Technical Report Documentation Page

1. Report No. IAC- 5-9049-01_R1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle GRAPHICAL ROUTE INFORMATION PANEL SIGNS FOR SOUTHBOUND I-35 AND SH 130 TRAVEL THROUGH AUSTIN		5. Report Date March 2014
		6. Performing Organization Code
7. Author(s) Gerald L. Ullman, Robert Brydia, Alicia A. Nelson, Laura L. Higgins, Richard T. Baker, and Tina S. Geiselbrecht		8. Performing Organization Report No.
9. Performing Organization Name and Address Texas A&M Transportation Institute College Station, Texas 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 70-3TTIA001
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, Texas 78701-2483		13. Type of Report and Period Covered Technical Report: July 2013–March 2014
		14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation.
Project Title: Southbound GRIP Sign Design Assistance for Austin

16. Abstract
A Graphic Route Information Panel (GRIP) is a proposed on-roadway signage approach to deliver information in advance of a driver decision point, using a combination of text, colors, and representative maps of the roadway system. The information basis for a GRIP sign is dynamic, reflecting changing roadway conditions such as congestion indicators and/or pricing levels. The purpose of this project is to determine the safe and optimal design features for a GRIP sign to be placed on Southbound Interstate 35 (I-35) north of, and within, Austin, Texas, to present drivers with information to affect a travel choice between I-35, which does not carry a toll, and State Highway 130 (SH 130), which does.

Based on the results of focus group studies, laptop-based human factors laboratory studies of driver sign comprehension, and driving simulator studies evaluating driver eye-glance behavior around GRIP signs, researchers developed recommended GRIP sign designs for I-35 near Georgetown. Additional steps required to ultimately fabricate, install, and operate this type of sign were also provided.

17. Key Words		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 214	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

GRAPHICAL ROUTE INFORMATION PANEL SIGNS FOR SOUTHBOUND I-35 AND SH 130 TRAVEL THROUGH AUSTIN

by

Gerald L. Ullman, PhD, P.E.
Senior Research Engineer

Robert E. Brydia
Research Scientist

Alicia A. Nelson
Associate Research Specialist

Laura L. Higgins
Associate Research Scientist

Richard T. Baker
Assistant Research Scientist

and

Tina S. Geiselbrecht
Associate Research Scientist

70-3TTIA001
Project Title: Southbound GRIP Sign Design Assistance for Austin

Performed in cooperation with the
Texas Department of Transportation

March 2014

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Gerald L. Ullman, P.E. #66876. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT. The TxDOT project monitoring committee consisted of Joe Adams, Shannon Crum, Mike Chacon, Charles Koonce, Marcy Saenz, John Nevares, and Greg Malatek. Their input on the GRIP options examined are gratefully acknowledged. The assistance of Bari Kotwal, Christine Yager, Sarah Young, Sandra Stone, Nada Trout, Jeff Miles, and Myunghoon Ko of TTI during data collection, reduction, and analysis is also gratefully acknowledged.

EXECUTIVE SUMMARY

Graphical route information panels (GRIPs) are believed to have significant potential for improving driver access to real-time information while en route. GRIPs typically use a combination of text, colors, and a map representing one or more roadways. The information basis for a GRIP sign is dynamic, reflecting roadway conditions that are changing, such as congestion indicators and/or travel times. GRIPs are in use in several countries, but to date, not in the United States.

GRIP signs can present significant information load to drivers. Unfortunately, the amount of information load generated by a particular GRIP designs cannot be estimated beforehand at this time. Thus, agencies contemplating the deployment of GRIP signs must ensure that the signs to be used are effectively understood and do not overload the typical driver. Information overload conditions can cause drivers to shed information, which can result in reduced decision-making accuracy. In addition, some drivers approaching a sign with too much information may also choose to significantly reduce their speed to increase their available sign viewing time. Such behavior leads to large speed differentials and is obviously undesirable from a safety perspective.

TxDOT has expressed interest in using GRIP signs on southbound Interstate 35 (I-35) approaching and through the Austin, Texas, metropolitan area. SH 130, a toll facility, bypasses Austin and offers both long-distance and local travelers a convenient alternative to the congested I-35, which runs through the center of the city. Therefore, this project was initiated to assist in the design of GRIP signs that could be used to be used. The project followed a traditional engineering design process, consisting of three key steps:

- Focus group studies of both Austin (familiar) and out-of-city drivers to determine key design elements and element options needed or desired for a GRIP sign.
- Computer-based laptop studies to systematically evaluate the key sign design element options upon driver comprehension and information loading.
- Driving simulator studies using eye-tracking technology to assess the potential influence of the best GRIP design(s) upon driver eye glance behavior to ensure that such signs do not cause unduly long glances.

Overall, the focus group studies verified that map orientation, and amount of real-time information load presented should all be systematically evaluated in human factors studies. Simplified map presentations (similar to routes shown on bus routes or subway maps) were not recommended for study, as focus group participant felt that a simplified map display could be misinterpreted and lead to confusion among drivers. Potential GRIP locations participants indicated that should be tested included I-35 in Georgetown (prior to the I-35/SH 130 interchange), Round Rock (prior to the I-35/SH 45 interchange), and Austin (prior to the I-35/US 290 interchange).

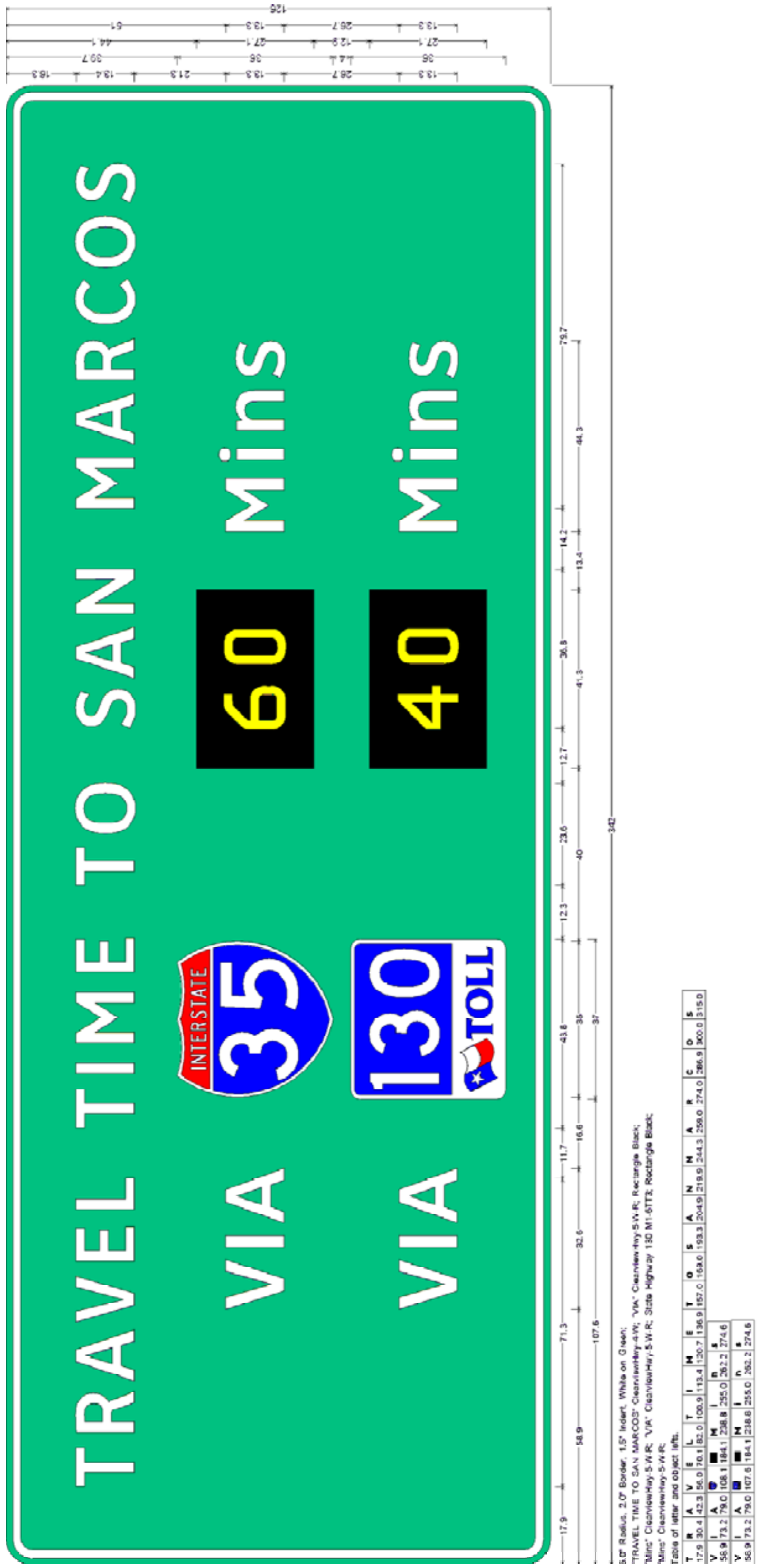
Laptop-based human factors laboratory studies of driver comprehension yielded several key results regarding potential GRIP sign designs. Performance scores of the various measures used in the study tended to be highest for the north orientation (northbound going upward on the sign, southbound going downward), but the differences between the north and track orientations in most cases were very small. Consequently, both orientations were included in later testing using the driver simulator. However, the track orientation sign created in a 3D format (similar to how in-vehicle navigational aids present information did not fare as well in the assessment) and was deleted from further consideration. Participants were very clear in expressing their preference for both route congestion information and travel time information for any GRIP sign deployment. However, significant differences were evident in the ability of drivers to perceive travel time information when a significant amount of route congestion information is also displayed. A distributed signing approach, with a text-based travel time sign providing relative travel times to San Marcos via I-35 and via SH 130 followed by a GRIP sign with colored route segments to indicate locations and intensity of congestion, tended to perform the best in terms of the performance metrics evaluated. However, a single GRIP with both route congestion and travel time information could be constructed, so long as the amount of route congestion information was reduced accordingly. Finally, assessments of the information load created by GRIP signs indicated that the two routes (i-35 and SH 130) combined could be divided into four segments each, and route congestion information could be presented in each segment without excessively overloading the driver. Other combinations could also be envisioned (more segments on one route, fewer on the other; having more segments but ensuring that fewer than four would be displayed as congested at any one time) that would still meet this information threshold.

A driver eye-glance behavior study was then conducted of a select subset of potential GRIP sign designs that met the design requirements resulting from the laboratory studies. Maximum glance durations of the GRIP design options were collected, as well as the total amount of time spent looking at the sign. The main emphasis of the study was on hypothetical trips being made southbound through Austin. However, for a few of the study iterations, a trip destination to the airport located within the limits of the GRIP sign was also investigated.

Overall, the results of the eye-glance study at the potential Georgetown sign location suggested that none of the GRIP sign design options tested would induce excessively long glances to the signs for drivers with destinations beyond Austin, so would not be likely to adversely affect safety. Glance times did increase if greater amounts of route congestion were presented, but the increase did not exceed the 2 second threshold shown in previous studies to be associated with increased crash risk. Either a combined route congestion and travel time (TT) GRIP could be used, or a two sign TT and route only GRIP sign could be deployed. The latter sequence of two signs would be more expensive to construct and deploy, but would have the advantage of being more flexible in portraying locations of congestion on I-35 and SH 130. It would also offer a greater factor of safety for driver use of the GRIPs for non-through trips.

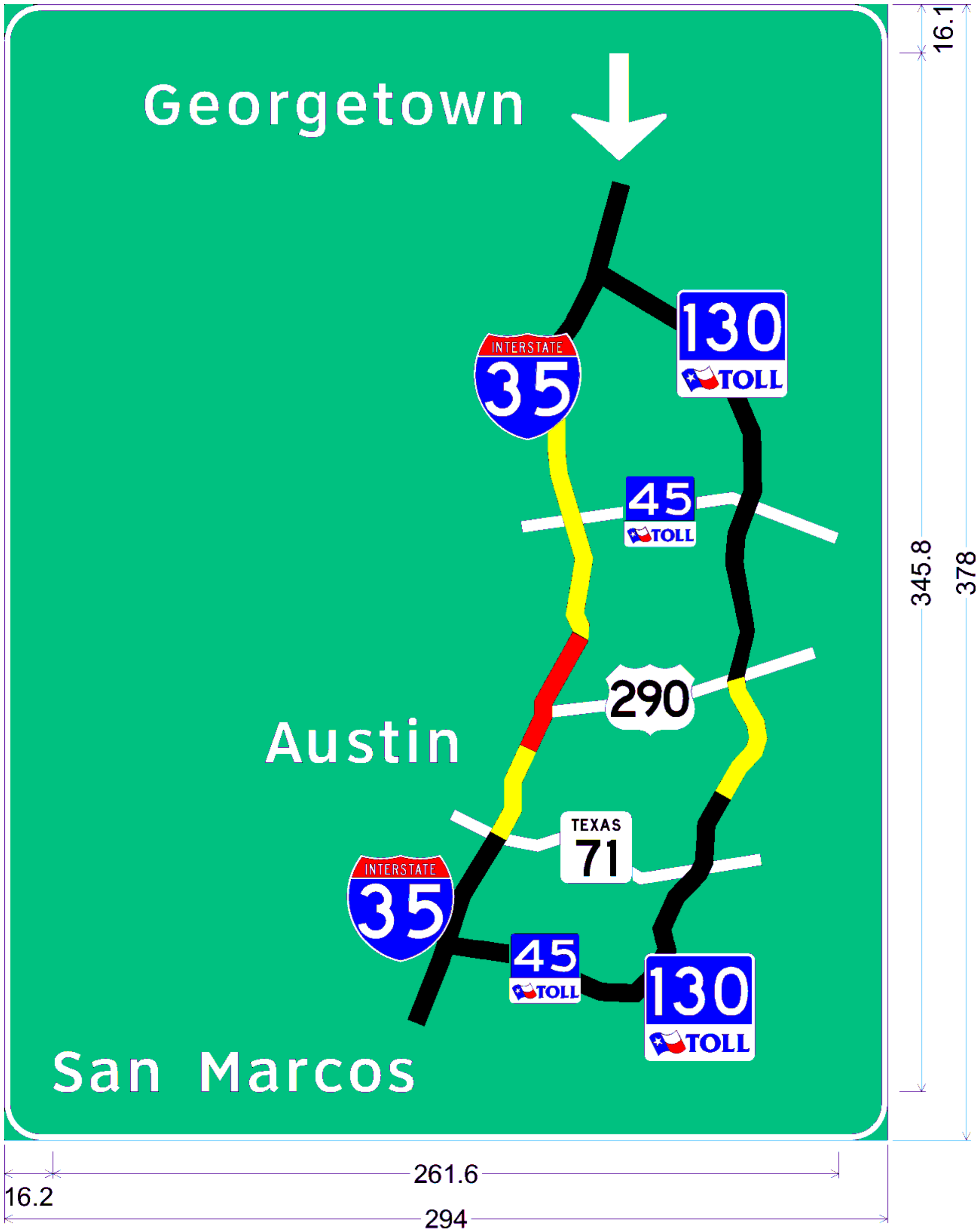
With regard to the other two potential sign locations, the results were less conclusive. For through trips, the Round Rock sign location (I-35/SH 45) resulted in maximum glance times that were below the 2 second threshold on average for all of the potential GRIP designs. However, when asked to consider a trip to the airport using information from a combined route congestion and TT GRIP, the majority of study participants had maximum glance durations in excess of 2 seconds. This occurred even though only a low information load was being displayed. For the US 290 potential sign location in Austin, even the through trips resulted in average maximum glance times in excess of 2 seconds. Trips to the airport increased glance times even more, such that two-thirds of the participants were exceeding the 2-second maximum glance duration threshold when viewing a route-only GRIP. Although the eye-glance studies were performed in a simulator and do not guarantee that such signs would pose safety problems, it was recommended that GRIP deployment focus only on the Georgetown sign location at this time. Once additional experiences with driver interpretation of, and response to, such signs in the actual driving environment, the potential deployment of GRIP signs at the other two location could be revisited.

Given the collective results of the various studies conducted under this project, designs for both a two-sign sequence (TT sign followed by a route congestion only GRIP sign) or a single combined route congestion + TT sign were developed, and are shown below:



Sign dimensions are in inches

Text-Based TT Sign for I-35 Southbound near Georgetown.

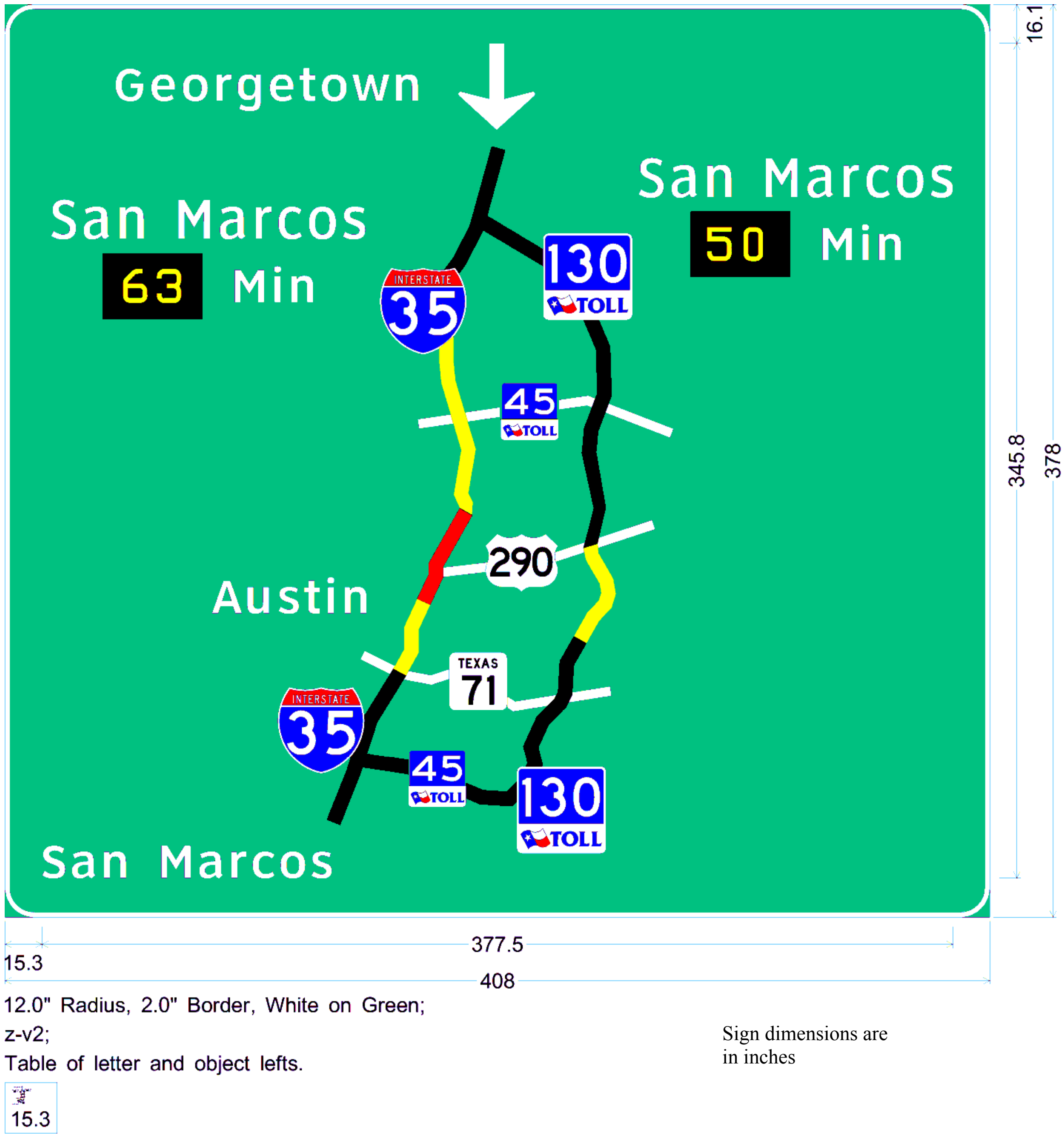


12.0" Radius, 2.0" Border, White on Green;
z-v2;
Table of letter and object lefts.

16.2

Sign dimensions are in inches

GRIP Sign without Travel Times, I-35 Southbound near Georgetown.



GRIP Sign with Travel Times, I-35 Southbound near Georgetown.

The signs themselves must be designed large enough so that motorists have at least 6 seconds of available viewing time to perceive and process the information presented. For I-35, this implies that the signs be legible from at least 600 feet away, and so the signs must use freeway guide sign lettering criteria and 18-inch high DMS insets for the TT displays. In both instances, the height of the GRIP sign is computed to be 378 inches, or slightly more than 31 feet. When travel times are included with the route condition map display, the width of the sign is computed to be 408 inches, or 34 feet. If the travel times and route condition map are presented separately (at least 800 feet apart), the TT sign width would be 258 inches, or slightly more than 21 feet wide by 150 inches, or 12 feet high. Meanwhile, the GRIP map display sign would still be 31 feet high, but its width would be reduced to 294 inches, or slightly more than 24 feet. The routes on the GRIP sign would be 6 inches wide.

Once TxDOT determines whether it is interested in one or two signs, there still remain a number of steps that must be accomplished before the signs can be fabricated and become a reality out on the road. These include applying for and receiving a request-to-experiment with a GRIP sign in Texas; designing a feasible sign support structure for the signs; developing software to interface with TxDOT Lonestar and with the electronic route condition modules; and developing fabrication techniques for the route condition elements.

TABLE OF CONTENTS

Page

LIST OF FIGURES .... **xvii**
LIST OF TABLES .... **xix**
INTRODUCTION **1**
BACKGROUND 1
PROJECT OBJECTIVES 6
GRIP SIGN REAL-TIME DATA NEEDS, SOURCES, AND AVAILABLE TECHNOLOGIES **7**
METHODOLOGY 7
REPRESENTATIVE TYPES OF GRIP SIGNS 7
GRIP Level 1 8
GRIP Level 2 9
GRIP Level 3 11
GRIP Level 4 12
DYNAMIC DATA FOR GRIP DISPLAYS 14
Data Availability 14
Data Collection 17
Data Transformation 17
Data Aggregation 18
Data Display 20
BUSINESS RULES FOR OPERATING GRIP DISPLAYS 22
Power Loss Response 22
Communications Loss Response 22
Data Loss Response 23
SUMMARY 23
FOCUS GROUP STUDIES TO DEFINE KEY GRIP CHARACTERISTICS **25**
FOCUS GROUP STUDY METHODOLOGY 25
RESULTS 26
GRIP Locations 26
Most Important Locations 27
Sign Sequence 28
Additional Locations 29
Information Presented 29
Display of Travel Times 31
Cross Streets and Intersections 32
Additional Information to Include on GRIPs 33
GRIP Route Coloring 33
Map Orientation 34
Perspective Views 36
Level of Map Realism 37
SUMMARY 40
NON-GRIP-RELATED COMMENTS FROM THE FOCUS GROUP STUDIES 42

HUMAN FACTORS STUDIES OF DRIVER COMPREHENSION AND INFORMATION LOADING OF GRIP SIGN DESIGN OPTIONS 43
OBJECTIVES 43
STUDY METHODOLOGY 43
Factors Evaluated 43
Experimental Design 46
Data Collection Procedures 46
Data Reduction and Analysis 48
STUDY RESULTS 49
Subject Demographics 49
Georgetown (I-35/SH 130) Sign 50
Round Rock (I-35/SH 45/SH 130) Sign 58
Austin (I-35/US 290/SH 130) Sign 64
OVERALL ASSESSMENT OF INFORMATION LOADING EFFECTS 70
STUDY PARTICIPANT PREFERENCES OF DISPLAY TYPES 74
SIGN RECOMMENDATIONS 75
Sign Orientation 75
Sign Display Types 76
Information Load Limits 76
DRIVER SIMULATION STUDIES TO ASSESS POTENTIAL SAFETY OF PROPOSED GRIP SIGN DESIGNS 77
OBJECTIVE 77
STUDY METHODOLOGY 78
Factors Evaluated 78
Experimental Design 80
Data Collection Procedures 81
Data Reduction and Analysis 83
STUDY RESULTS 83
Georgetown (I-35/SH 130) Sign 83
Round Rock (I-35/SH 45/SH 130) Sign 87
Austin (I-35/US 290/SH 130) Sign 92
IMPLICATION OF STUDY RESULTS ON GRIP SIGN DESIGN 95
RECOMMENDED SOUTHBOUND GRIP SIGN DESIGNS FOR AUSTIN 97
DESIGN FEATURES RECOMMENDED 97
NEXT STEPS 100

REFERENCES 103
APPENDIX A: FOCUS GROUP DISCUSSION GUIDE 105
APPENDIX B: GRIP SIGN TREATMENT COMBINATIONS TESTED IN HUMAN FACTORS LABORATORY STUDIES 129
APPENDIX C: HUMAN FACTORS LABORATORY STUDY ANSWER FORM 139
APPENDIX D: HUMAN FACTORS LABORATORY STUDY PARTICIPANT RESPONSES BY LOCATION 151
APPENDIX E: GRIP SIGN DESIGNS TESTED IN DRIVING SIMULATOR EYE-TRACKING STUDIES 167
APPENDIX F: DRIVER SIMULATOR PARTICIPANT INSTRUCTIONS AND STUDY ANSWER FORM 185

LIST OF FIGURES

Page
Figure 1. Early GRIP Examples from the Lodge Freeway Project, Detroit, MI. 2
Figure 2. International Link and Network GRIP Signs (*3*)... 3
Figure 3. Examples of Full and Partial Region GRIP Signs Evaluated in Texas (*11*). 4
Figure 4. Austin GRIP Signs Designs Tested (*12*). 5
Figure 5. Representative Sign for Level 1 GRIP. 8
Figure 6. Representative Sign for Level 2 GRIP. 10
Figure 7. Representative Sign for Level 3 GRIP. 12
Figure 8. Representative Signs for Level 4 GRIP. 13
Figure 9. I-35 Bluetooth Sensors Installed for Waco District *Traveler Information during Construction* Project. 15
Figure 10. SH 130 Bluetooth Sensors Installed for the Austin District. 16
Figure 11. Lonestar Treatment of Bluetooth (Probe) Sensor Data. 18
Figure 12. Lonestar Treatment of Radar (Point) Sensor Data. 18
Figure 13. TSS to TTA Aggregation. 19
Figure 14. TTA Links Showing Missing TSS Data. 19
Figure 15. Map of Potential GRIP Locations. 27
Figure 16. SH 130 Sign. 29
Figure 17. GRIP Information Options. 30
Figure 18. Sign Showing Travel Times as Presented to Participants during Introduction. 32
Figure 19. Map Orientations. 35
Figure 20. GRIP Perspectives. 36
Figure 21. Map Realism. 38
Figure 22. Contrasting Map Realism for Location 3 (I-35 at US 290). 39
Figure 23. Standard Text on a DMS. 41
Figure 24. Potential Hybrid Travel Time Sign. 41
Figure 25. Examples of GRIP Sign Orientations Tested. 44
Figure 26. Examples of Route and Travel Time Options Tested. 45
Figure 27. Examples of Route Congestion Levels Tested. 46
Figure 28. Example of Response Map Presented after Each GRIP Test Sign to Identify Locations of Congestion. 48
Figure 29. Effect of Display Type on Travel Time Recollection Accuracy. 72
Figure 30. Effect of Display Type on Accuracy of Extent of Congestion Recollection Accuracy. 73
Figure 31. Effect of Display Type of Recollection Accuracy of Congestion Location and Type. 73
Figure 32. Identification of Information Element Threshold Suggesting Participant Information Capacity. 74
Figure 33. Factors Evaluated in the Driving Simulator Study. 79
Figure 34. The TTI Driving Simulator. 81
Figure 35. ANOVA Results for Through Trips: I-35/SH 130 Location (Georgetown). 84
Figure 36. Average Maximum Glance Durations: I-35/SH 130 Location (Georgetown). 84
Figure 37. ANOVA Results for Through versus Airport Trips: I-35/SH 130 Location (Georgetown). 86

Figure 38. Average Maximum Glance Durations for Through versus Airport Trips (Low Information Load Level): I-35/SH 130 Location (Georgetown). 86
Figure 39. ANOVA Results for Through Trips: I-35/SH 45 Location (Round Rock). 88
Figure 40. Average Maximum Glance Durations: I-35/SH 45/SH 130 Location (Round Rock). 88
Figure 41. ANOVA Results for Through versus Airport Trips: I-35/SH 45/SH 130 Location (Round Rock).. 90
Figure 42. Average Maximum Glance Durations for Through versus Airport Trips (Low Information Load Level): I-35/SH 45/SH 130 Location (Round Rock)................................ 90
Figure 43. ANOVA Results for Through Trips: I-35/US 290/SH 130 Location (Austin). 93
Figure 44. Average Maximum Glance Durations: I-35/US 290/SH 130 Location (Austin). 93
Figure 45. ANOVA Results for Through versus Airport Trips: I-35/US 290/SH 130 Location (Austin). 94
Figure 46. Average Maximum Glance Durations for Through versus Airport Trips (Low Information Load Level): I-35/US 290/SH 130 Location (Austin). 94
Figure 47. Text-Based Travel Time Sign for I-35 Southbound near Georgetown. 98
Figure 48. GRIP Sign without Travel Times, I-35 Southbound near Georgetown. 99
Figure 49. GRIP Sign with Travel Times, I-35 Southbound near Georgetown. 100

LIST OF TABLES

Page

Table 1. Cost Comparison Estimates of GRIP Sign Options 24
Table 2. Study Participant Demographics (n=549). 50
Table 3. Percent Correct Detection of Congestion/No Congestion on Routes: Georgetown Sign. 51
Table 4. Percent Correct Perception of Extent (Length) of Congestion on Routes: Georgetown Sign. 53
Table 5. Percent Correct Location and Type (Color) of Congestion on Routes: Georgetown Sign. 54
Table 6. Percent Correct Recall of Travel Time Information Presented: Georgetown Sign. 55
Table 7. Percent Stated Diversion Choice to SH 130: Georgetown Sign. 57
Table 8. Percent Correct Detection of Congestion/No Congestion on Routes: Round Rock Sign. 59
Table 9. Percent Correct Perception of Extent (Length) of Congestion on Routes: Round Rock Sign. 60
Table 10. Percent Correct Location and Type (Color) of Congestion on Routes: Round Rock Sign. 61
Table 11. Percent Correct Recall of Travel Time Information Presented: Round Rock Sign. 62
Table 12. Percent Stated Diversion Choice to SH 130: Round Rock Sign. 63
Table 13. Percent Correct Detection of Congestion/No Congestion on Routes: Round Rock Sign. 65
Table 14. Percent Correct Perception of Extent (Length) of Congestion on Routes: Round Rock Sign. 66
Table 15. Percent Correct Location and Type (Color) of Congestion on Routes: Round Rock Sign. 67
Table 16. Percent Correct Recall of Travel Time Information Presented: Round Rock Sign. 68
Table 17. Percent Stated Diversion Choice to SH 130: Round Rock Sign. 69
Table 18. Study Participant Preferences Regarding Display Options. 75
Table 19. Glance Characteristics: I-35/SH 130 Location (Georgetown). 85
Table 20. Glance Characteristics of Through and Airport Trip at Low Information Load Level: I-35/SH 130 Location (Georgetown). 87
Table 21. Correct Route Choice for Through and Airport Trip at Low Information Load Level: I-35/ SH 130 Location (Georgetown). 87
Table 22. Glance Characteristics: I-35/SH 45/SH 130 Location (Round Rock). 89
Table 23. Glance Characteristics of Through and Airport Trips at Low Information Load Level: I-35/SH 45/SH 130 Location (Round Rock). 91
Table 24. Correct Route Choice for Through and Airport Trip at Low Information Load Level: I-35/SH 45/SH 130 Location (Round Rock) 92
Table 25. Glance Characteristics: I-35/US 290/SH 130 Location (Austin). 93

Table 26. Glance Characteristics of Through and Airport Trip at Low Information Load Level: I-35/US 290/SH 130 Location (Austin).. 95
Table 27. Correct Route Choice For Through and Airport Trip at Low Information Load Level: I-35/US 290/SH 130 Location (Austin).. 95

INTRODUCTION

Across the country, implementation of intelligent transportation systems (ITS) in most large and mid-range metropolitan areas has allowed agencies such as the Texas Department of Transportation (TxDOT) to continue to improve traveler safety and mobility. Much of the improvement attributable to these systems is due to the provision of real-time information regarding traffic conditions to travelers so that they can make better departure time, route, and even mode choice decisions. Much of this information is disseminated roadside through such mechanisms as highway advisory radio or more commonly, text-based messages displayed on dynamic message signs (DMS). Both research and practitioner experience with DMS has shown this technology to be very useful and effective in improving driver decision making. However, dissemination of information via text must be carefully controlled so that driver sign reading and information processing capabilities are not overloaded (*1*).

Oftentimes, the amount of information believed to be useful to travelers exceeds the allowable message limits of a text-based DMS. In such cases, presenting key information graphically would improve traveler access to and assimilation of such information. For example, many regions now have internet-based real-time travel maps that convey incidents, roadwork, and other locations of congestion in a region or along a route. Travelers can quickly scan the visual information presented and extract the key information that is directly relevant to them prior to heading out on their trip. The apparent usefulness of map-based real-time information on websites has raised interest in the potential provision of such information on roadside signs. Although not presently used in the U.S., variations of this type of signing are in use elsewhere in the world. These signs are typically referred to as graphical route information panels (GRIPs).

GRIPs are believed to have significant potential for improving driver access to real-time information while en route. GRIPs typically use a combination of text, colors, and a map representing one or more roadways. The information basis for a GRIP sign is dynamic, reflecting roadway conditions that are changing, such as congestion indicators and/or travel times.

BACKGROUND

Interest in the potential for presenting real-time traffic information in a graphical format has existed since the late 1960s. In fact, one of the first GRIP-type displays tested was on the Lodge Freeway surveillance and control project in Detroit, MI (*2*). A series of freeway and ramp signs were conceived with colored panels and arrows to illustrate travel conditions along certain portions of the corridor. Figure 1 illustrates these signs.

Figure 1. Early GRIP Examples from the Lodge Freeway Project, Detroit, MI.

A series of text-based DMS was also installed in the corridor to help provide real-time traffic information. The initial designs were conceived by the project team, constructed, and implemented. The decision was then made to evaluate the performance of the system. Ultimately, the evaluations indicated that many drivers did not respond to the signs. In-vehicle focus group studies suggested that the graphical signs may have exceeded driver information processing capabilities, such that drivers ignored the signs altogether (*2*).

Internationally, interest in GRIPs has existed since at least the early 1980s. A limited number of deployments has occurred in the Japan, the Netherlands, Germany, France, Australia, South Korea, and China (*3*). Figure 2 illustrates some of these deployments. Both link (single route) and network (multiple route) designs have been deployed. Studies that have been done on these types of signs suggest that GRIPs are preferred by many motorists and result in improved route choice behavior (*4*, *5*, *6*).

(a) Link GRIP signs from Australia, Netherlands, and China, respectively.

(b) Network GRIP signs from Netherlands, Japan, South Korea, France, and China, respectively.

Figure 2. International Link and Network GRIP Signs (*3*).

A few researchers have also attempted to assess and understand the cognitive aspects of GRIP signs. Collectively, the results indicate that there is an inverse relationship between the amount of information and complexity of the GRIP display and driver ability to interpret, process, and properly respond to the information presented (*4*, *5*, *7*, *8*, *9*). However, defining and quantifying complexity is a challenge (*10*). The layout of the network, the type and amount of text information presented, orientation relative to the direction of travel, and even the number of colors used to convey congestion could all combine to influence the amount of time drivers used to interpret and comprehend the sign, route choice accuracy, and other parameters.

The potential applicability of GRIP signs in Texas has received some attention as well. In one study (*11*), researchers used focus groups to evaluate different GRIP characteristics. A GRIP was combined with symbol icons for incidents and roadwork, and evaluated through a series of focus groups and laboratory studies. They found that Texas drivers can easily interpret route segment colors as indicative of travel conditions on that route segment, but prefer to have travel times or delay times as well to further quantify conditions. The number of cross-streets included in a GRIP was found to increase the difficulty of sign comprehension. Texas truck drivers indicated that they thought a GRIP sign such as the one included in Figure 3 provided too much information to be useful. This opinion did not change whether the routes in the GRIP portrayed an entire metropolitan area or just a portion of it.

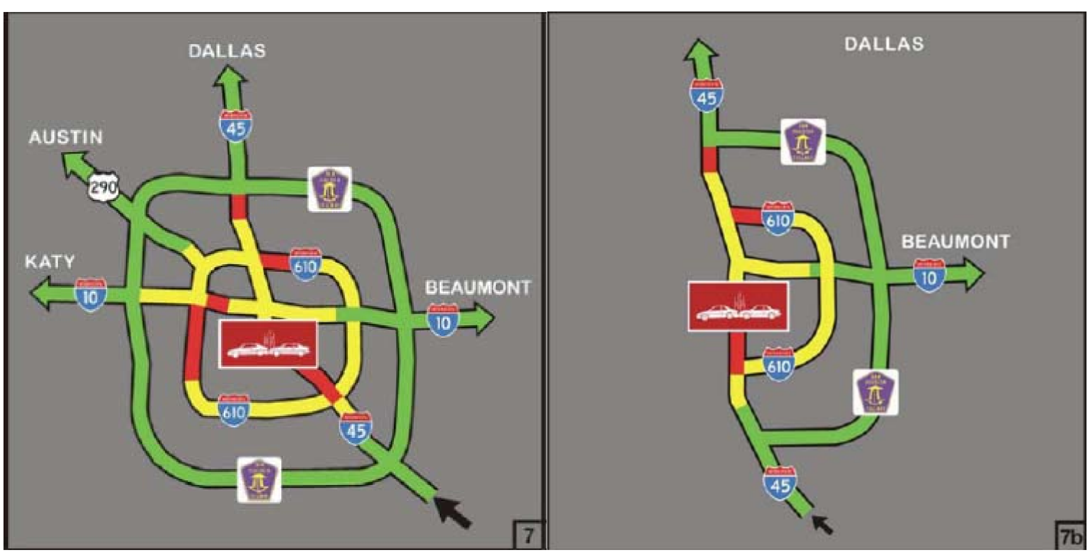
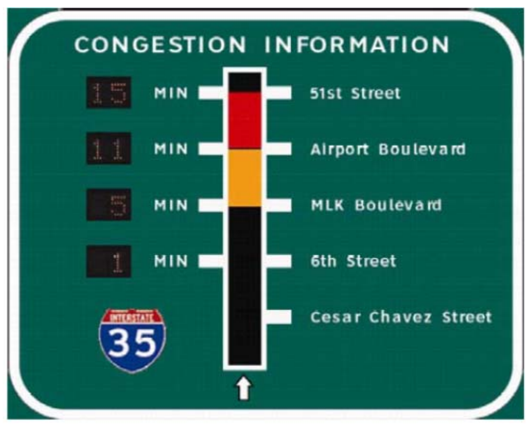


Figure 3. Examples of Full and Partial Region GRIP Signs Evaluated in Texas (*11*).

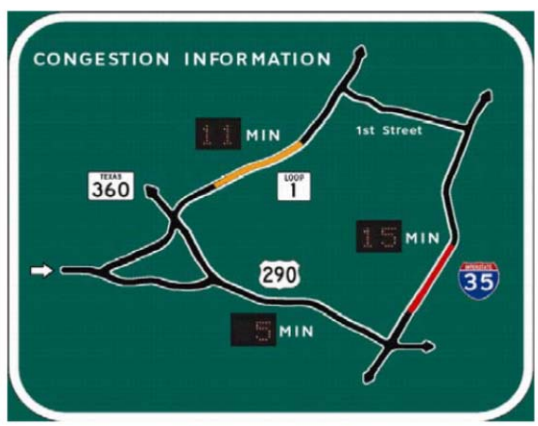
In another study, researchers hypothesized versions of both link and network GRIP signs for the Austin area, and conducted an internet-based, multiple choice survey to determine driver opinions about them, as depicted in Figure 4 (*12*). Once again, most (95 percent) Texas drivers were able to easily interpret the color coding of the routes as indicative of congestion locations and levels. GRIP signs with travel times were preferred over GRIP signs with no travel time information provided, and over text-based DMS alone. Study participants preferred a north orientation of the GRIP. This finding was in direct contrast to previous studies outside of the U.S. that indicated that the GRIP should be oriented to the direction of travel in order to be most effective (*8*). The potential for information overload was apparent in these graphs, and further research was suggested to ensure that an effective design was achieved that would not result in information overload.

Test Scenario A



Test Scenario B

Test Scenario C



Test Scenario D

Figure 4. Austin GRIP Signs Designs Tested (*12*).

In summary, GRIP signs have significant appeal to the motoring public and are being used throughout the world (but not in the U.S.). Unlike existing guidance for text-based DMS, it appears that many features of a GRIP can contribute to the information load that it presents to drivers. Unfortunately, these features are not well understood at this time. Therefore, agencies such as TxDOT that are contemplating the deployment of GRIP signs must ensure that the signs to be used are effectively understood and do not overload the typical driver. Positive guidance principles indicate that information overload conditions can cause drivers to shed information, which can result in reduced decision-making accuracy (*13*). In lieu of shedding, some drivers may also choose to significantly reduce their speed so as to increase their available sign viewing time in an attempt to assimilate all of the information. Such behavior leads to large speed differentials and is obviously undesirable.

PROJECT OBJECTIVES

TxDOT has expressed interest in using GRIP signs approaching and through the Austin, Texas, metropolitan area. SH 130, a toll facility, bypasses Austin and offers both long-distance and local travelers a convenient alternative to the congested I-35, which runs through the center of the city. To support this desire, a project was initiated to assist in the design of the GRIP signs to be used. This report documents the results of the project.

This project followed a traditional engineering design process, consisting of three key steps:

- Focus group studies of both Austin (familiar) and out-of-city drivers to determine key design elements and element options needed or desired for a GRIP sign.
- Computer-based laptop studies to systematically evaluate the key sign design element options upon driver comprehension and information loading.
- Driving simulator studies using eye-tracking technology to assess the potential influence of the best GRIP design(s) upon driver eye glance behavior to ensure that such signs do not cause unduly long glances.

In addition to the sign design tasks performed under this project, available GRIP technologies were critiqued, data and software needs and modifications were identified, and approximate costs of implementing GRIP signs were also assessed.

GRIP SIGN REAL-TIME DATA NEEDS, SOURCES, AND AVAILABLE TECHNOLOGIES

One of the first tasks performed under this project was to define the available technology options for GRIP signs in Texas, identify the data needs and usage requirements to dynamically operate the signs, and identify data handling decisions or business rules for implementing signs of this nature. Sign options were critiqued in terms of fabrication requirements and relative costs to fabricate. Meanwhile, data needs and usage requirements were considered from both a public agency and a private-sector perspective, and included considerations of the efforts that would be needed to integrate such signs into the TxDOT statewide transportation management center software package Lonestar™.

METHODOLOGY

Researchers conducted several in-depth phone calls with members of TxDOT and its consultants, specifically the Traffic Operations Division and the Southwest Research Institute in their role as the statewide integrator. Additional phone calls were conducted with industry representatives from sign manufacturers and transportation consultants. In total, more than 6 hours of detailed discussions with these experts contributed to the information contained in this technical memorandum.

As part of the assessment, an attempt was made to provide general estimates of costs associated with the fabrication, installation, and software support within Lonestar of each option discussed. This proved problematic in some cases, as the fabrication of some of the proposed signs, to the best knowledge of the researchers, have never actually been fabricated and installed. Even so, it is expected that these estimates can assist TxDOT by providing at least providing order-of-magnitude financial comparisons between the various options.

REPRESENTATIVE TYPES OF GRIP SIGNS

Four levels or representative types of GRIP sign designs were conceptualized to categorize the various display options and establish a consistent discussion basis for both the project team and external participants. Actual sign sizes were not estimated at this initial stage. Details regarding sign size were developed at the end of the project and are discussed at the end of the report.

GRIP Fabrication Option 1

Description

Figure 5 shows a representation of a Fabrication Option 1 GRIP sign. This type of panel would use a static background constructed with standard industry sheeting practices with the addition of two DMS inserts to communicate the travel time on each route. DMS inserts are commonly used in many applications today and are available off-the-shelf from various manufacturers. DMS inserts can also be used to display other information options such as speed, delay, or pricing, depending on the particular application.

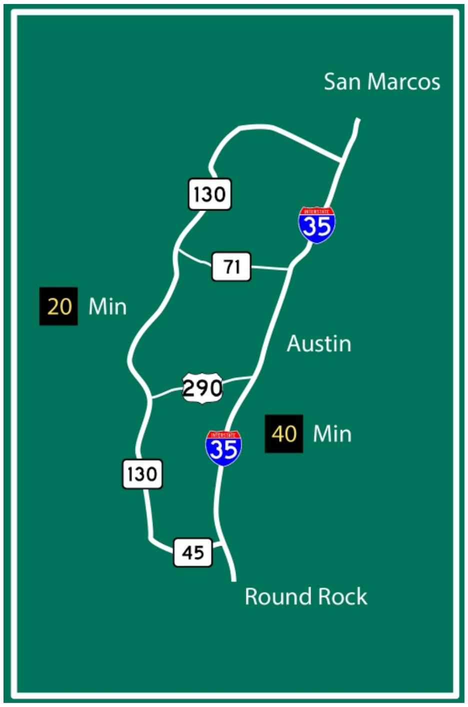


Figure 5. Representative Sign for Fabrication Option 1 GRIP.

Fabrication and Cost

In this GRIP option, the roadway representation is static and does not change with differing roadway conditions. The representation shown in Figure 5 uses white roadway segments on a green background. Overall, the fabrication of this type of GRIP panel is expected to be relatively simple.

While DMS inserts are available as an industry item, the graphics for Fabrication Option 1 GRIP signs will have to be designed exclusively for each location, much like how diagrammatic guide signs currently are fabricated. The overall cost of the panel itself is expected to be low to moderate, depending on the number of DMS inserts. The DMS inserts can be placed either (1) behind the panel in a cutout, flush with the surface, or (2) placed in front of the panel, which results in a depth of the insert on top of the sheeting of approximately 4–6 inches, depending on the manufacturer. Placement of the insert on the front of sheeting is an accepted industry practice and is not expected to impair visibility of the dynamic information to the traveler. If placing inserts behind the sign, an engineering analysis must be performed so the inserts do not to interfere with the structural back-panel members.

The DMS inserts will require a controller to interface with the data source. The controller translates the information in the incoming data stream to the actual display of the insert(s). Controllers of this type are industry standard items with most communicating using the National Transportation Communications for ITS Protocol (NTCIP). A single controller can talk to multiple inserts within a single sign.

For comparison purposes, the sign face fabrication is estimated at $10,000. Two, two-character DMS insets are estimated to be approximately $30,000. These insets can already be operated through Lonestar software, so no additional costs would be required there. The sign will need some type of roadside or overhead structure, which can range between $20,000 up to $50,000. Therefore, a median estimate of $35,000 is assumed for this assessment. A total cost estimate per location is therefore $75,000.

GRIP Fabrication Option 2

Description

Figure 6 illustrates the type of GRIP sign envisioned for Fabrication Option 2. In contrast to Option 1, some of the roadway elements in an Option 2 sign are dynamic and are envisioned to change colors according to the data input, typically speed or congestion. In the example below, those segments that are either shown in color or are dark (black) would be dynamic. Other routes that do not provide real-time information would be white as in the Option 1 sign. As with the Option 1 GRIP, significant questions also exist as to the visual aspects of signage of this type that will be addressed by other tasks within the project.

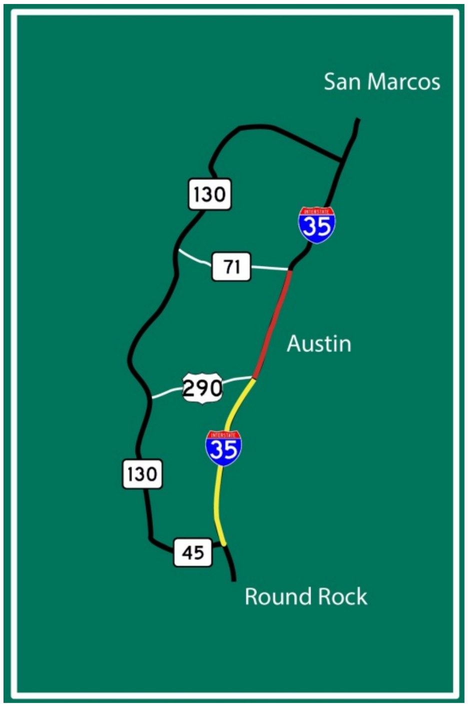


Figure 6. Representative Sign for Fabrication Option 2 GRIP.

Fabrication and Cost

It is anticipated that the various roadway segments would be constructed of Light Emitting Diodes (LEDs), which are capable of multiple colors. Each section of the roadway would consist of one or more pixel arrays, which are an assembly of individual LEDs. While LED pixel arrays are common industry items available from numerous manufacturers, the size required to be visible at the required decision sight distance is not currently known (although current DMS use of LEDs to create text-based characters could be used as a starting point). A significant physical panel design process would be required to determine the appropriate materials and the overall power and control requirements. Additionally, a careful mapping of each pixel array to the distance that it would represent on the roadway must be performed. Finally, a custom controller would have to be built that translates the incoming data stream to the input requirements of the pixel arrays, selecting colors and for each array dynamically in response to the data stream. Power requirements for this type of sign are also unknown as the number of LED pixel arrays could be quite significant, depending on their sizes. The LED pixel arrays can likely be placed on the front of the panel, similar to the DMS inserts for an Option 1 sign.

Overall, the fabrication of this type of panel is predicted to be significantly higher than the Option 1 sign in terms of both difficulty and cost. While the costs of the individual components are not significant, the engineering time to put the components together and design the custom controller is expected to be significant. For comparison purposes, it is assumed that the fabrication of the sign and controller would be approximately $100,000. Based on discussions with the TxDOT Traffic Operations Division (TRF) and Southwest Research Institute (SWRI), the statewide integrator, another $35,000 would be needed to create a user interface and framework within the Lonestar software to be able to operate the sign. This would be a one-time software development cost; future signs of this type would not require this additional expenditure. It is further assumed that the same type of structure that could support the Option 1 sign could support this Option 2 sign, so estimated at $35,000 again. A total cost for one Option 2 sign is therefore estimated at $170,000, while subsequent signs of the same design are estimated at $135,000.

GRIP Fabrication Option 3

Description

A Fabrication Option 3 GRIP, as illustrated in Figure 7, is a combination of Option 1 and Option 2 GRIPs previously described. At this level, both certain roadway elements and the text character sign inserts would be dynamic, based on available data. Many combinations of a combination design can be envisioned, such as a sign that depicts colors corresponding to congestion levels (or speeds) on the roadway segments and inserts, which show travel time or delay information. In the representation shown in Figure 7, the DMS inserts are showing travel time with the roadway segments indicating congestion levels along various segments.

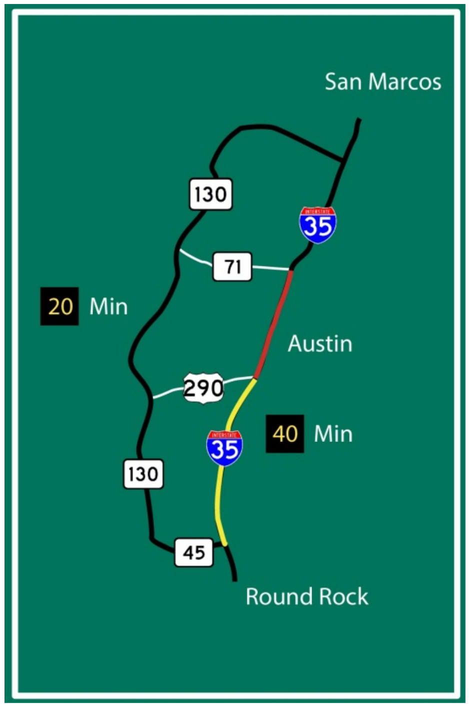


Figure 7. Representative Sign for Fabrication Option 3 GRIP.

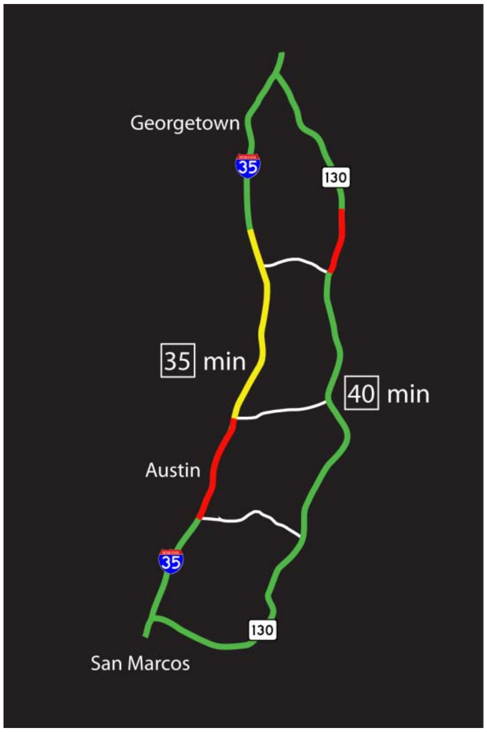
Fabrication and Cost

Overall, the fabrication and costs associated with a Fabrication Option 3 GRIP panel are predicted to be high, given the same design needs as both an Option 1 and Option 2 sign. The largest cost components will again be the custom controller and the physical sign design. For comparison purposes, it is assumed that the fabrication of the sign and controller would be approximately $130,000 (the same as an Option 2 GRIP plus the cost of two DMS insets). As for the Option 2 sign, the one-time software upgrade cost for Lonestar would be approximately $35,000. It is further assumed that the same type of structure that could support the Option 1 sign could support this Option 3 sign, and so is again estimated at 35,000. Therefore the total cost for the first sign of a Fabrication Option 3 GRIP is estimated at $200,000 while subsequent signs would be estimated at $165,000.

GRIP Fabrication Option 4

Description

A Fabrication Option 4 GRIP sign is conceptualized as a fully digital DMS, typically high-definition, and an existing product line from a number of manufacturers. The display may be on a dark background to minimize power consumption, or on a lit background as depicted here to maximize detection by motorists. Shown as two examples in Figure 8, an Option 4 GRIP is very analogous to a digital billboard, albeit with a focus on communicating dynamic travel information rather than advertisements. As with the other illustrations of potential GRIP displays, numerous design decisions exist for the particular format, colors, roadway geometry, labeling, and representation. Figure 8 should be viewed as a concept, not as a final design.



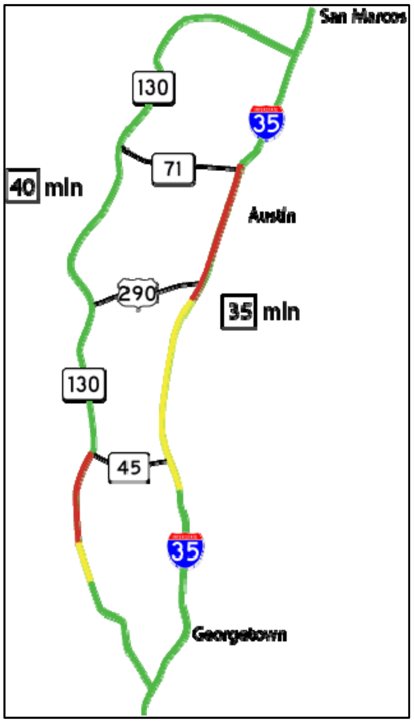


Figure 8. Representative Signs for Fabrication Option 4 GRIP.

Fabrication and Cost

Because Fabrication Option 4 GRIP signs could be off-the-shelf items, the engineering design aspects associated with their utilization for a GRIP display are largely insignificant. Controllers for these signs are also standard items and come as a package with the DMS unit. However, it is not immediately clear whether communication protocols for these types of displays have been standardized or developed to the level of detail that would be required for this proposed application. Consequently, programming costs to allow Lonestar to properly communicate and help operate this type of sign would be extensive. The cost of a fully digital DMS is also quite significant, in the range of $140,000 to $180,000 depending on the particular size and options. Additionally, there are some questions as to the applicability of these signs to locations that may require a largely vertical portrayal of the roadways as opposed to horizontal placements. For locations such as southbound I-35, trade-offs in the visual detail may be necessary, if the commercial products cannot be placed in a different orientation.

For comparison purposes, it is assumed that the sign and controller would be approximately $160,000. According to TRF and SWRI, the one-time software upgrade cost for Lonestar would be approximately another $160,000. It is further assumed that the structure that could support this type of sign would also be very significant, in the range of $75,000. A total cost of a single Fabrication Option 4 GRIP sign would therefore be $395,000, while subsequent signs placements of this type would be $235,000.

DYNAMIC DATA FOR GRIP DISPLAYS

The foundation of any GRIP display is the use of real-time data to drive the dynamic portions. While simple in concept, the collection, treatment, and display of roadway data have several critical components, including:

- Data availability and collection.
- Data transformation and aggregation.
- Data display.

Data Availability

For the proposed GRIP sign location on southbound I-35, there is a high level of available data from both public and private sector sources. It is important to understand that data availability may change depending on the location of GRIP signs and the extent of the geographical coverage displayed on any particular sign.

Public Sector Data

Within the Austin District on I-35, the Austin Traffic Management Center (TMC) known as the Combined Transportation, Emergency and Communications Center (CTECC) has extensive detector placements using radar sensors. Radar sensors operate as a point detector, indicating the speeds at a given point on the roadway. These sensors are integrated into the TMC's Lonestar implementation. Lonestar is the statewide TMC software developed and maintained by TxDOT for providing a standardized set of traffic management and traveler information capabilities across the state.

As part of the *I-35 Traveler Information during Construction* project with the TxDOT Waco District, 17 Bluetooth® (BT) detectors were recently installed in the I-35 corridor within the Austin District. BT detectors operate as a probe and create data that apply to a segment of the roadway, as opposed to a single point. Figure 9 shows the locations of the I-35 BT sensors. (Note that Figure 9 only displays the 14 sensor locations that are germane to this project. An additional three sensors were installed on I-35 south of Buda. Sensors were also installed on I-35 within the San Antonio District to provide a travel time capability down to Loop 1604.) All of the BT sensors report data to the Austin TMC. Together with the existing radar detectors, the Austin District has a robust capability of determining travel times on I-35 and has recently enhanced their traveler information by placing travel times on DMS throughout the I-35 corridor.

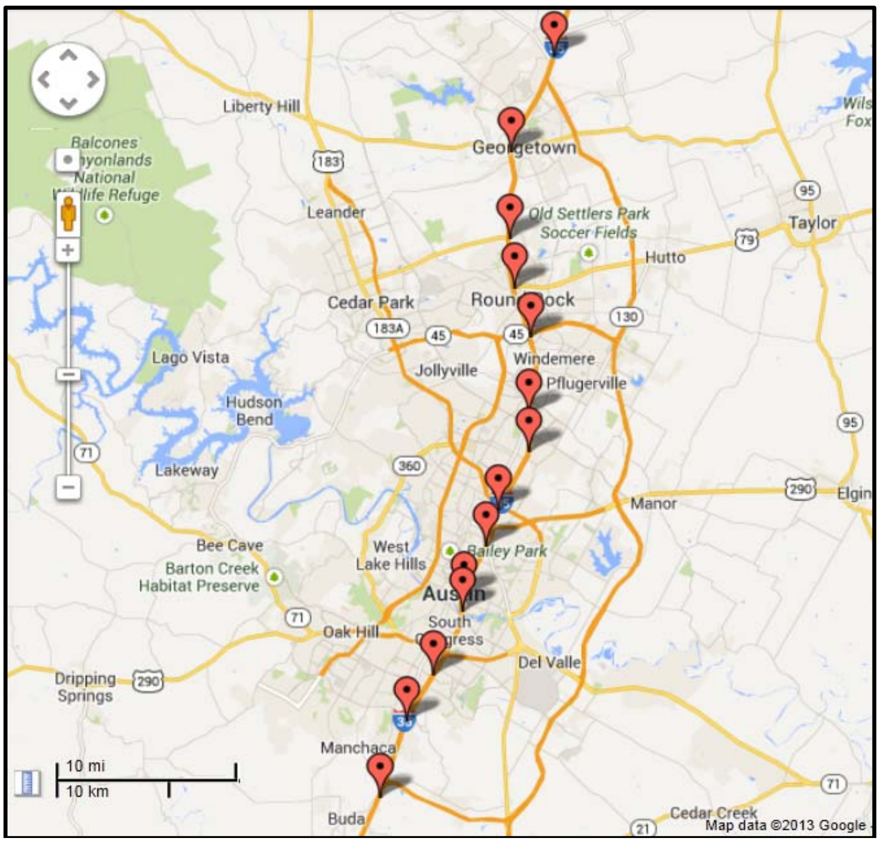


Figure 9. I-35 Bluetooth Sensors Installed for Waco District *Traveler Information during Construction* Project.

To develop data resources for SH-130, BT detectors were recently placed on the segments of the roadway from Georgetown through the intersection with SH 45. Figure 10 shows the 12 deployed sensors on the same map overlay as Figure 9 and illustrates that a comparative travel time capability now exists between I-35 and SH 130 across the most congested portion of Austin. All SH 130 BT detectors are also sending data to Lonestar at CTECC.

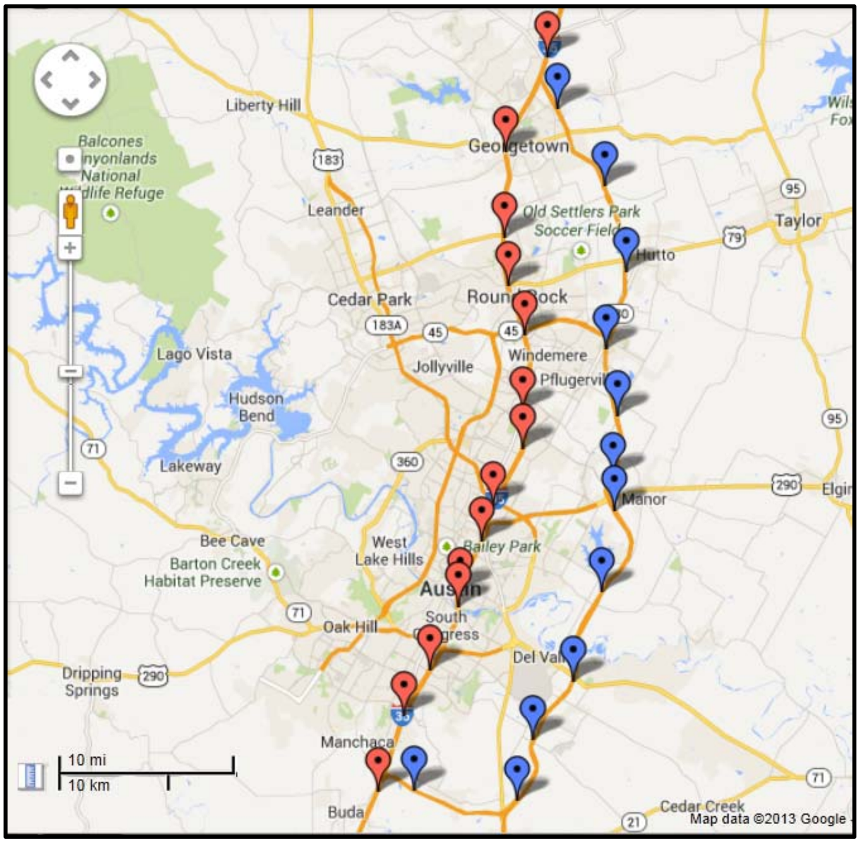


Figure 10. SH 130 Bluetooth Sensors Installed for the Austin District.

Private Sector Data

Several private sector companies, such as Inrix and Navteq provide roadway data consisting of speed and/or travel time as a commercial offering. Cost data for private sector offerings is highly dependent on the uses and outputs; additional usage increases the cost. Private sector companies are generally reluctant to provide wide-ranging cost information as they negotiate pricing based on specific usage of the data. Information from previous project interaction with private sector providers indicates general pricing at $800 to $1,000 per mile per year. That pricing was for an all-access, all usage provision and could be substantially different depending on the terms negotiated for any particular use.

Data Collection

For any usage, understanding the ability to collect the data follows closely upon the examination of the data availability. For the southbound I-35 proposed GRIP location, data from the sensors identified in Figure 9 and Figure 10 are already being collected by the Austin District Lonestar implementation. At most locations, the sensors transmit data to Lonestar using commercial cellular carriers. The Austin District radar detectors discussed previously also send their data to Lonestar. Lonestar understands the data format used by both types of sensors and can accept it with no restrictions. Through a cooperative software development agreement with the Florida Department of Transportation (FDOT), TxDOT would have the ability to enhance Lonestar with the ability to accept data from private sector data providers.

Data Transformation

The intent of the southbound I-35 GRIP location is to provide comparative travel time. Prior to aggregating data over long distances to provide travel times, data transformation routines are used to equalize data from different types of sensors.

Probe Data

For probe (BT) sensors, travel time is computed at the receiving host (Lonestar) by matching a unique device identification known as a media access control (MAC) address across two individual sensors. Each sensor records the time and MAC address and Lonestar performs a simple calculation to determine the travel time and average speed over the length of the segment. These individual segments are called Transportation Sensor Subsystem (TSS) links in Lonestar nomenclature. For BT data, Lonestar has the capability to skip a non-working detector and create a longer segment. This segment’s data are supplied to the original TSS links. Figure 11 illustrates the treatment of BT data within Lonestar. The creation of longer TSS links is an important component of providing options for data aggregation and presentation when sensors are off-line or data are missing.

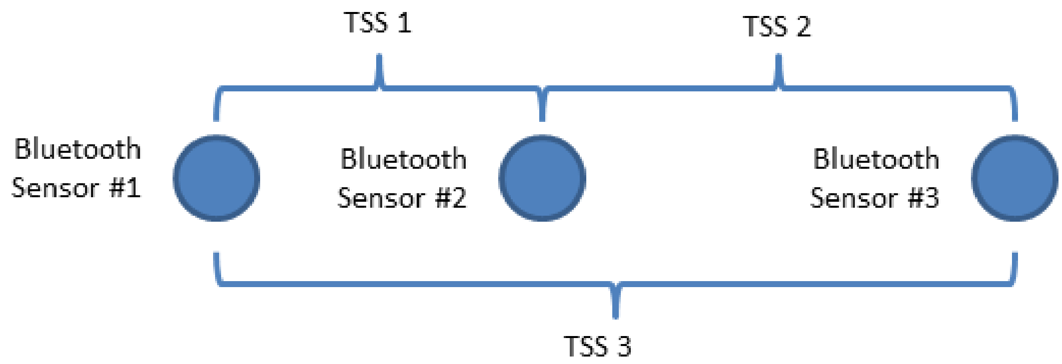


Figure 11. Lonestar Treatment of Bluetooth (Probe) Sensor Data.

Point Data

Because point data measures information about a specific point on the roadway, point data sources are treated differently than probe data sources. Internal to Lonestar, a point data source is applied to a specific segment of roadway, effectively stretching the data over the roadway. This is done by applying the speed to the length of the segment and using that speed value to compute a travel time. Figure 12 illustrates this treatment. Note that each TSS link constructed from a point source can be different lengths.

Figure 12. Lonestar Treatment of Radar (Point) Sensor Data.

Data Aggregation

Once individual TSS segments are configured from each data source, Lonestar aggregates data into Travel Time Application (TTA) links by combining one or more TSS links. This aggregation is illustrated in Figure 13 with each set of BT sensors as individual TSS links and the point radar detector creating another TSS link. All three TSS links together can be aggregated to create a Travel Time link that would be reported to the traveling public and which would serve as input to any of the GRIP options previously discussed. For a particular TTA link, portions of TSS links may also be used. This is especially relevant when creating a TTA link for display on a DMS for travel time to a particular exit on the road.

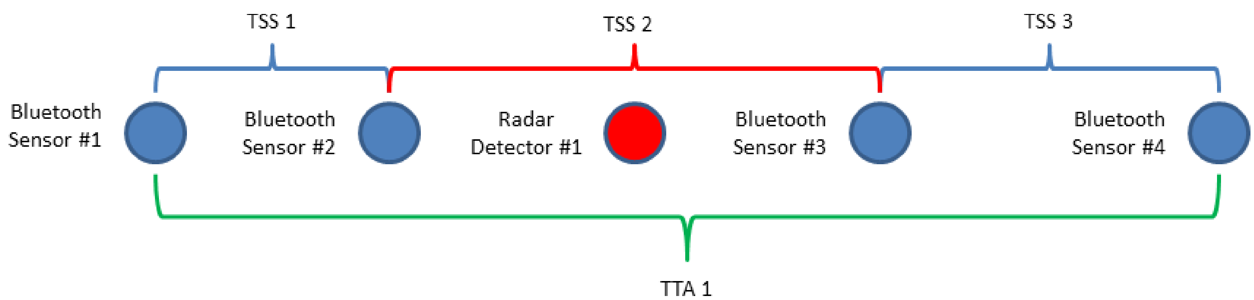


Figure 13. TSS to TTA Aggregation.

Note that Figure 13 illustrates only one possible configuration of the illustrated sensors. Additional TSS segments could be constructed between Bluetooth Sensor #2 and Bluetooth Sensor #3 or between Bluetooth Sensor #1 and Bluetooth Sensor #3. Figure 13 does not indicate distance and is not to any scale. TMC operations staff typically determine the optimal travel time links for their Lonestar implementation by considering the number and type of available sensors, the sensor reliability, the geographic locations of sensors, the roadway geometry, and the traveler information needs of the area.

Lonestar also has options built into the aggregation of TSS into TTA links pertaining to the availability of data. This option is illustrated in Figure 14 with data missing from the third TSS link. If the data availability parameter for this TTA link is set to 60 percent, meaning that 60 percent of the data must be available to be reported, the TTA link will still show data as 66.66 percent (2 of 3 TSS segments) is available. If the data availability parameter was set to 70 percent, no data would be reported as being available for TTA link 1.

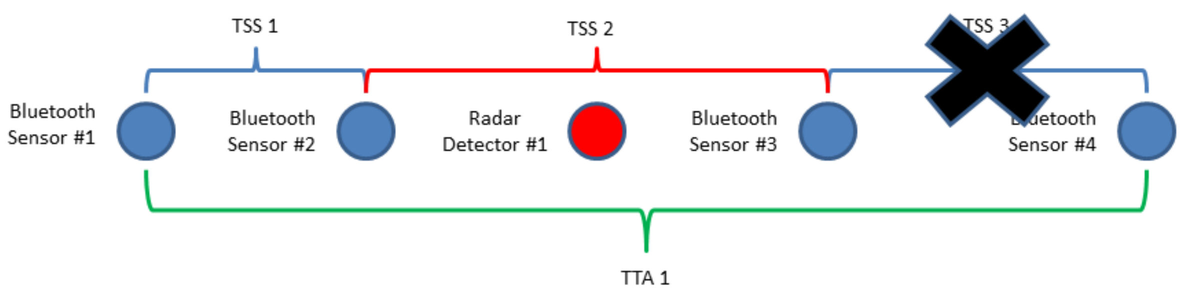


Figure 14. TTA Links Showing Missing TSS Data.

Data within Lonestar can also be set to expire after a configurable time limit, so that travelers do not continue to see outdated travel time information. Lonestar is an ideal software platform to provide traveler information via GRIP signs with the ability to:

- Receive data from multiple sensor types.
- Transform data into TSS links.

- Dynamically adjust TSS links.
- Aggregate TSS links into TTA travel time link.
- Account for missing data with the data availability parameter.
- Expire data to prevent old information.

Data Display

The display requirements for travel time data are unique to each GRIP sign fabrication option previously identified.

Fabrication Optionl 1 GRIP

The process of displaying data on an Option 1 GRIP is relatively straightforward. Two TTA links would be created, one for travel using I-35 and one for travel using SH 130, resulting in two travel times for traveling from point A (north of Austin) to point B (the point where SH 45 crosses I-35 in Kyle). That information would be sent to the dynamic message sign inserts in the panel to allow travelers to select an appropriate route. A single DMS controller can control both inserts and all data communication protocols are in-place and currently employed by Lonestar implementations.

Fabrication Option 2 GRIP

The process of displaying data on an Option 2 GRIP is significantly more complicated than for an Option 1 GRIP. Numerous decisions must be made to create and relate travel time segments to the physical sign segments built during the fabrication process. Existing data segments are not all the same length, but may need to be adjusted to relatively consistent lengths to allow for an easier fabrication process. Lonestar currently has no existing protocol to talk to the specialized controller that would be necessary for a sign of this type and that communication chain and protocol would have to be created.

Fabrication Option 3 GRIP

The process of displaying data on an Option 3 GRIP mirrors the Option 2 GRIP scenario. The same decision points exist to relate roadway travel time segments to physical sign segments built during the fabrication process. The Option 3 GRIP would also need the custom controller for the LED segments, in addition to the controller for the DMS inserts. It is conceivable that

Lonestar would have to use two communication channels to the sign, which could potentially complicate the communication channels. If this is the case, care would have to be taken to ensure that the data sent over each channel are in sync and reflecting the same travel time conditions as the other channel. These capabilities do not currently exist in Lonestar.

Fabrication Option 4 GRIP

While Option 4 GRIP signs could be off-the-shelf purchases from a number of manufacturers, the ability of Lonestar to dynamically drive these displays does not currently exist. Two options are available and discussions with Lonestar developers showed a solid understanding of each approach as well as the advantages and disadvantages of each. The development process would be straightforward, and some of the capabilities available from the FDOT relationship may be useful to reduce the development time for this capability.

The first option focuses on generating a number of graphics that represent every possible dynamic data configuration (both route color/graphics and text travel times). These graphics would then be pre-loaded into the digital sign memory, and Lonestar could call a specific graphic to be displayed based upon the data received by Lonestar from roadway detectors. The advantage to this method is that the communications channel to the sign is relatively simply and very low-bandwidth, so the reliability of information transfer is likely to be high. The disadvantage is that depending on the desired configuration of the roadway segments, the number of possible graphics might be quite large and would have to be checked against the available maximum memory storage of the sign.

The second option is to have Lonestar dynamically generate an image based on current data and then digitally capture that image and send it to the GRIP sign on a periodic basis. Essentially, Lonestar would have to generate an image similar to a real-time traffic map for a website display. The advantage of this option is that there are no limitations related to the on-board memory storage and accepting digital input is an inherent capability of the sign controller. The potential disadvantage is that digital images can be quite large and consume significant bandwidth, resulting in a time-consuming transfer process. Recently however, new graphics formats such as Portable Network Graphics (PNG) have been introduced, which allow high resolution and small sizes. If the digital DMS supports these types of graphics formats, transmission of the image on a recurring basis may not be a significant concern. This concern is only present over wireless communication links, such as cellular telephone. GRIP panels hard-wired into communication systems such as fiber would not have this potential limitation.

BUSINESS RULES FOR OPERATING GRIP DISPLAYS

Apart from the fabrication, data collection, and transformation needs of any of the GRIP levels, other aspects of operating GRIP displays must be considered. The intent of this section is to raise awareness of the types of operational planning that must take place prior to any fabrication and placement. Decisions on how to handle each business rule situation are the purview of the operating agency and may even be different by sign location or GRIP level.

Power Loss Response

Power losses related to GRIP signs can occur either at the roadside or at the point of data transmission to the sign from Lonestar. For roadside equipment, stored power via batteries may be an option if the sign is low-powered enough to be powered by solar energy. If at all possible, solar power storage must provide for a minimum of several days with weak or no recharging capability to account for cloud cover and inclement weather. If roadside equipment is powered by conventional power sources, battery backups may still be an option, but this likely to be an expensive addition. In general, only critical roadside equipment such as traffic signals operate on back-up battery power. A supplemental sign for traveler information would likely not warrant this additional expense.

Communications Loss Response

Power loss at the data transmission point is in reality a communications loss. To handle this situation, Lonestar uses the concept of an expiration time in the center to field messaging. If the field device does not receive an updated data transmission in a preset (and configurable) time limit, a default value stored in that sign is used. That default value may be a blank in the case of a DMS insert. Since new custom controllers would have to be built for an Option 2 and Option 3 GRIP, this communications facet must be built into the system.

The end result of a communications loss is there is no updated data to continue to provide dynamic data for display. In this case, analogous to the power loss situation, if the field device does not receive an updated data transmission in a preset (and configurable) time limit, a default value or action stored in that sign should be used. That default action may include blanking the sign until data are available. This issue more commonly occurs with cellular communications. One configuration aspect of the field equipment is that the communications channel must always be kept open and not allowed to lapse or go to sleep.

Data Loss Response

Lonestar has several techniques and configurable options to handle the situation where a partial data loss from one or more detectors occurs. Those existing options are thought to be sufficient to protect against this aspect of data loss. The larger problem occurs when the entire data stream is lost for whatever reason. To the GRIP panel, this situation mimics the communications loss scenario and operations should proceed with the same response.

SUMMARY

Four fabrication options of potential GRIP signs were identified and discussed. While Lonestar contains the data handling and aggregation capabilities to dynamically supply data for all levels of GRIP signage, the communications capability to talk to a GRIP sign today only exists for Option 1. Option 4 is projected to be the next easiest GRIP display to communicate with, based on existing market devices and the availability of software resources from FDOT. However, the ease of use is likely dependent upon the manufacturer selected and the controller capabilities of the sign selected in terms of memory availability, use on PNG graphical formats, and so on. Finally, Options 2 and 3 are not known to exist in any form within the U.S. and would require custom fabrication and development of a controller and a communications capability.

From the standpoint of cost, Table 1 provides a breakdown across the four sign levels evaluated. An Option 4 GRIP is a significant monetary expenditure for the device itself, as well as requiring a substantial roadside support structure. An Option 1 GRIP sign is a relatively low cost acquisition using existing fabrication techniques and market products and can be supported with relatively inexpensive support structures.

Table 1. Cost Comparison Estimates of GRIP Sign Options.

Cost Component	**GRIP Sign Fabrication Option 1**	**GRIP Sign Fabrication Option 2**	**GRIP Sign Fabrication Option 3**	**GRIP Sign Fabrication Option 4**
Sign Purchase/Fabrication	$40,000	$100,000	$130,000	$160,000
Lonestar Software Modifications	$0	$35,000	$35,000	$160,000
Sign Support Structure	$35,000	$35,000	$35,000	$75,000
TOTAL 1st Sign Installation	$75,000	$170,000	$200,000	$395,000
Subsequent Installations	$75,000	$135,000	$165,000	$235,000

FOCUS GROUP STUDIES TO DEFINE KEY GRIP CHARACTERISTICS

To begin the GRIP sign design process for southbound I-35 travelers in Austin, a series of focus group studies was conducted to gather motorist input on sign design features that should and should not be incorporated into subsequent human factors studies of driver sign comprehension. Initial discussions between TTI and TxDOT project staff yielded three potential locations where a GRIP sign could be useful to drivers:

- North of the I-35/SH 130 connection in Georgetown.
- North of the I-35/SH 45 interchange south of Round Rock.
- North of the I-35/US 290 direct connect in north Austin.

TxDOT and TTI staff also developed an initial list of key characteristics that would likely need to be considered in the sign design process, based on previous research on GRIPs, advanced traveler information systems, and other topics:

- Sign orientation relative to the direction of travel.
- Degree of route realism displayed (identical to geographical maps, simplified like subway maps are depicted).
- Type and amount of real-time information displayed (travel times only with static route maps, route maps only with real-time color inserts to indicate congested regions, both travel times and route color inserts).

In addition, it was suggested that a three-dimensional (3D) type portrayal, similar to how in-vehicle navigational aids portray maps, also be tested.

FOCUS GROUP STUDY METHODOLOGY

A focus group discussion guide was developed around the series of GRIP sign designs for each of the above potential locations. The discussion guide was reviewed and approved by the Texas A&M University Institutional Review Board (IRB). Appendix A provides the guide and GRIP images used in the focus group studies.

In August 2013, TTI staff convened three focus groups. Two sessions were convened in Austin and one in College Station. College Station was selected as a site for the purpose of obtaining feedback from drivers less familiar with Austin roads. A total of 10 participants were recruited for each session. Potential attendees were selected in a manner such that a range of incomes, education, races, and ages were represented at each session.

RESULTS

GRIP Locations

A central component of these focus groups was obtaining feedback on specific locations to install a GRIP sign in the southbound direction of I-35 in the northern Austin metropolitan region. Participants were told that three locations were currently being considered:

- The northern junction of I-35 and SH 130 north of Georgetown.
- The northern intersection of I-35 and the SH 45 toll facility in Round Rock.
- The northern intersection of US 290 and I-35 in North Austin.

Participants were shown the map in Figure 15 as a reference.

Focus group participants generally accepted these locations as proper for the purposes of conveying route and travel time information to drivers. Participants believed that the locations provided ample opportunity for drivers to assess whether they wished to bypass congestion in the central Austin region and take an alternative route. Minor issues were voiced with regard to location 3 at US 290 and I-35. Specifically, many participants, particularly those in the Austin sessions, felt that the sign should be placed prior to US 183 since it too is a viable alternative to I-35 for destinations in south Austin and beyond.

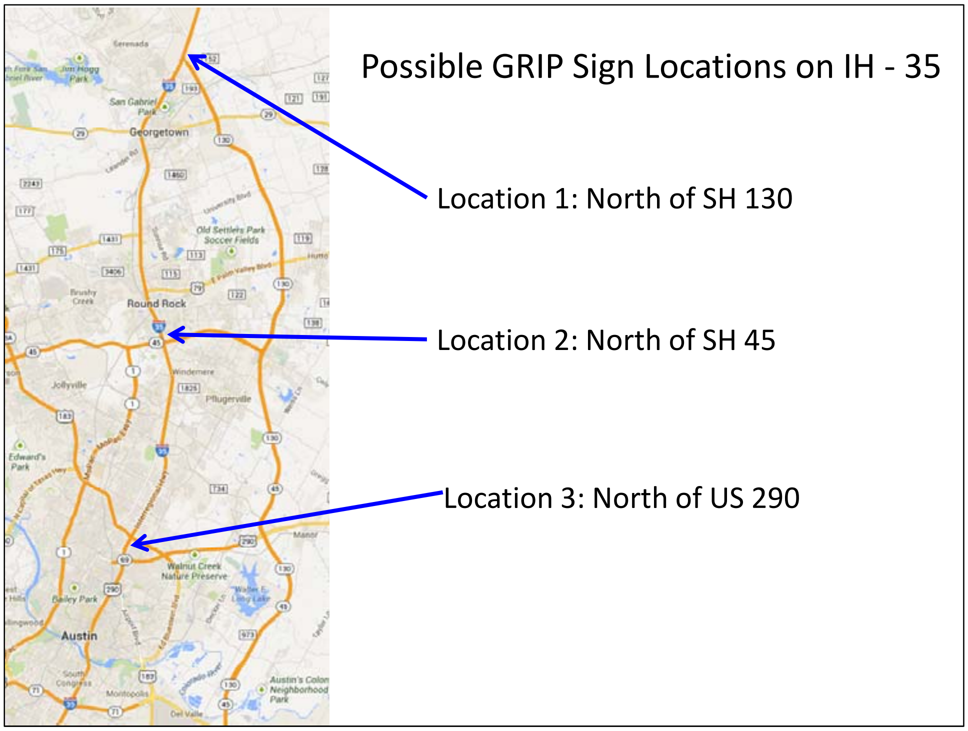


Figure 15. Map of Potential GRIP Locations.

Most Important Locations

After discussing each location the moderator asked participants which was most important. The question was phrased such that if only one GRIP could be placed in the southbound direction of I-35, where should that sign be placed. Participants were generally split between the first location (at the northern junction of I-35 and SH 130) and the second location (at I-35 and SH 45).

Participants who indicated that the far north location was the most important generally believed that it was important to give drivers traveling in from destinations in the north (such as Waco and the Dallas/Fort areas) as much warning as possible as to traffic conditions in Austin. This would give them the earliest opportunity to bypass Austin on SH 130 and enjoy the largest travel time savings.

Participants who supported the second location stated that that location would still provide drivers with enough opportunity to obtain information on Austin congestion and bypass before encountering it. They also stated that the SH 45 location would be much more beneficial to local drivers. Participants supporting the second location noted that the number of regional travelers coming into Austin from north of the first location was much smaller than those who would be traveling in from Georgetown and Round Rock. These drivers would not benefit from the first location.

The third location at US 290 and I-35 was deemed to be the least important for two reasons; the first being that I-35 was often congested at or before the US 290 and I-35 interchange. A second reason for the low level of support for location three was that taking US 290 to bypass I-35 through central Austin was not seen as generating the same time savings as taking SH 130 north of Georgetown or SH 45 in Round Rock. Some participants believed that the distance between US 290 and SH 130 is too great and that the potential time savings from using that facility to reach SH 130 would likely not be that significant compared to staying on I-35.

Sign Sequence

As part of the discussion the moderator showed participants a potential GRIP configuration for the first location at I-35 and SH 130 north of Georgetown as well as a separate sign with specific information on the SH 130 toll facility. Participants agreed that SH 130 should be identified explicitly as a toll road, and that the inclusion of a separate SH 130 sign was beneficial. However, there was no clear agreement as to whether the toll road sign or the GRIP should be placed first sequentially. Some participants believed that it would be better to show the GRIP and associated congestion and travel time information first, so that drivers would be aware of traffic conditions before they become aware of the upcoming toll facility. Others believed that the toll road sign should be placed first, as drivers should be aware that the bypass is tolled when they are receiving the congestion and travel time information.

There was unanimous agreement in all of the sessions that the SH 130 facility should be labeled on the GRIP with the toll logo indicated as shown circled in red in Figure 16. Some participants noted that not using the logo could be considered deceptive, as the SH 130 facility is not explicitly identified as being tolled in the GRIP configurations presented.

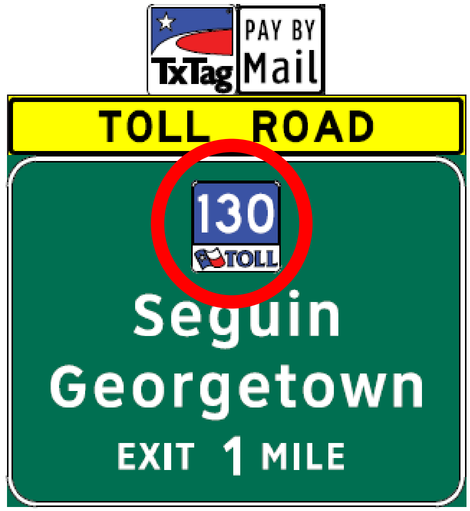


Figure 16. SH 130 Sign.

Many participants also indicated that it might be useful to include information on toll rates. However, this sentiment was not unanimous, as many believed such information would unnecessarily clutter the sign. It was also the belief of many that drivers who knew SH 130 was a toll road and still chose to use it to bypass I-35 would not be as concerned about the actual rates.

Additional Locations

In each of the sessions the moderator asked participants if there were additional locations where a GRIP might be installed on southbound I-35. In the first Austin session, participants noted that an additional sign should perhaps be placed on southbound I-35 just north of the intersection of TX 71 and I-35. This GRIP would contain the same type of information as the previous three locations but would show congestion and travel times through and around Buda and Kyle. Drivers would have the opportunity to bypass any congestion in those areas by taking TX 71 to SH 130. Some participants in this session also believed that the sign located at I-35 and US 290 should instead be placed just north of US 183. Many noted that US 183 is also a viable alternative to I-35 when seeking to bypass Austin, and that the GRIP should be placed such that drivers have the option of exiting there upon receiving congestion and travel time information.

Information Presented

Participants found the information presented on the example GRIPs to be useful and appropriate. During each session a slide was presented for each of the proposed locations that had three potential GRIP configurations, each featuring slightly different information and styles. The first GRIP configuration showed routes in and around Austin using consistent white coloration for routes with text boxes denoting travel times. The second configuration featured the same facilities but added yellow and red coloration to denote congestion levels on select routes. Non-congested routes were black. The third configuration was the same as the second except that it also included travel times. Figure 17 shows the three configurations presented to focus group participants.

Figure 17. GRIP Information Options.

With a few exceptions, participants preferred the third option (colors denoting congestion with travel times) to the other two simpler configurations. Participants preferred to have more information relative to less and did not feel that the addition of the travel times complicated the GRIP itself. Many felt that drivers would respond to the either the stated travel times, the coloration indicating congestion, or both in making their route choices depending on their personal preference and that it was good to provide both options.

There were participants, however, who preferred the simpler options. One participant in the second Austin session preferred the first option that only had travel times. This person noted that they were used to making travel decisions based on travel time as there are already signs providing such information on Texas roadways. This participant stated that if one route had a higher travel time than another then he would just assume that the route with the longer travel time was more congested and did not need to be differentiated with coloring. Other participants stated that they preferred the GRIP configuration with coloring to denote congestion without the inclusion of travel times. These participants believed that the travel times were unnecessary, as the coloration of the congested routes relayed the information adequately without complicating the map. These participants also generally believed that travel times might be difficult to interpret quickly while driving, noting that not all drivers would be going to the destinations for which travel times were provided.

Display of Travel Times

There was significant confusion in all three sessions as to the travel times presented on the GRIP configurations. Participants did comprehend the information as being travel times, but they generally were unsure of the destinations to which the information referred. Many assumed that they referred to travel times between the closest exit off of I-35 (from the perspective of the driver) and either the intersection of SH 130/SH 45 in south Austin or San Marcos. However, these participants noted that it was unclear as to whether this was an accurate assessment.

Some participants recommended that the travel times for SH 130 and I-35 be put at the same level horizontally on the map to improve comprehension. Having them level with each other makes the comparison more apparent and drivers can make faster decisions. It was also recommended that the size of the travel times needed to be increased. Participants noted that the travel times shown in the 3D perspective where best relative to the other configurations.

There was support among participants for including more travel time information on the GRIP signs, as many did not feel that having only travel times to the southern intersection of SH 30/SH 45 and I-35 was of much utility to them. One of the introductory slides discussing GRIPs showed a link sign with travel times to various destinations, as shown in Figure 18. There was support in the focus group sessions for incorporating a similar element into the final GRIP design with the caveat it would be important to not include too much information such that drivers would be overwhelmed. Participants recommended either imbedding the sign as shown in Figure 18 (which is orange and was expected to stand-out against the green of the GRIP) within the GRIP or list potential destinations and travel times down the side of the GRIP. Ultimately, the project team concluded that combining link and network GRIP information into a single sign would far exceed available information processing capabilities of drivers. Therefore, this recommendation was not pursued further in the human factors studies.

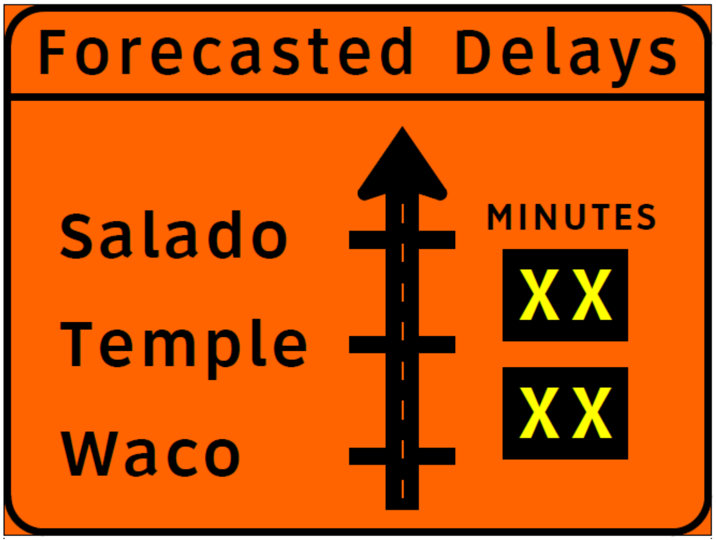


Figure 18. Sign Showing Travel Times as Presented to Participants during Introduction.

Cross Streets and Intersections

Participants generally found the intersecting roadways (SH 45, US 290, and TX 71) to be appropriate for inclusion on the GRIP configurations presented. One participant recommended that Mopac be included but was reminded that the purpose of the GRIP was to provide information on travel times savings for SH 130 versus I-35. Participants in the first Austin session recommended including Parmer Lane as a potential cross street, as it lies between SH 45 and US 290 and intersects SH 130 near Manor. Participants in the Austin sessions also recommended that US 183 be included as a cross street.

One aspect of the cross streets and intersecting highways shown on the GRIP configurations that caused slight confusion was how the lines representing roadways intersected on the sign itself. Many participants noted that the signs gave the reader the impression that TX 71 and US 290 do not extend east past SH 130 or west of I-35. Many believed that addressing this issue might improve the ability of those not familiar with the region to navigate using the GRIP. Several participants also noted that SH 130 should be extended south to Seguin and the southern intersection with I-35 be relabeled as SH 45.

Additional Information to Include on GRIPs

In the course of each session participants made recommendations on additional information that might be included in a GRIP. In most cases participants made recommendations with the caveat that it would be important to not make signs too complicated, as they would have to be read and comprehended while traveling at a high speed. Specific additional information that participants requested included:

- Information on severe weather that might affect road conditions (such as ice).
- Accident notifications.
- Travel times to and on intersecting roadways such as US 290 or TX 71.
- Traffic conditions in Kyle and Buda.

GRIP Route Coloring

Participants approved of the general coloration of the GRIP signs presented. Participants in one of the Austin sessions noted that the colors "jump out" and are easily distinguishable. However, in each session participants showed a slight level of confusion as to what the colors associated with the individual roadways was in reference to. Most assumed that the colors referred to congestion, with yellow signifying slight levels of congestion and red referring to heavy congestion. Participants noted that this is what would make the most sense for these colors but stated that it was not immediately clear. Furthermore, there was slight confusion about the black coloration for SH 130 and I-35 versus the white coloration on SH 45, US 290, and US 71 on some of the maps. Some participants were unsure as to whether the difference in color was for some significant reason.

Participants also indicated that they assumed the coloration denoting congestion would be dynamic, in that if there was no congestion on I-35 through the Austin area then those routes would not be colored yellow or red. On a similar note, participants in the first Austin session and the College Station recommended that additional colors be used to denote a lack of congestion. Participants in these sessions believed that if yellow and red were to be used to denote congestion on I-35 then the SH 130 facility should be colored green to denote free flow traffic. Participants generally recognized that the coloration of the facility would likely remain static as it is a tolled bypass and unlikely to be congested at any point in the day, but felt that the coloration would nonetheless convey to drivers that SH 130 is a congestion free alternative. The moderator pointed out to the group that the sign itself was green, which may reduce the visibility of the SH 130 route on the GRIP, and asked the group for ideas on how to address this but no suggestions were made. Some participants also questioned the ability to see the signs in the roadways that were shown in black as opposed to the white lettering currently used on green signs. There was also some concern about the ability to see this at night.

Map Orientation

One of the aspects of GRIP content that was presented in the focus groups sessions was the orientation of the maps themselves. Two orientations were presented to participants. The first, called the north/south orientation, showed roadways and direction in terms of a traditional map layout, with northern locations being at the top of the map and southern locations being at the bottom. The second orientation, the track location, showed the map and travel direction from the perspective of the driver. Thus, for a southbound driver, southern locations would be at the top of the map (farther from the perspective of the driver) and northern locations would be at the bottom of the map (closer to the driver). From the track perspective SH 130 was to the left of I-35, which would align with the perspective of a traveler coming into the Austin metropolitan area from the north. Figure 19 shows an example of these two orientations.

There was support in all three sessions for both orientations, but the track orientation tended to have the most support. Those expressing support for the track orientation generally stated that it simply “made sense.” One participant noted that they preferred that orientation because, as they were traveling, they would be able to know whether alternative roadways would be going to the left or the right by simply looking at the GRIP. Another participant noted that drivers are increasingly relying on Global Positioning System (GPS)-based devices for navigation assistance, and that such devises generally presented maps in the track orientation.

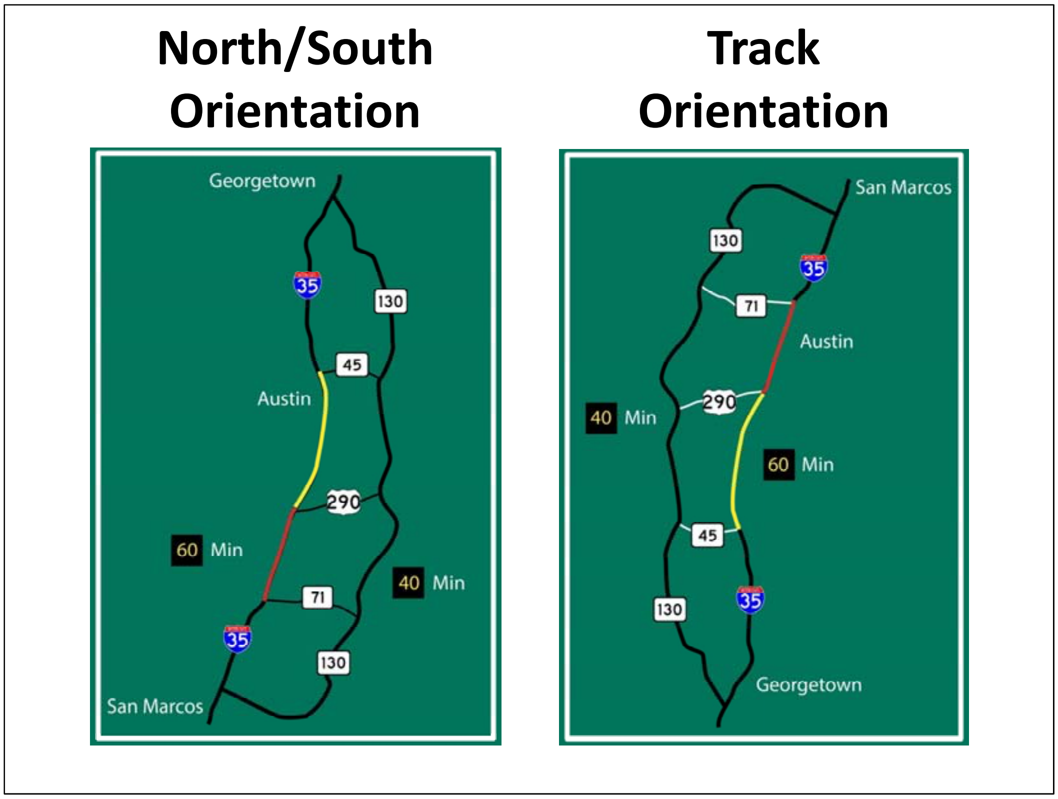


Figure 19. Map Orientations.

Those who supported the north/south orientations generally did so based on one of two reasons. The first reason was that the participant was simply more comfortable with reading maps in this orientation and believed that they would have less trouble interpreting the layout of the map at a high rate of speed. These participants often felt that they would have to convert their traditional map-based perspective of the region in order to interpret the routes on the GRIP correctly. A second reason cited for supporting the north/south orientation was that it would be easier for out of region travelers to interpret the route information. It was believed by many participants that such travelers would have a traditional map oriented perspective of the roadway when traveling in an unfamiliar area. They would have a perspective wherein SH 130 lies to right of I-35 as it is depicted on a traditional map. For these travelers it would be easier to interpret a route map based on this pre-existing perspective. Even participants who supported the track orientation felt that the north/south orientation would be easier to interpret for out of region travelers.

One of the additional perspectives that was presented to participants, and that will be discussed in the next section, was a 3D perspective. The 3D maps that were presented in track mode and contained a white arrow indicating the direction of travel. Participants in all three sessions noted that interpretation of any track perspective map would be greatly improved by including such an arrow, something that was absent from the maps shown in Figure 19.

Perspective Views

An additional aspect of potential GRIP configurations that was presented to focus group participants was that of perspective. Two differing perspectives were presented to each session. The simple perspective was, in essence, two dimensional in that the roadways were presented on the GRIP from the traditional overhead perspective. The second perspective was 3D and showed roadways tilted from the perspective of the driver with routes and destinations that were further away appearing to converge toward a horizon. Figure 20 show these two perspectives.

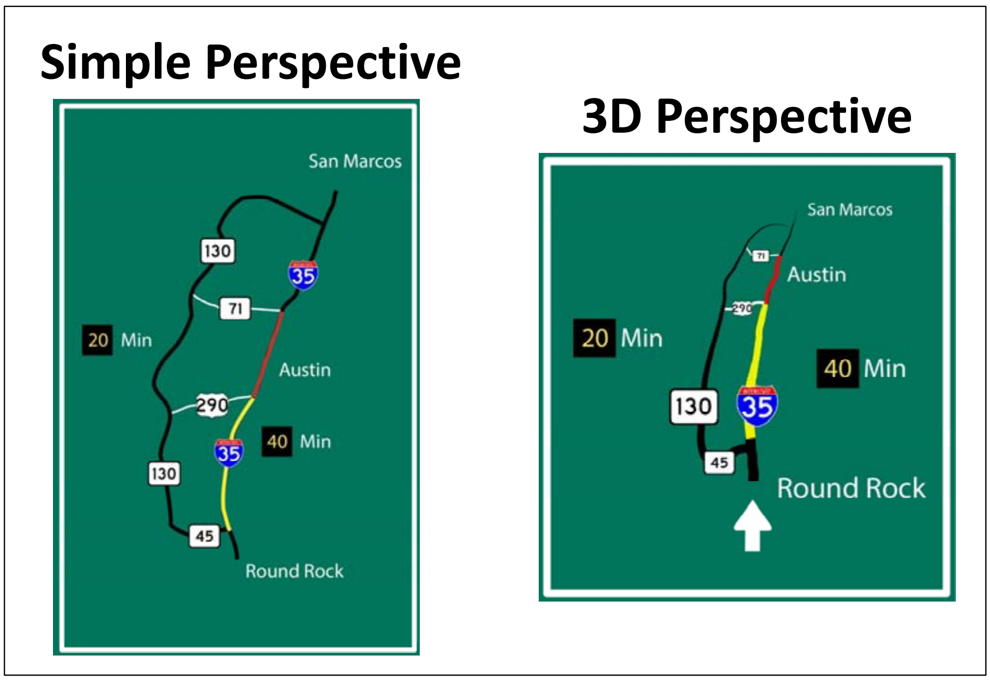


Figure 20. GRIP Perspectives.

Reactions to the different perspectives differed dramatically, even among the sessions themselves. For example, the 3D perspective did not have any support whatsoever in the first Austin session. Participants in that session believed that the 3D orientation made routes and destinations that were further south (and thus smaller) hard to read and decipher. Participants also believed that it was not immediately apparent that the perspective being presented was 3D, which might cause confusion among drivers who were trying to read and interpret the sign at high speed. Similar sentiments were expressed in all three sessions but were most pronounced in the first Austin session.

The 3D perspective enjoyed stronger, although not universal support in the second Austin session and the College Station session. Many voicing support for the 3D perspective stated that they simply liked the way it looked relative to the simple perspective. Others stated that they liked the 3D perspective because it resembled what might be seen on a GPS navigation device. Note that in the second Austin session and the College Station session, support for the 3D perspective grew as participants saw the maps repeated for each location. Most still preferred the simple perspective but stated that their opposition to the 3D perspective was declining as they got used to seeing it. This was not true for all participants, and even those who increased their support noted that it would be important to consider that many travelers would not have such an extended time to view the signs. It would perhaps be best to design them with consideration toward what is easiest to comprehend at first glance, which in this case would be the simple perspective.

Participants also believed that if the 3D perspective were to be adopted then the amount of information on the GRIP should be reduced. Participants stated that the signs should either be deployed at locations closer to downtown, which would reduce the amount of information contained and make the sign more readable, or the number of cross streets and destinations should be reduced.

Degree of Map Realism

A final aspect of GRIP layout that was evaluated by focus group participants was that of realism. For each location, participants were presented with a realistic map, where the orientation and shape of roadways was meant to reflect actual orientation and shape as closely as possible, and a less realistic map. The less realistic maps were simplified to show roads as running simply up-to-down or left-to-right. Several participants observed that this is similar to how subway and other transit maps are laid out in cities such as Dallas, New York, and Washington, D.C. Figure 21 shows examples of these maps.

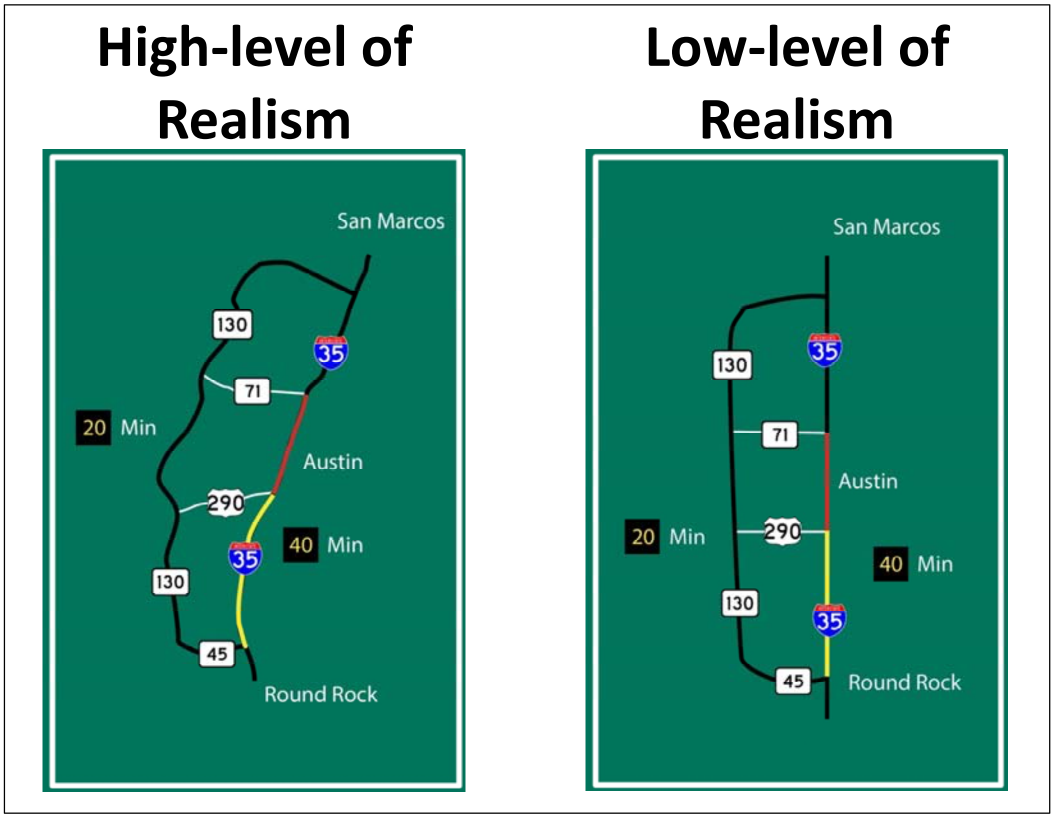


Figure 21. Map Realism.

Participants in all three sessions generally preferred the more realistic renderings of the area roadway network. Many believed that the simplified, low-degree realism maps gave false impressions about distance, especially with regard to the distances between intersecting roads and distances on those roads. For example, several participants noted that the distance between SH 130 and I-35 is not the same on SH 71 relative to US 290, but the simplified map would lead one to believe so. Some participants stated that if they saw a map depicting roads as being straight roads then they would expect those roads to, in fact, be straight. One participant stated that he or she would "freak out" if a road started curving when he or she were under the impression that it was straight because of a map.

As with the 3D perspective, participants felt that the realism presented on the maps was more appropriate for certain locations relative to others. For example, most did not feel that a low degree of realism was appropriate for location 1 (at the northern intersection of I-35 and SH 130). This was due to the fact that, because that location was the farthest away, there was a lot of information to convey that would be distorted by a low degree of realism. If the low degree approach to realism were adopted then it would be more appropriate for use in GRIP locations closer to downtown that features less information. For example, Figure 22 shows realistic (left) and low realistic (right) maps for location 3, located near the intersection of US 290 and I-35. Participants believed that the distortion of distance and roadway direction was less pronounced in this map relative to the map shown in Figure 21 because there is only one intersecting roadway shown: SH 71. One participant noted that the less realistic map looks like a cleaner version of the realistic map and still conveyed the information as accurately.

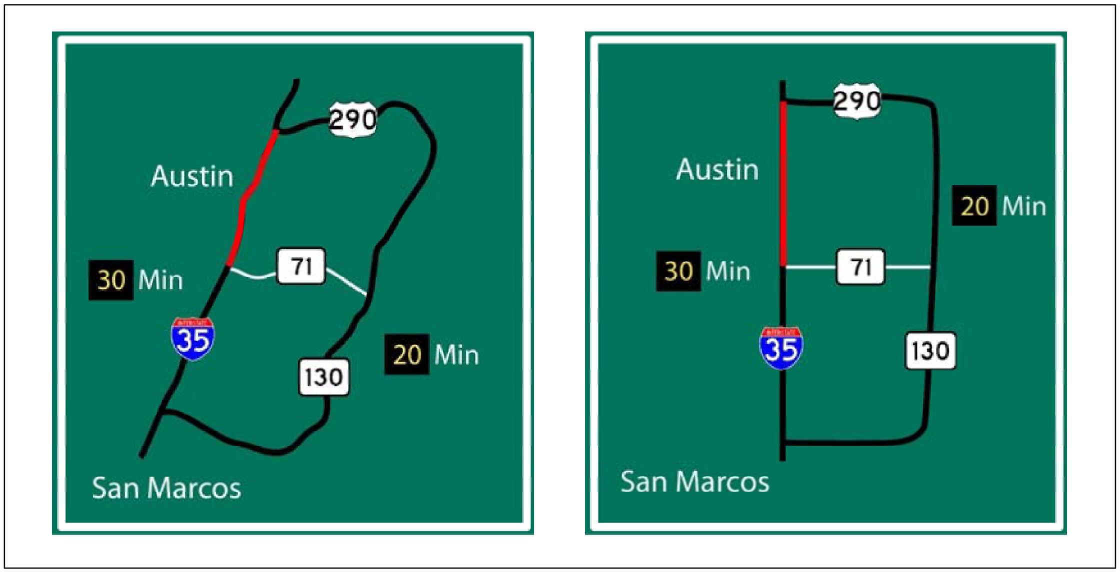


Figure 22. Contrasting Map Realism for Location 3 (I-35 at US 290).

Some participants recommended a hybrid approach to map realism. Some believed that the realistic maps were too realistic and gave a false impression of complexity relative to the false impression of simplicity in the less realistic maps. It was suggested that a simplified approach be adopted where the roads are portrayed in their correct alignment (not straight up-down or left-right) with general directional changes being shown. However, the "squiggles" that denote directional changes in the left map of Figure 22 are unnecessary as they likely do not reflect what the road is actually like. This hybrid approach was deemed best for GRIPs that had more information, such as location 1 at the northern intersection of I-35 and SH 130 that contained information on the entirety of the SH 130 and I-35 corridors through the Austin metropolitan area.

SUMMARY

In general, focus group participants understood the information that was presented on each GRIP in that it showed routes and travel times in the Austin area. There was some confusion in all of the groups on specific information contained in the GRIP signs, most notably regarding the specific destinations that the stated travel times referred to.

At times, it was apparent that many participants were not grasping the ultimate intent of the GRIP signs, which was to provide information on travel times for SH 130 versus I-35 so that travelers could divert to the tolled facility if they wished to avoid congestion. This was particularly apparent in the first Austin session, where participants seemed to view the GRIP as a mechanism for providing general travel information in the Austin area as opposed to simply comparing I-35 and SH 130.

A recurring theme through the sessions was the need for consistency. Participants generally felt that it was important to ensure that the same type of GRIP configuration be applied in all locations along the corridor.

Overall, the focus group studies verified that map orientation, and amount of real-time information load presented should all be systematically evaluated in the Task 2 human factors studies. Based on comments received during the studies, the researchers propose that the simplified map presentations not be included in the human factors studies. Focus group participants provided many reasons for why a simplified map display could be misinterpreted and lead to confusion among drivers. Where simple maps are appropriate for subways and LRT systems for passengers, it is not clear that it would offer the type of information loading simplification that the researchers had initially envisioned.

The research team also concurred with the focus groups' collective opinion that a static route ramp with DMS inserts presenting current travel times are not a desirable option. Given the inability of participants to know for sure what the limits were for the travel times being displayed, the static map with travel times would be less useful than even a standard text message presented on a dynamic message sign (Figure 23).

TRAVEL TIME TO SAN MARCOS	
VIA I-35	60 MIN
VIA SH 130	40 MIN

Figure 23. Standard Text on a DMS.

As such, researchers recommend that the simple static route map with DMS inserts be eliminated from further assessment. However, the recommendation did lead the researchers to consider the possibility that a combination of a simple hybrid guide sign presenting the above text information could be combined in sequence with a color-coded GRIP portrayal of route conditions. Such a sequence would be preferable based on human factors positive guidance principles, as it results in information spreading that leads to improved human information processing performance. Figure 24 illustrates how a hybrid sign might look. A driver would see this sign and then the GRIP color-coded route sign (without DMS insets) on the next sign.

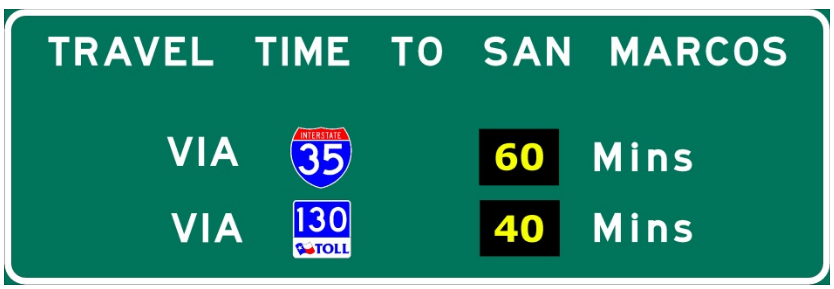


Figure 24. Potential Hybrid Travel Time Sign.

The focus groups also identified a number of specific changes that should be made to the GRIP images to enhance the ease of interpretation by drivers and reduce possible confusion:

- Toll route shields should be used to convey the SH 310 and SH 45 routes.
- The continuity of SH 130 south past the SH 45 connection to I-35 near Buda should be shown.
- The continuity of other routes connecting to SH 130 (US 290, SH 71) should also be shown.
- Travel times should be positioned adjacent to each other, and close to the beginning of the decision point, on all signs to facilitate comparison.
- Arrows showing where the driver is traveling should be used on all signs, not just the 3D versions.

NON-GRIP-RELATED COMMENTS FROM THE FOCUS GROUP STUDIES

The primary purpose of these focus groups was to assess GRIP signs as a means of communicating information on time savings for use of the SH 130 toll facility versus I-35. As in previous research regarding public use of the SH 130 facility, there were participants in each session who had used and continue to use the SH 130 facility, and those who did not use the facility out of either a principled opposition to toll roads or a general lack of knowledge of toll facilities in the Austin area. Opposition to toll roads based on principle is a problematic issue to address in terms of outreach and education, and it is not something that can be addressed by GRIP design. Fortunately such principled objection to tolls was expressed by only a few participants. However, the largest impediment to toll road use by participants was a lack of knowledge and experience with the facility. Many participants were unaware of where toll roads and specifically SH 130 would take them. This sentiment was highest in the College Station (non-users) session but was also expressed in both Austin sessions. Many were unsure of how to pay tolls or how tolls were assessed. For these participants, the uncertainty of taking the toll road could outweigh the uncertainty of being delayed by congestion. However, there are opportunities to address these types of issues with education and outreach efforts.

A second aspect of toll facility non-utilization was that many participants did not feel that the SH 130 is convenient for them. SH 130 is located several miles to the east of I-35 and is simply not convenient for many day-to-day commuters. Some participants noted that that their travel times would likely not improve due to their destinations not being very far south of downtown. These participants noted that the SH 130 facility is of more utility to drivers with destinations south of the Austin metro area such as San Marcos and San Antonio. These observations corroborate other research efforts undertaken by TTI to assess SH 130 use such as the legislatively mandated assessment of SH 130 usage (Rider 44) and a similar Federal Value Pricing Pilot Program (VPPP) sponsored assessment.

HUMAN FACTORS STUDIES OF DRIVER COMPREHENSION AND INFORMATION LOADING OF GRIP SIGN DESIGN OPTIONS

OBJECTIVES

Under this task, one objective was to evaluate driver comprehension of the various GRIP sign design prototypes identified through the focus group studies through a computer-based human factors laboratory study. In addition to comparing comprehension rates between sign design prototypes, another objective was to assess the amount of real-time information (presented as colored route segments indicating congestion and travel times) that drivers could assimilate in a limited-viewing time environment as would be experienced in an actual driving situation.

STUDY METHODOLOGY

Factors Evaluated

The human factors study included four main factors:

- Sign location.
- Sign orientation.
- Type of travel time information display.
- Amount of route congestion presented.

First, three potential locations for GRIP implementation were identified through TTI/TxDOT discussions and verified through focus group studies:

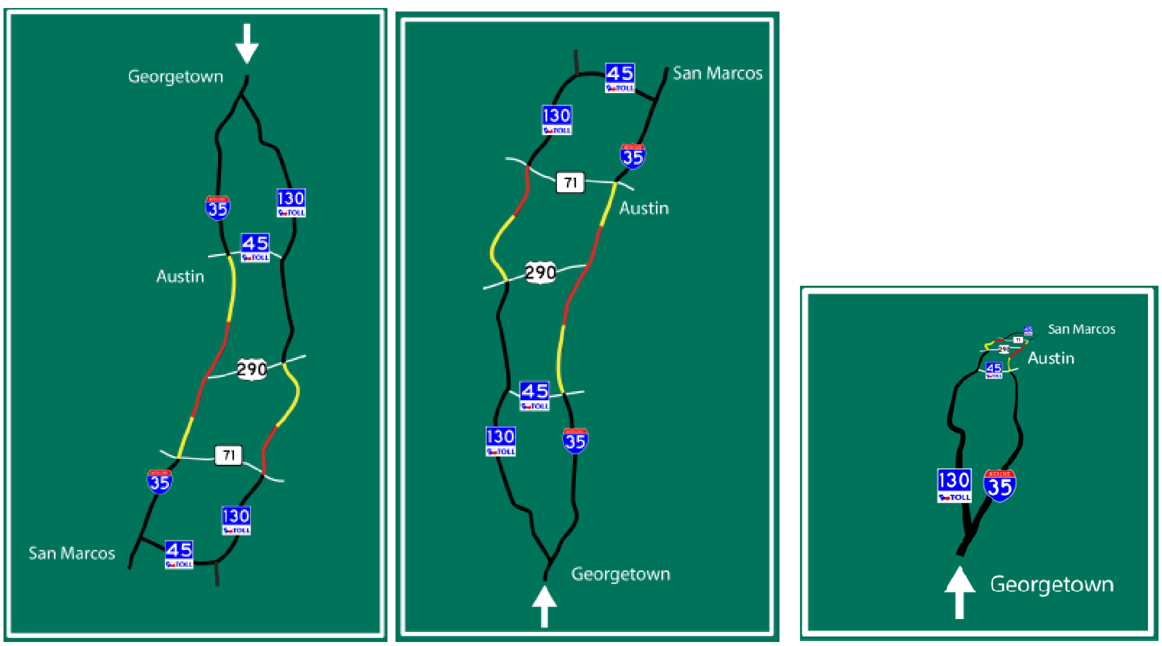
- Prior to the I-35/SH 130 interchange north of Georgetown.
- Prior to the I-35/SH 45 interchange in Round Rock.
- Prior to the I-35/ US 290 interchange in Austin.

For each possible sign location, three potential sign orientation schemes were then suggested:

- Map-like representation with southbound motorists reading the sign as driving from the top downward (i.e., north would be heading up the sign as in a traditional map orientation, referred to as the north orientation).

- Map-like representation with the southbound motorists reading the sign as driving from the bottom upward (i.e., north would be heading down the sign, referred to as the track orientation).
- A 3D perspective (similar to those used in personal navigation devices) with southbound motorists reading the sign from the bottom upward (i.e., the track orientation).

Figure 25 illustrates the three orientations of the roadways tested for the Georgetown sign location. Previous research has shown that some drivers find it easier to process map information when it is presented in a traditional north-up format, whereas other drivers process it easier when it is presented in an oriented forward view as typical GPS navigational units (up being the direction of travel).



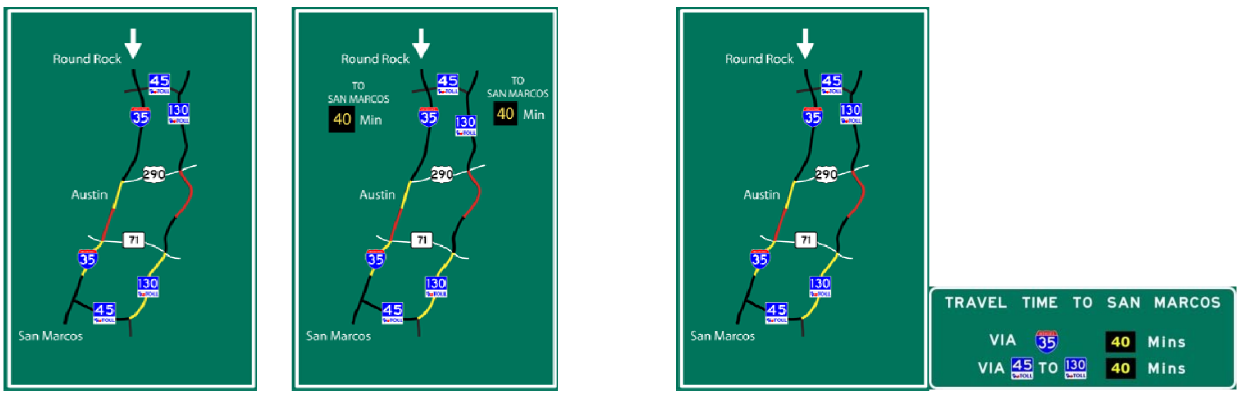
(a) North Orientation (b) Track Orientation (c) Track 3D Orientation

Figure 25. Examples of GRIP Sign Orientations Tested.

The focus groups also indicated a desire to have both route segments and travel time information presented, as both provide unique and valuable information when making a real-time route choice decision. However, past research has indicated concerns regarding information loading on GRIP signs. Therefore, three options regarding the presentation of travel time and route congestion information were included in the study:

- Graphic route congestion information only (no travel times).
- Graphic route congestion information and travel times to San Marcos presented on a single sign.
- Graphic route congestion information and travel times to San Marcos presented on two signs in sequence.

Figure 26 illustrates the different route and travel time display options evaluated. Note that the last option involves the spreading of information over a longer distance. This approach would require a second sign structure and sign, and thus is a more expensive option. However, this approach is a recommended positive guidance safety improvement technique when information loading concerns are present.



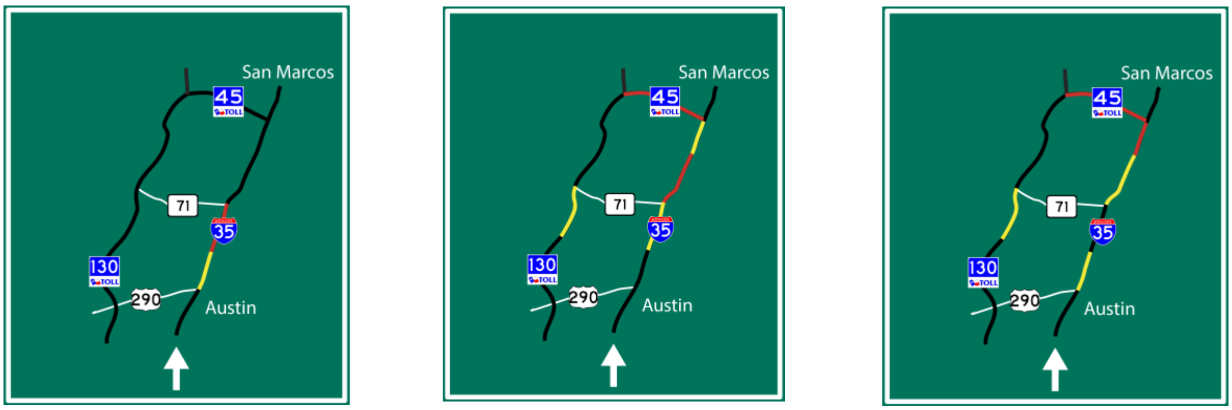
(a) Routes only (b) Routes and travel times (c) Routes with travel times (distributed)

Figure 26. Examples of Route and Travel Time Options Tested.

The final factor incorporated into the human factors studies was the amount of route congestion information presented. Three levels of congestion were ultimately developed and tested:

- Level 1 – no congestion on SH 130, only two sections (one yellow and one red) located adjacent to each other on I-35.
- Level 2 – two segments of congestion (one red and one yellow) not adjacent to each other on SH 130, three congestion segments (two yellow and one red) adjacent to each other on I-35.
- Level 3 – two segments of congestion (one red and one yellow) not adjacent to each other on SH 130, 3 or 4 segments of congestion (2 or 3 yellow, 1 red), some adjacent and some not, on I-35.

The researchers hypothesized that scanning and interpreting more and/or non-adjacent locations of congestion would involve higher information loading than would fewer and adjacent sections of congestion. Consequently, Levels 1 through 3 were believed to cover a fairly wide range of information loading conditions. Figure 27 illustrates the three congestion levels used. All together, these four factors comprised a total of $3 \times 3 \times 3 \times 3 = 81$ factor combinations to be evaluated. A complete depiction of all of the factor combinations can be found in Appendix B.



(a) Level 1 (b) Level 2 (c) Level 3

Figure 27. Examples of Route Congestion Levels Tested.

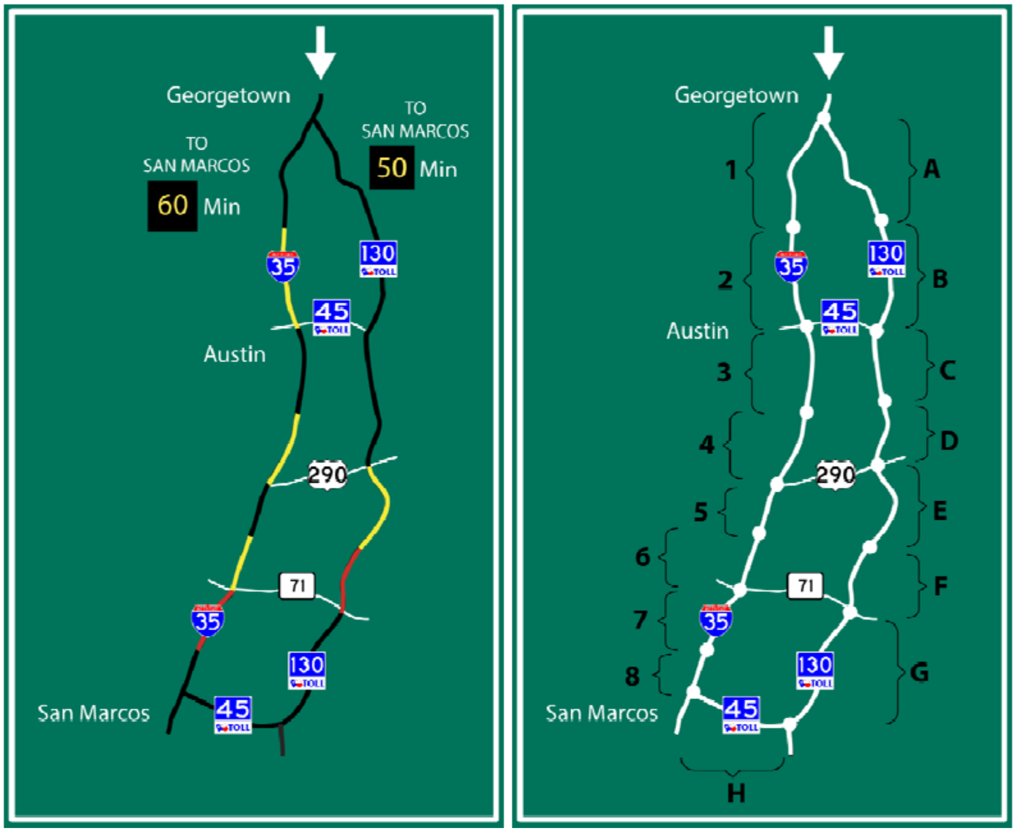
Experimental Design

The large number of treatment combinations included in the study prohibited researchers from employing a full factorial experimental design. Furthermore, the potential for learning effects to occur across the different congestion levels for a given sign configuration meant that a randomized block design (using sign location as a blocking variable) would not be practical. Researchers developed an experimental design that presented each subject with three iterations of each of the three sign locations, each with a different congestion level/route and travel time display option. This approach reduced the number of treatment combinations that had to be viewed by any one subject to nine (three per potential sign location). Nine different sign sequences, or scripts, were then developed to be followed by the researchers to address all 81 treatment combinations.

Data Collection Procedures

Microsoft Powerpoint© presentation software was used to present the signing configurations to subjects. Images of each treatment combination were drafted and inserted into an appropriate slide. The software was configured to display a particular sign for 6 seconds. Six seconds is consistent with available viewing times that exist for most freeway guide sign arrays. Subjects who agreed to participate in the study were positioned at a table with a laptop computer, read the instructions about the study and IRB protection requirements, were shown an example of the types of signs they would see, and were then led through the study. To do this, subjects were asked to envision themselves driving southbound on I-35 approaching Austin. They were shown a map of the corridor with an arrow showing their approximate location in order to better orient themselves. They were then told they would see a sign presenting them with information about the available routes. After each sign was presented, subjects were shown the sign without colors on the routes, but with the routes divided into segments labeled 1 through 8 or A through H. Figure 28 show an example of this coding map. Subjects were asked to identify which segments had been yellow or red, whether or not travel time information was presented, and recall the actual travel times displayed. Subjects were also asked about their awareness of the amount of tolls on SH 45/130, and whether or not they would use SH130 instead of I-35 if (1) no tolls were being collected or (2) the tolls that are normally collected for that trip were required to be paid if SH 130 were used(subjects were informed of the actual tolls required).

On average, the study required approximately 15 minutes to perform. Subjects were recruited at local drivers licensing stations in Houston, College Station, and Austin. In addition, some subjects were recruited at the Travis County Courthouse. Researchers collected data from at least 60 subjects for each treatment combination of interest, 30 from the Austin area as local drivers, and 30 from the College Station/Houston regions as non-local drivers. In total, data were collected from 549 drivers. Appendix C presents the data collection form used.



(a) GRIP Test Sign (b) Map for Response

Figure 28. Example of Response Map Presented after Each GRIP Test Sign to Identify Locations of Congestion.

Data Reduction and Analysis

Responses from each study participant were entered into a spreadsheet for analysis. A layered scoring system was developed to aid in interpreting the degree of understanding attained by the subjects, rather than only evaluating responses on an all-or-nothing correct scale. Different degrees of information transfer can be accomplished from these types of signs to a driver. For each GRIP sign treatment examined, points were assigned to the responses as follows:

- Recognition of congestion presence.
    - 1 point for each route that the subject correctly identified as having some congestion present.
- Recognition of the extent or length of congestion on each route.

    - 1 point per segment identified as being in congestion on each route, subtracting one point per segment if more segments identified than were actually in congestion.
- Recognition of correct congestion locations and levels of congestion.
    - Each segment correctly identified by location and color was assigned points equal to the number of segments shown on that route. If the location was one segment away from being correct, it received one point less than the number of segments; if two segments away, it received two less points than the number of segment on that route, etc.
- Travel time information.
    - If no times were presented in the display, 1 point if correctly responding with no travel time information.
    - If times were presented:
        - 1 point for correctly recognizing the presence of travel time information.
        - 1 point if correctly recognizing if I-35 time was greater than SH 130, or if the two times were equal.
        - 1 point each for correctly reporting the actual times shown for each route.

The subjects' scores in each category were then summed for each GRIP treatment combination and divided by the total possible score possible to achieve a percent correct value. Researchers then compared these percentages by each of the main factors considered in the study.

STUDY RESULTS

Subject Demographics

Table 2 presents the summary of the study participants with respect to gender, age, and education. Also shown are the statewide breakdowns of those variables. Samples from both Austin and College Station/Houston were fairly consistent with respect to age and gender, and were also in line with statewide Texas driver demographics. The two subject samples were also relatively consistent with respect to education, but the sample overall tended to be more highly educated than the Texas statewide driver demographics. However, this deviation from the statewide average was not expected to adversely affect the findings of the study. As expected, the two samples did vary dramatically in terms of their use of freeways and tollways in the Austin area. It is this difference in familiarity with the freeways and tollways in the Austin area that researchers believe would have the most effect on responses obtained in this study.

Table 2. Study Participant Demographics (n=549).

	Austin (n=269)	College Station/ Houston (n=280)	Total	TX Statewide Demographics
Gender:				
Male	53%	50%	51%	50%
Female	47%	50%	49%	50%
Age:				
18–35	37%	42%	40%	32%
36–54	38%	41%	39%	39%
55+	26%	17%	21%	29%
Highest Education Level Attained:				
High school	19%	17%	18%	48%
Some college	33%	36%	35%	29%
College graduate	48%	47%	47%	23%
Driven on an Austin Freeway:				
≤ 2/year	7%	85%	47%	NA
2/yr < X ≤ 2/mo	6%	11%	8%	
> 2/mo	87%	4%	45%	
Driven on an Austin Tollway:				
≤ 2/year	44%	94%	70%	NA
2/yr < X ≤ 2/mo	25%	4%	14%	
> 2/mo	31%	3%	16%	

Georgetown (I-35/SH 130) Sign

Recognition of Congestion Presence

Appendix D provides a summary of the percent of subjects correctly identifying the presence or absence of congestion on I-35 and SH 130 based on the various GRIP sign options presented. Overall, researchers found congestion detection rates between the Austin and the College Station/Houston participants to be essentially equal overall across all sign designs and congestion levels tested. Austin participants correctly identified 86.4 percent of the routes as having congestion or no congestion displayed, compared to 89.9 percent of the College Station/Houston study participants. Likewise, few differences were found with respect to both sign orientation and presence/type of travel time information displayed. As shown in Table 3, overall percentages of correct detection exceeded 85 percent for all sign perspectives and travel time options tested. One does see that the level of congestion presented decreases the percentages slightly. The effect is most noticeable for the two track sign perspectives when travel times are presented on the same GRIP sign. For those displays, the percent correct detection range drops from about 93 to 95 percent correct detection at level 1, down to 72 to 78 percent. The same magnitude of effect is not evident for the track perspective GRIP signs when the travel time information is presented on a separate sign (i.e., the distributed option).

Table 3. Percent Correct Detection of Congestion/No Congestion on Routes: Georgetown Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	92	96	96
Level 2	90	88	92
Level 3	86	83	87
Overall	89	89	92
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	95	95	94
Level 2	95	88	90
Level 3	81	78	80
Overall	90	87	88
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	92	93	97
Level 2	91	93	67
Level 3	82	72	89
Overall	88	86	84

Perceiving the Extent of Congestion

Once again, no differences in responses were detected between Austin and the College Station/Houston study participants. Table 4 summarizes the responses in terms of percentage of extent (length) of the routes correctly perceived as being in congestion. As would be expected, the percentages are somewhat lower than in Table 3. In addition, one sees that the track 3D perspective results in the lowest percentages across all three travel time display types. It does appear more difficult to assess exactly how much of each route is congested when the routes are presented in 3D perspective, especially when travel time information is also presented, which explains the lower scores. These data suggest that the study participants were best able to assess the amount of each route that was congested when the information was presented in the north orientation. The distributed approach to presenting the route and travel time information on separate signs also yielded slightly higher correct scores than did the combined route segments with travel time information presented on the same sign.

Recognizing the Type and Location of Congestion

Table 5 presents the percent correct scores of study participants in identifying both the location of the congestion segments on the routes, and the correct color of congestion (red or yellow). Looking across all sign orientation and travel time presentation options, one again sees a consistent trend in the scores as the level of congestion information presented increases. The scores drop to 50 percent or below for certain display options. The track 3D orientation sign was particularly affected, with participants correctly identifying only about 50 percent of the locations and colors of congestion, even at the lowest level of congestion. Conversely, study participants viewing the north orientations were able to recognize and recall up to 85 percent of the locations and colors of congestion for the lowest congestion condition tested. The addition of travel times to the displays at these high levels of recollection did reduce the participant scores; travel time had little effect on scores when overall scores were already hovering around the 50 percent value even with no travel time presented. In other words, at high congestion levels, study participants were essentially guessing as to the exact location and colors of congestion, and the introduction of travel times had little incremental effect on their guesses. At lower congestion levels, the addition of travel times did add to the overall information load levels that subjects were experiencing and result in degraded scores (albeit, often still higher than a 50/50 guess score).

Table 4. Percent Correct Perception of Extent (Length) of Congestion on Routes: Georgetown Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	79	69	78
Level 2	69	65	60
Level 3	65	57	62
Overall	71	64	67
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	80	66	74
Level 2	69	59	62
Level 3	52	49	53
Overall	63	55	59
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	52	56	60
Level 2	58	54	38
Level 3	51	37	49
Overall	54	47	45

Table 5. Percent Correct Location and Type (Color) of Congestion on Routes: Georgetown Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	85	72	72
Level 2	69	61	59
Level 3	64	51	58
Overall	69	61	63
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	80	65	69
Level 2	66	58	55
Level 3	61	45	53
Overall	69	56	59
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	50	52	53
Level 2	50	59	39
Level 3	47	33	44
Overall	49	48	45

Perception of Travel Times

Table 6 presents the participant scores in recognizing and recalling the travel times on the two routes, when such information was provided. Overall, subjects were very good at noting when travel time information was not presented, so scores for the routes-only displays (no travel time information) are not included in Table 6.

The scores are not consistently associated with level of congestion as were the scores in the previous tables. Instead, the scores for Level 2 are generally the highest, followed by Levels 1 and 3. The travel times presented for the Level 2 congestion condition were actually the same, which many participants correctly noted and apparently used when recalling the information. In effect, participants only needed to remember that the times were the same (occasional comments by the participants indicated that they focused on this fact often), and remember that number. In contrast, participants would have to remember two different numbers for the other congestion levels. Several participants also noted that the time on one route was greater or smaller than the one for the other route, but could only recall one of the numbers correctly. Such result was not unexpected and is consistent with other studies of driver route choice decision making.

Table 6. Percent Correct Recall of Travel Time Information Presented: Georgetown Sign.

North Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	74	78
Level 2	78	79
Level 3	49	73
Overall	67	77
Track Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	59	77
Level 2	73	79
Level 3	42	81
Overall	58	79
Track 3D Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	65	73
Level 2	80	84
Level 3	63	68
Overall	69	75

With respect a single GRIP versus the distributed GRIP displays, participant recollection of the travel time information was slightly higher for the distributed display option, particularly at the Level 1 and Level 3 congestion levels. The benefits of spreading route congestion and travel time information is evident in these results. One main reason for this improvement is that the total amount of time that participants had to assimilate the information presented was doubled (6 seconds for the travel time sign, 6 seconds for the route sign) in the distributed format than for the route and travel time together format (6 seconds total for that display). In addition, there was time between the display of the two signs (6 seconds) that allowed extra processing time of the travel time information prior to receiving the route congestion information.

Stated Preference Route Decisions

The final data element collected during the study was the participants' stated choice about whether they would divert to the SH 130 route in response to the GRIP display or would remain on I-35. Recall that two scenarios were presented to participants for their response:

- Would you divert to SH130 in response to the information presented if the tolls were not being collected?
- Would you divert if you knew that the toll was approximately $6.76 to take SH 130?

Table 7 presents the percentage of participants who indicated they would divert under each scenario for each of the GRIP display options tested. As would be expected, the percentages are highest for the Level 1 congestion condition in all cases, as this condition only showed congestion on I-35. Note that the presence of travel time information increased the diversion percentages relative to the routes only display. Also note that the "with toll" diversion percentages are much lower than the "no toll" version in all cases.

For the no toll conditions, the lowest percentage of stated diversion occurs for Level 2 congestion for all display options that include travel time information. Recall that this level was the one where the travel times displayed were equal for each route. This trend is not necessarily found in the routes only displays, illustrating the importance of the travel time information on the stated diversion decisions.

Summary

Based on an assessment across all of the performance metrics used, the route with travel times presented in a distributed manner performs the best overall. This sign results in percentages of correct recall and interpretation of route congestion that are almost comparable to the routes only displays, while providing travel time recall and interpretation comparable to the routes with travel time displays.

Table 7. Percent Stated Diversion Choice to SH 130: Georgetown Sign.

North Orientation						
Congestion Levels Presented	Routes Only		Routes with Travel Times		Route with Travel Times (Distributed)	
	No Toll	With Toll	No Toll	With Toll	No Toll	With Toll
Level 1	78	39	92	50	84	42
Level 2	63	24	46	26	60	25
Level 3	69	23	59	20	67	25
Overall	70	29	65	32	70	31
Track Orientation						
Congestion Levels Presented	Routes Only		Routes with Travel Times		Route with Travel Times (Distributed)	
	No Toll	With Toll	No Toll	With Toll	No Toll	With Toll
Level 1	72	35	84	43	83	42
Level 2	69	36	47	12	69	27
Level 3	62	33	64	19	67	29
Overall	68	35	65	25	73	32
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes with Travel Times		Route with Travel Times (Distributed)	
	No Toll	With Toll	No Toll	With Toll	No Toll	With Toll
Level 1	76	25	87	46	83	46
Level 2	68	21	54	20	68	25
Level 3	63	21	72	22	71	23
Overall	69	22	71	29	74	31

The data are less conclusive with respect to the best orientation to provide GRIP information to motorists. Based on the measure of performance selected, it does appear that the north orientation (northbound pointing upward) yielded slightly better percentages than the track orientation, although the improvement was not significant. The track 3D orientation resulted in poorer performance, however. It was especially difficult for study participants to accurately assess route conditions located a fair distance downstream of the sign (i.e., near US 290), due to the foreshortening of the routes to create the 3D visual perspective.

The data are also less clear as to the maximum amount of information that can be presented via GRIP signing. Increasing levels of congestion reduce driver ability to correctly recall and interpret the amount of congestion present and its location on a route. However, motorists may not necessarily need to be able to exactly recall and interpret congestion location in order to make improved route choice decisions; approximate assessments of location and length may be sufficient. Further examination of this variable, consolidated across all sign location options tested, is presented later in this chapter.

Round Rock (I-35/SH 45/SH 130) Sign

Recognition of Congestion Presence

Appendix D provides a summary of the percent of subjects correctly identifying the presence or absence of congestion on I-35 and SH 130 based on the various GRIP sign options presented at this second potential sign location. Overall, researchers found congestion detection rates between the Austin and the College Station/Houston participants to be essentially equal overall across all sign designs and congestion levels tested. Austin participants correctly identified 96 percent of the routes as having congestion or no congestion displayed, compared to 93.5 percent of the College Station/Houston study participants. Few differences were found with respect to both sign orientation and presence/type of travel time information displayed. As shown in Table 8, overall percentages of correct detection exceeded 85 percent for all sign orientations and travel time options tested. One does see that the level of congestion presented decreases the percentages slightly. The effect is again most noticeable for the two track signs. For those displays, the percent correct detection drops in range from about 97 to 99 percent correct detection at Level 1, down to 83 to 94 percent.

Perceiving the Extent of Congestion

Once again, no differences in responses were detected between Austin and the College Station/Houston study participants. Table 9 summarizes the responses in terms of percentage of extent (length) of the routes correctly perceived as being in congestion. The percentages are somewhat higher than in Table 8. This is counter to researcher expectations. Researchers had hypothesized that the routes might be more difficult to interpret, given that they were presenting only partial perspectives of I-35, SH 45, and SH 130 rather than the overall views of I-35 and SH 130 presented in the Georgetown sign. However, that does not appear to be the case. Rather, the fact that the route map represents a smaller length of roadway may have made the perception and interpretation task more manageable for participants.

Table 8. Percent Correct Detection of Congestion/No Congestion on Routes: Round Rock Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	95	96	96
Level 2	91	96	98
Level 3	97	86	99
Overall	94	93	98
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	99	97	98
Level 2	90	95	95
Level 3	96	88	92
Overall	95	93	95
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	99	97	99
Level 2	96	95	99
Level 3	93	94	83
Overall	96	95	94

The track 3D orientation results in the lowest percentages across all three travel time display types. Researchers had hypothesized that it might be more difficult to assess exactly how much of each route is congested when the routes are presented in 3D orientation, especially when travel time information is also presented. This seems to be the case, based on the lower scores shown. These data suggest that the study participants were best able to assess the amount of each route that was congested when the information was presented in the north orientation.

Table 9. Percent Correct Perception of Extent (Length) of Congestion on Routes: Round Rock Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	92	93	87
Level 2	66	70	79
Level 3	65	64	59
Overall	69	71	70
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	97	93	95
Level 2	69	73	69
Level 3	66	59	67
Overall	72	70	72
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	88	92	95
Level 2	73	71	71
Level 3	63	60	52
Overall	71	69	68

Recognizing the Type and Location of Congestion

Table 10 presents the percent correct scores of study participants in identifying both the location of the congestion segments on the routes and the correct color of congestion (red or yellow). Looking across all sign orientation and travel time presentation options, the consistent drop in the scores as the level of congestion information presented increases. However, the percentages are not as low as they were for the Georgetown sign discussed previously, suggesting that it was slightly easier for participants to interpret conditions when the length of the route is shorter. The scores did drop to 50 percent or below for two of the track 3D orientation displays. For the other displays, trends were fairly similar as a function of congestion level presented.

Table 10. Percent Correct Location and Type (Color) of Congestion on Routes: Round Rock Sign.

Congestion Levels Presented	Routes Only	Routes with Travel Times	Route with Travel Times (Distributed)
North Orientation			
Level 1	91	94	91
Level 2	65	68	75
Level 3	59	55	55
Overall	72	72	74
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	89	90	93
Level 2	66	69	61
Level 3	61	51	56
Overall	72	70	70
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	91	90	85
Level 2	65	66	68
Level 3	56	49	45
Overall	70	68	66

Perception of Travel Times

Table 11 presents the participant scores in recognizing and recalling the travel times on the two routes, when such information was provided. Overall, subjects were very good at noting when travel time information was not presented, so scores for the routes only displays (no travel time information) are not included in Table 11.

The scores in Table 11 are not consistently associated with level of congestion as were the scores in the previous tables. The travel times presented for the Level 2 congestion condition were the same, so participants only needed to remember that the times were the same (occasional comments by the participants indicated that they keyed on this fact often) and remember that number. In contrast, participants had to remember two different numbers for the other congestion levels, one for each route. No clear trend was observed with respect to participant ability to recall travel time information under the different display conditions for the GRIP sign at this location.

The fact that the route portion of the map was somewhat discontinuous, as opposed to the overall completeness of the route map for the Georgetown sign, may have added significant mental workload to the task of sign interpretation and recollection, and led to inconsistent results overall.

Table 11. Percent Correct Recall of Travel Time Information Presented: Round Rock Sign.

North Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	73	86
Level 2	69	83
Level 3	71	74
Overall	71	81
Track Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	65	80
Level 2	50	76
Level 3	63	72
Overall	59	76
Track 3D Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	67	87
Level 2	60	79
Level 3	73	74
Overall	66	80

With respect a single GRIP versus the distributed GRIP displays, participant recollection of the travel time information was higher for the distributed display option. This was particularly true at the Level 1 and Level 2 conditions.

Stated Preference Route Decisions

The final data element collected during the study was the participants' stated choice about whether they would divert to the SH 130 route in response to the GRIP display, or would remain on I-35. Recall that two scenarios were presented to participants for their response:

- Would you divert to SH130 in response to the information presented if the tolls were not being collected?
- Would you divert if you knew that the toll was approximately $7.09 to take SH 130?

Table 12 presents the percentage of participants who indicated they would divert under each scenario for each of the GRIP display options tested. The percentages are highest for the Level 1 congestion condition in all cases, as this condition only showed congestion on I-35. Note that the presence of travel time information increased the diversion percentages relative to the routes only display. Also note the with toll diversion percentages are much lower than the no toll version in all cases. The percentages are generally less than they were for the Georgetown sign under similar perspectives, display types, and levels of congestion.

Table 12. Percent Stated Diversion Choice to SH 130: Round Rock Sign.

North Orientation						
Congestion Levels Presented	**Routes Only**		**Routes with Travel Times**		**Route with Travel Times (Distributed)**	
	No Toll	**With Toll**	**No Toll**	**With Toll**	**No Toll**	**With Toll**
Level 1	75	23	75	29	88	55
Level 2	45	27	54	17	39	8
Level 3	44	12	67	23	72	25
Overall	55	21	65	23	66	29
Track Orientation						
Congestion Levels Presented	**Routes Only**		**Routes with Travel Times**		**Route with Travel Times (Distributed)**	
	No Toll	**With Toll**	**No Toll**	**With Toll**	**No Toll**	**With Toll**
Level 1	65	22	73	24	79	35
Level 2	39	24	38	23	42	18
Level 3	62	23	63	20	68	20
Overall	55	23	58	22	63	24
Track 3D Orientation						
Congestion Levels Presented	**Routes Only**		**Routes with Travel Times**		**Route with Travel Times (Distributed)**	
	No Toll	**With Toll**	**No Toll**	**With Toll**	**No Toll**	**With Toll**
Level 1	79	27	86	46	84	34
Level 2	43	15	48	17	49	13
Level 3	53	16	56	12	70	20
Overall	58	19	63	25	67	22

For the no toll conditions, the lowest percentage of stated diversion occurs for the Level 2 congestion condition for all display options that include travel time information. This trend is not evident for the north orientation but is somewhat evident for the two track orientations. Researchers believe that some learning effects may contribute to the better assessment of route only conditions for this sign location.

Summary

The data show that the route with travel times presented in a distributed manner performs the best overall. This sign results in percentages of correct recall and interpretation of route congestion that are almost comparable to the routes only displays, while providing travel time recall and interpretation comparable to the routes with travel time displays.

The data are also less conclusive with respect to the best orientation to provide GRIP information to motorists. The north orientation yielded slightly better percentages than the track orientation, although the improvement was not significant. The track 3D orientation performed poorer, but not by as much as it did in the Georgetown sign portion of the study.

Austin (I-35/US 290/SH 130) Sign

Recognition of Congestion Presence

Appendix D provides a summary of the percent of subjects correctly identifying the presence or absence of congestion on I-35 and SH 130 based on the various GRIP sign options presented at this third potential sign location. Overall, researchers found congestion detection rates between the Austin and the College Station/Houston participants to be essentially equal overall across all sign designs and congestion levels tested. Austin participants correctly identified 96 percent of the routes as having congestion or no congestion displayed, compared to 95 percent of the College Station/Houston study participants. Few differences were found with respect to both sign orientation and presence/type of travel time information displayed. As shown in Table 13, overall percentages of correct detection exceeded 85 percent for all sign orientations and travel time options tested; in most cases, it exceeds 90 percent. Unlike the other two sign locations examined, the level of congestion presented has only a small effect on the percentages. In addition, a correlation between congestion level on percent correct detection is not as strong.

In a few instances, the percentage (albeit very high) is slightly lower for congestion Level 2 than for congestion Level 3. However, none of these differences are significant.

Table 13. Percent Correct Detection of Congestion/No Congestion on Routes: Round Rock Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	99	97	100
Level 2	97	95	93
Level 3	94	99	98
Overall	97	97	97
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	99	94	99
Level 2	89	85	94
Level 3	94	94	96
Overall	94	91	96
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	100	99	98
Level 2	94	92	98
Level 3	92	89	94
Overall	95	93	96

Perceiving the Extent of Congestion

No differences in responses were detected between Austin and the College Station/Houston study participants with respect to this measure at this sign location. Table 14 summarizes the responses in terms of percentage of extent (length) of the routes correctly perceived as being in congestion. The percentages shown are higher than in either Table 4 or Table 9, suggesting that drivers perform better in assessing congested route information graphically for smaller route segments overall. The values in Table 14 are smaller than in Table 13, illustrating that as the level of detail requested from the participants increases, their performance ability decreases. As in all three sign locations, the track 3D orientation results in the lowest percentages across all three travel time display types. However, the amount of degradation is fairly small for this location. These data suggest that the study participants were best able to assess the amount of each route that was congested when the information was presented in the north orientation, albeit only slightly better.

Table 14. Percent Correct Perception of Extent (Length) of Congestion on Routes: Round Rock Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	99	96	90
Level 2	79	73	77
Level 3	71	77	76
Overall	79	78	77
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	97	85	89
Level 2	69	66	80
Level 3	68	74	75
Overall	72	71	79
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	94	98	91
Level 2	74	69	76
Level 3	65	68	73
Overall	73	72	77

Recognizing the Type and Location of Congestion

Table 15 presents the percent correct scores of study participants in identifying both the location of the congestion segments on the routes and the correct color of congestion (red or yellow). Scores again drop as the level of congestion information presented increases, regardless of the sign orientation and display type. However, the percentages are not as low as they were for either the Georgetown or the Round Rock signs discussed previously, adding support to the hypothesis that that it was slightly easier for participants to interpret conditions when the length of the route is shorter. For this sign location, none of the scores dropped below 50 percent for any sign orientations or display options tested. The north orientation performed slightly better.

Table 15. Percent Correct Location and Type (Color) of Congestion on Routes: Round Rock Sign.

North Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	95	93	89
Level 2	71	65	72
Level 3	65	71	75
Overall	77	76	78
Track Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	97	88	92
Level 2	62	62	73
Level 3	62	67	70
Overall	73	72	78
Track 3D Orientation			
Congestion Levels Presented	**Routes Only**	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	92	96	93
Level 2	69	66	76
Level 3	60	61	56
Overall	74	74	75

Perception of Travel Times

Table 16 presents the participant scores in recognizing and recalling the travel times on the two routes, when such information was provided. As before, scores for the routes only displays (no travel time information) are not included in the table. The scores in Table 16 tend to be associated with level of congestion, although less so for the distributed display format. Whereas the range or correct responses for the route and travel time display together ranged from 43 to 83 percent, depending on sign orientation and level of congestion, it ranged only between 72 and 83 percent for the distributed display format.

Table 16. Percent Correct Recall of Travel Time Information Presented: Round Rock Sign.

North Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	83	83
Level 2	67	84
Level 3	52	77
Overall	67	81
Track Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	81	72
Level 2	53	81
Level 3	43	75
Overall	59	76
Track 3D Orientation		
Congestion Levels Presented	**Routes with Travel Times**	**Route with Travel Times (Distributed)**
Level 1	78	83
Level 2	67	82
Level 3	54	72
Overall	66	79

Stated Preference Route Decisions

The final data element collected during the study was the participants' stated choice about whether they would divert to the SH 130 route in response to the GRIP display or would remain on I-35. Recall that two scenarios were presented to participants for their response:

- Would you divert to SH 130 in response to the information presented if the tolls were not being collected?
- Would you divert if you knew that the toll was approximately $4.38 to take SH 130?

Table 17 presents the percentage of participants who indicated they would divert under each scenario for each of the GRIP display options tested. The percentages are highest for the Level 1 congestion condition in all cases, as this condition only showed congestion on I-35. Unlike the previous two sign locations, the presence of travel time information did not consistently increase the diversion percentages relative to the routes only display. The with toll diversion percentages continue to be lower than the no toll version in all cases. The percentages are generally less than they were for the Georgetown sign under similar orientations, display types, and levels of congestion, but higher than those reported above for the Round Rock sign. This finding is strange given that the travel time difference of the two routes for Level 3 was only 5 minutes at this location, rather than the 10 minute difference shown for the other two locations for Level 3. Survey fatigue (the Austin signs were at the end of each iteration of the survey) may have played a role in these inconsistent results, or it may be that drivers simply felt more familiar and confident with the partial map representation at this location.

Table 17. Percent Stated Diversion Choice to SH 130: Round Rock Sign.

North Orientation						
Congestion Levels Presented	**Routes Only**		**Routes with Travel Times**		**Route with Travel Times (Distributed)**	
	No Toll	**With Toll**	**No Toll**	**With Toll**	**No Toll**	**With Toll**
Level 1	72	38	80	49	84	39
Level 2	71	40	43	18	39	24
Level 3	38	25	65	28	52	15
Overall	60	34	62	32	58	26
South Orientation						
Congestion Levels Presented	**Routes Only**		**Routes with Travel Times**		**Route with Travel Times (Distributed)**	
	No Toll	**With Toll**	**No Toll**	**With Toll**	**No Toll**	**With Toll**
Level 1	70	49	72	40	69	36
Level 2	43	31	47	38	42	37
Level 3	43	30	43	23	61	33
Overall	52	37	54	34	57	32
South Orientation (3D)						
Congestion Levels Presented	**Routes Only**		**Routes with Travel Times**		**Route with Travel Times (Distributed)**	
	No Toll	**With Toll**	**No Toll**	**With Toll**	**No Toll**	**With Toll**
Level 1	78	55	77	44	87	36
Level 2	69	33	56	31	48	25
Level 3	54	36	69	35	58	26
Overall	67	41	67	36	64	29

Summary

The data show that the route with travel times presented in a distributed manner performs the best overall. This sign results in percentages of correct recall and interpretation of route congestion that are almost comparable to the routes only displays, while providing travel time recall and interpretation comparable to the routes with travel time displays.

The data are also less conclusive with respect to the best orientation to provide GRIP information to motorists. The north orientation did yield slightly better percentages than the track orientation, although the improvement was not significant. The track 3D orientation performed poorer again, but not by as much as it did in the Georgetown sign portion of the study.

OVERALL ASSESSMENT OF INFORMATION LOADING EFFECTS

One of the more significant challenges associated with the assessment of GRIP sign designs is in determining what constitutes information and how much of that information can be presented on a GRIP without overloading drivers. Current text message design criteria for DMS is not directly applicable for GRIP signs, since much of the information presented is in graphical format. Researchers believe that drivers will use GRIP signs in much the same way that they currently use static guide signs; that is, drivers will scan the sign looking for information pertinent to their trip, and ignore or discard information that is not relevant. Consequently, criteria previously used to judge the adequacy of DMS messages in human factors studies, such as having at least 85 percent of drivers able to recall and interpret the entirety of a message, is not necessarily appropriate for a GRIP sign assessment.

Researchers and practitioners still cannot agree on an operational definition of information loading or overloading for guide signs, so it should not be a surprise that a clear metric of information overload for GRIP signs does not exist either. For this assessment, researchers opted to use the scoring system of information elements presented under the data analysis section as indicators of the total information load of the various congestion levels and display options tested. Researchers examined the percent correct scores of the various measures as a function of the total information elements in a particular sign configuration to assess the effect of increasing information elements upon driver performance. Researchers hypothesized that scores would decrease as information loading increases. Once loading exceeded human processing capabilities, performance levels would flatten out, most likely at a performance score of approximately 50 percent (i.e., basically guessing).

Researchers consolidated the results of the three sign locations together and plotted total information elements included in a sign versus the percent correct scores of the study participants for each of the three major measures:

- Recognition of congestion presence.
- Recognition of the extent or length of congestion on each route.
- Recognition of correct congestion locations and levels of congestion.
- Ability to assess travel times (for those display options that included travel time information).

The results of the analyses showed that the recognition of congestion presence decreased dramatically as the number of information elements presented on the GRIP increased. Referring back to Table 3, Table 8, and Table 13, there is a fairly high and consistent level of correct scores across the range of congestion levels, sign orientations, and display options. Analyses of the data indicated that even at the highest levels of information presented on the GRIPs, subjects were correctly detecting which routes had congestion present on them at least 85 percent of the time.

With regard to study participant ability to correctly process travel time information when presented, researchers did not detect a significant effect due to sign orientation. However, substantial differences are evident when the data are examined relative to whether the travel time was presented on a single GRIP sign or distributed across a text-based travel time sign and a GRIP sign. In Figure 29, a downward trend is evident for the single GRIP route and travel time sign as the number of information elements in the sign increase, but less so for the route and travel time distributed signs. The spreading of information across two signs allowed study participants to detect and process the travel time information more accurately than if the travel times were included on the same GRIP signs as the route congestion information. The better performance of the distributed display option is evident over the entire range of information element totals tested.

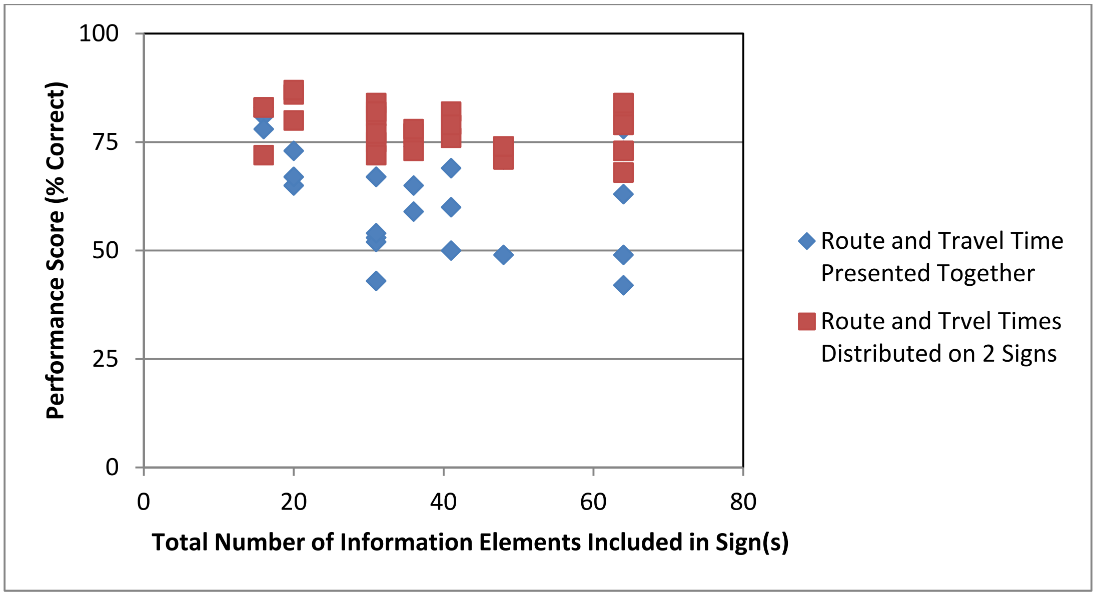


Figure 29. Effect of Display Type on Travel Time Recollection Accuracy.

The higher level of improvement in travel time accuracy scores for the distributed signs display option did not result in poorer performance in interpreting congestion extent, type, and location. As shown in Figure 30 and Figure 31, performance scores for the three display types (routes only, routes and travel times combined, and routes and travel times distributed) all overlap fairly closely. In Figure 30, the performance score, reflecting the accuracy of study participants in correctly assessing the approximate lengths of congestion on the routes, decreases linearly over the range of information elements included in the sign(s). In addition, the scores are approaching the 50/50 guessing level at the right end of the plot, suggesting that the signs with the highest number of information elements were approaching study participants' abilities to assess how much congestion was present on the routes. The effect of increasing information load is similar for all three display options (route congestion only, routes and travel times on a single GRIP, and routes and travel times distributed across two signs).

Figure 31 presents a similar graph, but this time looking at the study participant's ability to correctly identify congestion locations and colors. This corresponds to the highest degree of information detail attainable from a GRIP sign. Once again, a downward trend in performance is evident as the number of informational elements on the sign(s) increases. However, no clear trend is evident by display type. Furthermore, study participants reached the 50/50 guessing performance value sooner (as would be expected). As presented in Figure 32, researchers believe the degree of information saturation was reached once the information quantity exceeded about

45 elements. Based on these data, researchers would recommend limiting GRIP signs to information quantities below this 45 element threshold.

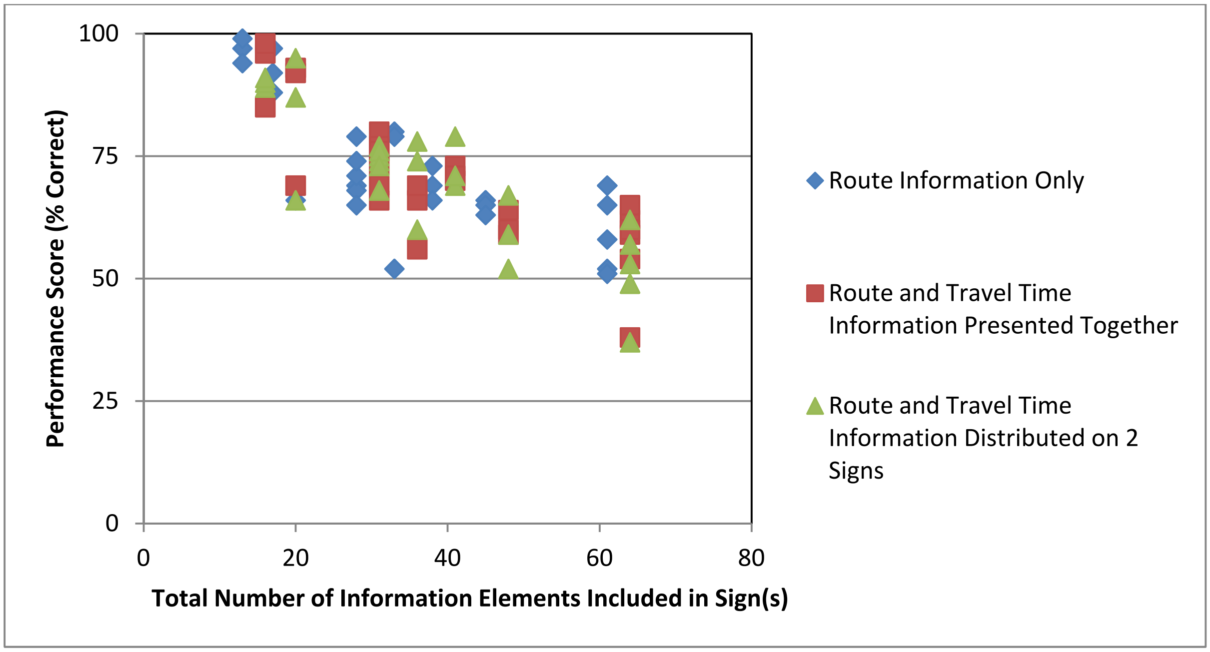


Figure 30. Effect of Display Type on Accuracy of Extent of Congestion Recollection Accuracy.

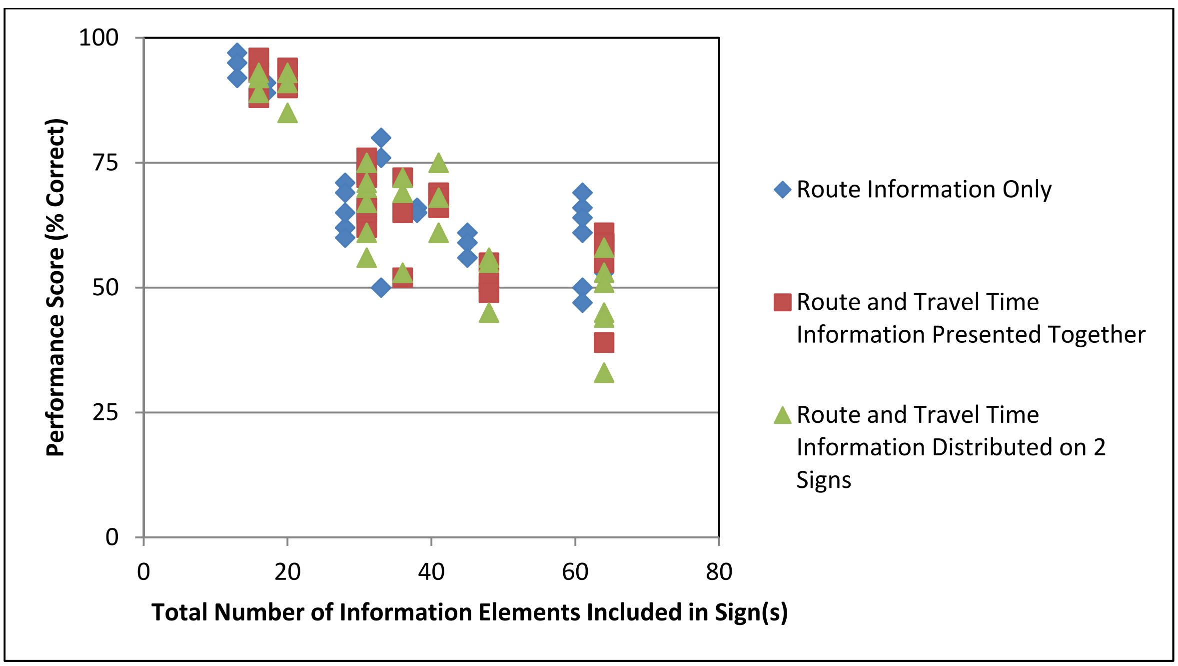


Figure 31. Effect of Display Type of Recollection Accuracy of Congestion Location and Type.

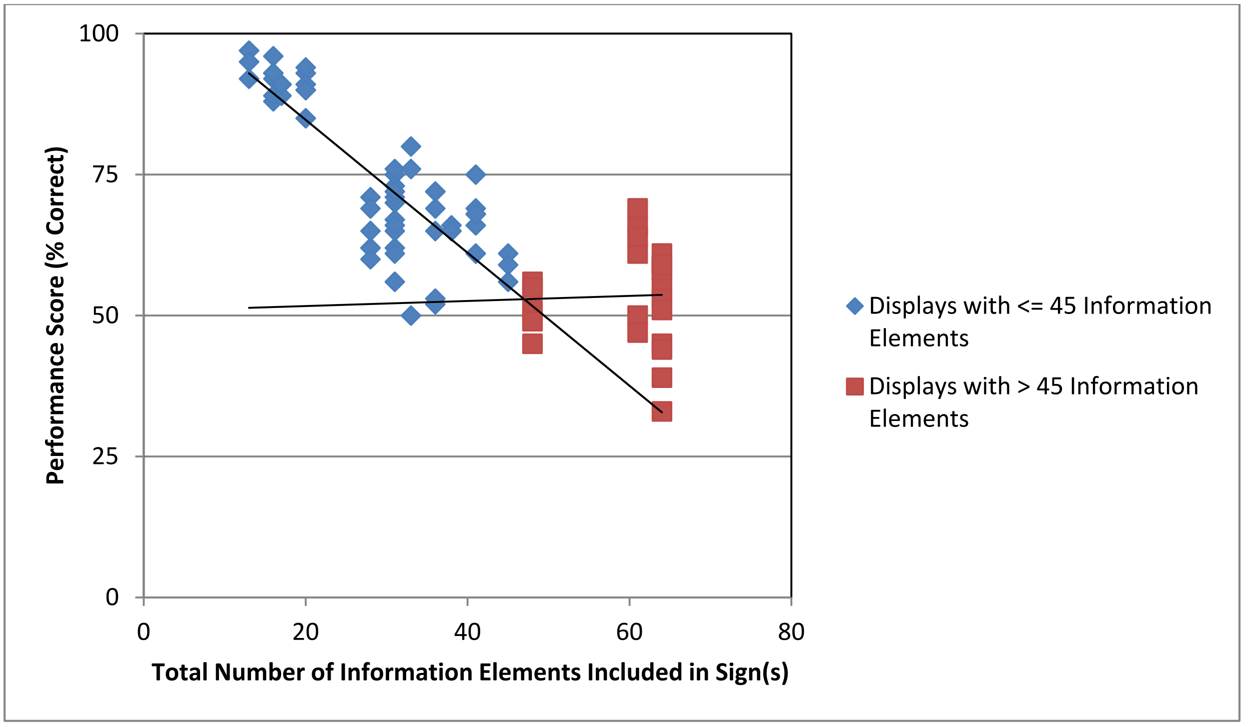


Figure 32. Identification of Information Element Threshold Suggesting Participant Information Capacity.

STUDY PARTICIPANT PREFERENCES OF DISPLAY TYPES

The final data collected from study participants was their preferences for the various display types presented to them during the study. Because of how the study had to be designed, all participants saw only one sign orientation, but with all three display options in all three potential sign locations. At the conclusion of each study, participants were shown the three display types (route information only, route and travel time information on the same GRIP, and route and travel time information distributed across two signs). Table 18 summarizes the preference results. Overall, both local (Austin) and non-local (Houston/College Station) participants preferred the distributed route and travel time signs, followed by the route and travel time signs together. Only 3 percent of the participants preferred the route only sign. Similarly, when asked which of the displays they liked the least, the route only sign was selected by 74 percent of the participants. As expected, the most common reason provided for their preference of the two signs and dislike of the route only display was the desire for both route and travel time information.

Table 18. Study Participant Preferences Regarding Display Options.

	Display Option Most Preferred	Display Option Least Preferred
Route Only Information	3%	74%
Route and Travel Time Information Together on 1 Sign	35%	16%
Route and Travel Time Information Distributed on 2 Signs	62%	10%

SIGN RECOMMENDATIONS

Taken together, the results of the human factors assessment of the GRIP signing options for southbound Austin yielded several practical insights regarding driver understanding and ability to process the types and amount of information presented by a GRIP sign. The following summarizes the researchers' interpretation of these results with regard to prototype signs being engineered, constructed, and installed along southbound I-35.

Sign Orientation

- Overall, performance scores of the various measures used in this study tended to be highest for the north orientation (northbound going upward on the sign, southbound going downward), so researchers recommend this orientation. The differences between the north and track orientations in most cases were very small. If desired for other reasons (such as ease of construction or operation), a track orientation sign would likely perform almost as well as a north orientation sign.
- The track orientation sign created in a 3D format similar to how in-vehicle navigational aids present information did not fare as well in the assessment. Although the metrics for this type of perspective were almost identical to the north and track orientation signs for the US 290 location, they were somewhat lower for the Round Rock and Georgetown locations. Most likely, this could be attributed to the difficulty in portraying congestion information far downstream on a route. The researchers do not recommend this approach be used for the Austin GRIP signs.

Sign Display Types

- Participants were very clear in expressing their preference for both route congestion information and travel time information for any GRIP sign deployment.
- Significant differences are evident in the ability of drivers to perceive travel time information when a significant amount of route congestion information is also displayed. Because of this, a distributed signing approach, based on positive guidance information spreading principles, tended to perform the best in terms of the performance metrics evaluated. The distributed format yielded similar abilities to detect routes with congestion, the approximate length of congestion, and even location and type (color) as a route only GRIP sign. At the same time, the distributed format yielded higher participant accuracy in recalling route travel time information compared to a combined route and travel time GRIP sign. This difference in performance is evident even when the number of information elements being presented is relatively low. Consequently, researchers recommended the distributed format, especially for the Georgetown GRIP sign location.

Information Load Limits

- Given that a standard operational definition and measurement protocol for GRIP sign information loading does not exist, researchers relied on the trends in performance of the various measures examined to assess where it appears that driver information loading was reached and exceeded. This appears to occur once the number of information elements (counting location, color, extent, and route elements as previous described) reaches approximately 45 elements. Assuming travel times for the two routes of interest in this study are to be retained, this implies that the two routes combined could be divided into four segments each, and route congestion information could be presented in each segment without reaching that threshold. Other combinations could also be envisioned (more segments on one route, fewer on the other; having more segments but ensuring that fewer than four would be displayed as congested at any one time) that would still meet this information threshold.

DRIVER SIMULATION STUDIES TO ASSESS POTENTIAL SAFETY OF PROPOSED GRIP SIGN DESIGNS

The results of the human factors testing presented in the previous chapter yielded recommendations on the maximum amount of information (expressed as a combination of a number of colored route segments to indicate congestion locations plus travel time via two routes) that drivers appear to be able to interpret and use. Those results also indicated that a distributed information format, with a text-based travel time (TT) sign preceding a route-only GRIP display, performed best from a driver comprehension perspective. However, a distributed information format doubles the number of signs and sign structure needed, which significantly increases deployment costs.

Although the human factors tests were essential to developing recommendations regarding GRIP sign designs for use at the three proposed locations along southbound I-35, questions still remained as to their potential use and effect upon the motoring public. Specifically given that such signs have not been previously used in the U.S., their presentation in a driving format may have unintended consequences that could adversely affect driving behavior. One of the primary concerns is the effect on driver focus and attention. Location and duration of driver eye glances to such signs can be used as an operational surrogate of focus and attention. For example, recent analyses of naturalistic driving data have suggested that excessively long glances away from the roadway, and long amounts of time in total focusing on non-roadway features, are associated with increased crash risk (*14*). Examination of how the proposed GRIP sign designs would affect driver focus and attention in terms of their eye-glancing behavior was identified as a key need of this project.

OBJECTIVE

The objective of this task was to ensure that the recommended sign designs from the human factors studies do not result in excessively long eye fixation times. Researchers specifically evaluated differences between a single GRIP with route congestion and TT information presented together and a distributed text-based TT sign and route-only GRIP. In addition, the effect of the GRIP signs on motorist route choice decisions and behaviors for non-through trips, i.e., those with destinations within the limits of the area portrayed on the GRIP display. To accomplish this, the TTI driving simulator was employed to create a driving world in which GRIP signs could be incorporated and driver eye glance behavior in response to the signs could be assessed.

STUDY METHODOLOGY

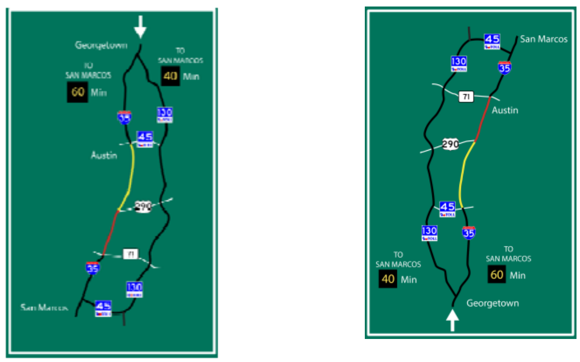
Factors Evaluated

As depicted in Figure 33, this study included four main factors:

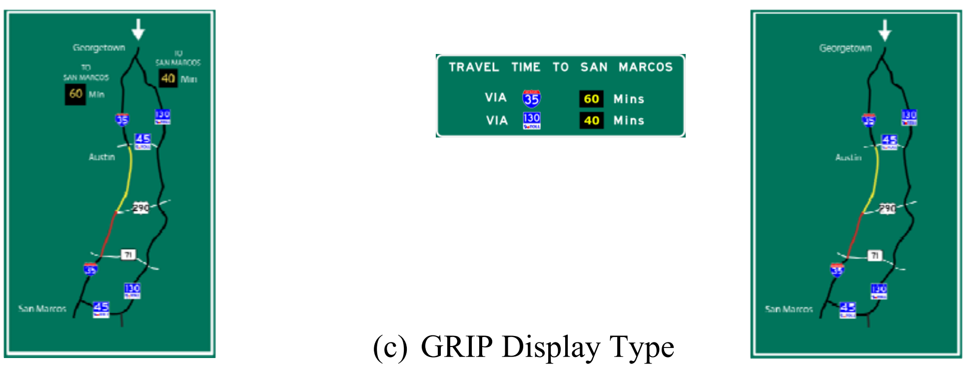
- Sign location (I-35/SH 130 split in Georgetown, I-35/SH 45 in Round Rock, and I-35/US 290 in Austin).
- Sign orientation (north orientation [north arrow up], track orientation [up in the direction of travel]).
- Type of GRIP (combined route congestion and TT on one sign versus text-based TT on one sign and route congestion on another in sequence).
- Amount of route congestion presented (two segments congested on one route, four segments congested across the two main routes [I-35 and SH 130]).

The human factors studies indicated that as long as the total amount of information presented on the signs was not excessive, drivers were able to interpret information on proposed GRIP sign designs at the three locations listed above. Consequently, all three were included here. The human factors studies did not yield a clear recommendation as to the best map orientation for the GRIP sign. Although it is known that some drivers do perform better interpreting a north arrow up display (i.e., people who tend to be better map readers), others perform better with their direction of travel oriented up (i.e., track orientation). Consequently, both orientations were included here to see if significant differences in eye fixations could be detected.

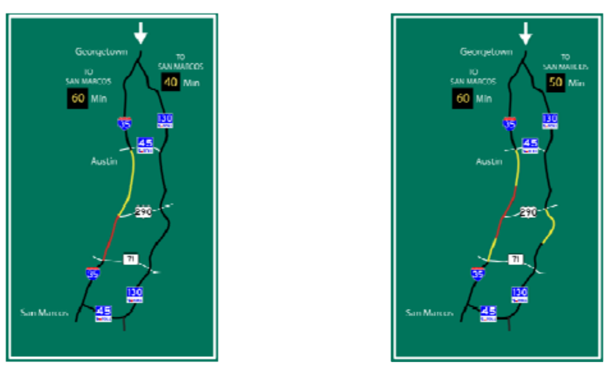
(a) Potential GRIP Sign Locations



(b) Sign Orientation



(c) GRIP Display Type



(d) Information Load Level

Figure 33. Factors Evaluated in the Driving Simulator Study.

Finally, the results of the human factors studies indicated that there is a limit in the number of route segments that can be color-coded at one time before drivers become overloaded. The data suggested that drivers could interpret up to four colored segments on both I-35 and SH 130, along with TT data to a specific destination on each route. This limit was based on driver ability to comprehend and recall congestion location, intensity, and travel times from the sign. The amount of time drivers might spend studying a GRIP to obtain that information was not assessed. A low information-load configuration consisting of only two segments on one of the routes was evaluated, along with a higher information loading condition with four or five route segments distributed across the two routes were color-coded. Thus, when combined with the single GRIP sign and two-sign sequence, multiple information load levels were tested, but with the expectation that all levels fell below the information overload limit for drivers.

Experimental Design

Over the course of the study for each participant, it was important that both I-35 and SH 130 were occasionally (and randomly) seen as the better route so that drivers would have to assimilate the information being presented on a sign rather than simply learn which route was always best and respond accordingly. Therefore, using the factors listed above, a total of 18 different sign treatments were developed for each potential sign location (one-half where I-35 was the better route and one-half where SH 130 was the better route). In addition, a question arose as to the potential implication of a driver using the GRIP sign(s) to determine a best route to a destination within Austin, as opposed to the best route through or around the city. An additional set of signs were created that focused on a potential trip to the airport. In some of the signs, congestion was shown as affecting I-35 beyond SH 71 (the turn off for airport traffic) and also affecting SH 130 before SH 71, whereas in other cases it showed congestion prior to SH 71 on I-35, but after SH 71 on SH 130. The study participant would have to interpret the congestion locations more exactly in deciding whether I-35 or SH 130 was a better route to the airport.

In all, a set of 24 GRIP signs were created (18 involving through trips, 6 involving local trips to the airport) for each potential sign location. Given that it was desired to evaluate all three potential sign locations, this would have meant presenting study participants with 72 signs or sign sequences. Trying to examine that many signs with the TTI driving simulator would have taken too long and increased the potential for simulator sickness to occur. Researchers divided this sign set into two groups of 36 signs per location, viewed in a series of the three potential sign locations for a total of 12 series per participant. The two groups were counterbalanced as best as possible so that the key factors (orientation, information load, and sign display type) were evenly distributed but randomized to minimize learning effects. Appendix E contains a complete depiction of all of the signs presented in these series.

Data Collection Procedures

The TTI driving simulator (Figure 34) was used to present the signing configurations to study participants. It consists of three display screens (representing left, center, and right viewing scenes), steering wheel, and operator pedals to control vehicle steering, acceleration, and braking. Audio speakers provide vehicle and road noise.

Figure 34. The TTI Driving Simulator.

A suburban interstate facility was created in the virtual driving world, similar to what exists north of Austin. Other vehicles were incorporated into the simulation world at a high enough density to require participant attention to them. In addition, the operating speeds of those vehicles were set lower than what the participant was instructed to drive (50 mph versus 60 mph, respectively) so that regular interactions with the other vehicles did occur. Because of the length of the simulation time and the desire to minimize the potential for simulator sickness to occur, the roadway was kept as a tangent over the duration of the study (i.e., no horizontal or vertical curve were used).

A non-intrusive eye-tracking system was connected to the simulator. This system uses infrared lights and sensors to continuously track eye position. Once calibrated, the system can reasonably identify when and where the participant is looking on the display screens. The original plan was to link the two systems electronically into a single data file so that the time and location of each sign display could be matched to eye fixations on the simulator displays to assess the number and duration of glances made to each sign. Unfortunately, data collection complications resulted in two separate files (sign display and participant eye fixations) that had to be manually aligned and analyzed.

Initially, the intent was to imbed each test sign into the simulated driving world, so that the sign would grow in size and become more legible as the participant approached it. However, the resolution capabilities of the system made it difficult to assess exactly when a given study participant was able to first read and comprehend the sign. Researchers decided to simply have the signs pop into the world at predetermined times at a fixed size on the screen and a resolution high enough to assure immediate readability. After a set period of presentation (selected as 6 seconds per sign for this study), the sign would then disappear. In this way, the effect of each sign on driver eye behavior could be most accurately measured.

A total of 30 drivers were recruited, 15 from Austin to represent familiar drivers and 15 from College Station to represent non-local drivers. An attempt was made to make the participant pool representative of the statewide driving population in Texas. Overall, an equal number of males and females were recruited. Participant ages ranged from 19 to 85 years, with an average age of 45 years.

Upon arrival to the testing center, each participant was provided information about the study, read the informed consent regarding their ability to withdraw if they so desired, and placed into the simulator chair. The eye tracking equipment was then calibrated. After calibration, the participant was allowed to operate the simulator for a short while to get used to the controls, and then a practice iteration of GRIP sign displays was provided to make participants aware of how the signs would appear on the screen. After each sign display, participants were told that they would be asked which route (I-35 or SH 130) would take. Participants were instructed to assume that tolls on SH 130 were temporarily suspended, so they did not need to consider the cost of the SH 130 route in their decisions. The study administrator initiated each iteration of three signs, and eye-tracker and driving simulator data were collected for each iteration. Upon conclusion of the 12th and final iteration (or if the participant chose to quit the study early), they were compensated for their time ($60 maximum, $30 minimum) depending on whether they completed all 12 iterations. Appendix F presents the participant instructions and data collection form used.

Data Reduction and Analysis

Eye-tracker data were extracted for each period in which a GRIP sign was being displayed. Maximum glance time and the percent of available viewing time used by the participant were computed. Participant choices as to the best route for each sign were also tabulated.

As noted earlier, the original intent of the study was to have the simulator and eye-tracker data integrated within the computing environment. Ultimately, set-up errors did not allow this to happen, so the two datasets had to be aligned and compared manually. For 12 of the 30 participants recruited and processed, subsequent data reduction uncovered issues with the eye-tracker video files used to align the two datasets. It was possible to still analyze four of those remaining datasets without the eye-tracker video, but not so for the other eight files. Consequently, the original 30 participant dataset had to be reduced to 22 participants for final analysis.

Maximum glance times were evaluated using analysis-of-variance (ANOVA) statistical techniques. Given that times were constrained at the lower end (no negative times were possible), a logarithmic transformation of the glance times was made prior to running the analysis. Overall statistics on average glance frequencies and percent utilization of available viewing times were also computed.

STUDY RESULTS

Georgetown (I-35/SH 130) Sign

As shown in Figure 35, the ANOVA results for this potential signing location indicated that neither sign orientation nor sign display type had a statistically significant effect on maximum glance durations. The amount of information load presented in the sign display was not significant at a $\alpha = 0.05$, but was for $\alpha = 0.10$.

GEORGETOWN I-35/SH 130 ANOVA Results					
SOURCE	DF	SS	MS	F-value	PROB > F
Sign Type	2	0.804	0.402	1.230	0.294
Info Load	1	1.091	1.091	3.338	0.069
Interaction	2	0.825	0.412	1.261	0.285
Within Groups	235	76.839	0.327		
Total	240	79.559	0.331		

Figure 35. ANOVA Results for Through Trips: I-35/SH 130 Location (Georgetown).

As shown in Figure 36, the average maximum glance duration times for both the combined route congestion and TT GRIP and for the route congestion GRIP only (TT on a separate sign) increased by 0.3 and 0.4 seconds, respectively. As a point of comparison, average maximum glance times of the TT sign was unchanged between the two information load conditions. This was expected, as the TT sign always presented the same amount of information each time it was used. One sees that the average maximum glance times for the TT sign was 1.5 seconds, which was greater than the average maximum glance times for either GRIP sign under the low information load condition. At the high information load condition, the average maximum glance times were equal to or only slightly longer than that of the TT signs.

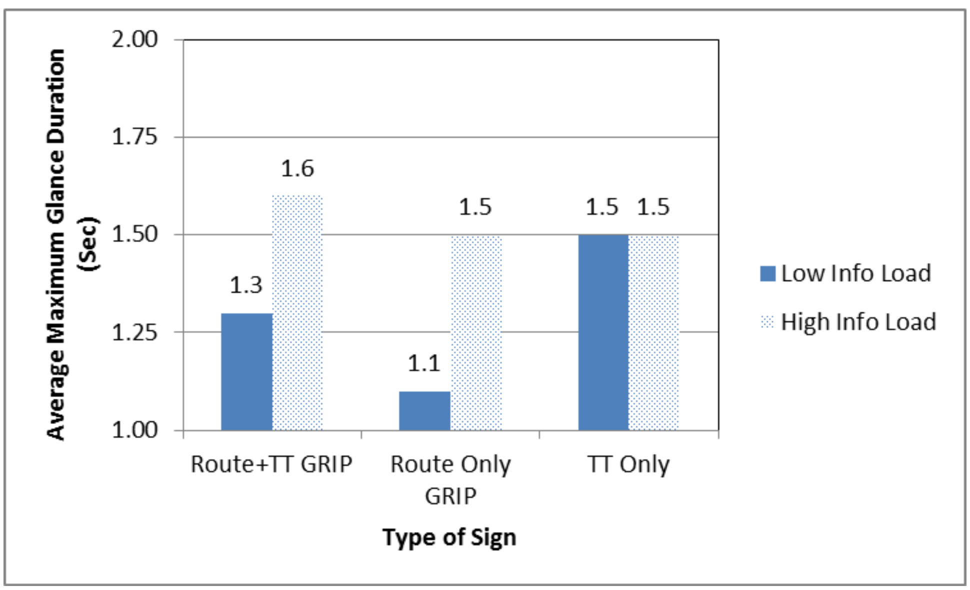


Figure 36. Average Maximum Glance Durations: I-35/SH 130 Location (Georgetown).

In addition to the average maximum glance times, the percentage of glances exceeding 2 seconds and the total amount of time used looking at each sign was also examined. The results, depicted in Table 19, also illustrate that the effect of sign type and information load was limited. The percentage of participants who had maximum glance durations greater than 2 seconds was slightly higher for the two types of GRIPs in the high information load condition, but the increase was not statistically significant. Likewise, the total amount of time spent looking at each sign, on average (summing the multiple glances made during sign presentation) was slightly higher in the high information load condition, but again was not significantly different.

Table 19. Glance Characteristics: I-35/SH 130 Location (Georgetown).

	Low Information Load	**High Information Load**
Percent of participants that exceeded 2 seconds maximum glance time:		
Combined Route + TT GRIP	28%	32%
Route Only GRIP	20%	34%
TT Sign Only	24%	23%
Total amount of available sign viewing time used by participants:**		
Combined Route + TT GRIP	2.5 seconds	2.7 seconds
Route Only GRIP	2.1 seconds	2.7 seconds
TT Sign Only	2.6 seconds	2.4 seconds

** All signs were presented for 6 seconds each

Overall, the results of the study of the sign options at this location indicate that, for motorists with destinations beyond Austin, either type of GRIP sign would be expected to perform acceptably even if the higher amount of information load tested were presented on the sign. For motorists who have destinations internal to Austin, though, the results are slightly different. Figure 37 presents ANOVA statistics for through versus airport-destined drivers. Overall, trip destination has a significant effect on maximum glance times.

Figure 38 illustrates the average maximum glance durations for the two types of trips. Even though the amount or route congestion level display is kept to only two segments, the location of that congestion relative to the airport destination did cause participants to view the signs longer. In fact, the internal trip destination increased driver information processing workload to a level similar to that obtained with the high information load signs previously described.

I-35/SH 130 Trip Destination ANOVA Results

SOURCE	DF	SS	MS	F-value	PROB > F
Sign Type	2	0.812	0.406	1.121	0.328
Trip Destination	1	2.029	2.029	5.600	0.019
Interaction	2	0.961	0.480	1.326	0.268
Within Groups	241	87.309	0.362		
Total	246	91.111	0.370		

Figure 37. ANOVA Results for Through versus Airport Trips: I-35/SH 130 Location (Georgetown).

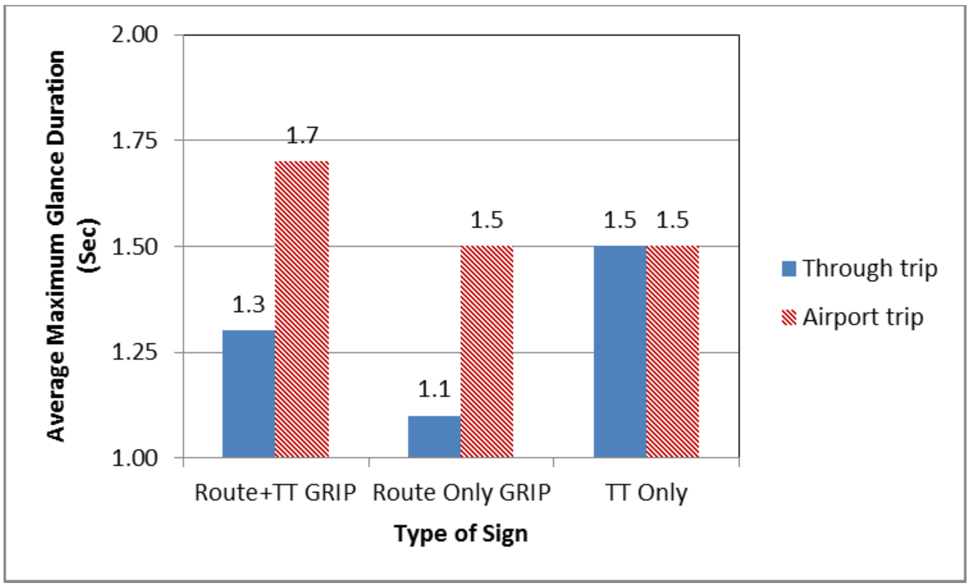


Figure 38. **Average Maximum Glance Durations for Through versus Airport Trips (Low Information Load Level): I-35/SH 130 Location (Georgetown).**

Table 20 illustrates that the airport-destination trips resulted in a greater percentage of participants who had maximum glance durations greater than 2 seconds. In fact, for the combined route congestion and TT GRIP presented with a low level of information (two route segments congested), 50 percent of the participants looked at the sign for more than 2 seconds at one time. In terms of the total amount of available sign viewing time used, participants with the airport as their destination used 0.6 to 0.9 seconds more, on average.

Table 20. Glance Characteristics of Through and Airport Trip at Low Information Load Level: I-35/SH 130 Location (Georgetown).

	Through Trip	Airport Trip
Percent of participants that exceeded 2 seconds maximum glance time:		
Combined Route + TT GRIP	28%	50%
Route Only GRIP	20%	45%
TT Sign Only	18%	24%
Total amount of available sign viewing time used by participants:**		
Combined Route + TT GRIP	2.5 seconds	3.1 seconds
Route Only GRIP	2.1 seconds	3.0 seconds
TT Sign Only	2.5 seconds	2.7 seconds

** All signs were presented for 6 seconds each

Additional evidence of the increased information load created by having participants interpret GRIP signs for a non-through trip can be seen in the accuracy of the route choices made during the study. Table 21 presents the percent of participants choosing the better route as a function of the sign type and trip type. Overall, the ability of participants to correctly select the better route was 13 to 18 percentage points lower than for the through trips. Since the TT information was not directly relevant to the airport trip, participants were forced to assess the potential location and colors of congestion on each route to decide which one would be preferable.

Table 21. Correct Route Choice for Through and Airport Trip at Low Information Load Level: I-35/ SH 130 Location (Georgetown).

	Through Trip	Airport Trip
Percent of participants selecting the better route:		
Combined Route + TT GRIP	88%	70%
Route Only GRIP	98%	85%

Round Rock (I-35/SH 45/SH 130) Sign

Figure 39 provides the ANOVA results for the Round Rock potential sign location for participants making a through trip beyond Austin. Unlike the results obtained for the potential sign location in Georgetown, the analysis of the potential Round Rock sign location indicated that information load did not have much of an effect on maximum glance durations. Rather, the type of sign presented was the only factor found to be statistically significant.

ROUND ROCK I-35/SH 45/SH 130 Trip Destination ANOVA Results					
SOURCE	DF	SS	MS	F-value	PROB > F
Sign Type	2	2.447	1.223	3.902	0.022
Info Load	1	0.092	0.092	0.294	0.588
Interaction	2	0.649	0.325	1.035	0.357
Within Groups	221	69.289	0.314		
Total	226	72.476	0.321		

Figure 39. ANOVA Results for Through Trips: I-35/SH 45 Location (Round Rock).

One possible reason that information load was not significant can be hypothesized by examining the average maximum glance durations for the various sign and information load conditions, shown in Figure 40. Note that the maximum glance duration averages of the TT signs were 0.3 to 0.4 seconds higher than they were for the Georgetown sign location. These numbers suggest that drivers may have been anticipating the next sign in each iteration, leading to slightly higher glance times than were observed for the Georgetown sign location, which were always the first sign location seen in each iteration.

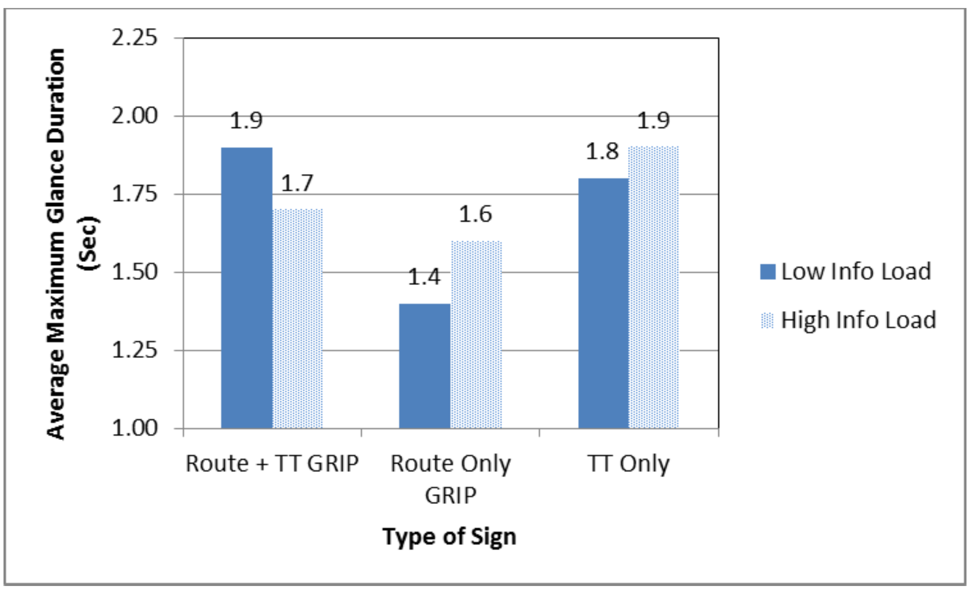


Figure 40. Average Maximum Glance Durations: I-35/SH 45/SH 130 Location (Round Rock).

The percentage of glances exceeding 2 seconds and the total amount of time used looking at each sign was also examined for this sign location. The results, depicted in Table 22, illustrate two key points:

- The effect of information load was evident for the route only GRIP, but not for the combined route + TT GRIP; for the low information load level, only 26 percent of the participants viewing the route only GRIP had maximum glance durations that exceed 2 seconds.
- Whereas participants viewing the combined route + TT GRIP sign had maximum glance durations that exceeded 2 seconds more than 40 percent of the time, this was still no more frequent than for the text-based TT signs for which 47 percent of participants had maximum glance durations that exceeded 2 seconds.

Table 22 shows the total amount of available viewing time used by participants for each sign and information load level. Overall, the times are a little higher than those shown in Table 20, suggesting that participants used a little more time viewing the proposed Round Rock sign options than the Georgetown sign options. Presumably, the Round Rock GRIPs were less representative of the overall Austin area routes than were the Georgetown GRIPs, which could have made it more difficult for participants to orient themselves to view the GRIP and interpret the route congestion and TT information presented.

Table 22. Glance Characteristics: I-35/SH 45/SH 130 Location (Round Rock).

	Low Information Load	**High Information Load**
Percent of participants that exceeded 2 seconds maximum glance time:		
Combined Route + TT GRIP	46%	41%
Route Only GRIP	26%	45%
TT Sign Only	36%	58%
Total amount of available sign viewing time used by participants:**		
Combined Route + TT GRIP	3.2 seconds	3.1 seconds
Route Only GRIP	2.5 seconds	3.2 seconds
TT Sign Only	3.3 seconds	3.3 seconds

** All signs were presented for 6 seconds each

Figure 41 presents ANOVA statistics for through versus airport-destined trips posed to the participants viewing some of the sign options at this location. Specifically, only the route-only signs and TT signs were compared, due to randomization limitations of the treatments during the experimental design process. As was the case for the Georgetown sign location, trip type was found to a have a significant effect on maximum glance times for the Round Rock signs. As Figure 42 illustrates, the internal trip to the airport resulted in participants increasing their maximum glance times to both the text TT signs and the route only GRIP sign. As might be expected, the increase was greater for the route only GRIP sign than for the TT sign, 0.7 second increase versus 0.3 second increase on average, respectively.

ROUND ROCK I-35/SH 45/SH 130 Trip Destination ANOVA Results					
SOURCE	DF	SS	MS	F-value	PROB > F
Sign Type	1	0.352	0352	1.131	0.290
Trip Destination	1	2.517	2.517	8.078	0.005
Interaction	1	0.224	0.224	0.718	0.399
Within Groups	104	32.405	0.312		
Total	246	35.498	0.332		

Figure 41. ANOVA Results for Through versus Airport Trips: I-35/SH 45/SH 130 Location (Round Rock).

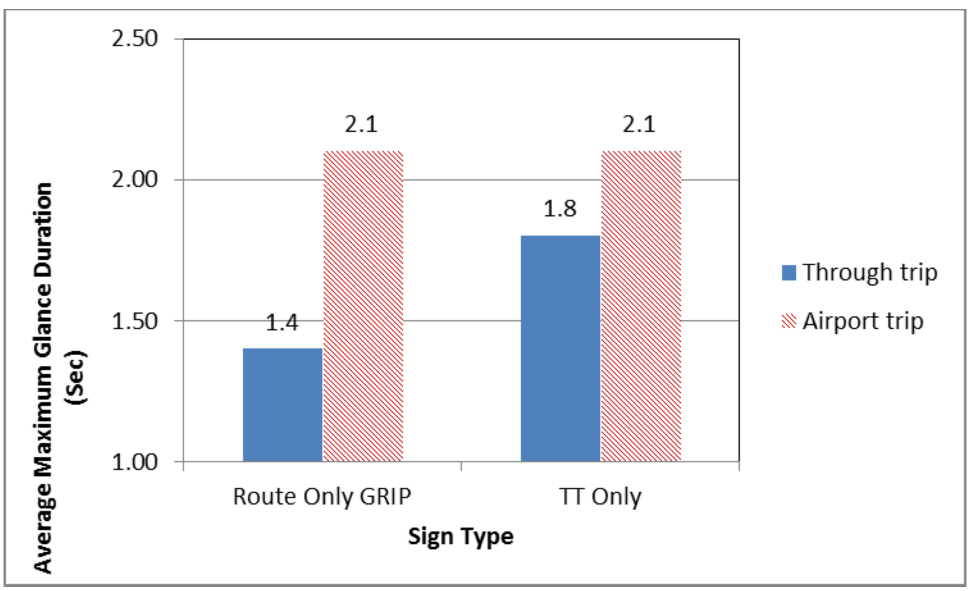


Figure 42. Average Maximum Glance Durations for Through versus Airport Trips (Low Information Load Level): I-35/SH 45/SH 130 Location (Round Rock).

Table 23 illustrates the percentage of participants who had maximum glance durations greater than 2 seconds for this sign location under the two trip purpose conditions. The only comparison that could be made at this location was at a low level of information load (two route segments congested) and the route only GRIP with a text-based TT sign in sequence. Although the average maximum glance duration did increase for the TT sign, the percentage of participants that exceeded a 2-second maximum glance remained the same for the two trip types. Conversely, the percentage of participants exceeding a 2-second glance time doubled (from 26 to 52 percent) when they were told to choose a route to the airport. The total amount of available viewing time also increased for the route only GRIP, but not the TT sign. Whereas participants used an average of 2.5 seconds total viewing the route only GRIP sign when instructed they were making a through trip, they used an average of 3.9 seconds viewing time total when told they were making a trip to the airport.

Table 23. Glance Characteristics of Through and Airport Trips at Low Information Load Level: I-35/SH 45/SH 130 Location (Round Rock).

	Through Trip	Airport Trip
Percent of participants that exceeded 2 seconds maximum glance time:		
Route Only GRIP	26%	52%
TT Sign Only	36%	36%
Total amount of available sign viewing time used by participants:**		
Route Only GRIP	2.5 seconds	3.9 seconds
TT Sign Only	3.3 seconds	3.4 seconds

** All signs were presented for 6 seconds each

Finally, Table 24 presents the percent of participants choosing the better route as a function of the sign type and trip type. Participants selected the better route for through trips 95 percent of the time, compared to only 68 percent of the time for trips they were making to the airport.

Table 24. Correct Route Choice for Through and Airport Trip at Low Information Load Level: I-35/SH 45/SH 130 Location (Round Rock)

	Through Trip	Airport Trip
Percent of participants selecting the better route:		
Combined Route + TT GRIP	94%	---
Route Only GRIP	95%	68%

Austin (I-35/US 290/SH 130) Sign

The analysis of the third potential sign location, I-35/US 290 to SH 130 in Austin, differed from the Round Rock sign location, but was somewhat consistent with the Georgetown sign location. As shown in Figure 43, type of sign did not have a significant effect on maximum glance times. Information load presented on the GRIP was not quite significant at $\alpha=0.05$, but was at $\alpha=0.10$. Meanwhile, as indicated in Figure 44, average maximum glance times were fairly high for both low and high information load levels for the route only GRIP and combined route and TT GRIP. Once again, it was the TT signs that received the longer maximum glance durations from participants (researchers believe that the longer average time for the lower information load level was an anomaly in the data). The fact that all of the times are substantially higher than were observed for the Georgetown signs is again concerning. Researchers believe that participants had more difficulty in interpreting maps only depicting a portion of the major routes within the metro area as opposed to the full map portrayal at the Georgetown sign location. However, this does not fully explain why the glance durations for the TT signs were also longer. One hypothesis is that since the sequence of sign locations was kept constant during the study, participants learned that the latter signs in sequence were more difficult to interpret and so spent more and more time over the course of the 12 iterations focusing on the information presented.

AUSTIN I-35/US 290/SH 130 Trip Destination ANOVA Results

SOURCE	DF	SS	MS	F-value	PROB > F
Sign Type	2	0.430	0.215	0.795	0.454
Info Load	1	0.016	0.162	0.058	0.810
Interaction	2	0.308	0.154	0.569	0.568
Within Groups	119	32.169	0.270		
Total	124	32.922	0.266		

Figure 43. ANOVA Results for Through Trips: I-35/US 290/SH 130 Location (Austin).

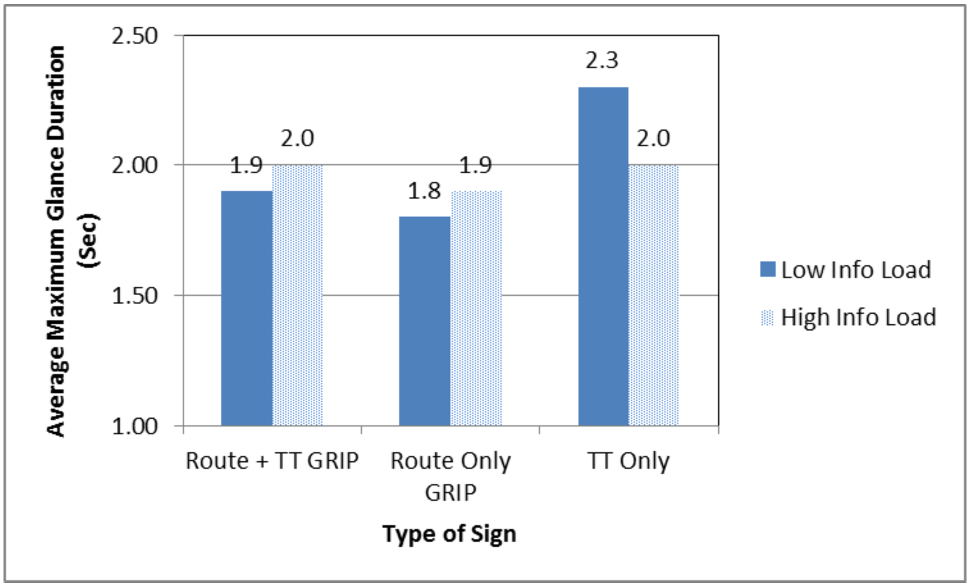


Figure 44. Average Maximum Glance Durations: I-35/US 290/SH 130 Location (Austin).

Table 25 provides a summary of long glance (greater than 2 seconds) frequencies and total amount of participant viewing time by sign type and information load level. As expected, the values are higher than were observed for the previous sign locations evaluated. Both types of GRIP signs experienced a high percentage of long glance times under the high information load level. For the low information load level, 44 percent of the participants had long glance times for the route only GRIP, compared to 55 percent of participants when viewing the combined route and TT GRIP sign. Participants spent between 3.0 and 3.8 seconds, on average, viewing each sign. The longest total viewing time (3.8 seconds) was associated with the combined route and TT GRIP with a high information load level.

Table 25. Glance Characteristics: I-35/US 290/SH 130 Location (Austin).

	Low Information Load	High Information Load
Percent of participants that exceeded 2 seconds maximum glance time:		
Combined Route + TT GRIP	55%	64%
Route Only GRIP	44%	64%
TT Sign Only	43%	29%
Total amount of available sign viewing time used by participants:**		
Combined Route + TT GRIP	3.3 seconds	3.8 seconds
Route Only GRIP	3.0 seconds	3.1 seconds

TT Sign Only	3.4 seconds	3.4 seconds

** All signs were presented for 6 seconds each

Figure 45 presents ANOVA statistics comparing through versus airport-destined trips for this potential sign location. Limitations in the experimental design only allowed for the combined route congestion and TT GRIP presenting a low information load to be evaluated. For this particular condition, trip type again had an effect on maximum glance times, but was less significant than was observed for the other potential sign locations. However, as Figure 46 illustrates, the internal trip to the airport did result in a larger average maximum glance duration as compared to participants who were instructed to assume they were making a trip through Austin. The lower level of statistical significance is primarily due to a lower overall sample size rather than the size of the differences observed.

AUSTIN I-35/US 290/SH 130 Trip Destination ANOVA Results

SOURCE	DF	SS	MS	F-value	PROB > F
Trip Destination	1	1.170	1.170	3.00	0.09
Within Groups	41	15.930	0.390		
Total	42	17.100	0.332		

Figure 45. ANOVA Results for Through versus Airport Trips: I-35/US 290/SH 130 Location (Austin).

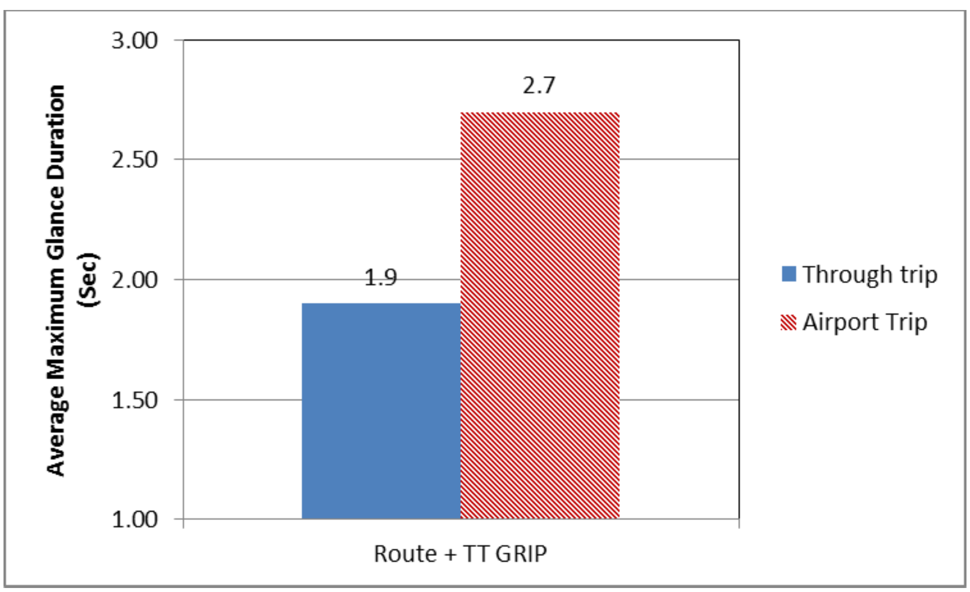


Figure 46. Average Maximum Glance Durations for Through versus Airport Trips (Low Information Load Level): I-35/US 290/SH 130 Location (Austin).

Table 26 shows that the majority of study participants who were deciding on the best route to the airport had maximum glance durations that exceeded 2 seconds, as compared to the 44 percent who had long glance durations when deciding on a route through Austin. The total amount of time spent viewing the GRIP sign was also much higher for the airport trip (4.2 seconds) compared to the through trip (3.0 seconds).

Table 27 presents the percent of participants choosing the better route as a function of the sign type and trip type. Participants selected the better route for through trips 95 percent of the time, compared to only 68 percent of the time for trips they were making to the airport.

Table 26. Glance Characteristics of Through and Airport Trip at Low Information Load Level: I-35/US 290/SH 130 Location (Austin).

	Through Trip	Airport Trip
Percent of participants that exceeded 2 seconds maximum glance time: Route Only GRIP	44%	68%
Total amount of available sign viewing time used by participants:** Route Only GRIP	3.0 seconds	4.2 seconds

** All signs were presented for 6 seconds each

Table 27. Correct Route Choice For Through and Airport Trip at Low Information Load Level: I-35/US 290/SH 130 Location (Austin).

	Through Trip	Airport Trip
Percent of participants selecting the better route:		
Combined Route + TT GRIP	87%	58%
Route Only GRIP	92%	---

IMPLICATION OF STUDY RESULTS ON GRIP SIGN DESIGN

This chapter documents the results of a driving simulator study designed to assess the effects of promising GRIP sign design options upon driver eye-fixation patterns. Maximum glance durations of the various GRIP design options were collected, as well as the total amount of time spent looking at the sign. The main emphasis of the study was on hypothetical trips being made southbound through Austin. However, for a few of the study iterations, a trip destination to the airport located within the limits of the GRIP sign was also investigated.

Overall, the results of the study at the potential Georgetown sign location suggested that all GRIP sign design options tested would not induce excessively long glances to the signs for drivers with destinations beyond Austin, so would not be likely to adversely affect safety. Glance times do increase somewhat if greater amounts of route congestion are presented, but the increase does not exceed the 2 second threshold shown in previous studies to be associated with increased crash risk. Likewise, the study suggests that drivers with destinations within Austin who view the GRIPs will have longer maximum glance times. Only a low information load condition was tested for these trips, but the maximum glance times were also less than 2 seconds on average. As a result, it appears feasible to safely construct and deploy a GRIP sign for this location. Either a combined route congestion and TT GRIP could be used, or a two sign TT and route only GRIP sign could be deployed. The former requires only one sign, but is more limited in terms of the route congestion information that could be safely displayed. The latter sequence of two signs would be more expensive to construct and deploy, but would have the advantage of being more flexible in portraying locations of congestion on I-35 and SH 130. It would also offer a greater factor of safety for driver use of the GRIPs for non-through trips.

With regard to the other two potential sign locations, the results are less conclusive. For through trips, the Round Rock sign location (I-35/SH 45) resulted in maximum glance times that were below the 2 second threshold on average for all of the potential GRIP designs. However, when asked to consider a trip to the airport using information from a combined route congestion and TT GRIP, the majority of study participants had maximum glance durations in excess of 2 seconds. This occurred even though only a low information load was being displayed. For the US 290 potential sign location in Austin, even the through trips resulted in average maximum glance times in excess of 2 seconds. Trips to the airport increased glance times even more, such that two-thirds of the participants were exceeding the 2-second maximum glance duration threshold when viewing a route-only GRIP.

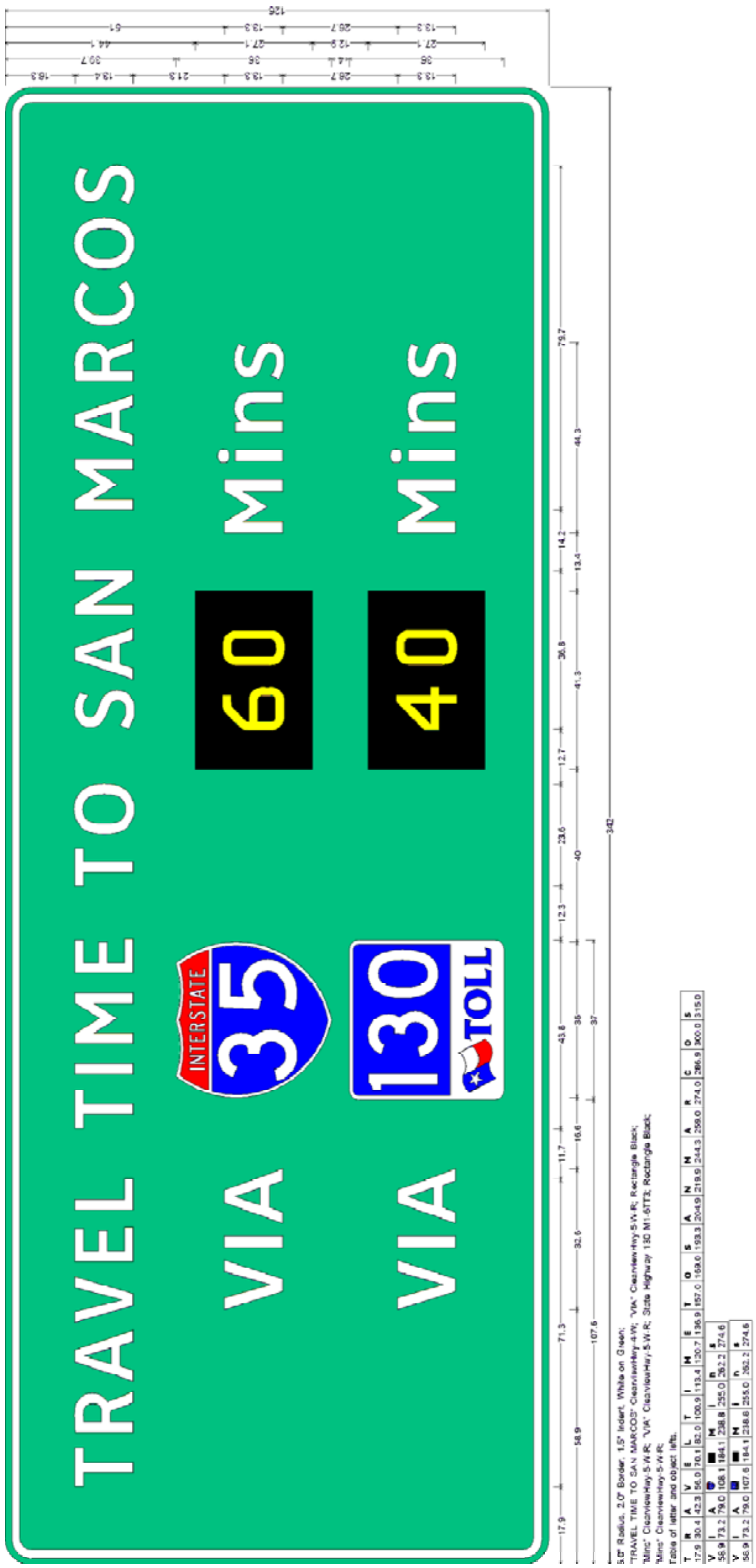
A driving simulator does not exactly replicate real-world driving, so the longer glances should not automatically be taken to indicate that such a sign is unacceptable. However, it does suggest caution and prudence be taken in introducing GRIP designs into the roadway environment.

RECOMMENDED SOUTHBOUND GRIP SIGN DESIGNS FOR AUSTIN

DESIGN FEATURES RECOMMENDED

As noted in the previous chapter, only one GRIP sign location can be recommended at this time until further field evaluations can be conducted of driver eye-glance behavior when using the GRIP sign to make real-time route choice decisions for destinations within the limits of the map display. In addition, although TTI staff recommend a two-sign sequence consisting of a text-based TT sign followed by a GRIP sign with route conditions only, it does appear that a single GRIP sign with route condition and travel times combined could deployed. The primary guiding principle would be that no more than 4 sections would display a congestion level other than normal at any given time. Concurrent segments displaying the same color would be counted as a single segment. If more than 4 sections are necessary, the controller software must aggregate sections in order to not overload driver understanding and perception. In contrast, use of the two-sign sequence would likely allow an additional route segment (a total of five) to be displayed at the same time.

For either GRIP option, the signs themselves must be designed large enough so that motorists have at least 6 seconds of available viewing time to perceive and process the information presented. For I-35, this implies that the signs be legible from at least 600 feet away. Using freeway guide sign lettering criteria and 18-inch high DMS insets for the TT displays, Figure 47 and Figure 48 present the dimensions of a two-sign sequence. For the single GRIP sign, Figure 49 illustrates the required dimensions. In both instances, the height of the GRIP sign is computed to be 378 inches, or slightly more than 31 feet. When travel times are included with the route condition map display, the width of the sign is computed to be 408 inches, or 34 feet. If the travel times and route condition map are presented separately (at least 800 feet apart), the TT sign would be 258 inches, or slightly more than 21 feet wide by 150 inches, or 12 feet high. Meanwhile, the GRIP map display sign would still be 31 feet high, but its width would be reduced to 294 inches, or slightly more than 24 feet. The routes would be 6 inches wide.



Sign dimensions are in inches

Figure 47. Text-Based TT Sign for I-35 Southbound near Georgetown.

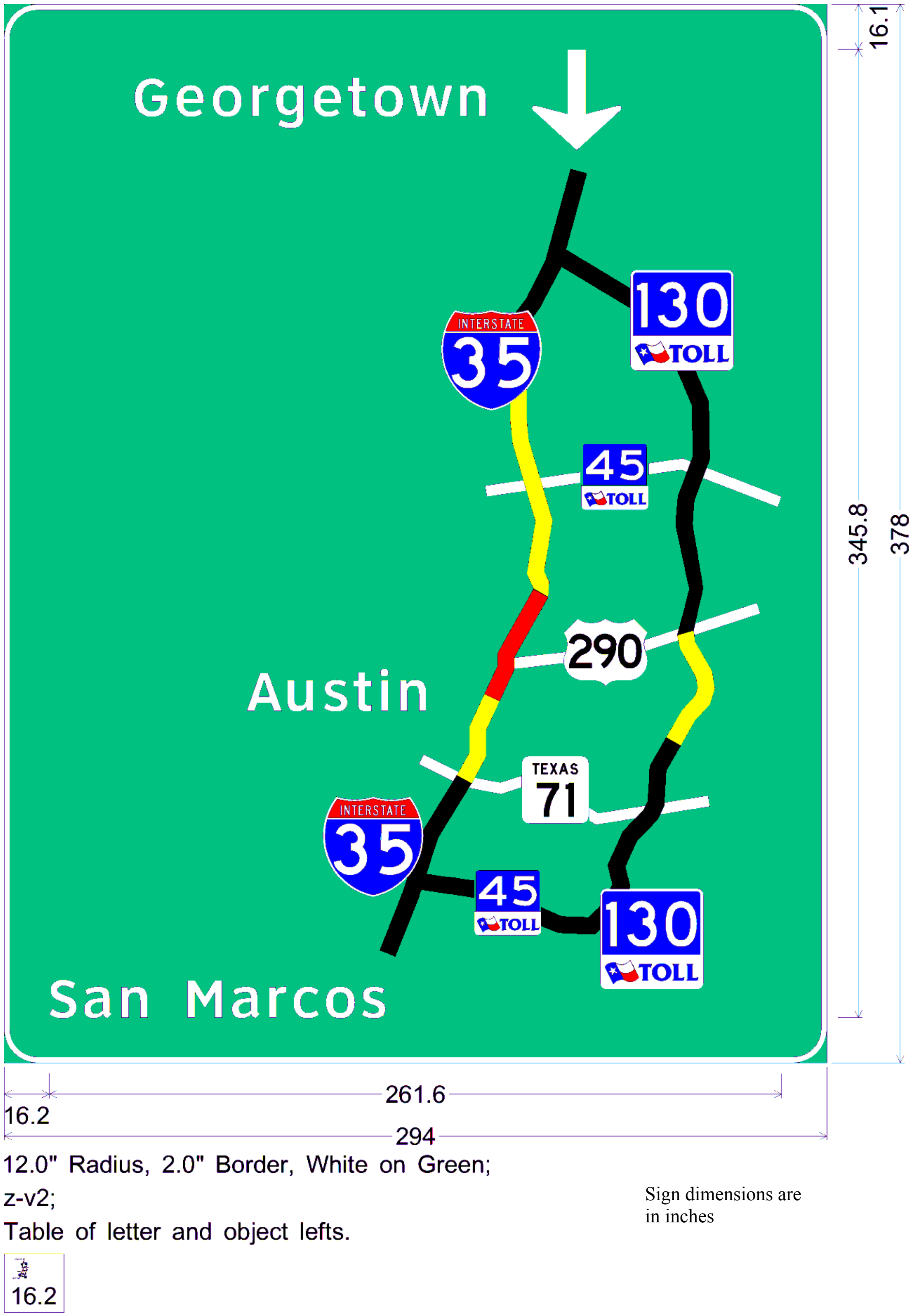


Figure 48. GRIP Sign without Travel Times, I-35 Southbound near Georgetown.

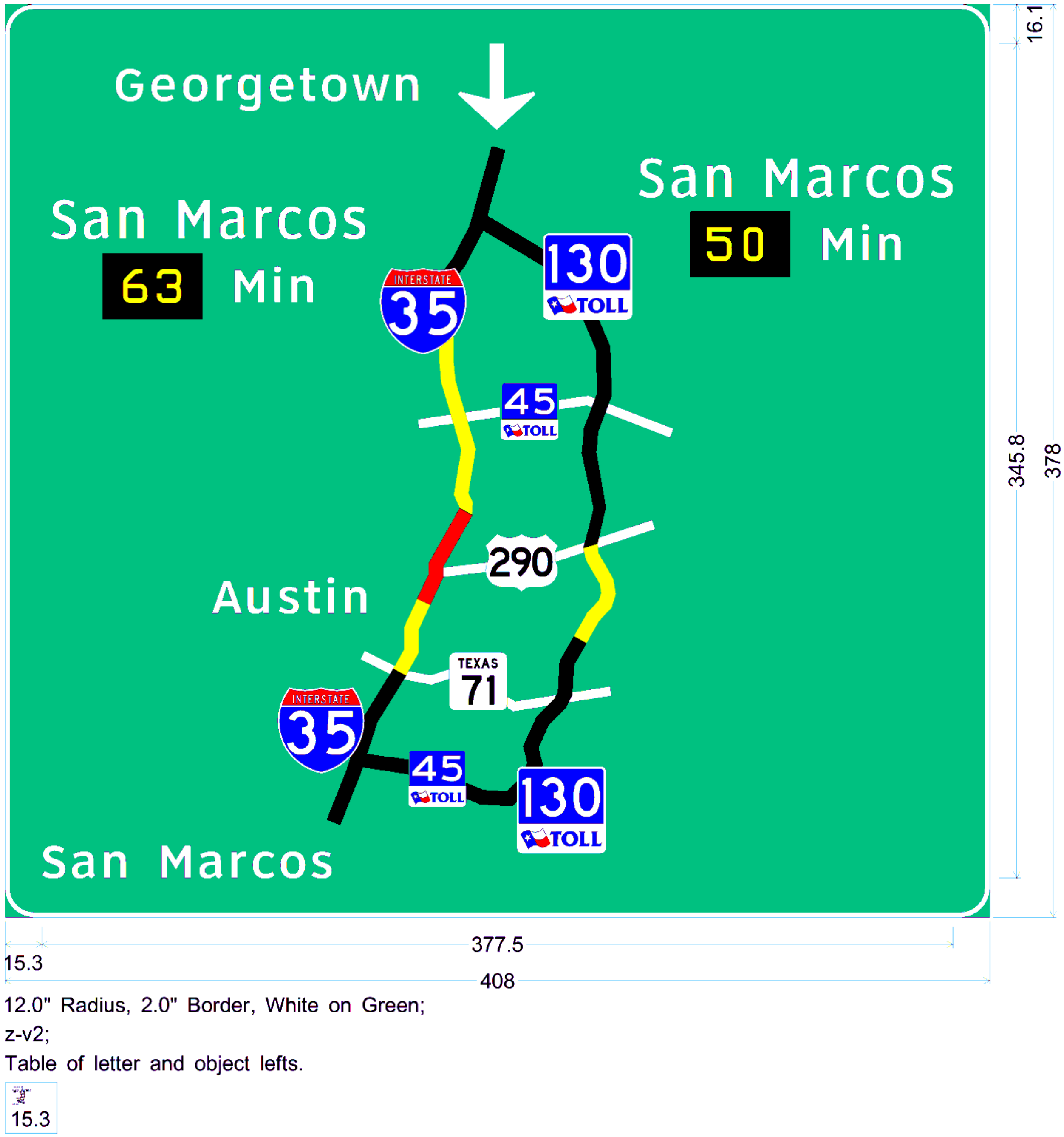


Figure 49. GRIP Sign with Travel Times, I-35 Southbound near Georgetown.

NEXT STEPS

The results of this project provided critical answers to the design of a GRIP sign (or signs) for use by southbound travelers on I-35. However, once TxDOT determines whether it is interested in one or two signs, there still remain a number of steps that must be accomplished before the signs can be fabricated and become a reality out on the road. These steps include the following:

- Applying for and receiving a request-to-experiment with a GRIP sign in Texas – the results of this project provide important data to show the Federal Highway Administration that the request is reasonable and addresses potential traveler safety questions. A request-to-experiment requires a field evaluation plan, which should again involve the use of eye-tracking equipment.
- Designing a feasible sign support structure for the signs – the TT sign could be accommodated by existing TxDOT sign support standards. However, the size of the GRIP signs presented here will require specially-designed support structures.
- Developing software to interface with TxDOT Lonestar and with the electronic route condition modules – the technology review provided at the front of this report indicated that the current Lonestar software does not support operation of the GRIP sign. Likewise, manufacturers of the technology that could be used to construct the route condition elements do not have control software in-house that could control the elements in the manner envisioned for this application.
- Identifying technologies and products available to construct the dynamic route display portion of the sign – one potential manufacturer is known, but there may be others. Depending on the technology available, new specifications that permit procurement of the technology will need to developed.
- Developing fabrication techniques for the route condition elements – It is believed that construction of the static portion of the GRIP would be achievable using current sign vendors and fabrication techniques. However, incorporating electronic elements to convey route segment condition into the sign in a manner sufficient to withstand the roadside environment in central Texas will likely require special considerations. It is possible that current DMS technology may offer insights into acceptable ways of accommodating the elements into the sign, but this will likely depend on the characteristics of the elements ultimately chosen for use.

REFERENCES

1. Dudek, C.L. and G.L. Ullman. *Dynamic Message Sign Message Design and Display Manual*. Report No. FHWA/TX-04/0-4023-P3. Texas Transportation Institute, College Station, TX. April 2006.
2. Pretty, R.L. and D.F. Cleveland. *The Effects of Dynamic Routing Information Signs on Route Selection and Freeway Corridor Operations*. NCHRP Contract 20-3A. HSRI Report No. TrS-4. 1970.
3. Gan, A., D. Saha, K. Haleem, P. Alluri, and D. McCarthy. *Best Practices in the Use of Hybrid Static Dynamic Signs*. Final Report, Contract No. BDK80 977-15. Lehman Center for Transportation Research, Florida International University, Miami, FL. December 2012.
4. Uchida, T., Iida, Y. and M. Nakahara. Panel Survey on Drivers' Route Choice Behavior under Travel Time Information. *Proceedings*, Vehicle Navigation and Information Systems Conference. 1994.
5. Alkim, T.P., P.H.J. van der Mede, and W.H. Janssen. Graphical Route Information Panels on Variable Message Signs. Tenth International Conference on Road Transport Information and Control, *Publication No. 472*. 2000. Pp. 32- 36.
6. Gan, H. and S. Chen. Why Do Drivers Change Routes? Impact of Graphical Route Information Panels. In *ITE Journal*, Vol. 83, No. 8, August 2013. pp. 38-43.
7. Richards, A., M. McDonald, G. Fisher, and M. Brakstone. Investigation of Driver Comprehension of Traffic Information on Graphical Congestion Display Panels Using a Driving Simulator. In *European Journal of Transportation and Infrastructure Research*, Vol. 4, No. 4, 2004. pp. 417-435.
8. Schonfeld, G., A. Reischl, and M. Tsavachidis. Dynamic Driver Information Goes Graphical – A New Quality in Urban Traffic Information. In *Proceedings,* 7th World Congress on Intelligent Transport Systems. Turin, Italy. 2000.
9. Lai, C. Drivers Comprehension of Traffic Information on Graphical Route Information Panels. In *Accident Analysis and Prevention*, Vol. 45, March 2012, pp. 565-571.
10. Dicke-Ogenia, M. *Psychological Aspects of Travel Information Presentation*. Master's Thesis, Delft University of Technology, The Netherlands. October 2012.
11. Ullman, B.R., N.D. Trout, and C.L. Dudek. *Use of Graphics and Symbols on Dynamic Message Signs: Technical Report*. Report No. FHWA/TX-08/0-5256-1. Texas Transportation Institute, College Station, TX. May 2009.
12. Aitken, R.J., G. Zhang, C.M. Walton, and A. Conway. Enhanced Traveler Information Dissemination Through Innovative Graphic Route Information Panels (GRIPs). *CD-ROM Compendium*, 89th Annual Meeting of the Transportation Research Board, Washington, D.C. January 2010.
13. Lunenfeld, H. and G.J. Alexander. *A User's Guide to Positive Guidance (3rd Edition)*. Report No. FWHA-SA-90-017. FHWA, U.S. Department of Transportation, Washington, D.C. September 1990.
14. Klaur, S.G., T.A. Dingus, V.L. Neale, J.D. Sudweeks, and D.J. Ramsey. *The Impact of Driver Inattention on Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data*. Report No. DOT HS 810 594. NHTSA, U.S. Department of Transportation, Washington, D.C. April 2006.

APPENDIX A: FOCUS GROUP DISCUSSION GUIDE

Improving Travel Information for Austin Drivers

using

Graphical Route Information Panels

(GRIPs)

Introductions

- Name
- Occupation
- Part of Austin you live in
- How much travel on freeways and toll roads you do

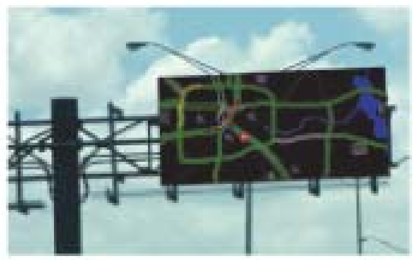
Spend a few minutes talking about driving experiences in Austin, the hassles, where things are really bad and congested. Ok if they talk a little about specific experiences, but don't want it to turn into a complaint session or attempts to "one up" each other.

Ground Rules

- One person talks at a time
- Disagreement is ok – name calling is not ☺
- Everyone's opinions are needed

What are GRIPs?

- Signs that display route and travel condition information together
- Many different options possible



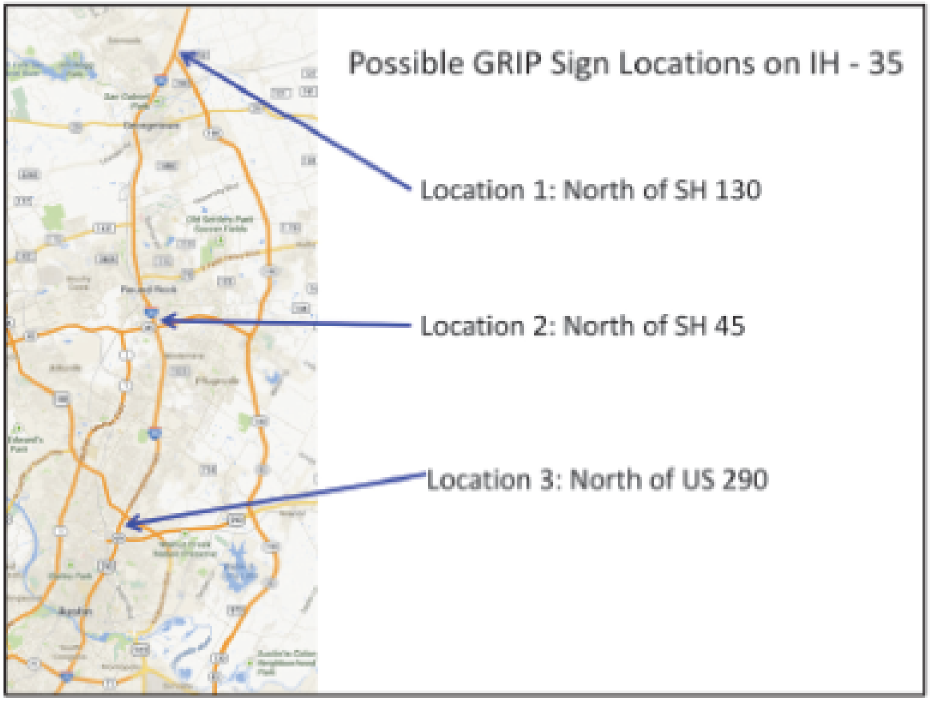
We are looking at various technologies that might be used. The GRIPs may be normal looking green signs with certain elements changed electronically, or it may be a fully electronic display that might look much like a travel map on an agency's website.

For example, these are mock ups of a) a simple sign to display delay information along I-35 through central part of the state, and b) how the Houston website travel map might look if displayed as a GRIP.

For our purposes today, we are going to present the sign options on green guide signs. That way, we can think about and compare the options directly. However, do keep in mind that the technology used may be different than what is shown.

Why are we here?

- Look at some GRIP ideas for Austin
  - Focus is on travelers coming from the north heading south
  - Possible locations
  - Possible designs
- Get your feedback
  - Other locations?
  - Ways to improve the designs?



Here is a map of Austin. Try to visualize yourself driving on I-35 up north by Georgetown heading south into Austin.

The first location being considered for a GRIP is southbound on I-35 before you reach the interchange with State Highway 130 (Toll Road). Here, drivers have the first decision whether to stay on I-35 and travel through the city, or use the toll road around the city.

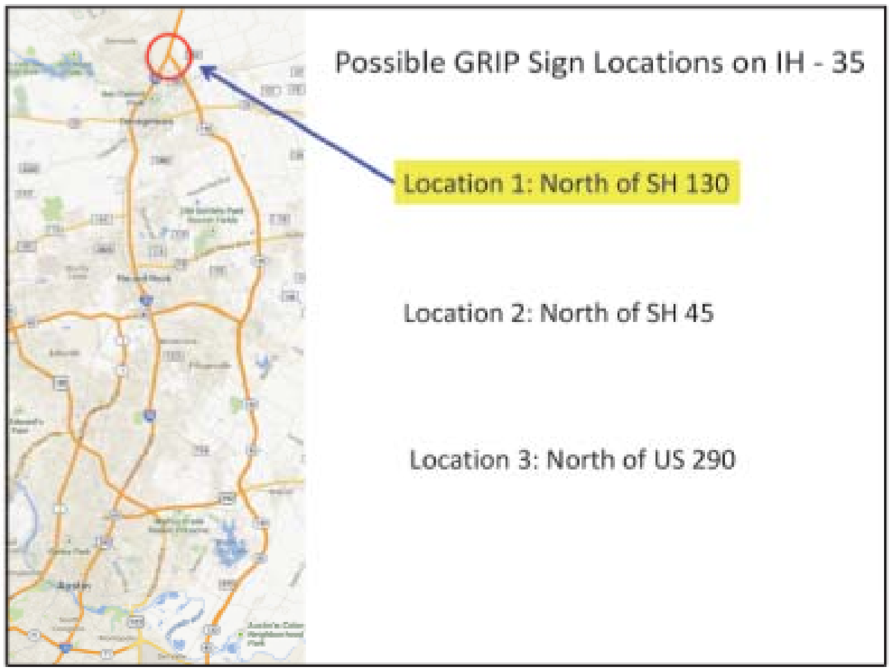
The second location would also be on I-35 southbound just before reaching the interchange with the state highway 45 toll road interchange.

The third location would be just before the interchange of I-35 and US 290.

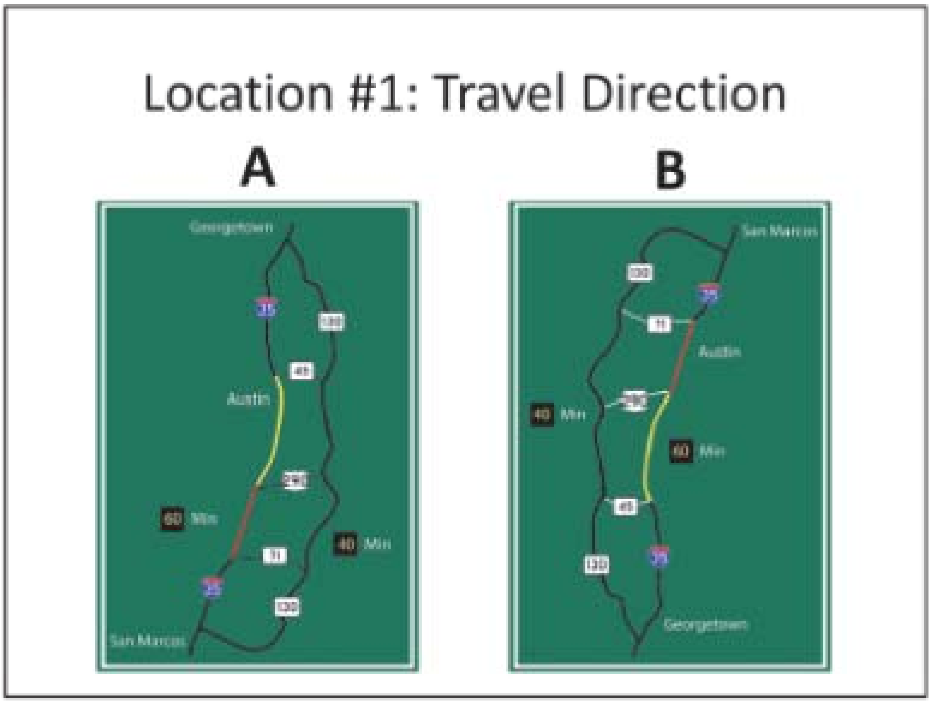
DISCUSSION:

Do all three of these locations seem reasonable and good possible spots for a GRIP sign? Why or why not?

Of the locations shown (and any others just discussed), which one or ones are the highest priority or would be the most beneficial? Why do you think that?



We are going to start off by first talking about location 1, which would be on IH-35 north of SH 130.



To begin, we want to talk a little about how the information might be positioned on the sign. These two GRIPs provide the same information to drivers coming into Austin from the north. One is oriented so that you would be coming down from the top; in the other you would be coming in from the bottom and going up

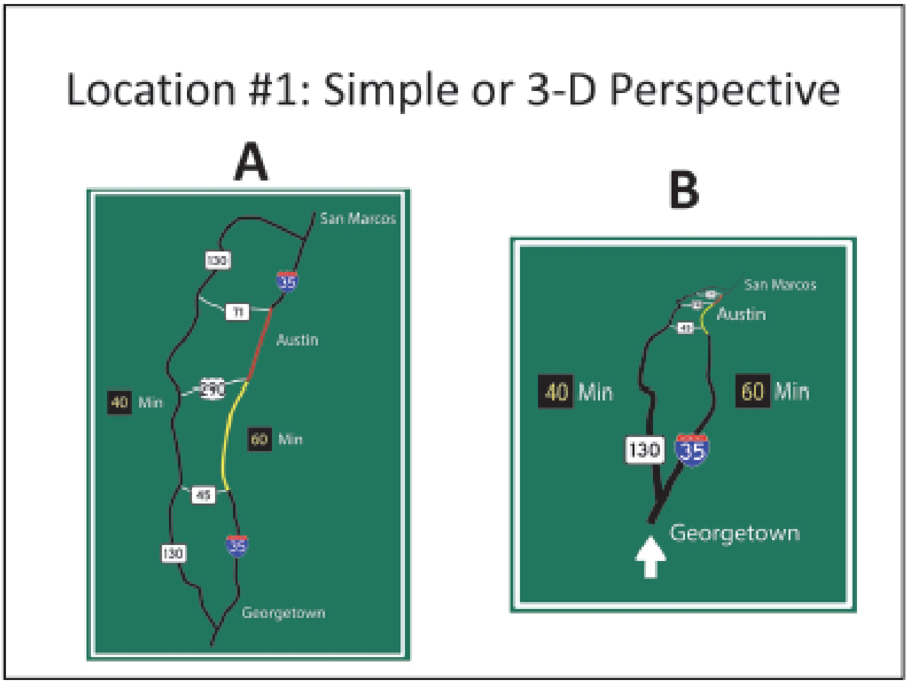
DISCUSSION:

What information jumps out at you from these images? What information is confusing?

Which of these approaches do you think is clearer and easier to understand? Why?

Is there anything you could do to either sign to make it clearer to a driver?

Both GRIPs show 3 cross streets (45, 290, 71). Do these make the signs clearer to understand or more confusing? Should more be shown? If so, which ones? If you had to pick just one to show, which would it be? Why? What if none of the cross streets were shown?

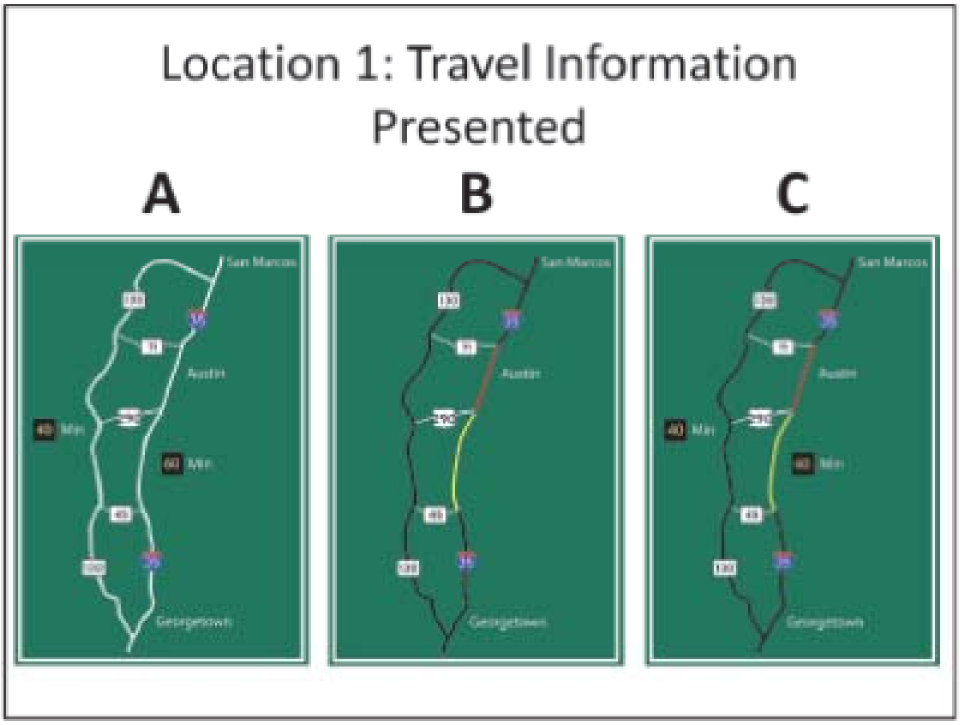


It may be possible to provide a 3-dimensional perspective of the driving route instead of a more typical top down view of the roadways. For the first location we are discussing up by Georgetown, here are two options that could be shown.

Discussion:

Do you think the 3-D perspective would be more or less confusing to motorists? Why?

Is there anything that could be done to the 3-D perspective GRIP to improve motorist understanding of what it meant? Why?



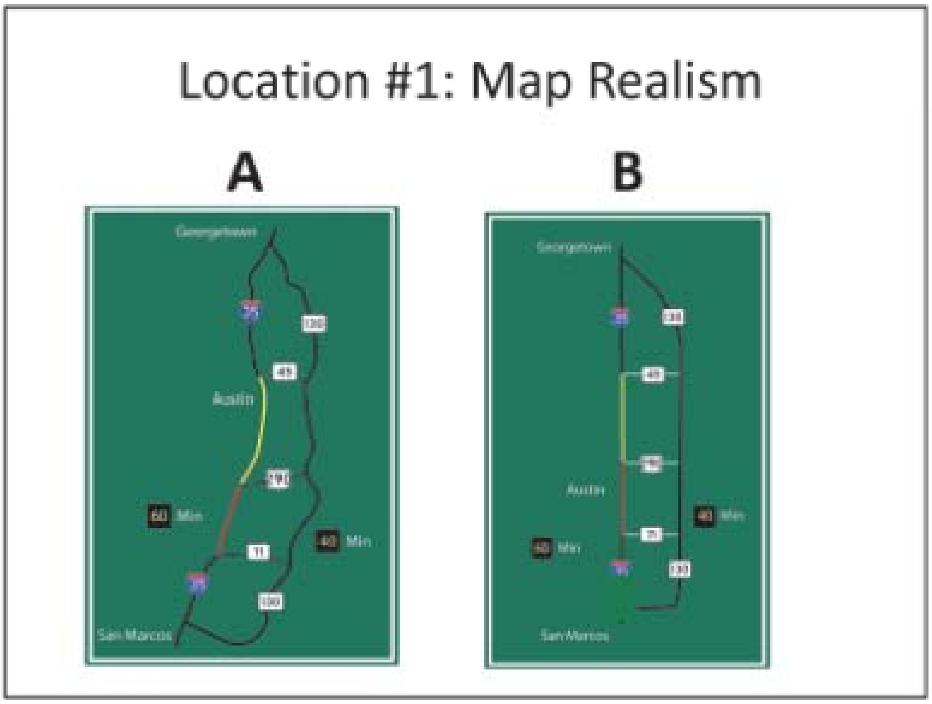
One of the things we have to decide is what type and how much information to provide to motorists on these signs. Here are three possible approaches to providing current travel condition information on the two key routes (I-35 and SH 130 Toll Road).

Discuss:

What information do you think is being presented on each of the three options shown? (*note: we want to explore whether or not they would expect the color of the lines to change in option 1. We also want to explore how they interpret the non-colored portions of the routes in options 2 and 3*).

Which of the options do you think would be most useful to a driver? Why?

Which one do you think would be least useful to a driver? Why?

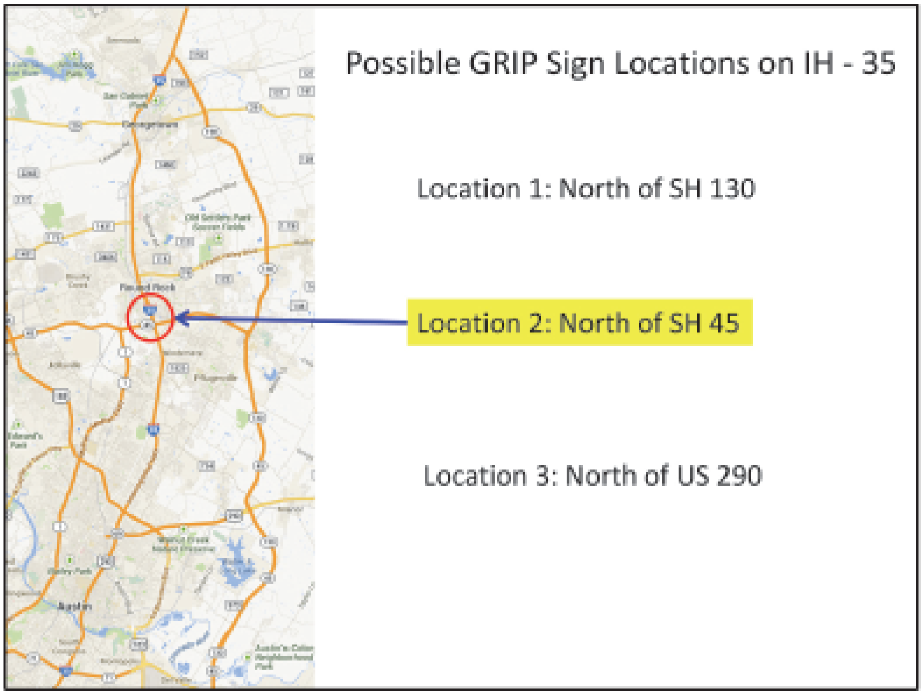


Another thing we need to decide on is how much detail to put into the route maps being displayed. For example, at our location 1 again, we could display either a highly accurate map like on the left, or a simplified representation of the routes like on the right.

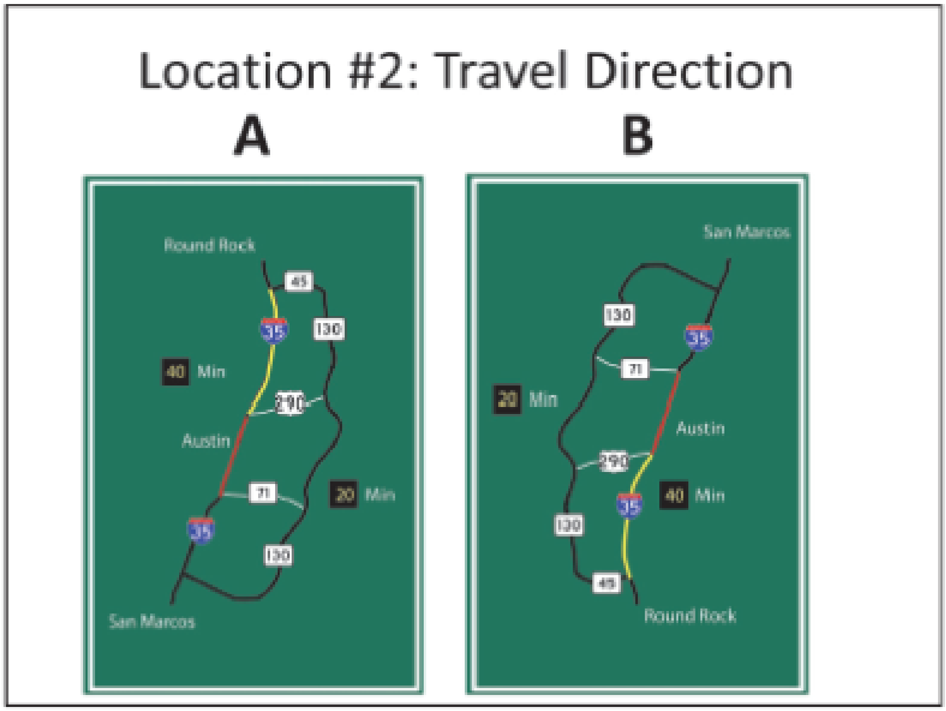
Discussion:

Which of these options do you think will work best for drivers? Why?

Could the simple option on the right be further improved (*note: keep in mind what was suggested for improvements for the left option from earlier, including whether the group prefers a top-down or bottom-up map presentation*)? Are more or fewer cross streets needed?



Now we'd like to look at some sign options for the second proposed location for southbound drivers on Interstate 35, which would be located just north of the entrance to the SH 45 toll road. We'll look at the same types of options for this location as we did for location 1.



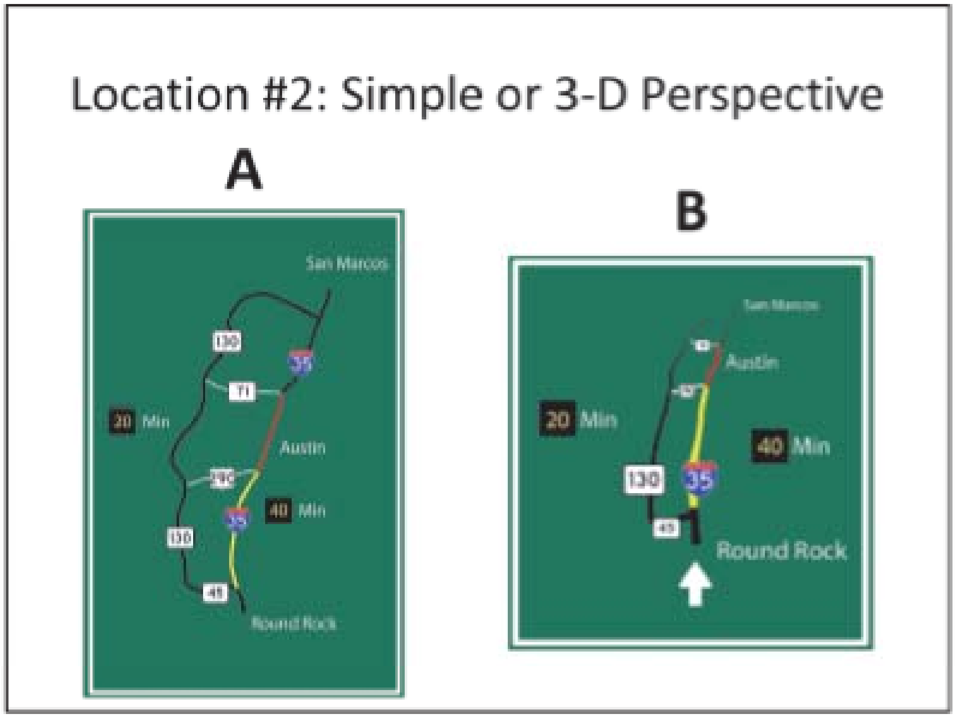
Again, these two GRIPs provide the same information to drivers coming into Austin from the north. One is oriented so that you would be coming down from the top; in the other you would be coming in from the bottom and going up

DISCUSSION:

Which of these approaches do you think is clearer and easier to understand for this location? Why? (*note: if they change opinions from location 1, discuss further why they changed their opinion*)

Is there anything you could do to either sign to make it clearer to a driver?

Both GRIPs still show 3 cross streets (45, 290, 71). Do these make the signs clearer to understand or more confusing? Should more be shown? If so, which ones? If you had to pick just one to show, which would it be? Why? What if none of the cross streets were shown?

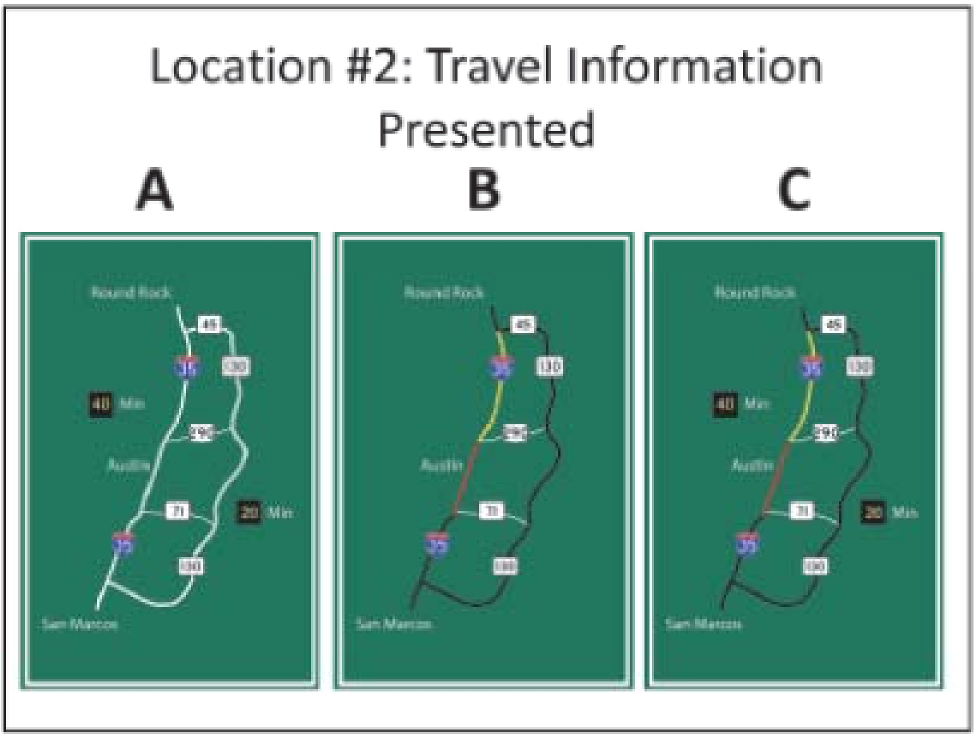


Next, here is how a simple GRIP or a 3-D perspective GRIP might look for this location.

Discussion:

Do you think the 3-D perspective would be more or less confusing to motorists? Why?

Is there anything that could be done to the 3-D perspective GRIP to improve motorist understanding of what it meant? Why?

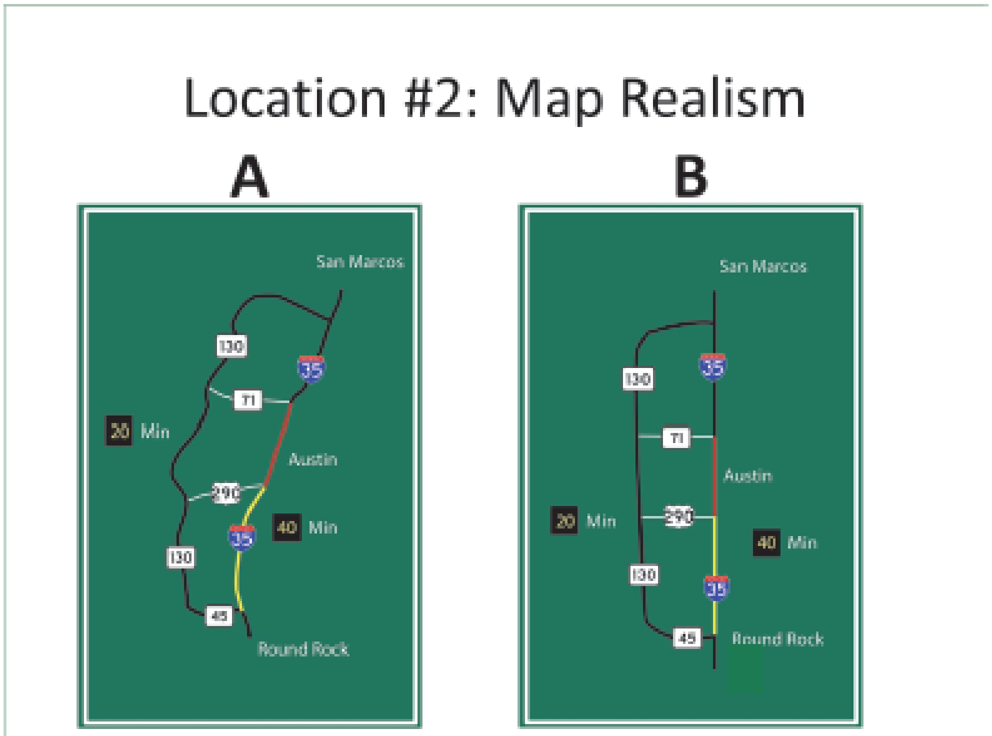


Here again are the options of travel condition information we discussed previously, as would be shown on a GRIP at location 2.

Discuss:

Which of the options do you think would be most useful to a driver at this location? Why? (*note: if you get different responses than was obtained for location 1, explore the specific reasons why a different display would be better here*)

Which one do you think would be least useful to a driver? Why? (*note: if you get different responses than was obtained for location 1, explore the specific reasons why a different display would be better here*)

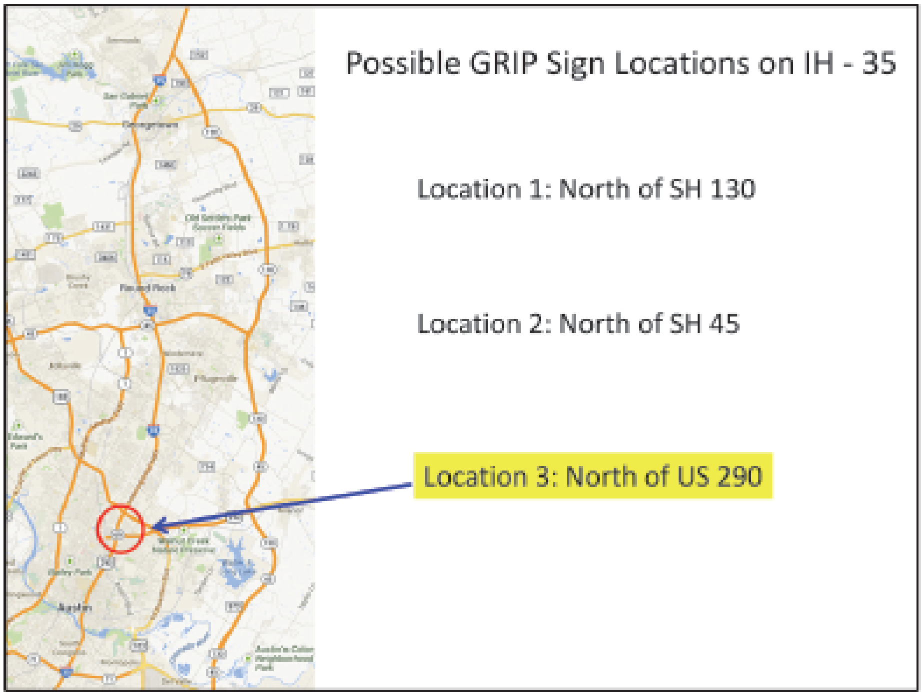


We will also have the decision here to use a realistic route map or a simplified map again.

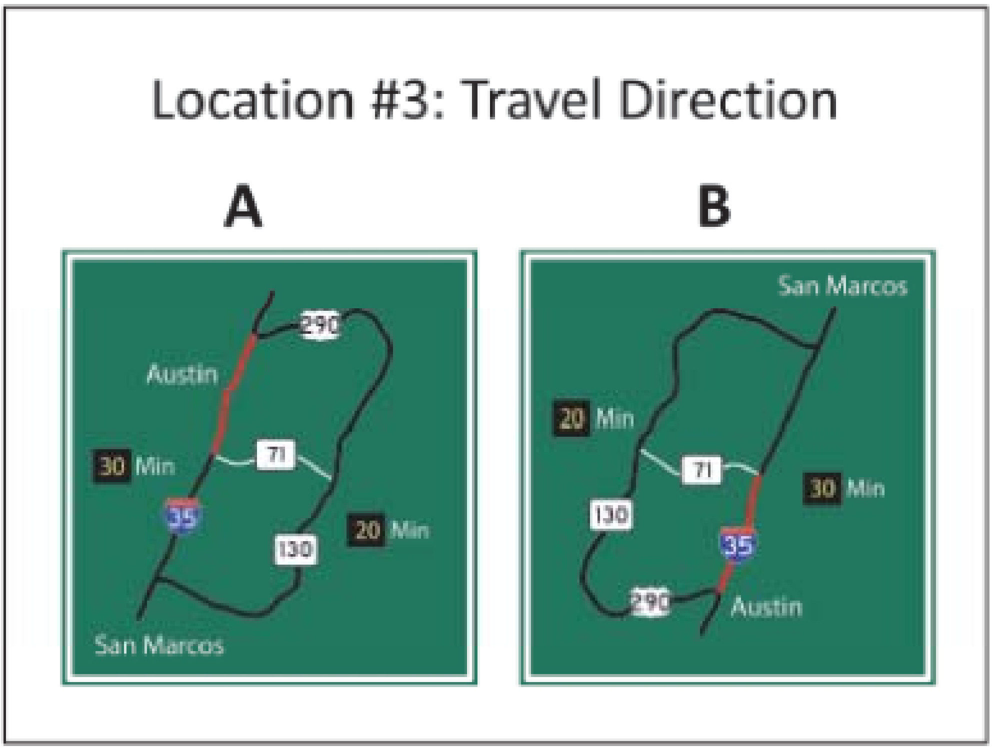
Discussion:

Which of these options do you think will work best for drivers? Why? (*note: if you get different responses than was obtained for location 1, explore the specific reasons why a different display would be better here. Keep in mind that these options are presented as traveling from the bottom to the top, whereas this was discussed in location 1 with the images portraying top down traveling*)

Could the simple option on the right be further improved (*note: keep in mind what was suggested for improvements for the left option from earlier, including whether the group prefers a top-down or bottom-up map presentation*)? Are more or fewer cross streets needed?



Now we'd like to look at some sign options for the third location for southbound drivers on Interstate 35, which would be located just north of US 290. We'll look at the same types of options for this location as we did for location 1.
do you think that?



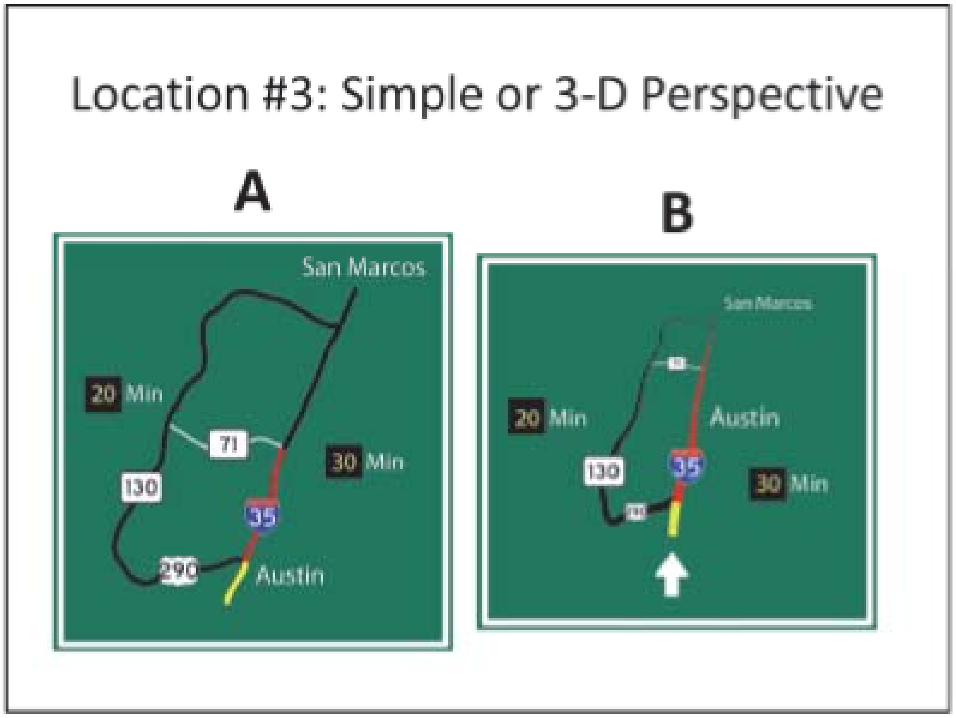
These two GRIPs provide the same information to drivers driving through Austin from the north. One is oriented so that you would be coming down from the top; in the other you would be coming in from the bottom and going up

DISCUSSION:

Which of these approaches do you think is clearer and easier to understand for this location? Why? (*note: if they change opinions from location 1, discuss further why they changed their opinion. Also, try to keep any suggestions for improving them from previous discussions in mind and mention them as you present them, i.e., an arrow showing where they are at might have been suggested, and so should be mentioned here*)

Is there anything you could do to either sign to make it clearer to a driver?

At this third location, both GRIPs show 2 cross streets (290, 71). Do these make the signs clearer to understand or more confusing? Should more be shown? If so, which ones? If you had to pick just one to show, which would it be? Why? What if none of the cross streets were shown?

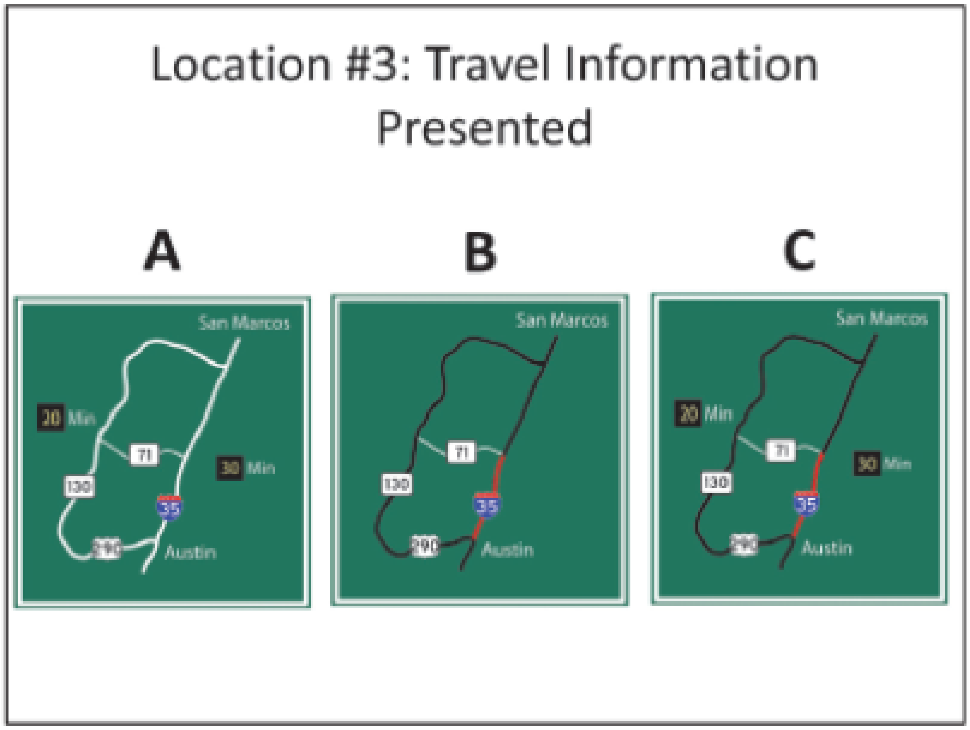


Here is how a simple GRIP or a 3-D perspective GRIP might look for this location.

Discussion:

Again, do you think the 3-D perspective would be more or less confusing to motorists? Why? (note: explore any differences you hear about the 3-D perspective here relative to what was said for locations 2 and 3).

Is there anything that could be done to the 3-D perspective GRIP for this location to improve motorist understanding of what it meant? Why?

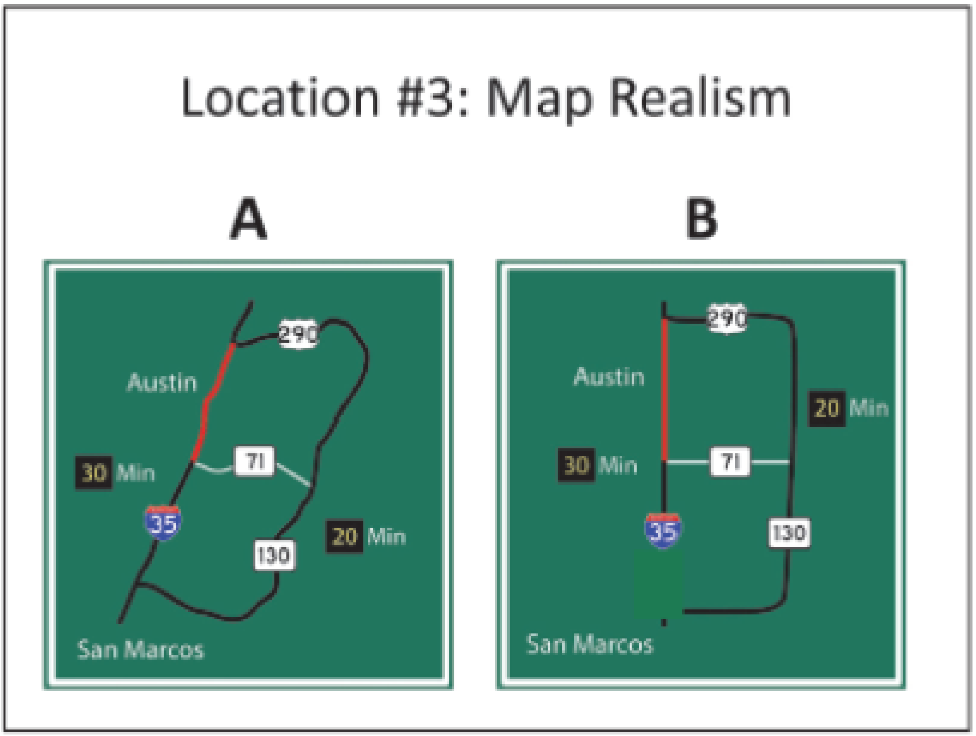


Here again are the options of travel condition information we discussed previously, as would be shown on a GRIP at location 3.

Discuss:

Which of the options do you think would be most useful to a driver at this location? Why? (*note: if you get different responses than was obtained for locations 1 or 2, explore the specific reasons why a different display would be better here*)

Which one do you think would be least useful to a driver? Why? (*note: if you get different responses than was obtained for location 1 or 2, explore the specific reasons why a different display would be better here*)



We will also have the decision here to use a realistic route map or a simplified map again at this location.

Discussion:

Which of these options do you think will work best for drivers? Why? (*note: if you get different responses than was obtained for locations 1 or 2, explore the specific reasons why a different display would be better here. Keep in mind that these options are presented as traveling from the bottom to the top, whereas this was discussed in location 1 with the images portraying top down traveling*)

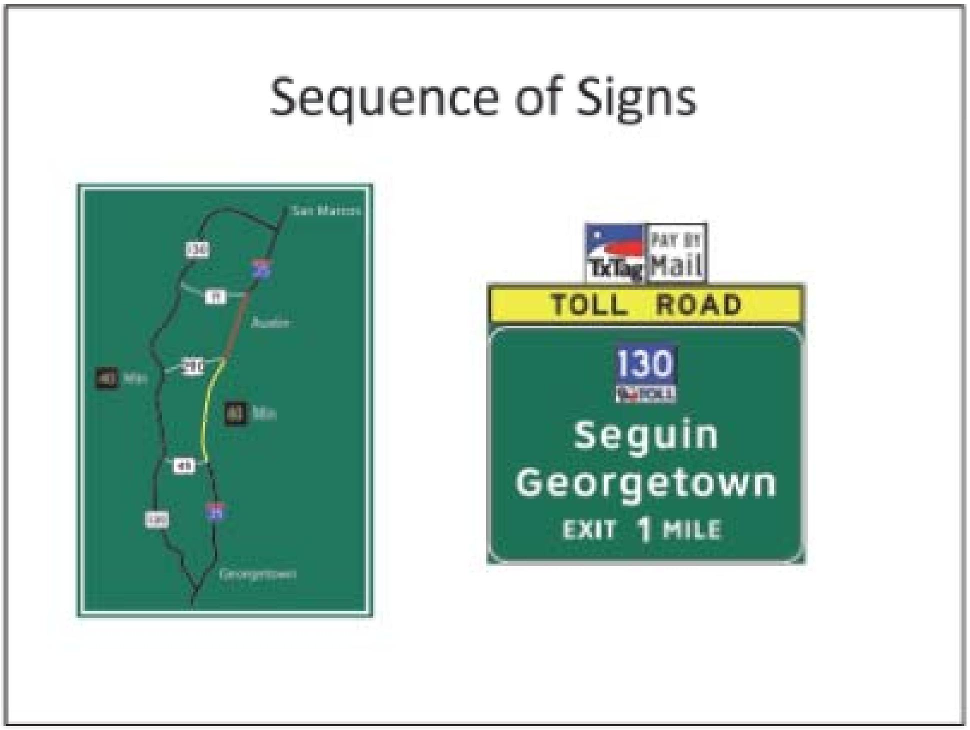
Could the simple option on the right be further improved (*note: keep in mind what was suggested for improvements for the left option from earlier, including whether the group prefers a top-down or bottom-up map presentation*)? Are more or fewer cross streets needed?

Other Suggested Locations

- Travel direction?
- Simple or 3-D perspective?
- Travel information presented?
- Map realism?

Assume for a minute that only one of these signs could be placed on I-35. At which of the three locations that was discussed today should the sign be placed (before 130, before 45, or before 290)?

What information should be presented on that one sign?



The last thing we want to discuss is how to present GRIP signs in relation to the other signs you'll see that each location. For example, information indicating that SH 130 is a toll road will be presented starting a mile from the interchange. The cost of traveling on SH 130 may also be presented.

DISCUSS:

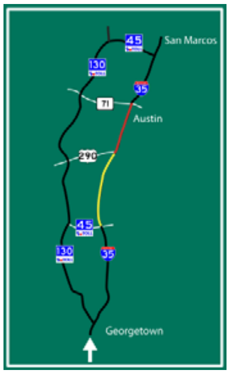
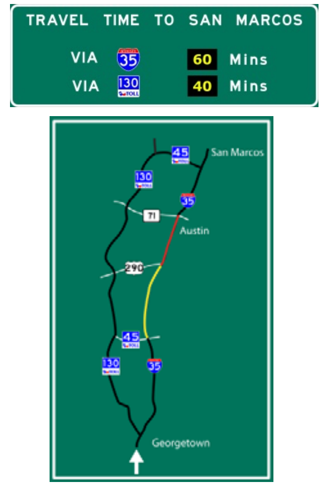
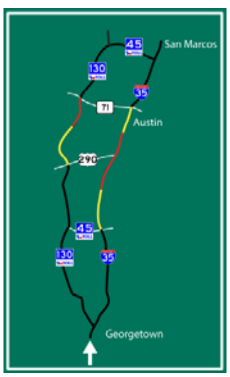
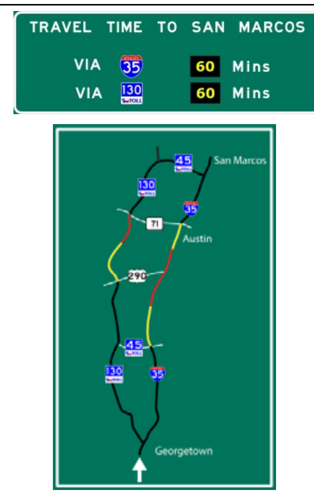
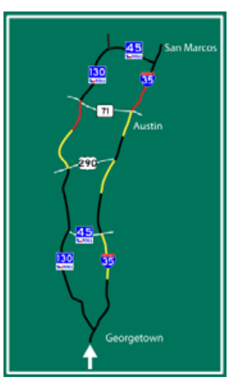
Assuming you were not familiar with Austin and its roadways, would it be better if you knew that SH 130 was a toll road before you saw a GRIP indicating travel conditions on I-35 and SH 130, or would it be better to see conditions, and then be told that it is a toll road? Why?

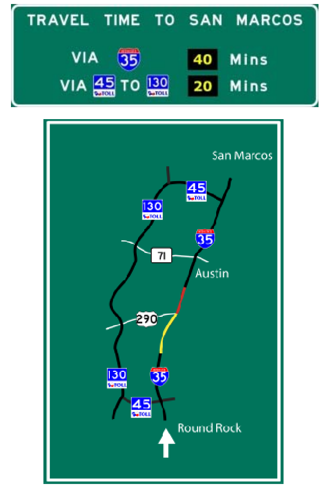
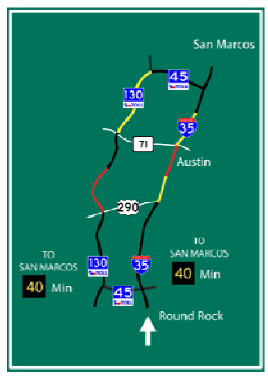
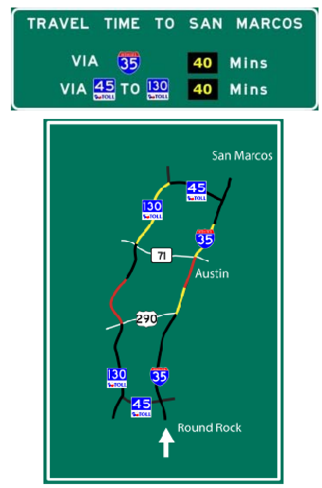
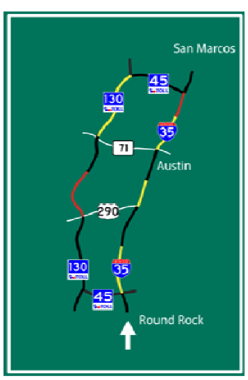
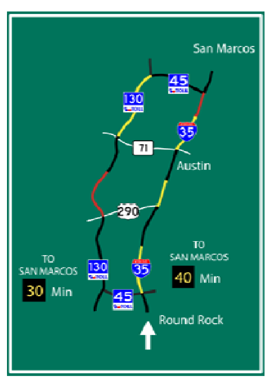
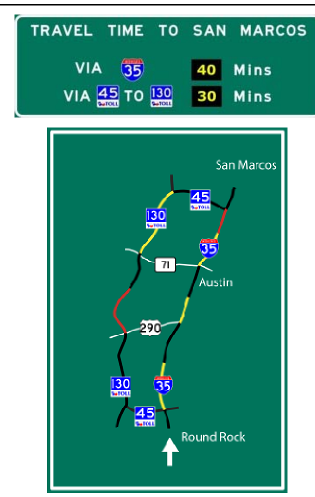
How important would it be to know how much the toll is?

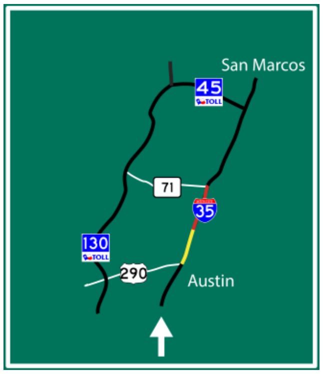
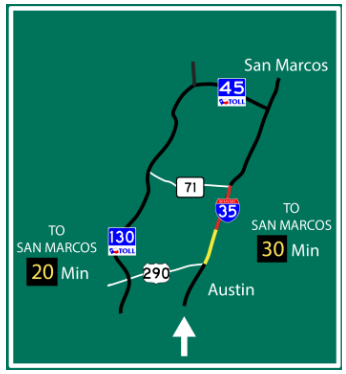
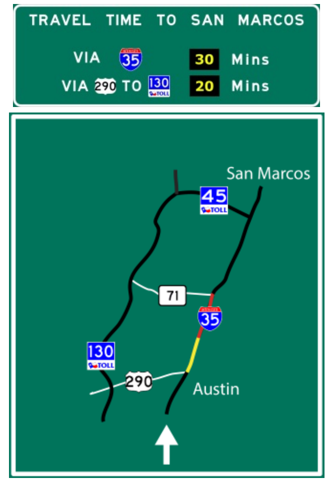
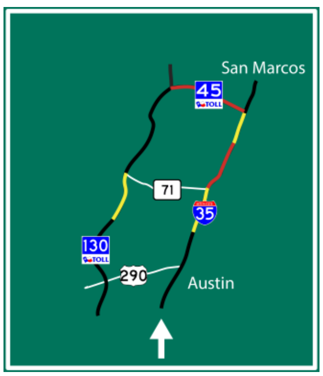
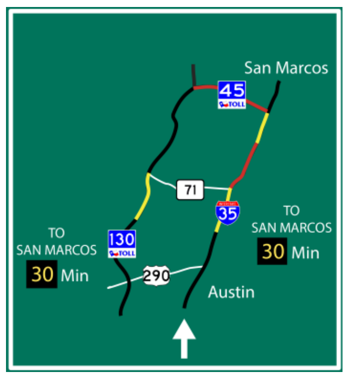
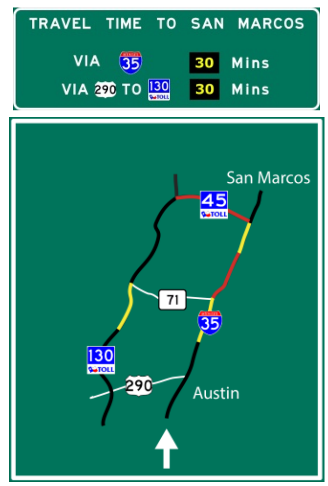
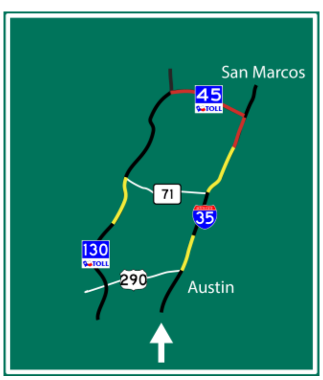
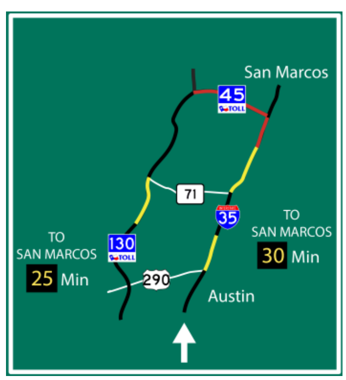
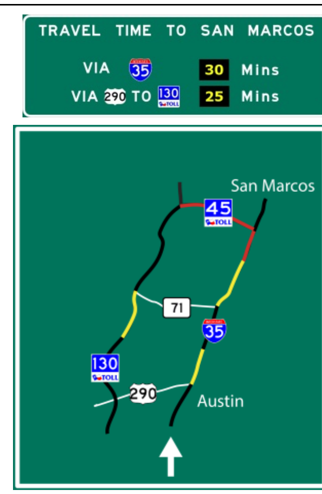
Are there any last comments or issues about these signs that you'd like to bring up?

Thank you for your time today!

APPENDIX B: GRIP SIGN TREATMENT COMBINATIONS TESTED IN HUMAN FACTORS LABORATORY STUDIES

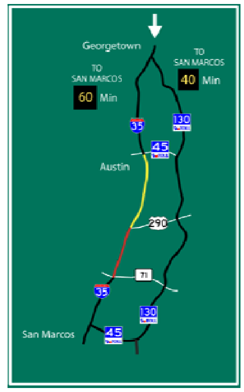
<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Level 1</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Level 2</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Level 3</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
</table>

	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Level 1			
Level 2			
Level 3			

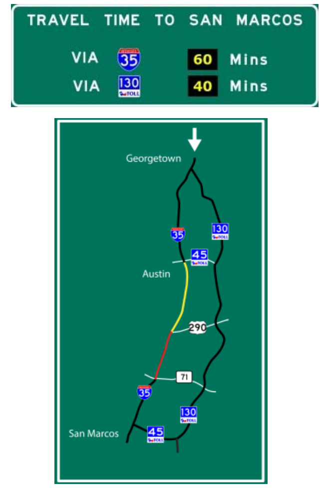
	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Level 1			
Level 2			
Level 3			

<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Level 1</td><td>

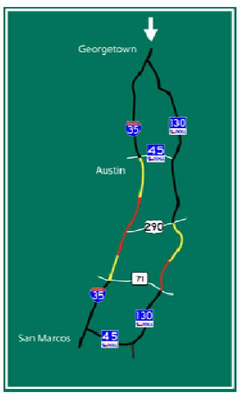
</td><td>



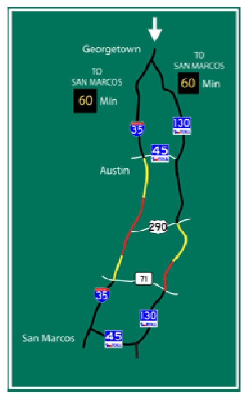
</td><td>



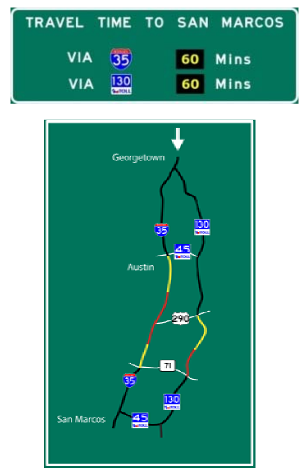
</td></tr>
<tr><td>Level 2</td><td>



</td><td>

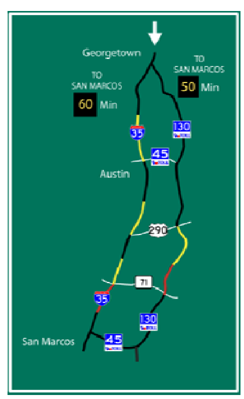


</td><td>

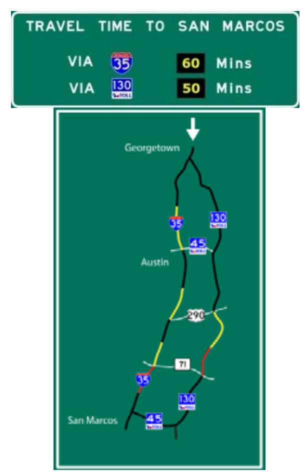


</td></tr>
<tr><td>Level 3</td><td>

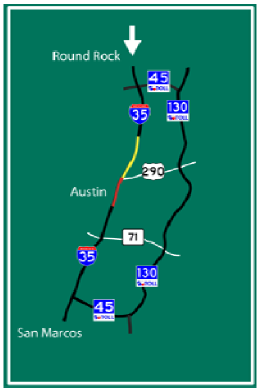
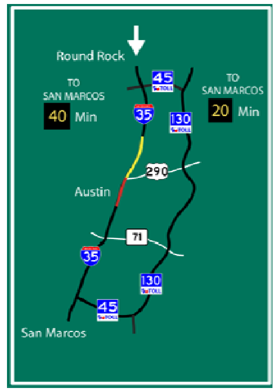
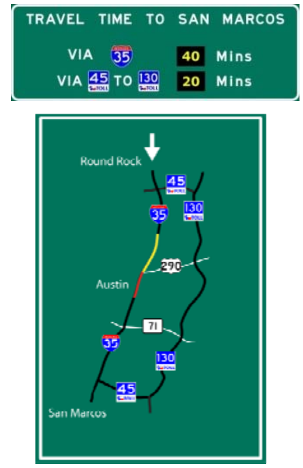
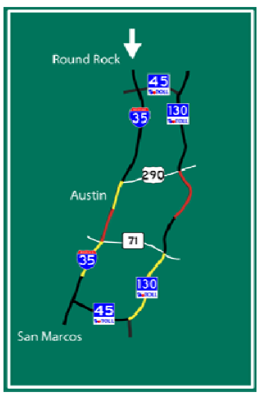
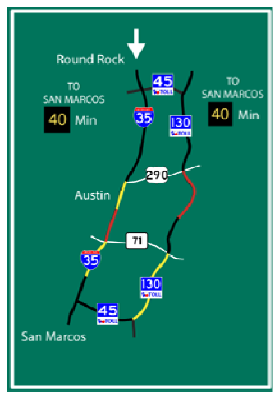
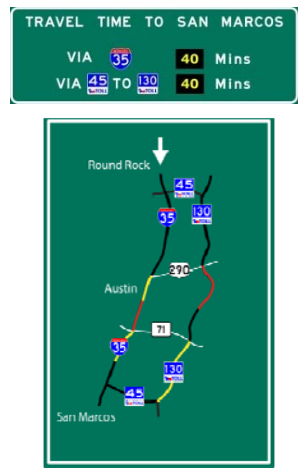
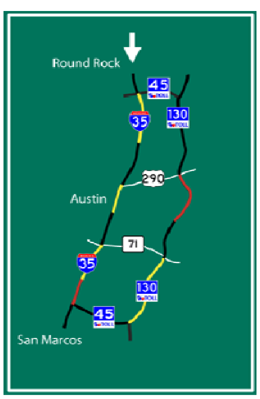
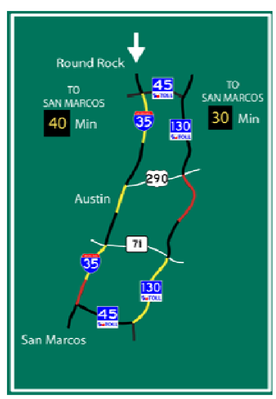
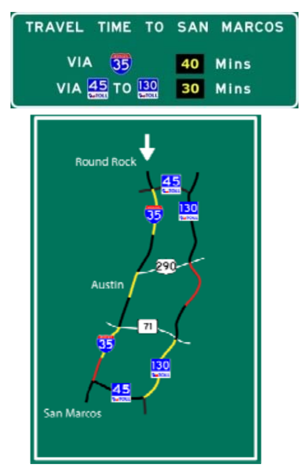
</td><td>

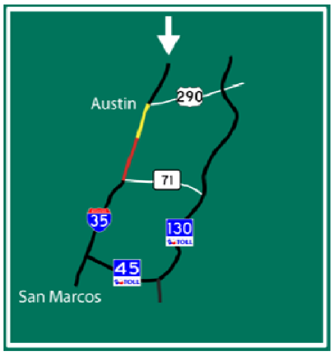
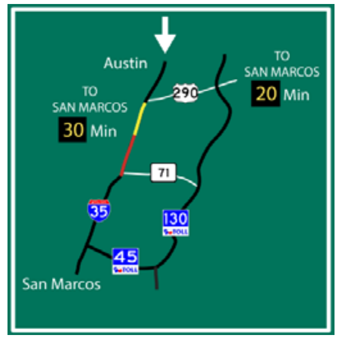
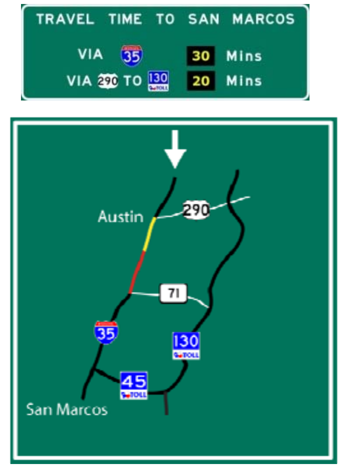
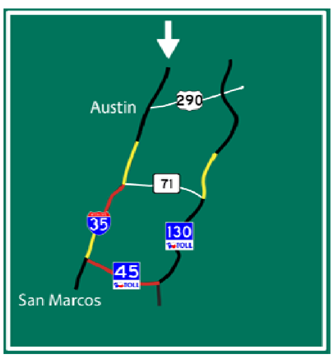
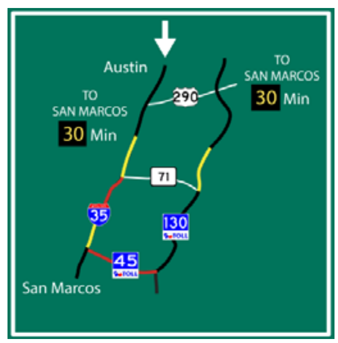
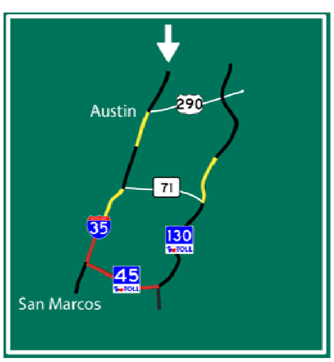
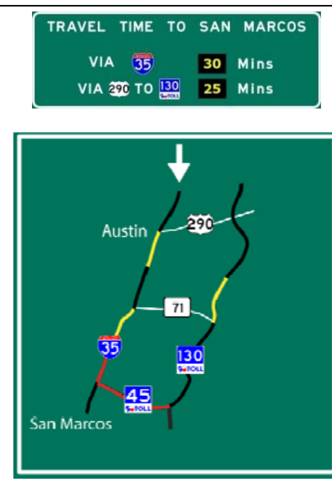


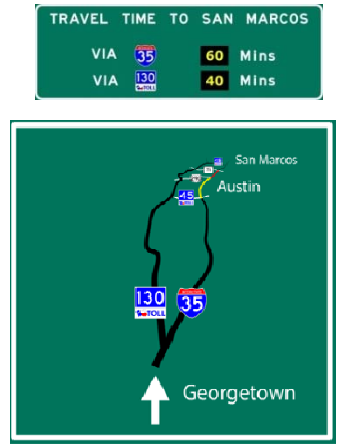
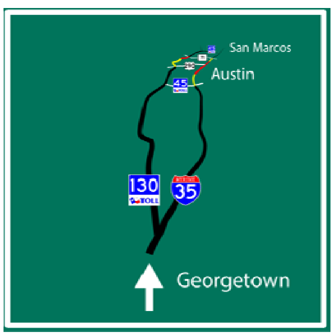
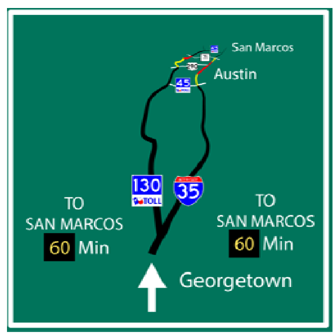
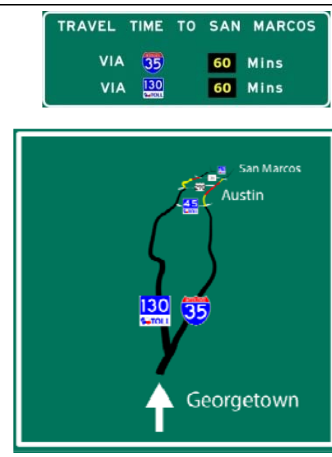
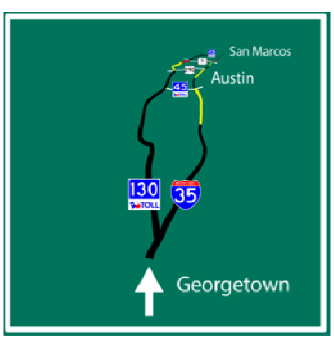
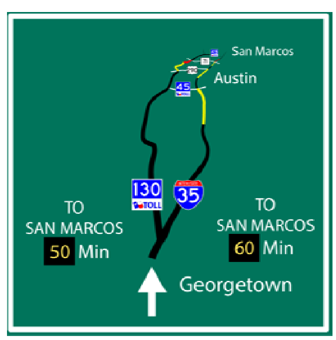
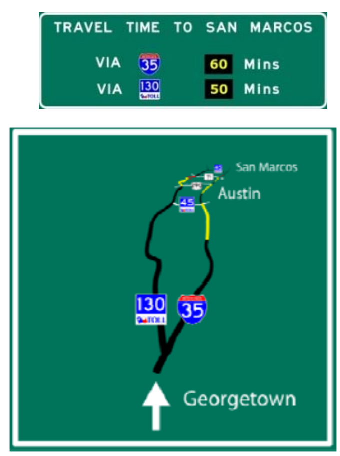
</td><td>

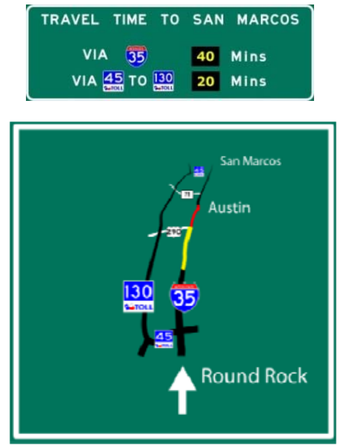
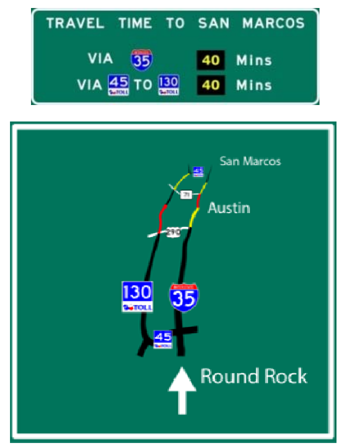
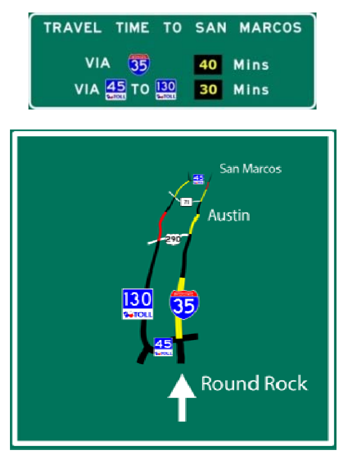


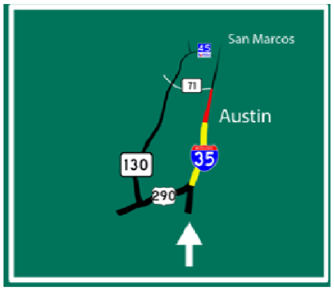
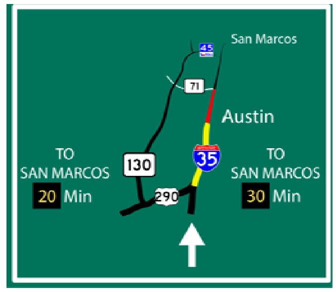
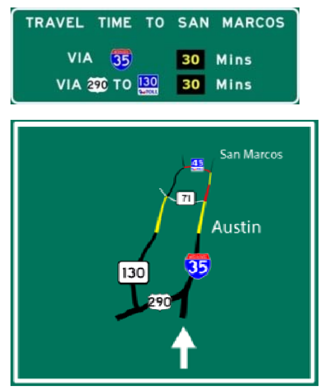
</td></tr>
</table>

<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Level 1</td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Level 2</td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Level 3</td>
<td></td>
<td></td>
<td></td></tr>
</table>

	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Level 1			
Level 2			
Level 3			

<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Level 1</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Level 2</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Level 3</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
</table>

	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Level 1			
Level 2			
Level 3			

	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Level 1			
Level 2			
Level 3			

APPENDIX C: HUMAN FACTORS LABORATORY STUDY ANSWER FORM

	Survey Form ___________
Location: _________________	Participant #____________
Date: ____________________	Researcher: ____________

ANSWER FORM

Southbound GRIP Sign Design Assistance for Austin

Would you be interested in participating in a survey (*circle one*)? Yes No

If "no," thank them and go to next potential participant.

If "yes," continue.

Great! This survey is being conducted by the Texas A&M Transportation Institute and is being sponsored by the Texas Department of Transportation. The purpose of the study is to determine your ability to understand and make decisions based on information that could be presented on overhead signs.

Do you currently have a driver's license (*circle one*): Yes No

If "no," thank them and go to next potential participant.

If "yes," continue.

What age group are you in (*circle one*)? 18–35 36–54 55+
NOTE: If the person is not at least 18, thank them and go to the next participant.

What is your highest level of education (*circle one*)? High School or less Some College College Degree

Study administrator to note gender (*circle one*): Male Female

Are you color blind? (*circle one*): Yes No

If "yes," thank them and go to next potential participant.

Your participation in this survey is strictly voluntary and you are free to quit at any time. All information will be anonymous, and there will be no information obtained that will link you to the survey in any way. The survey should take approximately 5 to 10 minutes. If you agree to participate, we will begin. *If they do not want to participate, thank them and go to the next participant.*

Driving Experience Question:

How often do you drive on any of the freeways in the Austin area? (*circle one*)

Two times a year or less Up to twice a month More than twice a month

How often do you drive on any of the tollways in the Austin area? (*circle one*)

Two times a year or less Up to twice a month More than twice a month

We are studying different ways of providing information to drivers to help in make driving decisions while they are traveling. These do not currently exist on the roadway. The signs will consist of roadway segments that will be dark if conditions are normal but will display other colors if congestion and slow speeds are present (much like the traffic maps you can find on the internet). Sections with very slow speeds are displayed in red, and sections that are only somewhat slow are shown in yellow. Other traffic information may also be presented. Here is an example of one possible type of sign with all roadway segments operating normally *(display the potential map sign*). In some cases, I may show you 2 signs one after the other, separated by a short blank time, as if you were seeing them one after the other as you drove. I will then ask you what sections of the roads were colored (and what colors they were). If travel times were shown in the sign such as here, I would ask you about them as well. I'll also ask you which route you might take, given the information that you saw on the sign.

For purposes of this survey, we would like you to pretend you are driving on Interstate 35 north of Austin, driving south and heading toward San Marcos. (*Show them the map of central Texas, with arrows portraying where they are and where they are heading*). As you can see, as you approach Austin, you have the option of staying on I-35 through the city, or taking the SH 130 Tollway around the city. Once you are in Austin, there are also a few locations where you could divert over to SH 130 if you so wanted. (*Point out the SH 45 and US 290 diversion points on the map*). Do you understand what you are pretending to do? (*If they are still confused, continue to work to explain to them the situation until they understand*).

We are now going to show you a series of experimental signs. Remember, after I let you look at the signs for a short period of time, I'm going to ask you some questions about the information included on the sign or signs to see how well you understood what was presented. We'll go through a series of three signs, and do that series 3 times, for a total of 9 times total.

Are you ready to begin?

1ST ITERATION

1st Sign: I-35 at the SH 130 split in Georgetown

The first sign you encounter is up at the north end of Austin. Here is the sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Now, I am going to show you a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? *(If they say yes, ask*) Can you recall the times?

____

____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or used SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

Do you know how much it is to use the SH 130 tollway around Austin? (*Write down no or the amount they think it is*) ___________________________

(*If they said they would not use SH 130 when it was free, do not ask this question*) If you knew that it would take $6.76 to take the tollway, would you have you stayed on I-35 or used SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

2nd Sign: I-35 at the SH 45 interchange in Round Rock

Now assume you are still going south on I-35, and are coming up on the interchange with the SH 45. As you approach the interchange, you see this sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Here again is a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? (*If they say yes, ask*) Can you recall the times?
____

____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or diverted over to SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

Do you know how much it is to use the SH 45/SH 130 tollway from this point around Austin? (*Write down no or the amount they think it is*) ___________________________

(*If they said they would not use SH 130 when it was free, do not ask this question*) If you knew that it would take $7.09 to take the tollways, would you have you stayed on I-35 or diverted to SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

3rd Sign: I-35 at the US 290 interchange in Austin

Finally, now assume you are still going south on I-35, and are coming up on the interchange with the US 290. As you approach the interchange, you see this sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Here again is a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? *(If they say yes, ask*) Can you recall the times?

____

____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or diverted over to SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

Do you know how much it is to use the SH 130 tollway from this point around Austin? (*Write down no or the amount they think it is*) ____________________________

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $4.38 to take the tollways, would you have you stayed on I-35 or diverted to SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

2nd ITERATION

1st Sign: I-35 at the SH130 split in Georgetown

The first sign you encounter is up at the north end of Austin. Here is the sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Now, I am going to show you a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? (*If they say yes, ask*) Can you recall the times?
____
____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or used SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $6.76 to take the tollway, would you have you stayed on I-35 or used SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

2nd Sign: I-35 at the SH45 interchange in Round Rock

Now assume you are still going south on I-35, and are coming up on the interchange with the SH 45. As you approach the interchange, you see this sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Here again is a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? *(If they say yes, ask*) Can you recall the times?

____

____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or diverted over to SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $7.09 to take the tollways, would you have you stayed on I-35 or diverted to SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

3rd Sign: I-35 at the US 290 interchange in Austin

Finally, now assume you are still going south on I-35, and are coming up on the interchange with the US 290. As you approach the interchange, you see this sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Here again is a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? *(If they say yes, ask*) Can you recall the times?

____
____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or diverted over to SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $4.38 to take the tollways, would you have you stayed on I-35 or diverted to SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

3rd ITERATION

1st Sign: I-35 at the SH 130 split in Georgetown

The first sign you encounter is up at the north end of Austin. Here is the sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Now, I am going to show you a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? (*If they say yes, ask*) Can you recall the times? ____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or used SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____   SH 130 ____   Unsure or don't know ______

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $6.76 to take the tollway, would you have you stayed on I-35 or used SH 130?

I-35 ____   SH 130 ____   Unsure or don't know ______

2nd Sign: I-35 at the SH 45 interchange in Round Rock

Now assume you are still going south on I-35, and are coming up on the interchange with the SH 45. As you approach the interchange, you see this sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Here again is a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? *(If they say yes, ask*) Can you recall the times?

____

____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or diverted over to SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $7.09 to take the tollways, would you have you stayed on I-35 or diverted to SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

3rd Sign: I-35 at the US 290 interchange in Austin

Finally, now assume you are still going south on I-35, and are coming up on the interchange with the US 290. As you approach the interchange, you see this sign (*Press the power point space bar, and the sign displays for 6 seconds*).

Here again is a map of the roadways and I want you to tell me where you saw color on the roadways, and what colors you saw (*Press the space bar again and the white graph with the dots and segments shown is displayed*).

Segments with Red: ____

Segments with Yellow: ____

Was any travel time information presented? *(If they say yes, ask*) Can you recall the times?

____

____

If you didn't have to pay a toll to use the tollway, would have you stayed on I-35 or diverted over to SH 130? (*If they are unsure, it is ok for them to say so*)

I-35 ____ SH 130 ____ Unsure or don't know ______

(*If they said they would not use SH 130 when it was free, do not ask this next question*) If you knew that it would take $4.38 to take the tollways, would you have you stayed on I-35 or diverted to SH 130?

I-35 ____ SH 130 ____ Unsure or don't know ______

PREFERENCES

During this survey we've shown you several different ways in which route and traffic condition information could be presented to you. I'd like to get your opinions on which of the versions you preferred. On this next slide, we show the three ways in which we presented roadway and traffic condition to you. In the first case both color segments and travel time information was presented. In the second, only color segments were presented. In the third, travel times were presented on the first sign, and then color segments on the second. Which of these versions did you like the best, and why?

____

Which version did you like the least, and why?

____

THANK YOU THAT COMPLETES THIS SURVEY!

APPENDIX D: HUMAN FACTORS LABORATORY STUDY PARTICIPANT RESPONSES BY LOCATION

Table D-1. % Correct Detection of Congestion/No Congestion on Routes: Georgetown Sign

North Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	89	96	97	96	93	99
Level 2	87	94	93	94	97	87
Level 3	84	89	84	82	90	85
Overall	86	93	93	93	93	90
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	93	97	95	94	92	97
Level 2	92	99	85	92	85	94
Level 3	85	78	78	78	69	92
Overall	90	91	86	88	82	94
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	95	89	92	95	97	97
Level 2	88	94	94	92	57	77
Level 3	79	85	71	73	87	91
Overall	88	89	85	87	80	88

Table D-2. % Correct Perception of Extent (Length) of Congestion on Routes: Georgetown Sign

North Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	71	87	68	70	78	78
Level 2	69	69	72	65	59	61
Level 3	63	68	60	54	60	65
Overall	64	70	67	62	61	64
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	82	78	67	64	75	72
Level 2	66	72	59	59	58	67
Level 3	58	47	51	47	52	54
Overall	64	62	56	53	57	61
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	56	48	55	57	58	61
Level 2	58	57	56	53	37	39
Level 3	46	56	37	37	51	47
Overall	54	54	49	48	46	45

Table D-3. % Correct Location and Type (Color) of Congestion on Routes: Georgetown Sign

Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
North Orientation						
	AUS	**CS/HOU**	**AUS**	**CS/HOU**	**AUS**	**CS/HOU**
Level 1	68	84	68	75	73	71
Level 2	69	68	59	62	55	62
Level 3	59	68	59	43	56	60
Overall	65	73	62	60	61	64
Track Orientation						
Congestion Levels Presented	**Routes Only**		**Routes w/Travel Times**		**Route w/TT (Dist.)**	
	AUS	**CS/HOU**	**AUS**	**CS/HOU**	**AUS**	**CS/HOU**
Level 1	83	77	62	68	72	66
Level 2	63	68	59	56	58	51
Level 3	65	57	46	44	50	56
Overall	70	67	58	56	60	58
Track 3D Orientation						
Congestion Levels Presented	**Routes Only**		**Routes w/Travel Times**		**Route w/TT (Dist.)**	
	AUS	**CS/HOU**	**AUS**	**CS/HOU**	**AUS**	**CS/HOU**
Level 1	68	84	68	75	73	71
Level 2	69	68	59	62	55	62
Level 3	59	68	59	43	56	60
Overall	65	73	62	60	61	64

Table D-4. % Correct Recall of Travel Time Information Presented: Georgetown Sign

North Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	74	73	71	85
Level 2	76	80	83	75
Level 3	36	62	68	78
Overall	62	72	74	79
Track Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	56	62	79	74
Level 2	58	88	69	88
Level 3	42	41	78	83
Overall	52	64	75	82
Track 3D Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	63	66	68	77
Level 2	75	84	88	80
Level 3	72	53	60	76
Overall	70	68	72	78

Table D-5. Percent Stated Diversion Choice to SH 130: Georgetown Sign

North Orientation

Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	83	72	37	41	93	90	57	42	77	90	27	50
Level 2	67	59	20	28	53	38	33	19	77	65	33	16
Level 3	73	65	27	19	63	55	20	19	83	63	37	28
Overall	74	65	28	29	70	61	37	27	79	73	32	31

Track Orientation

Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	67	77	30	40	80	87	50	35	86	79	52	31
Level 2	69	69	38	34	60	33	17	7	77	61	37	16
Level 3	57	66	37	28	48	79	21	17	77	57	37	20
Overall	64	71	35	34	63	66	29	20	80	66	42	22

Track 3D Orientation

Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	68	83	27	23	90	84	52	39	89	76	50	42
Level 2	75	61	23	18	60	48	23	16	72	63	24	25
Level 3	62	63	28	13	79	64	28	15	80	61	23	23
Overall	73	64	26	18	76	65	34	23	80	67	32	30

Table D-6. % Correct Detection of Congestion/No Congestion on Routes: Round Rock Sign

Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
North Orientation						
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	94	97	95	97	99	94
Level 2	90	91	99	94	97	99
Level 3	95	99	84	89	99	100
Overall	93	96	92	93	98	98
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	97	100	94	100	99	97
Level 2	87	94	92	97	94	97
Level 3	95	97	84	92	95	84
Overall	93	97	90	95	96	94
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	99	99	96	100	100	99
Level 2	95	97	95	96	98	100
Level 3	89	97	94	95	74	93
Overall	94	98	95	96	91	97

Table D-7. % Correct Perception of Extent (Length) of Congestion on Routes: Round Rock Sign

North Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	90	94	87	98	92	81
Level 2	65	67	73	68	78	79
Level 3	68	63	67	61	58	60
Overall	70	69	72	70	71	70
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	97	97	88	97	98	92
Level 2	64	74	70	77	68	71
Level 3	66	67	52	66	68	65
Overall	70	75	64	76	72	72
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	84	91	91	92	98	92
Level 2	70	77	75	67	76	66
Level 3	62	64	59	62	48	57
Overall	69	74	70	69	68	67

Table D-8. % Correct Location and Type (Color) of Congestion on Routes: Round Rock Sign

North Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	88	94	94	93	96	86
Level 2	65	64	71	65	73	77
Level 3	61	57	56	54	50	59
Overall	71	72	74	71	73	74
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	94	84	89	91	93	93
Level 2	63	68	69	69	61	60
Level 3	61	60	47	55	62	49
Overall	73	71	68	72	72	67
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	89	92	90	90	73	96
Level 2	63	67	66	65	66	69
Level 3	56	55	48	50	38	51
Overall	69	71	68	68	59	72

Table D-9. % Correct Recall of Travel Time Information Presented: Round Rock Sign

North Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	72	73	88	84
Level 2	64	73	78	87
Level 3	73	69	61	86
Overall	70	72	76	86
Track Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	60	69	80	80
Level 2	48	52	84	68
Level 3	49	77	71	72
Overall	52	66	78	73
Track 3D Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	74	59	93	81
Level 2	47	73	78	79
Level 3	72	73	73	74
Overall	64	68	81	78

Table D-10. % Stated Diversion Choice to SH 130: Round Rock Sign

North Orientation												
Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	73	77	27	19	73	77	23	35	87	88	53	57
Level 2	57	32	40	13	60	48	23	10	40	37	13	3
Level 3	57	31	17	7	70	63	27	19	73	71	30	19
Overall	62	47	28	13	68	63	24	21	67	65	32	26
Track Orientation												
Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	57	72	27	17	66	79	24	24	80	77	40	30
Level 2	40	37	27	20	43	32	23	23	45	38	21	14
Level 3	62	62	21	24	53	73	20	20	77	58	27	13
Overall	53	57	25	20	54	61	22	22	67	58	29	19
Track 3D Orientation												
Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	69	88	28	25	89	82	46	45	90	77	30	37
Level 2	43	42	17	13	45	50	21	13	43	55	14	12
Level 3	54	52	14	18	63	48	10	13	76	63	31	9
Overall	55	61	20	19	65	60	26	24	70	65	25	19

Table D-11. % Correct Detection of Congestion/No Congestion on Routes: Austin Sign

North Orientation						
Congestion Levels Presented	**Routes Only**		**Routes w/Travel Times**		**Route w/TT (Dist.)**	
	AUS	**CS/HOU**	**AUS**	**CS/HOU**	**AUS**	**CS/HOU**
Level 1	99	100	99	96	100	100
Level 2	97	97	95	95	95	92
Level 3	90	99	100	97	97	100
Overall	95	99	98	96	97	97
Track Orientation						
Congestion Levels Presented	**Routes Only**		**Routes w/Travel Times**		**Route w/TT (Dist.)**	
	AUS	**CS/HOU**	**AUS**	**CS/HOU**	**AUS**	**CS/HOU**
Level 1	98	100	94	95	100	97
Level 2	92	86	85	86	95	94
Level 3	89	99	97	92	95	97
Overall	93	95	92	91	97	96
Track 3D Orientation						
Congestion Levels Presented	**Routes Only**		**Routes w/Travel Times**		**Route w/TT (Dist.)**	
	AUS	**CS/HOU**	**AUS**	**CS/HOU**	**AUS**	**CS/HOU**
Level 1	100	100	100	97	95	100
Level 2	92	97	90	94	95	100
Level 3	92	92	87	91	95	94
Overall	95	96	92	94	95	98

Table D-12. % Correct Perception of Extent (Length) of Congestion on Routes: Austin Sign

North Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	98	100	97	94	90	89
Level 2	76	82	68	78	75	79
Level 3	71	72	80	75	82	70
Overall	77	80	77	79	80	75
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	98	95	87	83	88	90
Level 2	71	67	65	67	75	84
Level 3	68	69	76	73	77	73
Overall	72	72	72	71	78	80
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	98	89	97	98	86	95
Level 2	71	77	62	76	78	75
Level 3	66	65	61	74	75	71
Overall	73	73	66	78	77	77

Table D-13. % Correct Location and Type (Color) of Congestion on Routes: Austin Sign

North Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	96	94	91	95	90	87
Level 2	72	70	63	66	73	70
Level 3	64	65	71	70	76	74
Overall	77	76	76	76	79	78
Track Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	99	94	88	87	96	88
Level 2	63	60	58	65	67	78
Level 3	60	64	67	66	68	72
Overall	74	73	71	73	78	78
Track 3D Orientation						
Congestion Levels Presented	Routes Only		Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU	AUS	CS/HOU
Level 1	95	89	99	92	90	95
Level 2	64	74	63	69	76	76
Level 3	59	60	54	67	79	40
Overall	73	74	72	76	70	79

Table D-14. % Correct Recall of Travel Time Information Presented: Austin Sign

North Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	81	84	79	86
Level 2	57	76	82	85
Level 3				
Overall				
Track Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	72	90	62	81
Level 2	50	55	78	83
Level 3	33	53	78	71
Overall	52	66	73	78
Track 3D Orientation				
Congestion Levels Presented	Routes w/Travel Times		Route w/TT (Dist.)	
	AUS	CS/HOU	AUS	CS/HOU
Level 1	83	72	79	86
Level 2	58	75	83	80
Level 3	45	63	71	72
Overall	62	70	78	79

Table D-15. % Stated Diversion Choice to SH 130: Austin Sign

North Orientation

Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	67	76	30	45	87	72	50	47	80	87	43	35
Level 2	73	68	40	39	43	42	13	23	40	37	27	20
Level 3	47	28	27	22	70	60	33	23	50	53	17	13
Overall	62	57	32	35	67	58	32	31	57	59	29	23

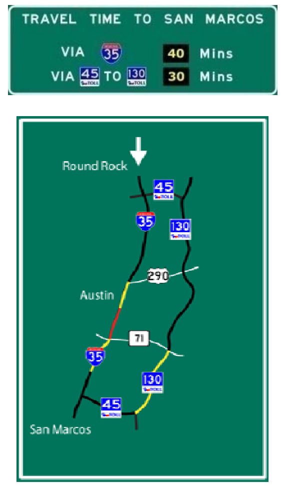
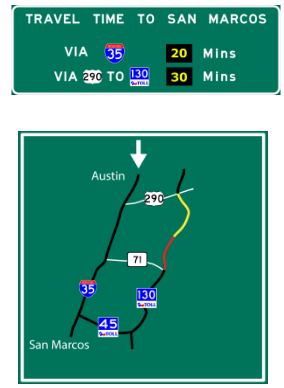
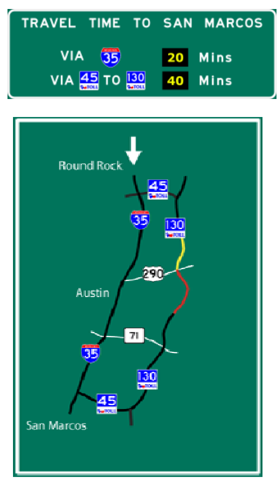
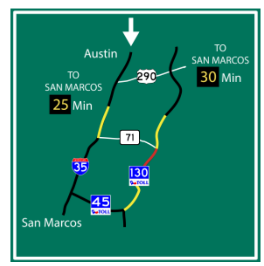
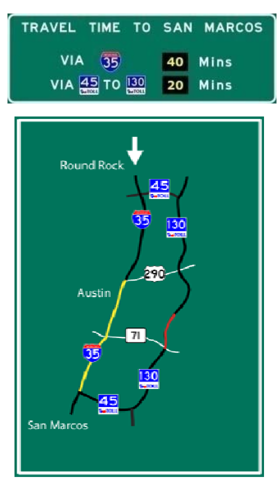
Track Orientation

Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	68	72	57	4147	73	70	40	40	63	74	32	40
Level 2	47	38	37	27	52	41	45	31	47	37	33	20
Level 3	43	43	33	27	47	39	33	13	55	66	28	38
Overall	53	51	42									

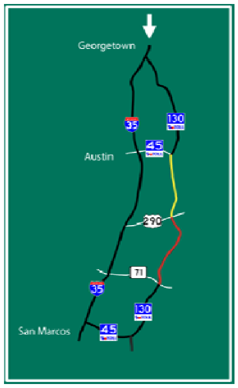
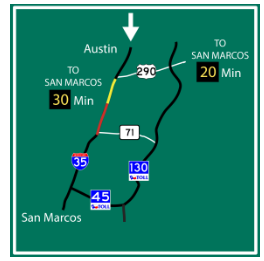
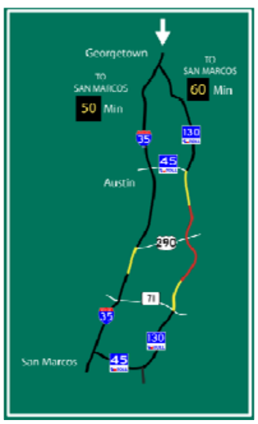
Track 3D Orientation

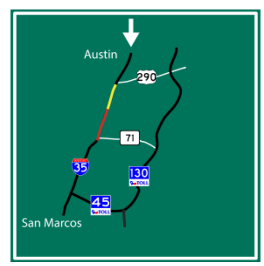
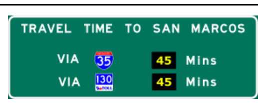
Congestion Levels Presented	Routes Only				Routes w/Travel Times				Route w/TT (Dist.)			
	No Toll		With Toll		No Toll		With Toll		No Toll		With Toll	
	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H	AUS	CS/H
Level 1	73	82	54	55	80	73	50	37	86	88	33	38
Level 2	66	72	28	38	54	58	25	36	53	43	27	23
Level 3	53	55	37	35	66	72	38	31	57	58	21	30
Overall	40	43	38	35	67	68	38	35	65	63	27	30

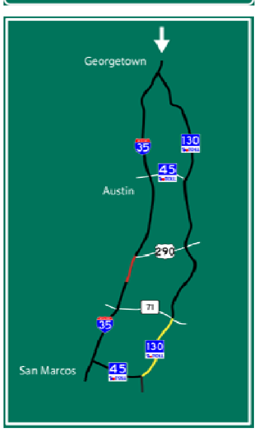
APPENDIX E: GRIP SIGN DESIGNS TESTED IN DRIVING SIMULATOR EYE-TRACKING STUDIES

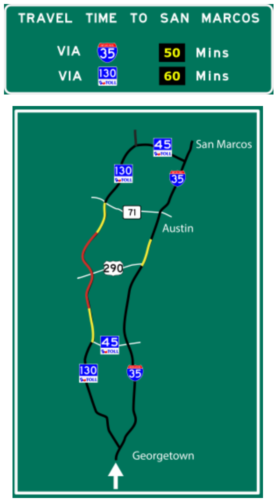
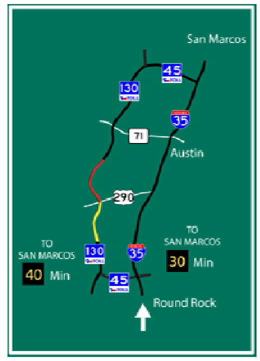
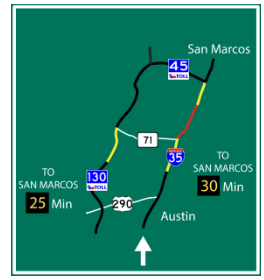
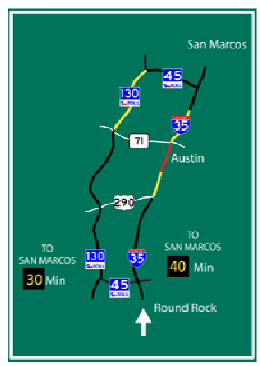
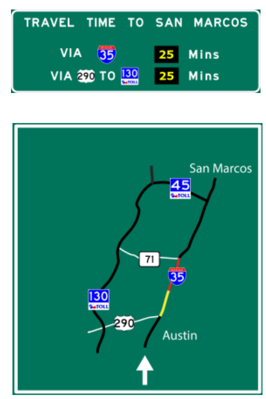
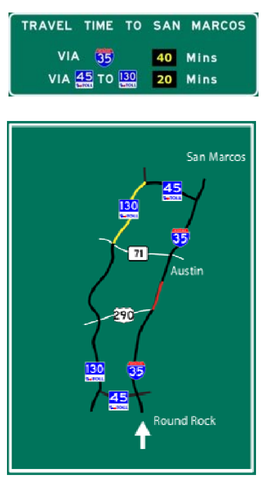
GRP A	1st Sign	2nd Sign	3rd Sign
Iteration 1			
Iteration 2			
Iteration 3 (Airport Destination)			

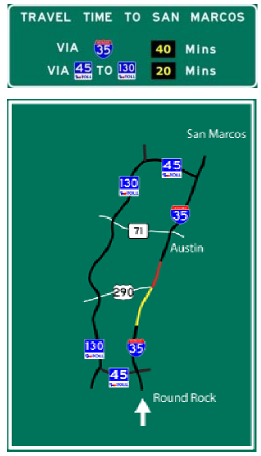
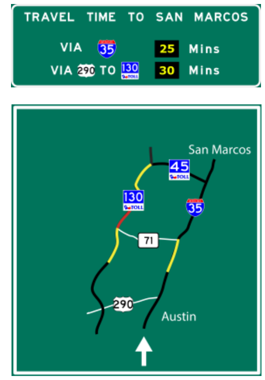
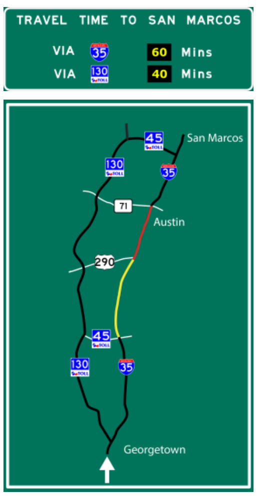
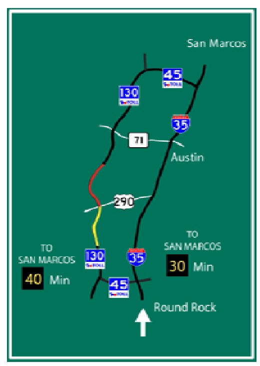
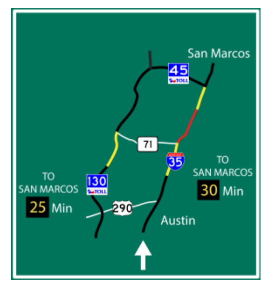
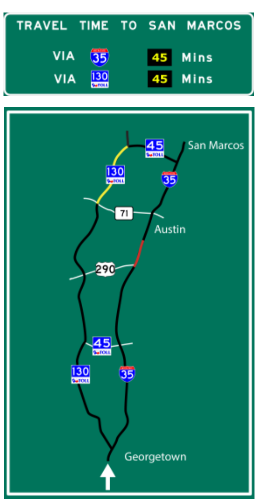
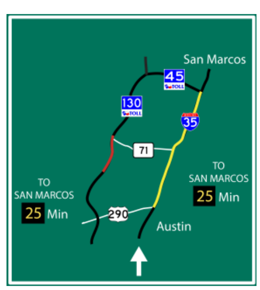
<table>
<tr><th></th><th>1st Sign</th><th>2nd Sign</th><th>3rd Sign</th></tr>
<tr><td>Iteration 4</td><td>

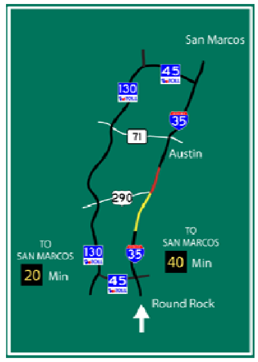
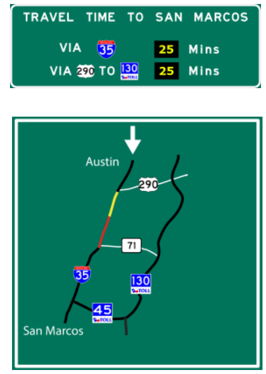
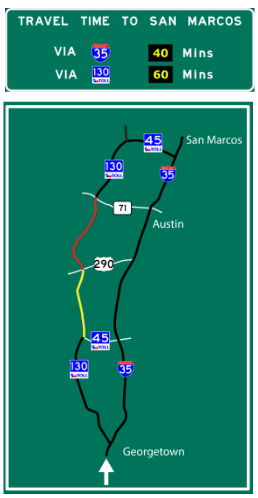
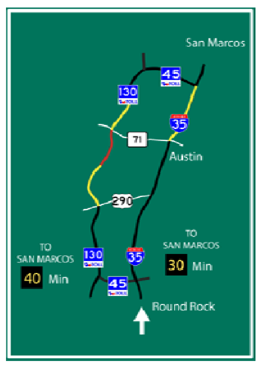
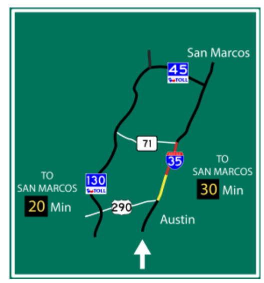
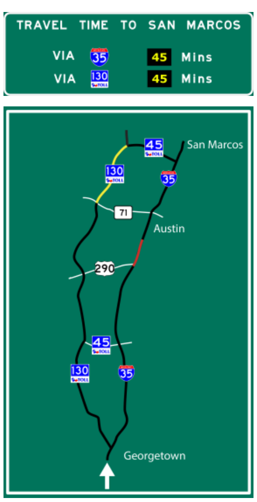
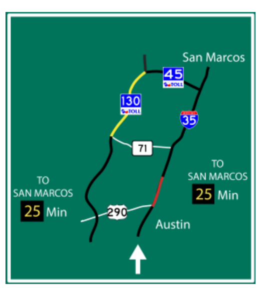

</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 5</td><td>
</td><td>
</td><td>

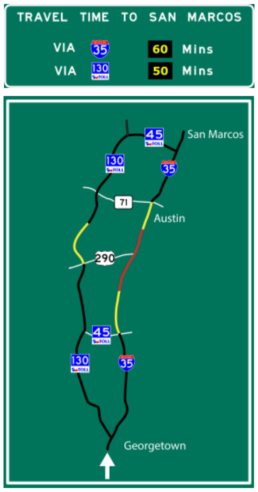
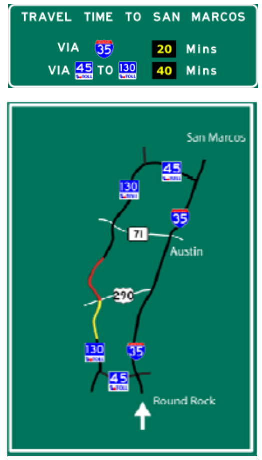
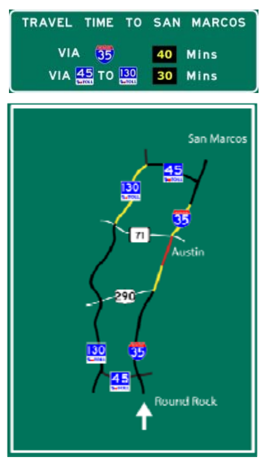
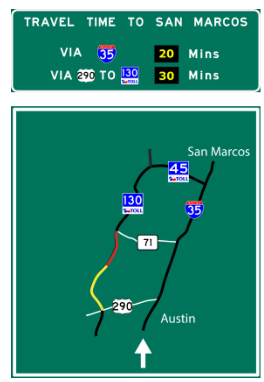
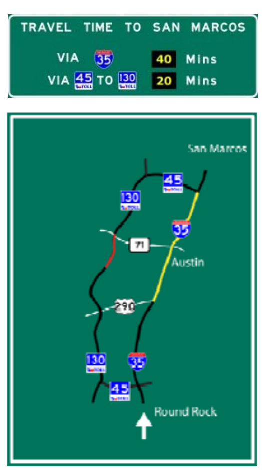

</td></tr>
<tr><td>Iteration 6 (Airport Destination)</td><td>

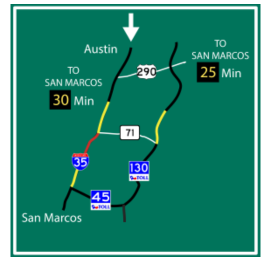
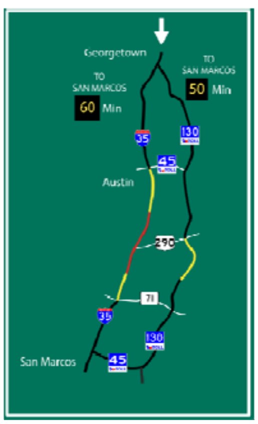
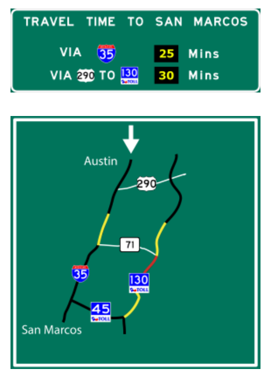
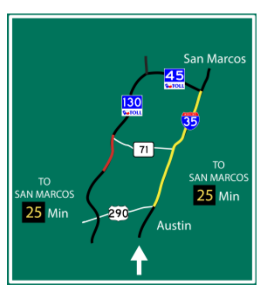

</td><td>
</td><td></td></tr>
</table>

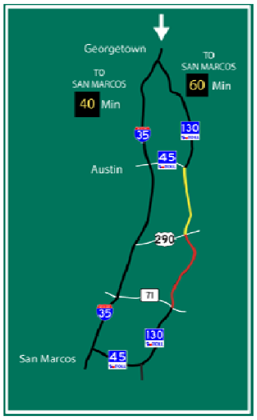
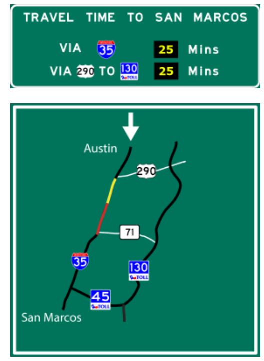
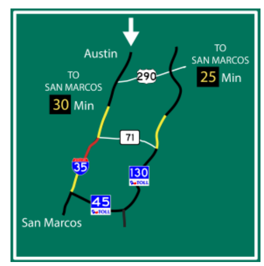
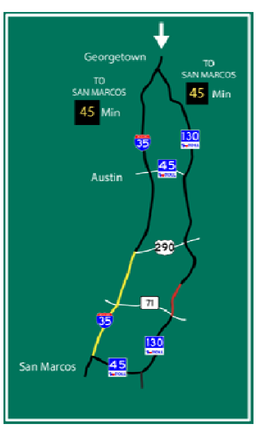
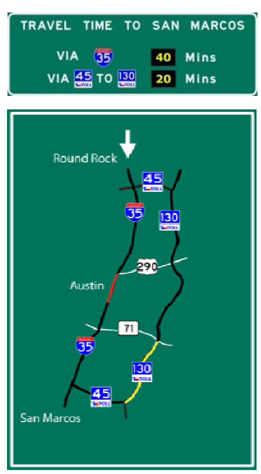
<table>
<tr><th></th><th>1st Sign</th><th>2nd Sign</th><th>3rd Sign</th></tr>
<tr><td>Iteration 7</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 8</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 9 (Airport Destination)</td><td>
</td><td>
</td><td></td></tr>
</table>

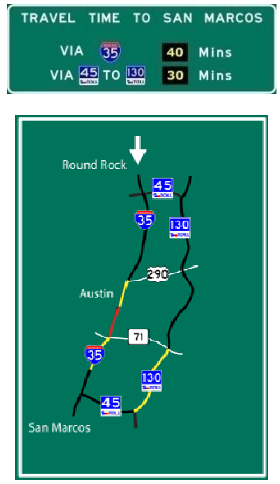
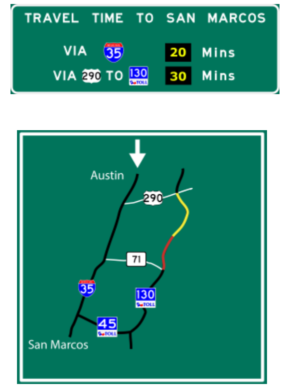
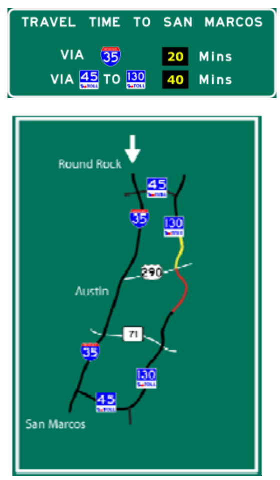
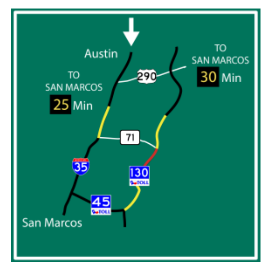
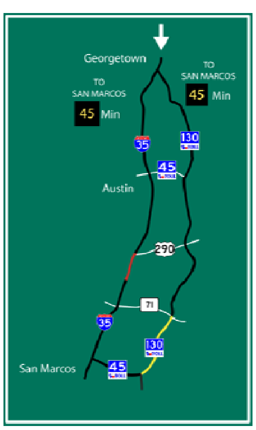
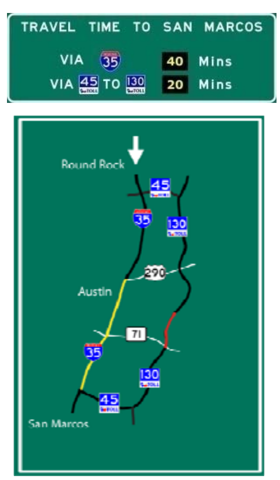
	1st Sign	2nd Sign	3rd Sign
Iteration 10			
Iteration 11			
Iteration 12 (Airport Destination)			

GRP B	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Iteration 1			
Iteration 2			
Iteration 3 (Airport Destination)			

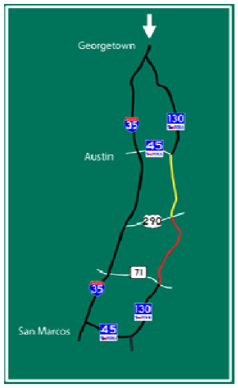
<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Iteration 4</td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Iteration 5</td>
<td></td>
<td></td>
<td></td></tr>
<tr><td>Iteration 6 (Airport Destination)</td>
<td></td>
<td></td>
<td></td></tr>
</table>

<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Iteration 7</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 8</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 9 (Airport Destination)</td><td>
</td><td>
</td><td></td></tr>
</table>

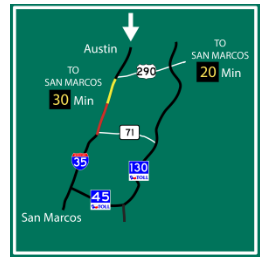
<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Iteration 10</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Iteration 11</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Iteration 12 (Airport Destination)</td>
<td>
</td>
<td>
</td>
<td></td></tr>
</table>

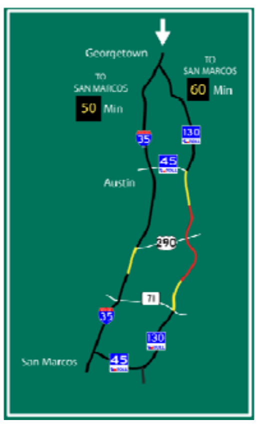
<table>
<tr><th>GRP A</th><th>1st Sign</th><th>2nd Sign</th><th>3rd Sign</th></tr>
<tr><td>Iteration 1</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 2</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Iteration 3 (Airport Destination)</td><td>
</td><td>
</td><td></td></tr>
</table>

<table>
<tr><th></th><th>1st Sign</th><th>2nd Sign</th><th>3rd Sign</th></tr>
<tr><td>Iteration 4</td><td>

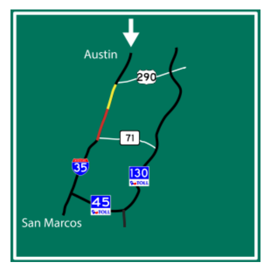
</td><td>

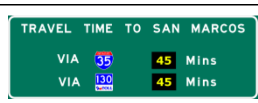

</td><td>


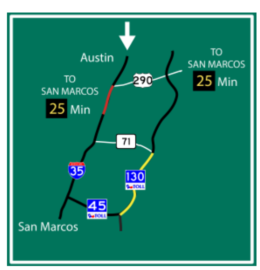
</td></tr>
<tr><td>Iteration 5</td><td>


</td><td>

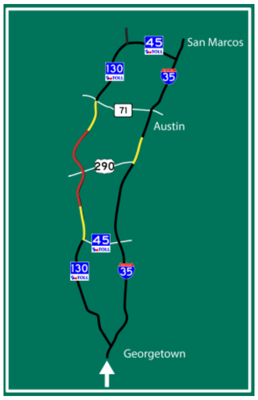
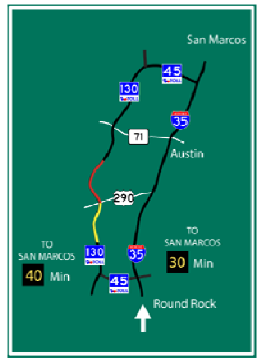
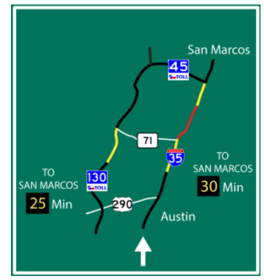
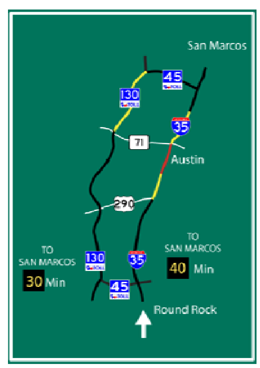
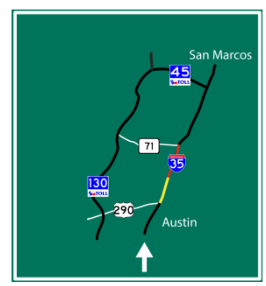
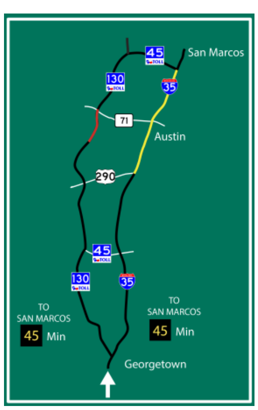
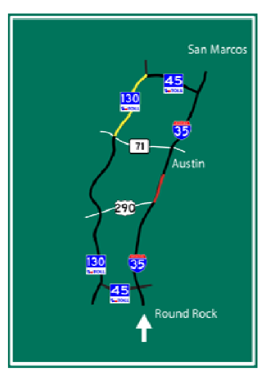

</td><td>

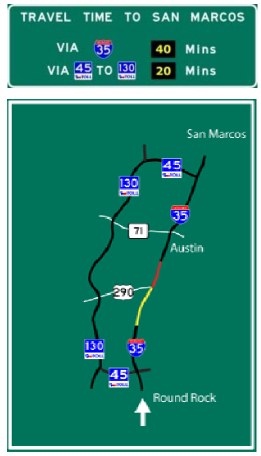
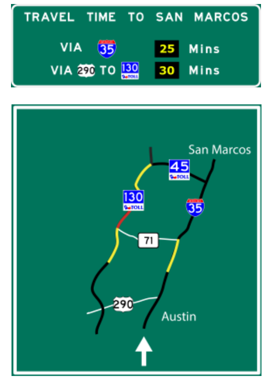
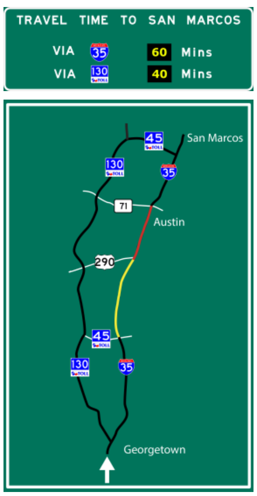
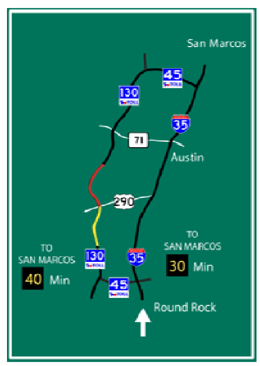
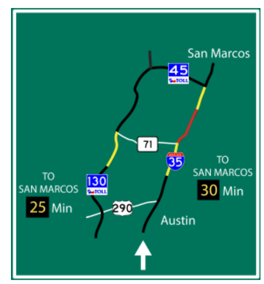
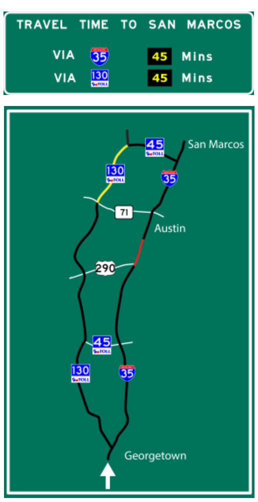
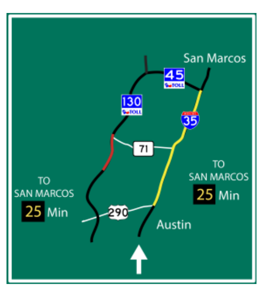



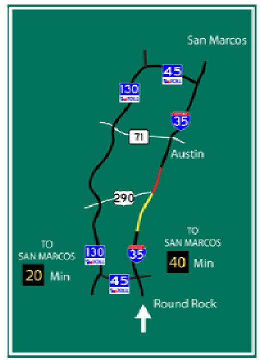
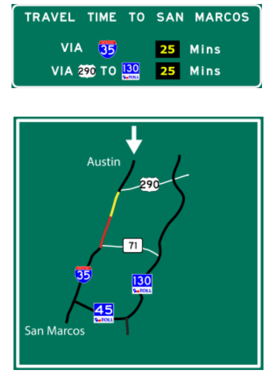
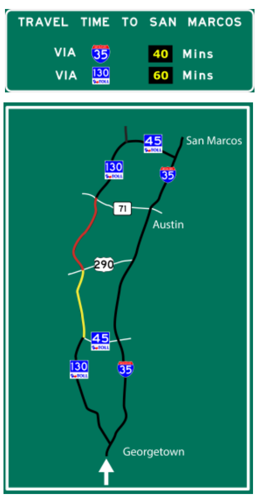
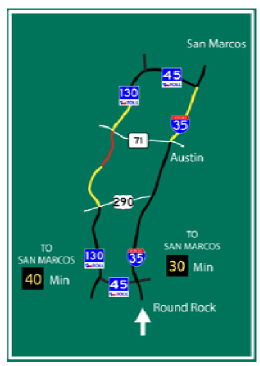
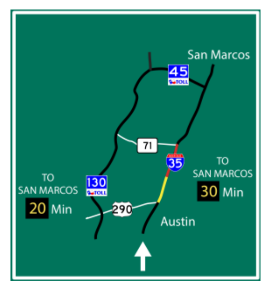
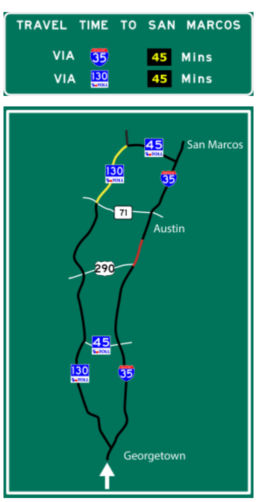
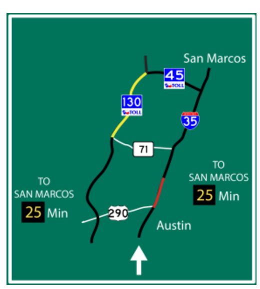
</td></tr>
<tr><td>Iteration 6 (Airport Destination)</td><td>


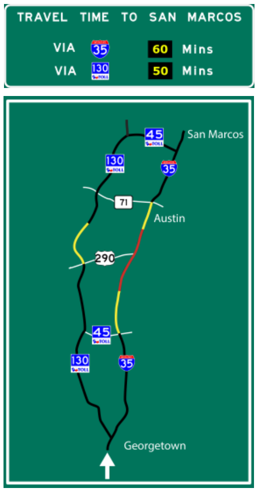
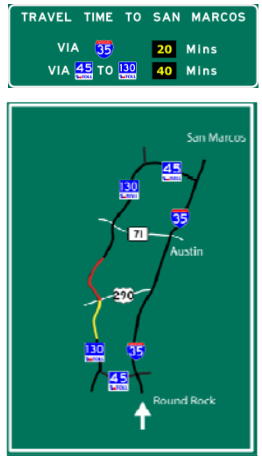
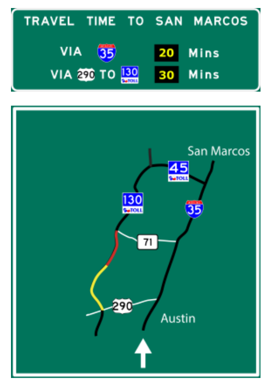
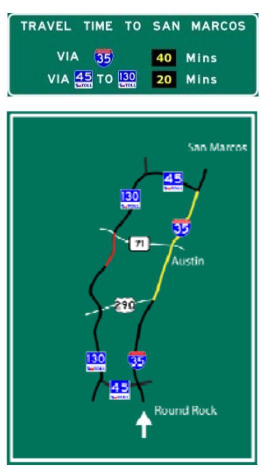
</td><td>


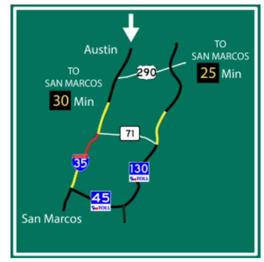
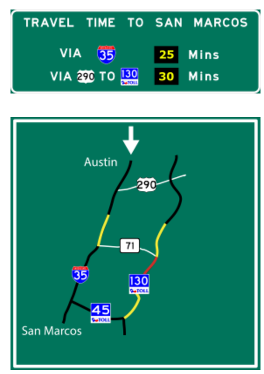
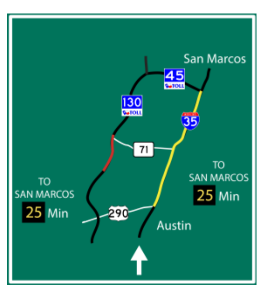
</td><td></td></tr>
</table>

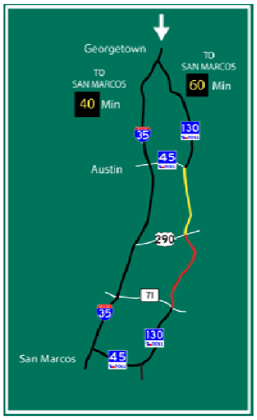
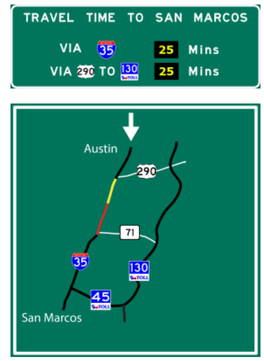
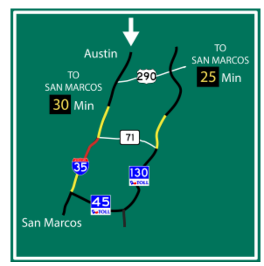
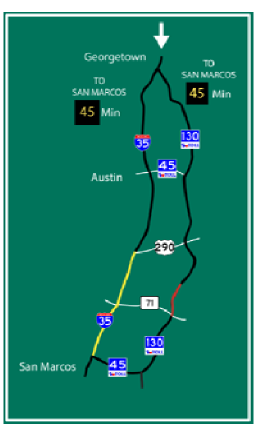
	1st Sign	2nd Sign	3rd Sign
Iteration 7	 		
Iteration 8			 
Iteration 9 (Airport Destination)		 	

<table>
<tr><th></th><th>1st Sign</th><th>2nd Sign</th><th>3rd Sign</th></tr>
<tr><td>Iteration 10</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Iteration 11</td>
<td>
</td>
<td>
</td>
<td>
</td></tr>
<tr><td>Iteration 12 (Airport Destination)</td>
<td>
</td>
<td>
</td>
<td></td></tr>
</table>

GRP B	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Iteration 1			
Iteration 2			
Iteration 3 (Airport Destination)			

	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Iteration 4			
Iteration 5			
Iteration 6 (Airport Destination)			

<table>
<tr><th></th><th>Color Map Only</th><th>Color Map + Travel Times</th><th>Map + Times Distributed</th></tr>
<tr><td>Iteration 7</td><td></td><td></td><td></td></tr>
<tr><td>Iteration 8</td><td></td><td></td><td></td></tr>
<tr><td>Iteration 9 (Airport Destination)</td><td></td><td></td><td></td></tr>
</table>

	Color Map Only	Color Map + Travel Times	Map + Times Distributed
Iteration 10			
Iteration 11			
Iteration 12 (Airport Destination)			

APPENDIX F: DRIVER SIMULATOR PARTICIPANT INSTRUCTIONS AND STUDY ANSWER FORM

Instructions

Practice (Begin reading as world is started)

The driving simulator you are in will react to your steering and pedal inputs to provide a realistic driving experience. During your drive in the simulator, please drive in a normal fashion. I can adjust your pedals at a position that is comfortable for you. You will only be using the accelerator and brake and will not need to use the clutch on the far left, nor will you use the paddles on the wheel. This means you won't be using your turn signal today. You'll notice there are 3 insets on your screens, 1 for your rearview mirror and two side mirrors. *[Adjust pedals and point out paddles or mirrors if there is any confusion]*

We will begin with a practice session to get you comfortable with driving in the simulator. You can slowly pull out onto the roadway and as you become comfortable, accelerate to a speed of 55 to 65 mph. Don't worry about driving at an exact speed limit; just do your best to try to stay in that range. *[Participant should be pulling out]*

[Once they are up to speed] How are you doing? Practice switching back and forth from the accelerator to the brake to get comfortable with the pedals. Also, practice switching lanes.

[Once you feel they are driving comfortably] Do you feel you've had enough practice? [*If no, allow them to practice a little longer*] Please slowly coast to a stop.

Introduction

For the experimental sessions, you will be driving on I-35 heading south in the direction towards San Marcos *[show them on a map].* As you drive, you will approach a large sign on your right. The sign will look like a map, and can have several components on it that can update as traffic conditions change *[show them an example sign].* The sign could tell you the travel times for taking I-35 to San Marcos, versus taking the 130 Toll Road. The map on the sign could also show colored segments indicating the levels of congestion. Red would be heavy congestion, yellow would be moderate, and a black roadway on the map would indicate free-flowing traffic.

Once you pass the sign, I will ask you some questions about what you saw and the decision you made. Always continue driving until I ask you to stop.

Remember to keep your speed between 55 to 65 mph and look out for the surrounding traffic. As in the real world, your priority is safe driving. Do you have any questions?

GRIP Simulator Study Group A

Facilitator: Please make any notes next to the sign for anything abnormal that may happen or for collisions, lane swerves or anything else that may happen while the sign is in view.

Sim Creator Model for all drives: TTIDMS.cmp

Drive: ttidms_Practice A

Practice ID: 99

Drive ID: 99

Before they start driving: (Show them the maps with the airport marked on it) Sometimes I will tell you are driving towards the airport. Here is where it is on the map. You could see a sign with a map oriented with North at the top, or North at the bottom. You will always be driving South in every scenario.

Let's get started on our first drive. Sometimes when you pass signs, you will pass two signs before I ask you which is the best route to take at that point. You will use the information from both of the signs to make your decision. That's what you'll see for these first signs. For all the drives you make today, assume the toll road is free.

(After Double signs) Which route is the best route to take, I-35 or 130?

☐ I-35 ☐ 130

Just as if driving on a real roadway, traffic conditions can change, so when you view the next sign, you may see different information from the previous sign(s). For the next sign, you will only view one sign before I ask which route you would take.

(After Single sign) Which route is the best route to take, I-35 or 130?

☐ I-35 ☐ 130

For each drive, you will pass signs at three points along the roadway before I ask you to stop. <u>This time, you are driving south on I-35 and trying to reach the airport.</u>

(After Single sign) Which route is the best route to take, I-35 or 130?

☐ I-35 ☐ 130

Please remember to drive between 55 and 65 mph and watch out for your surrounding traffic. You can now bring the car to a stop. We will now do 12 short drives just like we did. Remember traffic conditions and travel times can change from sign to sign. Also, you many view 1 or 2 signs before I ask you which route is best, so please wait until I ask before you respond. Any Questions?

Start Logging Eye tracker and scene camera! Time:_________

Drive 1: ttidms_A1 **Drive ID: A1**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

2. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

3. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

Drive 2: ttidms_A2 **Drive ID: A2**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

2. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

3. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

Drive 3: ttidms_A3 Drive ID: A3

This time, you are driving south on I-35 and trying to reach the airport.
You can begin. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

2. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

Drive 4: ttidms_A4 Drive ID: A4

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

3. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

Drive 5: ttidms_A5 **Drive ID: A5**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

3. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

****Drive 6:** ttidms_A6 **Drive ID: A6**

<u>This time, you are driving south on I-35 and trying to reach the airport.</u>
You can begin. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

Drive 7: ttidms_A7 **Drive ID: A7**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

3. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

Drive 8: ttidms_A8 **Drive ID: A8**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

3. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐ I-35 ☐ 130

****Drive 9: ttidms_A9** **Drive ID: A9**

<u>This time, you are driving south on I-35 and trying to reach the airport.</u>
You can begin. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

2. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

Drive 10: ttidms_A10 **Drive ID: A10**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

2. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

3. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

Drive 11: ttidms_A11 **Drive ID: A11**

You can begin. You are driving south on I-35 and trying to reach San Marcos. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

3. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

****Drive 12:** ttidms_A12 **Drive ID: A12**

This time, you are driving south on I-35 and trying to reach the airport.
You can begin. Again, just as if driving on a real roadway, traffic conditions can change, so when you view each sign, you may see different information from the previous sign.

1. *(Double Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

2. *(Single Sign)* Which route is the best route to take, I-35 or 130?
   ☐I-35 ☐130

Stop Logging Eye tracker and scene camera!