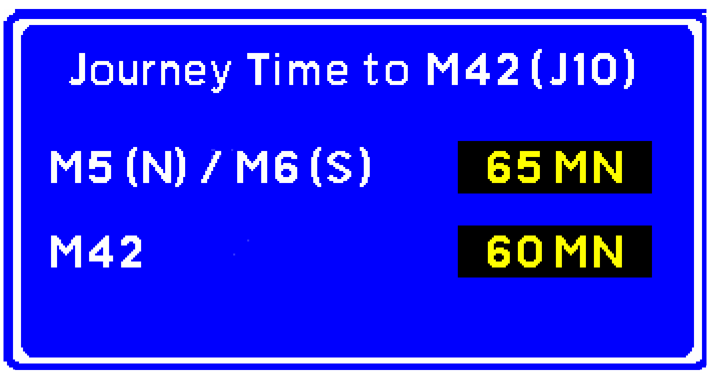

Sign 20

*Figure 2b. Sign Designs Used in the Research (continued). 7 is a flashing version of 14. A yellow and green scheme is used in Sign 15, while a yellow, green and red scheme is used in signs 14, 18 and 20.*

## Relationship between Travel Time CMS and Static Signs

47. How can CMS and static signage be used in concert to combine benefits?

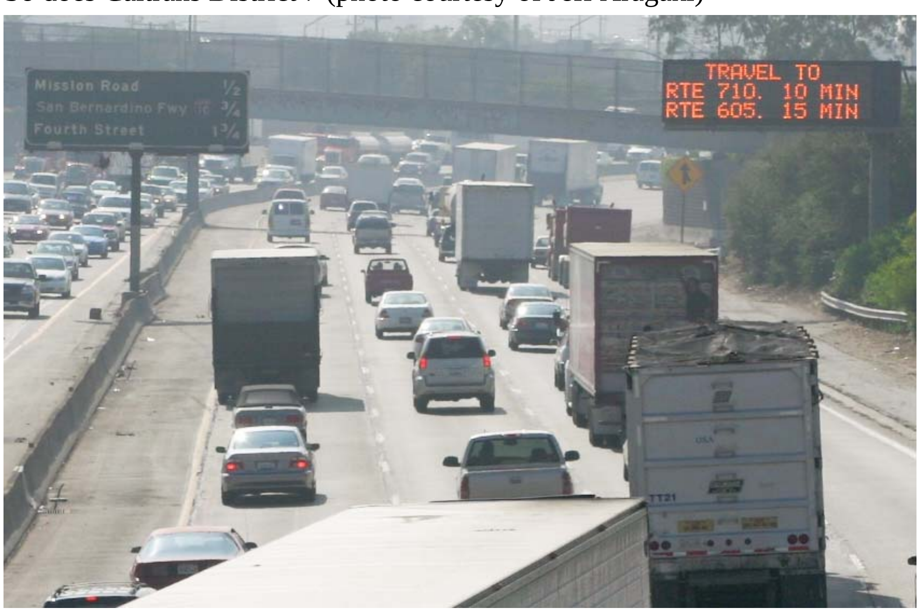
- o CA initially considered posting delay time on CMS with a static roadside sign that identifies normal drive time, but rejected the idea (Lively, pc).
- o Long Island is planning to implement travel time within static signage (PBS&J, 2004):
- o 

- o Graphical route maps, or GRIPS, typically have a static map and often have static destination text, but segments of the route or travel times can be varied.
- o Wisconsin recommends that exit designations be identical to phrasing on static signage (Wisconsin Department of Transportation, 2006).
- o Static signs should not be collocated with CMS because this may cause info overload (Agah, 2002).
- o UK project proposed combined static/variable journey time sign (Highways Agency, 2003):
- o 


48. Can travel time be used to help people coordinate (or encourage) use of other transportation modes (e.g., public transport)?
    - o This is a greater concern in Europe, where more viable transit alternatives often exist, than in the U.S. (Chen, 2002).
    - o In Cologne, Germany, arterial travel time is shown in contrast to other travel modes in the vicinity of park-and-ride locations to encourage people to use transit if roads are congested (see below) (Federal Highway Administration, 2006):

- 


49. Is it appropriate to collocate travel time CMS with other CMS or static signage?
    - San Antonio apparently does this:
    - 

    - So does Caltrans District 7 (photo courtesy of Jeff Aragaki)
    - 

# Message Prioritization, Hours of Use, and Failure Modes

50. Where does travel time fall in the CMS message priority hierarchy?
    - "Messages advising the driver of incidents, work zones, adverse weather, environmental, and road conditions, and other emergency situations shall take precedence over travel time messages." (Dudek, 2003)
    - In virtually all jurisdictions in the U.S., travel time is the default message, but it has the lowest priority except for public service announcements (e.g., Oregon Department of Transportation, 2005).
    - Orlando CMS show travel time as a default, but show congestion information instead when congestion occurs (Heller, pc).
51. During what hours should travel times be displayed?
    - Travel time may be shown during peak and off-peak hours (Dudek, 2003).
    - Houston is capable of 24-hour operation, but typically posts travel times between 5:30 am and 7:30 pm daily, and any other time that traffic becomes congested (e.g., following an incident) (Texas Department of Transportation, 2005).
    - As of August 2005, Los Angeles shows travel time 5 am to 7 am, Monday through Friday (Caltrans, 2006).
    - San Antonio displays travel times from 6 am to 10 pm.
    - Atlanta displays travel times from 6 am to 9 pm, Monday through Friday, and 8 am to 8 pm Saturday and Sunday (Webb, 2004).
    - Idaho plans to show travel time messages only during rush hours or related to special events because congestion in the area is generally very minor (Koeberlein, pc).
    - A survey found that the public did not want travel time information when traffic was flowing freely, so Oregon Department of Transportation only shows travel times when there is congestion (Oregon Department of Transportation, 2005).
    - Nashville shows travel time all the time, unless a higher priority incident message is displayed, which happens about 20% of the time.
    - In the Milwaukee area, travel time is shown 24 hours per day (Vik, pc). This is because it is a goal to keep signs from staying blank. Doug Dembowski believes that 24-hour travel time will not lead to drivers tuning out the signs because he thinks that drivers get accustomed to the signs and begin to only look at the numbers and they are attuned to changes from the usual numbers (Dembowski, pc).
    - Chicago shows travel times during rush hours (5-10 am, 3-7 pm) and after incidents (Illinois Department of Transportation, 2005).
    - In Salt Lake City area, Utah shows messages on weekdays from 6-9 am and 3:30 to 7 pm (Utah Commuterlink website).
    - Ventura County, California shows travel time from 5 am to 7 pm on weekdays (Hoops & Gallegos, 2006).
    - Orlando shows travel times all the time in accordance with its federal grant, but would have preferred to show travel times only when drivers need them (i.e., during hours when travel times are variable and unpredictable) (Heller, pc).
    - Missouri shows travel times only during rush hours because there is very rarely any congestion at other times, so travel time would not be beneficial. It was also felt that

keeping travel times on all day would lead drivers to ignore the information because the information was not helpful most of the time (Sommerhauser, pc).

52. What should CMS show when travel time is not displayed?
    - FHWA encourages operators to not leave CMS blank; make travel time the default display; and make all new urban CMS travel time-capable. However, travel time is generally lower priority than incident reports and amber alerts. In the U.S., there are currently no CMS dedicated to travel times (Meehan, 2005a).
    - The impetus for Wisconsin's travel time implementation was largely because people complained that CMSs were often blank and seemed like a waste of taxpayer money (Langer, 2005).
    - Idaho plans to make travel time a low priority, so it will be preempted by amber alerts and traffic management messages (Koeberlein, pc).
53. If travel time information is unavailable due to system failure or because travel time information is not shown at all times of the day, what should be shown? How do drivers react to a lack of travel time information and what reasons do they attribute to the lack of information?
    - Experience in many jurisdictions suggests that drivers hate blank signs, general safety messages (e.g., buckle up), and vague information (e.g., congestion ahead).
    - In the Bay Area, if one destination is not receiving good travel time data, the line is blanked out. If both destinations are not getting good data, the entire sign is blanked out (Travel times on changeable message signs in Caltrans district 4 – system architecture and operating rules, 2005).

# System Reliability and Accuracy

54. How accurate must travel time information be to gain and maintain public trust? What other factors influence perceived trustworthiness of travel time data?
    - FHWA recommends at least 90% accuracy, and never less than 80% (Meehan, 2005a).
    - For ATIS, "Across a typical trip, traffic information, such as congestion levels, should be at least 70% accurate." Local drivers may require higher levels of accuracy than drivers who are unfamiliar with an area (Campbell et al., 1998).
    - In a simulated ATIS evaluation, driver trust in the information provided was greatest at 100% accuracy, but even at 71% accuracy the information was still deemed useful. Driver performance and opinion suffered when accuracy was reduced to 43%. System inaccuracy had more detrimental effects on trust when drivers were in familiar settings (Kantowitz et al., 1996).
    - Simple algorithms are generally accurate enough without using advanced prediction models (Meehan, 2005a).
    - Oregon recommends accuracy of at least 70%; the travel time system is more accurate during free-flow conditions than during periods of congestion (Oregon Department of Transportation, 2005)
    - 70% of survey respondents in Japan felt that +/- 5 minutes is an acceptable range. Acceptable error range was insensitive to overall trip length (Chung et al., 2004).
    - In Chicago, most drivers believe that travel times are accurate even when they are not (Galas, pc).
    - In a London system designed to provide bus riders with predictive bus arrival times, 65% of surveyed riders felt that their average wait time decreased after the wait time system

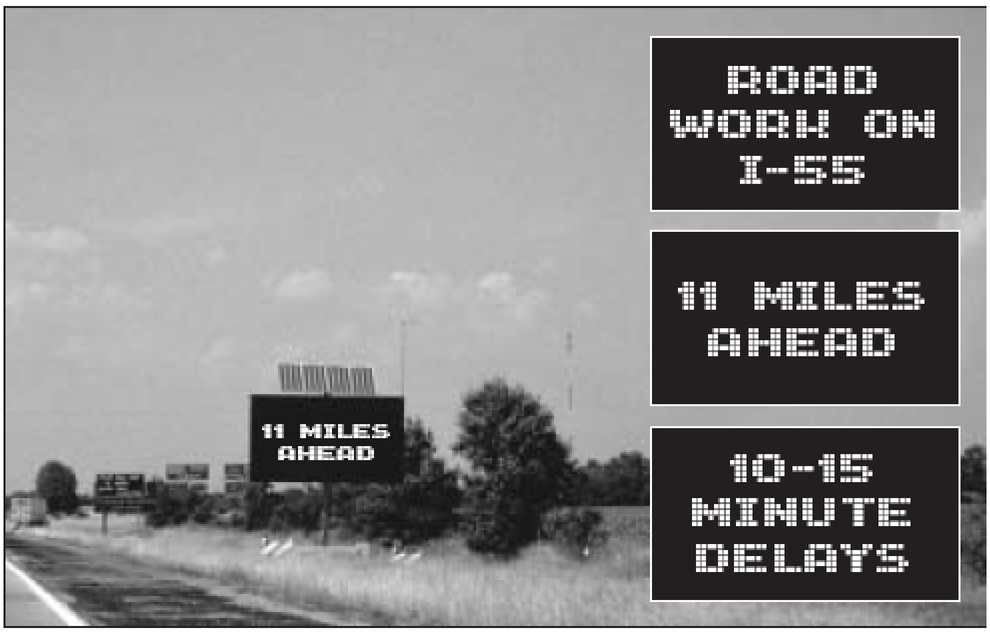
was implemented. Riders felt that bus arrival reliability increased even though it had, in fact, decreased (Smith et al., 1994; cited in Transit Cooperative Research Program, 2003).

55. How does travel time credibility affect the way people use travel time information?
    - Positive perceptions of traffic information accuracy has a significant effect on whether drivers choose to comply with route guidance information (Chen & Jovanis, 1779; cited in Lerner et al., 2000; Mahmassani & Liu, 1997; cited in Lerner et al., 1998).

## Mitigating Undesirable Results of Travel Time Information

56. What safety concerns do travel time messages raise? Might travel time messages lead to distraction, slowing, or unsafe driving by causing drivers to perform mental travel time/speed/rerouting calculations, pay too much attention to time (e.g., look at a watch or clock), or speed to try to beat calculated travel time estimates? Might encouraging people to divert to unfamiliar and non-freeway routes lead to an increase in crashes?
    - “Some agencies recommend that high accident locations should not be considered for VMS placement” (Enterprise, 2004, p 34).
    - A few agencies have reported drivers slowing to read travel time messages; Utah experienced traffic slowing soon after implementation (Meehan, 2005b) and Kansas City reports slowing as well as complaints of rear end crashes soon after implementation (Pinkerton, pc).
    - In Los Angeles area, traffic slowed measurably during the first days of travel time sign activity, but returned to baseline levels after two weeks (Caltrans, n.d.).
    - In California, drivers unfamiliar with travel time signs tend to slow to read signs. Locals slow down when travel times are first implemented, but grow accustomed to them quickly, though they will still slow if a novel message appears on a CMS usually used for travel time (Jenkinson, pc).
    - The majority of people who were “very dissatisfied” with travel times on CMS (36% of all survey respondents) believed that signs were causing drivers to slow down to read them (Caltrans travel time information project summary).
57. What are the best practices to prevent traffic from slowing and performing other unsafe behaviors?
    - Do not use animated/motion features because these can result in drivers looking away from the road for unsafe durations (Lerner et al., 2004).
    - Bay Area recommends seeking press coverage and posting message such as “TRAVEL TIMES COMING SOON ON THIS SIGN” a week before travel time launch (Margulici et al., 2006).
    - Shortly after starting to post travel time, Oregon Department of Transportation heard from police that drivers were slowing to read messages. Oregon Department of Transportation then began outreach campaign to educate public about travel time. They acknowledge that the outreach program should have begun before implementation (Oregon Department of Transportation, 2005).
    - In Utah, drivers slowed to read travel time messages after travel time was implemented. The problematic behavior was drastically reduced when Utah Department of Transportation responded with a public information campaign to educate the public (Meehan, 2005b).

## Presentation of Travel Time Information on Portable CMS

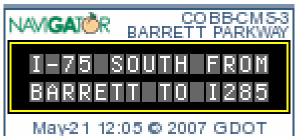
58. What are appropriate policies for use of travel times on portable CMS?
    - Except with rare exceptions the Gary-Chicago-Milwaukee (GCM) corridor does not allow portable CMS for travel times because space is too limited to provide detailed messages, visibility is insufficient, TMCs are generally not equipped to provide wireless real-time info to CMS not wired into system, and motorists do not expect travel times on portable CMS (GCM usage guidelines for portable CMS).
    - San Antonio has no plans to use portable CMS for travel time.
    - Roadside location may limit visibility.
    - Wisconsin demonstrated portable travel time in two work zones, but currently only use portable CMS for incident reporting, not travel time (Langer, 2005).
    - An Illinois demonstration used a 3-phase message for work zone information and delay time (see below) (Federal Highway Administration, 2004):
    - 

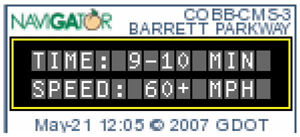

## Presentation of Travel Time Information on Non-Freeway Locations

59. How can freeway travel time be displayed prior to entering a freeway?
    - Wisconsin shows freeway travel time on arterials like this (showing one destination in each direction of travel on freeway) (Langer, 2005):

o 


o Altanta area (Barrett Parkway) has at least two smaller, two-phase board that display travel time messages prior to freeway entry (phase 1 on left, phase 2 on right) (Georgia Navigator web site):

o 

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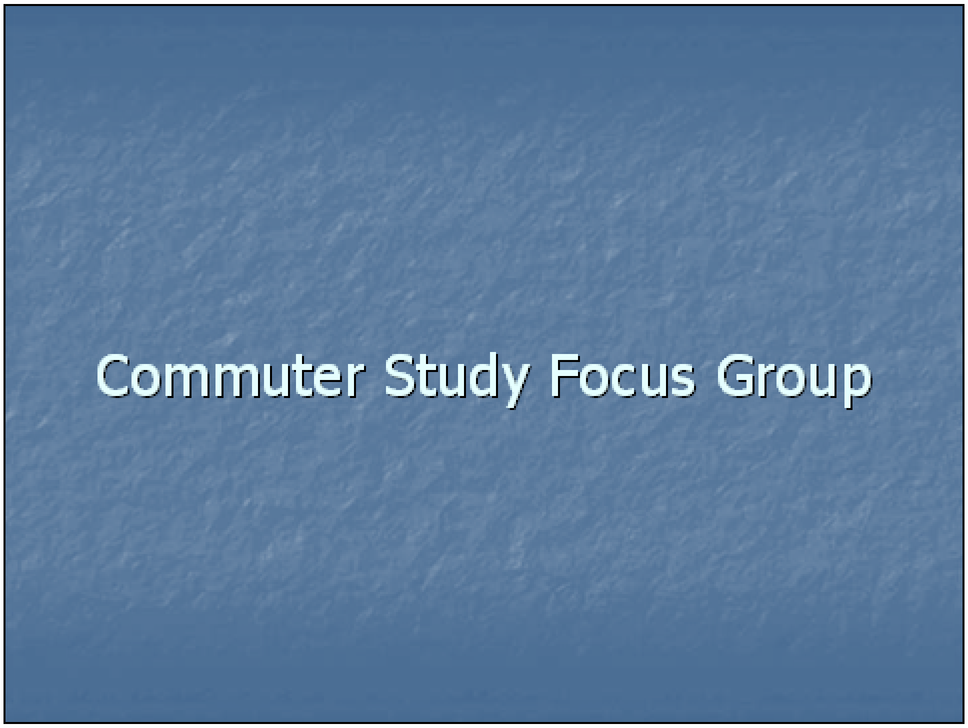
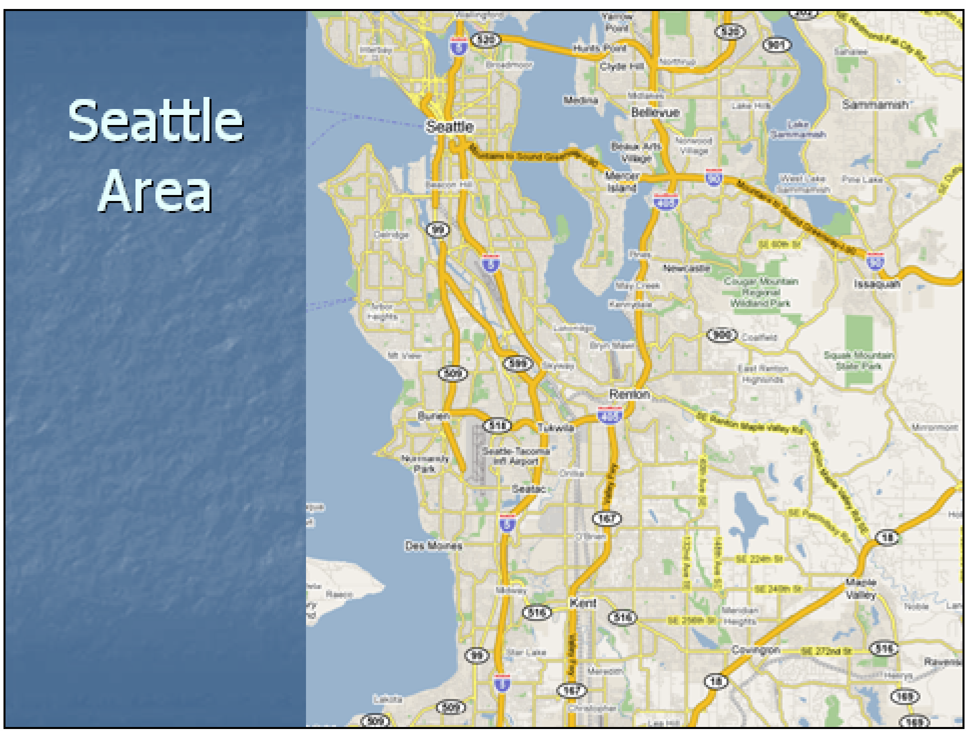
# Personal Communications

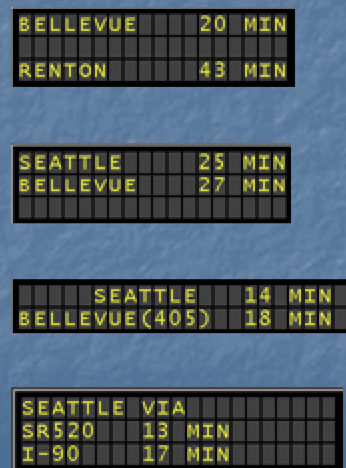
| Name | Affiliation | Travel Time Location |
|---|---|---|
| Clayton, Robert | Utah DOT | Salt Lake City, UT |
| Connell, Steve | Texas DOT | Forth Worth, TX |
| Dembowski, Doug | Wisconsin DOT | State of Wisconsin |
| Fariello, Brian | Texas DOT, San Antonio District | San Antonio, TX |
| Galas, Jeff | Illinois DOT | Chicago, IL |
| Heller, Jennifer | Florida DOT, District 5 | Orlando, FL |
| Jacobson, Eldon | Washington State DOT | Seattle, WA |
| Jenkinson, Mike | Caltrans | State of California |
| Koeberlein, Robert | Idaho DOT | Boise, ID |
| Lively, David | Caltrans | State of California |
| Pinkerton, Troy | Missouri DOT | Kansas City and St. Louis, MO |
| Sommerhauser, Mark | Missouri DOT | Kansas City and St. Louis, MO |
| Vik, Timothy | DAAR Engineering at Wisconsin DOT | State of Wisconsin |

## Appendix B: Focus Group Slides (Seattle)

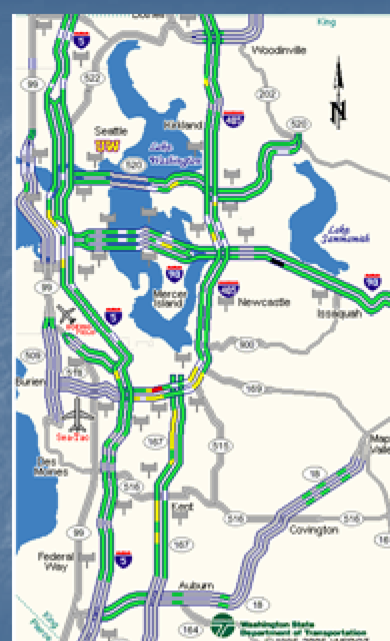


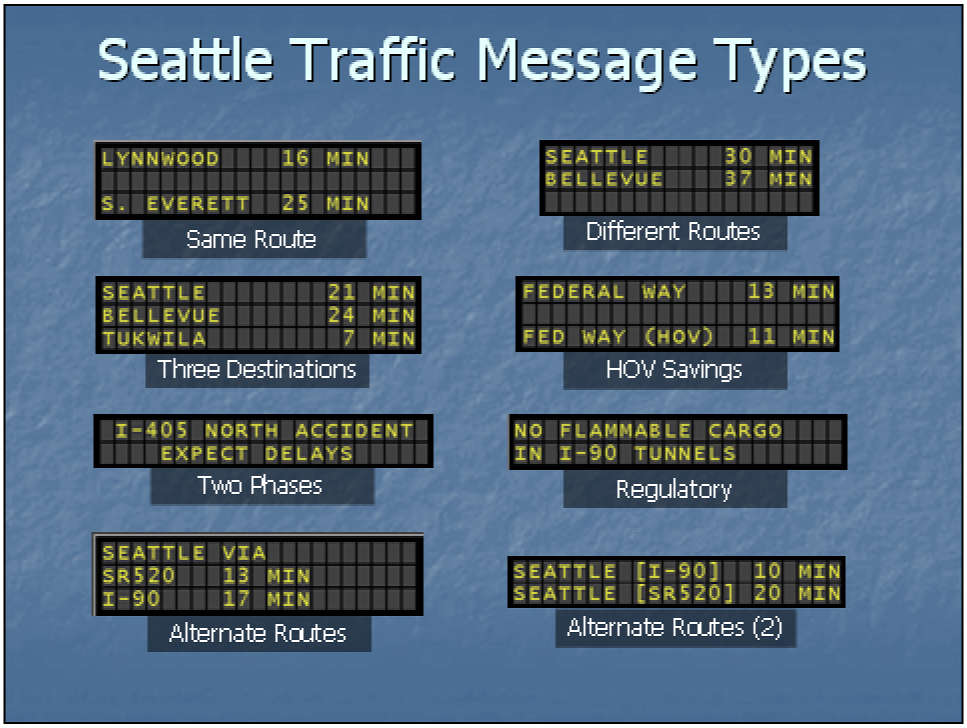



# Seattle Area Travel Time Signs


# Seattle Area Electronic Signs

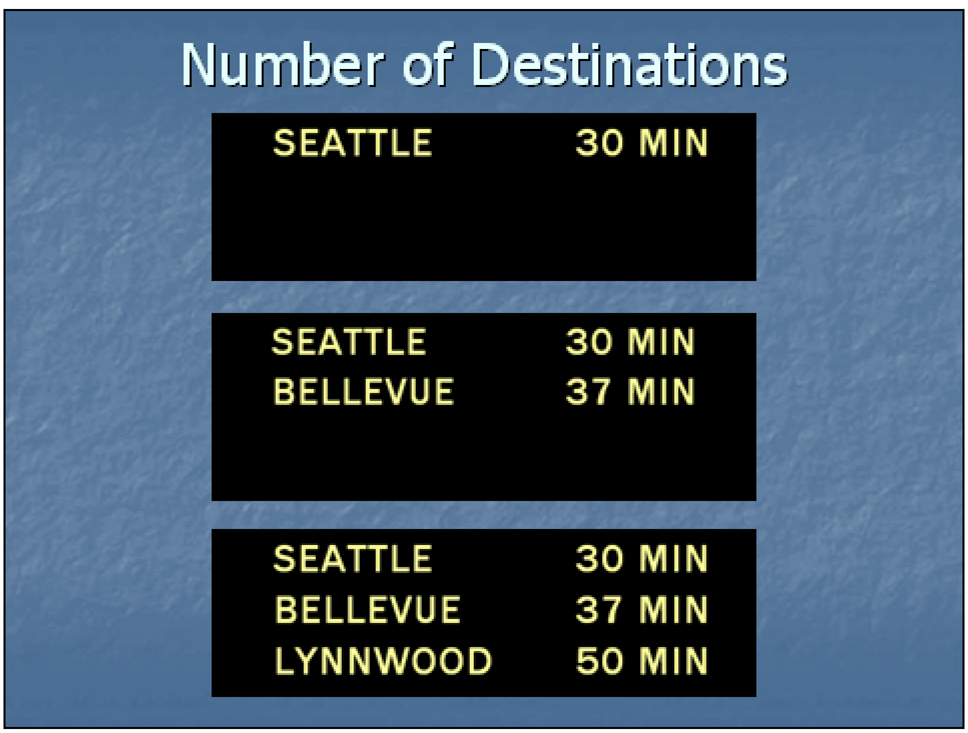


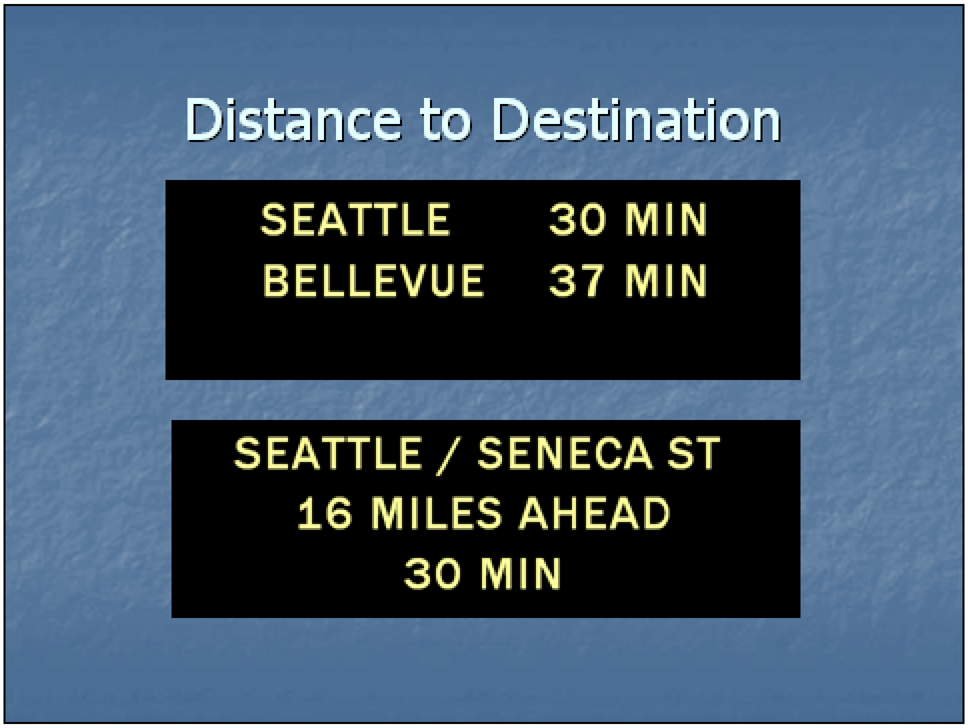

Seattle Traffic Message Types
LYNNWOOD 16 MIN
S. EVERETT 25 MIN
Same Route
SEATTLE 30 MIN
BELLEVUE 37 MIN
Different Routes
SEATTLE 21 MIN
BELLEVUE 24 MIN
TUKWILA 7 MIN
Three Destinations
FEDERAL WAY 13 MIN
FED WAY (HOV) 11 MIN
HOV Savings
I-405 NORTH ACCIDENT
EXPECT DELAYS
Two Phases
NO FLAMMABLE CARGO
IN I-90 TUNNELS
Regulatory
SEATTLE VIA
SR520 13 MIN
I-90 17 MIN
Alternate Routes
SEATTLE [I-90] 10 MIN
SEATTLE [SR520] 20 MIN
Alternate Routes (2)

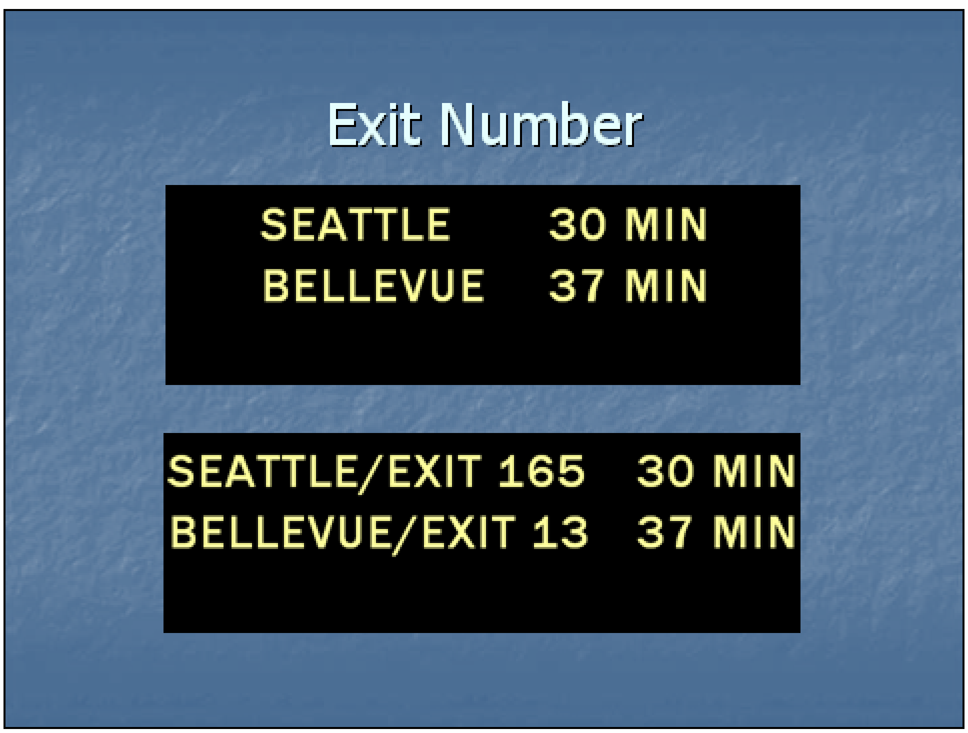

Other U.S. Travel Time Signs
FROM 17TH AVE.
TO I-70/71 SPLIT
APPROX. 4 MINUTES
Columbus, OH
TRAVEL TIME TO
IH10 7-9 MINS
IH35 10-12 MINS
San Antonio, TX
TRAVEL TIME
I-215 5 MIN
600 S 19 MIN
Salt Lake City, UT
FREEWAY TIME TO
HWY 100 AT I-43
9 MIN
Milwaukee, WI
TRAVEL TO
RTE 710. 10 MIN
RTE 605. 15 MIN
Los Angeles, CA
Atlanta, GA
TRAVEL TIME
TO DOWNTOWN
7 MIN AT 3:25
Houston, TX

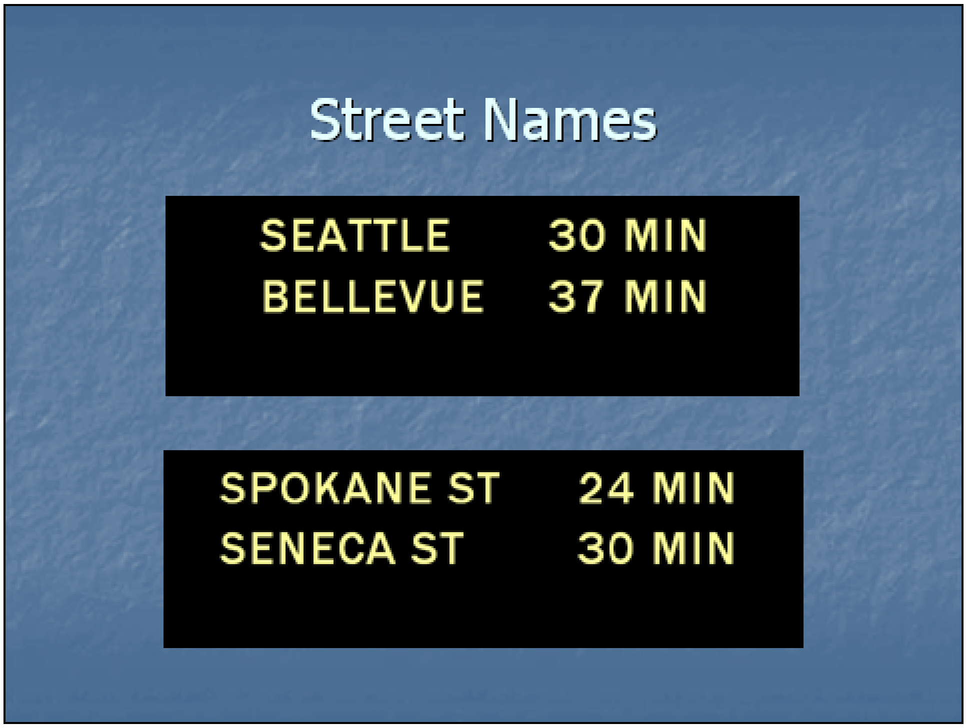

# Travel Time Sign Comparisons

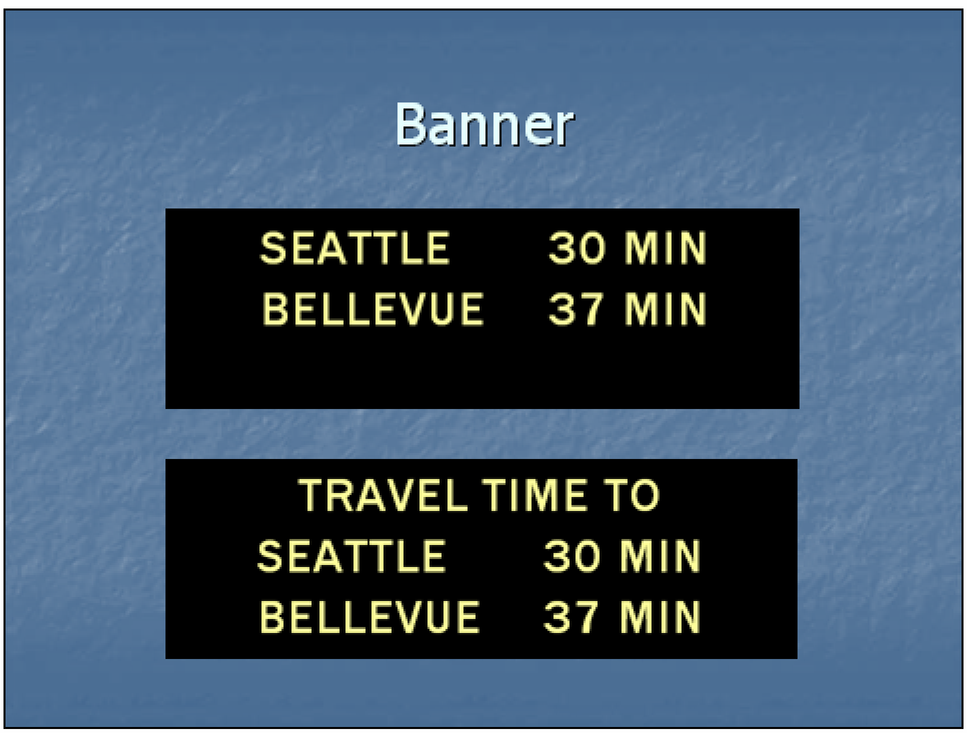

Time Format
SEATTLE 30 MIN
BELLEVUE 37 MIN
SEATTLE 28-32 MIN
BELLEVUE 35-39 MIN


Number of Destinations
SEATTLE 30 MIN
SEATTLE 30 MIN
BELLEVUE 37 MIN
SEATTLE 30 MIN
BELLEVUE 37 MIN
LYNNWOOD 50 MIN

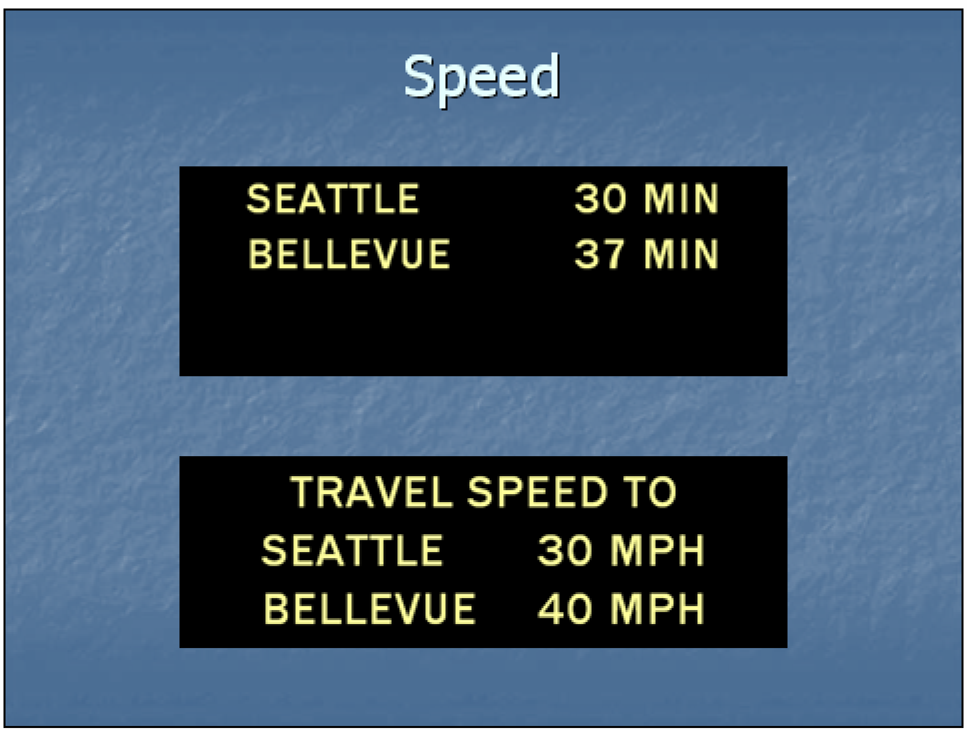

Distance to Destination
SEATTLE 30 MIN
BELLEVUE 37 MIN
SEATTLE / SENECA ST
16 MILES AHEAD
30 MIN


Exit Number
SEATTLE 30 MIN
BELLEVUE 37 MIN
SEATTLE/EXIT 165 30 MIN
BELLEVUE/EXIT 13 37 MIN

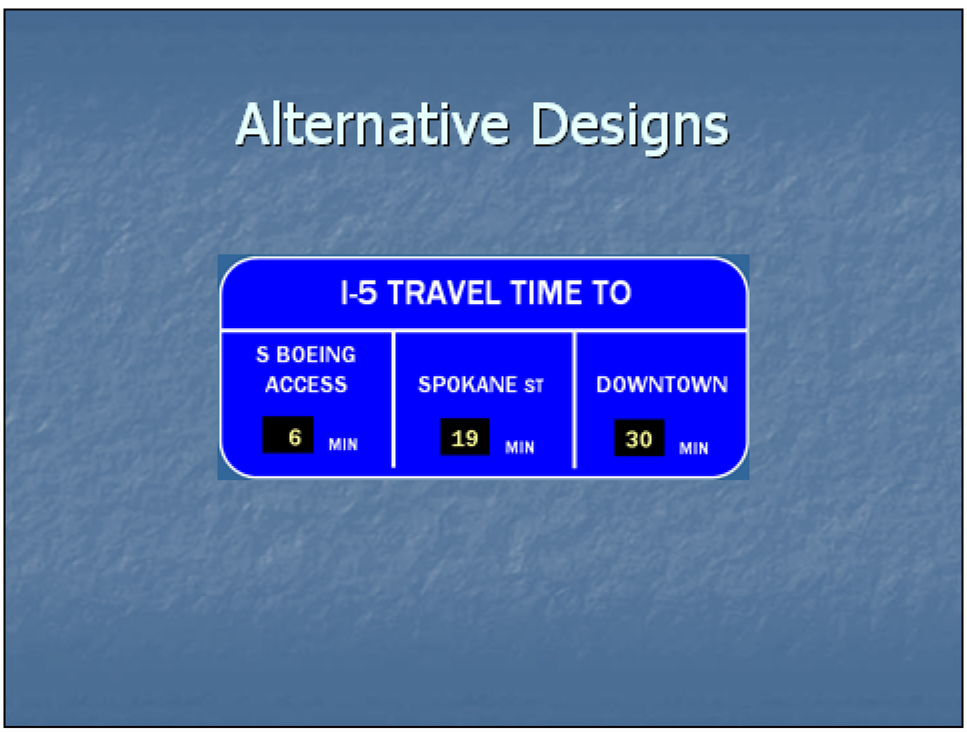

Street Names
SEATTLE 30 MIN
BELLEVUE 37 MIN
SPOKANE ST 24 MIN
SENECA ST 30 MIN

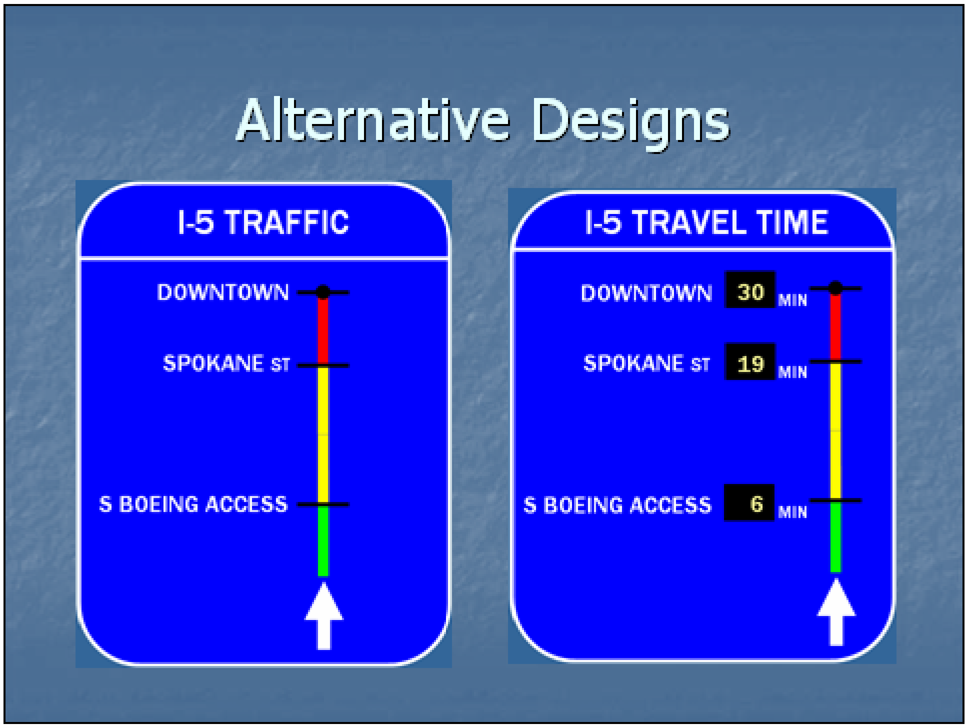

Banner
SEATTLE 30 MIN
BELLEVUE 37 MIN
TRAVEL TIME TO
SEATTLE 30 MIN
BELLEVUE 37 MIN

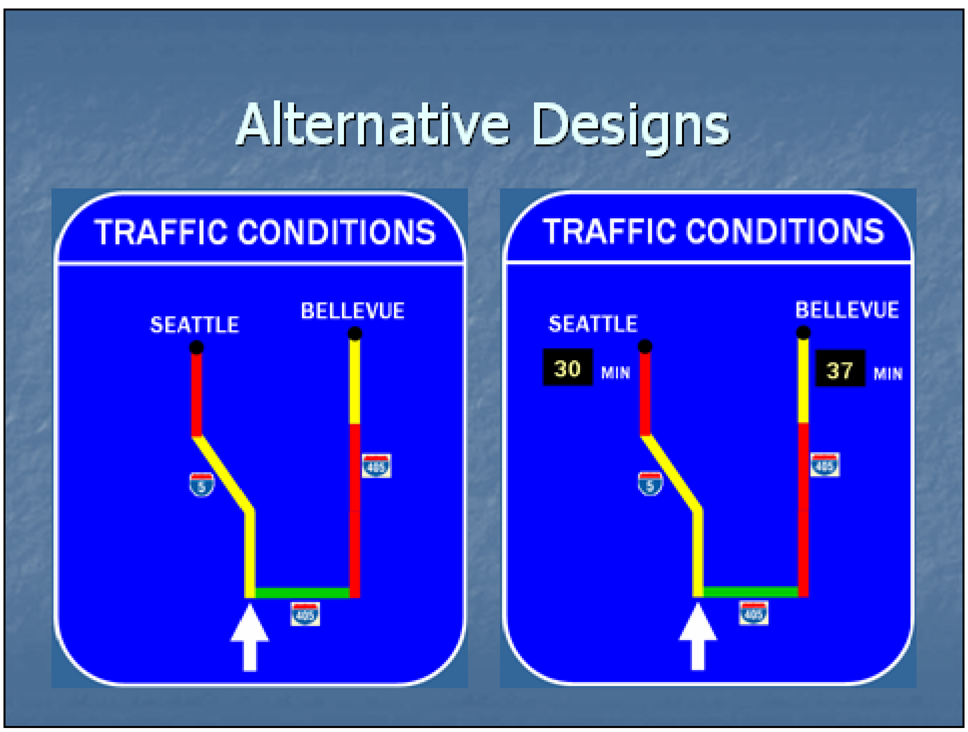

Timestamp
SEATTLE 30 MIN
BELLEVUE 37 MIN
SEATTLE 30 MIN
BELLEVUE 37 MIN
UPDATED 8:15 AM


Speed
SEATTLE 30 MIN
BELLEVUE 37 MIN
TRAVEL SPEED TO
SEATTLE 30 MPH
BELLEVUE 40 MPH


Delay
SEATTLE 30 MIN
BELLEVUE 37 MIN
DELAY TO
SEATTLE 16 MIN DELAY
BELLEVUE 14 MIN DELAY


Alternative Designs
I-5 TRAVEL TIME TO
S BOEING ACCESS
6 MIN
SPOKANE ST
19 MIN
DOWNTOWN
30 MIN


Alternative Designs
I-5 TRAFFIC
DOWNTOWN
SPOKANE ST
S BOEING ACCESS
I-5 TRAVEL TIME
DOWNTOWN
30 MIN
SPOKANE ST
19 MIN
S BOEING ACCESS
6 MIN


Alternative Designs
TRAFFIC CONDITIONS
SEATTLE
BELLEVUE
TRAFFIC CONDITIONS
SEATTLE
BELLEVUE
30 MIN
37 MIN


Alternative Designs
TRAFFIC SPEEDS
518 WEST 50 MPH
I-405 EAST 30 MPH
TRAFFIC SPEEDS
518
WEST
SPEED: 50 MPH
405
EAST
SPEED: 30 MPH

# Appendix C: Driver Log Form

Date: ________________ Trip start time: ________ am pm Trip completion time: ________ am pm

1. From what sources did you receive traffic information before starting your trip? *(check all that apply)*:

___TV ___Radio ___DOT website ___Other website ___511 call ___Family/friend Other *(specify)*: ________________

2. Did any of these pre-trip sources influence your route choice or any other trip decisions? Yes No

*If yes, explain:* ________________

3a. Did you start this trip at your usual home/work location? Yes No

*If not, explain:* ________________

3b. Did you complete this trip at your usual home/work location? Yes No

*If not, explain:* ________________

3c. Did you make any stops in between? Yes No

*If yes, explain:* ________________

4a. When you started your trip, did you plan to take I-5? Yes No 4b. Did you actually take I-5 on this trip? Yes No

5. Did you see any travel time signs on the road before reaching I-5? Yes No

*If yes, how did the travel time info affect your route choice?:* ________________

________________

6a. From what road did you enter I-5? ________________ 6b. At what road did you exit I-5? ________________

*If you did not take I-5, describe alternate route:* ________________

7a. What was your average speed on the freeway on this trip? *(check one)*:

___Less than 10 mph below speed limit ___10-19 mph below speed limit ___20-29 mph below speed limit ___30 or more mph below speed limit

7b. How did the level of congestion on the freeway compare to your typical commuting experience on this route? *(check one)*:

___Much worse than usual ___Slightly worse than usual ___Normal/typical ___Slightly better than usual ___Much better than usual

8. What information do you recall seeing on electronic signs on the freeway? *(check all that apply)*:

___Travel time ___Congestion/delay ___Incident (example: crash, disabled vehicle) ___Construction/work zone ___Lane closure ___Alternate route info

9. The information on electronic signs made me confident that my current route would be _?_ compared to an alternate route. (check one):

___faster ___slower ___about the same speed ___I was not confident whether my current route or an alternate route would be faster

10. Did you exit the freeway early to take an alternate route? Yes No

*a. Why or why not? (please include all factors in your decision):* ________________

________________

*b. If you exited the freeway to take an alternate route, describe your alternate route:* ________________

________________

11. Please rate how strongly you agree or disagree with each of the following statements about the electronic travel times signs you saw on this trip:

a. The travel time signs on my route influenced my route choice. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

b. The travel times I saw were accurate. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

c. The destinations shown on the travel time signs were relevant to my trip. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

d. The travel time signs caused drivers to slow down or drive dangerously. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

e. The travel time signs included more information than I could read as I passed them. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

f. Making use of the travel time signs saved me time on this trip. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

g. The travel time signs allowed me to predict when I would arrive at my destination. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

h. I am confident that I made the best decisions about my route. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

i. Overall, I liked having travel time presented during this trip. *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* ___not applicable

12. Of all the traffic information you saw or heard before or during your trip, what information was the most useful to you? *Specify the information source and the information it provided:* ________________

________________

13. What information that you did not receive before or during this trip would have been useful to you? ________________

________________

________________

14. Describe the weather on this trip (*check all that apply*): ___ Clear ___ Rain ___ Road wet ___ Fog

# Appendix D: Commuter Study Final Questionnaire

**Commuter Study Final Questionnaire**

***Complete this questionnaire after you have filled in your final trip log form, then mail it back to Westat in the postage paid envelope with your second week's log forms.***

**Please rate how strongly you agree or disagree with each of the following statements about the travel time signs in your area.**

| | |
|---|---|
| **1.** The travel time information is accurate. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **2.** Travel time signs are located at places where the information is useful to me. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **3.** The destinations shown on travel time signs are useful to me. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **4.** I understand what the destination names mean and where they are. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **5.** The travel time signs give me a good idea of how heavy traffic is on my route. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **6.** The travel time signs give me a good idea of when I will arrive at my destination. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **7.** The travel time signs give me information that helps me to save time on my trips. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **8.** I use travel time signs to decide which route I should take. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **9.** I have enough time to read the information I need on travel time signs. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **10.** Travel time signs cause me to look away from the road for too long. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **11.** I see other drivers slow down or drive dangerously in the area of travel time signs. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **12.** Travel time signs could be more useful to me if they were implemented differently. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |
| **13.** I would like travel time signs to show travel times to a particular destination using two different routes. | *Strongly disagree* → 1—2—3—4—5 ← *Strongly agree* |

**14.** Describe what you like most about travel time signs. ____________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**15.** Describe what you dislike most about travel time signs. ____________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

16. For each of the following characteristics of travel time signs, please briefly explain any ways in which travel time signs do not fully meet your needs and what improvements should be made.

- *Locations of travel time signs* ______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

- *Destinations listed on signs* ______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

- *Amount and type of information on each sign* ______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

- *Appearance/layout of information* ______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

- *Accuracy of travel time estimates* ______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

**17.** Do you use travel time signs to decide whether to stay on your planned route or divert to a different route?
*(circle one)* ___ Yes ___No *Why or why not?*

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

**18.** Is there any way that travel time signs could be improved to help you make better route decisions or to give you more information about alternate routes? Explain.

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

**19.** What other sources do you use to get traffic information? How do these sources compare to travel time signs in terms of usefulness to you? Is there any benefit to getting traffic information from multiple sources?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

**20.** Are there any other types of traffic information that you would prefer to see on signs instead of travel time? For example: average traffic speed, length or duration of delay, incident or lane closure information. Why or why not?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

**21.** What other changes would you like to see made to travel time signs? ________________________________

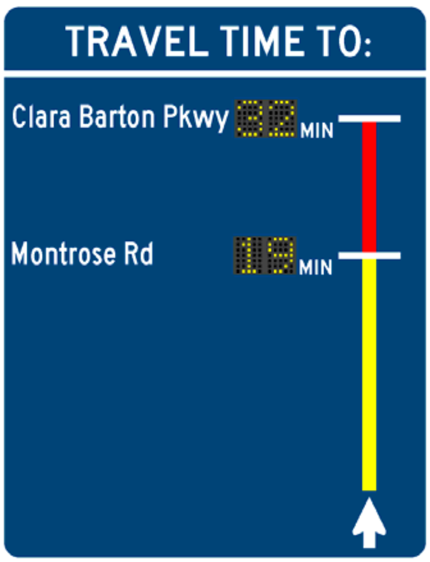
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

# Appendix E: Study 2 Sign Stimuli

## BASE SIGNS

**Basesign1**


**Basesign2**



# SIGNS 2 – 15

**Sign2**


**Sign3**


**Sign4 – phase 1**


**Sign4 – phase 2**


**Sign5**


**Sign6**


**Sign7**


**Sign8**


**Sign9**


**Sign10**


**Sign11**


**Sign12**


**Sign13**


**Sign14**


**Sign15**

# SIGNS 16 – 32

**Sign16**


**Sign17**


**Sign19**


**Sign20**


**Sign21**


**Sign22**


**Sign23**


**Sign24**


**Sign25**


**Sign26**


**Sign27**


**Sign28**


**Sign29**


**Sign30**


**Sign31**

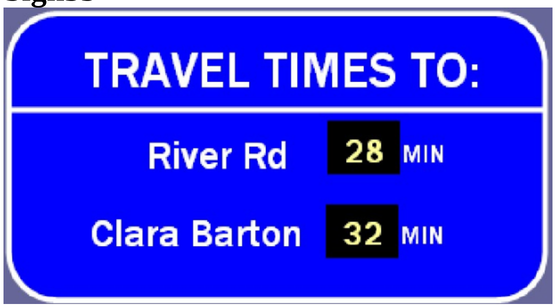

**Sign32**

## SIGNS 33 – 44

Sign33


Sign34


Sign35




Sign36 – phase 1


Sign36 – phase 2


Sign37


Sign38


Sign39


Sign40


Sign41


Sign42 – phase 1


Sign42 – phase 2


Sign43 – phase 1


Sign43 – phase 2


Sign44 – phase 1


Sign44 – phase 2

# DIAGRAMMATIC SIGNS 1 – 9

**Diagram1**


**Diagram2**

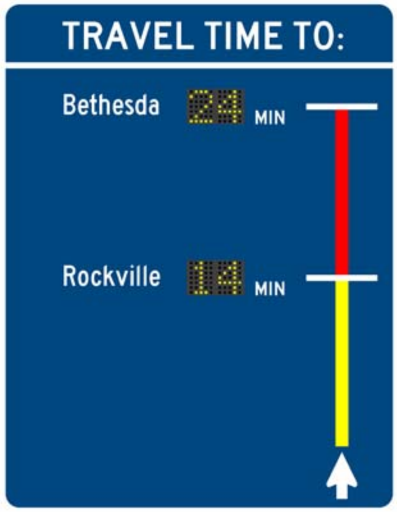



**Diagram3**

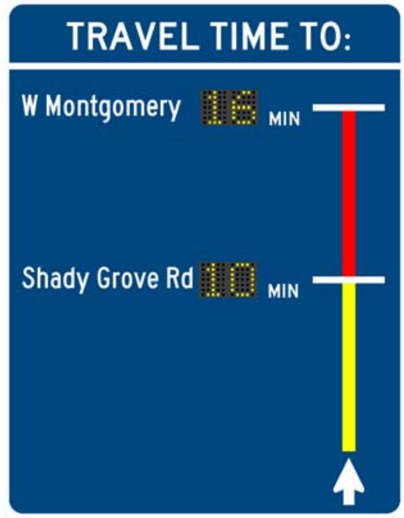



**Diagram4**

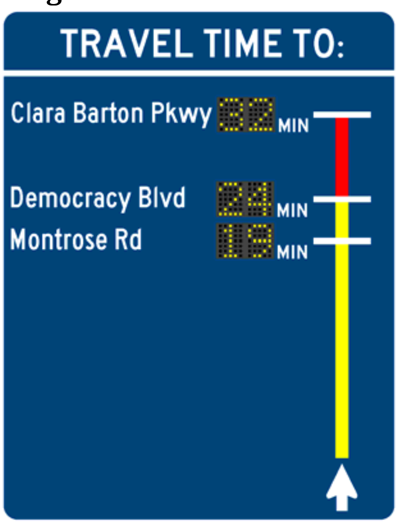



**Diagram5**


**Diagram6**

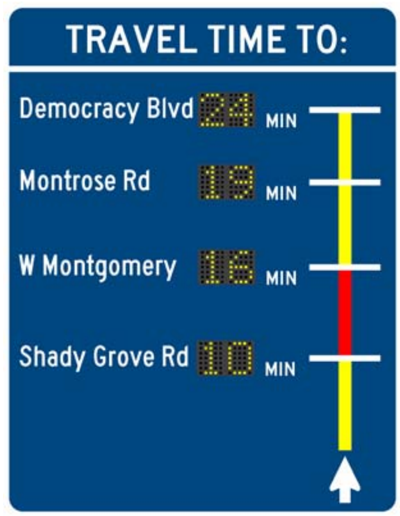



**Diagram7**

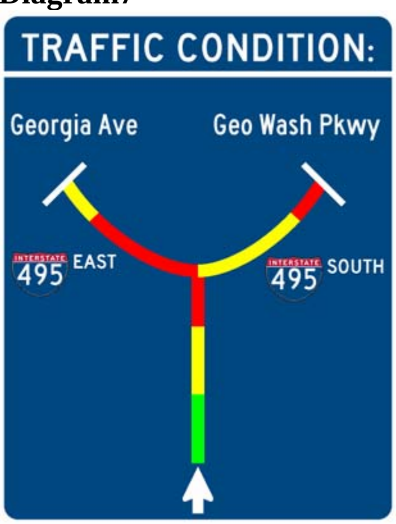



**Diagram8**

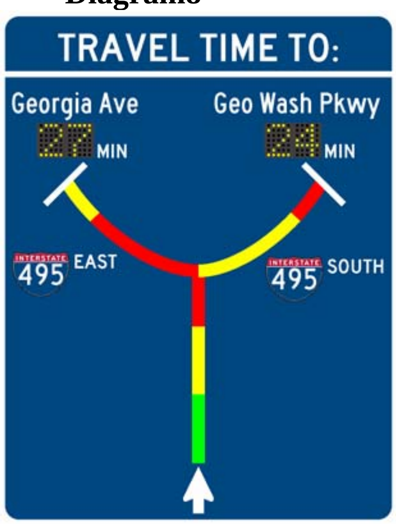
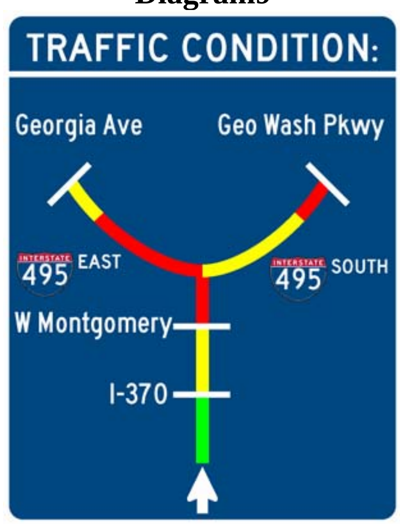



**Diagram9**



# HEAVY TRAFFIC MORNING SIGNS 1 – 6

**Hmorning1**


**Hmorning2**

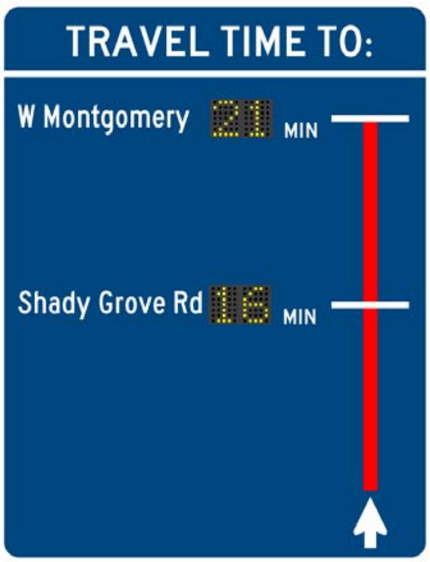

**Hmorning3**


**Hmorning4**


**Hmorning5 – phase 1**


**Hmorning5 – phase 2**


**Hmorning6**



# HEAVY TRAFFIC EVENING SIGNS 1 – 5

**Hevening1**


**Hevening2**


**Hevening3**


**Hevening4**


**Hevening5 – phase 1**


**Hevening– phase 2**

# UNFAMILIAR SIGNS 1 – 5

**Unfamiliar1**


**Unfamiliar2**


**Unfamiliar3**


**Unfamiliar4**


**Unfamiliar5 – phase 1**


**Unfamiliar5 – phase 2**

# BENCHMARKS

**Benchmark1**


**Benchmark2**


**Benchmark3**


**Benchmark4**


**Benchmark5**


**Benchmark6**

# Appendix F: Study 2 Mean Values for Each Sign

| Sign | Latency | Ease of Processing | Diversion | Confidence | Information units |
|---|---|---|---|---|---|
| Base1 | 3.96 | 8.11 | 4.69 | 7.93 | 5.00 |
| Base2 | 4.11 | 6.44 | 4.31 | 6.60 | . |
| Benchmark1 | 3.40 | 8.27 | 3.56 | 7.58 | 4.00 |
| Benchmark2 | 4.01 | 8.73 | 3.88 | 8.08 | 5.00 |
| Benchmark3 | 4.08 | 7.63 | 3.23 | 7.29 | 6.00 |
| Benchmark4 | 4.46 | 7.88 | 4.13 | 7.96 | 7.00 |
| Benchmark5 | 4.31 | 6.94 | 4.08 | 7.40 | 8.00 |
| Benchmark6 | 4.54 | 8.85 | 3.69 | 8.15 | 9.00 |
| Diagram1 | 3.87 | 6.38 | 4.48 | 6.23 | . |
| Diagram2 | 3.91 | 7.67 | 3.81 | 7.48 | . |
| Diagram3 | 4.09 | 6.13 | 3.96 | 6.77 | . |
| Diagram4 | 4.37 | 6.90 | 4.31 | 6.85 | . |
| Diagram5 | 4.54 | 5.13 | 4.13 | 6.15 | . |
| Diagram6 | 4.63 | 5.23 | 3.73 | 6.19 | . |
| Diagram7 | 4.49 | 4.65 | 3.92 | 5.13 | . |
| Diagram8 | 4.72 | 4.92 | 4.19 | 5.71 | . |
| Diagram9 | 4.76 | 5.06 | 4.02 | 6.02 | . |
| Hevening1 | 4.08 | 8.21 | 4.69 | 7.72 | 5.00 |
| Hevening2 | 4.44 | 8.38 | 4.94 | 7.73 | 7.00 |
| Hevening3 | 4.50 | 7.56 | 6.27 | 7.81 | 6.00 |
| Hevening4 | 4.17 | 8.38 | 5.69 | 7.92 | 5.00 |
| Hevening5 | . | 8.21 | 6.77 | 8.02 | 8.00 |
| Hmorning1 | 3.78 | 8.52 | 5.15 | 7.96 | 5.00 |
| Hmorning2 | 4.43 | 8.48 | 4.27 | 8.04 | 7.00 |
| Hmorning3 | 4.57 | 7.81 | 6.56 | 7.92 | 6.00 |
| Hmorning4 | 4.09 | 8.54 | 5.40 | 8.33 | 5.00 |
| Hmorning5 | . | 7.96 | 6.31 | 7.73 | 8.00 |
| Hmorning6 | 4.37 | 6.21 | 4.63 | 6.52 | . |
| Sign2 | 4.31 | 7.29 | 4.13 | 7.58 | 7.00 |
| Sign3 | 4.72 | 7.02 | 3.73 | 7.29 | 9.00 |
| Sign4 | . | 8.22 | 3.57 | 8.24 | 6.00 |
| Sign5 | 4.52 | 7.90 | 4.13 | 8.04 | . |
| Sign6 | 4.50 | 8.13 | 4.56 | 7.98 | 6.00 |
| Sign7 | 4.44 | 8.50 | 4.40 | 8.23 | 6.00 |
| Sign8 | 4.15 | 7.96 | 4.17 | 7.54 | 5.00 |
| Sign9 | 4.38 | 8.08 | 4.31 | 8.08 | 5.00 |
| Sign10 | 3.98 | 8.56 | 5.17 | 7.92 | 5.00 |
| Sign11 | 4.35 | 7.60 | 4.19 | 7.55 | 7.00 |
| Sign12 | 4.46 | 7.55 | 4.62 | 7.67 | 7.00 |
| Sign13 | 4.26 | 7.55 | 4.12 | 7.48 | 6.00 |
| Sign14 | 4.17 | 8.00 | 3.95 | 8.00 | 5.00 |
| Sign15 | 4.30 | 7.21 | 4.71 | 7.40 | 5.00 |
| Sign16 | 4.04 | 8.10 | 5.60 | 7.19 | 4.00 |

| | | | | | |
|---|---|---|---|---|---|
| Sign17 | 4.57 | 7.73 | 5.69 | 7.58 | 6.00 |
| Sign19 | 4.10 | 8.31 | 3.98 | 8.06 | 5.00 |
| Sign20 | 4.03 | 8.58 | 4.04 | 8.15 | 5.00 |
| Sign21 | 4.13 | 7.71 | 4.10 | 7.60 | 5.00 |
| Sign22 | 4.50 | 8.02 | 4.35 | 7.85 | 6.00 |
| Sign23 | 4.45 | 8.35 | 6.19 | 7.94 | 6.00 |
| Sign24 | 4.42 | 7.56 | 4.02 | 7.23 | 5.00 |
| Sign25 | 4.44 | 7.98 | 4.40 | 7.67 | 5.00 |
| Sign26 | 4.41 | 7.46 | 3.98 | 7.27 | 5.00 |
| Sign27 | 3.97 | 8.48 | 3.85 | 7.83 | 5.00 |
| Sign28 | 4.34 | 8.10 | 4.48 | 7.92 | 4.00 |
| Sign29 | 4.37 | 7.56 | 4.60 | 6.75 | 5.00 |
| Sign30 | 3.97 | 8.65 | 4.54 | 7.92 | 4.00 |
| Sign31 | 4.25 | 7.64 | 4.90 | 7.31 | 5.00 |
| Sign32 | 3.92 | 8.52 | 4.06 | 8.13 | 5.00 |
| Sign33 | 4.22 | 7.44 | 4.00 | 7.60 | 5.00 |
| Sign34 | 4.15 | 8.83 | 6.13 | 7.38 | 4.00 |
| Sign35 | 4.11 | 8.75 | 4.71 | 8.35 | 5.00 |
| Sign36 | . | 7.31 | 4.06 | 7.33 | 10.00 |
| Sign37 | 4.69 | 7.27 | 4.02 | 6.94 | 7.00 |
| Sign38 | 4.31 | 6.98 | 4.19 | 7.02 | 5.00 |
| Sign39 | 3.79 | 7.79 | 3.85 | 7.46 | 4.00 |
| Sign40 | 4.43 | 8.52 | 4.29 | 8.23 | 6.00 |
| Sign41 | 4.62 | 7.50 | 3.52 | 7.67 | 8.00 |
| Sign42 | . | 7.98 | 6.21 | 7.48 | 9.00 |
| Sign43 | . | 7.90 | 6.58 | 7.42 | 7.00 |
| Sign44 | . | 7.54 | 6.48 | 7.56 | 8.00 |
| Unfamiliar1 | 3.77 | 8.13 | 4.13 | 7.13 | 5.00 |
| Unfamiliar2 | 4.27 | 7.27 | 4.08 | 6.63 | 7.00 |
| Unfamiliar3 | 4.62 | 7.35 | 6.27 | 7.63 | 6.00 |
| Unfamiliar4 | 3.86 | 8.13 | 4.29 | 7.58 | 5.00 |
| Unfamiliar5 | . | 6.72 | 5.87 | 6.39 | 8.00 |