SHRP 2 Reliability Project L14

Effectiveness of Different Approaches to Disseminating Traveler Information on Travel Time Reliability

PREPUBLICATION DRAFT • NOT EDITED

SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

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EFFECTIVENESS OF DIFFERENT APPROACHES TO DISSEMINATING TRAVELER INFORMATION ON TRAVEL TIME RELIABILITY

PRELIMINARY DRAFT
FINAL REPORT

Prepared for
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TRANSPORTATION RESEARCH BOARD
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CONTENTS

LIST OF FIGURES ..... **ix**
LIST OF TABLES ..... **xi**
GLOSSARY OF TERMINOLOGY AND ACRONYMS ..... **xiv**
ABSTRACT ..... **xvi**
EXECUTIVE SUMMARY **1**
The Concept of Travel Time Reliability 1
Reliability Terminology – Human Factors Experiments 3
Focus Groups 4
Surveys 4
Lexicon Development 6
Utility Functions and User Behavior 6
First Utility Function Laboratory Study 6
Enhanced Utility Function Laboratory Study 7
Hypothesis #1 7
Hypothesis #2a (First Laboratory Study) 8
Hypothesis #3 8
Study Limitations 9
Potential Next Steps 9
Chapter 1 INTRODUCTION **1**
Background 2
Travel Time Reliability Information 2
Trip Planning for Habitual Trips When New to an Area 3
Pre-Trip Planning Immediately Prior to Departure 3
En Route Prior to a Route or Mode Choice Point 4
Informational Delivery Challenges 4
Scope and Purpose of Technical Report 4
Project Evolution 5
Chapter 2 LITERATURE REVIEW **9**
Travel Time Reliability Metrics 11
Importance of Travel Time Reliability 13
Travel Time Reliability and Highway Travel 13
Travel Time Reliability and Transit 15
Travel Time Reliability and Freight 15
Travel Time Information—State of the Practice 15
Real-Time Travel Time Information on Dynamic Message Signs 16
Reliability Information on DMSs 17
Reliability Information via Websites and Mobile Devices 17
Communicating Reliability Information in Non-Transportation Fields 18
Chapter 3 EXPERT INTERVIEWS **19**
Design of Telephone Interview 19
Telephone Interview Participants 19
Telephone Interview Results 19

What Is Travel Time Reliability? 20
Does Travel Time Reliability Information Have Value to the Public? 20
Does Travel Time Reliability Information Have Value to Transportation Operations Staff and Public Officials? 21
What Are the Potential Impacts of Providing Effective Travel Time Reliability Information? 21
Do You Currently Disseminate Travel Time Reliability Information? 21
What Are the Challenges to Disseminating Travel Time Reliability Information? 23
What Are the Short-Term and Long-Term Goals Regarding the Dissemination of Travel Time Reliability Information? 24
Chapter 4 TECHNOLOGY AND INNOVATION SCAN 25
Introduction and Context Setting 25
Underlying Technology Trends: Better Data to Come 26
Toll Tag Readers 27
License Plate Matching 28
Cell Phone Triangulation Using Towers 28
Bluetooth Tracking 29
GPS-Enabled Devices 30
Future Technologies 31
Synopsis of Underlying Technologies 32
Innovative Media for Traveler Information Users 33
Personal Navigation Devices 34
Applications for GPS-Enabled Mobile Devices 35
Crowdsourced Applications for Traveler Information 36
In-Vehicle Systems 38
Mobile Applications for Public Transit 38
Synopsis of Innovative Media 39
Traveler Information Market Participants 40
INRIX 40
Nokia/NAVTEQ 41
TomTom 41
Clear Channel 41
Westwood One 42
Google 42
Synopsis of Market Participants 42
Outlook for Traveler information, and Specifically Reliability Information 43
Considering Safety 45
Considering What Reliability Information Is Needed 45
Looking to the Future 46
Chapter 5 DEVELOPED AVENUES OF INVESTIGATION 49
Key Research Issues 49
Do Travelers Want This information? 49
Do Travelers Comprehend the Basic Idea of Reliability, as Separate from Real-Time Travel Time Information? 49
Do Travelers Comprehend the Variability Inherent in Reliability Information? 49
Do Travelers Comprehend the Average Travel Time? 50

What Terms and Displays Can Be Used to Best Communicate Average, Variability, and Reliability? 50
Can Travelers Assign a Dollar Cost Value to Reliability Information, or Incremental Changes in Reliability? 50
Is There a Role for Reliability Information in Real-Time Systems? 50
Do Travelers Want or Need Reliability Information En Route, or Is It Mainly a Pre-Trip Planning Tool? 50
Does a Traveler's Desire for This Information Change as a Function of Trip Purpose, Route, and Constraint? 50
Can Travelers Safely Use an En-Route In-Vehicle System? 51
Do Travelers Want to Actively Seek This Information (Pull) or Have It Sent to Them Automatically According to a Custom Trip Pattern That Is User-Entered (Push)? 51
How Can Multiple Data Sources and Factors Be Displayed for Reliability Information? 51
Will Travelers Change Their Habitual Time of Departure and Route Based on a Travel Time Reliability Information System? 51
Chapter 6 FOCUS GROUPS 53
Script Development 53
Discussion Guide Development Phase 1 53
Discussion Guide Development Phase 2 54
Discussion Guide Development Phase 3 54
Discussion Guide Development Phase 4 56
Participants 57
Results Summary 57
Lexicon Information 59
Chapter 7 USABILITY SURVEYS 61
Study Locations 61
Study Participants 62
Computer Survey 62
Influence of Focus Group Results 62
Survey Development 63
Research Method 68
Results 71
Key Findings 95
Chapter 8 OPEN-ENDED SURVEY 99
Research Method 99
Survey Design 99
Participants 101
Procedure 102
Results 104
Use of Buffer Time in Total Trip Time Estimation 104
Similar Meanings and Preference of Buffer Terms 110
Use of Total Trip Time Estimate 112
Similar Meanings and Preference of Total Trip Time Estimate Terms 116
Preference of Travel Time Uncertainty Terms 118
Similar Meanings and Preference of Normal Trip Time Terms 118

Conclusions 119
Buffer Time Terms 119
Total Trip Time Estimate Terms 120
Comparison of Travel Time Uncertainty Information 121
Comprehension of Terms for Normal Travel Time 121
Recommendations 121
Chapter 9 TRAVEL BEHAVIOR LABORATORY EXPERIMENT 123
Background 124
Literature Review 125
Experiment Plan 127
Pre- and Post-Experiment Survey 129
Experiment Description 130
Pre- and Post-Experiment Survey Findings 134
Pre-Experiment Survey, Sample Statistics 136
Post-Experiment Survey 142
Experimental Results 145
Confidence in On-Time Arrival Was Tempered with Reliability Information 146
Reliability Information Reduced Pre-Trip and En-Route Trip Stress for Unfamiliar Trips 146
Willingness to Pay for Traveler Information at Beginning of Trip Reflected Value for Reliability Information 147
Traveler Information Provided Trip Serenity Even When Trip Outcome Could Not Be Improved 148
Application of Results in Travel Utility Functions 150
Conclusions and Next Steps 151
Summary of Findings by Experimental Hypothesis 152
Chapter 10 ENHANCED LABORATORY EXPERIMENT 155
Experiment Scope and Hypotheses 156
Experimental Plan 157
Pre-Experiment Survey 161
Experiment #1 Description 161
Experiment #2 Description 163
Pre-Experiment Survey Findings 164
Demographic and Trip-Making Characteristics 164
Traveler Information and Road Use Characteristics 165
Importance and Definition of Arriving on Time 166
Travel Times and Trip Variability 167
Valuation of Reliability and Serenity 168
Experiment #1 Findings—Effectiveness and Valuation of Reliability Terms for Unfamiliar Trips 169
Pairwise Comparisons for Reliability Terms against the Baseline Pre-Trip Radio Information 170
Comparison of Equivalent Reliability Information Pairs 184
Experiment #2 Findings—Reliability Data Expedites Learning Curve for Trip Familiarity 189
Post-Experiment Survey Findings 192

Findings from Experiment #1 Post-Survey—Rating of Reliability Form Complexity and Usefulness 193
Findings from Houston-Chicago Post-Experiment Survey 194
Conclusions and Looking Forward 196
Chapter 11 LEXICON DEVELOPMENT 199
Frequently Used Terms 199
Terminology Assessment 200
95th Percentile Travel Time 201
Arrival Time 202
Average Travel Time 203
Buffer Index 204
Buffer Time 204
Delay Time 204
Departure Time 205
Free-Flow Travel Time 205
Peak Travel Time 205
Planning Time 205
Planning Time Index 205
Recommended Departure Time 206
Recommended Route 206
Reliability 206
Total Trip Time 207
Travel Time Savings 207
Travel Time Range 208
Trend Information 208
Lexicon Format 208
Limitations of Lexicon Information 209
Travel Time Reliability Lexicon 210
Chapter 12 FINAL REMARKS 219
Study Limitations 219
Key Findings on Travel Time Reliability Terminology 220
Key Study Observations On User Behavior 220
Hypothesis 1 220
Hypothesis 2a 221
Hypothesis 2b 222
Hypothesis 3 222
Potential Next Steps 223
Graphical Formats for Reliability Information 223
Reliability Information in the Context of More Complex Trip Planning 223
Mechanisms of Reliability Information Under-Valuation by Users 223
Predictive Reliability Information and the Experienced Traveler 223
Impact of Reliability Information on Broader Range of Travel-Related Choices 224
Monetization of Reliability Information Impacts 224
Traveler Responses to Increased Travel Time Reliability 224
Use of Reliability Information by the Freight Industry 225
Reliability Information in Public Transit 225

Combining Real-time and Reliability Information 225
Field Tests of Reliability Terminology 226
REFERENCES..... 227

Appendix A GENERAL LITERATURE REVIEW A-1
Appendix B TELEPHONE INTERVIEW GUIDE FOR EXPERT INTERVIEWS.....B-1
Appendix C DETAILED FOCUS GROUP SUMMARY.....C-1
Appendix D COMPUTER SURVEY QUESTIONS AND RESULTS TABLES D-1
Appendix E OPEN-ENDED SURVEY MATERIALS E-1
Appendix F TRAVEL BEHAVIOR LABORATORY EXPERIMENT DOCUMENTATION..... F-1
Appendix G SUPPLEMENTAL FIGURES FROM TRAVEL BEHAVIOR LABORATORY EXPERIMENT PRE-SURVEY G-1
Appendix H ENHANCED LABORATORY EXPERIMENT DOCUMENTATION H-1

LIST OF FIGURES

Figure 1-1. Seven Factors Contributing to Non-recurring Congestion. (Source: SHRP 2 Reliability Program).....1
Figure 1-2. SHRP 2 L14 research project activities. 5
Figure 1-3. SHRP 2 L14 project overview. 7
Figure 1-4. SHRP 2 L14 project task interrelationships. 8
Figure 2-1. Average travel time used by professionals (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). 9
Figure 2-2. Traveler travel time experiences (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). 10
Figure 2-3. Commuters plan trips based on the worst days, not the average day (Cambridge Systematics Inc. with Texas Transportation Institute, 2005).....11
Figure 2-4. Reliability measures capture the benefits of traffic management (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). 14
Figure 6-1. Shipping time graphic. 55
Figure 6-2. Monday travel time example.....55
Figure 7-1. Button box used for driver survey participant response entry. 70
Figure 7-2. Question 5 responses by arrival time flexibility. 73
Figure 7-3. Combined responses to Questions 15 and 16.....85
Figure 7-4. Illustration of responses to Question 18: Planning time terms. 88
Figure 7-5. Illustration of Question 19 responses: Buffer time terms. 90
Figure 8-1. Cumulative distribution of trip times that would be allowed for 70-minute trip. 107
Figure 8-2. Cumulative distribution of trip times that would be allowed for 50-minute trip. 110
Figure 8-3. Cumulative distribution of trip times that would be allowed for 55-minute trip. 114
Figure 8-4. Cumulative distribution of trip times that would be allowed for 45-minute trip. 116
Figure 9-1. Interface view when participants were seated for the experiment. 128
Figure 9-2. Road network for trip simulation. 133
Figure 9-3. Types of roads participants used for specific trip types. 137
Figure 9-4. Participants' on-time arrival importance by trip purpose. 138
Figure 9-5. Average trip duration by trip type. 139
Figure 9-6. Capturing trip time variability for participants' trips. 140
Figure 9-7. Participants vary in their definition of a late arrival. 140
Figure 9-8. Willingness to pay for guaranteed travel time. 141
Figure 9-9. Willingness to pay for late-arrival knowledge. 142
Figure 9-10. Ratings of traveler information usefulness at beginning of experiment. 143
Figure 9-11. Ratings of traveler information usefulness at end of experiment. 143
Figure 9-12. Participants' frequency for seeking traffic information for the work trip. 144
Figure 9-13. Media used in acquiring traffic information for work trips. 144
Figure 9-14. On-time arrival confidence trend during the trip. 147
Figure 9-15. Trend in willingness to pay (at beginning of trip) across simulation days. 148

Figure 10-1. Beginning screenshot for experiment #1 (on left) and #2 (on right).....159
Figure 10-2. Screenshots of trip departure decisions and travel along route.....160
Figure 10-3. Rank ordering of reliability terms based on information usefulness. 196

LIST OF TABLES

Table 2-1. Recommended reliability performance metrics from SHRP 2 Project L03, *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies* (Cambridge Systematics Inc., 2007). 13
Table 5-1. Key research issues and tasks. 52
Table 6-1. Final focus group discussion guide topics. 57
Table 6-2. Focus group participant demographics. 57
Table 7-1. Usability study participants. 62
Table 7-2. Example terminology from reviewed websites. 65
Table 7-3. Computer survey questions outline. 68
Table 7-4. Experimental design for those survey questions that varied across version. 68
Table 7-5. Gender and age of participants by city. 69
Table 7-6. Questions 1-4: Trip descriptions and corresponding reliability concepts. 71
Table 7-7. Questions 1-4 response summary. 72
Table 7-8. Question 5 responses by average commute time to work. 74
Table 7-9. Response choices for Question 8 based on Question 7. 77
Table 7-10. Question 9 responses by version. 79
Table 7-11. Question 10 responses based on term viewed in Question 9. 81
Table 7-12. Experimental design for Questions 15-16. 84
Table 7-13. Percent responses for “most” or “nearly all” for Questions 15 and 16. 86
Table 7-14. Responses to Question 18. 88
Table 7-15. Question 19 visuals and responses by version. 89
Table 7-16. Responses to Question 20 as a function of response to Questions 18 and 19. 91
Table 7-17. Responses to Question 28 as a function of response to Question 27. 94
Table 8-1. Experimental design for open-ended survey. 101
Table 8-2. Number of open-ended survey participants per city. 101
Table 8-3. Participant use of buffer term when planning for a trip. 105
Table 8-4. Distribution of trip times that would be allowed for 70-minute trip. 106
Table 8-5. Participant confidence in arriving at destination in 70 minutes or less. 108
Table 8-6. Distribution of trip times that would be allowed for 50-minute trip. 109
Table 8-7. Participant’s assessment of similar meanings of buffer terms. 111
Table 8-8. Participants’ preference for buffer terms. 111
Table 8-9. Participant use of total trip time estimate term when planning for a trip. 113
Table 8-10. Distribution of trip times that would be allowed for 55-minute trip. 114
Table 8-11. Participant confidence in arriving at destination in 55 minutes or less. 115
Table 8-12. Distribution of trip times that would be allowed for 45-minute trip. 116
Table 8-13. Participants’ assessment of similar meanings of total trip time estimate terms. 117
Table 8-14. Participants’ preference for total trip time estimate terms. 118
Table 8-15. Participants’ assessment of similar meanings of normal travel time terms. 119
Table 8-16. Participants’ preference for normal travel time terms. 119
Table 9-1. Responses by city and type of information received in commute experiment. 127
Table 9-2. Information acquired from experiment. 129
Table 9-3. Description of simulated commutes to work. 134

Table 9-4. Non-event day travel time profiles used in experiment.....134
Table 9-5. Event day travel time profiles used in experiment. 134
Table 9-6. Average threshold for late arrival. 135
Table 9-7. Willingness to pay for trip reliability and information on late arrival. 136
Table 9-8. Aggregate departure decisions for groups with different traveler information. 145
Table 9-9. Schedule offset costs based on experiment framework. 146
Table 9-10. Value of late-arrival information, expanded sample size. 149
Table 9-11. Value of late-arrival information, specific paired comparison. 150
Table 9-12. Application of Small et al. utility framework. 150
Table 10-1. Experiment layout and sample size using two distinct experiments. 158
Table 10-2. Linking reliability information type with simulated city and departure options. 162
Table 10-3. Average threshold for late arrival by on-time arrival importance and trip purpose. 167
Table 10-4. Average willingness to pay for reliable travel and late-arrival knowledge by trip purpose based on replies to pre-experiment survey. 169
Table 10-5. Trip decisions, outcomes, and valuations of textual 95th percentile reliability data compared to the baseline radio information. 173
Table 10-6. Trip decisions, outcomes, and valuations of textual average and 95th percentile reliability data compared to the baseline radio information. 174
Table 10-7. Trip decisions, outcomes, and valuations of textual 20th percentile, average, and 95th percentile reliability data compared to the baseline radio information. 176
Table 10-8. Trip decisions, outcomes, and valuations of reliability signposting compared to the baseline radio information. 178
Table 10-9. Trip decisions, outcomes, and valuations of graphic average and 95th percentile reliability information compared to the baseline radio information. 179
Table 10-10. Trip decisions, outcomes, and valuations of graphic 20th percentile, average, and 95th percentile reliability information compared to the baseline radio information. 181
Table 10-11. Trip decisions, outcomes, and valuations of auditory 95th percentile reliability information compared to the baseline radio information. 183
Table 10-12. Trip decisions, outcomes, and valuations of textual versus auditory 95th percentile reliability information. 185
Table 10-13. Trip decisions, outcomes, and valuations of textual versus graphic average and 95th percentile reliability information. 187
Table 10-14. Trip decisions, outcomes, and valuations of textual versus graphic 20th percentile, average, and 95th percentile reliability information. 189
Table 11-1. Proposed travel time terms/concepts to be included in lexicon. 201
Table 11-2. Lexicon format. 209
Table 11-3. Travel time reliability lexicon for *95th PERCENTILE*. 211
Table 11-4. Travel time reliability lexicon for *ARRIVAL TIME*. 212
Table 11-5. Travel time reliability lexicon for *AVERAGE TRAVEL TIME*. 213
Table 11-6. Travel time reliability lexicon for *BUFFER TIME*. 214
Table 11-7. Travel time reliability lexicon for *DEPARTURE TIME*. 215
Table 11-8. Travel time reliability lexicon for *RECOMMENDED DEPARTURE TIME*. 216
Table 11-9. Travel time reliability lexicon for *RECOMMENDED ROUTE*. 217

Table 11-10. Travel time reliability lexicon for *RELIABILITY*. 218

GLOSSARY OF TERMINOLOGY AND ACRONYMS

Term	Definition
95th Percentile Trip Time	Time identified for a specific travel route that indicates how bad delay will be on the heaviest travel days; 95 percent of trips along this route will take no more than this time to complete
Average Trip Time	Time identified for a specific travel route that is the average/statistical mean of all recorded trip times along the route over a specified time period (e.g. over a month or a year)
Buffer Index (BI), mean-based	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time
Buffer Index, median-based	The difference between the 95th percentile travel time and the median travel time, normalized by the median travel time
Buffer Time	The time that is calculated by multiplying the average trip time for a specific travel route by the buffer index
Failure/On-Time Measures, median-based	Percent of trips with travel times < (1.10, 1.25) * median travel time
Failure/On-Time Measures, speed-based[1]	Percent of trips with travel times < (50 mph, 45 mph, 30 mph)
Planning Time Indices	95th, 90th, and 80th percentile travel times divided by the free-flow travel time
Skew Statistic	The ratio of (90th percentile travel time minus the median) divided by (the median minus the 10th percentile)
Misery Index (modified)	The average of the top 5 percent worst travel times divided by the free-flow travel time
Utility Function	A measure of absolute or relative satisfaction or dissatisfaction, expressed as value or cost per defined unit

Acronym	Definition
AVL	Automatic vehicle location
CMS	Changeable message sign
DMS	Dynamic message sign
DSRC	Dedicated short range communications
ETA	Estimated time of arrival
FHWA	Federal Highway Administration
GPS	Global positioning system
GRIP	Graphical route information panel
HOT	High-occupancy/toll (lane or facility)
HOV	High-occupancy vehicle (lane or facility)
HUD	Head-up display
MUTCD	*Manual on Uniform Traffic Control Devices*
OBE	On-board equipment
PDA	Personal digital assistant
PND	Personal navigation device
RITA	Research and Innovative Technology Administration
RSE	Roadside equipment
SHRP 2	Strategic Highway Research Program 2
TMC	Traffic management center
TTI	Texas A&M Transportation Institute
VMS	Variable message sign

ABSTRACT

The second Strategic Highway Research Program (SHRP 2) Reliability Program aims to improve trip time reliability by reducing the frequency and effects of events that cause travel times to fluctuate in an unpredictable manner. Non-recurrent events such as crashes, work zones, special events, and weather disrupt normal traffic flow by causing reduced speeds, lane closures, and erratic driving maneuvers. The goals of the SHRP 2 Reliability Program focus on travel time variation—that characteristic of the transportation system that means the driver's current trip will take much longer than normally expected. For example, a driver must allow an hour to make a trip that normally takes 30 minutes. This transportation system characteristic is important for travelers and shippers and is a component of the congestion problem in which transportation agencies can make significant and measurable safety and traffic operational improvements even as travel demand grows. Reducing delay related to reliability has the added benefit of reducing primary and secondary crashes, vehicle emissions, and fuel use, and yields other benefits.

A key component of addressing the reliability issue related to urban mobility is conveying reliability-related information to system users so that they can informed decisions about their travel. This report documents the research conducted as part of SHRP 2 L14, *Effectiveness of Different Approaches to Disseminating Traveler Information on Travel Time Reliability.* A literature review was conducted to document existing practices and lessons learned regarding the communication of both travel- and non-travel-related reliability information. Expert interviews and a technology and innovation scan further examined the state of the practice in communicating information to travelers. A series of human factors experiments, including focus groups and surveys, assessed travelers' comprehension of and preferences for various reliability-related words and phrases. Finally, two laboratory experiments developed a utility function for travel time reliability information by observing participants' use of reliability information during simulated commute trips and soliciting their opinions regarding the monetary value of that information. The lexicon developed as the final task of this project is intended to provide recommendations on appropriate ways to introduce and provide travel time reliability information to travelers so that such information is most likely to be understood and used by travelers to influence their travel choices, while not presenting a safety hazard in the process.

EXECUTIVE SUMMARY

The second Strategic Highway Research Program (SHRP 2) Reliability Program aims to improve trip time reliability by reducing the frequency and effects of events that cause travel times to fluctuate in an unpredictable manner. Congestion caused by unreliable, or nonrecurring, events is roughly as large as congestion caused by routine bottlenecks (Cambridge Systematics Inc., 2003). Nonrecurring events such as crashes, work zones, special events, and weather disrupt normal traffic flow by causing reduced speeds, lane closures, and erratic driving maneuvers. The goals of the SHRP 2 Reliability Program focus on travel time variation—that characteristic of the transportation system that means the driver's current trip will take much longer than normally expected. For example, a driver must allow an hour to make a trip that normally takes 30 minutes. This transportation system characteristic is important for travelers and shippers and is a component of the congestion problem in which transportation agencies can make significant and measurable gains even as travel demand grows. Reducing delay related to reliability has the added benefit of reducing primary and secondary crashes, vehicle emissions, and fuel use, and yields other benefits.

Travel time reliability information includes static data about traffic speeds or trip times that capture historic variations from day to day and enable individuals to understand the level of variation in traffic. Unlike real-time travel time information, which provides a current snapshot of trip conditions and travel time, reliability information can be used to plan and budget in advance for a trip.

A key component to addressing the reliability issue related to urban mobility is conveying this reliability-related information to system users so that they can make informed decisions about their travel. The challenge for transportation professionals lies in selecting the best means of conveying that information so that it is usable and effective. The goal of this research project was to examine what combination of words, numbers, and other features of user information messages, along with communications methods and technology platforms, best communicate information about travel time and reliability to travelers so that they can make optimal travel choices from their point of view. Such choices include whether to take a trip or not, departure time, mode choice, and route choice.

THE CONCEPT OF TRAVEL TIME RELIABILITY

Past research related to travel time reliability has, for the most part, examined how people use their own experience to judge travel time reliability with regard to route choice or time of departure. Researchers have not specifically examined *when* people prefer to have this information or *how* they will use it. Many stated preference surveys allow users unlimited time to think about all of the possibilities. In an unpressured situation, the message content and display are not as critical as they would be in a time-pressured situation immediately prior to a departure or actually en route in the vehicle. These factors affect the optimal display, sequence of inputs required, and display of search results. It was these factors that were the main focus of this project.

Transportation professionals most commonly discuss travel time reliability in terms of historical average travel times calculated over periods of a year or longer, as shown in Figure 1- Executive Summary. A typical definition for travel time reliability would be the following:

> *The consistency or dependability in travel times, as measured from day to day and/or across different times of the day.*

However, most travelers do not experience the same average travel time each day. Travelers experience and remember something much different than the average throughout a year of commutes (Figure 2- Executive Summary). Their travel times vary greatly from day to day, and they remember those few bad days they suffered through unexpected increases in travel times. Research within the profession has shown that travel time reliability information can provide transportation system users with a more complete picture of the expected travel time along a particular route. The challenge is how to communicate that reliability information effectively to system so that they understand it clearly.

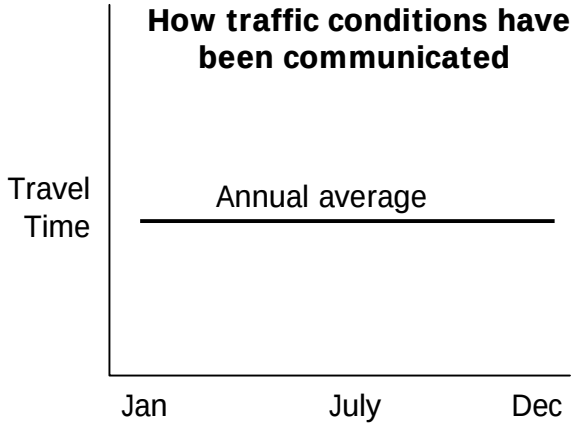


Figure ES-1. Average travel time used by professionals (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

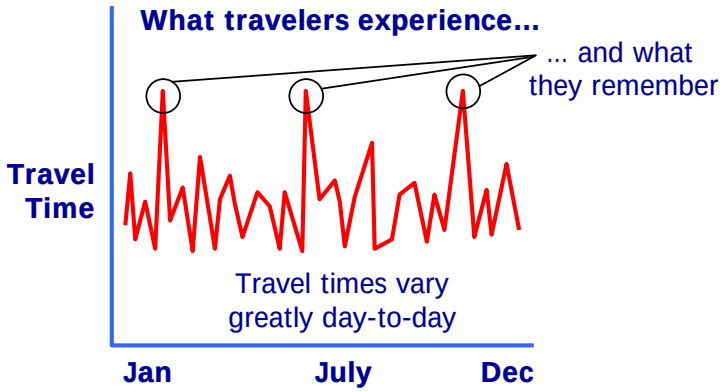


Figure ES-2. Traveler travel time experiences (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

To date, the primary travel time information conveyed to travelers, either pre-trip or en route, is real-time information. Real-time travel time messages have been in use in the U.S. for well over a decade, ever since traffic monitoring and integration systems became reliable. The most commonly used media for these messages are DMSs and transportation agency websites, but the widespread use of cell phones and other mobile devices is prompting a growing number of transportation agencies and providers to offer real-time updates on transportation conditions and options via e-mails, text messages, and Twitter feeds.

Real-time travel time estimates are most often provided for a particular roadway segment or a particular transit route based on recent travel speeds or conditions. Some agencies also provide travel time comparisons among two or more routes/roadways to help travelers make decisions about the route or transportation mode to take. Most recent and most rare are the information sources that advise travelers about travel time reliability as described in the preceding sections—the likelihood that the estimated travel time for a particular trip or trip segment will be dependable.

Given the complexity of the travel time reliability concept and the myriad of ways this information may impact system users, system operators, and service providers, the project team identified several potential issues that can be addressed in further detail and refined through additional investigation. These issues are discussed in the following sections.

RELIABILITY TERMINOLOGY – HUMAN FACTORS EXPERIMENTS

This project developed a lexicon to provide information on appropriate ways to introduce and provide travel time reliability information to travelers so that such information would most likely be understood and used by the travelers to influence their travel choices, while not presenting a safety hazard in the process. This document was developed based on an increasingly detailed series of human factors experiments and the development of a utility function, with input from a literature review, expert interviews, and a technology and innovation scan, all which provided key information and insight into how individuals comprehend and interpret travel time reliability information, how they use that information to make trip decisions, and how reliability terms can

be phrased to reach the highest percentage of travelers so that their travel decisions yield some benefit to them.

Focus Groups

The first human factors study was a series of focus groups in various cities across the United States, which included discussion of recurring and non-recurring conditions that affect travel times on roadways, of a hypothetical traveler information system that would provide information on travel time reliability, and of words and phrases that the participants used and preferred to describe travel time and reliability concepts.

Focus group participants used words such as *possibly, probably, chance,* or *likely* to describe variability at a certain time of day. Generally, they preferred for those words to have a descriptor in front such a "X% chance" or "highly likely" to make the term less general. When speaking about the additional time added to a trip to ensure on-time arrival, common terminology varied greatly with no real consensus. For example, terms like *additional time, traffic time, leeway, driving time, just in case time, fluff time,* and *additional drive time* all came up as possible descriptors. Unprompted, participants used the words or phrases *cushion, allow an additional X minutes for variables, tack on extra,* and *extra time* during discussion. Several terms came up unprompted in the discussion sessions. Several terms specifically addressed reliability information. Those included *reliability factors, plus or minus 10%, 9 out of 10 days.* Those that addressed a range of time were *approximately, usually, window of time instead of exact time, give or take, variation, cushion, buffer, time frame that's certain, average* and *depends.*

Surveys

A computer-based survey tested participants' comprehension of and preference for terms used to present reliability information and related trip planning concepts. An open-ended survey was later added to the computer-based survey to further test user comprehension of selected terms for crucial reliability concepts such as average trip time, buffer time, and 95th-percentile trip time.

The results of both surveys indicated that there is a disconnect between the technical terms used by professionals and the layperson's understanding of and preference for these terms, a finding which was also evident in the focus group comments. Results related to some of the specific concepts and terms tested in these surveys are as follows:

Average Travel Time

Only 18 percent of participants in the computer survey understood *average* to mean "about half the time, 10 days out of 20"; most interpreted it to mean "most of the time, 15 days out of 20". Other terms tested for this concept (*typical, historical, estimated*) were also more likely to be interpreted as meaning "most of the time" than as "about half the time." Of the four terms, *estimated travel time* was preferred by the highest number of participants; *typical* and *historical* were the least preferred.

The open-ended survey tested the terms *average, estimated, typical,* and *expected* for conveying a normal or "average" trip time. None of the four terms stood out as being significantly better or

worse for conveying this travel time concept, and there were no clear trends in participant preference.

Based on the focus groups and the two surveys, the research team selected *estimated travel time* as the preferred term for conveying the "average travel time" concept, followed by *average travel time* and *expected travel time*.

Buffer Time

The large majority (90 percent) of participants in the computer survey had a desire for information that a planned trip had a chance of taking longer than average. When asked to select a term to describe that additional time, only 10 percent selected *buffer time*, which is the term used by professionals in the travel time reliability field. The largest percentage (33 percent) of participants preferred *extra time* to describe this concept.

The open-ended survey tested the terms *added time*, *extra time*, *cushion time* and *recommended cushion time* for this concept. Of these, *recommended cushion time* was marginally more likely to encourage participants to calculate the total travel time that the researchers intended (adding a given buffer time to a given average trip time). The term *extra time* was somewhat more likely to result in a participant-selected total trip time that was slightly longer than the researchers intended. There was no clear participant preference among the four terms.

Based on the focus groups and the two surveys, the research team selected *extra time* as the preferred term for conveying the "buffer time" concept, followed by *added time*, then *recommended cushion*.

95th Percentile Travel Time

Only 37 percent of participants in the computer survey understood *95th percentile* to mean "nearly all the time, 19 days out of 20."

The open-ended survey tested the terms *95th percentile trip time, majority of the time, most of the time,* and *travel time for planning*. Of these, *majority of the time* resulted in the greatest percentage of participants selecting a trip time that most closely matched a 95th percentile travel time. *Most of the time* encouraged participants to select a trip time slightly longer than the 95th percentile trip time, but participants who saw this term were also the most confident that they would arrive at their destination on time. Participants who saw the term *95th percentile trip time* were the least confident about arriving on time.

Based on the focus groups and the two surveys, the research team selected *majority of the time* as the preferred term for this concept, followed by *most of the time, travel time for planning,* and *95th percentile trip time* (the latter to be used only with an accompanying description).

LEXICON DEVELOPMENT

The research team developed a structure for the lexicon that organized various data elements for each term in a way that could be applied to both reliability terms at a concept level and user interface phrases and terms. These elements include a definition, the usage of the term, the ranking of messages and/or terms to be used in order of preference, alternate phrases, and information technology platforms. This structure also provides a convenient checkbox matrix indicating the platforms for which each variant of the term is appropriate. The lexicon is included in Chapter 11 of this report, as Tables 11-4 through 11-11, and contains recommendations for terms describing the concepts of 95th percentile trip time, arrival time, average travel time, buffer time, departure time, recommended departure time, recommended route, and reliability.

Terms recommended by the research team in the lexicon were used to convey travel time reliability concepts to participants in the second (enhanced) utility function laboratory study.

UTILITY FUNCTIONS AND USER BEHAVIOR

Findings from the focus groups brought into question the relative value of reliability information, specific to travelers. The most frequent potential use of TTR information seemed to be for pre-trip planning of constrained, unfamiliar trips within a known community or trips within or to an unfamiliar location. For the unconstrained trip scenarios, overwhelmingly, most people would not use it, and weekends seemed to be the time it would be utilized the least.

In general, focus group participants believed the TTR system would be valuable in some instances but would be immensely more valuable if it contained real-time data in addition to historical data. They felt that a travel time reliability system would be useful when planning a trip to an unfamiliar location where there were significant time constraints on one or both ends of the trip. However, they were concerned that planning a trip based on historical information would not be accurate if it did not update based on current road and traffic conditions.

First Utility Function Laboratory Study

The objectives of the first utility function laboratory study were (1) to assess the value participants placed on traveler information, and specifically reliability information, within the context of a simulated time-constrained trip, and (2) to determine whether having reliability information helped to speed the transition from an unfamiliar commuter to an experienced commuter.

The computer-based laboratory experiment, prepared by Noblis and administered by the TTI research team in concert with the computer and open-ended surveys, presented participants with a scenario in which they were commuting in an unfamiliar city with a constrained arrival time (with penalties for both late and early arrival) for 2 work weeks – 10 commutes to work. Participants had access to one of three additive levels of travel time information for their planned route and optional route deviations: real-time DMS messages only, real-time DMS plus real-time travel time information, or real-time DMS plus both real-time and historical travel time information. Participants selected among three departure time options and two route modification points to arrive at their destination on time.

The results of this initial laboratory experiment showed that participants who received reliability information arrived on time more frequently than those who received real-time information only. Results concerning participants' perceived value of this information were inconclusive.

Enhanced Utility Function Laboratory Study

After careful assessment of the aforementioned travel time reliability terms and the results obtained in the various human factors studies and experiments conducted throughout the course of the L14 project, the research team established three key hypotheses related to the use and value of travel time reliability information from the user's perspective that were tested in the second, enhanced laboratory study.

Two slightly different experiments were developed for the enhanced laboratory study. In both experiments, the reliability information presented to participants did not vary from day to day but instead reflected the historic reliability of travel along a route. In addition to differing levels of reliability information, all participants received pre-trip and en-route advisory messages via simulated dynamic message signs as well as text-format "radio messages." In both experiments, participants selected a departure time based on pre-trip information, experienced travel time as a function of trip duration, and rated the value of the information simulated from day to day.

Experiment 1 framed the simulation as that of traveling for work to 5 different cities and commuting for 5 weekdays from each city's regional headquarters to a morning client meeting that was 40-60 minutes from headquarters. Each participant experienced four of the seven reliability-related data, a specific term each for a week. During one week, there was no reliability-related data.

Experiment 2 framed the simulation as that of traveling to a new city for work and making daily departure time decisions to work for a month (four weeks, five days a week). In this version, half of the participants received graphical 20th, average, and 95th percentile arrival time reliability information with a legend identifying data as "good day," "typical day," and "bad day." The other half of the participants did not receive reliability information.

Pre- and post-trip surveys during the commute simulation programs and surveys following the completion of the experiments measured participants' evaluations of the usefulness of the traveler information they received, their confidence in selecting trip times based on that information, their level of stress in completing their trips, and the monetary value they would place on the information.

Hypothesis #1

Hypothesis #1 states that the provision of accurate reliability information (in an easy-to-understand format) will result in improved on-time performance and lower generalized travel disutility compared to a control group receiving no reliability information. The results of the first laboratory study and the later enhanced laboratory study strongly supported this hypothesis. Of the seven different forms of delivery of reliability information tested in the experiment, users presented with five of these options demonstrated statistically significant reductions in weekly schedule offset costs compared to the control group receiving no reliability information. These five were also the simplest of the forms of reliability information, focusing on average and 95th

percentile travel time values, delivered in various forms. Participants receiving these simple forms of reliability information reduced schedule offset costs by 9-21 percent compared to the control group.

Hypothesis #2a (First Laboratory Study)

Hypothesis 2a, tested in the first laboratory study, proposed that while travel outcomes improved with the provision of reliability information, the perceived value of the reliability information would underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.

Findings from the first laboratory study supported this hypothesis. Measured perceptions of benefit associated with reliability information were not commensurate with the observed improvements in trip outcomes. Changes in the value of information and stress reduction, although generally favorable to reliability information, were not statistically significant.

Hypothesis #2b (Enhanced Laboratory Study)

Hypothesis #2b, tested in the enhanced laboratory study, states that experimental subjects receiving contextual information on underlying variation with numeric indicators reinforced with en-route information (travel time reliability signposting) will have improved on-time performance compared to both an experimental group that receives reliability information but no contextual information as well as a control group that receives no reliability information.

Hypothesis #2b was not supported by the enhanced laboratory study. The signposting concept was not successful for participants in the management of trip outcomes and stress reduction. To some degree, this was because of the complexity of the presentation. Signposting may still be a valuable concept to pursue in reliability information provision, but work remains to convey this in a more accessible manner.

Hypothesis #3

Hypothesis #3 states that the benefits of travel time reliability information will decline over time as both experimental and control subjects learn and understand the underlying travel time variability. That is, the benefit from reliability information during the first weeks will be larger than during the last weeks.

Findings from the first laboratory study were inconclusive. Participants with access to reliability information did see total early- and late-arrival penalties decline from week 1 to week 2 of the simulated trip-making. Control groups who did not receive this information were mixed, with one group realizing a reduction in total costs and another seeing a rise in these costs. Interestingly, participants' willingness to pay for reliability information declined over time in the simulation experiment, indicating that experience within the simulated trip began to offset the reliance on provided reliability information.

The enhanced laboratory study supported hypothesis 3. Participants using travel time reliability information in the first week of exposure to unfamiliar travel time variability patterns were equally effective in managing trip outcomes (late arrivals, schedule delays, and offset costs) as

their counterparts without reliability information after four weeks of experience in an unfamiliar system.

STUDY LIMITATIONS

It is important to note that the studies conducted in this project were laboratory studies, and none of these terms were tested in a field environment. Only in a field test with specific detailed travel behavior data can researchers determine the true impacts and benefits of the use of travel time reliability information on behavior and resulting trip performance. Of specific note is the fact that nowhere in the various human factors studies were the specific phrases suggested for display on DMSs tested specifically as being displayed on a DMS and as en-route information. These suggested phrases were developed by the research team based on the results discussed for the related terminologies. The team developed these phrases using the general guidance for DMS message development provided in the MUTCD. It is also important to note that the formatting of these travel time messages is very different from the standard messages used by state transportation agencies on DMSs.

POTENTIAL NEXT STEPS

Given the complexity of the travel time reliability concept and the myriad of ways this information may impact system users, system operators, and service providers, the project team identified several potential issues that can be addressed in further detail and refined through additional investigation. These issues include the following:

- Travelers' perceived value of reliability information in the context of more complex trip planning (e.g., a wider range of route and/or mode options);
- Mechanisms/reasons behind the under-valuation of reliability information by users;
- Changing effects and value of reliability information for travelers on familiar routes;
- Impacts of reliability information on travel-related choices such as home/work locations, facility locations for businesses, and others;
- Use of reliability information by the freight industry;
- Effects of reliability information in public transit.;
- Traveler responses to increased travel time reliability;
- Further examination of graphical formats for reliability information; and
- Field tests of reliability terminology.

Chapter 1 INTRODUCTION

The second Strategic Highway Research Program (SHRP 2) Reliability Program aims to improve trip time reliability by reducing the frequency and effects of events that cause travel times to fluctuate in an unpredictable manner. Congestion caused by unreliable, or nonrecurring, events is roughly as large as congestion caused by routine bottlenecks (Cambridge Systematics Inc., 2003). Nonrecurring events such as crashes, work zones, special events, and weather disrupt normal traffic flow by causing reduced speeds, lane closures, and erratic driving maneuvers. The goals of the SHRP 2 Reliability Program focus on travel time variation—that characteristic of the transportation system that means the driver's current trip will take much longer than normally expected (see Figure 1-1). For example, a driver must allow an hour to make a trip that normally takes 30 minutes. This transportation system characteristic is important for travelers and shippers and is a component of the congestion problem in which transportation agencies can make significant and measurable gains even as travel demand grows. Reducing delay related to reliability has the added benefit of reducing primary and secondary crashes, vehicle emissions, and fuel use, and yields other benefits.

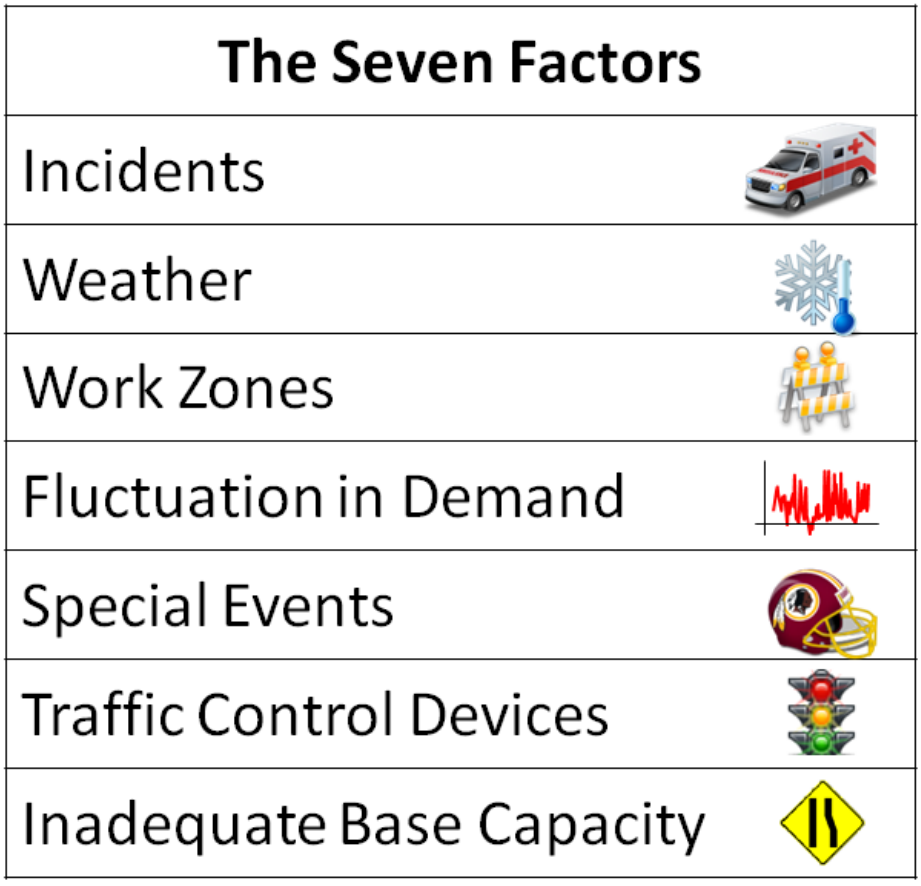


Figure 1-1. Seven Factors Contributing to Non-recurring Congestion. (Source: SHRP 2 Reliability Program).

BACKGROUND

The highway system in the United States (U.S.) is a critical component of American life. The Federal Highway Administration (FHWA) works to ensure that it provides extensive and flexible personal mobility to American citizens and efficient freight movement to support the domestic economy (FHWA, 2003). Both of these services are impacted by transportation investment and location decisions made by governmental entities across the country in their planning processes. However, an increase in travel by users, congestion, and environmental and financial constraints interfere with this system's ability to provide these services. For example, the growth in vehicle miles traveled (VMT) continues to outpace lane mile growth across the country. Between 1993 and 2000, the VMT increased by 2.7 percent annually, while the number of lane miles in the U.S. only grew by 0.2 percent annually during the same time period (FHWA, 2003). This growth in travel places a strain on a transportation system that is already overburdened.

Congestion interferes with daily life, and any method to alleviate it and improve trip reliability can help reduce its impact on productivity. Another reality of improving the transportation infrastructure today is that agencies must function within environmental constraints. Agencies must consider the environment in the planning of transportation projects, minimize the negative impacts of construction, and work to reduce transportation-related pollution in the process. They must demonstrate environmental stewardship and improve the environmental quality of their transportation decision-making (FHWA, 2002).

Financial constraints are another burden of transportation agencies. As public resources become more and more scarce, state and local governments are challenged with inadequate funding to meet growing transportation needs. An emerging trend in transportation spending is the reality that state and local governments are devoting a larger share of their capital spending on preserving and operating their existing transportation infrastructure, thereby leaving less money available for new roads and bridges and system enhancements (FHWA, 2002). All of these efforts to better manage the transportation infrastructure help to address the goals of the SHRP 2 Reliability program to enhance the quality of life for all system users by improving the reliability of the daily trip.

TRAVEL TIME RELIABILITY INFORMATION

Travel time reliability information includes cumulative data about traffic speeds or trip times that take into account historic variations from day to day and enable individuals to understand the level of variation in traffic. Unlike real-time travel time information, which provides a current snapshot of trip conditions and travel time, reliability information can be used to plan and budget in advance for a trip.

A key component to addressing the reliability issue related to urban mobility is conveying this reliability-related information to system users so that they can make informed decisions about their travel. The challenge for transportation professionals lies in selecting the best means of conveying that information so that it is usable and effective. The goal of this research project was to examine what combination of words, numbers, and other features of user information messages, along with communications methods and technology platforms, best communicate information about travel time and reliability to travelers so that they can make optimal travel

choices from their point of view. Such choices include whether to take a trip or not, departure time, mode choice, and route choice.

Past research related to travel time reliability has, for the most part, examined how people use their own experience to judge travel time reliability with regard to route choice or time of departure. Researchers have not specifically examined *when* people prefer to have this information or *how* they will use it. Many stated preference surveys allow users unlimited time to think about all of the possibilities. In an unpressured situation, the message content and display are not as critical as they would be in a time-pressured situation immediately prior to a departure or actually en route in the vehicle. These factors affect the optimal display, sequence of inputs required, and display of search results. It was these factors that were the main focus of this project. Logically, the trip-making process includes three points at which users would want to access travel time reliability information. These points are discussed in the following sections.

Trip Planning for Habitual Trips When New to an Area

When people move to a new area or start a new job, they must find the best mode, time of departure, and route for their commute. This can be accomplished by talking with neighbors and colleagues, trying different times if their work schedule allows, and trying different routes. Once the decision is made, the trip becomes routine. Users may find travel time reliability information helpful at this point in order to make direct comparisons across modes, routes, and times. System users would most likely seek out this information through an Internet source outside of the vehicle under no particular time pressure. The user may desire maps and tables as outputs and may wish to input two distinct scenarios and directly compare the results. In essence, the user would use the travel time reliability information in a series of what-if scenarios and weigh the potential travel time savings against the volatility in that travel time. This type of use may require a rich user interface with many input options, including specific origin-destination pairs. An analogous situation would be using a service like MapQuest™ to get door-to-door driving directions with specific addresses.

Pre-Trip Planning Immediately Prior to Departure

Many users may want to check traffic or check how transit is running just before departure. They may do this by visiting a traffic management center (TMC) website, consulting a smartphone or navigation system that includes real-time traffic information, or listening to a traffic advisory radio broadcast. This information is sought immediately prior to beginning the trip, i.e., not while driving. These users may be able to delay their departure, choose a known alternate route, or choose to take the bus rather than the train. For these purposes, users may want a subscription system where they have entered their origin-destination or typical route information once, and the system is able to show them the travel time information specifically for their route. The display can be simple text or a color-coded travel time system map common on many TMC websites. These users are not necessarily looking to find the best route. Rather, they are more likely to want to change their mode or departure time to avoid congested conditions and incidents.

En Route Prior to a Route or Mode Choice Point

Some users may use these same sources to seek information en route prior to a major interchange or key decision point in the network. Since travel time reliability will shift throughout the day and with incidents, these users may want to know reliability associated with the current conditions. For instance, route A may be the shortest mileage and trip time under level of service (LOS) A, but when conditions deteriorate due to traffic volume or an incident, the reliability suffers and now route B (though longer in distance) has a more reliable trip time. For these users, en-route information becomes useful because people cannot remember a whole set of values, such as when travel time is 20 minutes on route A, it is +/−5 minutes, but when travel time is 40 minutes, it is +/−15 minutes. Likewise, with mode shifts, users may use travel time reliability information to prompt the decision to divert to a park and ride and take transit. These users may not want to take the risk of being caught in traffic for a long period of time and prefer to ride the bus or train during congested conditions.

INFORMATIONAL DELIVERY CHALLENGES

Travel time reliability information delivered en route must take a different form because of the risks of distracted driving. Displays that have been designed and tested with users sitting in front of a computer screen with their full attention devoted to the task will not fare well in a moving vehicle. The safety concerns of requiring long eyes-off-the-road glances to displays are considerable. While designing in-vehicle and portable device displays was beyond the scope of this project, determining the key elements that should be present was part of the scope. This information can be used by automotive suppliers and smartphone manufacturers can include this information in systems that are already used to display travel time in-vehicle. Some systems use auditory messages as another way of presenting this information in-vehicle.

Clearly, the diverse needs for information by the user, the times at which the user may desire reliability information, and the broad range of communications media and information formats that already exist in the marketplace and are on the horizon create a challenge for the transportation profession set on conveying travel time reliability to its customers. Consequently, this project sought to answer the critical questions of *what*, *when*, and *how* for travel time reliability information.

SCOPE AND PURPOSE OF TECHNICAL REPORT

This report documents the research activities undertaken throughout the duration of the SHRP 2 L14 research project. The key product out of the research is a lexicon that was developed to provide information on appropriate ways to introduce travel time reliability information to travelers so that such information is most likely to be understood and used by the travelers to influence their travel choices, while not presenting a safety hazard in the process. This document provides detailed results of all of the tasks included in the study, as illustrated in Figure 1-2.

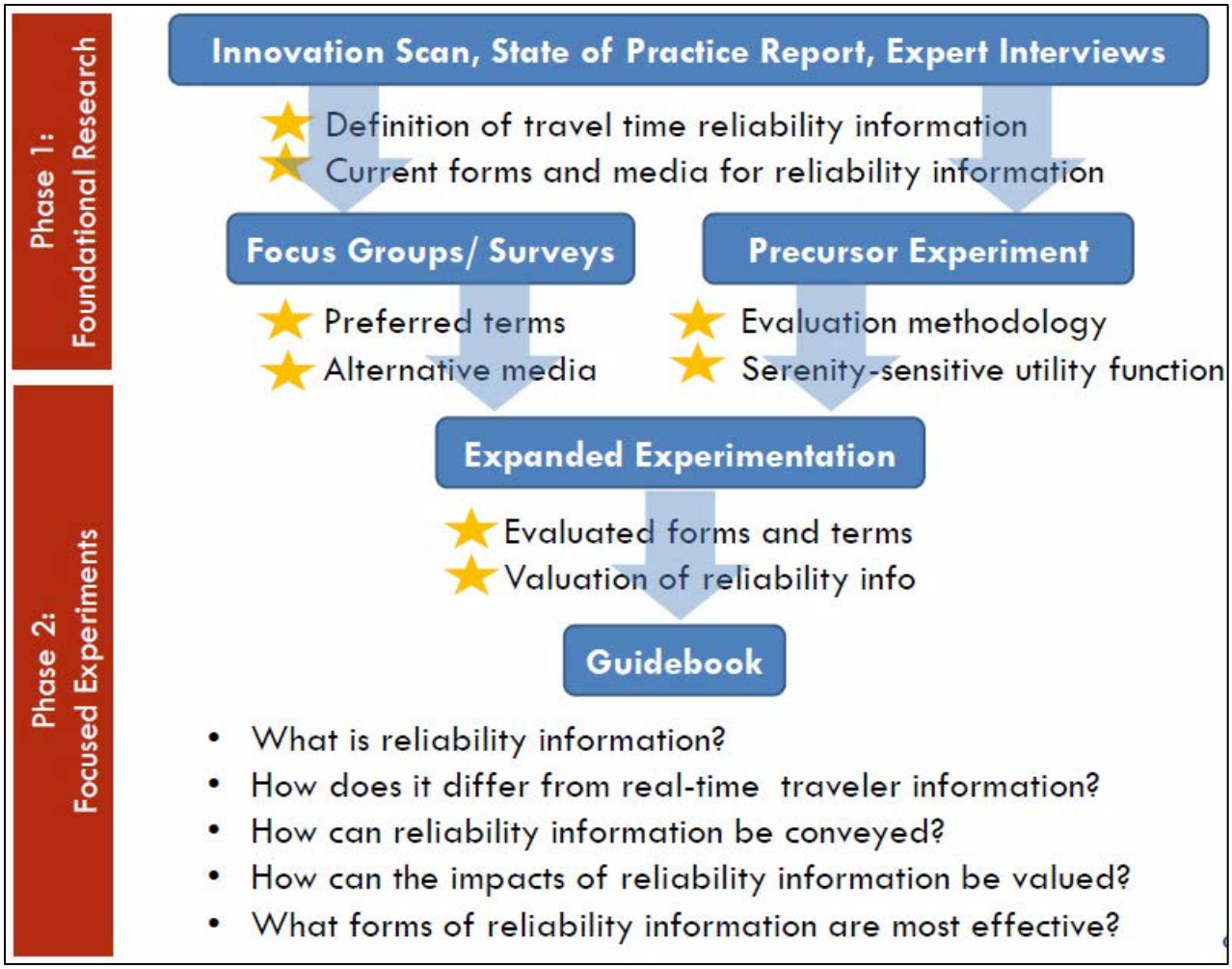


Figure 1-2. SHRP 2 L14 research project activities.

PROJECT EVOLUTION

Travel time reliability information includes static data about traffic speeds or trip times that capture historic variations from day to day and enable individuals to understand the level of variation in traffic. Unlike real-time travel time information, which provides a current snapshot of trip conditions and travel time, reliability information can be used to plan and budget in advance for a trip. The research undertaken as a part of the L14 project was the first to examine road user understanding of travel time reliability information in the United States. The approach was to apply a series of successively more focused methodologies that allowed a wide net to be cast initially to gather the broadest understanding of users' preconceived notions of travel time reliability. Developing and tailoring traveler information systems based on users' inherent understanding of trip reliability provides the best chance for a high level of user acceptance of the ultimate traveler information system.

The results of the three Phase I and five Phase II research activities contributed to the travel time reliability lexicon (task 13) and guidebook and deployment advisory (task 14) that are the primary products of this research project. These activities also informed the plans for the development of utility functions (task 12). The overall project concept is illustrated in Figure 1-3.

A few shifts in focus emerged after the proposal stage as a result of Phase I that modified some of the specific activities undertaken in Phase II. These modifications were reflected in the Phase II Management Plan and are summarized below.

- **Increase Focus on Market Demand for Information.** In the proposal, the team hypothesized that travelers would intrinsically value reliability information for trip planning purposes. In the Phase I tasks, it became apparent that many people—be they transportation agencies or general users—did not show a particular interest in providing or receiving this information. Phase II sought to determine more definitively if there is a market for this type of information, what value users may place on it, and how and when it might be used.
- **Elimination of the Field Operational Test.** In the original proposal, the team proposed to conduct a field operational test of the lexicon to gather real-world information on how travelers used the information conveyed and their resulting travel results. Initially, the team considered deploying the test using smartphones or some other in-vehicle device. With the United States Department of Transportation's (USDOT's) increasing emphasis on distracted driving, this approach was no longer a prudent course. Instead, the field operational test was later proposed as a web-based system intended to be accessed from a home computer exclusively. Participants would be recruited on the basis of access to a personal computer and would be instructed to not access the system from a portable mobile device. After further considerations of the challenges associated with conducting a field operational test and the limited control that the project team would have over the design of the web-based system, the team proposed the elimination of the field operational test. The team and the SHRP 2 L14 technical expert task group (TETG) agreed that the resources dedicated to the field operational test would be better utilized on other activities.
- **Eliminate Simulator Testing.** Since the project team decided to focus on a personal computer-based system as the testing platform, there was no need to test the system while driving. Therefore, the simulator study was also eliminated from the research plan. Because the driving simulator study was eliminated along with the field operational test, the research team was able to use project resources to add two additional human factors activities; therefore, the larger usability study also included an open-ended survey and an initial travel behavior laboratory experiment and was followed by an enhanced travel behavior laboratory experiment.

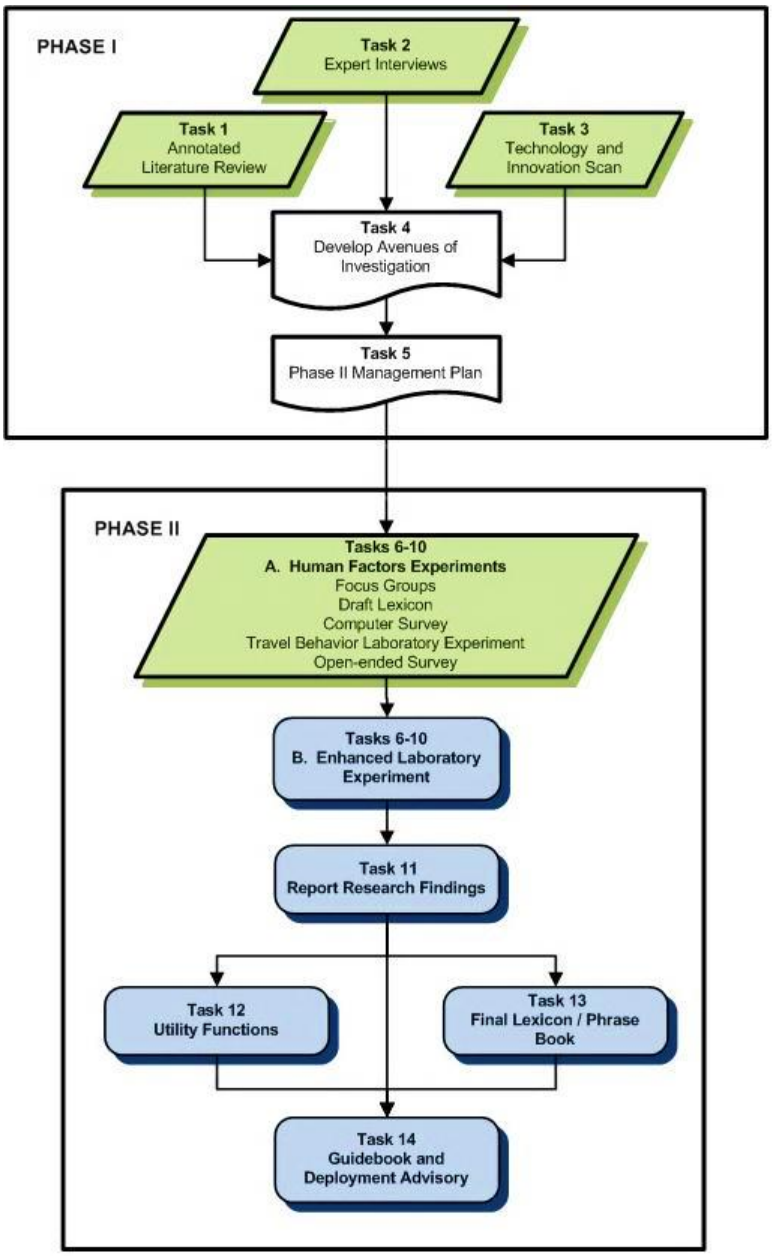


Figure 1-3. SHRP 2 L14 project overview.

The project team developed a diagram to summarize all of the research activities to make it clear how the activities interrelated and contributed to each other (see Figure 1-4). The remaining chapters in this report provide detailed information on all of the project tasks and specific results that were used to generate the final products.

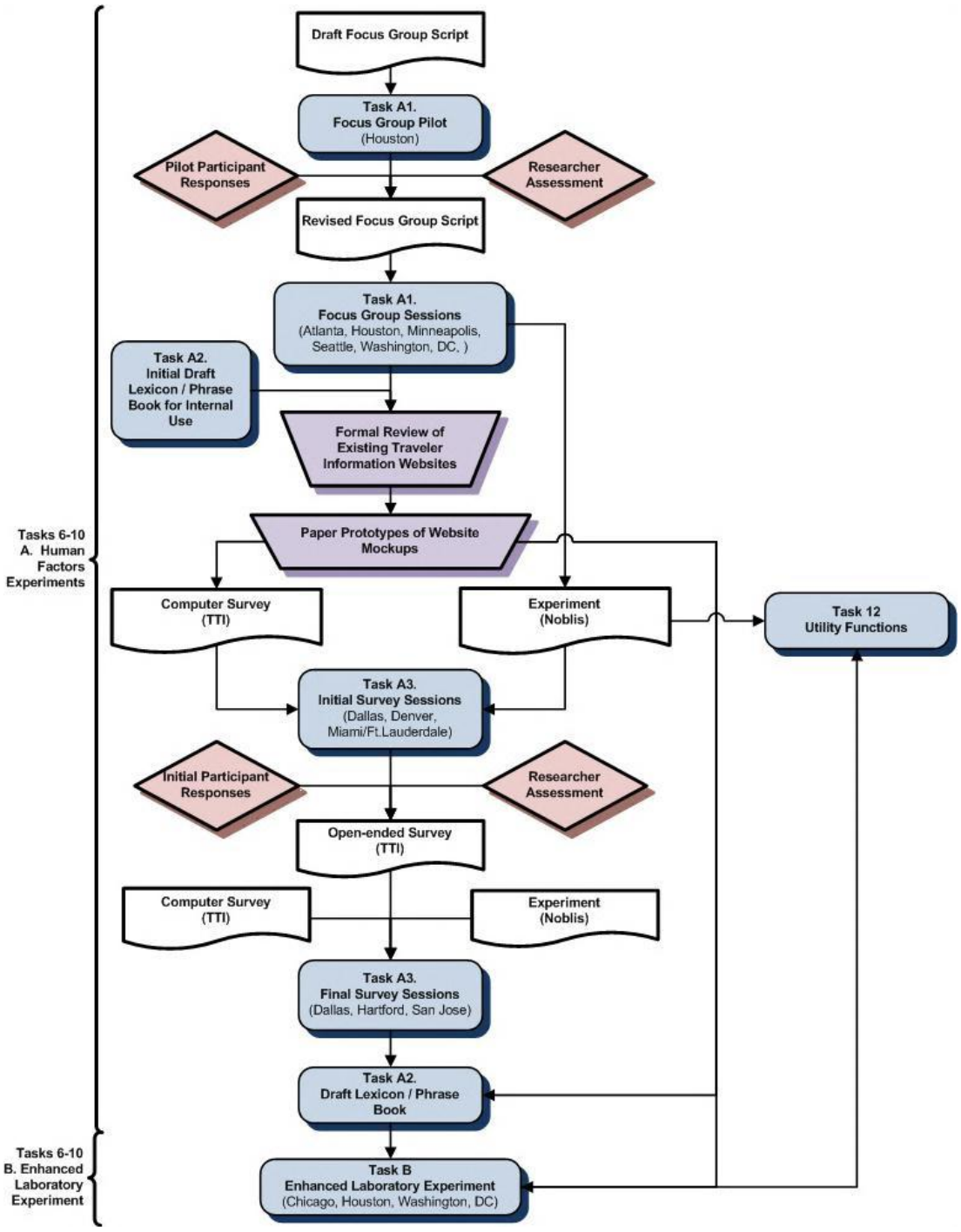


Figure 1-4. SHRP 2 L14 project task interrelationships.

Chapter 2 LITERATURE REVIEW

In the many cities where congestion is commonplace on the transportation system, drivers are accustomed to congestion and expect and plan for some increase in travel time, particularly during peak driving times. Many system users either adjust their schedules to avoid peak hours or budget extra time to allow for unexpected traffic congestion or incidents. However, problems arise when travel times are much higher than anticipated. Most travelers are less tolerant of unexpected travel time increases because those longer travel times cause travelers to be late for work or important meetings, to miss appointments, or to incur extra childcare fees. Moreover, shippers that face unexpected delays may lose money, disrupt just-in-time delivery, disrupt manufacturing processes, and lose their competitive edge on other shippers (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

Transportation professionals most commonly discuss travel time reliability in terms of historical average travel times calculated over periods of a year or longer, as illustrated in Figure 2-1. A typical definition for travel time reliability would be the following:

> *The consistency or dependability in travel times, as measured from day to day and/or across different times of the day.*

However, most travelers do not experience the same average travel time each day. As shown in Figure 2-2, travelers experience and remember something much different than the average throughout a year of commutes. Their travel times vary greatly from day to day, and they remember those few bad days they suffered through unexpected increases in travel times. Research within the profession has shown that travel time reliability information can provide transportation system users with a more complete picture of the expected travel time along a particular route. The challenge is how to communicate that reliability information effectively to road and transit system users so that they understand it clearly.

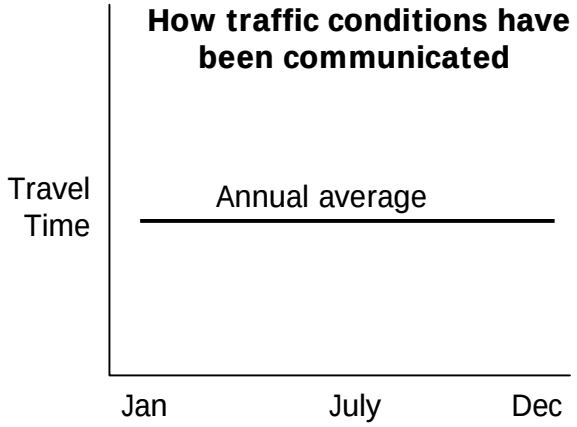


Figure 2-1. Average travel time used by professionals (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

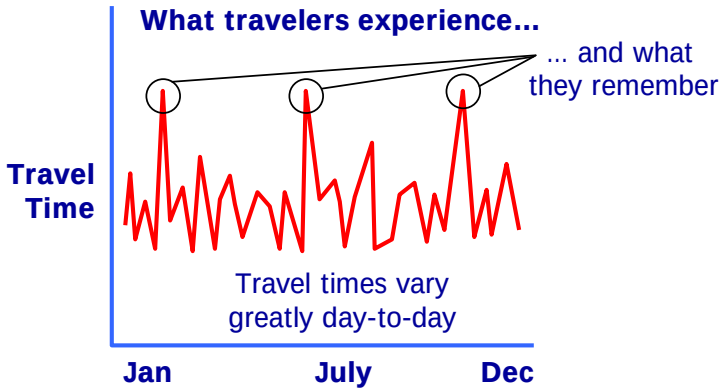


Figure 2-2. Traveler travel time experiences (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

Another example of illustrating travel time reliability is shown in Figure 2-3. This example shows travel time data from a major commuter route in Seattle, Washington. If there is no congestion along this route, travel times are about 12 minutes (e.g., see President's Day in the figure). On all other weekdays, the average travel time is 18 minutes. However, when traffic incidents and weather combine to cause unexpected congestion, travel times may be upwards of 25 minutes, or 39 percent longer than usual. Commuters who travel this route must plan for this variability if they want to arrive on time. If they plan their commute based on the average travel time, they will be late half the time and early the other half of the time. In other words, commuters have to build in a time cushion, or buffer, to their trip planning to account for the variability. If they build in a buffer, they will arrive early on some days, which is not necessarily a bad thing, but the extra time is still carved out of their day—time they could be using for other pursuits besides commuting.

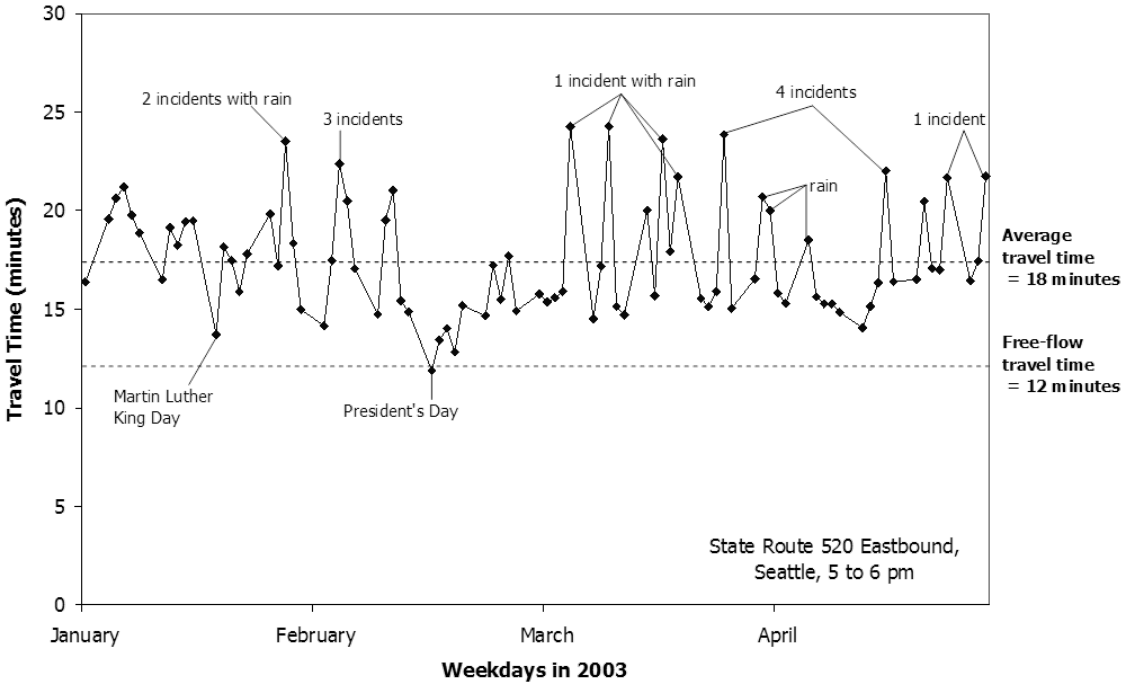


Figure 2-3. Commuters plan trips based on the worst days, not the average day (Cambridge Systematics Inc. with Texas Transportation Institute, 2005).

TRAVEL TIME RELIABILITY METRICS

The measurement of travel time reliability is an emerging practice. However, a few measures appear to have technical merit and are thought to be easily understood by nontechnical audiences. Most of these measures compare days with high travel times to days with average travel times. Four recommended measures are as follows:

- 90th or 95th percentile travel time;
- Buffer index;
- Planning time index; and
- Frequency the congestion exceeds some expected threshold (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

The 90th or 95th percentile travel time is a time identified for a specific travel route that indicates how bad delay will be on the heaviest travel days (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). These travel times are reported in minutes and seconds and are thought to be easily understood by commuters familiar with their trips. For this reason, this measure is ideally suited for traveler information. This measure has the disadvantage of not being easily compared across trips, as most trips will have different lengths. It is also difficult to combine route or trip travel times into a subarea or citywide average. Several reliability indices are presented below that enable comparisons or combinations of routes or trips with different lengths.

The buffer index represents the extra time cushion (or buffer) that most travelers add to their average travel time when planning trips to account for unforeseen delays and to ensure on-time arrival (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The buffer index is expressed as a percentage, and its value increases as reliability gets worse. For example, a buffer index of 40 percent means that for a 20-minute average travel time, a traveler should budget an additional 8 minutes (20 minutes × 40 percent = 8 minutes) to ensure on-time arrival most of the time. In this example, the eight extra minutes is called the buffer time. The buffer index is computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time.

The planning time index represents the total travel time that a traveler should expect or plan on when an adequate buffer time is included (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst-case travel time to a travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is useful because it can be directly compared to the travel time index (a measure of average congestion) on similar numeric scales. The planning time index is computed as the 95th percentile travel time divided by the free-flow travel time.

From a data perspective, continuous travel time data are the only way to establish reliability patterns empirically. While predictive methods—such as the ones being developed by the project team for the SHRP 2 L03 project *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies*—may be used in a reliability monitoring system where these data are unavailable, only continuously collected travel time data can produce the actual travel time distribution from which all reliability metrics are derived. For example, the reliability metrics being used in the SHRP 2 L03 project, as shown in Table 2-1, are all derivatives of the travel time distribution.

What is clear is that there is not agreement within the professional field on the terms to be used or what the mathematical calculations of each of the terms should be. If the professionals can't come to consensus on the technical terms, then the general public certainly will not do so. The purpose of the L14 project was to discover what terms the layperson would use to refer to these travel time reliability concepts and to encourage the use of those terms in communications with transportation system users.

Table 2-1. Recommended reliability performance metrics from SHRP 2 Project L03, *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies* (Cambridge Systematics Inc., 2007).

Reliability Performance Metric	Definition	Units
Buffer Index (BI), mean-based	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time	Percent
Buffer Index, median-based	The difference between the 95th percentile travel time and the median travel time, normalized by the median travel time	Percent
Failure/On-Time Measures, median-based	Percent of trips with travel times < (1.10, 1.25) * median travel time	Percent
Failure/On-Time Measures, speed-based[1]	Percent of trips with travel times < (50 mph, 45 mph, 30 mph)	Percent
Planning Time Indices	95th, 90th, and 80th percentile travel times divided by the free-flow travel time	None
Skew Statistic	The ratio of (90th percentile travel time minus the median) divided by (the median minus the 10th percentile)	None
Misery Index (modified)	The average of the top 5 percent worst travel times divided by the free-flow travel time	None

Note. "Speed" is the space-mean speed over the study section.

IMPORTANCE OF TRAVEL TIME RELIABILITY

Travel time reliability is significant to many transportation system users, whether they are vehicle drivers, transit riders, freight shippers, or even air travelers. Good system reliability is a valuable service that can be provided on privately operated and publicly operated highways alike. Because reliability is so important for transportation system users, transportation planners, operators, and decision-makers should consider travel time reliability a key performance measure.

Travel Time Reliability and Highway Travel

Travel time reliability is valuable to traffic professionals because it better quantifies the benefits of traffic management and operation activities than simple averages. For example, consider a typical before-and-after study that attempts to quantify the benefits of an incident management or ramp metering program. The improvement in average travel time may appear to be modest, as shown on the left side of Figure 2-4. However, reliability measures will show a much greater improvement—as illustrated on the right side of Figure 2-4—because they show the effect of improving the worst few days of unexpected delay.

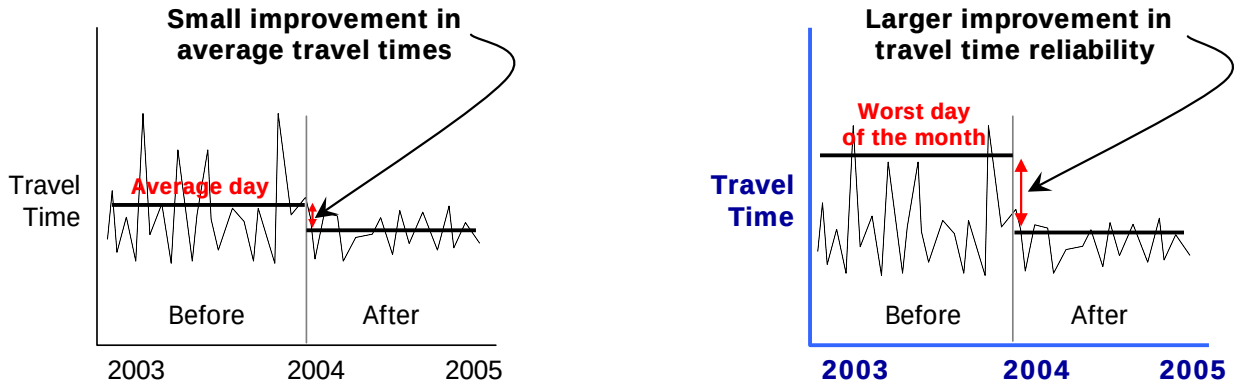


Figure 2-4. Reliability measures capture the benefits of traffic management (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

For drivers, travel time reliability information can be valuable when they are selecting a route. For example, the value of travel time reliability was assessed through a mail survey, trip diaries, and loop-detector data by Lam and Small (Lam & Small, 2001) soon after the first high-occupancy/toll (HOT) lane opened on State Route 91 in Riverside, California. The researchers found that for women in this study, the value of travel time reliability was actually higher than simple travel time information. For men, the value of time was roughly 50 percent higher than the value of reliability information. The reasons for this difference were not known from the data collected, though some have interpreted these data to indicate that women have more time-critical commitments related to childcare trips. For this study, the researchers defined travel time as the 90th percentile travel time minus the median. The authors discussed further how the transponder usage records of participants showed that there were few habitual users of the HOT lane. Rather, people made the decision whether to pay for the HOT lane on a daily basis depending on trip purpose and traffic conditions. It is in applications such as HOT lanes where travel time reliability information may be useful en route to help drivers make the purchase decision to use the HOT lanes. The influence of pre-trip and en-route travel information on route decisions has been demonstrated in other studies: an evaluation of the Washington State DOT's 511 travel information system in 2005 found that 21 percent of respondents changed their original travel plans based on information they got from the 511 system (PRR Inc., 2005). Drivers on an Orlando, Florida, toll road who stated that they used information from the state's 511 service or from dynamic message signs (DMSs) that displayed estimated delay times for the road were more likely to change their route in response to unexpected congestion.

A review of research on travel time and travel time reliability conducted by the Center of Urban Transportation Research (University of South Florida) includes the finding that most travelers value trip time reliability at least as much as actual trip time. In fact, when travelers' arrival and/or departure times were inflexible due to the nature of the trip, the value of reliability could be as much as three times that of trip time (Concas & Kolpakov, 2009).

Travel Time Reliability and Transit

Studies of transit ridership have shown that trip time reliability (including the reliability of a rider's wait time at transit stops) is more important to retaining riders than the trip and waiting times themselves. Wait-time reliability is particularly important, as transit riders tend to perceive time spent waiting for a transit vehicle as being longer than an equivalent amount of time spent riding in the vehicle. Real-time information that allows transit riders to schedule their own arrival at a transit stop and/or to monitor the wait time remaining until the vehicle's arrival increases rider confidence in the service (Perk, Flynn, & Volinski, 2008). Transit passengers surveyed in two cities ranked knowledge of when their bus would arrive and knowledge that it would arrive on time as the two most important factors affecting their decision to ride transit (Peng, Yu, & Beimborn, 2002).

Travel Time Reliability and Freight

In terms of economic value, reliability is probably more important to freight carriers and shippers than to personal travelers. With the rise in just-in-time deliveries (largely as a replacement to extensive warehousing), providing dependable (reliable) service has become extremely valuable, while failure to provide dependable service can increase costs considerably (Cambridge Systematics Inc., 2007). For example, improvements in transportation reliability play an important role in reducing inventory in the chemical supply chain for freight shippers. Because of the many nodes in the supply chain, upwards of one-third of all chemical inventory is in transit at any point in time. Inventory managers keep safety or buffer supplies to cushion against variability of inbound arrivals, and the amount of safety supplies increases with the degree of unreliability and the number of stocking locations (Cambridge Systematics Inc., 2007). However, the capacity to receive chemical supplies is limited by the size of the liquid storage silos. Balancing capacity with demand is a challenge. As transportation reliability decreases, wait time, dead freight, and cost increase (Cambridge Systematics Inc., 2006).

TRAVEL TIME INFORMATION—STATE OF THE PRACTICE

Real-time travel time messages have been in use in the U.S. for well over a decade, ever since traffic monitoring and integration systems became reliable. The most commonly used media for these messages are dynamic message signs (DMS) and transportation agency websites, but the widespread use of cell phones and other mobile devices is prompting a growing number of transportation agencies and providers to offer real-time updates on transportation conditions and options via emails, text messages, and Twitter feeds.

Real-time travel time estimates are most often provided for a particular roadway segment or a particular transit route based on recent travel speeds or conditions. Some agencies also provide travel time comparisons among two or more routes/roadways to help travelers make decisions about the route or transportation mode to take. Most recent and most rare are the information sources that advise travelers about travel time reliability as described in the preceding sections—the likelihood that the estimated travel time for a particular trip or trip segment will be dependable. The following sections provide a concise summary of the state of the practice regarding travel time information. A more detailed literature review of this information is provided in Appendix A.

Real-Time Travel Time Information on Dynamic Message Signs

Changeable, or dynamic, message signs (CMSs/DMSs) can be used to provide several types of travel time information to drivers:

- Travel time information between specified locations;
- Comparative travel times for alternate routes (e.g.. "Airport via Route 1—20 Min, I-94—35 Min");
- Time saved by taking an alternate route (e.g., "Accident at Exit 12; Use Route 46—Save 20 Min");
- Delay on the freeway; and
- Delay avoided by taking the alternate route (Dudek & Huchingson, 1991) (Dudek, 2004).

Displaying travel times on CMSs is not a universal practice; a 2008 survey of 100 traffic management centers in 40 states found that only 30 percent displayed travel times on some of the CMSs in their jurisdictions during peak traffic periods, and only 23 percent displayed travel times during the off-peak periods. Reasons for not displaying travel times on CMSs include (a) CMS not being located where travel time messages would be useful, and (b) a lack of communications infrastructure and software to maintain up-to-date information and messages. The primary lessons learned by the TMCs were that travel time information must be accurate, and it is difficult to display accurate travel times during rapidly deteriorating traffic operating conditions (e.g., transition between off-peak and peak period, occurrence of incidents, etc.) (Dudek, 2008).

To be effective, a CMS must communicate a meaningful message that can be read and understood by motorists within a very short time period, constrained by the available sight distance and design features of the CMS (Dudek, 2004) (Dudek, 2001) (Dudek, 2006). Some transportation agencies use signs that show one part of the message in static form (e.g., locations) and the travel times in changeable form. These types of signs are placed upstream of major diversion points where there is no need for full changeable message capability. While these signs likely contain more units of information than can be fully read by unfamiliar drivers, drivers who are familiar with the area would learn the static messages and only concentrate on the changeable travel times. One study of this sign type found that drivers rated the combined static/changeable format as easier to process than if the information was displayed on a traditional CMS (Lerner, Singer, Robinson, Huey, & Jennes, 2009).

As mentioned above, credibility of the message, in this case of the travel time provided, is also a concern; real-time travel times posted on CMSs are actually historical travel times based on the past several minutes or hours of travel speeds that have been recorded and thus may not reflect recent changes in traffic speeds. To alleviate the potential credibility problems that can result from a large difference between posted travel time and the travel time that drivers experience, some TMCs display a time stamp to indicate when travel speeds were last calculated; others display a range of estimated travel time (Houston TranStar Traffic Map, 2012) (San Antonio TransGuide, 2012).

Reliability Information on DMSs

The travel time ranges used by some TMCs in real-time travel time messages can be one way of including some travel time reliability information along with real-time travel time information, though studies have found that drivers tend to prefer single time values to ranges and to accept that the actual travel time may vary from the single value posted (Ban, Li, & Margulici, 2009) (Phoenix tightens travel time estimates, 2008). The French Ministry of Transportation in cooperation with the City of Paris experimented with another format: a travel time message that included slanted up and down arrows to indicate to drivers whether travel times were increasing or decreasing from the posted estimate (Abdelmename, 2010). Another study of travel time messages using trend arrows found that drivers took longer to process the information on CMSs when trend arrows were added and that they were more confident in the travel time value provided without a trend arrow (Abdelmename, 2010).

The Long Island Expressway uses the term *average travel time* on its combination static/CMS signs showing travel times to multiple destinations along a single route. This is actually a slight departure from its original request to FHWA to deviate from the *Manual on Uniform Traffic Control Devices* (MUTCD), which shows signs with the term *estimated travel time*. Both options use terms associated with travel time reliability, but in this case, the travel times displayed on the changeable portions of the signs are based on recent sensor data rather than longer-term historical data (FHWA, 2004).

Although symbols and pictograms on roadway signs have not been tested for use with travel time or reliability concepts, the results of research on their use on other types of road signs and CMSs indicate mixed results for driver comprehension (Luoma & Rama, 2001) (Arbaiza & Lucas, 2010) (Knoblauch, Nitzburg, Seifert, McGee, & Daily, 1995). Another category of graphical sign is a graphical route information panel (GRIP), which displays part of a road network using color coding to display information such as the level of traffic congestion on various roadway segments, similar to the color-coded traffic maps that appear on many TMC traveler information websites. Studies of GRIPs have identified several advantages over word messages, including the ability to convey more information about multiple roadways and to communicate with foreign travelers; a disadvantage is that drivers who have difficulty understanding maps may also have difficulty understanding GRIPs (Schouten, van Lieshout, & Spit, 1998) (Akim, van der Mede, & Janssen, 2000) (Techie-Menson, 2001). There are GRIPs in use in other parts of the world (not yet in the U.S.) that contain travel time information along with the graphical traffic status information; the effectiveness of these displays has not yet been determined (Lerner, Singer, & Huey, 2004) (Task Group 09, 2009).

Reliability Information via Websites and Mobile Devices

The types of travel time information offered on travel information websites vary, with real-time information much more commonly available than historical/reliability information.

Several websites operated by state or local TMCs reproduce the travel time messages displayed on DMSs; users can select a DMS location from a map of area freeways to check real-time travel times and conditions for a particular section of roadway. Color-coded freeway maps displaying

either traffic speeds or congestion levels are also common features. Other features available on some TMC maps are incidents and weather-related hazards such as snow/ice or flooding.

At the time of the literature review, only a handful of travel websites offered reliability information:

- The Wisconsin DOT website provides a table of current and normal travel times for highways in the Milwaukee area, with travel times that are 20 percent or more above normal shown in bold print (Kothuri, Tufte, Hagedorn, Bertini, & Deeter, 2007).
- Washington State DOT's website includes a similar table that also displays travel times for high-occupancy-vehicle (HOV) lanes, where applicable, and displays the 95th percentile travel time for an input roadway segment (Seattle Area Travel Times, 2012).
- The table of travel times on the Gary-Chicago-Milwaukee travel information website includes links from each average travel time estimate to a graph displaying detailed historical travel time data for the corresponding roadway segment (Travel Midwest Stats, 2012).
- Travel time reliability information for public transit routes is provided by Rutgers University. While most transit providers generate reliability information for their own use, few pass the information on to riders (On-Time Performance Stats, 2012).

Travel time information and traffic alerts are being communicated by a growing number of TMCs and transit providers via email, Twitter, and/or text message.

Communicating Reliability Information in Non-Transportation Fields

Cognitive science has shown that most people are not good at understanding statistical concepts and applying them to everyday situations such as medical diagnoses, gambling odds, or travel time probabilities (Gal, 2002). Qualitative terms for conveying statistical concepts (e.g., "probably," "most likely," "rarely") can be interpreted in different ways, and it is difficult to select a term that can be considered to have a consistent enough definition to communicate the desired message about probability to the public (Teigen, 1988) (Wallsten, Budescu, Zwick, & Kemp, 1993) (Biehl & Halpern-Felsher, 2001).

Medicine and weather forecasting are two fields that deal with probabilities and statistical concepts and must find ways of effectively communicating these concepts to the public. Graphical depictions of probabilities were shown to improve comprehension among study participants, both for the probability of rain in a weather forecast and for the probability that a course of medical treatment would be effective (Schwartz, 2009) (BBC News, 2007) (Price, Cameron, & Butow, 2007). Using numbers to supplement descriptive terms, expressing probabilities as frequencies (19 out of 20) instead of percentages, and using a consistent denominator or scale (e.g., expressing two hypothetical probabilities as "2 out of 10" and "9 out of 10," rather than expressing those same probabilities as "1 out of 5" and "9 out of 10") were other techniques recommended for communicating probabilities to medical patients (Paling, 2003).

Chapter 3 EXPERT INTERVIEWS

The Texas A&M Transportation Institute (TTI) research team conducted nine telephone interviews in February 2010. The purpose of the interviews was to gather information regarding the state of the practice for disseminating travel time reliability information. TTI researchers conducted interviews with experts in the public and private sector. As part of the interview, the research team asked questions related to the definition, computation, format, and users of travel time reliability information, as well as current applications and future plans for the dissemination of travel time reliability information. The research team also identified lessons learned and pitfalls related to providing travel time reliability information to the public. This chapter summarizes the information learned from the interviews.

DESIGN OF TELEPHONE INTERVIEW

The guide for the telephone interviews is located in Appendix B. TTI researchers developed this guide based on the results from the Task 1 annotated literature review and their expert knowledge of the subject matter. The interview guide was designed with a section for recording participant information, a script for introducing the interviewer and subject matter to the participant, and questions with space for free-form responses. Under most questions, additional instructions and/or potential responses were provided for the interviewer.

TELEPHONE INTERVIEW PARTICIPANTS

The TTI research team conducted nine telephone interviews of experts in the public and private sectors to gather information regarding the state of the practice for disseminating travel time reliability information. As part of the interview, the research team asked questions related to the definition, computation, format, and users of travel time reliability information, as well as current applications and future plans for the dissemination of travel time reliability information. The interview participants represented the following agencies and private companies:

- Maryland State Highway Agency (MD SHA);
- Metropolitan Transportation Commission in Oakland, California;
- Minnesota Department of Transportation (MnDOT);
- Utah Department of Transportation (UDOT);
- Virginia Department of Rail and Public Transportation;
- Washington State Department of Transportation (WSDOT);
- INRIX;
- TeleCommunications Systems (formerly Networks in Motion Inc.); and
- Ryder Logistics.

TELEPHONE INTERVIEW RESULTS

The following sections provide a concise summary of the results of the telephone interviews conducted by the project team by specific question.

What Is Travel Time Reliability?

First, TTI researchers asked the participants to define travel time reliability. The participants provided the following definitions (in no particular order):

- Measure that allows you to predict trip time on a day-to-day basis.
- How trip time fluctuates from normal.
- Assessment of riskiness of specific route.
- Statistical analysis of historical time pattern.
- Planning time index (i.e., 95 percent travel time index).
- Estimated travel time that needs to be at least 95 percent accurate to gain public trust.
- Travel time to use if you want to be late to work once a month.
- Buffer time or best time to leave.
- Travel time that you can feel comfortable with.
- One mile per minute average over the course of a full day.
- Goal of the agency looking for an efficient system.
- System performance monitoring.

The majority of these definitions deal with providing travel time based upon certain reliability criteria (e.g., 95 percent reliable, late once a month, best time to leave, etc.). Only a few described travel time reliability as a separate measure (e.g., how trip time fluctuates and riskiness of route).

Most of the participants also felt that travel time reliability was a historical data projection (e.g., using six months of data to estimate the 95th percentile travel time), not a real-time measure (e.g., estimate that can change based upon current conditions). However, two public sector participants and one private-sector participant stated that travel time reliability needs to be a real-time measure since it is affected by nonrecurring events (e.g., incidents), and it needs to be accurate for the public to trust it. Several participants also noted that it could be computed from historical data and updated with real-time data when a nonrecurring event arose.

Does Travel Time Reliability Information Have Value to the Public?

The overwhelming answer was yes. Currently, most of the agencies interviewed provide travel time estimates, but these can change drastically between the pre-trip and en-route stages if a nonrecurring event (e.g., incident) happens. Travel time reliability gives the public an idea of the riskiness of the route (what delay could be if a nonrecurring event occurs) or the buffer time needed to get to their destination on time. Thus, travel time reliability can be used by the public to make decisions regarding departure time, mode choice, and route choice. However, many of the participants noted that the public does not use the term *reliability* and may not understand statistical probability (i.e., 95 percent travel time index). Participants also felt that the value of travel time reliability information to the public would be affected by the accuracy of the data and their understanding of the measure.

Most participants thought that the primary audience would be local commuters that are familiar with the road network. However, participants expressed concern that travel time reliability information may be difficult for most commuters to understand.

Does Travel Time Reliability Information Have Value to Transportation Operations Staff and Public Officials?

All of the participants thought that travel time reliability information was of value to transportation operations staff and public officials. Within an agency, travel time reliability can be used to assess the performance of the transportation system and help agencies determine where improvements are needed. In addition, travel time reliability is another tool that can be used to manage transportation networks and justify programs such as incident management programs and freeway service patrols. One of the private-sector companies uses travel time reliability information to ensure minimum hours of travel, miles traveled, fuel usage, wear and tear on vehicles, and emissions, all of which have financial impacts. Two public-sector participants felt that transportation operations staff does not fully understand the impacts of nonrecurring congestion on the reliability and performance of the transportation system since the operators are normally focused on responding to current traffic conditions. These two public-sector participants thought that travel time reliability information could be used to demonstrate the impacts of nonrecurring congestion on system performance.

What Are the Potential Impacts of Providing Effective Travel Time Reliability Information?

Researchers asked the above question regarding the following four measures: customer satisfaction, travel choices, system reliability and performance, and management and public officials. Participants felt that the impact of providing travel time reliability on customer satisfaction was highly dependent upon whether or not the public understands the travel time reliability information provided and the accuracy of the information. Participants thought that the impact on travel choices was less clear since only a small portion of commuters may use the travel time reliability information for trip planning, and anecdotal evidence shows that users are more likely to change their schedule than mode or route. Participants expressed hope that travel time reliability information will improve system performance; however, it would be hard to quantify its effects. The impact of providing travel time reliability on management and public officials was already discussed.

Do You Currently Disseminate Travel Time Reliability Information?

Almost half of the agencies/companies contacted (four of the nine) are currently disseminating travel time reliability information. However, none are specifically measuring the effectiveness of conveying travel time reliability information to users. One private-sector company provides its customers (mainly DOTs and commercial companies) with data from which travel time reliability can be computed. In addition, one private-sector company uses travel time reliability internally to compute estimated time of arrivals (ETAs) and to determine reasons for late deliveries. The following sections contain a more detailed discussion of the two public agencies and two private companies that currently disseminate travel time reliability information.

Metropolitan Transportation Commission (MTC) in Oakland, California

In the San Francisco Bay Area, the 511 phone system and 511 website (http://www.511.org/) provide travel time reliability as a comparison between the typical and current travel times for a

particular roadway segment. *Typical* is the term used for the historical average driving time and speed between a starting and ending point for a particular day of the week and time of day. An averaging scheme that gives more weight to data that are current is used so that the typical values are representative of current, seasonal traffic patterns.

Users can see information in text or graphical form. The text version allows users to choose an origin-destination pair from drop-down menus, and then the current and typical travel times are displayed for several routes. The graphical version is accessed on the traffic map for the region. A user chooses the origin and destination by clicking the desired nodes shown on the map, and then the current driving time is computed and displayed.

If current travel conditions are unknown, the following message is provided: "Do not have a current driving time. Typical trip is XX minutes." For routes with lane closures, the following message is provided: "Cannot give travel time because a portion of the route is closed." Similar information is provided via the phone system; however, it is only provided for the specifically requested route or location.

There is also an alert feature that can be personalized by users. The alert sends trip information to a mobile device or email about a specific trip the user has established. Like the travel time tools on the website, the alert contains the current trip time and the typical trip time as a reference. Users can also receive a severity alert when the current travel times exceed a threshold established by the user (e.g., 10 minutes longer than the typical time).

Washington State Department of Transportation

The WSDOT website provides travelers the option to plan their commute using 95 percent reliable travel times. The commute calculator uses weekday travel time data from 6:00 a.m. to 7:00 p.m. to provide a reasonable approximation of the worst-case travel time scenario. If a commuter allows for the calculated travel time, he or she can expect to arrive at his or her destination on time 19 out of 20 working days a month (i.e., 95 percent of trips). Users choose an origin and destination from a predefined list of locations, as well as the time they need to arrive. The calculator then shows the user how long it will take to make the trip and a recommended time to leave to arrive at the destination on time. In 2008, WSDOT introduced a new analysis of reliability to complement the traditional measures. This new analysis included 50th percentile (median), 80th percentile (how much time to leave in order to be late one day per week), and 90th percentile (how much time to leave in order to be late two days per month) travel times.

INRIX

INRIX is a private-sector company that collects travel time information on roadways across the U.S. using global positioning system (GPS)-enabled probe vehicles. INRIX then aggregates these data and provides historical and/or real-time information to DOTs and commercial companies (e.g., Garmen, Ford, etc.), which in turn use these data to compute various statistics for performance measurement and to provide traffic conditions to the public. The historical information provided by INRIX does include the following reliability statistics: percentile speeds (e.g., 10th, 15th, 25th, 50th, and 85th) and failure rates at 30 mph, 50 mph, and 60 mph.

While INRIX's primary customers are DOTs and commercial companies, INRIX does have an iPhone application called INRIX Traffic whose end user is the public. There is a free version of the application with a color-coded map to compare current and future departure times. There is also a paid version of the application called INRIX Traffic Pro that lets users drive and record favorite routes, as well as frequent destinations, so the user can obtain fastest-route and when-to-leave information for these user-defined routes and locations.

TeleCommunications Systems

TeleCommunications Systems (formerly Networks in Motion Inc.) is a private-sector company that is similar to INRIX; however, its primary customer is the public.

The navigation software uses GPS navigation on a cell phone, allows the user to enter a destination, and then selects a route based on current traffic conditions. If an incident occurs once the user is in route, TeleCommunications Systems sends an incident alert that offers to re-route the user around the incident area. TeleCommunications Systems uses data from the public sector and proprietary algorithms to improve the data. It also calculates ETAs within ±5 percent. Over the years, TeleCommunications Systems has found that the color-coded information needs to be extremely accurate (95 percent) or users will not trust the information provided.

In addition to working with the public, TeleCommunications Systems also works directly with DOTs. Based on its review of the raw sensor data, in the past TeleCommunications Systems has reported problems with the DOTs' sensor networks and worked with DOTs to prioritize repair and deployment of future infrastructure.

What Are the Challenges to Disseminating Travel Time Reliability Information?

For the four public agencies that do not currently disseminate travel time reliability information (MD SHA, MnDOT, UDOT, and the Virginia Department of Rail and Public Transportation), the main challenges cited were:

- Inability to quickly collect and analyze data,
- Limited staffing, and
- Determining a format that will be accepted and understood by users.

These public agencies do not currently have a quick method (e.g., algorithms, software, etc.) that can be used to collect data and calculate travel time reliability information. In addition, due to workforce reductions, public agency staff does not have time to develop these methods internally. Also, they would prefer that a standardized format to depict travel time reliability information be developed prior to implementation. This format must be understood and considered valuable by the traveling public in order for them to be able to process and use travel time reliability information.

Additional challenges cited by other participants were:

- The need for quality data, and
- Implementation in multi-jurisdictional areas.

Obviously, the quality of the data will impact customer satisfaction and trust of the data provided. Several participants expressed concern regarding potential political impacts from disseminating travel time reliability information (e.g., what if one agency's reliability is not as good as another's). Also, agencies in the same area may have different sources, levels, and accuracy of information, which can make it difficult for a user to obtain information regarding an entire region.

What Are the Short-Term and Long-Term Goals Regarding the Dissemination of Travel Time Reliability Information?

For those agencies that do not currently disseminate travel time reliability information, most of them are beginning to internally discuss the idea of providing travel time reliability information to the public and would like for actual implementation to occur within years. Potential media mentioned by participants included the internet, 511 systems, and cell phone applications. For those agencies currently providing travel time reliability information, most of them wanted to improve data quality, expand coverage, provide customizable reports, provide via new media (e.g., cell phone applications), and provide new travel time reliability statistics (e.g., 50th percentile, 80th percentile, etc.).

Chapter 4 TECHNOLOGY AND INNOVATION SCAN

INTRODUCTION AND CONTEXT SETTING

Traveler information can be acquired by travelers today through a number of media. These media range from traditional roadside signage and broadcast media to newer electronic wireless and web-based media. The resulting mix of traffic and transportation system status data has greatly increased information accessibility and permitted an ever-greater degree of traveler-specific customization.

Organizations providing traveler information continue to broaden beyond traditional public agencies and news organizations to private corporations, data integrators, and social networking applications. Methods for measuring travel conditions have also evolved beyond traditional technologies such as loop detectors and infrared sensors to video imaging, cell phone tracking, Bluetooth monitoring, GPS traces, and traveler-to-traveler information sharing. In step, methods for integrating multiple data are becoming more sophisticated and complex, blending multiple sources of data including real-time and historic data that are both quantitative and qualitative in nature. Furthermore, the means for transmission of information are increasing in sophistication beyond dynamic message signs and web content toward in-vehicle devices with innovative voice-based transactions and heads-up displays (HUDs). These concurrent trends in technology and innovation will provide the potential for traveler information granularity, coverage, and accuracy far exceeding what has historically been available and consequently will offer the opportunity for delivering trip reliability information in a variety of forms, both traditional and newly conceived.

Trip reliability information for travelers can be interpreted through two distinct lenses: (1) information on historic trip time variability of a specific trip, and (2) the reliability of traveler information (e.g., how reliable is the message "expect delays" or "20 minutes to downtown)." For the first interpretation, one use of reliability information is to aid in determining an appropriate departure time and route based on the traveler's risk acceptability for late arrivals. For example, a traveler may budget 75 minutes for his or her trip to the airport because he or she has been informed that historically, the average travel time to the airport during that rainy Friday afternoon that he or she is traveling is 45 minutes, but the 95th percentile travel time is 70 minutes. For the second interpretation, the traveler while driving to the airport may be informed that the travel time is between 40-50 minutes and that there is a 10 percent probability that the trip will take over 50 minutes given current traffic conditions. The aforementioned example is one of many metrics through which trip reliability can be delivered to the traveler. The Literature Review chapter provided the definitions of trip reliability metrics; outlined the prevalent formats and types of reliability information disseminated mainly through variable message signs, 511 phone systems, and websites; described how reliability information is communicated in other fields, such as weather forecasts; and highlighted more recent means for transmission of traveler information including personalized emails, texts, and tweets. This chapter presents a technology and innovation scan that focuses on technology and innovation trends likely to impact the provision of traveler information over the next five years.

This scan is organized into three exploratory sections, each ending with a synopsis of findings. Following the three exploratory sections is a section discussing the outlook for traveler

information. The first section of this scan identifies the underlying technology trends that will drive the availability of better reliability data. The second section presents innovative media that have become center stage in the past few years for disseminating traveler information (i.e., portable navigation devices and applications on personal digital assistants [PDAs], smartphones, and mobile phones), media on the cusp of becoming center stage (in-vehicle agents), and future technologies such as integrated HUDs of reliability information. Examples of specific applications for these media are highlighted. The use of social media to reach travelers as well as the phenomena of crowdsourcing as it pertains to trip reliability information provision is explored in this section. The third section then identifies the market players in provision of traveler information.

Following the three exploratory sections, the scan presents the outlook for traveler information, specifically reliability data. In this section, the scan aims to address a number of foundational considerations as both technology and innovations enable opportunities for providing travelers information on trip reliability. Two foundational considerations are those of driving safety and varying needs for driver information.

Driver information overload and distraction is a critical issue gaining significant attention under the Obama administration. Most recently, in September 2009, the USDOT held a Distracted Driving Summit whose discussions related to distracted driving legislation will likely have direct implications on the means and content of delivering reliability information (NHTSA, 2012). Furthermore, in January 2010, the USDOT enacted prohibitions that ban truck and bus drivers from sending text messages on handheld devices while operating commercial vehicles. This issue is further discussed in the final section of this scan.

The most basic considerations for trip reliability information relate to the points during a trip that reliability information should be provided, the content of the reliability information to be provided, and how content differs as a trip is made from planning, origin, to ultimate destination. Another consideration regards how reliability information needs differ for travelers with familiarity and experience with a recurrent trip compared to a trip made without the benefit of day-to-day experience of the trip's reliability. Likewise, how might transmission media and message content differ based on the needs of different driver types and trip purposes (e.g., older drivers or newer drivers, commercial vehicle operators or carpool organizers)? Furthermore, what innovations can assist in efficiently meeting these varying needs? These considerations are also discussed in the final section of this scan.

The scan concludes with positions on likely trends in the landscape of traveler information on trip reliability in light of factors including market player alignment, better underlying technologies, and innovative media for displaying and acquiring information.

UNDERLYING TECHNOLOGY TRENDS: BETTER DATA TO COME

Major freeways in many metropolitan areas are instrumented with in-road or roadside sensors (e.g., inductive loop, radar, and video image detectors) to aid in monitoring performance of the road system, to better manage real-time operations, and to inform travelers of traffic conditions. Based on a survey of 78-108 metropolitan areas from the years 1999 through 2007, the percentage of freeway centerline miles under electronic surveillance has increased in line with a

pessimistic projection over the last decade, nearing 41 percent deployment (RITA, 2012). Given the costs associated with deployment and maintenance of roadside sensors, adding more sensors may be increasingly difficult to justify for public-sector agencies with mature traffic management/traveler information systems. These sensors measure traffic volume and occupancy and can measure or estimate spot speed.

From spot speeds, travel time is estimated through extrapolation methods, statistical methods, or methods based on traffic flow theory. The sensor provides performance information for a single location, and that location may not accurately represent the performance of the rest of the roadway segment associated with that location. Also, information is only available where sensors are present, which is mainly on freeways. Sensor technologies deployed for freeway systems are less effective on interrupted flow facilities like signalized arterials. Consequently, travel time reliability estimation is limited to measurement of roadway variability at points rather than along a stretch of roadway. The fundamental limitation from point sensors is that travel reliability must be inferred rather than directly observed since the sensors report on roadway segments, not trip makers.

As a whole, probe vehicle technologies differ in concept from spot speed sensors. Probe vehicle technologies enable direct measurement of travel time and space-mean speed, but for now, only a subset of all vehicles is monitored. The most prevalent probe vehicle technology in use over the past two decades is toll tags. Another probe vehicle technology, license plate matching, is able to monitor the majority of vehicles but at significantly higher costs. In the past decade, three key technology trends have enabled new means of collecting data that promise varying degrees of success in garnering far greater geographic coverage and granularity of data that can support estimation of trip reliability. These trends include the proliferation of cell phone usage, Bluetooth usage, and GPS-enabled devices. The application of these technologies for travel time and reliability information is discussed in detail after a brief discussion on both toll tag reader and license plate matching technologies.

Toll Tag Readers

Toll tag systems collect and record the time at which individual tag-equipped vehicles pass particular toll reader locations for the purpose of billing. By comparing the time at which a vehicle passes consecutive readers, the travel time can be measured for each toll tag vehicle. Given that ground infrastructure, communications, and necessary data sets are already present for the purposes of toll billing, agencies would incur a far lower cost in using these data to generate traveler information data on travel time and reliability. For closed toll systems, travel time data are highly accurate given only one path for travel and capture of entry and exit points.

As of the mid-1990s, agencies have placed toll readers not for the purpose of billing but rather to acquire travel time estimates along facilities where significant numbers of vehicles have toll tags. The Houston region has been very successful in using nonrevenue toll tag readers on non-toll highways to acquire and transmit traveler information. As of 2010, over 857 directional miles were being monitored using toll tag readers (Houston TranStar, 2010). Deployments of toll readers were attempted in San Antonio (Hicks & Carter, 2000), but level of market penetration proved insufficient for travel time and speed measurements through all times of day. During a similar deployment in Orlando, a number of issues regarding the actual path of vehicle travel

along arterial roads, the possibility of vehicle stops along the path, and low percentages of traffic having toll tags during off-peak hours, among other issues, made it an unsuccessful strategy (RITA, 2012). Consequently, travel times on facilities beyond tollways and highways with high concentrations of vehicles with toll tags have proven a challenge to estimate.

License Plate Matching

Another traditional probe vehicle technique that is able to monitor a far larger sample of the total traffic between two points, albeit at a higher expense, is license plate matching. Matching can be done either manually or through the use of portable computers, manual transcription of video, or video and character recognition. Only the last of the four methods is amenable to real-time monitoring, but it raises significant privacy issues and is cost-effective for only specialized studies.

Cell Phone Triangulation Using Towers

In order to route calls to a phone, the cell towers listen for a signal sent from the phone and negotiate which tower is best able to communicate with the phone. As the phone changes location, the antenna towers monitor the signal and the phone is roamed to an adjacent tower as appropriate. By comparing the relative signal strength from multiple antenna towers, a general location of a phone can be roughly determined regardless of whether the phone is in use. This triangulation process is used to anonymously track movement of cell phones and extrapolate such movements to measure travel times and roadway speeds. The triangulation technology has a location accuracy range of 50 to 150 meters.

The key strengths for use of cell phone triangulation to obtain traffic data include far lower deployment cost, potential for large sample size without recruitment or vehicle instrumentation, and potential for far greater geographic and temporal coverage. A key challenge to this technology is the inherent inaccuracy of position, direction, and speed identification. This inaccuracy makes distinctions difficult between walking and standing pedestrians, stop-and-go roadway traffic, and bus or transit services. Likewise, assignment of observations across multi-deck or closely parallel roads proves challenging. Travel time providers using cell phones as traffic probes also depend upon the willingness of wireless cell companies to provide the anonymous positional data of cell users in order to compute travel time estimations on roadways.

Key providers of cell tower triangulation systems include AirSage, CellInt, Delcan/ITIS, IntelliOne, Globis Data, and TrafficCast. Other players such as TomTom and INRIX are joining in the use of cell phone tracking techniques in Europe. Based on analyses of deployments by providers, the accuracy of travel time and travel speed data is relatively comparable for long road segments during free-flow conditions, and the technology is able to detect the occurrence of congestion. However, for shorter road segments and during moderate to lower speeds, this technology has not yet proved successful compared to traditional spot estimates. Following are snapshots of the first few entrants into this technology.

AirSage collects and analyzes real-time cell phone signals that produce more than 15 billion anonymous locations every day (AirSage, 2012). A number of evaluations have been conducted on AirSage's system, including tests in Salt Lake City, Utah; Minneapolis, Minnesota;

Milwaukee and Madison, Wisconsin; Atlanta and Macon, Georgia; and Hampton Roads, Virginia (Fontaine & Smith, 2007). The most recent, conducted by GeoStat, reports that for freeways evaluated in Detroit, San Diego, and New York, AirSage correctly detected congestion from 84 percent to 93 percent of the time but did not present analyses on the accuracy of travel time or speed measurements. In Minnesota, speed and travel time were compared with loop-detector data on I-394 East (2.9 miles), and with license plate matching data on County Road 81 (2.2 miles) (Liu, Danczyk, Brewer, & Starr, 2008). Results suggest significant differences during low-to-moderate speeds. The cell phone tracking system did not correlate with observed trends. In Hampton Roads, Virginia, speed data were not acceptable at speeds below 30 mph and travel time was not reliable (Liu, Danczyk, Brewer, & Starr, 2008).

CellInt combines its cellular data with GPS probes and other data streams and provides real-time road traffic information in the Skane Region of Sweden, Israel, Kansas City, and Atlanta. With regard to cellular tracking, CellInt uses a pattern matching geo-location approach, which provides the company with the ability to correlate each probe vehicle's position with a more exact location on a roadway. Reports are unclear as to whether estimates of accuracy are for peak periods or other conditions.

Delcan/ITIS provides a system for cell phone tracking that has been implemented in the Baltimore metropolitan region for Cingular users. Results from a pilot test conducted by the University of Maryland in 2006 suggest that average errors were in the 10 mph range on I-985 and 20 mph range on I-395, with significant quality degradation during peak periods. Another study using Estimotion Ltd, an ITIS product, compared the Estimotion cellular-based data with loop detectors and a small subset of GPS trace runs over a 14 km stretch of freeway in Israel (Bar-Gera, 2007). The study reported far greater noise using cellular data compared to loop detectors, with overall similar speed ranges.

TrafficCast, in strategic partnership with China Mobile, began deployment of the world's largest cellular probe system in Shanghai in September 2006. The anonymous mobile phone position and signaling data in China Mobile's GSM Network are collected, analyzed, and converted into travel time and speed information for major highways and surface streets in Shanghai. Currently, the system collects cellular data from 10 million subscribers in Shanghai and covers all roads within the Inner Ring Area, including 483 miles of major roads comprising 1700 roadway segments.

Bluetooth Tracking

Bluetooth is a telecommunications industry specification that defines the manner in which mobile phones, computers, personal digital assistants, car radios, and other digital devices can be easily interconnected using short-range wireless communications (Traffax Inc., 2012). The application of this technology that interconnects a mobile phone with a wireless earpiece to permit hands-free operation can be leveraged for use in traffic monitoring. Because each Bluetooth device has a unique media access code (MAC), traditional matching algorithms such as those used for license plate or toll tag tracking can be used to estimate travel time along a freeway or arterial.

The use of Bluetooth technology offers advantages in that travel time and space-mean speed are directly measured with greater accuracy for multiple modes of travel (road, transit, and walking) without a concern for personally identifiable information as with toll tags or cell phones. The radius of Bluetooth recognition is approximately 100 meters; consequently, the maximum measurement error is under 6 percent given a distance between trackers of 2 miles. This system would require the placement of Bluetooth receivers along the routes for which travel time information is desired, which is similar to toll tag receivers.

Bluetooth tracking has been applied as an alternative to floating car or other probe vehicle tests and can supplant such tactics in computing ground truth. Field tests using this technology have been performed by the University of Maryland on I-495 (Center for Advanced Transportation Technology, 2008) and by Purdue University with the Indiana Department of Transportation on I-465, SR-37, and other locations (Wasson, Sturdevant, & Bullock, 2008). The Texas A&M Transportation Institute began tests of Bluetooth tracking as a viable, cost-effective alternative for expansion of coverage of the TranStar system on arterial roadways. Initial results comparing Bluetooth tracking with license plate recognition systems on urban arterials within the city of Houston demonstrated sufficient concentrations of Bluetooth traffic and often superior travel time and speed data generated by Bluetooth tracking (Texas A&M Transportation Institute, 2012).

In June 2009, TrafficCast introduced BlueToad (Bluetooth Travel-Time Origination And Destination) traffic monitoring technology that traces anonymous Bluetooth signals to derive travel times, road speeds, and vehicle movements (TrafficCast, 2012). One other consideration with Bluetooth-enabled probe approaches is that Bluetooth is not a dedicated transportation wireless protocol and directly serves the needs of short-range wireless connectivity between mobile devices. Bluetooth will evolve over time, primarily in response to needs driven by these (non-traffic-related) applications. At a minimum, this will require the traffic-related probe technologies to evolve along with any changes in Bluetooth. There remains at least some risk that over the long term Bluetooth may evolve into a state where it no longer supports traffic data collection.

GPS-Enabled Devices

GPS is a satellite-based navigation system made up of a network of 24 active satellites placed into orbit by the U.S. Department of Defense. GPS works in any weather conditions, anywhere in the world, 24 hours a day, and can be used without a subscription fee. GPS receivers use trilateration to calculate the user's exact location on the earth based on radio signals from satellites. Whereas cellular technology enables location accuracy near 100 meters, GPS technology enables location accuracy of less than a few meters, along with highly accurate speed, trip distance, and travel time computations.

What can degrade the GPS signal and thus affect accuracy in downtown settings is the signal multipath effect, which occurs when the signal bounces off tall buildings or rock surfaces before reaching the receiver. The location accuracy also degrades at very low speeds and during vehicle stops, which can cause difficulty in assigning road use for dense urban networks. Furthermore, as with cell phone triangulation, distinctions on whether the device transmission is during walking, transit use, or auto use are difficult to make.

Application of GPS technology for fleet management has become common for both public and private fleet operators, ranging from goods delivery vehicles to public bus transit. Many studies have investigated the use of dedicated fleets of vehicles equipped with GPS including FedEx and UPS trucks, taxi fleets, and transit fleets (Schafer, Thiessenhusen, & Wagner, 2002) (Bertini & Tantiyanagulchai, 2004). These studies demonstrate that GPS-based estimation of travel time and roadway speeds far exceed existing granularity and accuracy and that a market penetration around 2 percent in the vehicle fleet is sufficient for quality estimates of travel time and speed. The location and speed of mobile devices with GPS capability can be tracked.

Nearly 4.1 million mobile phones were active worldwide at the end of year 2008 (Tryhorn, 2009). Among new features in mobile devices (e.g., smartphones or PDAs), GPS is one of the most common, especially for mid- to high-end mobile devices. Most individual mobile devices have settings that enable or disable GPS, and mobile device providers can track and record locations for devices with GPS enabled.

At present, a number of private traveler information providers leverage real-time GPS reports from commercial and consumer vehicles/devices in providing estimates of travel speed and travel time. INRIX blends real-time road sensor data with billions of real-time data points from over one million GPS-enabled commercial and consumer devices in taxis, service vehicles, airport shuttle services, cars, and long-haul trucks (INRIX, 2012). NAVTEQ, a wholly owned subsidiary of Nokia, integrates GPS data from Nokia handsets into NAVTEQ Traffic™ products in Europe and North America. Google has also begun using GPS-enabled mobile devices to acquire probe data.

As a part of the Mobile Millennium project between the University of California's California Center for Innovative Transportation (CCIT), the California Department of Transportation (Caltrans), and Nokia, the first real-time permanent traffic monitoring system using GPS data began development in mid-2008 with 100 vehicles traveling with their GPS-enabled Nokia phones (University of California, Berkeley, 2012). This project continued with plans for greater attention to arterial coverage and ended in 2010. During this time, a number of crowdsourcing services (e.g., Waze, GoogleMaps, and Ahamobile) emerged that use GPS-enabled mobile devices to make available experiences of drivers in their service either through active driver reporting or passive GPS tracing.

Future Technologies

Connected Vehicles is a suite of technologies and applications that uses wireless communications to provide connectivity among vehicles, as well as between vehicles, wireless devices, and the roadway infrastructure. These technologies are in essence similar to toll tag readers but with far richer information and greater emphasis on vehicle safety and driver assistance applications. On-board equipment (OBE) integrated with vehicle electronic systems could be designed to anonymously relay information on speeds and vehicle conditions such as traction control, or anti-lock braking activation, which are proxies for road surface conditions. The OBE could transmit this data anonymously to road side equipment (RSE), which in turn could relay the information to be turned into useful traffic data. Safety applications are expected to operate through dedicated short-range communications (DSRCs) that take place over a dedicated 75 MHz spectrum band around 5.9 GHz, allocated by the U.S. Federal

Communications Commission for vehicle safety applications. Applications with less-stringent latency requirement (e.g., traveler information) may utilize a broader range of communication links, ranging from DSRC to Wi-Fi and other wide-area media. Many Connected Vehicle technologies are still in the research and development phase, with some innovative safety applications emerging into the market. With regard to travel time and travel time reliability data acquisition, however, they are not expected to have significant near-term market impact.

Synopsis of Underlying Technologies

Traditional in-road and roadside technologies have been around for over half a century, and although these technologies have documented difficulties with system reliability, geographic availability, and travel time accuracy, they are able to adequately measure the flow, occupancy, and volume of traffic along major roadways—data that are invaluable to the management and operation of roadway infrastructure.

Among newer probe technologies, GPS mobile devices offer the greatest promise given that GPS's data accuracy is far superior compared to cell phone tower triangulation, and it would require no additional infrastructure as would be needed with Bluetooth tracking. Advantages of advanced probe vehicle techniques include low costs per unit of data, continuous and automated data collection without disruption to traffic, ability to directly measure travel times, and fewer privacy concerns. Furthermore, while traditional probe systems such as transit automatic vehicle location (AVL) have high implementation costs and fixed infrastructure constraints such as locations of receiving antennas, the proliferation of cellular and GPS-enabled mobile devices provides tremendous opportunities for data accuracy, coverage, and reliability that have never been available before.

There are some notable advantages to Bluetooth tracking technologies compared to GPS and cell phone tracking. Foremost, Bluetooth tracking does not entail the recording of any personally identifiable data. Thus, use of this technology eliminates privacy concerns associated with GPS and cellular sources of data. Additionally, the data generated through GPS and cellular devices require agreements with private parties, and the ownership of the data typically remains with a private-sector entity. Bluetooth data can be acquired directly by public agencies at relatively lower costs compared to toll tag technologies, and data ownership rights remain with the public agency.

The data to support end-to-end trip reliability will be increasingly available in the near future. The potential availability of advanced probe data also comes with new challenges for developing efficient means of processing, presenting, and archiving data. More complex processes for merging probe data with traditional data will need to be developed in order to provide to system managers and travelers information that is both timely and relevant. Another issue for would-be data integrators will be managing relationships between public agencies and commercial mobile phone corporations with regard to access and use of vehicle location and speed data from mobile subscribers. The need for traditional traffic monitoring techniques will remain for the foreseeable future, given public agency needs for data on traffic volumes and occupancy as well as other functions such as intersection management and tolling.

INNOVATIVE MEDIA FOR TRAVELER INFORMATION USERS

Traditionally, travelers have relied on commercial radio, television, and highway advisory radio for traveler information. Information content from these media is generalized, covering locations of accidents and qualitative descriptions of localized roadway traffic conditions such as "slow" or "congested." Additionally, content and delivery time from these media are on a schedule determined by the media rather than traveler needs. Changeable message signs, transportation agency websites, and phone services followed, supplementing qualitative traffic reports with more precise quantitative data that covers ranges of travel speed, construction and event information, transit options and times to arrival, and travel time estimates along primary and alternate paths. Travelers can acquire data when they need it, but accessibility is limited by when travelers can access the websites. Furthermore, travelers frequently have to perform relatively extensive searches to find the data they need. Concurrent with improved public-sector information provisions on CMSs and traveler information websites, new consumer electronics emerged in the marketplace. In 2000, the Federal Communications Commission (FCC) designated 511 as the national travel information telephone number across the country, spurring the growth of roadway traffic information content available by phone. In 2009, the Federal Highway Administration submitted a *Notice for Proposed Rulemaking* for the Real-Time System Management Information Program. The FHWA proposes "general uniformity among the real-time information programs to ensure consistent service to travelers and to other agencies." This notice outlines, among other items, requirements for the timeliness, availability, and accuracy of traffic content (Real-Time System Management Information Program, 2010).

In 2001, two satellite radio providers, Sirius Satellite Radio and XM Satellite Radio began providing music, news, talk, traffic, and weather content in vehicles through paid subscriptions. Subscribers receive the same programming anywhere in the footprint of the service. An advantage over commercial radio, where travelers wait for localized traffic information between music broadcasts, satellite radio provides local traffic and weather information continuously in a loop format on a dedicated channel. In 2008, the two companies completed a merger and continue to provide hundreds of channels including localized traffic data for over a dozen metropolitan regions.

In more recent years, public and private websites have begun to offer personalized information through emails to travelers based on routes of interest to the traveler. At the same time, a number of personal navigation devices (PNDs) have come to market through private commercial enterprises that enable acquisition of real-time information along with turn-by-turn trip routing. Public agencies, local morning television shows, and commercial radio broadcasters are leveraging newer communication media to deliver traveler information. For example, KIROTV7 in Seattle sends messages of traffic on Twitter (called tweets), a free social networking and micro-blogging service that enables its users to send and read other users' updates on their text-messaging phones. While most states only distribute information on traffic, a few states, such as Washington, let motorists tweet about traffic conditions. State agencies providing traffic information via Twitter include California, Colorado, Delaware, the District of Columbia, Illinois, Indiana, Kansas, Louisiana, Maine, Maryland, Minnesota, Mississippi, Missouri, Nebraska, New York, North Carolina, Oregon, Tennessee, Texas, Utah, and Virginia (The Washington Times, 2009). Tweet content varies from state to state; some states use tweets to

distribute up-to-the-minute traffic congestion and others reserve tweets for emergencies such as hurricane evacuations.

With greater availability of PDAs and smartphones in the past three years, a number of applications have become available for travelers to acquire real-time traffic information along with routing support over their mobile devices. Such applications use information from public agencies, data from private commercial enterprises, and GPS or user input directly from traveling subscribers.

Another technology coming to market around the same time as traveler information on GPS-enabled mobile devices is that of vehicle telematics systems (or early in-vehicle agent technologies). These systems control operations of relevant in-vehicle devices based on driver requests or vehicle actions. The vehicle, in essence, has a built-in computerized hub/interface and various services/applications can be subscribed to for use in the vehicle.

Another phenomenon in traveler information that is gaining momentum is crowdsourcing. A crowdsourced network gathers reports directly from drivers themselves, bringing information on even smaller side or neighborhood roads to the individuals using the network. Many applications only receive information when either the driver actively sends a message or turns on the application, while some phones continue to send speed and location data even when the map/traffic application is not being used. Some crowdsourced media are standalone enterprises, while others intertwine crowdsourced data with public traffic and other private data to provide traveler information.

As of mid-2009, there were nearly 35 million factory-installed and aftermarket in-dash navigation systems, over 90 million PNDs, and an estimated 28 million navigation-enabled mobile handsets with GPS used worldwide (Berg InSight, 2009). Features beyond turn-by-turn guidance, such as local search, traffic flow information, speed camera locations, and real-time travel time are now available through these media for travelers. What is missing by and large is the presence of trip reliability information, as well as assessments on the accuracy and completeness of information provided. The following sections highlight the state of the art in PNDs, GPS-enabled mobile devices, vehicle agents, crowdsourced applications, and mobile applications specific to transit.

Personal Navigation Devices

PNDs first entered the market in the early 1980s, but these devices only contained maps for a small area. The PND market expanded rapidly in the last decade to the point where highly capable low-end devices now sell below $100 per unit. The newest generation of PNDs offers many more features, such as real-time traffic information, Bluetooth compatibility, touch screen buttons, voice and command control, and spoken direction with text-to-speech. Following the increased competition and trends toward multipurpose GPS-enabled mobile devices, many players have exited the PND market as of 2009. Going forward, the PND industry is likely to see further consolidation and additional exits. The four major vendors of PNDs are Garmin, Magellan (MiTAC Corp.), Navigon, and TomTom.

As the PND/smartphone convergence phenomenon in the navigation market continues, the major PND vendors have begun developing application versions of their standalone GPS devices with additional features, while others are pushing toward adding cellular technology to their portable devices with hopes to maintain their market position. The next section highlights mobile applications from PND vendors as well as others vying for market share.

Applications for GPS-Enabled Mobile Devices

Apple, Research in Motion (BlackBerry), HTC, LG, Nokia, Palm, Samsung, and T-Mobile all offer smartphones, which can be broadly defined as multipurpose GPS-enabled mobile communication and computing platforms. The iPhone, BlackBerry, Droid, and others have applications that enable travelers to access traffic information. For example, the free California Traffic Report application for iPhone users was introduced in February 2009, and within the first 10 days, over 2600 individuals downloaded the application (Ramsey, 2009). The application offers personalized reports with real-time commute times based on data supplied by Caltrans.

PND vendors are also transitioning from marketing single-purpose navigation devices to providing navigation applications for multipurpose mobile devices. Navigon introduced in 2009 a third update to the iPhone application with text-to-speech features and live traffic called the Navigon *MobileNavigator* (Ngo, 2009). This product is not a free application. The Magellan RoadMate for iPhone inherits many of the features of the RoadMate 1470 PND including spoken street names, NAVTEQ maps, three-dimensional (3D) landmarks, in-app music control, and a pedestrian mode, but it does not yet offer real-time traveler information.

Other popular traffic applications include GPS Traffic by eMobile, Traffic Vizzion, Traffic Gauge, and Google Maps. Traffic Vizzion, which partnered in April 2009 with INRIX, offers on the BlackBerry real-time viewing of traffic cameras across 180 cities and a suite of additional functions for GPS-enabled BlackBerries (Traffic Vizzion, 2012). Traffic Gauge offers applications for multiple platforms in nearly a dozen cities with color-coded maps and states that it only uses actual real-time data to guide users around traffic (TrafficGauge Inc., 2012). Traffic.com recently released its free application for BlackBerry. The application gives the user a detailed view of traffic conditions, including color-coded traffic-flow maps, incident data, mass transit data, and more (Zeis, 2009).

In November 2009, Google Maps introduced as a free service the application Google Maps Navigation for mobile devices running the Google-developed open-source Android 2.0 mobile operating system. This application enables both voice guidance and automatic routing and provides traffic information through color-coded maps. Color-coded traffic maps are also accessible for free and are based on crowdsourced GPS data from application users. If this application expands in popularity commensurate with the success of other Google services, the viability of PND devices and other paid traffic applications available may be called into question. The business model for the consortium of Google, partnering telecommunications companies, and partner device manufacturers is to establish the dominant multipurpose mobile platform. These devices recover costs for Google by ensuring ease of access to Google search engines and other Google-branded services that generate revenue based on large numbers of users performing searches and viewing advertisements.

Most recently, during the Consumer Electronics Showcase in January 2010, INRIX debuted its Traffic Pro application for the iPhone and iPod (INRIX Traffic Pro, 2010). This appears to be the first device to provide real-time, trip-based, travel time prediction capability. The technology merges data on the current traffic conditions, weather forecasts, event information, and roadwork with historic day of week, seasonal, holiday, weather, and accident data to predict travel time at 15-minute intervals. This application is now available for a few metropolitan regions in the United States. The application answers basic questions for travelers, such as when to leave to get home, what's the best route, when to expect to arrive home, and whether there are any accidents or events along the way. The level of accuracy of the predictive data is still unclear. A previous iPhone traffic application, offered by INRIX, covered 126 cities in the U.S. That INRIX application, like many others, provided color-coded traffic congestion maps but differed in its forecast function, which let users see what traffic was predicted to look like up to an hour in advance (Cunningham, 2009).

Crowdsourced Applications for Traveler Information

Crowdsourcing is potentially a win-win strategy for both consumers and businesses, and it has significant implications for potentially transforming traditional roles in traffic condition data collection, aggregation, and provision. Crowdsourcing enables creation of new services at reduced costs and can offer participants value from the experience of peers. Crowdsourcing has been driven by the explosive growth of GPS-enabled mobile devices, leaps in software technology, and willingness of consumers to contribute to a shared experience.

There are a number of companies that aim to provide traffic information through the experience of their members. Some use experiential knowledge to share information among members, while others actually use GPS data from members to share information among users and to improve traveler information estimates beyond the application's mobile users. Crowdsource services highlighted below include Aardvark, Ahamobile, Waze, Google Maps, and INRIX.

Aardvark, founded in late 2007, launched its mobile social networking search application for the iPhone in September 2009. The application uses Facebook or an email import to determine a user's social network. Users receive notifications when someone in their network has a question that they may be able to answer. The service may solicit input from networks of those in the user's network and consequently have a far larger pool of experts. A user, for example, may ask what the best route from San Francisco to San Diego might be on a Wednesday afternoon. Responses usually arrive within five minutes. This service, of course, extends far beyond traffic information but can easily gain enough members and experts to support information on trip reliability where no institutional data are available.

AhaMobile launched in September 2009 a new version of its free iPhone app, providing real-time traffic reports using a voice-based, non-map-centric approach with national traffic coverage and a few entertainment and social media features (Rao, 2009). Using Aha's application, drivers record and share their personal traffic reports, up to 15 seconds in length, on their iPhone to help those around them. The audio messages, called Aha Shouts, are broadcast to nearby drivers. Shout content can be traffic related (e.g., bottlenecks, speed traps, or accidents) as well as on other topics unrelated to traffic (e.g., sharing a karaoke performance). Shouts can be posted to Twitter or Facebook. Posts are automatically populated and include shout type, the user's

current location and speed (for traffic shouts), and a link to play the shout. In addition to Facebook and Twitter integration, users of Aha's app can listen to INRIX and Clear Channel traffic, get nearby restaurant information pulled from Yelp, find the closest bathroom along the trip route from SitOrSquat, and identify speed camera locations from Photoenforced.com.

Emphasis in Aha Mobile is on the top markets, including Los Angeles, San Francisco, Washington, DC, New York, Boston, Chicago, Dallas, Detroit, Houston, Atlanta, Miami, and Seattle. The organization plans to sell 10-second advertising spots on the application in the future and hopes to integrate into cars to make the application sustainable. Additionally, the organization plans to begin moving into other platforms such as the BlackBerry and will also aim to integrate its product with automakers and car navigation systems (Roizen, 2009). The set of applications, as with other in-vehicle, non-driving activities, can pose a significant safety hazard by distracting motorists from the task of driving.

Waze debuted in the U.S. market in May 2009 after success in Israel with over 80,000 downloads, 90 percent geographic coverage, 10,000 daily users, and over 85 percent arrival time accuracy (Martin, 2009). This free social mobile application has the goal of mapping road networks through community member use and enabling members (called wazers) to share their road experiences in real time with local wazers. The U.S. Census Bureau TIGER maps are the foundation of the Waze map network. The U.S. version posts Westwood One alerts in addition to member alerts. The business plan is to create a complete road network comparable to products by NAVTEQ or TeleAtlas and then to sell this information, all while providing value to Waze members through real-time traffic information. Rollout is planned first for San Francisco, Boston, and Chicago, with coverage for the U.S. within a year. Participation in Waze requires the Droid, iPhone, Symbian, Windows Mobile, or J2ME operating systems.

Google Maps for Mobile has been around since 2007 and provides the functionality of Google Maps on the web, such as current location, driving directions, satellite views, and phone numbers and addresses for local businesses. In April 2008, Google Maps debuted a feature that allows users to view traffic congestion patterns by time of day and day of week. In 2009, Google debuted Google Maps Navigation (beta version) on most phones, including the Android, BlackBerry, iPhone, and others. This free application provides turn-by-turn GPS navigation with voice guidance. Additionally, business listings, street views, traffic, and transit/walking directions are all accessible.

The traffic data are from various data sources including crowdsourced from users who have the My Location feature turned on. From mobile users with GPS-enabled devices, location and speed are acquired from GPS data directly, while cell tower triangulation is applied to estimate location and speed for mobile devices without GPS. Google Maps already has 50 million active users across various mobile phones, but it is unclear what percentage of users has enabled the My Location feature (Arrington, 2009). Even if a small fraction of users enable My Location, the quantity of data acquired from this crowdsourced media will be significant.

INRIX Traffic, unlike Google Maps, receives GPS probe data including speed and location from every INRIX Traffic application user. INRIX is the world's largest crowdsourced driver network with over 1.3 million GPS-enabled vehicles, mobile devices, and road sensors. INRIX has been crowdsourcing GPS-enabled vehicle data commercially to deliver traffic information

since 2006. These data are combined with billions of real-time speed data points from commercial and consumer vehicles, as well as road sensor information from DOTs across the country. INRIX delivers traffic content to clients and consumers on terrestrial and satellite radio, on broadcast and cable TV, through wireless applications and services, and via the Internet.

In-Vehicle Systems

Since 1995, OnStar has offered 24-hour access to advisors, a connection to emergency assistance, and access to OnStar hands-free calling. This was a key introduction in moving in-vehicle connectivity beyond simpler car-phone technologies. General Motors (GM) continues to offer and market OnStar across a broad range of its vehicle fleet. BMW links together multiple in-vehicle functions, including navigation, in its iDrive in-vehicle system. Both OnStar and iDrive generally do not support aftermarket media players and mobile devices except through industry standards like Bluetooth.

In 2007, Ford, with development from Microsoft, introduced to the market SYNC on 12 Ford, Lincoln, and Mercury models. SYNC is now available on over 20 Ford, Lincoln, and Mercury models.

SYNC permits drivers to bring virtually any digital media player or mobile phone into their vehicle and operate these devices using voice commands, the vehicle's steering wheel, or radio controls. In 2009, Sirius TravelLink joined the SYNC consortium, offering access to up-to-the-minute information and entertainment content through the vehicle's navigation system. This includes current gas prices from an estimated 120,000 filling stations, local real-time traffic information for 78 markets, coast-to-coast weather conditions with five-day forecasts, sports scores, and movie listings. Voice data commands and voice information response limit driver distraction. In May 2009, Ford shipped its millionth SYNC-installed vehicle (Cooney, 2009). Most recently, in January 2010, Ford announced that the SYNC system will be able to speak incoming tweets; however, SYNC does not yet have the functionality for drivers to send tweets (The Associated Press, 2010).

Mobile Applications for Public Transit

Many transit agencies provide open data that enable independent programmers to create useful transit tools for riders. The website City-Go-Round has information on 113 apps that use open data from 96 transit agencies (Transit App Gallery, 2012). Although there are many applications for public transit, what could not be found were multimodal mobile applications that combine both auto and transit-based trips. A scan of mobile applications follows.

In 2010, the Washington Metropolitan Area Transit Authority (WMATA) began releasing transparent data sets so third parties could develop applications for mobile devices that provide train arrival and departures information, predict bus arrivals, locate bus routes and list elevator/escalator outages. There are over 10 mobile applications that provide next-bus arrival time information for TriMet (Portland, Oregon, and suburbs). Other applications, such as UniBus for the iPhone, provide additional features including searching for nearby bus stops and routes. PDXbus for the iPhone offers trip planning functions for Portland bus and train services.

An application without real-time data, called ExitStrategy NYC, offer users the ideal place to stand in the transit train to be in position for an efficient exit based on the layout of the exit station, saving minutes of time in the exit process. Other features of the application include bus maps of all five boroughs and entry points for train stations. The application Google Maps for Mobile also offers bus, train, and ferry transit information for more than 50 cities worldwide. The application provides the combination of walking and transit options.

Synopsis of Innovative Media

Historically, the value of traffic data has been limited by mediocre quality, incomplete coverage, and limited accessibility. In the near future, travelers will increasingly have continuous access to high-quality traveler information with detailed coverage beyond major freeways. This has been and will continue to be spurred by a confluence of three trends: established and projected market share for GPS-enabled devices (mobile and in-vehicle), availability of simplified mobile and in-vehicle applications for traveler information, and growth in crowdsourced data from GPS-enabled devices sharing vehicle speed and location information.

ABI Research, a market intelligence company specializing in global connectivity and emerging technology, predicts GPS will become a standard feature on all mobile devices, and "location awareness will be synonymous with smart devices, a point where personal navigation, social spatial knowledge, and location-specific contextual information will be assumed handset capabilities" (Montgomery, 2009). Consequently, the quantity of GPS probe data collected through crowdsourcing will likely experience continued growth as well.

That said, there are clear indicators that the current media providing traffic information do not have sufficient market share or critical mass as data collectors; consequently, the levels of accuracy, precision, and coverage reliability of traveler information is not uniformly excellent. Roadways with larger numbers of vehicles, that is freeways, tend to have more consistently accurate travel time estimates from mobile technologies, much like roadside sensor deployments. Moreover, their processes of data integration and quality assurance, by and large, have not been made publically available. Public-sector purchasers of probe data are increasingly linking payment with accuracy requirements. A search on the accuracy of most PNDs and mobile and crowdsourced applications yield forums with comments of poor navigation, incorrect traffic information content, and product shortcomings (Android Applications, 2012). INRIX is one of the few entities with published overviews of its processes for collecting, aggregating, and quality checking its data presented in INRIX Traffic products (Martin, 2009).

Traditional traveler information media such as commercial radio and television are likely to remain and provide value to technology-averse travelers. Furthermore, media such as changeable message signs, public agency websites, and 511 phone services are also likely to continue because they are accessible without the need for GPS-enabled mobile devices. One consideration, however, is that those that use the public web and 511 services are early technology adopters who have a need for traveler information, and these individuals may be more likely to transition to more innovative media, consequently reducing the patronage of public traveler information websites.

The providers of traveler information media that are likely to be the most successful are those that provide increasingly simplified, personalized, multifunctioning interfaces with voice-based communications (e.g., in-vehicle systems). The standalone devices such as the PNDs of the past decade will likely face a period of integration to mobile or in-vehicle platforms, or otherwise face significant decline.

TRAVELER INFORMATION MARKET PARTICIPANTS

Roles among data collectors, data integrators, data providers, and delivery media providers of real-time traffic information are all shifting. In a traditional model of relationships in regional traveler information, a public agency (typically a state DOT or metropolitan planning organization [MPO]) provided resources and leadership. In some cases, these agencies collected the data and managed a related traveler information service. Other agencies elected to turn over one or more functions after data collection (e.g., systems development, management, and operations of traveler information systems) to the private sector. Private-sector partners, in turn, managed the information systems and developed applications to (a) provide real-time data to the traveler on behalf of the public agency, and (b) provide real-time data to the public agency for traffic management functions.

While this traditional relationship may still remain the norm for many urban areas, the private sector is increasingly acting in the roles of data collector and data integrator, as well as traveler information service provider. The private sector is active in looking for innovative means of data collection and aggregation, including probe vehicle data and data from multiple private sources, through partnerships to leverage its market share, particularly in the navigation system arena. This shift is driven by the reality that one of the most important enhancements for navigation systems is real-time traffic. Consequently, organizations that provide mobile media and media content strive to increase their position in first-hand acquisition of the broadest geographic content of traveler information. This shift will increasingly turn the public sector into a potential consumer for private-sector data, and with it will come the responsibility to adhere to the data privacy needs of the private sector. The following subsections discuss the key players in the traveler information market with focus on market presence, partnerships, and integration.

INRIX

INRIX is a traffic information provider for many public agencies' TMCs. Like others in this field, it has engaged in a number of partnerships for data exchanges with organizations including TomTom, Clear Channel Radio's Total Traffic Network, Navigon, and others. Notably, INRIX provides the I-95 Corridor Coalition and its 11 state partners real-time traffic information through data licensing. INRIX also provides data to the Wisconsin DOT and Alabama DOT (under subcontract to Jacobs Carter Burgess) (INRIX, 2012). INRIX has also been very active, expanding operations into Europe and multiplying the number of partnerships with traffic providers to continuously increase the coverage, quality, and accuracy of its traffic information and routing engines. In April 2009, INRIX positioned itself to be the exclusive commercial licensor of traffic camera information from Traffic Vizzion, a leading developer of traffic camera data services (INRIX, 2009).

Nokia/NAVTEQ

The trend toward vertical integration and toward partnerships in the PND arena steepened around 2006 with Navteq's purchase of Traffic.com, a provider of personalized traffic information in 50+ metropolitan areas in the U.S. This acquisition provided NAVTEQ with proprietary traffic content, as well as the technology and expertise to deliver that content to a wide variety of customers across multiple industries including America Online (AOL), Microsoft, and Garmin (TSC Staff, 2006). In August 2007, TomTom expressed its intention to acquire TeleAtlas, one of the two providers of map content for all of the major navigation device producers. In response to TomTom's move, and to bolster its position in location-based services, Nokia bought the Navteq mapping service in October 2007 (Niccolai, 2007). Consequently, Nokia subsidiaries now produce the mobile media, the map content for use in the mobile media, and the traffic information data for use in travelers' mobile media.

TomTom

In 2006, TomTom was the leading provider of navigation devices with over 35 percent of the market share of installed and personal navigation devices. In 2007, TomTom also began working with mobile providers to acquire data through cell phone tower triangulation (Farivar, 2006). It now provides HD Traffic™ and IQ Routes™ to its devices as well as to third-party applications in Europe. These products are based on a data fusion engine that aggregates probe data (GPS and cellular), incident data, TMC messages, and historic speed data. TomTom's HD Traffic is based on direct agreements with carriers across Europe for the collection of granular real-time traffic and speed profile data allowing widening coverage and rerouting capabilities. TomTom completed acquisition of TeleAtlas in 2008.

TomTom more recently announced an exclusive partnership with SFR, a French mobile company, to make its real-time traffic service available in France in 2009. This follows similar agreements with Vodafone in The Netherlands, Germany, and the United Kingdom (UK) (ABI: win-win partnerships key to traffic data, 2008). Given competition from INRIX in European crowdsourcing, TomTom, in April 2009, turned to TrafficCast to provide real-time traffic on the TomTom GO Live 740 PND model (Privat, 2009). Consequently, TomTom is a PND vendor with map content (TeleAtlas) that generates crowdsourcing traffic data and purchases traffic information (TrafficCast) to provide value navigation for commercial fleets and individual travelers.

Clear Channel

Clear Channel Communications Inc. began in the 1970s as owners of AM and FM radio stations and in the late 1980s entered the television market with acquisition of television stations. Through continued acquisitions, Clear Channel owned or programmed a total 1100 worldwide radio stations and 700,000 outdoor advertising displays by the year 2000. In January 2007, Clear Channel's Total Traffic Network and INRIX Inc. announced that they were extending their existing partnership to include real-time traffic speed data from INRIX's Smart Dust Network, which intelligently combines the largest GPS-enabled vehicle probe network in the world with speed information from conventional road sensors and numerous other sources. Most recently, in November 2009, Clear Channel Radio's Total Traffic Network (CCTTN) announced that its

real-time traffic service reached more than 125 million users, spanning broadcast, mobile, and in-vehicle devices (ClearChannel, 2009). Mazda has joined other leading automotive original equipment manufacturers (OEMs), including BMW, MINI, and Volvo, in offering the service.

Westwood One

Westwood One began as a provider of content on the radio including simulcast in the 1970s and is now one of the largest producers and distributors of radio programming in the United States. In 1999, Westwood One acquired Metro Networks, provider of 1800 traffic reporters in markets across the United States, and this subsidiary with Westwood One unified a number of helicopter aviation companies providing traffic reporting under Global Traffic Network. Then in 2000, Westwood One acquired Smart Routes. Smart Routes was funded by government grants and provides traffic reports for local DOTs, provides the product smarttraveler.com, and specializes in delivering operation support, program management, data collection/fusion, and 511 services for local and regional public agencies. In 2009, Westwood One, through Metro Networks, partnered with Traffic Land and began providing national traffic video along with its existing traffic incident data, speed and flow information, and over 1000 traffic reporters and anchors (Westwood One, 2009). It also partnered with TrafficCast to provide road speed data. Westwood One provides content to both Navteq and On Star.

Google

A relatively recent entrant in the traveler information marketplace with significant resources is Google. In 2005, Google released Google Maps and within two years began supporting multipath driving directions, local business searches, street views, and mobile applications and officially launched Google Traffic Info including real-time traffic flow conditions for 30 major metropolitan cities. Google acquires traffic information from TrafficCast as well as other sources. In August 2009, Google entered the crowdsourcing arena for data acquisition through the Google Maps for mobile "My Location" feature. The feature acquires GPS or cell-based probe data for Google to use in their provision of traveler information and improved mapping. As of October 2009, Google replaced their primary geospatial data provider, Tele Atlas, with their own data gathered from their StreetView cars in the US (Blumenthal, 2009). And, around the same time Google introduced its free Navigation device on the Droid, completing nearly seamless vertical integration of traveler information provision from data collection, data integration, data provision, and delivery media. Their dominance will likely mean significant streamlining amongst data integrators, data providers, and delivery media.

Synopsis of Market Participants

The navigation market experienced significant contraction and concentration in the past three years. For example, MiTAC acquired Navman and Magellan in 2007 and 2008, respectively (Privat, 2008). Navigon exited the US Market in 2009 (Vochin, 2009) as well JVC in 2007 (Martin, 2007). Unlike the navigation market, the traveler information business is in the midst of its market concentration and contraction, particularly in light of recent Google announcements for crowdsourcing and navigation. At present, a complex web of partnering relationships are enabling data providers to make available an array of content from roadway speeds, camera and video images, incident data, real-time and predictive travel times to more unique information

such as location-based gas station prices and other points of interest. But as Google continues to leverage crowdsourcing for acquisition of traffic data and offer free navigation and traveler information services, business models for Google's competitors will have adapt. The trend toward vertical integration is expected to continue, as the costs and technological barriers to data collection, integration and provision continue to decline.

With trends of more accurate crowdsourced data through mobile GPS devices, the traveler information providers have the opportunity for creating new reliability metrics and reliability services. These providers could be from either the public or private sectors, but our expectation is that the private sector will lead innovation and deployment of new services. This is based on the key role that traveler information is playing in the battle for mobile device market share and the relatively impoverished condition of traditional public sector providers (e.g., state DOTs and regional MPOs).. The key to success in either case will be whether providers are able to present reliability services with sufficient clarity and simplicity for customers to find value in this content. Conceivably, reliability services will be able to suggest travel time ranges based on driver and environmental tendencies such as whether the mobile users follow or lead traffic, or whether weather might contribute to greater variability. The presence of reliability data in the suite of traffic offerings to mobile traffic customers will be an effective litmus test on whether travelers have an inherent value to travel reliability information.

In the United States and in Europe, public agencies have served as the primary source of traveler information, and specifically, real-time traffic and trip reliability information. The technologically savvy population and those that most needed traveler information were the first to actively use public sources such as the web or 511. This same population is likely to transition to traveler information provided by private mobile device for their data may likely supersede by leaps that which is available by public providers in terms of customization, seamlessness, accuracy, and coverage. One might envision that even the technologically averse driver may have access to advanced in-vehicle telematics, such as SYNC, if they acquire higher end vehicles that provide more advanced active and passive safety systems. Still, for a significant portion of the population in the foreseeable future, information sources such as variable message signs, radio, and television will still hold value. In particular VMS has the ability to reach the entire road population. Consequently, the public sector traveler delivery model will continue but may lose some levels of patronage to private traveler information delivery agents.

OUTLOOK FOR TRAVELER INFORMATION, AND SPECIFICALLY RELIABILITY INFORMATION

Traveler information providers operate on the principles that that people want to be as fully informed as possible and that the only impediment to this is the availability of information itself. Travelers in possession of all the facts are expected to make a rational and efficient choice as to the most attractive travel option, and technology is clearly the means for delivery of this information. Traditionally, barriers to traveler's use of information included the complexity in accessing information, the absence of information beyond freeways, and uncertainty regarding its accuracy. Given the tremendous opportunities afforded through the proliferation of mobile and in-vehicle devices for probe vehicle data collection and traveler information provision, the

potential is real for complex reliability information to be made available among the suite of other data at the fingertips of travelers.

Although travel reliability data at present is available from only a handful of public sector information providers and by and large is even less available from private traveler information sources, there is a significant opportunity for reliability-related applications to be rapidly developed and adopted.

Traveler information services can be identified in both *push* and *pull* paradigms. In *push* paradigm services, the service provider initiates an action to push information to travelers based on user information preference parameters. That is, information is provided to users without direct action on their part to acquire information. Under the *pull* paradigm, a user initiates a search for information, as in logging onto a computer pre-trip to check a congestion map. While both push and pull paradigms are appropriate for the provision of travel reliability information, there is increasing development of new push paradigm services as the capability to deliver personalized context-specific alerts is increasingly refined. For example, at many public and private traveler information sites (e.g. Traffic.com and San Francisco Bay Area's 511.org), travelers can set up trip routes for specific times of day and receive alerts via email, phone, or text when traffic for the set routes exceeds the norm.

In the future, more advanced *push* systems or vehicle agent systems may use reliability information along with situational awareness in filtering what information is provided. For example, one might envision that route reliability may be used to filter a long set of alternate routes for a trip to two options based on pre-specified reliability preferences of the traveler. Alternatively, reliability information may be actively provided when the agent is aware of driving on roads/times of day that are not recurrent routes for the vehicle; while only predictive travel time and incident information is communicated to the traveler for work commute trips.

The acquisition of roadway data has traditionally been spearheaded by public agencies, with data made available freely to all entities from radio stations to television broadcasts. This is dramatically shifting to the case where trip-based data are being collected by private entities with ownership rights to the data. With this shift, public agencies have to pay for trip reliability and other trip-related data, which at some point may be cost prohibitive and consequently shift the provision of tailored traveler information even more to the domain of private entities in the future.

To acquiring trip-based data from cellular, GPS-enabled, or satellite devices requires communication from the handset through the phone provider to the data integrator, which in turn offers services of traveler information directly to the traveler or to third parties entities to form bundled services. Private providers of traveler information have had limited success thus far with financially viable stand-alone real-time traveler information services across the nation. This connectivity, along with the need for financial viability, has led to significant vertical integration in the industry as navigation device manufacturers merge with real-time data integrators. The trend will be in greater bundling of traveler information with roadway navigation and other in-vehicle services such as weather, news, voice-based phone and music requests, and other functions. These functions are likely to be integrated services through in-vehicle agents such as the Ford SYNC, while heads-up displays are likely to be reserved for safety applications. As

these more tailored services and systems come to the marketplace, both driving safety and user needs will remain key considerations.

Considering Safety

At the same time that more complex data are being made available to travelers, lawmakers are contending with the ever-growing issue of how technology leads to driver distraction and have begun passing legislation limiting many in-vehicle behaviors, such as texting and communicating on handheld devices. Visual distraction is the primary concern with mobile devices. As of 2012, six states had banned handheld cell phones, 39 states had banned text messaging for all drivers, and 32 states and the District of Columbia had banned all cell phone use (handheld and hands-free) by novice drivers (Governors Highway Safety Association, 2012).

Recently, in the research community, an FHWA-supported project called the Mobile Millenniums was suspended until issues related to driver distraction were addressed. This project gives travelers a mobile device with traffic information and uses these devices as GPS probes. Given this movement against in-vehicle distraction, one wonders whether at some point, the providers of ever-complicated map-based products will also find limitations on their use.

Four societal factors are converging that may potentially make driving a far more unsafe activity: increasing congestion, greater use of mobile technologies by younger and less-experienced drivers, greater numbers of mobile technologies (gadgets) taking drivers' eyes off the roads, and the ageing of the population marked by declines in cognitive and visual functioning (Eby, 2009). Technology can also benefit in mitigating the negative outcomes of these societal factors by managing the distraction source through workload management systems (e.g., Saab Dialogue Manager, Volvo Intelligent Driver Information System [IDIS], and National Highway and Transit Safety Administration's SAfety VEhicle using adaptive Interface Technology [SAVE-IT]), reducing the workload driving task (e.g., adaptive cruise control and lane-keeping assistance), and mitigating negative outcomes of distraction (e.g., crashworthiness vehicle body improvements and crash-imminent braking systems). For example, IDIS delays incoming phone calls or other non-essential information if the driving situation requires greater attentiveness, such as during acceleration or lane shifting (Volvo, 2006).

The potential for technology-based distractions in the vehicle is a serious and timely issue. Providers of mobile applications, in response to this safety consideration, have begun shifting from visual directions and manual entry to auditory directions and verbal entry. In the same vein, providers of traveler information, including trip reliability information, must take heed when developing new information interfaces and information content.

Considering What Reliability Information Is Needed

Travelers require information for three main purposes: to identify travel options (e.g., mode, route, timing, and destination), to assess characteristics of alternatives (e.g., comparing the time between different options), and to complete a trip successfully. Trip reliability information will aid in the latter two of these purposes, and the demand for specific reliability information will be dependent on the travel context and user characteristics. The reality is that most people, most of the time, do not consult travel information because the majority of trips are familiar and local,

have minimal day-to-day variability, and are of a nature that does not necessitate a stringent on-time arrival (Peirce & Lappin, 2004).

For the trips when travelers are not fully familiar and have lesser knowledge of day-to-day variability, reliability information will prove valuable. For example, when planning a trip to a new client, a worker might benefit from knowing that the reliability of travel on a major arterial is far greater than the freeways during Friday mornings, and although it may take a few more minutes, it would reduce the risk of a late arrival. This example demonstrates the value of situational reliability information—reliability for a roadway or trip based on factors such as time of day, day of week, weather conditions, and other considerations such as the occurrence of major sporting events or holiday travel.

Reliability information can also be tailored to encompass driver characteristics as well—perhaps offering data on the ranges of likely travel time that reflect differences in outcomes for a traveler whose driving style is to go with the flow, compared to one who prefers to lead. Reliability data can also prove valuable for traveler information systems that provide information based on levels of user tolerance to travel time variability. The system may provide the route with the greatest likelihood of arriving on time based on reliability data in the system database.

Another flavor of reliability information may be that of probability. For example, a traveler could be informed that there is a 60 percent probability that taking the arterial route will reduce his or her overall trip time given the occurrence of an accident on the freeway. In this case, the 60 percent may be a reflection of comparing travel time distributions on the two facilities in addition to some predictive estimates of travel time. The task for the industry and this initiative is to identify what pieces of trip reliability data would best support travelers' decision-making needs in light of where they are along their trip process (i.e., trip planning or en route) and their situational circumstances (e.g., on a freeway during rain), as well as to provide these data in a way that is clear and concise.

Looking to the Future

This section presents a short summary of observations regarding emerging technology and innovation trends and how they are likely to impact reliability-related services in the near term.

- Conditions are favorable for reliability-related traveler information services to develop.
  - Data to support end-to-end trip reliability assessment are in place or emerging in most urban markets and major inter-urban corridors.
  - Costs to acquire and assemble travel time data will continue to decline because of increasing market share of GPS-enabled devices and innovations in crowdsourcing.
  - There are increasing options for free or near-free services on GPS-enabled mobile devices.
  - New market players with significant resources (e.g., Google) are entering the market and are looking to differentiate their services.
  - Consumer demands for higher accuracy in travel time provision may be reflective of a hidden demand for reliability data.
- That said, there is limited signaling from the traveler information market regarding reliability-related applications. Mobile traveler information content is more or less the

same as what is available on public traffic websites—map-based speed ranges, trip times, and incident details. The primary focus for mobile traveler information seems directed at increasing geographic coverage and providing more user-friendly applications. The exception to this comes from a few sources that combine reliability-type data to provide real-time predictive travel times, as is the case with INRIX's Traffic or a few services providing travel time range to suggest reliability of the trip information.

- The GPS and cell-phone-based travel time and roadway speed information will be highly valued by travelers, but the analysis of these data with other relevant information will enable travelers to make better trip choices and system operators to make more efficient operations decisions.
- More and more travelers will obtain trip information through private-sector providers as they expand ownership of trip-based traveler information data through technologies such as GPS and cell phone tracking.
- Traditional methods of traveler information (e.g., VMSs, commercial radio) will still be relevant to the large part of the population that is not early technology adopters. Variable message signs can reach the entire driving population of a roadway and will continue to prove valuable. In addition, traveler information on commercial radio will continue to be present given its strength in garnering advertising revenue.
- No standard methods or lexicon to deliver reliability information to travelers has emerged either in the United States or Europe. The Institute of Transportation Engineers (ITE) standard Message Sets for External Traffic Management Center Communications (MS/ETMCC) and the Society of Automotive Engineers (SAE) Standard J2354 Advanced Travel Information Systems (ATIS) define the structure for messages containing traffic data elements and data phrases (RITA, 2012). None of the intelligent transportation system (ITS) standards provide a clear structure for transmitting information relating to reliability, or probability for forecasts of travel time. Furthermore, the development of the traveler information systems described in this report has been largely independent of these standards, and the private sector has preferred to use data exchange formats it has developed rather than public-sector standards.
- There may be a longer-term opportunity for trip reliability services to be integrated into emerging intelligent agent technologies. The foundational technologies are already present for increasingly capable in-vehicle agent technologies (i.e., next-generation vehicle telematics) to meet a road user's information and entertainment needs with seamless connectivity. The agent has the potential to serve in increasingly complex roles as the arbiter of what information is made available to the traveler, as well as when and how this information is presented.

Chapter 5 DEVELOPED AVENUES OF INVESTIGATION

Tasks 1 through 3 of this project examined previous literature, expert opinions, and state-of-the-art technology and future trends concerning the dissemination of travel time reliability information. Based on the results of these tasks, the project team formulated a focused set of paths of investigation for the original research to be conducted in Phase II. During this task, the TTI team analyzed the information from the previous tasks to hone the research efforts to ensure that a manageable and realistic experimental design was developed for the remainder of the project. The reality is that not enough time nor dollars existed to examine every feasible combination of technology platforms, communication channels, message sets, and message formats to arrive at a single solution to the challenge of disseminating travel time reliability information. Thus, this task focused on summarizing the key gaps that emerged from tasks 1-3 related to the most effective means of communication reliability information to travelers.

KEY RESEARCH ISSUES

Through the work in task 4, the research team identified several key emerging research issues that were addressed in Phase II of the project. The following items highlight those key research issues, the answers to which were pursued in the remainder of the project.

Do Travelers Want This information?

The key issue is to determine if there is a market demand for reliability information. Clearly, transportation planners, policymakers, and operations staff find value in reliability data as a performance metric. It is not obvious that travelers find the same value.

Do Travelers Comprehend the Basic Idea of Reliability, as Separate from Real-Time Travel Time Information?

During Phase I of this project, the research team struggled with separating these two concepts in discussion, writing, and planning. In discussions with the experts interviewed, Technical Coordinating Committee members, and even other Reliability Program researchers, it became clear that most people lapse into talking about real-time information when the topic is information dissemination. This is to be expected because most travelers have experience with freeway changeable message signs that display current conditions. The L14 team continued to correct people about this misunderstanding and stress the role of historical data in travel time reliability information.

Do Travelers Comprehend the Variability Inherent in Reliability Information?

The literature review showed, across several domains, how poorly people understand the concepts of variability, probability distributions, and uncertainty.

Do Travelers Comprehend the Average Travel Time?

Travelers may be making their trip time estimates on a near-worst-case basis, rather than on the average time the trip might take. If a regular commuter always travels in a narrow time window during peak hours, the overall 24/7 average is not relevant for him or her. Thus, he or she may have a different concept of typical and/or average.

What Terms and Displays Can Be Used to Best Communicate Average, Variability, and Reliability?

The most easily comprehended system needs to use terms that are generated by laypeople, even if they are not technically precise.

Can Travelers Assign a Dollar Cost Value to Reliability Information, or Incremental Changes in Reliability?

It is important to understand whether travelers might be willing to pay a premium for reliability information. Also, understanding the value travelers place on reliable trips might provide insight into how agencies might prioritize design and operational improvements to improve reliability on critical routes.

Is There a Role for Reliability Information in Real-Time Systems?

For algorithm designers, certainly historical travel time information can be used along with real-time data to improve the accuracy of real-time predictions of travel time for a particular trip. From a traveler point of view, however, the role for this historical data is unclear. If the real-time system says a trip is X minutes, travelers may not really care if it is typically X-10 minutes. Real-time data seem to trump historical data, as real-time data are most pertinent to today's trip. It may be that systems need to be opaque about their use of the historical data.

Do Travelers Want or Need Reliability Information En Route, or Is It Mainly a Pre-Trip Planning Tool?

Assuming travelers can comprehend these concepts and a lexicon can be developed, it is not clear if they would use it en route. The more apparent use for these systems is as a pre-trip planning tool to select recurring times of departure, routes, and modes. This may mean the travelers only access the system once when initially planning a commuting route or a particular trip to a new destination.

Does a Traveler's Desire for This Information Change as a Function of Trip Purpose, Route, and Constraint?

Trips are always made in a context. It may be that for constrained trips (e.g., need to get to the airport), reliability information is valuable and desirable for route choice or time of departure selection. However, for unconstrained trips (e.g., grocery shopping), reliability information is not desired since there is no penalty for being late or early.

Can Travelers Safely Use an En-Route In-Vehicle System?

With the emerging evidence of driver distraction due to in-vehicle devices—whether nomadic, such as cell phones and portable navigation systems, or native to the vehicle—traveler safety is an important question. Travelers may use en-route reliability information to make route or mode shift decisions that involve a complicated decision-making process that may require repeated queries to the system to examine alternatives. This level of cognitive effort and interaction with a system is surely distracting. Again, an opaque calculation by the system resulting in simple alternative route advice may be necessary. As more states are banning all use of manual input devices, especially smartphones, the deployment of these systems must be carefully considered. The task 2 technology scan revealed that the future holds more automation and customization in smartphone and navigation system applications. With these tools, distraction effects may be mitigated. En-route use of in-vehicle systems was not ultimately tested in the human factor studies, since the decision was made to replace the field operational test with the enhanced laboratory experiment.

Do Travelers Want to Actively Seek This Information (Pull) or Have It Sent to Them Automatically According to a Custom Trip Pattern That Is User-Entered (Push)?

For both pre-trip planning systems and en-route systems, it is not clear if reliability information needs to be push or pull. Since reliability is calculated on a historical basis and changes slowly over time, it is not clear if there is an urgent need for a push. Push data, instead, would be limited to real-time information. Users may desire a quarterly update or a push message when the reliability index of their selected route changes above some user-provided threshold value.

How Can Multiple Data Sources and Factors Be Displayed for Reliability Information?

Reliability algorithms use many factors to make travel time predictions including weather, time of day, day of week, construction, transit system schedules, etc. Do travelers need to know all of these factors, and do they need to be displayed at all? It may be that travelers develop trust in a system, but all of the calculations are hidden from them or are only available on secondary informational screens.

Will Travelers Change Their Habitual Time of Departure and Route Based on a Travel Time Reliability Information System?

Humans are creatures of habit. In many ways, regular commuters have done all of the reliability calculations in their head using their N = 1 data set. They know that when it rains, it usually takes five extra minutes, and if they leave at 7:40 instead of 7:30, the traffic is worse. It is not clear if travelers will develop trust in a system enough to make them change these regular habits.

As the research project moved forward, the project team attempted to answer these questions within the framework of Phase II, as illustrated in Table 5-1.

Table 5-1. Key research issues and tasks.

Question	Task 6-10 A1: Focus Groups	Task 6-10 A3: Computer Survey	Task 6-10 A3: Travel Behavior Laboratory Experiment	Task 6-10 A3: Open-Ended Survey	Task 6-10 B1: Enhanced Laboratory Experiment
Do travelers want this information?	X	X	X	na	X
Do travelers comprehend the basic idea of reliability, as separate from real-time travel time, information?	X	X	X	X	X
Do travelers comprehend the variability inherent in reliability information?	X	X	X	X	X
Do travelers comprehend the average travel time?	X	X	X	X	X
What terms and displays can be used to best communicate average, variability, and reliability?	na	X	na	X	X
Can travelers assign a dollar cost value to reliability information, or incremental changes in reliability?	X	na	X	na	X
Is there a role for reliability information in real-time systems?	X	na	X	na	X
Do travelers want or need reliability information en route, or is it mainly a pre-trip planning tool?	X	na	na	na	na
Does a traveler's desire for this information change as a function of trip purpose, route, and constraint?	X	na	X	na	X
Can travelers safely use an en-route in-vehicle system?	na	na	na	na	na
Do travelers want to actively seek this information (pull) or have it sent to them automatically according to a custom trip pattern that is user-entered (push)?	X	na	na	na	na
How can multiple data sources and factors be displayed for reliability information?	na	na	X	na	X
Will travelers change their habitual time of departure and route based on a travel time reliability information system?	X	na	X	na	X

Chapter 6 FOCUS GROUPS

Human factor research done to date on traveler information systems has, for the most part, been concerned with segment trip time displays based on historical data. Another line of inquiry has focused on driver faith in the accuracy of the times displayed. The research undertaken as a part of the L14 project was to first examine user understanding of reliability information. The approach was to use a series of successively more objective methodologies using a mix of methods that allowed a wide net to be cast initially to gather the broadest understanding of users' preconceived notions of travel time reliability. Building information systems based on users' inherent understanding provides the best chance for a high level of user acceptance of the ultimate system.

Task A1 was the first of the series of human factor methodologies. The task involved conducting a series of focus groups in various cities across the country using a script developed by the project team. This script was based on the results of the literature review, the expert interviews, and the technology and innovation scan.

SCRIPT DEVELOPMENT

The first step associated with the focus group task was to develop the script, or discussion guide, from which the facilitators would work during the focus group sessions. The following sections highlight the steps the research team took in the development of the discussion guide for the focus groups.

Discussion Guide Development Phase 1

The focus group discussion guide went through several iterations and pre-tests with TTI staff unfamiliar with the project. The first draft of the discussion guide was based on the questions posed in the proposal as well as the results from the literature review, the expert interviews, and the technology and innovation scan. The project team used those research questions and related task results to develop the following set of objectives/questions to address:

- What things affect how long it takes to make a trip?
- What are drivers' understandings of travel time?
- What do drivers think of the accuracy of the travel time provided by current systems?
- How does past experience of travel times influence drivers' perceptions/interpretation of drive time?
- When is it the most important to drivers to have an accurate travel time prediction?
- How do drivers currently receive travel time information?
- When do drivers most need travel time information?
- How does reported travel time affect drivers' decisions of whether to take a trip or not, departure time, mode choice, and route choice?
- How does network travel time influence drivers?
- What travel time terminology makes the most sense to drivers?
- What is the best format to convey travel time?

Researchers quickly realized that this list of questions did not differentiate enough between systems that provided real-time information and those that would provide a predicted travel time or information about reliability based on historical data. Therefore, the objectives were narrowed to focus more directly on the concept of reliability as defined by the transportation profession:

- How do drivers plan their trip using their own knowledge of the network?
- When is it the most important to drivers to have an accurate travel time prediction?
- Do drivers want reliability information, when do they need it, and how would they like to receive it?
- What are drivers' understandings and trust of traveler information that is currently provided, and how accurate do they think it is?
- What travel time reliability terminology makes the most sense to drivers?
- What is the best method and format to convey travel time reliability?

Discussion Guide Development Phase 2

At this point in the discussion guide development, researchers began to fear that too much discussion of travel time may cause the focus group to run long as well as lead the participants astray. There was a fear that it would be difficult to get participants to distinguish between real-time travel time and travel time reliability. Researchers planned to get into the meat of the discussion earlier and eliminate some of the upfront objectives by jumping straight to (a) identifying the need for travel time reliability information, and (b) determining what travel time reliability terminology and sources make the most sense to drivers. Because the statistical concepts underlying reliability may be hard to grasp, the research team wanted to pull from other, more familiar, domains to talk about the statistical concepts. Scenarios unrelated to transportation were developed to discuss reliability in hopes of drawing out words and phrases that drivers use to discuss the concept. These scenarios included probability terms used in weather predictions and ranges of delivery dates for packages. Following these examples, the researchers planned to turn the discussion to a travel time reliability example and include various graphic examples to convey reliability.

Discussion Guide Development Phase 3

After further consideration, the research team members decided they would begin the focus groups with non-travel time reliability scenarios and avoid mentioning travel time reliability until halfway through the discussion. The first pilot focus group was conducted with non-transportation TTI employees using this discussion guide. The scenarios discussed were as follows:

- Weather prediction.
- Restaurant wait time.
- Online order shipping time.
- Prime parking spots (based on time of arrival).

The online order shipping time example described a scenario where 10 people ordered a package on the same day and the shipper estimated a delivery window of 5-9 days. The graphic shown in Figure 6-1 was used to illustrate the actual days people received their packages. It was meant to

encourage discussion of probability distribution and was intended to generate words and phrases people would use to describe the reliability of the shipping service. This same distribution was shown in a traffic context later in the focus group session to show a distribution of travel times.

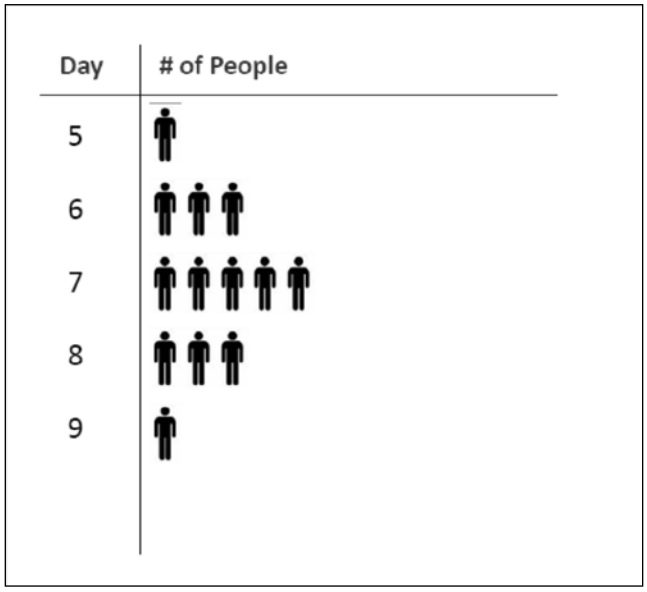


Figure 6-1. Shipping time graphic.

After the initial pilot, additional graphics, such as the one shown in Figure 6-2, were added to the focus group discussion once the concept of travel time reliability had been introduced by the facilitator. Using similar graphics, the research team explored different formats, colors, and symbols to display travel time reliability.

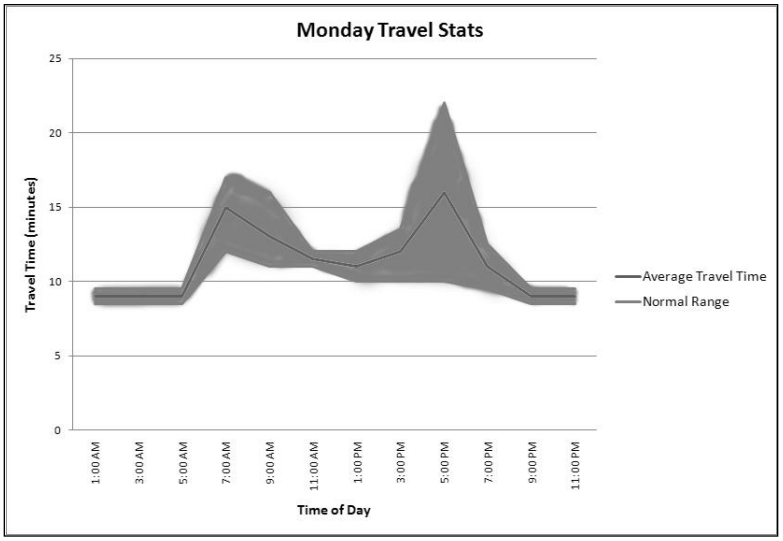


Figure 6-2. Monday travel time example.

After these script revisions, two official pilot focus groups were conducted in Houston using the target demographics for participants. Although the two groups ran smoothly, the format of

starting with non-transportation-related scenarios to discuss terms did not work as researchers planned. While these everyday examples were understood, the pilot group participants had great trouble making the leap from these scenarios to a traffic situation. Other feedback we received from the pilot group indicated that participants were confused by being invited to come to a focus group about travel information and then being asked about seemingly unrelated topics like weather and shipping.

For example, when asked what a "70 percent chance of rain means to you," participants would respond that they needed to leave earlier to allow more time on the road, rather than discussing the variability of the weather. Another problem that emerged during these pilots was that the discussion and questions were not drawing many terms out of the participants that the team could use to develop a lexicon.

Additionally, the participants overwhelmingly disliked the graphics shown as possible output for providing reliability information. They found they contained too much information and were too confusing. This feedback led researchers to think that they were showing the drivers very limited options for displaying this type of information and possibly biasing their opinions on the usefulness of the system.

Overall, researchers still did not believe that the participants were truly separating the concepts of real-time travel data and historical travel data. The travel examples based on these everyday scenarios were also not effective at imposing penalties for being wrong or late. The research team decided to make major revisions to the discussion guide to present travel situations that varied in whether or not they were constrained by either departure or arrival time. The team also decided that the presentation of alternative graphic displays of travel time were not productive in generating lexicon terms, so those images were not included in the final version.

Discussion Guide Development Phase 4

The final discussion guide was broken into several different topics, as seen in Table 6-1. It began by having separate discussions about nonrecurring conditions and incidents that affect spot travel time and recurring conditions that are related to network reliability and general variability of travel time on segments. Once the difference between the two concepts was established in participants' minds, the facilitators described a potential traveler information system that used historical data to predict trip times. The research team felt that by presenting details of a specific type of travel information system that utilized system reliability data, the subsequent discussion could be more fruitful. After a brief description of such a system, participants were asked directly whether they saw value in such a system. The researchers then presented trip scenarios to determine where people would use reliability information and what words they would choose to describe situations and fill in sentences. These trip scenarios were established after discussions with L14 partner Noblis and the L02 team as well. The scenarios varied in their time constraint and in the familiarity of the destination. One scenario involved using the system to decide whether or not the traveler had time to insert a task along the way to work. This was a use case identified by the L02 team. More thorough descriptions of these tasks and the discussion questions are presented in Appendix C.

Table 6-1. Final focus group discussion guide topics.

	Constrained Arrival Time	Constrained Departure Time	Unconstrained
Unfamiliar Destination	Appointment with new doctor	na	Weekend evening party locally Weekend getaway three hours away
Familiar Destination	Regular commute	Choosing day of the week for class after work	Pick up produce from farm co-op anytime Saturday
Task Insertion	na	na	Stop by neighbors to feed cat

PARTICIPANTS

Ten focus group sessions were conducted in five cities across the nation: Atlanta, Houston, Minneapolis, Seattle, and Washington, DC. Table 6-2 shows the demographic breakdown of all the participants. In Houston, focus group sessions were conducted at the TTI office. In all other cities, sessions were held in conference rooms of local hotels.

Recruitment criteria for participation were as follows: must have been aged 18-80, possessed a valid driver's license, and commuted to work regularly. The research team worked to select a representative sample of drivers who either drove to new locations regularly or had time restraints that impacted their trips, such as children's schedules.

Table 6-2. Focus group participant demographics.

	Houston Pilot 1	Houston Pilot 2	Seattle 1	Seattle 2	Minneapolis 1	Minneapolis 2	Atlanta 1	Atlanta 2	Wash DC 1	Wash DC 2	Houston 1	Houston 2	Totals
Total # of Subjects*	10	10	11	10	10	10	9	10	9	10	9	8	116
# of Males	5	6	1	4	3	4	5	5	5	4	3	4	49
# of Females	5	4	8	5	7	6	4	5	4	6	6	4	64
Average Age of Subjects**	35.9	46.3	30.4	37.0	38.4	38.6	42.9	36.7	36.1	36.3	43.8	32.4	37.9

*Not all subjects chose to fill out their information, which is why the number of males and females may not add up correctly.

**Not all subjects chose to fill out their information, so the average is calculated from those who did.

RESULTS SUMMARY

Based on feedback from the focus groups, it appeared that the majority of the participants believed the system could be helpful and was a good idea. However, as the scenarios were introduced, it was difficult for the researchers to determine if anyone would actually use it. As

shown previously in Table 6-1, participants were presented several scenarios during the session that depicted constrained and unconstrained situations. The most frequent use seemed to be for pre-trip planning of constrained, unfamiliar trips within a known community or trips within or to an unfamiliar location. For the unconstrained trip scenarios, overwhelmingly, most people would not use it, and weekends seemed to be the time it would be utilized the least.

In general, participants believed the travel time reliability (TTR) system would be valuable in some instances but would be immensely more valuable if it contained real-time data in addition to historical data. They felt that a travel time reliability system would be useful when planning a trip to an unfamiliar location where there were significant time constraints on one or both ends of the trip. However, they were concerned that planning a trip based on historical information would not be accurate if it did not update based on current road and traffic conditions. There was also a concern that the predictions provided by the reliability system would not be more accurate than those existing mapping tools. Many said they make their actual travel decisions on the day of the event and check traffic daily. Hence, they would not need to use the system to predict future trips. Some participants also said that they would prefer a "focus on coordinating getting information together with real-time information than calculating odds." This strong desire, and possible need, for real-time information could indicate distrust in a TTR-type system. This distrust of the system was further assessed by the open-ended surveys when determining how much additional time participants would add to the given travel time and why they added it.

When asked how they currently planned a trip, most participants used a mapping tool such as Google Maps, MapQuest, their GPS, or another system to give them a starting travel time. However, they all factored in additional time onto the mapping tool estimate. They expected to calculate their own time and were not bothered by having to do this. They also indicated they did not know from where the time estimates provided by the mapping tools came. (At the time the focus groups were conducted, travel times provided by online mapping tools were generally based on the average of the posted speed limits along the mapped route; real-time traffic information was not yet included in calculations.) Drivers relied heavily on personal experience, and many simply assumed an hour to get to a new destination. Overall, the participants had a good understanding that traffic is not the same every time of day or every day of the week, and they understood that many variables can affect traffic and the existing systems are lacking in taking that into effect. Researchers used the computer survey and open-ended survey to expand on how drivers decide how much time to allow for a trip, particularly the additional time they add, and how various travel time terms could influence that decision.

Overall, participants preferred to enter in an exact address as opposed to simply choosing a starting city or general area. They also wanted the ability to specify a trip calculation based on time of departure or time of arrival. The computer survey continued investigation on this topic by addressing the preferred terminology to be used for the departure and arrival times.

When prompted, participants wanted to see multiple route options in their output. They also wanted to be able to compare choices and make their own decisions on which route to take. Participants seemed interested in having the ability to enter a window of time and rely on the system to tell them what time to leave in order to spend the shortest amount of time on the road. There was no clear preference on text or graphical output; however, several mentioned that both should be used. One participant thought the output "should say 'there is a 90 percent probability

you are going to make it here in XX minutes,'" showing a good understanding of the intention of the system. Another suggested "the longest this trip has taken historically is XX." Both the computer survey and the open-ended survey covered what the output should look like that would best instill confidence in the system.

The general public may not use this system on a regular basis. Rather, individuals with consistent reasons to use the system may be more likely to use it regularly given the diversity of their daily trips. For example, professionals in the sales industry, delivery services, or businessmen who frequently travel to new locations would be potential active users.

There was a concern amongst many groups that users would get the system confused with a real-time system and that people would not understand that the travel times would be a calculated number and there could still be variation. Participants felt that real-time information was more important than reliability information and would be the most misunderstood component of the system. To investigate this concept further, questions were incorporated into the computer survey to assess understanding of a real-time versus historical-based system.

When asked by the facilitator, most said they would not pay to use the system in website form. Drivers seemed to realize nothing is free and were open to the idea of paying a nominal fee for a cell phone application or GPS addition. Some of the participants stated that they would actively use the system if their employers would pay for it. Others suggested selling it to Google or paying some amount to add it to Google's existing navigation system.

In response to who would provide this system to the public, one participant summarized the groups' response by saying, "If a private company wants to charge a fee, I have no problem with it, but if the government does, I do." As long as access to the system was free, people did not seem to have a strong preference as to whether it was run by a DOT or private enterprise.

LEXICON INFORMATION

When talking about variability in travel time, participants preferred a wide variety of terms. Participants viewed sentences and had the opportunity to fill in the blanks with the term they thought best explained the scenario. TTI divided the sentences into two major groups: (1) those sentences concerned with the system's output to describe the time of day a driver takes a trip, and (2) those sentences that addressed the idea that the system would tell a driver about alternate modes of transportation.

Most often, they chose general words such as *possibly*, *probably*, *chance*, or *likely* to describe variability at a certain time of day. Generally, they preferred for those words to have a descriptor in front, such a "X% chance" or "highly likely" to make the term less general. When talking about traffic patterns at a specific time of day, participants used *varie*s, *changes*, and *increases/decreases* most often.

When discussing the output terminology the system would use to provide different ways or routes to travel, participants used the words *faster*, *more reliable*, *easier*, and *likely*. When speaking about the additional time added to a trip to ensure on-time arrival, common terminology varied greatly with no real consensus. For example, terms like *additional time, traffic time, leeway, driving time, just-in-case time, fluff time,* and *additional drive time* all came

up as possible descriptors. Unprompted, participants used the words or phrases *cushion, allow an additional X minutes for variables, tack on extra,* and *extra time* during discussion.

Several terms came up unprompted in the discussion sessions. Several terms specifically addressed reliability information. Those included *reliability factors, plus or minus 10%,* and *9 out of 10 days.* Those terms that addressed a range of time were *approximately, usually, window of time instead of exact time, give or take, variation, cushion, buffer, time frame that's certain, average,* and *depends.*

The most common terms discussed from the focus groups were included in both the computer survey and the open-ended survey. The computer survey spent time addressing what to call travel times, departure times, and additional times, while the open-ended survey spent extensive time on how these various terms influenced participants' decision-making and trust of the system.

Chapter 7 USABILITY SURVEYS

The usability portion of this project ultimately consisted of three research activities: a multiple-choice survey conducted on a laptop computer, an open-ended survey, and a computer-based experiment intended to simulate daily trips. Each research activity produced different types of data that were analyzed separately and, where applicable, in comparison to one another. The usability study activities were employed to achieve the following primary objectives:

- To determine comprehension of and preference for reliability terms.
- To elicit additional terms for potential inclusion in the lexicon.
- To test user acceptance and trust in the information described by various reliability terms.
- To determine drivers' use of reliability information, the serenity benefits of having access to reliability information, the drivers' willingness to pay for that information, as well as whether reliability information helps drivers to form their own personal historical framework for expected travel times.

The human factor studies planned for tasks 6-10 were presented and approved by the panel in June 2010. They consisted of focus groups and a usability study. As conceived at that time, the usability study would employ computer-based multiple-choice testing of terminology and website interface features. This objective testing would allow rapid testing of large numbers of participants because data entry and scoring could be automated. The computer survey was developed and deployed in the fall of 2010.

The computer survey presented test items asking participants to select departure times in response to a sample traveler information website that provided total trip time estimates. After approximately half the participants were tested, researchers reviewed interim results and found that a large portion of people were adding their own buffer time on top of the total trip time recommended by the system. Unfortunately, it was not clear whether this was due to a lack of interest in the terms used or a lack of understanding of how to apply them conceptually in the survey environment. The research team decided to add an open-ended aspect to the survey to investigate this critical question in more depth.

STUDY LOCATIONS

The usability study activities were conducted in five cities that were selected based on their traffic congestion rankings in TTI's Annual Mobility Report (Schrank, Lomax, & Eisele, 2011), as well as on the presence and availability of transit service and high-occupancy vehicle and/or high-occupancy toll (HOV/HOT) lanes:

- Dallas, Texas.
- Miami, Florida.
- Denver, Colorado.
- San Jose, California.
- Hartford, Connecticut.

The intent was to ensure that study participants would likely be familiar with the possibility of altering a travel mode or paying a fee to travel on a less-congested roadway. Dallas data collection was conducted in two waves, with half the participants tested at the start of the data collection period and half at the end. The open-ended survey was conducted only in San Jose, Hartford, and during the second wave in Dallas.

STUDY PARTICIPANTS

Participants for the study were recruited through Craig's List ads, by word of mouth, and by distributing flyers containing information about the study within the cities. Because the study's focus was regular commuters, drivers under age 60 were targeted. Older drivers were allowed to participate if they still worked outside of the home and commuted regularly. Table 7-1 summarizes the numbers of participants that participated in each of the three study activities.

Table 7-1. Usability study participants.

City	Computer survey + open-ended survey	Computer survey only	Travel behavior experiment + open-ended survey	Travel behavior experiment only	Open-ended survey totals	Total participants per city
Dallas	31	31	14	1	45	**77**
Denver	0	61	0	15	0	**76**
Miami	0	67	0	10	0	**77**
San Jose	54	0	20	0	74	**74**
Hartford	53	3	17	4	70	**77**
Totals	138	162	50	30	189	**381**

COMPUTER SURVEY

The objectives of the survey were to test comprehension of and preferences for terms used to present reliability information, as well as to test initial concepts for a website presenting this information that was planned to be developed for the field study. A total of 300 drivers participated in the computer survey.

Influence of Focus Group Results

The focus groups that were conducted in a previous task of the project provided the research team with some information regarding travelers' uses for reliability information. They also provided the team with a large set of terms that participants preferred and/or suggested to describe travel time reliability. The focus group results indicated that drivers perceived the most value in travel time reliability information in the context of an unfamiliar trip with a constrained departure time, arrival time, or both. They tended to view real-time information as more useful in most instances, and many felt that historical travel time information for a given route would be more relevant for trip planning with real-time conditions figured in. Most stated an unwillingness to pay for such information on a website but were somewhat amenable to a nominal fee for reliability information provided via a mobile/smartphone application or as an

addition to a GPS system. A number of potential lexicon terms for travel time reliability and related concepts were presented by the researchers to the focus groups, and some additional terms and phrases were suggested by the focus group participants.

Besides providing several of the terms that were tested in the usability surveys, the focus group results influenced the next phase of the research in several ways:

- A travel behavior laboratory experiment was added to better gauge the potential value of reliability information to drivers.
- An open-ended survey was added to further clarify comprehension of and preferences for various terms.
- Questions were included in the computer-based survey and in the open-ended survey to elicit more potential lexicon terms.
- Due to a lack of fundamental understanding of the reliability concept expressed by focus group participants, the research team concluded that this misunderstanding would not likely be clarified by graphical representation, resulting in the research team reducing the emphasis on graphical displays for reliability outputs.
- Strong consideration was given to including real-time information along with historical information on the field operational test website.

Survey Development

The computer-based survey presented participants with multiple-choice questions on concepts and terms associated with the presentation of reliability information. The objectives of the survey were to test comprehension of and preferences for terms used to present reliability information, as well as to test initial concepts for a website presenting this information that was planned to later be developed for the field operational test. A list of specific research questions based on these objectives guided the development of this portion of the usability study:

- What terms should be avoided?
- What are the best terms for general use?
- What input features are the most desired for websites and similar tools?
- What output features are the most desired?
- What output features are the best understood?
- Will drivers use a travel time reliability information website, and when?
- What information should be included in user instructions/frequently asked questions (FAQs)?

Travel Information Website Reviews

The first step of the computer survey development was a review of existing travel information websites, including those that offer some type of information regarding historical travel times. The websites were identified through the literature review, expert surveys, and technology and innovation scan activities in Phase I of the project. Researchers reviewed 16 websites operated by state DOTs, metropolitan TMCs, airports/airlines, and private-sector vendors. The reviewed websites included the following:

- Arizona 511.
- Lake Michigan Interstate Gateway Alliance.
- Colorado DOT.
- Florida 511.
- Florida DOT, District Four.
- Georgia DOT.
- 511, Los Angeles.
- Navteq Traffic.com.
- Phoenix Valley Metro, AZ.
- TxDOT Transguide, San Antonio.
- 511 Travel Info, San Francisco.
- San Diego Transportation, CA.
- Washington State DOT.
- FlightStats.
- FlightCaster.

The website reviews examined the formats of the home page and/or the primary traffic information page, the labeling of any links or buttons/banners for accessing information about historical travel time information, the mechanism and labeling for trip information input by the user, and the format and terminology used for the output information. The research team compiled lists of terms and labels for possible testing, including the websites' terms for trip inputs (origin and destination, departure and/or arrival times) and outputs (average historical travel time, 95th percentile trip time, recommended departure time). These were compared with terms and phrases from the focus group results. Table 7-2 provides examples of trip information input and output terms collected from reviewed websites.

Table 7-2. Example terminology from reviewed websites.

Input/Output Type	Terminology Used
Origin/Destination/Road/Route	Available locations. Segment start location/Segment end location. Type in address, intersection or landmark. Where does your trip start?/Where does your trip end? A (origin)/B (destination). Select your origin/Select your destination. Where are you starting from?/Where are you going?
Departure/Arrival/Time Window	Estimated time of arrival. Depart on time. Best time to travel. Leave my starting point at/Arrive at my destination at. Select day and time for historical data display. What time do you need to get there?
Current Trip	Travel time current. Current travel time. Leave at [time]. Drive time now/delay. Fastest now. Direct drive. Current conditions: avg speed, min speed, max speed.
Historical Trip/Reliability	Travel time average. Average travel time (minutes). Current travel time (minutes). Normal range. Avg overall travel time. Normal travel time. Drive time @ speed limit. Average speed. Typical travel time. Your 95% reliable travel time is 25 minutes. 95% of the time you would need to leave at 7:35 AM to arrive by 8:00 AM.

Selection of Test Platform

Initially, the research team intended to conduct the usability study using an interactive mock-up of a travel information website to test input and output terminology associated with travel time reliability information, as well as related screen titles and labels. Elements of some of the reviewed travel time websites, such as overall screen layout, maps of roadways with available travel information, and dialog boxes for user inputs, were adapted to portray a fictional urban area. The study as originally conceived would use keystroke logging, eye-tracking, observation

of participant inputs, and verbal feedback from participants to test comprehension of and preference for input and output terms related to travel time reliability.

However, as the researchers further defined the types of questions that would best determine participants' comprehension of reliability terms, it became clear that an interactive website, even one with limited functions, would not be the most suitable study platform for those questions. The primary concern was that other website usability issues (graphic design, website hierarchy/organization, etc.) could confound the primary research questions regarding terminology/lexicon for the participants. Second, testing several different terms for each of the several website input and output possibilities would require multiple versions of the website to be built, which would have been impractical under the time budgeted for this task.

Ultimately, the research team decided to use a multiple-choice survey to address comprehension and preference questions regarding reliability terms and associated trip information. The survey was conducted on laptops using the SuperLab™ software to present questions and instructions and to collect participant answers. The designs for the mock-up website pages were presented to participants as static pictures to provide context for some of the survey questions. This study format allowed researchers to test multiple participants at once, allowed testing of multiple terms in the context of a single simulated webpage, and minimized the effects of website usability issues and biases that did not pertain to the reliability terminology being investigated.

Some of the survey questions asked participants about specific terms used on an example webpage. Preliminary versions of the SuperLab™ survey showed a split screen with the sample webpage on one portion of the screen and the question on the other. It was determined in pilot testing that these images were too small and difficult to read on a computer screen and may pose difficulties for participants with reduced vision, or even bifocals. So a three-ring binder was created to hold full 8½ x 11 inch color printouts of each of the webpage screen shots. The binder pages served as visual aids for most of the questions in the remainder of the survey. Displaying the simulated webpages in the binder had the advantage of allowing participants unlimited viewing time of each image, including the ability to look back and forth between the image and the on-screen question.

Paper Prototyping of Webpage Examples Used in Survey

A human factor usability research technique called paper prototyping was used to develop the simulated website screens displayed during the survey. This method developed in the computer interface design field allows rapid early-stage testing of webpage input and output screens without requiring computer coding. The research team printed screenshots of some of the reviewed travel information websites and cut out individual text and graphic elements such as user input boxes, roadway maps, text links and buttons, and various output formats for trip travel times. Initially these webpage pieces were physically arranged and adhered in place as the team members agreed on the content and format of each simulated screen. User input was also obtained from other TTI staff members and student workers to help finalize the look of each screen. It was decided that this simulated website would display a fictional city rather than a real location to avoid the possibly confounding effects of selecting a city that happened to be familiar to some participants and not to others. To that end, several road maps from the real traveler

information website were composited to create a network of roadways that bore no immediate resemblance to any one city but had the overall look of a metropolitan area. Once each screen's arrangement was finalized, it was recreated using graphics software.

Selection of Terms and Questions

In deciding which terms to test with participants in the SuperLab™ survey, the research team began with the various terms and phrases for trip parameters and travel time/reliability used by the reviewed websites, as well as from the terms mentioned most frequently by participants during focus groups. The research team organized the survey by first defining categories of trip inputs (origin/destination, arrival/departure times, other route/trip preferences, labels for input buttons, map titles) and outputs (historical and current trip times, average vs. 95th-percentile trip times) that could reasonably be included in a travel time reliability information website. For each of these input and output categories, the team listed (a) potential terms, and (b) questions that could be used to test user comprehension and preference for each of the terms.

The research team developed the survey questions collaboratively over several sessions, as described above. An outline format was developed for research team members to list potential travel time, reliability, and other input/output terms and phrases within topic categories (e.g., Website Input Screen—origin/destination field). For each set of terms, researchers proposed question types that could be used to test comprehension of and preference for the terms.

A brief outline of the final survey questions is presented in Table 7-3. Questions 1-8 were asked before any explanation of the hypothetical website was provided. These were asked to get naïve participants' reactions to terms and input screens as a new user to the system would encounter on such a site. A description of the motivation behind each set of questions is provided below, along with pictures of the stimulus screens and binder pages (if applicable) and results tabulation. It was not possible to test all possible terms with every person because the survey would be too lengthy. Thus, for a small number of questions, multiple versions of the survey were created, as shown in Table 7-4. The participants were divided across four different versions of the survey, versions A-D.

Table 7-3. Computer survey questions outline.

Questions 1-4	Preconceived understanding of four terms or reliability: reliable, predictable, consistent, best.
Question 5	Importance of reliability.
Questions 6-8	Understanding websites for current and future general purpose.
Explanation of website and its purpose	
Questions 9-10	Trip planning terms tested by versions: predict trip, plan trip, create trip, get trip.
Questions 11-12	Departure/arrival terms.
Questions 13-14	Website map titles.
Questions 15-17	Trip time terms by versions: average, typical, historical, estimated, 95th percentile, worst case, maximum, most common.
Questions 18-20	Departure time terms by versions: recommended, estimated, 95th percentile, suggested.
Questions 21-22	Desire for possible additional time (over the average).
Question 23	Type of travel time metric (average, most common, worst case, etc.).
Questions 24-26	Fill-in-the-blank terminology: • It is _____ that your trip will take 45 minutes. • Your trip time may _____ from the average time by 20 minutes. • It will take _____ 20 minutes to make your trip.
Question 27	95th percentile term understanding.
Question 28	Trust = instilling phrases.
Question 29	Will drivers change mode of travel?

Table 7-4. Experimental design for those survey questions that varied across version.

Question #	**Version of Survey**			
	A	**B**	**C**	**D**
9-10	Predict Trip	Plan Trip	Create Trip	Get Trip
15	Average	Typical	Historical	Estimated
16	95th Percentile	Worst Case	Maximum	Most Common
18-20	Recommended	Estimated	95th Percentile	Suggested

Research Method

Participant Demographics

Researchers surveyed a total of 300 participants. The following list of demographic and driving questions was asked for each participant:

- Gender.
- Age.
- Education.
- How often participants drove on freeways on weekdays between 6 a.m. and 7 p.m.
- How often participants traveled to a different city and drove in that city.
- Flexibility of participants' arrival time to work each day.

- How much time it took the participants on average to commute to work each day.
- How much time it took the participants on average to commute from work each day.
- How much the participants' travel time to/from work could vary from day to day.
- Participants' travel requirements during their work day.

The gender and age distribution of the participants is shown in Table 7-5. A total of 150 females and 150 males participated in the surveys. Additional information that was collected about the participants, their driving characteristics, and the flexibility of their work schedules is included in Appendix D.

Table 7-5. Gender and age of participants by city.

Gender	Age Range	Dallas	Miami	Denver	San Jose	Hartford	Total	Percentage
Male	18-29	3	9	16	11	6	45	15.00%
	30-39	5	8	6	5	8	32	10.67%
	40-49	8	7	9	2	5	31	10.33%
	50-59	7	11	3	5	6	32	10.67%
	60+	3	2	2	3	0	10	3.33%
Female	18-29	10	10	8	9	14	51	17.00%
	30-39	7	5	5	5	2	24	8.00%
	40-49	9	6	5	6	11	37	12.33%
	50-59	8	9	7	6	4	34	11.33%
	60+	2	0	0	2	0	4	1.00%
Grand Total		**62**	**67**	**61**	**54**	**56**	**300**	**100.00%**

The sample represented a wide variety of education and employment. The educational attainment of 23 percent with a bachelor's degree was close to the comparable U.S. Census number of 27 percent. The age distribution of the participants was well distributed across the age range recruited. Ninety-three percent of participants drove daily or a few times a week. Nearly 50 percent of the participants had jobs where they had to arrive at work at a specific time, while the remaining people had some flexibility in their jobs. Most of the participants did not drive during the day much for their jobs. Our sample purposely included people who did not work outside the home because this group often is taking multiple mid-day trips for household errands and may be more flexible in its travel plans.

Average daily commute times ranged from less than 10 minutes to over 50 minutes. These background questions also asked how much a person's travel time varied from day to day. The values for this question depended on the average trip time but also ranged from 5 minutes to greater than 30 minutes. Interestingly, 15 people reported that their 21-30 minute trip could vary by more than 30 minutes. These comments could be an indication that these people misunderstood that the question was asking about additional travel time above the average and instead answered by choosing the category representing their total trip time.

Experimental Design and Procedure

The survey was developed using the survey software SuperLab™. The software allows measurement of keystroke logging. A binder containing printouts of website screenshots was also used for sections of the survey.

All survey questions were answered on a computer using a seven-key response box. Figure 7-1 shows the response box used for the study. The use of a simple response box reduced entry errors and made it easier for people who did not routinely use a computer keyboard to participate in the survey. With the use of the button box, the survey was limited to multiple choices, with no open-ended answer opportunities.

Before beginning the study, each participant read and signed a consent form explaining the details of the survey and his or her rights as a participant.



Figure 7-1. Button box used for driver survey participant response entry.

Before beginning the survey, participants were given the following instructions:

> *Today you will be viewing website screens in the binder next to you and then will be asked questions about what you see. You will use the button box you see in front of you labeled 1-7 to enter your responses.*
>
> *You will only need to flip the binder page when you see the symbol to the right.*
>
> *Please raise your hand if you have a question at any time.*

The instructions included a picture of an orange book symbol that would appear on the computer screen to alert participants to view a binder slide.

Results

Questions 1-4: Reliability Concepts

The first set of survey questions was aimed at uncovering participants' preconceived ideas of four different terms for reliability that were frequently used in the focus groups.

Instructions on the computer screen read "Now we will ask you a set of questions about what words you use to describe the trips you take. (You will not need to use the binder yet)."

Questions 1 through 4 were constructed using short descriptions of four trips, identified with fictional travelers' names (Laura's trip, Bob's trip, Sue's trip, and Tom's trip). The numerical values provided for the described trips all represented an underlying average travel time of 25 minutes, while representing different travel time reliability concepts. Table 7-6 lists the four trip descriptions and the travel time reliability concept that each description represented.

Table 7-6. Questions 1-4: Trip descriptions and corresponding reliability concepts.

Trip Description	Reliability Concept
"Laura's trip is 20 miles and ordinarily takes 25 minutes."	Typical travel time (most frequently occurring)
"Bob's trip is 20 miles and can take anywhere from 15 to 40 minutes."	Low reliability trip with a large travel time range
"Sue's trip is 20 miles and always takes less than 30 minutes."	Maximum travel time
"Tom's trip is 20 miles and can take anywhere from 20 to 30 minutes."	High reliability trip with a small travel time range

Each question featured a different underlined term, and then asked the participants to choose which of the four described trips the term best described:

- Question 1—Whose trip is the most reliable?
- Question 2—Whose trip is the most predictable?
- Question 3—Whose trip is the most consistent?
- Question 4—Whose trip is the best trip?

In this way, participants were given a term, such as *reliable*, and asked which of the described trips best fit that term. The same four trip descriptions were repeated in each of the four questions.

A summary of the responses across this set of questions is shown in Table 7-7. For all four terms seen by participants (*reliable*, *predictable*, *consistent*, and *best trip*), the trips described using the typical travel time or the maximum travel time were selected most often. It is interesting to note that there was little difference in the preference for terms between options 2 and 4 despite the fact that the trips described had considerably different travel time ranges: one with a wide range of 25 minutes (option 2) and one with a narrow range of 10 minutes (option 4). The term *consistent* was selected equally for trips that varied by a range of 25 minutes (option 2) and for a

trip with a range of 10 minutes (option 4). This could be due to a dislike of examining multiple numbers, expressed as a range.

Table 7-7. Questions 1-4 response summary.

Response Choice	Reliable (Question 1)	Predictable (Question 2)	Consistent (Question 3)	Best Trip (Question 4)
1. Laura (Typical Travel Time)	40.00%	42.33%	49.33%	47.67%
2. Bob (Large Range of Travel Times)	8.00%	10.67%	5.67%	8.33%
3. Sue (Maximum Travel Time)	39.00%	37.00%	39.33%	26.67%
4. Tom (Small Range of Travel Times)	13.00%	10.00%	5.67%	17.33%

Question 5: Importance of Trip Planning Factors

The next question's aim was to understand what factors are important to people when planning a trip, or more specifically, whether or not people even considered reliability when making trip planning decisions. The word *predictable* was used in the question option to represent reliability and was selected because it was often used in the focus groups. Question 5 asked participants "When taking a trip over 20 miles, which is the most important to you?" The provided response options for this question were as follows:

- Choosing a route that takes the least amount of time on the road.
- Choosing a route that takes the fewest number of miles to get to my destination.
- Choosing a route that has the most predictable travel time, even though it is more miles.

The majority of the participants, 68.67 percent, said they would choose a route that takes the least amount of time. Fewer than 20 percent selected "most predictable travel time." In retrospect, the wording of this particular first answer option may have led people to discount the importance of predictability when the first option was worded with such certainty. An improved version of this question may have added the phrase "or time" to the last option. These data are presented in further detail in Figure 7-2, which shows the pattern of responses as a function of the respondent's work arrival flexibility as indicated in the preliminary demographics questions. This figure shows predictable travel times are more important for those with inflexible work start times than they are for those with more flexible work schedules. This result is reasonable given that workers with inflexible work start times will need to know they will arrive to work on time, as they cannot afford to be late. Results according to average commute time to work are shown in Table 7-8.

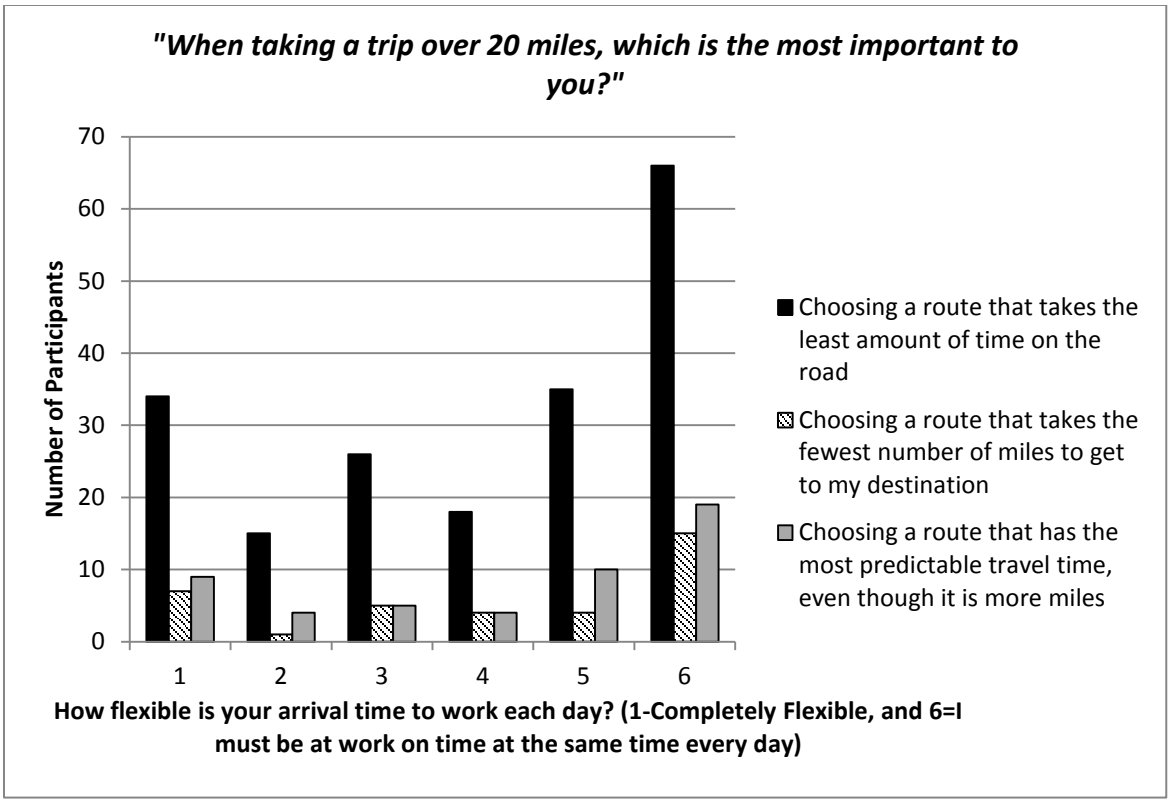


Figure 7-2. Question 5 responses by arrival time flexibility.

Table 7-8. Question 5 responses by average commute time to work.

	How much time does it take you on average to commute to work each day?							
When taking a trip over 20 miles, which is the most important to you?		**< 10 min**	**11-20 min**	**21-30 min**	**31-40 min**	**41-50 min**	**> 50 min**	**I don't work outside the home**
	Choosing a route that takes the least amount of time on the road.	68%	66%	70%	78%	53%	69%	74%
	Choosing a route that takes the fewest number of miles to get to my destination.	18%	14%	13%	3%	18%	23%	9%
	Choosing a route that has the most predictable travel time, even though it is more miles.	15%	20%	17%	19%	29%	8%	17%
	n	40	99	71	37	17	13	23

Questions 6-8: Terms for Website Trip Planning Feature Links

In preparation for Question 6, participants received instructions on the computer screen to open the binder to page 1. Page 1 of the binder was a picture representing the home page of the simulated travel information website. This screen was designed to resemble a page that travelers would likely see first when accessing the website of a transportation management center or 511 center, including links for general news, advertisements, social networking options, and assorted menus. The only indication that there was trip planning information available on this simulated website was a features box with a group of links to "current trip," "future trip," and "traffic alerts." When reviewing the handful of websites that offered travel time reliability information, the research team noticed that it was not always obvious where to find that information on the site. The website images were created by the research team to be generic and did not include real road numbers or destination names.

Websites that offer reliability-based planning tools will need to be careful to distinguish these planning tools from real-time information. There are likely usability benefits to designing input and output screens of reliability-based planning tools with a similar look and feel as real-time information sites that are maintained by the same agency. This similarity, however, could result in confusion between what is real time and what are predictions based on historical data. Focus group participants indicated that they would like a system that blended real-time and historical data to make better predictions. They also indicated that they didn't entirely trust solely

historical data for predictions and would double-check current conditions on a real-time system before departing. The systems presented in this survey assumed that these two functions would be separate. The researchers felt that it was important to isolate the reliability-based planning tools in the study given the lack of research and knowledge in this area. Without this isolation, the results would be confounded by the influence of real-time information. Future research could investigate the blending of these two information sources as expressed by focus group participants.

For Questions 6-8, researchers wanted to briefly assess participants' understanding that the developed website focused on historical trip planning as opposed to real-time information. Questions 6 and 7 asked about the terms *current* and *future* to assess participants' ideas of the timeframe for planning, i.e., that *future* meant later in the day or a future day, not just a few minutes from now. Question 8 approached the future trip concept in a slightly different way by specifically asking about the purpose of entering day and time in the input box. These questions included response option "I don't know" because at this point in the survey, a thorough explanation of reliability had not been provided to the participants. These early questions were intended to gauge participants' naïve understanding of these terms.

Question 6 asked "If you click on the Current Trip button, what do you think you'll get?" Responses options for this question were as follows:

- It will take me to a webpage that will allow me to enter information about a trip I want to take right now.
- It will take me to webpage that will tell me what all the roadways in the area are like right now.
- It will take me to a webpage that will allow me to enter information about a trip I want to take later in the day or tomorrow.
- I don't know.

The responses to Question 6 indicated that about half the participants believed that when they select the Current Trip link on the website, they would be able to enter and obtain information about their specific trip at that point in time, and approximately 30 percent believed the website would tell them about general roadway conditions at that point in time. This indicated some confusion over whether the site would be providing personalized or general information. Given that this was the first question utilizing the binder slides, this result carried less importance, especially when considering the results from Question 7.

Question 7 asked about the Future Trip link shown on the simulated webpage: "If you click on the Future Trip button, what do you think you'll get?" A new answer option was added to this question to allow participants to express skepticism at a system's ability to predict future travel times; the response options for this question were therefore as follows:

- It will take me to a webpage that will allow me to enter information about a trip I want to take right now.
- It will take me to webpage that will tell me what all the roadways in the area are like right now.

- It will take me to a webpage that will allow me to enter information about a trip I want to take later in the day or tomorrow.
- Nothing, because there is no way to predict what a future would be like.
- I don't know.

The research team felt it was likely that some portion of respondents would not be able to conceive of a system that would make predictions beyond current conditions. As expected, 11.15 percent of the participants said there was no way to predict what a trip in the future would be like. Encouragingly, approximately 80 percent of the participants said the website would allow them to enter information about a trip they wanted to take later in the day or tomorrow. This indicated a high comprehension of the term *future* to mean beyond the immediate timeframe. It must be noted, however, that participants had just answered the previous question, which contrasted future with current and may have prompted the comparison of the two terms.

Question 8 took a different approach to assessing participants' timeframe comprehension. Before Question 8, participants were told to flip to a binder slide showing a detailed view of the Trip Planner website's input box; this instruction was followed with the statement "This is taken from a website you can use to find out information about a trip you want to take." The input box included input blanks for trip date and time, similar to the one used to enter parameters about a future trip on San Francisco's 511.org Predict-a-Trip webpage. Question 8 asked, "Why do you think you enter a time and date when using this website?" Response options were as follows:

- Because the website does not know what day or time it is.
- Because I am wanting information about a trip I am about to take right now.
- Because I am wanting information about a trip I may take in the future.
- I don't know.

Over half the participants said they would be getting information about a trip in the future, but 35 percent said they would be getting information about a trip they were about to take at that moment. Nine percent responded that "the website does not know what day or time it is."

These three questions taken together offer different ways to assess drivers' understanding of the real-time nature of a website such as this. Question 7 showed that 81 percent of participants understood the term future trip to mean a trip later in the day or tomorrow rather than one with a more immediate departure. The results of Question 8 then were somewhat surprising, where 35 percent of people indicated that they thought the purpose of the time input box was because the trip was imminent. Further analysis on the relationship and pattern of responses across these two questions is shown in Table 7-9. Of those who indicated that future trip meant a non-imminent departure, only 52 percent thought that the purpose of entering a time and date would be for planning a future trip. This result indicates that the labeling of the input box needs to be consistent and clear. For instance, in the sample website, the input box was labeled *Future Trip.* The results from Question 7 indicate that *Future Trip* may be a better label to confirm that the date and time being entered are for a future trip.

Table 7-9. Response choices for Question 8 based on Question 7.

	Why do you think you enter a time and date when using this website?			
Answered Question 7, *Future Trip* means...	Because the website does not know what day or time it is.	Because I am wanting information about a trip I am about to take right now.	Because I am wanting information about a trip I may take in the future.	I don't know.
It will take me to a webpage that will allow me to enter information about a trip I want to take later in the day or tomorrow.	9%	35%	52%	4%

Survey Section Providing Explanation of Sample Travel Time System

Before continuing any further in the survey, researchers wanted to make sure that participants had a clear understanding of the website system and that it was using historical data to help plan a trip rather than providing real-time information. What makes reliability information different from real-time information is that it can only be calculated from historical data to provide the travel time frequency distributions from which reliability performance measures are derived. Thus, it was important to spell out this distinction for the average driver participating in our surveys. Because so few traveler information websites identified in the literature review currently use historical data to make travel time predictions, we were relatively certain that few or none of our participants would have been exposed to them. This was another reason to provide a lengthy explanation, in order to equate the information and experience of all participants. This explanation was developed by the research team based on examples that performed well in the focus groups.

The following explanation was given to the participants.

> *The remaining survey questions will ask you about the setup and words used in a travel time website.*
>
> *This travel time system will make predictions about travel time based on detailed records of freeway conditions that the department of transportation keeps. The system uses data about all trips taken on freeways in the past 5 years and factors in expected delays to predict a very accurate trip time estimate for your specific trip.*
>
> *It is different from existing mapping tools such as MapQuest because the system knows that travel time varies depending on factors such as traffic, special events, weather, and holidays.*

As a driver, this tool would be very helpful in planning a trip you will take in the future. Users have the ability to enter a starting location and destination and the date, day of the week, and time you want to take your trip.

For example, if you had a doctor's appointment and wanted to know how long it would take to get there from your office, the system will give you a different time estimate on Monday morning at 7:30 a.m. than it will if you were to take your trip Wednesday afternoon at 3 p.m.

The important thing to remember is that this is not telling you about traffic now, it is telling you about a specific trip you choose for the future.

Questions 9-10: Terms to Convey Immediacy of Departure

Questions 9 and 10 continued to test potential terms to be used on a trip planning website but also tested participants' comprehension of the future trip concept as explained above. The binder slide accompanying Question 9 displayed the same trip planning webpage with trip inputs for origin, destination, day, and time of a trip, as well as a circled website button; participants were asked, "What do you think will happen when you fill in the fields in the box and then select the button circled?"

The answer options provided for Question 9 were selected to test whether participants would be able to distinguish the type of information provided by a travel time reliability website from the types of information that are available through other types of mapping or travel information websites:

- The map will display the route with the shortest distance.
- The website will give me step-by-step driving directions for my trip.
- The website will tell me how long my trip will take right now.
- The website will tell me how long my trip will take for the date/time I enter.
- The website will show me if there are any accidents or construction on my trip right now.
- It will do nothing.
- I don't know.

The wording of some of these answers came from comments heard in the focus groups. "The map will display the route with the shortest distance" and "The website will give me step-by-step driving directions for my trip" are answers that would describe a mapping website such as MapQuest or GoogleMaps, but these websites do not provide historical travel time information. "The website will tell me how long my trip will take right now" and "The website will show me if there are any accidents or construction on my trip right now" could both be descriptors for websites offering real-time traffic information. "It will do nothing" was included as an indicator that a participant might not understand the format or function of the input box.

Question 9 was the first question of the survey to vary by survey version, in order to present the same question using four different terms. This experimental design offered the opportunity to test multiple options without overwhelming each participant with a lengthy and repetitive survey.

The term on the circled button shown in the webpage picture in the binder varied amongst the versions to say *predict trip, plan trip, create trip,* or *get trip*. Table 7-10 shows a comparison of the overall results for the four versions. For all four versions, the most common response was the correct one—"The website will tell me how long my trip will take for the date/time I enter"—with the term *create trip* receiving the most correct responses. The second most common response for all versions was that "The website will give me step-by-step driving directions for my trip." A few participants who were deciding between these two responses commented to researchers that the response "The website will give me step-by-step driving directions for my trip" could also be correct, given that the website would likely provide both types of information (step-by-step route directions AND the expected travel time for the route). This was to be expected, as most Internet mapping websites provide both route directions and an estimated travel time. Our survey, however, forced participants to choose a single response.

Table 7-10. Question 9 responses by version.

Response Choices	Version A: Predict Trip	Version B: Plan Trip	Version C: Create Trip	Version D: Get Trip
1. The map will display the route with the shortest distance.	7.89%	4.05%	6.67%	14.86%
2. The website will give me step-by-step driving directions for my trip.	17.11%	27.03%	16.00%	20.27%
3. The website will tell me how long my trip will take right now.	6.58%	8.11%	1.33%	5.41%
4. The website will tell me how long my trip will take for the date/time I enter.	63.16%	56.76%	72.00%	58.11%
5. The website will show me if there are any accidents or construction on my trip right now.	1.32%	1.35%	0.00%	0.00%
6. It will do nothing.	2.63%	1.35%	2.67%	0.00%
7. I don't know.	1.32%	2.70%	1.33%	1.35%

Since Question 9 had four different versions, Question 10 was added to the survey to give everyone a chance to see all four terms from all of the versions. Question 10 then simply asked preference for a term for the button on a website to initiate the trip planning function. The response options were as follows:

- Predict trip.
- Plan trip.
- Create trip.
- Get trip.
- Submit.
- Go.

- OK.

The first terms were the items that were used in the four versions of Question 9. The other three were taken from websites reviewed and were terms typically used on any type of website to initiate action after inputting options.

Before being presented with Question 10, the participants were asked to flip to page 6 in the binder and were told "This page in the binder shows the 'Trip Planner' box. When you fill in the information asked for in the box and hit the circled button with the question marks, the website will show you a route and travel time for the trip you entered." Question 10 asked participants to choose from a list of terms that best represented the purpose of this button:

- Predict trip.
- Plan trip.
- Create trip.
- Get trip.
- Submit.
- GO.
- OK.

As seen in Table 7-11, the most frequently selected terms were *predict trip* (28 percent) and *plan trip* (25 percent). It is interesting to note that those people who saw those terms in Question 9 (versions A & B) were no more likely to answer that question correctly than people who saw the other terms, but Question 10 shows an overall preference for them. Normal computer action initiation terms such as *Go* and *OK* were not preferred.

This repeating of all possible terms in Question 10 provided an opportunity to assess whether respondents were consistent in their choices or whether they preferred a term in Question 10 over the single term tested in Question 9. Preferences expressed in Question 10—when shown all the terms—broken out by how a person responded in Question 9—when shown a single term—are shown in Table 7-11. This table shows that most people preferred a different term than the one shown in their original version.

Table 7-11. Question 10 responses based on term viewed in Question 9.

		Term viewed in Question 9			
		Predict Trip (Version A)	**Plan Trip (Version B)**	**Create Trip (Version C)**	**Get Trip (Version D)**
Response to Question 10 when selecting favorite term from a list	Predict Trip	36%	25%	25%	27%
	Plan Trip	25%	27%	28%	19%
	Create Trip	12%	13%	19%	14%
	Get Trip	4%	4%	7%	14%
	Submit	17%	15%	17%	22%
	GO	3%	8%	3%	4%
	OK	4%	8%	1%	1%

Questions 11-12: Terms to Describe Departure and Arrival Time Constraints

The background web screenshot for Questions 9 and 10 included a box labeled "Time," which was not specifically part of Questions 9 and 10 and was only briefly mentioned in the explanation. The focus groups had indicated that people sometimes need to plan trips around departure time constraints and other trips around arrival time constraints. Some websites reviewed provided the option to indicate either a departure or arrival time. The survey did not specifically ask for a preference for entering arrival or departure time because the constraints are so trip specific. As a best practice, the researchers recommend that travel information website developers should consider offering departure and arrival constraints as an input option.

Questions 11 and 12 addressed preferences for the term or phrase that best described the time participants would want to start their trip or the time they would want to reach their destination. Terms and phrases that were presented as answer choices in these questions came from the reviewed travel time websites.

For a trip start time (Question 11), the largest percentage of participants (35 percent) preferred the phrase *departing at*. *Leave at* (23 percent) and *what time will you start your trip?* (21 percent) ranked second and third in popularity. None of these terms was a clear winner, but the top three preferences all shared the feature of being a specific time rather than an upper limit for a time range for departure time.

Question 12 asked, "What phrase do you prefer to describe what time to you want to reach your destination?" Response options were as follows:

- Arrive at.
- Arrive by.
- What time do you want to get there?
- What's the earliest you can arrive?
- What's the latest you can arrive?

For the trip arrival time input, 47 percent of participants preferred *arrive by*, and 33 percent preferred *arrive at*. These responses showed a willingness to accept uncertainty in arrival time by choosing "by," which can mean "no later than." These two results together showed a tolerance for early arrival but a preference for specific departure times. An X^2 test goodness-of-fit test showed significant differences between the five responses overall and also between *arrive at* and *arrive by*. This means that *arrive by* is the best term to use to ask for desired arrival time input.

Questions 13-14: Map and Travel Time Output Terminology

Before moving on to Questions 13 and 14, the participants were asked to flip to page 8 in the binder showing the Trip Planner site. They were then presented with the following information:

> *This page in the binder shows the map of the Forest City area. It also shows an "Advanced" link at the bottom of the Trip Planner box. When you select the circled link, you will be taken to a webpage that allows you to enter additional information about the trip you'd like to take. Now flip to page 9. The orange segments on this map indicate where data has been collected on the roadways in the past to predict future travel times. Only the orange segments have this data and are able to be selected for your route. This map does not tell you anything about the current conditions of the roadways.*

The website screens shown on page 8-10 of the binder displayed a map of roadways. Selected roadways, meant to represent the fictional city's network of freeways and other major roadways, appeared as heavy orange lines, while many smaller roads were shown as thin gray lines. In the actual cities and regions that currently collect travel time data, these data are most often collected only on freeways and perhaps on some managed lanes/facilities; they are generally not available for arterial and local streets. While this may change in the future, it is important to convey to drivers that a travel time prediction (whether real time or based on historical data) is only valid for roadways on which data are being collected.

The screen shown on page 11 of the binder displayed the same underlying map, but with a superimposed line marking the route of a particular trip. This screen accompanied Question 14, which was the first question to address outputs from a travel time reliability website.

The questions that referred to these maps attempted to address participants' understanding of the roadway segments in the database. One of the research team's observations in the website review was that labeling output can affect understanding. Thus, Questions 13 and 14 addressed titles for these system coverage maps. Some of the terms and phrases offered as potential map titles were taken from existing travel time websites, and additional options were developed by the research team.

Question 13 asked participants to choose a map title, or phrase, to describe the website map before a route had been selected. Available responses for this question were as follows:

- Map of Forest City.
- Road segments with available travel information.

- Road segments with historical data.
- Forest City's available travel information.
- Forest City's historical data.

For the map showing all available routes, participants most frequently preferred the two phrases that included "available travel information" in the title; "Forest City's available travel information" was preferred by 34 percent of participants and "road segments with available travel information" was preferred by 32 percent. "Map of Forest City" was preferred by 18 percent of participants. The phrases containing "historical data" performed relatively poorly, with 11 percent of participants preferring "road segments with historical data" and 6 percent preferring "Forest City's historical data." Questions 6 through 13 addressed terminology that could potentially become part of a lexicon for travel time reliability information, but the terms tested by that group of questions pertain to user inputs about potential trips. Beginning with Question 14, the survey began to focus less on terminology pertaining to website usability and more on terms for conveying travel time reliability. The following questions addressed the types of terms that could be used for the outputs of a travel time reliability website or other information delivery system and that would likely form the core of a travel time reliability lexicon.

Question 14 provided a trip scenario described in the question on the computer screen as "This map displays a route based on the start and end locations and the trip times you specified to arrive at your destination at 8:15 AM." The question then asked for preference for a title term used for the output map that displayed a calculated trip route. The options provided for Question 14 were selected from the reliability literature review and the terms used in the focus groups:

- Best route.
- Least variable time.
- Most consistent trip.
- Most reliable trip.
- Most predicable trip.
- Forecasted trip.
- Historical trip conditions.

The most frequent response was *best route*, selected by 49 percent of participants. This concurred with the focus group feedback that indicated a preference for simple terms.

Questions 15-17: Trip Time Output Terminology

Existing websites and focus group results provided a large number of terms that could potentially be used to describe projected trip times and the variability of those times. The research team used many of these terms as answer options in Questions 15 through 28.

Questions 15 through 17 tested terms that could be used to describe a projected trip time based on historical information. Questions 15 and 16 were included to test how participants would view a historically based trip time provided by a website (or other information source). Would

they assume, based on the terms used, that the given trip time was an average or midpoint of a range, that it was a near-guarantee, or conversely that it would be unreliable?

Because of the number of terms that the research team wished to test, the same question was asked as Question 15 and Question 16, and the trip time term tested in each of the questions was varied among four survey versions, as shown in Table 7-.

Table 7-12. Experimental design for Questions 15-16.

	Version of Survey			
Question #	**A**	**B**	**C**	**D**
15	Average	Typical	Historical	Estimated
16	95th Percentile	Worst Case	Maximum	Most Common

Question 15 tested the first four terms describing a trip time, varying by survey version. The trip time term that was used varied amongst the versions to say *average*, *typical*, *historical*, or *estimated trip time*. The question asked the participants how often they would expect the trip to take the indicated time of 25 minutes or less based on the term used. Five answer choices were shown:

- Almost never (1 day out of 20).
- Less than half the time (5 days out of 20).
- About half the time (10 days out of 20).
- More than half the time (15 days out of 20).
- Nearly all the time (19 days out of 20).

The answer choice "nearly all the time (19 days out of 20)" was based on the Washington State DOT's travel time reliability website, which provides a 95th percentile trip time based on historical data and in the past expressed 95th percentile as "19 out of 20." The answer choice "about half the time (10 days out of 20)" would be an appropriate certainty level for a website providing a historically based average trip time. "More than half the time (15 days out of 20)" was based on a focus group response. The other two options were added by the research team in order to allow a full range of confidence levels.

Of the terms tested in Question 15's four versions, version B (Typical Trip Time) scored the highest, with 58 percent of the participants seeing this version indicating they would expect the trip to take 25 minutes or less "most of the time," although *average* and *historical* trip time terms scored the highest for participants choosing "nearly all of the time." It is important to note here that although participants preferred the term *average*, the results from Question 15, version A indicated that they misunderstood the mathematical definition of *average*. Over half of the participants for this version indicated that *average* meant that the trip time would be in the expected range most or nearly all of the time, when mathematically the correct answer would have been "about half the time," which was selected by only 18 percent of participants.

Question 16 asked the same question providing a second term in the circled region, again varying by version (*95th percentile*, *worst case*, *maximum*, or *most common trip time*).

Of the terms tested in Question 16, the term *most common trip time* scored the highest percentage of the answer choice "most of the time," with 43 percent of participants selecting this response, but scored the lowest percentage (16 percent) for the answer choice "nearly all of the time." The term *95th percentile trip time* scored the highest percentage of responses for "nearly all of the time." But even for that term, only 37 percent of participants correctly chose the mathematical meaning of the term.

Since the eight reliability terms were spread across two questions, it is helpful to view Figure 7-3, which shows how responses to Questions 15 and 16 compared across the terms tested. If a traveler information service provider wishes to label a trip time prediction that is derived from the 95th percentile times, these data suggest that the terms *maximum trip time* and *95th percentile trip time* would be the best. If should be noted, however, that focus group results showed a strong dislike of the statistical-sounding term *95th percentile*. It is also interesting to note how poorly the term *worst case* did in this question. The 95th percentile could indeed be thought of as a near-worst-case travel time prediction, but when the *worst case* term was used on the output box, many people thought that it would take 25 minutes or less rarely, when it really was intended to convey the opposite. If the worst-case travel time is reported as 25 minutes, then the trip will nearly always take less than 25 minutes.

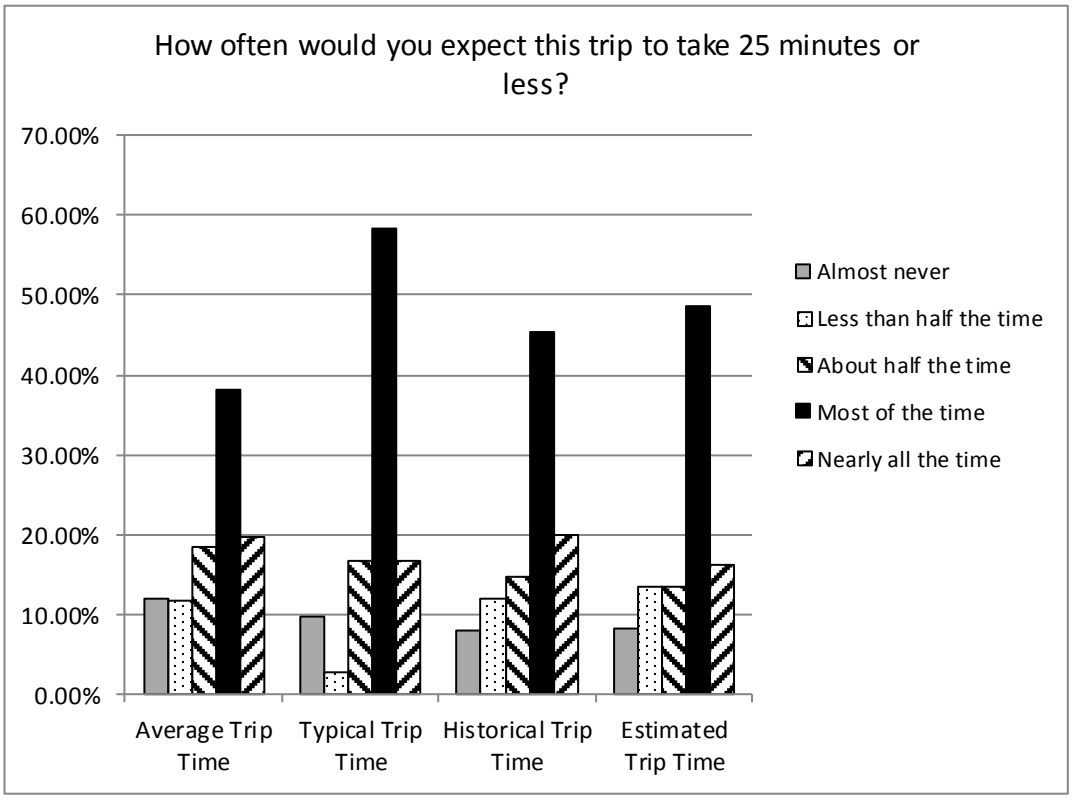


Figure 7-3. Combined responses to Questions 15 and 16.

Another way to examine these results is to look at the number of responses to the highest two categories: "most" and "nearly all." If the purpose of the term is to convey that this is the trip

time estimate that the system has the most confidence in, then these two highest categories could be considered a success. Using this metric, the term *typical* does the best job of conveying that the provided trip time will encompass the actual trip time most or nearly all of the time, as shown in Table 7-13.

Table 7-13. Percent responses for "most" or "nearly all" for Questions 15 and 16.

Term Questions 15 and 16	Total % of Responses for "Most" or "Nearly All" of the Time
Average	57.90%
Typical	75.00%
Historical	65.33%
Estimated	64.87%
95th Percentile	64.47%
Worst Case	38.66%
Maximum	53.33%
Most Common	59.46%

The experimental design purposely allowed for each participant to only see two of the eight terms being evaluated to avoid bias and reduce survey length. Question 17 allowed participants to indicate their preference for terms from the larger set. Seven of the eight travel time terms from Questions 15 and 16 were presented to participants in Question 17 (a maximum of seven terms could be tested in any given question because of the seven answer choices available with the button pad). When faced with this limitation, the research team members decided to drop *most common trip time* from the preference rating question because they felt it unlikely that an agency would want to use trip time statistical mode in its traveler information. When asked to choose a preferred term to grammatically modify *trip time*, 43 percent of the participants chose *estimated*, and 33 percent chose the term *average*.

Questions 18-20: Planning and Buffer Time Terminology

Questions 18 through 20 presented travel time reliability information as a recommended departure time rather than as an estimated trip time. Many current map and navigation systems simply provide an estimated trip time, and the user must subtract that time from the desired arrival time in order to calculate when he or she should leave (or add it to the desired departure time to calculate when they will arrive). The questions in this section began by providing participants with the scenario that the website was "telling you the time to leave, and the map displays a route based on the start and end locations and the time of day you specified." In this way, this set of questions explored whether participants understood that the website had already included a buffer time in its total trip time estimate. In the focus groups, it was apparent that the majority of people would not trust a system that provided an overall trip time and would add their own buffer on top of it. This could pose a real problem for systems that use reliability data to calculate a predicted trip time that accounts for the variability and cushion time needed. If users add their own buffer on top of those estimates, they would most likely arrive far too early.

Question 18 presented alternative ways of expressing the technical concept of planning time, which represents the total travel time that should be allowed. This planning time is calculated by some researchers as an index and by others as an actual time representing the sum of some central tendency or free-flow condition plus some buffer time. Question 19 asked about terms that could be used for buffer time, which FHWA defines as the extra time, or time cushion, that travelers add to their average travel time.

The presentation of a recommended departure time is used by the Washington State DOT's travel time website for the Seattle area, which provides a recommended departure time based on the origin, destination, day of travel, and time of arrival specified by the traveler. Similar to Questions 15 and 16, Question 18 tested different terms describing a provided departure time to see what the effect of each of those terms was on the credibility of the provided departure time to participants. For this question, the research team assumed the provided departure time to be based on a 95th percentile trip time.

The binder slide for Question 18 showed a circled departure time term that varied across the four survey versions to say *recommended*, *estimated*, *95th percentile*, or *suggested departure time*. All of these terms appear on travel time websites and/or were mentioned in the focus groups. The question asked the participants how often they would expect to arrive at their destination on time if they left at the departure time provided by the fictional website. Table 7- includes the overall results for the four versions, and these same results are illustrated in the graph in Figure 7-4.

When comparing the four versions with the four different departure time terms, only about 39 percent said they would expect to arrive on time "nearly all of the time" when the term 95th percentile was used, demonstrating a lack of understanding of the mathematical meaning of the term *95th percentile*. The overall small number of people who selected "nearly all of the time" as a response is troubling and indicates some lack of trust in the accuracy of such predications. However, it is important to note that across the four different departure time terms, a majority—though not overwhelming—of respondents realized that they would arrive "most of the time" based on the information provided. While there was no clear standout term, they could all be used on a website, albeit with a descriptor. Furthermore, given that only a fraction of respondents understood the term *95th percentile*, it is safe to say that most of the participants would build in their own buffer time, even though it is already included in the time provided.

Table 7-14. Responses to Question 18.

Response Choices	Version A: Recommended Departure Time	Version B: Estimated Departure Time	Version C: 95th Percentile Departure Time	Version D: Suggested Departure Time
1. Almost never (1 day out of 20)	2.67%	5.33%	4.00%	1.37%
2. Less than half the time (5 days out of 20)	4.00%	4.00%	2.67%	5.48%
3. About half the time (10 days out of 20)	18.67%	10.67%	13.33%	19.18%
4. Most of the time (15 days out of 20)	58.67%	65.33%	41.33%	52.05%
5. Nearly all the time (19 days out of 20)	17.33%	14.67%	38.67%	23.29%

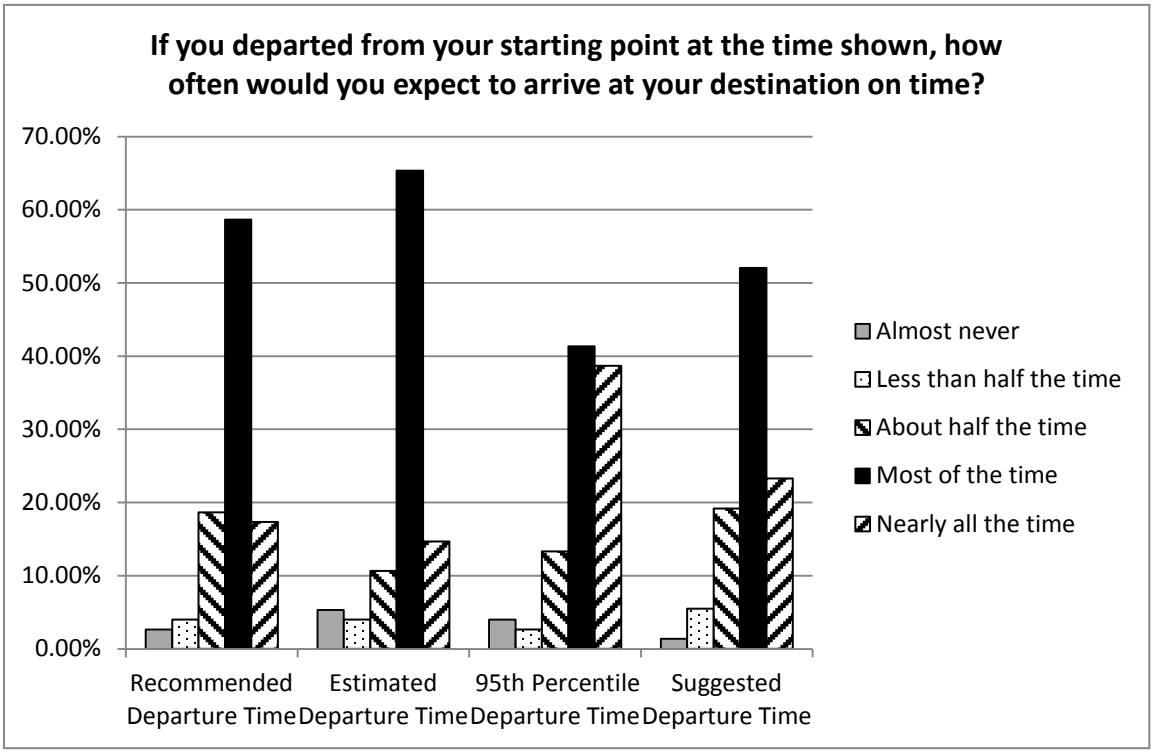


Figure 7-4. Illustration of responses to Question 18: Planning time terms.

As a follow up, Question 19 tried to determine what additional travel time, if any, participants would add based on the term used to describe the provided departure time. Participants were asked, "If it is important that you arrive at your destination at 8:15, what time would you leave for this trip?" Possible responses were in five-minute increments from 7:30 (20 minutes before

the departure time provided by the website) to 8:05 (15 minutes after the departure time provided by the website). This question was included as an additional indicator of how participants viewed the credibility of the provided departure time. Would people add additional buffer time to the provided total trip time?

Comparison of the results for all versions of Question 19 are shown in Table 7- and in Figure 7-5. Regardless of the term used, a majority of participants chose to leave earlier than the departure time provided by the fictional website. This is important to note because the terms tested were proposed as surrogates for planning time, which presumably already includes a buffer time. These results indicate either a lack of understanding or a lack of trust in the departure times provided by such a system. This agrees with many of the comments made during the focus groups as well.

Table 7-15. Question 19 visuals and responses by version.

Response Choices	Version A: Recommended Departure Time	Version B: Estimated Departure Time	Version C: 95th Percentile Departure Time	Version D: Suggested Departure Time
1. 20 minutes before departure time shown	35.53%	36.00%	29.33%	35.14%
2. 10 minutes before departure time shown	27.63%	34.67%	34.67%	35.14%
3. 5 minutes before departure time shown	14.47%	20.00%	16.00%	18.92%
4. At departure time shown	18.42%	4.00%	17.33%	6.76%
5. 5 minutes after departure time shown	2.63%	1.33%	1.33%	0.00%
6. 10 minutes after departure time shown	0.00%	4.00%	0.00%	2.70%
7. 15 minutes after departure time shown	1.32%	0.00%	1.33%	1.35%

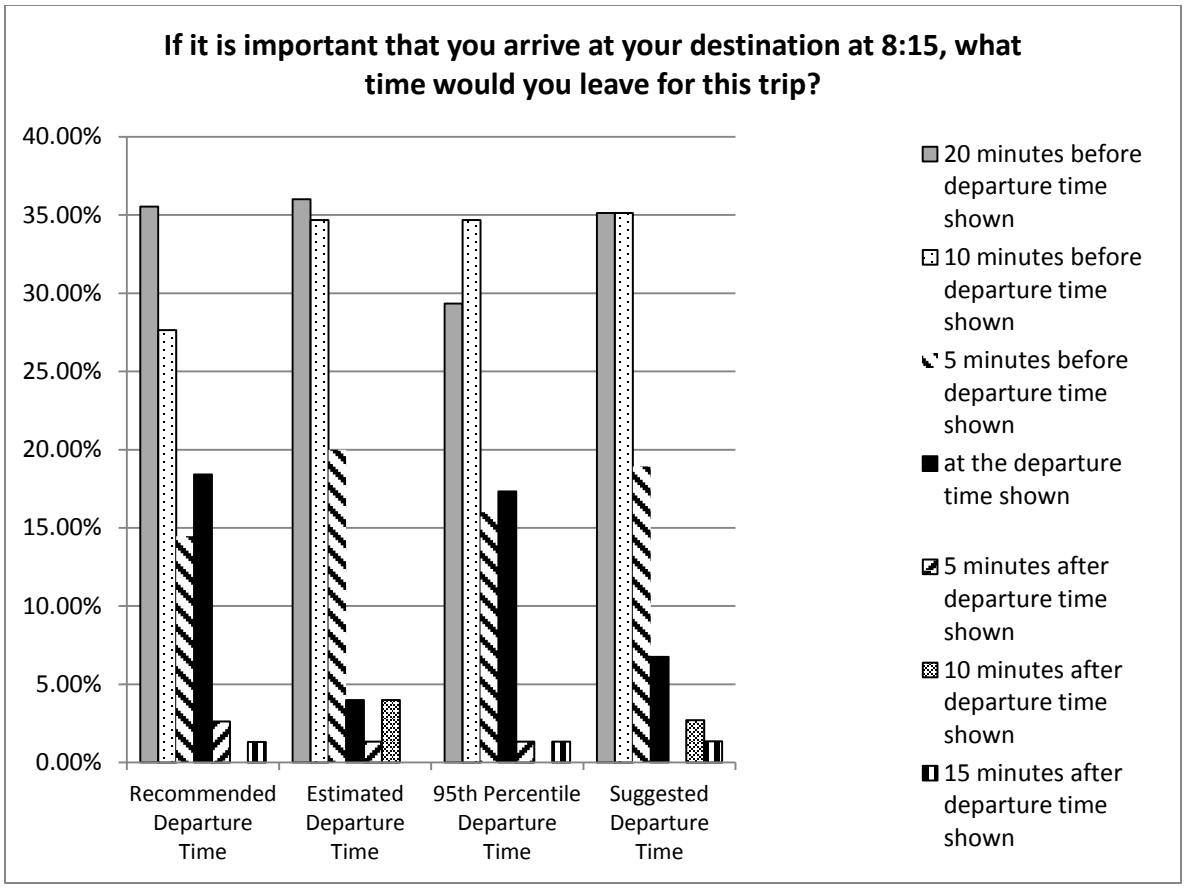


Figure 7-5. Illustration of Question 19 responses: Buffer time terms.

Because each person only saw one potential term in the previous two questions depending on his or her survey version, Question 20 presented a list of departure time terms (*recommended departure time, estimated departure time, 95th percentile departure time,* and *suggested departure time*) and asked participants to choose the term they most preferred. Almost half of the participants preferred *recommended departure time.* The term *95th percentile departure time* was favored by less than five percent of the participants. The research team noted that these preferences were markedly different from the terms that showed the best comprehension in Question 18. This led to further analysis, as shown in Table 7-16, which shows a cross-tabulation of preferences expressed in Question 20 as a function of response to Question 18, which asked more directly about comprehension of the term. It shows that 57 percent of those who saw *recommended departure time* in their comprehension question still preferred it over the other alternatives. Across all versions, *recommended departure time* received most of the shifts in preference, meaning that 40 to 45 percent of people preferred this term to the one they saw in their own version of the survey.

Table 7-16. Responses to Question 20 as a function of response to Questions 18 and 19.

		Term viewed in Questions 18 and 19			
		Recommended Departure Time (Version A)	Estimated Departure Time (Version B)	95th Percentile Departure Time (Version C)	Suggested Departure Time (Version D)
Preferred Term in Question 20	Recommended Departure Time	57%	45%	43%	43%
	Estimated Departure Time	14%	28%	23%	19%
	95th Percentile Departure Time	4%	3%	9%	1%
	Suggested Departure Time	25%	24%	25%	36%

Questions 21-22: Buffer Time Terminology

These questions were included to explore participants' understanding of buffer time and whether they wanted an information system to present them with a buffer time value. Questions 21 and 22 assessed participants' desire to be told the amount of potential variability associated with a predicted trip time. Question 21 presented participants with the assumption that the trip time provided by the fictional website was an average time for the specified trip, based on past travel time information, and that the actual trip time had some chance of being longer than average, depending on roadway conditions and nonrecurring congestion factors. Participants were asked if they would want to know how much additional time their trip could take, over the average time provided. Almost 9 out of 10 participants wanted to know how much additional time a trip could take beyond the average time provided.

Question 22 asked participants which term they preferred to describe the additional time. From the options provided (*buffer*, *departure window*, *leeway*, *cushion*, and *extra*), approximately 33 percent of the participants favored the term *extra*, while another 28 percent favored *departure window*.

Because these concepts of average and buffer time are so critical to reliability information, the research team created an open-ended survey to examine this issue further. This study is presented in the following chapter.

Question 23: Preference for Travel Time Distribution Output

Question 23 examined what type of travel time metric drivers would prefer to receive from a system using historical trip time data as its resource. This question reminded participants that the fictional website's system for predicting trip times was based on historical data, and with this in mind, asked what type of trip time calculation they would want the system to provide. The response options provided were designed to represent different travel time metrics that could be calculated from historical travel time data:

- An average time (statistical mean).
- A worst-case time (95th percentile).
- A range of times it could take (5th percentile time to 95th percentile time).
- The best-case time it could take (5th percentile time).
- The most likely time it would take (statistical mode, most frequently occurring value).
- The time where half the trips would take longer and half would take shorter (statistical median).

The most frequently expressed preferences were for an average time (31 percent of participants), a range of times the trip could take (29 percent of participants), or the most likely time the trip would take (24 percent of participants). Although *average* was the most frequent response, it must be interpreted in light of the results of Question 15, which showed an incorrect mathematical interpretation of *average* by many of the participants. The low popularity of *worst case* and *best case* were somewhat in contrast to many of the comments heard during the focus groups, where participants indicated they would like the worst case to be presented, and they would make adjustments from that based on their individual risk tolerance.

Questions 24-26: Travel Time Variability Terminology

Questions 24 through 26 explored additional terms and phrases that can be used to express travel time variability. These questions arose from similar concepts discussed in the focus groups, and the terms presented as options in these questions also came primarily from focus group responses. Each question provided participants with a fill-in-the-blank sentence and gave them a list of reliability terms to select from in order to complete the sentence. In each case, participants were advised to select the term that would give them the most confidence about the trip time information provided.

Question 24 presented a trip time derived from historical data using the sentence "It is _____ that your trip will take 45 minutes." Response options for this question included *forecasted, anticipated, estimated, probable, likely, reliable,* and *predicted*. Over half of the participants (56 percent) preferred *estimated* to complete this sentence.

Question 25 presented a sentence describing the potential variability of a trip time: "Your trip time may _____ from the average time by 20 minutes." Of the options provided (*differ, vary, fluctuate, change, go up or down, increase or decrease,* and *deviate*), 59 percent of participants selected *vary* to complete the sentence.

Question 26 began with the sentence "It will take _____ 20 minutes to make your trip." Of the terms presented as options to complete this sentence (*about, approximately, give or take, an estimate of, around, roughly,* and *an average of*), 69 percent of participants preferred *approximately*.

Question 27: 95th Percentile Trip Time Terminology

Researchers wanted to further explore drivers' understanding of the term *95th percentile trip time* since it is commonly used by traffic engineers but may be misunderstood by the general

public. Question 27 asked, "What does 95% time mean to you?" The response options for this question were as follows:

- It will take 95% of the provided trip time to arrive.
- 95 times out of 100 it will take the provided time to arrive.
- The system is 95% confident that its provided time is accurate.
- 95 times out of 100 it will take at or less than the provided time to arrive.
- The time it takes you to complete 95% of the distance of your trip.
- I don't know.

Four of the six response options provided were developed by the research team to represent what the team members felt could be likely or possible misconceptions about the term. The correct answer, also included in the response options, is "95 times out of 100 it will take at or less than the provided time to arrive." Only 14 percent of participants chose this answer.

The most commonly selected answer (44 percent of participants) was "95 times out of 100 it will take the provided time to arrive," which may indicate that these participants misunderstood the meaning; this answer implies that the provided time is the same for every trip, rather than being the upper end of a time range. The second most frequently selected answer (32 percent of participants) was "The system is 95% confident that its provided time is correct to arrive." While the second group chose a description that's not technically correct, they still had a general understanding that the chances of arriving within the given time are high. In terms of travel behavior decisions, this level of understanding may indeed be acceptable.

Question 28: System Trust Terminology

In an attempt to determine the best wording to explain that the website system's travel time estimation is trustworthy and additional time does not need to be added to the provided trip time, Question 28 asked what statement best communicated this concept. The response options for this question were all based on a 95th percentile trip time (though for simplicity, the usual modifier specifying that the trip time could be less than the 95th percentile time was not mentioned):

- It is 95% reliable that your travel time will be 45 minutes.
- 19 out of 20 times your travel time will be 45 minutes.
- Your maximum trip time is 45 minutes.
- There is low variability to your trip time of 45 minutes.
- The worst-case travel time is 45 minutes.
- The system is very certain that your trip will take 45 minutes.

The wording of one of the options ("19 out of 20 times") was taken from a travel website, and the other wording options were developed by the research team.

Most participants either chose a statement using the phrase "Your maximum trip time is…" (selected by 38 percent) or "It is 95% reliable that your travel time will be…" (selected by 34 percent). The remaining phrases were rarely selected.

It is interesting to compare the responses for Questions 27 and 28 within a person. Table 7-17 shows this relationship and presents a contingency table for the two items. For those people who answered Question 27 correctly (Q: What does 95% mean to you? A: 95 times out of 100), only 12 percent felt that the phrase "19 out of 20" was the best wording to convey that users need not add their own buffer time, even though these two are mathematically equivalent. Those people who understood 95% mathematically, as evidenced by Question 27, preferred the phrases *95% reliable* or *maximum trip time* to convey trustworthiness.

Table 7-17. Responses to Question 28 as a function of response to Question 27.

	Question 28 Responses— Which of these statements uses wording that best explains that the provided travel time given to you is trustworthy and you do not need to add additional time?					
Answered Question 27—What does 95% time mean to you?	It is 95% reliable that your travel time will be 45 minutes.	19 out of 20 times your travel time will be 45 minutes.	Your maximum trip time is 45 minutes.	There is low variability to your trip time of 45 minutes.	The worst-case travel time is 45 minutes.	The system is very certain that your trip will take 45 minutes.
It will take 95% of the provided trip time to arrive.	42.11%	15.79%	31.58%	0	0	10.53%
95 times out of 100 it will take the provided time to arrive.	31.30%	12.21%	41.98%	1.53%	7.63%	5.34%
The system is 95% confident that it's provided time is correct to arrive.	38.14%	4.12%	36.08%	5.15%	4.12%	12.37%
95 times out of 100 it will take at or less than the provided time to arrive.	34.15%	4.88%	36.59%	4.88%	9.76%	9.76%
The time it takes you to complete 95% of the distance of your trip.	0	25.00%	25.00%	0	25.00%	25.00%
I don't know.	0.33%	0.33%	1.00%	0	0.33%	0.67%

Question 29: Travel Mode Shift Information

Currently, most travel time websites provide travel time (and sometimes reliability information) for roadway driving only; or, if a website provides estimated times for a transit or managed-lane trip, those times are located on a different page of the site, and travel time and/or reliability comparisons are not automatic. The data underlying route planners and real-time information for different modes are most often provided by different agencies. If reliability information indeed

will have any effect on mode choice as envisioned by the profession, then a comparison of modes' reliability may need to be presented to users. Before that cross-agency communication and interoperability is developed, the survey sought to assess users' likelihood of changing modes at all.

As a final question then, the survey asked participants if they would change their transportation mode if the system showed a different mode would be quicker for that day. Encouragingly, three out of four (76 percent) participants said that they would change their mode if they could.

Key Findings

Reliability and Travel Time Distribution Concept Understanding

- The large majority (90 percent) of participants had a desire for information that a planned trip had a chance of taking longer than average (Question 21). When asked to select a term to describe that additional time, only 10 percent selected *buffer time*, which is the term used by professionals in the travel time reliability field.
- Only 18 percent of participants understood *average* to mean "about half the time, 10 days out of 20"; they interpreted it to mean "most of the time, 15 days out of 20" (Question 15). While this is not necessarily an incorrect interpretation of the term, it could be incorrect if the underlying distribution of travel times is skewed, which it typically is. Designers of traveler information systems and performance measures need to be sensitive to the layperson's understanding of such terms as *average* and distinguish the technical use from the everyday use.
- Likewise, only 37 percent of participants understood *95th percentile* to mean "nearly all the time, 19 days out of 20" (Question 15). While this term was the most successful of the eight tested in conveying "19 days out of 20," the fact that it was selected by under 40 percent of the participants is troubling. Because this is such a critical and common performance metric for reliability calculations, it is important to be sensitive to this finding. As indicated by the focus groups as well, most people do not like statistical-sounding terms such as this. The term *typical* did the best job of conveying that the system-provided trip time would encompass the actual trip time most or nearly all of the time.
- When asked directly what *95% time* meant, 44 percent of participants correctly answered that it meant that 95 times out of 100, it would take the provided amount of time to make a trip. Another 32 percent thought that the 95 percent term meant the system was 95 percent confident in its prediction. These findings again speak to the need to use a more everyday term, even though it may not be technically correct. An FAQ or glossary section of a traveler information system could provide the technical definition.
- The response pattern of most participants indicated that when given a total trip time estimate by the system (that was based on typical time plus some buffer time), they would still add their own buffer time onto the system estimate (Question 18 and 19). Regardless of the term used, a majority of participants chose to leave earlier than the departure time provided by the fictional website. This is important to note because the

terms tested were proposed as surrogates for planning time, which presumably already includes a buffer time. These results indicate either a lack of understanding or a lack of trust in the departure times provided by such a system. This agrees with many of the comments made during the focus groups as well.

- When asked directly about system trust and the need to add one's own buffer time "just in case," participants were split between preferring *maximum trip time* and *95% reliable that your travel time will be xx minutes*. Again, this indicates that some portion of the population is interpreting the 95 percent phrase to refer to system confidence and accuracy, not a point on a travel time distribution (Question 28).
- If reliability information will have any effect on mode choice as envisioned by the profession, then a comparison of modes' reliability may need to be presented to users. Before that cross-agency communication and interoperability is developed, the survey sought to assess users' likelihood of changing modes at all. Encouragingly, three out of four (76 percent) participants said that they would change their mode if they could.

Website Interface Design

- Use ***future trip*** as a button label, section header, or navigation button to convey that the trip being planned is not imminent and will be based on historical, rather than real-time, travel time data. This term is particularly appropriate for home page locations to invite users to enter the trip planning section of the website. Question 7 showed that 81 percent of participants understood the term *future trip* to mean a trip later in the day or tomorrow rather than one with a more immediate departure. The results from Question 7 also indicate that *future trip* may be the best label to use on input screens for date and time to reinforce that the trip being planned is a future trip.
- For action initiation on trip planning systems, terms like ***predict trip*** and ***plan trip*** are preferred over standard action labels such as *OK* or *Go* (see Question 9 and 10 results). Terms like *predict trip* and *plan trip* could be used at the bottom of trip detail input screens.
- For trip detail input screens, users preferred the term ***arrive by*** as a prompt for entering their desired arrival time. This term could be used as the stem for a drop-down menu where a user would select a time from a list (Question 12). This term is short enough to be useful for full websites, mobile website front-ends, and smartphone applications.
- For the map showing all available routes, participants most frequently preferred the two phrases that included "available travel information" in the title. It is also interesting to note the relatively poor performance of phrases that contained "historical data."
- For output screens, the term ***best route*** was preferred as a map title or output section header. This concurred with the focus group feedback that indicated a preference for simple terms (Question 14).
- Across all versions, ***recommended departure time*** received most of the shifts in preference, meaning that 40-45 percent of people preferred this term to the one they saw in their own version of the survey (Question 20).

- In reporting the output of travel time calculations, reliability information could be conveyed through the following phrases (the word in italics was the most popular term of those tested in the survey:
  - It is *estimated* that your trip will take 45 minutes.
  - Your trip time may *vary* from the average time by 20 minutes.
  - It will take *approximately* 20 minutes to make your trip.

Throughout this survey, it was repeatedly apparent that there is a disconnect between the technical terms used by professionals and the layperson's understanding of and preference for these terms. This finding was evident in the focus group comments as well. The lexicon and guidebook that are part of the L14 project will hopefully bridge this gap and make it easier for professionals to communicate these concepts to transportation system users.

Chapter 8 OPEN-ENDED SURVEY

The objective of the open-ended survey was to determine whether the presentations of both an indicator of the normal trip time and an indicator of reliability (buffer time or total trip time estimate) were correctly interpreted by drivers. Conceptually, the total of a driver's average or normal travel time plus the buffer time a driver adds for contingencies (uncertainty of conditions) is the driver's estimated trip time for planning purposes:

Normal trip time + buffer time = total trip time estimate

TTI researchers developed the open-ended, paper-based survey to determine which combinations of terms representing a normal trip time, a buffer time, and/or the ultimate trip time to plan for would be best for conveying trip time reliability information.

RESEARCH METHOD

Survey Design

The following potential terms were tested for comprehension and preference for conveying the normal travel time at a particular time of day:

- Average travel time.
- Estimated travel time.
- Expected travel time.
- Typical travel time.

Terms tested to represent the buffer time for a given trip (as per the equation above) included the following:

- Added time.
- Cushion time.
- Extra time.
- Recommended cushion time.

Finally, the terms tested to represent the total trip time that drivers should plan for to protect themselves against being late (i.e., "total trip time estimate" in the above equation) were the following:

- 95th percentile travel time.
- The majority of the time the travel time is xx minutes or less.
- Most of the time the travel time is xx minutes or less.
- Travel time for planning.

These terms were based on focus group results, terms being evaluated in the usability studies, and the expertise and experience of the TTI research team. Some terms initially considered in the focus groups and usability surveys were not evaluated here in order to keep this part of the

study short enough to mesh with the current surveys and experiments already in progress at the time. Terms *worst-case* or *maximum* were not tested here, as agency concerns regarding liability and credibility would likely preclude them from using such absolute terms. Similarly, the term *most common* could be perceived by motorists in a way that would reduce agency credibility and so was not evaluated in this portion of the surveys. Negative feedback from focus groups was used to remove the terms *buffer* and *leeway* from analysis. The term *departure window* was considered to be adequately examined in the existing usability study. The term *added travel time* was not included in the initial survey and was not offered by focus group participants; however, it is believed that one reason that it was not suggested was because a version of the term was used by facilitators to explain the concept, and so it was evaluated here.

These terms were presented to participants in the context of two scenario-based, multipart questions. Scenario 1 presented participants with a term for the normal trip time and a term for the buffer time (as defined in the above equation). Scenario 2 presented participants with a term for the normal trip time and a term for the total trip time estimate. Because of the large number of terms to be tested in these scenarios, it was not practical to test every term in every combination with every participant, so a total of 16 versions of the survey were created, as shown in Table 8-1. Participants were divided across the 16 survey versions, with 11 to 12 participants taking each version.

Table 8-1. Experimental design for open-ended survey.

Survey Version	Scenario 1 Terms		Scenario 2 Terms		Number of Participants
	Normal Trip Time	Buffer Time	Normal Trip Time	Total Trip Time Estimate	
A	Average	Cushion	Expected	95th percentile	12
B	Average	Extra	Typical	Trip time for planning	11
C	Average	Added	Estimated	Most of the time	12
D	Expected	Recommended cushion	Average	Majority of the time	12
E	Expected	Cushion	Average	95th percentile	12
F	Expected	Extra	Typical	Most of the time	12
G	Expected	Added	Estimated	Trip time for planning	12
H	Typical	Recommended cushion	Expected	Majority of the time	12
I	Typical	Cushion	Average	Trip time for planning	12
J	Typical	Extra	Expected	95th percentile	12
K	Typical	Added	Estimated	Most of the time	12
L	Estimated	Recommended cushion	Typical	Majority of the time	12
M	Estimated	Cushion	Average	Most of the time	12
N	Estimated	Extra	Expected	Trip time for planning	12
O	Estimated	Added	Typical	95th percentile	11
P	Average	Recommended cushion	Estimated	Majority of the time	11

Participants

A total of 189 participants completed open-ended surveys in the three cities. Table 8-2 lists the number of open-ended survey participants in each city. Detailed demographic information on the participants was not recorded for this survey but was believed to be representative of the driving populations in each location.

Table 8-2. Number of open-ended survey participants per city.

City	Participated in Computer-Based Survey	Participated in Travel Behavior Experiment	Total Participants per City
Dallas	31	14	45
Denver	0	0	0
Miami	0	0	0
San Jose	54	20	74
Hartford	53	17	70
Totals	138	50	189

Procedure

The open-ended survey was administered to participants who had completed either the computer survey or travel behavior laboratory experiment. A researcher administered the open-ended survey by both reading the questions to the participant and recording the participant's answers. The individual interviews took place in a separate room away from the computer testing and took 15-20 minutes to complete.

For some of the questions, cards describing the travel scenario were placed in front of the participants to lessen their working memory load. The interviewer read aloud the text on the card, and the participant was allowed to re-read the text if desired and examine the questions and answer alternatives while discussing the item. The survey materials from version A are presented in Appendix E.

The survey participant was presented with two hypothetical scenarios. Each scenario placed the participants in a hotel in the morning, and their destination was to a meeting in a downtown office building. They were able to get travel time information from a hotel website before they left the hotel for the meeting.

Scenario 1 read as follows, where the blanks were replaced with one of the four terms being evaluated to convey the normal trip time and one of the four terms representing the buffer time.

> *Imagine that you are in a hotel in an unfamiliar city and have an important business meeting first thing this morning at a downtown office building. You will need to leave the hotel during the peak period in order to arrive at the business meeting. You are trying to decide how much travel time to allow for your drive to downtown. You cannot be late to the meeting, but you do not want to arrive too early. You know that you can park right next to the building and do not need to allow additional time to search for parking. You also know that you can get current travel time information from the hotel website. Before you drive to your downtown meeting, you check the website and obtain the following information…*
>
> ***The _____ travel time to downtown is 40 minutes***
>
> ***and***
>
> ***the _____ time to downtown is 30 minutes.***

As shown below, scenario 2 was presented in an identical format, but with the normal travel time to downtown set at 30 minutes instead of 40 minutes and a total trip time estimate (representing the sum of the normal time and a buffer time) set at 55 minutes. Again, the blanks were replaced with one of the four terms being evaluated to convey the normal trip time and one of the four terms representing the total trip time estimate. As noted in Table 8-1, for each survey version, different terms were used to represent the normal trip time in scenario 1 and scenario 2.

> *Imagine that you are again in a hotel in another unfamiliar city and have an important business meeting this morning at a downtown office building. As before, you will need to leave the hotel during the peak period in order to arrive at the business meeting. You are*

trying to decide how much travel time to allow for your drive to downtown. You cannot be late to the meeting, but you do not want to arrive too early. You know that you can park right next to the building and do not need to allow additional time to search for parking. You also know that you can get current travel time information from the hotel website. Before you drive to your downtown meeting, you check the website and obtain the following information …

The _____ travel time to downtown is 30 minutes

and

_____ travel time to downtown is 55 minutes [or less].

After each scenario was provided to a participant (with the blanks replaced with the appropriate terms), the participant was asked the following questions:

- How much time would you allow for your drive to downtown?
- How did you decide on that time?
- What does the (*average, estimated, expected,* or *typical*) travel time mean to you about how long your drive will take?
- For scenario 1: What does the (*added, cushion, extra,* or *recommended cushion*) time mean to you about how long your drive will take?
- For scenario 2: What does the (*95th percentile time, majority of the time, most of the time, or travel time for planning time*) mean to you about how long your drive will take?
- How likely are you to reach downtown in (*70 for scenario 1; 55 for scenario 2*) minutes or less?
- For scenario 1: If the (*added, cushion, extra,* or *recommended cushion*) time had been 10 minutes, how much time would you have allowed for your drive, and why? (Note: The response implying the desired use of that term would be 50 minutes.)
- For scenario 2: If the (*95th percentile time, majority of the time, most of the time, or travel time for planning time*) had been 45 minutes, how much time would you have allowed for your drive, and why? (Note: The response implying the desired use of that term would be 45 minutes.)

At the end of each scenario, the participant was shown the remaining possible terms being tested to convey uncertainty and asked to indicate whether each one meant the same thing as the term he or she had originally seen in the website message. If not, the participant had to explain why the term was different. Finally, the participant was asked which term he or she preferred to convey travel time uncertainty information.

After the participant had answered questions concerning both scenarios, the participant was asked whether he or she preferred the travel time uncertainty information in the first scenario (buffer time) or the second scenario (total trip time estimate).

RESULTS

The following sections discuss the use of the buffer time terms and total trip time estimate terms by participants when determining the total trip time they would allow for the scenario provided in the website messages. To evaluate effectiveness, researchers examined the distribution of participant-selected trip times relative to the total trip time intended by the message. For this evaluation, the greater the percentage of participants selecting travel times within the 10- to 15-minute range around that total trip time value, the more effective the message was deemed. This rationale was based on the fact that trip times selected much below the total trip time result in motorists being late more frequently than desired, and trip times selected much higher than the total trip time result in excessively early arrival time for the majority of trips made.

Use of Buffer Time in Total Trip Time Estimation

The responses to the questions regarding how much time the participants would allow for their trip were initially analyzed by each normal trip time/buffer term pair to determine whether the normal trip time terms impacted the use of the buffer term. Researchers did not identify any clear trends that indicated the normal trip time term affected the use of the buffer term, so the data for each buffer term were aggregated across the normal trip time terms for further analysis.

Researchers explored how the type of buffer term used may influence the extent to which motorists may or may not incorporate the amount of buffer time presented in a message into their travel plans. At the simplest level of analysis, four possible ways were envisioned in which motorists would use the times presented in scenario 1 (the normal trip time and the buffer value) to estimate the time they would allow for their trip:

- Participants could ignore the buffer value and base their trip time strictly on the normal trip time value provided.
- Participants could ignore the normal trip time value and base their trip time strictly on the buffer time value provided (implying that there was confusion as to the intent of the buffer term).
- Participants could combine the normal trip time and the buffer time values together to come up with the trip time they would allow (the intended use of the buffer time value).
- Participants could add some time other than the buffer time value to the normal trip time in order to come up with the trip time they would allow for (the amount of other time added may or may not be influenced by the buffer term used to convey that value).

The percentage of participants who selected trip times they would allow for in each of these categories is presented in Table 8-3. Overall, very few participants indicated they would allow only for the normal trip time. Whether this was the result of being provided a buffer time or was simply the normal trip planning behavior of the participants is unknown. In addition, very few participants stated they would only allow for the buffer time provided in the website message, indicating that only a small percentage of participants were confused by the intent of the buffer term. Comparing across the four buffer terms, *recommended cushion time* resulted in the greatest percentage of participants who added the buffer time to the normal trip time (28 percent), followed closely by *added time* (23 percent). When the term *cushion time* was

used, only 8 percent of the participants added the normal trip time and buffer time to determine the amount of time they should allow for the trip. Still, the majority of participants added some other value to the normal trip time when choosing the trip time they would allow for in scenario 1.

Table 8-3. Participant use of buffer term when planning for a trip.

Participant Use of Buffer Term	Percent of Participants				
	Buffer Term Viewed				Average
	Added (n = 47)	Cushion (n = 48)	Extra (n = 47)	Recommended Cushion (n = 47)	
Used normal trip time only	4	17	4	6	**8**
Used buffer term only	2	4	2	6	**4**
Added normal trip time and buffer time values together	23	8	15	28	**19**
Added normal trip time and some other value together	66	67	66	55	**63**
Total	**95**[a]	**96**[b]	**87**[c]	**95**[d]	**94**[e]

[a]Does not add up to 100 percent since researchers categorized 5 percent of the responses as "other."
[b]Does not add up to 100 percent since researchers categorized 4 percent of the responses as "other."
[c]Does not add up to 100 percent since researchers categorized 13 percent of the responses as "other."
[d]Does not add up to 100 percent since researchers categorized 5 percent of the responses as "other."
[e]Does not add up to 100 percent since researchers categorized 6 percent of the responses as "other."

Additional insights into the trip times that participants indicated they would allow for (as a function of the trip time uncertainty term) are presented in Table 8-4. As would be expected, the percentages for the "35-44 min" and "25-34 min" groups are similar to those of the "used normal trip time only" and "used buffer term only" rows in

Table 8-3, respectively. In addition, those in the "65-74 min" column correlate with the "added normal trip time and buffer time value together" column in

Table 8-3. The distribution of trip times that would be allowed shows some small differences by type of trip time uncertainty term used.

Table 8-4. Distribution of trip times that would be allowed for 70-minute trip.

Trip Times Allowed for	Percent of Participants				
	Buffer Term Viewed				Average
	Added (n = 47)	Cushion (n = 48)	Extra (n = 47)	Recommended Cushion (n = 47)	
< 25 min		2	4		**2**
25-34 min	4	6	6	8	**6**
35-44 min	6	17	6	8	**9**
45-54 min	6	32	11	11	**15**
55-64 min	28	27	24	30	**27**
65-74 min	24	8	19	28	**20**
75-84 min	11	8	15	13	**12**
≥ 85 min	21		15	2	**9**
Total	**100**	**100**	**100**	**100**	**100**

Note. Normal trip time = 40 minutes, buffer time provided = 30 minutes.

This is also illustrated in Figure 8-1, which shows the cumulative distribution of trip times that would be allowed by participants as a function of the buffer time used. Based on these data, 70 percent of the participants who saw the term *recommended cushion* chose a trip time that was within 15 minutes of the total trip time provided in the website message. Thus, it would appear that the term *recommended cushion time* has the greatest ability to encourage the selection of a trip time that would most closely align with the amount of trip time uncertainty that the operating agency would be attempting to convey. When the terms *added time* and *extra time* were shown, a greater percentage of participants choose travel times that exceeded the 70-minute intended value. This suggests a potentially lower level of confidence implied by these two terms and led to participant decisions to allow more buffer time than was presented in the message. Participants also did not have as much confidence in the term *cushion time*, but instead of allowing more time than presented, they chose to use a value less than the sum of the normal trip time and buffer time in deciding on the amount of time to allow. This suggests that the term *cushion time* may convey more of a sense of excessive uncertainty in the trip time than is desired.

The same trends regarding the confidence participants expressed in use of the trip time uncertainty terms are evident in Table 8-5, which shows participant responses to the question "How likely are you to arrive at your destination in 70 minutes or less?" Overall, 85 percent of the participants viewing the *recommended cushion time* term responded "absolutely (100 percent chance)" or "very likely (95 percent chance)." For the *added time*, *extra time*, and *cushion time* terms, the percent of participants selecting those two categories corresponded to 74 percent, 70 percent, and 69 percent, respectively.

(Normal Trip Time = 40 minutes, Buffer Time Provided = 30 minutes)

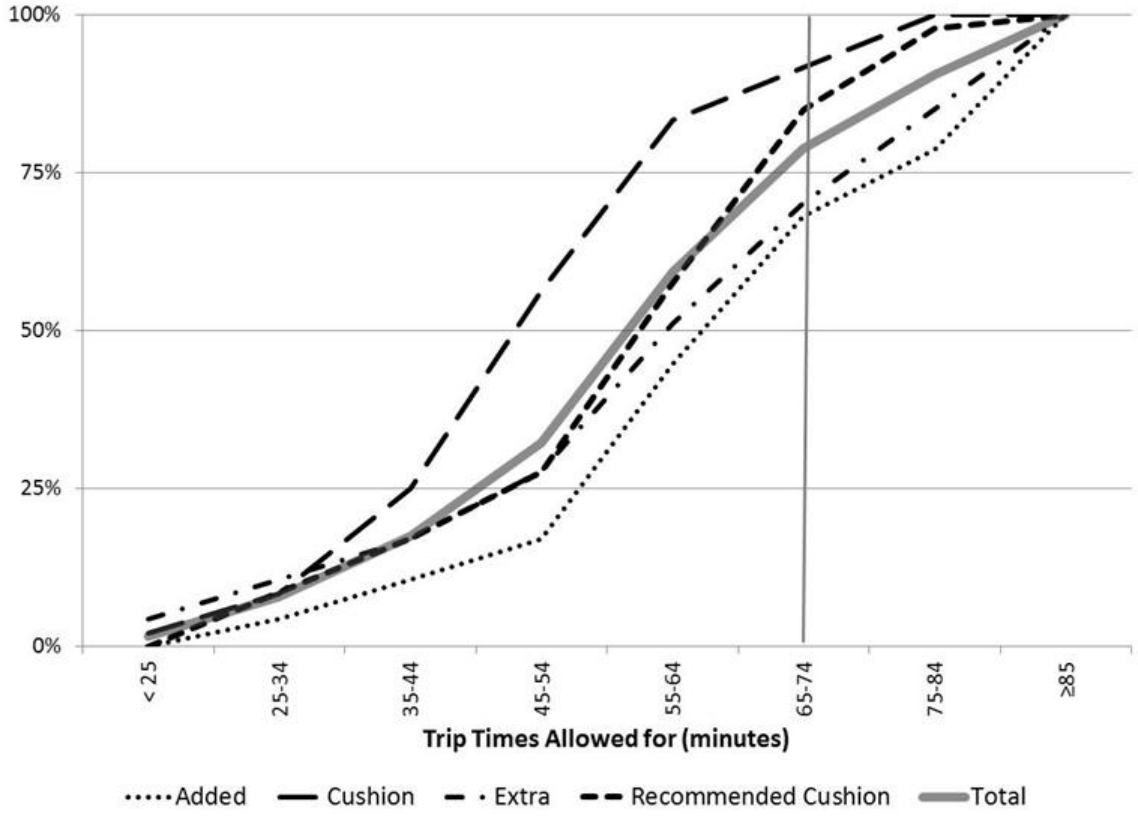


Figure 8-1. Cumulative distribution of trip times that would be allowed for 70-minute trip.

Table 8-5. Participant confidence in arriving at destination in 70 minutes or less.

Participant Confidence	Percent of Participants				
	Buffer Term Viewed				Average
	Added (n = 47)	Cushion (n = 48)	Extra (n = 47)	Recommended Cushion (n = 47)	
Absolutely certain (100% chance)	21	17	15	23	**19**
Very likely (95% chance)	53	52	55	62	**56**
Probably (75% chance)	19	21	26	11	**19**
Unsure (50/50 chance)	7	8	4	2	**5**
Doubtful (Less than 50/50 chance)	0	2	0	2	**1**
Total	**100**	**100**	**100**	**100**	**100**

Note. Normal trip time = 40 minutes, buffer time provided = 30 minutes.

The next question asked of participants for this scenario was what their choice of trip time allowed if the normal trip time remained at 40 minutes but the trip time uncertainty value was only 10 minutes. The responses to that question are summarized in Table 8-6 and shown in Figure 8-2. In this situation, it is apparent that very small trip buffer values are unlikely to be given a high degree of confidence, regardless of the term used. Whereas the term *recommended cushion time* once again showed the greatest percentage of participants selecting the sum of the normal and uncertainty trip time values (i.e., 50 minutes), a large portion of participants chose trip times longer than this amount. Furthermore, there did not appear to be a significant difference in responses as a function of trip time uncertainty term used. This implies that it may be difficult for drivers to accept and trust a route-specific buffer value that is less than their own generic buffer that has been developed through years of driving experiences and other influences.

Table 8-6. Distribution of trip times that would be allowed for 50-minute trip.

Trip Times Allowed for	Percent of Participants				
	Buffer Term Viewed				Average
	Added (n = 47)	Cushion (n = 48)	Extra (n = 47)	Recommended Cushion (n = 47)	
< 25 min	2	6	9	9	6
25-34 min	2	4	0	2	2
35-44 min	0	10	2	6	5
45-54 min	38	35	38	45	39
55-64 min	45	33	43	30	38
65-74 min	9	6	4	4	6
75-84 min	2	2	2	4	3
Total	**98**[a]	**96**[b]	**98**[c]	**100**	**99**[d]

Note. Normal trip time = 40 minutes, buffer time provided = 10 minutes.
[a]Does not add up to 100 percent since 2 percent of the participants did not provide an answer.
[b]Does not add up to 100 percent since 4 percent of the participants did not provide an answer.
[c]Does not add up to 100 percent since 2 percent of the participants did not provide an answer.
[d]Does not add up to 100 percent since 1 percent of the participants did not provide an answer.

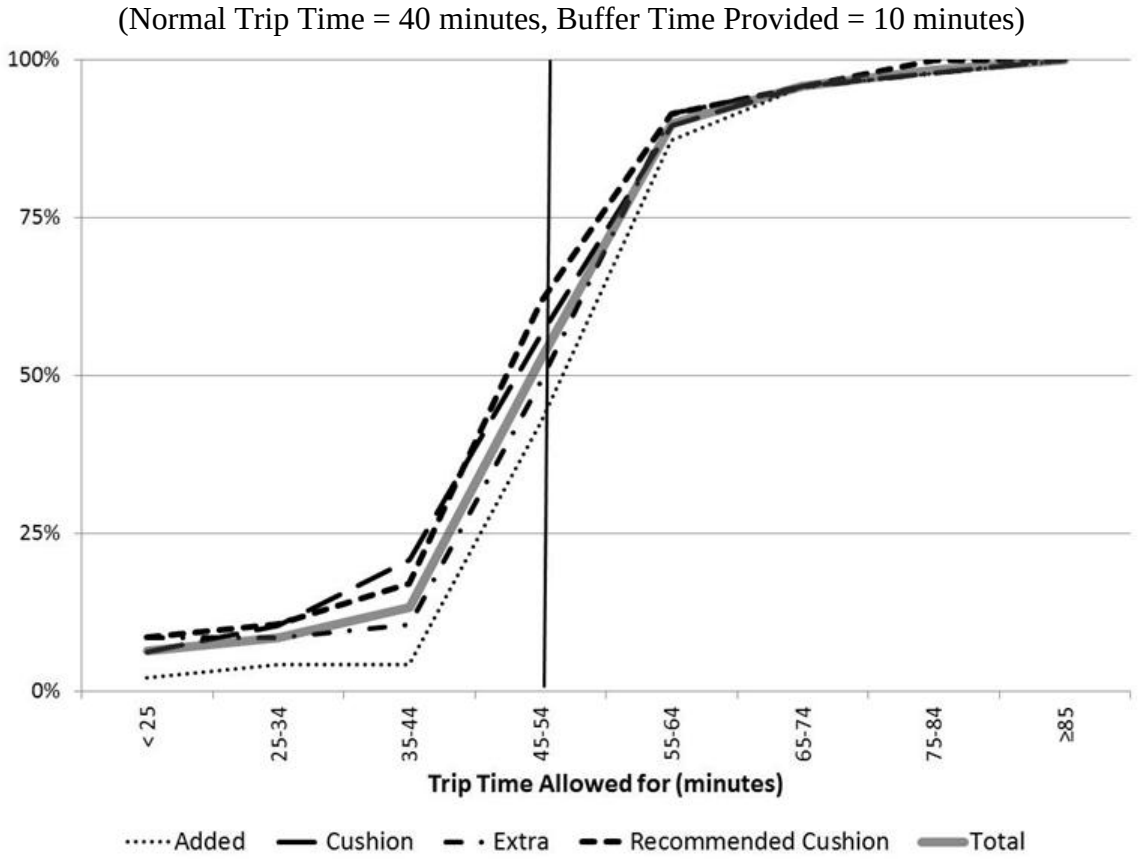


Figure 8-2. Cumulative distribution of trip times that would be allowed for 50-minute trip.

Similar Meanings and Preference of Buffer Terms

Another portion of the survey addressed whether participants thought the buffer term provided in the scenario 1 website message meant the same thing as the remaining buffer terms (those not originally viewed by the participant). The percentage of participants who indicated that various terms implied the same meaning is provided in Table 8-7. Overall, two clear trends existed as to whether participants viewed certain terms as similar. Those participants who saw either the *added time* or *extra time* terms rated the other as having a similar meaning. Likewise, those who saw either *cushion time* or *recommended cushion time* viewed the other as having the same meaning. As discussed previously, *added time* and *extra time* terms resulted in similar trends in Figure 8-2, so it is not surprising that these two terms were viewed to have similar meanings. However, the trip times allowed by participants shown in Table 8-7 were not similar between the *cushion time* and *recommended cushion time* terms.

The percentage of participants who preferred each of the terms tested is shown in Table 8-8. Overall, the results did not indicate a clear preference for any of the terms since no single term was preferred by more than one-third of the participants, on average. However, the preference data did reflect the pairs of terms that were viewed to have similar meanings: *cushion time* and *recommended cushion time* were preferred over *added time* or *extra time.*

Table 8-7. Participant's assessment of similar meanings of buffer terms.

Terms Compared	Percent of Participants				
	Buffer Term Viewed				Average
	Added (n = 47)	Cushion (n = 48)	Extra (n = 47)	Recommended Cushion (n = 47)	
Added means the same as **Cushion**	43	50	n/a	n/a	**46**
Added means the same as **Extra**	81	n/a	66	n/a	**73**
Added means the same as **Recommended Cushion**	43	n/a	n/a	43	**43**
Cushion means the same as **Extra**	n/a	50	40	n/a	**45**
Cushion means the same as **Recommended Cushion**	n/a	73	n/a	72	**73**
Extra means the same as **Recommended Cushion**	n/a	n/a	36	49	**43**

Note. Shaded cells not evaluated.

Table 8-8. Participants' preference for buffer terms.

Preferred Term	Percent of Participants				
	Buffer Term Viewed				Average
	Added (n = 47)	Cushion (n = 48)	Extra (n = 47)	Recommended Cushion (n = 47)	
Added	17	17	15	15	**16**
Extra	15	10	13	32	**17**
Cushion	34	25	45	30	**33**
Recommended Cushion	32	48	26	23	**32**
Added or Extra	2	0	0	0	**1**
None	0	0	3	0	**1**
Total	**100**	**100**	**100**	**100**	**100**

Use of Total Trip Time Estimate

Again, the responses to the questions regarding how much time the participants would allow for their trip were initially analyzed by each normal trip time/total trip time estimate term pair to determine whether the normal trip time terms impacted the use of the total trip time estimate term. Researchers did not identify any clear trends that indicated the normal trip time term affected the use of the total trip time estimate term, so the data for each total trip time estimate term were aggregated across the normal trip time terms for further analysis.

The next analysis explored how the total trip time estimate terms influence the extent to which motorists may or may not use a total trip time to plan for in their travel plans. At the simplest level of analysis, four possible ways were envisioned in which motorists would use the times presented in scenario 2 (the normal trip time and the total trip time value) to estimate the time they would allow for their trip:

- Participants could ignore the total trip time estimate and base their trip time strictly on the normal trip time value provided.
- Participants could ignore the normal trip time value provided and base their trip time strictly on the total trip time estimate provided (the intended use).
- Participants could combine the normal trip time and the total trip time estimate together to come up with the trip time they would allow for (the intended use of the buffer time term).
- Participants could add some other time (their own buffer) to the normal trip time or the total trip time estimate to come up with the trip time they would allow for (the amount of other time added may or may not be influenced by the total trip time estimate).

The percentage of participants who selected trip times they would allow for in each of these categories is presented in Table 8-9. Overall, very few participants indicated they would allow only for the normal trip time provided in the website message. In addition, very few participants combined the values for the two terms provided. Comparing the four total trip time estimate terms, the *majority of the time* term resulted in the greatest percentage of participants who based their trip time strictly on the total trip time estimate provided. Still, on average, 37 percent of the participants added some other value to the total trip time estimate to come up with the trip time they would allow for in scenario 2.

Additional insights into the trip times that participants indicated they would allow for (as a function of the trip time uncertainty term) are presented in Table 8-10. The majority of the trip time values were in the "45-54 min" and "55-64 min" groups, which were within 10 minutes of the total trip time estimate value (55 minutes). These times are a product of those participants that used the total trip time estimate, the total trip time estimate plus some other small time, or the normal trip time plus some other larger time.

The distribution of trip times that would be allowed shows some small differences by type of total trip time estimate term used. This is also shown in Figure 8-3. Based on these data, it would appear that the term *majority of the time* resulted in the largest percentage of participants (79 percent) choosing times within 10 minutes of the total trip time estimate (55 minutes)

conveyed in the website message for scenario 2. When the terms *most of the time* and *95th percentile* were shown, a greater percentage of participants chose travel times that exceeded the total trip time estimate presented in the message (23 and 35 percent, respectively). This suggests a potentially lower level of confidence implied by these two terms and led to decisions to allow more time than was presented in the message. Conversely, many participants that viewed the term *travel time for planning* chose to use a value less than total trip time estimate in deciding on the amount of time to allow. This suggests that the term *travel time for planning* may convey more of a sense of a maximum trip time.

Table 8-9. Participant use of total trip time estimate term when planning for a trip.

Participant Use of Total Trip Time Estimate	Percent of Participants				
	Total Trip Time Estimate Viewed				Average
	95th Percentile (n= 46)	Majority of the Time (n = 48)	Most of the Time (n = 48)	Travel Time for Planning (n = 47)	
Used normal trip time only	4	4	0	4	**3**
Used total trip time estimate only	24	37	25	31	**29**
Added normal trip time and total trip time estimate values together	7	0	0	2	**2**
Added normal trip time and some other value together	13	15	29	40	**24**
Added total trip time estimate and some other value together	50	40	38	19	**37**
Total	**98[a]**	**96[b]**	**92[c]**	**96[d]**	**95[e]**

[a]Does not add up to 100 percent since researchers categorized 2 percent of the responses as "other."
[b]Does not add up to 100 percent since researchers categorized 4 percent of the responses as "other.
[c]Does not add up to 100 percent since researchers categorized 8 percent of the responses as "other."
[d]Does not add up to 100 percent since researchers categorized 4 percent of the responses as "other."
[e]Does not add up to 100 percent since researchers categorized 5 percent of the responses as "other."

Table 8-10. Distribution of trip times that would be allowed for 55-minute trip.

Trip Times Allowed for	Percent of Participants				
	Total Trip Time Estimate Viewed				Average
	95th Percentile (n = 46)	Majority of the Time (n = 48)	Most of the Time (n=48)	Travel Time for Planning (n = 47)	
< 25 min	2	0	0	0	**1**
25-34 min	4	4	4	8	**5**
35-44 min	7	2	4	11	**6**
45-54 min	7	11	25	23	**16**
55-64 min	45	68	44	50	**52**
65-74 min	11	2	7	4	**6**
75-84 min	11	9	8	2	**7**
≥ 85 min	13	4	8	2	**7**
Total	**100**	**100**	**100**	**100**	**100**

Note. Normal trip time = 30 minutes, total trip time estimate provided = 55 minutes.

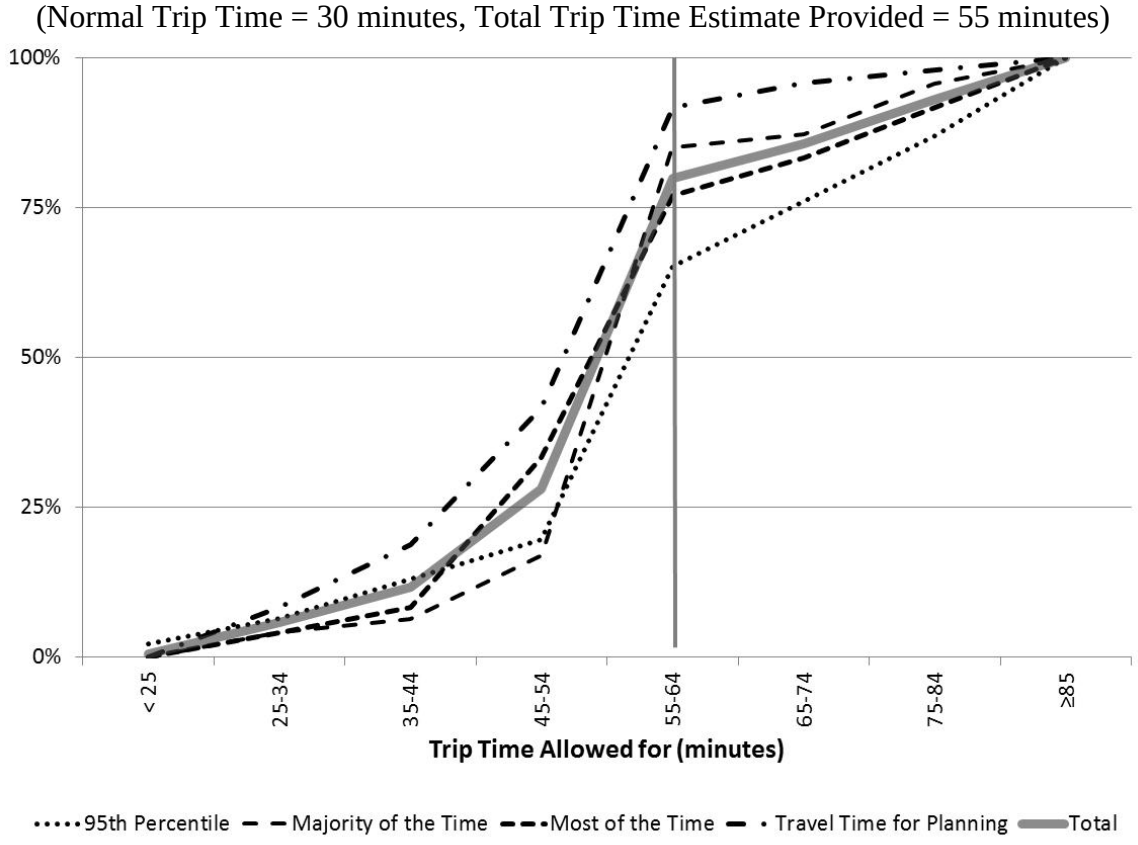


Figure 8-3. Cumulative distribution of trip times that would be allowed for 55-minute trip.

Table 8-11 shows the participants' confidence in how likely they were to arrive at the destination in 55 minutes or less for the trip time uncertainty terms used in scenario 2. Strangely, the term *most of the time* resulted in the largest percentage of participants (75 percent) selecting "absolutely (100 percent chance)" or "very likely (95 percent chance)." This was unexpected since 23 percent of the participants chose a travel time that exceeded the total trip time. For the *travel time for planning* term, the percent of participants selecting those two categories was 73 percent. This was expected since 92 percent of the participants chose a travel time that was less than the total trip time estimate. For both the *majority of the time* and *95th percentile* terms, the percent of participants selecting those two categories corresponded to only 62 percent and 54 percent, respectively.

The final question asked of participants for this scenario was what their choice of trip time allowed if the normal trip time remained at 30 minutes but the total trip time estimate was 45 minutes (10 minutes less than in the original scenario 2). The responses to that question are summarized in Table 8-12 and shown in Figure 8-4. The majority of the trip time values were in the "45-54 min" and "35-44 min" groups, which was again within 10 minutes of the total trip time estimate value (45 minutes). This shows that most of the participants did shift the trip time they would allow for to match the total trip time estimate presented. However, for all of the trip time uncertainty terms used, there was a larger percentage of participants who chose a trip time longer than the total trip time estimate, showing less confidence in the smaller total trip time estimate value. This again implies that it may be difficult for drivers to accept and trust a total trip time estimate that is closer to the normal trip time.

Table 8-11. Participant confidence in arriving at destination in 55 minutes or less.

	Percent of Participants				
	Total Trip Time Estimate Viewed				
Participant Confidence	95th Percentile (n = 46)	Majority of the Time (n = 48)	Most of the Time (n = 48)	Travel Time for Planning (n = 47)	Average
Absolutely certain (100% chance)	2	9	21	13	**11**
Very likely (95% chance)	54	53	54	60	**56**
Probably (75% chance)	20	27	17	15	**20**
Unsure (50/50 chance)	17	9	8	10	**11**
Doubtful (Less than 50/50 chance)	7	2	0	2	**2**
Total	**100**	**100**	**100**	**100**	**100**

Note. Normal trip time = 30 minutes, total trip time estimate provided = 55 minutes.

Table 8-12. Distribution of trip times that would be allowed for 45-minute trip.

Trip Times Allowed for	Percent of Participants				
	Total Trip Time Estimate Viewed				Average
	95th Percentile (n = 46)	Majority of the Time (n = 48)	Most of the Time (n = 48)	Travel Time for Planning (n = 47)	
< 25 min	4	0	2	2	**2**
25-34 mins	4	4	2	4	**4**
35-44 min	0	11	15	17	**11**
45-54 min	48	49	44	50	**48**
55-64 min	26	28	27	25	**26**
65-74 min	3	2	2	0	**1**
75-84 min	13	4	4	2	**6**
≥ 85 min	2	2	4	0	**2**
Total	**100**	**100**	**100**	**100**	**100**

Note. Normal trip time = 30 minutes, total trip time estimate provided = 45 minutes.

(Normal Trip Time = 30 minutes, Total Trip Time Estimate Provided = 45 minutes)

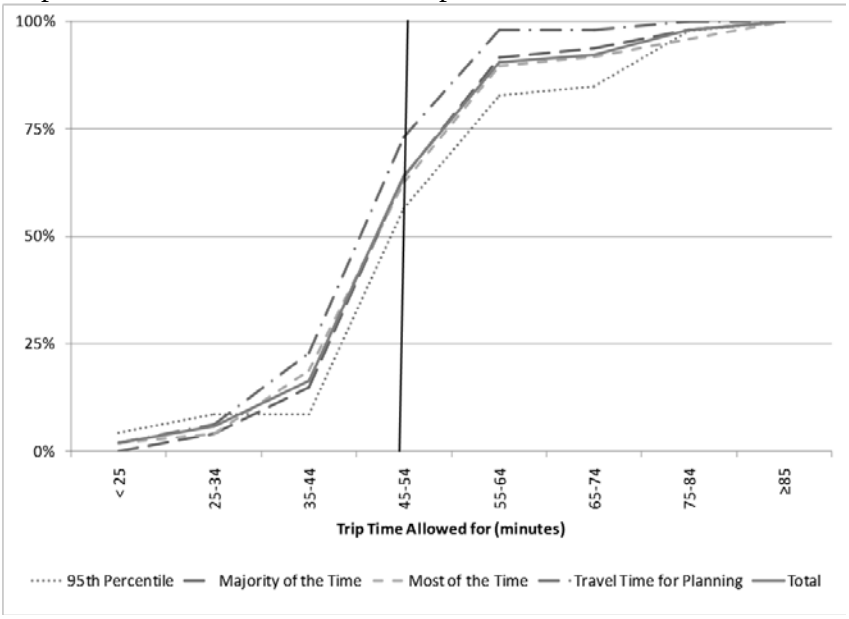


Figure 8-4. Cumulative distribution of trip times that would be allowed for 45-minute trip.

Similar Meanings and Preference of Total Trip Time Estimate Terms

Next, researchers asked whether participants thought the total trip time estimate term provided in the scenario 2 website message meant the same thing as the remaining total trip time estimate terms. The percentage of participants who indicated that various terms implied the same

meaning is provided in Table 8-13. Overall, one clear trend existed as to whether participants viewed certain terms as similar. Those participants who saw either the *majority of the time* or *most of the time* terms rated the other as having a similar meaning. This was not surprising considering the similar trends for these two terms shown in Figure 8-1. No other term combinations were viewed as being similar by most participants.

The percentage of participants who preferred each of the terms tested is shown in Table 8-14. These findings revealed that there was no clear consensus as to the most preferred total trip time estimate term. However, the preference data did reflect that the *majority of the time* and *most of the time* terms were similarly preferred.

Table 8-13. Participants' assessment of similar meanings of total trip time estimate terms.

Terms Compared	Percent of Participants				
	Total Trip Time Estimate Viewed				Average
	95th Percentile (n = 46)	Majority of the Time (n = 48)	Most of the Time (n = 48)	Travel Time for Planning (n = 47)	
95th Percentile means the same as **Majority of the Time**	68	45	na	na	**56**
95th Percentile means the same as **Most of the Time**	49	na	54	na	**52**
95th Percentile means the same as **Travel Time for Planning**	13	na	na	32	**22**
Majority of the Time means the same as **Most of the Time**	na	91	79	na	**85**
Majority of the Time means the same as **Travel Time for Planning**	na	26	na	47	**36**
Most of the Time means the same as **Travel Time for Planning**	na	na	29	64	**46**

Note. Shaded cells not evaluated.

Table 8-14. Participants' preference for total trip time estimate terms.

Preferred Term	Percent of Participants				
	Total Trip Time Estimate Viewed				Average
	95th Percentile (n = 46)	Majority of the Time (n = 48)	Most of the Time (n = 48)	Travel Time for Planning (n = 47)	
95th Percentile	21	15	10	13	**15**
Majority of the Time	34	30	63	30	**39**
Most of the Time	26	38	17	47	**32**
Travel Time for Planning	15	17	10	8	**12**
95th Percentile or Majority of the Time	2	0	0	0	**1**
None	2	0	0	2	**1**
Total	**100**	**100**	**100**	**100**	**100**

Preference of Travel Time Uncertainty Terms

Participants were also asked whether they preferred the travel time uncertainty information in the first scenario (buffer time) or the second scenario (total trip time estimate). Overall, 60 percent of the participants preferred to be provided the normal travel time and the total trip time estimate (scenario 2). Of these participants, about half preferred the total trip estimate term because the total number was provided (i.e., they did not have to add multiple values). Another 20 percent thought the total value would be more accurate or exact than the two pieces of information that had to be added together.

Similar Meanings and Preference of Normal Trip Time Terms

Researchers also asked whether participants thought the normal trip time term provided in the scenario 2 website message meant the same thing as the remaining normal trip time terms. As shown in Table 8-15, on average, 76 percent of the participants viewed the *estimated* and *expected* terms as having a similar meaning. Likewise, participants viewed *average* to have a similar meaning as *typical* (70 percent). No other clear trends existed as to whether participants believed that the various normal travel time terms had similar meanings.

The results of the participants' preferences for the normal travel time terms are summarized in Table 8-16. These findings revealed that there was no clear consensus as to the most preferred normal travel time term.

Table 8-15. Participants' assessment of similar meanings of normal travel time terms.

Terms Compared	Percent of Participants				
	Normal Travel Time Term Viewed				Average
	Average (n = 48)	Estimated (n = 47)	Expected (n = 48)	Typical (n = 46)	
Average means the same as **Estimated**	63	66	na		**64**
Average means the same as **Expected**	42	na	48	na	**45**
Average means the same as **Typical**	71	na	na	70	**70**
Estimated means the same as **Expected**	na	68	83	na	**76**
Estimated means the same as **Typical**	na	40	na	37	**39**
Expected means the same as **Typical**	na	na	52	43	**49**

Table 8-16. Participants' preference for normal travel time terms.

Preferred Term	Percent of Participants				
	Normal Travel Time Term Viewed				Average
	Average (n = 48)	Estimated (n = 47)	Expected (n = 48)	Typical (n = 46)	
Average	13	30	13	24	**20**
Estimated	58	21	52	33	**41**
Expected	16	40	25	39	**30**
Typical	13	9	10	4	**9**
Total	**100**	**100**	**100**	**100**	**100**

CONCLUSIONS

Buffer Time Terms

- Approximately 20 percent of participants added the normal travel time and buffer time to determine the amount of time they should allow for the trip. The particular buffer time term used may have had a small influence on this value. The *recommend cushion time* term resulted in the greatest percentage of participants who added the buffer time to the normal trip time, while the *cushion time* term resulted in the least.
- Participants who saw *recommended cushion time* were more likely to select a total trip time that was clustered closely around the 70-minute total trip time implied by the

website message. This term also produced the highest confidence among participants that they would arrive at their destination in 70 minutes or less. Even though *recommended cushion time* and *cushion time* were viewed to have a similar meaning, participants who saw *cushion time* were more likely to choose a trip time less than 70 minutes, implying that participants had less trust in this term.

- Participants viewed the terms *added time* and *extra time* as having a similar meaning. In addition, those who saw *added time* or *extra time* were more likely to choose a trip time that exceeded 70 minutes, suggesting that they had somewhat less confidence in these terms and so added even more time to ensure on-time arrival; or perhaps suggesting that they did not fully understand the intent/purpose of these time values.
- Results did not indicate a clear preference for any of the buffer terms. The terms *recommended cushion time* and *cushion time* were selected most frequently, but only by about one-third of the participants for each.
- When the buffer time was reduced to 10 minutes (from 30 minutes), participants did not reduce their total trip time estimate by that same amount. Such a result suggests that the participants did not totally trust the buffer time values, regardless of the term used. It may be difficult to get drivers to accept a trip uncertainty value that is less than the general uncertainty values they have learned through their own experiences when making trip time decisions.

Total Trip Time Estimate Terms

- Results of the survey indicated that approximately 30 percent of participants used a total trip time measure for determining the amount of time they should allow for a particular trip. The particular total trip time term used may have had a small influence on this value. The *majority of the time* term resulted in the greatest percentage of participants who strictly used the total trip time measure, while the *95th percentile* term resulted in the least.
- The term *majority of the time* did result in a greater percentage of participants who would select that time, or a value near it, when deciding how much time to allow for a particular trip. Even though the terms *majority of the time* and *most of the time* were judged to have similar meanings by participants, participants who saw *most of the time* were more likely to choose a trip time that exceeded 55 minutes, implying a lower level of confidence for this term. Participants who saw the term *95th percentile* were also more likely to choose a travel time that exceeded 55 minutes. Conversely, participants who viewed the term *travel time for planning* were more likely to choose a value less than 55 minutes, suggesting that this term may convey more of a sense of a maximum trip time and could result in drivers being late more often than they had hoped if they relied on such a term.
- No clear consensus existed in terms of the total trip time term preferred by participants. The terms *majority of the time* and *most of the time* were selected most frequently, but only by about one-third of the participants for each.
- Changing the value of the total trip time estimate (relative to the normal trip time estimate) did affect the time participants chose to allow for a trip. However, as with the

buffer time terms, it does appear that participant selection of a time to allow for a trip depended on how the value of the total trip time estimate compared to their own personal buffer that had developed over time based on their own experiences. Terms that implied a buffer less than 20 minutes appeared to be less trusted by drivers.

Comparison of Travel Time Uncertainty Information

- Use of a buffer time or a total trip time resulted in similar levels of confidence in arriving on time at a destination. Overall, 75 percent and 67 percent of the participants, respectively, indicated that their trip would certainly or very likely take less than the value shown, further indicating that they recognized it as an upper limit to the amount of travel time it might take.
- A slight preference was detected among participants for the use of total trip time terms over the use of buffer terms. This most likely occurred because many drivers would prefer not to have to do the math to add a normal trip time and a buffer time together in order to estimate the trip time they should allow for.

Comprehension of Terms for Normal Travel Time

- None of the four terms evaluated to convey normal travel time appeared to impact the participants' selection and use of the buffer time or total trip time estimates.
- Participants viewed the terms *estimated* and *expected* to have similar meanings. In addition, participants judged the terms *average* and *typical* to have similar meanings. No other clear trends existed as to whether participants believed that the various normal travel time terms had similar meanings.
- No clear trends existed with regards to participant preference of the normal travel time terms. The terms *estimated* and *expected* garnered the most support, but only by about one-third or so of the participants for each.

RECOMMENDATIONS

- Since the four normal travel time terms evaluated performed similarly and no clear preference was identified, researchers believe that any of the four terms may be used to convey the normal travel time.
- Both types of travel time uncertainty terms (buffer time and total trip time estimate) similarly influenced the extent to which motorists may or may not utilize the travel time uncertainty in their travel time decisions. However, participants did prefer to be provided with the total trip time estimate. In addition, researchers feel that providing the total trip time estimate decreases workload and the potential for math errors, which could otherwise lead to distrust of the information provided by an agency. Thus, a total trip time estimate term appears to be preferable to a buffer term when trying to convey trip time uncertainty information. Furthermore, researchers recommend the use of the term *majority of the time* to describe the total trip time estimate.
- The above notwithstanding, if an agency still desires to use a buffer time to convey travel time uncertainty, researchers recommend the use of the term *recommended cushion time*.

Chapter 9 TRAVEL BEHAVIOR LABORATORY EXPERIMENT

Utility is a measure of absolute or relative satisfaction. Conversely, disutility is a measure of dissatisfaction. In the case of travel, disutility assessments translate the dissatisfaction associated with travel into quantified and monetized measures. Trip disutility is the complex and collective bottom-line outcome considering interactions among traveler needs and preferences, trip purpose, travel conditions, perceived and objective trip time, and travel time uncertainty—in addition to the direct costs of travel, such as fuel or fares. Trip disutility functions assign value, or cost per unit, for specific components associated with trips, such as travel time and schedule delay. Valuations based on reductions in travel disutility are central to cost-benefit analyses for transportation investments and, more recently, for traffic operations decisions such as value pricing of high-occupancy toll lanes.

There have been many studies that assess the value of travel time, schedule delay, and reliability associated with travel, and a number that further refine the valuation to reflect specific traveler and modal characteristics. Fewer studies further assess reductions in trip disutility resulting from the provision of traveler information. What is still relatively unexplored is the monetized reduction in trip disutility associated with the provision of travel time reliability information. Travel time reliability information, as defined in the SHRP 2 L14 effort, encompasses a broad range of information that describes underlying trip time variability and other contextual data travelers use to manage delay and on-time performance. This includes information describing the statistical variation in travel time dependent on departure time choice, data describing on-time performance and lateness risk by route and destination, and contextual information to interpret cueing throughout the travel experience allowing travelers to better assess travel time and lateness risk both pre-trip and en route. Travelers who make repeated similar trips at the same time of day accumulate an internalized assessment of trip travel time variability based to gauge lateness risk. Relative to these familiar travelers, it is expected that for unfamiliar trips, travelers would perceive a larger benefit from travel time reliability information.

This experiment described in this chapter aimed to measure the perceived value of trip reliability information and how the valuation of this information changes with increasing trip familiarity. This assessment of how reliability information can reduce travel disutility included the consideration of a particular aspect, *trip serenity*, or the reduction of stress en route associated with potential late arrival. The experiment captured variations in reported stress associated with the on-time performance at trip start, while en route, and at trip end among scenarios with varying levels of traveler information and trip outcomes.

The objectives of the experiment were (a) to assess the value participants placed on traveler information, specifically reliability information, within the context of a simulated time-constrained trip; and (b) to determine whether having reliability information helped to speed the transition from an unfamiliar commuter to an experienced commuter. The underlying conjecture in the experiment was that providing reliability information allows an unfamiliar traveler to manage the trade-off between on-time performance and travel budget (time allocated to travel) more effectively and with less stress. Put another way, provision of reliability information to travelers unfamiliar with underlying travel time variability patterns was expected to both

improve overall trip outcomes (reduction of early and late schedule delay, better on-time performance and reduced delay) and to reduce perceptional disutility associated with these improved outcomes. Three experimental hypotheses were posed:

1. Provision of accurate reliability information will result in improved on-time performance and lower generalized travel disutility compared to a control group receiving no reliability information.
2. While travel outcomes improve with the provision of reliability information, the perceived value of the reliability information will underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.
3. Benefits of reliability information will decline over time as both experimental and control subjects learn and internalize an understanding of underlying travel time variability. That is, the benefit from reliability information in the first few weeks will be larger than in the last few weeks.

To meet experimental objectives and to best fit within the activities undertaken within the overall SHRP 2 L14 project, Noblis selected a trip simulation approach to the experiment. The experimental strategy and corresponding evaluation tools were prepared by Noblis, while the experiment was administered by the TTI staff. Data generated by the experiment were analyzed by Noblis in support of the SHRP 2 L14 task 12, Estimate Utility Functions.

The experiment presented 80 participants with a scenario in which they were commuting in an unfamiliar city with a constrained arrival time (with penalties for both late and early arrival) for 2 work weeks—10 commutes to work. Participants had access to one of three additive levels of travel time information for their planned route and optional route deviations: real-time advisory messages only, real-time advisories plus real-time travel time information, or real-time advisories plus both real-time and reliability (historical travel time range) information. Participants selected among three departure time options and two potential alternate route options to arrive at their destination on time. All participants received the real-time advisory messages (from simulated DMSs deployed along the simulated route), while a subset of participants had to actively acquire the higher levels of real-time and reliability information by pressing an interface button. The experiment was conducted in the same five cities (Dallas, Denver, Miami, Hartford, and San Jose) that were visited for implementation of the SHRP 2 L14 computer survey.

BACKGROUND

Within the SHRP L14 project, two activities, a driver simulation study and a field test, were expected to generate data that would be leveraged to measure the perceived value of trip reliability information, the goal of the Utility Function Evaluation task (task 12). The elimination of the simulator testing along with a re-casting of planned field testing precluded the acquisition of data critical to the completion of task 12. At the same time, findings from Phase 1 focused attention on quantifying the relative value of reliability information. Based on these changes in project direction, Noblis and TTI proposed an experiment using subjects traversing a simulated trip to meet the goals of task 12. This experiment was designed to assess the serenity benefits from trip reliability information and translate the value of trip reliability information

through assessment of trip disutility levels. This experiment was also designed to work within the implementation framework of the existing SHRP 2 L14 Computer Survey task. The experiment was developed by Noblis and deployed by TTI in concert with the planned computer surveys.

LITERATURE REVIEW

The valuation of travel by individuals has been of interest in transportation research for decades, with earliest valuations focusing on the travel time component of travel. Valuation of travel time for work trips expanded to valuation by travel mode and for non-work trips. Since the 1960s, studies through econometric, stated preference, and revealed preference models have assessed valuation of travel. Over time, researchers have developed more complex frameworks for this valuation to more truly reflect actual valuation by travelers by considering factors such as travel conditions (e.g., congestion, reliability) and traveler characteristics (e.g., trip purpose, scheduling flexibility).

Vickery (1963) suggested expanding travel valuation beyond travel time to consider the concept that the penalty for being early would be less than for being late for the work commute. The concept of time constraints on a trip and travelers' preference for a specific arrival time was furthered by Gaver (1968), who hypothesized that trip disutility is a linear function of travel time and early and late schedule delays. Small (1982) built on earlier work using a scheduling delay framework to explicitly tie departure time choice to the utility function of a traveler. Using data from 527 San Francisco Bay Area auto commuters, Small formulated a model with specific components for travel time, early arrival, late arrival, and a fixed late-arrival penalty. Hendrickson and Plank (1984), utilizing journey-to-work data from Pittsburgh, deconstructed the valuation to differentiate free-flow travel time, congested travel time, modal costs, linear early and late arrival, and quadratic terms for early and late arrival. This work confirmed that for the work trip, late time has far greater disutility compared to early time, and that once an individual is quite late for work, additional late time has relatively little additional disutility.

A parallel theoretical framework was proposed by Jackson and Jucker (1982), where trip disutility is a function of the expected travel time and travel time variance, the latter of which reflects the valuation of reliability but without differentiation for trip arrival outcome. Polak (1987) proposed alternatives where the variability term can be quadratic or exponential (for travelers with absolute risk aversion). Black and Towriss (1993) then extended this work to develop a reliability ratio as the ratio of the value of reliability to the value of time.

Noland and Small (1995) combined these two approaches by explicitly including the uncertainty of travel time in the trip scheduling approach through a random variable that reflects the travel time variability. Small et al. (1999) conducted surveys of thousands of households in southern California and found that the value individuals place on travel time and trip reliability varies based on the level of congestion as well as for passenger versus freight travel. Furthermore, based on this large stated preference survey, researchers found that a quadratic term for early schedule delay best reflects observations. Below are the form and estimated parameters of the research by Small et al. These were applied to our current experiment to compare perceived benefit measures with utility-based outcomes.

$$c = \alpha T + \beta_{SDE}(SDE) + 2\ \beta_{SDE2}(SDE)^2 + \gamma(SDL) + \theta D_L$$

c: *Cost of travel (disutility)*
T: Travel time
SDE: Schedule delay early
SDL: Schedule delay late
D_L: Late-arrival index $= \begin{cases} 1 & \text{if } SDL > 0 \\ 0 & \text{otherwise} \end{cases}$

The estimates of the parameters are:
α: \$0.0564/min (linear cost of in-vehicle travel time)
β_{SDE}: \$-0.023/min (linear component of quadratic early cost)
β_{SDE2}: \$0.005/min (quadratic component of quadratic early cost)
γ: \$0.310/min (linear cost of late arrival)
θ: \$2.87 (one-step penalty for arriving late)

Small et al. (2005) found that commuters differ substantially in how they value travel time and reliability, and that the average valuation of both is quite high and is considerably higher when measured in real as opposed to hypothetical scenarios. More recent work has explored variants in the form of the early- and late-arrival components as well as the form by which to represent travel time variance (e.g., Bates et al., 2001; Tilahun and Levinson, 2010). Other research addressed the inclusion of risk attitudes in trip scheduling models (Senbil and Kitamura, 2004; Michea and Polak, 2005; Li et al., 2010) and extended the formulation to consider trip chains (Jenelius et al., 2011).

With the growth in public real-time traveler information in the 1990s, travel valuation research expanded to valuation of traveler information, as it not only provides trip makers the ability to save travel time but also provides serenity benefits and the ability to shift activities to accommodate trip uncertainty. Many have estimated the system-level travel time savings from traveler information through network simulation models (e.g., Wunderlich, 1998), while others have focused on willingness to pay through stated preference surveys (e.g., Khattak et al., 2003).

Ziang and Levinson (2006) focused on the benefits in reduction in driver uncertainty when traveler information is provided at the beginning of a trip. In this study, traveler information (static value of travel time) for multiple routes was provided to travelers. Travelers were asked to make a trip using multiple route options. Participant travel was recorded through GPS units, and participants were then asked to rank order travel among these multiple routes as well as provide ratings on the quality of the trips. Using regression, multinomial, and rank-ordered models, the authors founds that travelers had perception biases and systematically misperceived certain aspects of their trip. Furthermore, accurate information was valued only for commute and event trips, and not for other trip purposes, such as recreation.

Basu and Maitra (2010) applied a stated preference approach to compare traveler (both taxi and private vehicle) valuation of traffic information on a variable message sign. Information was presented in two forms: instantaneous travel time, and an additive level of information, which was a categorical variable for variation in instantaneous travel time from the previous estimate.

The application of two different types of logit models resulted in valuation of travel time variation at par or greater than the value of travel time for private-car trip makers. For taxi trip makers, both models indicated that valuation of travel time variation was greater than travel time.

EXPERIMENT PLAN

Several iterations of an initial experimental design were considered by the Noblis team. Constraints of overall testing session length and resources required for participant sample size restricted the number of factorial combinations that could be tested. The final chosen form of experiment focused specifically on making an initially unfamiliar routine time-constrained trip. The travel behavior experiment was programmed using Visual Basic for Applications (VBA) within the Microsoft Excel environment. Several iterations of quality assurance and testing were completed on the multiple laptop computers used in the field to create accurate visual appearance and macro execution based on varying performance levels and settings among field laptops.

The experiment was conducted in five cities—Dallas, Denver, Miami, Hartford, and San Jose—over a period of four months and acquired information from 80 participants. Experiment participants were recruited through advertisements on Craigslist.com. Table 9-1 presents the number of participants by city. These cities were selected to include a diverse survey population that had experiences with varying levels of traffic congestion, commute lengths, and highway network connectivity.

Table 9-1. Responses by city and type of information received in commute experiment.

City	Experiment Dates	Participant Count	VMS	VMS+ RT	VMS + RT + HISTORIC
Dallas	2/14/2011, 2/15/2011	15	6	5	4
Denver	12/8/2010, 12/9/2010	15	3	4	8
Hartford	1/18/2011 - 1/20/2011	21	9	7	5
Miami	11/30/2010- 12/2/2010	10	1	3	6
San Jose	1/11/2011 - 1/13/2011	19	7	5	7
Total		**80**	**26**	**24**	**30**

Figure 9-1 presents the screenshots of the Excel-based interface that served as the starting point for experiment participants, as well as a sample experiment screenshot. Each participant was seated in front of a dedicated laptop with a mouse and was required to maneuver the mouse to click on interface buttons, radio buttons, or drop-down menus. Participants did not use the keyboard during the experiment. Upon arrival at the survey room, participants were seated and provided a brief explanation about the intent of the experiment. Participants completed a pre-experiment survey of 10 complex questions, followed by a group-led experiment and a post-experiment 4-question survey. Table 9-2 summarizes the information requested in the three sections of the experiment.

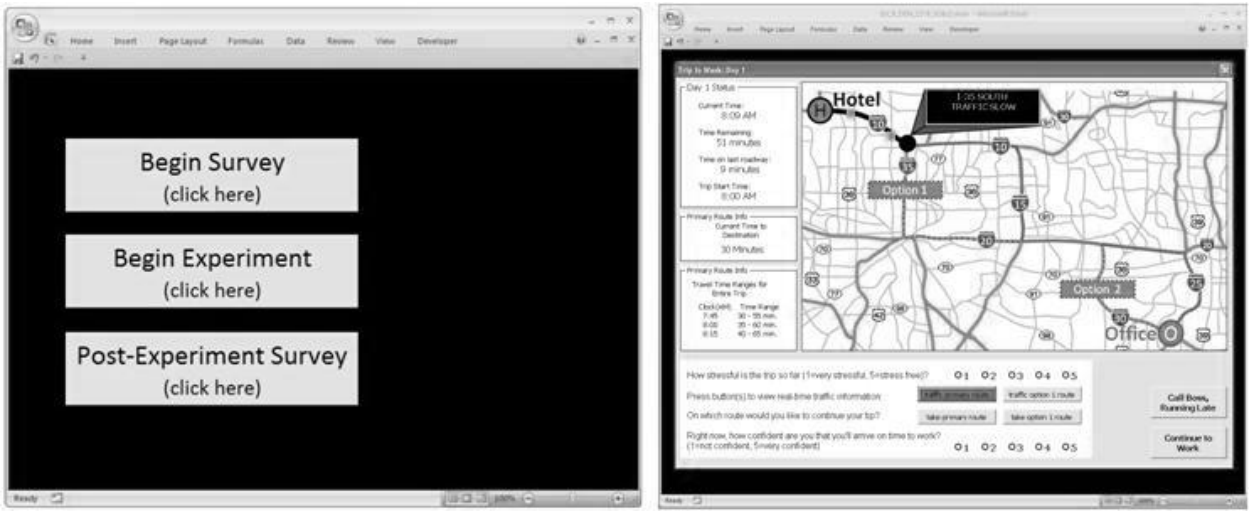


Figure 9-1. Interface view when participants were seated for the experiment.

Participants independently completed the pre-experiment survey ("Begin Survey" button in Figure 9-1) and waited for a moderator to jointly commence the commute experiment ("Begin Experiment" button in Figure 9-1). The pre-experiment survey requested socioeconomic, travel purpose, roadway usage, and schedule integrity questions. The socioeconomic information framed the characteristics of participants and can be compared against the population at large or with other future experimental groups. The travel purpose, schedule integrity, and roadway usage questions together identified the types of trips for which on-time arrival was most important to participants, the frequency with which those trips were made, and whether the trips for which on-time arrival was most critical were made on roadways where traveler information is usually available. The detailed descriptions and outcomes of the pre-experiment survey are presented later in this chapter.

The commute experiment was begun through instruction to the participant group by the moderator. The moderator read aloud the contextual setup text presented in the experiment and informed participants that different individuals would have access to differing levels of traveler information. Participants were instructed to not share their successful or failed commute strategies with each other to prevent participants with lower levels of traveler information from acquiring insight afforded to participants with more precise traveler information. The moderator supported participants for the first day of travel by presenting on large visual images the location of specific types of information and decision sets. Thereafter, participants used experiment information and made commute decisions at their own pace to complete commutes to work. While the intent of the experiment was to have participants complete 20 commute days (1 commute month), time and resource constraints required curtailing the experiment to 10 commute days.

Participants indicated willingness to pay for traveler information, on-time arrival confidence level, trip stress level, satisfaction level with trip outcome, and traveler information usefulness for each of the 10 completed trips. Data supporting the experiment were designed to represent a moderate level of trip variability as well as temporal consistency among departure time, traveler

information, and trip experiences. The details related to the simulation data set along with the outcomes from the commute experiment are presented later in this chapter.

Table 9-2. Information acquired from experiment.

Pre-Survey Information Acquired	Experiment Information Acquired	Post-Survey Information Acquired
• Gender, age, education • Travel frequency by trip purpose (work, education, childcare, medical, recurring social) By Trip Purpose for trips with frequency selection other than "none": • On-time arrival importance • Average travel time • "Bad day" additional time Quantification of "late" • Willingness to pay travel time guarantee • Willingness to pay knowledge of late impending arrival en-route time guarantee	Participants selected the following for the beginning and subsequent segments of each trip (as applicable): • whether to view traffic information • willingness to pay amount for information viewed • start time for trip • Route selection • level of confidence for an on-time arrival • level of stress for the trip thus far At the end of each trip, participants also selected the following: • overall level of stress for the entire trip • level of happiness with trip outcome • overall level of usefulness of traffic information • willingness to pay amount for all the information viewed during this trip.	• Usefulness of traffic info at o beginning of experiment o end of experiment • Sources of traffic information participant uses for their travel (radio, television, computer, hand-held or dashboard devices)

As with the pre-implementation survey, the moderator instructed participants to independently complete the post-experiment survey. The post-experiment survey was brief, consisting of four questions. This survey requested participants to rate the usefulness of traveler information at the beginning and toward the end of the experiment. This information was used to corroborate participants' responses within the commute experiment. The format and findings of the post-experiment survey are presented later in this chapter.

Pre- and Post-Experiment Survey

The pre-experiment and post-experiment surveys developed a baseline of participant characteristics that were useful in comparing participant characteristics with the population at large. Key data acquired through the surveys for this comparison included gender, age, educational level, and traveler information usage. Additionally, the survey questions aimed to explore whether the participant population made trips that would benefit most from traveler information—that is trips that were sufficiently long, required stringent on-time arrivals, and used facilities where such information would be available (i.e., highways). Participants with

these routine trip-making characteristics were likely to better internalize trade-off requested in the simulation experiment, and their responses were more likely to reflect true trip decision-making. The specific text of pre- and post-experiment questions and the response options for questions are presented in Appendix F.

The survey questions also enabled the development of lateness thresholds, that is, exploring what participants perceived as arriving late based on their specification for on-time arrival importance and trip purpose. These thresholds can be applied in future work to refine the form of utility functions.

Willingness to pay for guaranteed travel time (zero trip variability/100 percent trip reliability) and willingness to pay for knowledge of late arrival were both assessed to compare with sensitivities observed through the experiment. We expected *a priori* that participants with high on-time arrival importance would be willing to pay more for this guarantee or arrival outcome information.

At the end of the simulation experiment, the survey asked participants what their most important objective was when making departure time decisions (reason for choosing a departure time—call family, reduce parking fee, avoid late arrival, arrive exactly on time). The survey also asked their perceived usefulness from traveler information at beginning and end of trip. These data provided a clearer holistic understanding of what drove participants' departure choices and whether a value loss occurred in their rating of traveler information usefulness.

Experiment Description

The key goals of the experimental design were (a) to assess the value participants placed on traveler information, and the reliability information component, within the context of a simulated time-constrained trip; and (b) to determine whether having reliability information helped to speed the transition from an unfamiliar commuter to an experienced commuter. The expectation was that participants with higher levels of traveler information would assign more positive valuation to questions regarding usefulness of traffic information, trip stress, and trip outcome satisfaction during the first week while they were unfamiliar with the trip variability. Furthermore, the expectation was that those with higher levels of information were likely to perform better on event and non-event days because higher levels of information would speed the transition from unfamiliar to experienced commuter. In making these determinations, we conducted comparisons of mean valuation among participants with different levels of information and computation of utility values based on trip outcomes.

Appendix F presents the narrative given on-screen and communicated verbally to prepare participants for the simulation experiment. In essence, participants were in a new town for work and had to arrive on time to work or otherwise incur a $25 late-arrival fee. Once during the simulation experiment, participants could inform their employer of a late arrival and avoid the late-arrival fee. Early arrival cost (parking cost) was introduced at $4.00 per hour, and an incentive for later departure was introduced in the form of time spent video-chatting with family back home. Participants were requested to select among three departure times (7:45 a.m.,

8:00 a.m., and 8:15 a.m.) and multiple routes for a simulated travel to work over a 2-week period, totaling 10 commutes.

Participants received one of three levels of information. L1 participants received only qualitative information pre-trip and en route. L2 participants received the same qualitative information as L2 and also could view real-time estimate of route-specific travel time to destination. Real-time information was presented in the simulation at five-minute increments. L3 participants had access to the same information as L2 and also could view static travel time reliability information.

Figure 9-2 presents the trip network and identifies the waypoints along the trip where qualitative DMS messages were presented. The image in Figure 9-2 is from the simulation tool for a participant with L3 traveler information, where the participant had clicked on the "traffic primary route" button.

A qualitative DMS message was visible at the start of the trip ("H" in Figure 9-2) and at two waypoints along the trip. The DMS message sets are presented in Appendix F along with their frequency of use. Participants chose route options and whether to view additional travel information, if available to them at waypoints 1 and 2. During the commute, participants had information (left panel of Figure 9-2) regarding the current simulation time, time remaining for them to complete their trip on time, time to traverse the previous segment of roadway, and when they had started their trip.

Specific questions regarding levels of trip stress and on-time arrival confidence had to be completed at each waypoint and at the beginning and end of each trip, as relevant. The specific types of data collected through the simulation experiment are presented in Appendix F. Among the 10 commute days, half were non-event days and half were event days, as listed in

Table 9-3. The order of days remained consistent among all participants. Commute times were designed for temporal and route consistency and were reflective of event and non-event days. Table 9-4 and Table 9-5 present average travel times and range of travel time by time of departure and route for event and non-event days, respectively. The specific travel times for each day are presented in Appendix F. Based on the simulation travel times, the optimal departure time to meet the schedule-constrained arrival of 9:00 a.m. was 8:15 a.m. for non-event days and 8:00 a.m. on all event days except for day 8, the heavy rain day. On this day 7:45 a.m. was the departure time required for an on-time arrival.

The DMS, real-time, and reliability data that were presented to participants aligned with the commute times they experienced. That is, the quality of the traveler information was good. Only on days 5 and 10 did the real-time travel time estimate at the beginning of the trip differ significantly from experience, and that was because accidents were simulated to occur after trip departure.

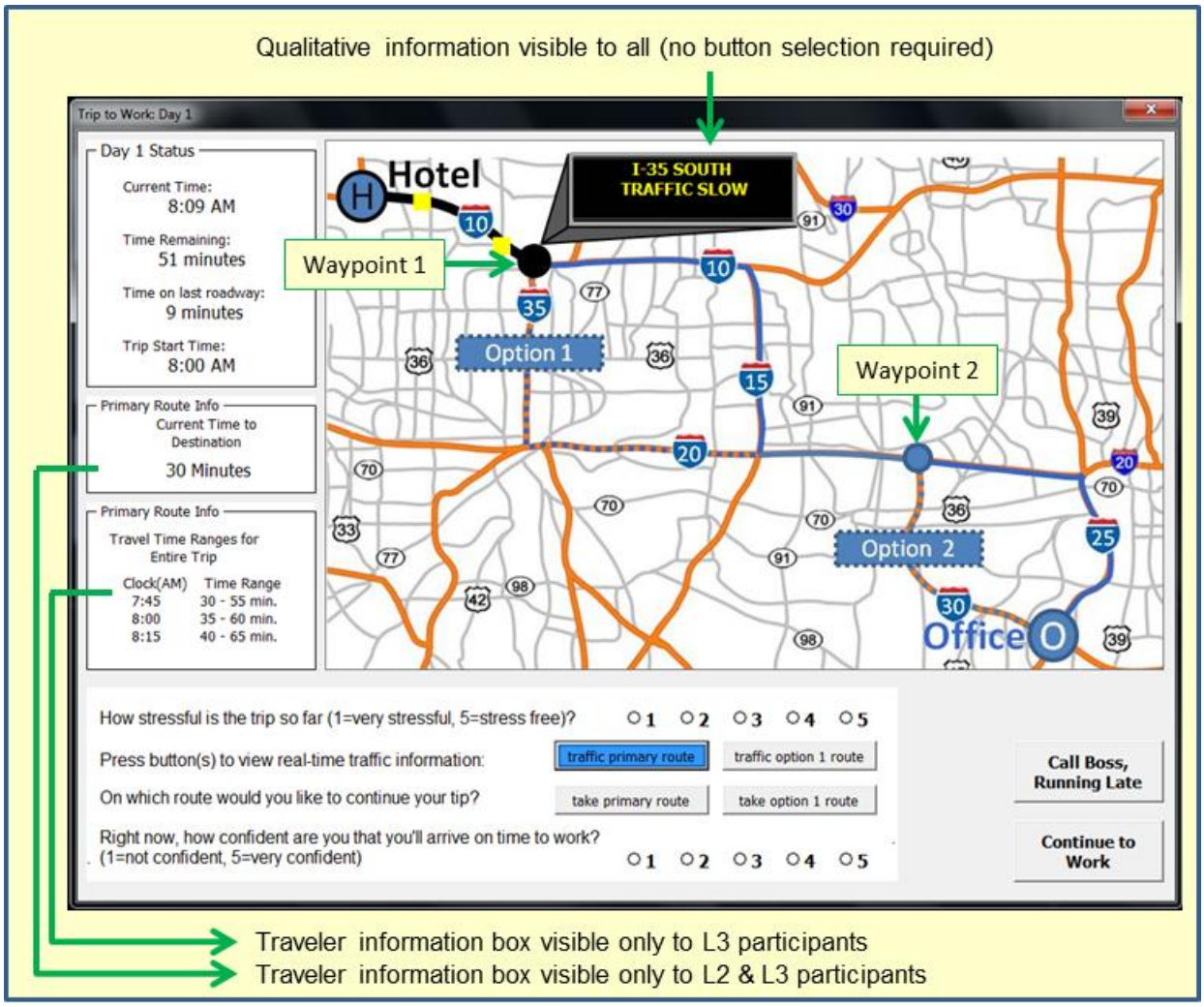


Figure 9-2. Road network for trip simulation.

Table 9-3. Description of simulated commutes to work.

	Simulation Day	Description of Day	Ideal Departure Time*	Alternate Route Far Better^
Week One	Day 1	Non-event traffic day		No
	Day 2	Higher than usual traffic, moderate delays all routes		No
	Day 3	Non-event traffic day		No
	Day 4	Non-event traffic day		No
	Day 5	Minor accident at 7:50 am affecting all routes, minor delays		No
Week Two	Day 6	Blocked lane on primary route from 7:15-8:00am, moderate delays		Yes
	Day 7	Non-event traffic day		No
	Day 8	Heavy rain day, significant delays all routes		No
	Day 9	Non-event traffic day		No
	Day 10	Minor accident at 8:00am affecting primary route		No
*ideal departure time avoids late arrival and minimizes excessive early arrival				
^alternate route equivalent for most days, superior for one simulated day				

Table 9-4. Non-event day travel time profiles used in experiment.

Departure Time	Average and Range of Travel Time by Route for Non-Event Days			
	primary	Option 1	Option 2	Option 1 & 2
7:15 AM	32.8 (31-35)	36.4 (34-39)	34.2 (33-36)	37.6 (35-41)
8:00 AM	37.2 (34-41)	40.4 (38-43)	39.4 (36-43)	42.0 (38-43)
8:15 AM	41.2 (38-45)	44.6 (40-47)	43.6 (41-47)	45.6 (44-49)

Table 9-5. Event day travel time profiles used in experiment.

Departure Time	Average and Range of Travel Time by Route for Event Days			
	primary	Option 1	Option 2	Option 1 & 2
7:15 AM	47.6 (37-64)	45.8 (37-61)	48 (37-63)	46.6 (38-62)
8:00 AM	56.4 (47-66)	53.6 (45-66)	56 (42-68)	52.4 (38-65)
8:15 AM	57.8 (47-71)	56.4 (39-71)	57.8 (47-73)	55.6 (42-74)

PRE- AND POST-EXPERIMENT SURVEY FINDINGS

The pre- and post-surveys provided insight on the characteristics and preferences of participants. A total of 80 participants completed the surveys. A greater subset of participants made work and medical trips with some frequency compared to school, childcare, or other routine trips. These work and medical trips more often use highways, are longer compared to school or childcare trips, and have higher requirements for on-time arrival compared to childcare or other routine trips. Consequently trips made to work and medical appointments are ideal for using traveler information. However, the familiarity with traffic for routine work trips will likely make reliability information a lower value add-on compared to real-time information. Conversely, when planning non-routine work or medical appointment trips, reliability information will provide a higher add-on value compared to only real-time information.

What it meant to be late was far more precise (within 2 minutes of scheduled arrival time) for many participants making work (41 percent of participants) and childcare trips (53 percent of participants), while all participants making school trips selected a lateness threshold of 10 minutes or less. For these participants with a narrow lateness threshold, trip reliability played a significant role in budgeting travel time for this trip. These participants were also willing to pay more for a guarantee of travel time or to know during the beginning of a trip that they would arrive late.

Table 9-6 lists the average minutes late participants characterized as arriving late. Across all participants and trip purposes, the average threshold for characterizing a trip as late was 6.7 minutes beyond the desired arrival time. As expected, individuals who indicated arriving on time was very important had a far smaller lateness threshold. For example, participants who indicated that a work on-time arrival was very important (category 5) believed that arriving 4.9 minutes past their scheduled arrival time was considered late, whereas this value was 17.0 minutes for participants who indicated that on-time arrival at work was somewhat important.

Table 9-6. Average threshold for late arrival.

Lateness Threshold (minutes) Based on On-Time Arrival Importance and by Trip Purpose						
Arrival Importance (1=unimportant, 5= very important)	*Trip Destination by Purpose*					All Trips
	work	school	childcare	medical	other	
1	na	4.8	20.0	na	15.0	9.0
2	na	10.0	25.0	5.0	22.5	17.0
3	17.0	6.0	7.0	7.1	9.0	9.2
4	5.1	5.6	11.8	7.3	10.7	8.3
5	4.9	6.0	3.3	5.7	5.5	5.1
Average Lateness Threshold	5.8	5.9	6.0	6.2	9.3	**6.7**

Given that the experiment simulated a work trip, participants were asked to identify how frequently they sought out traffic information for this type of trip. Over 90 percent of participants that made work trips also sought out traffic information at least once or more per week. Among the participants that made daily work trips, 40 percent also sought out traffic information daily. Participants often used multiple media for acquiring traffic information. Among the 80 participants, nearly 60 percent used radio, while television, computer, and handheld or dashboard devices were used by 43 percent, 28 percent, and 23 percent, respectively.

The expectation would be that eliminating trip variability would be valued far more than knowing en route that you'll be late. Based on survey responses, however, participants were willing to pay only slightly more to eliminate travel time variability than to be forewarned of a late arrival. As expected, more important on-time arrivals translated to a greater willingness to pay. Furthermore, among the various trip purposes, participants were willing to pay most to eliminate trip variability for work trips and to know of a late work arrival. On average, across all

trips, participants indicated that they would be willing to pay $0.85 per trip to eliminate travel time variability and $0.72 to be informed of a late arrival. Table 9-7 lists participants' average willingness to pay by trip purpose and by importance for an on-time arrival.

Table 9-7. Willingness to pay for trip reliability and information on late arrival.

Willingness to Pay (WTP) Responses by On-Time Arrival Importance and by Trip Purpose*										
Arrival Importance (1=unimportant, 5= very important)	*Eliminate Trip Variability (Guaranteed Travel Time)*					*Know You're Going to be Late (Late Arrival Traveler Information)*				
	work trips	school trips	childcare trips	medical trips	other trips	work trips	school trips	childcare trips	medical trips	other trips
1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3	$0.55	NA	NA	$0.78	$0.30	$0.30	NA	NA	$0.58	$0.25
4	$0.52	$0.75	NA	$0.23	$0.34	$0.59	$0.54	NA	$0.45	$0.45
5	$1.38	$1.18	$1.17	$0.98	$0.73	$1.23	$0.91	$0.86	$0.90	$0.14
Average WTP	$1.20	$0.93	$1.05	$0.77	$0.37	$1.08	$0.73	$0.73	$0.74	$0.28

*cells report value where number of observations is 5 or more

Participants' valuation (usefulness) of the traffic information solicited through the post-experiment survey was neutral to somewhat useful at the start of the experiment. The neutrality diminished with transference more to the "somewhat useful" category and the "rarely/not useful" categories. The relative valuation between the three levels of information received was only moderately different. Approximately 20 percent of participants who received DMS-only information (L1) negatively rated its usefulness. Surprisingly, only 8 percent of L2 participants negatively rated its usefulness, while 13 percent of the third tier of information negatively rated its usefulness. The differences in outcomes, however, were not statistically significant.

Pre-Experiment Survey, Sample Statistics

The participants' median age range was 40-49 years. Nearly half had a college degree or higher , whereas only 25 percent of the U.S. population (age 25 and older) has completed a college or postgraduate degree. While most participants made work trips (94 percent) or trips for a medical appointment (94 percent), a few participants did indicate that they never made these types of trips (6 percent). Conversely, 55 percent and 60 percent of participants never made school-related or childcare trips, respectively. In addition, although nearly all participants made work-related trips, only 60 percent commuted daily to work. Furthermore, only 13 percent commuted daily to either school or childcare. As expected, no participant made daily medical-related trips. Figures summarizing basic statistics related to participants' gender, age, education, and types of trips made are included in Appendix G.

Approximately 25 percent of participants that made trips to work, school, and medical appointments traveled using mostly highways. Only 9 percent and 17 percent of participants who made childcare and other routine trips, respectively, did so primarily through highway travel. Most frequently, trips were made through a combination of travel on highways and

signalized roadways. Based on road-type use trends among participants, and the fact that traveler information is available mostly on highways, approximately a third of the participants (those using primarily signalized and neighborhood roads) that made a specific type of trip would likely not have traveler information relevant to their trip. Figure 9-3 displays these results.

Participants unanimously indicated that for every type of trip they made, arriving on time was between "somewhat important" and "very important," based on a 5-point scale, with 3 equaling "somewhat important" and 5 equaling "very important." All 36 experiment participants (100 percent) that indicated that they made school trips identified that arriving on time was very important. Nearly all (86 percent and 88 percent, respectively) experiment participants that indicated that they made trips to work or medical appointments also identified that arriving on time was very important. Figure 9-4 presents a chart summarizing participants' ratings for on-time arrival importance by trip type.

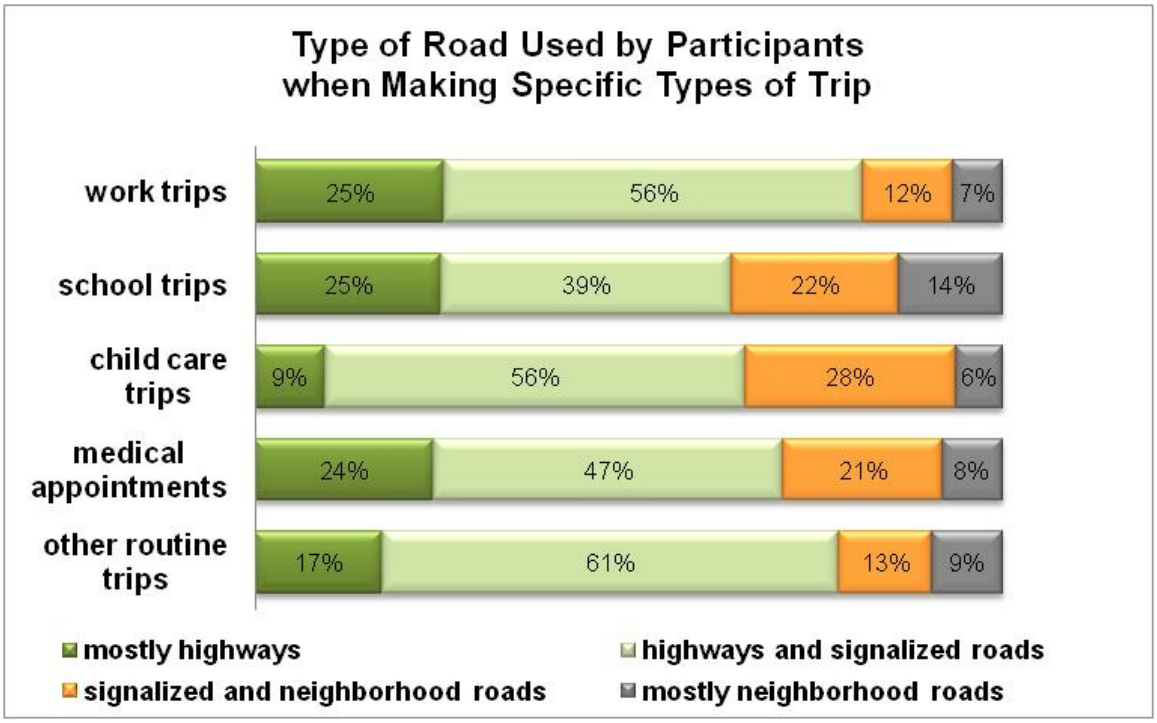


Figure 9-3. Types of roads participants used for specific trip types.

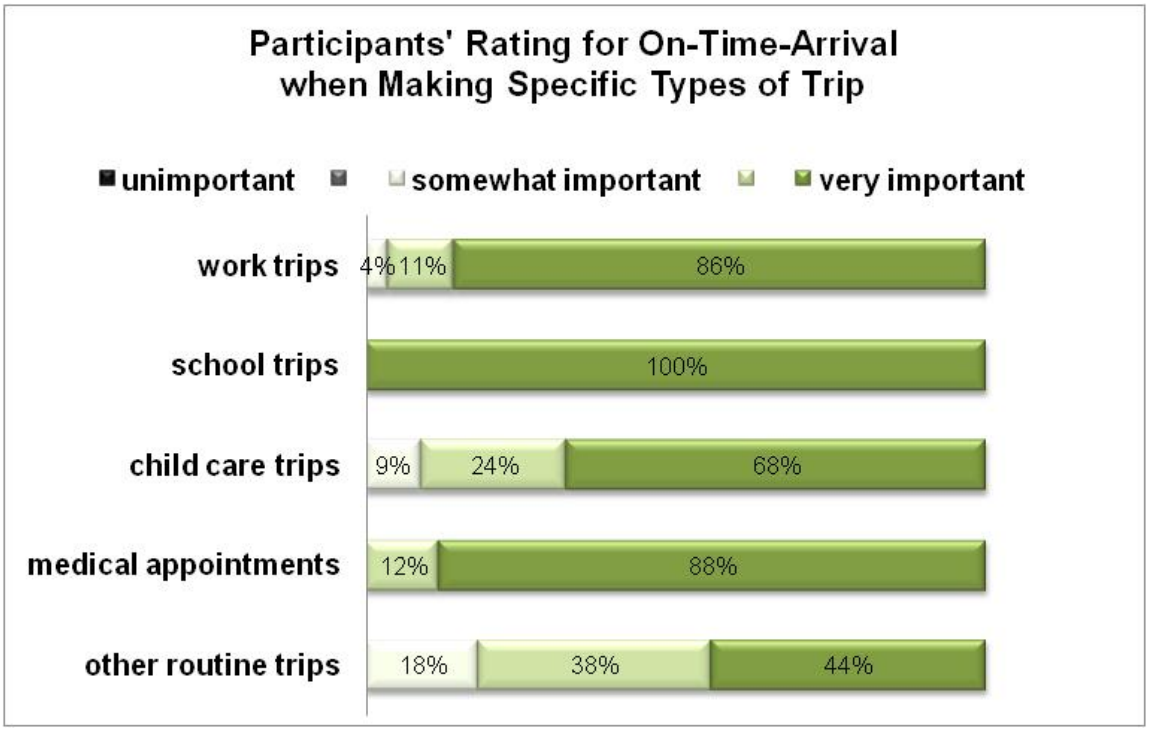


Figure 9-4. Participants' on-time arrival importance by trip purpose.

Figure 9-5 presents a chart summarizing participants' normal trip time for the subset of participants that made a specific trip type. Most participants (58 percent) had an average work-trip time that ranged between 10 and 30 minutes, while 30 percent of participants that traveled to work experienced an average travel time greater than 30 minutes. Participants' medical appointments appeared to have a similar average trip time distribution to participants' work trips. Average travel times for work and medical-related trips were generally greater than average travel times for school and childcare trips.

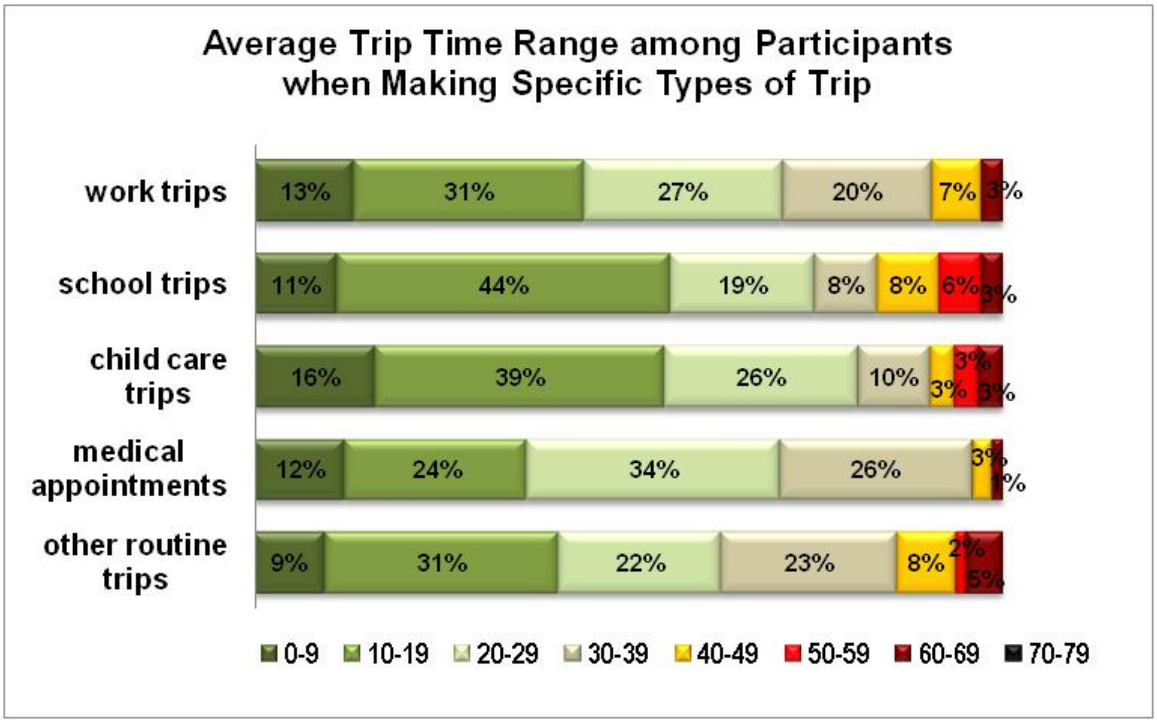


Figure 9-5. Average trip duration by trip type.

Figure 9-6 presents a chart summarizing participants' additional travel time on a bad day. Over 50 percent of participants that made childcare trips experienced very low levels of trip variability (0-10 minutes of extra travel time), while only 41 percent making work trips had the same low level of trip variability. One in four participants that made work trips indicated that on a bad day, their trip can take 30 or more additional minutes beyond their average trip time, while only one participant had that level of variability for his or her childcare trip.

Yet, what it meant to be late was far more precise for work and childcare trips compared to the other trip types. One in five participants who made work trips categorized arriving late as arriving even a minute beyond his or her scheduled arrival time, and another one in five set the late-arrival bar to two minutes within the scheduled arrival time. Late arrivals for childcare trips were perceived by participants as even more time sensitive. These outcomes are presented in Figure 9-7.

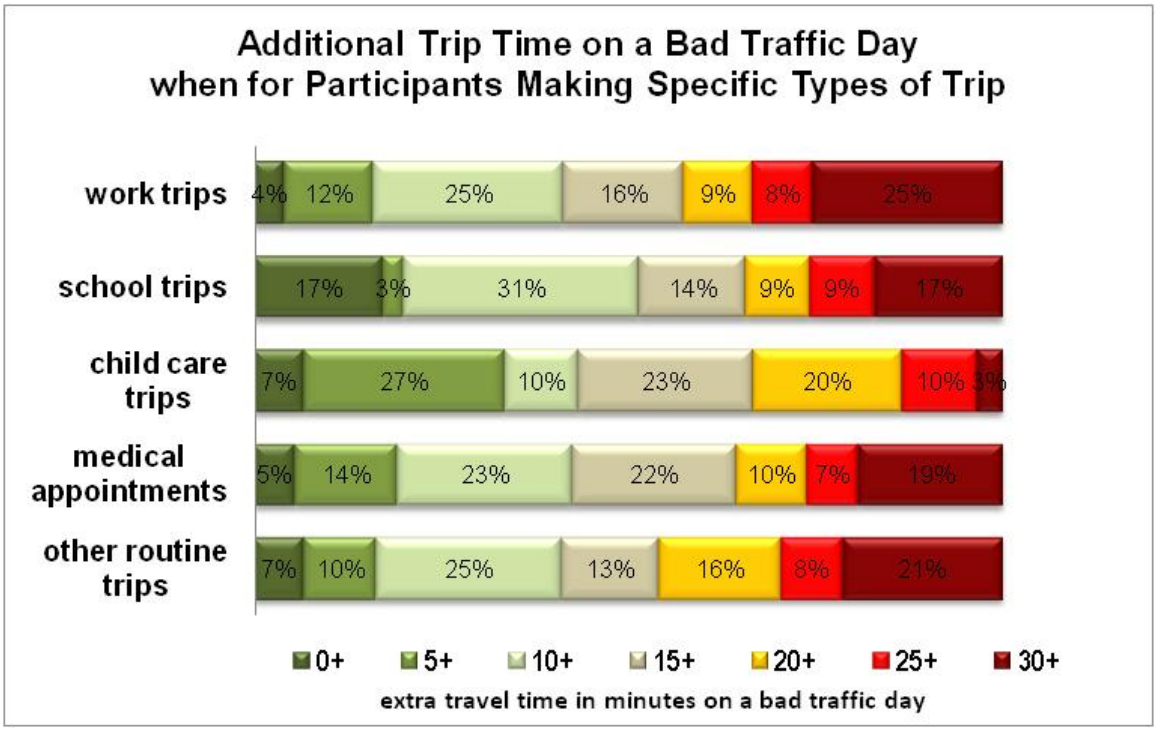
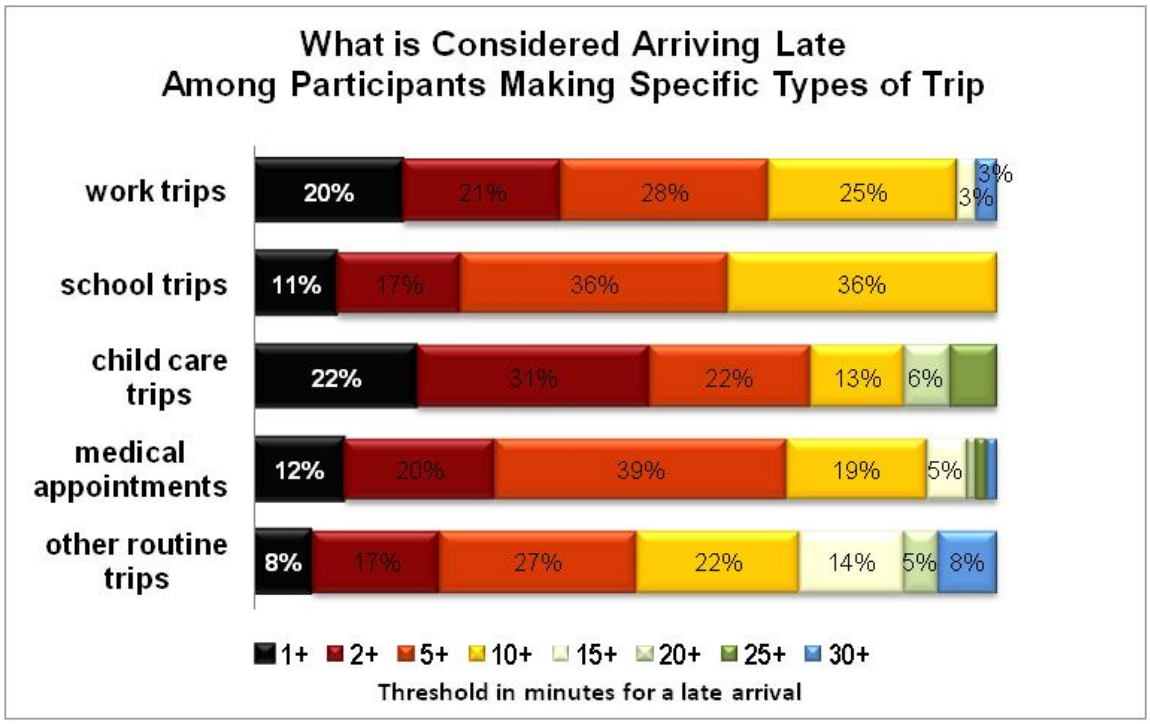


Figure 9-6. Capturing trip time variability for participants' trips.



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Figure 9-7. Participants vary in their definition of a late arrival.

Figure 9-8 presents a chart summarizing participants' willingness to pay for a guaranteed travel time to their destination. Over 80 percent of participants were willing to pay something to eliminate the variability in travel to work, while only 42 percent of participants that made other routine trips were willing to pay money to reduce their trip variability. This was, of course, because such trips have a far lower on-time arrival importance. On average, participants who made work trips were willing to pay $1.20 per trip to eliminate trip variability. For childcare trips, this value was $1.05, and for school-related trips, the value was $0.93.

Surprisingly, nearly as many people (76 percent) were willing to pay for information showing that they would arrive late for a work trip as were willing to pay to reduce their work-trip time variability (81 percent). Furthermore, they were willing to pay nearly as much for the information ($1.08 versus $1.20), even though this information would not improve their travel time or trip outcome. The average willingness to pay amount for school, childcare, and medical trips was the same, at $0.73 per trip. Figure 9-9 presents a chart summarizing participants' willingness to pay for late-arrival knowledge.



Figure 9-8. Willingness to pay for guaranteed travel time.

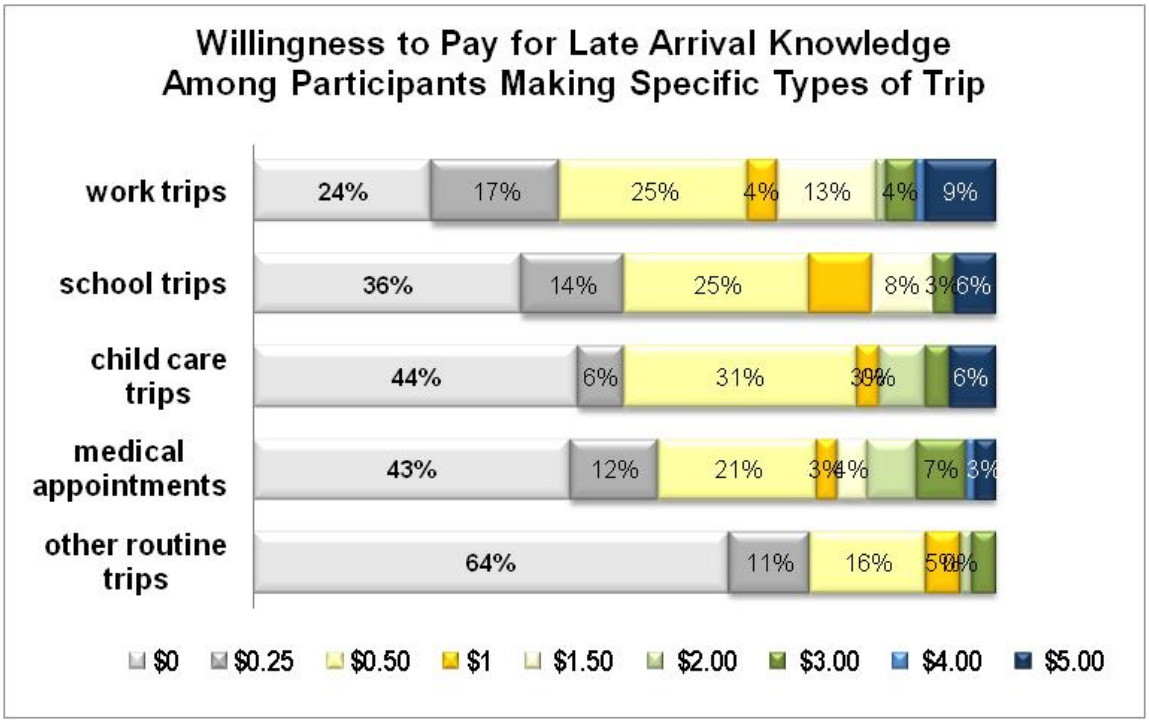


Figure 9-9. Willingness to pay for late-arrival knowledge.

Post-Experiment Survey

Participants were answered four brief questions after completing the simulation experiment. The first question asked about their perceived usefulness of traveler information at the start of the simulation and their perceived usefulness of the traveler information after having completed the experiment. Figure 9-10 and Figure 9-11 map out participants' responses to these questions.

At the beginning of the experiment, about half of the participants who received L1 and L2 were neutral (48 percent and 52 percent, respectively) about the usefulness of the traveler information, while fewer believed it was somewhat useful (44 percent and 30 percent, respectively). Many more L3 participants rated the information as somewhat to very useful (57 percent) than rated it neutrally (33 percent). At the end of the experiment, the L1 and L2 groups who were neutral shifted significantly more to the positive and slightly to the negative. The L3 group had a far less pronounced shift to the positive.

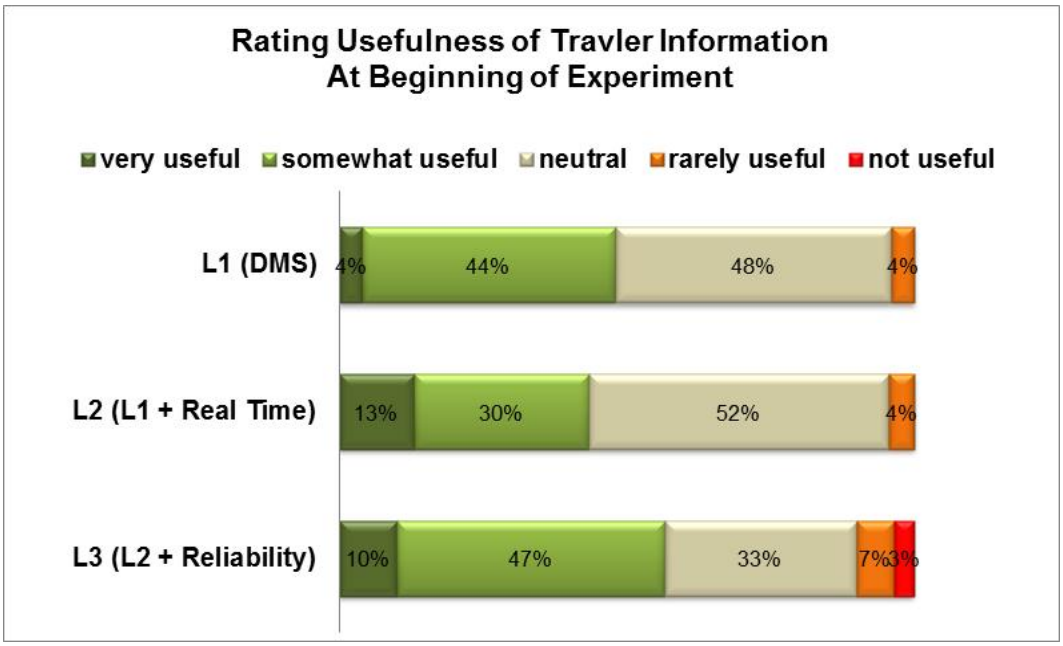


Figure 9-10. Ratings of traveler information usefulness at beginning of experiment.

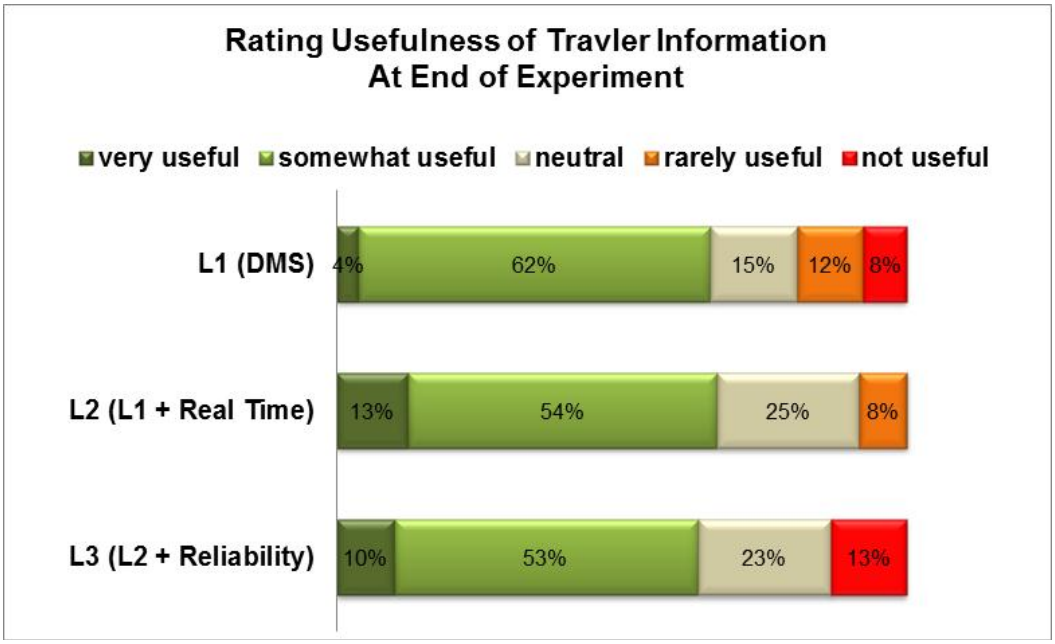


Figure 9-11. Ratings of traveler information usefulness at end of experiment.

During the post-experiment survey, participants also revealed how frequently they sought out traffic information for the work trip and the types of information they used to acquire this information. Participants' responses were aggregated and are presented in Figure 9-12 andFigure 9-13. Most participants frequently sought out traffic information, and 30 percent did

so every day. Most used multiple media in acquiring this information. Over half of the participants that sought out traffic information for the work commute used the radio.

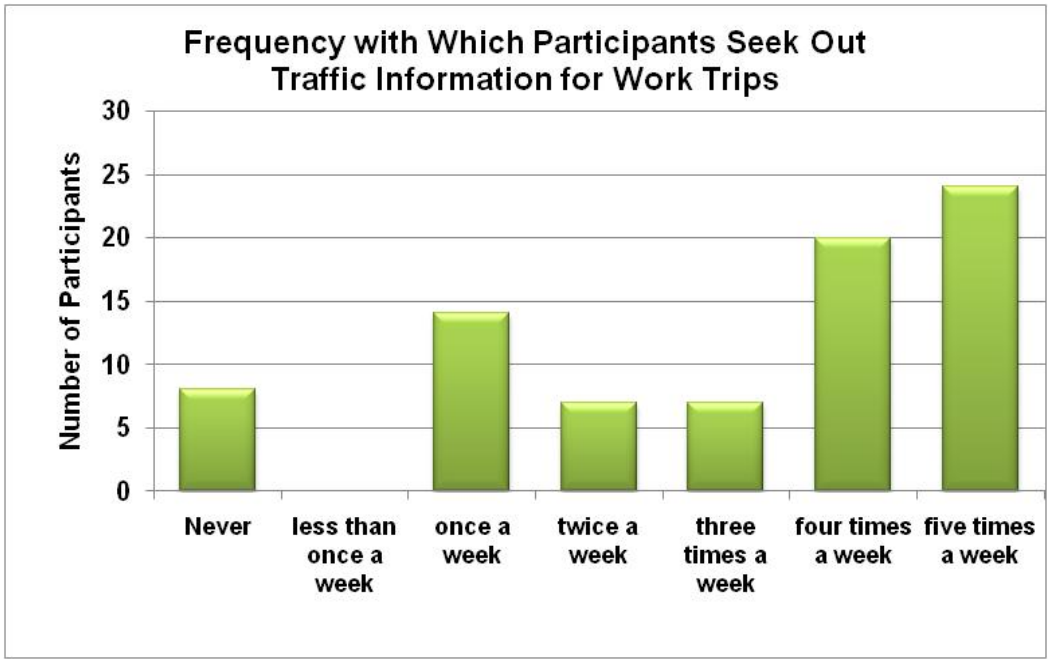


Figure 9-12. Participants' frequency for seeking traffic information for the work trip.

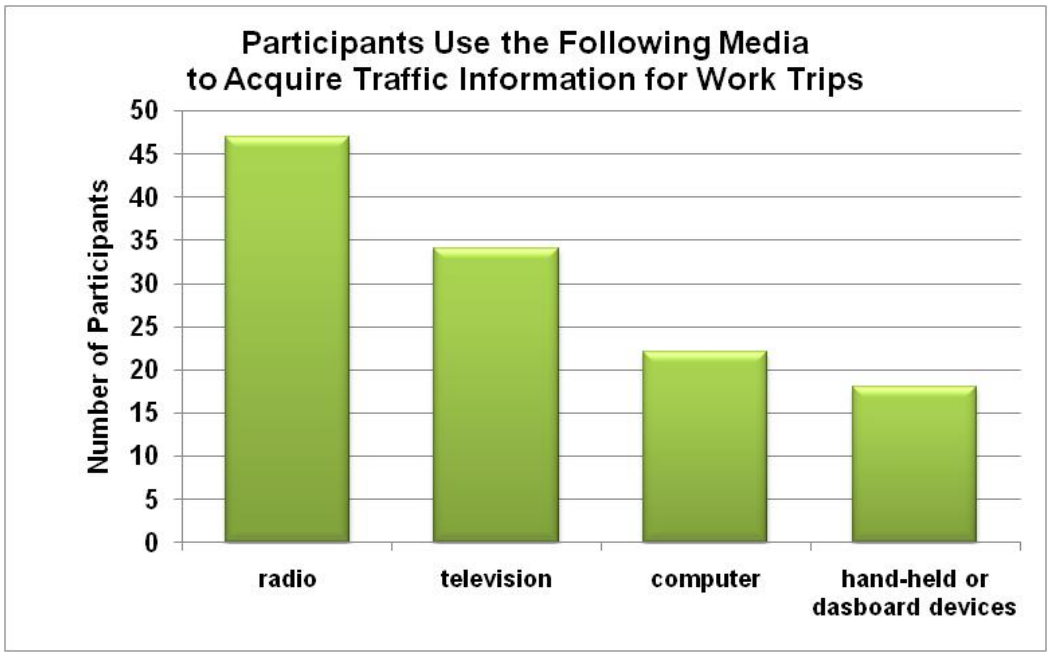


Figure 9-13. Media used in acquiring traffic information for work trips.

EXPERIMENTAL RESULTS

Participants who received all three information sets (qualitative message sets on roadside message signs along route, real-time travel time at five-minute granularity, and static travel time ranges based by time of departure) were referred to as receiving L3 information. Participants who only received the qualitative message sets were referred to as receiving L1 information, and participants who received the qualitative message sets and real-time travel time information were referred to as receiving L2 information.

Participants with L3 information were more conservative in departure time decisions compared to the L1 and L2 groups for non-event days. This was likely because the reliability information that supplemented L3 participants' real-time information increased their awareness of trip variability and resulted in this groups' greater travel time budget. Only 23 percent of participants with reliability information departed at 8:15 a.m. on non-event days, while 30 percent and 45 percent of participants receiving L1 and L2 information, respectively, departed at 8:15 among participants. Conversely, L2 participants budgeted the least travel time for their trips. Table 9-8 summarizes the departure time decisions of participants by information level for event and non-event days.

Table 9-8. Aggregate departure decisions for groups with different traveler information.

	Non-Event Days			Event Days		
Departure Time	L1 (DMS)	L2 (DMS+ RT)	L3 (DMS+RT+REL)	L1 (DMS)	L2 (DMS+ RT)	L3 (DMS+RT+REL)
7:45	16%	7%	17%	30%	34%	34%
8:00	54%	48%	60%	51%	40%	48%
8:15	30%	45%	23%	19%	26%	18%

The trip objective for participants was to depart no earlier than 8:00 a.m. so that they could spend that time checking in on family. At the same time, the participants were asked to arrive before 9:00 a.m. to work to avoid a $25 work penalty and to avoid parking fees of $4.00 per hour. Note that all of these motivations constructed for these simulated trips were hypothetical, and there were no variations in participant compensation tied to performance within the experiment. Given that L3 participants chose to depart earlier compared to L1 and L2 participants, they more often missed time with their family. L3 participants missed morning family time on average 2.6 out of 10 days, while L2 participants missed an average of 2.0 out of 10 days.

Participants with reliability information (L3) arrived late 1.5 days out of 10 on average, while their counterparts with L2 and L1 information arrived late on average 2.1 days out of 10. The average total late-arrival cost for participants, based on the experimental framework and 10 commute days, was $45, $39, and $28 for L1, L2, and L3 information recipients. The average early arrival costs were $11, $9, and $11 for L1, L2, and L3 participants. Table 9-9 breaks down late and early costs by week and by event and non-event days. Based on the cost layouts presented to experiment participants, those receiving reliability information in addition to the other sets of information (L3 participants) had the overall lowest schedule offset cost of $38.61. In-vehicle travel time costs are not a component of the calculations presented in Table 9-9.

Table 9-9. Schedule offset costs based on experiment framework.

Costs for Sechdule Offset Based on Experimental Framework									
	Late Arrival Cost			Early Arrival Costs			Total Cost*		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
All 10 Simulation Days	$ 45.19	$ 38.54	$ 27.50	$ 10.36	$ 8.88	$ 11.11	$ 55.55	$ 47.42	$ 38.61
Week One	$ 18.27	$ 20.83	$ 15.83	$ 5.52	$ 4.05	$ 5.46	$ 23.79	$ 24.89	$ 21.29
Week Two	$ 26.92	$ 17.71	$ 11.67	$ 4.84	$ 4.82	$ 5.65	$ 31.76	$ 22.53	$ 17.32
Non-Event Days	$ 10.58	$ 9.38	$ 5.00	$ 6.40	$ 4.86	$ 6.77	$ 16.98	$ 14.24	$ 11.77
Event Days	$ 34.62	$ 29.17	$ 22.50	$ 3.95	$ 4.01	$ 4.34	$ 38.57	$ 33.18	$ 26.84

*total cost incudes only early and late schedule offset and not in-vehicle travel time

Confidence in On-Time Arrival Was Tempered with Reliability Information

Participants' level of confidence for an on-time arrival at the beginning of each trip was equivalent on average among the three traveler information groups and did not vary significantly from week 1 to week 2. At waypoint 1 (first decision point), for non-event days, arrival confidence on average was nearly the same as at the beginning of the trip. However, on event days, participants' levels of confidence for on-time arrivals decreased by 8 percent, 21 percent, and 13 percent for L1, L2, and L3 participants. Having quantitative information (L2) on delay caused a significant decrease (4.2 to 3.3, average from trip start to waypoint 1) in level of confidence, while knowing overall variability of the trip in addition to quantitative information (L3) mitigated this degradation in confidence (4.1 to 3.5, average trip start to waypoint 1).

At waypoint 2 (second decision point), the trend was similar to waypoint 1 in that arrival confidence was lower for event days compared to non-event days. L1 participants continued to have lesser confidence for an on-time arrival from waypoint 1 to waypoint 2, while L2 participants' average level of confidence increased from waypoint 1 to waypoint 2. At waypoint 2, they often passed the event causing delay and had additional information increasing their confidence for an on-time arrival. The average level of confidence for L3 participants was equivalent from waypoint 1 to waypoint 2. Figure 9-14 presents graphically the average change in level of confidence for an on-time arrival from the beginning of the trip to waypoint 1 and 2.

Reliability Information Reduced Pre-Trip and En-Route Trip Stress for Unfamiliar Trips

The level of serenity along trips was solicited through the questions asking level of stress at specific points along the trip. At the first waypoint, participants generally selected values representing neutral (value of 3) to stress-free travel (value of 5). Higher levels of traveler information generally did not equate to less stress at the first trip waypoint. Interestingly, for participants receiving L1 information, the first commute day was the day with the highest average level of stress at this first waypoint, followed by the eighth day (bad weather and highest travel times). For L2 participants, the average stress level at waypoint 1 was nearly equivalent for the first day of commute and event day 6. For L3 participants, participants found travel more stressful at waypoint 1 on most event days compared to the first day of commute. The higher serenity levels for the first day of travel (at the beginning of the trip) for L3 participants coupled with their higher willingness to pay for traveler information at this waypoint suggested that there was a value to reliability information for unfamiliar trips.

The level of serenity (1 = very stressful, 5 = stress free) selected by participants at the end of the trip was nearly equivalent to that at the first waypoint across all non-event days (average of 4.1 rating). Further inspections revealed that the level of serenity (stress reduction) was lower (by 0.4-0.5 points) for non-event days in the first week compared to non-event days in the second week. This again illustrates the learning curve with unfamiliar trips. Furthermore, as expected, participants' level of serenity for event days was on average 20 percent lower than on non-event days (4.1 versus 3.2). Average differences among groups with different information levels did not prove significant for end-of-trip serenity levels. The question soliciting happiness with trip outcome yielded findings that were nearly identical to the question soliciting level of stress information at trip end.

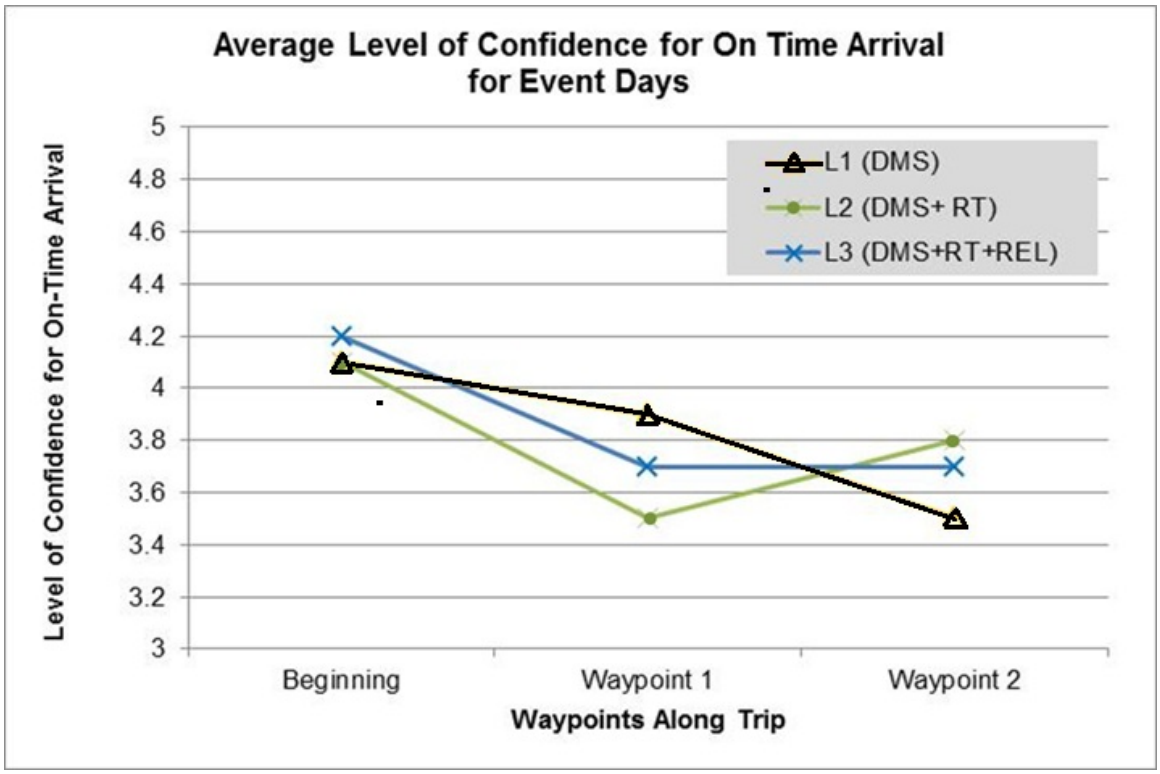


Figure 9-14. On-time arrival confidence trend during the trip.

Willingness to Pay for Traveler Information at Beginning of Trip Reflected Value for Reliability Information

The possible range of willingness to pay participants could select at the beginning of the trip was $0.00 to $1.50. At the beginning of each trip day, participants' willingness to pay for traveler information was slightly higher on average for L3 information ($0.61) compared to the other two groups ($0.54 for L1, $0.55 for L2). Furthermore, the willingness to pay trend line had a negative slope for L3 participants. Providing reliability bands, in addition to real-time travel times, helped participants become familiar with the work trip more quickly; consequently, they were willing to pay less for information at the beginning of the trip further into the experiment. Conversely, the willingness to pay trend line had a positive slope for L2 participants, suggesting

that the real-time information was continuing to help them gain an inherent understanding of the trip's variability. Figure 9-15 presents these trends; however, these trends likely would have changed had participants completed additional simulation days.

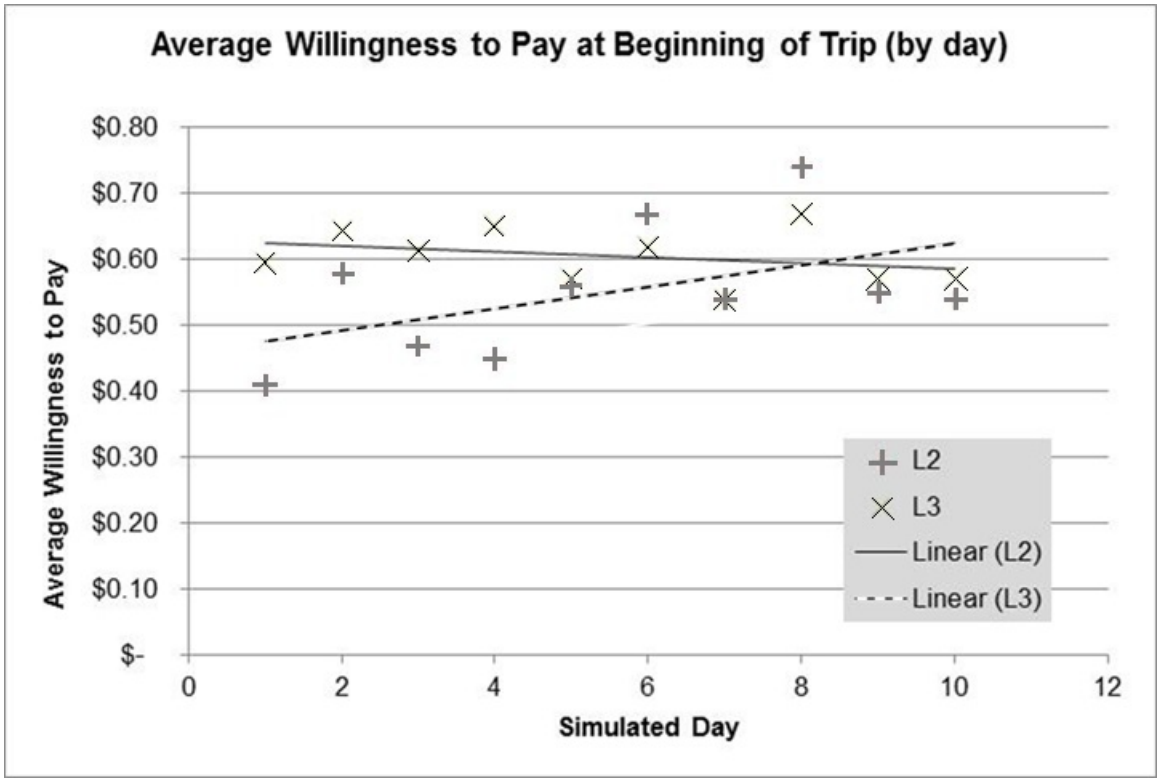


Figure 9-15. Trend in willingness to pay (at beginning of trip) across simulation days.

The possible range of willingness to pay participants could select at the end of the trip was $0.00 to $5.00. The average among the three groups was $2.30. Surprisingly, this measure did not show significant sensitivity in aggregate from week 1 to 2 or for event and non-event days. Participants were, on average, willing to pay only slightly more ($0.02-$0.07) for traveler information on event days compared to non-event days; however, these differences were not statistically significant. Further, participants receiving L1 information were, on average, willing to pay $0.15-$0.17 more per trip compared to participants receiving L3 and L2 information.

Traveler Information Provided Trip Serenity Even When Trip Outcome Could Not Be Improved

Traveler information can benefit travelers even when the information itself does not reduce travel time by allowing travelers to adjust their schedule to accommodate a late arrival. In the simulation experiment, participants were allowed an opportunity to simulate a call to work to inform their employer that they would be arriving late (and avoid the $25 late-arrival penalty). This penalty avoidance could only be used once during the simulated two-week period. We compared the trip characteristics and trip experience for each participant who used this opportunity against another trip made by the same individual where the arrival outcome was also

that of a late arrival but without the call option exercised. The expectation was that having the opportunity to call the employer would provide a level of serenity that would translate into lower trip stress, greater happiness with trip outcome, and higher perceived usefulness of traveler information compared to a comparable trip without the call option.

Among the 80 participants, 33 arrived late and chose to inform their employer of a late arrival. Of these 33, 11 called their employer at the first waypoint, and 22 did so at the second waypoint. Of the 33 participants, 7 did not arrive late any other day. Consequently, the sample set became 26 because a point for comparison was not available for those 7 participants. A few of the 26 participants arrived late on multiple days. For this circumstance, the day with an arrival delay similar to the day they chose to call their employer was selected for a paired comparison.

Of the 26 paired trips analyzed, 6 pairs were made by participants who received L1 traveler information, 11 pairs were made by participants who received L2 traveler information, and the remaining 8 were made by participants who received L3 traveler information. The paired trips had the same departure time for 20 of 26 pairs. In three pairs, the trip where the call to employer was made departed at 8:00 a.m., while their counterpart departed at 8:15 a.m. The reverse occurred for the remaining three pairs.

On average, the 26 trips for which a call for late arrival was made required 5 minutes of additional in-vehicle time and arrived 5 minutes earlier than their paired counterparts. When able to call their employer regarding a late arrival, participants found the trip less stressful, were happier with their trip outcome, and found traveler information more useful. The difference with regard to happiness of trip outcome was statistically significant at the 99 percent level and the difference in the usefulness of traveler information was statistically significant at the 95 percent level. All other differences were statistically significant at the 90 percent level with the exception of willingness to pay, where the difference was significant at the 80 percent level. Outcomes of the paired analyses are presented in Table 9-10.

Table 9-10. Value of late-arrival information, expanded sample size.

Trip Metrics sample size = 26 paired trips	Average Trip Value		Statistical Sig. of Differences in Paired Data
	Participants Phoned Ahead	Paired Counterpart	
Average in-vehicle travel time (minutes)	61.2	56.3	95%
Average minutes late	13.9	18.8	95%
Trip Stressfulness (1=very stressful, 5=stress free)	***1.92***	***1.81***	75%
Happiness with trip outcome (1=unhappy, 5=very happy)	***2.12***	***1.31***	99%
Usefulness of traveler information (1=not useful, 5=very useful)	***3.88***	***3.19***	99%
Willingness to pay for traveler information ($0-$5)	$2.73	$2.50	85%

The fact that the difference in travel times and arrival delay were statistically significant between the paired sets suggested that the trips may not have in fact be equivalent with regard to travel times and arrival outcome. Upon further investigation, it was observed that for 14 of the 26 paired trips, the difference in arrival delay was greater than 10 minutes and that these differences may have clouded the assessment of serenity benefits. Therefore, a second analysis with only 12 paired trips was conducted.

This more focused analysis confirmed that knowledge of a late arrival en route provided a serenity benefit as captured by lower trip stress, greater happiness with trip outcome, and higher rating for traveler information usefulness. In this analysis, the differences among pairs was not statistically significant for in-vehicle travel time and average minutes late. Furthermore, for this sample, the average difference in willingness to pay for traveler information was $0.25 and was statistically significant. These findings are presented in Table 9-11.

Table 9-11. Value of late-arrival information, specific paired comparison.

Trip Metrics sample size - 12 paired trips	Average Trip Value		Statistical Sig. of Differences in Paired Data
	Participants Phoned Ahead	Paired Counterpart	
Average in-vehicle travel time (minutes)	58.2	56.4	75%
Average minutes late	8.2	7.7	75%
Trip Stressfulness (1=very stressful, 5=stress free)	***2.33***	***1.75***	93%
Happiness with trip outcome (1=unhappy, 5=very happy)	***2.50***	***1.50***	99%
Usefulness of traveler information (1=not useful, 5=very useful)	***4.25***	***3.25***	99%
Willingness to pay for traveler information ($0-$5)	**$2.75**	**$2.50**	96%

APPLICATION OF RESULTS IN TRAVEL UTILITY FUNCTIONS

A typical method for valuation of trips to work involves the application of the cost function (utility model) proposed by Small et al. (1999). This model, based on a population of commuters along SR 91 in California, estimates in-vehicle travel time to cost $3.38 per hour, which authors professed is low. They attributed this low value to participants placing greater interest on trip variability tradeoffs. The cost per hour for late arrival is $18.60 with a $2.87 one-step penalty for arriving late. Furthermore their models' cost for early arrivals provides a quadratic penalty for very early arrivals.

Application of this utility model, and model parameters, to all trips simulated in this experiment yielded an average cost of $5.25 per trip, or $52.55 for the set of 10 trips. This cost includes early- and late-arrival costs as well as in-vehicle travel time. Trip costs were slightly lower for L3 participants compared to L1 and L2, but the differences were not statistically significant. Table 9-12 breaks down late and early costs by week and by event and non-event days. As expected, total per-participant trip costs for event days were far greater than costs on non-event days, and these differences were statistically significant. Difference in cost among different traveler information groups was not statistically significant for event days.

Table 9-12. Application of Small et al. utility framework.

Costs for Sechdule Offset Based on Small et al Framework									
	Late Arrival Cost			Early Arrival Costs			Total Cost*		
	L1	L2	L3	L1	L2	L3	L1	L2	L3
All 10 Simulation Days	$ 10.84	$ 11.87	$ 9.69	$ 24.08	$18.52	$ 25.02	$ 53.76	$ 50.62	$ 53.05
Week One	$ 5.69	$ 7.91	$ 6.37	$ 14.05	$ 9.10	$ 13.06	$ 28.62	$ 27.19	$ 28.40
Week Two	$ 5.14	$ 3.96	$ 3.32	$ 10.03	$ 9.42	$ 11.97	$ 25.14	$ 23.43	$ 24.65
Non-Event Days	$ 1.89	$ 1.48	$ 0.82	$ 15.64	$10.35	$ 16.31	$ 24.11	$ 19.80	$ 23.43
Event Days	$ 8.95	$ 10.39	$ 8.86	$ 8.44	$ 8.16	$ 8.71	$ 29.65	$ 30.83	$ 29.61

*total cost includes late and early schedule offset plus in-vehicle travel time

The schedule offset costs as outlined in the experiment and the trip costs as per Small et al.'s model admittedly are inherently different in form; consequently, these cannot be directly compared. Small et al.'s model has a greater penalty for very early arrivals and lesser penalty for late arrivals compared to the simplified framework of this experiment. Furthermore, the total costs based on the experimental framework do not include in-vehicle travel time.

What does prove useful from this experiment is participants' valuation of trip serenity. Based on participants' stated willingness to pay for traveler information, and differences in this value when being able to simulate a call to their employer while having same trip outcome, we suggest an additional term to the Small et al. model to include a cost discount for the serenity benefit of traveler information. The proposed model is:

$$c = \alpha T + \beta_{SDE}(SDE) + 2\ \beta_{SDE2}(SDE)^2 + \gamma(SDL) + \theta D_L + \lambda D_I$$

c: *Cost of travel (disutility)*
T: Travel time
SDE: Schedule delay early
SDL: Schedule delay late

D_L: Late-arrival index $= \begin{cases} 1 & \text{if } SDL > 0 \\ 0 & \text{otherwise} \end{cases}$

D_I: Late-arrival info index $= \begin{cases} 1 & \text{if late arrival information is acquired en - route} \\ 0 & \text{otherwise} \end{cases}$

Based on this model form, the λ reflects the reduction in trip cost for having information en route that the outcome of the trip will be a late arrival. The proposed value λ based on the findings of this study would be -$0.25. This value is based on an average trip length of 55 minutes with an approximate travel time range of 45-70 minutes. Traveler information of late arrival was received by participants on average 35 minutes into the trip, which was 20 minutes prior to their trip end and 15 minutes prior to their planned arrival.

To note, in the pre-experiment survey, participants' average willingness to pay for knowledge of a late arrival for the trip to work ranged from $0.30 to $1.23, depending on how important an on-time arrival was for the group. The average willingness to pay among participants was $1.08 based on a 10-point scale from $0.00 to $5.00. These findings compared to those from the experiment illustrate that stated willingness to pay was somewhat higher that what was measured in the simulation, but both stated and observed significance of information on late arrivals was valuable.

CONCLUSIONS AND NEXT STEPS

In this section, we summarize experimental findings with respect to our three key experimental hypotheses. In addition, a number of next steps are identified for possible inclusion in possible follow-up experimentation.

Summary of Findings by Experimental Hypothesis

The first hypothesis stated that provision of accurate reliability information would result in improved on-time performance and lower generalized travel disutility compared to a control group receiving no reliability information.

Findings from this study supported this hypothesis. Experimental participants who received reliability information were on time more frequently (85 percent versus 79 percent) and had lower total late and early arrival penalties associated with the simulated trip ($38.61 versus $47.42 and $55.55 in the two control groups). Both findings were statistically significant with 95 percent confidence despite the relatively small sample size of the experiment.

The second hypothesis proposed that while travel outcomes improved with the provision of reliability information, the perceived value of the reliability information would underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.

Findings from this study supported this hypothesis. Measured perceptions of benefit associated with reliability information were not commensurate with the observed improvements in trip outcomes. Changes in the value of information and stress reduction, although generally favorable to reliability information, were not statistically significant. The implication is that although reliability information can be useful in managing trip time variability, the apparent value of this information is lost in the context of learning over time. It is likely that the experimental subjects internalized the reliability information as one element in this learning process, rather than considering its value outside of their learning process. Providers of reliability information may face an uphill battle in measuring perceptional impacts of reliability information impacts even when such information is useful in improving trip outcomes.

The third hypothesis was that benefits of reliability information would decline over time as both experimental and control subjects learned and internalized an understanding of underlying travel time variability. That is, the benefit from reliability information in the first few weeks would be larger than in the last few weeks.

Findings from this study were inconclusive. Participants with access to reliability information did see total early- and late-arrival penalties decline from week 1 to week 2 of the simulated trip-making. Control groups who did not receive this information were mixed, with one group realizing a reduction in total costs and another seeing a rise in these costs. Interestingly, participants' willingness to pay for reliability information declined over time in the simulation experiment, indicating that experience within the simulated trip began to offset the reliance on provided reliability information.

Based on the post-experiment survey, for groups without reliability information, many more individuals perceived a positive overall usefulness of traveler information at the end of the experiment than at the beginning. In contrast, in the group with reliability information, the swing toward the positive proved more muted. This suggests that as groups without reliability information used the real-time information to learn about trip variability, more found value in the information. For those with reliability information, trip variability knowledge was already

present; consequently, its usefulness remained consistent from the beginning to the end of the experiment. Overall, however, a two-week period was observed to be too short to make any definitive statements regarding this hypothesis.

Chapter 10 ENHANCED LABORATORY EXPERIMENT

Reliability information encompasses a broad range of information that describes underlying trip variability and other contextual data travelers use to manage delay and on-time performance. This includes information describing the statistical variation in travel time dependent on a departure time choice, data describing on-time performance and lateness risk by route and destination, and contextual information to interpret cueing throughout the travel experience—all allowing travelers to better assess travel time and lateness risk both pre-trip and en route.

The SHRP 2 L14 project, prepared a lexicon to provide guidance on the provision of reliability information for transportation operations professionals, agency public information officers, and the research community regarding the provision of reliability information. The lexicon is intended to both orient the reader regarding the concept and potential value of reliability information as well as provide guidance on the terms, graphics, and delivery media used to provide reliability information.

Toward the development of the lexicon, researchers completed two parallel activities, each addressing a specific aspect of reliability information. First, coordinated focus groups and survey instruments were utilized to develop a draft lexicon of phrases that could be used to convey reliability information. Second, a protocol and experimental materials were developed to quantitatively assess the value of reliability information in a travel behavior simulation. The benefits from reliability information were measured in terms of improved traveler on-time performance, reduced total time allocated to travel, and reduced stress regarding uncertainty about on-time arrival (Shah and Wunderlich, 2011).

While identifying terms and phrases preferred by travelers in describing travel time reliability, the lexicon development effort did not quantitatively evaluate the effectiveness of reliability-related terms and phrases in improving on-time reliability. The initial experiment showed that providing reliability information does improve on-time performance and reduce delays (even in the presence of real-time condition information). However, the initial experiment did not include a systematic assessment of alternative terms, phrases, or delivery media for reliability information.

The goal of this experiment was to quantitatively evaluate through a travel simulation the effectiveness of reliability-related terms, phrases, and delivery media in reducing traveler stress and improving on-time arrival reliability. Additionally, the experiment solicited perceptions of information value and understandability. Further, this experiment tested the hypothesis that reliability information will expedite the transition from unfamiliar traveler to routine commuter.

This chapter defines the experimental plan and outlines the specific experiments and surveys that were implemented to meet the scope and hypotheses described in the following subsection. It also summarizes the findings from the pre-experiment survey, focusing on the demographic and trip-making characteristics of study participants. Additional chapter content includes detailed findings from the first simulation experiment (experiment #1), highlighting the valuation and quantitative benefits from different forms of pre-trip reliability information; a summary of the

findings from the second experiment (experiment #2), quantifying the change in reliability information valuation and benefits over a one-month simulation period; and an exploration of the ratings and rankings on the usefulness and complexity of the reliability forms specifically for use with experiment #1 and for use in general trip planning associated with unfamiliar trips. The final section presents in a succinct format the findings of this experiment with regard to the defined hypotheses and suggests future research options.

EXPERIMENT SCOPE AND HYPOTHESES

Although reliability information can be useful to any traveler, one result from earlier research using focus groups indicated that reliability information can be most usefully targeted at unfamiliar travelers who are planning or executing a trip where there is a high level of uncertainty regarding travel time and on-time performance. These unfamiliar travelers are most likely to underestimate or overestimate travel times and have the highest stress associated with on-time reliability, precisely because they have not made these trips many times and accumulated experience related to travel time, delays, and the underlying pattern of variation on potential travel routes. Further, reliability information is expected to prove effective at expediting the transition from unfamiliar traveler to routine commuter. Consequently, this set of experiments focused on the unfamiliar traveler.

Observed in many disciplines including traffic operations is that direct assessments of comprehension are often worse than comprehension assessed through indirect means, such as a freeway lane choice in a driving simulator in response to a particular guide sign design. The travel behavior simulation approach used in this experiment provided a way to indirectly assess comprehension and can be thought of as a type of revealed preference survey as well. This study examined three key hypotheses:

1. Provision of accurate reliability information (in an easy-to-understand format) will result in improved on-time performance and lower generalized travel disutility compared to a control group receiving no reliability information.
    a. While travel outcomes improve with the provision of reliability information, the perceived value of the reliability information will underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.
    b. Provision of reliability information using different textual, graphical, and auditory forms will result in differences in both accrued on-time reliability benefits as well as perceived benefit. We expect these differences among experimental groups will be smaller than between any group and the control (no reliability information) group.
2. Experimental subjects receiving contextual information on underlying variation with numeric indicators reinforced with en-route information (reliability signposting) will have improved on-time performance compared to both an experimental group that receives reliability information but no contextual information as well as a control group that receives no reliability information.

3. Benefits of reliability information will decline over time as both experimental and control subjects learn and understand the underlying travel time variability. That is, the benefit from reliability information during the first weeks will be larger than during the last weeks.

Phrases describing reliability identified as preferred by travelers in the lexicon were quantitatively evaluated in a controlled experiment to answer the hypotheses proposed above. The specific phrases, graphics, and delivery media evaluated in the experiment were selected based on the lexicon findings and accepted by the SHRP 2 L14 Technical Expert Task Group. The specific reliability-related terms, phrases, and delivery media assessed in this experiment are listed below:

1. Text-based 95th percentile travel time referred to as "the majority of the time."
2. Text-based average and 95th percentile travel time referred to as "estimated travel time and extra time for unexpected delays."
3. Text-based 20th, average, and 95th percentile travel time referred to as "good day," "typical day," and "bad day."
4. Text and visual/colored signposting with travel time ranges associated with color.
5. Graphical average and 95th percentile arrival time with a legend identifying data as "estimated and extra time."
6. Graphical 20th, average, and 95th percentile arrival time with a legend identifying data as "good day," "typical day," and "bad day."
7. Voice-based 95th percentile travel time referred to as "the majority of the time."

These seven presentations of reliability data were introduced to subsets among 240 participants from three metropolitan regions: Washington, DC; Chicago, Illinois; and Houston, Texas. The reliability information presented to experiment participants did not vary from day to day but did instead reflect the historic reliability of travel along a route by time of day. In addition to the reliability information, all participants received pre-trip and en-route advisory message sets that reflected radio and qualitative dynamic message sets.

EXPERIMENTAL PLAN

Two experiments were developed and implemented to address the study hypotheses. Both experiments used the framework of the travel behavior simulation approach developed in previous efforts (Shah et al., 2011); however, the implementation of this framework differed by the type of travel and information provided. The content of each experiment was developed to work within the constraints of overall testing session length (90 minutes). Within the framework of the experiments, participants selected a departure time based on pre-trip information, experienced travel time as a function of trip duration, and rated the value of the information simulated from day to day.

In both experiments, the reliability information presented to participants did not vary from day to day but instead reflected the historic reliability of travel along a route. In addition to differing levels of reliability information, all participants received pre-trip and en-route advisory messages that reflected qualitative dynamic message sets and radio messages, albeit in text format. In both

experiments, the participants selected a departure time within a 30-minute window to minimize schedule offset for a morning commute along a single route along freeway facilities.

The experiment was conducted in three cities—Chicago, Houston, and Washington, DC, over a period of two months and acquired information from approximately 240 participants. Experiment participants were recruited through advertisements on Craigslist.com. Requirements for participation included a valid U.S. driver's license; fluency in reading, writing, and speaking English; a commute to work that included 20+ minutes of freeway travel; and familiarity with online mapping tools such as Google Maps or MapQuest. The last of these requirements was placed to ensure that participants would have proficiency in the use of computers and familiarity with viewing maps, which were the basis for visually presenting the travel simulation.

Table 10-1 presents the number of participants by city. These cities were selected to include a diverse survey population that had experiences with high levels of traffic congestion, commute lengths, and highway network connectivity.

Each participant was provided and used a dedicated laptop with a mouse and headphones. Participants were required to use the mouse to click on interface buttons, radio buttons, or drop-down menus. Participants did not use the keyboard for any part of the experiment. Upon arrival in the survey room, participants were seated and provided a brief explanation about the intent of the experiment. Participants in both experiments completed the same pre-experiment survey of 12 multipart questions, followed by the group-led experiment and varying post-experiment surveys. Appendix G lists the specific data types requested and generated from the pre-experiment survey questions.

Table 10-1. Experiment layout and sample size using two distinct experiments.

Experimental Layout and Sample Size							
Two Distinct Experiments:		**#1** 5 cities, 1 week each city*				**#2** 1 city*, 4 weeks	
	Implementation Version	1	2	3	4	5	6
	Planned Participant Count	90	30	30	30	30	30
	Valid "good" Participant Count	98	29	25	33	30	30
Reliability Data Content	A. Control (no reliability info)	✓	✓	✓	✓	✓	na
	B. Textual 95th	✓	na	✓	na	na	na
	C. Textual Avg + 95th	✓	✓	✓	✓	na	na
	D. Textual 20th + Avg + 95th	✓	✓	na	✓	na	na
	E. Visual and textual signposting	✓	na	na	na	na	na
	F. Graphical presentation of "C"	na	✓	✓	na	na	na
	G. Graphical presentation of "D"	na	✓	na	✓	na	✓
	H. Auditory presentation of "B"	na	na	✓	✓	na	na
*city refers to travel in simulated city for participants and not city of experiment implementation							

The travel behavior simulation was programmed using VBA within the Microsoft Excel environment. Several iterations of quality assurance and testing were completed on the multiple laptop computers used in the field to create and support consistent visual appearance and accurate macro execution based on varying performance levels and settings among field laptops. Figure 10-1 presents the screenshots of the Excel-based interface, which served as the starting point for experiment participants for experiments #1 and #2. The screenshots are identical with the exception of the post-game survey, which was implemented within experiment #1 but was not relevant to experiment #2.

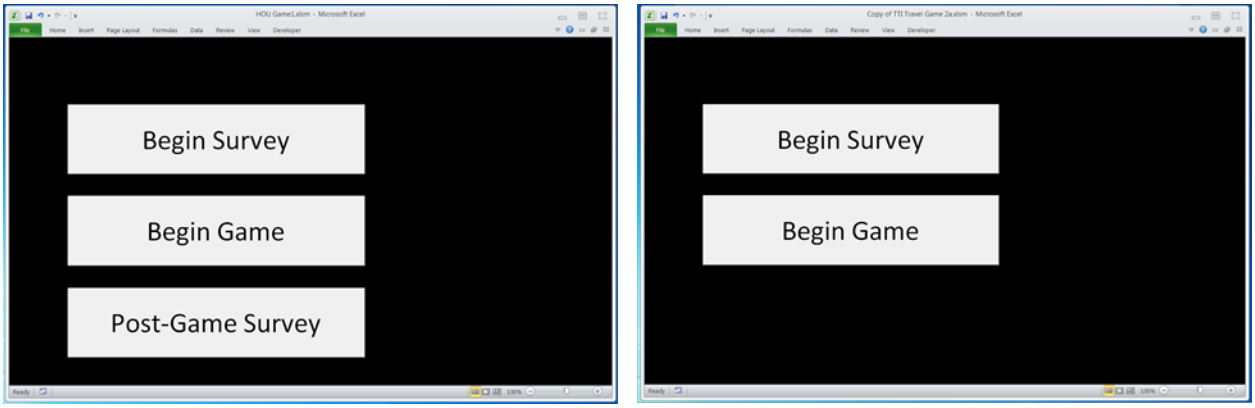


Figure 10-1. Beginning screenshot for experiment #1 (on left) and #2 (on right).

Participants independently completed the pre-experiment survey ("Begin Survey" button in Figure 10-1) and waited for a moderator to jointly commence the commute experiment ("Begin Experiment" button in Figure 10-1). The pre-experiment survey requested socioeconomic, travel purpose, roadway usage, and schedule integrity information. This socioeconomic information framed the characteristics of participants and can be compared against the population at large or with other future experimental groups. The travel purpose, schedule integrity, and roadway usage questions together identified the types of trips for which on-time arrival was most important to participants, the frequency with which these trips were made, and whether the trips for which on-time arrival was most critical were made on roadways where traveler information was usually available. The detailed descriptions and outcomes of the pre-experiment survey are presented later in this chapter.

The commute experiment began through instruction to the participant group by the moderator. The moderator read aloud the contextual setup text presented in the experiment and informed participants that different individuals would have access to differing levels of traveler information. Participants selected departure time, their confidence in arriving on time, and usefulness of trip information before beginning each trip. The interface presented the movement of a vehicle along segments of the defined route. The duration of the vehicle travel paralleled by a factor the trip duration based on the selected departure. For example, a 30-minute trip required the participant to view progress over 6 seconds, while a 60-minute trip required the participant to view progress over 12 seconds.

At the end of each simulated trip, participants were provided trip outcome statistics in the form of simulated arrival time, trip duration, schedule offset, and cost of travel. At the end of each trip, participants were also asked to indicate willingness to pay for traveler information, trip stress level, and traveler information usefulness. Figure 10-2 presents two screenshots of the Excel-based interface for making the initial trip departure decisions and for the trip experience for a specific day of commute. Figure 10-2 also illustrates the implementation of the highway message board.

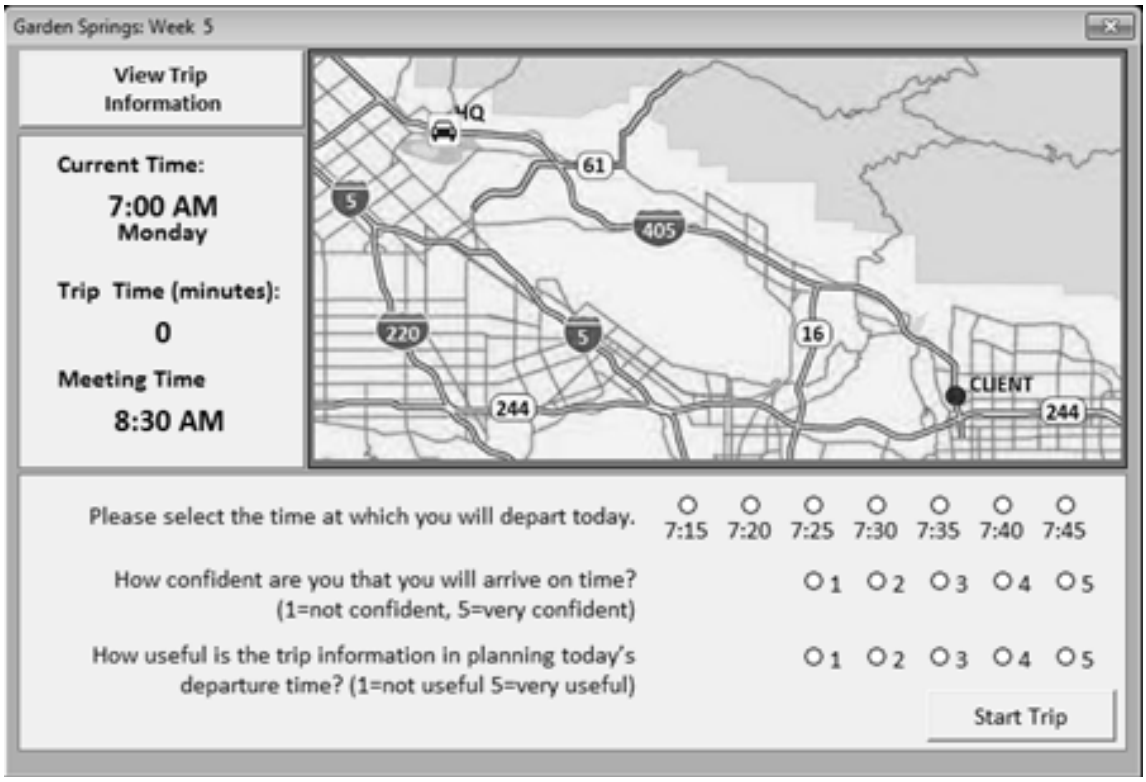


Figure 10-2. Screenshots of trip departure decisions and travel along route.

The moderator supported participants for the first day of travel by presenting on large visual images the location of specific types of information and decision sets. Thereafter, participants independently navigated information and made commute decisions at their own pace to complete commutes to work over a one-week period. Participants were still given the option of moderator support for navigating the experiment but not for interpreting reliability information.

Travel time and radio message data supporting the experiment were designed to represent a moderate level of trip variability as well as temporal consistency among departure time, traveler information, and trip experiences. The outcomes from the commute experiment are presented later in this chapter.

Pre-Experiment Survey

The pre-experiment survey was delivered to all participants and developed a baseline of participant characteristics that were useful in comparing participant characteristics with the population at large. Key data acquired through the surveys for this comparison included gender, age, educational level, and traveler information usage. Additionally, the survey questions aimed to explore whether the participant population made trips that would benefit most from traveler information—that is trips that were sufficiently long, required stringent on-time arrivals, and used facilities where such information would be available (i.e., highways). Participants with these routine trip-making characteristics were likely to better internalize trade-off requested in the simulation experiment, and their responses were more likely to reflect true trip decision-making. The specific text of pre-experiment questions and the response options for questions are presented in Appendix H.

The survey questions also enabled the development of lateness thresholds, that is, exploring what participants perceived as arriving late based on their specification for on-time arrival importance and trip purpose. These thresholds can be applied in future work to refine the form of utility functions.

Willingness to pay for guaranteed travel time (zero trip variability/100 percent trip reliability) and willingness to pay for knowledge of late arrival were both assessed to compare with sensitivities observed through the experiment. We expected *a priori* that participants with high on-time arrival importance would be willing to pay more for this guarantee or arrival outcome information.

Experiment #1 Description

The first experiment framed the simulation as that of traveling for work to 5 different cities and commuting for 5 weekdays from each city's regional headquarter to a morning client meeting that was 40-60 minutes from headquarters. Each participant experienced four of the seven reliability-related data, a specific term each for a week. During one week, there was no reliability-related data. The order of the type of data received was randomly defined. The visual make-up of highway and arterials for each of the simulated cities was fictional and did not parallel any actual city. This was done to remove the potential for participants' affiliation and familiarity with traffic in actual cities.

The goal of the first experiment was to quantitatively evaluate the effectiveness of reliability-related terms, phrases, and delivery media in reducing traveler stress and improving on-time arrival reliability. Additionally, the first experiment solicited perceptions of information value and understandability. The specific reliability-related terms, phrases, and delivery media assessed were compared to a baseline without reliability information. The baseline and reliability terms tested in this experiment are listed below. The visual delivery of these message sets through the simulated commute is presented in Appendix H.

- No reliability information (baseline).
- Text-based 95th percentile travel time referred to as "the majority of the time."

- Text-based average and 95th percentile travel time referred to as "estimated travel time and extra time for unexpected delays."
- Text-based 20th, average, and 95th percentile travel time referred to as "good day," "typical day," and "bad day."
- Text and visual/colored signposting with travel time ranges associated with color.
- Graphical average and 95th percentile arrival time with a legend identifying data as "estimated and extra time."
- Graphical 20th, average, and 95th percentile arrival time with a legend identifying data as "good day," "typical day," and "bad day."
- Voice-based 95th percentile travel time referred to as "the majority of the time."

Based on the experimental design outlined in Table 10-1, six unique city networks were developed such that a participant experienced a different visual network/city with each of the five weeks of commute. Table 10-2 identifies for each information type the name of the associated simulated city and the specific off-peak travel times, meeting time, and departure options available.

A narrative was presented on screen and communicated verbally to prepare participants for the simulation experiment. In essence, participants were in a new town for work and had to arrive on time to work or otherwise incur a $25 late-arrival fee. Early arrival cost (parking cost) was introduced at $12.00 per hour. Participants were requested to select among 7 departure times and multiple routes for a simulated travel to work over a 5-week period, totaling 25 commutes. This narrative and the visual of each simulated city are included in Appendix H.

Table 10-2. Linking reliability information type with simulated city and departure options.

Defined Simulated City, Departure and Required Arrival Options by Reliability Information Type							
Info Code	**Reliability Information Type**	**City**	**City Name**	**Off-Peak Travel Time**	**Meeting Time**	**Departure Time Range (earliest-to-latest)**	
A	Baseline	1	Prairie Cliffs	30	8:30 AM	7:25 AM	7:55 AM
B	Text 95th	2	Garden Springs	30	8:00 AM	6:55 AM	7:25 AM
C	Text 95th + average	3	Port Frederick	40	8:30 AM	7:15 AM	7:45 AM
D	Text: Good, Typical, Bad	4	Sioux Rapids	50	9:00 AM	7:35 AM	8:05 AM
E	Reliability Signpost	5	Harrisonville	30	9:00 AM	7:55 AM	8:25 AM
F	Graphic 95th + Avg	5	Harrisonville	40	8:00 AM	6:45 AM	7:15 AM
G	Graphic: Good, Typical, Bad	1	Garden Springs	50	8:30 AM	7:05 AM	7:35 AM
H	Audio: 95th + average	6	New Glaxtonberg	40	9:00 AM	7:45 AM	8:15 AM

For each week, or conversely, for each reliability information type, participants experienced one good traffic day, two typical traffic days, one day somewhat worse than typical, and one that was a bad day. The order of these five days varied from city to city, while the order of the cities varied from participant to participant. Travel times generally increased with later departure options. Appendix H presents the data that fueled participant trip experiences by city, day of the week, and time of day.

Participants in this experiment made two valuations and a departure time decision pre-trip, as well as three valuations at the end of each simulated commute. Additionally, at the end of each week, participants provided five additional valuations, both of which repeated inquiries pre- and post-trip. When making end-of-week valuations, participants were provided summary statistics for the week's travel and a visual of the reliability information made available to them that week. Participants were also instructed to share their achievement expressed through cost of travel at the end of each week to encourage investment in engaging the simulated decision-making.

These pre-trip valuations, post-trip valuations, and end-of-week valuations were based on a 5-point scale with 1 representing the least value and 5 representing the greatest value. These valuations included:

- Pre-trip usefulness of traveler information (1 = not useful, 5 = very useful).
- Pre-trip on-time arrival (OTA) confidence (1 = not confident, 5 = very confident).
- Post-trip usefulness of traveler information (1 = not useful, 5 = very useful).
- Post-trip level of stress in completing the trip (1 = not stressful, 5 = very stressful).
- Post-trip willingness to pay for information per trip ($0, $1, $2, $3, $4).
- End-of-week information helpful in reducing commute stress (1 = not at all, 5 = absolutely).
- End-of-week overall information usefulness (1 = not useful, 5 = very useful).
- End-of-week information helpful in better managing departure decisions (1 = not at all, 5 = absolutely).
- End-of-week level of difficulty in understanding information (1 = very easy, 5 = very difficult).
- End-of-week willingness to pay per trip for information viewed ($0, $1, $2, $3, $4).

At the end of this experiment, participants were instructed to complete the Excel-based post-trip survey. This survey presented the set of four reliability terms used during the experiment and asked participants to rate the relative value of each form of reliability information with regard to useful and complexity. Findings from this post-experiment survey as well as other post-experiment metrics are presented later in this chapter.

Experiment #2 Description

The second experiment framed the simulation as that of traveling to a new city for work and making daily departure time decisions to work for a month (four weeks, five days a week). This second experiment tested the hypothesis that reliability information will expedite the transition from unfamiliar traveler to routine commuter. Here, half of the participants received graphical 20th, average, and 95th percentile arrival time reliability information with a legend identifying

data as “good day,” “typical day,” and “bad day.” This reliability information was labeled type G and is presented in Table 10-2. The other half of the participants did not receive reliability information, which is presented in Table 10-2 by information code A. Both groups of participants received pre-trip and en-route advisory messages that reflected qualitative dynamic message sets and radio messages, albeit in text format.

The process by which they received information was similar to that described in the opening narrative included in Appendix H. Differences included the fact that reliability information type A used the same data and simulated city layout as information type G, New Glaxtonberg. The travel time and radio message data viewed in experiment #2 was the same as that for experiment #1. The transition screen of simulated commutes from week to week was that of a weekly planner rather than an aircraft as used in experiment #1. Finally, slight differences were made with regard to weekly summaries.

End-of-week valuations and post-experiment valuations were not collected for this experiment given that the objective was to evaluate trip decisions and outcomes. In lieu of these, and based on post-hoc analysis of experiment times for completion of experiment #2 at the first city execution of the experiment (Washington, DC), the team chose to implement a second, paper survey instrument for experiment #2 participants as well as for experiment #1 participants who finished earlier than others. This survey is also included in Appendix H.

PRE-EXPERIMENT SURVEY FINDINGS

The pre-experiment surveys completed through the Excel-based interface provided insight on the characteristics and travel sensitivities of participants. The intent of the pre-experiment survey was also to determine how well suited the general travel characteristics of participants were to the simulation scenarios they experienced in the experiment. All participants completed the pre-experiment surveys (n = 251). The findings from this survey are summarized in the following subsections and highlighted here.

Overall, many participants did make long trips for work and other trip purposes. They often indicated having high on-time arrival importance as well as low thresholds for late arrivals. More individuals valued reliability (guaranteed travel time) and were willing to pay more for a reliable travel time compared to valuation of late-arrival knowledge. Participants frequently used traveler information for their work commutes. Participant characteristics exhibited in the pre-experiment survey paralleled the simulation scenarios that were presented to participants through the experiment. Consequently, participants were well suited for and were likely to respond effectively to the simulation experiment.

Demographic and Trip-Making Characteristics

Experiment participants leaned toward the male gender and were generally older and more highly educated compared to national averages. Nearly 60 percent of participants were male, and the median age range among all participants was 40-49 years. Close to half of all participants had a college degree or higher, whereas only 25 percent of the U.S. population (age 25 and older) has completed a college or postgraduate degree. The implication of the

demographic difference between the study participants and the population at large is unclear. A more highly educated sample may potentially be better able to interpret traveler information; however, an older population may be less familiar with technology applications.

Participants were asked to record the frequency with which they made work, childcare, school, medical, and other routine trips. Trip-making frequency choices presented to participants included never, less than once a month, 1-3 times a month, once a week, 2-4 times a week, and daily. All participants made trips for childcare (100 percent), and nearly all made trips for work (98 percent), medical appointments (90 percent), or other trips (92 percent) with some frequency. Conversely, 69 percent of participants never made school-related trips. Additionally, although nearly all participants made work-related trips, only 71 percent commuted daily to work. Furthermore, 57 percent made daily trips for childcare. As expected, only 2 percent of participants made daily medical-related trips, and 8 percent made daily school-related trips. The goal for experiment participation was to solicit individuals who routinely commuted to work, and based on the aforementioned statistics, this was achieved in selecting a participant sample.

Figures summarizing the specific distributions for gender, age, and education level, and summarizing participant trip types as discussed above, are included in Appendix I. Supplemental figures for the following section are also contained in Appendix I.

Traveler Information and Road Use Characteristics

Participants also revealed how frequently they sought out traffic information for their work trip and the media they used to acquire this information. Participants' responses were aggregated and are presented in Figure 10-. When making work trips, most (81 percent) sought out traffic information with some frequency, and over 30 percent did so five or more times a week. Most used multiple forms of media in acquiring this information. Over 60 percent of participants that sought out traffic information for the work commute consulted the radio. Further, two out of five participants used their desk/laptop or mobile device, such as a smartphone or tablet. This usage supersedes vehicle dashboard systems for acquisition of traveler information. Given these high rates of information usage, the expectation was that participants would relate well to the experimental scenarios presented of using traveler information in planning a work trip.

Given that the experiment simulated travel along highways, the pre-experiment survey requested information on the types of facilities used in making routine trips for work, childcare, school, and medical and other needs. Among individuals that made work trips, 88 percent of participants used highways or a combination of highways and arterials on their work commute. Highways were used less often for other types of trips compared to work trips. For childcare, school, and medical trip makers, 45 percent to 51 percent of participants also used highways or a combination of highways and arterials. Transit was used by only a handful of participants for all trip purposes except childcare (for which transit was not used by any participants).

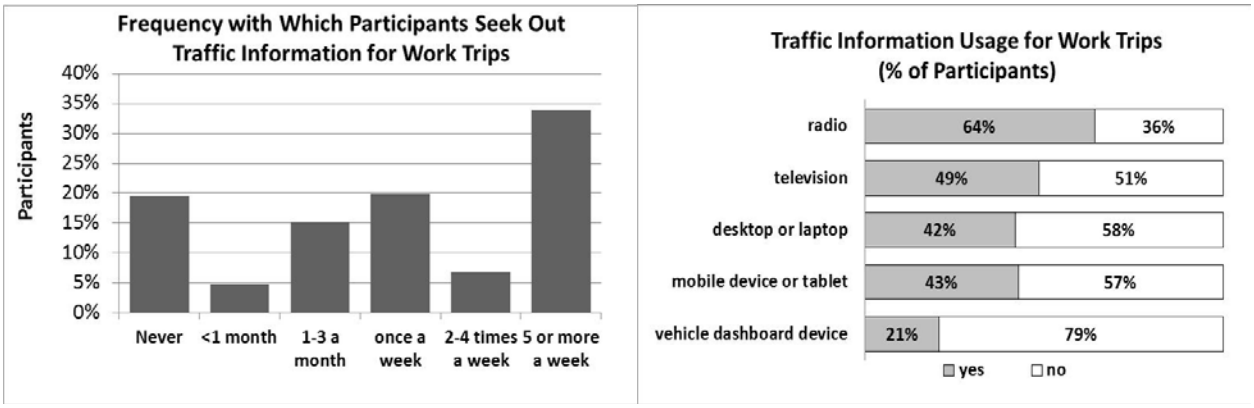


Figure 10-3. Frequency and types of traffic information used for work trips.

Importance and Definition of Arriving on Time

Participants were asked to rate the importance of an on-time arrival and were also asked about their sensitivity to arriving late. Participants overwhelmingly indicated that for work, school, childcare, and medical appointments, arriving on time was between "somewhat important" and "very important," based on a 5-point scale, with 1 equaling "not important" and 5 equaling "very important." Among participants that indicated that they made work trips, 84 percent suggested that arriving on time was very important. Arriving on time to school, childcare, or medical destinations was less frequently cited as very important. Between 64 percent to 68 percent of individuals making school, childcare, and medical trips indicated that arriving on time was very important for their trips.

Participants' ratings for importance of arriving on time did not parallel their definition for late arrival. While 84 percent indicated on-time arrival as very important for work trips, only 23 percent defined late as arriving beyond the planned arrival time (1 or more minutes late). What it meant to be late was more precise for work and childcare trips compared to the other trip purposes. Within the simulation experiment, we modeled the exact meaning for late arrival (1 or more minutes late) as was paralleled by 23 percent of participants for work trips. Almost the same proportion of childcare trip makers (24 percent) also categorized arriving late as arriving a minute beyond their scheduled arrival time. Over 80 percent of participants believed that arriving 10 or more minutes beyond a scheduled arrival was considered late. The most frequent threshold for arriving late was citied at five minutes beyond their scheduled arrival time.

Table 10-3 lists what participants on average defined as arriving late by the importance they placed on arriving on time. Across all participants and trip purposes, the average threshold for characterizing a trip as late was 13.6 minutes beyond the desired arrival time. As expected, individuals who indicated arriving on time was very important had a far smaller lateness threshold. For example, participants who indicated that a work on-time arrival was very important (category 5) believed that arriving on average 12.1 minutes past their scheduled arrival time was considered late, whereas this value was 15.8 minutes for participants who indicated that on-time arrival at work was somewhat important (category 4).

Table 10-3. Average threshold for late arrival by on-time arrival importance and trip purpose.

Lateness Threshold (minutes) Based on On-Time Arrival Importance and by Trip Purpose						
Arrival Importance (1=unimportant, 5= very important) (sample size)	*Trip Destination by Purpose*					All Trips
	work	school	childcare	medical	other	
1 (3)	5.0	na	na	6.0	15.6	11.5
2 (7)	25.1	19.2	22.0	11.3	15.4	18.5
3 (9)	20.4	12.6	17.9	19.5	17.5	17.9
4 (21)	15.8	14.6	16.2	14.1	15.5	15.1
5 (206)	12.2	12.6	11.1	11.9	12.6	12.1
Average Lateness Threshold	13.1	13.4	12.5	13.1	15.2	**13.6**

Travel Times and Trip Variability

Two pre-survey questions addressed participants' normal trip time by trip purpose and the additional time that participants' trips might take on a bad day of traffic. Trips made to work required on average the greatest travel time, while trips made for childcare required the least travel time based on participant response. The largest share of participants required on average 20-40 minutes to complete a trip. At least a few participants indicated that travel took 60 or more minutes on average to their work, school, childcare, medical, or other destination. Among participants that made work trips by car, 42 percent had an average work trip time that was similar to the times presented in the experiment (40 or greater minutes), while another 45 percent traveled slightly lower work trip times, ranging from 20-40 minutes.

Work trips had by far the greatest level of variability for participants, as is evidenced by the 42 percent that indicated their work trip time could increase by as much as 30 minutes on a bad day of traffic. Childcare trips had the least magnitudes of variability, with 52 percent of participants indicating an additional time under 15 minutes.

As a trend, participants noting longer average trip times also noted having greater magnitudes in travel time increases for bad traffic days. Figure 10- presents a 3D visual of participants' additional travel time on a bad day compared to their average travel time specifically for work trips. The highest peaks in the visual indicate that for work trips, the greatest frequency of response was for trips that took 30-39 minutes on average with an extra time of 30 or more minutes on bad traffic days. The next two most frequent replies were for work trips that were 40-49 or 60+ minutes on average with trip variability of 30+ minutes on a bad day. These three most frequent response categories are highlighted in black in Figure 10- and represent 31 percent of all participant responses for work trips.

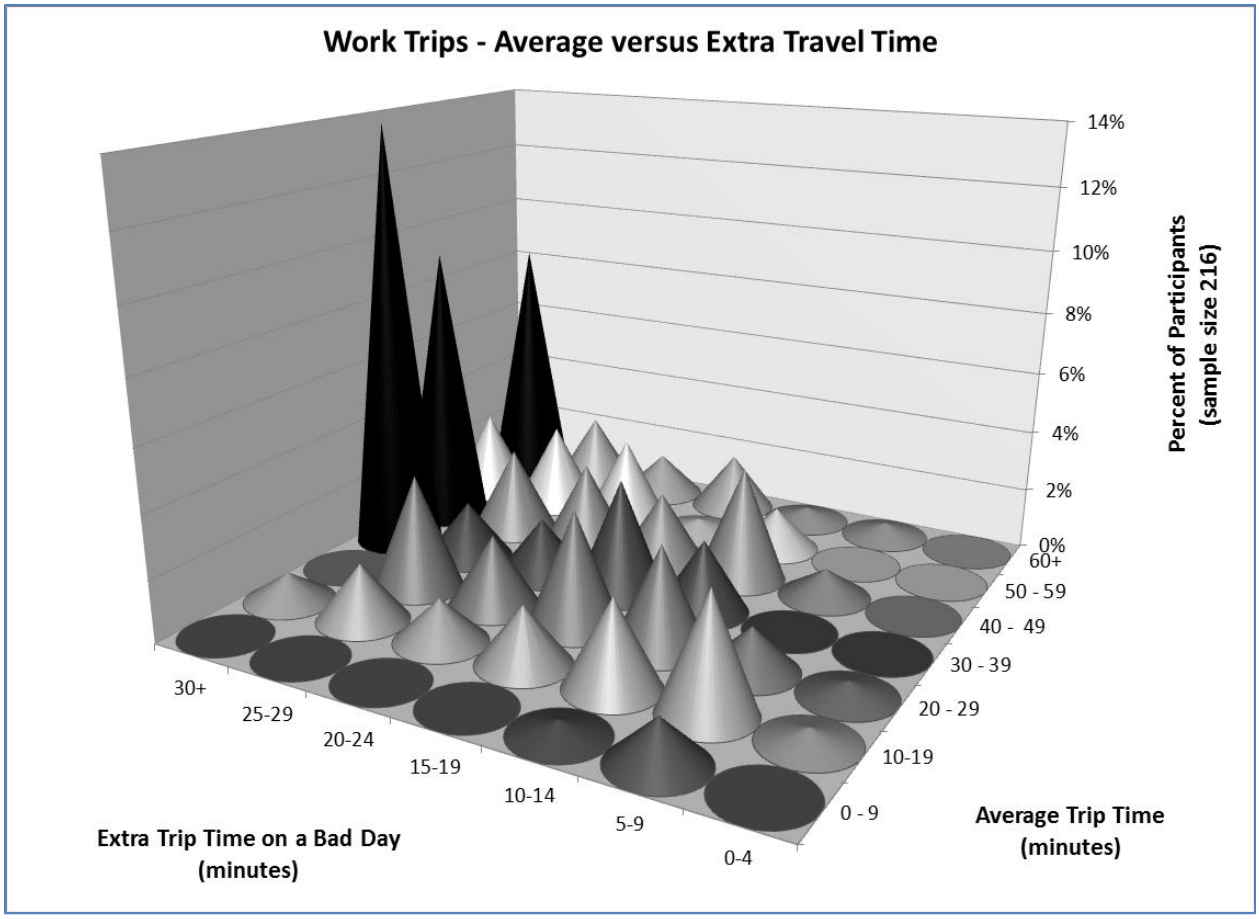


Figure 10-4. Travel time and extra time entries for work trips.

Valuation of Reliability and Serenity

Two more survey questions gauged participants' willingness to pay for a guaranteed travel time to their destination and their willingness to pay for knowledge of a late-arrival trip outcome. The first question placed a value on a guaranteed arrival time (i.e., a reliable travel time) and measured individuals' willingness to pay to eliminate uncertainty in travel times. The second question placed a value on the knowledge of an adverse trip arrival outcome (i.e., a late arrival) en route. Although an individual cannot change their trip outcome, they can use this information to adjust their subsequent activities and inform individuals of schedule offsets. Further, sometimes information, even if not acted upon, provides travelers with a greater level of serenity simply by knowing what is to come. The knowledge question, consequently, placed a value on this serenity effect.

Approximately 68 percent of individuals indicated they were willing to pay to ensure a reliable travel time. Participants more often were willing to pay for this guaranteed time for work trips compared to other trip purposes. For example, 20 percent of individuals who made work trips indicated that they would be willing to pay $4.00 to $5.00 per trip for a guaranteed travel time. This value was only 10 percent for school trips. This was, of course, because work trips had a

far higher on-time arrival importance. On average, participants who made work trips were willing to pay $1.69 per trip to eliminate trip variability. Table 10-4 summarizes the average valuation for guaranteed travel time and knowledge of late arrivals among participants for specific trip types.

The majority of individuals found value in knowing they would be late for work, school, childcare, and medical trips. Fewer individuals were willing to pay for knowledge of a late arrival (60 percent) compared to reducing trip time variability (68 percent). Further, the amounts individuals were willing to pay for knowledge of a late arrival were somewhat lower than for a guaranteed travel time. On average, participants were willing to pay $0.87 for late-arrival information en route versus $1.20 for a guaranteed travel time. This makes sense given that a guaranteed travel time mitigates adverse trip arrival outcomes, while the knowledge of a late arrival does not enable changing of an adverse trip outcome.

Table 10-4. Average willingness to pay for reliable travel and late-arrival knowledge by trip purpose based on replies to pre-experiment survey.

Trip Purpose	Value of Reliable Travel	Value of Late-Arrival Knowledge
Work trips	$1.69	$1.27
School trips	$1.05	$0.89
Childcare trips	$1.28	$1.23
Medical appointments	$1.10	$0.82
Other routine trips	$0.81	$0.27
Average	$1.20	$0.87

EXPERIMENT #1 FINDINGS—EFFECTIVENESS AND VALUATION OF RELIABILITY TERMS FOR UNFAMILIAR TRIPS

Participants in this experiment made two valuations and a departure time decision pre-trip, as well as three valuations at the end of each simulated commute. Additionally, at the end of each week, participants provided five additional valuations, both of which repeated inquiries pre- and post-trip. These valuations were based on a 5-point scale, with 1 representing the least value and 5 representing the greatest value. These valuations included:

- Pre-trip usefulness of traveler information (1 = not useful, 5 = very useful).
- Pre-trip OTA confidence (1= not confident, 5 = very confident).
- Post-trip usefulness of traveler information (1= not useful, 5 = very useful).
- Post-trip level of stress in completing the trip (1 = not stressful, 5 = very stressful).
- Post-trip willingness to pay for information per trip ($0, $1, $2, $3, $4).
- End-of-week information helpful in reducing commute stress (1 = not at all, 5 = absolutely).
- End-of-week overall information usefulness (1 = not useful, 5 = very useful).
- End-of-week information helpful in better managing departure decisions (1 = not at all, 5 = absolutely).

- End-of-week level of difficulty in understanding information (1 = very easy, 5 = very difficult).
- End-of-week willingness to pay per trip for information viewed ($0, $1, $2, $3, $4).

In addition to the user-provided valuation, the experiment yielded trip outcome metrics that included average minutes of early schedule delay if early, average minutes of late schedule delay if late, and frequency of late arrivals per week. Based on the predefined costs for early and late arrivals, the week's schedule offset costs were also computed.

These metrics were compared pairwise between the specific reliability information (type B through H, as defined in Table 10-2) and the baseline traveler information (type A), which did not provide reliability information. The sample size for comparisons varied based on the specific pairs, and specific findings are presented in the next subsection and summarized in tabular formats. In the second subsection, the three reliability constructs (types B-D) are compared to their counterparts, delivered either using auditory or graphical methods.

Pairwise Comparisons for Reliability Terms against the Baseline Pre-Trip Radio Information

This section presents results from pairwise comparisons for participants that completed simulated commutes for both the reliability term being tested and the baseline information, which did not contain reliability data. A summary of trends are first discussed here. Each of the seven following subsections presents the detailed pairwise comparisons in the order below:

1. Textual 95th percentile travel time information compared to no reliability information.
2. Textual average and 95th percentile travel time information compared to no reliability information.
3. Textual 20th percentile, average, and 95th percentile travel time information compared to no reliability information.
4. Signposting reliability information.
5. Graphic average and 95th percentile travel time information compared to no reliability information.
6. Graphic 20th percentile, average, and 95th percentile travel time information compared to no reliability information.
7. Audio 95th percentile information compared to no reliability information.

When comparing against the baseline pre-trip information, trip outcomes were more positive for participants using the textual and audio reliability information and somewhat better using the graphical average and 95th percentile data. Trip outcomes when using the graphic good, typical, and bad information as well as the reliability signposting were not significantly better than the baseline.

Trip outcomes did not correlate with willingness to pay for information. Furthermore, participants' responses for willingness to pay for information viewed varied significantly when asked post-trip compared to when asked at the end of the week. For example, although participants performed better when using textual 95th percentile reliability information than the baseline, participants' willingness to pay for the information was not significantly higher than

baseline when asked at the end of the week. When asked post-trip, participants were willing to pay approximately $0.16 per trip more for the reliability information as compared to the baseline. Alternately, participants did not have better trip outcomes when using the graphic good, typical, and bad information, but they were willing to pay $0.42 per trip more compared to the baseline information when asked post-trip.

Ratings for information usefulness when asked post-trip were either lower than the baseline or otherwise not significantly different, even when trip outcomes were better with the reliability information. One reason for this phenomenon may be that when participants were late, they faulted more strongly the reliability information if available; however, in the absence of reliability information, they may have faulted inherent traffic rather than the baseline radio information. Consequently on late-arrival days, usefulness ratings were far lower in the presence of reliability information. Once participants sufficiently disassociated with the immediate trip outcome, they tended to rate the reliability information usefulness higher compared to the baseline information. A similar outcome was observed in ratings for post-trip stress reduction compared to the end-of-week rating for the reliability information's effectiveness at reducing stress.

With regard to ratings on the level of difficulty in understanding the information presented, all but two forms of information did not yield statistically significant differences between baseline and the reliability information. The signposting and the graphical good, typical, and bad information had ratings differentials when compared against the baseline, which suggests that these forms of information are more difficult to understand.

Textual 95th Percentile Reliability Information versus Baseline (Type B vs. A)

Among all experiment participants, 123 individuals made a week (5 days) of simulated commutes to work using the textual 95th percentile reliability information (type B) and also made a week (5 days) of simulated commutes to work using no reliability information (type A). The specific text used to deliver reliability information was "the majority of the time." The simulated commute decisions were pairwise analyzed for trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in

Table 10-5.

The trip outcomes for participants using type B information included average lower frequency of late arrival (40 percent fewer late arrivals) and lower magnitudes of late delay (0.6 minutes less) at the expense of higher magnitudes of early arrivals (3.1 minutes earlier) when compared to the use of type A information. Trip outcome with regard to the schedule offset costs, as defined for the experiment, was that participants when using the type B information had a total week's cost that was 21 percent lower ($10.02) compared to the week they did not receive reliability information.

Participants having access to type B information generally departed on average a few minutes earlier (3.9 minutes), had a higher pre-trip on-time arrival confidence rating (3.6 vs. 3.4), and had a higher information usefulness rating (3.4 vs. 3.0). As expected, participants' end-of-week ratings regarding pre-trip information reducing stress, proving useful, and helping manage departure decisions were higher for type B (95th percentile reliability information) compared to the baseline.

An unexpected and conflicting outcome was that participants gave the reliability information a higher usefulness rating pre-trip but a lower rating post-trip compared to the no reliability information scenario. Yet, at the end of the week, they again rated reliability information as more useful. This might be explained by participants' penalizing the reliability information for poor trip outcomes while attributing normal congestion when not having reliability data. At the end of the week, participants came to recognize through valuation a higher usefulness for reliability information. Similarly, when asked at the end of the week, individuals were willing to pay on average $0.10 more for type B information; however, this differential did not prove statistically significant. Yet, for the same question at the end of each trip, participants were willing to pay about $0.15 more per trip for type B information, and this differential was statistically significant.

Finally, when asked how difficult it was to understand the traveler information, participants rated both type A and B nearly identically. That is, participants did not find understanding the "majority of the time" reliability information any more difficult than understanding the radio message without reliability information.

Table 10-5. Trip decisions, outcomes, and valuations of textual 95th percentile reliability data compared to the baseline radio information.

Comparison of Participant Response Text 95th Percentile vs. No Reliability Information				
Metrics	(123 sample size)	Control	Text 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.4	17.5	100%
	Average Late Schedule Delay (minutes)	6.9	6.3	93%
	Frequency of Late Arrivals (1-5)	1.4	0.9	100%
	Week's Schedule Offset Costs	$48.01	$37.98	100%
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.7	2.9	100%
	Avg OTA confidence (1 = not, 5 = very)	3.4	3.6	100%
	Avg Pre-Trip Usefulness (1 = not, 5 = very)	3.0	3.4	100%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.51	$2.67	96%
	Avg Post-Trip Usefulness	2.7	2.5	97%
	Avg Post-Trip Stressfulness	2.7	3.2	100%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.0	3.3	99%
	Usefulness (5 = very useful)	3.1	3.4	99%
	Manage Departure Decisions (5 = absolutely)	3.2	3.4	91%
	Difficulty in Understanding Info (5 = very difficult)	2.1	2.1	Not S.S.
	Willingness to Pay ($/trip)	$2.78	$2.68	Not S.S.

Textual Average and 95th Percentile Reliability Information versus Baseline (C vs. A)

Among all experiment participants, 185 individuals made a week (5 days) of simulated commutes to work using the textual average and 95th percentile reliability information (type C) and also made a week (5 days) of simulated commutes to work using no reliability information (type A). The specific text used to deliver reliability information was "estimated travel time, and extra time for unexpected delays." The simulated commute decisions were pairwise analyzed to evaluate trip outcome and valuations of information. For both weeks, participants also received

radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-6.

Table 10-6. Trip decisions, outcomes, and valuations of textual average and 95th percentile reliability data compared to the baseline radio information.

Comparison of Participant Response Text Average and 95th Percentile vs. No Reliability Information				
	Metrics (185 sample size)	Control	Text Avg + 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.4	16.1	99%
	Average Late Schedule Delay (minutes)	7.4	5.0	100%
	Frequency of Late Arrivals (1-5 times a week)	1.5	1.1	100%
	Week's Schedule Offset Costs	$49.29	$41.07	100%
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.7	3.1	100%
	Avg OTA confidence (5 = very confident)	3.4	3.6	100%
	Avg Pre-Trip Usefulness (5 = very useful)	3.0	3.5	100%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.34	$2.65	100%
	Avg Post-Trip Usefulness (5 = very useful)	2.7	2.5	99%
	Avg Post-Trip Stressfulness (5 = very stressful)	2.7	3.5	100%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.0	3.5	100%
	Usefulness (5 = very useful)	3.1	3.6	100%
	Manage Departure Decisions (5 = absolutely)	3.2	3.7	100%
	Difficulty in Understanding Info (5 = very difficult)	2.0	2.2	Not S.S.
	Willingness to Pay ($/trip)	$2.61	$2.83	99%

The trip outcomes for participants using type C information included average lower frequency of late arrival (28 percent fewer late arrivals) and lower magnitudes of late delay (2.7 minutes less on average) at the expense of slightly higher magnitudes of early arrivals (1.7 minutes earlier) when compared to the use of type A information. Trip outcome with regard to the schedule offset costs, as defined for the experiment, was that participants when using the type C information had a total week's cost that was 17 percent lower ($8.20) compared to the week they did not receive reliability information.

Participants having access to type C information generally departed on average a few minutes earlier (2.5 minutes), had a higher pre-trip on-time arrival confidence rating (3.6 vs. 3.4), and had a higher information usefulness rating (3.5 vs. 3.0). As expected, participants' end-of-week ratings regarding pre-trip information reducing stress, proving useful, and helping manage departure decisions were higher for type C compared to the baseline.

Conflicting outcomes were observed between post-trip and end-of-week valuations for information usefulness and effectiveness in reducing stress. Participants gave the reliability information type C a higher usefulness rating pre-trip but a lower rating post-trip (3.5 vs. 2.5) compared to the no reliability information week ratings of (3.0 to 2.7). Yet, at the end of the week, they again rated the type C reliability information as more useful (3.6 vs. 3.1). This might be explained by participants' penalizing the reliability information for poor trip outcomes while attributing normal congestion for poor trip outcomes when not having reliability data. Once away from the immediate disappointment of a poor trip outcome, participants came to recognize the usefulness of the information and provided a valuation for reliability information. Similarly, at the end of each trip with type C information, participants indicated on average higher levels of stress compared to the end of each trip with no reliability information (3.5 vs. 2.7), yet at the end of the week, they generally provided higher ratings to the value of type C information in reducing stress (3.5 vs. 3.0).

When asked at the end of the week, individuals were willing to pay on average $0.22 more for type C information compared to the baseline; however, for the same question at the end of each trip, participants were willing to pay about $0.31 more per trip. Finally, when asked how difficult it was to understand the traveler information, participants rated type C slightly more challenging to understand (2.2 vs. 2.0) compared to the baseline information; however, this difference was not statistically significant. That is, participants did not find understanding the "estimated travel time, and extra time for unexpected delays" reliability information any more difficult than understanding the radio message without reliability information.

Textual 20th Percentile, Average, and 95th Percentile Reliability Information versus Baseline (D vs. A)

Among all experiment participants, 160 individuals made a week (5 days) of simulated commutes to work using the textual 20th percentile, average, and 95th percentile reliability information (type D) and also made a week (5 days) of simulated commutes to work using no reliability information (type A). The specific text used to deliver reliability information was "good day, typical day, and bad day." The simulated commute decisions were pairwise analyzed to evaluate trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-7.

The trip outcomes for participants using type D information included average lower frequency of late arrival (26 percent fewer late arrivals) and lower magnitudes of late delay (3.4 minutes less on average) when compared to the use of type A information. For the week using type D information, participants' early schedule delay was 0.8 minutes less than for the week using type A information; however, this outcome was not statistically significant. These trip outcomes

resulted in a 13 percent lower ($6.60) total week's cost compared to the week participants did not receive reliability information.

Table 10-7. Trip decisions, outcomes, and valuations of textual 20th percentile, average, and 95th percentile reliability data compared to the baseline radio information.

Comparison of Participant Response Text 20th Percentile, Average, and 95th Percentile vs. No Reliability Information				
	Metrics (160 sample size)	Control	Text 20th + Avg + 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.5	13.7	Not S.S.
	Average Late Schedule Delay (minutes)	7.4	6.0	100%
	Frequency of Late Arrivals (1-5 times a week)	1.5	1.2	99%
	Week's Schedule Offset Costs	$49.62	$42.99	100%
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.7	3.6	Not S.S.
	Avg OTA confidence (5 = very confident)	3.4	3.6	100%
	Avg Pre-Trip Usefulness (5 = very useful)	3.0	3.5	100%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.32	$2.57	100%
	Avg Post-Trip Usefulness (5 = very useful)	2.7	2.5	100%
	Avg Post-Trip Stressfulness (5 = very stressful)	2.7	3.5	100%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.0	3.6	100%
	Usefulness (5 = very useful)	3.1	3.6	100%
	Manage Departure Decisions (5 = absolutely)	3.3	3.7	100%
	Difficulty in Understanding Info (5 = very difficult)	2.0	2.1	Not S.S.
	Willingness to Pay ($/trip)	$2.59	$2.69	Not S.S.

Participants when having access to type D information did not depart significantly earlier than when having type A information. They did have a higher on-time arrival confidence and rated the information they viewed as more useful (3.5 vs. 3.0) pre-trip compared to the week where they made pre-trip decisions without reliability information. At the end of each trip made using type D information, participants were willing to pay on average $0.25 more per trip for this information. This differential in willingness to pay, however, was not observed when asked at the end of the week.

Conflicting outcomes were observed between post-trip and end-of-week valuations for information usefulness and effectiveness in reducing stress. Participants gave the reliability information type D a higher usefulness rating pre-trip and at the end of the week, but a lower rating post-trip compared to the no reliability information week ratings. This might be explained by participants' penalizing the reliability information for poor trip outcomes while attributing normal congestion for poor trip outcomes when not having reliability data. Once away from the immediate disappointment of a poor trip outcome, participants came to recognize the usefulness of the information and provided a valuation for reliability information.

Similarly, at the end of each trip, participants indicated on average higher levels of stress when using type D information compared to the end of each trip with no reliability information (3.5 vs. 2.7), yet at the end of the week, they generally provided higher ratings to the value of type D information in reducing stress (3.6 vs. 3.0).

Finally, when asked how difficult it was to understand the traveler information, participants rated type D slightly more challenging to understand (2.1 vs. 2.0) compared to the baseline information; however, this difference was not statistically significant. That is, participants did not find understanding the "good day, typical day, and bad day" reliability information any more difficult than understanding the radio message without reliability information.

Reliability Signposting Versus Baseline (E vs. A)

The concept of signposting is one wherein individuals are provided a color-coded trip path that reflects historic levels of congestion along key road segments of the trip route. Along with the color-coded historic congestion, a travel time range is provided. A total of 98 participants completed both a week of simulated commutes using the reliability signposting data (type E) and a week having the control information (type A).

There was no statistically significant difference in trip outcomes with regard to late arrivals or magnitude of late schedule delay. Further, this was the one form of reliability information that exhibited a statistically significant higher rating for difficulty in understanding the information presented. In addition, although reliability signposting ratings for end-of-week usefulness and ability to reduce stress were higher than the control, these differences did not prove statistically significant. Table 10-8 summarizes the key metrics for reliability signposting.

Graphical Average and 95th Percentile Reliability Information versus Baseline (F vs. A)

Among all experiment participants, 54 individuals made a week (5 days) of simulated commutes to work using the graphic average and 95th percentile reliability information (type F) and also made a week (5 days) of simulated commutes to work using no reliability information (type A). The specific graphic used to deliver reliability information was a bar chart with "estimated travel time, and extra time for unexpected delays," using departure time as the x-axis and arrival time as the y-axis. The graphic is presented in Appendix H, Figure H-6. The simulated commute decisions were pairwise analyzed to evaluate trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-9.

Table 10-8. Trip decisions, outcomes, and valuations of reliability signposting compared to the baseline radio information.

Comparison of Participant Response Reliability Signposting vs. No Reliability Information				
	Metrics (62 sample size)	Control	Reliability Signposting	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.6	17.1	100%
	Average Late Schedule Delay (minutes)	7.0	6.6	Not S.S.
	Frequency of Late Arrivals (1-5 times a week)	1.8	1.8	Not S.S.
	Week's Schedule Offset Costs	$48.57	$46.95	Not S.S.
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.7	3.4	100%
	Avg OTA confidence (5 = very confident)	3.5	3.4	Not S.S.
	Avg Pre-Trip Usefulness (5 = very useful)	3.0	3.3	100%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.57	$2.69	Not S.S.
	Avg Post-Trip Usefulness (5 = very useful)	2.6	2.6	Not S.S.
	Avg Post-Trip Stressfulness (5 = very stressful)	2.9	3.2	100%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.0	3.1	Not S.S.
	Usefulness (5 = very useful)	3.1	3.3	Not S.S.
	Manage Departure Decisions (5 = absolutely)	3.3	3.3	Not S.S.
	Difficulty in Understanding Info (5 = very difficult)	2.1	2.5	99%
	Willingness to Pay ($/trip)	$2.77	$2.76	Not S.S.

The trip outcomes for participants using type F information proved statistically significant above the 80th percentile, but not at the 95th percentile. This may have been the case because of the smaller sample size involved in the evaluation. Nonetheless, for the week participants used type F information, they did on average have a lower frequency of late arrival (16 percent fewer late arrivals) and lower magnitudes of late delay (1.0 minutes less on average) without greater magnitudes of early arrivals when compared to the week with type A information. Trip outcome with regard to the schedule offset costs, as defined for the experiment, was that participants when

using the type F information had a total week's cost that was 9 percent lower ($7.70) compared to the week they did not receive reliability information.

Participants having access to type F information had a higher pre-trip on-time arrival confidence rating (3.6 vs. 3.3) and a higher pre-trip information usefulness rating (3.6 vs. 3.1). As expected, participants' end-of-week ratings regarding pre-trip information reducing stress, proving useful, and helping manage departure decisions were significantly higher for type F compared to the baseline.

Table 10-9. Trip decisions, outcomes, and valuations of graphic average and 95th percentile reliability information compared to the baseline radio information.

Comparison of Participant Response Graphic Average and 95th Percentile vs. No Reliability Information				
	Metrics (54 sample size)	Control	Graphic Avg + 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.7	13.7	Not S.S.
	Average Late Schedule Delay (minutes)	6.9	5.9	87%
	Frequency of Late Arrivals (1-5 times a week)	1.5	1.2	84%
	Week's Schedule Offset Costs	$49.35	$41.63	91%
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.5	3.5	Not S.S.
	Avg OTA confidence (5 = very confident)	3.3	3.6	100%
	Avg Pre-Trip Usefulness (5 = very useful)	3.1	3.6	100%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.39	$2.73	97%
	Avg Post-Trip Usefulness (5 = very useful)	2.7	2.6	Not S.S.
	Avg Post-Trip Stressfulness (5 = very stressful)	2.6	3.7	100%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	2.9	3.8	100%
	Usefulness (5 = very useful)	3.2	4.0	100%
	Manage Departure Decisions (5 = absolutely)	3.0	4.0	100%
	Difficulty in Understanding Info (5 = very difficult)	1.9	2.0	Not S.S.
	Willingness to Pay ($/trip)	$2.48	$2.70	Not S.S.

Conflicting outcomes were observed between post-trip and end-of-week valuations for information usefulness. Participants rated graphic reliability information type F higher with

regard to usefulness pre-trip and end of week, but post-trip rating differences between type F and type A information were not statistically significant. This might be explained by participants' penalizing the reliability information for poor trip outcomes while attributing normal congestion for poor trip outcomes when not having reliability data. Once away from the immediate disappointment of a poor trip outcome, participants came to recognize the usefulness of the information and provided a more positive valuation for reliability information. Similarly, at the end of each trip with type F information, participants indicated on average higher levels of stress compared to the end of each trip with no reliability information (3.7 vs. 2.6), yet at the end of the week, they generally provided higher ratings to the value of type F information in reducing stress (3.8 vs. 2.9).

When asked at the end of the week, participants rated willingness to pay for information higher for type F compared to A; however, this difference was not statistically significant. For the same question at the end of each trip, participants were willing to pay about $0.34 more per trip. Finally, when asked how difficult it was to understand the traveler information, participants rated type F slightly more challenging to understand (2.0 vs. 1.9) compared to the baseline information; however, this difference was not statistically significant. That is, participants did not find understanding the graphical reliability information any more difficult than understanding the radio message without reliability information.

Graphical 20th Percentile, Average, and 95th Percentile Reliability Information versus Baseline (G vs. A)

Among all experiment participants, 62 individuals made 5 days of simulated commutes to work using the graphic 20th percentile, average, and 95th percentile reliability information type G. The same 62 individuals also made 5 days of simulated commutes to work using no reliability information (type A). The specific graphic used to deliver reliability information was a bar chart with "good day, typical day, and bad day" using departure time as the x-axis and arrival time as the y-axis. The graphic is presented in Appendix H, Figure H-7. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-10.

Table 10-10. Trip decisions, outcomes, and valuations of graphic 20th percentile, average, and 95th percentile reliability information compared to the baseline radio information.

Comparison of Participant Response Graphic 20th Percentile, Average, and 95th Percentile vs. No Reliability Information				
	Metrics (62 sample size)	Control	Graphical 20th + Avg + 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.4	14.4	Not S.S.
	Average Late Schedule Delay (minutes)	8.2	9.4	91%
	Frequency of Late Arrivals (1-5 times a week)	1.6	1.6	Not S.S.
	Week's Schedule Offset Costs	$51.82	$50.85	Not S.S.
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.7	3.8	Not S.S.
	Avg OTA confidence (5 = very confident)	3.3	3.4	Not S.S.
	Avg Pre-Trip Usefulness (5 = very useful)	3.1	3.4	98%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.02	$2.44	99%
	Avg Post-Trip Usefulness (5 = very useful)	2.7	2.8	Not S.S.
	Avg Post-Trip Stressfulness (5 = very stressful)	2.7	3.2	99%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.0	3.2	Not S.S.
	Usefulness (5 = very useful)	3.2	3.4	Not S.S.
	Manage Departure Decisions (5 = absolutely)	3.2	3.3	Not S.S.
	Difficulty in Understanding Info (5 = very difficult)	1.9	2.3	99%
	Willingness to Pay ($/trip)	$2.26	$2.35	Not S.S.

Participants rated graphical information as more useful than the control pre-trip; however, differences in trip outcomes for participants that used type G and type A information were not statistically significant at the 95 percent level. Neither differences in selected departure times nor on-time arrival confidence ratings were statistically significant. Surprisingly, participants when asked post-trip were willing to pay $0.42 more per trip for type G information. This willingness to pay more for type G information did not materialize when asked at the end of the week. End-of-week valuations related to stress, usefulness, or managing departure decisions was slightly higher for type G information; however, differences were not statistically significant.

Most noticeable, when asked how difficult it was to understand the traveler information, participants rated type G more challenging to understand (2.3 vs. 1.9) compared to the baseline information, and this difference was statistically significant. That is, participants found understanding this three-tiered graphical reliability information more difficult than understanding the radio message without reliability information.

Auditory 95th Percentile Reliability Information versus Baseline (H vs. A)

Among all experiment participants, 25 individuals made a week (5 days) of simulated commutes to work using the textual 95th percentile reliability information (type H) and also made a week (5 days) of simulated commutes to work using no reliability information (type A). The delivery of auditory reliability information was achieved through wav files being played while participants were wearing headphones. The visual of the interface is shown in Appendix H, Figure H-8. As participants shifted the departure time bar, they heard the reliability messages. The text being heard was the same as the text written in Appendix H, Figure H-2. Only the reliability information was delivered through audio. The radio message continued to be delivered through textual reading. The simulated commute decisions were pairwise analyzed for trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-11.

Participants having access to type H information departed on average a few minutes earlier (3.5 minutes). Consequently, when early, they arrived on average 2.6 minutes earlier, and when late, they were on average 4 minutes less late than their baseline counterparts. The auditory information enabled participants to reduce the frequency of late arrivals by 37 percent and reduce the overall schedule offset costs by $7.19, or 17 percent.

Participants rated type H information higher than baseline for on-time arrival confidence and trip usefulness pre-trip. Further, participants were on average willing to pay $0.64 per trip more for the type H information compared to the baseline when asked at the end of each trip. When asked again at the end of the week, the differential in willingness to pay was only $0.12 per trip, and this differential did not prove statistically significant. Still, participants' end-of-week ratings regarding pre-trip information reducing stress, being useful, and helping manage departure decisions were higher for type H compared to the baseline.

Table 10-11. Trip decisions, outcomes, and valuations of auditory 95th percentile reliability information compared to the baseline radio information.

Comparison of Participant Response Auditory 95th Percentile vs. No Reliability Information				
	Metrics (25 sample size)	Control	Auditory 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	13.4	16.0	99%
	Average Late Schedule Delay (minutes)	8.2	4.2	100%
	Frequency of Late Arrivals (1-5 times a week)	1.6	1.2	99%
	Week's Schedule Offset Costs	$50.10	$42.91	95%
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.7	3.0	100%
	Avg OTA confidence (5 = very confident)	3.3	3.6	92%
	Avg Pre-Trip Usefulness (5 = very useful)	3.0	3.4	99%
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.08	$2.72	100%
	Avg Post-Trip Usefulness (5 = very useful)	2.8	2.4	99%
	Avg Post-Trip Stressfulness (5 = very stressful)	2.5	3.4	100%
End-of-Week Valuation	Reduce Stress (5 = absolutely)	2.9	3.3	97%
	Usefulness (5 = very useful)	3.0	3.5	98%
	Manage Departure Decisions (5 = absolutely)	3.0	3.5	97%
	Difficulty in Understanding Info (5 = very difficult)	2.1	2.0	Not S.S.
	Willingness to Pay ($/trip)	$2.45	$2.57	Not S.S.

An unexpected and conflicting outcome was that participants gave the reliability information a higher usefulness rating pre-trip but a lower rating post-trip compared to the no reliability information scenario. Yet, at the end of the week, they again rated reliability information as more useful. This might be explained by participants' penalizing the reliability information for poor trip outcomes while attributing normal congestion when not having reliability data. At the end of the week, they came to recognize through valuation a higher usefulness for reliability information.

When asked how difficult it was to understand the traveler information, participants rated both type A and H nearly identically. That is, participants did not find understanding the auditory "majority of the time" reliability information any more difficult than understanding the radio message without reliability information

Comparison of Equivalent Reliability Information Pairs

The reliability content presented to participants textually in types B, C, and D was also presented in a second format. Type B reliability information was also presented in audio format (type H), while type C and D information was presented in graphical formats (type F and G, respectively). These three pairs were compared to examine whether a specific format of delivery resulted in different trip outcomes and information valuations.

The only difference that was both statistically and practically significant when comparing the text versus auditory 95th percentile reliability information (types B and H) was that individuals were willing to pay about $0.21 more post-trip for the text-based information compared to the auditory information. This outcome could be attributed to the fact that participants, hoping to complete the experiment faster, preferred the quick read compared to the longer auditory delivery of information. This would likely be different in a real-world environment where individuals would probably be multitasking and may prefer auditory traveler information.

Comparing the graphic and textual version of average and 95th percentile reliability data on the travel times also did not yield statistically significant valuations and outcomes, with two exceptions. The graphic data correlated with a slightly later departure time and consequently lower magnitudes of early schedule delay compared to the textual version of the data, yet higher magnitude of late schedule delay for the graphic data did not prove statistically significant. The graphic data were also rated slightly higher for reducing trip stress at the end of the week.

Comparing the graphic and textual version of 20th percentile, average, and 95th percentile reliability data on the travel times did yield statistically significant differences in trip departure decisions and outcomes. When using graphic information, participants were late more often and had higher magnitudes of late schedule offsets but not higher magnitudes of early schedule offsets. These outcomes translated to a $7.33 higher week's trip cost compared to when using text-based information. Although the textual presentation of reliability information (type D) yielded far better trip outcomes compared to the graphical presentation (type G), differences in willingness to pay for the information were not statistically significant.

The following subsections provide pairwise analyses in the following order:

1. Textual 95th versus auditory 95th percentile reliability information (type B vs. H).
2. Textual versus graphical average and 95th percentile reliability information (type C vs. F).
3. Textual versus graphical 20th percentile, average, and 95th percentile reliability information (type D vs. G).

Textual 95th versus Auditory 95th Percentile Reliability Information (Type B vs. H)

Among all experiment participants, 25 individuals completed 5 days of simulated commutes to work using the textual 95th percentile reliability information (type B) and another 5 days of simulated commutes using auditory 95th percentile reliability information (type H). These simulated commute decisions were pairwise analyzed to evaluate trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-12.

Table 10-12. Trip decisions, outcomes, and valuations of textual versus auditory 95th percentile reliability information.

Comparison of Participant Response—Text versus Auditory 95th Percentile				
	Metrics (25 sample size)	Text 95th	Auditory 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	16.6	16.9	95%
	Average Late Schedule Delay (minutes)	5.8	4.3	Not S.S.
	Frequency of Late Arrivals (1-5)	1.2	1.1	Not S.S.
	Week's Schedule Offset Costs	$43.72	$43.26	Not S.S.
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	2.9	2.9	Not S.S.
	Avg OTA confidence (1 = not, 5 = very)	3.6	3.6	Not S.S.
	Avg Pre-Trip Usefulness (1 = not, 5 = very)	3.3	3.5	Not S.S.
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.76	$2.55	95%
	Avg Post-Trip Usefulness	2.5	2.5	Not S.S.
	Avg Post-Trip Stressfulness	3.0	3.4	Not S.S.
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.1	3.2	Not S.S.
	Usefulness (5 = very useful)	3.2	3.5	Not S.S.
	Manage Departure Decisions (5 = absolutely)	3.4	3.5	Not S.S.
	Difficulty in Understanding Info (5 = very difficult)	2.4	2.0	92%
	Willingness to Pay ($/trip)	$2.68	$2.41	Not S.S.

The expectation was that reading textual 95th percentile traveler information and listening to the same information would enable participants to have equivalent trip outcomes. This proved to be true (shown in Table 10-12), as differences in pre-trip selection, trip outcomes, post-trip

valuation, and end-of-week valuation were either by and large not statistically significant or significant in magnitude. There was a statistically significant difference in terms of magnitudes of early arrival when participants were early; however, the difference was less than 2 percent and consequently not practically significant.

The only difference that was both statistically and practically significant was that individuals were willing to pay about $0.21 more post-trip for the text-based information compared to the auditory information. Although not statistically significant, participants were also willing to pay $0.27 more at the end of the week for the text-based information. This was likely because text could be read far more quickly compared to having to listen to the information in the experiment. Participants wanted to finish the experiment as quickly as possible and wanted to minimize the time required to acquire the information received. In real-world situations, the auditory could prove more valuable, as measured by willingness to pay, given that individuals are likely to be multitasking when listening to traveler information.

Textual versus Graphical Average and 95th Percentile Reliability Information (Type C vs. F)

Among all experiment participants, 54 individuals completed 5 days of simulated commutes to work using the textual average and 95th percentile reliability information (type C) and another 5 days of simulated commutes using the graphical display of this reliability information (type F). These simulated commute decisions were pairwise analyzed to evaluate trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-13.

Table 10-13. Trip decisions, outcomes, and valuations of textual versus graphic average and 95th percentile reliability information.

Comparison of Participant Response Text vs. Graphical Average and 95th Percentile				
Metrics	(54 sample size)	Text	Graphic	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	16.8	13.7	100%
	Average Late Schedule Delay (minutes)	5.3	5.9	Not S.S.
	Frequency of Late Arrivals (1-5)	1.2	1.2	Not S.S.
	Week's Schedule Offset Costs	$44.43	$41.63	Not S.S.
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.1	3.5	97%
	Avg OTA confidence (1 = not, 5 = very)	3.6	3.6	Not S.S.
	Avg Pre-Trip Usefulness (1 = not, 5 = very)	3.6	3.6	Not S.S.
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.57	$2.73	Not S.S.
	Avg Post-Trip Usefulness	2.5	2.6	Not S.S.
	Avg Post-Trip Stressfulness	3.5	3.7	Not S.S.
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.4	3.8	99%
	Usefulness (5 = very useful)	3.8	4.0	Not S.S.
	Manage Departure Decisions (5 = absolutely)	3.7	4.0	Not S.S.
	Difficulty in Understanding Info (5 = very difficult)	2.2	2.0	Not S.S.
	Willingness to Pay ($/trip)	$2.78	$2.70	Not S.S.

Reading textual reliability information or interpreting this information through a graphical presentation should have enabled participants to have equivalent trip outcomes. However, this was predicated on the expectation that individuals were able to correctly interpret information independent of delivery media, which often was not the case.

Participants, while having access to the text-based information, chose to depart on average slightly earlier (on average 2 minutes earlier), and consequently arrived on average 3.1 minutes earlier compared to when they had access to the graphical form of the same information. Further, participants on average when using the graphical format indicated a higher stress reduction compared to the text-based information (3.8 vs. 3.4) when asked at the end of the week. These differences were statistically significant.

Differences in trip outcomes as well as pre- and post-trip valuations for all other metrics were not statistically significant. Although differences did not prove statistically significant, average participant ratings for post-trip and end-of-week information usefulness were slightly higher for the graphical presentation of information.

Textual versus Graphical 20th Percentile, Average, and 95th Percentile Reliability Information (Type D vs. G)

Among all experiment participants, 62 individuals completed the 5 days of simulated commutes to work using the textual 20th percentile, average, and 95th percentile reliability information

(type D) and another 5 days of simulated commutes using the graphical display of this reliability information (type G). These simulated commute decisions were pairwise analyzed to evaluate trip outcome and valuations of information. For both weeks, participants also received radio messages pre-trip and viewed dynamic message signs along the trip route. Analysis outcomes are presented in Table 10-14.

The hypothesis was that reading textual reliability information or interpreting this information through a graphical presentation would enable participants to have equivalent trip outcomes. This was predicated on the expectation that individuals would be able to correctly interpret information independent of delivery media, which proved not to be the case with reliability type H presented graphically.

Individuals rated the textual information as more effective in managing departure decisions compared to the same information presented graphically (3.8 vs. 3.3). Further, individuals, when given the textual information, had less frequent late arrivals and lower magnitudes of late schedule delay compared to when given this information graphically. The overall week's schedule offset cost for graphical information was $7.30 (17 percent) higher than the same information presented textually.

Pre-trip on-time arrival confidence and information usefulness ratings did not exhibit any statistically significant difference. Post-trip, individuals rated the usefulness of the graphical reliability information higher (2.8 vs. 2.6) than the textual reliability information. While at the end of each week, the only statistically significant difference in valuation was that the textual information was rated as more effective in reducing stress and managing departure decisions, there was no statistically significant difference in participants' willingness to pay for either form of reliability information.

Table 10-14. Trip decisions, outcomes, and valuations of textual versus graphic 20th percentile, average, and 95th percentile reliability information.

Comparison of Participant Response Text vs. Graphical 20th Percentile, Average, and 95th Percentile				
	Metrics (62 sample size)	Text 20th + Avg + 95th	Graphic 20th + Avg + 95th	Stat. Sig.
Trip Outcomes	Average Early Schedule Delay (minutes)	14.0	14.4	Not S.S.
	Average Late Schedule Delay (minutes)	6.1	9.4	100%
	Frequency of Late Arrivals (1-5 times a week)	1.3	1.6	99%
	Week's Schedule Offset Costs	$43.52	$50.85	99%
Pre-Trip Selection	Avg Dep Time Selected (1 = earliest, 7 = latest)	3.5	3.8	98%
	Avg OTA confidence (5 = very confident)	3.5	3.4	Not S.S.
	Avg Pre-Trip Usefulness (5 = very useful)	3.4	3.4	Not S.S.
Post-Trip Valuation	Avg Willingness to Pay ($/trip)	$2.37	$2.44	Not S.S.
	Avg Post-Trip Usefulness (5 = very useful)	2.6	2.8	97%
	Avg Post-Trip Stressfulness (5 = very stressful)	3.4	3.2	Not S.S.
End-of-Week Valuation	Reduce Stress (5 = absolutely)	3.6	3.2	99%
	Usefulness (5 = very useful)	3.6	3.4	Not S.S.
	Manage Departure Decisions (5 = absolutely)	3.8	3.3	100%
	Difficulty in Understanding Info (5 = very difficult)	2.1	2.3	Not S.S.
	Willingness to Pay ($/trip)	$2.40	$2.35	Not S.S.

EXPERIMENT #2 FINDINGS—RELIABILITY DATA EXPEDITES LEARNING CURVE FOR TRIP FAMILIARITY

The objective of this experiment was to determine whether having reliability information helped to speed the transition from an unfamiliar commuter to an experienced commuter. The underlying conjecture in the experiment was that providing reliability information allows an unfamiliar traveler to manage the trade-off between on-time performance and travel budget (time allocated to travel) more effectively and potentially with less stress. Put another way, we expected *a priori* that provision of reliability information to travelers unfamiliar with underlying travel time variability patterns would improve overall trip outcomes (reduction of early and late schedule delay, and better on-time performance) as well as reduce perceptional disutility associated with these outcomes. Additionally, we conjectured that benefits of reliability information would decline over time as both experimental and control subjects learned and internalized an understanding of underlying travel time variability. That is, the benefit from reliability information in the first few weeks would be larger than in the last few weeks.

A total of 32 individuals completed this experiment without reliability information (type A), and a different 30 individuals competed this experiment with graphic reliability information that provided 20th percentile, average, and 95th percentile travel times (type G) categorized as "good, typical, and bad." Both groups G and A received the same radio message as text and had the

same departure time options with the same potential travel time experiences. The same set of data were presented from week to week with one good traffic day, two typical traffic days, and two bad traffic days. The order of these days was different from week 1 through 4 but was consistent from participant to participant. In effect, the same level of trip variability occurred from week to week.

The four trip outcome metrics are summarized in the grouped chart presented in Figure 10-. Outcomes included weekly averages for magnitude of early schedule delay when early, magnitude of late schedule delay when late, frequency of late arrivals, and total schedule offset cost for the week's commute. Given the smaller and non-pairwise sample size, the differences from week to week were statistically significant between weeks 1 and 2 and to a lesser extent from weeks 2 to 3 with regard to schedule offset costs and frequency of late arrivals. Likewise, differences from week to week were statistically significant from weeks 1 to 2 for pre-trip usefulness. Other differences from week to week were not statistically significant but practically significant.

Providing reliability information allows unfamiliar travelers to manage the trade-off between on-time performance and travel budget (time allocated to travel) more effectively. Overall outcomes in terms of reduction of early and late schedule delay and lower frequencies of late arrivals were observed week after week for participants using type G information compared to participants who were not provided reliability information. Furthermore, trip outcome benefits from reliability information in the first few weeks were larger than in the last few weeks. Benefits of reliability information did decline from the first to third weeks, while benefits from the third to the fourth week were relatively stable.

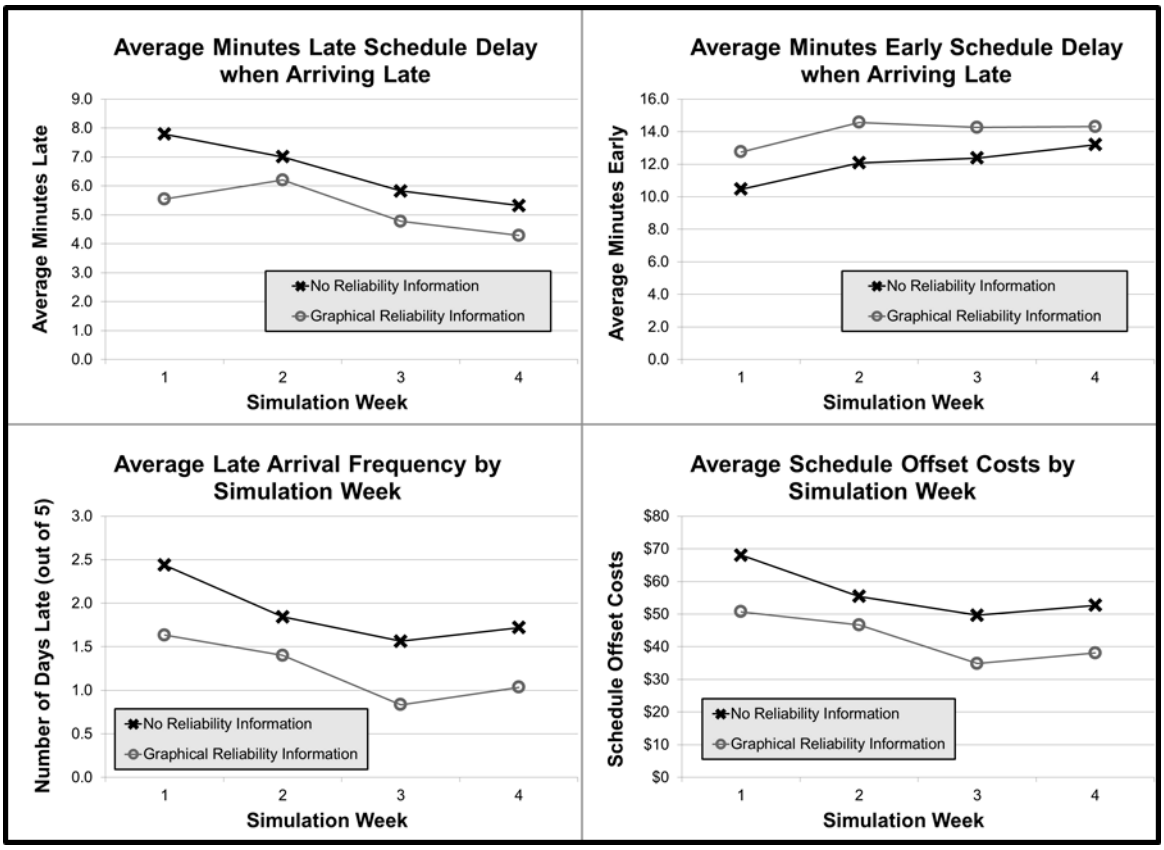


Figure 10-5. Changes in schedule offset from week 1 through week 4.

Whereas trip outcome benefits are generally clear from provision of reliability information to unfamiliar travelers, this information does not always translate with regard to reduced perceptional disutility associated with outcomes. Figure 10- summarizes the pre-trip on-time arrival confidence, post-trip valuation of stress and information usefulness, and average willingness to pay for reliability information. Prior to trip start, participants with reliability information expressed higher on-time arrival confidence from week to week. Surprisingly, post-trip participants with reliability information rated trip usefulness near equivalent to participants without reliability information. Even more, participants assigned higher trip stress values and lower willingness to pay for trips made with reliability information.

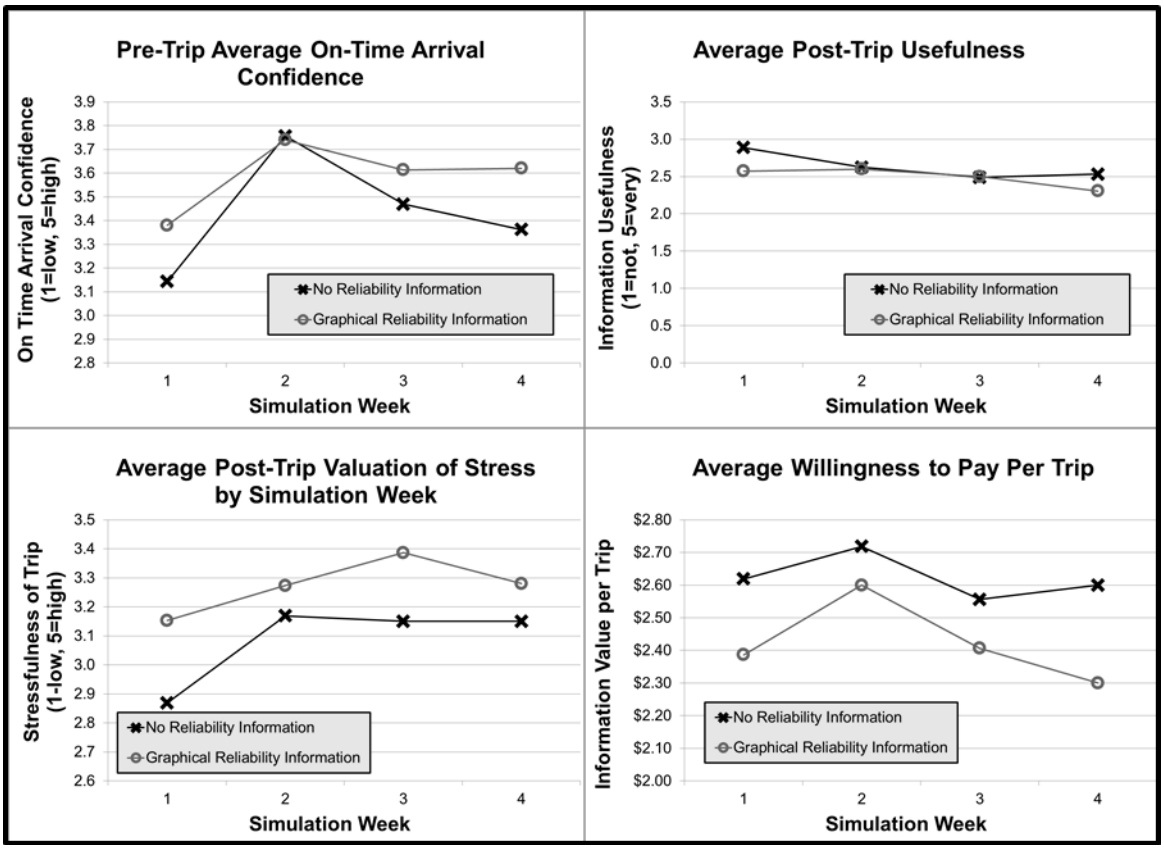


Figure 10-6. Changes in trip valuations from week 1 through week 4.

POST-EXPERIMENT SURVEY FINDINGS

Participants that completed experiment #1 involving multiple forms of reliability information completed a post-experiment survey within the Excel-based environment. This survey asked the participants to rate on a 7-point scale the complexity and usefulness of the four types of reliability information they used in the simulation, paying attention to the relative ratings among the information types. This was the first opportunity for participants in this experiment to view the four sets of reliability information together on one screen. Findings from this post-experiment survey are presented in the first subsection herein.

Additionally, individuals recruited in Chicago and Houston were asked to complete a paper-based survey requesting they rank order the six visual forms of information (audio excluded). They were also asked to rate three additional factors:

- The complexity of the information presented (same as experiment #1 post-survey).
- The individual's ease of understanding the information presented.
- The usefulness of reliability information specific to unfamiliar trips.

The second factor focused on the individual, while the first factor focused on the general. We expected that individuals would rate their ease of understanding information more positively, even when rating the complexity of the information as high. The third factor focused on the

usefulness beyond the work trips in experiment #1 to all trips where individuals were unfamiliar with the underlying trip variability. Findings from this Chicago-Houston post-experiment survey are presented in the second subsection herein.

Findings from Experiment #1 Post-Survey—Rating of Reliability Form Complexity and Usefulness

Figure 10- summarizes the outcome of this post-experiment survey. Shown in Figure 10-7 are the average ratings given for usefulness (left axis, outer bars) and information complexity (right axis, inner bars). To note, for all types of information, the usefulness rating is greater than the complexity rating. The greater the difference between the two bars, the more effective the information. Consequently, from post-experiment survey findings, the 95th and average graphic information was most effective (2.2 rating difference between usefulness and complexity), followed by audio 95th percentile reliability information (2.1 rating difference) and textual 95th percentile (2.0 rating difference) reliability information. This paralleled observations from experiment #1 individual ratings.

The reliability signposting and the graphical presentation of bad, typical, and good reliability information were the two forms of information with the highest complexity ratings and lowest usefulness ratings. Consequently, based on the limited exposure (5 trips) to each information form, these two delivery forms for reliability information were least recommended. This paralleled observations from the experiment #1 individual ratings. 203

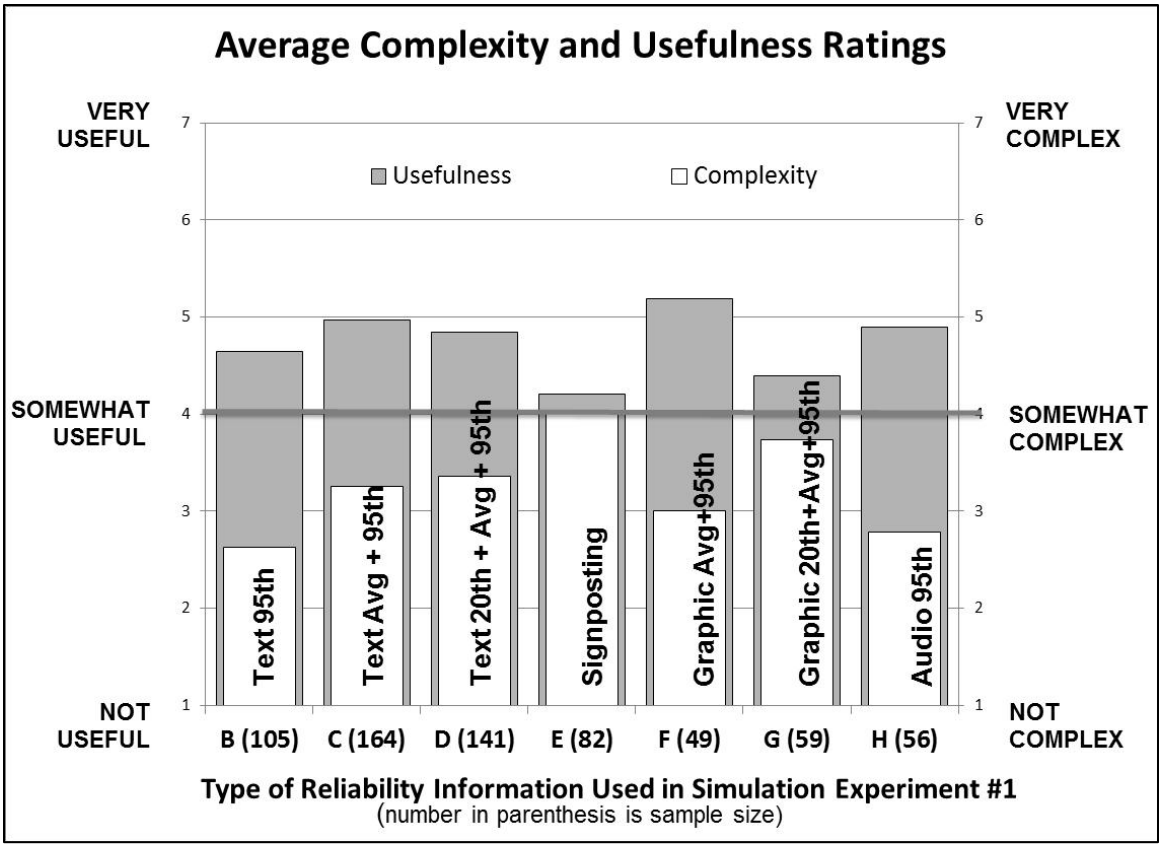


Figure 10-7. Average complexity and usefulness rating of reliability terms in experiment #1.

Findings from Houston-Chicago Post-Experiment Survey

Of the 183 participants in the Chicago and Houston experiments, 7 did not complete the paper survey. Of the 176 remaining individuals that did complete the paper survey, 122 participants completed experiment #1, 42 participants completed experiment #2, and 12 participants were excluded from experiment analyses because they did not provide complete or realistic responses within experiment #1 or #2.

The overall ranking of the six types of reliability information with regard to information usefulness and complexity is presented in Figure 10- and Figure 10-, respectively. The relative ranking for information types clearly indicates that the textual average and 95th percentile reliability information was ranked highest for usefulness among terms, followed by the textual 20th percentile, average, and 95th percentile reliability terms. Third was the graphic average and 95th percentile reliability terms. This ranking of usefulness differed from ratings summarized earlier. The difference can be attributed to the fact that the ratings were for many individuals who did not in fact use the reliability terms but were ranking them. Further, this ranking was for all unfamiliar trips, compared to specifically a work-trip rating in Table 10-10. Nonetheless, the top three reliability terms were the same in both surveys (excluding audio).

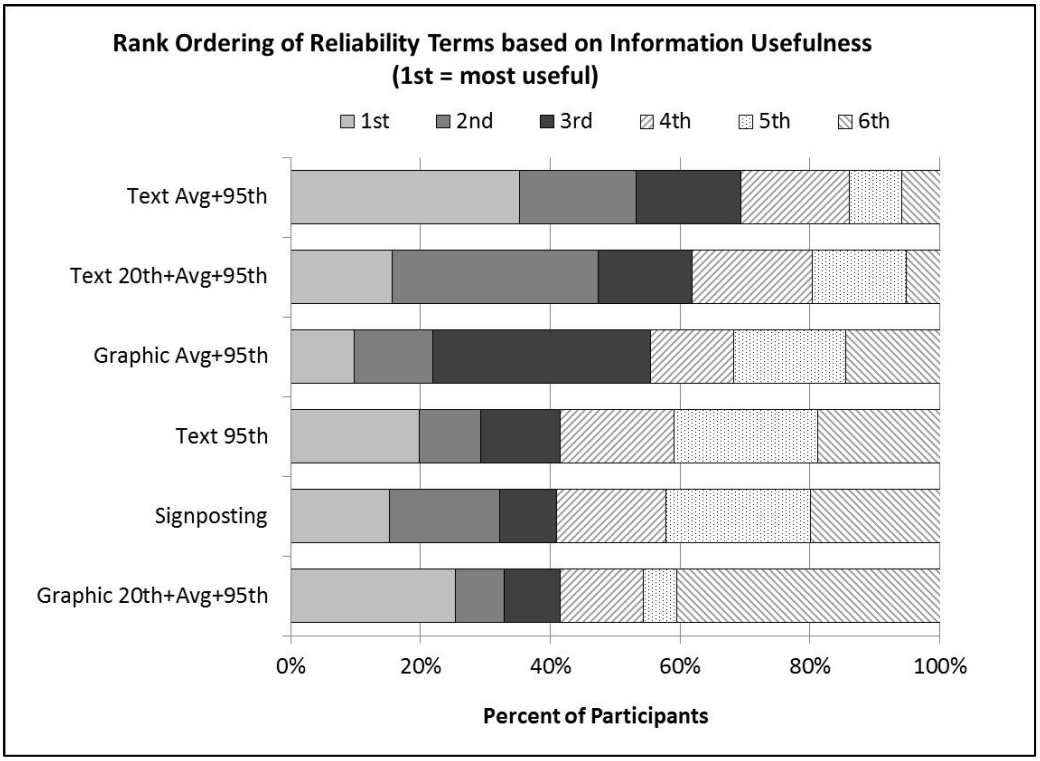


Figure 10-8. Rank ordering of reliability terms based on information usefulness.

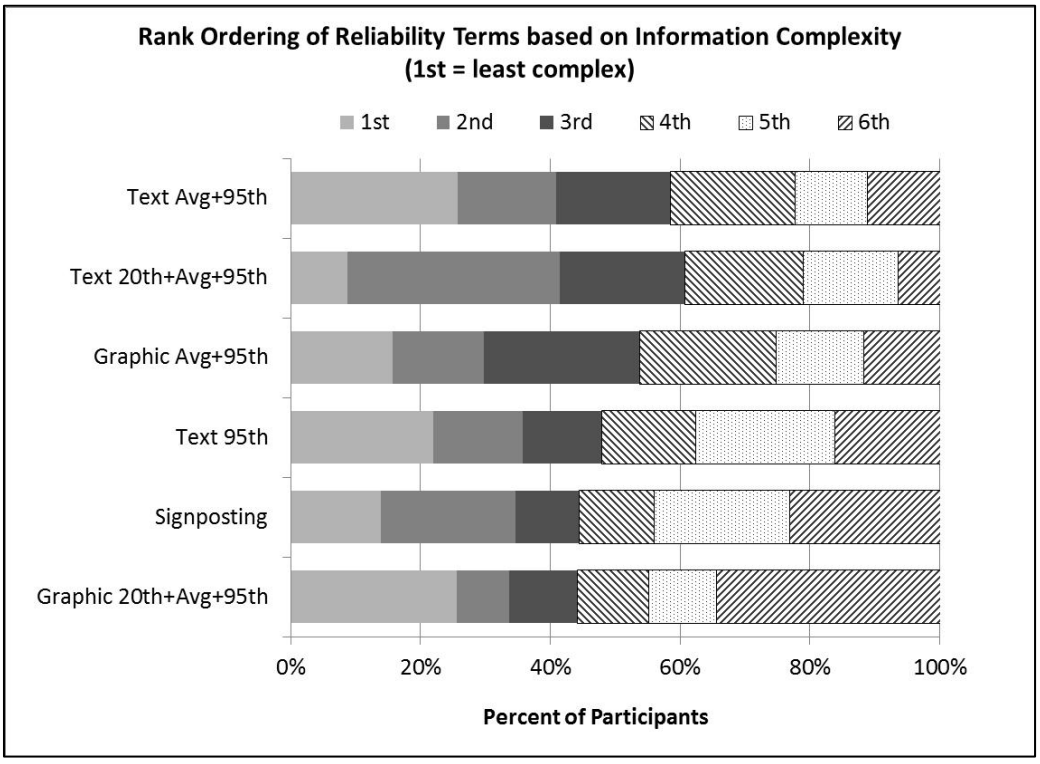


Figure 10-9. Rank ordering of reliability terms based on information complexity.

What was surprising was the bipolar response to the more complex *good, typical, and bad* graphic term. Nearly 25 percent of participants ranked this reliability term first (most useful), while 40 percent ranked this term sixth (least useful). There was no difference in response rates for experiment #1 users compared to experiment #2 users for this reliability term. Clearly, people either strongly preferred of strongly disliked the three-level graphical form.

Rankings of reliability terms based on information complexity yielded similar results to rankings based on usefulness, as shown in Figure 10-. The least complex forms of information were the textual average and 95th percentile information along with the textual 20th percentile, average, and 95th percentile information. The most complex forms of information included the graphic with three levels of travel time as well as the signposting concept.

Overall ratings for reliability term complexity confirmed that the graphical three-tier form of reliability information and reliability signposting was selected on average as most complex, lowest ease in understanding, and lowest usefulness. Conversely, the graphical and textual average and 95th percentile reliability forms were least complex and showed greatest ease in understanding. Figure 10-3 summarizes the average ratings for perceived complexity, understandability, and usefulness of reliability terms.

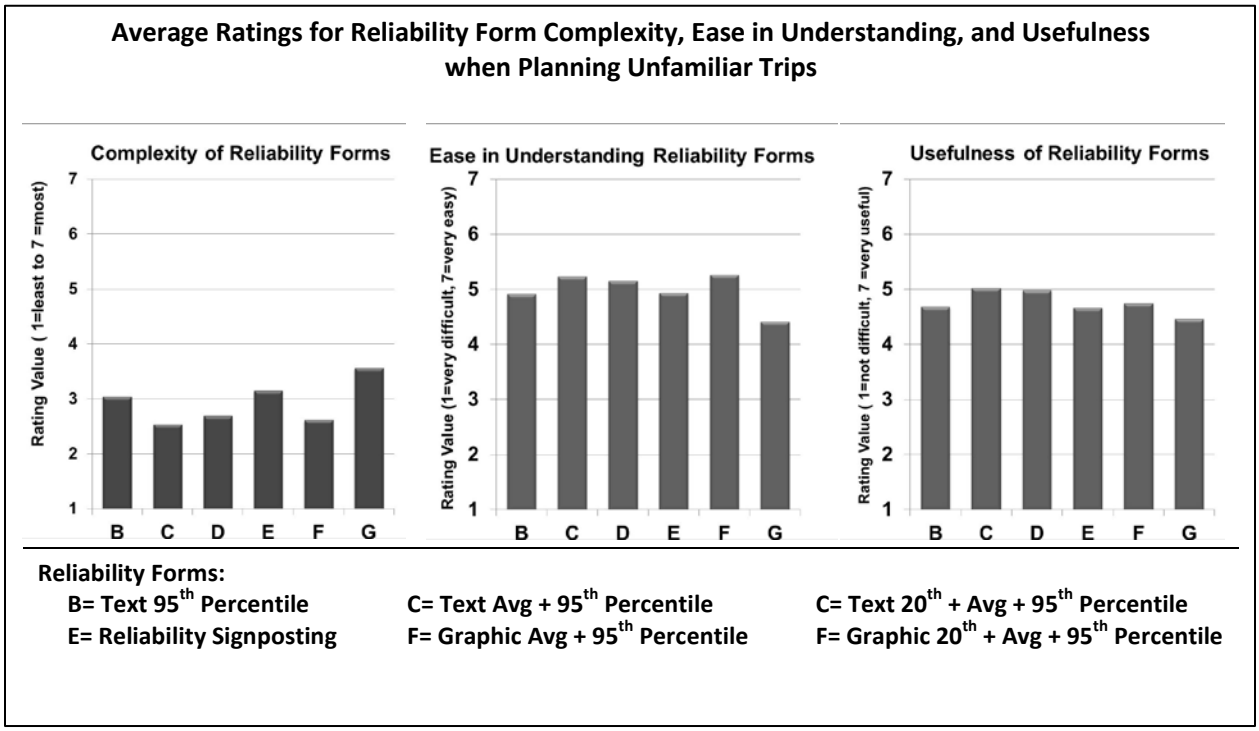


Figure 10-3. Rank ordering of reliability terms based on information usefulness.

CONCLUSIONS AND LOOKING FORWARD

This study conducted two sets of experiments across three cities involving approximately 240 individuals to quantitatively assess the effectiveness of specific reliability terms in

improving trip outcomes and to identify whether the valuation and perceived usefulness suggested by participants correlated with their quantitative trip outcomes. Travel time valuations traditionally are based on experiments where participants make tradeoffs between money-time- and other factors. The goal of our experiments were to determine the relative revealed performance and stated preferences for different types of reliability information and we were able to additionally provide quantitative estimate of the value of reliability information in reducing the frequency of late arrivals and recognized a greater willingness-to-pay for information of some types.

In these experiments, the value of reliability information to drivers was based on trip cost as predefined in each experiment, including costs of early and late arrival.

The overall trip cost was noted as significantly higher for those without reliability information. The value of knowing one will be late for a trip (serenity benefit) was determined based on participants' difference in willingness to pay for information at the end of a trip.

The study developed three hypotheses, and findings related to each of these hypotheses are described below:

Hypothesis 1 stated that provision of accurate reliability information (in an easy-to-understand format) would result in improved on-time performance and lower generalized travel disutility compared to a control group receiving no reliability information.

Hypothesis 1 was strongly supported. Of the seven different forms of delivery of reliability information tested in this experiment, users presented with five of these options demonstrated statistically significant reductions in weekly schedule offset costs compared to the control group receiving no reliability information. These five were also the simplest of the forms of reliability information, focusing on average and 95th percentile travel time values, delivered in various forms. Participants receiving these simple forms of reliability information reduced schedule offset costs by 9 to 21 percent compared to the control group.

Hypothesis 1a posited that while travel outcomes improve with the provision of reliability information, the perceived value of the reliability information would underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.

Hypothesis 1a was strongly supported. For each of the simple forms of reliability information tested, improvements in trip outcomes were clear and statistically significant. For example, frequency of late arrivals declined 16 to 40 percent when participants received reliability information in these forms compared to when they did not receive reliability information. Reported stress reduction reported at the end of each week was also statistically significant, in a similar range from 10 to 31 percent. However, participant willingness to pay for reliability information compared to willingness to pay for baseline (real-time) information was often not statistically significant. For example, participants receiving the simple text + 95th percentile reliability information reduced late arrivals by 40 percent and reported a 10 percent reduction in stress. However, these same participants were willing to pay on average only $0.10 more for

reliability information ($2.78 versus $2.68 per trip), a difference too small to be statistically significant.

Hypothesis 1b stated that provision of reliability information using different textual, graphical, and auditory forms would result in differences in both accrued on-time reliability benefits as well as perceived benefits. We expected these differences among experimental groups would be smaller than between any group and the control (no reliability information) group.

Hypothesis 1b was supported. Provision of simple forms of reliability information had similar results whether provided in text, graphic, or auditory forms. The more complex graphical and signposting concepts were not effective.

Hypothesis 2 proposed that experimental subjects receiving contextual information on underlying variation with numeric indicators reinforced with en-route information (reliability signposting) would have improved on-time performance compared to both an experimental group that received reliability information but no contextual information as well as a control group that received no reliability information.

Hypothesis 2 was not supported. The signposting concept was not successful for participants in the management of trip outcomes and stress reduction. To some degree, this was because of the complexity of the presentation and the brevity with which participants were required to learn and interpret information content. Signposting may still be a valuable concept to pursue in reliability information provision, but work remains to convey this in a more accessible manner.

Hypothesis 3 posited that benefits of reliability information would decline over time as both experimental and control subjects learned and understood the underlying travel time variability. That is, the benefit from reliability information during the first weeks would be larger than during the last weeks.

Hypothesis 3 was supported. Participants using reliability information in the first week of exposure to unfamiliar travel time variability patterns were equally effective in managing trip outcomes (late arrivals, schedule delays, and offset costs) as their counterparts without reliability information after four weeks of experience in an unfamiliar system. Within the four-week constraints of the experiment, both reliability information users and control group counterparts reduced offset costs through week 3, at which time costs leveled off. That said, the difference in realized offset costs between the two groups was still significant even in weeks 3 and 4, roughly 25 percent ($40 versus $50). This implies that reliability information still has value at four weeks of experience, and presumably may still have value longer than four weeks since the gap in performance between week 1 and week 4 between the two groups narrowed only from 40 percent to 25 percent.

Chapter 11 LEXICON DEVELOPMENT

The measurement of travel time reliability is an emerging practice. However, a few measures appear to have technical merit and are easily understood by nontechnical audiences. Most of these measures compare days with high travel times to days with average travel times. Four recommended measures are as follows:

- 90th or 95th percentile travel time.
- Buffer index.
- Planning time index.
- Frequency the congestion exceeds some expected threshold (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

FREQUENTLY USED TERMS

The 90th or 95th percentile travel time is a time identified for a specific travel route that indicates how bad delay will be on the heaviest travel days (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). These travel times are reported in minutes and seconds and are thought to be easily understood by commuters familiar with their trips. For this reason, this measure is ideally suited for traveler information. This measure has the disadvantage of not being easily compared across trips, as most trips will have different lengths. It is also difficult to combine route or trip travel times into a subarea or citywide average. Several reliability indices are presented below that enable comparisons or combinations of routes or trips with different lengths.

The buffer index represents the extra time cushion (or buffer) that most travelers add to their average travel time when planning trips to account for unforeseen delays and to ensure on-time arrival (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The buffer index is expressed as a percentage, and its value increases as reliability gets worse. For example, a buffer index of 40 percent means that for a 20-minute average travel time, a traveler should budget an additional 8 minutes (20 minutes × 40 percent = 8 minutes) to ensure on-time arrival most of the time. In this example, the eight extra minutes is called the buffer time. The buffer index is computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time.

The planning time index represents the total travel time that a traveler should expect or plan on when an adequate buffer time is included (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst-case travel time to a travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is useful because it can be directly compared to the travel time index (a measure of average congestion) on similar numeric scales. The planning time index is computed as the 95th percentile travel time divided by the free-flow travel time.

From a data perspective, using continuous travel time data is the only way to establish reliability patterns empirically. While predictive methods—such as the ones being developed by the project team for the SHRP 2 L03 project *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies*—may be used in a reliability monitoring system where these data are unavailable, only continuously collected travel time data can produce the actual travel time distribution from which all reliability metrics are derived. For example, the reliability metrics being used in the SHRP 2 L03 project are all derivatives of the travel time distribution.

What is clear is that there is not agreement within the professional field on the terms to be used or what the mathematical calculations of each of the terms should be. If the professionals cannot come to consensus on the technical terms, then the general public certainly will not do so. The purpose of the L14 project was to discover what terms the layperson would use to refer to these travel time reliability concepts and to encourage the use of those terms in communications with transportation system users.

TERMINOLOGY ASSESSMENT

The most basic considerations for trip reliability information relate to the points during a trip that reliability information should be provided, the content of the reliability information to be provided, and how content differs as a trip is made from planning, origin, to ultimate destination. Another consideration regards how reliability information needs differ for travelers with familiarity and experience with a recurrent trip compared to a trip made without the benefit of day-to-day experience of the trip's reliability. Likewise, how might transmission media and message content differ based on the needs of different driver types and trip purposes (e.g., older drivers or newer drivers, commercial vehicle operators or carpool organizers)? Furthermore, what innovations can assist in efficiently meeting these varying needs?

The literature review, expert interviews, and technology scan completed in Phase I of the project identified the reliability terms that are used by the transportation profession to describe the travel time reliability of a transportation system. This initial list, shown in Table 11-1, was drawn primarily from the FHWA Travel Time Reliability information brochure (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006) and the TTI Urban Mobility Report (Schrank, Lomax, & Eisele, 2011). The list also includes user interface terms identified through the review of traveler information websites conducted in preparation for the surveys. The human factor studies conducted in the L14 project (focus group discussions, a computer-based multiple-choice survey, an open-ended survey, the initial travel behavior laboratory study, and the enhanced laboratory study) were intended to discover what terms the layperson would use and understand to refer to these travel time reliability concepts and to determine to what extent travel time reliability information would inform travel decisions and the value of this information to system users.

Terms for some of the listed parameters were not tested in the human factor studies: (a) terms that have few or no logical alternatives and that are considered by the research team to be words/phrases that would be readily recognized by laypeople, (b) terms pertaining to reliability measures that would be unlikely to be used by laypeople (e.g., buffer and travel time indices), or (c) terms that were close parallels to other tested parameters (e.g., *planning time*, which is similar

in output to *95th percentile trip time*). The following sections describe the terminology tested in the various human factor studies and results that influenced the development of the lexicon.

Table 11-1. Proposed travel time terms/concepts to be included in lexicon.

Technical Term	Technical Definition
95th Percentile	The point on a travel time frequency distribution at which 95 percent of the trips made would be at or less than the identified time.
Arrival Time	The time at which a traveler would arrive after a trip.
Average Travel Time	An average of all travel times calculated over a specified time interval for a specified trip or roadway segment. The period of time over which the average is calculated is not consistent within the profession.
Buffer Index	A multiplier that represents the extra time or time cushion a traveler must add to his or her average travel time when planning trips to ensure on-time arrival.
Buffer Time	The average travel time multiplied by the buffer index.
Delay Time	The amount of extra time spent traveling due to congestion.
Departure Time	The time at which a traveler would depart for a trip.
Free-Flow Travel Time	Travel time for a trip under free-flow conditions (LOS A).
Peak Travel Time	The free-flow travel time added to the delay time.
Planning Time	The free-flow travel time multiplied by the planning time index.
Planning Time Index	A multiplier that represents how much total time a traveler should allow to ensure on-time arrival.
Recommended Departure Time	A time of departure calculated by a traveler information system that would ensure an on-time arrival for a given level of risk tolerance.
Recommended Route	A route between two points calculated by a traveler information system that would ensure an on-time arrival for a given level of risk tolerance.
Reliability	A consistency or dependability in travel times, as measured from day to day or across different times of day.
Total Trip Time	The total time a trip would take, door to door.
Travel Time Index	Peak travel time/free-flow travel time.
Travel Time Range	The range of travel times that can be expected and could be anchored by any two points on the travel time frequency distribution.
Trend Information	An indication that congestion is changing.

95th Percentile Travel Time

The 95th percentile travel time is a time identified for a specific travel route that indicates how long a given trip could take on the heaviest travel days (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The following terms for communicating 95th percentile travel times were discussed in the focus groups and/or tested in one or both of the surveys:

- 95th percentile trip time.
- Majority of the time.

- Most of the time.
- Travel time for planning.
- Maximum trip time.
- Worst-case trip time.
- X out of Y days (e.g., 19 out of 20 days).

Of these terms, *maximum trip time* and *worst-case trip time* were not tested due to potential credibility concerns on the part of a public agency. The phrase *19 out of 20 days* was not tested in surveys but is a probability expression that has been shown in the literature to be more readily understood by the general population than percentages or percentiles.

Majority of the time, used as part of the sentence "the majority of the time your trip will take *XX* minutes or less," was most likely to be interpreted correctly by participants as representing a trip time that would apply to unusually heavy traffic and unusual delays. This phrase was used to describe 95th percentile travel times in the enhanced laboratory study.

The term *95th percentile* was not well understood by survey participants, and participants who were presented with a 95th percentile trip time were less confident about arriving on time compared to participants who viewed the same trip time described with other tested terms (e.g., *majority of the time, most of the time*). Participants viewing *95th percentile trip time* were likely to add their own buffer time on top of the total trip time provided.

Most of the time, used as part of the sentence "most of the time your trip will take __ minutes or less," produced the greatest (expressed) confidence in arriving by the time shown, but participants still tended to add their own buffer time to the time provided.

Participants given a trip time described as *travel time for planning* were more likely to view that time as a maximum trip time or worst-case scenario rather than the 95th percentile time that was intended.

Arrival Time

Alternate terms for arrival time—the time that a traveler arrives at his or her destination at the end of a trip—were not tested since it is a commonly used phrase. However, phrases that a traveler might use to describe a desired arrival time were presented in the computer survey.

For a scenario in which a traveler would enter a preferred arrival time into a travel time calculator (in order to receive a recommended departure time), the survey offered the following phrases:

- Arrive by.
- Arrive at.
- What time do you want to get there?
- What's the earliest you can arrive?
- What's the latest you can arrive?

By a statistically significant margin, the largest percentage of participants preferred *arrive by*, with *arrive at* the second most frequently selected option. These responses showed a willingness to accept either an on-time or an early arrival, since "by" can mean "no later than." The other three phrases were selected much less frequently by participants. The research team concluded from the survey results that *arrive by* is the best of the tested terms to use to ask for desired arrival time input.

Average Travel Time

The technical definition of average travel time is an average of all travel times calculated over a specified time interval for a specified trip or roadway segment. The period of time over which the average is calculated is not consistent within the profession.

Terms to communicate average travel time were discussed in focus groups and tested in both surveys:

- Average travel time.
- Estimated travel time.
- Expected travel time.
- Typical travel time.
- Historical travel time.

Average, *estimated*, *expected*, and *typical travel time* were all terms that were mentioned by focus group participants. *Historical travel time* is used by some travel time websites to distinguish an average trip time based on past travel time data. In the open-ended survey, there was no clear preference or effect on comprehension among the terms *average, estimated, typical*, and *expected* travel times. However, in the computer-based survey, *estimated travel time* was preferred by the largest number of participants, followed by *average travel time*. *Typical travel time* and *historical travel time* were selected least frequently by participants in the computer-based survey.

Estimated travel time was selected to describe a calculated average travel time in the enhanced laboratory study.

Average travel time was addressed in two additional ways in the focus groups and in the computer survey. The sentence "It will take ___ 20 minutes to make your trip" was presented to focus groups to elicit potential terms for describing average trip time. Responses included *about, an estimate of, approximately, around, an average of, roughly, give or take,* and *at least.* When tested in the computer-based survey, *approximately* was preferred by a majority of participants, followed by *about, an estimate of,* and *an average of.*

The sentence "It is ____ that your trip will take 45 minutes" was completed by focus group participants and in the computer survey, *estimated* was preferred the highest number of participants, followed by *likely* and *predicted*.

Buffer Index

The buffer index represents the extra time cushion (or buffer) that most travelers add to their average travel time when planning trips to account for unforeseen delays and to ensure on-time arrival (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The buffer index is expressed as a percentage, and its value increases as reliability gets worse. For example, a buffer index of 40 percent means that for a 20-minute average travel time, a traveler should budget an additional 8 minutes (20 minutes × 40 percent = 8 minutes) to ensure on-time arrival most of the time. In this example, the eight extra minutes is called the buffer time. The buffer index is computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time.

Terminology for the buffer index was not tested in the human factor studies, as this is a metric that is unlikely to be used by roadway users.

Buffer Time

Buffer time is defined as the average travel time multiplied by the buffer index. When speaking about the additional time added to a trip to ensure on-time arrival, focus group participants suggested terms and phrases including *additional time, traffic time, leeway, driving time, just-in-case time, fluff time, additional drive time, cushion, allow an additional X minutes for variables, tack on extra,* and *extra time*. Terms that were tested in one or both surveys included the following:

- Added time.
- Buffer time.
- Cushion.
- Departure window.
- Extra time.
- Leeway.
- Recommended cushion.

Of these tested terms, *extra time* was preferred by the most participants in the computer survey, followed by *departure window*; in the open-ended survey, *recommended cushion*, *added time*, and *extra time* all performed well. *Buffer time* was preferred by the least number of participants in the computer survey and so was not tested in the open-ended survey. Despite the popularity of *departure window* in the computer survey, the research team does not recommend its use as a synonym for *buffer time*.

Extra time was used to describe buffer time in the travel time information provided to participants in the enhanced laboratory study.

Delay Time

Terminology for delay time was not tested in the human factor studies; instead, terms were tested for the related concept of buffer time.

Departure Time

Focus group participants wanted the ability to specify a trip calculation based on time of departure or time of arrival. The computer survey continued investigation on this topic by addressing the preferred terminology to be used for the departure and arrival times. Terms and phrases tested in the survey included the following:

- Departing at.
- Leave at.
- What time will you start your trip?
- Leave by.
- Departing by.
- What's the earliest you can start your trip?
- What's the latest you can start your trip?

Departing at, leave at, and *what time will you start your trip?* were the top three terms selected by participants, showing a preference for specific departure times versus a range of potential departure times (as could be implied by the other four tested phrases).

Free-Flow Travel Time

Terminology for free-flow travel time (i.e., travel time for a trip under free-flow conditions) was not tested in the focus groups or surveys. In the enhanced laboratory study, one of the graphical travel time information formats included projected trip times on a great day for travel speeds, along with corresponding times for average/typical and bad days. The "great day" trip time was intended to represent free-flow travel time.

Peak Travel Time

Terminology for peak travel time (free-flow travel time added to delay time) was not tested in the human factor studies. Terms for the similar concept of 95th percentile travel time were tested instead.

Planning Time

Terminology for planning time (free-flow travel time multiplied by the planning time index) was not tested in the human factor studies. Terms for the similar concept of 95th percentile travel time were tested instead, and *travel time for planning* was one of the alternatives tested to represent 95th percentile travel time.

Planning Time Index

The planning time index is used to calculate the total travel time that a traveler should expect or plan on when an adequate buffer time is included (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst-case travel time to a travel time in light or free-flow traffic. For example, a

planning time index of 1.60 means that for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is computed as the 95th percentile travel time divided by the free-flow travel time.

Terminology for planning time index was not tested in the human factor studies, as this is a metric that is unlikely to be used by roadway users.

Recommended Departure Time

Recommended departure time is defined as the time of departure calculated by a traveler information system that would ensure an on-time arrival for a given level of risk tolerance. The following terms were tested in the computer-based survey to describe this calculated time of departure:

- Recommended departure time.
- Estimated departure time.
- 95th percentile departure time.
- Suggested departure time.

Of the tested terms, *recommended departure time* was preferred most frequently by survey participants, followed by *suggested* and *estimated*; *95th percentile departure time* was the least preferred.

Recommended Route

A recommended route in the context of travel time reliability is defined as the route between two points calculated by a traveler information system that would ensure an on-time arrival for a given level of risk tolerance. Terms tested in the computer survey to describe a route provided to a traveler by a traveler information system included the following:

- Best route.
- Forecasted trip.
- Most reliable trip.
- Most predictable trip.
- Most consistent trip.
- Historical trip conditions.
- Least variable time.

Of the tested terms, the most frequently preferred was *best route*, followed by *forecasted trip* and *most reliable trip*. While the term *recommended route* was not tested in the surveys, its similarity to participant-preferred terms like *recommended departure time* and *recommended cushion* likely indicates that *recommended route* would also be a strong candidate.

Reliability

Terms for both reliability and variability were discussed in focus groups and tested in the computer survey. Most often, focus group participants chose general words such as *possibly*,

probably, *chance*, or *likely* to describe variability at a certain time of day. Generally, they preferred for those words to have a descriptor in front, such as "X percent chance" or "highly likely," to make the term less general. When talking about traffic patterns at a specific time of day, participants used *varies*, *changes*, and *increases/decreases* most often. Focus group participants preferred the terms *reliable* and *consistent* when describing the reliability of a roadway or mode.

The computer survey described four different fictional trips that were actually trip times presented in different ways: a typical/average trip time, a maximum trip time, a small trip time range, and a large trip time range. Participants were then asked to select a term that they felt described each of those trip times:

- Predictable.
- Reliable.
- Consistent.
- Best.

All four terms were treated similarly by participants: they were selected to describe the typical and maximum trip times much more frequently than to describe either of the trip time ranges.

Terms for trip time variability were also tested in the computer survey, using the sentence "your trip time may ___ from the average trip time by 15 minutes." Response options included the following:

- Vary.
- Differ.
- Fluctuate.
- Change.
- Go up or down.
- Increase or decrease.
- Deviate.
- Is longer or shorter.

Of these options, *vary* was preferred most frequently, by far, by survey participants.

Total Trip Time

Terminology for total trip time was not tested in the human factor studies since it is a commonly used phrase and few synonyms exist.

Travel Time Savings

Terminology for *travel time savings* was not tested in the human factor studies since it is a commonly used phrase and few synonyms exist.

Travel Time Range

In focus groups, terms used to compete the sentence "It will take _____ 10 to 30 minutes to make your trip" were *about, approximately, between, around, on average, likely, anywhere from, somewhere between, usually*, and *ideally*.

In the computer survey, two hypothetical trips for which travel time ranges were provided were not as frequently described by participants as *reliable, predictable*, or *consistent* compared to trips for which a single (typical/average or 95th percentile) trip time was provided.

Historical travel time information in the first travel behavior laboratory study was presented in the form of trip time ranges.

Trend Information

Terms for trend information (an indication that congestion is changing) were not tested in the human factor studies. Travel planning websites that were reviewed during focus group preparation and survey development often indicated trend information graphically (if they indicated it at all).

LEXICON FORMAT

The research team identified several key elements of a lexicon entry that were deemed necessary to completely present each term. The elements are:

- *Technical Term*—the formal travel time reliability term to be defined.
- *Definition*—a definition of the term within the reliability framework.
- *Usage*—a general description of when an agency might use the reliability term or for what purpose it would use the term in the traveler information system.
- *Recommendation*—the ranking of the messages and/or terms to be used in order of preference.
  - *Best*—represents the term(s), phrase(s), and/or format(s) that performed the best in the human factor studies and will most likely yield the desirable behavioral results when conveyed to system users.
  - *Adequate*—represents term(s), phrase(s), and/or format(s) that performed reasonably well in the human factor studies and will not likely present significant comprehension problems for system users.
  - *Avoid*—represents terms(s), phrase(s), and/or format(s) that did not perform well in the human factor studies or are recommended to avoid for noted reasons.
- *Alternate Phrase*—an alternative term or phrases of different lengths that would work on some technology platforms but not on others.
- *Information Technology Platforms*—identification of appropriate media and technology interfaces for each alternative. This list of technology platforms could continue to evolve as new media are introduced. These might include portable navigation devices,

Connected Vehicle (formerly IntelliDrive℠) on-board equipment, and advanced car stereo or satellite radio systems. An initial list is included in the example shown and includes:

- *Web*—intended to mean full website format viewed from a full-sized personal computer screen in a full-featured Internet browser.
- *Mobile Web*—intended to mean a website format viewed from mobile devices such as smartphones and tablet computers.
- *Dynamic Message Sign*—roadside dynamic message signs.
- *Text*—includes short message service (SMS) text messages and social network text messages, such as Twitter™, viewed on a mobile device.
- *Mobile Application*—specially designed user interfaces optimized to work on a specific smartphone operating system. These apps include user input and output screens and data entry mechanisms, such as drop-down text boxes and scrolling menus, specifically designed for the touchscreen or keyboard supported by that operating system.

An example format for the data elements the research team identified for travel time reliability is illustrated in Table 11-2. This structure organizes the data elements above in a way that can be applied to both reliability terms at a concept level and user interface phrases and terms. This structure also provides a convenient checkbox matrix indicating the platforms for which each variant of the term is recommended.

Table 11-2. Lexicon format.

Technical Term	**95th Percentile**
Definition	The point on a travel time frequency distribution at which 95% of the trips made would be at or less than the identified time.
Usage	To describe the longest time a driver can expect a trip to take.

Recommendation	**Alternate Phrase**	**Wording Context/ Additional Information**	**Information Technology Platforms**				
			Web	**Mobile Web**	**Text**	**Mobile Application**	**Dynamic Message Sign**
Best			√	√	√+	√+	X
Adequate			√	√	√+	√+	X
Avoid			N/A	N/A	N/A	N/A	N/A

LIMITATIONS OF LEXICON INFORMATION

It is important to note that the studies conducted in this project were laboratory studies, and none of these terms were tested in a field environment. Only in a field test with specific detailed travel behavior data can researchers determine the true impacts and benefits of the use of travel time reliability information on behavior and resulting trip performance. Of specific note is the fact that nowhere in the various human factor studies were the specific phrases suggested for display on DMSs tested specifically as being displayed on a DMS and as en-route information. These suggested phrases were developed by the research team based on the results discussed for the related terminologies. The team developed these phrases using the general guidance for

DMS message development provided in the MUTCD. It is also important to note that the formatting of these travel time messages is very different from the standard messages used by state transportation agencies on DMSs. For many of the reliability terms, their use on a DMS would present various challenges to the traveler including:

- Drivers are conditioned to see real-time travel information displayed on DMSs on freeway corridors, and reliability information may confuse them when placed on DMSs.
- Any reliability information displayed on a DMS would need to be relative to the specific location of the sign on the freeway facility, as drivers would have begun their trips from various locations in the region's transportation network.
- Messages providing departure time or buffer time information are not appropriate for DMSs since travelers would need to see these messages prior to starting their trip, not en route.

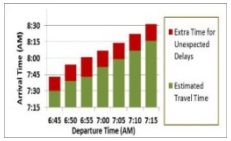
TRAVEL TIME RELIABILITY LEXICON

The following tables present the specific lexicon of phrases for each travel time reliability term tested in the various human factors studies. The tables are as follows:

- Table 11-3. Travel time reliability lexicon for *95th PERCENTILE*.
- Table 11-4. Travel time reliability lexicon for *ARRIVAL TIME*.
- Table 11-5. Travel time reliability lexicon for *AVERAGE TRAVEL TIME.*
- Table 11-6. Travel time reliability lexicon for *BUFFER TIME.*
- Table 11-7. Travel time reliability lexicon for *DEPARTURE TIME.*
- Table 11-8. Travel time reliability lexicon for *RECOMMENDED DEPARTURE TIME.*
- Table 11-9. Travel time reliability lexicon for *RECOMMENDED ROUTE.*
- Table 11-10. Travel time reliability lexicon for *RELIABILITY*.

Table 11-3. Travel time reliability lexicon for *95th PERCENTILE.*

Technical Term	**95th Percentile**
Definition	The point on a travel time frequency distribution at which 95% of the trips made would be at or less than the identified time.
Usage	To describe the longest time a driver can expect a trip to take.

Recommendation	Alternate Phrase	Wording Context/Additional Information	Information Technology Platforms				
			Web	Mobile Web	Text	Mobile Application	Dynamic Message Sign
Best	Majority of the time	*"The majority of the time, your trip will take X minutes or less."*	√	√	√+	√+	X
		MAJORITY OF TIME TRIP TO [DESTINATION] X MIN OR LESS	√	√	√	√	√>
		Graphical representation of the average + 95th percentile.	√	√	X	√	X
Adequate	Most of the time	*"Most of the time, your trip will take X minutes or less."*	√	√	√+	√+	X
		MOST OF THE TIME TRIP TO [DESTINATION] X MIN OR LESS	√	√	√	√	√>
	Travel time for planning	*"Travel time for planning is X minutes or less."*	√	√	√+	√+	X
	95th percentile trip time	*"The 95th percentile trip time is X minutes or less."* Provide description such as "19 out of 20 days."	√	√	√+	√+	X
Avoid	Maximum trip time Most common trip time Worst-case trip time	Agency concerns regarding liability and credibility.	N/A	N/A	N/A	N/A	N/A

+Underlined terms to be removed for this platform; other phrase shortening may be possible depending on user preference.
>The formatting of this travel time message is very different from the standard messages used by state transportation agencies on DMSs.

Table 11-4. Travel time reliability lexicon for *ARRIVAL TIME*.

Technical Term	**Arrival Time**
Definition	The time at which a traveler would arrive after a trip.
Usage	To tell the driver when he/she can expect to arrive at his/her destination.

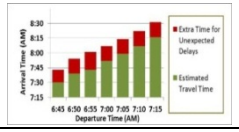
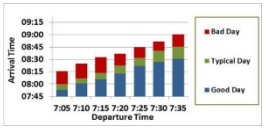
Recommendation	Alternate Phrase	Wording Context/Additional Information	Information Technology Platforms				
			Web	Mobile Web	Text	Mobile Application	Dynamic Message Sign
Best	**Arrive by**	*"Arrive by X:XX a.m./p.m."*	√	√	√	√	X
		ARRIVE BY X:XX AM/PM	√	√	√	√	√>%
Adequate	**Arrive at**	*"Arrive at X:XX a.m./p.m."*	√	√	√	√	X
		ARRIVE AT X:XX AM/PM	√	√	√	√	√>%
	What time do you want to get there?	This question would be used by a traveler to enter a preferred arrival time into a travel time calculator to receive a recommended departure time.	√	√	X	√	X
	What's the earliest you can arrive	This question would be used by a traveler to enter a preferred arrival time into a travel time calculator to receive a recommended departure time.	√	√	X	√	X
	What's the latest you can arrive?	This question would be used by a traveler to enter a preferred arrival time into a travel time calculator to receive a recommended departure time.	√	√	X	√	X
Avoid							

> The formatting of this travel time message is very different from the standard messages used by state transportation agencies on DMSs.

% Term may present ambiguity to the viewers, as they would not see a specific destination.

Table 11-5. Travel time reliability lexicon for *AVERAGE TRAVEL TIME.*

Technical Term	**Average Travel Time**
Definition	An average of historical travel times calculated over a specified time interval for a specified trip or roadway segment.
Usage	To describe the typical travel time a driver can expect a trip will take.

Recommendation	**Alternate Phrase**	**Wording Context/Additional Information**	**Information Technology Platforms**				
			Web	**Mobile Web**	**Text**	**Mobile Application**	**Dynamic Message Sign**
Best	**Estimated travel time**	*"Estimated travel time is X minutes."*	√	√	√+	√+	X
		"It is estimated that your trip will take X minutes."	√	√	√+	√+	X
		EST THAT TRIP TO [DESTINATION] WILL TAKE X MIN	√	√	√	√	√>
	Approximate travel time	*"It will take approximately X minutes to make your trip."*	√	√	√+	√+	X
		APPROX X MIN TO [DESTINATION]	√	√	√	√	√>
Adequate	**Typical travel time**	*"Typical travel time is X minutes."*	√	√	√+	√+	X
		Graphical representation of the average + 95th percentile (typical day and bad day).	√	√	X	√	X
		Graphical representation of the 20th percentile + average + 95th percentile (good, typical, and bad day).	√	√	X	√	X
	Average travel time	*"Average travel time is X minutes."*	√	√	√+	√+	X
	Expected travel time	*"Expected travel time is X minutes."*	√	√	√+	√+	X
Avoid	**Historical Travel Time**	Difficult to determine relevance with no comparison to real-time information.	N/A	N/A	N/A	N/A	N/A

+ Underlined terms to be removed for this platform; other phrase shortening may be possible depending on user preference.

> The formatting of this travel time message is very different from the standard messages used by state transportation agencies on DMSs.

Table 11-6. Travel time reliability lexicon for *BUFFER TIME.*

Technical Term	**Buffer Time**
Definition	The average travel time multiplied by the buffer index.
Usage	To describe how much extra time a driver should plan for a trip he/she wishes to take.

Recommendation	Alternate Phrase	Wording Context/Additional Information	Information Technology Platforms				
			Web	Mobile Web	Text	Mobile Application	Dynamic Message Sign
Best	Extra time	*"Extra time for trip is X minutes."*	√	√	√+	√+	X
		EXTRA TIME TO [DESTINATION] IS X MIN	√	√	√	√	X
Adequate	Added time	*"Added time for trip is X minutes."*	√	√	√+	√+	X
		ADDED TIME TO [DESTINATION] IS X MIN	√	√	√	√	X
	Recommended cushion	*"Recommended cushion for trip is X minutes."*	√	√	√+	√+	√
Avoid	Cushion	Preference shown for other terms.	N/A	N/A	N/A	N/A	N/A
	Buffer time						
	Departure window						
	Leeway						

+ Underlined terms to be removed for this platform; other phrase shortening may be possible depending on user preference.

Table 11-7. Travel time reliability lexicon for *DEPARTURE TIME.*

Technical Term	**Departure Time**
Definition	The time at which a traveler would depart for a trip.
Usage	To indicate the time a traveler departs for a trip. For DMS applications, message would need to be set in context with other information, such as destination, travel time, or route.

Recommendation	Alternate Phrase	Wording Context/Additional Information	Information Technology Platforms				
			Web	Mobile Web	Text	Mobile Application	Dynamic Message Sign
Best	**Departing at**	*"Departing at X:XX a.m./p.m."*	√	√	√	√	X
	Leave at	*"Leave at X:XX a.m./p.m."*	√	√	√	√	X
Adequate	**What time will you start your trip?**	This question would be used by a traveler to enter a start time into a travel time calculator to receive an arrival time.	√	√	X	√	X
	Leave by	*"Leave by X:XX a.m./p.m."*	√	√	√	√	X
	Departing by	*"Departing by X:XX a.m./p.m."*	√	√	√	√	X
	What's the earliest you can start your trip?	This question would be used by a traveler to enter a start time into a travel time calculator to receive an arrival time.	√	√	X	√	X
	What's the latest you can start your trip?	This question would be used by a traveler to enter a start time into a travel time calculator to receive an arrival time.	√	√	X	√	X
Avoid							

Table 11-8. Travel time reliability lexicon for *RECOMMENDED DEPARTURE TIME.*

Technical Term	**Recommended Departure Time**
Definition	A time of departure displayed to a traveler that is calculated by a traveler information system and would ensure an on-time arrival for a given level of added delay.
Usage	To indicate the time a driver should depart for a trip to ensure he/she arrives at his/her destination on time. For DMS applications, would need to be set in context with other information, such as destination, travel time, or route.

Recommendation	**Alternate Phrase**	**Wording Context/Additional Information**	**Information Technology Platforms**				
			Web	**Mobile Web**	**Text**	**Mobile Application**	**Dynamic Message Sign**
Best	**Recommended departure time**	*"Recommended departure time is X:XX a.m./p.m."*	√	√	√+	√+	X
Adequate	**Suggested departure time**	*"Suggested departure time is X:XX a.m./p.m."*	√	√	√+	√+	X
	Estimated departure time>	*"Estimated departure time is X:XX a.m./p.m."*>>	√	√	√+	√+	X
	95th percentile departure time	*"The 95th percentile departure time is X:XX a.m./p.m."* Provide description such as "19 out of 20 days."	√	√	√+	√+	X
Avoid							

+ Underlined terms to be removed for this platform; other phrase shortening may be possible depending on user preference.

>> Can be used if term is NOT being used to mean average trip time.

Table 11-9. Travel time reliability lexicon for *RECOMMENDED ROUTE.*

Technical Term	Recommended Route
Definition	A route between two points calculated by a traveler information system that would provide the best probability of on-time arrival to a specific destination.
Usage	To describe the route a driver should take for a planned trip to ensure he/she arrives on time to his/her destination.

Recommendation	Alternate Phrase	Wording Context/Additional Information	Information Technology Platforms				
			Web	Mobile Web	Text	Mobile Application	Dynamic Message Sign
Best	Best route	*"Best route is via [facility]."*	√	√	√+	√+	X
		BEST ROUTE TO [DESTINATION] TAKE [FACILITY]	√	√	√	√	√>
Adequate	Forecasted trip	*"Forecasted trip is via [facility]."*	√	√	√+	√+	X
		FORECASTED TRIP TIME VIA [FACILITY] X MIN	√	√	√	√	√>
	Most reliable trip	*"Most reliable trip is via [facility]."*	√	√	√+	√+	X
		MOST RELIABLE TRAVEL TIME TO [DESTINATION] TAKE [FACILITY]	√	√	√	√	√>
	Most predictable trip	*"Most predictable trip is via [facility]."*	√	√	√+	√+	X
		MOST PREDICTABLE TRAVEL TIME TO [DESTINATION] TAKE [FACILITY]	√	√	√	√	√>
	Most consistent trip	*"Most consistent trip is via [facility]."*	√	√	√+	√+	X
		MOST CONSISTENT TRAVEL TIME TO [DESTINATION] TAKE [FACILITY]	√	√	√	√	√>
Avoid	Historical trip conditions Least variable time	Difficult to determine relevance with no comparison to real-time information. Preference shown for other terms.	N/A	N/A	N/A	N/A	N/A

+ Underlined terms to be removed for this platform; other phrase shortening may be possible depending on user preference.

> The formatting of this travel time message is very different from the standard messages used by state transportation agencies on DMSs.

Table 11-10. Travel time reliability lexicon for *RELIABILITY.*

Technical Term	Reliability
Definition	A consistency or dependability in travel times between two points, as measured from day to day or across different times of day.
Usage	To describe the variability of travel times to drivers so they can plan their trip with more robust information.

Recommendation	Alternate Phrase	Wording Context/Additional Information	Information Technology Platforms				
			Web	Mobile Web	Text	Mobile Application	Dynamic Message Sign
Best	**Predictable**	*"Most predictable trip"*	√	√	√	√	X
Adequate	**Reliable**	*"Most reliable trip."*	√	√	√	√	X
	Consistent	*"Most consistent trip."*	√	√	√	√	X
	Vary	*"Trip varies."*	√	√	√	√	X
Avoid	**Differ**	Preference shown for other terms.	N/A	N/A	N/A	N/A	N/A
	Fluctuate						
	Change						
	Go up or down						
	Increase or decrease						
	Deviate						

Chapter 12 FINAL REMARKS

The SHRP 2 Reliability Program aims to improve trip time reliability by reducing the frequency and effects of events that cause travel times to fluctuate in an unpredictable manner. As the program planning document points out, congestion caused by unreliable, or nonrecurring, events is roughly as large as congestion caused by routine bottlenecks (Cambridge Systematics Inc., 2003). Nonrecurring events such as crashes, work zones, special events, and weather disrupt normal traffic flow by causing reduced speeds, lane closures, and erratic driving maneuvers.

Travel time reliability information includes static data about traffic speeds or trip times that capture historic variations from day to day and enable individuals to understand the level of variation in traffic. Unlike real-time travel time information, which provides a current snapshot of trip conditions and travel time, reliability information can be used to plan and budget in advance for a trip. A key component to addressing the reliability issue related to urban mobility is conveying this reliability-related information to system users so that they can make informed decisions about their travel. The challenge for transportation professionals lies in selecting the best means of conveying that information so that it is usable and effective. The goal of this research project was to examine what combination of words, numbers, and other features of user information messages, along with communications methods and technology platforms, best communicates information about travel time and reliability to travelers so that they can make optimal travel choices from their point of view. Such choices include whether to take a trip or not, departure time, mode choice, and route choice.

This document provided a comprehensive description of the increasingly detailed series of human factor experiments and the development of a utility function, which with input from a literature review, expert interviews, and a technology and innovation scan, provided key information and insight into how individuals comprehend and interpret travel time reliability information, how they use that information to make trip decisions, and how reliability terms can be phrased to reach the highest percentage of travelers so that their travel decisions yield some benefit to them.

The key product of this study is the lexicon of travel time reliability terms. The research team identified several key elements of a lexicon entry that were deemed necessary to completely present each term and how it might be used within the transportation community.

The research team developed a structure for the lexicon that organizes these data elements in a way that can be applied to both reliability terms at a concept level and user interface phrases and terms. This structure also provides a convenient checkbox matrix indicating the platforms for which each variant of the term is recommended.

STUDY LIMITATIONS

It is important to note that the studies conducted in this project were laboratory studies, and none of these terms were tested in a field environment. Only in a field test with specific detailed travel behavior data can researchers determine the true impacts and benefits of the use of travel

time reliability information on behavior and resulting trip performance. Of specific note is the fact that nowhere in the various human factor studies were the specific phrases suggested for display on DMSs tested specifically as being displayed on a DMS and as en-route information. These suggested phrases were developed by the research team based on the results discussed for the related terminologies. The team developed these phrases using the general guidance for DMS message development provided in the MUTCD. It is also important to note that the formatting of these travel time messages is very different from the standard messages used by state transportation agencies on DMSs.

KEY FINDINGS ON TRAVEL TIME RELIABILITY TERMINOLOGY

The human factors studies found that several of the reliability terms that are commonly used and understood by transportation professionals, such as *95th percentile*, *buffer time*, *buffer index*, and even *average trip time*, are not necessarily preferred or consistently understood by travelers. The results of the focus groups, the computer survey and the open-ended survey indicated that participants did not like statistical sounding terms and were likely to interpret those terms inaccurately. For instance, significant numbers of participants interpreted *95th percentile trip time* as being a time about which a trip prediction system was 95 percent confident; and/or estimated that an *average trip time* would apply to approximately 75 percent of trips rather than approximately 50 percent of trips. In most cases, there was no single term or phrase for a given reliability concept that was a "slam dunk;" i.e., understood and preferred by a large majority of participants. However, there were generally one to three terms in each category that tested reasonably well with study participants, and which the research team feels are good candidates for pilot testing and/or further testing in field studies. The lexicon lists the tested terms for eight categories of travel time reliability information (as well as sample graphics for some information categories) along with the research team's recommendations regarding their use.

KEY STUDY OBSERVATIONS ON USER BEHAVIOR

After careful assessment of the aforementioned travel time reliability terms and the results obtained in the various human factor studies and experiments conducted throughout the course of the L14 project, the research team established three key hypotheses related to the use and value of travel time reliability information from the user's perspective that were tested in the enhanced laboratory study. The following sections highlight these hypotheses and the results from the study—all of which were combined with the results from the other human factor experiments to develop the lexicon.

Hypothesis 1

The first hypothesis stated that the provision of accurate reliability information (in an easy-to-understand format) would result in improved on-time performance and lower generalized travel disutility compared to a control group receiving no reliability information.

Findings from the first laboratory study supported this hypothesis. Experimental participants who received reliability information were on time more frequently (85 percent versus 79 percent) and had lower total late and early arrival penalties associated with the simulated trip ($38.61

versus $47.42 and $55.55 in the two control groups). Both findings were statistically significant with 95 percent confidence despite the relatively small sample size of the experiment.

The results of the enhanced laboratory study strongly supported this hypothesis. Of the seven different forms of delivery of reliability information tested in the experiment, users presented with five of these options demonstrated statistically significant reductions in weekly schedule offset costs (i.e., costs established in the experiment for early and late arrivals) compared to the control group receiving no reliability information. These five were also the simplest of the forms of reliability information, focusing on average and 95th percentile travel time values, delivered in various forms. Participants receiving these simple forms of reliability information reduced schedule offset costs by 9 to 21 percent compared to the control group.

Hypothesis 1a

Hypothesis 1a stated that while travel outcomes improve with the provision of reliability information, the perceived value of the reliability information would underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.

The enhanced laboratory study results strongly supported this hypothesis. For each of the simple forms of reliability information tested, improvements in trip outcomes were clear and statistically significant. For example, frequency of late arrivals declined 16 to 40 percent when participants received reliability information in these forms compared to when they did not receive reliability information. Reported stress reduction reported at the end of each week was also statistically significant, in a similar range from 10 to 31 percent. However, participant willingness to pay for reliability information compared to willingness to pay for baseline (real-time) information was often not statistically significant. For example, participants receiving the simple text + 95th percentile reliability information reduced late arrivals by 40 percent and reported a 10 percent reduction in stress. However, these same participants were willing to pay on average only $0.10 more for reliability information ($2.78 versus $2.68 per trip), a difference too small to be statistically significant.

Hypothesis 1b

Hypothesis 1b stated that the provision of reliability information using different textual, graphical, and auditory forms would result in differences in both accrued on-time reliability benefits as well as perceived benefits. The study team expected these differences among experimental groups would be smaller than between any group and the control (no reliability information) group.

The enhanced laboratory study supported this hypothesis. Provision of simple forms of reliability information had similar results whether provided in text, graphic, or auditory forms. The more complex graphical and signposting concepts were not effective.

Hypothesis 2a

Hypothesis 2a (tested in the first laboratory study) proposed that while travel outcomes improved with the provision of reliability information, the perceived value of the reliability information

would underestimate the realized benefit in terms of reduced delay, improved on-time reliability, and reduced stress.

Findings from the first laboratory study supported this hypothesis. Measured perceptions of benefit associated with reliability information were not commensurate with the observed improvements in trip outcomes. Changes in the value of information and stress reduction, although generally favorable to reliability information, were not statistically significant. The implication is that although reliability information can be useful in managing trip time variability, the apparent value of this information is lost in the context of learning over time. It is likely that the experimental subjects internalized the reliability information as one element in this learning process, rather than considering its value outside of their learning process. Providers of reliability information may face an uphill battle in measuring perceptional impacts of reliability information impacts even when such information is useful in improving trip outcomes.

Hypothesis 2b

Hypothesis 2b (tested in the second laboratory study) stated that experimental subjects receiving contextual information on underlying variation with numeric indicators reinforced with en-route information (reliability signposting) would have improved on-time performance compared to both an experimental group that received reliability information but no contextual information as well as a control group that received no reliability information.

Hypothesis 2 was not supported by the enhanced laboratory study. The signposting concept was not successful for participants in the management of trip outcomes and stress reduction. To some degree, this was because of the complexity of the presentation. Signposting may still be a valuable concept to pursue in reliability information provision, but work remains to convey this in a more accessible manner.

Hypothesis 3

Hypothesis 3 stated that the benefits of reliability information would decline over time as both experimental and control subjects learned and understood the underlying travel time variability. That is, the benefit from reliability information during the first weeks would be larger than during the last weeks.

Findings from the first laboratory study were inconclusive. Participants with access to reliability information did see total early- and late-arrival penalties decline from week 1 to week 2 of the simulated trip-making. Control groups who did not receive this information were mixed, with one group realizing a reduction in total costs and another seeing a rise in these costs. Interestingly, participants' willingness to pay for reliability information declined over time in the simulation experiment, indicating that experience within the simulated trip began to offset the reliance on provided reliability information.

The enhanced laboratory study supported hypothesis 3. Participants using reliability information in the first week of exposure to unfamiliar travel time variability patterns were equally effective in managing trip outcomes (late arrivals, schedule delays, and offset costs) as their counterparts

without reliability information after four weeks of experience in an unfamiliar system. Within the four-week constraints of the experiment, both reliability information users and control group counterparts reduced offset costs through week 3, at which time costs leveled off. That said, the difference in realized offset costs between the two groups was still significant even in weeks 3 and 4, roughly 25 percent ($40 versus $50). This implies that reliability information still has value at four weeks of experience and presumably may still have value longer than four weeks since the gap in performance between week 1 and week 4 between the two groups narrowed only from 40 percent to 25 percent.

POTENTIAL NEXT STEPS

Given the complexity of the travel time reliability concept and the myriad of ways this information may impact system users, system operators, and service providers, the project team identified several potential issues that can be addressed in further detail and refined through additional investigation. These issues are discussed in the following sections.

Graphical Formats for Reliability Information

Two graphical formats were tested in this study's second laboratory experiment as alternatives for presenting reliability information to drivers. These two formats were rated by participants as being "more complex" and therefore less easy to use than the same information presented in a text format. However, other graphical formats may prove useful as alternative or supplemental methods for communicating reliability information to drivers. Further research should be conducted to assess the potential usefulness and usability of "star" ratings, Harvey Balls, and other graphical formats for conveying reliability information.

Reliability Information in the Context of More Complex Trip Planning

Our research looked only at single-occupancy highway trips with time of departure choice. We conjecture that the more complex the range of travel choices available to the user (with low overall travel time variance correlation), the more valuable reliability information will be in reducing late trip arrivals and schedule offset costs.

Mechanisms of Reliability Information Under-Valuation by Users

While it is clear from this work that travelers do not attribute improved trip outcomes to access to reliability information, it is not clear exactly why this is true. It may be that travelers see the experiment as a game in which they are actively learning and discounts inputs to their learning process compared to an assessment of their own innate powers of deduction. A set of structured experiments to uncover the mechanisms of the perception of travel time reliability information can be constructed to investigate this interesting result.

Predictive Reliability Information and the Experienced Traveler

One tantalizing morsel from the second experiment calls into question our assumption from the focus group activity that reliability information will have value primarily for unfamiliar travelers. In the second experiment, the difference in schedule offset costs between users of reliability

information and the control group declined from 40 percent in the first week to 25 percent in the fourth week. The experiment begs the question of how many weeks would be required until the performance of the two groups were the same, or if indeed such a convergence would actually occur. This may imply that there is some inherent value in providing accurate data to the users even if they have acclimated themselves to it in a non-quantitative way. Another key observation is that the underlying patterns of travel time variation did not change in our experiment—and therefore there may be a value in predicting trends in travel time variability and tailoring reliability information even for the most experienced traveler.

Impact of Reliability Information on Broader Range of Travel-Related Choices

Reliability information provision may have benefits in other choices not studied in this experiment. This includes decisions on telework, both in terms of the practical value of telework on a regular basis or dynamic telework decisions to remain at home rather than risk being en route at the time of a critical meeting (whether in-person or virtual). Another decision potentially informed by reliability information includes a home purchase or new job acceptance decision with travel-related impacts, as well as facility location decisions for businesses and supply chain managers.

Monetization of Reliability Information Impacts

The first traveler behavior laboratory experiment looked specifically at the monetization of reliability information impacts and derived a parameter for serenity benefits associated with knowing as early as possible about possible trip outcomes (late or otherwise). Additional work in this area suggested by the experience with the enhanced laboratory experiment includes the potential development of utility functions that cover a broader range of serenity impacts, as well as a new class of multimodal functions addressing more complex trip chains and tours. Further, the development and documentation of practical methods of data collection for the local calibration of reliability information-sensitive utility functions is another valuable extension to this research. Additional exploration of serenity impacts under constrained and unconstrained rescheduling options would also be of value using an experimental structure similar to the one designed for this study.

Traveler Responses to Increased Travel Time Reliability

A before-and-after study of traveler responses to changes in travel time reliability along particular corridors could provide a real-world assessment of the value travelers place on reliability. Such a study would involve selecting corridor segments that have recently or will soon experience a significant change in travel time reliability, due to an operational change such as initiation of congestion pricing or the opening of an parallel facility. Surveys of travelers along the corridor before (ideally) and after the change would examine travel patterns and preferences and the value respondents place on travel time reliability; in the case of a newly established priced facility, this value could be indexed to the amount that travelers would be willing to pay to travel on the more reliable facility. Simulation-based tests similar to those conducted for this study (described in Chapters 9 and 10) would be another approach to further assessing the relative value of and responses to travel time reliability information within different

trip situations. Either simulation-based or field-test studies would examine drivers' trade-off decisions for travel routes, times, and modes, through stated and/or revealed preferences.

Use of Reliability Information by the Freight Industry

Commercial drivers plan routes based primarily on cost-effectiveness and will tend to select the most direct route (based on distance) or a route that allows them to avoid traffic congestion or other obstructions. Drivers and dispatchers consider time of day, traffic patterns in major metropolitan areas, and construction when planning routes and when considering route diversions during a trip. A driver that delivers to regular repeat customers will often develop "usual" routes and will stick to them unless conditions dictate otherwise. If a driver has a time-sensitive delivery, the travel time along a given route becomes more important, and the driver and/or the company will be more likely to opt for a toll facility or other route option that provides a more reliable trip time (Higgins, 2013 (not yet published)). It is reasonable to hypothesize, therefore, that commercial drivers would not only value TRR information, but would also be better able (compared to commuters) to express that value monetarily. Research should be conducted to examine the potential valuation and utilization of travel time reliability information by the freight industry.

Reliability Information in Public Transit

The human factors studies and utility function development conducted in this study focused on drivers; however, the literature indicates that reliability information is also valuable to transit riders. Similar research should be developed to further examine the effects of information about transit travel time and arrival reliability on riders' mode decisions, departure time decisions, stress levels, and satisfaction with the transit service.

Combining Real-time and Reliability Information

Feedback from the focus groups and computer survey indicated that travelers consider real-time travel time information to be a valuable and even necessary addition to historical data when planning trips. Research is needed to determine how best to combine real-time and historical travel time information to provide the most useful and accurate information to travelers. SHRP 2 L15A, *Forecasting and Delivery of Highway Travel Time Reliability Information*, developed a prototype of a forecasting website (MyRoadTripAdvisor.com) that predicts travel time for a given route based on both historical patterns and current conditions, including incidents, weather, and work zones. The website offers registered users the options to save frequent trips by name and to have travel time forecasts for scheduled trips pushed to them by email, text message, or telephone. This demonstration project provided real-time and travel time reliability information for portions of I-66 in Northern Virginia. Because the two projects (L14 and L15A) were conducted during the same time period, different sets of terminology were developed for communicating reliability concepts; future research might involve testing MyRoadTripAdvisor with terminology from L14's lexicon, as well as testing additional verbal and/or graphical options for communicating real-time and reliability information to travelers.

Field Tests of Reliability Terminology

A field test of the lexicon terminology is one way to implement and validate the results of this project's human factors studies and utility function development, by collecting data about travelers' use of pre-trip and en route reliability information in a real-world environment. A field test would use recommended reliability terms and formats from the lexicon as part of the provided information on a localized travel website, on DMS, and/or via other media and messaging techniques in a selected city or cities. As mentioned above, the prototype website developed by SHRP L15A would be a potential starting point for such a field test.

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APPENDIX A GENERAL LITERATURE REVIEW

OVERVIEW

In cities where congestion is commonplace on the transportation system, drivers are accustomed to congestion and expect and plan for some increase in travel time, particularly during peak driving times. Many system users either adjust their schedules to avoid peak hours or budget extra time to allow for unexpected traffic congestion or incidents. However, problems arise when travel times are much higher than anticipated. Most travelers are less tolerant of unexpected travel time increases because those longer travel times cause travelers to be late for work or important meetings, to miss appointments, or to incur extra childcare fees. Moreover, unexpected delays in the transportation of goods by a freight carrier or shipper can result in disruption in just-in-time delivery and manufacturing processes and cause the carrier or shipper to lose money and their competitive edge (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

Transportation professionals most commonly discuss travel time reliability in terms of historical average travel times calculated over periods of a year or longer, as illustrated in Figure A-1. A typical definition for travel time reliability would be the following:

> *The consistency or dependability in travel times, as measured from day to day and/or across different times of the day.*

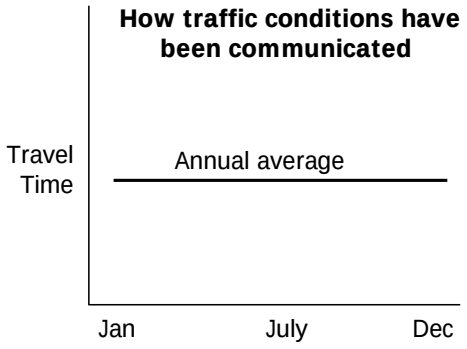


Figure A-1. Average travel time used by professionals (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

Most travelers do not experience the same average travel time each day. As Figure A-2 shows, travelers experience and remember something much different than the average throughout a year of commutes. Their travel times vary greatly from day to day, and they remember those few bad days they suffered through unexpected increases in travel times. Research has shown that travel time reliability information can provide transportation system users with a more complete picture of the expected travel time along a particular route. The challenge is how to communicate that reliability information effectively to road and transit system users so that they understand it clearly.

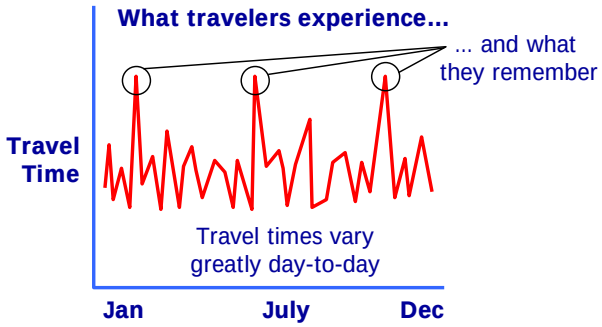


Figure A-2. Traveler travel time experiences (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

Another example of illustrating travel time reliability is shown in Figure A-3. This example shows travel time data from a major commuter route in Seattle, Washington. If there is no congestion along this route, travel times are about 12 minutes (e.g., see President's Day in the figure). On all other weekdays, the average travel time is 18 minutes. However, when traffic incidents and weather combine to cause unexpected congestion, travel times may be upwards of 25 minutes, or 39 percent longer than usual. Commuters who travel this route must plan for this variability if they want to arrive on time. If they plan their commute based on the average travel time, they will be late half the time and early the other half of the time. In other words, commuters have to build in a time cushion, or buffer, to their trip planning to account for the variability. If they build in a buffer, they will arrive early on some days, which is not necessarily a bad thing, but the extra time is still carved out of their day—time they could be using for other pursuits besides commuting.

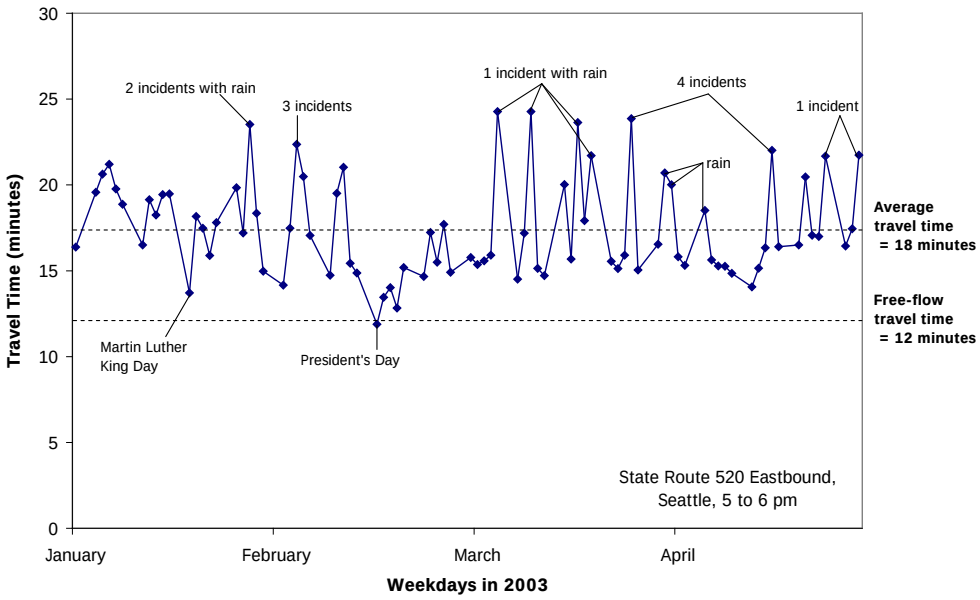


Figure A-3. Commuters plan trips based on the worst days, not the average day (Cambridge Systematics Inc. with Texas Transportation Institute, 2005).

Travel Time Reliability Metrics

The measurement of travel time reliability is an emerging practice. However, a few measures appear to have technical merit and are thought to be easily understood by nontechnical audiences. Most of these measures compare days with high travel times to days with average travel times. Four recommended measures are as follows:

- 90th or 95th percentile travel time;
- buffer index;
- planning time index;
- frequency the congestion exceeds some expected threshold (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

The 90th or 95th percentile travel time is a time identified for a specific travel route that indicates how bad delay will be on the heaviest travel days (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). These travel times are reported in minutes and are thought to be easily understood by commuters familiar with their trips. For this reason, this measure is ideally suited for traveler information. This measure has the disadvantage of not being easily compared across trips, as most trips will have different lengths. It is also difficult to combine route or trip travel times into a subarea or citywide average.

Two indices that enable comparisons or combinations of routes or trips with different lengths are buffer index and planning time index. The buffer index represents the extra time cushion (or buffer) that most travelers add to their average travel time when planning trips to account for unforeseen delays and to ensure on-time arrival (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The buffer index is expressed as a percentage, and its value increases as reliability gets worse. For example, a buffer index of 40 percent means that for a 20-minute average travel time, a traveler should budget an additional 8 minutes (20 minutes × 40 percent = 8 minutes) to ensure on-time arrival most of the time. In this example, the eight extra minutes is called the buffer time. The buffer index is computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time.

The planning time index represents the total travel time that a traveler should expect or plan on when an adequate buffer time is included (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006). The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst-case travel time to a travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is useful because it can be directly compared to the travel time index (a measure of average congestion) on similar numeric scales. The planning time index is computed as the 95th percentile travel time divided by the free-flow travel time.

From a data perspective, continuous travel time data are the only way to establish reliability patterns empirically. While predictive methods—such as the ones being developed by the project team for the second Strategic Highway Research Program (SHRP2) L03 project *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies*—may be used in a

reliability monitoring system where these data are unavailable, only continuously collected travel time data can produce the actual travel time distribution from which all reliability metrics are derived. For example, the reliability metrics being used in the SHRP2 L03 project, as shown in Table A-1, are all derivatives of the statistical distribution of travel times.

What is clear is that there is not agreement among transportation experts on the terms to be used or what the mathematical calculations of each of the terms should be. If transportation professionals cannot come to consensus on the technical terms, then the general public certainly will not do so. The purpose of the L14 project is to determine what terms the layperson would use to refer to travel time reliability concepts and to encourage the use of those terms in communications with transportation system users.

Table A-1. Recommended reliability performance metrics from SHRP2 Project L03 (Cambridge Systematics Inc., 2007).

Reliability Performance Metric	Definition	Units
Buffer Index (BI), mean-based	The difference between the 95th percentile travel time and the average travel time, normalized by the average travel time	Percent
Buffer Index, median-based	The difference between the 95th percentile travel time and the median travel time, normalized by the median travel time	Percent
Failure/On-Time Measures, median-based	Percent of trips with travel times < (1.10, 1,25) * median travel time	Percent
Failure/On-Time Measures, speed-based[1]	Percent of trips with travel times < (50 mph, 45 mph, 30 mph)	Percent
Planning Time Indices	95th, 90th, and 80th percentile travel times divided by the free-flow travel time	None
Skew Statistic	The ratio of (90th percentile travel time minus the median) divided by (the median minus the 10th percentile)	None
Misery Index (modified)	The average of the top 5 percent worst travel times divided by the free-flow travel time	None

[1] "Speed" is the space-mean speed over the study section.

IMPORTANCE OF TRAVEL TIME RELIABILITY

Travel time reliability is significant to many transportation system users, whether they are vehicle drivers, transit riders, freight shippers, or even air travelers. Good and consistent system

reliability is a valuable service that can be provided on privately operated and publicly operated highways alike. Because reliability is so important to transportation system users, transportation planners, operators, and decision-makers should consider travel time reliability a key performance measure.

Travel Time Reliability and Highway Travel

Travel time reliability is valuable to traffic professionals because it better quantifies the benefits of traffic management and operation activities than simple averages. For example, consider a typical before-and-after study that attempts to quantify the benefits of an incident management or ramp metering program. The improvement in average travel time may appear to be modest, as shown on the left side of Figure A-4. However, reliability measures will show a much greater improvement—as illustrated on the right side of Figure A-4—because they show the effect of improving the worst few days of unexpected delay and will be much more meaningful to the transportation system users.

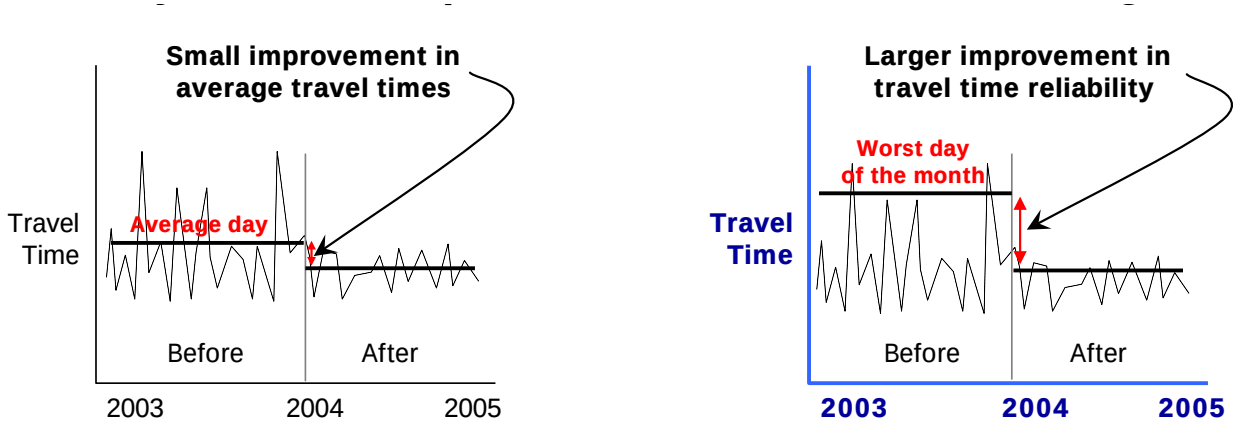


Figure A-4. Reliability measures capture the benefits of traffic management (Texas A&M Transportation Institute with Cambridge Systematics Inc., 2006).

For drivers, travel time reliability information can be valuable when they are selecting a route. For example, the value of travel time reliability was assessed through a mail survey, trip diaries, and loop-detector data by Lam and Small (Lam & Small, 2001) soon after the first high-occupancy toll (HOT) lane opened on State Route 91 in Riverside, California. The researchers found that for women in this study, the value of travel time reliability was actually higher than simple travel time information. For men, the value of time was roughly 50 percent higher than the value of reliability information. The reasons for this difference were not known from the data collected, though some have interpreted these data to indicate that women have more time-critical commitments related to childcare trips. For this study, the researchers define travel time as the 90th percentile travel time minus the median travel time. The authors discuss further how the transponder usage records of participants show that there were few habitual users of the HOT lane. Rather, people made the decision whether to pay for the HOT lane on a daily basis depending on trip purpose and traffic conditions. It is in applications such as HOT lanes where travel time reliability information may be useful en route to help drivers make the purchase decision to use the HOT lanes. The influence of pre-trip and en-route travel information on route

decisions has been demonstrated in other studies: an evaluation of the Washington State Department of Transportation's (DOT's) 511 travel information system in 2005 found that 21 percent of respondents changed their original travel plans based on information they got from the 511 system (PRR Inc., 2005). Drivers on an Orlando, Florida, toll road who stated that they used information from the state's 511 service or from dynamic message signs (DMSs) that displayed estimated delay times for the road were more likely to change their route in response to unexpected congestion.

A review of research on travel time and travel time reliability conducted by the Center of Urban Transportation Research (University of South Florida) includes the finding that most travelers value trip time reliability at least as much as actual trip time. In fact, when travelers' arrival and/or departure times were inflexible due to the nature of the trip, the value of reliability could be as much as three times that of trip time (Concas & Kolpakov, 2009).

Travel Time Reliability and Transit

Studies of transit ridership have shown that trip time reliability (including the reliability of a rider's wait time at transit stops) is more important to retaining riders than the trip and waiting times themselves. Wait-time reliability is particularly important, as transit riders tend to perceive time spent waiting for a transit vehicle as being longer than an equivalent amount of time spent riding in the vehicle. Real-time information that allows transit riders to schedule their own arrival at a transit stop and/or to monitor the wait time remaining until the vehicle's arrival increases rider confidence in the service (Perk, Flynn, & Volinski, 2008). Transit passengers surveyed in two cities ranked knowledge of when their bus would arrive and knowledge that it would arrive on time as the two most important factors affecting their decision to ride transit (Peng, Yu, & Beimborn, 2002).

Travel Time Reliability and Freight

In terms of economic value, reliability is probably more important to freight carriers and shippers than to personal travelers. With the rise in just-in-time deliveries (largely as a replacement to extensive warehousing), providing dependable (reliable) service has become extremely valuable, while failure to provide dependable service can increase costs considerably (Cambridge Systematics Inc., 2007). For example, improvements in transportation reliability play an important role in reducing inventory in the chemical supply chain for freight shippers. Because of the many nodes in the supply chain, upwards of one-third of all chemical inventory is in transit at any point in time. Inventory managers keep safety or buffer supplies to cushion against variability of inbound arrivals, and the amount of safety supplies increases with the degree of unreliability and the number of stocking locations (Cambridge Systematics Inc., 2007). However, the capacity to receive chemical supplies is limited by the size of the liquid storage silos. Balancing capacity with demand is a challenge. As transportation reliability decreases, wait time, dead freight, and cost increase (Cambridge Systematics Inc., 2006).

REAL-TIME TRAVEL INFORMATION—STATE OF THE PRACTICE

Real-time travel time messages have been in use in the U.S. for well over a decade, ever since traffic monitoring and integration systems became available and reliable. The most commonly

used media for these messages are dynamic message signs and transportation agency websites, but the widespread use of cell phones and other mobile devices is prompting a growing number of transportation agencies and providers to offer real-time updates on transportation conditions and options via emails, text messages, and Twitter feeds.

Real-time travel time estimates are most often provided for a particular roadway segment or a particular transit route, based on recent travel speeds or conditions. Some agencies also provide travel time comparisons among two or more routes/roadways to help travelers make decisions about the route or transportation mode to take. Most recent and most rare are the information sources that advise travelers about travel time reliability as described in the preceding sections—the likelihood that the estimated travel time for a particular trip or trip segment will be dependable. This section describes some of the real-time travel information messages that are being provided to travelers on dynamic message signs, on websites, and via mobile devices, as well as some of the lessons learned about providing travel information.

Dynamic Message Signs

Two department of transportation surveys of state and local agencies in 2007 found that incident reports were the most common form of real-time traffic information provided to travelers in large metropolitan areas in the U.S., followed by travel times and then travel speeds (United States Government Accountability Office, 2009). Dudek reported in 2008 that travel time information was displayed on DMSs by 18 DOTs in the U.S. The primary reasons cited in the 2008 report as to why travel time information was not displayed on changeable message signs (CMSs) by some state DOTs were that (a) infrastructure and/or software was not available, and (b) congestion was not a problem (Dudek, 2008).

The Georgia DOT (GDOT) began posting travel time messages on dynamic message signs in 1998, using the qualitative descriptors "moving very well," "moving well," "moving slowly," and "moving very slowly." Responding to requests from Georgia drivers for more precise terminology, GDOT used its travel management software (NaviGAtor) to generate approximate travel times along roadway segments. Drivers now see a three-line message: the name of a destination (such as a highway exit), the distance to that destination in miles, and a travel time range based on the average speed along the roadway segment. GDOT does not post travel times for distances greater than 15 miles since the accuracy of the time range decreases at greater distances (Dudek, 2008). Other signs in the Atlanta region alert drivers that travel time information can be obtained by dialing 511 anywhere in the state (NaviGATOR 511 Real-Time Traffic Map, 2012).

DMSs of the type developed for the Georgia DOT are also being used by the Oregon and Tennessee DOTs. Oregon DOT provides travel time estimates on highways in the Portland area using travel time ranges such as "12-15 MIN" (FHWA, 2005a). Ranges of travel times are also used by Tennessee's SmartWay intelligent transportation system in the Nashville and Knoxville areas (FHWA, 2005b), on DMSs operated by the Illinois State Toll Highway Authority on Chicago-area highways (FHWA, 2005c), and by the Texas Department of Transportation in the San Antonio area (FHWA, 2005d).

While travel time ranges are one way to express the travel time reliability of a highway segment, a California Partners for Advanced Transit and Highways (PATH) program study in 2009 found that most commuters surveyed (71 percent) preferred travel time estimates to be displayed as an exact number of minutes rather than as a range of minutes (29 percent) (Ban, Li, & Margulici, 2009). A similar preference was found among Arizona commuters; the Arizona DOT changed the format of its travel time estimation signs to provide to-the-minute precision rather than 5-minute estimation windows, based on commuter feedback (Phoenix tightens travel time estimates, 2008).

A study of DMS messaging performed by Battelle for the Federal Highway Administration (FHWA) in 2004 recommended including the distance in miles along with travel time. The study found that distance information is particularly useful to travelers who are unfamiliar with the area and enables them to mentally estimate the amount of delay from the distance coupled with the estimated travel time (PBS&J, 2004).

Real-time travel time messaging tends to be most effective on a road where travel times are likely to change with reasonable frequency. If travel times are too static, drivers tend to view the messages as static rather than dynamic and therefore less credible (Meehan, 2005). This freshness factor may hold true for travel time reliability information as well. Some agencies, such as Houston TranStar, provide a time-stamp, for example, "Travel time—to US 59—6 min at 10:10," to their travel time signs and web-based information to assure users that the information is current (Houston TranStar Dynamic Message Signs, 2012).

Messages on DMSs on highways in the United Kingdom (U.K.) change from travel time estimates (number of miles and minutes to given destinations under normal traffic flow conditions) to travel delay descriptions and estimates (e.g., "Segment name—Accident—15 minutes delay") in response to roadway incidents. Delay time estimates are based on typical traffic profiles of individual road segments according to time of day and known traffic generators (Traffic England Traffic Map, 2012).

Some agencies have started to show comparative travel times to certain destinations via different routes. Washington State DOT has recently installed new travel time signs in the Seattle area showing side-by-side travel time estimates for two different routes to a common destination (Washington State Department of Transportation, 2012). Signs such as this would be natural places to add information about travel time reliability along the two routes. Signs showing comparative travel times in general-purpose and HOT lanes are another location where travel time reliability could be added and could prove useful to motorists making route decisions during a trip. Consideration must be given, however, to the amount of information that drivers can read while passing a sign. The 2009 DMS study recommended that travel times for high-occupancy vehicle (HOV) lanes and general-purpose lanes not be provided together on one sign, as this could result in too much information for drivers to process during the time they have to look at the sign (Ban, Li, & Margulici, 2009). This recommendation may be mitigated by other conclusions of the study, including the finding that travelers who see travel time messages on DMSs on their regular route can begin to anticipate elements of the messages and therefore read and understand them in less time than they would otherwise need (Ban, Li, & Margulici, 2009).

The first travel time signs in use for a managed lane facility were on an HOT lane along I-15 in San Diego. Research has shown that users consistently overestimate their travel time savings (Brownstone & Small, 2009). For this reason, agencies have been reluctant to post travel times in managed lanes for fear that when actual comparative travel times are shown, drivers may not choose to use the managed lane. Other research has shown, however, that drivers value the trip time reliability offered by managed lanes (Lam & Small, 2001).

The Long Island Expressway uses the words "Average Travel Time" on its signs showing travel times to multiple distances along a single route (see Figure A-5). However, the original request to FHWA to deviate from the *Manual on Uniform Traffic Control Devices* showed signs with the words "Estimated Travel Time" (Request for Interpretation: 2-55(I)—CMS Display of Travel Time, 2004).



Figure A-5. Northern state parkway signs on Long Island (Source: FHWA).

The presentation of travel time is not limited to highways and highway travel. The Wisconsin DOT provides highway travel times to specified destinations via the freeway on selected arterials prior to freeway entrance ramps to provide drivers with information to make route choices (Peng, Guequierre, & Blakeman, 2004). A DMS pilot program in the San Francisco Bay Area provides travelers with both highway and Caltrain (transit) travel times to selected destinations, along with the arrival time of the next train (Mortazivi, 2009).

Real-time bus and/or train arrival information is available in increasing numbers of U.S. cities, posted on DMSs at transit centers and on transit websites. Some transit providers also provide real-time notifications about route delays and diversions. A real-time train arrival sign at one of Washington, DC's Metro stations is shown in Figure A-6.



Figure A-6. Next-train sign at a Washington Metro station (Source: Texas A&M Transportation Institute [TTI]).

Real-time arrival signs tend to be viewed positively by transit customers. Customer surveys conducted by transit agencies in the U.S. and abroad found that real-time arrival information at transit stops made riders feel more confident, particularly at night, and even improved riders' overall perception of the quality of transit service provided (Schweiger, 2003).

Travel Websites

Many state DOT transportation management centers (TMCs) and partner transportation agencies provide users with real-time travel information via websites. The format and features of these websites vary considerably. For example, the California Department of Transportation (Caltrans) reproduces the travel time information displayed on DMSs on Los Angeles area freeways via its TMC website (California Department of Transportation District 7, 2012).

The Tennessee SmartWay website (TDOT SmartWay, 2012) and the Utah DOT CommuterLink website (Utah Commuterlink, 2012) both provide real-time travel information to online users by posting real-time photos of the travel time DMS signs, as well as color-coded highway maps showing road conditions (hazardous, patches of ice/snow, flooded), traffic flow, incident and construction locations and descriptions, and real-time camera views of highway locations. The U.K. Highways website features the same types of information and also provides advance notification of future construction sites and expected future events (such as holiday travel) that are likely to affect roadway conditions and traffic speeds (Traffic England Traffic Map, 2012).

The roadway information website provided by the Ontario, Canada Ministry of Transportation displays a similar traffic map, with green, yellow, and red traffic flow categories labeled "moving well (75 km/h and above)," "moving slowly (40 to 75 km/h)," and "very slow (less than 40 km/h)" (Ontario Ministry of Transportation, 2012).

Travel time reliability information is starting to make appearances on transportation websites. The Wisconsin DOT website provides a table of current and normal travel times for Milwaukee-area highways. Travel times that are 20 percent or more above normal are shown in bold print (Kothuri, Tufte, Hagedorn, Bertini, & Deeter, 2007). The Washington State DOT provides a similar trip time table, also including times for the same roadway segments if the HOV lane is used (Washington State Department of Transportation, 2012).

The travel information website for the Gary-Chicago-Milwaukee corridor also displays a table of current and average travel times and traffic speeds for highways along the corridor (RoadStats, LLC, 2012). The user can then click on the average travel time number for each segment to view a graph detailing the most recently collected travel time, the average travel time for all historical data samples, and the normal range of travel time values by time period over a 24-hour period each day. The graph also includes three speed thresholds, indicating what the travel time would be for the segment with no traffic congestion (traffic moving at 55 mph or higher), with moderate traffic congestion (54-35 mph), and with heavy traffic congestion (34-15 mph) (RoadStats, LLC, 2012).

Washington State DOT has recently added a feature to its travel time website that displays the 95th percentile travel times (Washington State Department of Transportation, 2012). A user enters an origin-destination pair from a drop-down menu containing names of suburbs, and the system displays a text message, as shown in Figure A-7. The Driving Times[SM] feature on the San Francisco Bay Area's 511 website also allows the user to enter the origin and destination of his/her driving trip; in return, the website generates multiple potential routes for the trip, displaying the current and typical/historical trip times for each route, along with a table of minimum, maximum, and average current traffic speeds (and typical historical speed) on each of the route's roadway segments (see Figure A-8). The site's Predict-a-Trip[SM] feature allows the user to view the typical traffic speeds and travel times of the same route options for some future trip by inputting the day and time period (511 SF Bay, 2012).

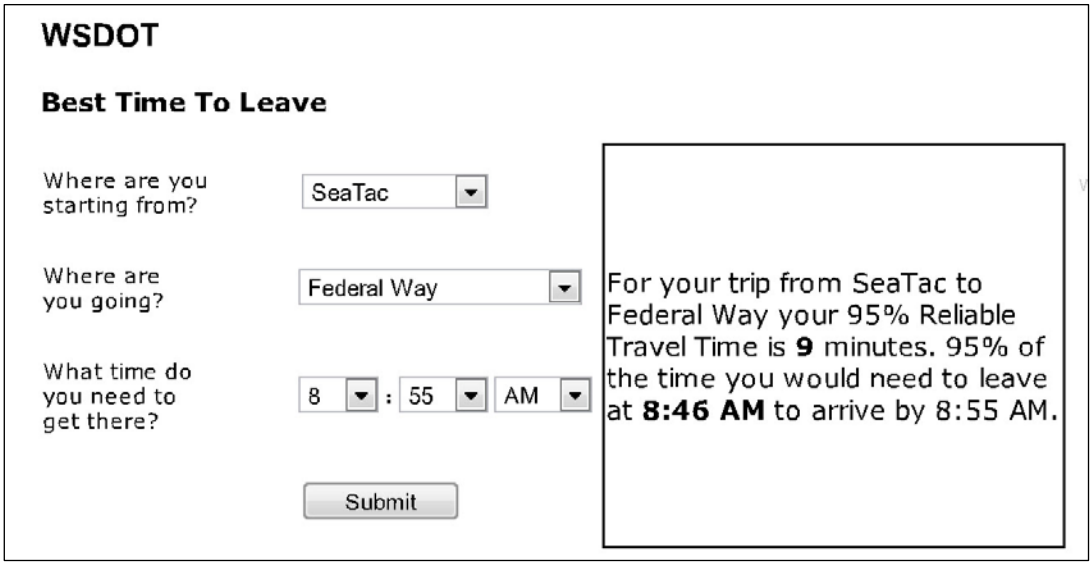


Figure A-7. Travel time reliability display from Washington State DOT (Washington State Department of Transportation, 2012).

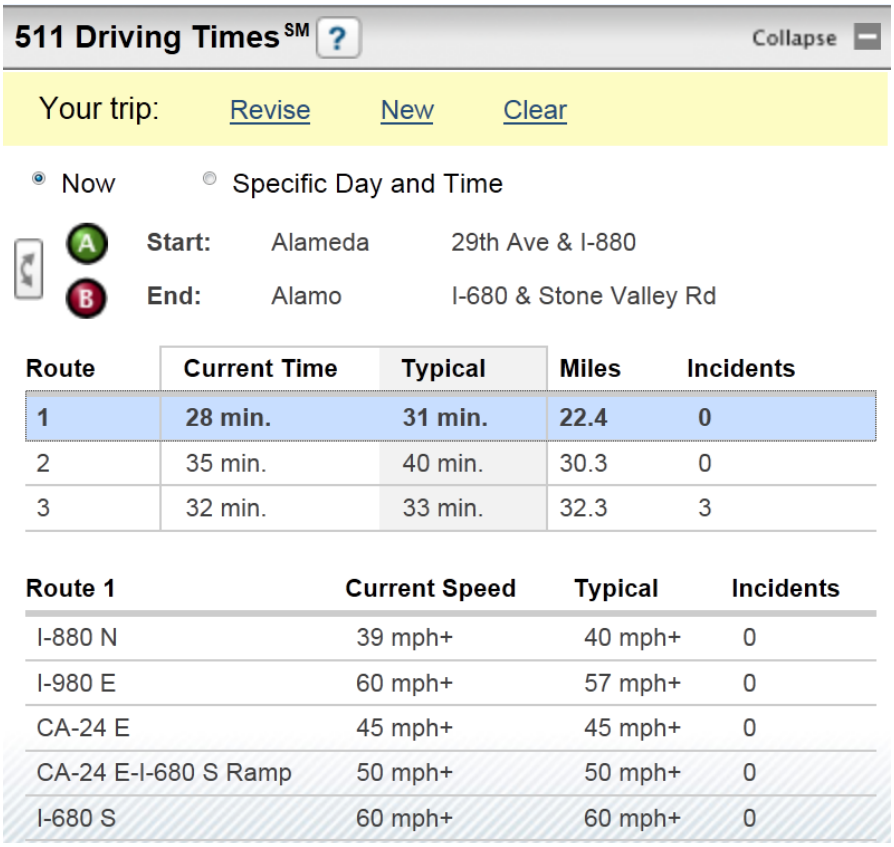


Figure A-8. Driving times and traffic speeds for an input origin-destination pair (511 SF Bay, 2012).

Many airlines now provide on-time performance histories for particular flight numbers/times that can be viewed by customers making online reservations. In addition, third-party websites compile information from multiple airlines and airports to provide estimates, or forecasts, about a flight's on-time performance. The FlightCaster website tracks both current delays and historical on-time performance for U.S. domestic flights to estimate a specific flight's departure time; six delay factors are also shown on the forecast, with color-coded icons to signal potential problems (FlightCaster, 2012). Similarly, the FlightStats website shows historical on-time performance information for airline routes using named categories—"on-time," "late," "very late," "excessive," "cancelled," and "diverted"—along with the percentage of flights in each category. The percentages are also shown on a bar graph (FilghtStats Inc., 2012).

Route-by-route reliability information is generated by many transit systems for planning purposes but is only rarely provided as part of transit customer information. Rutgers University in New Jersey has posted on-time performance history information for its bus routes, including percentages for on-time, early, and late arrivals (Rutgers, The State University of New Jersey, 2012). More transit systems may follow, especially if traveler demand for this information grows. Evidence of increasing demand for transit reliability information includes the provision of a performance dashboard for TriMet transit routes in the Portland region (TriMet, 2012).

Emails, Texts, Tweets—Mobile Device Messaging

In addition to accessing the Caltrans website for travel times in the Los Angeles area, motorists may also subscribe to a free service that provides the same information to their mobile device. Similarly, Houston TranStar offers free, personalized email alerts to its system users of incidents and travel times on Houston-area freeways. The alerts can be sent to any device capable of receiving email or text messages, including personal computers, mobile phones, personal digital assistants, and text pagers (Houston TranStar, 2012). A similar messaging service is provided by the Regional Transportation Commission of Southern Nevada's Freeway and Arterial System of Transportation (FAST) program (Regional Transportation Commission of Southern Nevada, 2012). The Arkansas State Highway Department has begun using Twitter to notify motorists about highway conditions (Arkansas State Highway and Transportation Department, 2012).

The Washington Metropolitan Area Transit Authority's (WMATA) e-alerts provide information about service delays or disruptions on Washington, DC's MetroRail, Metroaccess paratransit services, and elevators at Metro's transit centers (Washington Metropolitan Area Transit Authority, 2012). WMATA has also begun to broadcast these alerts via Twitter, though soon after the new medium was adopted, it was discovered that subscribers were receiving only partial messages. This was due to limitations on the Twitter message length, which was truncating the longer messages that had been developed for an email format. WMATA is looking for ways to provide the same information to its Twitter subscribers using shorter messages (Hohmann, 2009).

The Bay Area Rapid Transit system in San Francisco provides real-time service information to its passengers via its mobile website (for those with access to an Internet connection), via emailed and text-messaged service advisories, and most recently, via Twitter updates (Rhodes, 2009). Boston's T-Alerts provide the same service for passengers on Massachusetts Bay Transportation Authority (MBTA) buses and trains (Massachusetts Bay Transportation Authority, 2012).

COMMUNICATING RELIABILITY INFORMATION—OTHER RESEARCH

The challenge with conveying travel time reliability information to users is ensuring that they understand the message. Cognitive science has shown that most people are not good at understanding statistical concepts and applying them to everyday situations, such as medical diagnoses and gambling odds, and variability in stochastic processes, such as traffic (Gal, 2002). Statistical literacy is related to overall aptitude with numbers, literacy, and cultural components. Research has shown significant cultural differences in understanding statistical concepts, and those related to risk in particular (Wright, et al., 1978).

Communicating probabilities or risks using only qualitative language can lead to misunderstandings, simply because the listener (or reader) may ascribe a different meaning to a descriptive word than was intended. The English language has a multitude of terms used for concepts of uncertainty and risk, but attempts to systematically map them to numerical probabilities have failed (Teigen, 1988). Research has shown that people switch between numerical (e.g., "50-50 chance") and verbal (e.g., "probably") in unpredictable ways controlled more by grammar than by probability values (Wallsten, Budescu, Zwick, & Kemp, 1993). In

one study, tests of various probability terms (e.g., "certainly," "definitely," "possibly," "probably," "rarely") with adolescents and young adults indicated that individual definitions of the terms were not consistent enough to convey information effectively to the general public. Absolute numbers, such as percentages or percentage ranges, were recommended instead of qualitative language (Biehl & Halpern-Felsher, 2001).

Some suggestions and recommendations for communicating risk and probability to the public come from two non-transportation fields: weather forecasting and medicine. Although most people are familiar with weather forecasts on television and in other media, the probabilities used in those forecasts (e.g., "20 percent chance of rain") are not widely understood. In a study comparing several weather report formats, 43 percent of participants correctly interpreted a weather forecast that included symbolic icons depicting a weather condition (such as rain) and graphs showing the percent likelihood of that condition. When forecast information included graphs that showed the chance of rain AND the chance of no rain, the number of participants correctly understanding the forecast rose to 52 percent (Schwartz, 2009). An experiment conducted with university students in the U.K. found that participants who were given a graph of forecast temperatures that included information about the probability, or uncertainty, of those temperatures answered questions about the forecast more accurately than the participants who were given the temperature graph by itself (BBC News, 2007).

A medical diagnosis or a decision about possible courses of treatment usually involves probabilistic data—e.g., the probability that a test result is accurate or the likelihood of various outcomes of a treatment. In a 2003 article for the *British Medical Journal*, several techniques were recommended for helping patients understand the risks and benefits associated with medical treatments:

- Avoid the use of purely descriptive terms; supplement qualitative language with numbers.
- Use a consistent denominator/numerical scale.
- Provide both positive and negative outcomes (e.g., 3 percent chance of negative outcome AND 97 percent chance of positive outcome).
- Express probabilities as absolute numbers (75 percent of cases have Outcome A, 25 percent have Outcome B) rather than in relative terms (three times as many cases have outcome A than have outcome B).
- Use visual aids such as pie charts and graphs to illustrate probabilities (Paling, 2003).

Studies examining both doctors' and patients' comprehension of probability-based information have found that many people understand frequencies (e.g., 19 out of 20) better than percentages or proportions (95 percent or 0.95). Presenting probabilities related to cancer screenings as a set of frequencies rather than as a set of percentages resulted in quicker and more accurate comprehension of those probabilities by study participants, particularly if several probabilities had to be considered in tandem (Hanoch, 2004).

People presented with quantitative health risk information in pictograph formats perceived the information most accurately when it was presented in one compound graph (in which the proportions/percentages of the potential outcomes added up to 100 percent) than if the same information was presented as two side-by-side graphs (Price, Cameron, & Butow, 2007).

The goal to establish a lexicon to convey travel time reliability information is quite similar to that of establishing a lexicon to convey downstream traffic state information (i.e., what are traffic conditions downstream?) on a DMS that TTI researchers addressed in the late 1970s. Through a series of standard and innovative laboratory experiments, researchers developed and tested numerous text and graphical representations of downstream traffic conditions (Dudek, Huchingson, Koppa, & Edwards, 1978).

Research results showed that traffic descriptors should be displayed only for unusual traffic conditions (i.e., due to an accident). Displaying traffic descriptors during normal, recurrent peak-period traffic conditions was discouraged. In addition, the acceptable ways of conveying traffic information were different in small cities than in large cities (Dudek & Huchingson, 1986).

As seen in the state-of-the-practice examples, a variety of terms are currently being used to describe travel times and the likelihood or reliability of those times. *Average*, *historical*, *95 percent reliable*, and *typical* are just some of the terms used, and these may have different meanings to drivers depending on the context in which they are used.

A variety of formats is also seen for the estimated travel times, as previously discussed. Although early studies warned practitioners about the presentation of travel time information (whether it was done in terms of actual times, delays, time saved, etc.) because of the potential of the information to be refuted by travelers and thus reduce credibility of the system with drivers, more recent research suggests that drivers recognize (to some degree) the inherent variability and potential for change in travel time information (Dudek, Trout, Booth, & Ullman, 2000). Furthermore, such variance does not lead to reduced credibility of the information with drivers, nor does it reduce the desire for such information. As an example, both of the formats of travel time displays shown in Figure A-9 were equally understood to imply an approximate travel time that may not be exactly what is experienced by drivers reading that information at a particular point along their route. As mentioned previously, some drivers prefer the single time value format (e.g., 20 minutes) over a range of times, even though they know that time may vary somewhat.

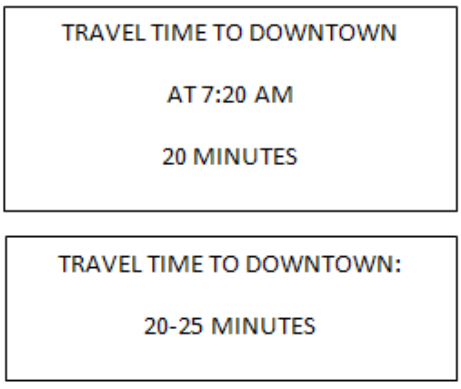


Figure A-9. Comprehended travel time displays (Dudek & Huchingson, 1991).

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APPENDIX B TELEPHONE INTERVIEW GUIDE FOR EXPERT INTERVIEWS

CONTACT INFORMATION

Contact Person:_____

Company/Agency:_____ Position:_____

Telephone Number:_____

Email:_____

Date & Time of Survey:_____

INTRODUCTION

Hello. My name is _____, and I am with the Texas Transportation Institute.

The Texas Transportation Institute is currently working on a SHRP 2 (Strategic Highway Research Program) project for the Transportation Research Board to recommend the best approaches for disseminating travel time reliability information to travelers.

One of the first steps in our study is to gather information about the state-of-practice of disseminating travel time and travel time reliability information. We are gathering the information via telephone interviews with a select group of private companies and public agencies regarding their experiences.

You are being contacted because you have been identified as the person in your company/agency who can help us with the information we are seeking.

If the contact expresses that they are not the correct person to talk to:

Can you please give me a different person in your company/agency that would be the right person to talk with about travel time reliability information?

Contact Person:_____

Position:_____ Telephone Number:_____

Email:_____

Researcher Note: Anticipated responses are indicated in Blue. Other instructions in Red.

(Researchers are trying to identify how the participating entity views travel time reliability and current state-of-the-practice. Focus should be on format and wording of this information.)

PRACTICE, DEFINITIONS, AND USERS

1. In your own words, how do you define travel time reliability (non-technical definition)?
   Let them express their definition before we get into technical perspectives below. Pay close attention to the specific words/phrases used by the participants.

   Make sure they give a definition of travel time reliability rather than a definition for travel time.

   Researchers may provide FHWA definition once they have responded to this question as a clarification on our use of the phrase of travel time reliability.

   FHWA Definition: "The consistency or dependability in travel times as measured from day to day and/or across different times of day.

2. Do you see travel time reliability as a static (*or historical*) data projection or as near-real-time data (*changing with conditions at the time*)?
   "Static"—driven primarily by historical data (e.g., using 6 months of data to estimate the 95th percentile travel time).

   "Real-time"—estimates that can change based upon conditions at the time the user requests the travel time information.

   Another way of stating this: Is the TT reliability information about the trip at this point in time or about how this trip "performs" all the time?

3. In your opinion, does travel time reliability information have value to the public or your customers? Yes/No
   a. If yes—Explain what you believe the value to be.
   b. If no—Why not?

      Is there another form of information that is more valuable to the public or your customers?

4. In your opinion, does travel time reliability information have value to transportation operations staff and/or to public officials?

5. Do you currently disseminate travel time reliability information? Yes/ No

   If no, has this type of information been considered for use by your company/agency? Yes/No

   a. If yes—Why was this type of information not used?
   b. If no—Is there a specific reason that your company/agency is not considering the use of travel time reliability information? *If no to question # 5—skip to question #15. If yes—continue with #6.*

6. What travel time reliability information do you provide to the public and/or to your customers?
   Specific measures provided (95th percentile, "best/worst" estimate, some sort of confidence level, average condition with an additional attribute [increasing, decreasing, remaining the same], etc.)

   Be sure to identify the form and wording they are using for these measures. Ask for specific examples if possible (could be that they send you a document or plan).

7. What travel time reliability information do you provide to agency management or to public officials?

8. How is travel time reliability defined and computed for what is provided (as identified in Question #5)?
   Refer specifically to examples they have given to gain understanding of how they are defining reliability.

   For example, is reliability simply a form of the confidence they have on the average conditions estimate, or does it truly incorporate information from the last 6 months or year. It could also be a specific calculation method.

9. Who are your current users (or customers), and what are the primary uses of the travel time reliability information you provide?
   Traveler information for typical commuters (software tools, text messages, maps), media outlets, etc.

   If customer is not end user (or commuter)—Is it possible for me to contact your customer(s) to discuss further with them how they are using the provided travel time reliability information? Get Contact Information

APPLICATIONS

10. How are you currently communicating travel time reliability information to your users (e.g., what media, format, phrasing, etc.)?
    Software packages and/or trip planners for subscribers, text messages, etc.
    Accessible via computer, phone, etc.
    Include media methods such as social networking sites.

11. Do you communicate (i.e., phrase or format) travel time reliability information to your users differently based on the method of communication (*for example: desktop computers vs. phone application*)? Yes/No

    If yes, explain the differences (or changes)?

    Specifically address the different communication tools identified in Question 8. Ask for examples to be provided (possibly through email).

Identify if the information dissemination is a "push" (or automatic) system or a "pull" (user has to seek out the information) system.

Identify distinctions in the graphical user interface and the level of detail that can be provided for different screen sizes, etc. Also identify differences in wording based on space (character) limitations, etc.

12. If information distributed nationally—Does the form of communication or terminology you use change based on the area (region) it is being distributed to?
    Example: the term XXXXX may be understood in New York, but not in Houston.

    Or Seattle may prefer a desktop application where Miami prefers a phone-in system.

13. Can we get samples of the travel time reliability information you provide?
    Examples: website, software, subscription service, or email.

14. What information are you providing if there is a catastrophe (e.g., unexpected road closures/failures, airport closure)?
    Here we want to know how they handle unexpected system changes and "bad news" on the system. What do they communicate to users when experiencing extremely bad situations (relatively low/unknown reliability)?

15. Are you currently measuring your effectiveness of conveying travel time reliability information to users? Yes/ No

16. If yes—What measures of effectiveness are used?
    Examples: track website hits and/or feedback, commuter or other customer feedback to office, customer satisfaction (possibly through a survey)

    Might also ask feedback on the number of users signed up as a surrogate effectiveness measure.

FUTURE DIRECTIONS AND CHALLENGES

17. Do you think there is a market or use for providing travel time reliability information? Yes/No

18. If yes—What do you think this market is?
    Business or planning applications, transit, general commuter

19. If no—What do you believe would need to change to create this market?
    (i.e., what specific market forces at work? expressed interest from a specific stakeholder(s)? policy changes, at national or local level, etc.).

20. What is your agency's/company's short-term (e.g., the next year or next product cycle) vision for reporting travel time reliability to your users?
    What would you like to provide? What might change? Recognize that private sector will be reluctant to discuss.

21. What is your agency's/company's long-term vision (beyond five years) for reporting travel time reliability to your users?
    What would you like to provide? What might change? Recognize that private sector will be reluctant to discuss.

22. What are your agency's/company's challenges that keep you from "rolling out" travel time reliability according to your vision in the near term (within five years) and beyond five years as identified in questions #14 and #15?
    Typical challenges include financial resources, data limitations, data screening/reduction, identifying user needs, satisfying the needs of users of different communication platforms.

ADDITIONAL COMMENTS

23. In your opinion, what are the potential impacts of providing effective travel time reliability information in terms of:

24. Customer satisfaction?

25. Impact on travel choices?

26. Impact on system performance and reliability?

27. Impact on management and public officials?
    This will include their opinions and might be supported by feedback from users (commuters, media outlets), transit operators, transportation agency staff, others.

    With public sector or transit participants, identify good and bad impacts to their organization/agency.

28. Do you have any notable lessons learned that you would like to share related to estimating and/or communicating travel time reliability?
    Where are the difficulties/challenges? What advice they might provide to others?

29. Do you have any additional comments or opinions that would help us understand the state-of-the-practice in reporting travel time reliability?

30. Are you aware of other agencies/companies with whom we should speak about travel time reliability information? Yes / No

    If yes, do you have contact information for them?

CLOSING

Thank you for your time and your support of this research effort. If you have any questions regarding this study, please feel free to contact me at [provide phone #] or the principal investigator for this project, Susan Chrysler, at XXX-XXX-XXXX.

APPENDIX C DETAILED FOCUS GROUP SUMMARY

INTRODUCTORY QUESTIONS

This appendix includes the slides and script used to conduct each of the focus groups, along with a summary of comments. The session began with the facilitator welcoming the group (Figure C-1) and reviewing the ground rules for the focus group, which were shown in Figure C-2.



Figure C-1. Welcome (Slide 1).

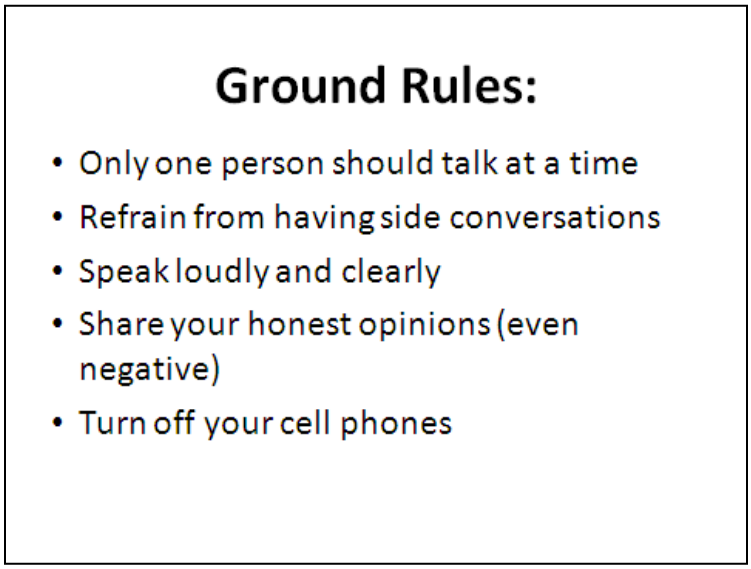


Figure C-2. Ground rules (Slide 2).

Next, the participants introduced themselves using the prompts on Figure C-3. This gave the group a chance to relax, to get to know each other, and to become comfortable with participating in the discussion. They referenced their responses to the questionnaire they filled out upon

arrival to give the facilitator an idea of the types of situations where timeliness was important. For the remainder of this appendix, the prompts and questions from the group facilitator are found as italicized headings.

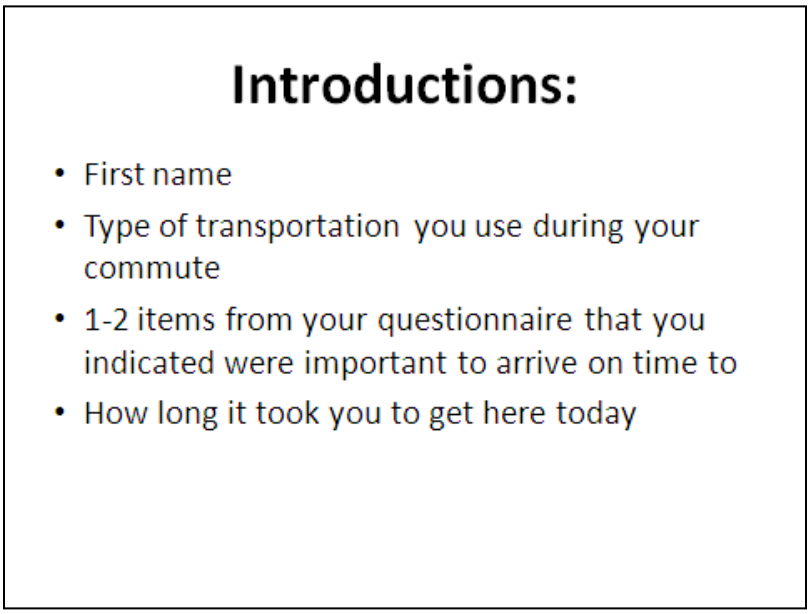


Figure C-3. Introductions (Slide 3).

What causes travel time variation?

Discussion began with a brainstorming activity that required participants to list factors/events that made them early or late to their destination. The facilitator created a list on the screen of everything that was said. After the initial list was generated, the facilitator pointed out the day-to-day or single occurrences and asked what things affected the time it took to make a regular or recurring trip. Responses initially focused on events such as accidents, weather and personal factors. Once the focus was shifted to repeating factors, the responses were focused on time of day, traffic levels, events and holidays. Once the focus of the discussion had been shifted to predictable events, the facilitator moved on to the next question.

And how did you decide what time to leave to get here today?

The next topic began discussion about use of online mapping tools and navigation systems to help plan trips. Every individual was familiar with some type of online mapping tool and had used one at least once. A few participants even had the printout with directions to the focus group location with them. Several participants stated that they used personal experience and familiarity with the area and main roads to determine their leaving time.

Overwhelmingly, participants stated they added additional time to starting travel time given to them by the system. They were not bothered by having to do this. Drivers relied heavily on personal experience and several simply assume an hour to get to a new destination. One participant said, “I always give myself one hour no matter where it is. There is nowhere I am going to go that’s going to take me anywhere past an hour to get to, so if it’s a doctor’s

appointment, if it's a job interview, I give myself an hour." In Seattle, one participant said that the down side of arriving early was that she "could have done something else" with her time. Most acknowledge that there was a cost with arriving early but it was still better to be significantly early as opposed to late. The open-ended survey looked deeper into this additional time that drivers add, and studied if they followed trends, such as whether drivers always add the same amount of time to a trip, or whether they add a time proportional to the estimated trip time. This questioning can help assess a driver's confidence in a travel time reliability (TTR) system.

For the most part, participants had not considered how MapQuest or another mapping tool calculated the estimated trip time. Some answered that it was a factor of distance and speed limit, while others thought someone had driven each route and recorded it.

The topic of accuracy was addressed next and participants were asked: *MapQuest tells you the same travel time all the time. Is travel time always the same at different times of day? Days of week?*

At this point, participants began to think about recurring influences in terms of their individual trip. Differences in traffic at certain times of day and certain days of the week were brought up. Most groups said traffic was worse on Mondays and Fridays. Holidays, special events, and construction were all mentioned as well. Overall, the participants had a good understanding that traffic is not the same at every time of day or day of the week and understood there are many variables that can affect traffic and the existing systems.

One participant spoke about the uncertainty in general: "It's hard to guesstimate a time because every situation, every day is different. This weekend won't be like next, and this Monday won't be like next Monday."

The open-ended survey expanded on this topic by using different terms and phrases to describe travel time and then asked participants how certain they were that they would get to work on time.

Is MapQuest estimate of time accurate?

When asked, participants said MapQuest times were not accurate, and they added additional time to the estimate based on their own experiences. Some even said they used two mapping sources, averaged them, and then added additional time. Drivers relied heavily on personal knowledge, and several simply assumed an hour to get to a new destination.

They overwhelmingly agreed that MapQuest and other existing mapping tools do not factor any of the variables, predictable or not, into their trip time calculations. In fact, most participants had never considered how MapQuest or another mapping tool calculated the estimated trip time. Some answered that it was a factor of distance and speed limit, while others thought someone had driven each route and recorded it.

TERMS TO IDENTIFY TRAVEL TIME VARIATION

The facilitator asked what words or phrases participants would use to describe the fluctuation in time it takes to make a trip. Participants brainstormed words and phrases out loud before being

shown the slide below. Some responses included: *unknown, approximately, unpredictable, variable, average traffic time, flexible travel time, additional, at least,* and *delay.*

Next, participants were asked to identify terms that best fit in the sentences shown in Figure C-4. This exercise forced participants to use terms that would be tested in future studies and considered for the lexicon.

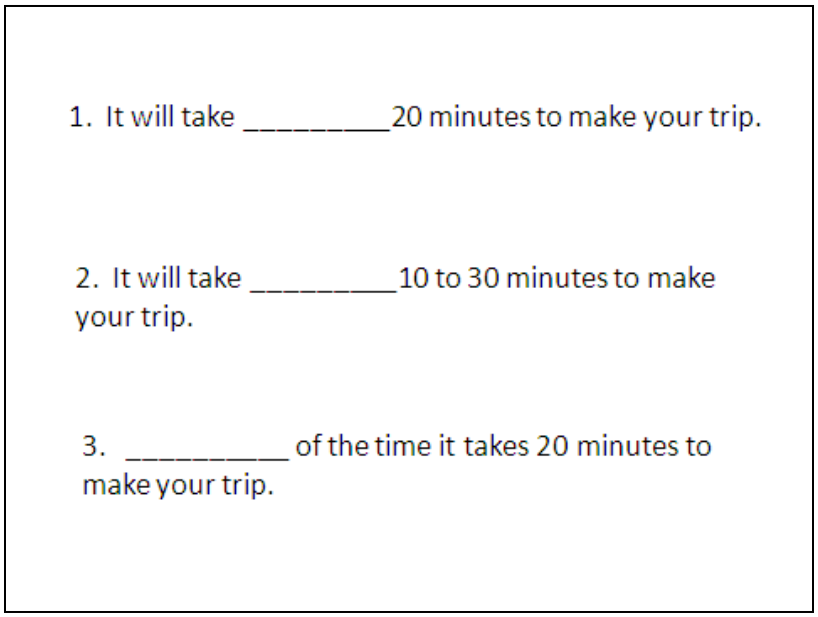


Figure C-4. Sentence completion (Slide 4).

To determine which words are best to describe trip time estimation, the first sentence read, "It will take ___ 20 minutes to make your trip." Responses varied greatly, but *about, approximately,* and *at least* were all mentioned in at least three of the cities. Other words or phrases used to complete this sentence were *minimum, average, more than, over, roughly, usually,* and *estimated.* This question was also included in the computer survey, and these responses from the focus groups helped form the multiple-choice responses for the survey.

The second sentence in Slide 4 was written to gain insight into words used to describe a range of time. Terms used to complete the sentence were *about, approximately, between, around, on average, likely, anywhere from, somewhere between, usually,* and *ideally*.

"____ of the time it takes 20 minutes to make your trip" was the third sentence participants were asked to complete. Responses included the terms *most, some, half, seldom, majority, often, a good portion, 75%,* and *1/8.*

TRAVEL TIME RELIABILITY SYSTEM

After Figure C-4, a hypothetical travel time reliability system was introduced to participants as a "system that could make better predictions about your expected travel time but considering all the factors we listed." The explanation served to transition from factors that affect a trip to the value of travel time reliability information. The system was explained as one that:

- Users could enter specific "to" and "from" destinations.
- Would use more factors than just distance and speed limit.
- Would use sensors in the road to continuously gather data.
- Would have a record of weather conditions, road construction, and accidents.

When initially introduced, almost all participants said that this system would be valuable. However, as discussion continued, participants began to express primary interest in real-time information. They did see a value for the historical reliability information in certain instances, primarily those who were new in an area or traveled often. However, they didn't see it as a tool for daily use. In fact, one participant said that he would rather "focus on coordinating getting the information together with real-time info than calculating the odds." In order to represent this suggested usage and to appeal to most drivers, this information was used to create the scenario in the open-ended survey, which involved an unfamiliar, yet constrained trip.

Most participants felt that this system would be the most useful before they began their trip. However, some felt that it would be valuable during a trip to have the ability to change routes. Almost all saw the value of pre-trip planning and the cost involved in wasting time. They felt that online access through a website would be the most effective. Other methods of accessing the information are Smartphone applications and global positioning system (GPS) units. The desire to have this information available on mobile devices demonstrated that participants did not appreciate the historical vs. real-time distinction.

Participants seemed to believe that this system would be helpful in several specific situations. Evacuations, moving to new areas, buying a house, or general travel to unfamiliar areas were all mentioned as situations where they would possibly want access to historical information. Overwhelmingly, participants agreed that the system did not have any value when used for daily trips. Weekends seem to be the time it would be utilized the least.

In Seattle, participants repeatedly discussed the idea that high-occupancy vehicle (HOV) lanes saved time. However, they never touched on the greater reliability of those lanes. When asked directly whether the HOV lane was faster or just less extreme, four people responded that it was simply less extreme. One person said that "information about the extremes of different lanes is useful."

Participants were still hesitant to think that the time estimates produced by the system would be accurate. Education would be critical to the understanding and application of this reliability information. Concern was expressed about taking valuable time to plan their trip in advance, only to begin their drive and encounter an incident that would have been realized with real-time information.

If the system provides a travel time based off a 95th percentile or worst-case situation, then drivers will need to be educated that they do not need to add the same buffer time as before. Due to the wide lack of trust in any system, this still may be hard to do, although most participants did believe that a system based on historical data would be more accurate than the systems they currently use. Future tasks in this project assessed participant understanding of the term *95th percentile* as well as similar concepts and terms.

SYSTEM INPUT AND OUTPUT

The participants were shown an example of an input screen (Figure C-5) and then asked additional questions about the input and output options they would prefer.

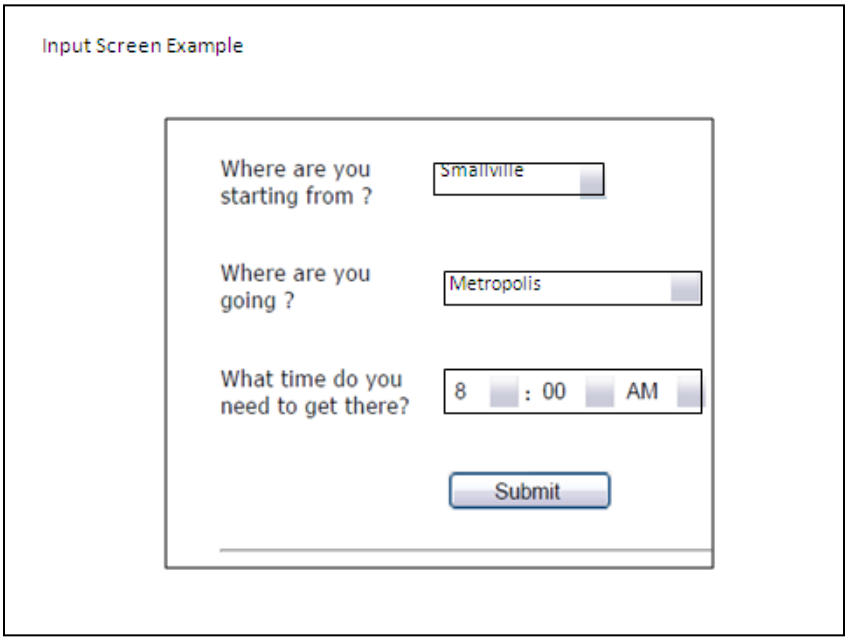


Figure C-5. Input screen (Slide 5).

What would you like to be able to input/personalize? Is "what time do you want to arrive" the right question?

What type of information would you like our new system to provide you with?

Do you want the system to tell you how sure it is of its estimate?

When asked what they would like to be able to input or personalize, participants came up with several additions to make the input screen more specific. All groups mentioned a more specific origin/destination entry box. Some wanted to be able to enter the zip codes and some specific addresses in addition to the city. Although noted that participants want flexibility in their input, researchers realize that most TTR system origin/destinations will be limited by the data available on the roadways. This was the case for the Houston field operational test.

Most drivers wanted the ability to choose between "What time are you leaving?" and "What time do you want to arrive?" Participants mentioned that the time constraint may come on either end of the trip and has the potential to affect their travel time estimate. Other specific entry items mentioned included the ability to specify the date or day of the week, the best- and worst-case scenario travel time, and a suggestion of a different and more efficient departure time. The specific phrasing of these questions was covered in the computer survey; however, the preference between a departure and an arrival time option was not discussed since it is dependent on the conditions of the trip.

All participants agreed that the system should provide multiple route options. It should recommend one route but also show alternate routes with the same level of detail. One participant said that the output should give the trip in distance as well as the estimated time so the user can make their own trip time adjustment. It has been discussed whether to include this functionality in the field operational test, but it may not be feasible to implement with the website system that has already been developed.

When the research team asked participants if they wanted the system to tell how sure it is of its estimate, reaction was mixed. Several participants expressed hesitation in trusting a system that was not positive of its estimate. Others felt that they would like to know how confident they could be that the predicted time would allow them to arrive at their destination on time.

What should the output look like? Just words, a graph, a map?

Groups were split on whether the output information should be shown as a graph, picture, map, text, or combination of any of those. Most mentioned that color coding is helpful, and travel time information should be provided for the return trip as well. In Houston, both groups suggested including landmarks to help navigation, and all groups mentioned being provided multiple route options so they could choose the best fit for them. One participant said that it would be beneficial if specific driving directions could be sent to his cell phone.

When prompted, participants in Seattle liked the idea of getting real-time alerts for their current trips, and all agreed that they would like travel time information for surface streets so that they had a choice about taking the freeway. They also mentioned the addition of parking information into the system because that is the element that provides the greatest variability in their daily trips.

USE CASES

In order to determine under which scenarios travel time reliability information is valuable, four scenarios were introduced. One of them was a constrained unfamiliar trip, one a constrained familiar trip, another was an unconstrained unfamiliar trip, and the last an unconstrained familiar trip.

Scenario One: Constrained Unfamiliar

The first scenario presented was an appointment with a new doctor.

> *You have an appointment with a specialist you have never seen before on Thursday, and you are not familiar with the area of town the office is located in. You have to tell your boss by Tuesday what time you will need to get off work on Thursday, so you need to plan ahead.*

This scenario was another instance in which a large number of participants said that they relied on mapping tools such as a GPS or MapQuest, and all added additional time to those estimates. Others relied on their previous knowledge of the area, and several stated they simply leave an hour in advance. Unprompted, one participant did mention that “the downside of being

somewhere early is that you could have done something else." However, all agreed that they would rather be early than late to important events such as appointments.

The majority of the participants replied that they would potentially use the system in a situation such as this one. One person said, "It would good if we were going somewhere we didn't know anything about traffic. [I would] already know the traffic patterns here, so if I was traveling, it would be more useful." However, most verbalized that they would still be skeptical of the estimated trip time and add additional time. As previously mentioned, since participants seemed in favor of a TTR system for a constrained/unfamiliar trip, the open-ended survey's scenario was modeled after this criterion.

Scenario Two: Constrained Familiar

The second example (constrained/ familiar) involved making a decision about aerobics class. Depending on the make-up of the group, this example would be changed to an activity for a young child that required taking them and picking them up somewhere.

> *You are trying to decide whether to sign up for the Monday/Wednesday or the Tuesday/Thursday aerobics class at your new gym. Class starts at 6 p.m., and you can't leave work until 5 p.m. each day.*

Generally, groups in all cities mentioned that they could assume traffic is heavier on Mondays and Fridays, so they would avoid those days. This highlighted their awareness of variability.

Overall, the consensus was that people would not use the new system to aid in making this decision. While a handful said they may check it to make sure there isn't a special event (e.g., large church that meets on Wednesday evenings), the majority felt that they would "plan around their life, not traffic." Several also voiced that they did not trust that the difference in trip time each day would vary enough to justify the time spent checking the system for a short-term class. Another individual suggested he would rather ask someone familiar with the route and base his estimates and decision on that information rather than checking the system.

Scenario Three: Unconstrained Unfamiliar

One example of an unconstrained unfamiliar local trip is going to a birthday party.

> *You are going to a friend's birthday. The party starts at 7 p.m. and is at a house you have not been to before.*

For this example, participants overwhelmingly agreed that they would not use the reliability system. Most said all they would need was basic directions from the GPS unit in-car or from an existing mapping tool, and time was not critical: "If you are a couple of minutes late in this situation it is not as critical as catching a plane or work or an appointment." One individual mentioned that they might use the system to get a map and check construction status, but overall, this situation did not warrant the use of a pre-planning function.

Scenario Four: Unconstrained Unfamiliar

The other example of an unconstrained and unfamiliar event is a trip that requires travel to an area you are not familiar with. Trip destinations were changed for each focus group city to represent a destination that was within several hours of their homes.

> *You are taking a trip to Mt. Bachelor to go skiing and have to drive through Portland to get there. You are not familiar with Portland but have heard that there are times where the traffic is heavy and travel times are slow.*

Participants were asked if they would use a system like the one discussed to determine which day of the week or time of day they would want to drive through Portland. This scenario was difficult to gauge because participants did not seem to have a strong opinion. While most saw the value, they were still not sure they would take the time to consult the system. Some said the trip was simply a convenience, so time was not critical and they would not consult historical information, just the use of a map. Others said that there would need to be a significant time savings before they changed the time they chose to leave. Still another said they may use the system simply to determine what the traffic situation was, although it would have little or no bearing on their departure time decision. It was also recommended that the system have the potential to include rest stops and trip planning features in addition to peak traffic alerts to increase system usefulness.

In some cities, when time allowed, this example was used to introduce the possibility of the system helping to determine mode change. Participants were asked directly if they would use the system to choose whether to take the train or the bus instead. Most said they would not. However, some cities with established forms of alternative transportation seemed open to considering the idea of mode change. One individual said he "would probably still take the bus if I had been planning on it, but I might take the bus that lefthalf an hour earlier than the one I'd usually take." Overall, participants said that the decision to change mode would be motivated by schedule and convenience more than time.

Scenario Five: Unconstrained Familiar

One unconstrained and familiar trip example involved participating in a food co-op.

> *You participate in a food co-op and have to go pick your box up every Saturday morning sometime between 8 a.m. and 2 p.m. The produce is distributed in a church parking lot 20 minutes from your house.*

The primary response to this scenario was that traffic is not the same on weekends, and if participants were going to use any system, they would check a source that provided real-time data. Almost everyone said that they would not use this system because Saturday's plans vary from weekend to weekend, and they would base the pickup time solely on their personal schedule for the day. They would not necessarily go at the same time each week. Several agreed that the system may be valuable if they could enter a time window and it had the capability to tell them the most efficient time to make the trip.

Scenario Six: Unconstrained Familiar

The other unconstrained familiar trip example involved choosing a day of the week to feed the neighbor's cat.

> *Your neighbor is attending overseas training for their job and will be gone for 3months. The families on your street are volunteering to take care of their cat one day a week. You are asked to pick a morning you are available to feed the pet every week. You realize the traffic is typically worse on some days than others.*

None of the participants said that they would use the system in this situation. All felt that they would choose a day based solely on their personal schedule, not on traffic. Others also felt that the trip from home to work would be very familiar, so they would know from experience what the best day to add a task would be. One participant said, "It would take longer to use the system than to just (feed the cat)."

Scenario Seven: Comparing Two Routes with Different Reliability Values

To get an understanding of the words that would be used when talking about these types of trips and the kind of information the new system would provide, a scenario was presented, as shown in Figure C-6, and participants were asked to describe the differences.

> *Bob and Fred are neighbors who work at the same office building, but they take different routes to work. They constantly argue about whose route is better, so they decide to keep track of their arrival times for 2 weeks. They leave their houses at the same time every morning. Here are the results:*

	Bob's Way		Fred's Way	
	Minutes Early	Minutes Late	Minutes Early	Minutes Late
M		1	7	
T	2			2
W	1			5
Th		2	4	
F		2	8	
M	3		5	
T	1			7
W		3	2	
Th		1		8
F	2		4	

Figure C-6. Bob and Fred timecards (Slide 6).

These values were chosen because both routes had an identical mean, but the standard deviation of Bob's way was 1.254, and the standard deviation of Fred's way was 4.675.

Overall, participants thought that Bob's route was better even though they were both early five times and late five times. Unprompted, they said Fred's route had *unreliable factors*, was *more erratic*, and had *more variance,* while Bob's route was *more reliable, predictable,* and *consistent*. One participant said they cannot be compared because "late is late and early is early," and they were each early and late five times, while another said he would choose Fred's route because he was early by more.

Participants were shown Figure C-7 and asked to fill in the blank on how to describe the routes Fred and Bob take.

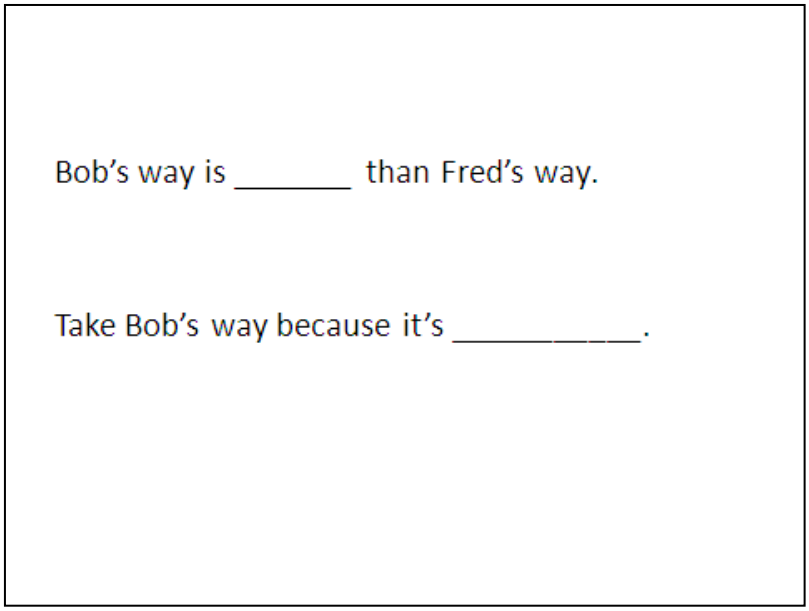


Figure C-7. Bob and Fred sentence completion (Slide 7).

Answers included the following: Bob's way is *reliable, more efficient, predictable, better, safer, shorter, more direct, better probability, more consistent, faster, quicker, less problematic, less risky*.

Take Bob's way because it *works, is reliable, consistent, a better way, dependable, precise, dependable, more thorough, unbelievable, less likely to be late, more efficient, doesn't fluctuate*.

These terms provided by the focus group participants were also used in the questions asked in the computer survey.

FILL-IN-THE-BLANK ACTIVITY

The next section of the discussion was intended to gauge the terms used by drivers to describe the uncertainty in traveling. Nine sentences were presented, and participants were asked to write their initial responses on the blank sheet of paper in front of them. The words were discussed,

and then a list of words, previously generated by the research team and shown in red on the slide, was shown. After both the participants' initial responses and the list of word choices were shown, each participant indicated their favorite term for that particular sentence or concept. Due to time constraints, not all sentences were discussed in every city.

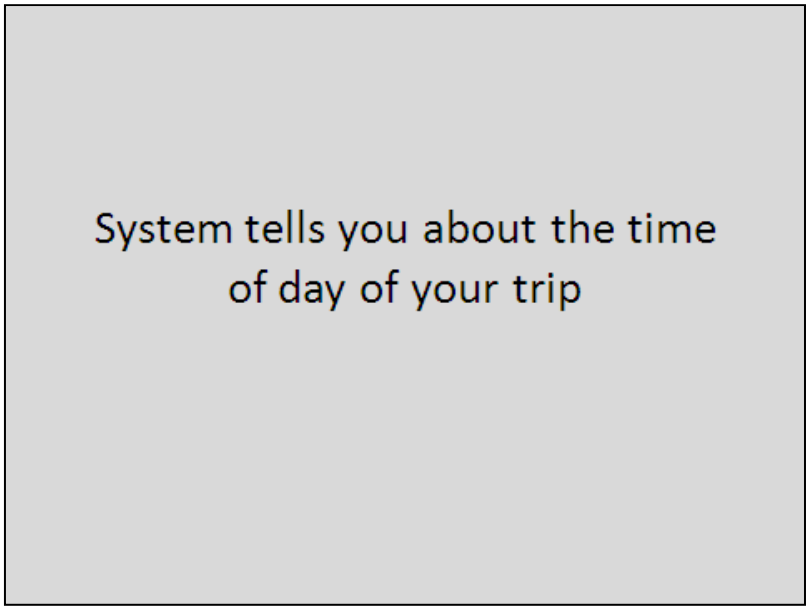
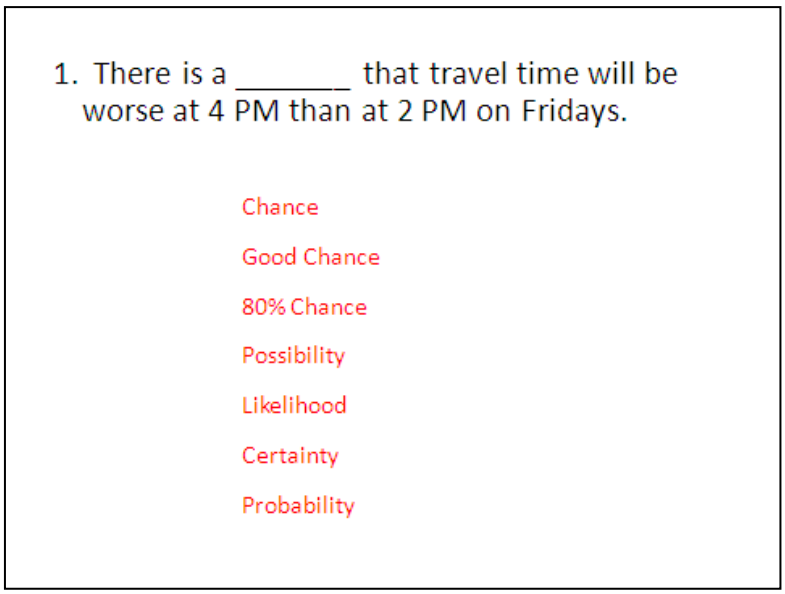


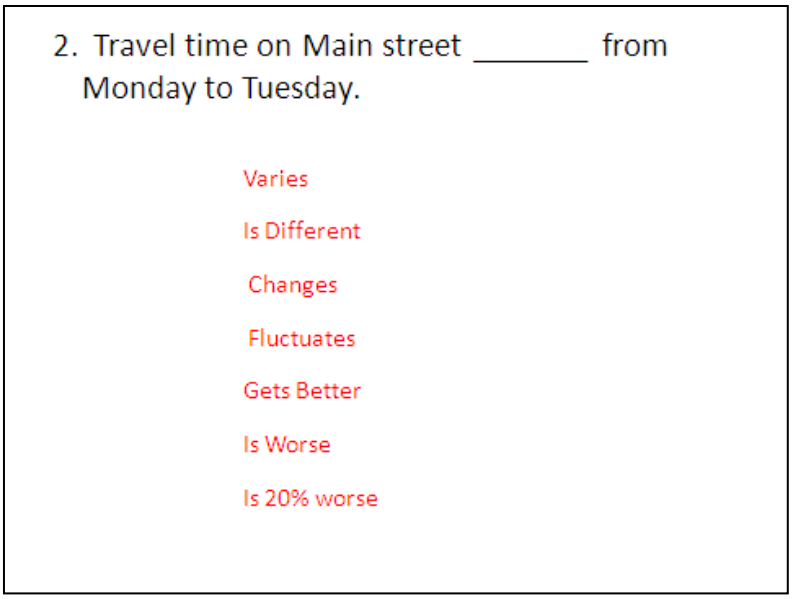
Figure C-8. Topic slide (Slide 8).



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-9. Sentence 1 (Slide 9).

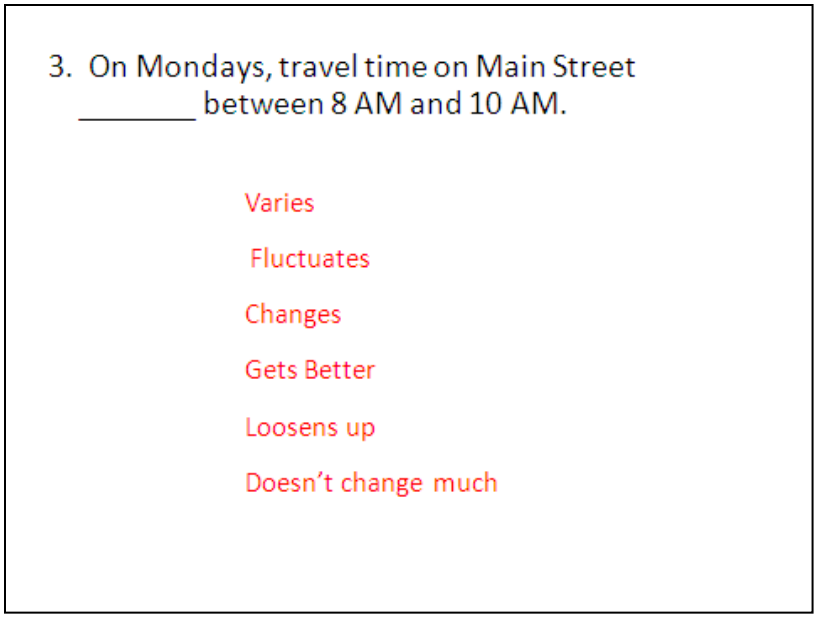
Slide (Figure C-8) introduced the discussion regarding a travel information system that provides information about travel times based on time of day. *Chance* and *possibility* were the two terms most preferred by participants in all cities for the sentence shown in Figure C-9. Several suggested that chance was broad and should be qualified by saying *X% chance*, *slight chance*, or *good chance*. Other popular terms included *certainty, likelihood*, and *probability*.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

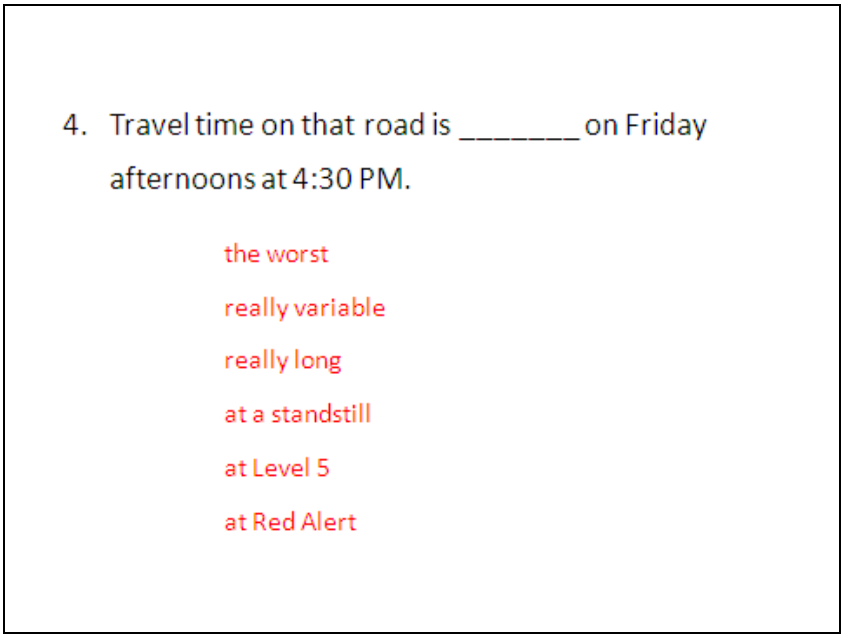
Figure C-10. Sentence 2 (Slide 10).

Referring to Figure C-10, *varie*s, *changes*, and i*ncreases/decreases* were the preferred terms to complete this sentence describing variability by day. Words such as *congested*, *fluctuates*, *lighten*s, and *stinks* were also suggested.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-11. Sentence 3 (Slide 11). No specific term received overwhelming support to fill in the blank for the sentence seen in Figure C-11. In most cities, no word or phrase was voted on by more than three people. In Seattle, the phrases *is most congested*, *is slow*, and *gets better/worse* were each preferred by two individuals. Other suggestions were *is historically bad*, *peaks*, or *fluctuates*. Three participants in Houston thought that *increases* was the word to best complete the sentence. Atlanta had the most variability, as nine terms received multiple votes. *Is terrible* and *is worst* were the top two choices, while *lousy*, *awful*, *horrible*, *is longer/shorter*, *congested*, and *chaos* rounded out the group. Washington, DC, preferred *congested* or *is longer/shorter* by a narrow margin, and Minneapolis felt that *increases/decreases* was the best term to describe traffic in that time window.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-12. Sentence 4 (Slide 12).

Congested, *possible*, and *likely* were the most used terms to fill in the blank shown in Figure C-12. *Horrible*, *grid lock*, *certain*, *expected*, *extremely slow*, and *unpredictable* were also mentioned as words to describe this situation.

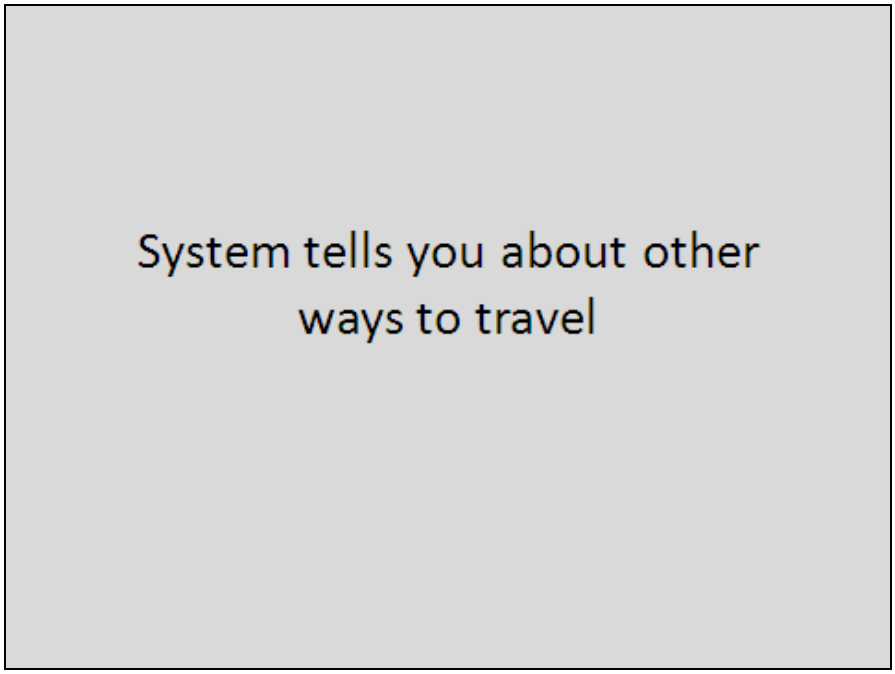
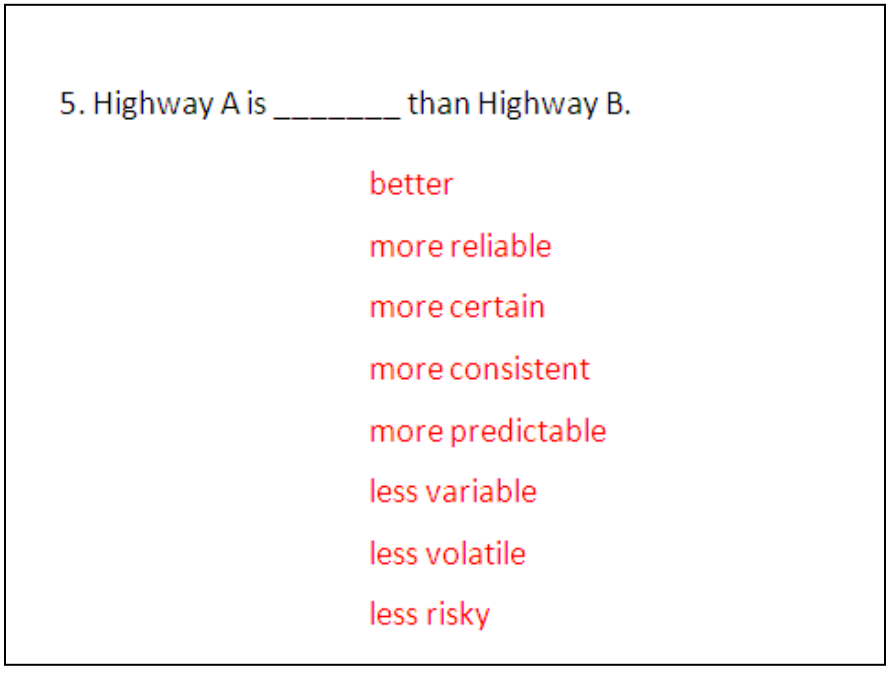


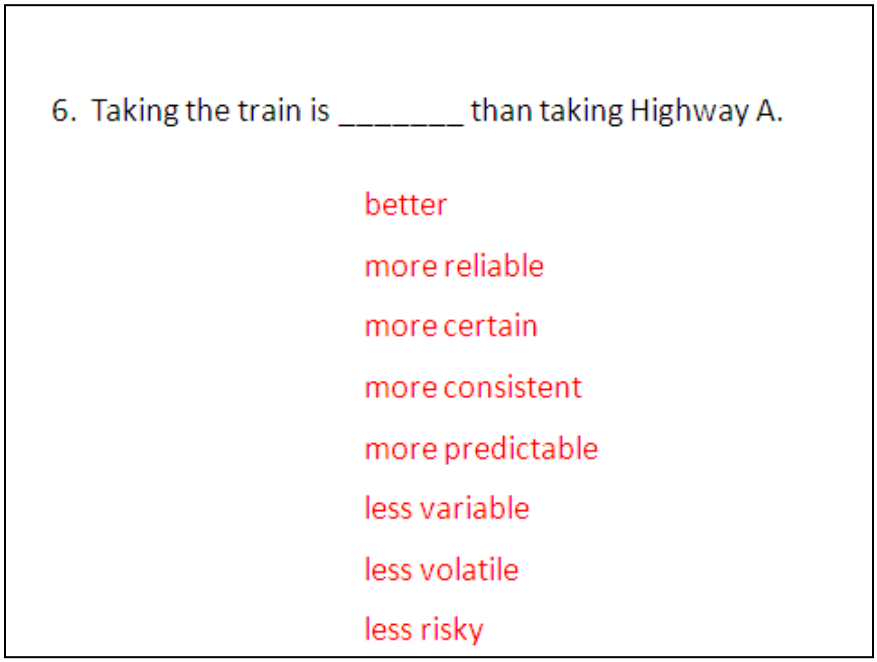
Figure C-13. Topic slide (Slide 13).



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-14. Sentence 5 (Slide 14).

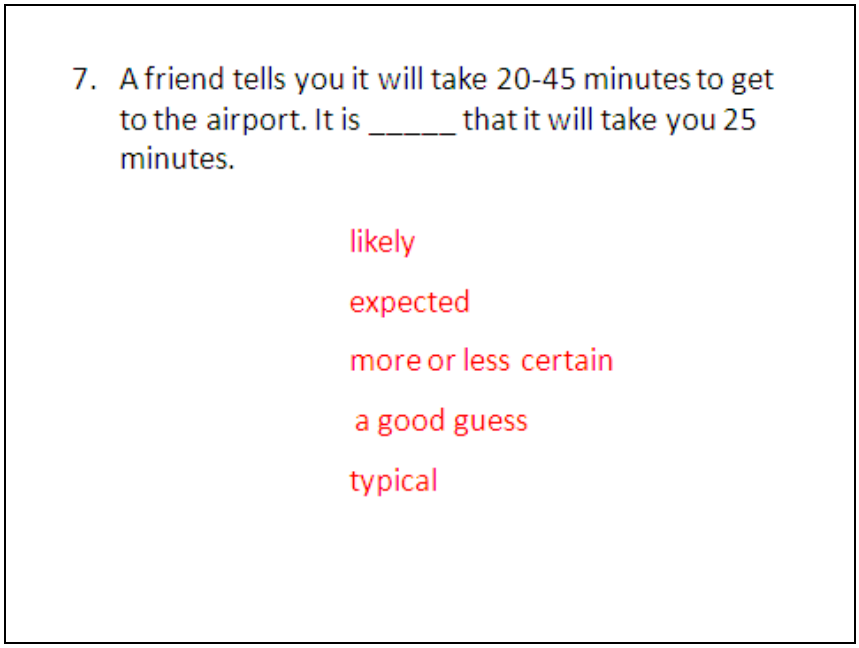
Slide 13 (Figure C-13) introduced discussion of alternate routes or modes provided by a travel time reliability system. Participants thought that the terms *faster* and *more reliable* were the best descriptors to fit the scenario in Figure C-14.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-15. Sentence 6 (Slide 15).

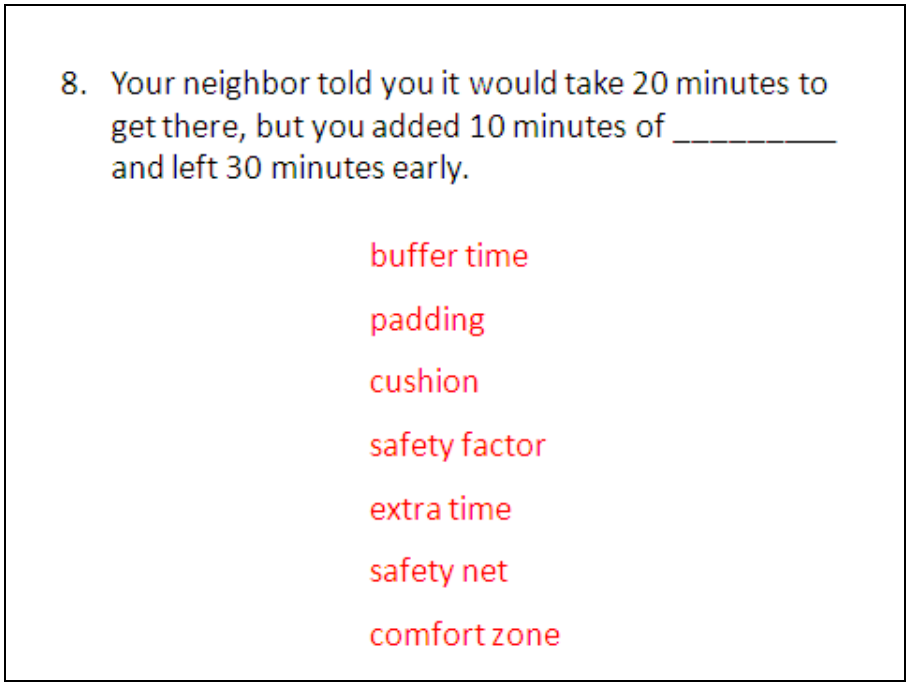
Unprompted, the majority of terms provided by participants for the sentence in Figure C-15 dealt with time. For example, *faster, slower, easier,* and *quicker* were mentioned. After participants viewed the prompts, they still believed those terms to be the best. *More consistent* was also liked after it was shown.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-16. Sentence 7 (Slide 16).

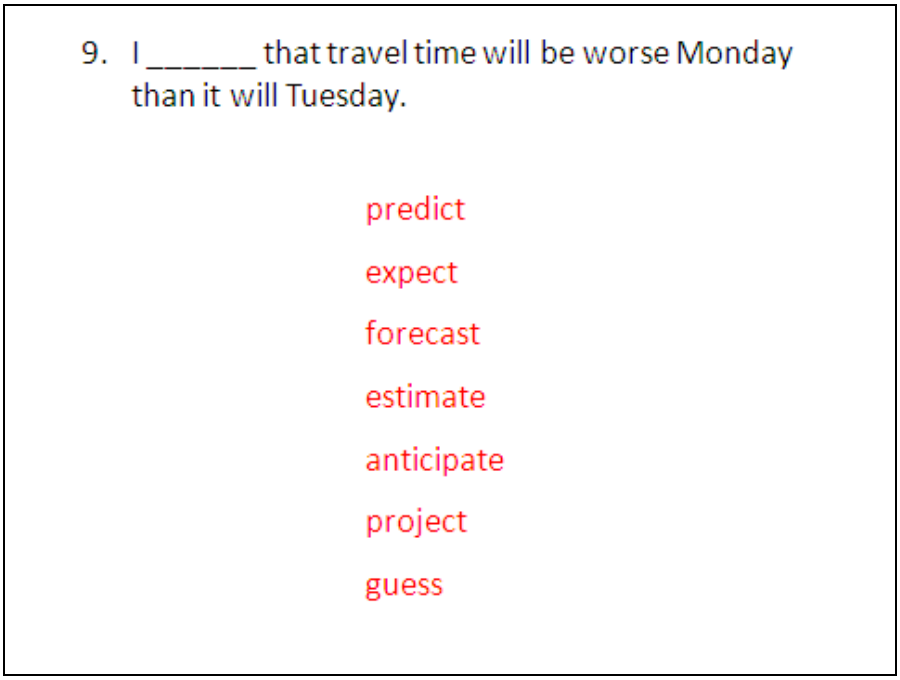
In Figure C-16, *likely* and *unlikely* were chosen by the majority of participants that viewed this sentence as the word that best verbalized the uncertainty. *Doubtful*, *probable*, and *typical* were also mentioned as options.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-17. Sentence 8 (Slide 17).

There was a variety of responses to the question in Figure C-17, and it was dependent on personal preference. Words that were mentioned that were not prompted were *additional time, traffic time, parking time, wiggle room, leeway, window, driving time, just-in-case time, gap time, fluff time, flex time, human error, allowance, lead time,* and *additional drive time*. *Leeway* was mentioned in several groups and was well liked in Seattle, Washington, DC, and Minneapolis. *Extra time* seemed to be the most popular term among all cities.



Note: The list of words below the sentence was shown after participants contributed their initial responses to promote further discussion.

Figure C-18. Sentence 9 (Slide 18).

The sentence in Figure C-18 also resulted in a variety of answers. *Know*, *expect*, and *predict* were the three most preferred responses. One participant even recommended using the phrase *know from experience*. Other well-liked answers were *believe* and *assume*.

VALUE AND UNDERSTANDING OF THE SYSTEM

To conclude the session, participants were asked several questions about the overall value of the system and who the users of the system may be. Participants said that primary users of the system would be individuals that drive in new locations on a regular basis. Specific occupations mentioned in the groups were salesmen, delivery drivers, and businessmen who travel to new places regularly. Another target audience identified by participants was drivers who are new to a city or area. The system could be used in determining how and when to leave for work or appointments or to help in decisions about where to buy a house or accept a job.

When asked which element of the system would be most understood by users of the travel time reliability system, all of the participants expressed concern that drivers would assume they were being presented with real-time information. They felt that the concept of historical travel time data would confuse drivers, especially once they realized there was no real-time component. Some participants said that without a firm grip on reliability information, drivers would not understand what made this system different from any of the other options currently available. However, this misunderstanding could be rectified with driver education and clear explanations on the site. Others were concerned with presenting information in terms of percentages because

they felt the average driver does not understand what a percentage is telling them or where the data came from.

In trying to understand the value provided by a travel time reliability system, researchers asked participants if they would pay to use the system. Overwhelmingly, drivers said that they would not pay for the use of a website. There are other free options available that are working well for them right now, and they could not justify the expense. However, most said that they may pay a single or annual nominal fee for the convenience of a cell phone application or an additional upgrade to their GPS package. A few people said that they would pay for separate software, and one participant mentioned that companies may be willing to pay for use of the system if they employed a large number of people who drove to new places often. In that case, the time and money savings would justify the expense of the information. When asked whether they would pay for use during a certain situation or circumstance, several said that they would.

The final question asked whether the public department of transportation should provide this travel time reliability information or whether it should be provided by a private company. Initially, participants verbalized no strong opinion on this topic, but by the end of the discussion, they were leaning toward private companies. They felt that private companies would have the resources to respond more quickly to demands and more motivation to maintain and improve the system because it was their source of income. When prompted, participants were open to the idea of a private company charging for use of the travel time data because it must make a profit. While they felt that the government would have more access to information about construction, they were not confident that the system would be as user friendly or well maintained. A few participants still felt that it was the government's responsibility to provide this information.

APPENDIX D COMPUTER SURVEY QUESTIONS AND RESULTS TABLES

QUESTIONS 1-4: RELIABILITY CONCEPTS

Figure D-1 displays the computer screen participants viewed for Question 1. Questions 2-4 varied the underlined term to *predictable*, *consistent*, and *best trip*, as shown in Table D-1.

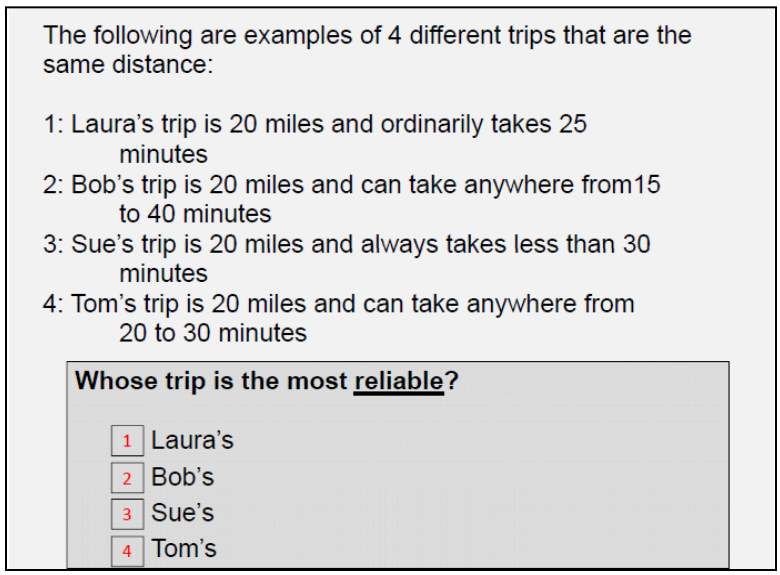


Figure D-1. Question 1 visual.

Table D-1. Questions 1-4 response summary.

Response Choices	Reliable (Question 1)	Predictable (Question 2)	Consistent (Question 3)	Best Trip (Question 4)
1. Laura (Typical Travel Time)	40.00%	42.33%	49.33%	47.67%
2. Bob (Large Range of Travel Times)	8.00%	10.67%	5.67%	8.33%
3. Sue (Maximum Travel Time)	39.00%	37.00%	39.33%	26.67%
4. Tom (Small Range of Travel Times)	13.00%	10.00%	5.67%	17.33%

QUESTION 5: IMPORTANCE OF TRIP PLANNING FACTORS

Figure D-2 displays the computer screen participants viewed for Question 5 and the question responses.

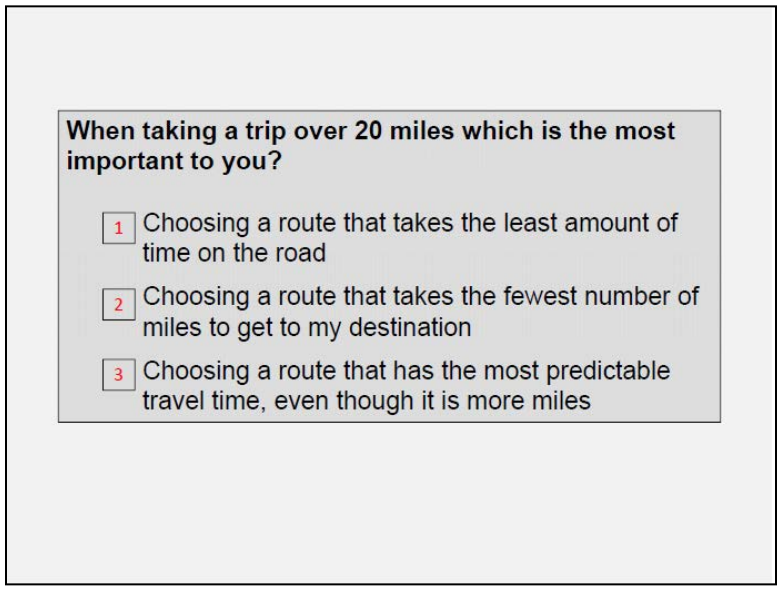


Figure D-2. Question 5 visual.

Table D-2. Question 5 response summary.

Response Choices	Percentage
1. Least time	68.67%
2. Fewest miles	13.00%
3. Most predictable time	18.33%
Grand Total	100.00%

QUESTIONS 6-8: TERMS FOR WEBSITE TRIP PLANNING FEATURE LINKS

Figure D-3 displays the binder page participants viewed prior to Question 6. Figures D-4, D-5, and D-6 show the computer screen visuals and results for Questions 6, 7, and 8, respectively.

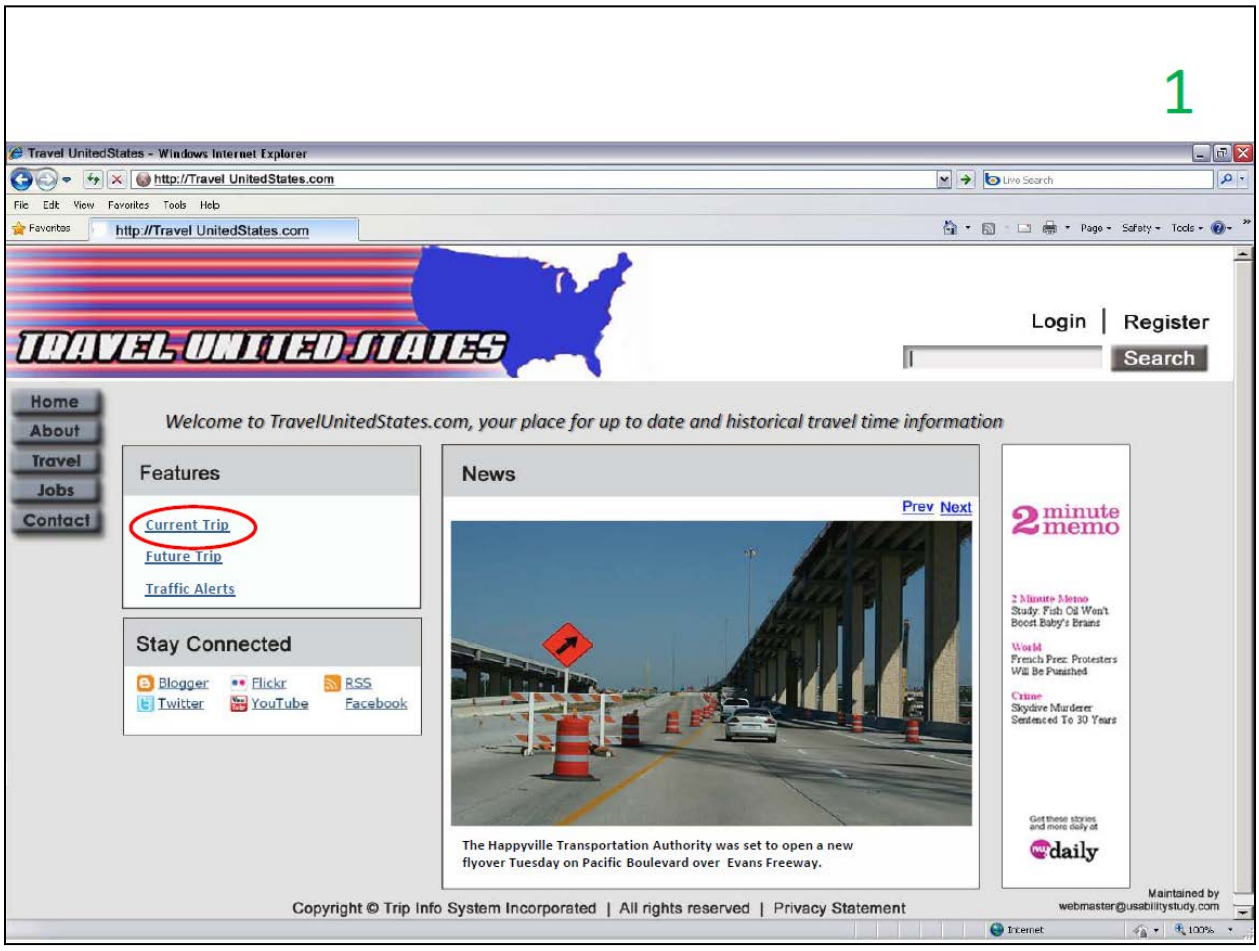


Figure D-3. Visual from binder used to introduce example traveler information website.

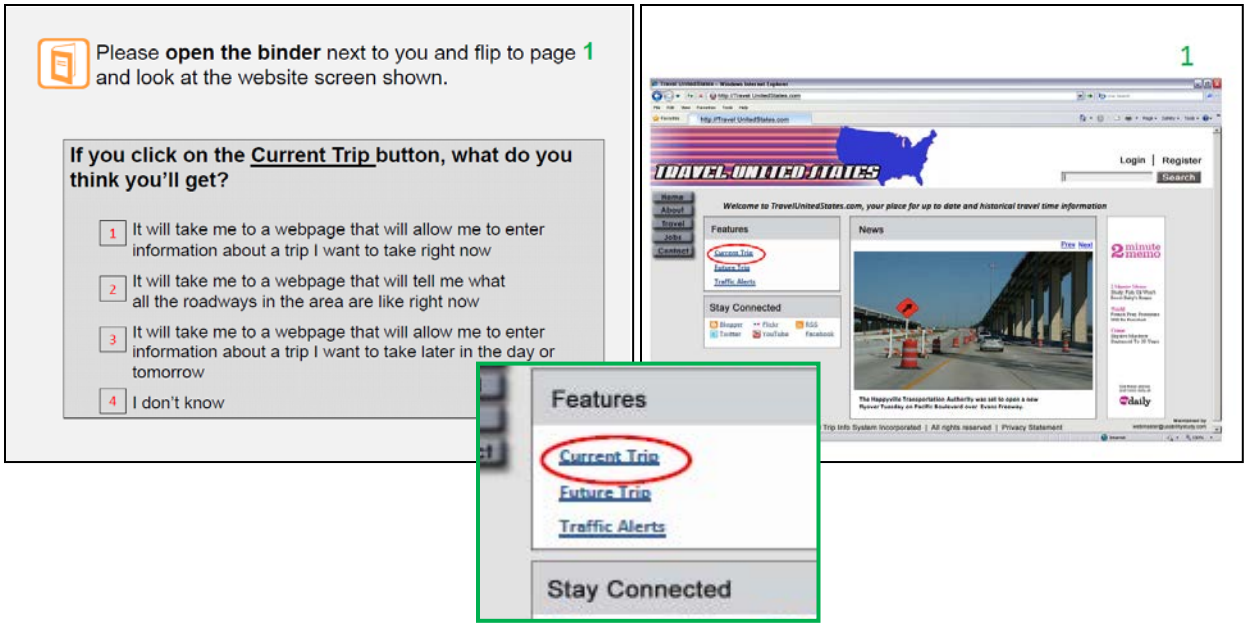


Figure D-4. Question 6 visuals.

Table D-3. Question 6 response summary.

Response Choices	Percent
1. It will take me to a webpage that will allow me to enter information about a trip I want to take right now.	53.90%
2. It will take me to webpage that will tell me what all the roadways in the area are like right now.	31.97%
3. It will take me to a webpage that will allow me to enter information about a trip I want to take later in the day or tomorrow.	8.18%
4. I don't know.	5.95%
Total	100.00%

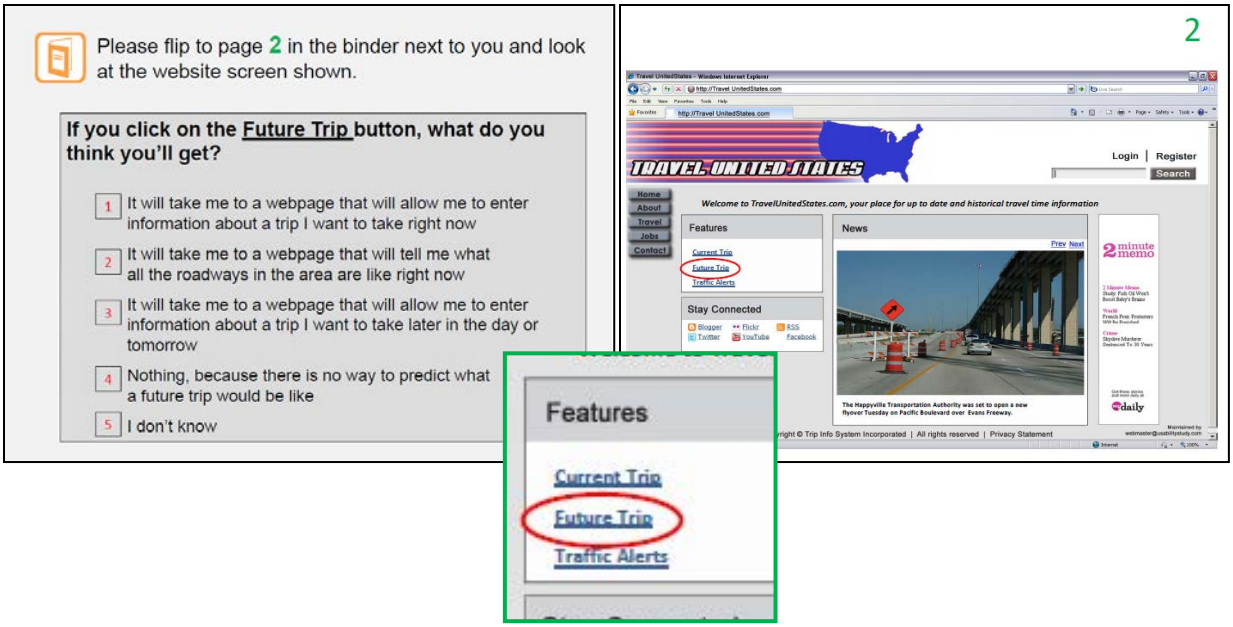


Figure D-5. Question 7 visuals.

Table D-4. Question 7 response summary.

Response Choices	Percent
1. It will take me to a webpage that will allow me to enter information about a trip I want to take right now.	1.12%
2. It will take me to webpage that will tell me what all the roadways in the area are like right now.	4.83%
3. It will take me to a webpage that will allow me to enter information about a trip I want to take later in the day or tomorrow.	81.41%
4. Nothing, because there is no way to predict what a future would be like.	11.15%
5. I don't know.	1.49%
Total	100.00%

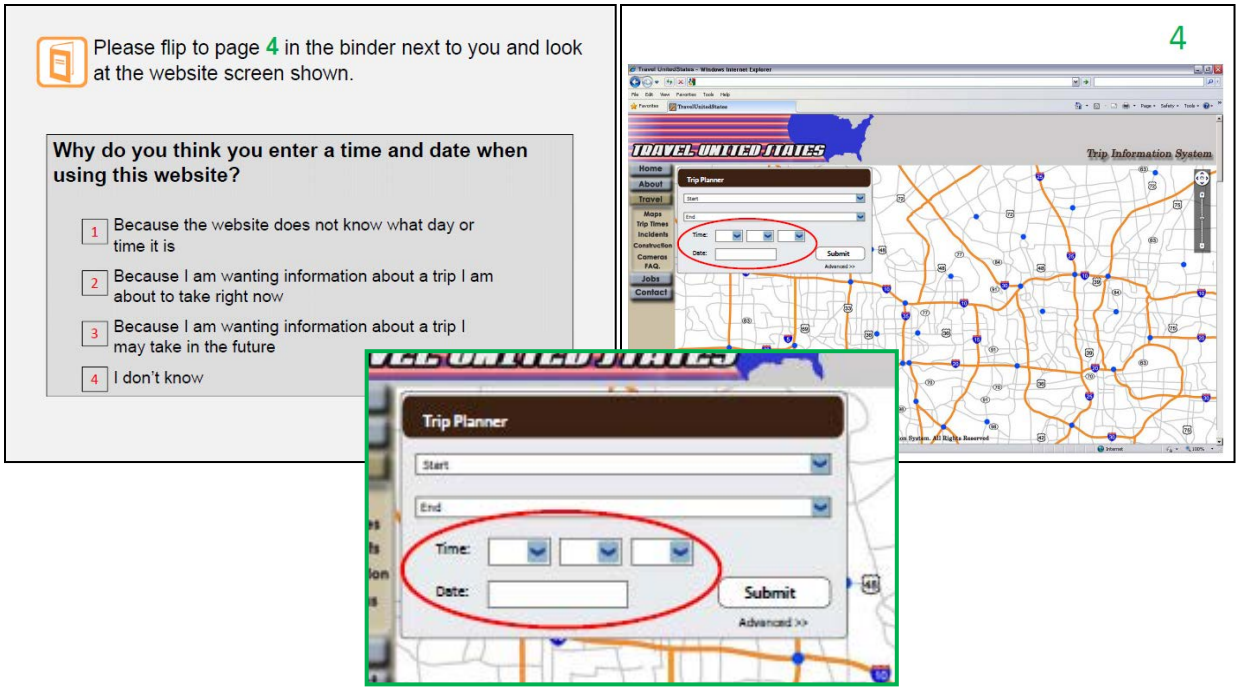


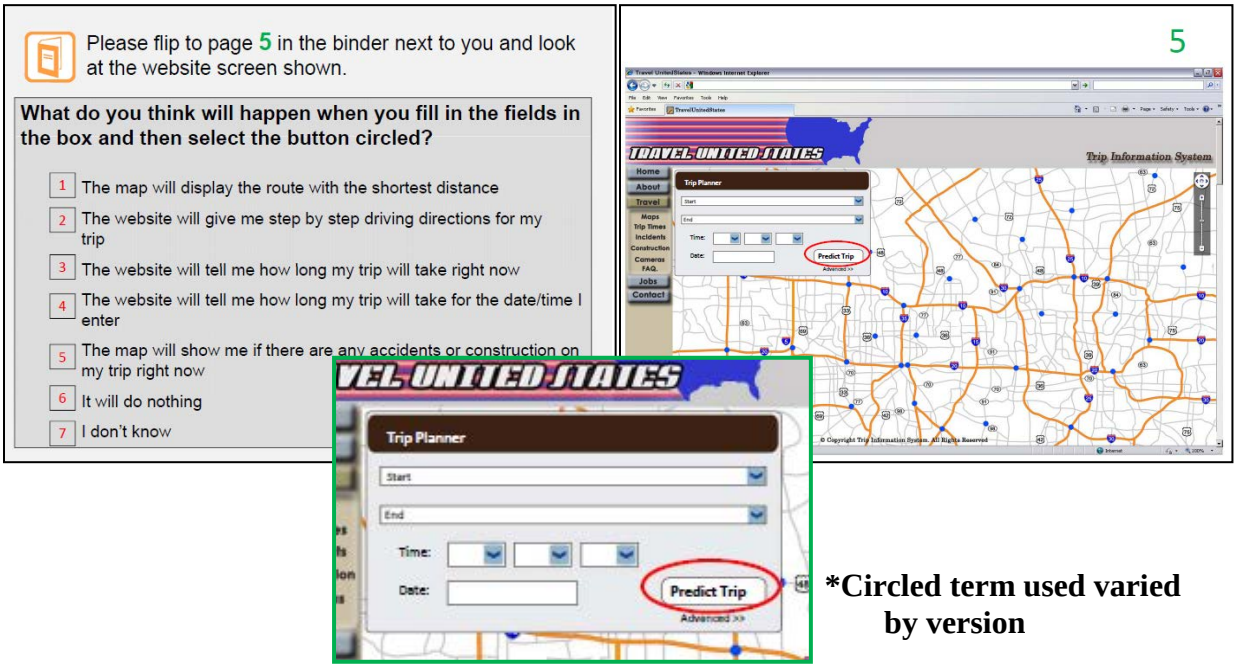
Figure D-6. Question 8 visuals.

Table D-5. Question 8 response summary.

Response Choices	Percent
1. Because the website does not know what day or time it is.	9.00%
2. Because I am wanting information about a trip I am about to take right now.	35.33%
3. Because I am wanting information about a trip I may take in the future.	51.67%
4. I don't know.	4.00%
Total	100.00%

QUESTIONS 9-10: TERMS TO CONVEY IMMEDIACY OF DEPARTURE

Figure D-7 displays the visuals and results for Question 9, Version A; other versions of this question substituted other terms for the circled term *Predict Trip* shown in this figure, as shown in the table. Figure D-8 displays the visuals and results for Question 10.



***Circled term used varied by version**

Figure D-7. Question 9 visuals.

Table D-6. Question 9 response summary.

Response Choices	Version A: Predict Trip	Version B: Plan Trip	Version C: Create Trip	Version D: Get Trip
1. The map will display the route with the shortest distance.	7.89%	4.05%	6.67%	14.86%
2. The website will give me step-by-step driving directions for my trip.	17.11%	27.03%	16.00%	20.27%
3. The website will tell me how long my trip will take right now.	6.58%	8.11%	1.33%	5.41%
4. The website will tell me how long my trip will take for the date/time I enter.	63.16%	56.76%	72.00%	58.11%
5. The website will show me if there are any accidents or construction on my trip right now.	1.32%	1.35%	0.00%	0.00%
6. It will do nothing.	2.63%	1.35%	2.67%	0.00%
7. I don't know.	1.32%	2.70%	1.33%	1.35%

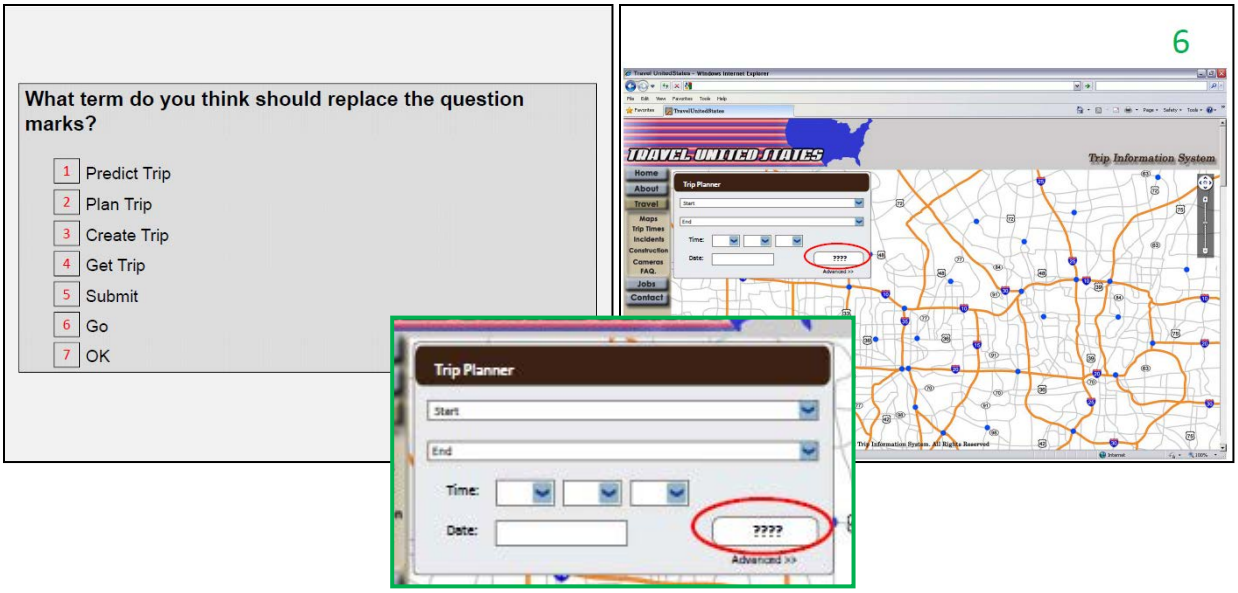


Figure D-8. Question 10 visuals.

Table D-7. Question 10 response summary.

Response Choices	Percentage
1. Predict Trip	28.33%
2. Plan Trip	24.67%
3. Create Trip	14.33%
4. Get Trip	7.00%
5. Submit	17.67%
6. Go	4.33%
7. OK	3.67%
Grand Total	100.00%

QUESTION 11-12: TERMS TO DESCRIBE DEPARTURE AND ARRIVAL TIME CONSTRAINTS

Figure D-9 shows the visuals and responses for Question 11. Figure D-10 shows the visuals and responses for Question 12.

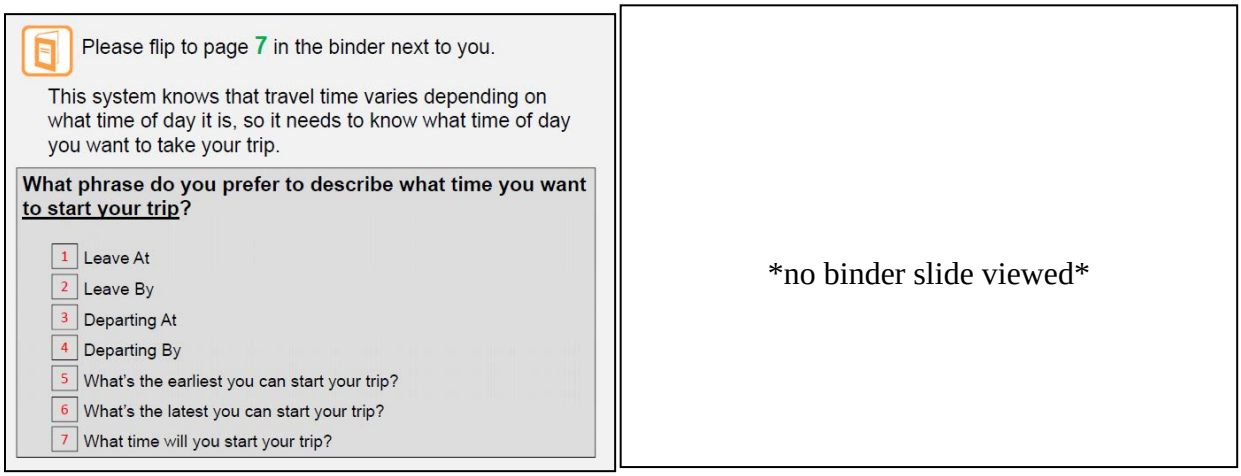


Figure D-9. Question 11 visuals.

Table D-8. Question 11 response summary.

Response Choices	Percentage
1. Leave at	23.33%
2 Leave by	7.00%
3. Departing at	34.67%
4. Departing by	8.00%
5. What's the earliest you can start your trip?	4.33%
6. What's the latest you can start your trip?	1.33%
7. What time will you start your trip?	21.33%
Total	100.00%

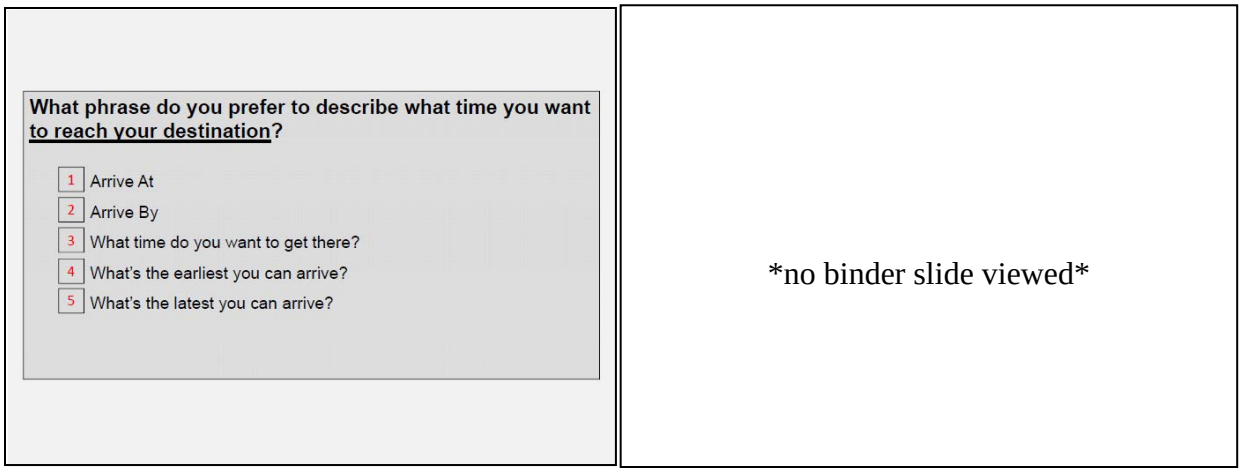


Figure D-10. Question 12 visuals.

Table D-9. Question 12 response summary.

Response Choices	Percentage
1. Arrive at	33.33%
2. Arrive by	47.00%
3. What time do you want to get there?	14.33%
4. What's the earliest you can arrive?	1.67%
5. What's the latest you can arrive?	3.67%
Grand Total	100.00%

QUESTIONS 13-14: MAP AND TRAVEL TIME OUTPUT TERMINOLOGY

Figures D-11 and D-12 display the binder pages presented to participants prior to Question 13. Figure D-13 displays the visuals and results for Question 13. Figure D-14 displays the visuals and results for Question 14.

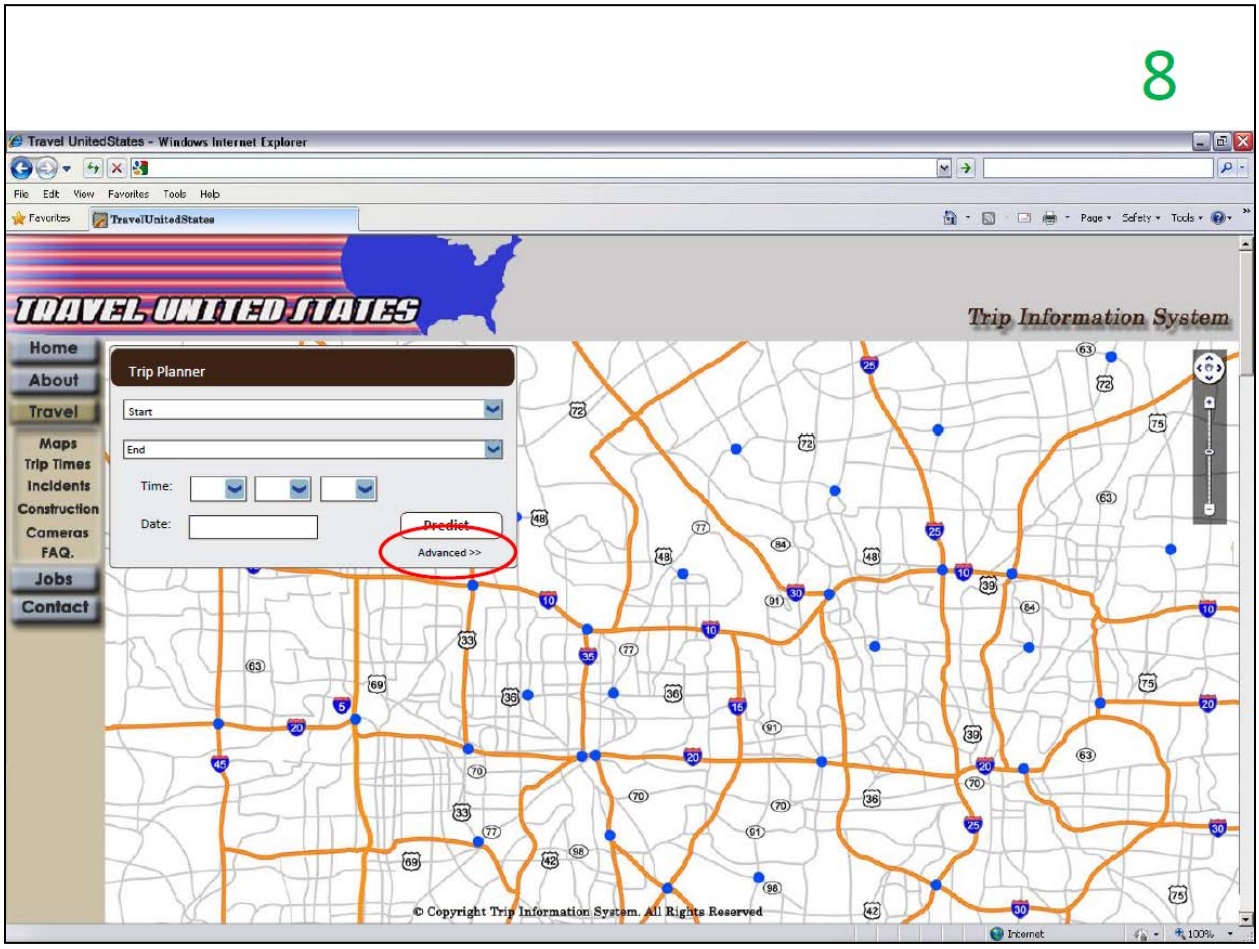


Figure D-11. Webpage binder to introduce map-based output screen.

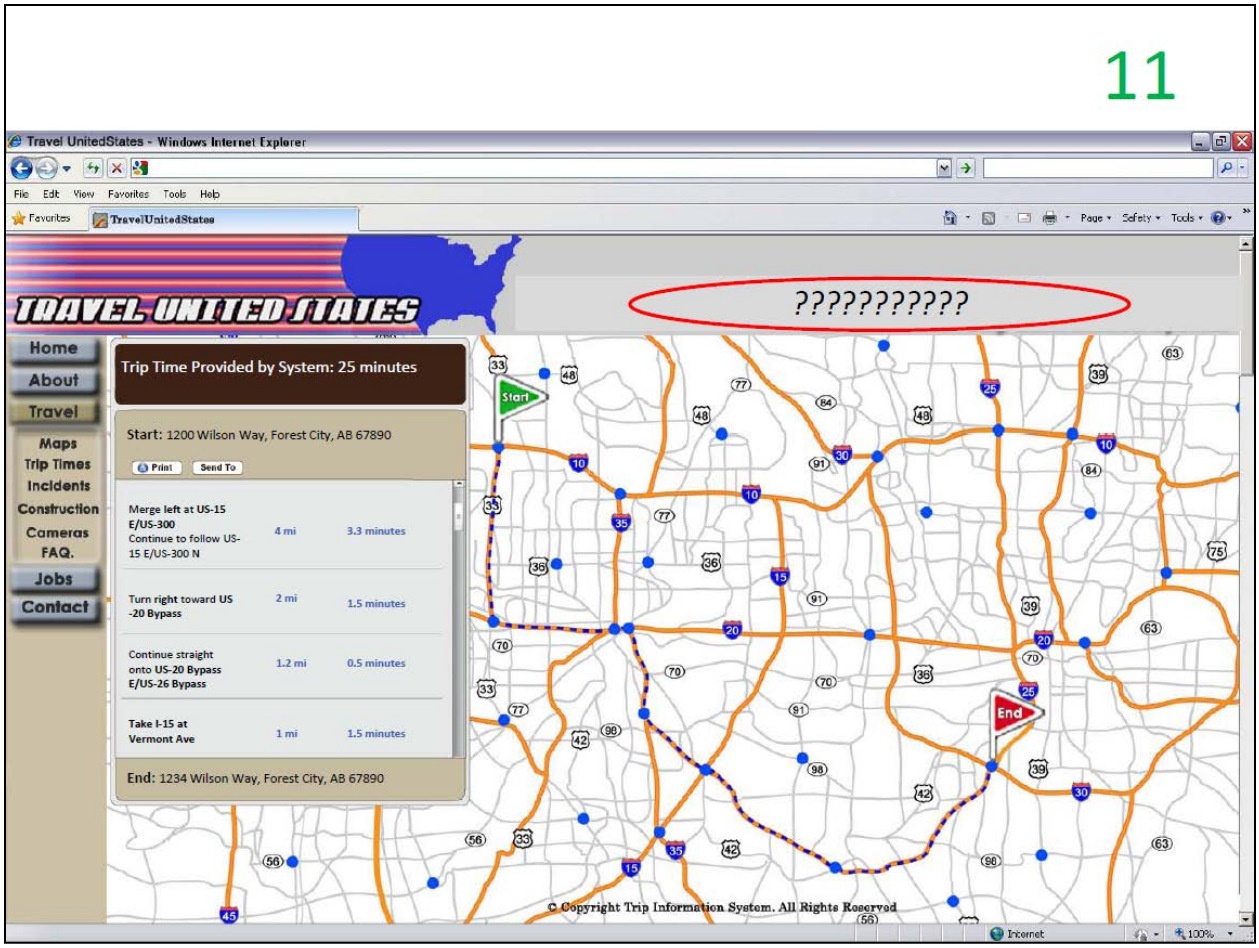


Figure D-12. Map output showing trip route and travel times.

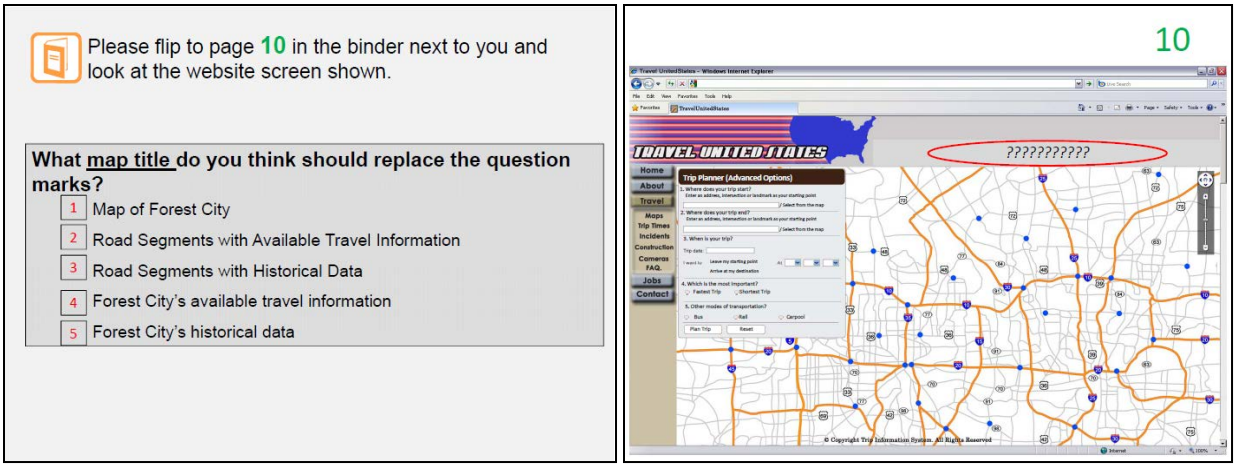


Figure D-13. Question 13 visuals.

Table D-10. Question 13 response summary.

Response Choices	Percentage
1. Map of Forest City	17.67%
2. Road segments with available travel information	32.00%
3. Road segments with historical data	10.67%
4. Forest City's available travel information	33.67%
5. Forest City's historical data	6.00%
Grand Total	100.00%

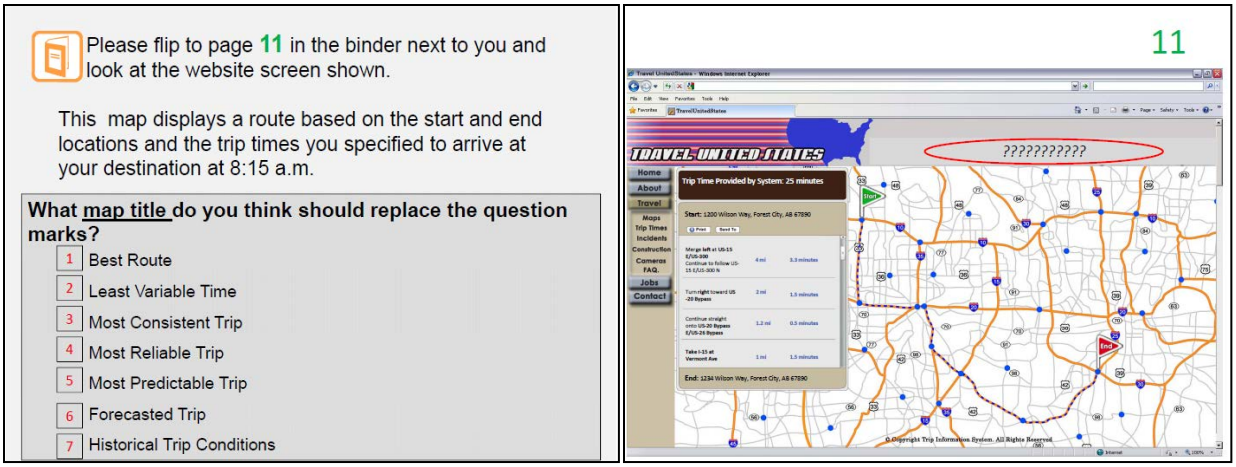


Figure D-14. Question 14 visuals.

Table D-11. Question 14 response summary.

Response Choices	Percentage
1. Best Route	49.00%
2. Least Variable Time	2.00%
3. Most Consistent Trip	6.00%
4. Most Reliable Trip	15.00%
5. Most Predicable Trip	7.33%
6. Forecasted Trip	18.00%
7. Historical Trip Conditions	2.67%
Grand Total	100.00%

QUESTIONS 15-17: TRIP TIME OUTPUT TERMINOLOGY

Figure D-15 displays the visuals for Question 15, Version A. In Versions B through D of the survey, the term *average trip time* was replaced by the terms shown in the table. The table in Figure D-15 also displays the question responses.

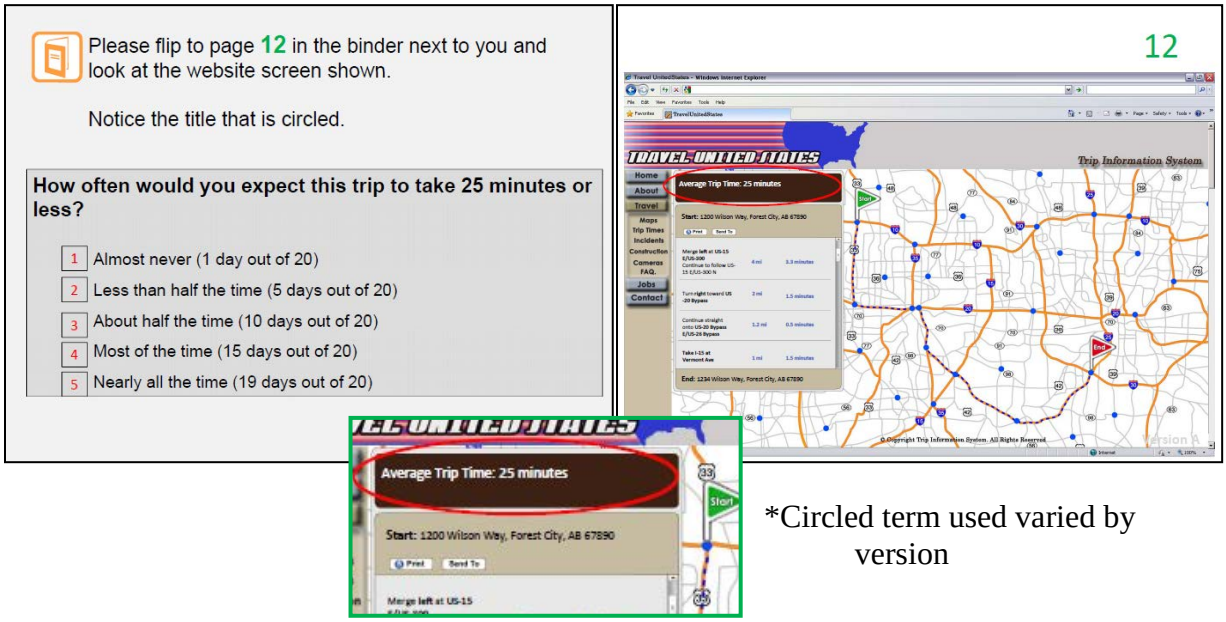
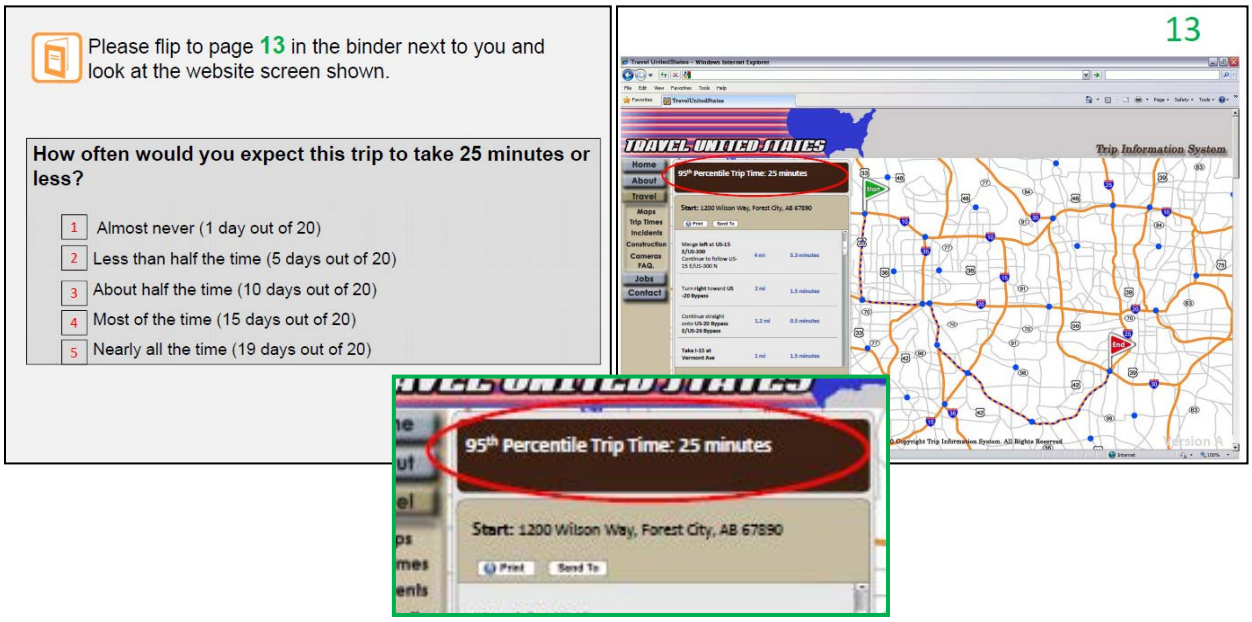


Figure D-15. Question 15 visuals.

Table D-12. Question 15 response summary.

Response Choices	Version A: Average Trip Time	Version B: Typical Trip Time	Version C: Historical Trip Time	Version D: Estimated Trip Time
1. Almost never (1 day out of 20)	11.84%	9.72%	8.00%	8.11%
2. Less than half the time (5 days out of 20)	11.84%	2.78%	12.00%	13.51%
3. About half the time (10 days out of 20)	18.42%	16.67%	14.67%	13.51%
4. Most of the time (15 days out of 20)	38.16%	58.33%	45.33%	48.65%
5. Nearly all the time (19 days out of 20)	19.74%	16.67%	20.00%	16.22%

Figure D-16 displays the visuals for Question 16, Version A. In Versions B through D of the survey, the term *average trip time* was replaced by the terms shown in the table. The table in Figure D-16 also displays the question responses.



***Circled term used varied by version**

Figure D-16. Question 16 visuals.

Table D-13. Question 16 response summary by version.

Response Choices	Version A: 95th Percentile Trip Time	Version B: Worst-Case Trip Time	Version C: Maximum Trip Time	Version D: Most Common Trip Time
1. Almost never (1 day out of 20)	9.21%	16.00%	4.00%	9.46%
2. Less than half the time (5 days out of 20)	10.53%	32.00%	21.33%	13.51%
3. About half the time (10 days out of 20)	15.79%	13.33%	21.33%	17.57%
4. Most of the time (15 days out of 20)	27.63%	17.33%	24.00%	43.24%
5. Nearly all the time (19 days out of 20)	36.84%	21.33%	29.33%	16.22%

Figure D-17 displays the visuals and responses for Question 17.

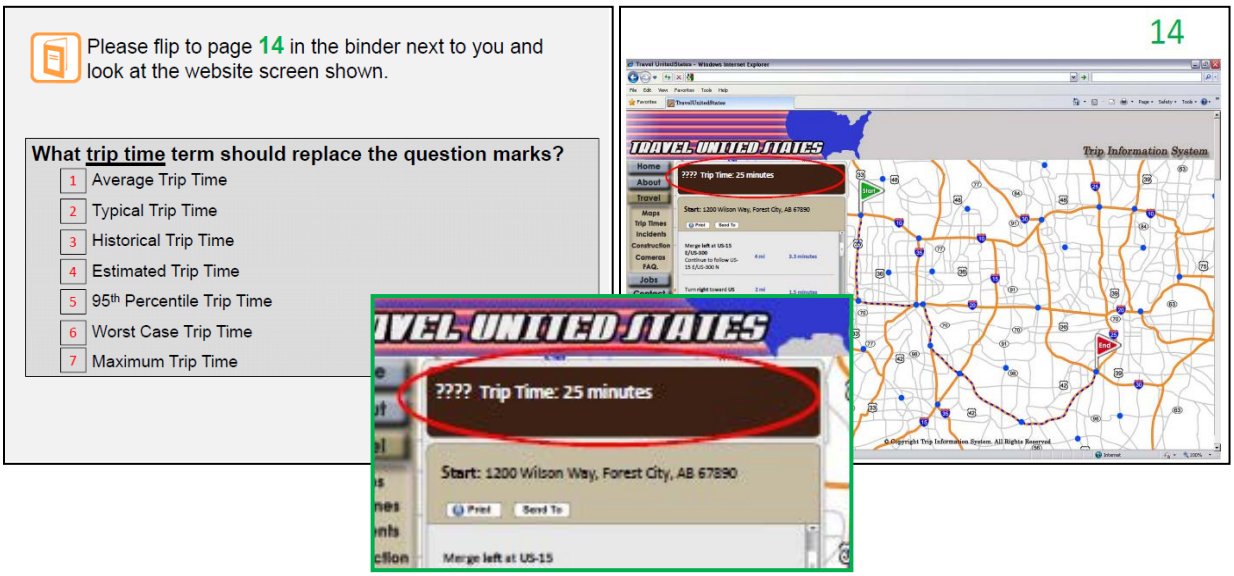


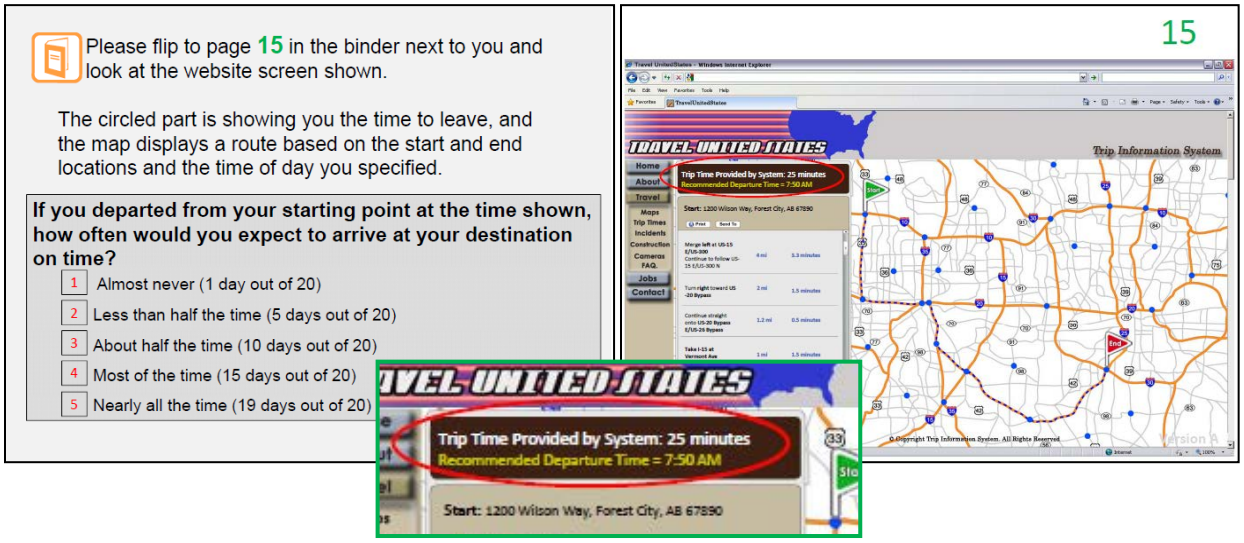
Figure D-17. Question 17 visuals.

Table D-14. Question 17 response summary.

Response Choices	Percentage
1. Average Trip Time	33.00%
2. Typical Trip Time	9.00%
3. Historical Trip Time	4.00%
4. Estimated Trip Time	43.33%
5. 95th Percentile Trip Time	3.00%
6. Worst Case Trip Time	1.67%
7. Maximum Trip Time	6.00%
Grand Total	100.00%

QUESTIONS 18-20: PLANNING AND BUFFER TIME TERMINOLOGY

Figure D-18 displays the visuals for Question 18, Version A. In Versions B through D of the survey, the term *recommended departure time* was replaced by the terms shown in the table. The table in Figure D-18 also displays the question responses.



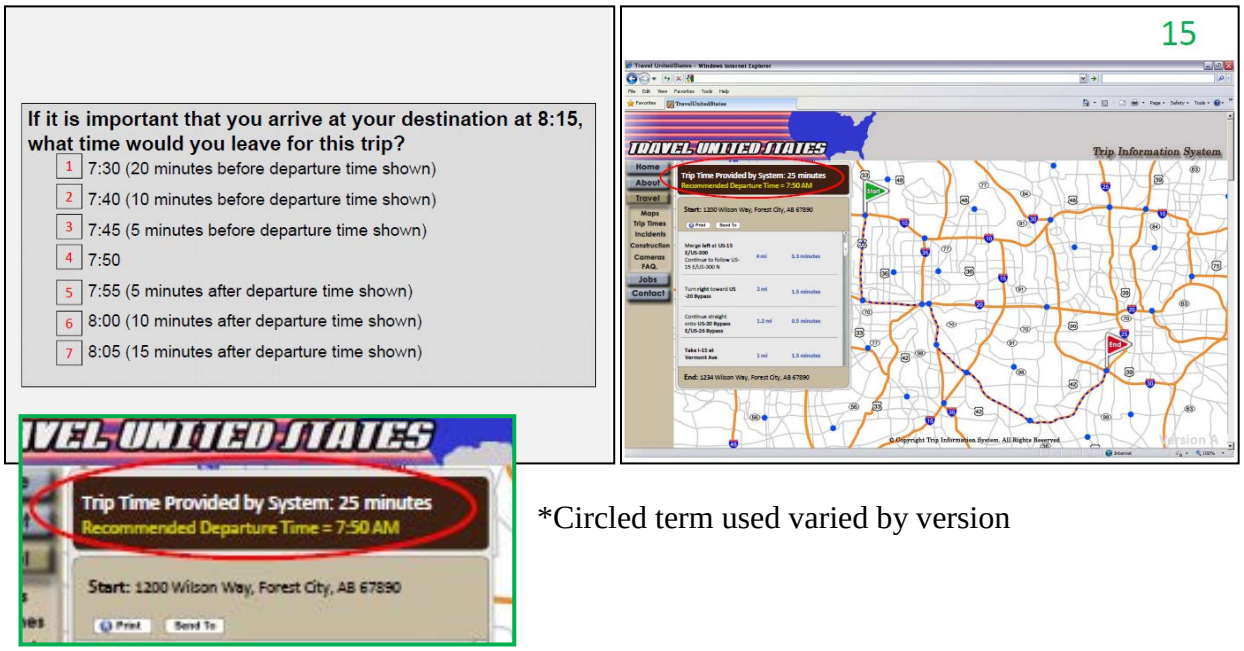
*Circled term used varied by version

Figure D-18. Question 18 visuals.

Table D-15. Question 18 response summary.

Response Choices	Version A: Recommended Departure Time	Version B: Estimated Departure Time	Version C: 95th Percentile Departure Time	Version D: Suggested Departure Time
1. Almost never (1 day out of 20)	2.67%	5.33%	4.00%	1.37%
2. Less than half the time (5 days out of 20)	4.00%	4.00%	2.67%	5.48%
3. About half the time (10 days out of 20)	18.67%	10.67%	13.33%	19.18%
4. Most of the time (15 days out of 20)	58.67%	65.33%	41.33%	52.05%
5. Nearly all the time (19 days out of 20)	17.33%	14.67%	38.67%	23.29%

Figure D-19 displays the visuals for Question 19, Version A. In Versions B through D of the survey, the term *recommended departure time* was replaced by the terms that are shown in the table. The table in Figure D-19 also displays the question responses.



*Circled term used varied by version

Figure D-19. Question 19 visuals.

Table D-16. Question 19 response summary.

Response Choices	Version A: Recommended Departure Time	Version B: Estimated Departure Time	Version C: 95th Percentile Departure Time	Version D: Suggested Departure Time
1. 20 minutes before departure time shown	35.53%	36.00%	29.33%	35.14%
2. 10 minutes before departure time shown	27.63%	34.67%	34.67%	35.14%
3. 5 minutes before departure time shown	14.47%	20.00%	16.00%	18.92%
4. At departure time shown	18.42%	4.00%	17.33%	6.76%
5. 5 minutes after departure time shown	2.63%	1.33%	1.33%	0.00%
6. 10 minutes after departure time shown	0.00%	4.00%	0.00%	2.70%
7. 15 minutes after departure time shown	1.32%	0.00%	1.33%	1.35%

Figure D-20 displays the visuals and responses for Question 20.

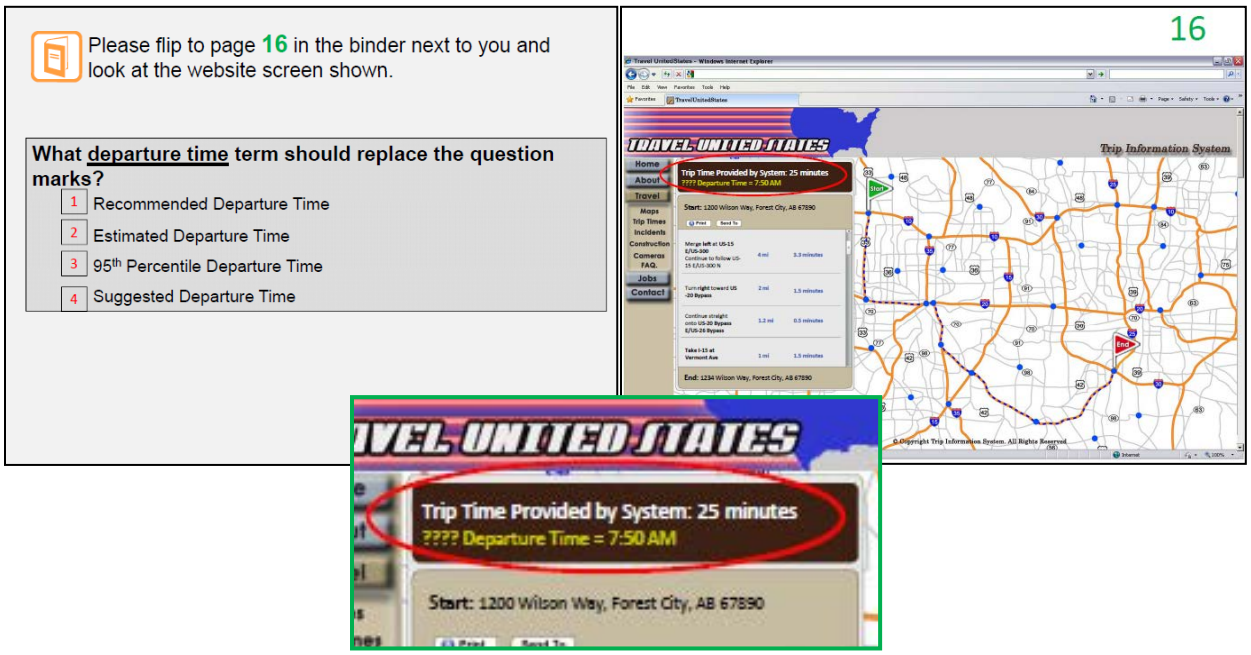


Figure D-20. Question 20 visuals.

Table D-17. Question 20 response summary.

Response Choices	Percentage
1. Recommended Departure Time	47.00%
2. Estimated Departure Time	21.00%
3. 95th Percentile Departure Time	4.33%
4. Suggested Departure Time	27.67%
Grand Total	100.00%

QUESTIONS 21-22: BUFFER TIME TERMINOLOGY

Figure D-21 displays the visuals and responses for Question 21.

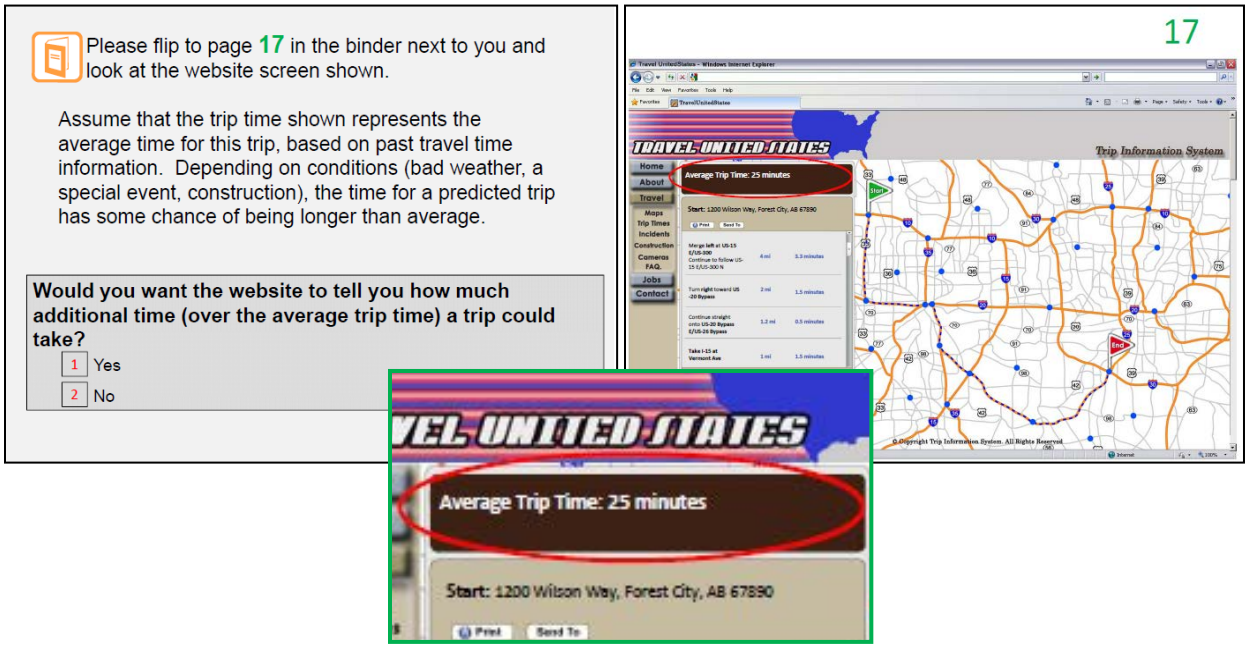


Figure D-21. Question 21 visuals.

Table D-18. Question 21 response summary.

Response Choices	Percentage
1. Yes	88.33%
2. No	11.67%
Grand Total	100.00%

Figure D-22 displays the visuals and responses for Question 22.

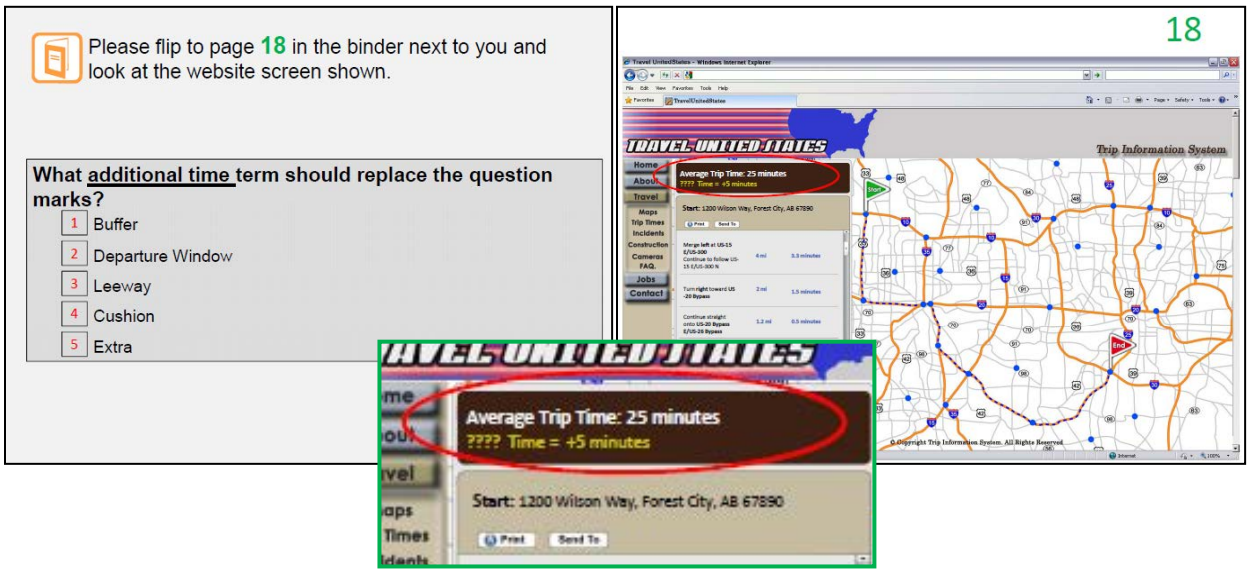


Figure D-22. Question 22 visuals.

Table D-19. Question 22 response summary.

Response Choices	Percentage
1. Buffer	10.33%
2. Departure Window	28.00%
3. Leeway	15.67%
4. Cushion	13.33%
5. Extra	32.67%
Grand Total	100.00%

QUESTION 23: PREFERENCE FOR TRAVEL TIME DISTRIBUTION OUTPUT

Figure D-23 displays the visuals and responses for Question 23.

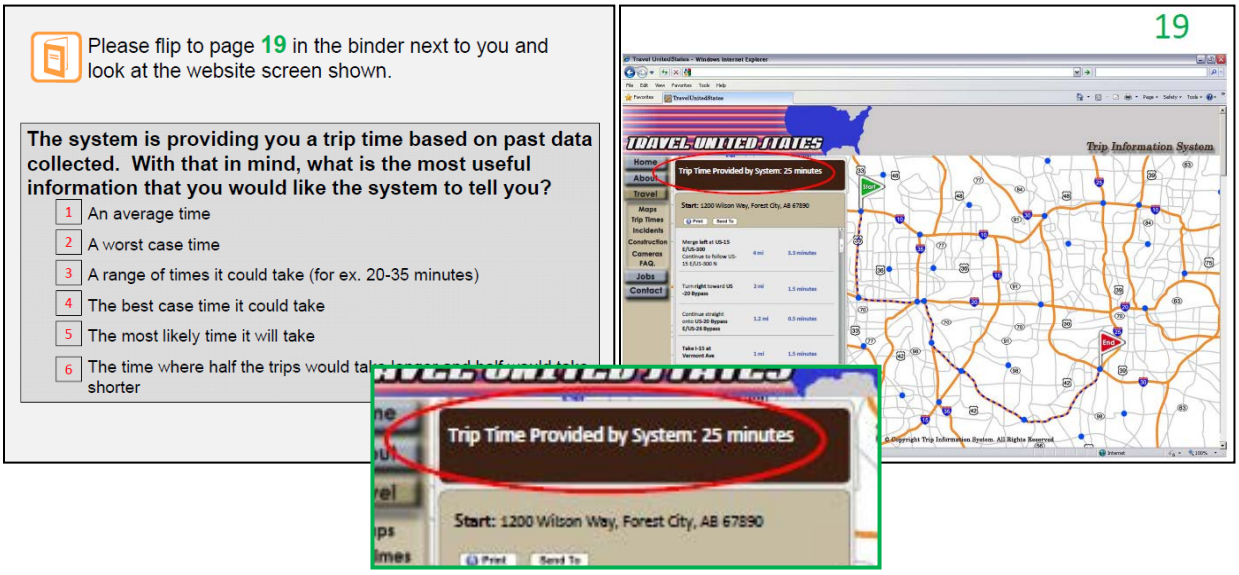


Figure D-23. Question 23 visuals.

Table D-20. Question 23 response summary.

Response Choices	Percentage
1. An average time	30.67%
2. A worst-case time	8.00%
3. A range of times it could take	28.67%
4. The best case time it could take	7.00%
5. The most likely time it will take	24.33%
6. The time where half the trips would take longer and half would take shorter	1.33%
Grand Total	100.00%

QUESTIONS 24-26: TRAVEL TIME VARIABILITY TERMINOLOGY

Figure D-24 displays the visuals and responses for Question 24.

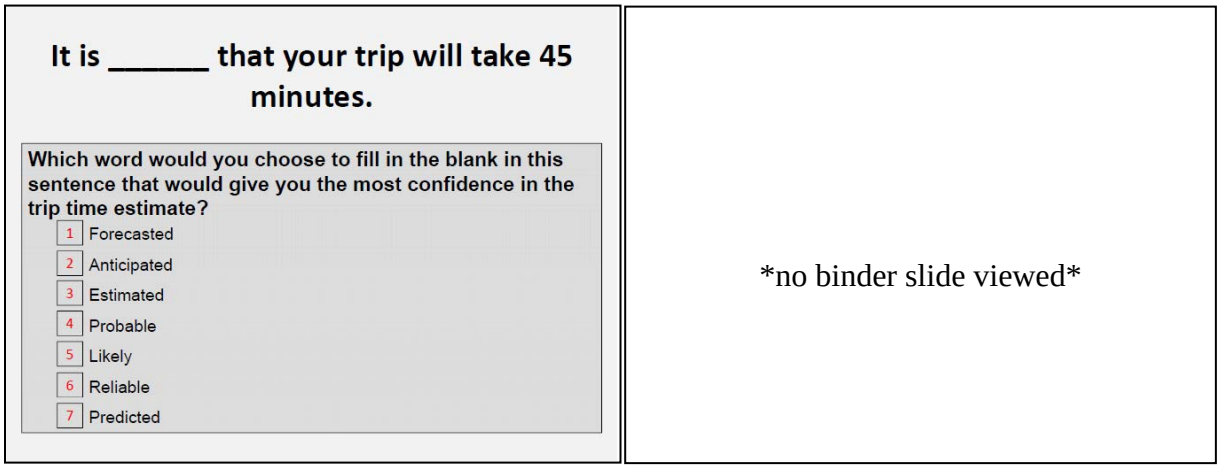


Figure D-24. Question 24 visuals.

Table D-21. Question 24 response summary.

Response Choices	Percentage
1. Forecasted	5.33%
2. Anticipated	7.33%
3. Estimated	56.00%
4. Probable	1.67%
5. Likely	10.67%
6. Reliable	6.00%
7. Predicted	13.00%
Grand Total	100.00%

Figure D-25 displays the visuals and responses for Question 25.

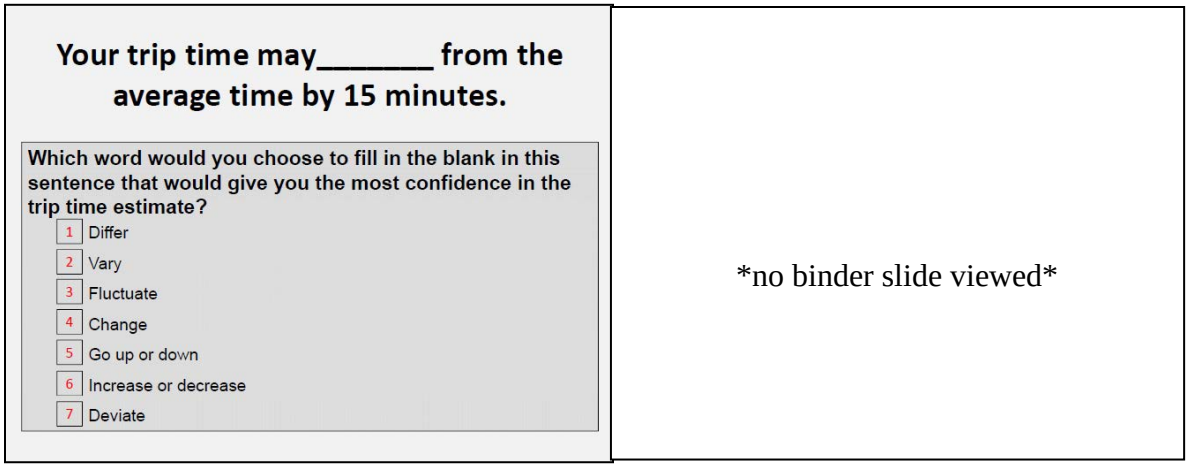


Figure D-25. Question 25 visuals.

Table D-22. Question 25 response summary.

Response Choices	Percentage
1. Differ	7.00%
2. Vary	59.33%
3. Fluctuate	10.67%
4. Change	8.33%
5. Go up or down	0.33%
6. Increase or decrease	6.00%
7. Deviate	8.33%
Grand Total	100.00%

Figure D-26 displays the visuals and responses for Question 26.

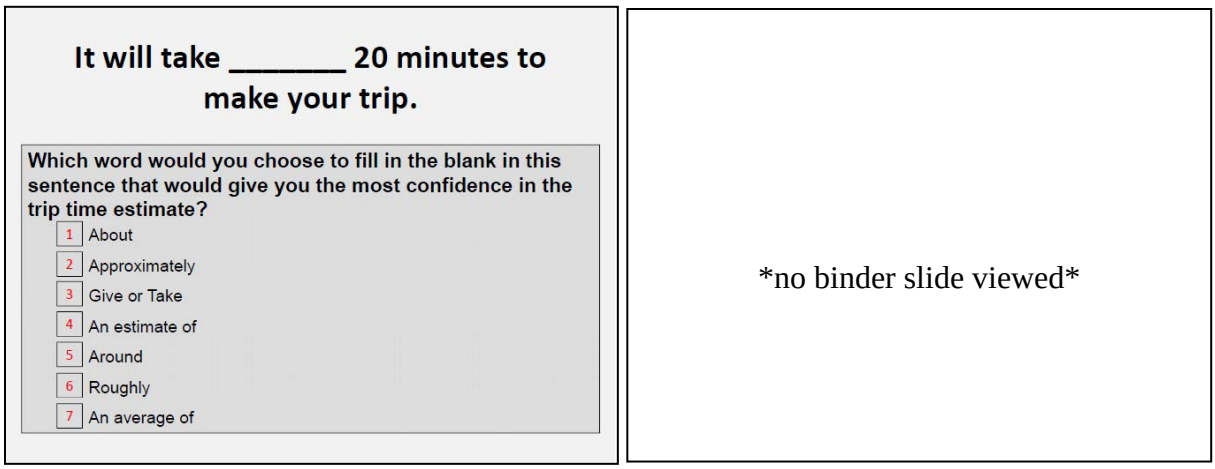


Figure D-26. Question 26 visuals.

Table D-23. Question 26 response summary.

Response Choices	Percentage
1. About	7.33%
2. Approximately	69.00%
3. Give or take	1.33%
4. An estimate of	8.67%
5. Around	1.33%
6. Roughly	2.00%
7. An average of	10.33%
Grand Total	100.00%

QUESTION 27: 95TH PERCENTILE TRIP TIME TERMINOLOGY

Figure D-27 displays the visuals and responses for Question 27.

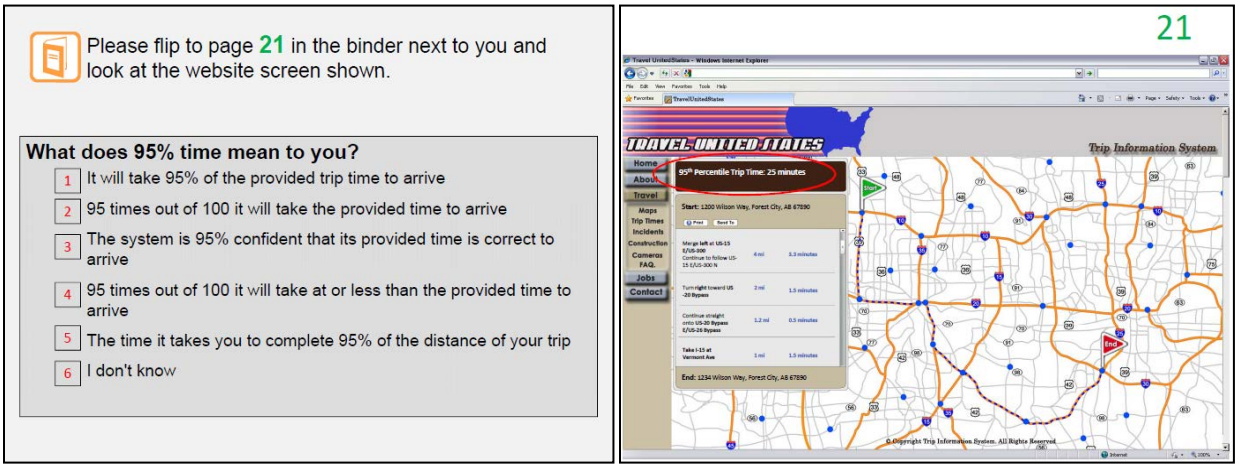


Figure D-27. Question 27 visuals.

Table D-24. Question 27 response summary.

Response Choices	Percentage
1. It will take 95% of the provided trip time to arrive.	6.00%
2. 95 times out of 100 it will take the provided time to arrive.	44.00%
3. The system is 95% confident that its provided time is accurate.	32.33%
4. 95 times out of 100 it will take at or less than the provided time to arrive.	13.67%
5. The time it takes you to complete 95% of the distance of your trip.	1.33%
6. I don't know.	2.67%
Grand Total	100.00%

QUESTION 28: SYSTEM TRUST TERMINOLOGY

Figure D-28 displays the visuals and responses for Question 28.

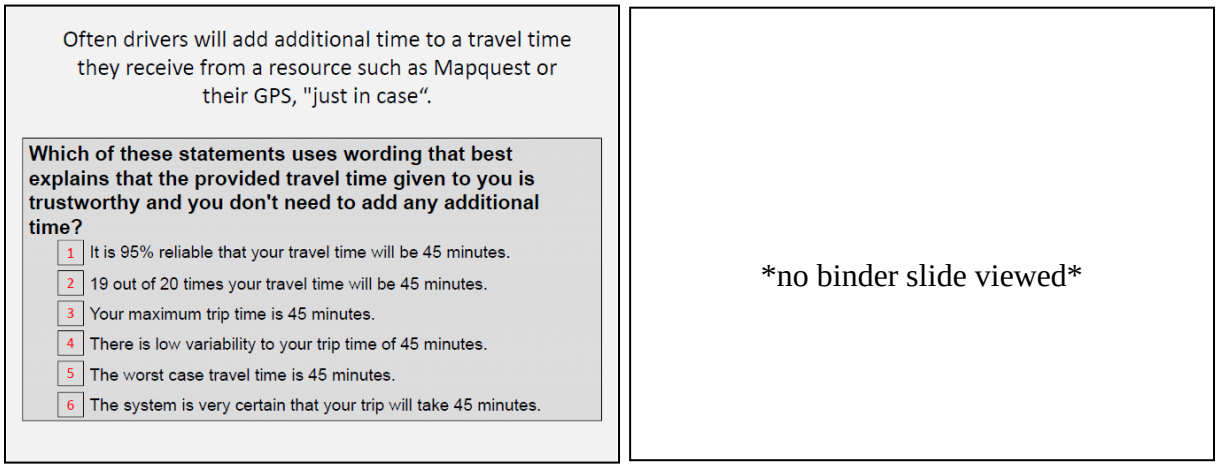


Figure D-28. Question 28 visuals.

Table D-25. Question 28 response summary.

Response Choices	Percentage
1. It is 95% reliable that your travel time will be 45 minutes.	33.67%
2. 19 out of 20 times your travel time will be 45 minutes.	9.00%
3. Your maximum trip time is 45 minutes.	38.33%
4. There is low variability to your trip time of 45 minutes.	3.00%
5. The worst-case travel time is 45 minutes.	6.67%
6. The system is very certain that your trip will take 45 minutes.	9.33%
Grand Total	100.00%

QUESTION 29: TRAVEL MODE SHIFT INFORMATION

Figure D-29 displays the visuals and responses for Question 29.

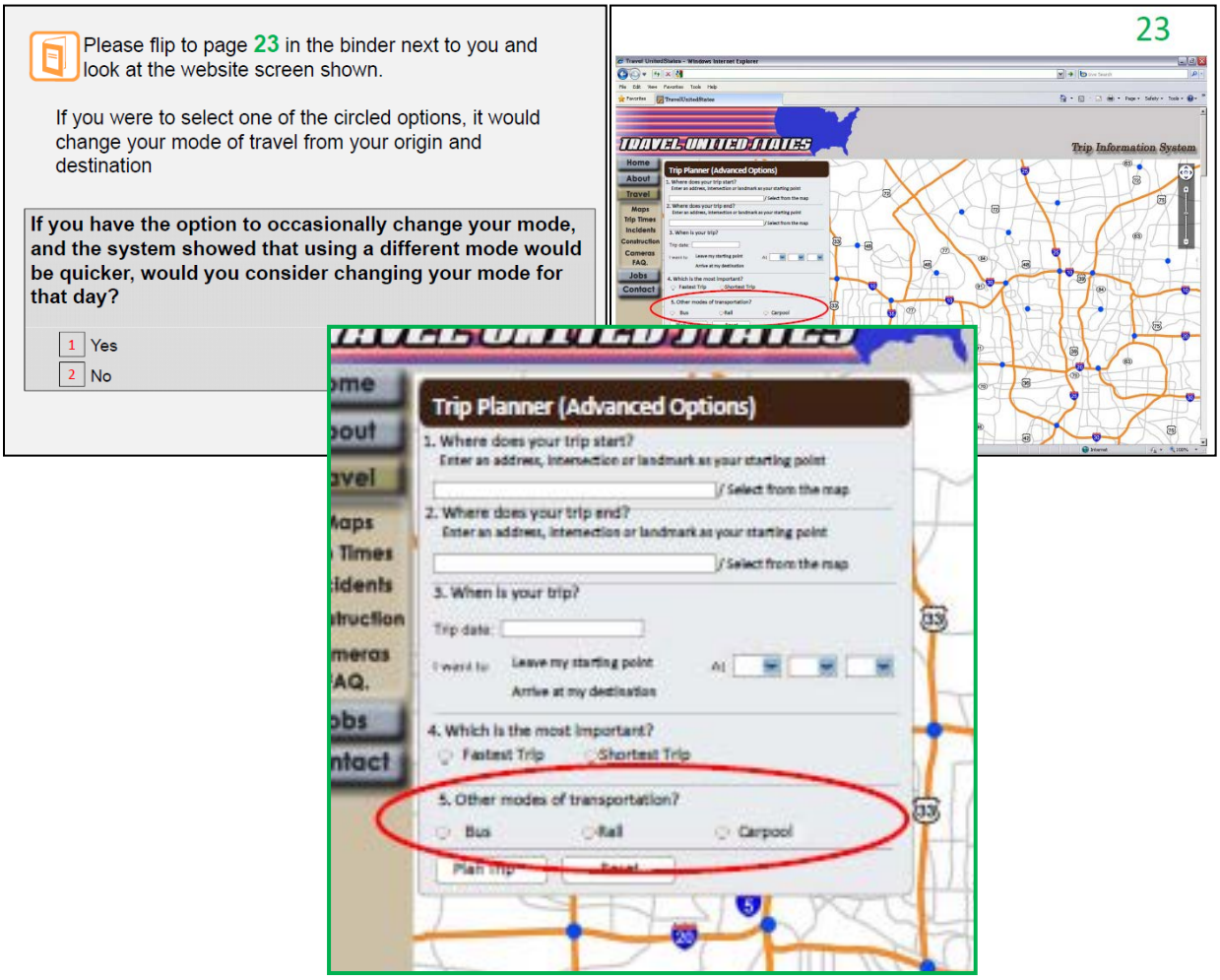


Figure D-29. Question 29 visuals.

Table D-26. Question 29 response summary.

Response Choices	Percentage
1. Yes	76.33%
2. No	23.67%
Grand Total	100.00%

APPENDIX E OPEN-ENDED SURVEY MATERIALS

INTRODUCTION

The open-ended survey materials consisted of: (1) a survey form that was completed by the researcher and included instructions to the researcher for administering the survey, and (2) a set of cards for each survey question that was presented to the survey participant. The scenario cards for Questions 1 and 2 repeated the travel scenario information that the researcher read aloud to the participant, including the two sentences describing travel time parameters. Additional cards for each scenario included:

- A reference card listing five confidence levels.
- A total of six cards providing three alternate terms for each of the two travel time parameters in the scenario.

The survey and cards were created in 16 different versions in order to present different combinations of the travel time reliability terms to the participant pool. Each participant saw only one version of the survey. This appendix contains Version A of the survey, followed by the corresponding cards.

SURVEY FORM AND QUESTIONS

Date: _____ City:_____ Subject #: _____ Survey: A

Study Type: ❑ Survey ❑ Experiment Occupation: _____

Question 1 objective: Determine whether motorists understand an (average, expected, typical, estimated) travel time term and a (cushion, added, extra) time term when presented together, and understand that they can be added together to come up with an arrival-time-constrained travel time.

1. *(Show participant Survey A Question 1 card.)* Imagine that you are in a hotel in an unfamiliar city and have an important business meeting first thing this morning at a downtown office building. You will need to leave the hotel during the peak period in order to arrive at the business meeting. You are trying to decide how much travel time to allow for your drive to downtown. You cannot be late to the meeting, but you do not want to arrive too early. You know that you can park right next to the building and do not need to allow additional time to search for parking. You also know that you can get current travel time information from the hotel website. Before you drive to your downtown meeting, you check the website and obtain the following information …

   The *average* travel time to downtown is 40 minutes

   and

   the *cushion* time to downtown is 30 minutes.

Questions 1a and 1b objective: Determine if motorists will use both the terms above to estimate how much time to allow for a trip. Emphasis should be on determining if they considered the (cushion, added, extra) time at all in their travel time estimate. So, if they use less than 70 minutes or more than 70 minutes, make sure to get them to explain what they added together and why.

a) How much time would you allow for your drive to downtown? _____

_____

b) How did you decide on that time? _____

_____

Question 1c objective: Determine if motorists understand that their time may be longer or shorter than what is shown (average, expected, typical, estimated). Facilitator should make sure responses indicate the participants' opinions about whether their particular travel time is likely to be much longer or shorter than this value.

c) What does the ***average*** travel time mean to you about how long your drive will take?

_____

_____

Question 1d objective: Determine if motorists understand that the (cushion, added, extra) time represents the additional time it may take if traffic problems or other factors occur that make their trip take longer than normal. Facilitator might need to rephrase the question as "why would an agency try to provide this time to drivers?"

d) What does the ***cushion*** time mean to you about how long your drive will take?

_____

_____

Question 1e objective: Determine what probability of a successful arrival (prior to the meeting time) drivers would associate with the two terms.

e) *(Show participant the card with the scale below on it.)* If you combined the *average* travel time and *cushion* time together (70 minutes), how likely are you to reach downtown in 70 minutes or less?

- ❑ Absolutely certain (100% chance)
- ❑ Very likely (95% chance)
- ❑ Probably (75% chance)
- ❑ Unsure (50/50 chance)
- ❑ Doubtful (less than 50/50 chance)

Why did you select this as your answer? _____

_____

_____

Question 1f objective: Determine if small cushions are not likely to be as useful or believed by motorists. Facilitator should make sure the response indicates what, if anything, they do with the 10 minute (cushion, added, extra) time when they make their decision.

f) If the *cushion* time had been 10 minutes, how much time would you have allowed for your drive? Why?

_____

_____

Question 1g objectives: Determine whether motorists perceive (cushion, recommended cushion, added, and extra) time to mean the same thing or not, and if different, how are they different. Facilitator should make sure to determine this for all terms, not just compared to term given in scenario above. Facilitator will also obtain the participant's term preference and opinion regarding a better term to use.

g) *(Show participant Survey A Card Set #1.)* Which of these terms means the same thing as the *cushion* time (*check all that apply*)?

❑ Recommended cushion ❑ Added ❑ Extra ❑ None of them

For those terms not selected, why are these terms different than the <u>*cushion*</u> time? *If more than one term is not selected, make sure to also determine if those terms have the same or different meaning.*

_____

_____

Which term do you like the best and why?_____

_____

_____

Can you think of a better term to use? _____

Question 2 objective: Determine whether motorists understand an (average, expected, typical, estimated) travel time term and a (95th percentile, travel time for planning, most of the time less than, majority of the time less than) travel time term when presented together, and understand that the reliability term indicates a recommended travel time to plan for in an arrival-time-constrained situation.

2. *(Show participant Survey A Question 2 card.)* Imagine that you are again in a hotel in another unfamiliar city and have an important business meeting this morning at a downtown office building. As before, you will need to leave the hotel during the peak period in order to arrive at the business meeting. You are trying to decide how much travel time to allow for your drive to downtown. You cannot be late to the meeting, but you do not want to arrive too early. You know that you can park right next to the building and do not need to allow additional time to search for parking. You also know that you can get current travel time information from the hotel website. Before you drive to your downtown meeting, you check the website and obtain the following information …

   The <u>*expected*</u> travel time to downtown is 30 minutes

   and

   the <u>*95th percentile travel time*</u> to downtown is 55 minutes.

Questions 2a and 2b objective: Determine if motorists will use the longer travel time for planning purposes, or if they simply add their own number to the (average, expected, typical, estimated) value.

a) How much time would you allow for your drive to downtown? _____

_____

b) How did you decide on that time? _____

_____

Question 2c objective: Determine if motorists understand that their time may be longer or shorter than what is shown (average, expected, typical, estimated). Facilitator should make sure responses indicate the participants' opinions about whether their particular travel time is likely to be much longer or shorter than this value.

c) What does the *expected* travel time mean to you about how long your drive will take?

_____

_____

Question 2d objective: Determine if motorists understand that the (95th percentile, travel time for planning, most of the time less than, majority of the time less than) represents the worst-case situation, and that most travel times to downtown do not take this long. Facilitator might need to rephrase the question as "why would an agency try to provide this time to drivers?"

d) What does the statement "the *95th percentile travel time* to downtown is 55 minutes" mean to you about how long your drive will take?

_____

_____

Question 2e objective: Determine what probability of a successful arrival (prior to the meeting time) drivers would associate with these terms.

e) (*Show participant the card with the scale below on it.*) Given the statement "*the 95th percentile travel time to downtown is 55 minutes,*" how likely are you to reach downtown in less than 55 minutes?

- ❑ Absolutely certain (100% chance)
- ❑ Very likely (95% chance)
- ❑ Probably (75% chance)
- ❑ Unsure (50/50 chance)
- ❑ Doubtful (less than 50/50 chance)

Why did you select this as your answer? _____

_____

_____

Question 2f objective: Determine if a smaller difference between the (average, expected, typical, estimated) and the (95th percentile travel time, travel time for planning, most of the time less than, majority of the time less than) is less likely to be useful or believed by motorists. Facilitator should make sure the response indicates what, if anything, they do with the smaller time value provided when they make their decision.

f) If the statement had been "*the 95th percentile travel time to downtown is 45 minutes,*" how much time would you have allowed for your drive? Why?

_____

_____

Question 2g objectives: Determine whether motorists perceive (average, expected, typical, estimated) time to mean the same thing or not, and if different, how are they different. Facilitator should make sure to determine this for all terms, not just compared to term given in scenario above. Facilitator will also obtain the participant's term preference and opinion regarding a better term to use.

g) *(Show participant Survey A Card Set #2.)* Which of these terms means the same thing as the *expected* travel time (*check all that apply*)?

❑ Average ❑ Typical ❑ Estimated ❑ None of them

For those terms not selected, why are these terms different than the *expected* travel time? *If more than one term is not selected, make sure to also determine if those terms have the same or different meaning.*

_____

_____

Which term do you like the best and why?_____

_____

_____

Can you think of a better term to use? _____

Question 2h objectives: Determine whether motorists perceive the (95th percentile travel time, travel time for planning, most of the time less than, majority of the time less than) to mean the same thing or not, and if different, how are they different. Facilitator should make sure to determine this for all terms, not just compared to term given in scenario above. Facilitator will also obtain the participant's term preference and opinion regarding a better term to use.

h) *(Show participant Survey A Card Set #3.)* Which of these terms means the same thing as the *95th percentile travel time is 55 minutes* (*check all that apply*)?

- ❑ The travel time for planning to downtown is 55 minutes or less.
- ❑ Most of the time the travel time to downtown is 55 minutes or less.
- ❑ The majority of the time the travel time to downtown is 55 minutes or less.
- ❑ None of them.

For those terms not selected, why are these statements different than the *95th percentile travel time is 55 minutes*? *If more than one term is not selected, make sure to also determine if those terms have the same or different meaning.*

_____

_____

Which term do you like the best and why?_____

_____

_____

Can you think of a better term to use? _____

3. In the first example, you preferred *(insert term selected as best in question 1g)*, and for the second example, you preferred *(insert term selected as best in question 2h)*. Which of these two terms do you prefer for indicating the amount of uncertainty in travel time for your trip downtown? Why do you prefer this term?

_____

_____

Do you have any other comments?

_____

_____

CARDS FOR QUESTION 1, SURVEY VERSION A

Scenario Card

Question 1

Imagine that you are in a hotel in an unfamiliar city and have an important business meeting first thing this morning at a downtown office building. You will need to leave the hotel during the peak period in order to arrive at the business meeting. You are trying to decide how much travel time to allow for your drive to downtown. You cannot be late to the meeting, but you do not want to arrive too early. You know that you can park right next to the building and do not need to allow additional time to search for parking. You also know that you can get current travel time information from the hotel website. Before you drive to your downtown meeting, you check the website and obtain the following information…

The average travel time to downtown is 40 minutes

and

the cushion time to downtown is 30 minutes.

Reference Card Left Visible to Participant as Memory Aid for Confidence Ratings

Absolutely certain (100% chance)
Very likely (95% chance)
Probably (75% chance)
Unsure (50/50 chance)
Doubtful (less than 50/50 chance)

Alternate Terms Card Set 1

The <u>cushion</u> time to downtown is __ minutes.
The <u>added</u> time to downtown is __ minutes.
The <u>extra</u> time to downtown is __ minutes.
The <u>recommended cushion</u> time to downtown is __ minutes.

Alternate Terms Card Set 2

The <u>average</u> travel time to downtown is __ minutes.
The <u>typical</u> travel time to downtown is __ minutes.
The <u>expected</u> travel time to downtown is __ minutes.
The <u>estimated</u> travel time to downtown is __ minutes.

CARDS FOR QUESTION 2, SURVEY VERSION A

Scenario Card

Question 2

Imagine that you are again in a hotel in another unfamiliar city and have an important business meeting this morning at a downtown office building. As before, you will need to leave the hotel during the peak period in order to arrive at the business meeting. You are trying to decide how much travel time to allow for your drive to downtown. You cannot be late to the meeting, but you do not want to arrive too early. You know that you can park right next to the building and do not need to allow additional time to search for parking. You also know that you can get current travel time information from the hotel website. Before you drive to your downtown meeting, you check the website and obtain the following information …

The expected travel time to downtown is 30 minutes

and

the 95th percentile travel time to downtown is 55 minutes.

Reference Card Left Visible to Participant as Memory Aid for Confidence Ratings

Absolutely certain (100% chance)
Very likely (95% chance)
Probably (75% chance)
Unsure (50/50 chance)
Doubtful (less than 50/50 chance)

Alternate Terms Card Set

The 95th percentile travel time to downtown is __ minutes.
The travel time for planning to downtown is __ minutes or less.
Most of the time the travel time to downtown is __ minutes or less.
The majority of the time the travel time to downtown is __ minutes or less.

APPENDIX F TRAVEL BEHAVIOR LABORATORY EXPERIMENT DOCUMENTATION

PRE- AND POST-EXPERIMENT SURVEY QUESTION AND RESPONSE CATEGORIES

	Pre-Experiment Survey Questions
1.	Please select your gender and age range.
2.	Please select your highest level of education.
3.	How frequently do you make the following types of trips?
4.	What types of roads do you use when you drive to the following destinations?
5.	For the following types of trips, how important is it for you to arrive at a specific time?
6.	On average, how much time do the following trips take for you to complete by car?
7.	On a bad day, **how much more time** do the following trips take for your to compete by car?
8.	For the following types of trips, what would you consider as arriving late?
9.	Say you could be guaranteed a travel time before you make your trip. How much would you pay for this guarantee when making the following types of trips?
10.	Say you could be informed during the beginning of your trip that you will arrive late. How much would you pay for this information when making the following types of trips?
	Post-Experiment Survey Questions
1.	Which of the following objectives was most important in your departure time decisions at the beginning and at the end of the experiment?
2.	How useful was traffic information at the beginning of the experiment and at the end of the experiment?
3.	When making work trips in the real world, how often do you seek out traffic information?
4.	when making work trips in the real world, which of the following sources do you use to get traffic information?

1a. Gender		1b. Age
(drop down menu)		(drop down menu)
female		18-29
male		30-39
		40-49
		50-59
		60-69
		70-79
		80+

2. Education
(drop down menu)
no high school diploma
high school diploma
some college
Bachelor's degree
graduate degree

3. Frequency of Trips by trip type (matrix)		
trip types		frequency options (radio button)
to work		never
to school/college		less than once a month
to childcare pick-up		1-3 times a month
to medical appointments		once a week
to non-work meetings*		2-4 times a week
		5 or more times a week
*meeting for social, hobby, or religious activities		

#Questions 4-10 exclude trip type categories with frequency response of "never" in Question 3.

4. Type of roads used by trip destination (matrix)#		
trip types		road options (drop-down menu)
to work		mostly highways
to school/college		highways and signalized roads
to childcare pick-up		signalized and neighborhood roads
to medical appointments		mostly neighborhood roads
to non-work meetings*		transit
		other means of travel

5. Importance of arriving at a specific time#		
trip types		level of importance (radio buttons)
to work		not important
to school/college		*-intermediate without caption-*
to childcare pick-up		somewhat important
to medical appointments		*-intermediate without caption-*
to non-work meetings*		very important

6. Average time to destination when driving in car	
Trip Destinations	**time range options (drop down menu)**
to work	0 - 9 minutes
to school/college	10 - 19 minutes
to childcare pick-up	20 - 29 minutes
to medical appointments	30 - 39 minutes
to non-work meetings*	40 - 49 minutes
	50 - 59 minutes
	1 hour or more
	trip not made by car

7. Additional time to destination on a "bad day"	
Trip Destinations	**time range options (drop down menu)**
to work	0 - 9 minutes
to school/college	10 - 19 minutes
to childcare pick-up	20 - 29 minutes
to medical appointments	30 - 39 minutes
to non-work meetings*	40 - 49 minutes
	50 - 59 minutes
	1 hour or more
	trip not made by car

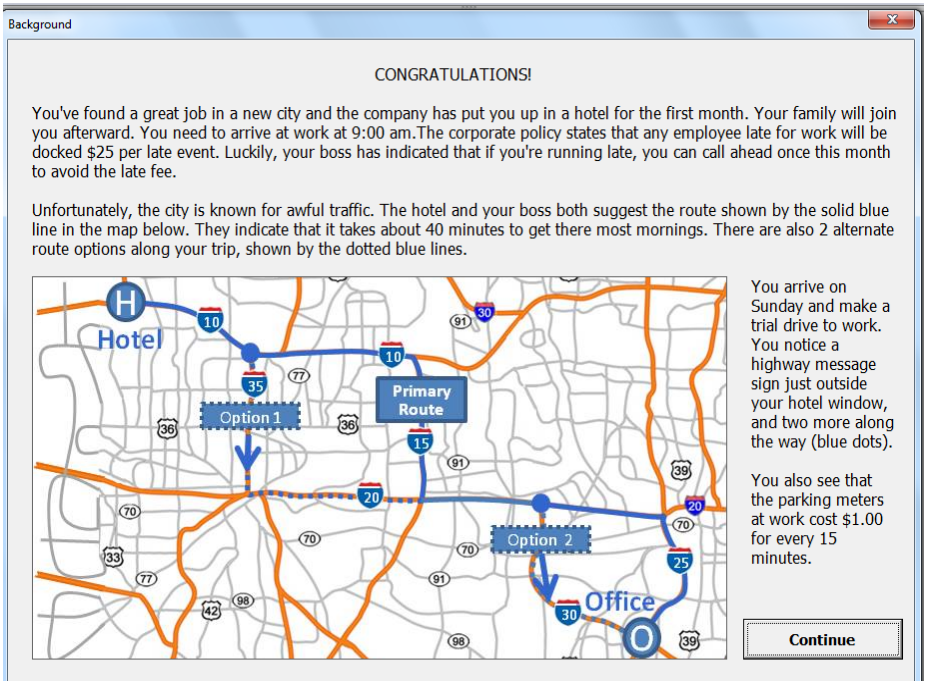
8. How many minutes beyond planned arrival time is considered late	
Trip Destinations	**time range options (drop down menu)**
to work	1 minute
to school/college	2-4 minutes
to childcare pick-up	5-9 minutes
to medical appointments	10 - 14 minutes
to non-work meetings*	15 - 19 minutes
	20 - 24 minutes
	25-29 minutes
	30 or more minutes

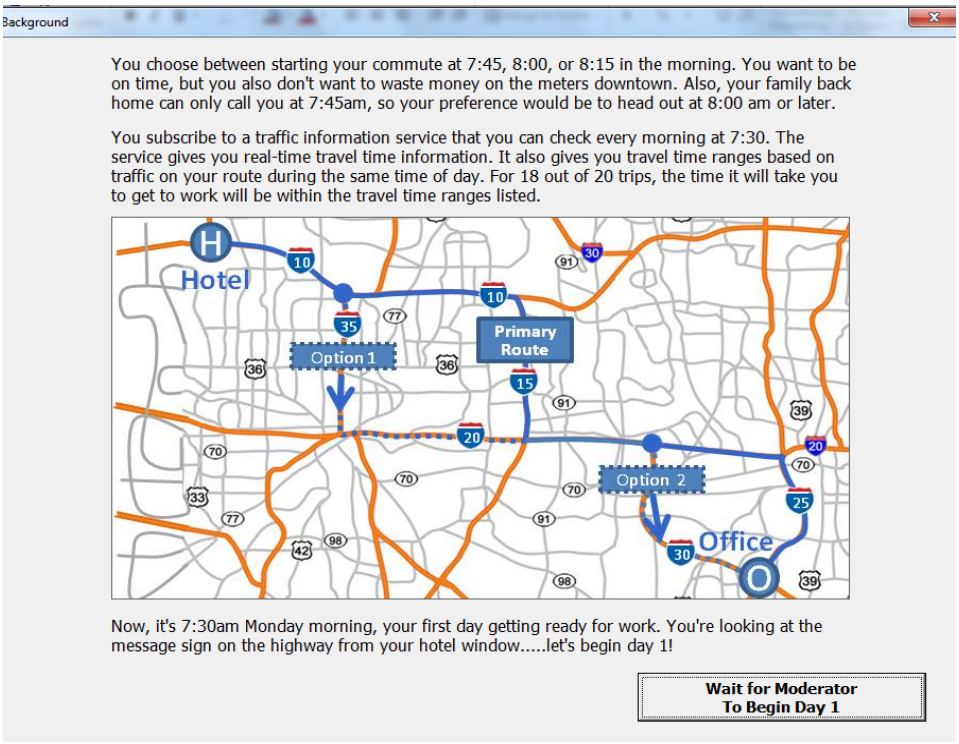
9. Willingness to pay (WTP) for guaranteed travel time	
Trip Destinations	**WTP options (drop down menu)**
to work	$0.00
to school/college	$0.50
to childcare pick-up	$1.00
to medical appointments	$1.50
to non-work meetings*	$2.00
	$3.00
	$4.00
	$5.00

10. Willingness to pay (WTP) for late arrival information	
Trip Destinations	**WTP options (drop down menu)**
to work	$0.00
to school/college	$0.50
to childcare pick-up	$1.00
to medical appointments	$1.50
to non-work meetings*	$2.00
	$3.00
	$4.00
	$5.00

1a. Most important objective at beginning of trip	
code value	level of usefulness
0	n/a
1	calling family
2	reducing parking fee
3	avoiding late arrival
4	arriving exactly on-time
1b. Most important objective at end of trip	
code value	level of usefulness
0	n/a
1	calling family
2	reducing parking fee
3	avoiding late arrival
4	arriving exactly on-time
2a. Usefulness of traveler information at beginning of experiment	
code value	level of usefulness
1	not useful
2	*-intermediate without caption-*
3	somewhat useful
4	*-intermediate without caption-*
5	very useful
2b. Usefulness of traveler information at end of experiment	
code value	level of usefulness
1	not useful
2	*-intermediate without caption-*
3	somewhat useful
4	*-intermediate without caption-*
5	very useful
3. How often do you seek traveler information	
code value	level of usefulness
0	Never
1	less than once a week
2	once a week
3	twice a week
4	three times a week
5	four times a week
6	five times a week
4. Types of media used to seek traveler information (all that apply)	
code value	level of usefulness
0=-no, 1 = yes	radio
0=-no, 1 = yes	television
0=-no, 1 = yes	computer
0=-no, 1 = yes	hand-held or dasboard devices

SIMULATION EXPERIMENT NARRATIVE SCREENSHOTS





MESSAGE SETS USED IN SIMULATION

Start Point Qualitative Message Sets	
DMS/Radio Messge Sets	Frequency
I-10 NO DELAYS NEXT 10 MILES	7
I-10 TRAFFIC SLOWS NEXT 10 MILES	1
STALLED VEHICLE I-10E AT ROUTE 77	1
LIMITED VISIBILITY REDUCE SPEED	1

Waypoint 1 Qualitative Message Sets			
DMS/Radio Messge Sets	Frequency by Departure Time		
	7:45	8:00	8:15
I-10 E NO DELAYS NEXT 10 MILES	6	5	4
I-35 SOUTH TRAFFIC SLOW	0	1	1
I-10 E TRAFFIC SLOWS NEXT 5 MILES	1	1	3
I-20E ACCIDENT 2 MILES BEFORE I-30	0	1	1
STALLED VEHICLE I-10E AT ROUTE 77	1	1	0
LIMITED VISIBILITY REDUCE SPEED	1	1	1
I-10 E TRAFFIC SLOWS NEXT 10 MILES	1	0	0

Waypoint 2 Qualitative Message Sets From Primary Route			
DMS/Radio Messge Sets	Frequency		
	7:45	8:00	8:15
I-20E NO DELAYS NEXT 5 MILES	9	7	5
I-20E TRAFFIC SLOWS NEXT 5 MILES	0	1	3
LIMITED VISIBILITY REDUCE SPEED	1	1	1
ACCIDENT AT I-25 S LEFT LANE BLOCKED	0	1	1

Waypoint 2 Qualitative Message Sets from Option 1 Route			
DMS/Radio Messge Sets	Frequency		
	7:45	8:00	8:15
I-20E NO DELAYS NEXT 5 MILES	9	7	5
I-20E TRAFFIC SLOWS NEXT 5 MILES	0	1	2
I-30 SOUTH SLOW TRAFFIC	0	0	1
LIMITED VISIBILITY REDUCE SPEED	1	1	1
ACCIDENT AT I-25 LEFT LANE BLOCKED	0	1	1

DATA TYPE ACQUIRED IN THE SIMULATION EXPERIMENT

1. Information Type	
Code Value	**Corresponding Information Level**
0	DMS information
1	DMS + real time information
2	DMS + real time + reliability information
2. City Code	
Code Value	**Corresponding City**
1	Dallas, Texas
2	Denver, Colarado
3	Hartford, Massachusetts
4	Miami, Florida
5	San Jose, California
3. Trip Number by Day	
day of trip	**description of day**
1	average traffic day
2	high congestion day, moderate delays all routes
3	average traffic day
4	average traffic day
5	minor accident affecting all routes, minor delays
6	blocked lane on primary route, moderate delays
7	average traffic day
8	heavy rain day, significant delays all routes
9	average traffic day
10	minor accident affecting primary route
4. Departure time selected for trip	
code value	**departure time options**
1	7:45 AM
2	8:00 AM
3	8:15 AM
5. Willingness to pay (WTP) *at beginning of trip* for the information viewed	
code value	**WTP options (drop down menu)**
0.00	$ 0.00
0.25	$ 0.25
0.75	$ 0.75
1.00	$ 1.00
1.50	$ 1.50
6. Level of confidence for on time arrival at *beginning of trip*	
code value	**confidence values**
1	not confident
2	*-intermediate without caption-*
3	neutral
4	*-intermediate without caption-*
5	very confident
7. Number of clicks on "traffic info on primary route" button *at beginning of trip*	
code value	**interpredation**
0	did not click button to view information
1	clicked once to view information
:	:
n	clicked n times to view information

8. Time on first roadway segment	
information provided to participant in upper left information box	
n	*"minutes spent on last roadway: n"*
9. Level of stress upon reaching decision point 1	
code value	**stress values**
1	very stressfull
2	-intermediate without caption-
3	neutral
4	*-intermediate without caption-*
5	stress free
10. Number of clicks on "traffic info on primary route" button *at decision point 1*	
code value	**interpredation**
0	did not click button to view information
1	clicked once to view information
:	:
n	clicked n times to view information
11. Number of clicks on "traffic info on option 1" button *at decision point 1*	
code value	**interpredation**
0	did not click button to view information
1	clicked once to view information
:	:
n	clicked n times to view information
12. Route selection at *decision point 1*	
code value	**route options**
1	primary route
2	route option 1
13. Level of confidence for on time arrival when at decision point 1	
code value	**confidence values**
1	not confident
2	*-intermediate without caption-*
3	neutral
4	*-intermediate without caption-*
5	very confident
14. Choice to call work to inform them of a late arrival at decision point 1	
code value	**route options**
0	did not call to inform of a late arrival
1	did call to inform of a late arrival
15. Time on 2nd roadway segment (primary or option 1)	
information provided to participant in upper left information box	
n	*"minutes spent on last roasway: n"*
16. Level of stress upon reaching decision point 2	
code value	**stress values**
1	very stressfull
2	-intermediate without caption-
3	neutral
4	*-intermediate without caption-*
5	stress free

17. Number of clicks on "traffic info on primary route" button *at decision point2*	
code value	**interpredation**
0	did not click button to view information
1	clicked once to view information
:	:
n	clicked n times to view information
18. Number of clicks on "traffic info on option 1" button *at decision point 2*	
code value	**interpredation**
0	did not click button to view information
1	clicked once to view information
:	:
n	clicked n times to view information
19. Route selection at *decision point 2*	
code value	**route options**
1	primary route
2	route option 1
20. Level of confidence for on time arrival when at decision point 2	
code value	**confidence values**
1	not confident
2	*-intermediate without caption-*
3	neutral
4	*-intermediate without caption-*
5	very confident
21. Choice to call work to inform them of a late arrival at decision point 2	
code value	**route options**
0	did not call to inform of a late arrival
1	did call to inform of a late arrival
22. Time on 3rd roadway segment (primary or option 2)	
information provided to participant in upper left information box	
n	*"minutes spent on last roasway: n"*
23. Overall stressfulness of the trip	
code value	**stress values**
1	very stressfull
2	-intermediate without caption-
3	neutral
4	*-intermediate without caption-*
5	stress free
24. Happiness with trip outcome	
code value	**happness value**
1	unhappy
2	-intermediate without caption-
3	neutral
4	*-intermediate without caption-*
5	very happy

25. Usefulness of traffic information for this trip	
code value	**usefulness value**
1	not useful
2	-intermediate without caption-
3	neutral
4	*-intermediate without caption-*
5	very useful
26. Willingness to pay for traffic information viewed for this trip	
code value	**stress values**
0	$0.00
1	$1.00
2	$2.00
3	$3.00
4	$4.00
5	$5.00
27. Total trip time	
n	**minutes of travel in vehicle**
28. late arrival fee	
X	**$25.00 if late arrival**
29. extra parking cost	
$Y	**$4.00 per hour at 15 minute increments**

TRAVEL TIME PROFILES BY SIMULATION DAY

	Departure Time	Actual Travel Time on Route Taken			
Day 1		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	35	38	34	37
	8:00 AM	40	41	40	43
	8:15 AM	43	47	43	44
Day 2	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	37	39	39	39
	8:00 AM	47	45	48	44
	8:15 AM	47	49	50	49
Day 3	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	34	39	36	41
	8:00 AM	41	43	43	43
	8:15 AM	45	46	47	49
Day 4	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	31	36	33	37
	8:00 AM	36	41	38	43
	8:15 AM	41	47	44	46
Day 5	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	40	43	42	45
	8:00 AM	57	59	59	62
	8:15 AM	68	71	72	74
Day 6	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	64	49	63	49
	8:00 AM	63	53	63	53
	8:15 AM	47	39	47	43
Day 7	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	32	35	35	38
	8:00 AM	35	39	40	43
	8:15 AM	38	40	43	45
Day 8	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	58	61	59	62
	8:00 AM	66	66	68	65
	8:15 AM	71	70	73	70
Day 9	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	32	34	33	35
	8:00 AM	34	38	36	38
	8:15 AM	39	43	41	44
Day 10	Departure Time	Actual Travel Time on Route Taken			
		primary	Option 1	Option 2	Option 1 & 2
	7:15 AM	39	37	37	38
	8:00 AM	49	45	42	38
	8:15 AM	56	53	47	42

APPENDIX G SUPPLEMENTAL FIGURES FROM TRAVEL BEHAVIOR LABORATORY EXPERIMENT PRE-SURVEY

The following figures summarize statistics related to participants' gender, age, education, and types of trips made; these questions were included in the pre-experiment survey that was part of the first travel behavior laboratory experiment described in Chapter 9.

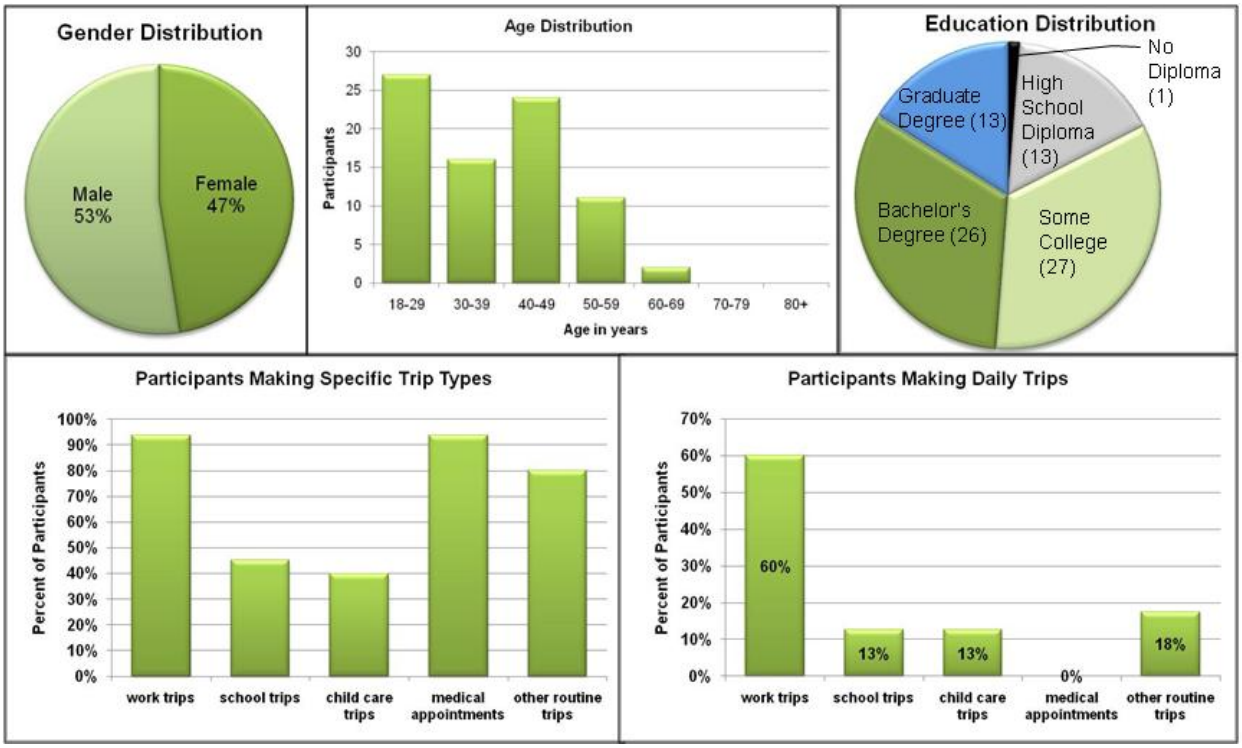


Figure G-1. Demographic and trip-making characteristics of experiment participants.

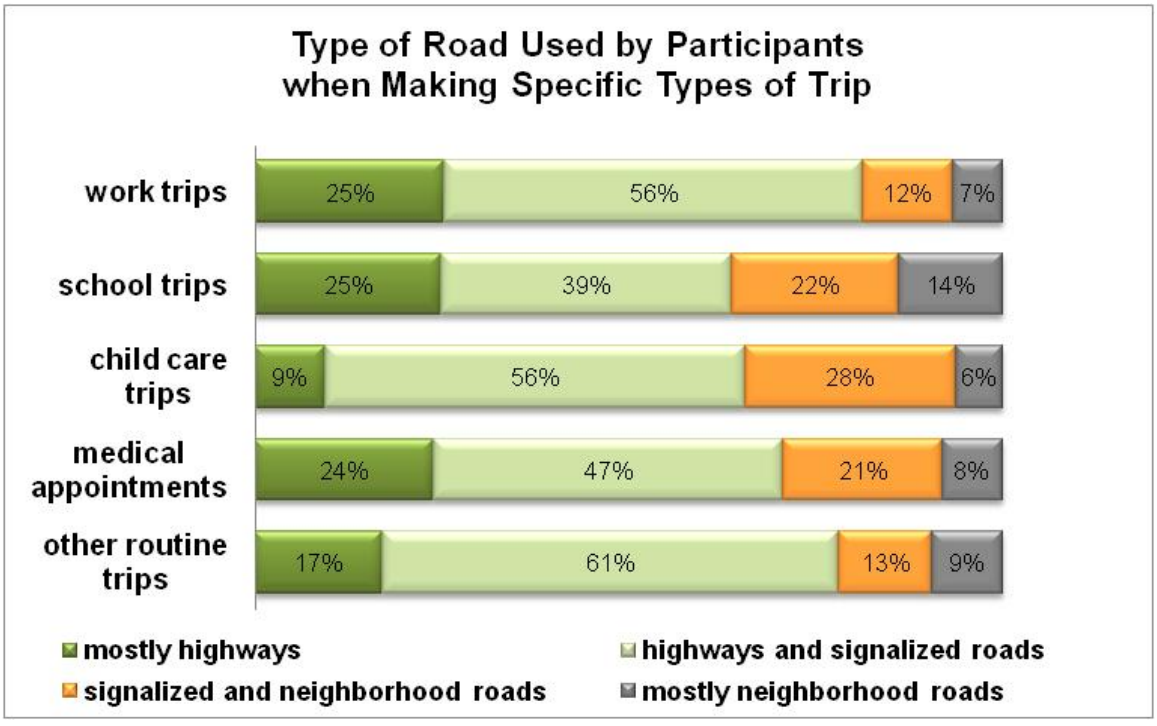


Figure G-2. Types of roads participants use for specific trip types.

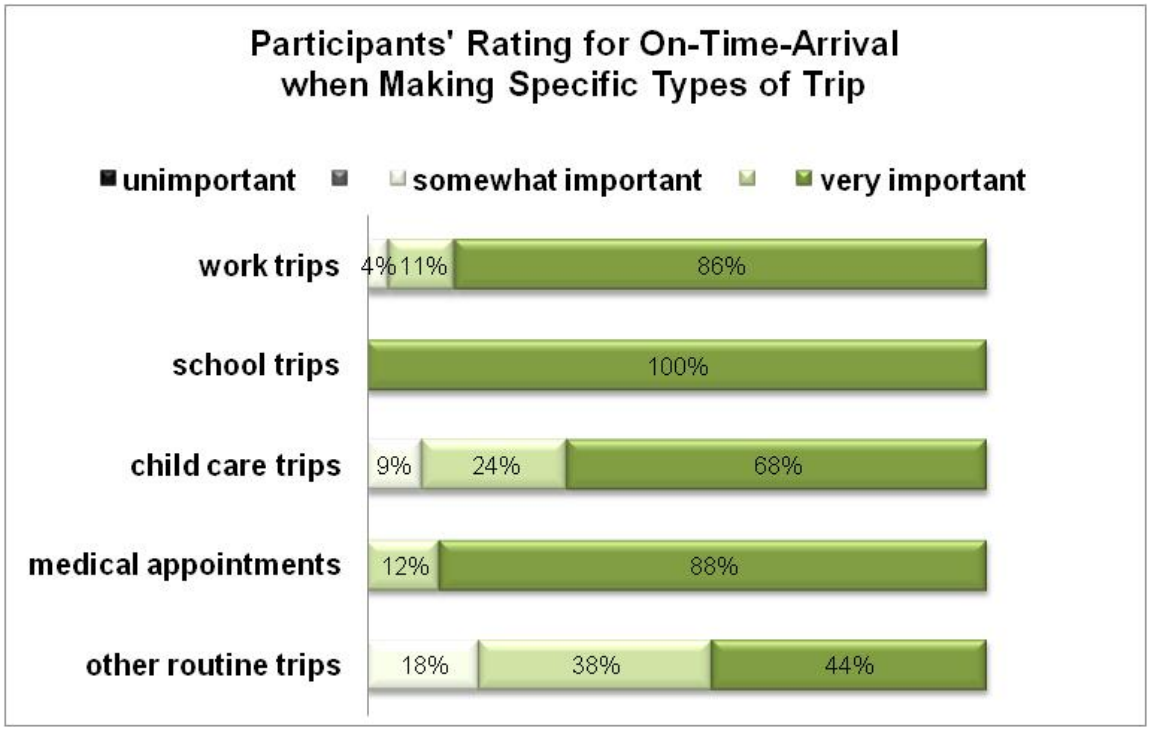


Figure G-3. Participants' on-time-arrival importance by trip purpose.

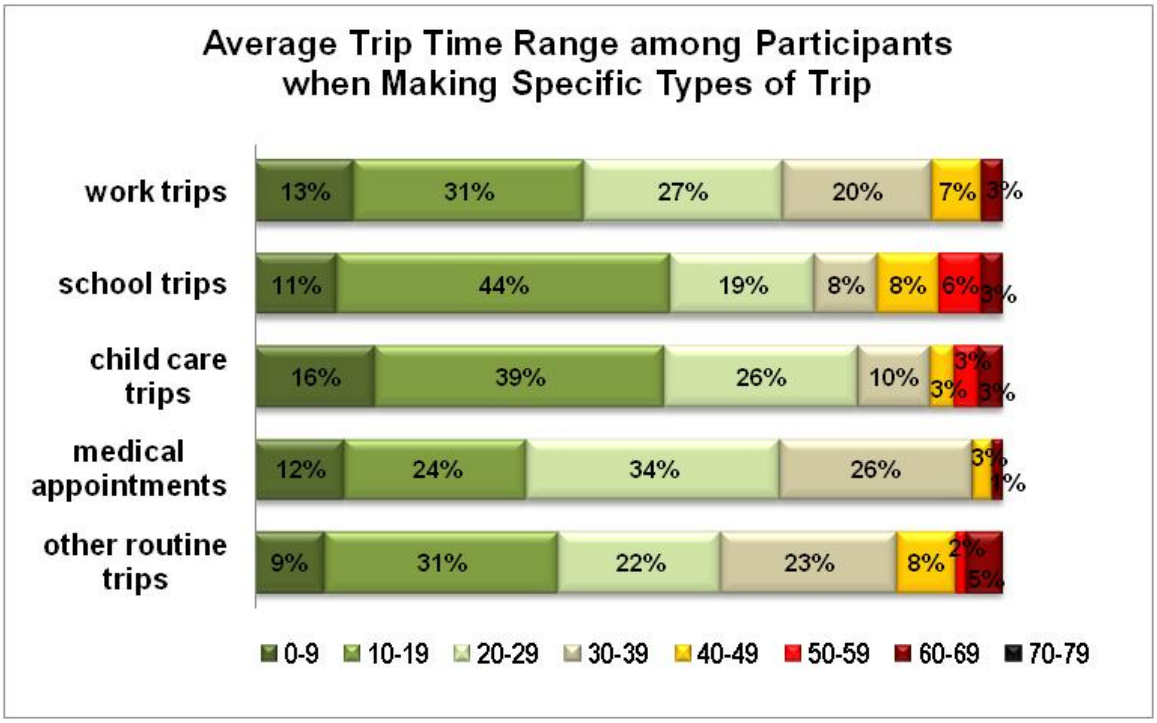


Figure G-4. Average trip duration by trip type.

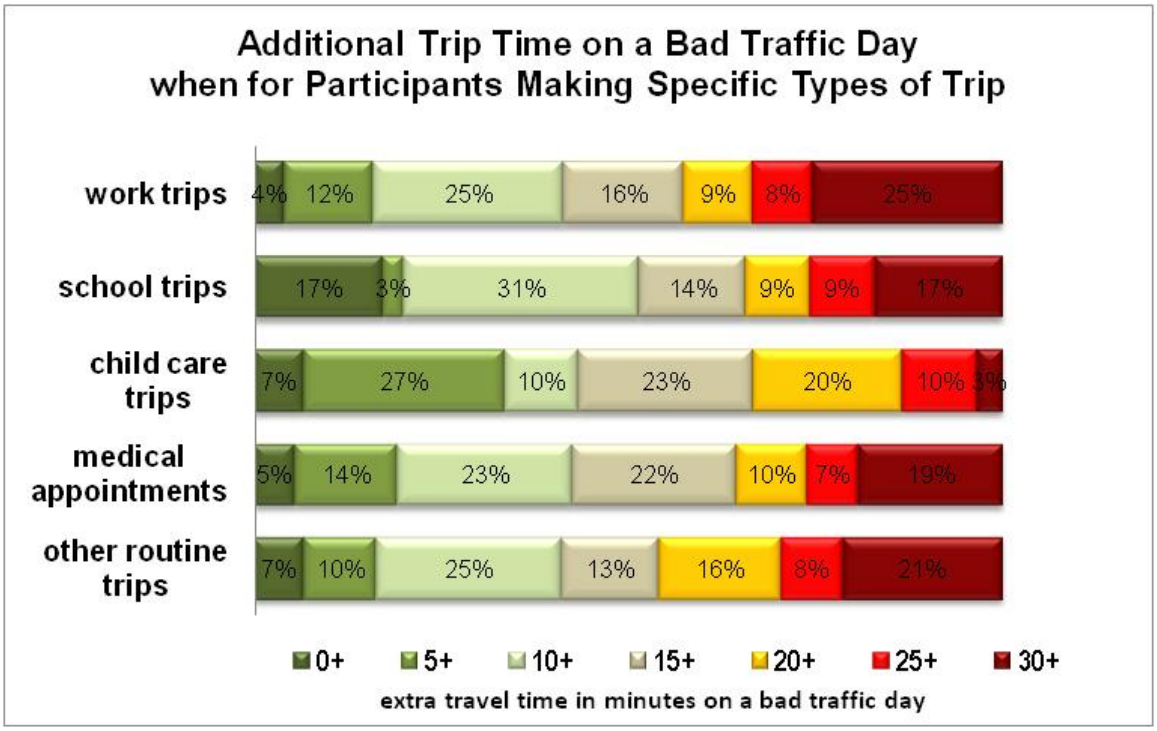


Figure G-5. Capturing trip time variability for participants' trips.

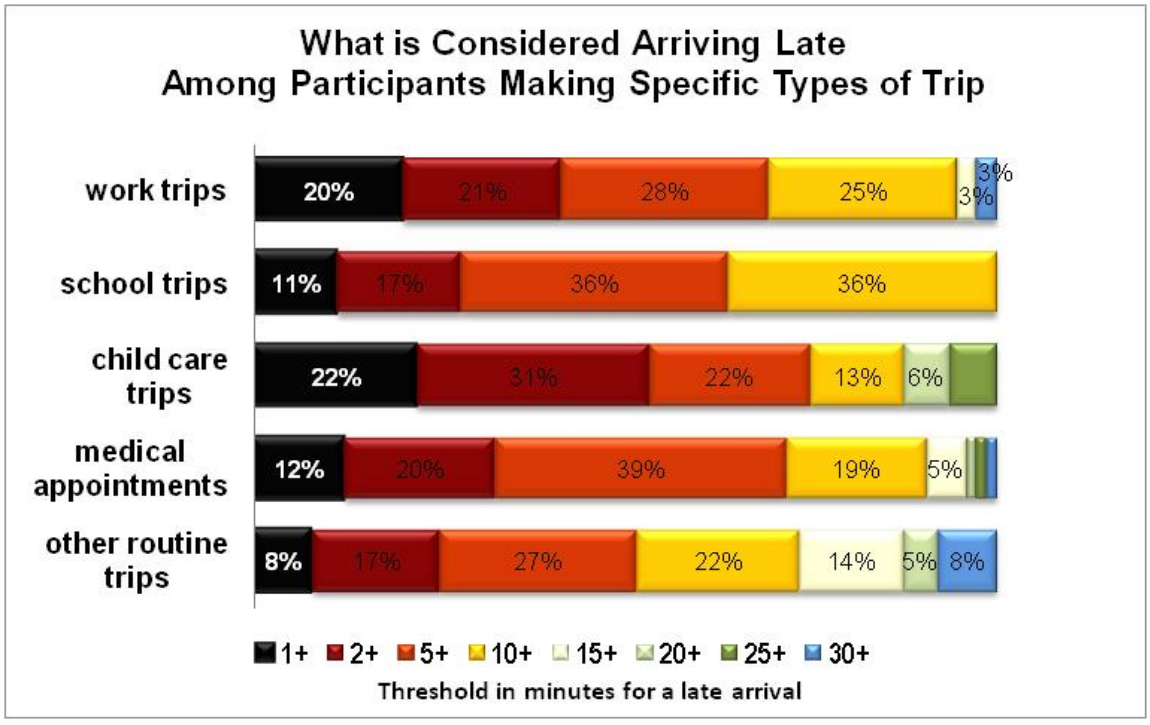


Figure G-6. Participants vary in their definition of a late arrival.



Figure G-7. Willingness to pay for guaranteed travel time.

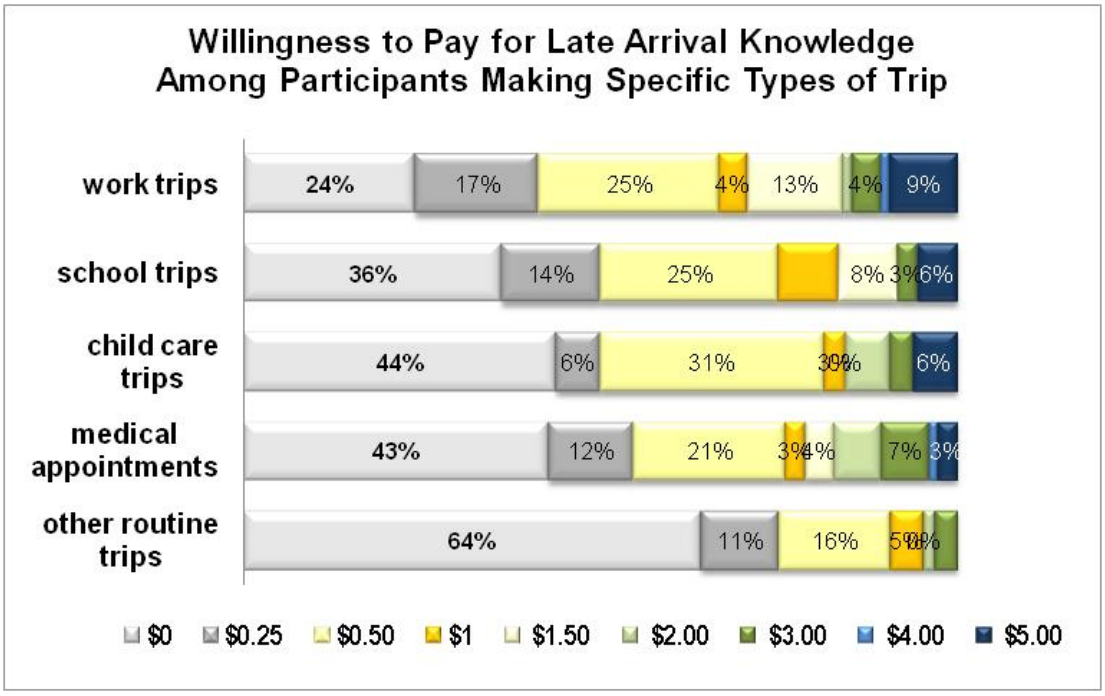


Figure G-8. Willingness to pay for late arrival knowledge.

APPENDIX H ENHANCED LABORATORY EXPERIMENT DOCUMENTATION

PRE-EXPERIMENT SURVEY QUESTIONS 1-12

The 12 pre-experiment questions presented to participants are listed below in Table H-1. These were completed within an Excel-based application.

Table H-1. Pre-experiment survey questions.

Pre-Experiment Survey Questions	
1.	Please select your gender and age range.
2.	Please select your highest level of education.
3.	How frequently do you make the following types of trips?
4.	When making work trips, how often do you seek out traffic information?
5.	If you seek out traffic information for work trips, what sources do you use? (check all that apply)
6.	What types of roads do you use when you drive to the following destinations?
7.	For the following types of trips, how important is it for you to arrive at a specific time?
8.	On a typical day, how much time do the following trips take you to complete by car?
9.	On a bad day, how much more time do the following trips take for you to complete by car?
10.	For the following types of trips, what would you consider as arriving late?
11.	Say you could be guaranteed a travel time before you make your trip. How much would you pay for this guarantee when making the following types of trips?
12.	Say you could be informed during the beginning of your trip that you will arrive late. How much would you pay for this information when making the following types of trips?

The potential response levels for each question are outlined in Table H-2.

Table H-2. Potential pre-experiment survey questions.

1a. Gender	1b. Age
(drop-down menu)	**(drop-down menu)**
female	18-29
male	30-39
	40-49
	50-59
	60-69
	70-79
	80+

2. Education
(drop-down menu)
no high school diploma
high school diploma
some college
bachelor's degree
graduate degree

3. Frequency of trips by trip type (matrix)	
trip types	**frequency options (radio button)**
to work	never
to school/college	less than once a month
to childcare pick-up	1-3 times a month
to medical appointments	once a week
to non-work meetings*	2-4 times a week
	5 or more times a week
*meeting for social, hobby, or religious activities	

4. Frequency for seeking traffic info for work trips
frequency options (radio button)
never
less than once a month
1-3 times a month
once a week
2-4 times a week
5 or more times a week

5. Sources for acquiring traffic information for work trip
options (select all that apply)
radio
television
desktop/laptop
hand-held device/tablet
vehicle dashboard device

Table H-3. Potential pre-experiment survey questions (continued).

Questions 6-12 exclude trip type categories with frequency response of "never" in Question 3.	
6. Types of roads used by trip destination (matrix)[#]	
trip types	**road options (drop-down menu)**
to work	mostly highways
to school/college	highways and signalized roads
to childcare pick-up	signalized and neighborhood roads
to medical appointments	mostly neighborhood roads
to non-work meetings*	transit
	other means of travel
7. Importance of arriving at a specific time[#]	
trip types	**level of importance (radio buttons)**
to work	not important
to school/college	*-intermediate without caption-*
to childcare pick-up	somewhat important
to medical appointments	*-intermediate without caption-*
to non-work meetings*	very important
8. Average time to destination when driving in car	
trip destinations	**time range options (drop-down menu)**
to work	0-9 minutes
to school/college	10-19 minutes
to childcare pick-up	20-29 minutes
to medical appointments	30-39 minutes
to non-work meetings*	40-49 minutes
	50-59 minutes
	1 hour or more
	trip not made by car
9. Additional time to destination on a "bad day"	
trip destinations	**time range options (drop-down menu)**
to work	0-9 minutes
to school/college	10-19 minutes
to childcare pick-up	20-29 minutes
to medical appointments	30-39 minutes
to non-work meetings*	40-49 minutes
	50-59 minutes
	1 hour or more
	trip not made by car

Table H-4 (continued). Potential pre-experiment survey questions.

10. How many minutes beyond planned arrival time is considered late	
trip destinations	**time range options (drop down menu)**
to work	1 minute
to school/college	2-4 minutes
to childcare pick-up	5-9 minutes
to medical appointments	10-14 minutes
to non-work meetings*	15-19 minutes
	20-24 minutes
	25-29 minutes
	30 or more minutes
11. Willingness to pay (WTP) for guaranteed travel time	
trip destinations	**WTP options (drop-down menu)**
to work	$0.00
to school/college	$0.50
to childcare pick-up	$1.00
to medical appointments	$1.50
to non-work meetings*	$2.00
	$3.00
	$4.00
	$5.00
12. Willingness to pay (WTP) for late arrival information	
trip destinations	**WTP options (drop-down menu)**
to work	$0.00
to school/college	$0.50
to childcare pick-up	$1.00
to medical appointments	$1.50
to non-work meetings*	$2.00
	$3.00
	$4.00

VISUALS OF RELIABILITY FORMS PRESENTED TO EXPERIMENT PARTICIPANTS

Experiment participants have the option of viewing pre-trip information. Figure H-1 through Figure H-8 illustrate the forms of specific reliability data available pre-trip to participants.

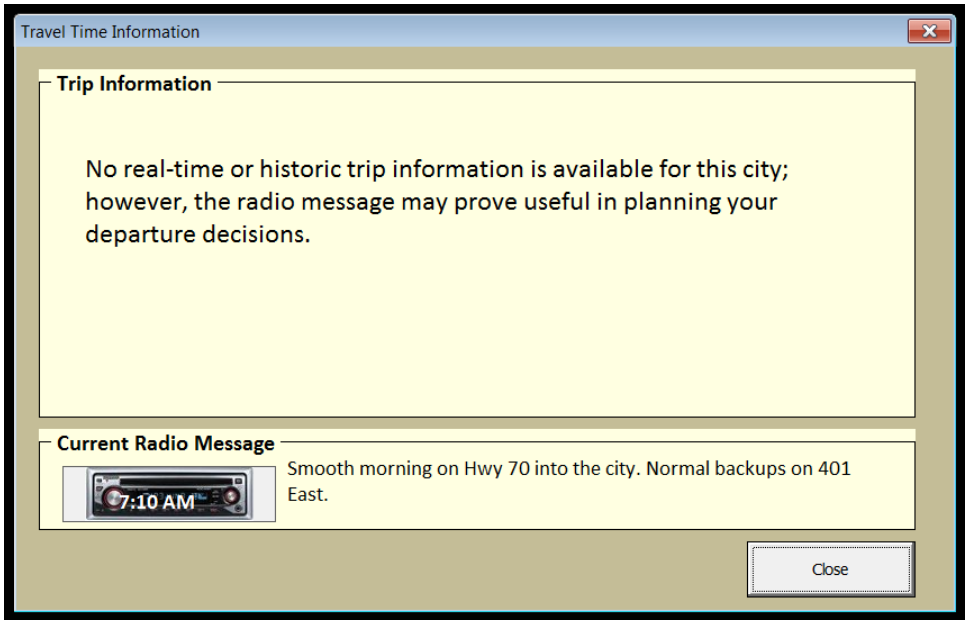


Figure H-1. Information Type A—only radio message, no reliability data.

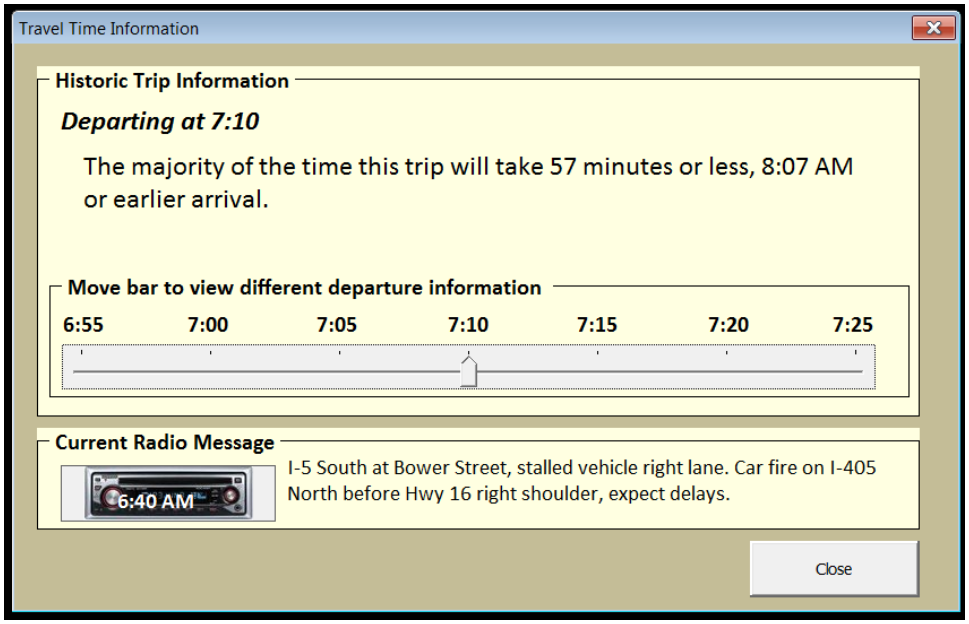


Figure H-2. Information Type B—textual 95th percentile travel time and arrival times by time of departure.

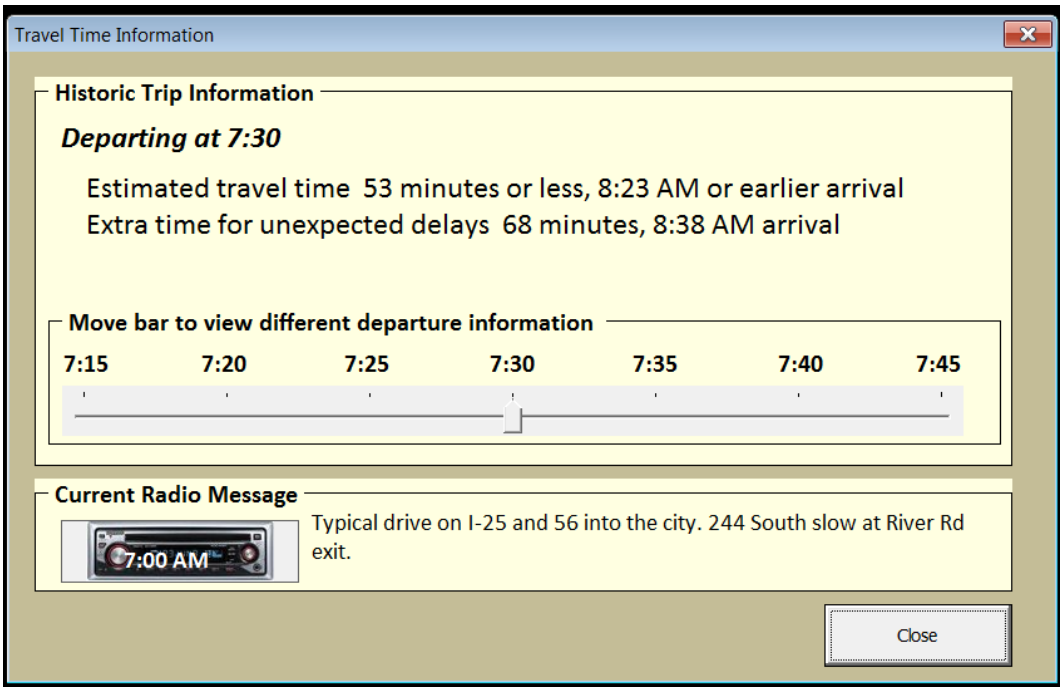


Figure H-3. Information Type C—textual average and 95th percentile travel and arrival times by time of departure.

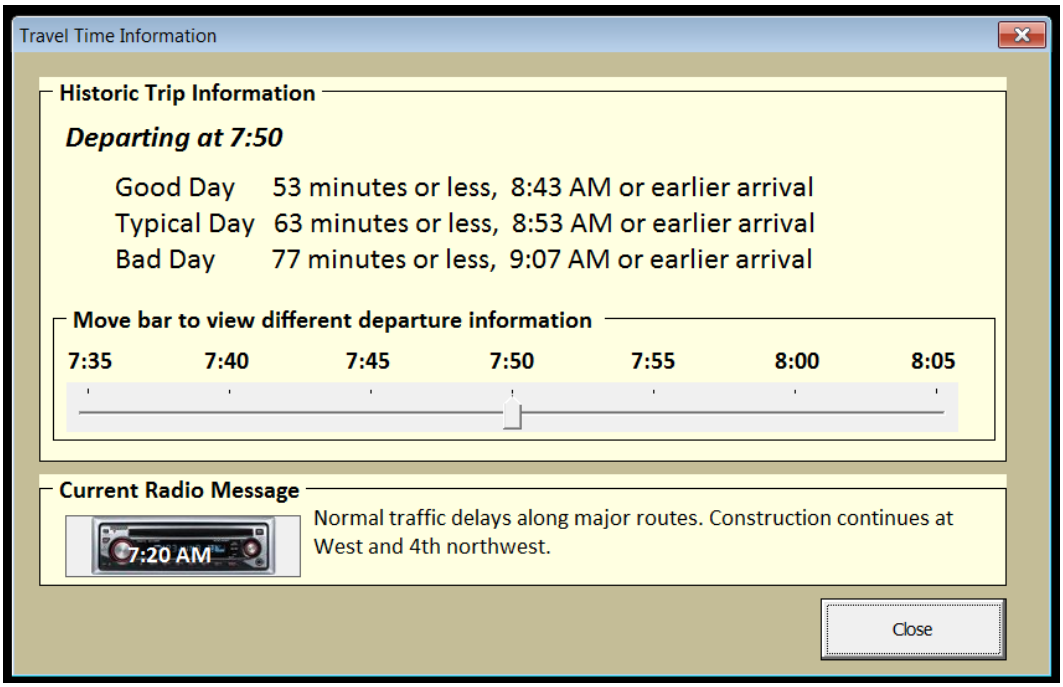


Figure H-4. Information Type D—textual 20th percentile, average, and 95th percentile travel and arrival times by time of departure.

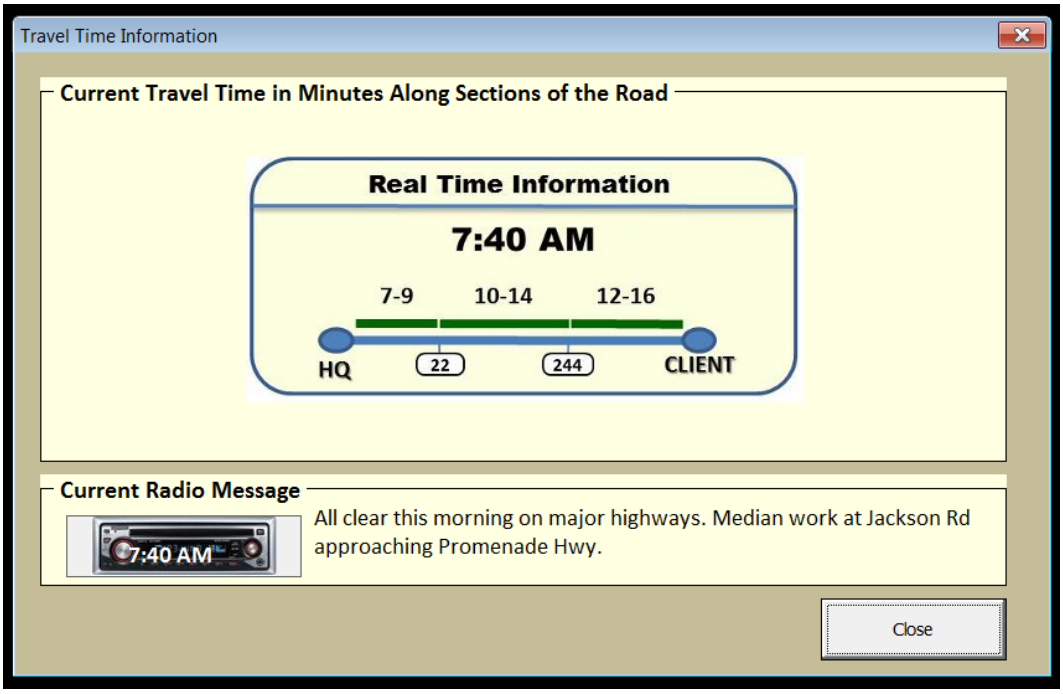


Figure H-5. Information Type E—visual and textual signposting.

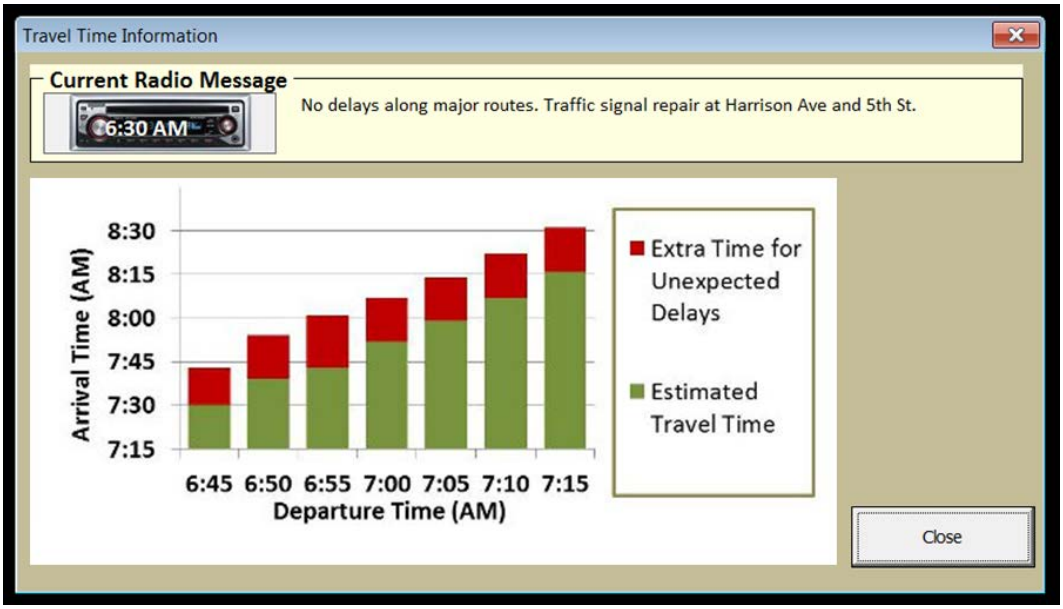


Figure H-6. Information Type F—graphic presentation of average and 95th percentile travel and arrival times by time of departure.

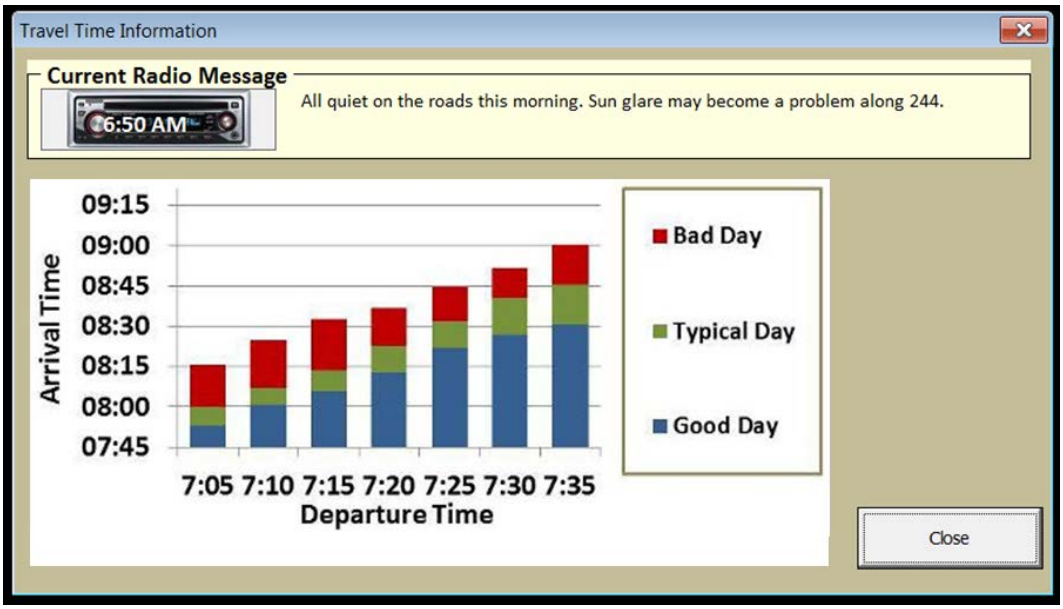


Figure H-7. Information Type G—graphic presentation of 20th percentile, average, and 95th percentile travel and arrival times by time of departure.

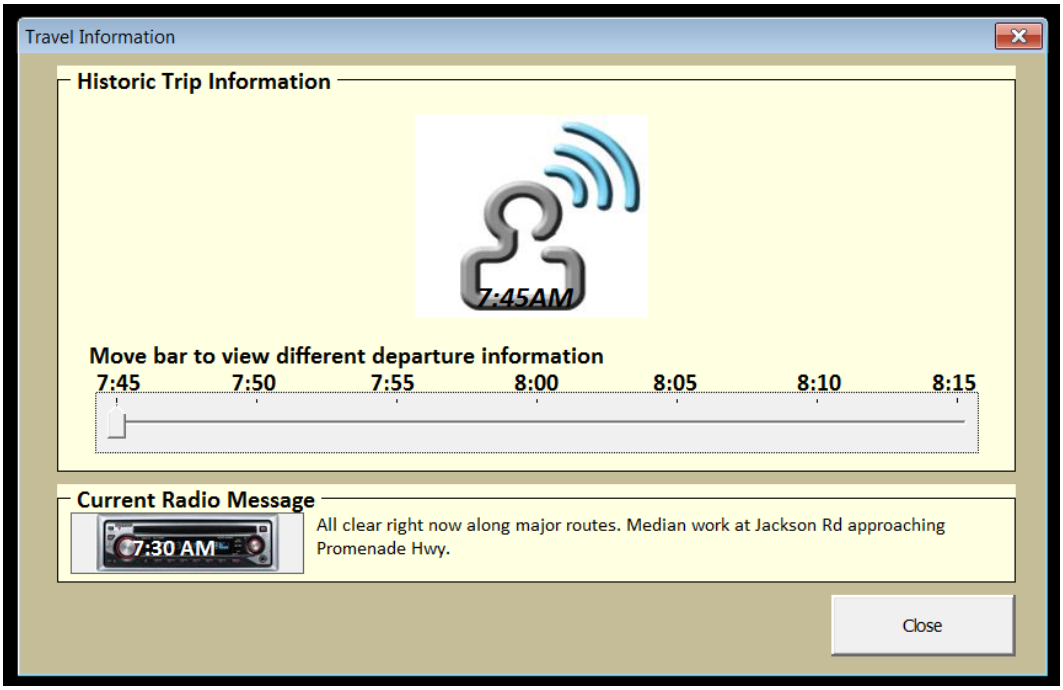


Figure H-8. Voice-based 95th percentile travel time and arrival times by time of departure.

EXPERIMENT #1 STORYLINE AND SCREENSHOTS

Herein, the simulated commute storyline is presented through screenshots. Figure H-9 presents the first visual once a user begins the experiment by selecting the “start game” button. The

experiment moderators review the introduction and read aloud the content. Once participants click the "begin experiment" button shown in Figure H-9, the first randomly selected city and information type replaces the introduction. This screen, shown in Figure H-10, provides a visual of the fictitious regional traffic network and the locations of the simulated starting point (headquarters [HQ]) and ending point (client) of the daily commute. Also presented is the trip distance, free-flow travel time, desired arrival time, and potential departure time options. Upon reviewing this information, participants click on "start week" and are presented the screenshot presented in Figure H-11. From this point, participants select the "view trip information" button. This step is demonstrated by the experiment moderators.

The reliability information is presented next to the map, as shown in Figure H-12. The reliability information with the Harrisonville fictional city illustrates the signposting reliability information. Depending on the type of reliability information presented, the city name and trip information content will vary. After closing the information content, individuals choose a departure time, arrival confidence, and information usefulness. Then participants click on "start trip." If any information is incomplete, they are asked to complete it before they can progress.

The participant then views the completion of the trip as the vehicle icon progress each main roadway illustrated through dashed lines. This is illustrated in Figure H-13. The duration that individuals wait to complete the trip is a function of a baseline number of seconds and an additional time corresponding to the extra time based on that day's predetermined departure time based travel time. At intermediary points, DMS messages display information that corresponds with the travel time. Once the simulated trip is complete, summary statistics are emphasized at the bottom of the screen (see Figure H-14), and participants indicate their willingness to pay for the reliability information viewed, the information's usefulness, and the level of stress experience waiting for the simulated trip to complete. Then participants click on "next trip" and complete four additional trips, repeating the screenshots displayed in Figures H-11 through H-14.

At the end of five trips, a summary statistic highlights their performance over the week, as illustrated through Figure H-15. Participants answer five questions again on reliability information value, usefulness, and ease of use. They then click on "next city" and await further instructions from the moderator. During this wait time, they will see Figure H-16. At this juncture, the moderator will ask the participants in the session to share their overall week's cost and experiences to foster a competitive and collaborative environment and to maintain the group's engagement in the experiment. As a group, participants then begin the next city, viewing a different city name and information, as is illustrated in Figure H-10.

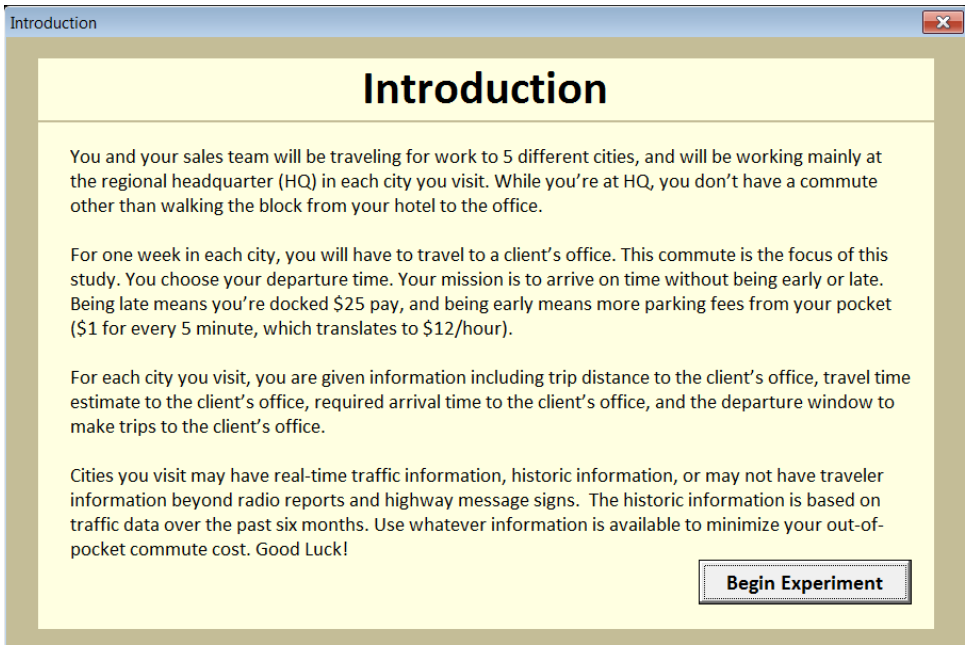


Figure H-9. Introduction screen at start of simulation game.

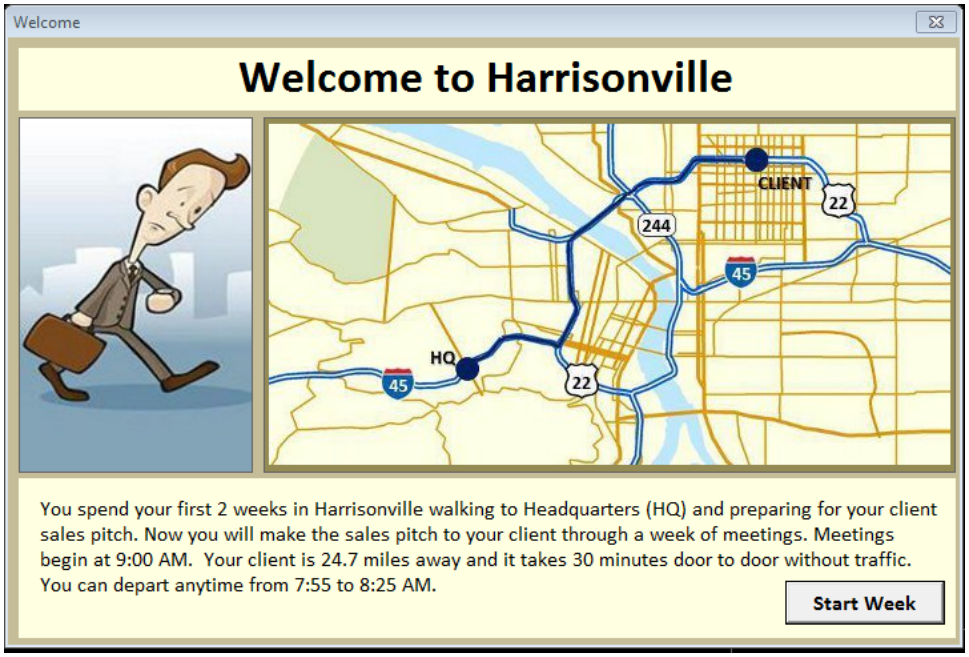


Figure H-10. City introduction screenshot and trip-making details.

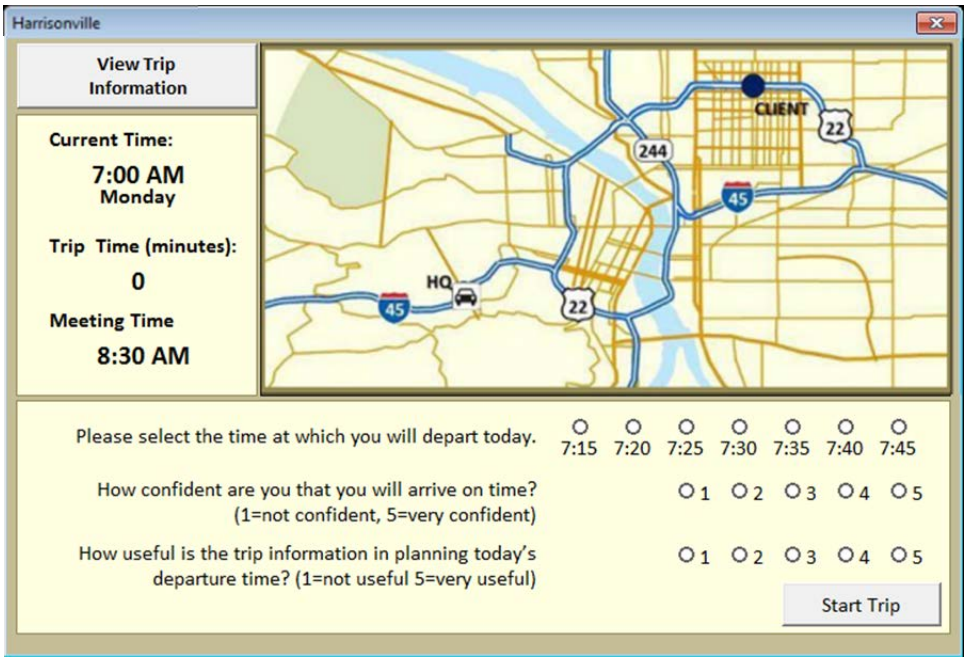


Figure H-11. Trip decision screenshot.

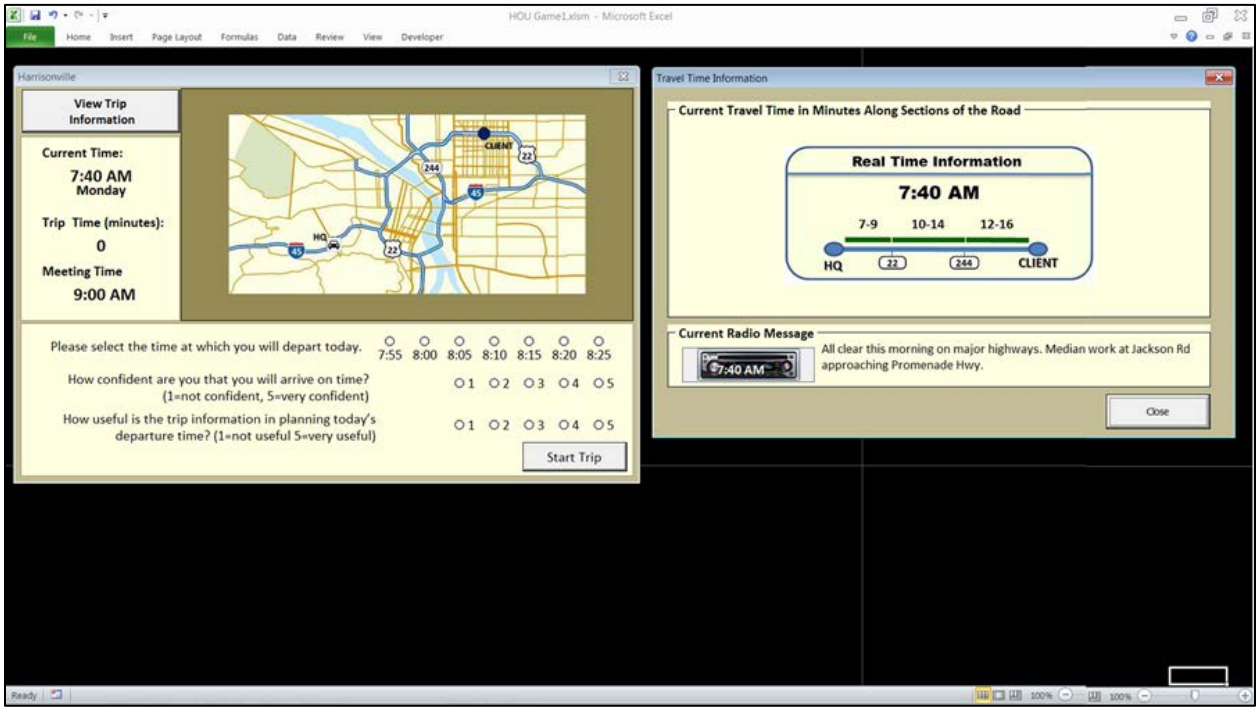


Figure H-12. Screenshot of trip decision form with reliability information being viewed.

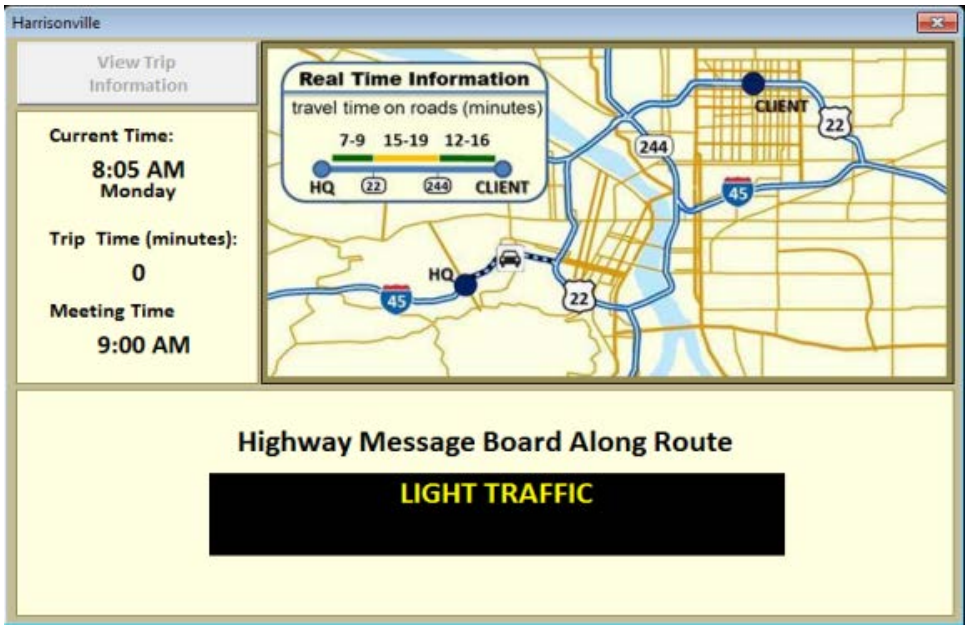


Figure H-13. Screenshot of simulated travel with highway message sign.

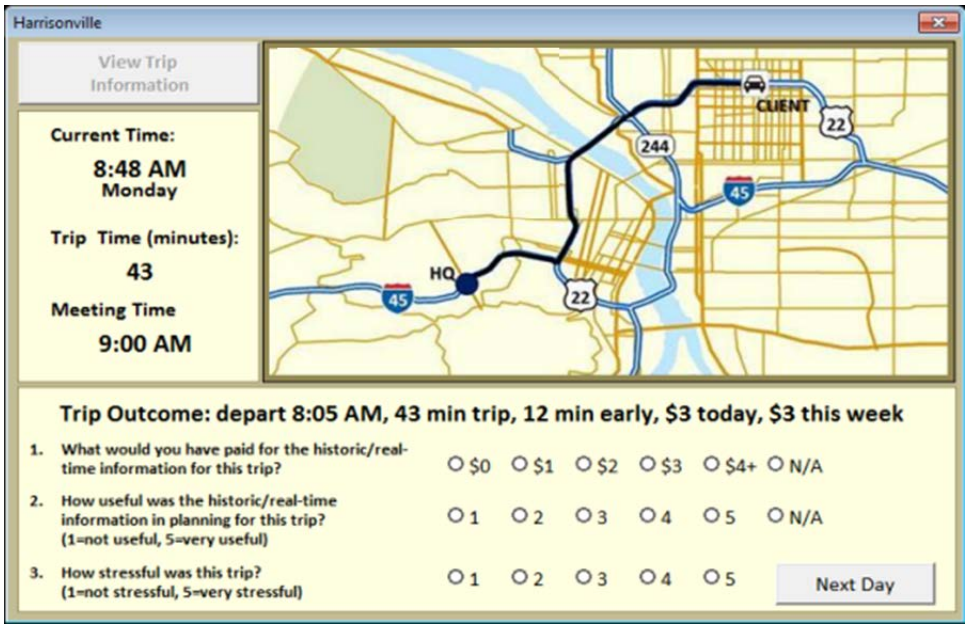


Figure H-14. End-of-trip form proving trip metrics and requesting end-of-trip information.

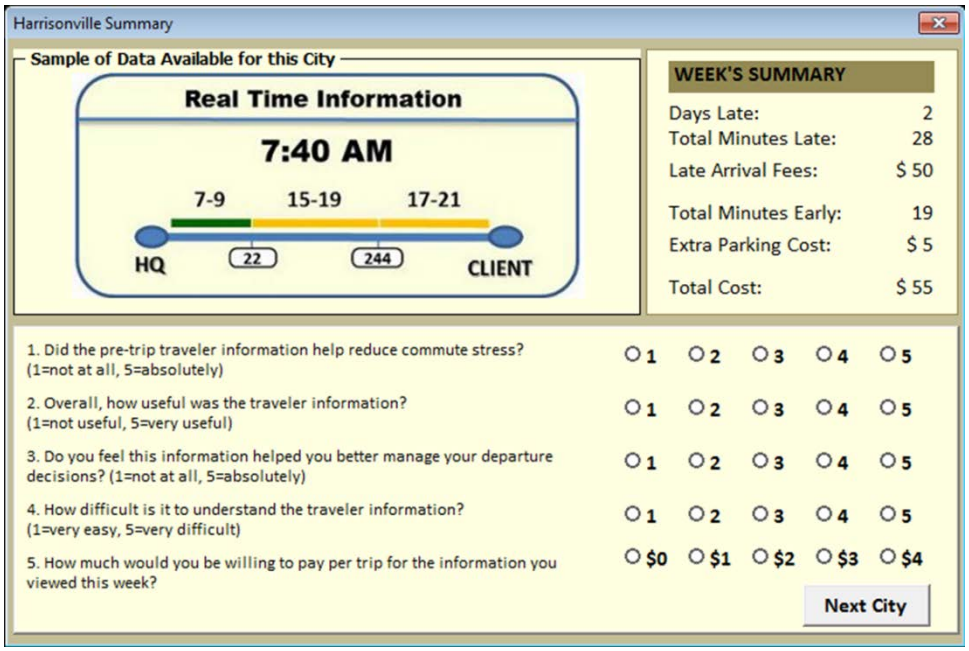


Figure H-15. End-of-week form requesting information on reliability term.



Figure H-16. Transition slide presented between weeks of simulated commute.

SCREENSHOTS OF THE SIX FICTIONAL CITIES DEVELOPED FOR SIMULATED COMMUTES

Figure H-17 through Figure H-22 display the fictional cities developed by the researchers for the simulated commutes in the experiment.



Figure H-17. City screenshot for Prairie Cliffs used for baseline travel information.



Figure H-18. City screenshot for Garden Springs used for text 95th percentile and graphic good, typical, and bad reliability terms.

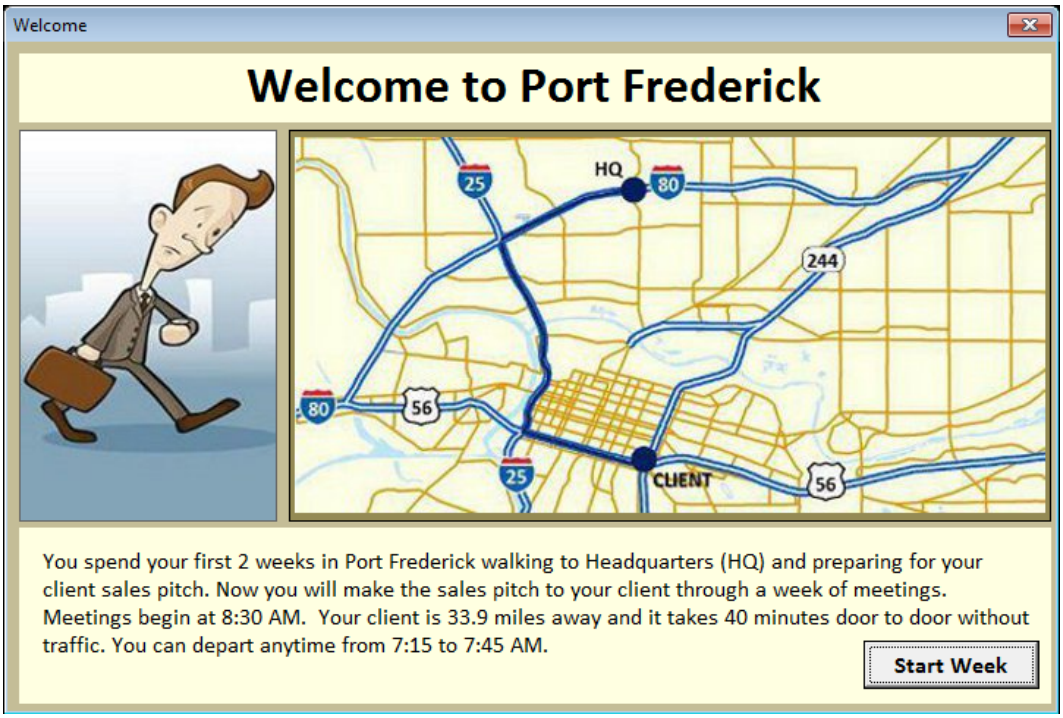


Figure H-19. City screenshot for Port Frederick used for the text average and 95th percentile reliability terms.

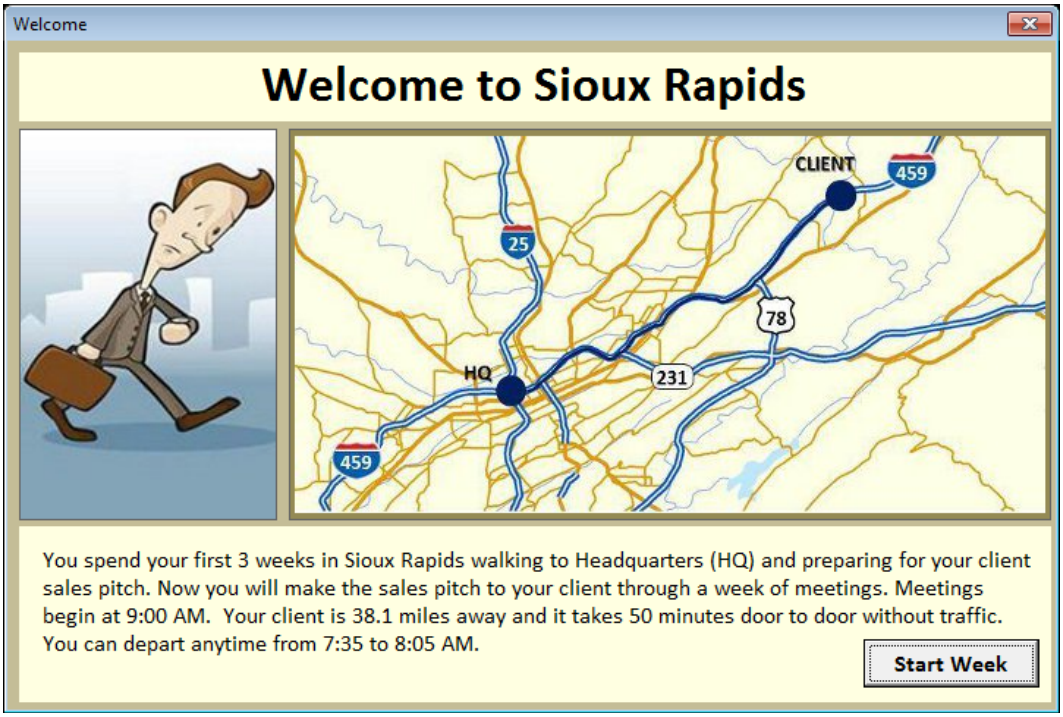


Figure H-20. City screenshot for Sioux Rapids used for text good, typical, and bad reliability terms.

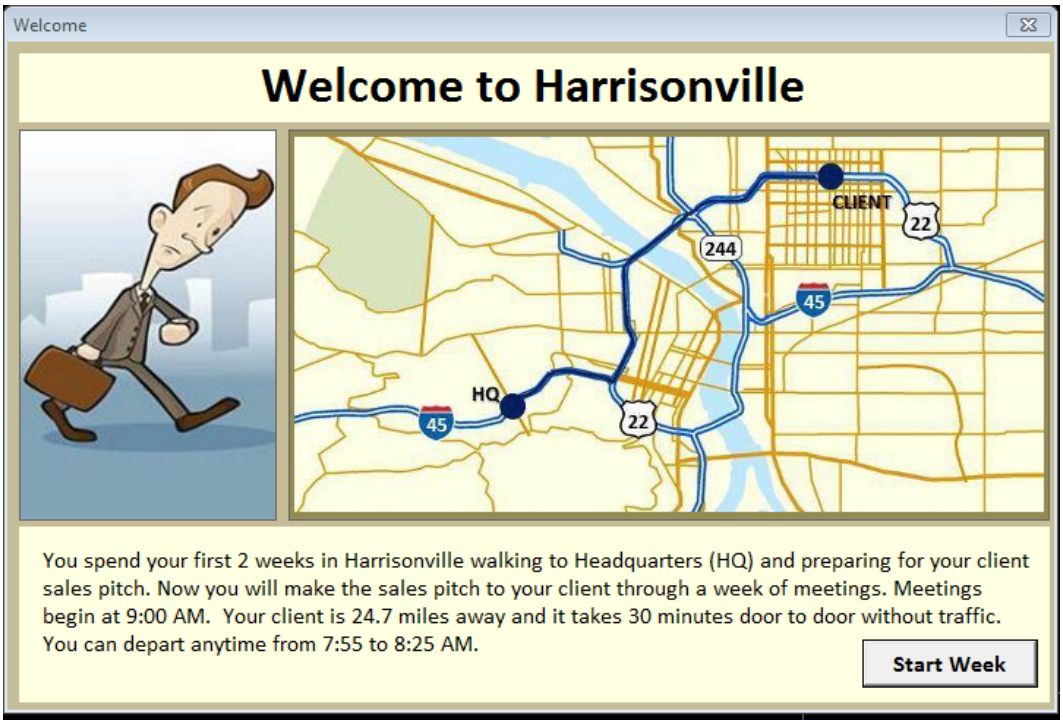


Figure H-21. City screenshot for Harrisonville used for reliability signposting and graphic average + 95th percentile reliability terms.



Figure H-22. City screenshot for New Glaxtonberg used for the audio 95th percentile reliability term.

TRIP TIME DATA TABLES FOR EXPERIMENT #1

Data for Reliability Content A: No Reliability Information				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
A	1	1	30	good
A	1	2	32	good
A	1	3	34	good
A	1	4	34	good
A	1	5	37	good
A	1	6	38	good
A	1	7	39	good
A	2	1	44	moderate
A	2	2	51	moderate
A	2	3	56	moderate
A	2	4	57	moderate
A	2	5	59	moderate
A	2	6	62	moderate
A	2	7	66	moderate
A	3	1	31	typical
A	3	2	37	typical
A	3	3	39	typical
A	3	4	40	typical
A	3	5	42	typical
A	3	6	49	typical
A	3	7	53	typical
A	4	1	47	bad
A	4	2	59	bad
A	4	3	61	bad
A	4	4	55	bad
A	4	5	53	bad
A	4	6	53	bad
A	4	7	52	bad
A	5	1	35	typical2
A	5	2	42	typical2
A	5	3	43	typical2
A	5	4	46	typical2
A	5	5	45	typical2
A	5	6	47	typical2
A	5	7	50	typical2

Data for Reliability Content B: Textual 95th Percentile				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
B	1	1	44	moderate
B	1	2	51	moderate
B	1	3	56	moderate
B	1	4	57	moderate
B	1	5	59	moderate
B	1	6	62	moderate
B	1	7	66	moderate
B	2	1	31	typical
B	2	2	37	typical
B	2	3	39	typical
B	2	4	40	typical
B	2	5	42	typical
B	2	6	49	typical
B	2	7	53	typical
B	3	1	47	bad
B	3	2	59	bad
B	3	3	61	bad
B	3	4	55	bad
B	3	5	53	bad
B	3	6	53	bad
B	3	7	52	bad
B	4	1	35	good
B	4	2	42	good
B	4	3	43	good
B	4	4	46	good
B	4	5	45	good
B	4	6	47	good
B	4	7	50	good
B	5	1	30	typical2
B	5	2	32	typical2
B	5	3	34	typical2
B	5	4	34	typical2
B	5	5	37	typical2
B	5	6	38	typical2
B	5	7	39	typical2

Data for Reliability Content C: Textual Average and 95th Percentile				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
C	1	1	44	typical2
C	1	2	50	typical2
C	1	3	52	typical2
C	1	4	54	typical2
C	1	5	54	typical2
C	1	6	57	typical2
C	1	7	59	typical2
C	2	1	40	typical
C	2	2	46	typical
C	2	3	50	typical
C	2	4	51	typical
C	2	5	55	typical
C	2	6	55	typical
C	2	7	59	typical
C	3	1	55	bad
C	3	2	69	bad
C	3	3	70	bad
C	3	4	63	bad
C	3	5	62	bad
C	3	6	63	bad
C	3	7	62	bad
C	4	1	42	good
C	4	2	40	good
C	4	3	44	good
C	4	4	45	good
C	4	5	47	good
C	4	6	49	good
C	4	7	48	good
C	5	1	55	moderate
C	5	2	64	moderate
C	5	3	66	moderate
C	5	4	63	moderate
C	5	5	64	moderate
C	5	6	70	moderate
C	5	7	74	moderate

Data for Reliability Content D: Textual 20th, Average, and 95th Percentile				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
D	1	1	53	typical
D	1	2	57	typical
D	1	3	60	typical
D	1	4	58	typical
D	1	5	63	typical
D	1	6	68	typical
D	1	7	68	typical
D	2	1	68	bad
D	2	2	75	bad
D	2	3	82	bad
D	2	4	74	bad
D	2	5	72	bad
D	2	6	74	bad
D	2	7	74	bad
D	3	1	54	typical2
D	3	2	61	typical2
D	3	3	62	typical2
D	3	4	63	typical2
D	3	5	64	typical2
D	3	6	72	typical2
D	3	7	71	typical2
D	4	1	63	moderate
D	4	2	70	moderate
D	4	3	78	moderate
D	4	4	73	moderate
D	4	5	75	moderate
D	4	6	79	moderate
D	4	7	82	moderate
D	5	1	51	good
D	5	2	53	good
D	5	3	52	good
D	5	4	55	good
D	5	5	58	good
D	5	6	60	good
D	5	7	57	good

Data for Reliability Content E: Signpost Reliability				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
E	1	1	35	typical2
E	1	2	42	typical2
E	1	3	43	typical2
E	1	4	46	typical2
E	1	5	45	typical2
E	1	6	47	typical2
E	1	7	50	typical2
E	2	1	30	good
E	2	2	32	good
E	2	3	34	good
E	2	4	34	good
E	2	5	37	good
E	2	6	38	good
E	2	7	39	good
E	3	1	47	bad
E	3	2	59	bad
E	3	3	61	bad
E	3	4	55	bad
E	3	5	53	bad
E	3	6	53	bad
E	3	7	52	bad
E	4	1	31	typical
E	4	2	37	typical
E	4	3	39	typical
E	4	4	40	typical
E	4	5	42	typical
E	4	6	49	typical
E	4	7	53	typical
E	5	1	44	moderate
E	5	2	51	moderate
E	5	3	56	moderate
E	5	4	57	moderate
E	5	5	59	moderate
E	5	6	62	moderate
E	5	7	66	moderate

Data for Reliability Content F: Graphical Average and 95th Percentile				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
F	1	1	42	good
F	1	2	40	good
F	1	3	44	good
F	1	4	45	good
F	1	5	47	good
F	1	6	49	good
F	1	7	48	good
F	2	1	55	bad
F	2	2	69	bad
F	2	3	70	bad
F	2	4	63	bad
F	2	5	62	bad
F	2	6	63	bad
F	2	7	62	bad
F	3	1	44	typical2
F	3	2	50	typical2
F	3	3	52	typical2
F	3	4	54	typical2
F	3	5	54	typical2
F	3	6	57	typical2
F	3	7	59	typical2
F	4	1	55	moderate
F	4	2	64	moderate
F	4	3	66	moderate
F	4	4	63	moderate
F	4	5	64	moderate
F	4	6	70	moderate
F	4	7	74	moderate
F	5	1	40	typical
F	5	2	46	typical
F	5	3	50	typical
F	5	4	51	typical
F	5	5	55	typical
F	5	6	55	typical
F	5	7	59	typical

Data for Reliability Content G: Graphical 20th, Average, and 95th Percentile				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
G	1	1	63	good
G	1	2	70	good
G	1	3	78	good
G	1	4	73	good
G	1	5	75	good
G	1	6	79	good
G	1	7	82	good
G	2	1	54	bad
G	2	2	61	bad
G	2	3	62	bad
G	2	4	63	bad
G	2	5	64	bad
G	2	6	72	bad
G	2	7	71	bad
G	3	1	51	typical2
G	3	2	53	typical2
G	3	3	52	typical2
G	3	4	55	typical2
G	3	5	58	typical2
G	3	6	60	typical2
G	3	7	57	typical2
G	4	1	68	moderate
G	4	2	75	moderate
G	4	3	82	moderate
G	4	4	74	moderate
G	4	5	72	moderate
G	4	6	74	moderate
G	4	7	74	moderate
G	5	1	53	typical
G	5	2	57	typical
G	5	3	60	typical
G	5	4	58	typical
G	5	5	63	typical
G	5	6	68	typical
G	5	7	68	typical

Data for Reliability Content H: Auditory 95th Percentile				
Info Code	**Day**	**Dep Time**	**TT (min)**	**Type of Day**
H	1	1	40	typical
H	1	2	46	typical
H	1	3	50	typical
H	1	4	51	typical
H	1	5	55	typical
H	1	6	55	typical
H	1	7	59	typical
H	2	1	55	moderate
H	2	2	64	moderate
H	2	3	66	moderate
H	2	4	63	moderate
H	2	5	64	moderate
H	2	6	70	moderate
H	2	7	74	moderate
H	3	1	42	good
H	3	2	40	good
H	3	3	44	good
H	3	4	45	good
H	3	5	47	good
H	3	6	49	good
H	3	7	48	good
H	4	1	44	typical2
H	4	2	50	typical2
H	4	3	52	typical2
H	4	4	54	typical2
H	4	5	54	typical2
H	4	6	57	typical2
H	4	7	59	typical2
H	5	1	55	bad
H	5	2	69	bad
H	5	3	70	bad
H	5	4	63	bad
H	5	5	62	bad
H	5	6	63	bad
H	5	7	62	bad

EXPERIMENT #2 SCREENSHOT FOR TRANSITIONING PARTICIPANTS FROM WEEK TO WEEK



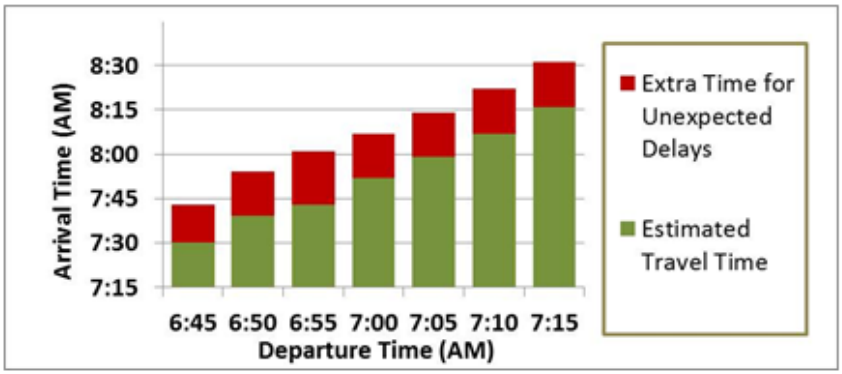
POST-EXPERIMENT PAPER SURVEY CONDUCTED IN HOUSTON AND CHICAGO

POST GAME SURVEY

Thank you for completing the traffic game! Below are a number of formats presenting different types of historic travel time information. Historic travel time information may be helpful in planning unfamiliar trips, particularly when on-time arrival is critical. For each format below, please tell us three things:

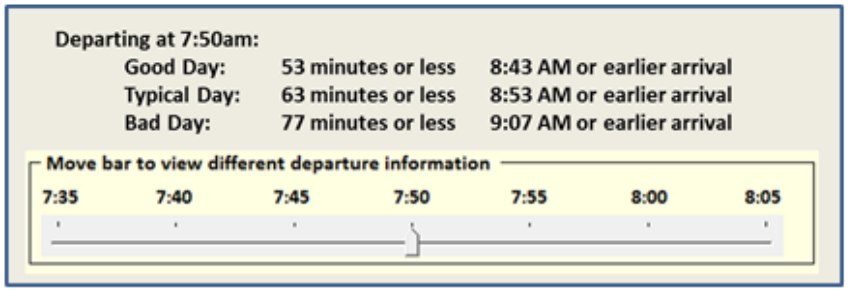
(1) How easily are you are able to understand information presented?
(2) How useful would this information prove when planning unfamiliar trips?
(3) How complicated is the information that is presented?

FORMAT 1: Historic Graph presenting estimated travel time, and extra time for unexpected delays



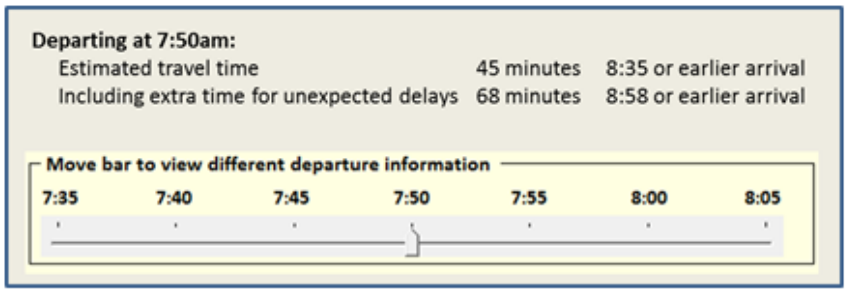
1a. How complicated is the information that is presented? 1 2 3 4 5 6 7
(1 = not complicated 4=neutral 7= very complicated)
1b. How easily are you are able to understand information presented? 1 2 3 4 5 6 7
(1 = very difficult 4=neutral 7= very easily)
1c. How useful would this information prove when planning unfamiliar trips? 1 2 3 4 5 6 7
(1 = not useful 4=neutral 7= very useful)

FORMAT 2: Historic Text with a slider bar for departure time presenting estimates for good, typical, and bad traffic days



2a. How complicated is the information that is presented? 1 2 3 4 5 6 7
(1 = not complicated 4=neutral 7= very complicated)
2b. How easily are you are able to understand information presented? 1 2 3 4 5 6 7
(1 = very difficult 4=neutral 7= very easily)
2c. How useful would this information prove when planning unfamiliar trips? 1 2 3 4 5 6 7
(1 = not useful 4=neutral 7= very useful)

FORMAT 3: Historic Text with a slider bar for departure time presenting estimated and extra travel time information

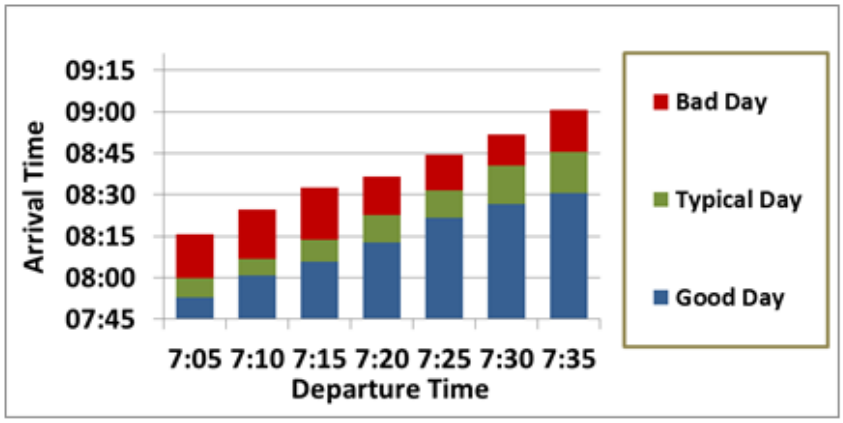


3a. How complicated is the information that is presented? 1 2 3 4 5 6 7
(1 = not complicated 4=neutral 7= very complicated)

3b. How easily are you are able to understand information presented? 1 2 3 4 5 6 7
(1 = very difficult 4=neutral 7= very easily)

3c. How useful would this information prove when planning unfamiliar trips? 1 2 3 4 5 6 7
(1 = not useful 4=neutral 7= very useful)

FORMAT 4: Historic Graph presenting arrival times for good, typical, and bad days

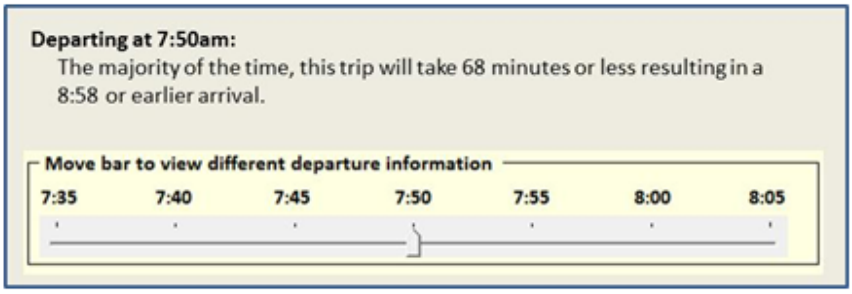


4a. How complicated is the information that is presented? 1 2 3 4 5 6 7
(1 = not complicated 4=neutral 7= very complicated)

4b. How easily are you are able to understand information presented? 1 2 3 4 5 6 7
(1 = very difficult 4=neutral 7= very easily)

4c. How useful would this information prove when planning unfamiliar trips? 1 2 3 4 5 6 7
(1 = not useful 4=neutral 7= very useful)

FORMAT 5: Historic Text with a slider bar for departure time, presenting travel time information

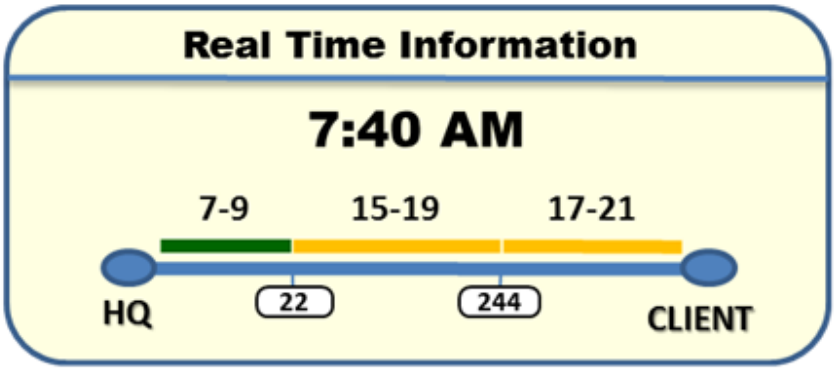


5a. How complicated is the information that is presented? 1 2 3 4 5 6 7
(1 = not complicated 4=neutral 7= very complicated)

5b. How easily are you are able to understand information presented? 1 2 3 4 5 6 7
(1 = very difficult 4=neutral 7= very easily)

5c. How useful would this information prove when planning unfamiliar trips? 1 2 3 4 5 6 7
(1 = not useful 4=neutral 7= very useful)

FORMAT 6: **REAL TIME** color coded lines presenting current travel time ranges



6a. How complicated is the information that is presented? 1 2 3 4 5 6 7
(1 = not complicated 4=neutral 7= very complicated)

6b. How easily are you are able to understand information presented? 1 2 3 4 5 6 7
(1 = very difficult 4=neutral 7= very easily)

6c. How useful would this information prove when planning unfamiliar trips? 1 2 3 4 5 6 7
(1 = not useful 4=neutral 7= very useful)