Driver Expectations When Navigating Complex Interchanges

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FOREWORD

Interchange navigation presents a range of challenges that are different from those associated with driving on continuous roads. For example, interchanges force drivers to make time-sensitive task demands (i.e., forced-paced tasks). More specifically, drivers at unfamiliar interchanges must read the available signage, observe pavement markings, and determine a path through the interchange before they reach the gore point. Additionally, driver errors at interchanges are often more difficult to correct since drivers may transfer to a grade-separated freeway, highway, or roadway that provides limited access points to return to the original roadway. Clear navigation signage is needed to guide drivers and reduce errors.

Although there has been previous research performed on signage in general, research specifically on interchange signage has been limited. There is little consensus on a best way to design signs for interchanges, and, in general, the current data on sign design is incomplete. The objective of this project was to begin addressing these information needs. This project yielded several overall conclusions related to driver expectations at complex interchanges. Namely, most drivers have problems at complex unfamiliar interchanges and feel stressed when they are surprised, are required to perform multiple lane changes in a short distance, or do not receive the information they expect. Several recommendations for sign designs are offered to help address these conditions. This report will be useful to traffic-safety researchers and traffic engineers responsible for highway design and public safety.

Monique R. Evans
Director, Office of Safety
Research and Development

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16. Abstract
The purpose of this project was to develop a method for determining driver expectations at interchanges and to use that method to determine how these expectations affect driver behavior at interchanges that vary in level of complexity, including provision of initial recommendations for navigation signage to aid complex interchange design. Interchange navigation presents a range of challenges that are different from those associated with driving on continuous roads, and driver errors at interchanges are often more difficult to correct since drivers transfer to a grade-separated freeway, highway, or roadway, which provides limited access points for their return to the original roadway. Clear navigation signage is needed to guide drivers and minimize errors. Although there has been previous research performed on signage in general, research specifically on driver expectations and interchange signage has been limited. Moreover, there is little consensus on a single best way to design signs for interchanges, and available data present an incomplete picture of guidance relevant to sign design.

This project involved multiple tasks to study driver expectations, including: (1) a literature review of prior work on driver navigation problems and driver expectations at interchanges, (2) a series of focus groups to collect qualitative information about driver expectations, (3) a task analysis of different interchange navigation scenarios, and (4) an experimental study to collect data on driver performance given various complex interchange signage alternatives.

This project yielded several overall conclusions related to driver expectations at interchanges. The focus groups indicated that most drivers have problems at complex, unfamiliar interchanges, and they become stressed when they do not receive the information they expect, if they are surprised, or required to execute multiple lane changes in a short distance. The task analysis indicated that multiple concurrent driving tasks may be common in complex interchanges, and could lead to higher workload. Finally, the empirical data collection activities showed, among other findings, that perceptual factors associated with the spatial layout of signs have a significant impact on driver interpretation of guidance information. The problems that drivers experience, and their responses to those challenges potentially have implications for safety and capacity at complex interchanges.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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EXECUTIVE SUMMARY

BACKGROUND

The focus of this project is on driver signing and marking expectations at complex interchanges. An *interchange* is defined as "a system of interconnecting roadways providing for traffic movement between two or more highways that do not intersect at grade."(pg. 15)[1] Some factors that contribute to interchange complexity include high mainline traffic volumes, dense spacing of ramps resulting in extensive use of auxiliary lanes, multiple lane changes needed for following a desired route, and rapid sequencing of driver decision points coupled with high driver attention demands, among other factors. Complex interchanges are often associated with uncommon vehicle maneuvers such as lane splits, lane drops, and left exits, which may be confusing to drivers.

Interchange navigation is a common driver task when traveling on freeways and highways, and it presents a range of challenges that are different from those associated with driving on continuous roads. Although there has been previous research performed on signage in general, research specifically on interchange signage has been limited. There is little consensus on a single best way to design signs for interchanges. In general, the data present an incomplete picture of guidance relevant to sign design, which suggests that a better understanding of driver expectations and actions at interchanges is required. The tasks in this project were designed to begin addressing these information needs.

OBJECTIVES

The purpose of this project was to develop a method for determining driver expectations at interchanges and to use that method to determine how these expectations affect driver behavior at interchanges that vary in level of complexity. This also included providing initial recommendations for navigation signage to aid complex interchange design.

PROJECT OVERVIEW

This project included multiple tasks to study driver expectations at complex interchanges. The primary data collection tasks included the following:

- **Task 2—Literature review**: A review of prior work on driver navigation problems and driver expectations at interchanges and intersections.

- **Task 4—Gather feedback from drivers**: A series of focus groups used to collect qualitative information about driver expectations from drivers.

- **Task 7—Collect experimental data about driver expectations at interchanges**: An experimental study conducted to collect data on driver performance given various complex interchange signage alternatives.

Some activities in this project were done in collaboration with the Texas Transportation Institute (TTI), which conducted research on improving signing and markings at complex interchanges as

part of a separate project. The key tasks from the current report are described in the following subsections.

Task 2—Literature Review

The objective of task 2 was to conduct a literature review of prior work on driver navigation problems and driver expectations at interchanges and intersections and identify the key issues. Task 2 focused on identifying relevant methods for investigating driver expectations for future project tasks (tasks 4 and 7). It was also used to gain an understanding of background literature on driver expectations.

Task 4—Gather Feedback from Drivers

The overall objective of task 4 was to collect qualitative information about driver expectations. Twelve focus groups in three metropolitan areas (Seattle, WA; Columbus, OH; and Washington, DC) were used to obtain driver opinions, thoughts, and beliefs about their expectations in complex interchange scenarios. In particular, the specific objectives of the focus groups were to obtain information about the sources of expectation-related problems that drivers encounter and the kinds of remedies that drivers suggest for these problems.

These objectives were addressed by having participants view dynamic scenarios comprised of video footage of a vehicle navigating a complex interchange and asking participants questions and engaging them in discussions at various points during the video drive. Each scenario began with participants being given an overview of the driving objectives for the scenario and any other relevant context (e.g., direction, etc.). The same video scenario was shown to participants three times. The first time was used to collect individual responses from participants without a group discussion. In particular, participants were shown the scenario video, which was paused at key points in the drive (referred to as "critical points"). These critical points corresponded to times or locations in which drivers needed to make key decisions, where they may have had difficulty, or where their expectations were of particular interest (e.g., after viewing a guide sign). During this pause, participants were asked questions, and they wrote down their answers individually. This process was repeated until all critical points within a scenario had been covered. In subsequent presentations of the dynamic scenario, the moderator engaged drivers in more detailed discussions of the various issues associated with each critical point.

Task 7—Collect Experimental Data about Driver Expectations at Interchanges

The objective of task 7 was to collect empirical data on driver performance given various complex interchange signage and marking alternatives. The basic approach involved using group data collection sessions to obtain information about driver lane preference responses and participants' interpretations of guide signs. A slideshow presentation showed static photographs of freeway backgrounds with overlaid fabricated interchange signs (similar to the method used by Chrysler et al.).[(2)] The participants were then asked specific questions about elements of the signs, lane selection, and lane permissions in relation to what was shown on the slide. A total of 183 licensed male and female drivers participated in the group data collection sessions in this study (84 males and 99 females). The ages of participants ranged from 18 to 76 years old (mean = 44.0 years and standard deviation (SD) = 15.2 years).

FINDINGS AND CONCLUSIONS

The conclusions are organized around the two primary objectives of this project, which involve answering the following questions: (1) how do expectations affect driver behavior and (2) what are the related recommendations for sign design?

How Do Expectations Affect Driver Behavior?

The activities conducted in this project provided information about several aspects of this question. These aspects are discussed in the following sections.

Definition of Driver Expectations

Based on the literature review, it was clear that the concept of driver expectations has not been thoroughly defined with specific regard to interchanges and common driver maneuvers at interchanges. However, this concept has received consideration with regard to broader driving tasks, and there are several existing definitions of driver expectations. The majority of definitions identified typically include some variation of the definition provided by Lunenfeld and Alexander that states that expectancy is "a driver's readiness to respond to situations, events, and information in predictable and successful ways."(pg. 153)[3]

Key Driver Expectations Regarding the Navigation of Complex Interchanges

The primary conclusions related to driver expectations come from the focus group discussions, which are presented in chapter 3 of this report. Some of the following conclusions are specific to individual scenarios covered in the focus groups, while others are relevant to more than one scenario:

- Drivers expect that there will be functional relationships between lanes on the roadway and arrows/text on signs and that the signs themselves will make these relationships clear.
- Drivers expect that the distance between a guide sign and a "last chance" decision point will be sufficient to allow for making any necessary lane changes in a safe and timely manner.
- Drivers expect that they will have more than one opportunity to obtain necessary destination and lane information before they need to make a final decision regarding lane choices.
- Drivers expect that the freeway system (i.e., lanes, arrows, signs with text, lane markings, etc.) will provide them with the necessary information to construct a mental model and that it will be sufficient to support timely and accurate decisions about lane choice.
- Drivers expect that the information available to them through the freeway system will be sufficient to support decisions about lane choices. At the least, they will never have to move over more than one lane at the last moment.

- Drivers expect that the freeway system will provide sufficient information to support decisions about all route choices, not just frequent or popular choices.

Key Challenges to Drivers

The task analysis indicated that drivers face several key challenges in interchange driving.[4] These challenges include the following:

- **Multiple concurrent visual activities:** Typically, on ramps and curves, drivers face multiple concurrent visual tasks. Performing these concurrent visual tasks likely involves switching between targets, and they require that drivers manage where they deploy their glances, which increases workload. Drivers may also be forced to take shortcuts (i.e., only reading part of a sign), or make decisions with less thought and deliberation than they may prefer.

- **The time limited nature of interchange driving:** A key problem for drivers is having sufficient time to make sound decisions in some of the more time-limited situations. In particular, some decisions must be made quickly in relation to other tasks, such as reading signs and managing traffic interactions, which can interfere with decisionmaking. Another challenge is the time limitations imposed by interchange geometry, such as sight-distance restrictions and lane drops/gore points. These elements are fixed in time and space for drivers, and they place limits on the time available to conduct intervening activities. While drivers always have the option of slowing down to give themselves more time, this is yet another decision. Also, many drivers feel social pressure to keep up with traffic, and several drivers reported in the focus groups that they would rather miss their exit and double-back when faced with time-pressure conditions.

- **Managing and interpreting navigation information:** Driver navigation expectations for less common destinations may be significantly more complicated to understand. More specifically, drivers have to keep track of more information to determine where to go in absence of direct navigation information. This not only requires drivers to work harder to manage the navigation information, but it also makes it more likely that drivers will make incorrect decisions. The task 4 focus groups indicated that drivers expect signs to provide sufficient information to support decisions about all route choices, not just frequent or popular destinations.

What are the Key Recommendations for Sign Design?

The following subsections summarize the key conclusions and findings regarding recommendations for sign design that were identified in this project.

Key Design Principles and Guidance from Existing Research

One outcome of the task 2 literature review was an initial set of key design principles. The "Results" section in chapter 2 of this report provides additional details about specific steps that can be taken to address each design principle. The initial set of key design principles includes the following:

1. Provide adequate forward sight distance.
2. Provide transition cues.
3. Minimize attention-dividing conditions.
4. Provide navigation information to address all of the driver information needs.
5. Maintain compatibility between the interchange and the visual cues.
6. Design to accommodate the drivers' expectations and abilities.
7. Warn drivers of situations that may violate their expectations.
8. Allow drivers to recover after making an error.
9. Design for simplicity.
10. Design for consistency and predictability.

The task 7 empirical activities yielded several findings that support the development of specific recommendations for guide sign design. The spatial organization and layout of guide sign information have an important influence on driver interpretation of signs and their expectations of upcoming interchange geometry. The most consistent finding from task 7 is that perceptual factors related to the organization of information on a sign influence how drivers interpret the sign. The focus group discussions also provided similar findings. These perceptual factors can involve the layout of informational elements, how sign elements are grouped, and/or the position of the sign on the sign bridge. The data suggest that some drivers formed strong expectations based on the arrangement of sign information in certain situations. Also, there is evidence from this same topic that drivers confused left-exit panels with exit only panels when those panels were located on the right side of a sign bridge. This suggests that the expectations that drivers had related to sign position biased their understanding of the sign. Under time-constrained driving conditions, these expectations can influence their reading of signs. Other specific findings related to the influence of perceptual factors are discussed in the chapter 4.

Understanding the perceptual factors that influence guide sign interpretation is important because they represent attributes that can be exploited to make signs more useful to drivers. However, if signs are designed without proper consideration of these factors, it could also lead to unnecessarily complicated or confusing guide signs. This is especially important for complex interchanges because signs typically communicate more information, the interchanges are more

likely to be unique and unfamiliar to drivers, and the interchanges are uncommon and are more likely to involve atypical geometric elements.

Up arrows yield consistently better results than down arrows in terms of accurate driver understanding of permissible interchange movements and efficient option-lane usage. In topics 1, 2, and 4 (as part of the seven topics in task 7), up arrows led to more efficient option lane usage or better comprehension of permissible movements when compared to down arrows. Up arrows differ from down arrows in multiple ways. They often have a clearer visual alignment with a single roadway lane. The movement information can be inherent in the arrow (e.g., curved to the right for a right exit, straight for the through destination). Additionally, since the curvature of the arrow can vary according to destination direction, up arrows can be grouped with other up arrows pointing in the same direction (e.g., to indicate that both an option lane and an exit only lane lead to the same destination). Overall, these findings suggest that drivers require additional or specific information about option lanes and the movements they represent and that up arrows can be used more effectively to provide this option lane information.

An aspect of sign comprehension that was examined in this study was how drivers visually group destination information with other sign elements and particular roadway lanes. A key sign element used for communicating which information goes together is the type of separator used to divide destination labels on the sign. Three separators were investigated in this study: vertical lines, hyphens, and multiline separations. In addition to these, data suggest that the presence of an exit only panel—and more specifically, the space it occupied along the bottom of the sign—may also have acted as a visual separator. The results for the various separators include the following:

- Vertical lines caused drivers to associate the destination on either side of the line with only the lane below the destination label. This separator appeared to supersede the effects of an exit only panel that spanned the entire sign width.

- Hyphen separators had mixed results. When used with an exit only panel that spanned the entire sign width, hyphen separators were predominantly interpreted as indicating that both lanes go to both destinations. When used with an exit only panel that only spanned the rightmost of two exiting lanes, the hyphen separator caused some drivers to associate each destination with only the lane immediately below it.

- Multiline separators did not function as a separator at all; rather, they led drivers to group both of the destinations with both of the lanes that they were centered above. This type of grouping was best for pairing multiple destinations with the same information. This happened regardless of the style of exit only panel used.

It is clear that separation cues influence how drivers associate destination information with specific lanes. Although these elements were not tested exhaustively or necessarily in isolation, these findings demonstrate the importance of the choice of separator, as each led to different expectations for the upcoming roadway, particularly when used in conjunction with an exit only panel. Additionally, the exit only panel itself deserves consideration as a separator since it appeared to influence how drivers grouped destination information with lanes.

Key Recommendations

Based on the work conducted in this project, the following recommendations were made for follow-up activities, which can be used to gain an understanding of driver expectations at complex interchanges:

- Conduct additional research to obtain a more complete understanding of the influence of perceptual factors on guide sign interpretation.
- Systematically apply methodologies to additional interchanges with existing navigation challenges.
- Conduct new research to understand why up arrows are more effective at communicating permissible lane information.
- Use new information from the current project to update the human factors design guidelines for *Human Factors Guidelines for Road Systems*. [5]
- Develop a work plan for using the Second Strategic Highway Research Program (SHRP2) naturalistic driving data to validate the initial findings related to driver interpretations of and expectations at complex interchanges.

CHAPTER 1. INTRODUCTION

The purpose of this project was to develop a method for determining driver expectations at interchanges and to use that method to determine how these expectations affect driver behavior at interchanges that vary in level of complexity. This also includes providing initial recommendations for navigation signage to aid complex interchange design.

BACKGROUND

The focus of this report is on driver signing and marking expectations at complex interchanges. An *interchange* is defined as "a system of interconnecting roadways providing for traffic movement between two or more highways that do not intersect at grade."(pg. 15)[1] Some factors that contribute to interchange complexity include the following:

- High mainline traffic volumes.
- Dense spacing of ramps resulting in extensive use of auxiliary lanes.
- System (freeway to freeway) interchanges with service (freeway to roadway) interchanges closely adjacent to and/or nested within the functional limits of the system movements.
- Multiple lane changes needed for following a desired route.
- Rapid sequencing of driver decision points coupled with high driver attention demands.
- An egress-type movement to the left or right for continuing on the designated route.
- Maneuvers that may be contrary to driver expectations or directional intuition.

Complex interchanges are often associated with uncommon vehicle maneuvers, such as lane splits, lane drops, and left exits, which can cause confusion among drivers.

Interchange navigation is a common driver task when traveling on freeways and highways, and it presents a range of challenges that are different from those associated with driving on continuous roads. One problem with interchanges is that drivers are confronted with time-sensitive task demands (i.e., forced-paced tasks). More specifically, drivers at unfamiliar interchanges must read the available signage, observe pavement markings, and determine a path through the interchange before they reach the gore point. As an additional source of stress, driver errors at interchanges are often more difficult to correct since drivers transfer to a grade-separated freeway, highway, or roadway which provide limited access points for their return to the original roadway. These factors emphasize the need for clear navigation signage to guide drivers and minimize errors.

Although there has been previous research performed on signage in general, research specifically on interchange signage has been limited. There is little consensus on a single best way to design signs for interchanges. In general, the data present an incomplete picture of guidance relevant to

sign design, which suggests that a better understanding of driver expectations and actions at interchanges is required. The tasks in this project were designed to begin addressing these information needs.

OBJECTIVES

The specific objectives of this project were as follows:

- Develop a method for determining driver expectations at interchanges and use that method to determine how these expectations affect driver behavior at interchanges that vary in level of complexity.

- Develop recommendations for navigation signage to aid complex interchange design.

PROJECT OVERVIEW

This project included multiple tasks to study driver expectations at complex interchanges. The task outcomes are summarized below with a brief description as follows:

- **Task 2—Literature review:** A review of prior work on driver navigation problems and driver expectations at interchanges and intersections.

- **Task 3—Focus group protocol:** A protocol for acquiring information from drivers about their expectations at interchanges and about the problems they encounter when navigating complex interchanges.

- **Task 4—Gather feedback from drivers:** A series of focus groups used to collect qualitative information about driver expectations from drivers in accordance with the task 3 protocol.

- **Task 5—Task analysis:** A task analysis of different interchange navigation scenarios used to provide information that, together with other task information, can be used to determine driver expectations at interchanges.

- **Task 6—Data collection plan:** A plan for collecting empirical data on driver performance given various complex interchange sign and marking alternatives.

- **Task 7—Collect experimental data about driver expectations at interchanges**: An experimental study to collect data on driver performance given various complex interchange signage alternatives in accordance with the task 6 plan.

Note that some of the activities in this project were done in collaboration with TTI, which conducted related research on improving signing and markings at complex interchanges as part of task 6.

Figure 1 shows the relationships between the project tasks (blue) and the project objectives/ outcomes (orange). Tasks 2, 3, and 6 were mainly used for planning other tasks and gaining background information about the issues of interest. Tasks 4, 5, and 7 were data collection tasks.

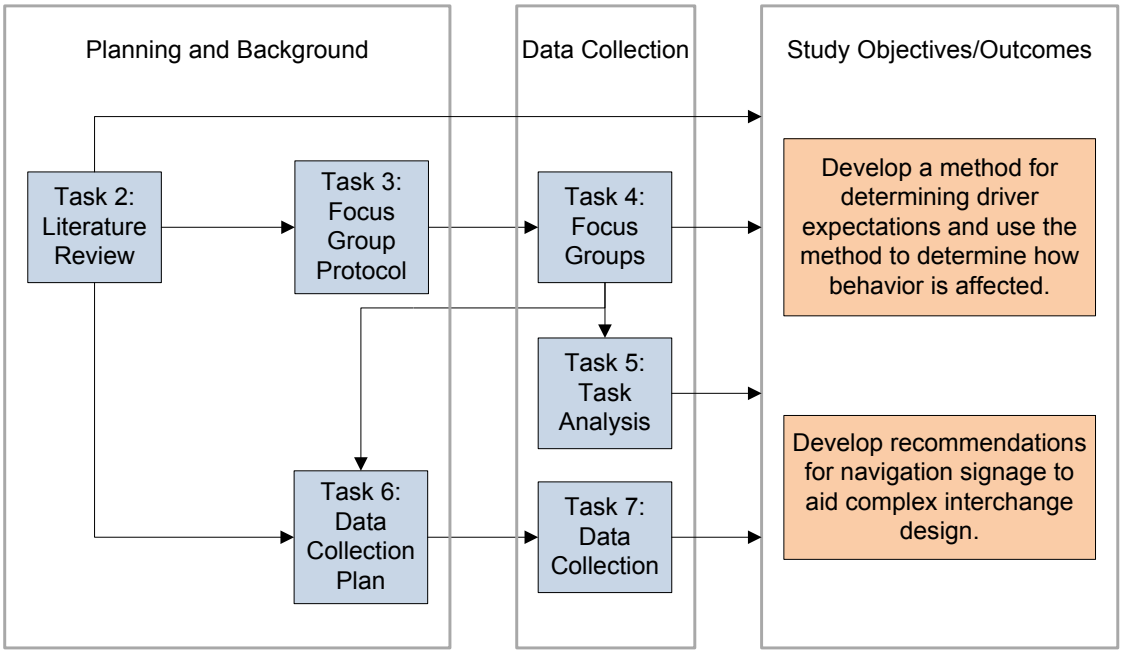


Figure 1. Illustration. Overview of study tasks and information flow between tasks.

Each of the links in figure 1 represents a contribution that one task made to the following task. These relationships are further discussed by task in the following sections.

Task 2—Literature Review

The project began with a literature review. Through this review, a list of geometries and expectation elements that can be challenging to drivers at interchanges was created. These geometries and expectation elements were used to search for candidate scenarios in the task 3 focus group protocol. Task 2 was also used to contribute the methodology to the task 6 data collection plan. In addition, task 2 contributed directly to the study outcomes by providing a summary of existing design principles and guidance for designing roadway elements that conform to driver expectations.

Task 3—Focus Group Protocol

The scenarios developed in the task 3 focus group protocol incorporated the geometries and interchange elements associated with driver expectations identified in the literature review. These were used in addition to the complexity factors identified in the TTI project.[(6)] The task 3 outputs included a moderator guide, dynamic scenario videos, and a response booklet for the task 4 focus groups.

Task 4—Gather Feedback from Drivers

The focus group activities provided inputs for several tasks and contributed directly to the overall project objectives of identifying driver expectations at interchanges. Specifically, the key themes related to driver navigation strategies from the focus groups led to the formulation of the driver navigation model in the task 5 task analysis. Drivers in the focus groups provided details about

driver strategies for using the information that they read, filling in information that they needed, and creating new expectations. Additionally, focus group comments validated the driver activities and provided the specific scenarios and key maneuvers used in the task analysis.

Some of the driver challenges or interesting expectation trends identified in the focus groups were incorporated into the data collection plans developed in task 6. These plans also utilized some of the guide signs identified as being problematic in certain driving scenarios discussed in the focus groups.

Task 5—Task Analysis

The task analysis primarily contributed to the study objectives by providing information about how various interchange elements affect driver tasks and performance and by identifying the key driving challenges during specific interchange navigation scenarios. The results of this analysis are included in a separate report.[4]

Task 6—Data Collection Plan

The task 6 data collection plan was developed using a methodology identified during the literature review, and it used several of the signs that gave drivers problems during the focus group driving scenarios. Candidate topics were selected in conjunction with TTI as part of their driving simulator scenario development activities done in parallel with this project.[6]

Task 7—Collect Experimental Data about Driver Expectations at Interchanges

The task 7 data collection primarily contributed to the study objectives by measuring driver behavior in relation to specific sign elements and determining very specific relationships between navigation sign elements and driver decisions.

OVERVIEW OF REPORT

This report provides a description of the tasks, activities, and results of the literature review, focus groups, and data collection activities conducted in this project. The body of this report contains the following three chapters, one for each of these tasks:

- Chapter 2: Task 2—Literature Review.
- Chapter 3: Task 4—Focus Groups.
- Chapter 4: Task 7—Collect Experimental Data about Driver Expectations at Interchanges.

The technical chapters are followed by an overall “Conclusions and Recommendations” chapter and report appendices.

CHAPTER 2. TASK 2—LITERATURE REVIEW

The objective of task 2 was to conduct a literature review of prior work on driver navigation problems and driver expectations at interchanges and intersections and identify the key issues. This chapter provides a summary of the findings of this literature review. Task 2 was conducted to identify relevant methods for investigating driver expectations for future project tasks. It was also used to gain an understanding of the background literature on driver expectations.

This chapter contains three technical sections:

- **Task 2 Methods**: Provides an overview of the methods that were used to find the source documents to review and describes how the reviews were conducted.

- **Task 2 Results**: Provides a detailed discussion of the definition of driver expectations, driver expectation findings related to specific roadway elements, listings of applicable variables that were used in reviewed sources to collect information about driver expectations at interchanges or related topics, and a summary of how information about driver expectations has been applied in terms of design guidance.

- **Task 2 Conclusions**: Discusses the research gaps that can be filled, possible criterion for selecting interchanges, and potential scenarios for use in future tasks.

TASK 2 METHODS

This section describes the methods used to conduct the literature search and summarizes the resulting source information.

Literature Searches

The literature search began with defining keywords to find sources containing information regarding driver expectations and behavior at interchanges. As a part of the *Human Factors Guidelines* project, a number of terms were found that appear to be the most efficient at distinguishing research related to human factors and safety.[7] The four terms identified include human factors, driver behavior, driver behaviour, and driver performance. These terms were used in the initial literature search to narrow the results to those relevant to the driver. Note that much of the existing human factors research related to interchanges involves signage. Given that this topic was the focus of task 6—and comprehensively reviewed as part of that project—the researchers limited their inclusion of signage research to those studies that directly addressed driver expectations.

All of the searches were performed in the Transportation Research Information Services database. An initial search of the keywords “driver expectations” and “interchange” did not produce any relevant documents. As a result, the search terms were broadened, and a search was conducted using general terms to look for driver-relevant information at interchanges. Following this search, another search was performed to narrow the results to driver expectations and driver information needs at interchanges. Table 1 shows the search keywords that were used and the number of results that were obtained.

Table 1. Keywords used and number of records returned for literature searches.

Search Number	Keywords	Number of Records
0	"driver expectations" AND "interchange"	0
1	"interchange" AND ("human factors" OR "driver behavior" OR "driver behaviour" OR "human behavior" OR "human behavior" OR "driver performance" OR "human performance")	241
2	"interchange" AND driver AND ("confusion" OR "expectations" OR "expectancies" OR "information")	93 (50 records not included in search #1)

After conducting the searches, the researchers broadened the scope and reviewed some sources regarding driver expectations without focusing on interchanges. An initial search was performed using the PsycInfo database; however, no relevant results were found. General references containing information about driver expectations were found through references provided by existing sources and general Web searches.

Upon obtaining the search results, the titles and abstracts were thoroughly inspected, and articles that were clearly not related to the topic were removed from the lists. The remaining relevant documents were ordered or downloaded from the Internet for closer review.

Finally, while conducting the literature review, any secondary research sources cited in reviewed documents that seemed relevant to driver expectations were reviewed as well.

Structured Literature Review Forms

The general approach used to summarize the literature was based on literature syntheses that were conducted in past projects that involved using structured review forms to identify key information from research sources. (See references 8–11.) In particular, these structured review forms typically contain fields to capture information about dependent and independent variables, useful methodological approaches, and summaries of key findings and conclusions. A concise, structured review form was developed and is shown in figure 2.

Document:	
Method/Study Type:	
Configuration:	Driver Expectation Elements:
General Approach:	
Methods:	
Independent Variables:	
Dependent Variables:	
Study Findings and Conclusions:	
Other Information:	
Caveats/Comments:	

Figure 2. Illustration. Structured review form.

The top two rows of the form include space to fill in general descriptive information about the source such as the full document reference and the study type. The third row contains two fields that can be used to classify the reviews. "Configuration" refers to the primary geometry that was examined in the study, while "Driver Expectation Elements" refers to any elements of the roadway environment that have been shown to potentially violate driver expectations (e.g., ramp spacing, guide signing/markings, route continuity, etc.). This field also provides an indication of the applicable engineering elements of the research (i.e., signs, markings, or geometry). The fourth line labeled "General Approach" provides a concise overview of the purpose of the study, while the fifth line labeled "Methods" describes the study methods in appropriate detail. Since

one of the subgoals of this task was to examine the available methods for gathering expectation data from drivers, some of the reviews focused on the methodology used without providing findings or conclusions. In these cases, the methods are contained in the "Study Findings and Conclusions" section of the form. Another sub-goal of this task was to formulate and quantify the independent and dependent variables that can provide useful information about driver expectations. Therefore, the independent and dependent variables each have a corresponding section on the form. The remainder of the form is devoted to the findings, conclusions, and other information. At the bottom, there is a place for describing any comments related to the applicability of the particular source or caveats regarding the research method.

TASK 2 RESULTS

This section presents a summary of the results that were found in the sources examined during the literature review. These results are presented in four sections. The first section includes definitions of driver expectations from the research sources. The second section includes a summary of how empirical findings relate to specific interchange elements. The third section lists the independent and dependent variables used to measure expectations in the sources reviewed during the literature search. Finally, the fourth section provides a summary of how findings related to driver expectations have been incorporated in existing design guidance.

Definition of Driver Expectations

One of the objectives of the literature review was to try to provide a clear definition of the term "driver expectations," and to describe the implication that these expectations have for driver behavior, performance, and decisionmaking.

Based on the literature review, it was clear that the concept of driver expectations has not been thoroughly defined with specific regard to interchanges and common driver maneuvers at interchanges. However, this concept has received consideration with regard to broader driving tasks, and there are several existing definitions of driver expectations.[12,3,13] The majority of the definitions typically include some variation of the comprehensive definition and are provided by Lunenfeld and Alexander.[3] They define expectancy as "a driver's readiness to respond to situations, events, and information in predictable and successful ways."(pg. 153)[3] Attributes of driver expectations are as follows:[3]

- Expectancy influences response speed and accuracy.
- Drivers tend to anticipate upcoming situations and events that are common to the road they are traveling.
- The more predictable the roadway feature, the less likely will be the chance for errors.
- Drivers experience problems when they are surprised.
- Drivers, in the absence of counter evidence, assume that they will only have to react to standard situations.

- The roadway and its environment upstream of a site create an expectancy of downstream conditions. Drivers experience problems in transition areas and locations with inconsistent design or operation.

- Expectancies are associated with all levels of driving performance and all aspects of the driving situation. This includes expectancies relative to speed, path, direction, the roadway, the environment, geometric design, traffic operations, and traffic control devices.

Other researchers have added other useful aspects to this definition. These include elements such as the formation of expectations and the impact of expectations at different levels of the driving task. Expectations are formed from the following two processes:[14,15]

- Long-term expectancies are based on the driver's mental model and arise from experience and education (e.g., all vehicles will travel in the same direction).

- Short-term expectancies are based on long-term expectancies but include recent situational information (e.g., vehicle location of adjacent vehicle in the next moment).

The following list includes various forms of expectations that are required while driving:[14]

- **Control**: Vehicle lateral control, speed, and road tracking.

- **Guidance**: How the driver travels the roadway, responds to traffic, selects a safe path, and perceives and avoids hazards. Guidance also includes how the driver reacts to and uses information, decisionmaking, and overall driving strategies.

- **Navigation**: Pre-trip planning, route choice, in-trip route diversions, use of route markers and guide signs, selection of interchange exits, and locating destinations.

For the most part, the items apply reasonably well to interchange driving situations. Together, these elements provide a broad view of how driver behavior may be affected by driver expectations at interchanges. This formulation of driver expectations was used in this project.

Driver Expectations Related to Roadway Elements

This section summarizes empirical findings about driver expectations related to specific interchange elements. The findings are organized by type of performance measure rather than by interchange element because of certain limitations regarding the interpretation of results.

In general, few on-road/simulator study results were found that directly address driver expectations regarding a specific roadway element. Consequently, researchers can only indirectly make inferences about driver expectations based on driver behavior, such as the number of missed exits or decision sight distances. In particular, differences in driver performance associated with these factors can indicate that the driving situation has matched or contradicted the driver's expectations of the situation. For example, a sign that systematically causes drivers to make required lane changes at the last possible second might contribute to drivers having incorrect expectations about which lane they should occupy. However, the same performance

differences can also reflect problems with sign comprehension, reading time, or personal preference. The same late lane changes could also occur if it takes drivers longer to read and comprehend the sign, which likely has little to do with incorrect driver expectations.

Fisher et al. acknowledged this problem with interpreting performance results in terms of driver expectations. Specifically, they noticed that the driver's motives behind lane changes are not well understood.[16] For example, drivers may change lanes toward the mainline to get out of the way of exiting drivers, or they may prefer not to use an option lane to ensure that they do not miss their exit. In fact, the authors found that drivers change lanes as a factor of conservative behavior rather than a misunderstanding of the meaning of the sign.[16] They suggested that until drivers gain experience with a particular configuration, the effect of modifying the signage would be difficult to evaluate.

Keeping this caveat in mind, there is still information about driver expectations that can be implied from existing research. One study tested signage for two-lane exits with option lanes in which drivers were asked to take the lane necessary to reach their destination.[17] They found that the proportion of unnecessary lane changes (generally lane changes out of the option lane) was significantly higher when the destination was an exit rather than the mainline. This suggests that drivers expect to need to be in the lane closest to the exiting direction to be able to exit. However, as previously stated, drivers may have other unknown motives for their lane changes.

Some research sources used driver confidence as an indirect measure of expectation.[17,2,18] The basic logic is that drivers should be more confident in a decision if it matches their expectations. In the signage study performed by Chrysler et al., participants were asked which lane(s) would take them to their destination and how confident they were in their decisions.[2] In general, the signs that caused the highest percentage of correct lane choices also were assigned the highest confidence scores by participants. Some of the signs that were tested, however, received high confidence scores for one of the traffic movements (e.g., the through traffic condition) but not the alternative traffic movement (e.g., the exiting traffic condition), which suggests that drivers form expectations for individual traffic movements rather than for all information presented on the sign as a whole. In another study of central business district signage performed by McNees, the message that drivers expected to see was often the same as the message that drivers preferred to see.[19]

A common theme throughout the reviewed sources was that violated expectations cause longer response times and more incorrect responses. In one study examining lane drop markings, the installation of markings led to a significant decrease in lane changes, a decrease in erratic maneuvers, and earlier lane changes overall, which could be interpreted as the sign improving the drivers "readiness" to respond and make decisions.[20] In another study of lane drop signage, it was found that 58 percent of participants expected a lane drop to occur even when no lane drop panel was present.[18] This result could be due to the fact that lane drops were the focus of the study, or it could indicate a true trend in terms of driver expectations at freeway exits.

Driver expectations also impact driver information acquisition. Borowsky, Shinar, and Parmet studied the eye gaze of drivers while they viewed "No Right Turn" and "No Left Turn" signs in expected and unexpected locations.[21] They found that experienced drivers identified the signs more accurately than inexperienced drivers when the signs were located in the expected location.

However, when the sign location did not match the expectations of the experienced drivers, their identification accuracy was worse than the inexperienced drivers. Experienced drivers seem to rely on their expectations and may be less likely to notice information in unexpected locations. "It was concluded that drivers should be warned when signs are placed in unexpected locations.

The empirical finding regarding driver expectations are summarized as follows:

- Drivers expect to need to be in the lane closest to the exiting direction to be able to exit.[17]
- Drivers expect lane drops at exits.[18]
- Signs and lane markings appear to be effective ways to set driver expectations at interchanges.[20]
- Driver expectations impact driver information acquisition.[21]

As discussed at the beginning of this section, another important finding that must be acknowledged is that driver expectations are sometimes difficult to disentangle from driver motivations, performance factors (e.g., reading distance), preferences, and familiarity, among other factors. This suggests that the types of approaches may be less suitable for the current project than approaches that ask drivers directly about their expectations about interchange driving.

Variables

This section provides lists of all of the independent and dependent variables that were used to measure driver expectations in the sources reviewed during the literature search. The variables generally relate to signage, markings, or geometry. These variables were considered in project activities related to identifying candidate empirical methods for task 7 data collection.

Independent Variables

Table 2 lists the dependent variables that were used in the source documents. These variables are categorized by variable type (i.e., sign-related, markings-related, or geometry-related variable).

Overall, these variables mainly relate to the specifics of the driving environment as presented to the participants. Variables of this nature include the type of stimulus presented (e.g., signs and markings), qualities of that stimulus, and the geometry of the scenario. Other miscellaneous variables include those related to the participants (e.g., experience level) and the scenario in general (e.g., traffic volumes).

Table 2. Independent variables found during the literature search categorized by variable type.

Variable	Reference
Variables Related to Signs	
Destination (mainline or exit)	16 and 17
Driver experience level	21
Original lane position	16 and 17
Sign location (right or left side of the road)	21
Sign location (with reference to the interchange)	19
Sign message (words, symbols, plaques, etc.)	18, 19, and 21
Sign position (over left or right lane)	18
Sign type (conventional, diagrammatic, etc.)	2, 17, 18 and 22–25
Variables Related to Markings	
Type of pavement markings	19, 23, and 25
Variables Related to Geometry	
Exit direction	24
Interchange geometry, including exit geometries	2 and 26
Interchange spacing	27
Number of exiting lanes	24
Overall scenario picture	15
Presence of option lanes	24
Side of lane reduction (left or right)	25
Traffic volumes	26 and 27

Dependent Variables

Table 3 lists the dependent variables that were used in the source documents. These variables are categorized by the main focus of the study (i.e., evaluate signage, markings, or geometric aspects).

Overall, the variables relate to three types of measurements used to record driver behavior and expectations. The three types of measurements include the following:

- **Driver errors:** Number of missed exits, unnecessary lane changes, erratic maneuvers, etc.
- **Operational measures**: Lane change distance, response time, vehicle speed, etc.
- **Subjective driver measures**: Sign expectations, certainty of choice selection, and difficulty of sign comprehension.

Table 3. Dependent variables found during the literature search categorized by study type.

Variable	Reference
Sign Evaluation Studies	
Choice/response correctness	2, 18, 23, and 24
Decision sight distance	24
Lane change distance (first and final)	17 and 22
Number of fixations on the target	21
Number of missed exits	16 and 17
Number of switchbacks (lane change and then return to the initial lane)	22
Number of unnecessary lane changes	16 and 17
Response time	18 and 19
Sign expectation (which sign drivers expect)	19
Sign identification accuracy	21
Sign preference (which sign drivers prefer)	19
Subjective certainty of choice correctness	2, 17, 18
Subjective difficulty of sign comprehension	17
Markings Evaluation Studies	
Number and location of lane changes	20 and 25
Number, location, and type of erratic maneuvers	20
Traffic volumes	20
Geometric Evaluation Studies	
Crash frequency	27
Groupings of "if, then" statements (card sort)*	15
Labels for card groups (card sort)*	15
Lane change location	28
Lane position	26
Number of lanes crossed during a lane change	28
Responses to expectation questions (what participants expect and why they expect that)	15
Speed	26

*"Card sort" refers to an experimental methodology where participants sort cards printed with statements into piles of similar statements and then name each pile.

Applications of Expectations Research

Several of the sources that provided information about expectations were based on literature reviews, analytical reviews, observational data, or expert judgment. The findings from these reports often involved design principles or guidance that was relevant to the overall objectives of the project, including developing recommendations for navigation signage to aid complex interchange design. Some of the design guidance identified applied broadly to roadway design, general interchange design, and specific roadway elements. The following list provides a compilation of the most relevant design information categorized under broad themes that were seen across sources.

The principles refer to driver expectations as well as the related categories of design consistency and interchange design:

1. Provide adequate forward sight distance.

    - Continuous visual cues should be provided before a lane reduction.[29]
    - Sightline restrictions should be avoided.[3]
    - Sight distance is required due to the reliance on visual information and for complex decisionmaking.[30]
    - Visibility should be proportional to feature criticality.[31]

2. Provide transition cues.

    - Provide a taper at lane reductions that allows for a smooth transition and informs the driver that the lane is ending.[29]
    - Look for possible expectancy violations where changes in roadway characteristics (e.g., geometrics, design, or operation) or changes in operating practices (e.g., speed zones, no passing zones, or signal timings) occur.[3]
    - Provide adequate transitions.[31]

3. Minimize attention dividing conditions.

    - Resolve conflicts when information sources compete.[30]
    - Use spreading by moving less important information upstream or downstream.[30]

4. Provide navigation information to address all of the driver information needs.

    - Appropriate signing is needed to guide drivers.[32]
    - Drivers expect in-trip cues and services to guide them.[12]
    - Drivers expect the roadway information to tell their current location and provide information to help them to their destination.[12]
    - If drivers need to change course during a trip, they expect to be provided with the necessary information to do so.[12]
    - Navigation information should satisfy all driver information needs.[30]
    - Information-related error sources should be eliminated. Deficient, ambiguous, confusing, missing, misplaced, blocked, obscured, small, illegible, or inconspicuous displays should be avoided.[30]

- Interchange information should not be so far upstream that it is forgotten by the time that the interchange is reached (may require repetition.[30]
- All available navigation aids and treatments should be used.[30]
- For lane drops with option lanes, the following should be clearly communicated:[17]
    - The right lane can only reach the exit.
    - The option lane leads to either the exit destination or the mainline.
    - Any other lane only reaches the mainline.
    - The identifying information for each destination (e.g., street name, destination name, etc.).

5. Maintain compatibility between the interchange and the visual cues.
    - Create lane reduction transitions on the better side of the freeway for the observed traffic and geometric conditions.[29]
    - Coordinate visual and operational transitions; disguise the operational reduced lane upstream from the physical drop so that the lane appears to be physically dropped (even if the pavement for the lane exists beyond the transition.[29]
6. Design to accommodate the drivers' expectations and abilities.
    - Expectancies occur with all driving task levels and driving phases.[14]
    - Drivers experience problems and make errors when their expectations are violated.[14]
    - Drivers believe that the roadway will not mislead or confuse them.[12]
    - Be aware of features that drivers may find unusual or special.[3]
    - Information that reinforces expectancies helps drivers respond faster, whereas information that violates expectancies leads to longer task times and/or errors.[30]
    - Be responsive to task demands and driver attributes; avoid overloading the driver too much or too little processing demand.[30]
    - Design for drivers and target populations.[30]
    - Design to give the driver what he expects to see.[31]
7. Warn drivers of situations which may violate their expectations.
    - Structure driver expectations through advanced warning.[14]

- At a lane reduction, notify drivers that the lane is not continuous.[29]

8. Allow drivers to recover after making an error.

    - Provide adequate escape areas at lane drops.[29]

    - Provide a forgiving roadside at critical features.[31]

9. Design for simplicity.

    - For route continuity, provide a route on which changing lanes is not necessary to continue on the through route. It is better to have the greater number of lanes continue on the through route.[32]

    - For lane balance, arrange the traffic lanes (using auxiliary and option lanes) to minimize the required number of lane shifts.[32]

    - Provide adequate ramp spacing to allow for clear and simple guide signing and to prevent congestion from heavy traffic entering and exiting.[32]

    - Avoid creating compound geometric features.[31]

10. Design for consistency and predictability.

    - Drivers should not be surprised by the roadway elements or vehicle movements.[14]

    - Drivers anticipate based on elements common to the road they are on (i.e., transition locations and unexpected features cause problems.[14]

    - More predictable design and operation leads to fewer errors.[14]

    - Be aware of features that are unique to a particular roadway.[3]

TASK 2 CONCLUSIONS

Overall, the amount of research that was directly related to driver expectations was relatively limited. However, enough information was obtained to support the development of other tasks in this project by broadening the scope of research examined to include driver expectations and comprehension of roadway elements. The following sections discuss the information provided by the literature review related to priority research gaps, relevant criterion for choosing interchanges, and potential scenarios for future tasks.

Priority Research Gaps

From the examination of the source documents, it is clear that there are several issues that have not been fully resolved by the current research on driver expectations at interchanges. Two of the most important and apparent research gaps are described in the following subsections.

Isolation of Driver Expectations

From this literature review, it is evident that research results about driver expectations are intertwined with results on driver performance and behavior. This finding makes it difficult to draw direct conclusions about driver expectations unless the researchers explicitly asked the participants about their expectations. In general, this also suggests that several types of empirical approaches used in previous research were less suitable for this project than approaches that directly ask drivers about their expectations of interchange driving. In particular, for other project tasks, it was necessary to be clear with participants that the data being collected were directly related to their expectations about interchange driving.

Driver Expectations Related to Specific Roadway Elements

Another important research gap identified in the current research literature is that there is little research that specifically identifies driver expectations for specific interchange elements[1]. A tentative list of expectations was compiled in the results section of this chapter; however, those represented tentative findings had alternative explanations that did not necessarily involve driver expectations. What is needed is a more systematic approach to cataloging driver expectations at different points during interchange driving.

Useful Metrics for Selecting Interchanges

In addition to addressing topics already discussed in this chapter, the literature review also identified useful metrics for selecting the interchanges that were examined in other project tasks.

A key metric identified in some studies was interchange complexity. More specifically, in one study, ratings of complexity were assigned to a number of intersection scenarios to select those that would provide information about the complexity of interaction situations.(15) The six dimensions of complexity used in the study included number of interaction partners, number of types of interaction partners, number of intersection branches, the type of intersection (signalized or priority), the number of pieces of static information present, and which partner has the right of way. Some of these are applicable to interchanges. This topic was also examined in task 6, which provided a list of interchange features that appeared to be related to interchange complexity.(33)

Another available metric is the driver information load as presented by Lerner et al.(34) This metric focuses mainly on the information present in the driving environment in terms of signs, and it also incorporates the roadway demand. This metric could be used to determine the load for the driver at an interchange. One disadvantage is that this method does not have an all-inclusive way to account for elements that violate driver expectations.

A final metric is the use of the existing design principles and expectation checklist items that were found in the research. Candidate interchanges could be examined using these checklist items to determine how many principles are violated in a particular situation.

[1]The exception to this may be sign information, but this was covered in less detail in the current report since it is the focus of task 6.

Potential Scenarios for Focus Groups and Task Analyses

The literature review identified a variety of geometries and specific interchange elements associated with driver expectations (referred to as "expectation elements") that are useful to consider when developing scenarios for examining driver expectations. These components represent issues related to challenging situations at interchanges and include the following:

- Interchange spacing.
- System/service interchange.
- Lane drop.
- Exits.
- Multiple exit lanes.
- Option lanes.
- Splits.
- Left exit.
- Lane reduction.
- Entrance ramp.
- Weaving section.

Expectation Elements

Elements of interchange navigation where expectation-related issues may exist include the following:

- **Ramp spacing**: The spacing between entrance and exit ramps, including the consideration of collector-distributor roads.[32]
- **Guide signing/markings**: Signage and markings at the interchange.[32]
- **Route continuity**: Continuance on the main route should not require a lane change.[32]
- **Lane balance**: The arrangement of lanes to minimize the number of shifts, including the use of auxiliary and option lanes.[32]
- **Advance guide signing**: Signing installed ahead of the interchange.[32]
- **Sign consistency**: The uniformity of sign layout, legend, and materials through a corridor.[32]

- **Interchange spacing**: The separation of system and service interchanges.
- **Maneuver direction**: Maneuvers contrary to directional intuition (e.g., exiting toward the south to travel northbound).
- **Rapid decisions**: Rapid sequencing of driver decision points coupled with high driver attention demands.
- **Forced maneuvers**: Drivers are forced to exit the freeway or change their path due to a lane reduction or a lane drop.

This list represents a core set of scenario elements that were considered during the development of interchange driving scenarios for other project tasks.

Overall, the amount of information from existing research sources that was directly related to driver expectations was limited. However, by using relevant information from other research domains, it was still possible to find information about methods, variables, and other results that were useful for developing and conducting several of the remaining project tasks.

CHAPTER 3. TASK 4—GATHER FEEDBACK FROM DRIVERS

The overall objective of task 4 was to collect qualitative information about driver expectations from drivers in accordance with the methods outlined in the task 3 protocol. Twelve focus groups in three metropolitan areas (Seattle, WA; Columbus, OH; and Washington, DC) were used to obtain driver opinions, thoughts, and beliefs about their expectations in complex interchange scenarios. In particular, the specific objectives of the focus groups were to obtain information about the sources of expectation-related problems that drivers encounter and the kinds of remedies that drivers suggest for these problems. This includes aspects such as what makes drivers comfortable or uncomfortable in certain interchange scenarios. These objectives were addressed by having participants view video footage of a vehicle navigating a complex interchange and asking them questions and engaging them in discussions at various points during the video. An effort was also made to obtain information that could be used in future project tasks. This included asking drivers about their general strategies when navigating interchanges, specific actions they take, what type of information they look for when making certain decisions, and when and where they seek this information.

This chapter contains the following three technical sections:

- **Task 4 Methods**: Provides information about the focus group participants, procedures, materials, selected interchanges, and data analysis plan.
- **Task 4 Results**: Contains the results of the warm-up activity and summaries of all of the scenario discussions.
- **Task 4 Conclusions**: Discusses the main trends that were observed during the focus group sessions.

TASK 4 METHODS

This section describes the methods used to conduct and analyze the focus group data.

Participants

This section describes the general approach for selecting focus group locations and defining the participant demographic make-up of each session as well as the recruiting methods.

Focus Group Locations

The general approach for determining the focus group locations was to select locations that had large urban populations serviced by major freeway interchanges. Resources were set up to support participant recruitment and conduct the focus groups. This approach helped lower costs and reduce risks associated with having to conduct these activities remotely. Based on these requirements, the selected focus group locations were Seattle, WA; Washington, DC; and Columbus, OH. Four focus group sessions were held in each location.

Demographic Sampling Objectives

Each focus group session was comprised of up to 12 licensed adult drivers[2]. Individual focus group sessions were open to drivers of all age groups; however, researchers tried to balance age and gender in each. In particular, an approximately equal number of males and females was scheduled from each of the young (< 30), middle (30–55), and older (55+) driver age groups. Table 4 shows the actual demographic composition of the sessions.

Table 4. Demographic composition of each focus group.

Session	Women's Ages			Men's Ages			Total
	18–35	36–54	55+	18–35	36–54	55+	
Seattle, WA, April 19, 6 p.m.	2	2	2	2	1	2	11
Seattle, WA, April 21, 2 p.m.	2	1	1	1	0	2	7
Seattle, WA, April 21, 6 p.m.	0	2	2	2	2	2	10
Seattle, WA, April 22, 6 p.m.	1	2	2	1	2	2	10
Columbus, OH, April 27, 2 p.m.	1	2	2	1	2	2	10
Columbus, OH, April 27, 6 p.m.	2	2	2	2	2	2	12
Columbus, OH, April 28, 2 p.m.	1	2	2	1	2	2	10
Columbus, OH, April 28, 6 p.m.	1	2	2	1	2	1	9
Washington, DC, May 4, 2 p.m.	1	3	0	2	2	2	10
Washington, DC, May 4, 6 p.m.	2	1	2	1	1	1	8
Washington, DC, May 5, 2 p.m.	0	0	2	1	2	0	5
Washington, DC, May 5, 6 p.m.	1	2	2	2	1	1	9
Total	14	20	22	16	19	19	111

Print and online advertisements were the primary methods for recruiting drivers. Specifically, recruitment advertisements were posted in the following sources as needed: Craigslist®, local newspapers, and the contractor's driving study recruitment Web site.

One concern with the focus groups was that the number of participants in each session was expected to be relatively small (nine or less as originally planned). Small sessions run the risk of having a reduced diversity of viewpoints. This issue was addressed in two ways. The first was to include a mix of driver ages and genders in each session to promote differences in driving experience and strategies. The second was that group discussions were supplemented with individual written responses to key interchange driving questions. This provided additional data and reduced data transcription requirements.

Procedures and Materials

The primary data collection activity was the discussion of interchange scenarios using a dynamic scenario presentation (video-based), including individual discussion questions in a scenario response booklet. The following sections describe the primary data collection methods and corresponding materials that were used to present the focus group stimuli.

[2]The focus groups were planned under the assumption that no more than nine participants could be included in any one session. This limit was relaxed, yet the overall plan still reflected the initial number.

Dynamic Scenarios

The dynamic scenario approach involved a video-based depiction of a single drive/maneuver through an interchange which started well in advance of the interchange and ended some time after the maneuver was compete. This approach is described in more detail in the following sections.

General Approach

Dynamic scenarios involved participants viewing a video recording of a drive through an interchange. The moderator introduced the activity by explaining to the participants that they would be viewing a video of interchange driving. Each scenario began with participants being given an overview of the driving objectives for the scenario and any other relevant context.

The same video scenario was shown to participants three times. The first time was used to collect individual responses from participants without a group discussion. Specifically, participants were shown the scenario video, which was paused at key points in the drive (referred to as "critical points" (see figure 3)). These critical points corresponded to times or locations in which drivers needed to make key decisions, where they may have had difficulty, or where their expectations were of particular interest (e.g., after viewing a guide sign). During these pauses, participants were asked questions, and they wrote down answers individually. The response booklet used in this activity is provided in appendix A. This process was repeated until all critical points within a scenario had been covered.

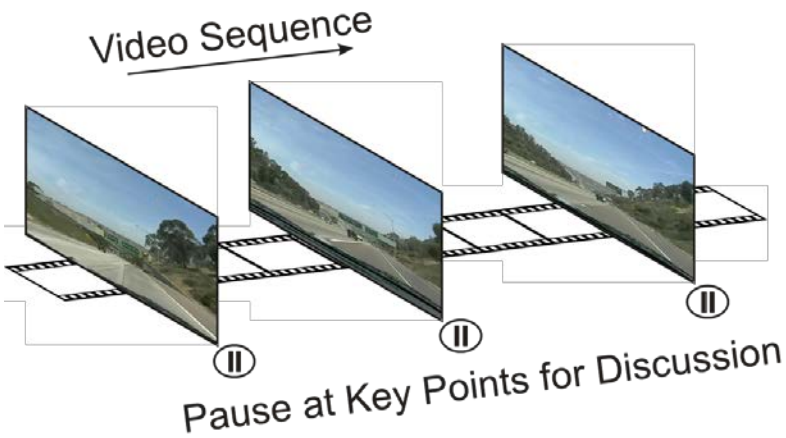


Figure 3. Illustration. Focus group video discussion method.

The second time, the video was shown without interruptions so that participants could get a sense of the flow and timing of the entire drive.

The third time followed the same procedure as the first viewing; however, the pauses were used to engage participants in discussions of the questions about their expectations and their understanding of the situation at that point in the drive. When suitable, the moderator probed participants about driving difficulties, violations of their expectations, and potential remedies for these problems.

Materials

The primary experimental materials were videos of a pilot vehicle navigating the selected interchanges. The videos were filmed from the perspective of a person traveling inside the vehicle. The entire video was geared toward a single interchange scenario with one driving objective (i.e., exiting at a left exit, choosing an exit lane at a two-lane exit, navigating closely spaced critical points, etc.). Each video contained two to four critical points depending on the nature of the interchange and the driving maneuver.

Note that because of the quality of the video footage, sight distances for signs were shorter than in the real world. Participants were provided with separate pictures of the key information sources during the critical points (i.e., higher resolution printed images of overhead signs) to ensure that they had all the information they needed to make relevant driving decisions.

An important concern with the production of video footage was the possibility that drivers may be familiar with the interchanges and know immediately how to execute the maneuver without additional information about the interchange. Not only would this undermine the researchers' ability to investigate how interchange signage and other elements affect driver expectations, but it would also introduce an unwanted source of variance across participants and locations. This was particularly a concern for the focus groups in Seattle, WA, which is where the researchers were based and where it was most cost effective to film the scenarios.

To address this problem, interchanges in Portland, OR, were filmed. These interchanges were far enough away that most Seattle, WA, drivers were unfamiliar with them. Researchers also tried to screen out Seattle, WA, participants who had spent significant time driving in Portland, OR, or who had lived there in the past.

Selection of Interchanges

Three interchanges were selected from those available in the greater Portland, OR, area. The criteria for selecting them was somewhat opportunistic based on which complex interchanges were available in the area and filming constraints (e.g., lighting). Candidate scenarios were evaluated based the types of complexity elements that occurred during each scenario drive. The complexity elements were comprised of those from Chrysler et al. and from those found in the task 2 literature review of this project (see table 5).[33] An overview of each of the three selected scenarios is provided in the following section.

Interchange 1: Visually Challenging Option Lanes

Drivers start on the bridge portion of I-405S/US-30W with the intention of following US-30W. Drivers begin in the left middle lane and must change into the right middle lane to exit using the option lane. After exiting, they encounter another option lane that services the Vaughn Street exit and US-30W. Drivers stay to the left of the gore point to continue on US-30W (not shown in the video). This scenario highlights option lanes, sightlines limited by roadway geometry, and misaligned arrow-per-lane symbols.

Interchange 2: Four-Lane Split with Complex Advance Guide Signs

Drivers start by driving straight on US-30W with the intention of following the signs to City Center. They are in the middle lane when they encounter the first sign for the upcoming roadway split. The first advance guide sign shows City Center as a destination, and the rest do not. When they reach the split, their lane becomes an option lane, and they follow the left leg to City Center. This scenario highlights inconsistent advance signage, limited visibility of signage due to obstructions, and multiple destinations in a close area.

Interchange 3: Poorly Signed Left Exit with Multiple Lane Changes

Drivers start by merging with US-30E onto the I-405N/US-30E bridge with the intention of taking the I-5S exit at the end of the bridge (they have not yet encountered guide sign information about this maneuver). They begin in the right middle lane. Because drivers do not know where the exit is, a potential course would be to choose a suitable lane based on prior expectations. The guide signs appear shortly before the exit, and drivers must make two rapid left lane changes into the option lane to exit onto I-5S/US-30E. This scenario highlights inadequate advance guide signs, an exit in the opposite direction of driver expectations, and lane changes under time pressure.

Table 5 shows the identified complexity factors for each scenario.

Table 5. Complexity factors identified for each scenario.

Complexity Factor	Interchange 1	Interchange 2	Interchange 3
Limited visibility of signage/ diverge points due to obstructions		X	X
Sight lines limited by roadway geometry	X		
Visually cluttered/complex signage	X	X	X
Inadequate sign guidance			X
Low degree of guide sign consistency		X	
Misaligned lane arrows	X		
Pavement marking information	X	X	
Exit decision required before driver is in immediate interchange vicinity	X	X	X
Limited decision time for required lane-change maneuvers		X	X
Closely spaced merge/diverge			X
Exits that diverge in direction opposite of expectations			X
Option lane	X	X	X
Lane drop			
Route split		X	
Multiple exit lanes	X		
Multiple destinations in a close area	X	X	X

Through movement looks like or feels like an exit	X	X	
Route running in a different cardinal direction than is designated			
More than two major highways/ freeways at interchange area	X		X
System/service interchange combination	X		
Multiple exits/destinations served by single freeway exits	X	X	

X indicates "contains factor."

Focus Group Topics

A primary objective of the focus groups was to obtain information from drivers about their expectations at interchanges and about the problems they encounter when navigating complex interchanges. This included identifying the sources of expectation-related problems and the types of remedies that drivers may employ to deal with these problems. However, the specific set of topics addressed depended on the available driving scenarios. Based on this set, it was possible to cover the following topics (additional information about these topics is provided in the Moderator's guide in appendix B):

- Guide signage (arrow-per-lane and diagrammatic signs).
- Guide sign consistency and placement.
- Option lanes.
- Lane selection.
- Maneuver direction (e.g., left-side exits).
- Multiple lane changes.
- Geometric limitations (visual perspective, low sight distance, etc.).

Focus Group Questions

The primary data collected in the focus groups were comprised of the individual participant responses to questions and group discussion summaries that occurred at the critical points in each scenario. These critical points were selected to correspond with times or locations in which drivers needed to make key decisions, where they may have had difficulty, or where their expectations were of particular interest. The questions included both specific references to ongoing elements at those points and general questions about the problems that drivers could be experiencing with the interchange. The final list of questions is included in the moderator's guide (see appendix B).

The focus group sessions also included a warm-up activity in which the groups discussed common characteristics of simple interchanges based on participant responses. This activity accomplished an important objective in that it gave participants the correct frame-of-reference to provide the desired level of detail for their comments during the focus groups. It also got participants thinking about their baseline expectations at interchanges without explicitly telling them what the researchers were looking for. Specific instructions to prime participants are potentially counterproductive when collecting expectation information because they unduly influence the issues that drivers focus on when providing their responses.

Session Timelines

The overall session length was expected to be 90 min with a break about halfway through. The following list provides a general overview of the timeline for the sessions:

- **Introduction (10 min)**: Moderator and participant introductions were conducted, along with disclosures and an explanation of plans and expectations for the next 1.5 h.

- **Warm-up exercises (10 min)**: The moderator directed the participants to discuss characteristics of simple interchanges to put them in the appropriate frame-of-mind.

- **Interchange scenario discussions (55 min)**: Dynamic scenario exercises were used to gain participants' input about the problems in the interchange scenarios and the remedies they suggest to deal with these problems.

- **Break (5 min)**: A break was provided where participants were invited to use the restroom, grab a snack, and stretch their legs.

- **Closing (5 min)**: The moderator provided the group members with an opportunity to share information about any topic that they may have previously omitted.

- **Questionnaires (5 min)**: Participants were asked to complete a brief questionnaire containing questions about their demographics, overall driving experience, interchange driving experience, and familiarity with the specific interchanges discussed.

Data Analysis Plan and Objectives

The raw data in the analysis were the words, phrases, sentences, and non-verbal responses of the focus group participants. The analysis followed a similar approach to one that has been used in other focus group research for the Federal Highway Administration.[35] Focus group sessions were attended by the moderator and another researcher who primarily acted as an observer/ note taker and helped with focus group materials. Both these personnel were responsible for the analysis, and they examined all data (video recordings, notes, and post-session summaries) for patterns emerging from participant discussions. To analyze and summarize the focus group discussions, both the moderator and observer performed the following tasks:

- Took notes during each of the focus group sessions.

- Developed a summary of each focus group session organized around the key questions/issues addressed during the session. This involved recording individual participant comments that pertained to topics of interest.

- Met to review the summary, compare impressions, discuss differences/discrepancies, and share comments about group interaction, peer pressure, respondent competition, contaminating influences, and subject sensitivity.

- Contributed interpretations and inferences and pointed out any possible biases and contradictions.

- Reviewed video recordings of the focus groups.

- Compiled key findings in a top-line results summary.

- Performed a content analysis on the relevant participant comments.

The basic demographic and driving history questionnaire data were entered into a Microsoft Excel® spreadsheet, and any discrepancies were resolved by visual inspection to ensure data entry accuracy. Descriptive statistics were calculated for these and any written or survey responses that required a quantitative or categorical answer.

TASK 4 RESULTS

The results for the warm-up activity and the primary focus group discussions are presented in the following sections.

Warm-Up Activity Results

Before beginning the dynamic scenarios, drivers were asked some general questions about their expectations at freeway interchanges during a warm-up activity. They were asked to think about what they would expect at a simple interchange traveling from a three-lane freeway onto a major local road. Figure 4 shows a photo shown to participants during the warm-up. The moderator then walked through a set of questions in each focus group session, and participants provided their responses.

Figure 4. Photo. Interchange shown during the warm-up activity.

For each focus group, researchers kept record of whether or not the group mentioned a particular response. If a response was given by at least one individual in a group, the group was included in the count for that response option. The responses given by the majority of the groups (at least seven different groups) are shown in table 6. This table represents driver baseline expectations for simple, easy-to-navigate interchanges, and it serves as a comparison for driver expectations for the more complex interchanges discussed in the main part of the focus group sessions. The complete set of responses is shown in appendix C.

Table 6. Summary of the most common responses given during the warm-up activity.

Question	Most Common Response	Number of Groups
Where is the exit?	On the right	12
How many lanes would the exit have?	One lane	11
What happens to the travel lane after the exit?	It exits and also continues (option lane)	11
Where are the signs placed?	Overhead	7
How far ahead of the exit are the signs?	1 mi	7
	0.5 mi	8
Are there multiple sets of signs?	Yes	7
What should the signs say?	Destination name	8
	Exit number	8
	Exit distance	8
Do you rely on lane markings?	No consensus of respondents	

Focus Group Discussion Results

The results of the focus group discussions are presented in the following sections, which are organized by scenario. Each scenario begins with a description of the roadway, including an aerial view of the interchange showing the driving route and key interchange features/challenges encountered along the way. The scenario driving objectives are also described. These are followed by an overview diagram of the scenario (see figure 5 for a description of the elements in the diagram) and an image of the driving scene at each critical point with an accompanying list of discussion points. The discussion topics for each critical point were based on the interchange complexity factors listed in table 5, in addition to other aspects of the critical point that might influence driver expectations (driver expectancy factors). This information was included in the scenario summaries because it represents some of the elements of interchange driving that were focal points of the discussions.

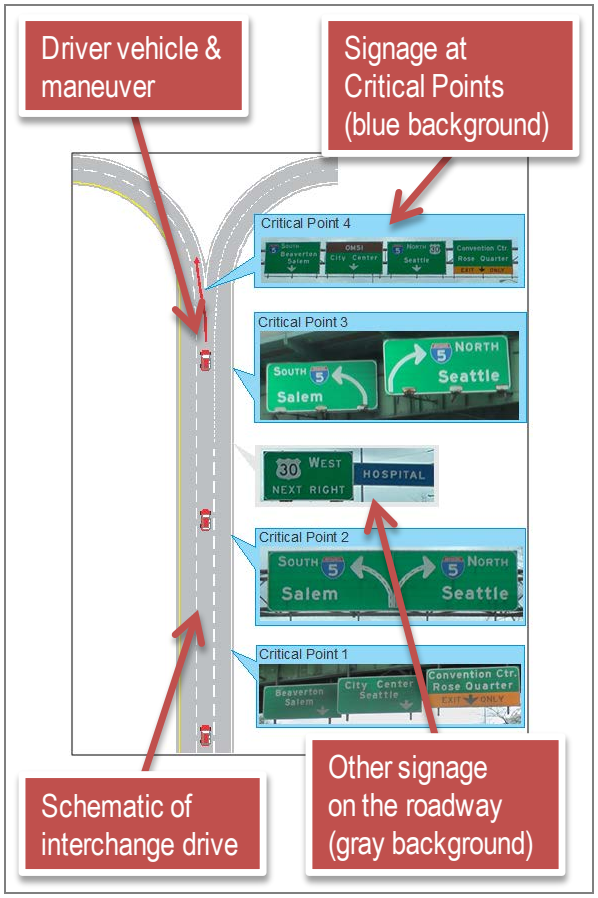


Figure 5. Illustration. Description of information elements in scenario overview diagrams.

Following the scenario overview information, each critical point is discussed in sequential order. This discussion begins with a brief description of the critical point and an image of the scenario driving scene, which shows some of the key information that participants refer to in their discussions (this image is a larger version of the one shown in figure 5). Also included in this section are the results of the response booklet questions.

The primary results of the focus group discussion are presented after the critical point driving scene images. These are comprised of brief descriptions of key themes and opinions/ideas discussed at each critical point. Because each critical point represents a unique set of driving circumstances, the discussions covered different types of topics, although there were recurring elements across critical points. In order to facilitate reading of the discussion points, they were presented using a similar structure in each critical point discussion. The high-level discussion categories included the following:

- **Sign interpretation**: This section included an enlarged image of the signs that were shown at the critical point. The discussion included ways in which drivers understood various sign elements such as arrows, exit plaques, and destination information.

- **Expectations and strategies**: This section provided a discussion of drivers' expectations at that critical point. Driver strategies for coping with the information provided and the decision that they have to make are also highlighted.

- **Challenges**: This section related to the specific challenges and issues that may have given drivers problems or made them uncomfortable at the critical point.

- **Improvements**: This section featured driver-suggested improvements for the signs, markings, and geometry at the critical point.

- **Driver actions**: This section included information about what drivers would do if they were faced with certain information at a particular critical point.

Note that depending on the nature of the discussions, not all of these categories were covered for each critical point. Within each category, key themes and opinions/ideas were summarized. These were typically followed by one to three quotes that were representative of similar comments made by participants. One objective of the example quotes was to capture some of the nuances of the associated comments. These summaries also provided a general sense of the frequency with which a theme or opinion occurred or the level of agreement among participants. In particular, each summary statement included a reference to a magnitude level. The magnitude terms used were based on the following scale:

One < Few < Some < Several < Many < Most < Almost All

The quotes are provided without attribution to individual drivers (to protect privacy), and the demographic category of the speaker (age, gender, and location) were also omitted. During the analysis, it became clear that there were almost no consistent response patterns based on driver demographics. A likely explanation for this is that all demographic groups were represented in most focus group sessions. Consequently, to simplify the presentation of quotes, this information was excluded. Also, some quotes were edited for readability, and missing words were added (denoted by square brackets). Care was taken to preserve the intended meaning of the comments.

Scenario 1

Roadway Description

The roadway in scenario 1, which was located in Portland, OR, was primarily the upper deck of a bridge that exited to a freeway. The bridge deck had four lanes, all moving in the same direction. The sight distance on the bridge was limited by crest vertical curvature. Figure 6 shows an aerial view of the roadway.

Original image: ©2011 Google®; map annotations provded by Battelle (see "Acknowledgements")

Figure 6. Photo. Aerial view of scenario 1 roadway.[36]

The extent of the video footage is shown as a solid yellow line, and the remainder of the intended route is shown as a dashed line.

Driving Objectives

Drivers were told that their objective was to get onto Route 30 West. Figure 7 shows the signs that drivers encountered and the maneuvers that they had to make during the scenario drive. The relative locations of critical points are also highlighted.

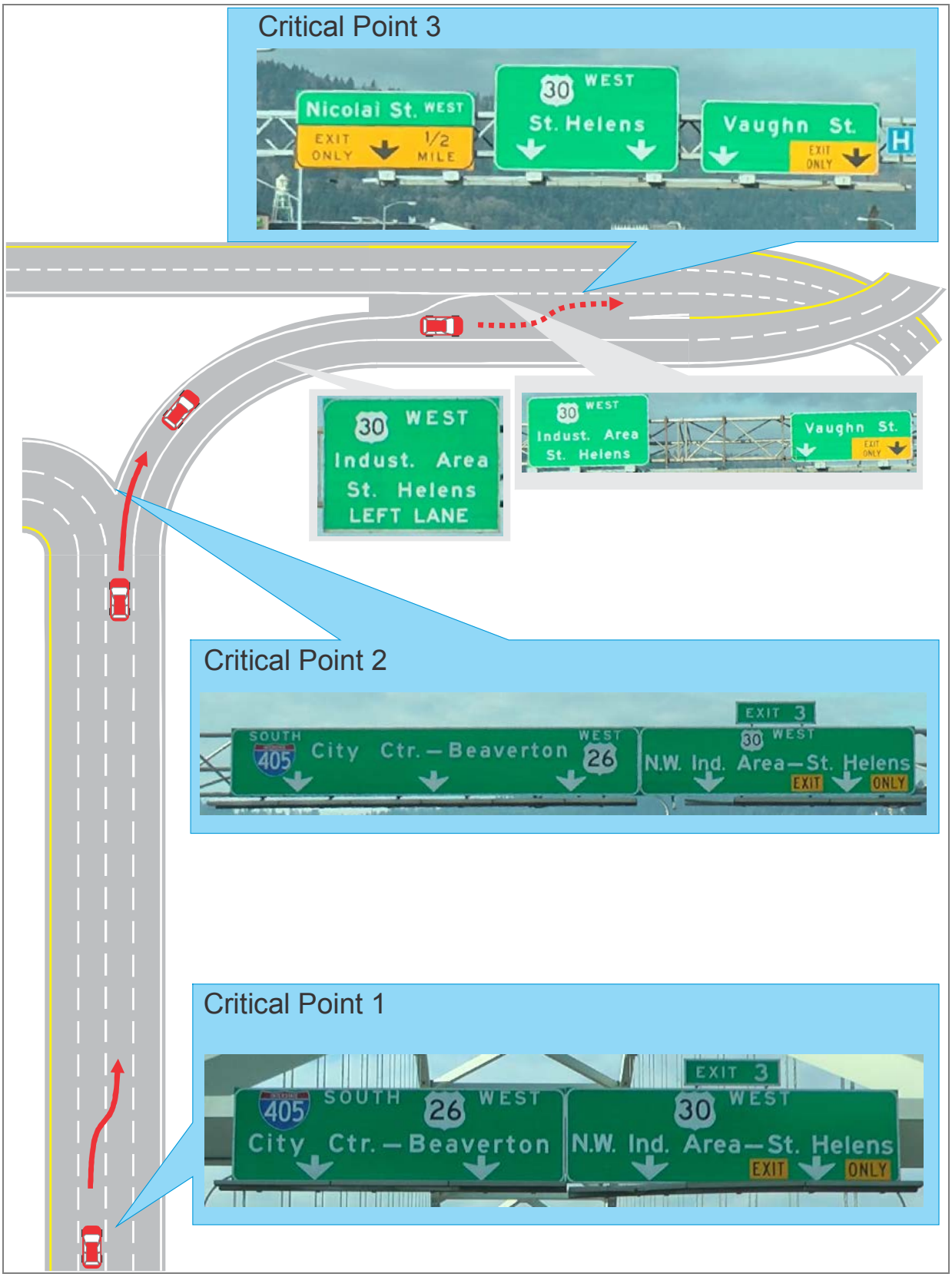


Figure 7. Illustration. Sign information and required vehicle maneuvers in scenario 1.

Scenario 1 Critical Point 1

At the first critical point, drivers were faced with two overhead guide signs with arrow-per-lane directions (see figure 8). Because of the crest vertical curve, drivers did not have a view of the roadway geometry ahead.

Figure 8. Photo. Image presented to drivers for discussion in scenario 1 critical point 1.

Key topics for this critical point in the group discussion included the following:

- How drivers interpreted the arrow-per-lane sign.
- What drivers expected the exit ahead to look like based on the sign information.

Response Booklet Question

Since drivers' sight distance was limited by the crest vertical curve in the bridge, they were asked to respond with which of the roadway geometries in figure 9 through figure 13 they expected based on the sign information available in the driving scene image.

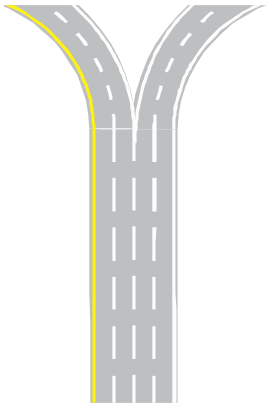


Figure 9. Illustration. Response option for scenario 1 critical point 1—two-lane split.

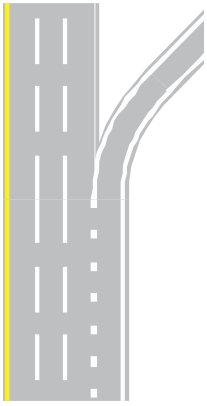


Figure 10. Illustration. Response option for scenario 1 critical point 1—single exit.

Figure 11. Illustration. Response option for scenario 1 critical point 1—two exits.

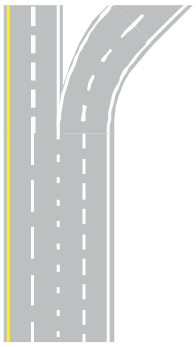


Figure 12. Illustration. Response option for scenario 1 critical point 1—two-lane exit.

Figure 13. Illustration. Response option for scenario 1 critical point 1—split with option lane.

The distribution of responses is shown in figure 14. The 107 responses are graphed based on the percentage of drivers within each age group who provided that response. Six drivers chose multiple lane combinations and were not included in the graph. In general, drivers expected to see one or two upcoming exits. These expectations were likely influenced by the exit only information above the rightmost lane since both frequent responses represent two versions of that lane exiting with either the right inside lane exiting immediately after (two-exit option) or at some time in the future (single-exit option). Older drivers were less likely to expect a split, and no older drivers chose the actual roadway geometry (split with an option lane).

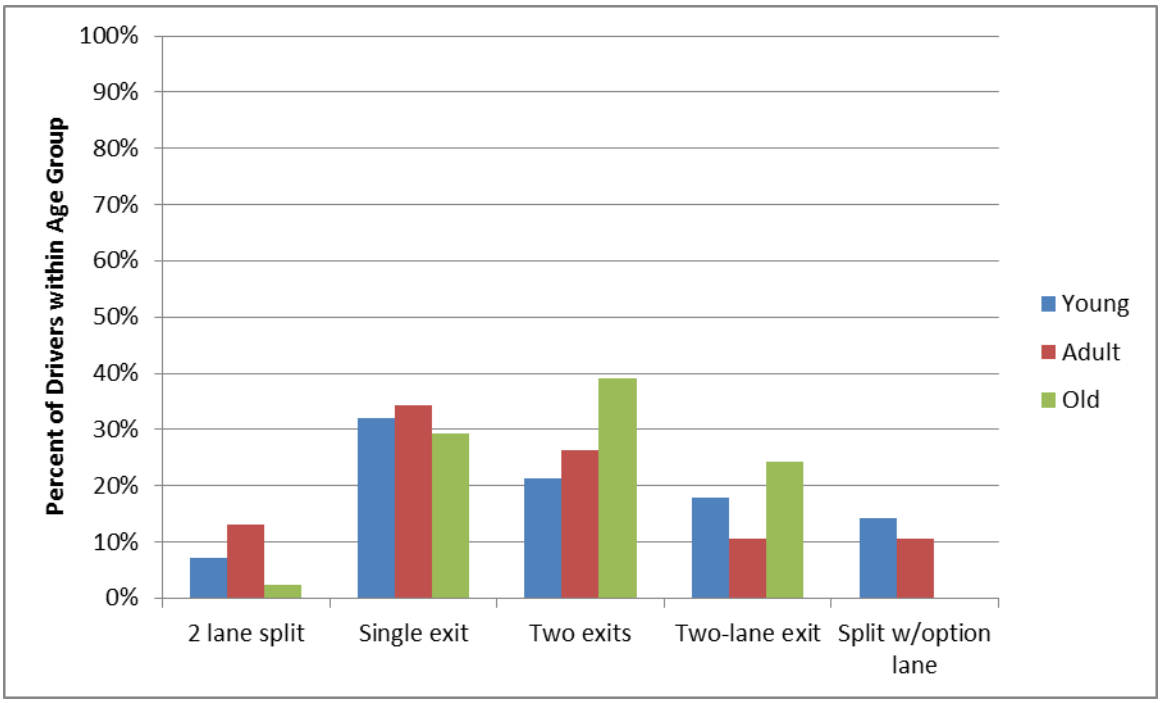


Figure 14. Graph. Booklet response distribution for scenario 1 critical point 1 (number of responses (*N*) = 101).

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following sections.

Interpretation of Sign Elements:

The sign in the first critical point was a set of two arrow-per-lane guide signs (see figure 15). The St. Helens destination was positioned over the exit only plaque.

Figure 15. Photo. Guide signs associated with scenario 1 critical point 1.

Arrow-Per-Lane Signs:

When asked, almost all of the drivers said that the arrows referred to specific lanes. Furthermore, each arrow corresponded to a specific destination. Driver responses include the following:

- "[The arrows point to] the lane you should be in to go to the area that's being indicated."

- "Whatever is below this arrow is the lane you want to be in for whatever's above it."

Destination Information—Exit 3 and 30 West:

On the right-hand guide sign, both the sign for Exit 3 and the notation for 30 West were centered above the two downward-pointing arrows. Exit 3 was listed on a smaller, separate sign. Several drivers noticed the split between the two large guide signs and interpreted the Exit 3 sign to apply to both of the lanes on the right-hand sign. For the most part, drivers correctly interpreted this information. Driver responses include the following:

- "Exit 3 is just for the sign on the right because the signs don't connect."

- "Exit 3 is [the two right] lanes."

One driver was uncomfortable with the association of Exit 3 with two destinations. This may have been because the driver felt that those destinations would be served by different exits. The driver indicated that, "I believe that for Exit 3, the exit sign should be over either St. Helens or NW Indy."

The "30 West" label was centered over the two destinations/arrows, so some drivers thought that 30 West could be reached from both of the two right lanes. They indicated that, "That is a little bit confusing, but I'm thinking that 30 West is definitely available to both right-hand lanes at this point."

Some drivers continued this thought by indicating that the right-hand lanes were for two destinations, both on 30 West. Driver responses include the following:

- "If you want 30 West, regardless of what it says, you stay in the right two lanes and then it will get more specific the farther you go, like more instructions. If you want St. Helens, you don't have to stay to the right, I don't think that's true."

- "[Exit 3] is the name of the entire exit, and it just shows different areas that you can go to from that interchange."

- "If I saw that, I'd realize that 30 West is one thing, but there's a commercial route and a bypass."

A few drivers thought that 30 West only referred to the right-middle lane. One such driver indicated that, "I wouldn't know where St. Helens is, if it's east or west. So, I would be staying in the third lane. I know I'm on 30 West and the 30 is over the NW Industrial Area, and it's not really over St. Helens."

Exit Only:

It was less clear to drivers how the exit only indication corresponded to destination information. A few drivers provided varying opinions as follows:

- "That's Exit Only for 30 West, that's what my impression would be."

- "Since the Exit Only is only under St. Helens, I assumed that it only applies to St. Helens."

- "I take it as, the right lane [St. Helens Exit Only] is guaranteed to get off of the freeway you're on right now. If you're under the arrow just to the left of that, you can get off on 30 West or continue where you're going."

Driver Expectations and Strategies:

The first critical point was located immediately before the crest on the bridge, which blocked the drivers' view of the upcoming geometry. There was no consensus about what the exit configuration would look like, and drivers described a variety of different configurations that they expected. There was also no real sense of concern because they expected to receive clarifying information closer to the exit.

Some drivers expected to see a split. Driver responses include the following:

- "[I would expect to see] a split, just because of the four individual lanes."

- "I thought it would be a fork eventually because you can go west in the right two lanes, but then it's saying South, like I-405, so it's going to have to turn somewhere."

- "The arrows tell you [everything]—they say it all. If it wasn't going to split, you wouldn't have that many arrows there."

- "I thought since I-405 is a major freeway, I expected that the split to the right would be smaller. But it turns out that they were equal."

Some drivers expected to see a dual or a two-part exit, and their responses were as follows:

- "I thought there were going to be two exit ramps here—the first one on the far right with an Exit Only and then the next one was dual direction."

- "I would expect the left three to go straight through and there would be a veer off of the right two lanes. So you would have three going straight through, two exiting, and then the far right for St. Helens might have a further veer-off in the middle of the ramp."

Most drivers expected some sort of exit, although a few drivers expressed confusion over whether it was a one- or two-lane exit. Driver responses include the following:

- "There would be an exit on the right."

- "One lane exiting right away."

- "I would expect two lanes to [exit] because "Exit 3" is over both of the two right lanes, the two right arrows."

- "I would expect the Exit Only for St. Helens to be immediate and the Exit 3 for 30 West to be later."

- "I couldn't tell, from this sign at least, if the St. Helens and the NW Industrial Area would exit together, or if there would be a separate exit for St. Helens and another one for the Industrial Area since that was an Exit Only."

A few drivers expected to receive more signs describing what would happen with the exits. Driver responses include the following:

- "[I would expect to see] more signs."

- "As a driver, I don't feel comfortable. I don't feel like, "Oh, I know where I'm going for sure." But, I'm not super worried because I think I'll get more signage."

A few drivers expected the roadway to roughly continue straight on the other side of the bridge as follows:

- "Just look at the sign, the road doesn't necessarily have to split—it could just keep going straight. It could, and then just have the St. Helens exit go off."

- "It's difficult to tell because at this point, all of the arrows indicate that you'd be going straight because there aren't any indications that you would be making a left or right turn at any particular time. My impression was that the two on the left were going to go straight and the two on the right would veer off, but there's nothing really that would indicate it based on that sign."

- "[I would expect to see] four lanes [on the other side of this bridge]."

Challenges:

At the first critical point, drivers were mainly challenged by reading the signs. The volume of text presented as well as the lack of definition between the left and right sign panels were mentioned as challenges by some drivers as follows:

- "The sign above the one on the right that says Exit 3, I didn't even catch that until we stopped to look at it for 5 minutes. There's so much text up there already."

- "I would like to see a little more definition of the difference. It's kind of broken there [into two signs], and when you're going through there at 60, 70 miles per hour you may not even see that."

Only one driver commented about arrow-per-lane signs in general and how the arrows visually line up with lanes at this point. The driver indicated that, "This is pretty straightforward with the arrows, but sometimes in general, when I see the arrows, [I can't figure out which lane they point to]."

Improvements:

Drivers also had a number of suggestions for sign improvements. For several drivers, the first area for improvement focused on the grouping of destination information on the signs as follows:

- "Is that a hyphen? Do you go to NW Indy Area and St. Helens on 30 West [to the right] or is it NW Indy Area [in the right middle lane] and St. Helens [in the far right lane]. Similarly with the sign on the left, I don't know what the hyphen means. It looks exactly like it's just one street or one area categorized."

- "I think it should say NW Industrial Area AND 30 West left lane because you have to look at the Exit Only sign too and you know you're going to get to St. Helens on that Exit Only."

- "I thought 30 was for the whole thing and I realize now it isn't. So, they should say "local" or put some other little thing up there to tell you it's just a surface street or split the sign in two maybe because I thought you could get on 30 from both of [the two right lanes] or they were for two directions on 30."

For several drivers, the second area for improvement was the addition of distance information to the sign. Driver responses include the following:

- "I think you should have some advance notice like "quarter mile ahead" or "exit half mile" because you've got limited sight distance coming over the crest of the bridge and if there's heavy traffic or it's foggy, you don't necessarily know how far the exit is going to be."

- "Then again, on the right side, the 30 West sign, it doesn't say when it is, so it may continue for a while and then branch off."

A few drivers found that they were able to deduce some distance information from the fact that they were on the top of a bridge. One driver indicated that, "I don't know that I would anticipate a split by looking at that and being on the top of a bridge. First of all, I'm on a bridge, how many things can they do on the top of a bridge. I don't know that I would be anticipating that these would split into different directions as a result of that signage."

Scenario 1 Critical Point 2

At the second critical point, drivers saw the same signs that they did at the first critical point (see figure 16). The main difference is that drivers were then faced with a split, and the third lane became an option lane. Additionally, the lane marking between the third and fourth lanes became a solid white line.

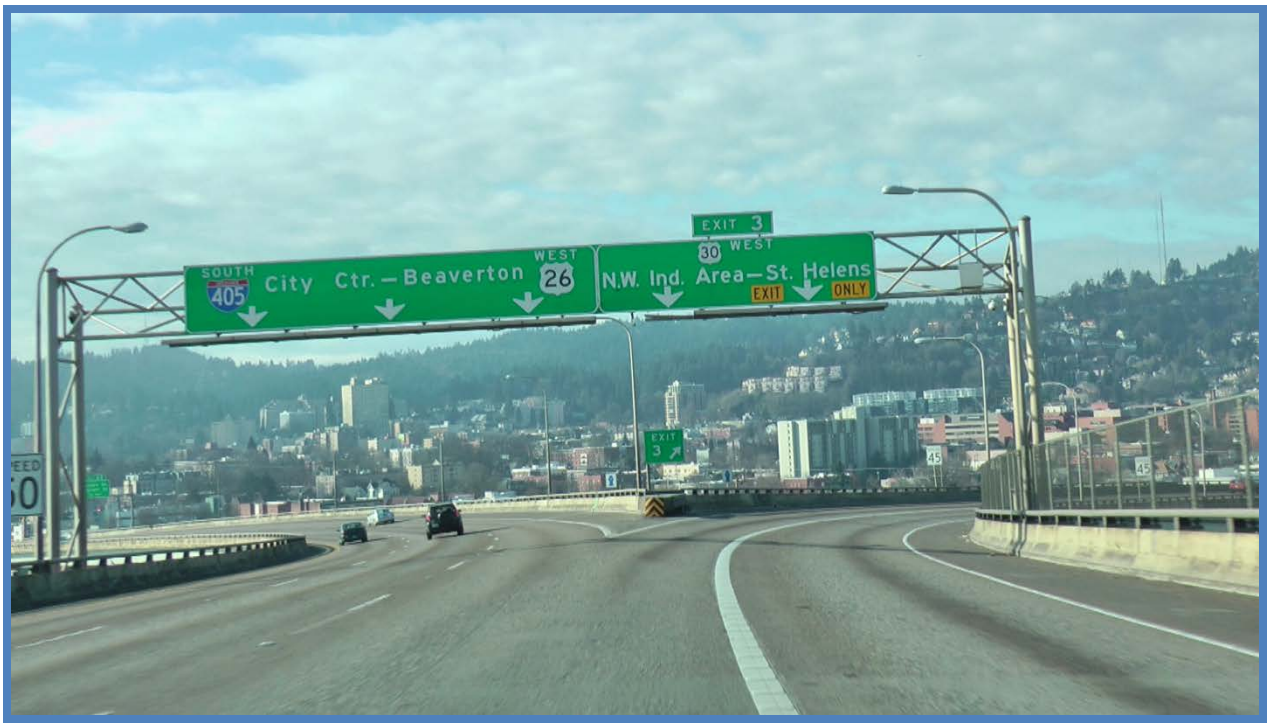


Figure 16. Photo. Image presented to drivers for discussion in scenario 1 critical point 2.

Key topics in the group discussion for this critical point included the following:

- Which lane drivers would choose to follow 30 West.
- Drivers' opinions about option lanes.

Response Booklet Question

At the second critical point, drivers were faced with a lane decision for 30 West. Figure 17 shows the lane options as presented in the response booklet. Lanes 3 and 4 were two legs of the same option lane. The 30 West destination was listed on a sign above lanes 4 and 5.

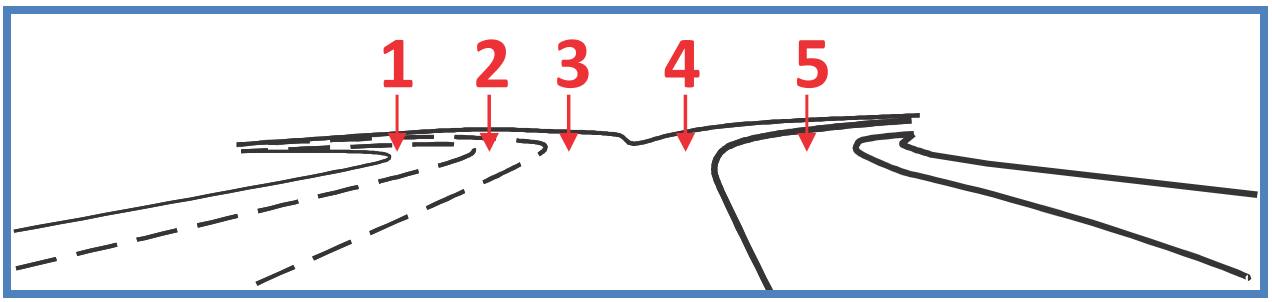


Figure 17. Illustration. Lane numbers for lane choice decisions in scenario 1 critical point 2.

As shown in figure 18, the majority of drivers chose lane 4 to get to 30 West. Interestingly, older drivers were the most likely to choose lane 5, which was labeled as an exit only lane and was separated from lane 4 by a solid white line.

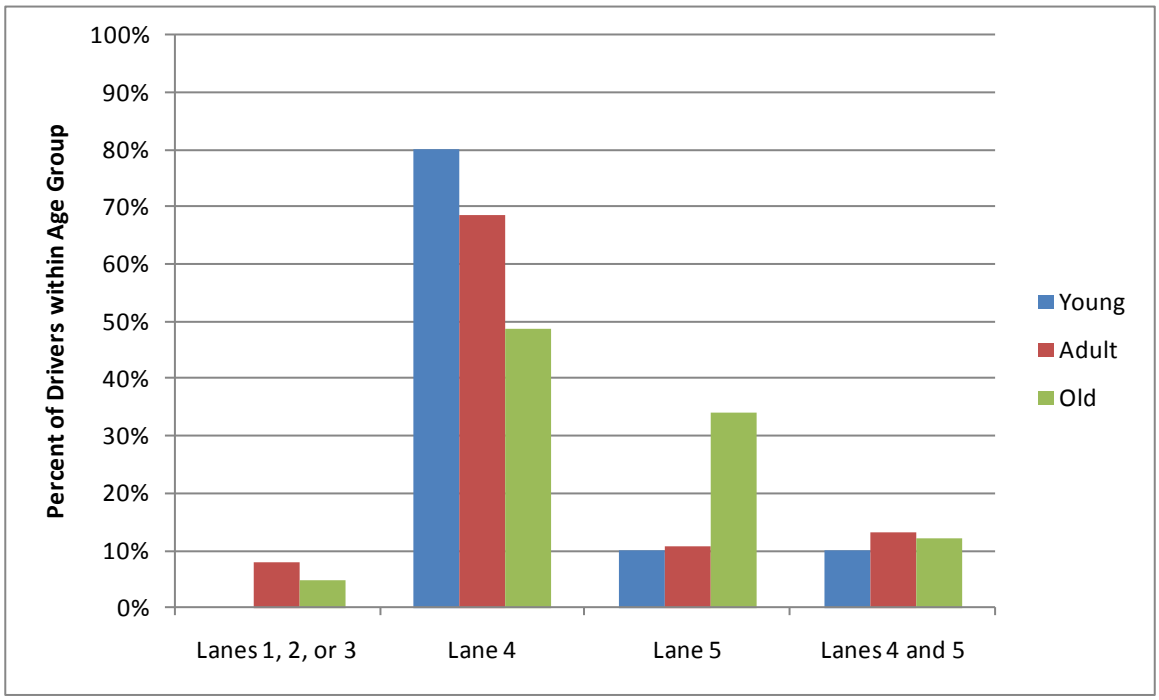


Figure 18. Graph. Booklet response distribution for scenario 1 critical point 2 (*N* = 109).

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Interpretation of Sign Elements:

The signs that drivers discussed in the second critical point were the same as in the first critical point (see figure 19). The context was different, however, since drivers could clearly see the freeway split at this time. Note that because the sign was the same, driver interpretation of the sign elements is not covered in this critical point.

Figure 19. Photo. Guide signs associated with scenario 1 critical point 2.

Driver Expectations and Strategies:

At the second critical point, drivers were asked to make a lane choice decision for 30 West. Several drivers were uncomfortable with associating the 30 West sign element with multiple lanes. They either used other sign elements to make their decision (e.g., the exit only plaque) or tried to deduce which area (i.e., St. Helens or NW Industrial) was serviced by 30 West. Driver responses include the following:

- "How would you know if Highway 30 would lead you to the Industrial Area or to St. Helens? If you get into the inside [inside right lane] where it says NW Industrial, and then around the corner and it says 30 to St. Helens. You have to get over real quick. Hopefully there's enough space in these areas to get where you need to go."

- "If I didn't know the city, I just had to go to 30 West, then I would be very confused at that particular spot, which of those two lanes is 30 West, can I get there both ways."

Lanes 4 or 5:

Many drivers stated that they would choose either lane 4 or lane 5. Some of the decision factors that would help them choose a lane include keeping their options open and knowing which specific destination on 30 West they want. Driver responses include the following:

- "At the last minute, if I'm in that fourth lane, I can make a choice either here (fifth lane) or there (fourth lane) at the last minute, versus being locked into that fifth lane."

- "If I know where I'm going—like the destination is St. Helens—then I would know that I want the [rightmost] lane. But if I didn't know the city, I just had to go to 30 West, then I would be very confused at that particular spot. I don't know which of those two lanes is 30 West. Can I get there both ways?"

Lane 4:

Most drivers chose lane 4 to avoid the exit only lane. Driver responses include the following:

- "And since there's nothing on any of these signs that gives you any inclination as to what the distance is, how do you know that you won't go around that curve and be automatically on an exit ramp. Especially with that solid line down the middle of both lanes, it seems to me to be saying "hey, make up your mind", so that's why I chose 4."

- "Either of the two right lanes will take you to 30 West, but the far right lane is just an exit for St. Helens. So, I'd stay out of the Exit Only lane."

- "Since there're two exits, it says "exit" up top and it says "Exit Only" to the bottom right; that makes me think that there's not only an exit coming up immediately, but a separate exit in addition to this 30 West exit. So that's one of the reasons why I picked to go in lane 4 because I'm thinking that there's going to be an exit immediately going onto a side street and that's not where we wanted to go, we wanted to go to 30 West."

Lane 5:

However, a few drivers were uncomfortable eliminating the exit only lane and chose to be in lane 5, the rightmost lane. Driver responses include the following:

- "I chose lane number 5. I don't know why but the Exit Only sign made me think I have to be in that lane."
- "[I chose lane 5 because] that's where you would be bearing when you're going on the exit."
- "I took the Exit Only because I thought that was 30 West and also [because] somebody might be [splitting left] and I might be [splitting right]. See I didn't know if 30 was going to St. Helens or going to the Industrial Area."

Scenario 1 Critical Point 3

As drivers came around the curve on the exit, they were faced with multiple additional sets of signs. Critical point 3 was placed at the last set of these signs right before an exit (see figure 20). Two sets of signs before this critical point (not shown) indicated to drivers that 30 West and St. Helens were in the left lanes.

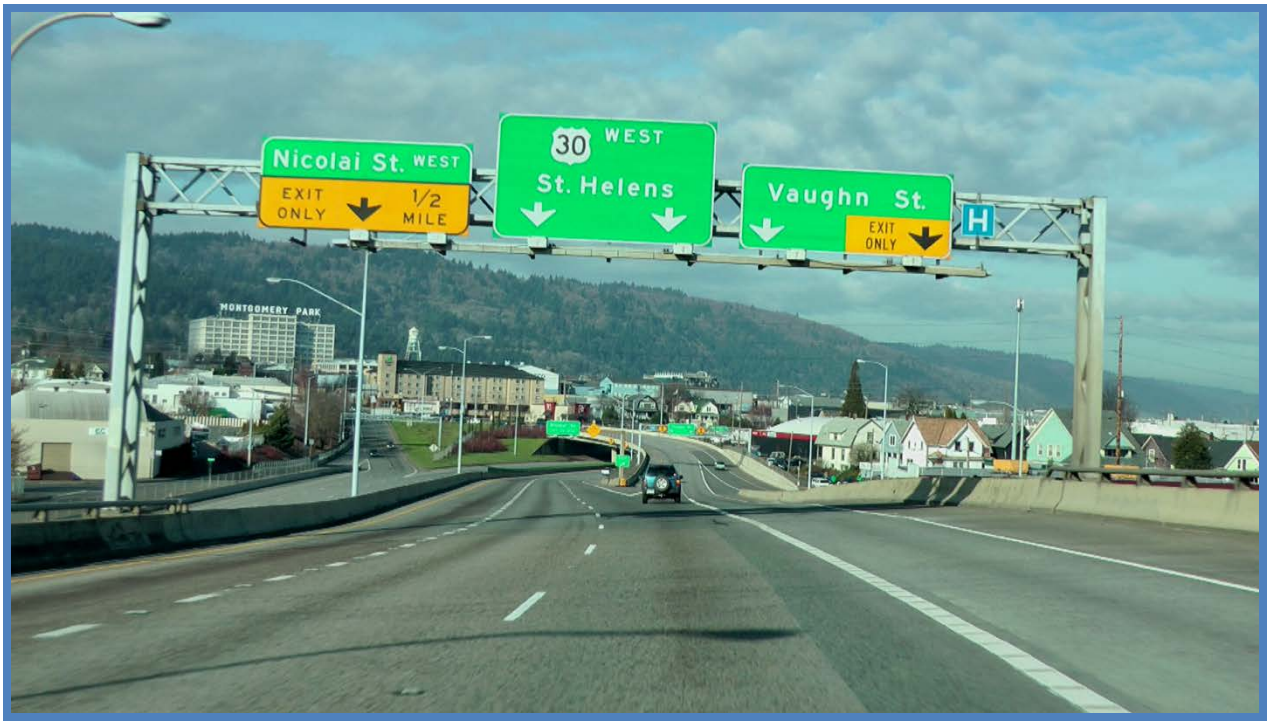


Figure 20. Photo. Image presented to drivers for discussion in scenario 1 critical point 3.

Key topics in the group discussion for this critical point included the following:

- The arrows and how well they indicated the lanes.

- Lane destinations.

Response Booklet Question

At the third critical point, drivers were asked whether 30 West continued over the bridge or under the bridge. This was an operationally relevant question since 30 West was their ultimate destination. At this point, the vehicle was in an option lane—the left leg led to 30 West, and the right leg led over an overpass to Vaughn Street. The lane was marked by two arrows, one for each destination. The visual perspective makes the lane direction ambiguous; however, the length of the pause at the critical point and drivers' ability to count lanes to match with destination arrows allowed most drivers to figure out that 30 West was under the bridge. Figure 21 shows the distribution of responses. Two older drivers were unsure and circled both responses. As a result, they are not included in the graph.

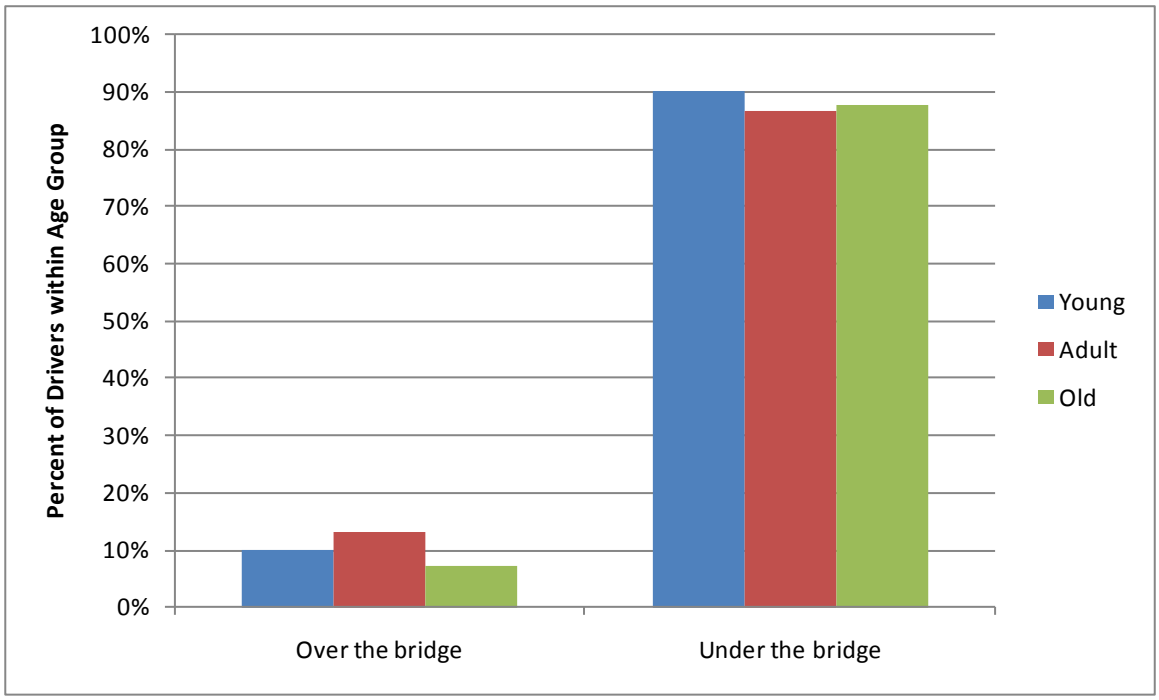


Figure 21. Graph. Booklet response distribution for scenario 1 critical point 3 (*N* = 107).

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Interpretation of Sign Elements:

The signs that drivers discussed in the third critical point were three arrow-per-lane signs (see figure 22). The option lane was indicated by the rightmost arrow on the middle sign (St. Helens), and the leftmost arrow on the right sign (Vaughn St.). The Nicolai St. sign was the first sign where drivers encountered information about that destination.

Figure 22. Photo. Guide signs associated with scenario 1 critical point 3.

Lane Destinations:

By the time drivers got to this last bank of signs, many were confused by the discontinuity of destination information that had been provided to them. Driver responses include the following:

- "And [now there's] no mention of the Industrial Area, which I guess is Vaughn and Nicolai, who knows. So it should say "Nicolai" and "Vaughn Street" instead of the Industrial Area."

- "The wording is not consistent. What you're telling me is changing constantly. What happened to NW Industrial and Vaughn St came out of nowhere. Just leave it out, you're confusing me. Just say "St. Helens" and keep it that way."

Arrows for the Option Lane:

Several drivers were able to understand that two arrows on separate signs pointed to the same lane, the option lane for St. Helens and Vaughn Street. Driver responses include the following:

- "What lets you know you have an option lane is that the right arrow for St. Helens and the left arrow on Vaughn Street, that's the exact same lane. It marks the same lane so it lets you know that you do have an option."

- "I'm pretty sure the right arrow on the Vaughn Street sign and the left arrow on the St. Helens sign should be pointing to the same lane."

However, some other drivers had difficulty determining this. One stated that, "The fact that the left arrow on the Vaughn Street sign and the right arrow on the St. Helens sign point to the same lane is confusing. You have to deduce it yourself."

The mismatch between the number of arrows (five) and the number of lanes (four) added to the confusion for some drivers. Driver responses include the following:

- "I see five arrows, but I count four lanes even though one might be that option lane."

- "I would never have enough time driving to figure out what I figured out [from the driving scene image]."

- "One of the really confusing things about that is that there are five arrows and there are only four lanes because that Exit Only looks like it's over the [break-down] lane. And then you've got the second sign from the left, the second arrow for Vaughn Street looks like it's in the right-hand lane and then you've got the two for St. Helens. And then you're going to come up to that "Y", and you're going 'where am I?'"

Driver Expectations and Strategies:

At the third critical point, drivers encountered new destination information, which led to some confusion because the change in the destination set was unexpected.

At the second critical point, the right lane was labeled "Exit Only" and had the destination St. Helens with an arrow. After that point, the drivers rounded the corner of the two-lane exit ramp and saw another sign stating "St. Helens Left Lane," which contradicted the previous signs. At the third critical point, "Vaughn Street" was marked in the right lane and "St. Helens" was marked in the middle two lanes. This discontinuity of lane association with destination information violated some drivers' expectations. Driver responses include the following:

- "Coming around the bridge, the sign to St. Helens was on the far right. I would've been in the right lane if I was going to St. Helens and didn't know the road. But now, as soon as I come out of that exit, I have to get left because I'm in the wrong lane. To me, that's the worst thing about what we've seen so far because St. Helens is an Exit Only on the far right and then they want you to go left once you get out of that bend."

- "St. Helens starts off on an Exit Only and then it ends up on the left side and then there's another Exit Only [to the right]."

This change in lane destination would have upset a few drivers. Driver responses include the following:

- "Now you've got to merge all the way over, that could be a problem. I would be upset when I saw you had to merge left."

- "They told me to get far right, Exit Only; now they're telling me to go far left? I'm irked! As a driver, I'm stressed, because merging is stressful. I know what I'm going to do, I don't know what you're going to do. You're asking me to get three lanes over, not just one."

Challenges:

At critical point 3, the driver's perspective was such that the arrows on the arrow-per-lane signs did not align, and the arrow for the option lane looked like it allowed the driver to take either branch to reach the destination 30 West. Several drivers were unsure about which lane to take. Driver responses include the following:

- "I thought the sign in the middle was kind of confusing too because it looks like if you go straight you'll be on 30 but if you go off to the right you'll also be on 30. I didn't think it was clearly marked."

- "I've been able to figure out how to go to 30 West, but I think that if I was driving it, I would have been just as likely to end up in the right lane of the option lane as going under the bridge."

- "You almost think you could do both—I had to actually count the lanes to figure it out. It absolutely looks like you could follow [the blue SUV] and get to St. Helens."

Many drivers were able to correctly deduce the answer given the pause in the video. Driver responses include the following:

- "The reason I said under the bridge is because when you look at Vaughn, it looks like it's going up, so 30 West has to be going under."

- "Being there, you could more clearly see that the far right area was a shoulder and the one arrow was definitely to Vaughn so you could have a fairly clear indication that 30 [West] was going under the bridge."

- "A reasonable driver will see that two of the lanes are Exit Only, one lane goes over the bridge, and the 30 [West] is the two center lanes going through."

Some drivers noted that this was sometimes a challenge with arrow-per-lane signs. Driver responses include the following:

- "I think it's often the case that when you're pointing to the lanes like that—that from a distance it looks different—they seem to shift over when you get closer. You think it's the middle two lanes and then you get closer and realize it's the left two lanes or something like that. I don't think you can necessarily tell, maybe because the road curves."

- "It all depends on the angle. If you're in that lane, you can properly use the arrows; if you're in another lane, the arrows throw you off."

Improvements:

Several drivers thought that canted or tilted arrows would more clearly convey that the option lane serves both St. Helens and Vaughn Street. This suggestion most frequently came from drivers in the Columbus, OH, focus groups, as they frequently encounter these types of arrows.

One implementation would have diagonal-pointing arrows on the existing option lane sign. Driver responses include the following:

- "A lot of places in Columbus when they do that they have the arrows pointed [downward and toward each other] at an angle. The right arrow on the 30 West sign would point slightly off to the right and down, and the Vaughn Street sign, the left arrow would point slightly to the left and down."

- "I've also seen situations like this where those arrows representing the same lane would be angled pointing toward the same one of four. [I think that would make it clearer.] Or a visual that shows a split coming up."

One driver thought of another implementation, which would have diagonal arrows on an additional sign at the gore point. The driver indicated that, "One of the things that I've seen that helps at interchanges like this is right at the point of that "Y", they'll have a sign that says "30 West" with an arrow pointing to the left and "Vaughn Street" with an arrow pointing to the right. So that as you're coming up, you can look at it and it tells you (gestures split)."

Option Lanes in General

In critical point 2, drivers provided opinions about option lanes in general.

Positive Opinions:

Many drivers liked option lanes, especially in unfamiliar areas, because they provided more margin for error when they were not sure which lane to choose. They also felt that they had more time to make a lane decision. Driver responses include the following:

- "I think it's good because in instances where you're not familiar with the area and say you're three lanes over and you have to merge three lanes say in a quarter of a mile, that's one less lane that you have to merge over, so it makes it safer."

- "I think it lets me make that last-minute decision at the furthest place I can if I'm confused coming up to it, then you can make a decision. Instead of having to get over, you can go either way."

- "I like that they give me enough time so that if I know that an exit is coming up, I can be in there if I'm not quite sure where I'm getting off. I don't like when some are option lanes and some are Exit Only lanes (alternating), it causes unnecessary lane changes and then suddenly you can't get back over."

Negative Opinions:

However, some drivers preferred to avoid option lanes, if possible. One reason for this preference was driver familiarity with the interchange. Driver responses include the following:

- "If I know where I'm going, I'd rather take the Exit Only lane."

- "[If I'm a local] I like the dedicated exit lanes. If I know I'm going to 30 West, I want to be over there in enough time to make that turn."

Another reason that a few drivers gave for staying out of the option lane was to avoid drivers who use the option lane but are not sure where they are going. Driver responses include the following:

- "I think option lanes make me nervous though because that's people's panic lane. If they're right at the end and they don't know where they're going, that's more chances for them to freak out and move to the next lane. So I don't like that sometimes."

- "My only problem with them is if someone is in front of you and wants to exit over to the 30 but hesitates just a little, you're doing 60, you have to be very observant and slow down to let them do that. Some people will go past where the white lines are and then still merge over. Other than that I agree with what he said. I like them, but you just have to be careful."

- "When you're going like that and you're going to make a decision, you have to be much aware of what's behind you because there are going to be cars right up on you while you're trying to make a decision. And too, when someone is behind you, they assume that you know where you're going."

A few drivers mentioned that they would avoid option lanes when there is congestion. Driver responses include the following:

- "In this scenario when there's no traffic, I'm looking at the option lane because if I'm seeing something I don't expect I can always just change my mind in the option lane on days like this, but during rush hour I'd go in the dedicated lane."

- "If I know where I'm going, I prefer one of the other lanes because traffic can sometimes stack up in that option lane. Especially if less traffic is going my way, more traffic is going the other way."

- "The other nice thing about them is if all of a sudden you saw that the option lane was getting really congested [off the exit] and you knew that the next exit along would get you where you wanted to go, you could opt to stay in that lane."

Scenario 1 Key Themes

Some of the key themes expressed in scenario 1 are as follows:

- Drivers do not get a clear picture of an upcoming interchange with an uncommon geometry based solely on arrow-per-lane guide signs. However, this does not necessarily cause problems or stress for drivers since they expect to get more useful or detailed information closer to the interchange.

- Lack of continuity in the set of destinations encountered by drivers makes some drivers uneasy. In particular, drivers may develop expectations about which destinations are possible for their exit/maneuver. When this set of destinations changes unexpectedly

(e.g., NW Industrial Area disappearing or Nicolai St. appearing seemingly out of nowhere) without corresponding exits and entrances, it can lead to driver confusion.

- Drivers seem to interpret lane arrows rather narrowly to correspond to information that is directly above or grouped with the arrow. For example, while both NW Industrial Area and St. Helens could be reached by either right-hand lane, because the destinations were each directly above an arrow, drivers instead paired each destination with one of the lanes. There was even an inclination for some drivers to pair the 30 West destination with a lane even though it was in between both arrows. This tendency led to problems later in the scenario because drivers associated the rightmost lane, which was an exit only lane, with St. Helens when the exit was for a different destination (Vaughn St.).

- Option lanes are particularly appreciated and used by drivers who are unfamiliar with an area but are used more strategically at familiar interchanges (e.g., to avoid congestion). However, some drivers still prefer the certainty associated with exit only lanes.

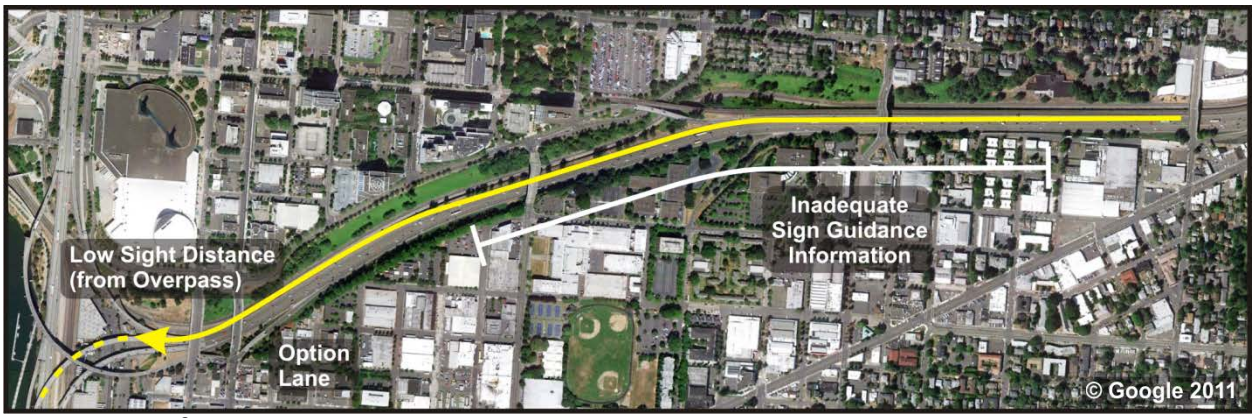
- Lane arrows require extra work from drivers when they are used to denote option lanes. This information is indirect in the sense that drivers have to deduce that the two destinations point to a single lane as well as to other lanes that head off in different directions.

- Drivers like distance information for upcoming exits.

Scenario 2

Roadway Description

The roadway used in scenario 2 was primarily a sunken freeway with a limited view of the surrounding urban area. The freeway was crossed by several overpasses that limited sight distance in curves. Figure 23 shows an aerial view of the roadway.



©2011 Google®; map annotations provded by Battelle (see "Acknowledgements")

Figure 23. Photo. Aerial view of scenario 2 roadway in Portland, OR.[37]

The extent of the video footage is shown as a solid yellow line, and the remainder of the intended route is shown as a dashed line.

Driving Objectives

Drivers were told that they were on 30 W driving in from the outskirts of town, and their objective was to get to the Portland City Center. To ensure that drivers did not think they were going to Seattle, WA (a destination that figures prominently on the signs), drivers were reminded that they were in Portland, OR. Figure 24 shows the signs that drivers encountered and the maneuvers that they had to make during the scenario drive. The relative locations of critical points are highlighted.

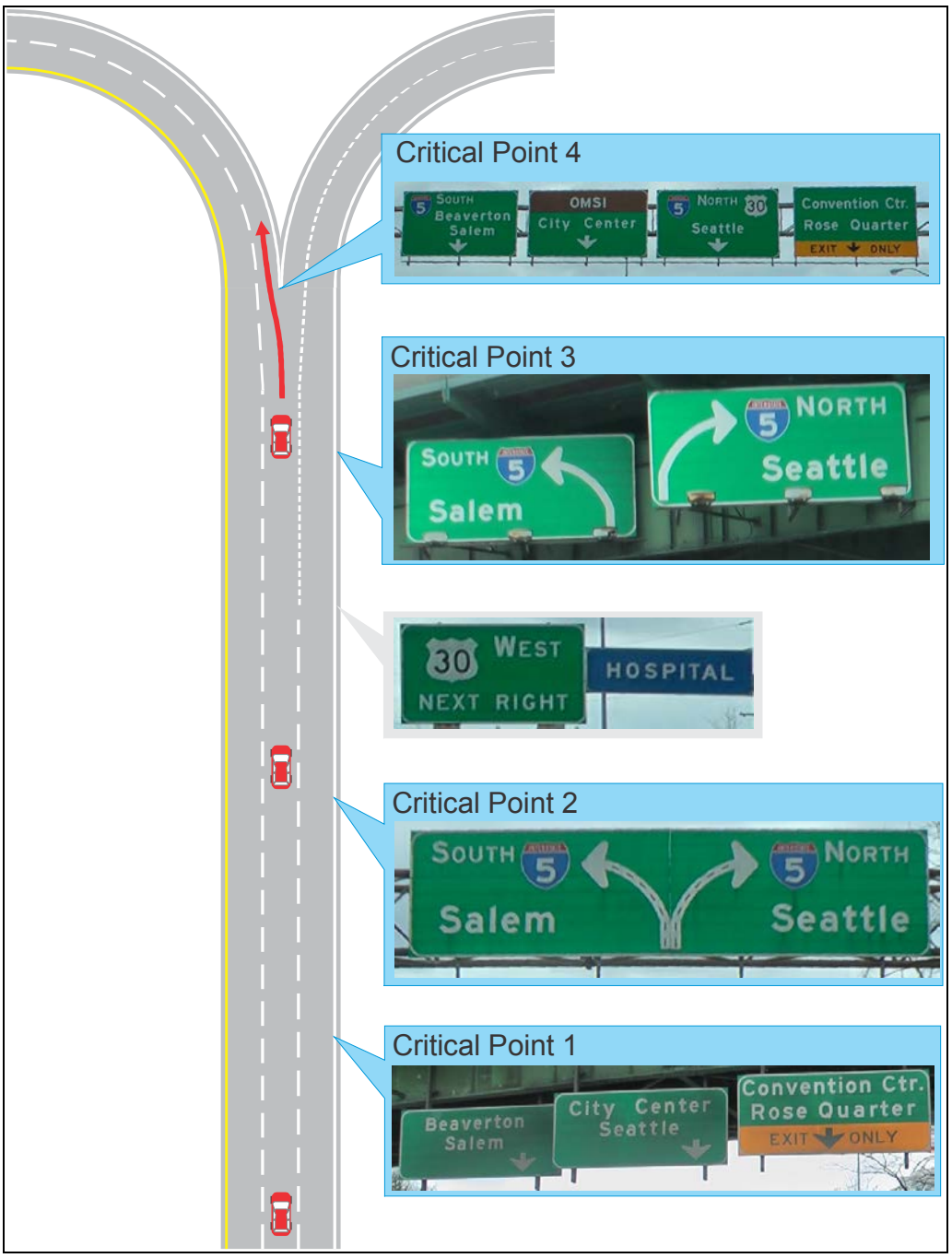


Figure 24. Illustration. Sign information and required vehicle maneuvers in scenario 2.

Scenario 2 Critical Point 1

At the first critical point, drivers approached a bank of signs mounted to an overpass (see figure 25). The vehicle was already in the correct lane for reaching the target destination.

Figure 25. Photo. Image presented to drivers for discussion in scenario 2 critical point 1.

A key topic for this critical point in the group discussion was the meaning of multiple destinations listed on the same sign.

Response Booklet Question

At the first critical point for the second scenario, drivers were presented with arrow-per-lane signs with multiple destinations on each sign. Drivers were asked to select whether the signs indicated that City Center and Seattle were serviced by the same exit or whether the middle lane allowed them to reach both destinations. Figure 26 shows the distribution of responses. Five drivers either wrote in their own responses or selected both options and were not included in the figure. Most drivers thought that the middle lane would lead them to both destinations but that it did not necessarily indicate an exit.

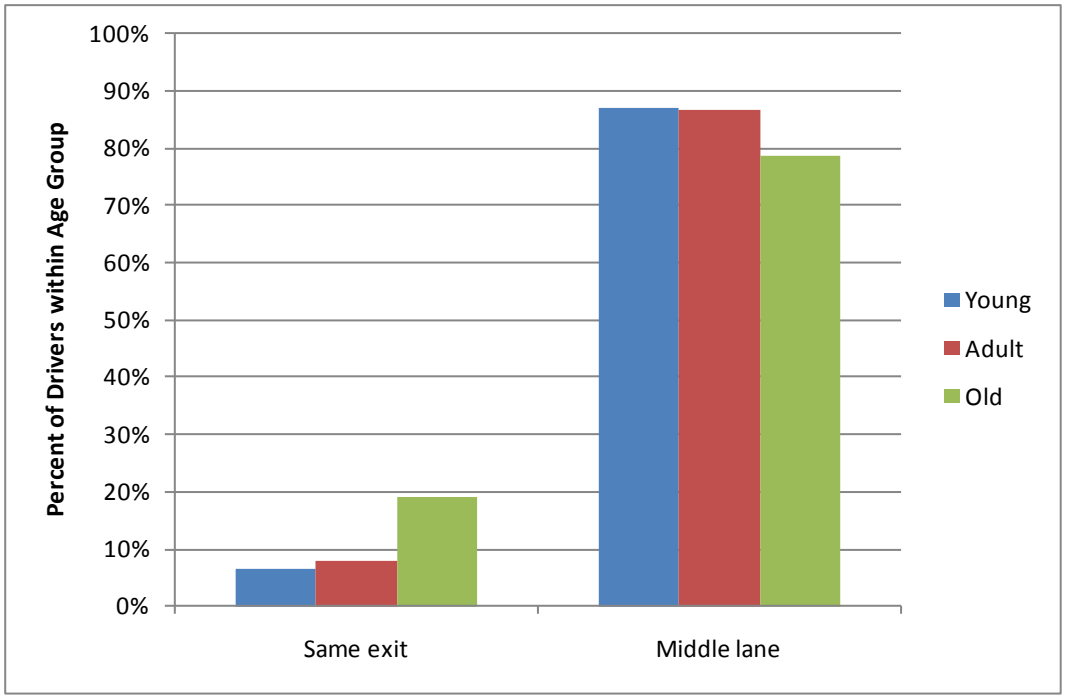


Figure 26. Graph. Booklet response distribution for scenario 2 critical point 1 (*N* = 111).

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Sign Interpretation:

The signs that drivers discussed in the first critical point were three destination signs with downward pointing arrows (see figure 27). For the most part, drivers were able to obtain the key information from the signs.

Figure 27. Photo. Guide signs associated with scenario 2 critical point 1.

Multiple Destinations:

Almost all drivers correctly interpreted the meaning of the sign where the two destinations above the arrows could be reached by taking the indicated lane.

Driver responses include the following:

- "You take the same lane to get to both locations."
- "If you follow the signs, you will get to both locations at some point. And then the signs will get more specific as you get closer to your exit."
- "I would know to stay in that lane. I know that there are going to be some changes down the line, but I will be okay if I stay in [the center] lane. That lane will take us to both."

Destination Order:

Some drivers also interpreted the order of the destinations as indicating the relative proximity of each destination. One driver indicated that, "I always read this as the first one [top destination] is the closest location and the last one [bottom destination] is the furthest location…and that the first one is close by but the second one is very far away."

However, there were also some other drivers who did not see the destination order as communicating relative distance. One driver indicated that, "I didn't assign any meaning to the order of the destinations. I'm new to town, looking for City Center, I see it on the sign with the arrows, so I'm going to stay in this lane. I didn't think about order—I'm scanning the signs quickly, watching for traffic around me."

Expectations and Strategies:

A few drivers were confused by the layout of the sign information. In particular, these drivers tried to assign meaning to systematic sign characteristics that they were unfamiliar with—in this case, the placement of the arrows on the right side of two of the signs. One driver commented, "Why are the arrows to the right of the signs? What are they trying to say? I'm not used to this, and it makes me wonder if it has a specific meaning."

Challenges:

A few drivers reported confusion or problems distinguishing the multiple destinations on the signs. This is certainly a potential problem with drivers who are unfamiliar with an area; however, it may have also arisen because the scenarios lacked sufficient contextual cues to clearly differentiate City Center from Seattle (i.e., no drivers from the Seattle groups had this problem since it was obvious to them that the scenario was not in Seattle). Driver responses include the following:

- "I'm used to seeing "City Center" paired with the name of the city. So I wanted to read that as "Seattle City Center" not Portland."

- "The way the sign is written, it looks like there is only one destination. There's no slash or divider separating the destinations. If you are coming from out of town, you might not know that those are two separate destinations."

- "I'm trying to get to Portland City Center. I don't understand why Seattle is even on this sign. It's just confusing to me. There is no definition between the two. Same font, same color, you assume it's the same grouping—it just looks like a single destination."

Scenario 2 Critical Point 2

Shortly after passing the signs in critical point 1, drivers reached the next sign (see figure 28). Drivers did not need to change lanes at this point.

Figure 28. Photo. Image presented to drivers for discussion in scenario 2 critical point 2.

Key topics in the group discussion for this critical point included the following:

- What information diagrammatic signs provide about upcoming interchanges.

- Drivers' opinions about the information this sign provides regarding the City Center destination.

Response Booklet Question

At the second critical point, the objective destination, City Center, was not included on the sign. Drivers were asked whether they would go north or south on Interstate 5 to reach City Center. Figure 29 shows the distribution of responses. Four drivers either stated "neither south nor north"

or that they did not know. Almost all of the drivers said that they would go north to reach City Center. The listed destination for the northbound direction, Seattle, was paired with City Center on a previous sign at critical point 1.

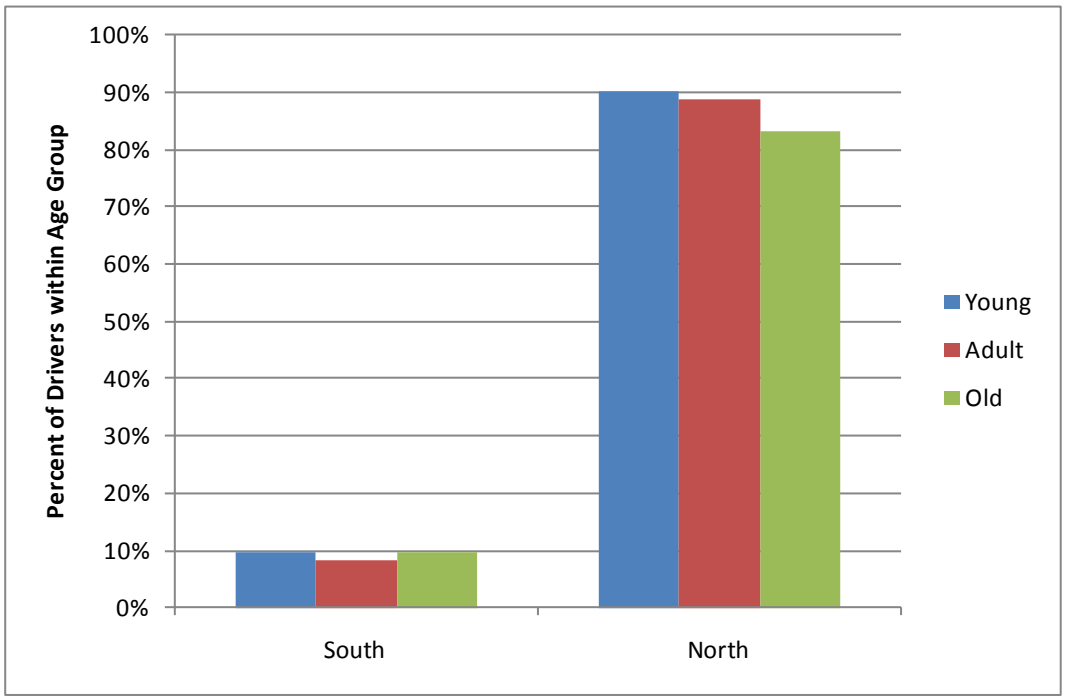


Figure 29. Graph. Booklet response distribution for scenario 2 critical point 2 (*N* = 105).

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Sign Interpretation:

The diagrammatic sign indicated that the freeway will eventually split into two directions. It will also go from three lanes to two lanes in each of the north and south directions (see figure 30). The center lane is shown as an option lane that goes in both directions. Only two of the original destinations are shown on this sign.

Figure 30. Photo. Guide sign associated with scenario 2 critical point 2.

Route Guidance Information:

Several drivers reported using the diagrammatic sign primarily for obtaining a high-level view of what happens at the interchange and where they need to go, but they did not particularly focus on the more detailed sign elements. Driver responses include the following:

- "I typically don't take them absolutely literally, just as a general idea of what will happen."
- "I just follow the arrow and look for the [destination] that was closest to the one that I was going to."
- "I'm not going to register the dotted lines that quickly. I can see them, but all I'm going to register is the splitting arrows, and the words, and maybe the I-5 [symbol]."
- "It happens too fast for me to even notice the lane dots. I'm looking at the fact that it splits and there's Seattle and Salem, and that's all."

It was also clear to several drivers that the sign indicated that there was no option to go straight. Driver responses include the following:

- "It's going to force you to make a decision. You can only go one way or the other way."
- "You can't go straight."

Information About Lanes:

Although some of the quotes listed in the previous subsection indicate that some drivers ignored the lane information provided in diagrammatic signs, many drivers used this sign element to obtain a more literal interpretation of how the lanes will transition at the interchange. Driver responses include the following:

- "My impression is that the middle lane is the option lane. You start with three lanes and then it will split to four lanes."
- "I do take literally that if you are in the center lane, you will have to make a decision at some point."
- "It relates to what you have right now, and relates to what you will encounter in the future."

Misinterpretation of Diagrammatic Sign Information:

Some drivers also indicated that they had difficulty determining what happens to the middle lane, or they incorrectly assumed that this lane would continue through the split. Driver responses include the following:

- "Under normal circumstances, I'm very visual and I like pictures like this a lot and process them faster, but I get very confused because I couldn't figure out what happens to the middle lane. There are only two arrows."

- "I misread the number of lanes before the split. It only looked like two lanes to me, so this sign was more confusing than anything. I couldn't figure out what the middle lane that I'm in now was going to do."

- "What that is telling me is that you are approaching a major interchange where you are going to have a choice of going north or south. If you don't want either of those, than just stay in the middle lane and go through."

Expectations and Strategies:

The presentation of this diagrammatic sign after the destination sign (critical point 1) caused problems related to driver expectations for drivers because the diagrammatic sign did not provide additional information about their specific destination (City Center).

Some drivers reported becoming uncomfortable when they did not get the information they expected (i.e., where to go for City Center). Driver responses include the following:

- "The sign tells you there are three lanes and two directions, but it doesn't tell you which way to go."

- "I'm forced to guess. And I shouldn't be."

- "At this point, I would be freaking out. Where did City Center go?"

The key outcome of the missing information about City Center was that most drivers incorrectly assumed that the grouped destinations (City Center and Seattle) shared the same direction, not just the same lane[3]. Driver responses include the following:

- "Because of the way that Seattle and City Center are linked on the sign, I thinking that they are going to be linked on the road."

- "Because the last sign said Seattle and City Center, I would be thinking that I need to go right here [towards Seattle]."

- "My inclination after seeing this sign would be to get into the right lane, because I think Seattle and City Center go together. This would make it very difficult for me to take the [correct] exit later on because I'd be in the wrong lane."

- "I'd probably get into the right lane, since I think I have to go right to Seattle to get to City Center."

[3]Note that it is possible that the association between City Center and Seattle was influenced by drivers answering the response booklet question for this critical point. In particular, that question asked drivers to specify a direction for City Center, which may have implicitly caused them to assign the Seattle direction to City Center when they may have otherwise remained more neutral about this until they received more information.

A few drivers openly recognized that they were being required to imply or guess the direction of City Center based the association between City Center and Seattle on the previous sign. This caused drivers annoyance that they had to make this assumption. Driver responses include the following:

- "A problem I have with this type of sign is that you have to keep track of two destinations in case your destination doesn't show up on all the signs"

- "When I saw this I had to stop and think: okay Seattle and City Center were joined on the other sign so I better follow Seattle. If you are driving, you don't want to have to take that extra step in thinking, especially if you are not familiar with the area."

A few drivers alluded to the concept of route continuity (i.e., the center lane to continue). In absence of other information, these drivers expected to continue on the main route and not exit. Driver responses include the following:

- "Experienced drivers expect the center lane to go through. Having a sign that tells you it is a through lane is even better."

- "If you stay in the middle, you stay on 30W."

- "I thought that I had to stay on US-30 to get to City Center since we didn't see any more signs about it. Just before this, we saw a sign that said US-30 next right, so I would have been in the right lane. At this point, I would have not had enough time to change into the [correct] lane."

Challenges:

One specific challenge identified by a few drivers is that they found the switch between the arrow-per-lane and diagrammatic signs to be a source of concern. Driver responses include the following:

- "This sign is not consistent with what we've seen up to this point. We went from a sign that is talking about lanes to one that is talking about direction."

- "There should be better consistency in the signs. I don't like having different types of signs in that short of a distance. It is confusing."

Improvements:

Drivers mentioned a few ways in which signage could have been improved to make it easier for them to navigate the interchange. A few drivers mentioned that distance information would have been useful for estimating how much time they had to prepare for the interchange split. Driver responses include the following:

- "I like exit distance information on signs. I don't like signs that don't have them because you don't know when the next sign is coming."

- "Neither of these sets of signs says how far until the split happens. If they signs did [provide distance information] it would give me a chance to prepare for the split."

Also, several drivers had suggestions for addressing the primary navigation challenge, which was the lack of information telling them which direction to go for City Center. Driver responses include the following:

- "How hard would it have been to [put] City Center above Salem. Then there would not have been any question."

- "Wouldn't this sign be easy to fix? You just need to add in City Center and Convention Center/[Rose Quarter]. It's not like there is a lack of space for it."

Driver Actions:

With regard to specific driver actions, a few drivers reported that if they do not understand a sign or if they have uncertainty about the sign information, a safe strategy seemed to be to stay in the middle lane. Driver responses include the following:

- "This sign did not really tell me what to do. I would stay in the center lane, but I couldn't figure that out from the sign."

- "I would try to stay in the middle lane as long as possible until I got more specific instructions about where to go. Because based on this sign, I have no idea where to go."

- "This sign threw me because—based on the previous sign—I was expecting the highway to continue straight, and the exit for City Center to be an exit. I wasn't expecting an actual highway split like this. And when it said Seattle to the right, now I'm not sure where to go. Last thing I saw about City Center was to stay in the middle lane. I'll do that, but I'm totally confused."

Scenario 2 Critical Point 3

The third critical point was near an overpass that held two signs that provided similar information as the sign at the previous critical point (see figure 31). The roadway at this point begins curving to the right and upwards, and sight distance is limited by the overpass directly ahead and another one just beyond that one.

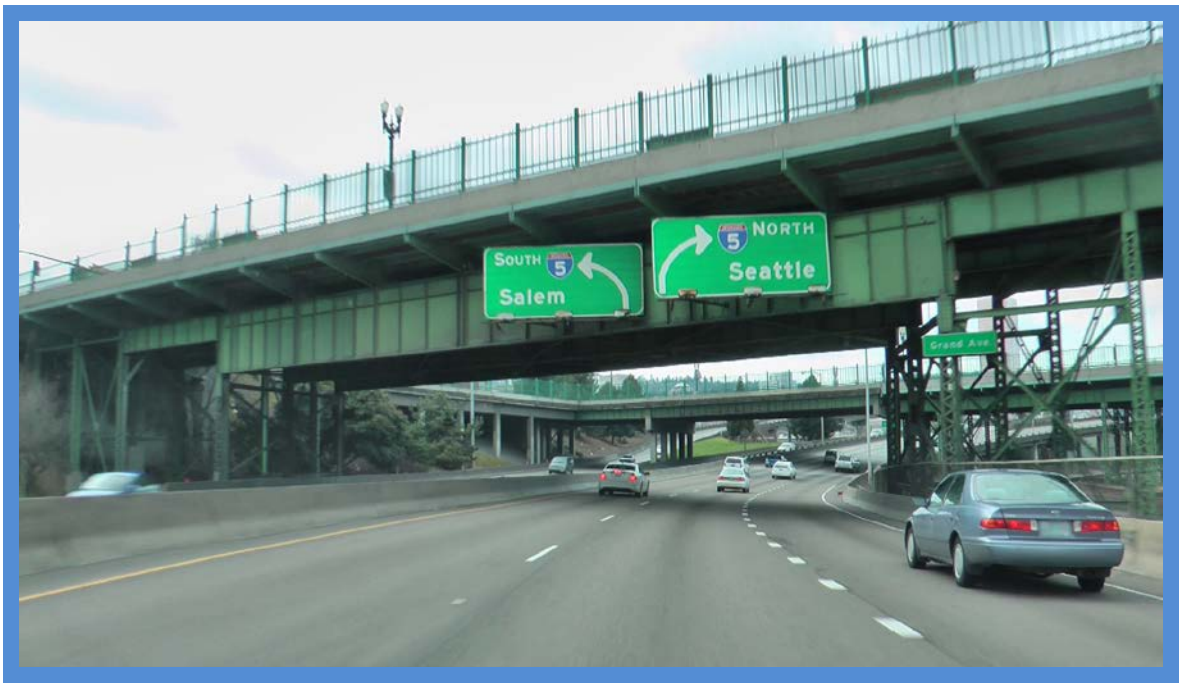


Figure 31. Photo. Image presented to drivers for discussion in scenario 2 critical point 3.

Key topics in the group discussion for this critical point included the following:

- What information the arrows communicated about the upcoming roadway geometry.
- The relationship between the arrows and the individual lanes.

Response Booklet Question

No response booklet question was asked for this critical point due to time constraints.

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Sign Interpretation:

The signs at this critical point contained much of the same information as the diagrammatic sign in the previous critical point but without the lane information (see figure 32). The direction information was presented on separate signs, and this may have led to driver confusion about how to interpret the relationship between the directional arrows and the lanes on the road.

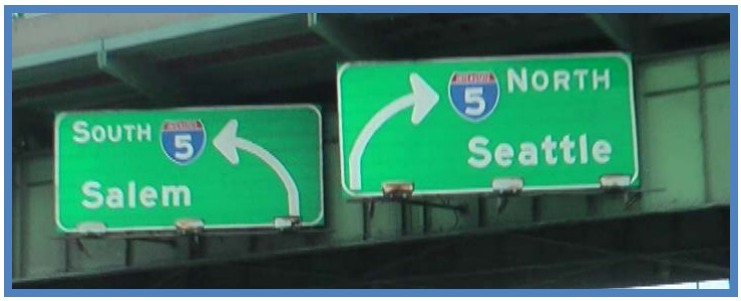


Figure 32. Photo. Guide signs associated with scenario 2 critical point 3.

Split Information:

For the most part, the information about the freeway split was adequately communicated by the signs. Several drivers viewed these signs as providing directional information, specifically indicating a north/south or a left/right split. Driver responses include the following:

- "I interpret these arrows as showing a major split in I-5, something is changing drastically. It's just not a small turn in the road."
- "I see the arrows as directional because typically, if the arrows pertain to lanes, they point down towards the lanes."
- "My impression from the previous sign and this one is that all of the lanes are split and your options are north or south. I wouldn't assume that the center lane would go anywhere other than north or south."
- "That's also telling me that I'm approaching I-5 and that I have a chance to go north or south."

Arrow Position:

Several drivers also tried to link arrows to specific lanes on the road even though this sometimes resulted in incorrect conclusions about what the lanes did. Driver responses include the following:

- "These signs are kind of weird. There are three lanes here but only two arrows. So I couldn't figure out which lane went with which arrow."
- "I see the arrows as showing what the outside lanes do, but I cannot figure out what the center lane does from this sign."
- "I'm assuming the two lanes on the right are going to go to Seattle, and the one lane on the left goes to Salem."

There were also a few drivers who mapped the arrows to their spatial impression of the roadway geometry. Driver responses include the following:

- "Another thing that is confusing is that the road goes to the right, and there's an arrow that goes to the right. But there is also an arrow that goes to the left, but no road that goes to the left."

- "If you look at the road, the left lanes look like they go straight. I was expecting it to curve off more. It does not look like the sign at all. This is a little confusing to me."

Timing of Split:

For a few drivers, seeing the "split arrows" repeatedly implied the imminence of the split.

- "I would expect the split to be close, since those are the only signs that I'm seeing now."

Lane Markings:

The exit lane markings caused confusion for at least one driver. It was not clear which part of the split contained the actual exit.

- "I know that the [exit lane markings] on the right represent an exit. I'm asking myself, what the center lane is for. I'm expecting the left lane to cut out South and the right lane to take me North. So I'm really concerned about what am I still doing in the center lane."

Expectations and Strategies:

Several drivers expressed frustration about not getting the information they needed about City Center. However, based on their responses to the first sign in the scenario, most seemed to understand that the center lane would take them to City Center. This suggests that drivers became concerned if they drove extended stretches without seeing expected information. Driver responses include the following:

- "After I see this sign after the last one, this is where I start to get worried. I haven't seen anything about City Center in a while."

- "If I was going to City Center, I'd be totally confused at this point. City Center just disappeared."

- "I don't know what's coming up."

- "I would be much more comfortable up there with three signs for the three lanes. I don't have much time to figure this out when I have to watch for traffic and so forth. I really want them to tell me what will happen so I can just worry about being in the correct lane without having to figure out where I'm going."

Scenario 2 Critical Point 4

In critical point 4, drivers encountered a bank of guide signs immediately after traversing a combination horizontal/sag-vertical curve that passed under an overpass (see figure 33). This created a blind curve that limited sight distance and the amount of time that drivers had to view the sign information. Another potential challenge to drivers was the gore point immediately ahead of them. Because the gore point occurred following a horizontal curve, drivers needed to continue steering to the left to avoid it (if they were headed to City Center).

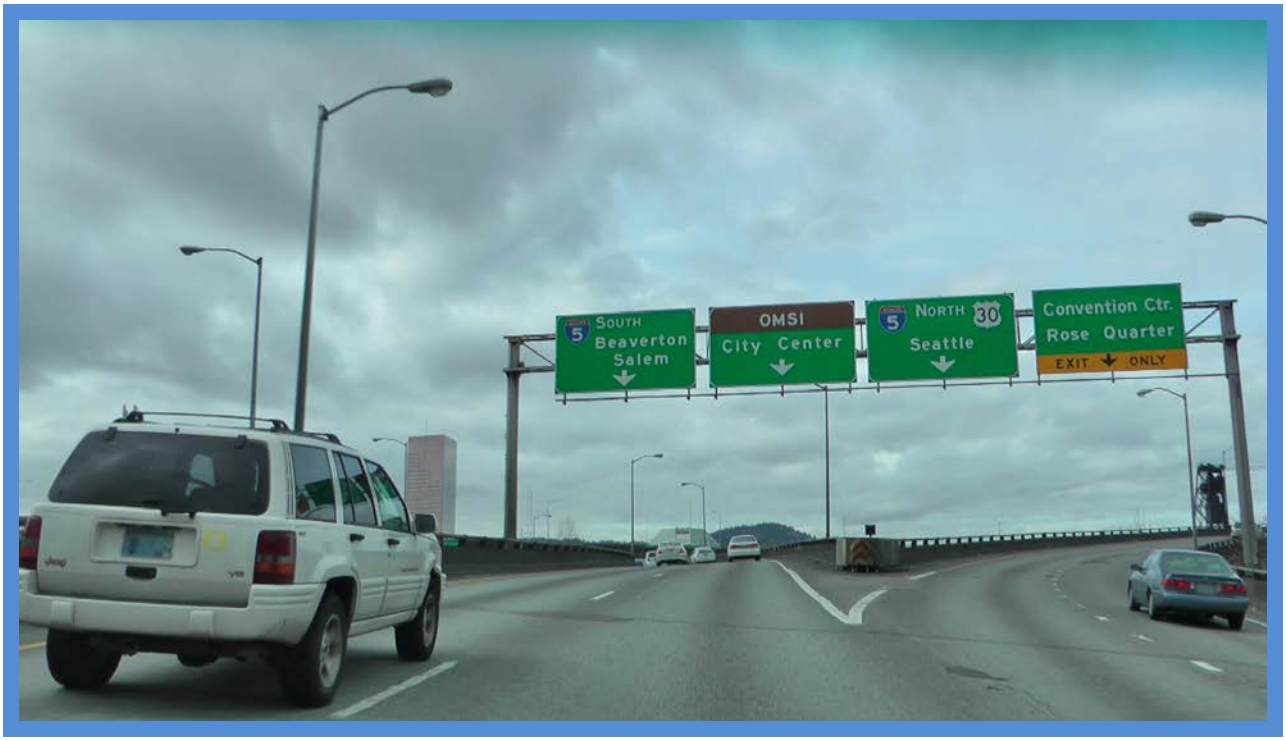


Figure 33. Photo. Image presented to drivers for discussion in scenario 2 critical point 4.

Key topics in the group discussion for this critical point included the following:

- What information surprised drivers.
- Strategies for sign reading given the large amount of information presented.

Response Booklet Question

At the final critical point in scenario 2, drivers were asked five questions that all focused on whether the approach signage adequately prepared them for various dimensions of the freeway lane split. The response distribution is shown in figure 34.

Generally, drivers felt unprepared for most aspects of the split. Many of the drivers knew that a split was coming; however, few knew which lane to be in or which direction to go. One surprising result was that except for younger drivers, the majority of drivers in other age

groups did not expect that they could go in both directions from the center lane despite previous signage indicating that they could. Younger drivers were also the most prepared for the split.

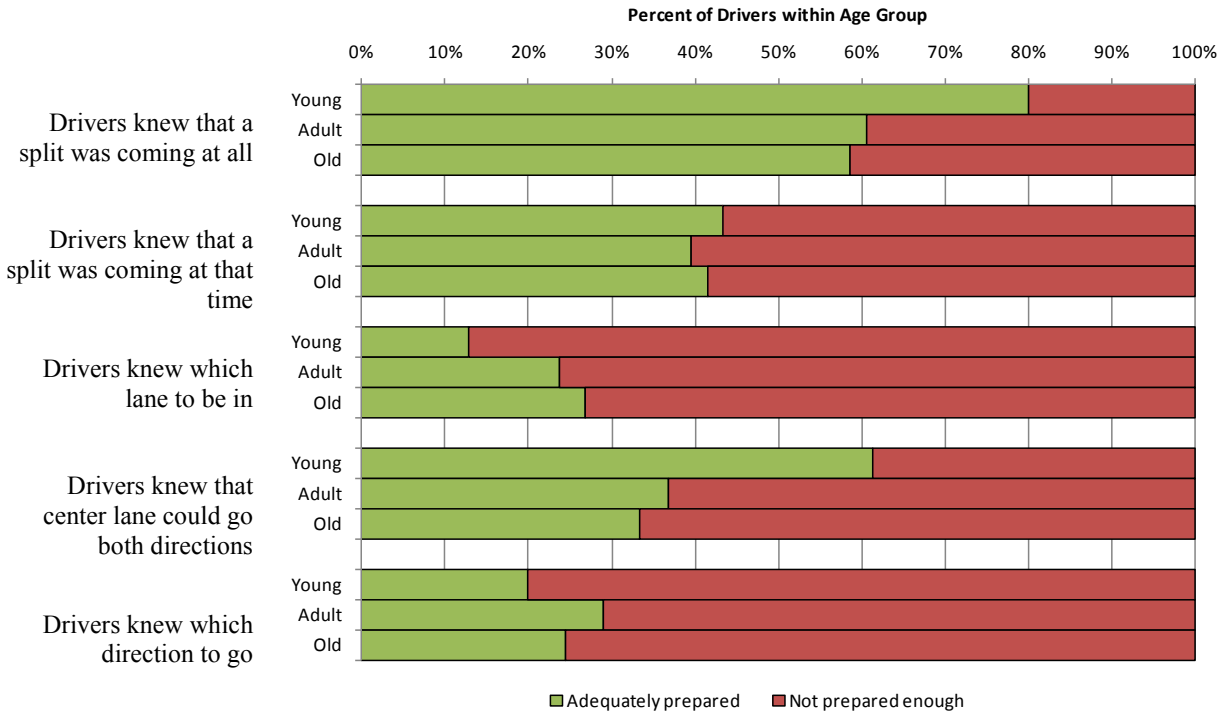


Figure 34. Graph. Booklet response distribution for scenario 2 critical point 4 (*N* = 109 to 111).

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Sign Interpretation:

The signs in critical point 4 were comprised of one guide sign for each lane, including a down arrow (see figure 35). The key sign for the scenario navigation task was the left-middle sign (City Center). Also included on that sign was destination information for a local tourist attraction (the Oregon Museum of Science and Industry (OMSI)). Drivers saw another sign for this attraction earlier during the approach.

Figure 35. Photo. Guide signs associated with scenario 2 critical point 4.

Sign Information:

Some drivers reported that they liked the sign information but thought that the information would have been more useful if it had been provided earlier. Driver responses include the following:

- "The sign itself is pretty good. But it comes too late."
- "Why couldn't they have shown this earlier?"
- "I think the sign comes too late. You don't see it until you are very close to where you have to make a decision, because of the overpass [blind curve]. But if you put that sign on the overpass itself, it might confuse people more [since they can't see all four lanes]. But you have to find some way to give drivers more preparation."

Sign Reading:

Some drivers reported that when faced with the time-limited viewing conditions represented by the current critical point, their primary method of obtaining sign information would be to scan for key information. Driver responses include the following:

- "I would look for the sign with City Center on it. Everything else I would ignore."
- "I would be in panic mode at this point, so I would be scanning quickly for the City Center sign."
- "I think somehow we pick out what we are looking for amongst all the other stuff. We see instantly, there it is."

However, a few drivers reported that they would read from left to right. One stated, "I read these from left to right as fast as I can, and I stop reading as soon as I see what I want. Because you don't have time to read all that and make your lane change."

Expectations and Strategies:

A key challenge in the current scenario is that immediately prior to seeing the signs at this point, most drivers were prepared to follow signs for Seattle to get to City Center. This incorrect expectation was likely formed based on the destination signs at the start of the scenario and compounded by the fact that drivers received no other information about City Center until this last set of signs. Driver responses include the following:

- "All the signs I've seen before this said Seattle right or 30W right. There was nothing to prepare me to separate City Center from either 30W or Seattle."
- "We were sold a couple of signs back that if we stayed in the lane for Seattle, we were going to go to City Center. So I'm prepared to go in one direction, but, what the heck? Now I have to go in the other direction."

- "My assumption from City Center being labeled with Seattle, then City Center not [appearing on any of the later signs] was that I would follow the signs for I-5 to get to City Center. So it is likely that I would be at the far right lane at this point because it was marked for exit."

- "The previous signs were worse than [providing no information] because the misled you into believing that City Center was in the opposite direction."

The uncertainty leading up to the final set of signs would have also caused some drivers to feel stressed out by the split. Driver responses include the following:

- "What annoys me is that if I'm from out of town, I'm going to end up going in the wrong direction and end up somewhere that is totally unknown to me. Then I don't know how I'm going to figure out how to get back to where I wanted to go."

- "It is very stressful, especially if everyone is going 5 mi above the speed limit."

- "I'm relieved that it's an option lane. Before that, I would be stressed because I'd be thinking: Do I need to [change lanes]?"

Challenges:

Drivers reported multiple challenges related to reading the sign information and also with regard to the situation in general.

Sign Reading:

Many drivers identified sign elements that would have made obtaining the information they need from the signs more difficult. These challenges included too much information, mismatched expectations causing them to look for information in the wrong place, and distracting information that was not central to their navigation task. Driver responses include the following:

- "There's too much to read."

- "There are so many signs, even if you have time to read them, you are never going to have enough time to decide what to do here."

- "I look for City Center, but in this situation it's not where I expect it to be. So that starts me looking at the other signs, and I'm looking at a bunch of junk that I don't need to be looking at."

- "Seeing the OMSI sign with the different background really distracted me, since I hadn't seen anything about it before."

- "I just noticed that the Seattle sign says 30 on it, which makes it even more confusing, since I thought 30 would take me to City Center. If you were fixated on the 30, you might have read the wrong sign."

Many drivers also discussed the challenges caused by the geometry of the interchange, in particular, the limited sight distance and sign reading time that occur because the split happens almost immediately following a blind curve under an overpass. Driver responses include the following:

- "Putting the signs up just beyond those curves like that makes them impossible to see until it is almost too late."

- "I'm a very visual person, I thought that rounding the corner is really deceiving because all of the sudden you have to make a decision. The corner really throws me."

- "Because of the curve to the right, if you are in the right lane and want to get to the left it makes it even more scary."

Situation-Specific Challenges to Navigating the Split:

Many drivers had comments related to several factors that made navigating the split particularly challenging. Comments on limited time include the following:

- "There's not enough time to make that decision, especially with traffic and distractions."

- "I think you are pretty much prepared that there is a split coming, but in terms of finding out which lane you have to be in, not really. It's too late."

One driver commented on incorrect direction assumptions, "I didn't have a good picture of how this would turn out. Now I'm scrambling to figure out what I have to do with no time to do that. Luckily, I'm already in the [correct] lane, but I still don't like being in this situation."

Comments on multiple required subtasks include the following:

- "You come up out of that last [blind] curve, and you have a very short amount of roadway—a very small timeframe—to read all that information and change lanes if you have to. There's not enough [distance] to make a safe lane change at that point because you have to read it, make a decision, look to see if you are clear, before you reach the [gore point]."

- "Finding what you need from the sign is just one part of this. Then you have to decide, can you do this, can you accomplish the maneuver? Or do you just decide that you can't and try to find another route."

Comments on required awareness of other vehicles include the following:

- "You have to be alert. This comes up on you so fast. You have to be aware of traffic around you, you have to be ready to switch lanes quickly, plan to have room to switch lanes if you can, or hope that someone will let you in."

- "You also have to watch out for other drivers. You always see someone trying to make these last minute lane changes with no consideration for others on the road."

Improvements:

Some drivers had ideas for improvements that would state/verify their split direction, but they generally acknowledged that the option lane was fine. Driver responses include the following:

- "The original sign is accurate because the center lane splits. Back then, I would have appreciated knowing ahead left."

- "A big logo or insignia on the pavement saying which lane to go to City Center would be very helpful here."

Driver Actions:

Despite the challenges of navigating the interchange split, some drivers would try to get into the correct lane to City Center even if they were in the rightmost lane. From any lane, they would only have to maneuver over one lane or just steer to the left (if they are in the option lane). However, they acknowledged that there could be risks associated with their actions. Driver responses include the following:

- "What I would do would depend on how much traffic there is. You only have to navigate one lane—you can usually manage."

- "I would try to veer left if I could do it without getting into an accident."

- "I was ready to peel off right. I'm still in the correct lane, but I may have already started to curve to the right. Now I'm swinging back over."

- "I would have been in the right lane and cut somebody off [trying to get to the center lane]."

One driver also commented on how driver reactions to the split had implications for safety at this location and stated, "Since these signs are only visible at the last minute, you have several drivers making decisions at the same time. Chances are someone may decide that they are in the wrong lane and try to change lanes when it's not safe to do so, and [that could lead to crashes]."

Several drivers also reported different coping strategies for similar interchange-driving situations. Driver responses include the following:

- "In this [location], I'd expect to see someone going slow with their turn signal on, trying to get in the [correct] lane."

- "I would probably just end up going in the wrong direction and trying again."

- "When I travel to someplace I've never been before, I always give myself an extra hour to take care of things like this [missing an exit]."

- "I usually have a passenger with me. I get them to help me out with the signs."

Scenario 2 Key Themes

Some of the key themes expressed in scenario 2 are as follows:

- Even simple diagrammatic signs can be misinterpreted by drivers if the interchange they depict is confusing or unfamiliar to the driver. Option lanes or changes in the number of lanes at different points along the interchange may contribute to this likelihood.

- Drivers who are unfamiliar with an area appreciate feedback that they are in the correct lane or have not missed their exit.

- Drivers seem to actively construct a mental model of the interchange as they encounter sign information or other cues. If they are missing information they need, they may adopt a "wait-and-see" attitude. Otherwise, they will make assumptions about missing information based on the information available (e.g., pairing City Center with Seattle directional information). However, drivers may not be comfortable doing this.

- Some drivers appreciate consistency in sign types.

- Drivers like knowing distance information for upcoming exits.

- A default driver strategy in the face of uncertainty is to drive in a lane that has options or that is easy to change out of into other likely destination lanes. In some sense, there may be a tradeoff between increasing the likelihood of making a one-lane/simple lane change but decreasing the likelihood of having to make a two-lane/stressful lane change.

Scenario 3

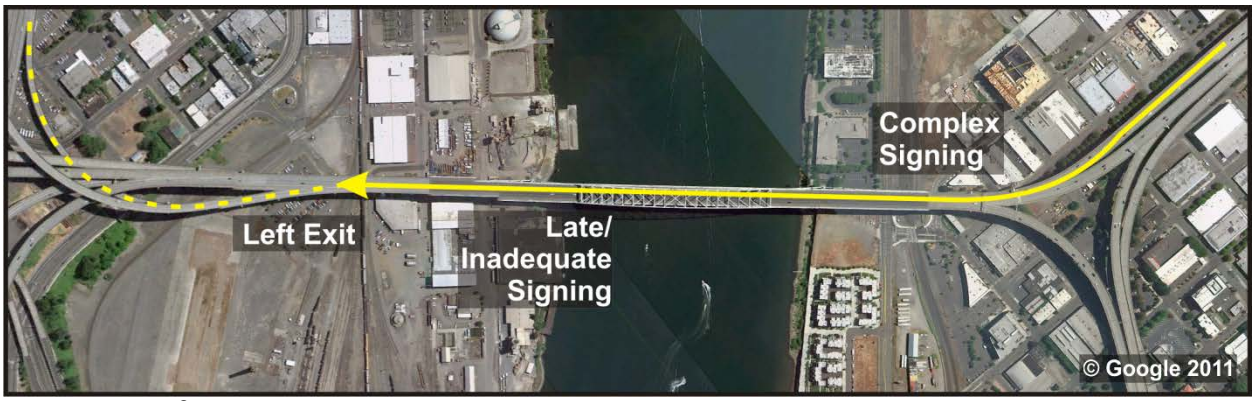
Before viewing the video for scenario 3, drivers looked at a map of the area with their intended maneuver marked (see figure 36). This map helped provide some directional orientation that would normally be present if they were actually driving.

©2011 Google®; map annotations provded by Battelle (see "Acknowledgements")

Figure 36. Illustration. Map of scenario 3 roadways and maneuver.[38]

Roadway Description

The roadway was the lower deck of a bridge in Portland, OR (coincidentally, the same bridge that was driven in scenario 1). The bridge deck had four lanes, all traveling in the same direction. The bridge was fairly enclosed by support pillars on either side of the roadway. Figure 37 shows an aerial view of the roadway.



©2011 Google®; map annotations provded by Battelle (see "Acknowledgements")

Figure 37. Photo. Aerial view of scenario 3 roadway.[39]

The extent of the video footage is shown as a solid yellow line, and the remainder of the intended route is shown as a dashed line.

Driving Objectives

Drivers were told that their objective was to get onto I-5S. Figure 38 shows the signs that drivers encountered and the maneuvers that they had to make during the scenario drive. The relative locations of critical points are shown.

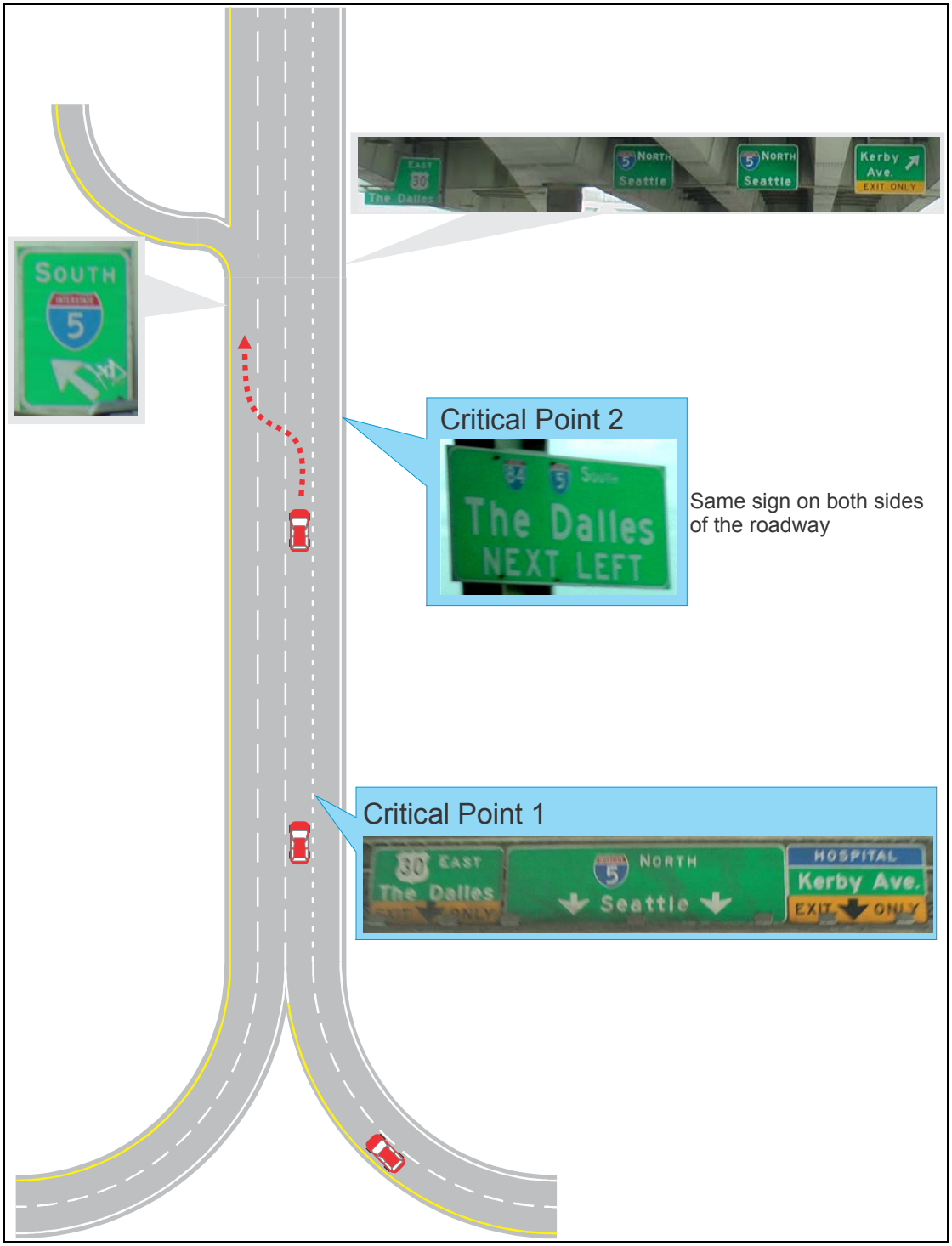


Figure 38. Illustration. Sign information and required vehicle maneuvers in scenario 3.

Scenario 3 Critical Point 1

After merging onto the bridge deck, drivers saw a bank of signs overhead (see figure 39). There were four lanes, with the two leftmost lanes being the continuation of a separate entrance ramp that merged onto the bridge at the same time. The lane markings for the rightmost lane indicated that it was an exit only lane.

Figure 39. Photo. Image presented to drivers for discussion in scenario 3 critical point 1.

Key topics in the group discussion for this critical point included the following:

- Drivers' feelings and strategies given that no information about their destination was provided by the guide signs.
- Drivers' lane choices.

Response Booklet Question

At the first critical point for the third interchange, drivers were anticipating exit information, but their destination was not listed on any of the signs. They were asked which lane they would feel most comfortable in without sign guidance for their destination. Figure 40 shows the lane choice options as they were numbered in the response booklet.

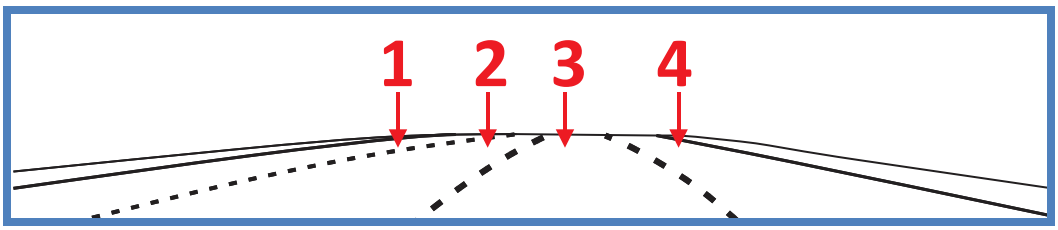


Figure 40. Illustration. Lane numbers provided in response booklet for scenario 3 critical point 1.

Figure 41 shows the distribution of responses. Most drivers were comfortable in lane 3, although a few drivers chose lane 4. There were no notable age differences between responses.

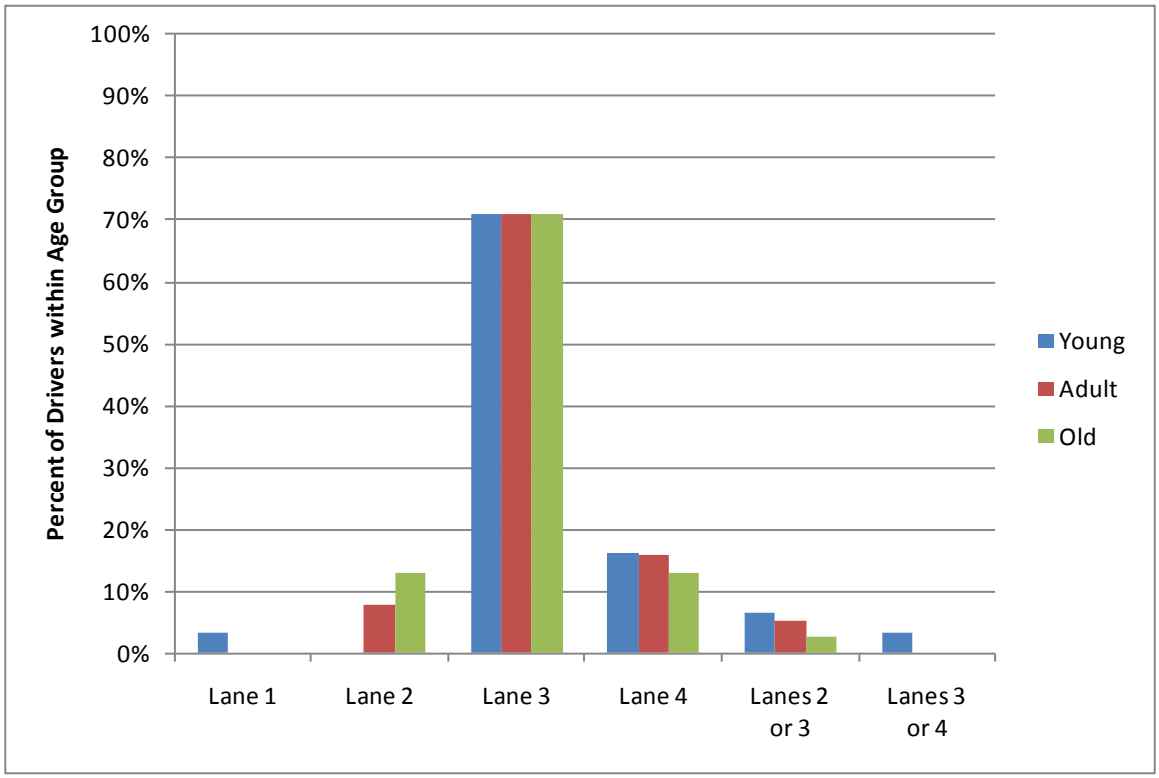


Figure 41. Graph. Booklet response distribution for scenario 3 critical point 1 (*N* = 107).

As a follow-up question, drivers were asked why they would be most comfortable in the lane that they chose. The top responses for lane 3 are as follows:

- Exits are usually to the right.
- Drivers avoid the exit only lanes.
- Drivers head toward I-5 and hope that a right-hand exit for south appears.
- "South" should be to the right according to the map.

The top responses for lane 4 are as follows:

- The right-hand lane should head south.
- The map suggests that the route toward the south is to the right of the current direction.
- Drivers remembered seeing the hospital on the map, so they followed the signs there.

These responses are largely consistent with the discussion themes from this critical point, which are summarized following sections.

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Sign Interpretation:

The overhead signs provided arrow-per-lane information (see figure 42). None of the signs provided any information about the drivers' destination at this point.

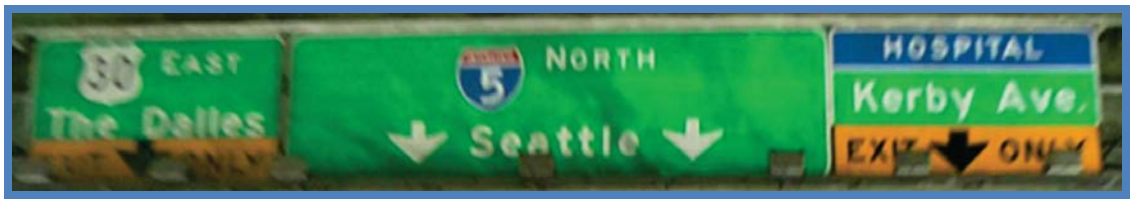


Figure 42. Photo. Guide signs associated with scenario 3 critical point 1.

The absence of information about the drivers' destination in the first bank of signs was obvious to drivers, and it prompted a variety of reactions including frustration and thinking that they may have missed their exit.

Some drivers found the destination information provided by the signs to be inadequate for getting to I-5S. Driver responses include the following:

- "I don't see that these signs apply. Hopefully, there is another one [about I-5S] down the road."
- "These signs are not good. They don't say which way to go for I-5S."
- "The signs don't give enough information to know which lane to be in."

A few drivers expressed frustration that I-5S destination information was left out while information about other destinations was provided. Driver responses include the following:

- "It makes me frustrated immediately. Knowing that I-5 is my destination, and I see signs for every other destination, except a major highway, that's pretty frustrating."
- "I'm disturbed because there is so much emphasis to I-5N but not South at all."

The absence of expected information made several drivers think that they had missed the exit or gotten lost. Driver responses include the following:

- "I would have thought that I was lost, because I see signs for I-5N but not I-5S, at that point I would think that I was going the wrong way."
- "I would think that I would have to turn off to get to I-5S, and somehow I missed the exit."

Expectations and Strategies:

The key expectation in this critical point is related to where drivers expected the exit to occur. Given that this information was not present in the first bank of signs encountered, drivers relied on other bases for these expectations. Some drivers expected a right-side exit based on general previous experience with interchanges. Driver responses include the following:

- "My assumption is that there is a right-hand exit on the bridge. Most exits are off to the right, so that is what I would assume in this case."

- "My assumption was, without seeing it, that I was in the middle lane going to exit right."

- "Because left exits are not as common, there should have been some warning on the [initial set of signs] about where that exit is."

Several drivers reported that their expectations about which side the exit was on were based their general sense of direction. Driver responses include the following:

- "It's counterintuitive to get onto I-5S on the left because that means you are going to travel north to go south. I would have guessed that I would be exiting on the right."

- "Just by default, I'm going to be in the right lane because I'm going to assume that the off ramp is going to go towards the direction of the freeway you are going to. Not the opposite way."

- "I'm thinking I'm going right. If you are going North East and you want to head to the South, you are going to turn right."

Some drivers formed their expectations about the direction of the exit based on the spatial relationships seen on the initial map. Driver responses include the following:

- "I would've stayed in the [right middle] lane. From the map, South is to the right, so I would assume that the exit would be to the right."

- "From looking at the map, you know logically that 5 South is to the right."

- "My reaction was to get into the far right lane because my assumption looking at the map was that the Exit Only lane would lead to I-5S-bound, even though it did not say so."

Challenges:

The sense of being in a confined space on the bottom bridge deck made a few drivers uncomfortable. Driver responses include the following:

- "I don't like bridges either, so I'm already concentrating on being on a bridge without having to think about looking for other signs too."

- "I think it is dangerous to have to look all the way to the right. The bridge deck gives you tunnel-vision and you just want to look straight ahead."

- "With double-decker bridges, I kind of take it for granted that they are always confusing. They always have the signs in funny spaces, and they are difficult to see past those beams there. When I drive this I just tell myself: It's going to be confusing, it's going to be horrible, but I'll make it."

Improvements:

Drivers had opinions about where freeway exit information should be displayed. Many of them suggested that placing the information above the eventual exit lane would be helpful. Driver responses include the following:

- "They could have had something that said "The Dalles" and "I-5S" on that sign [on the left], so you would know to look for that."

- "If the sign only has that much space, I think it would be better to leave "The Dalles" off in order to put 5 South on."

- "Even if they don't have any words, just I-5S with an arrow."

Many drivers suggested placing I-5S information near the I-5N information. Driver responses include the following:

- "They could have said I-5N and South on the middle sign. Or, added 'I-5S left lane.'"

- "Why didn't they put the I-5S on the left side of the sign and the I-5N on the right side of the sign? And then you're splitting [tilted] arrows."

- "They don't need 3 feet of green on either side of the Seattle. They could've made the [I-5N for Seattle] sign a little bit smaller so that there would be room on the other sign to put on the I-5S."

Driver Actions:

Several drivers reported inherently trusting that they will get the information they need eventually (in enough time to make a decision) and that they are willing to continue down the road until they get it. Driver responses include the following:

- "Sometimes what I do in a situation like this when I don't see signs for my [destination] is keep going towards the highway [I-5N in this case], hoping that there is going to be signage for my destination eventually."

- "I'd stay in a neutral lane, like one of those two that say I-5N, because the other two are exit lanes, and assume that you're going to be provided with me instructions later."

- "If nothing makes sense on any of the signs, keep going straight until something does."

Some drivers were prepared to exit the freeway to get better directions if necessary. Driver responses include the following:

- "Exiting right away [even if it is the wrong exit] can save you time because if you are continuing in the wrong direction, you don't know when the next exit is. So you might as well take the first exit, get things straight [by asking directions,] and get back on track."

- "I figured, I'd take the right lane, and exit, check the map again and look for signage around the exit since there was nothing to indicate I-5S."

- "I would just get off the freeway."

Several drivers reported adopting a "hedging" strategy in which they stayed in the middle lane, allowing them to make lane changes if needed. Driver responses include the following:

- "I would stay in the middle lane because that would give me some options up ahead as to what lane I needed to be in…until I found the next sign."

- "I would stay in the middle lanes, so you can go right or left."

- "I try to stay on the inside lanes. I don't go in the hammer lane, and I don't go in the outside right-hand lane."

In absence of navigation information, a few drivers used landmarks (i.e., from the map) to get a sense of the exit direction. Driver responses include the following:

- "I would go ahead and get in the far right because I have this flash on the map of seeing this H for hospital. I have North, I don't have South, but I know the hospital is that way (to the right). So my inclination would be to get to the far right and follow the hospital signs."

- "I always look for landmarks. And when I had my trusty map, I saw a hospital. So when I saw a sign that said "Hospital, Kirby Avenue," I chose that lane to be in to make my exit."

- "If I was looking at the map again or trying to glance at it while driving, the Kirby Hospital is close to that interchange, so my assumption would have been to stay in lane 3 [middle right]. Hopefully then I'm either still going to be close to the exit for the hospital, which looks like it's taking me in the general direction that I'm going, or there is going to be a sign for I-5 coming up."

A few drivers also used a similar approach to get a sense of the distance to the exit. Driver responses include the following:

- "I wouldn't think that the hospital exit will take me to I-5S, but I'd still use it as an indicator that my exit is coming up."

- "I know the hospital is before where I want to go, it looks like a little local exit just to get off the bridge, so I'm staying in [the third] lane, waiting for my exit to come."

Scenario 3 Critical Point 2

At this critical point, drivers encountered identical guide signs on the left and right bridge supports (see figure 43). The exit for the driver's destination (I-5S) was on the left.

Figure 43. Photo. Image presented to drivers for discussion in scenario 3 critical point 2.

Key topics in the group discussion for this critical point included the following:

- Drivers' opinions about the placement of the signs.
- Drivers' opinions about multiple lane changes.

Response Booklet Question

At the second critical point, drivers viewed side-mounted guide signs that indicated I-5S and "The Dalles" would be exiting to the left. They were asked what surprised them about the required maneuver. The responses were categorized into seven categories, which were then ranked by response frequency (see table 7).

Table 7. Rank of booklet responses for scenario 3 critical point 2 (*N* = 92).

Rank	Description of Element
1	**Left exit:** Drivers did not expect a left exit. Many based this expectation on the map provided.
2	**New information:** Drivers received no previous indication of I-5S.
3	**Destination consistency:** The Dalles, 30E, I-84, and I-5S all had changing associations on the signs.
4	**Sign placement:** Previous signs were overhead, but these signs were on the sides, and the symbols were not very visible.
5	**Redundant signage:** Both signs provided the same information.
6	**Sign on right:** The nearest sign was located on the right side of the freeway for an exit on the left.
7	**Quick lane changes:** Drivers were being required to make multiple lane changes over a short distance.

The most commonly mentioned surprising element was that the exit was on the left. This surprised drivers for two reasons: (1) the map set up their initial expectation for a right exit and (2) most exits are on the right-hand side of the roadway. The next two most common responses relate to the destination information provided—that there was no previous indication of I-5S and the inconsistency of the destinations provided between the various sets of signs. Drivers were also surprised by sign placement and that the same sign information was in two different locations. The third most frequently reported surprising element was how little time drivers had to get over to the exit lane at that point.

Focus Group Discussions

The key themes covered during the discussion of this critical point are summarized in the following subsections.

Sign Interpretation:

The guide signs on either side of the roadway provided the first information to drivers about the location of their exit, which was on the left (see figure 44). The I-5S information was provided with other destination information and was not as easy to see as the other elements.

Figure 44. Photo. Guide sign associated with scenario 3 critical point 2.

Sign Placement:

Many drivers expected better consistency with regard to the placement of consecutive signs. Driver responses include the following:

- "I would have expected to see the signs in the same place [overhead] as I did before."
- "When you first came onto that bridge area, it always set the precedent of signs are above, so you're going to keep looking above."
- "The signs have all been overhead and I wouldn't be looking to the sides necessarily."
- "I believe in consistency. Then you know where to look. If it's been overhead, they should keep it overhead."

Some drivers had concerns about the possibility of missing signs because of low visibility or occlusion by other vehicles. Driver responses include the following:

- "There could have been a truck there and you wouldn't even see it. If you're in a regular car and there's an SUV, you probably wouldn't be able to see it. And if it's a semi and it goes on and on and on, you'd miss your chance to see it."
- "This is a perfect world setting as far as traffic, but if you've got all of those lanes filled or you've got a tractor trailer driver on that extreme left, you're not going to see that sign at all."
- "Those could be tough to see of the weather was bad."

A few drivers observed that sign visibility could be reduced because they exist outside the normal field of view. Driver responses include the following:

- "The signs don't even appear to be within the travel lanes. They appear to be outside the field of view. I wouldn't expect to see any important signs in those locations."
- "You are not looking to the sides, you are looking ahead."

Sign Information/Elements:

Some drivers expected information about major destinations or freeways to be prominently displayed and that the I-5S symbol was not only small, but also overshadowed by other sign information. Driver responses include the following:

- "I wouldn't be looking for a sign for I-5S there because the sign for I-5N was so prominent."
- "My impression is that we would hit the exit for the north, and then the south would be next, and it would also be marked in the same fashion."

- "If you were looking at the sign on the right and just looking for I-5S, you might not read the whole sign and associate it with [an exit on the right side]."

Some drivers also reported some confusion caused by seemingly unnecessary or unexpected information elements as follows:

- "If I saw these two signs on either side of the road, my brain probably wouldn't even register them because I would see that they both say 'The Dalles' [and I'm not looking for The Dalles] and that's in large letters and South is very small letters. They should also put the word "left" larger than anything."

- "The Dalles is very prominent on that sign, but that's not going to help me. And I-5S is really tiny."

- "I see I-84 and then I see I-5S next—the previous sign just said I-5N—I wouldn't expect to see I-84 before I see I-5S. That's not the way it appears on the map. You get to I-5S before I-84."

- "Where did I-84 come from?"

Redundant Signs:

Some drivers also felt that providing two identical signs was potentially more of a distraction than a benefit. Driver responses include the following:

- "It's a bit of a distraction. I would want to know, does [the left-side] sign say the same thing as the [right-side] sign? If I'm looking for I-5S and I haven't seen it, then I'm going to want to know what do both signs say? You'd be wondering, did I miss something?"

- "The fact that there are two of them, if you don't know that they are the same sign you may waste time looking at both of them when you don't have to."

- "If you're trying to look at both signs, you might miss the exit."

Expectations and Strategies:

Some drivers would have expected that being in the right middle lane was the most logical choice, given the lack of useful guidance information. Driver responses include the following:

- "Lane 3 [center right] is the only logical lane to be in because you don't want to go to Dalles, you don't want to go north, and you don't want to get on Kirby Ave. So what other option do you have?"

- "I would have been in the third lane because the outside lanes are both exiting, so I would expect my exit to be further ahead. And I would assume that the odds are I would have to exit right."

- "With two lanes clearly marked as exits on either side, I'm going to stay in the middle."

- "I expect Kirby Ave to come before I-5S, so I would not get in the far right lane."

Several drivers expected and would have liked to receive distance information to help them decide whether to attempt the multiple lane changes. Driver responses include the following:

- "If [the sign] had said half a mile or 200 ft—if you knew, it might give you a little help whether to cut three lanes over."

- "I'm not sure at this point it would register to me how fast the exit was coming up, because it also doesn't say that anywhere. From this perspective, I might have trouble seeing that exit. So I think I would try to get over, thinking I probably have more room than I actually do."

- "This would have been a perfect time to give distance [information], so you know that I-5S is coming up right away."

Driver Actions:

Drivers reported that they would respond to last-minute multiple lane changes in a variety of different ways, often depending on the driving conditions. Some drivers reported that they would slow down to give themselves more time to execute the maneuver, while others hoped that adjacent drivers would let them into the lane. Driver responses include the following:

- "I'd slow down to try to give myself enough time to get over."

- "I would immediately slow down and then figure out where I should go."

- "I would just slow down and put my blinker on until somebody let me over. I may end up 10–15 mi/h under the speed limit, but eventually, someone lets me over."

- "I'll slow down until someone lets me in."

Most drivers would attempt to get to the exit if traffic was light enough. Driver responses include the following:

- "I might try if it's this light of traffic."

- "I'd try to move over, if it seems safe."

- "If there were no other cars with you, you get to the left exit."

A few other drivers acknowledged the challenges caused by other traffic. Driver responses include the following:

- "I was expecting to be turning off to the right, so now I'm going to be trying to get to the left in traffic that is probably going 10 mi/h faster than I am because they know where they are going. I don't like that."

- "You could confuse or upset other drivers, and cause road-rage on their part."

There were also a few drivers who would just keep going to I-5N, turn around, and get onto I-5S coming back. Driver responses include the following:

- "If it was clear, I'd try to make my way in. But if there was a lot of traffic, I'd just keep going."

- "It depends on traffic. The safest thing to do is pass it and find your way back."

A few drivers recognized that they simply would not have made the exit. Driver responses include the following:

- "I tend to drive on the right because I tend to drive slowly. I would have just missed that exit."

- "If I clearly understood that sign and realized what I had to do, yes I would do it. But the likelihood of me putting that all together in time is probably not great."

- "Here, you don't know that the exit is to the left until you're almost there, and in heavy traffic, you don't have room to safely change lanes, turn on your turn signal, check your blind spot, and do that twice before you're on that exit."

Multiple Lane Changes in General:

Drivers also provided opinions about multiple lane changes at interchanges in general. In particular, they recognized several considerations that would influence whether or not they would decide to make a lane change.

Influencing Factors:

Many drivers reported being influenced by whether or not traffic volume and speed allowed for multiple lane changes. Driver responses include the following:

- "In rush hour traffic, it's really, really hard [to make multiple quick lane changes]."

- "It depends on the traffic. I think it is very dangerous when you are in traffic."

Several drivers described the safety-related considerations of making multiple lane changes. Drive responses include the following:

- "I would go into serious mode of blind spots, looking, merging, thinking, trying to assess if I can make it over there safely, if someone is going to let me in, because there comes a point where I just let it go, I'm not going to make it."

- "There's other times where you just have to say "I missed it, oh well, if I come back that way again I'll know what to do" but let me just go up an exit, turn around, and continue on my way. It's too dangerous; we should never be in that much of a rush."

- "I'd check to see if there was enough room to get over, and if there wasn't, I'd have to do a back-track, rather than risk my life just to get over."

A few drivers considered the distance available.

- "If there is adequate space, then they are fine. A mile or two to get over a couple lanes—that's fine, you have time to do that."

- "I like a lot of distance [when making lane changes]. At least three cars from me, so I can make sure I can get over and still have a [safety envelope]."

Challenges:

Drivers also identified several factors that can make multiple lane changes more challenging. A few drivers felt that multiple lane changes to the left were more challenging than to the right. Driver responses include the following:

- "When you are making a change to the left, you have to realize that that is the fast lane you are pulling in front of."

- "The big difference for me is on the left versus on the right. If [multiple lane changes] happen on the right, I would be expecting that and be ready. But on the left I would not be expecting that. For me, it feels more hazardous."

- "It's hard if you are moving left than if you are moving right. It's harder to turn to look around for other traffic [in that direction]."

A few drivers mentioned the influence of other merging drivers. Driver responses include the following:

- "There's always going to be somebody who's going to try to get over when it's not safe. So that's the other thing when I'm in that situation that I'm thinking is, oh no, who's going to come and slam into me."

- "A lot of people don't seem to know how to merge in traffic, so they will slow down to almost nothing. That causes congestion, and the whole thing backs up."

One driver noted that poor weather increases the difficulty level and stated, "Rain and poor weather would also make it harder."

Also, one driver mentioned that unfamiliarity with the interchange or driving at night would make the maneuver more challenging. The driver indicated that, "[Multiple lane changes] are challenging, especially if you don't know where you're going, or you're unfamiliar with the area, or it's at night."

Several drivers commented on how stressful they perceive multiple lane changes to be. Driver responses include the following:

- "It's extremely stressful, especially in short distances, heavy traffic, when you're going fast."
- "For stress, I'd give [multiple lane changes] a 10/10."
- "If it's at the last minute, it usually makes me feel nervous."

A few drivers also found multiple lane changes effortful. Driver responses include the following:

- "It forces me to concentrate all my attention on driving and think logically about what I'm doing. That's when I tell my passengers that I need to focus on what I'm doing."
- "You have to watch for traffic to your [side] and behind you for more than one lane. That's a lot of people you have to watch."

A few drivers also reported a general dislike of multiple lane changes. Driver responses include the following:

- "They're the worst. I think they're the most likely to cause accidents."
- "If I have to make multiple lane changes, I don't think someone was doing their job. The job of the engineering should be to plot out the course to let the driver know what's coming up and what they have to do to maneuver get where they have to go."

A few other drivers reported going out of their way to avoid interchanges with multiple lane changes. Driver responses include the following:

- "I know for myself, particularly as I get older, I will purposefully just avoid certain times of day. I don't even want to get a job downtown. I don't want to be in this situation."
- "Every time you do it, your stress level gets really high. I tend to use a different entrance just to avoid that."
- "I usually find that if I'm driving somewhere and I have one of those [multiple lane changes], I often just avoid them and do a different exit. I hate those."

Scenario 3 Key Themes

Some of the key themes expressed in scenario 3 are as follows:

- Drivers have an egocentric view of interchange information. They want information about their route to be clearly available, and they may perceive information about other routes to be a distraction if it interferes with information about their route. They do not seem to be very aware of the trade-offs that engineers must make regarding what information gets displayed.

- Directional relationships among roadways (e.g., from maps, location of landmarks, or cardinal direction) may also represent another source of expectations for exit location. This is probably not something that overrides the expectation of a right exit based on what drivers typically experience; however, it might suggest that left exits that also have these directional mismatches could benefit from special consideration.

- Drivers place a certain amount of trust in the idea that interchange signage will provide the information they need in a way that still gives them enough time to do what they have to do. If they do not see the information they need, they are willing to continue without it for a while. However, this trust erodes as they go longer without seeing the information they need.

- Drivers can determine information they do not get from signs. For example, for the I-5S exit, they used cardinal direction, landmarks, and other destinations/exits to obtain proximity information.

- Drivers have expectations regarding what and how destination information is presented. For example, major freeways should be prominent, and different directions of the same freeway should be treated similarly.

- Some drivers are less comfortable making lane changes to the left than to the right. Because they are merging into a lane with faster traveling vehicles, it feels more hazardous. There are also concerns about visibility/blind spot checking.

TASK 4 CONCLUSIONS

Drivers expected that there would be functional relationships between lanes on the roadway and arrows/text on signs and that the signs themselves would make these relationships clear. For example, when looking at signs with arrow-per-lane information, drivers interpreted the arrows as corresponding to information that was directly above or grouped somehow with the arrows. In scenario 1, this led to an unnecessarily restricted view of which destinations were served by each lane. This tendency to look for relationships also occurred with other sign information such as route shields and exit only plaques. Additionally, option lane arrows created more work for drivers since they had to discern that multiple destinations could be reached by a single lane, which branched into different directions.

Drivers expected that the distance between a guide sign and a final (or last chance) decision point would be sufficient to allow for making any necessary lane changes in a safe and timely manner. Moreover, drivers utilized distance information for upcoming exits so that they knew how much time they had to make a lane change.

Drivers expected that they would have more than one opportunity to obtain necessary destination and lane information before they needed to make a final decision regarding lane choices. A second opportunity to see the same information may also serve as a confirmation for drivers. Unfamiliar drivers in particular may appreciate feedback that they are in the correct lane or have not missed their exit.

Drivers expected that that the freeway system would provide them with the necessary information to construct a mental model and that it would be sufficient to support timely and accurate decisions about lane choice. Drivers seemed to actively create a mental model of the interchange as they drove through it. If they were missing information that they needed, they may have adopted a "wait and see" attitude, making assumptions about the missing information or filling in the information using supplementary information that was available about the area (e.g., cardinal directions, landmarks, etc.). Drivers generally trusted that the information that they needed would be provided to them in enough time to act.

Drivers expected that the information available to them through the freeway system would be sufficient to support decisions about lane choices so that they would never have to move over more than one lane at the last moment. Drivers trusted that they would get the information that they needed in a timely manner. However, in the face of uncertainty or unfamiliar surroundings, some drivers adopted a strategy of staying in an option lane where it would be easy to change into other likely destination lanes. This shows a tradeoff between increasing the likelihood of making one lane change while decreasing the likelihood of making multiple lane changes. Other drivers preferred the certainty associated with using exit only lanes.

Drivers expected that the freeway system would provide sufficient information to support decisions about all route choices, not just frequent or popular choices. Drivers tended to have an egocentric view of destination information; they want their destination information to be clear. Additionally, when the set of destinations listed on a sign changed (destinations were added or removed from a series of guide signs), drivers became uneasy.

CHAPTER 4. TASK 7—COLLECT EXPERIMENTAL DATA ABOUT DRIVER EXPECTATIONS AT INTERCHANGES

The objective of task 7 was to use the experiment protocol developed in task 6 to collect empirical data on driver performance given various complex interchange signage and marking alternatives. The basic approach involved using a brief questionnaire to collect driver responses about lane preference or understanding lane movements in different interchange driving scenarios. The approach was similar to ones applied in previous studies and involved presenting slides of different interchange navigation scenarios and collecting driver responses about their interpretation of guide signs or how they would navigate the interchange scenario.[(2)]

These activities were coordinated with the driving simulator study conducted by TTI as part of a parallel project.[(6)] In particular, the identification of research topics was conducted jointly between a contractor and TTI, and the selection of specific research questions was also coordinated. For several of the topics presented in this section, similar scenarios were examined in both projects to obtain complementary data (i.e., driver performance measurements when following particular signs in the TTI simulator and driver interpretation/understanding of those same signs in task 7).

The general approach used in task 7 involved holding group data collection sessions to obtain driver lane preference responses and their interpretations of guide signs. A Microsoft PowerPoint® presentation showed static photographs of freeway backgrounds with overlaid fabricated interchange signs (similar to the method used by Chrysler et al.).[(2)] The participants were then asked specific questions about elements of the signs, lane selection, and lane permissions in relation to what was shown on the slide. They used response booklets to mark their answers.

This chapter contains the following three technical sections:

- **Task 7 Methods**: Provides an overview of participant demographics, procedures, materials, selection of scenarios/maneuvers, and the data analysis plan.
- **Task 7 Results**: Discusses each of the seven topics that were investigated.
- **Task 7 Conclusions**: Describes the primary conclusions from the data collection activity.

TASK 7 METHODS

This section describes the methods used to conduct and analyze the data collected during task 7.

Participants

Demographics

A total of 183 licensed male and female drivers participated in the group data collection sessions (84 males and 99 females). The ages of participants ranged from 18 to 76 years old (median age = 44.0 years and SD = 15.2 years), and they reported living in an urban area for an average

of 30.9 years (range = 1–66 years and SD = 17.3 years). Participants reported having their licenses for an average of 26.4 years (range = 1–50 years and SD = 15.3 years) and driving an average of 15.2 hours per week (range = 1–150 h and SD = 16.4 h). Most participants (161) reported driving through major interchanges similar to those presented to them weekly, daily, or multiple times per day, while the remaining participants (22) reported driving through major interchanges only about once per year or once per month. Some participants (43) indicated that they had been a professional driver, while most participants (140) had not.

Session Details

Group sessions comprised of 2 to 15 participants (depending on attendance). All of the participants were recruited using online advertisements posted on Craigslist®. An effort was made to balance the overall participant pool across the age and gender groups. In particular, researchers attempted to enroll an approximately equal number of males and females from each of the young (18–35 years old), middle (36–54 years old), and older (55+ years old) driver age groups. Individual sessions were imbalanced with regard to these groups, but that should not have affected the results since the participants did not interact with each other during the sessions. This overall balancing strategy also provided flexibility for scheduling individuals at sites that were geographically convenient for them. The composition of each group is shown in table 8.

Table 8. Demographic composition of each data collection session.

Session	Presentation Order	Women's Ages			Men's Ages			Total
		18–35	36–54	55+	18–35	36–54	55+	
Tukwila, November 2, 1:30 p.m.	1	2	2	1	0	1	1	7
Tukwila, November 2, 3 p.m.	1	1	2	2	1	1	0	7
Tukwila, November 2, 4:30 p.m.	1	2	2	2	3	0	1	10
Tukwila, November 2, 6 p.m.	1	5	2	3	2	0	0	12
Edmonds, November 3, 11 a.m.	1	0	1	1	3	4	2	11
Edmonds, November 3, 12:30 p.m.	1	0	1	1	0	2	0	4
Edmonds, November 3, 2 p.m.	1	0	2	0	0	0	0	2
Edmonds, November 3, 3:30 p.m.	1	1	1	2	0	1	0	5
Greenwood, November 4, 1:30 p.m.	1	2	2	3	3	0	1	11
Greenwood, November 4, 3 p.m.	1	3	2	4	1	0	1	11
Greenwood, November 4, 4:30 p.m.	1	3	0	3	5	1	1	13
Greenwood, November 4, 6 p.m.	1	4	2	2	0	0	1	9
Bellevue, November 8, 11 a.m.	2	0	2	2	0	2	2	8
Bellevue, November 8, 12:30 p.m.	2	1	1	1	0	2	0	5
Bellevue, November 8, 2 p.m.	2	0	1	0	2	2	0	5
Bellevue, November 8, 3:30 p.m.	2	2	1	3	4	1	0	11
Phinney, November 15, 2 p.m.	2	2	1	3	4	2	3	15
Phinney, November 15, 3:30 p.m.	2	2	2	3	1	1	4	13
Phinney, November 15, 5 p.m.	2	1	4	1	3	2	2	13
Phinney, November 15, 6:30 p.m.	1	0	0	0	4	1	6	11
Total		31	31	37	36	23	25	183

Data Collection Locations

Data were collected in five locations across the metro Seattle area. Each data collection session was 30–45 min long. The sessions were held at community and senior centers with the capability of seating a medium-sized group and appropriate projection equipment. Sites were distributed across the greater Seattle area to allow participants to select a convenient site to participate. Four sessions were held at each site in a given day. Two pilot sessions were conducted for practice purposes.

Participants were seated as close to the projection screen as possible. Additionally, researchers tried to avoid having participants sit at large angles away from the center axis of the visual projection to avoid distorting their perspective of the arrows and lanes.

Procedures and Materials

This section describes the methodological approach and experimental materials used for data collection.

General Approach

When each group began, participants were given an overview of the session and a booklet to record their responses (the moderator guide is provided in appendix D). They were then shown a three-part Microsoft PowerPoint® presentation containing either 78 or 85 questions about interchange signs. Each question followed the same presentation format (see figure 3). The questions were set up by providing drivers with a specific driving goal. Then, an image of a freeway with an overlaid sign was shown for a fixed duration. This provided conditions that mimicked some aspects of real-world driving, such as having a limited amount of time to inspect each sign and deduce its meaning. Following the image presentation, drivers were shown a question and asked to circle a response in their booklet. This series of activities was repeated until all of the questions were presented. At the end of all of the scenarios, participants were asked to respond to a short set of demographic and driving history questions.

Presentation

The presentation contained images depicting a driver's view of the freeway. These images showed the interchange sign under investigation with other contextual elements such as the roadway and pavement markings. The specific set of signs used was developed in conjunction with TTI to ensure consistency in the stimulus sets between this study and the simulator study.[6]

The overall presentation was divided into three parts. Each part contained questions that comprised of four slides that followed a similar format. These slides are further discussed in the following sections. There were some differences between presentation parts, and where applicable, the differences in format between parts are described.

Introduction Slide:

The first slide provided the navigation objective. Each of the navigation objectives was phrased in a similar format (i.e., "You want to take [exit number, freeway number, route name] to get to [destination name]"). The presentation of this slide was not timed; the experimenter read the slide aloud to participants, paused for approximately 1–2 s, and then advanced to the next slide. The introduction slide also contained the question number so that participants could follow along in their response booklets.

Preparation Slide:

The second slide was a preparation slide. The purpose of this slide was to prepare participants to see the test slide by providing a visual countdown to the slide transition. The preparation slide displayed three dots that appeared individually, from left to right, at 0.5-s intervals. The total slide presentation lasted 2 s before advancing to the test slide.

Test Slide:

The third slide was the test slide, which was shown for 4 s. The test slide showed the test sign mounted on a sign support (or overpass) with an appropriate freeway background. Each of the signs was presented on a photograph of a freeway without any indication of the upcoming interchange (e.g., no diverging exit lanes, gore areas, etc.). The background gave visual context to the sign without any additional cues. There were three groups of test slides, each of which provided a varying degree of information about the lanes. This was necessary because the questions were different in each part, and the information was tailored so that it provided the information and context required to answer the question but not information that would imply a particular response. The different lane information across parts included the following:

- **Part 1**: Showed the lane that the participant was driving in using a blue arrow.
- **Part 2**: Displayed with all of the lanes on the slide numbered. The lane that the participants were in was highlighted in blue.
- **Part 3**: Had the lanes numbered without any indication of the lane that the participants were driving in.

Note that all trials associated with each movement used the same background slide. Only the sign types and destination information varied. All trials in topic 2 used the same background slide.

Question Slide:

The final slide was the question slide. The question slide was presented until everyone had circled a response (approximately 5–10 s). If a participant took a long time to respond, he/she was asked to give the best guess, and then the moderator continued with the presentation. The question slide always displayed the same background as the test slide; however, the guide sign was always occluded by a blue box surrounding the question text. This was done to prohibit participants from using the sign to answer the question. The question slide also presented the

question number to keep participants on track in their response booklets. The three parts of the presentation had different questions and lane information as follows:

- **Part 1**: The question slides in part 1 all asked which lane the participants would take to reach their destination. They were asked to base their choice on their normal driving patterns assuming light traffic. Each question called for a single lane choice selection. The test slides in this group also had the lanes numbered to allow participants to circle the corresponding lane number in their booklets.

- **Part 2**: The question slides in part 2 varied, but the majority asked questions on the participants' understanding of where the lanes would go (e.g., "To go to [destination name], do you have to change lanes right away?" and "Will your lane take you to [destination name]?"). Participants were asked to answer as though they were driving in the highlighted lane.

- **Part 3**: The question slides in part 3 asked participants to circle the lane or lanes that would take them to a given destination. They were given the target destination on the introduction slide and on the question slide so that the focus was on sign comprehension rather than destination memory. For this set of questions, they were asked to circle all of the lanes that would take them to a destination even if there were multiple lanes that would do so.

Figure 45 shows an overall view of the standard slides for each question and the timing of the slide presentation.

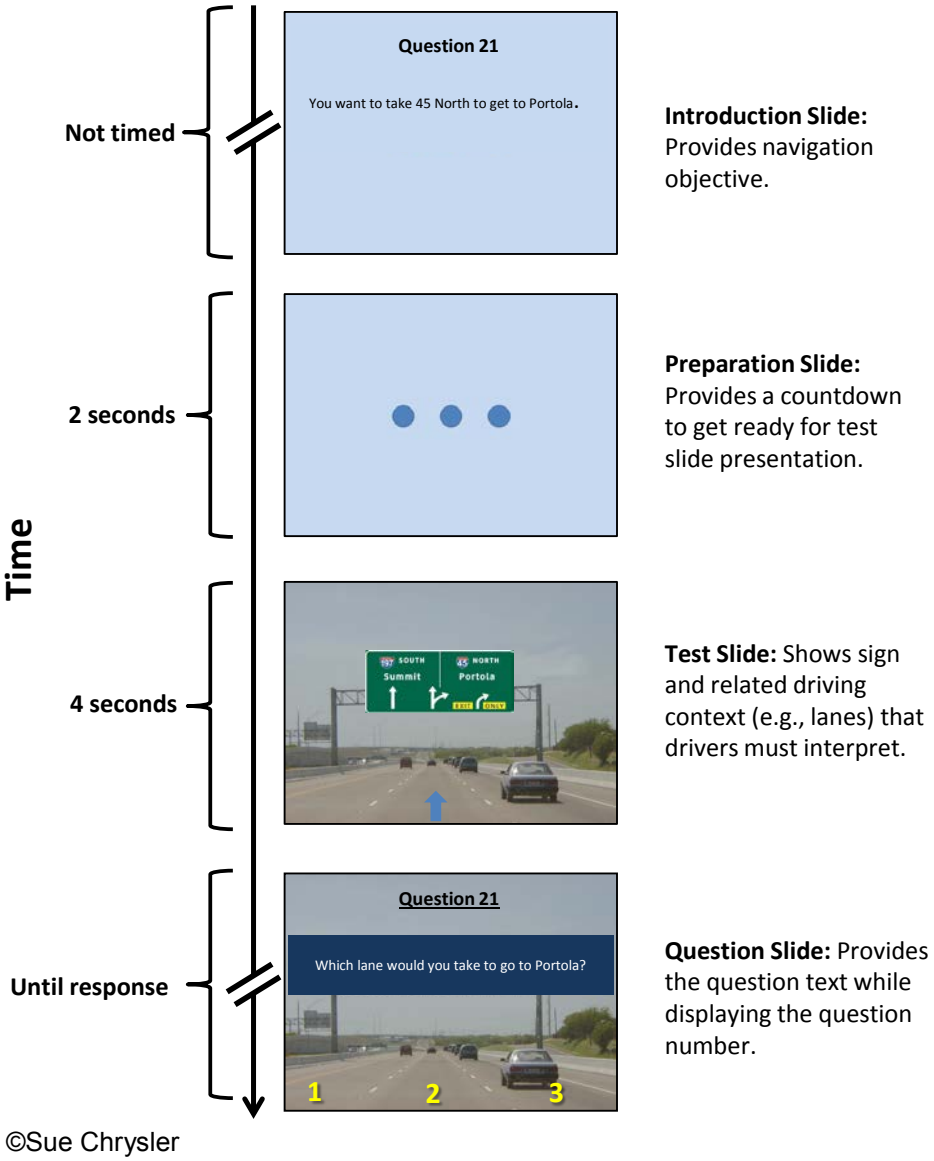


Figure 45. Illustration. Timeline of stimuli slide presentation.

Slide Order

The slide order was counterbalanced to reduce the order effects of using a single presentation set. Two slide orders were created, and an effort was made to distribute the questions within each set to vary the possible start lanes, movements, and topics, as well as to reduce predictability. Another major difference between the slide sets was the number of questions. Slide order 1 contained 78 questions, while slide order 2 contained 85 questions. When creating slide order 1, a major concern was keeping the session to a reasonable length of time. After it was determined that the sessions would finish in time, seven additional questions were added to examine additional maneuvers that would provide a more complete analysis of the topics chosen. This larger set was then reordered to become the slide order 2 set.

Response Booklets

Each participant recorded his/her answers to the questions about the images in response booklets. The response options in the booklets were all multiple choice to facilitate rapid responses and easy data scoring. This also eliminated response ambiguity which could have arisen from geometric drawings or long written responses.

At the end of the questionnaire, some basic information was collected about driver demographics, such as age and gender. In addition, limited information about the participants' driving patterns and history such as how long they have been driving, how many hours they drive each week, and how frequently they drive through interchanges were also collected. The information was linked to participants' written responses from the interchange scenarios but not any personally identifying information. A copy of the demographic questions from the response booklets is included in appendix E.

Selection of Scenarios and Maneuvers

The selection of scenarios was coordinated with TTI. Candidate topics were generated using three sources drawn from earlier work in both projects. These included the following:

- A list of complex interchanges in the United States developed as part of the TTI simulator study using a spreadsheet tool and input from State transportation departments.[6]

- A sample of complex signs and interchange navigation maneuvers identified from the list of complex interchanges that were potentially challenging for drivers to understand.

- Driver comments from the task 4 focus groups related to aspects of complex interchanges that they found to be challenging to navigate.

Using these sources, both teams worked together to select relevant interchange driving scenarios. An initial list of 19 scenario topics was developed, from which a subset of questions were selected for implementation in task 7. Key considerations for selecting topics for task 7 included the following:

- Questions about driver expectations identified in previous tasks in this project (task 4 focus groups).[40]

- Questions about driver expectations that were relevant to important unresolved issues from existing research (as identified in the task 2 literature review).[41]

- Questions about driver expectations that could contribute to a more complementary or more detailed understanding of signs examined in the TTI simulator study.[6]

Table 9 lists the research question selected for each topic and indicates if the topic corresponded to a similar topic investigated in the TTI simulator study.[6] It was not possible to investigate the exact same set of topics in each project because some questions could only feasibly be addressed using one data collection approach or the other but not both. For questions covered in both

projects, the information obtained in each study was largely complementary. In particular, the TTI simulator captured performance-based measures such as whether drivers executed unnecessary lane changes or when they initiated their movements. In contrast, the static photo approach used in this study captured driver comprehension and interpretation of sign information and their corresponding expectations about the upcoming interchange configuration.

There was originally an eighth topic included in the data collection. The only purpose of the eighth topic was to gather data that would supplement the data collected in the TTI simulator study.[6] The topic did not end up being a part of the simulator study and was therefore removed from the analysis in this project.

Table 9. Topic descriptions.

Topic	Research Question	Related Task 6 Topic
1	How do guide sign option lane information and arrow type affect driver lane preference in exit and through movements?	Topic 1
2	How is driver exit lane preference affected by arrow type and the degree to which option lane arrow information is spatially integrated or separated?	None
3	How effective are different sign designs for indicating left exits and how do drivers interpret the sign information?	Topic 6
4	How does the layout of destination information on guide signs affect how drivers associate specific lanes with destinations?	None
5	How do drivers interpret different types of destination separators on guide signs that indicate where lanes go for a two-lane exit with a downstream split?	Topic 3
6	Are there limits on the number of lanes that can be effectively communicated by diagrammatic signs?	None
7	What are effective guide sign designs for signing two interstate exits within close proximity of each other?	Topic 2

The movements were selected to gather the needed data from the topic (e.g., investigating option lane usage or comprehension of left exit information). After selecting the relevant movements, it was found that for a large percentage of the trials, participants were asked to exit rather than continue to the through destination. In response, additional trials were added to balance the responses so that drivers would be less likely to anticipate their next movement. Within each part of the presentation, an effort was made to distribute the slides with signs related to the same topic and signs requiring the same movement.

Data Analysis Plan and Objectives

This section describes the data entry and analysis process.

Data Entry and Verification

Data used in the analyses were the driver responses to scenario questions. The responses were entered into a Microsoft Excel® spreadsheet for all of the sessions. Data quality was ensured by

double-checking entered responses with the original written responses in the booklets. First, discrepancies were resolved using visual inspection. Issues such as multiple responses for questions that only allowed a single lane selection were resolved. Second, for all of the topics where it was appropriate, nonsensical responses were double-checked for data entry errors (e.g., responses where the chosen lanes would not lead to the given destination). Third, a random selection of booklets was rechecked in their entirety.

Data Analysis

Descriptive statistics were calculated for all of the responses, and these are reported in summary tables in the results section of this chapter. Most of these descriptive statistics involved calculating response percentages for each slide question, which typically corresponded to a particular combination of sign set and vehicle movement. Some topics had two slides that addressed the same question (i.e., repeated trials). In these cases, the percentage correct was based on averaged responses across like trials. Pair-wise *t*-tests were used to determine the significance levels for comparisons of interest. Note that the researchers did not control for experiment-wise error. The complete set of *t*-test comparisons conducted for all research topics is provided in appendix F.

The demographic questionnaire responses were summarized using means and SDs.

Caveats

It should be noted that the broader objective of the data collection activities in task 7 was to gain an understanding of driver expectations at various complex interchanges. This task was not strictly applied research to evaluate the relative effectiveness of candidate guide sign design alternatives for implementation at specific locations. Consequently, there were instances in which the signs used in this study departed from current *Manual on Uniform Traffic Control Devices* (MUTCD) recommendations.[1] This was necessary to balance out potential confounds and to obtain findings that provided clearer insight about the factors underlying driver expectations and assumptions that they make. Moreover, a deliberate effort was made to relate the questions examined to the dynamic scenarios discussed in the task 4 focus groups. Consequently, some of the task 7 sign elements were based on outdated sign designs (e.g., down arrows on advance signs), but this was done to provide comparisons that were relevant to the focus group findings and baseline comparisons of sign designs that drivers were familiar with (i.e., down arrows are still common in the Pacific Northwest). This approach was justified because it provides a better understanding of the more psychological dimensions related to driver expectations at complex interchanges.

TASK 7 RESULTS

The results of the seven research topics examined are presented in the following sections.

Topic 1: Option Lane Arrow Types and Driver Lane Preference

This topic examined driver lane preference for through and exit movements at freeway exits that include exit only and option lanes. The task 4 focus group participants had a variety of opinions to choose from about option lane use during exits.[40] Some preferred to use an option lane

because they could avoid last-minute lane changes if they chose not to exit. Others preferred exit only lanes because they valued the certainty that the exit only lane provided regarding taking the correct exit.

This topic also examined multiple sign types. These included the MUTCD arrow-per-lane signs (which use up arrows) and signs with down arrows.[1] Although the down arrows are not recommended for this purpose by the MUTCD, they are more common in Seattle, WA, where the data were collected, and they are consistent with the signs used in the task 4 focus groups. Additionally, they are relevant because some focus group participants reported that it was sometimes difficult to correctly match the down arrow symbol to the appropriate lane depending on the visual perspective, thereby making interchange navigation more challenging.

Additionally, two variations of the exit movement were investigated in this topic. The first involved exiting from the option lane, which could be accomplished without making a lane change. The second variation involved exiting from the through lane, which required at least one lane change regardless of whether the option lane or exit lane was selected for the exit movement. The rationale for including both types of movements was to determine if drivers preferred using a different lane to exit if they were required to make at least one lane change.

Research Question

The research question posed for this topic is as follows: how do guide sign option lane information and arrow type affect driver lane preference in exit and through movements?

Sample Slides

During data collection, drivers were given a target destination and were asked to report their preferred lane for reaching that destination. Comparisons were made between the following three signing conditions:

- Up arrows with signing for the through movement (sign set A).
- Down arrows with signing for the through movement (sign set B).
- Down arrows only signing for the exit, not the through movement (sign set C).

An example test slide for the option lane to exit movement is shown in figure 46. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** You want to take 45 North to get to Portola.
- **Question:** Which lane would you take to go to Portola?

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Figure 46. Photo. Example test slide from topic 1—option lane to exit movement.

An example test slide for the through lane to exit movement is shown in figure 47. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** You want to take 22 East to get to Fairview.
- **Question:** Which lane would you take to go to Fairview?

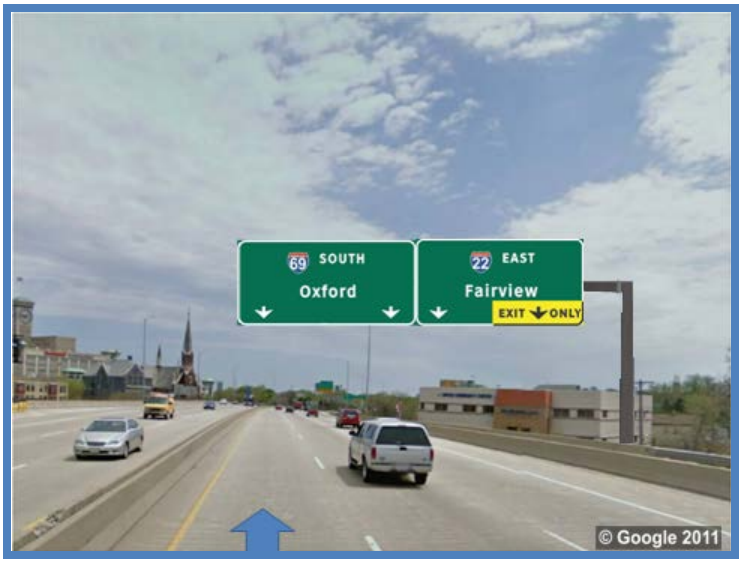

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Figure 47. Photo. Example test slide from topic 1—through lane to exit movement.[(42)]

Response Summary

Figure 48 through figure 50 show sign sets A through C for topic 1.

Figure 48. Illustration. Topic 1—sign set A.

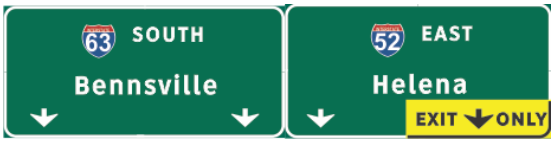


Figure 49. Illustration. Topic 1—sign set B.

Figure 50. Illustration. Topic 1—sign set C.

Table 10 shows the lane preference responses for topic 1. The responses are summarized for each sign set by movement (i.e., start lane to desired destination, such as option lane to exit destination).

Table 10. Preferred lane responses for topic 1.

Movement	Option to Exit		Through to Exit		Option to Through	
Preferred Lane	**Option**	**Exit**	**Option**	**Exit**	**Option**	**Through**
Sign set A (see figure 48)	45.1%	54.9%	52.7%	47.3%	59.9%	39.0%
Sign set B (See figure 49)	41.2%	58.2%	16.5%	83.5%	64.1%	34.8%
Sign set C (see figure 50)	46.7%	52.7%	44.0%	53.8%	62.9%	36.5%

This topic examined whether driver lane preference while exiting was affected by information about the option lane provided by the signs. In sign set A, both possible movements from the option lane were indicated (through or exit). In sign set B, the presence of an option lane was indirectly implied by down arrows corresponding to two separate destinations pointing to the same lane. In sign set C, there was minimal indication that lane 2 was an option lane since it was not signed for multiple destinations. The findings related to driver lane preference while exiting are described for each of the three movements in the following subsections.

Option Lane to Exit:

For each sign set, just less than half of the drivers reported that they would stay in the option lane to exit the freeway, while a majority of drivers indicated that they would make an unnecessary

lane change to the exit only lane even though they could have exited from their current lane. This pattern held regardless of sign set.

Through Lane to Exit:

For this movement, drivers were required to make at least one lane change because they started in the through lane in contrast to the previous movement in which they were able to exit from the option lane and avoid lane changes altogether. When comparing this difference in starting lane, the results were markedly different across sign sets. For sign set A, there was a slightly greater preference for using the option lane to exit when starting in the through lane than in the option lane (52.7 versus 45.1 percent, $p < 0.05$). For sign set C, the starting lane did not affect which lane drivers preferred to use for exiting the freeway (44.0 versus 46.7 percent chose the option lane).

In contrast to the results for sign sets A and C, the starting lane had a substantial effect on lane preference with sign set B. In particular, 83.5 percent of drivers preferred the exit only lane when starting in the through lane compared to 58.2 percent when starting in the option lane. Drivers in this condition overwhelmingly chose to avoid the option lane for exiting (only 16.5 percent chose it). One reason for this may have been because the visual perspective from the through lane may have made it difficult to unambiguously align both down arrows with the option lane. Consequently, drivers may have tried to avoid the corresponding uncertainty by selecting the exit only lane.

In some respects, using down arrows to communicate option-lane information resulted in poorer option lane usage than providing no option lane information at all. For example, sign set C, which only provided exit destination signing, led to significantly more distributed lane preferences for the through-to-exit movement than sign set B.

Option Lane to Through:

For the option-to-through movement, 35 to 40 percent of drivers made an unnecessary lane change for each sign set. The percentage of drivers who moved out of the option lane and into the through lane, however, was nearly the same across sign sets, and none of the differences were significant.

Findings

Overall, sign design and starting lane affected driver lane choice for different movements. The movement that showed the greatest differences in terms of lane preference across sign sets was the through-to-exit condition. In this condition, sign set B led to the fewest drivers preferring the option lane, followed by sign set C and then sign set A, which led to the most even distribution between the option and exit lanes. In some ways, this pattern matches the degree of usefulness or certainty of the information provided about the option lane by the different sign sets. In particular, sign set B provided potentially confusing or ambiguous information about the option lane, possibly due to the poor alignment of the down arrows with the option lane from the through lane visual perspective. Sign set C provided no indication about the center lane being an option lane, and sign set A provided the most complete and detailed information about the option

lane. Thus, there is a correspondence between the specificity and clarity of the option lane information and the extent to which drivers were willing to stay in the option lane.

With regard to consideration of arrow type, the up arrows in sign set A led to more option lane preference than the down arrows in sign sets B and C. Note that down arrows are more common than up arrows in Seattle, WA. If driver familiarity is a factor, then an even higher performance level might be expected within a focus group comprised of drivers who have been exposed to these signs in their normal driving environment; this could be investigated in future research. The single down arrow without through destination information in sign set C, however, led to more option lane preference than sign set B. This suggests that other factors aside from arrow type are possibly affecting lane preference.

The TTI simulator study asked a similar question as the present one in their topic 1.[6] This study found that drivers also made unnecessary lane changes in all movements using comparable sign configurations to those used in the present study. However, the TTI study did not find evidence for the asymmetry between the down arrow signs (sign set B) and the other signs in the through-to-exit condition. This raises the possibility that the difference in the current study could be an artifact of the static stimulus presentation method and/or the way the visual perspective was depicted in the current study.

Another way in which the topic 1 signs differed from each other is that the arrow information in the up arrow set was integrated (i.e., the arrow branched), while the down arrows were not integrated (i.e., two distinct arrows). One explanation for the difference in lane preference observed in the through-to-exit movement is that integrated arrow information is easier to interpret. In particular, the up arrow provides direct information about the option lane, whereas drivers must determine that the two down arrows infer an option lane since each arrow indicates a separate destination. Not only is the up arrow simpler to interpret, but it probably leads to less uncertainty about the nature of the option lane.

Topic 2: Option Lane Arrow Type and Separation

Topic 2 was an extension of topic 1. It further examined the issue of the integration of option lane arrow information. Similar to topic 1, both up and down arrows were investigated; however, the difference in topic 2 was that integrated and separated versions of each arrow type were presented to drivers.

Note that while it was not possible to draw down arrows as a single sign element, canted down arrows were used to provide lane guidance information that was perceptually more cohesive and which could be more clearly aligned with the option lane. In addition, the start lane was always the second lane from the left to make the lane arrangement comparable to the through-to-exit condition of topic 1.

Research Question

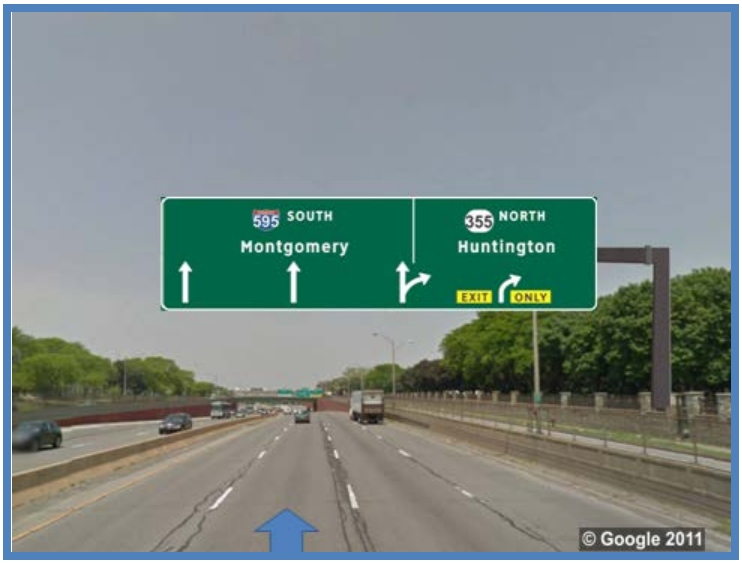
The research question posed for this topic is as follows: how is driver exit lane preference affected by arrow type and the degree to which option lane arrow information is spatially integrated or separated?

Sample Slides

During data collection, drivers were given a target destination and asked to report their preferred lane for reaching that destination.

An example test slide for the through lane to exit movement is shown in figure 51. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** You want to take 355 North to get to Huntington.
- **Question:** Which lane would you take to go to Huntington?



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(see "Acknowledgements")

Figure 51. Photo. Example test slide from topic 2—through lane to exit movement.[43]

Response Summary

Figure 52 through figure 55 show sign sets A through D for topic 2.

Figure 52. Illustration. Topic 2—sign set A.

Figure 53. Illustration. Topic 2—sign set B.

Figure 54. Illustration. Topic 2—sign set C.

Figure 55. Illustration. Topic 2—sign set D.

Table 11 shows a summary of the lane preference responses for topic 2 for each type of arrow and option lane arrow integration (i.e., separated or integrated). The responses are summarized for each sign set by preferred lane.

Table 11. Lane preference responses for topic 2.

	Separated Option Lane Arrow			Integrated Option Lane Arrow		
Up Arrows	Sign Set A			Sign Set B		
	Preference	Option (percent)	Exit Only (percent)	Preference	Option (percent)	Exit Only (percent)
		44.2	55.2		49.5	55.2
Down Arrow	Sign Set C			Sign Set D		
	Preference	Option	Exit Only	Preference	Option	Exit Only
		28.6	70.9		23.2	75.7

Arrow Integration:

Overall, arrow integration was not associated with a significant difference in driver lane preference. Option lane preference for the up arrow sign sets A and B (44.2 versus 49.5 percent, *p*-value = not significant) and for down arrow sign sets C and D (28.6 versus 23.2 percent, *p*-value = not significant) were not significantly different from each other.

Arrow Type:

Arrow type was associated with significant differences in driver lane preference. In particular, for separated arrows, the up arrow sign set A led to significantly more drivers selecting the option lane than the corresponding down arrow in sign set C (44.2 versus 28.6 percent, $p < 0.0001$). Similarly, for integrated arrows, the up arrow sign set B led to significantly more drivers selecting the option lane than the corresponding down arrow in sign set D (49.5 versus 23.2 percent, $p < 0.0001$). Overall, the up arrows led to a more equal distribution of lane preferences between the option and exit only lanes than the down arrows. Moreover, this finding is in line with the topic 1 results for a nearly identical sign with down arrows in which a strong majority of drivers preferred the exit only lane (83.5 percent in topic 1 sign set B) when making the same movement involving exiting from the through lane (70.9 percent in sign set C and 75.7 percent in sign set D in topic 2).

Findings

Arrow integration was not associated with a difference in driver lane preferences for signs with either up or down arrows. However, arrow type did make a significant difference. Specifically, up arrows led to more distributed lane preferences, while down arrows led to a greater preference for the exit only lane. This pattern of results is consistent with the findings from topic 1 where the up arrows led to the most option lane preference.

Although arrow type seems to be a consistently significant factor, another possibility is that other visual cues exclusive to up arrows facilitated the interpretation of the option lane information. For example, the up arrow above the option lane in sign set A curves to the right and is the same as the arrow above the exit lane. This visual similarity and the corresponding visual grouping of the like arrows might provide another direct indication of its association with the exit lane.

Topic 3: Left Exit Notation

This topic examined driver understanding of different approaches for indicating left exits. It was a parallel topic to one investigated in the task 6 TTI simulator study.[6] Specifically, this topic compared the 2009 MUTCD left exit standards to a yellow left exit panel and a plain/green left exit number plaque.[1] Sign set A had a yellow left exit number plaque atop the guide sign, sign set B had a yellow panel at the bottom of the guide sign, and sign set C was similar to sign set A except the plaque was green instead of yellow (see figure 56 through figure 58). The primary differences between these signs were that the left exit panel in sign set B had a similar appearance and placement to an exit only panel, and sign set C was less conspicuous than the other sign sets because it lacked the yellow color. Note that sign set C was not included in the TTI simulator study.

Figure 56. Illustration. Example exit notation used in topic 3 questions—sign set A.

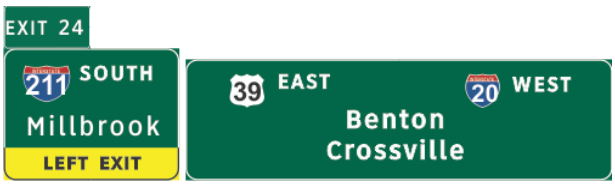

Figure 57. Illustration. Example exit notation used in topic 3 questions—sign set B.

Figure 58. Illustration. Example exit notation used in topic 3 questions—sign set C.

Research Question

This topic covered a broader research question by examining three specific sub-questions. The research question was, how effective are different sign designs for indicating left exits and how do drivers interpret the sign information? The three specific sub-questions were as follows:

1. Are drivers more likely to confuse the left exit panel (sign set B) with an exit only panel because of its similar design?

2. If the exit sign is on the right-hand side of the sign bridge, do drivers notice that the exit is on the left?

3. What information do drivers rely on more, the placement of the sign on the sign bridge or the left exit notation on the sign (i.e., yellow plaque, panel, or plain word)?

Sample Slides

Drivers were given a start lane and target destination. After seeing the test slide, they were asked if they would have to change lanes to reach their destination.

An example test slide for the lane 1 to through destination movement is shown in figure 59. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** You want to take 39 East to get to Benton.

- **Question:** To get to Benton, do you have to change lanes?

Figure 59. Photo. Example test slide from topic 3—lane 1 to through destination.[44]

An example test slide for the lane 3 to left exit movement is shown in figure 60. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** You want to take 112 North to Croton.
- **Question:** To get to Croton, do you have to change lanes?

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Figure 60. Photo. Example test slide from topic 3—lane 3 to left exit.[45]

Response Summary

For the first question (i.e., are drivers more likely to confuse the left exit panel (sign set B) with an exit only panel because of its similar design?), the exit sign was placed on the left side of the sign bridge, and drivers began in the left lane (lane 1). The test question asked if drivers had to leave lane 1 to continue in the through direction. The correct answer was that they did not because the sign did not indicate that the left exit was a lane drop. If drivers indicated that they had to leave the lane more frequently with sign set B (i.e., lower percent correct), then this would suggest that they were more likely to confuse it with an exit only sign. Figure 61 through figure 63 show sign sets A through C for topic 3 question 1.

Figure 61. Illustration. Topic 3 question 1—sign set A.

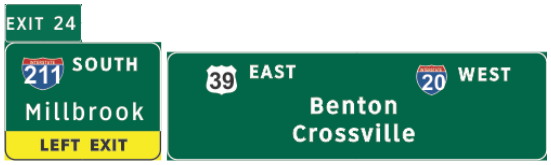

Figure 62. Illustration. Topic 3 question 1—sign set B.

Figure 63. Illustration. Topic 3 question 1—sign set C.

The percentage of correct responses by drivers indicating that they were not required to change lanes to continue to the through destination is as follows:

- Sign set A: 10.9 percent.
- Sign set B: 6.0 percent.
- Sign set C: 19.1 percent.

Surprisingly, the majority of drivers responded that the left lane would not go to a through destination; however, there is no clear evidence that drivers were more likely to confuse sign set B with an exit only lane than sign set A. Sign set C yielded significantly better performance than sign set A (19.1 versus 10.9 percent, $p < 0.01$) and sign set B (19.1 versus 6.0 percent, $p < 0.001$). However, this difference could be because sign set C did not contain any yellow markings, which may have made it less visible to drivers. In this case, accuracy might be higher because drivers did not adequately perceive the pertinent left exit information rather than because of any sign-specific benefit.

This question was also investigated in topic 6 of the TTI simulator study.[6] Similar to the current findings, 35 and 55 percent (sign sets A and B, respectively) of drivers made an unnecessary lane change out of the left lane after seeing the left exit sign.

For the second question (i.e., if the panel is on the right-hand side of the sign bridge, do drivers notice that the exit is on the left?), the exit sign was placed on the right side of the sign bridge, and drivers began in the right lane (lane 3). Figure 64 through figure 66 show sign sets A through C for topic 3 question 2.

Figure 64. Illustration. Topic 3 question 2—sign set A.

Figure 65. Illustration. Topic 3 question 2—sign set B.

Figure 66. Illustration. Topic 3 question 2—sign set C.

The percentage of correct responses by drivers indicating that they were required to change lanes to exit is as follows:

- Sign set A: 41.5 percent.
- Sign set B: 28.4 percent.
- Sign set C: 29.5 percent.

In general, driver understanding of the signs was still poor overall. Sign set A led to significantly better performance than sign set B (41.5 versus 28.4 percent, $p < 0.001$) and sign set C (41.5 versus 29.5 percent, $p < 0.01$). It is possible that the difference between sign sets A and C is due to the visibility of the left notation on the sign. However, sign visibility cannot explain the difference between sign sets A and B because both contain yellow markings. Moreover, in a topic 1 control condition (not shown), there is a version of sign set B that had an exit only panel (same layout and color), and drivers chose the correct exit lane almost 100 percent of the time, which suggests that panel visibility was not a limitation. In contrast, the initial hypothesis that drivers may misinterpret sign set B as being an exit only panel is consistent with the current findings because most drivers opted to stay in the right lane—which is under the panel—when instructed to exit to the left. Overall, sign set A appeared to do the best job at drawing attention to the left exit while minimizing confusion with an exit only panel.

Driver understanding in the previous two questions was low overall. In question 2, the placement of the sign on the right was incongruent with the notation of the left exit. It was possible that the poor performance was due to drivers expecting the exit sign to be positioned over the exit lane. For the third question (i.e., what information do drivers use more, the placement of the sign on the sign bridge or the left exit notation on the sign (i.e., plaque, word, or panel)?), the sign configurations were the same as in question 1 (left exit sign over the left lane); however, drivers began in lane 2 (the middle lane) and were asked to take the left exit destination. Figure 67 through figure 69 show sign sets A through C for topic 3 question 3.

Figure 67. Illustration. Topic 3 question 3—sign set A.

Figure 68. Illustration. Topic 3 question 3—sign set B.

Figure 69. Illustration. Topic 3 question 3—sign set C.

The percentage of correct responses by drivers indicating that they were required to change lanes to exit is as follows:

- Sign set A: 86.9 percent.
- Sign set B: 95.6 percent.
- Sign set C: 76.0 percent.

Performance on this question was greatly improved over that of the previous two questions. The differences between each of the three signs in this question were significant at $p < 0.01$. One explanation for this finding may be related to the varying levels of visual salience of the different left exit notations. In particular, the sign with the largest area of yellow shading (sign set B) performed the best, the second most yellow area performed second best (sign set A), and the sign with no yellow shading performed the worst (sign set C). Note that the comparison in question 3 provides the best measure of sign visibility because it is not confounded with sign placement on the sign bridge.

To provide a full answer to question 3, it is necessary to compare the question 3 signs with those used in the previous question. In both questions, the left exit notation was identical between the compared sign sets (which controls for visibility and notation format). The only difference between the two questions was the relationship between the exit sign placement on the sign bridge and the side of the freeway exit; they were either congruent (question 3) or incongruent (question 2). Table 12 shows the comparisons between congruent and incongruent sign placement. Driver response accuracy was consistently higher with the congruent sign placement for each sign set (all comparisons are significant at $p < 0.0001$).

Table 12. Sign placement comparisons between questions 2 and 3 sign sets.

Sign Set	Question 3 (Congruent)	Question 2 (Incongruent)	Difference	*p*-value
A	86.9 percent	41.5 percent	45.4 percent	< 0.0001
B	95.6 percent	28.4 percent	67.2 percent	< 0.0001
C	76.0 percent	29.5 percent	46.5 percent	< 0.0001

Since the only difference between sign sets was the placement of the exit sign on the sign bridge, it is possible that the sign placement side is a significantly stronger informational cue to drivers than the left exit notation alone.

This finding complements the results of the TTI simulator study.[6] In particular, that study found that drivers generally understood which side of the roadway that the left exit was located; however, it was unclear from the data if that difference was due to the left exit notation or the placement of the sign on the sign bridge. The findings from this task 7 study suggest that sign placement provides the information that drivers rely on the most.

Findings

This topic investigated three aspects of signing left exits. Question 1 results showed that drivers had difficulty understanding that the left lane could continue through with all sign sets. One explanation for this is that drivers' default assumption is that an exit lane is a lane drop unless the sign indicates otherwise. This is a safe assumption for drivers who want to continue through the interchange (e.g., the cost of being wrong is changing lanes rather than exiting the freeway). This is also consistent with focus group comments indicating that drivers prefer to avoid uncertainty in their interchange movements.

The results from question 2 provided support for the notion that the left exit sign panel in sign set B may be confused with an exit only panel since most drivers remained in the rightmost lane even though the sign indicated a left exit. While this interpretation was not directly supported by the question 1 results, the trend was in the right direction, and the TTI simulator results for the question 1 scenario were consistent with this interpretation. In addition, both questions 1 and 2 suggested that the green left exit number plaque was less noticeable to drivers than the other left exit notations.

Questions 2 and 3 showed that sign placement on the sign bridge was a significantly stronger cue to drivers than left exit notation. Overall performance was best with sign set A primarily because it avoided the potential for confusion with exit only signing. These findings also highlight that sign placement is an important factor in forming driver expectations.

Topic 4: Two-Lane Exit with Two Destinations

One notable finding from the task 4 focus groups is that drivers tend to assign meaning or significance to the visual layout of guide sign elements. For example, on multiple occasions, drivers linked a destination incorrectly with a specific lane or with exit only information if they were visually adjacent on the guide sign. For example, in scenario 1 of the focus group sessions, drivers were faced with a sign bridge almost identical to sign set B (see table 16). Some drivers

had a tendency to associate the destination immediately above the exit only panel with only the lane directly below it, although both exit lanes allowed drivers to travel to either destination listed on the sign.

The current topic investigated some drivers' inherent tendency for grouping elements within a sign and with roadway lanes positioned underneath. This topic also investigated whether this pattern was exclusive to down arrows or whether up arrows were also affected. The specific question compared drivers' tendency to link destinations with specific lanes using two different types of destination separators. The first was destinations separated by a hyphen (hyphen separation), and the second sign layout involved stacking destinations on multiple lines (multiline separation). In this case, destinations are not aligned with any particular lane, so the visual cues that may compel grouping are not present.

Research Question

The research question for this topic is as follows: how does the layout of destination information on guide signs affect how drivers associate specific lanes with destinations?

Sample Slides

This topic did not have a specific vehicle movement associated with the questions. For each sign set, participants were asked to circle the lane or lanes that would take them to a given destination. Their perspective was from one of the middle lanes on the roadway. All of the lanes were numbered, though the lane that they were in was not noted in any way.

An example test slide for topic 4 is shown in figure 70. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** Circle the lane or lanes that take you to Harris.
- **Question:** Can you circle the lane or lanes that take you to Harris?

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Figure 70. Photo. Example test slide from topic 4.[46]

Response Summary

Figure 71 through figure 74 show sign sets A through D for topic 4.

Figure 71. Illustration. Topic 4—sign set A.

Figure 72. Illustration. Topic 4—sign set B.

Figure 73. Illustration. Topic 4—sign set C.

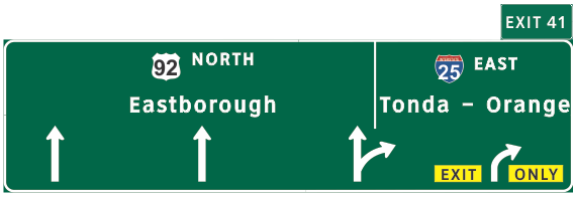

Figure 74. Illustration. Topic 4—sign set D.

Table 13 shows a summary of driver lane selection responses for topic 4. The lanes are numbered to correspond with the numbering in figure 70. The responses are summarized for each sign set by the position of the destination information on the sign and the participants' lane selection(s). For each sign set, the correct response was that both the option and the exit lanes (lanes 3 and 4) would take the driver to either destination. While a response of either lane 3 or lane 4 would also lead the driver to the indicated destination, these answers suggest that drivers may have misinterpreted the sign information.

Table 13. Lane selections for topic 4.

	Multiline Separation				Hyphenated Separation			
Down Arrows	Sign Set A				Sign Set B			
		Lane Selection (percent)				Lane Selection (percent)		
	Destination	Lane 3	Lane 4	Lanes 3 and 4	Destination	Lane 3	Lane 4	Lanes 3 and 4
	Top (Feria)*	8.8	13.2	76.4	Left (Beacon)	35.7	3.3	56.6
					Right (Stilwell)	0.0	56.6	41.8
Up Arrows	Sign Set C				Sign Set D			
		Lane Selection (percent)				Lane Selection (percent)		
	Destination	Lane 3	Lane 4	Lanes 3 and 4	Destination	Lane 3	Lane 4	Lanes 3 and 4
	Top (Winona)	5.8	11.6	79.7	Left (Tonda)	31.9	6.0	59.3
					Right (Orange)	0.0	46.4	50.7

Note: Although the destinations are listed in the response summary tables, multiple signs, each with different sets of destination names, were used to examine each sign set.

Exit Destinations:

The results in table 13 indicate that drivers were significantly more accurate in determining that both exit destinations were served by lanes 3 and 4 when multiline separators were used (sign sets A and C). This holds true for both the up arrow signs (79.7 versus 59.3 percent, $p < 0.0001$) and the down arrow signs (76.4 versus 56.6 percent, $p < 0.0001$).

Examining the errors that drivers made in the hyphen separation condition provides insight about how some drivers interpreted the signs. More specifically, for drivers who incorrectly selected only one lane, the selected lane almost always corresponded to the lane located under the destination label. Also, this effect was slightly stronger with the hyphen-separated down arrows than the hyphen-separated up arrows (35.7 versus 31.9 percent for lane 3 and 56.6.versus 46.4 percent for lane 4).

Another trend is that drivers who made errors in the hyphen separation condition were somewhat more likely to do so in the exit only lane (lane 4) than in the option lane (lane 3). This trend held true for both arrow types; however, it was only significant for the down arrows (sign set B, $p < 0.0001$ and sign set D, p = not significant). If drivers are making this association based on position of the destination above a lane, then there should be no difference between option lane and exit lane errors. Alternatively, other factors could be influencing some drivers' interpretation of the sign information, such as the presence of the exit only panel over only one of the two exiting lanes, the destination position at the edge of the sign, or other bias toward the exit only lane.

Through Destination:

A major differentiator between the arrow types was performance with through lane destinations. The responses to these questions are shown in table 14. Lanes 1 and 2 represent the two left through lanes, while lane 3 is the option lane. Accordingly, the first row (lanes 1 and 2) shows

the proportion of incorrect responses that indicate that drivers had a poor understanding that the third lane is an option lane to serve the through destination.

Table 14. Through lane selections for topic 4.

Arrow Type/ Destination Separation	Sign Set A: Down Arrow Multilane	Sign Set B: Down Arrow Hyphenated	Sign Set C: Up Arrow Multilane	Sign Set D: Up Arrow Hyphenated
Lanes 1 and 2	81.3 percent	89.9 percent	15.9 percent	14.8 percent
Lanes 1, 2, and 3 (option)	12.1 percent	8.7 percent	80.8 percent	83.0 percent

It is clear when looking at through destination performance that the down arrows (sign sets A and B) performed worse in terms of understanding of the option lane (i.e., only 12.1 and 8.7 percent fully correct (i.e., drivers selected all the lanes that would take them to the correct destination, including the option lane)). This may be because the up arrow signs (sign sets C and D) show a single lane leading to multiple destinations using branching arrow heads. In contrast, sign sets A and B only indirectly indicated that lane 3 is an option lane.

Findings

The results from this question suggest that the spatial relationship between the exit destinations and the arrows seems to be important for communicating lane assignment information. In particular, multiline-separated destinations caused a higher proportion of participants to associate the indicated destination with both lanes than the hyphen-separated destinations. In contrast, hyphen-separated destinations had a higher proportion of participants to associate the destination that was immediately above the arrow with solely the lane below the arrow.

Additionally, in terms of option lane understanding, the up arrows substantially outperformed the down arrows. This is perhaps due to the direct and clear communication of the two movements in a single arrow.

An interesting trend was also apparent in the errors made in the multiline separation condition. Specifically, when asked to reach the top destination, drivers who made incorrect responses tended to choose lane 4 (the exit only lane) over lane 3 (the option lane), suggesting that they associate the top destination with the first exit. This is consistent with the focus group discussion in which some participants thought that the top destination would exit before the bottom destination, perhaps motivating them to move all the way toward the anticipated exit direction.

Topic 5: Signing a Two-Lane Exit with a Downstream Split

Topic 5 examined a research question that was similar to the one in topic 4. Specifically, it investigated driver understanding of guide signs for a two-lane exit that divides after the exit. This question corresponds to topic 3 in the TTI simulator study, which examined driver lane choice in a two-lane interchange exit with a downstream split.[6] Similar to topic 4, the current question compared different methods for separating destination labels. These included the multiline and hyphenated separators used in topic 4 in addition to a vertical line separator.[1] One difference from the sign layout in topic 4 was that the exit only panel extended the full length of the guide sign so that both destinations were always above this panel.

The key question in this topic was whether participants believed the sign information indicated an immediate split (i.e., they immediately had to change lanes) or a downstream split (i.e., they could stay in either lane until after they exited; see figure 75). Each of the three sign sets used a different method of listing and separating the two destinations. Sign set A used a multiline separator, sign set B used a vertical line separator, and sign set C used a hyphen separator. The test question always asked if the participants had to immediately change lanes to reach the indicated destination. In the relevant data trials in which drivers started in one of the two rightmost lanes, the correct answer was always "No." Each sign set tested a single exit destination, except for sign set A, for which the top and bottom exit destinations were tested.

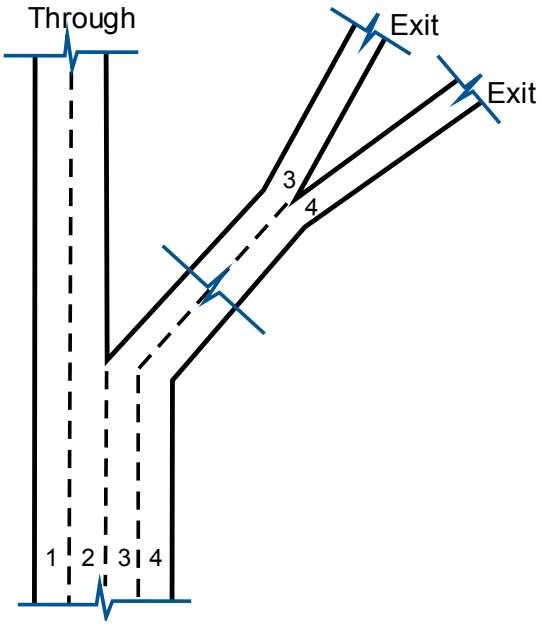

Figure 75. Illustration. Topic 5 geometry split after a two-lane exit.

Research Question

The research question for this topic is as follows: how do drivers interpret different types of destination separators on guide signs that indicate where lanes go for a two-lane exit with a downstream split?

Sample Slides

Participants were positioned in one of the two exit lanes. From their lane, drivers were asked if they had to immediately change lanes to go to one of the exit destinations.

An example test slide for the lane 3 to top exit movement is shown in figure 76. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** You want to take Exit 45 to Madison.
- **Question:** To go to Madison, do you have to change lanes right away?

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Figure 76. Photo. Example test slide from topic 5.[47]

Response Summary

Figure 77 through figure 79 show sign sets A through C for topic 5 (note that lane 1 is on the left and lane 4 is on the right for each figure).

Figure 77. Illustration. Topic 5—sign set A.

Figure 78. Illustration. Topic 5—sign set B.

Figure 79. Illustration. Topic 5—sign set C.

Table 15 shows the summary of responses for topic 5. The responses are summarized for each sign set by the movement that participants were asked to take.

Table 15. Lane restriction responses for topic 5.

Sign Set	Movement	Percent Correct
A	Lane 3 to top exit (Madison)*	89.6
	Lane 3 to bottom exit (Englewood)	96.7
B	Lane 4 to left exit (Malartic)	33.7
C	Lane 3 to right exit (Sebastian)	90.7

Note: Although the destinations are listed in the response summary tables for understanding, multiple signs, each with different sets of destination names, were used to examine each sign set.

For signs with the multiline (sign set A) and hyphen separators (sign set C), almost all drivers understood that they did not have to change lanes immediately to reach their destination. These sign sets were better at communicating that both of the exiting lanes would allow drivers to reach both destinations and that the drivers would not need to change lanes right away. In contrast, drivers were more likely to respond that they needed to change lanes when the vertical line separator (sign set B) was used ($p < 0.0001$ for all comparisons). Unlike the other separators, the vertical line separator caused drivers to associate each destination with only the lane that was positioned under it.

The results for the hyphen separator sign design appear to contradict the results from topic 4, which found that the hyphen separation led some drivers to associate each destination with only the lane below it. This occurred with both up and down arrow signs. One possibility is that the exit only panel is a salient cue when it comes to communicating what happens to specific lanes. In particular, in topic 4, the exit only panel only covered the rightmost lane, whereas in the current topic, it covered both exiting lanes, perhaps leading to drivers' grouping together both destinations above the exit only. Following this interpretation, it would also be necessary to posit that the vertical line separator supersedes the effectiveness of the exit only panel at grouping lanes.

At this point, it seems that the spatial organization of sign elements influences driver interpretation of guide signs; however, additional information is needed to develop a clear understanding of how individual elements, such as separator type and exit panel placement, affect these interpretations.

Findings

Multiline and hyphen separators led drivers to think that they did not immediately have to change lanes to reach their destination. The vertical line separator was the only separation method that caused participants to think that they had to change lanes immediately to reach either destination. However, the exit only panel spanning the entire exit sign also gave a cue to participants that both lanes would exit together. The exit only panel appears to have a stronger effect than the hyphen separation but not the vertical line separation.

The results from the current topic are also complementary to those found in topic 3 of the TTI simulator study, which used comparable sign sets.[6] In particular, the TTI topic 3 asked the inverse question of the current topic; that is, which lane would take drivers to a specific destination (i.e., each lane was assigned to a single destination rather than both destinations to both lanes in the current topic). The TTI findings indicate that drivers were better at determining

the correct single destination when they were arranged horizontally with a vertical line separator than when the destinations were stacked on multiple lines. Similar to the current findings, vertical line separators led to drivers associating destinations with the individual lanes below, whereas drivers did not make these specific lane assignments with multiline-separated destinations.

Topic 6: Multilane Diagrammatic Signs

One aspect of complex interchanges that can make navigation a challenge is a large number of lanes, especially if they include multilane exits or splits. Diagrammatic signs can be used to communicate navigation information in a more literal format; however, drivers' ability to interpret these signs may be compromised when the number of lanes is high. In particular, drivers in the focus groups mentioned having difficulty reading the information provided by diagrammatic arrows. For example, the dashed lane lines on these signs are small, and some drivers reported difficulty seeing them or that they usually do not have time to see and make use of this information.[40] With regard to the cognitive aspects of reading these signs, drivers have additional mental operations to conduct, including counting the lanes, determining which lane goes to which destination, and determining which of these lanes they currently occupy. Adding more lanes to the diagrammatic arrow makes these tasks even more difficult.

The current topic investigated if there are limits to the number of lanes that can be effectively communicated by diagrammatic arrow signs. There were two factors of interest, including the total number of lanes on the roadway and the difficulty of the navigation task decision (i.e., task difficulty). The total number of lanes on the roadway varied from four to nine, and all of the lanes were represented on the diagrammatic arrow on the sign. Task difficulty was examined by varying the drivers' lane position so that the navigation task was either easy or hard. In the easy condition, the point-of-view was from a vehicle in one of the outside lanes, which made it possible to answer the question without close examination of the diagrammatic arrow. In the hard condition, the point-of-view was the from a center lane adjacent to the split, which required additional scrutiny of the sign to determine the correct answer. Sample combinations of each of these variables are shown in table 19. For each combination, participants were asked if their lane would take them to a designated destination.

Another factor that was investigated was the presentation of an even or odd number of lanes in the diagrammatic sign. With an even number of lanes, the two branches of the arrow were the same width, whereas with an odd number of lanes, one more lane went to the through destination than the exit destination, making the through arrow branch slightly wider than the exit arrow branch. In particular, the hard condition task may be simplified with an odd number of lanes since the size difference between the two branches of the arrow is immediately apparent. There are strategies that drivers can use to make answering this question easier, including counting the number of lanes in the narrower branch of the split or determining that they are in the center lane and matching that position to the wider branch of the split. If these types of strategies are used by drivers, then their accuracy may be better on hard trials with an odd number of lanes.

Research Question

The research question for this topic is as follows: are there limits on the number of lanes that can be effectively communicated by diagrammatic signs?

Sample Slides

On each of the signs, all of the lanes on the roadway were numbered to help drivers assess the size of the roadway. This was done to more easily simulate real-world driving, where drivers presumably have a better idea of the size of the roadway that they are travelling on as well as their position on the roadway. Since the slide presentation did not provide much time to get a sense of the freeway size, the lane numbers helped facilitate this in addition to reducing variability from potential lane-counting errors.

Example test slides are show in figure 81 through figure 83. Example introduction and question information presented to participants include the following:

- **Introduction:** You are in lane 1 and want to take 94 South to Fairview.
- **Question:** Will your lane take you to Fairview?

Figure 80. Photo. Odd number of lanes (easy task difficulty).[48]

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Figure 81. Photo. Odd number of lanes (hard task difficulty).[49]

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Figure 82. Photo. Even number of lanes (easy task difficulty).[50]

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Figure 83. Photo. Even number of lanes (hard task difficulty).[51]

Response Summary

Table 16 shows a summary of the percent of correct responses by number of lanes for each task difficulty condition.

Table 16. Percent correct responses for easy/hard and odd/even conditions.

Number of Lanes	Easy Task Difficulty	Hard Task Difficulty	
		Odd Lanes	Even Lanes
4	98.4 percent	—	86.9 percent
5	94.5 percent	82.5 percent	—
6	92.9 percent	—	72.0 percent
7	97.8 percent	82.0 percent	—
8	97.3 percent	—	58.2 percent
9	89.6 percent	72.7 percent	—

— Indicates combinations that are not possible.

Collapsing across the number of lanes on the roadway, the difference in percentage correct between the easy and hard conditions was significant ($p < 0.001$). The values in table 20 are shown in graphical form in figure 84. Overall performance is lower in the hard condition, and there appears to be a downward trend in accuracy as the number of lanes increases. In addition, this downward trend is more pronounced with an even number of lanes in the hard condition.

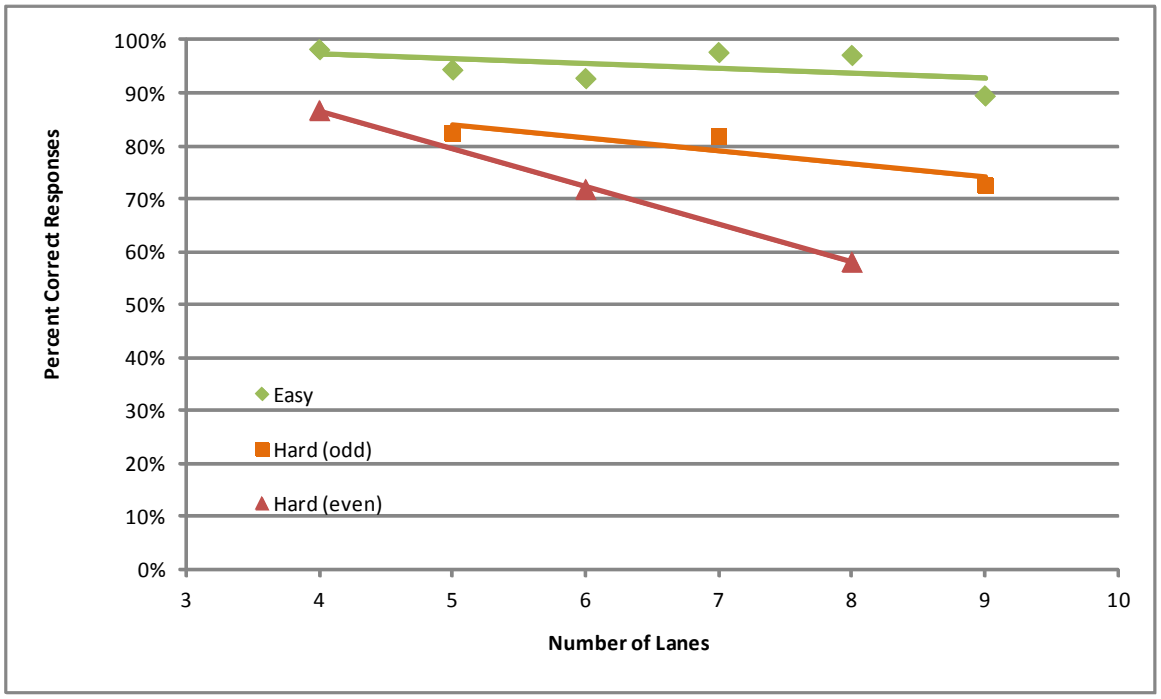

Figure 84. Graph. Percent of correct responses by total number of roadway lanes for topic 6.

Findings

When positioned in an edge lane (easy condition), drivers were able to determine if their lane would lead to a given destination with only a slight decrease in accuracy as the number of lanes on the roadway increased. When positioned in a middle lane adjacent to the split (hard condition), drivers performed better with roads with an odd number of lanes than with roads with an even number of lanes; however, it is premature to tell if this effect is relevant for actual signs. These findings are consistent with the hypothesis that reading complex diagrammatic signs imposes cognitive workload on drivers and their ability to accurately interpret the sign information within the context of their driving situation is limited.

It should be noted that none of the diagrammatic signs examined included an interior option lane, which is inconsistent with MUTCD requirements.[1] It was necessary to exclude option lanes to make it possible to have only a single correct answer to the test question. Also, the exclusion of the option lane does not detract from the main finding that for arrows with many lane markings, some drivers appeared to have difficulty matching physical interchange lanes to the lanes depicted on the diagrammatic arrow.

Topic 7: Signing Two Freeway Exits in Close Proximity

The research conducted as part of topic 7 was based on a research question investigated in the TTI simulator study.[6] More specifically, TTI examined methods for signing two freeway exits within close proximity when three destinations must be indicated (nearest exit, second exit, and through movement). The geometry for this interchange is shown in figure 85.

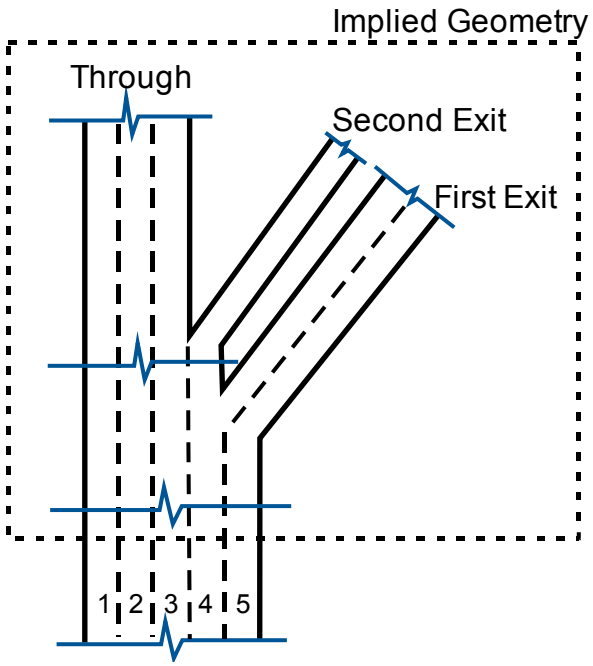

Figure 85. Illustration. Topic 7 roadway geometry—three destinations at two closely spaced exits.

TTI developed three sign alternatives to examine when drivers change lanes in addition to their use of option lanes. In the current topic, researchers tested those three sign sets in addition to two sign designs based on modifications of two of the original sign sets. The objective was to obtain additional information about driver understanding of the movements indicated by the signs and how they interpreted different sign elements.

Research Question

The research question for this topic is as follows: what are effective guide sign designs for signing two interstate exits within close proximity of each other?

Sample Slides

The slide questions used in this topic were the same as that in topic 4. For each slide set, participants were asked to circle the lane or lanes that would take them to a given destination. They were asked to circle multiple lanes if applicable. This approach provided a relatively complete mapping of drivers' understanding of where they expect the lanes to go based on the sign information. All of the lanes were numbered, and the drivers' perspective was from the center of the roadway, although the lane that they were in was not noted in any way.

An example test slide for topic 7 is shown in figure 86. The corresponding introduction and question information presented to participants was as follows:

- **Introduction:** Circle the lane or lanes that take you to Wilton.
- **Question:** Can you circle the lane or lanes that take you to Wilton?

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Figure 86. Photo. Example test slide from topic 7.[52]

Response Summary

Figure 87 through figure 91 show sign sets A through C for topic 7. Note that the sign set numbering was selected to be consistent with the TTI driving simulator sign sets.[6] Variations on the primary sign group are indicated with the addition of the numeral 2 in the label (e.g., A2).

Figure 87. Illustration. Topic 7—sign set A.

Figure 88. Illustration. Topic 7—sign set A2.

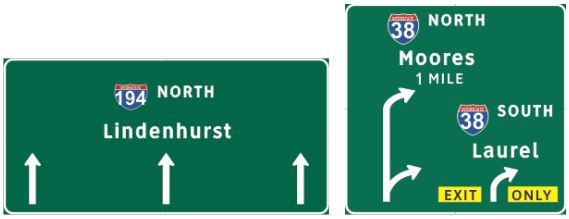


Figure 89. Illustration. Topic 7—sign set B.

Figure 90. Illustration. Topic 7—sign set B2.

Figure 91. Illustration. Topic 7—sign set C.

Researchers initially investigated absolute performance (i.e., did drivers circle all of the correct lanes) since this is the best measure of driver understanding of the sign information. However, overall accuracy with this measure was generally poor for several of the sign sets and movements. This poor performance may have resulted from the complexity of the task overall (e.g., circling four lanes in some questions) or complexity of the sign sets in general. Specifically, there were some underlying driver-based factors likely related to the layout of the signs that may have contributed to poor absolute performance. To obtain a better understanding

of the relative effectiveness of the different signs, researchers instead used a more lenient measure of accuracy that determined whether drivers would have reached the indicated destination using any of the lanes that they circled and that none of the lanes that they circled only took them to an incorrect destination. This measure is the percentage shown in parentheses in table 17.

Table 17. Lane selections for topic 7.

Sign Set*	Through (percent)	Second (Middle) Exit (percent)	First (Rightmost) Exit (percent
A	14.5 (79.7)**	3.8	82.6 (98.6)
A2	35.7 (94.0)	69.6	68.1 (96.2)
B	96.2 (97.3)	72.0	21.4 (96.2)
B2	87.9 (90.1)	84.1	26.4 (94.5)
C	59.9 (95.1)	38.5	42.9 (96.2)

* The sign set numbering was selected to be consistent with the TTI driving simulator sign sets. Variations on the primary sign group are indicated with the addition of the numeral 2 in the label (e.g., A2).
** Value shown in parentheses sums all responses that included at least one lane that would get to the intended destination, and no lanes that would not get drivers to their destination (i.e., respondent did not completely understand the sign but he/she would have reached his/her destination).

Findings related to different travel movements are discussed in the following subsections.

Through Movement:

For the through movement, all of the signs performed well with the exception of sign set A ($p < 0.05$ for all comparisons). Sign set A provided the least amount of information about the lanes for the through movement. Although the sign for the through movement was identical to that for sign set A2, in sign set A2, the second exit sign points to a particular lane (lane 4) and has an exit only panel, allowing some participants to eliminate that lane as a possible through destination lane. Since drivers were not provided with comparable information about the second exit in sign set A, it appears that without this information, they might have assumed that lane 4 was an option lane.

First Exit Movement:

For the first (rightmost) exit, none of the signs were significantly different when considering all responses that would allow drivers to reach their desired destinations ($p > 0.05$ for all comparisons). For sign sets B and B2, the majority of participants only circled lane 5 (73.6 and 65.9 percent, respectively) to reach the first exit. It seems that the curved first exit

branch over lane 4 was not strongly associated with the first exit destination, so drivers were less certain that lane 4 would also take them to the first exit.

Second Exit Movement:

The main differentiator in sign performance for this topic was the second exit movement. The only lane that led to the second exit was lane 4, meaning that there was only one correct response. For this particular movement, sign sets A2, B, and B2 yielded similar good performance (the difference between sign sets A2 and B2 was marginally significant at $p < 0.05$). The differences between the groups of sign sets A2, B, and B2 and sign sets A and C were all significant ($p < 0.001$ for all comparisons).

Sign set A performed the worst when considering the second exit movement. This may be because it provided the least specific information regarding the movement required for the second exit, and it did not include lane arrows. It is possible that drivers made different assumptions or answered the question differently than with other signs and movements. In particular, they may have viewed the question as, "which lane(s) can you be in now and still reach Exit 2?" rather than, "which lane would take you all the way to the Exit 2 destination?" This is supported by the types of answers the drivers provided. These include selecting only lane 3 (e.g., positioning their car under sign), selecting lanes 1–3 (e.g., all through lanes but avoiding the option lane), and selecting lanes 1–4 (e.g., same as previous but with the option lane). Nevertheless, the results from sign set A suggest that there may be a substantial degree of variation in driver expectations about this type of movement if they are not provided information about lanes and lane movements.

Sign set C also yielded relatively poor driver understanding of the second exit movement. One reason for this may have been the complexity of the sign. In particular, it may be difficult to quickly determine that lane 4 is an option lane based on the visual composition of this sign. For example, drivers may have looked at the first exit and noticed that it was two lanes and then seen the second exit (noticeably narrower than the first) and guessed that it was the third lane without noticing that the through movement had three lanes. This interpretation is consistent with the findings from topic 6 where increased arrow complexity led to errors in interpreting the diagrammatic arrow. Anecdotally, sign set C was also the only sign set that elicited verbal participant reactions and comments about the complexity of the sign.

Sign set A2 yielded a reasonably high degree of accuracy for the second exit movement (69.6 percent). However, approximately half of the individuals who answered the question incorrectly responded that lane 3 could be taken to get to the second exit (15.9 percent). Lane 3 was below the exit only panel but was not the correct lane. This is consistent with the findings from topic 3 that indicated that when drivers see a yellow panel below a sign, some have a tendency to position their vehicles underneath that sign to reach the destination. In addition, sign sets B and B2 performed similarly well for this movement.

Findings

The sign sets were assessed by movement and evaluated in terms of which provided the most accurate description of which lanes led to each destination. In real driving situations, drivers can

gather more information about upcoming exits as they get closer to the exits themselves; however, in situations such as this one, that approach can lead to last-minute lane changes and confusion. Looking across all of the possible movements, sign sets A2, B, and B2 seemed to perform the best. The biggest differentiating factor was the signing of the second exit since it closely followed the first exit. Sign set A2 caused some drivers to think that the second exit was reached by the third lane. Sign sets B and B2 led to some confusion with the first exit movement since drivers had difficulty associating the curved part of the option lane arrow with the first exit destination. Overall, each sign caused some specific challenges with lane assignment.

The findings from the current topic were generally similar with those from topic 2 of the TTI simulator study.[6] In particular, that study found that sign set B yielded fewer incorrect lane changes than sets A and C and that the second exit movement generally gave drivers the most difficulty. Note that sign sets A2 and B2 were not investigated in the TTI simulator study.

TASK 7 CONCLUSIONS

Key Conclusions

The spatial organization and layout of guide sign information have an important influence on driver interpretation of signs and their expectations of upcoming interchange geometry. The clearest and most consistent finding from the present study is that perceptual factors related to the organization of information on a sign influence how drivers interpret the sign. This can involve the layout of informational elements, how sign elements are grouped, and/or the position of the sign on the sign bridge. The data suggest that some drivers formed strong expectations based on the arrangement of sign information in certain situations. This is especially apparent in topic 3 in which sign placement on the bridge was a stronger cue than the specific sign notation for communicating a left exit. Also, there is evidence from this same topic that drivers confused left exit panels with exit only panels when those panels were located on the right side of the sign bridge. This suggests that the expectations that drivers had related to sign position biased their understanding of the sign. In time-constrained driving conditions, these expectations can influence their reading of signs and make the difference between correctly or incorrectly interpreting a guide sign.

Some of the other findings from this study that support the notion that perceptual factors are important for the interpretation of guide signs include the following:

- Uncertainty caused by visual perspective/alignment of lane information may have caused drivers to deliberately avoid the option lane.

- Drivers tended to link destinations with specific lanes if they were horizontally adjacent and separated by a hyphen.

- In the hard task difficulty condition, visual cues unique to diagrammatic signs with an odd number of lanes led to better performance than an even number of lanes in which the visual information was less distinctive.

- Visual grouping between the curved option lane up arrows and the first exit destination label may have been compromised because of too much horizontal separation.

Understanding the perceptual factors that influence guide sign interpretation is important because they represent attributes that can be exploited to make signs more useful to drivers. However, if signs are designed without proper consideration of these factors, it could also lead to unnecessarily complicated or confusing guide signs. This is especially important for complex interchanges because signs typically communicate more information, the interchanges are more likely to be unique and unfamiliar to drivers, and the interchanges are uncommon and are more likely to involve atypical geometric elements.

There was a high degree of variability across drivers with regard to how they interpreted the same signs. The independent variables used in this study yielded consistent and explainable trends in driver responses across the topics examined. This indicates that, overall, there are systematic factors that underlie aggregate driver responses to the research questions. However, the results also show a substantial degree of variation across drivers. While there were many signs sets for which overall driver agreement was high (i.e., average response greater than 85 to 90 percent or less than 15 to 20 percent (negative agreement)), for many other signs, the degree of agreement was much lower. This suggests that in some situations, groups of drivers had different interpretations of sign information and consequently, individual differences between drivers may play an important role in their interpretation of guide sign information. Understanding the source of these individual differences and which aspects of sign design have the potential to minimize these differences could be a valuable approach for developing effective guide signs. The current investigation did not look at response patterns within individuals or within specific types of drivers (e.g., younger versus older drivers); however, possible avenues for examining these types of findings are discussed in the Recommendations section at the end of this report.

Another key high-level finding from task 7 is that the basic data collection methodology was effective for obtaining information about driver expectations and interpretations of guide sign information. This is consistent with earlier studies that employed this approach to investigate driver exit lane preferences and with the driver behavior observed in the task 6 simulator study.[2] However, there are still clear limitations to this methodology that should be kept in mind when assessing the relevance of the current findings to guide sign design. Some of these limitations include the following:

- The cost of making incorrect lane choices was low. Specifically, there was no penalty or driver stress associated with making incorrect or suboptimal navigation decisions. This is different from real-world driving where choosing the wrong lane may result in losing time, having to exit the freeway, or even getting lost. Realistic costs could have led drivers to be more careful with their responses, resulting in higher accuracy. However, since the focus of the current analysis was on relative performance across signs, this factor would have been mostly held constant across the relevant sign comparisons.

- The interaction with the road environment was not incorporated. In some ways, the test slides showed the guide signs under ideal conditions. Several of the factors that can make

sign reading more challenging were not present with the static sign presentation approach used. Ways in which the sign presentations were optimal include the following:

  - The size or visual angle of signs was constant (no sign expansion), which meant that signs were equally readable throughout the trial presentation (unlike a sign that grows in size visually as drivers get closer).
  - There were no requirements to multitask while reading the signs, such as watching for other vehicles or preparing to make a lane change.
  - There was no occlusion of signs by other vehicles, such as large trucks.
  - There was a relaxed time limit (i.e., 4-s presentation duration).

- A side effect of trying to maintain consistency across slide backgrounds and the need to fabricate roadway scenes to match research questions is that these approaches may have introduced some response bias related to the artificiality of the test slides. For example, effects attributed to skewed visual perspective in through-to-exit movement in topic 1 may have been exaggerated by the composition of the test slides.

These methodological concerns highlight the complexity that drivers face when trying to read sign information when navigating complex interchanges. The static conditions are unable to adequately capture these dynamics, and it may be necessary to confirm some of the current findings with additional data collection approaches that provide a more realistic representation of the interchange driving task.

Note that there were other task 7 conclusions that applied directly to the overall project objectives. These are discussed in chapter 5 of this report. These include the following:

- Up arrows yield consistently better results than down arrows in terms of accurate driver understanding of permissible interchange movements and efficient option lane usage.
- Destination separators varied in terms of how they led drivers to match destinations with particular lanes.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This project yielded several overall conclusions related to driver expectations at complex interchanges. These conclusions are organized around the following two primary objectives of this project:

- How do expectations affect driver behavior?
- What are the related recommendations for sign design?

The findings related to each objective are discussed in the following sections.

How Do Expectations Affect Driver Behavior?

The activities conducted in this project provided information about several aspects of this question. These aspects are discussed in the following sections.

Definition of Driver Expectations

Based on the literature review, it was clear that the concept of driver expectations has not been thoroughly defined with specific regard to interchanges and common driver maneuvers at interchanges. However, this concept has received consideration with regard to broader driving tasks. There are several existing definitions of driver expectations.[12,3,13] The majority of definitions that were found typically included some variation of the comprehensive definition provided by Lunenfeld and Alexander , which states that expectancy is "a driver's readiness to respond to situations, events, and information in predictable and successful ways."(pg. 153)[3] Some of the attributes of driver expectancy include the following:

- Drivers tend to anticipate upcoming situations and events that are common to the road they are traveling.
- Driver expectancy influences response speed and accuracy.
- The more predictable the roadway feature, the less likely will be the chance for errors.
- Drivers experience problems when they are surprised.
- Drivers, in the absence of counter evidence, assume that they will only have to react to standard situations.
- The roadway and its environment upstream of a site create an expectancy of downstream conditions. Drivers experience problems in transition areas and locations with inconsistent design or operation.

- Expectancies are associated with all levels of driving performance and all aspects of the driving situation. This includes expectancies relative to speed, path, direction, the roadway, the environment, geometric design, traffic operations, and traffic control devices.

The empirical findings regarding driver expectations are as follows:

- Drivers expect to need to be in the lane closest to the exiting direction to be able to exit. [17]

- Drivers expect lane drops at exits.[18]

- Signs and lane markings appear to be effective ways to set driver expectations at interchanges.[20]

- Driver expectations impact their information acquisition.[21]

Key Driver Expectations Regarding the Navigation of Complex Interchanges

The primary conclusions related to driver expectations come from the focus group discussions described in chapter 3. Some of the conclusions are specific to individual scenarios covered in the focus groups, while others are relevant to more than one scenario. The conclusions include the following:

- Drivers expect that there will be functional relationships between lanes on the roadway and arrows/text on signs and that the signs will make these relationships clear.

- Drivers expect that the distance between a guide sign and a final (or last chance) decision point will be sufficient to allow for making any necessary lane changes in a safe and timely manner.

- Drivers expect that they will have more than one opportunity to obtain necessary destination and lane information before they need to make a final decision regarding lane choices.

- Drivers expect that the freeway system will provide them with the necessary information to construct a mental model and that it will be sufficient to support timely and accurate decisions about lane choice.

- Drivers expect that the information available to them through the freeway system will be sufficient to support decisions about lane choices; at the least, they will never have to move over more than one lane at the last moment.

- Drivers expect that the freeway system will provide sufficient information to support decisions about all route choices, not just frequent or popular choices.

How Various Interchange Elements Affect Driver Tasks and Performance

This question was primarily addressed in the task analysis described in an earlier project report.[4] This analysis provided high-level information about how some interchange elements have the potential to affect driving, and the relevant findings are briefly summarized for various interchange elements as follows:

- **Curves/ramps**: These represent one of the most significant sources of elevated driver workload because these elements inherently involve a greater number of driving tasks, and they contain more time-based restrictions on task performance and decisions.

- **Guide signs**: These represent a key source of driver visual and cognitive workload, and they can make the cognitive navigation task unnecessarily complicated depending on what information is presented and how it is laid out on the sign. The spacing and placement of signs (particularly with sight-distance restrictions) is also a key determinant of workload.

- **Merge/weave sections**: These sections impose visual and psychomotor demands on drivers as they manage their interactions with other traffic.

- **Option lanes**: Signs that indicate option lane information using down arrows may lead to unnecessary effort because they require drivers to integrate disparate information and deduce the intended meaning. Also, diagrammatic signs rely on relatively small sign elements (lane marking symbols) to communicate option lane information, which may be difficult for drivers (especially older drivers) to see at fast speeds. This may cause them to miss this important information.

Key Challenges to Drivers

The task analysis also indicated that drivers face several key challenges in interchange driving. These challenges include the following:[4]

- **Multiple concurrent visual activities**: Typically, on ramps and curves, drivers face multiple concurrent visual tasks that likely involve switching between targets, and they require that drivers manage where they deploy their glances, which increases workload. Drivers may also be forced to only read part of a sign or make decisions with less thought and deliberation than they may prefer. As the task 4 focus groups indicated, these types of rushed actions make drivers uncomfortable and stressed out about interchange driving.

- **Time-limited nature of interchange driving**: A key problem for drivers is having sufficient time to make sound decisions in some of the more time-limited situations. In particular, some decisions must be made close in time to other tasks that can interfere with decisionmaking, such as reading signs and managing traffic interactions. Another challenge is the time limitations imposed by interchange geometry, such as sight-distance restrictions and lane drops/gore points. These elements are fixed in time and space for drivers, and they place hard limits on the time available to conduct intervening activities. While drivers always have the option of slowing down to give themselves more time, this

is yet another decision. Also, as the task 4 focus groups indicate, many drivers feel social pressure to keep with the flow of traffic. Several drivers reported that they would rather miss their exit and double-back when faced with time-pressure conditions.

- **Managing and interpreting navigation information**: Driver navigation expectations for less common destinations may be significantly more complicated to understand. More specifically, drivers have to keep track of more information to figure out where to go in absence of direct navigation information. This not only makes drivers work harder but makes it more likely that drivers will make incorrect decisions. The task 4 focus groups indicated that drivers expect signs to provide sufficient information to support decisions about all route choices, not just frequent or popular destinations.

Safety and Capacity Implications of Driver Expectations Findings

The findings from this project illustrate some of the implications of driver expectations on safety and capacity at complex interchanges. Effects related to safety and capacity are discussed in the following subsections. It should be noted that this information is primarily based on qualitative focus group discussions or empirical data from a limited set of drivers. Therefore, these findings should be viewed as suggestive of the driver expectations that could impact safety or capacity, but their link to actual traffic data is not confirmed in any way in this project.

Safety:

The concerns related to safety generally involve drivers at complex interchanges having to execute multiple actions with limited time, which can lead to drivers making more mistakes in situations that generally have lower margins for error. Some of the specific safety-related implications are as follows:

- **Multiple lane changes in a short distance**: Drivers reported their previous experiences with other drivers making multiple last-second lane changes to reach exits, and some reported that they would do so themselves. This could lead to drivers taking excessive risks while changing lanes or executing them before fully preparing (e.g., foregoing shoulder checks).

- **Time-limited actions**: According to the task analysis results and driver comments about the focus group scenarios, the time available to read certain guide signs can be limited by sight or reading distance. This limits the subsequent time available to make navigation decisions or execute maneuvers such as lane changes. Rushing these activities could promote driver errors that lead to unsafe conditions (e.g., erratic driving to complete a maneuver in time).

- **Concurrent driver tasks**: The task analysis indicated that drivers can sometimes encounter increased activity levels on ramps such as changing speed, steering, reading signs, and making lane changes. There is potential for interference across these various activities (e.g., drivers reading a sign could lose vehicle control on curved exit ramps).

Capacity:

Most of the implications regarding interchange capacity involve uneven lane usage; however, effects related to drivers slowing or missing exits are as follows:

- **Lane usage**: Several of the results from the empirical data collection suggested that if drivers have some uncertainty about whether the option lane serves their destination (e.g., due to ambiguous destination information on guide signs) or if they are unsure that it is an option lane (e.g., poor alignment of guide sign arrows with lanes on a curved segment), they will strongly prefer getting into the exit only lane over using the option lane. The converse is also true. Specifically, if drivers have any doubts that an exit only lane will lead to their destination, they will try to be in the option lane to avoid mistakenly exiting the freeway. This is consistent with a general trend observed in the focus group comments in which drivers reported being conservative with their lane choices when faced with uncertainty about which lane serves their movement. In these cases, drivers prefer to avoid outside lanes so that they have more options and can avoid making multiple lane changes in a short distance.

  It is worth noting that the described lane usage patterns pertain mostly to drivers who are unfamiliar with the interchange. There were focus group comments suggesting that familiar drivers actually improve capacity by avoiding congested lanes when they know that other lanes will also take them to their destination. An extension of this notion is that if drivers clearly understand which lane goes where, they may make better use of less crowded lane alternatives. Therefore, if it is possible to communicate lane information sufficiently using guide signs or other approaches, even unfamiliar drivers could act as familiar drivers and optimize capacity.

- **Other impacts on capacity**: The project identified other ways in which capacity can be negatively affected by driver actions in response to complex guide sign information. As alluded to in the previous paragraph, the strategies that drivers adopt for dealing with uncertainty involves making additional lane changes, many of which may be unnecessary. Another common driver action that can reduce capacity is that drivers in the focus groups reported slowing down to read signs or to give themselves more time to make decisions or change lanes. Finally, a less direct impact on capacity is related to drivers missing exits because they could not complete the movement in time or because they felt that it was unsafe to execute a movement. Drivers commonly reported that they would exit and re-enter the freeway to try to make their intended exit, which unnecessarily increases traffic flow, although by a small amount.

Recommendations for Sign Design

The following sections summarize the key conclusions and findings regarding recommendations for sign design that were identified in this project.

Key Design Principles and Guidance from Existing Research

One outcome of the task 2 literature review was an initial set of key design principles, which include the following:

1. Provide adequate forward sight distance.
2. Provide transition cues.
3. Minimize attention-dividing conditions.
4. Provide navigation information to address all of the driver information needs.
5. Maintain compatibility between the interchange and the visual cues.
6. Design to accommodate the drivers' expectations and abilities.
7. Warn drivers of situations which may violate their expectations.
8. Allow drivers to recover after making an error.
9. Design for simplicity.
10. Design for consistency and predictability.

The "Results" section in chapter 2 provides additional details about specific steps that can be taken to address each design principle.

Findings Related to Sign Design from the Task 7 Data Collection Activities

The task 7 empirical activities yielded several findings that support the development of specific recommendations for guide sign design. The spatial organization and layout of guide sign information have an important influence on driver interpretation of signs and their expectations of upcoming interchange geometry. The clearest and most consistent finding from task 7 is that perceptual factors related to the organization of information on a sign influence how drivers interpret the sign. The focus group discussions also provided similar findings. These perceptual factors can involve the layout of informational elements, how sign elements are grouped, and/or the position of the sign on the sign bridge. The data suggest that some drivers formed strong expectations based on the arrangement of sign information in certain situations. This is especially apparent in topic 3 of task 7 in which sign placement on the bridge was a stronger cue than the specific sign notation for communicating a left exit. Also, there is evidence from this same topic that drivers confused left exit panels with exit only panels when those panels were located on the right side of the sign bridge. This suggests that the expectations that drivers had related to sign position biased their understanding of the sign. Under time-constrained driving conditions, these expectations can influence their reading of signs and make the difference between correctly or incorrectly interpreting a guide sign. Other specific findings related to the influence of perceptual factors are discussed in the "Conclusions" section of chapter 4.

In the focus groups, most drivers appeared to interpret down lane arrows rather narrowly to correspond to the destination that is directly above or grouped with the arrow. For example, in scenario 1, while both NW Ind. Area and St. Helens destinations could be reached by either of the two right lanes, most drivers paired each destination with only the lane directly below the corresponding lane arrow. This tendency led to problems later in the scenario because drivers associated the rightmost lane, which was an exit only lane, with St. Helens when the exit was for a different destination (Vaughn St.).

Understanding the perceptual factors that influence guide sign interpretation is important because they represent attributes that can be exploited to make signs more useful to drivers. However, if signs are designed without proper consideration of these factors, it could also lead to unnecessarily complicated or confusing guide signs. This is especially important for complex interchanges because signs typically communicate more information, the interchanges are more likely to be unique and unfamiliar to drivers, and the interchanges are uncommon and are more likely to involve atypical geometric elements.

Up arrows yield consistently better results than down arrows in terms of accurate driver understanding of permissible interchange movements and efficient option lane usage. In topics 1, 2, and 4, up arrows led to more efficient option lane usage or better comprehension of permissible movements when compared to down arrows. Up arrows differ from down arrows in multiple ways. They often have a clearer visual alignment with a single roadway lane. The movement information can be inherent in the arrow (e.g., curved to the right for a right exit or straight for the through destination). Additionally, since the curvature of the arrow can be varied by destination direction, up arrows can be grouped with other up arrows pointing the same direction (e.g., to indicate that both an option lane and an exit only lane lead to the same destination). Overall, these findings suggest that drivers require additional or specific information about option lanes and the movements they represent and that up arrows can be used more effectively to provide this option lane information.

An aspect of sign comprehension that was examined in this study was how drivers visually group destination information with other sign elements and particular roadway lanes. A key sign element used for communicating which information goes together is the type of separator used to divide destination labels on the sign. Three separators were investigated in this study: vertical lines, hyphens, and multiline separations. In addition to these, data suggest that the presence of an exit only panel (more specifically, the space it occupied along the bottom of the sign) may also have acted as a visual separator. The results found for the various separators are as follows:

- Vertical lines caused drivers to associate the destination on either side of the line with only the lane below the destination label. This separator appeared to supersede the effects of an exit only panel that spanned the entire sign width.

- Hyphen separators had mixed results. When used with an exit only panel that spanned the entire sign width, hyphen separators were predominantly interpreted as indicating that both lanes go to both destinations. When used with an exit only panel that only spanned the rightmost of two exiting lanes, the hyphen separator caused some drivers to associate each destination with only the lane immediately below it.

- Multiline separators did not function as a separator at all; rather, they led drivers to group both of the destinations with both of the lanes that they were centered above. This type of grouping was best for pairing multiple destinations with the same information. This happened regardless of the style of exit only panel used.

Clearly, separation cues influence how drivers associate destination information with specific lanes. Although these elements were not tested exhaustively or necessarily in isolation, these findings demonstrate the importance of the choice of separator, as each led to different expectations for the upcoming roadway, particularly when used in conjunction with an exit only panel. Additionally, the exit only panel itself deserves consideration as a separator since it appeared to influence how drivers grouped destination information with lanes.

RECOMMENDATIONS

Based on the work conducted in this project, there are several recommendations for follow-up activities that can help researchers understand driver expectations at complex interchanges. Follow-up activities related to the task analysis are provided in the task 5 report.[4] Follow-up activities related to task 7 data collection are described in this section.

Additional research should be conducted to obtain a more complete understanding of the influence of perceptual factors on guide sign interpretation. The current research clearly demonstrates that perceptual factors exert a strong influence on driver interpretation and responses to guide sign information. The first conclusion in the previous section discusses the significance of this finding in detail. However, while the data collected in task 7 provides an initial appreciation of the importance of perceptual factors on driver expectations and their interpretation of guide signs, the resulting data represent an initial look at some of these factors. A more comprehensive and systematic approach is required to fully understand the role of information layout and organization on driver comprehension and interpretation of guide signs.

As mentioned previously, a key benefit of understanding the perceptual factors that influence guide sign interpretation is that they represent attributes that can be exploited to make signs more useful to drivers. Also, failing to properly consider these factors could lead to unnecessarily complicated or confusing guide signs. There are other useful applications for this type of information that a more detailed investigation of this topic would provide as follows:

- **Developing recommendations for sign design and layout**: Currently, most of these perceptual elements are not considered in the design process, and they are not typically directly addressed in the MUTCD.[1] New sign designs require engineers to make many decisions regarding placing information elements, grouping elements, arrow types, etc., particularly when creating a novel sign for a new, complex interchange. Specific information about the consequences of element usage can assist informed decisions for these new sign designs, and it can be incorporated into existing sign design references.

- **Identifying cost effective sign design trade-offs for new or refurbished guide signs**: Similar to the previous point, each sign element has an associated production cost, which may be factored into the design decisions. When considering element-level trade-offs, it

is important to know the consequences of selecting a particular element in terms of driver behavior to determine if a low-cost compromise is viable.

- **Diagnosing problem interchanges**: In situations where traffic engineers are noticing a disparity in the distribution of lane usage, lane changes close to the gore point, or unnecessary slowing, it may be possible to use information about driver comprehension of sign elements as a diagnostic tool to specifically determine which elements or groupings are causing driver confusion.

Overall, the importance of perceptual factors in guide sign design is a relatively unexplored topic, yet the data from the current research indicates that it is potentially a key topic for designing guide signs that can be quickly and accurately understood by drivers. Conducting additional research in this area will support activities that will improve guide sign design and facilitate driver navigation of complex interchanges.

Systematically Apply Methodologies to Additional Interchanges with Existing Navigation Challenges

This project made good progress in developing methods and tools for identifying driver expectations at complex interchanges and applying the findings to generate solutions for problems that drivers encounter. A logical extension of this work is to apply this process to additional complex interchanges that are known to cause problems for drivers. Using the approaches from this project in a systematic way would also be very useful for refining these methods, developing tools that engineers could use to identify specific problems at complex interchanges, and then finding solutions for addressing them. An example of a geometry that could be evaluated is interchanges that include collector-distributor roadways. These roadways would be valuable to investigate since there is little guidance available regarding designing for driver expectations there, and they can be complicated for drivers to navigate (e.g., a single exit may need to include signage for a complex configuration of multiple future exits or interchanges that it serves).

To extend the current methodology to examine other interchanges, the following steps would need to be taken:

1. Identify candidate complex interchanges with potential navigation issues that could be addressed. Once the target interchanges have been identified, it would be necessary to work with State transportation departments and other stakeholders to understand their design challenges/constraints and identify information needs regarding driver navigation.

2. Conduct focus groups, task analyses, and empirical data collection to obtain information about driver expectations, specific stressors or challenges encountered, information needs, and workload/task requirements at the selected interchanges. This information will be used to develop signing strategies and specific guide sign designs that meet driver information needs for the tested interchanges. These strategies and designs could then be evaluated at key points along the roadway and for specific movements with a new driver sample. This would involve measuring driver comprehension, driver assumptions and expectations, and resulting actions (e.g., lane choices) using data collection approaches developed in the current project.

3. Develop specific recommendations for improving signing at the interchanges examined and more general recommendations that can be applied to related systems.

A key outcome from this research would be specific recommendations for signing plans that are validated by driver testing for each interchange investigated in the project. This would include specific guide sign designs that were shown to best support driver navigation and expectations. More general recommendations would be developed for related interchanges, which would be turned into a guidance document to inform new designs or improvements at other related interchanges. Another outcome would be to refine the approaches and tools developed in this current driver expectations project to make them more directly applicable and useful for solving a broader set of signing design challenges.

Conduct Research to Understand Why Up Arrows are More Effective at Communicating Permissible Lane Information

In several topics examined in this study, up arrows outperformed down arrows in aspects of lane usage or communicating lane assignments. This leads to the question: which characteristics of up arrows make them more effective? Although up arrows are conceptually similar to down arrows, it appears that there may be a basic difference between them that causes drivers to perceive them differently. For example, if drivers are reading the arrows from base to point, down arrows appear to be focused on assigning destinations to lanes, while up arrows start at the driver and point to where they are going. Similarly, because up arrows can show multiple curvatures or directional combinations, they can be used to communicate additional information to drivers, often in an implicit manner (e.g., using the same curvature to visually associate movements in separate lanes that reach the same destination).

Conducting research to obtain a clear understanding of how drivers interpret different aspects of up arrows could provide additional tools for communicating interchange movements in a manner that can be immediately understood by drivers. This is especially important at complex interchanges because arrows are often used in unconventional ways to communicate novel, complex information (e.g., sign sets B and B2 in topic 7).

The new information from the current project can be used to update the *Human Factors Guidelines for Road Systems*.[5] The publication has an entire chapter of guidelines dedicated to interchanges; however, information about the effects of various sign elements on driver expectations in complex interchanges is clearly lacking.[5] It would be valuable for roadway designers to have more information about the consequences of using certain sign elements over others in terms of the effects on driver understanding and lane selection. An immediate contribution of the current study could be to fill some of the knowledge gaps about these issues. Some information from the current study that could be applied to the *Human Factors Guidelines for Road Systems* includes the following:[5]

- There is a limit on the number of lanes that can be depicted and successfully comprehended on a diagrammatic guide sign (see topic 6). This limit is even smaller for signs with an equal number of lanes in each branch of a split than an unequal number of lanes in each branch.

- Complex signs for depicting the upcoming geometry can assist driver understanding (see topic 7). However, each destination is impacted by the individual elements used, and it is important to consider every possible driver movement.

- Overall, individual sign elements impact driver grouping and lane assignments for each destination. Although many aspects of sign design are regulated by the MUTCD , when designing a novel sign, it is important to consider the assigned meaning of each element that is used because drivers assign meaning to each element that they see.[1]

Conduct a More Comprehensive Analysis of Individual Response Patterns

This recommendation originates from the discussion on variability in driver interpretation of guide signs. The task 7 response booklet was used to collect demographic information about driving history and experience with interchanges; however, neither this information nor information about driver demographics, such as age, were included as factors in the analyses. A simple follow-up activity for this project would be to take a closer look at the importance of these factors as predictors of driver responses. For example, professional drivers may have more effective strategies for focusing on key elements of signs while ignoring less relevant information. If this pattern was observed in the new analysis, then it could lead to sign designs that better promote the identification of key information over secondary information. There are also important questions that can be investigated, including the following:

- Are there groups of drivers who consistently interpret signs the same way?

- Are these groups defined by demographics, driving experience, or some other factor?

- At the level of the individual, how stable are the views that define the groups (i.e., drivers responding the same way every time they see a particular sign element versus supplying responses that are situation-specific)?

The results from the current investigation show that there is still a substantial degree of unaccounted variance in driver responses. Obtaining a better understanding of this variance can provide additional information that can support the design of effective interchange guide signs.

Another longer-term approach for furthering researcher understanding of driver expectations at complex interchanges is to develop work plans for investigating these questions using SHRP2 naturalistic driving data. The SHRP2 naturalistic driving study is a large, on-road data collection effort that involves instrumenting approximately 3,000 drivers' own vehicles with an advanced data collection system including internal and external viewing cameras, forward radar, Global Positioning Systems (GPSs), and other sensors. Data collection is ongoing until the end of 2013, with data becoming available afterward. An important and unique aspect of SHRP2 data is that it will record a driver's behavior over a potentially large number of repeated traversals of the same interchanges. Using these data, it should be possible to develop baseline interchange navigation profiles for specific drivers using data from repeated movements over frequently traversed simple and complex interchanges. For example, one aspect of a driver's profile could reflect the degree to which that individual prefers the option lane versus an exit only lane. It might also be possible to identify factors that lead to changes in this behavior (e.g., a driver who typically

prefers an exit only lane may choose the option if traffic is heavy). It should also be possible to examine the same driver at complex interchanges that they rarely traverse to determine how behavior in a comparable, unfamiliar complex interchange differs from the baseline profile. Using this approach, it may be possible to correlate features of the complex interchanges (e.g., geometry, sign information, etc.) with changes in behavior relative to baseline performance. This activity could provide information about how features of complex interchanges impacted driving behavior, and these findings could be used to provide behavioral validation of the types of findings observed using static and driving simulator data collection approaches.

It might also be possible to examine driver behavior at unfamiliar complex interchanges at a finer level of detail. For example, in-vehicle video data could provide information about when drivers look at signs and how much time they spend reading them. Other vehicle data can provide information about changes in vehicle speed as drivers prepare for movements as well as measurements of the distances at which they try to initiate lane changes. The data can also provide indications of navigation errors in the form of GPS traces that show interchange reentry and exit at different locations. Overall, the SHRP2 naturalistic driving data provide a rich and comprehensive dataset for expanding this initial work to obtain a better understanding of driver expectations at complex interchanges.

APPENDIX A. TASK 4 RESPONSE BOOKLET

This appendix shows the response booklet filled out by participants in the task 4 focus groups.

1

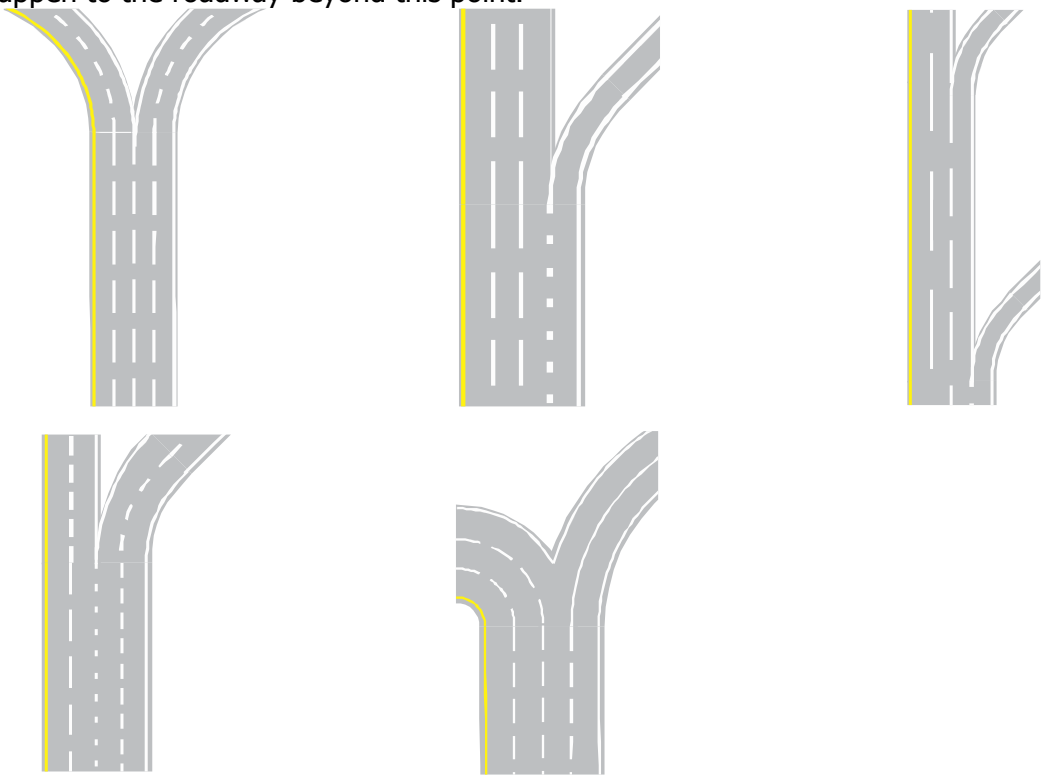
Driver Expectations at Complex Interchanges
Focus Group Response Booklet

Interchange 1: Objective 2

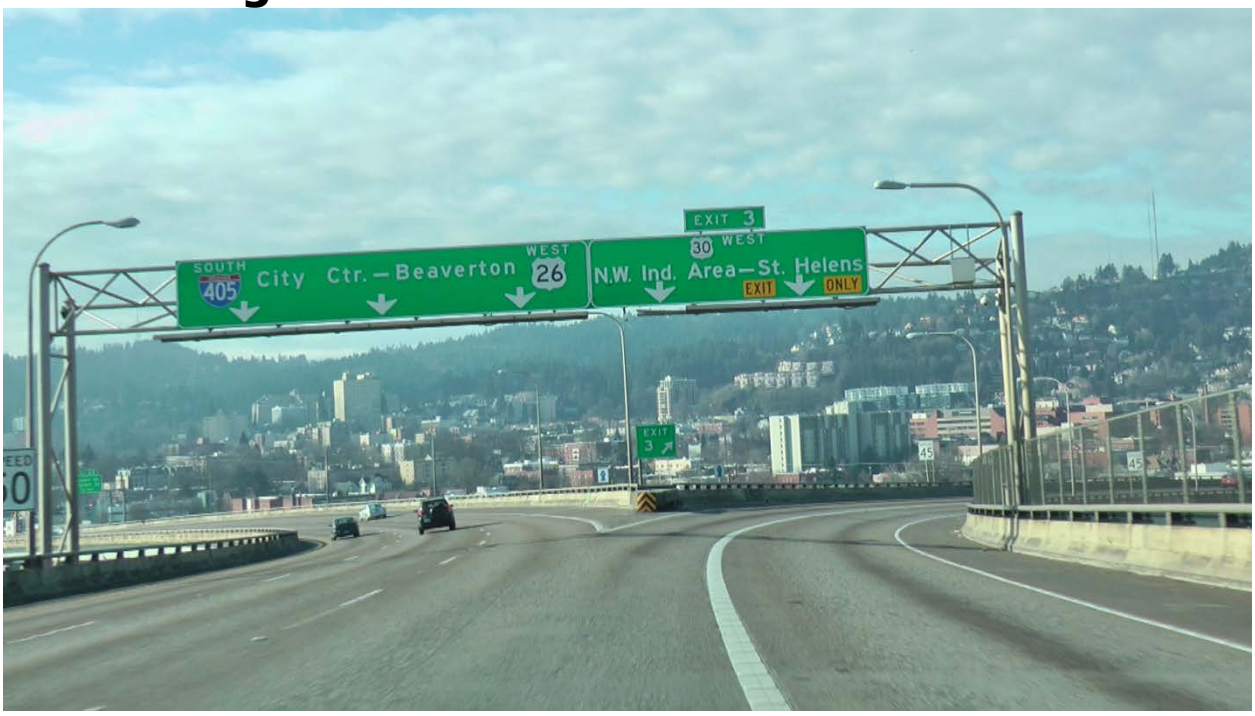
Your objective is to get onto US-30 West.

Interchange 1: Critical Point 1 3

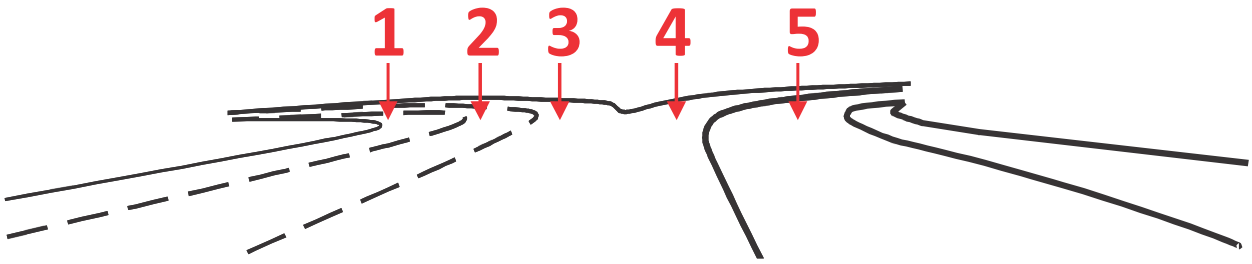
Using the information provided in the signs, circle the picture that best shows what you think will happen to the roadway beyond this point.



Interchange 1: Critical Point 2 4



Circle the number of the lane that you would choose to go to US-30 West.



Interchange 1: Critical Point 3 5

Please circle your response.

Does US-30 West continue over the bridge or under the bridge?

Over the bridge Under the bridge

Interchange 2: Objective 6

You are driving on 30 West and your objective is to reach the City Center.

Interchange 2: Critical Point 1 7

Please circle your response.
One of the signs says both "City Center" and "Seattle". Choose the answer below that *best* describes how you interpret this:

a) The same exit allows you to go both to "City Center" and "Seattle."
b) The middle lane allows you to go to both "City Center" and "Seattle."

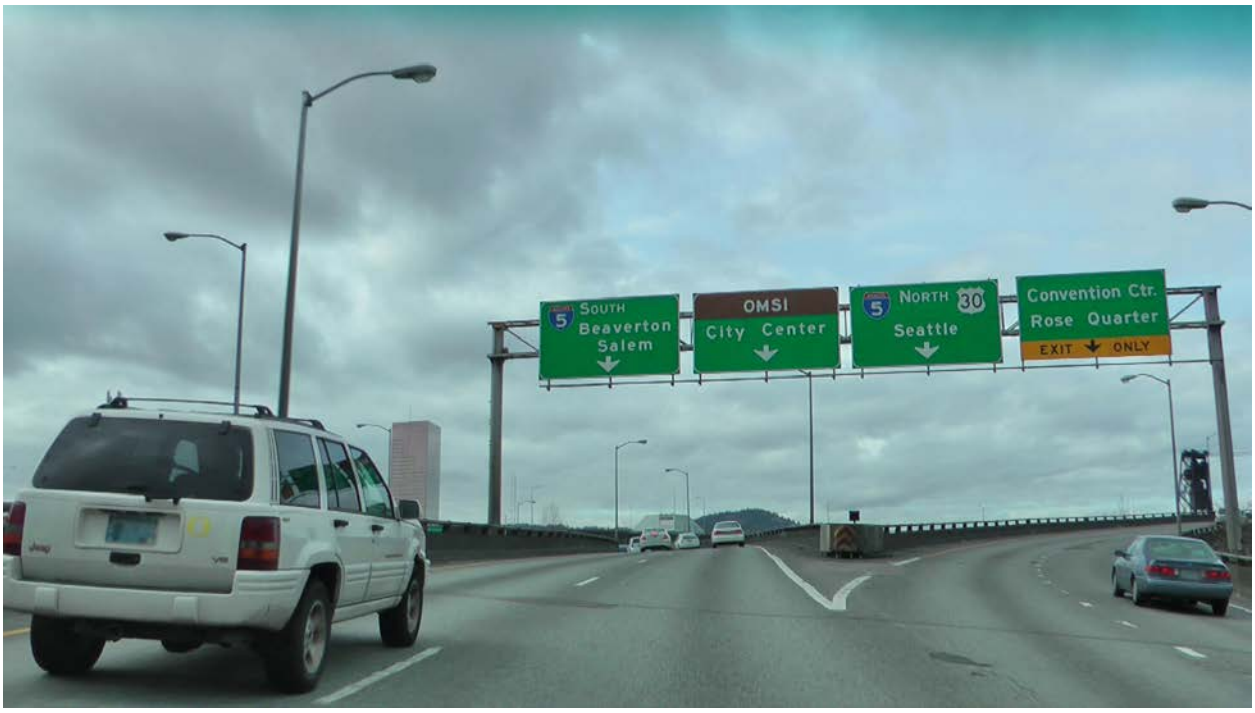
Interchange 2: Critical Point 2 8

Which direction would you go to reach City Center? Please circle your response below.

South North

Interchange 2: Critical Point 3 9

Interchange 2: Critical Point 4 10



How well did the guide signs that you previously encountered prepare you for the following aspects of the freeway lane split (please mark one option per row)?

	Adequately Prepared	Not Prepared Enough
That a split was coming at all		
That a split was coming at that time		
That you knew which lane to be in		
That the center lane could go in both directions		
That you knew which direction to go		

Interchange 3: Objective 11

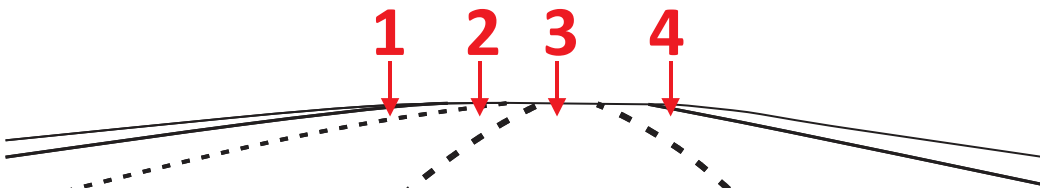
Your objective is to get onto Interstate 5 South.

[Editor's Note: ©2011 Google®; map annotations provded by Battelle (see "Acknowledgements")]

Interchange 3: Critical Point 1 12

Please circle the number for your lane choice.

Knowing that you have to exit soon, which lane would you feel most comfortable in and why?



Why?

_____

_____

Interchange 3: Critical Point 2 13

Both signs say the same thing

Did anything surprise you about the required maneuver? If so, what?

_____

_____

Questionnaire 14

Thank you for your participation in the focus group session. Please take a few minutes to answer the questions provided on the next couple of pages.

1) Age: _____
2) Gender (circle one): Male Female
3) How many years have you been a licensed driver? _____
4) How many years have you lived in an urban area? _____
5) What is the make and model of the vehicle that you drive most regularly?

- Make: _____ Model: _____

6) How many hours do you drive per week (on average)? _____
7) How frequently do you drive through major interchanges (like those seen today)?
    a. Never
    b. About once per year
    c. About once per month
    d. Weekly
    e. Daily
    f. Multiple times per day

Questionnaire (Continued) 15

8) Have you ever lived in Portland, Oregon? Yes No
If yes, when, and for how long?
_____

9) Have you ever been any type of professional driver (i.e., truck driver, delivery driver, etc)?
Yes No
If yes, please briefly describe your position.
_____
_____

10) How familiar were you with each of the interchanges before you saw them today?

Interchange 1

Not at all | Seemed familiar | Knew it well

Interchange 2

Not at all | Seemed familiar | Knew it well

Interchange 3

Not at all | Seemed familiar | Knew it well

APPENDIX B. TASK 4 MODERATOR GUIDE

This appendix shows the moderator guide used to lead the task 4 focus groups.

I. INTRODUCTION [10 MINUTES]

Good (afternoon/evening). I'm glad you could take time out of your day to be here. My name is Christian Richard, and I am the moderator for today's discussion. Helping me out today will be my co-moderator, Monica Lichty. The purpose of today's group is to talk about a number of topics related to yourselves, driving, and your experiences at freeway interchanges. As you were probably told by the person who called you, we will be here for about an hour and a half.

SELF-DISCLOSURES:

Before we begin, I'd like to make some self-disclosures. Monica and I are scientists that work for a company called Battelle, which conducts research for clients on a wide variety of subjects. My particular group does research investigating ways to make roadways safer and easier for drivers to use.

Our discussions here today are part of a larger project looking at the design and construction of highway interchanges. Monica and I are travelling around the country talking to groups like yours and giving them opportunities to share their thoughts, ideas, and feelings about interchanges. That's what we'll do here tonight.

Just so you know, my job is only to report what you have to say back to my client, the Federal Highway Administration of the U.S. Department of Transportation. I have no vested interest in your answers. I am not here to sell you anything, and my job will continue regardless of how you answer. Thus, I encourage you to be honest, and feel free to offer both positive and negative comments.

BROADER DISCLOSURES:

As you also may have noticed, this session is being videotaped. This is not because we want to keep track of "who said what" but more to keep a record of today's information for our report. Monica and I are doing a number of these groups in multiple cities, and it would be difficult for us to remember the specifics of each group without having something to help verify what we're reporting. I assure you, the tape will be used for no other purpose, and the recording will be destroyed once this project is over.

GROUND RULES:

Before we get started, I'll go over some ground rules that will help us get the information we need and help you get an idea about how focus groups work.

1. The first is to please speak clearly and one at a time so that everyone in the group can hear you. Also, keep your voice level at least as loud as mine is now so that the microphones can pick up what you say.

2. Since focus groups are conducted with complete confidentiality, we are using first names only. None of you will be identified by name in our report or anywhere else.

3. You are each being paid for your time to be here because we are interested in what you have to say. Thus, it is important that we hear from everyone. There will be times when you may be the only one in the group that feels a particular way. Please speak up when this occurs as this group represents a larger population. You may not think the same way as anyone in this room, but you may be representing the ideas of thousands of other people that are not here tonight. All opinions are valuable. There are no right or wrong answers.

4. We are also here today to get information about your opinions and experiences. This is important because you are the drivers that have to navigate interchanges. It's also why we are more interested in hearing about your own experiences than those of others you know. As you may have already experienced, highway engineers don't always get their road designs right. This cartoon [PPT slide 2] points out the fact that sometimes design ideas don't always make perfect sense in practice.

5. The last thing is that, at any time, you can feel free to get up and get additional refreshments or go to the restroom if you would like. We will also take a short break about halfway through the session.

Are there any questions about how this focus group will work? OK, before we begin, let's go around the room and introduce ourselves by giving our first names and a brief description of where we'd be and what we'd be doing if we weren't here right now.

Now that we all know each other, let's get started.

II. WARM-UP EXERCISES [10 MINUTES]

I mentioned earlier that this group is part of a larger project that is gathering data about what drivers expect to see at interchanges.

Before I go any further, I want to make sure we are all talking about the same things when I refer to interchanges. Specifically, I'm talking about the collection of ramps, exits, overpasses, signs, lanes marking, and other things you encounter when one freeway intersects with another freeway or a set of busy local roads. Most of you are probably familiar with clover leaf interchanges. [PPT slide 3] This is the kind of roadway that I'm talking about.

So, raise your hand if you have ever been lost, missed an exit, or driven on an interchange that you found to be confusing. [Look at responses.] This is one of the main things we will be discussing tonight.

As an aside, have you ever driven in an interchange that looked like one of these [PPT slide 4]?

These complex interchanges show up in the real-world as well, not just in cartoons [PPT slide 5].

We will be talking a lot about challenging interchanges in the next hour, but first, I'd like to start off by talking a little bit about simpler interchanges. Ones that most people would find easy to

drive through. As a group, let's try to draw a typical interchange based on what you normally expect to encounter at a simple interchange. [PPT slide 6]

Imagine you are driving down a freeway with 3 lanes and you need to exit onto a major local road.

1. Where would you typically expect the exit to be?
   - How many lanes would it have?

2. What happens to the freeway lane that leads up to the exit?
   - Does it end after the exit or does branch it off and continue down the freeway?

3. Where do you expect the signs to be along the road?

4. How far ahead do you expect the signs to be?

5. Do you expect more than one set of signs?
   - What purpose should they serve?

6. What should the signs say?

7. Do you expect to rely on lane markings at all?

III. DYNAMIC INTERCHANGE SCENARIO DISCUSSIONS [45 MINUTES]

For the next part of the focus group, were going to talk about specific interchanges. We will be viewing video footage of a vehicle driving through three different interchanges; the videos were filmed from the driver's perspective. As we view these videos, imagine that you are driving on these roadways for the first time, so you have to rely on the information from the video to figure out how to get through the interchange.

All three of the videos were filmed in Portland, OR.

We will discuss each interchange, one at a time. For each interchange, our discussion will follow a similar format.

1. First, we will play the video, stopping at two to three points along the way. During these times, you will have a chance to read the signs. At some of these points, we will ask you to answer a question in the booklet in front of you. During this video, we ask that you do not discuss the interchange with the other people in the group because it is important to form your own expectations as you watch the video.

2. The second time, we will play the video all the way through, uninterrupted, so that you can get an idea of the flow and timing of the entire drive.

3. After these two viewings, we will watch the video one more time, stopping at some of the same points to discuss things as a group. We will discuss some of the same questions as the first time through, but also feel free to add any other thoughts that you have.

Discussions about driving can cover many topics but we are most interested in finding out what you are thinking as you're "driving" along the roadway, how you expect the roadway to look, and what signs you expect to see.

So now if everyone can turn to page 2 in your booklet, we'll start the scenario.

III-1) Interchange 1: Visually Challenging Option Lanes

For this first drive, you are crossing a bridge on I-405, and your objective is to get onto US-30 West.

Booklet Question 1: It is important to us to get your initial impressions, so please do not go back and change your responses after move on to the next question.

Critical Point 1: Read Overhead Guide Signs

1. Does anyone know what the arrows mean? (intro to arrow-per-lane signs.)
    - What information goes with the arrow (above and below)?
2. What do you expect will happen beyond this point?
   Since you can't see what's ahead, do you think the signage should be different?

Critical Point 2: Read Exit Signage

1. Which lane did you choose to go to 30 West?
    - Did anyone choose the middle lane? What is the reason?
    - Did anyone choose the right lane? What is the reason?
2. The middle lane is called an option lane, because it typically gives you the option to go one way or the other. In general, what do you think about option lanes?
    - Would you prefer to use them or stay out of them?
3. Is there anything that makes you uncomfortable/that you don't like? (Reference to option lane with forced decision.)

Critical Point 3: Read Final Signage

1. How well do the arrows indicate where the lanes go?
    - Did you use them to make your decision?
2. If you stay in this lane, where will you end up?
3. Does 30 West go over or under the bridge?

4. Is there anything that makes you uncomfortable/that you don't like?

Before we move onto the next scenario, we will take a 5-minute break. Feel free to stretch your legs and grab a snack.

III-2) Interchange 2: Four-Lane Split with Complex Advance Guide Signs

For this drive, you are currently on 30 West, and your objective is to reach the City Center.

Critical Point 1: Read Arrow-Per-Lane Signs

1. What does it mean that there are multiple destinations on the same sign?
    - Do you take the same lane to get there?
    - Do the destinations share the same exit?
2. In general, what do you expect this type of information to mean on an interchange sign?
    - Do you ever get confused abbreviations, place names, or other destination information on interchange signs? (Note that this is an optional question.)

Critical Point 2: Read Diagrammatic Sign

This is called a diagrammatic sign, because it provides more of a "picture" of what the lanes do. Are you familiar with these?

1. What does this sign tell you about the interchange geometry?
2. Which direction do you go to get to City Center (North or South)?
    - This sign looks inconsistent if you interpreted the previous sign in terms of destinations rather than lanes.
3. How literally do you interpret "diagrammatic" signs? Do you expect there to be three or four lanes when the split occurs?

Critical Point 3: Read Split Diagrammatic Signs

1. At this point, what kind of idea do you have about what's ahead?
2. Do the arrows tell you anything about what happens in each lane?
    - Would you ever interpret these as "Arrows-per-lane?"

Critical Point 4: Read Final Arrow-Per-Lane Signs

1. Did the previous signs adequately prepare you for this?

2. What, if anything, are some of the things that may have made you uncomfortable in this situation?

    - Timing.

    - Gore point.

    - Complexity of information.

3. If you were driving in this interchange, would you try to read the signs? What information would you be looking for the most? How would you get the information you need from them?

III-3) Interchange 2: Poorly Signed Left Exit with Multiple Lane Changes

For this drive, you are going to pretend that you are using a map to get to a destination that you are unfamiliar with. Your objective is to get onto Interstate 5 South. So please look at this map before we begin. Essentially, you are going North over the bridge on I-405 to get to I-5S. The exit is at the end of the bridge.

Critical Point 1: Read Overhead Signs

1. What do you think about this batch of signs? (Were they useful? (Note that this is an optional question.))

    - What information would improve these signs?

2. Which lane would you choose for I-5S?

3. If you don't have any useful information, what would you try to do about which lane you are in?

Critical Point 2: Read Side-Mounted Guide Signs

NOTE: there is also a guide sign on the right

1. Did you expect to see signs mounted on the sides? (Where do you expect important information to be displayed at an interchange?)

2. What would you try to do in this situation? Would you try to get into the left lane?

3. In general, what do you think about multiple lane changes at interchanges?

    - How do multiple lane changes rate in terms of difficult they make interchange driving and increase in stress levels?

IV. CLOSING

Thank you again for taking the time to come out and talk with us this [afternoon, evening]. Before closing, are there any additional thoughts you'd like to offer about the topics we discussed? [If not, conclude the session, if so, briefly allow additional thoughts to come forward.]

V. QUESTIONNAIRES

Before you leave, we ask that you please complete a questionnaire. This questionnaire asks some basic demographic questions and a few questions about your driving history. You may skip any of the questions that you do not feel comfortable answering. When you are finished, please return it to Monica or myself. We will be in the lobby handing out the stipends and getting you to sign receipts.

APPENDIX C. TASK 4 COMPLETE RESPONSES FROM WARM-UP ACTIVITY

Table 18 provides a summary of the responses from the focus group warm-up activity. Note that the counts in the table correspond to the number of groups where a particular answer was provided.

Table 18. Summary of responses from focus group warm-up activity.

Question	Seattle, WA	Columbus, OH	Washington, DC	Total
Questions Related to the Exit				
Where is the exit?				
On the right	4	4	4	12
On the left	0	0	0	0
Sometimes on the left	1	2	2	5
How many lanes would the exit have?				
One lane	3	4	4	11
Two lanes	1	3	1	5
Usually one but sometimes two	0	1	1	2
Depends on exit roadway size	1	0	0	1
Four lanes	0	1	0	1
Could cut off in multiple directions (e.g., North-South, Exit A-B, etc.)	0	0	1	1
What happens to the travel lane after the exit?				
It exits and also continues (option lane)	3	4	4	11
It ends (lane drop)	1	3	1	5
Depends if it is marked exit only or not	2	1	1	4
Depends on the traffic volume on the freeway or exiting roadway	2	0	0	2
Questions Related to the Interchange in General				
Where are the signs placed?				
Overhead	2	4	1	7
On the right	2	2	1	5
On the side	0	2	0	2
On the left	1	0	0	1
How far ahead of the exit are the signs?				
2 mi	0	0	1	1
1.5 mi	1	0	1	2
1 mi	3	2	2	7
0.75 mi	0	1	1	2
0.50 mi	3	3	2	8
0.25 mi	1	2	1	4
500 ft	0	0	2	2
300 ft	1	0	0	1
At the exit	0	0	2	2

Are there multiple sets of signs?				
Yes	1	3	3	7
No	1	0	0	1
What should the signs say?				
Destination name	2	3	3	8
Exit number	3	2	3	8
Exit distance	3	2	3	8
Exit only (sometimes)	1	2	1	4
Which lane exits	2	1	0	3
Cardinal direction of the exit roadway	1	1	1	3
Amenities	1	0	1	2
Route number	0	1	1	2
Heading of the road (toward a city or town)	0	1	1	2
Warnings (e.g., reduce speed, sharp curve, etc.)	1	0	1	2
Arrows	0	0	1	1
Information for other upcoming exits	1	0	1	1
Mile number	0	1	0	1
No reentry	0	1	0	1
Speed limit	0	0	1	1
Location of landmarks	0	0	1	1
Do you rely on lane markings?				
No	3	1	1	5
Mentioned destination pavement markings	1	3	1	5
Sometimes	1	3	0	4
If it is a solid white line	1	1	1	3
Yes	0	2	0	2
Only in the exit lane	1	0	0	1
If it is a lane drop	1	0	0	1
Markings if they are related to an infraction fee	1	0	0	1
Arrows	0	1	0	1

APPENDIX D. TASK 7 MODERATOR GUIDE

This appendix shows the moderator guide used to lead the task 7 data collection sessions.

1) **Introduce Researchers**
   a. Moderator leading today's session.
   b. Researcher helping check in.
   c. Work for Battelle, a company that provides research results to clients on a wide variety of subjects. Our particular group does research to find ways to make roadways safer and easier to use.
2) **Purpose**
   a. Doing a series of groups gathering information about freeway interchanges and the signs that mark them.
   b. Part of a larger project investigating what drivers expect at interchanges.
   c. A summary of your response data today will be reported back to our client, the Federal Highway Administration of the U.S. Department of Transportation; totally anonymous and aggregate, not associated with any identifying information such as your name or phone number.
   d. Today we will be going through a slide presentation with interchange images, and you will be recording your responses to some questions in the response booklets.
3) **Review the Sample Slide Set**
   a. Hand out the booklets.
   b. Each question will be presented in the same way—first the driving goal, then the image, then a question.
   c. Introduction slide
      i. Provides a driving goal.
      ii. Gives you additional context for the scenario in which you'll be answering questions. I will read the slide aloud to you while it is displayed on the screen. Just like when you're actually driving, when you view these images, we want you to have a goal in mind of where you are going. This slide will give you that goal.
   d. Preparation slide
      i. Three dots for 2 s total to let you know that the image is coming.
   e. Test slide
      i. Image of parts of an interchange with one or more navigational signs on the image.
      ii. Signs use some real place names, but are not from real places, so you would not find these combinations of destinations in the real world.
      iii. When you see the image, it will be a driver's perspective view from a particular lane. Pretend like you are really driving on that particular road, in that particular lane (some have an arrow).
      iv. The image will be shown for a limited amount of time—only 4 s.
   f. Question slide
      i. Then, a question will cover up the sign and you will have a short amount of time to circle an answer in your response booklet.
      ii. The question on the slide will be numbered with a set of responses in your booklet.
      iii. If you do not remember, please select your best guess.
      iv. Limited amount of time to answer—I will give a you a 5-s warning before moving on.

g. We will view pictures in this sequence for the duration of the session
    i. 78 questions (85 questions for order 2) in total included in three slide sets.

4) Ground Rules

a. Please don't discuss the slides with others in the room—we want to know what each of you thinks individually, so we ask you to record your own response.
b. We will not be taking an official break since the session is only 1 h.

5) Questions?

6) Part 1 Introduction

a. For this set of questions, I would like you to imagine that you are driving on a freeway, trying to get to a certain destination. As you approach an interchange, a sign ahead gives you information about where to go. Using the information on the sign, I want you to choose which lane you want to take to continue on to your destination. For all of the questions in this first set, you will be asked which lane you would choose to get to your destination.
b. When you see the question, all of the lanes on the road will be numbered. Simply circle the number in your booklet that matches the lane you would take.
c. We are interested in finding out about your preferred lane in each situation. Try to base your selection on how you normally drive and assume that there is only light traffic on the road. There will be an arrow on each slide to show you which lane you are in. Pretend that you are actually driving in that lane, so if you are going to choose another lane to get to your destination, you would have to make one or more lane changes.
d. Please only circle one lane choice.

7) Part 2 Introduction

a. For this next set of questions, the driving scenarios are very similar—you'll see more signs that you have to read. The main difference is that the questions in this section ask about your understanding of where the lanes go. For the slides in this set, all of the lanes will be numbered, and the lane that you are currently driving in will be highlighted in blue. Please answer the questions as though you were driving in that lane.

8) Part 3 Introduction

a. For the last set of questions, you will be asked to identify all of the lanes that go to a specific destination. You will also get to see the name of the destination before the sign appears.
b. Please circle all of the lanes that you think will take you to the indicated destination. More than one lane may lead to the destination.

9) End of Session

a. Thanks for coming today!
b. Please fill out the demographic information sheet in the back of your booklet.
c. When you are finished, give your booklet to the researcher, and she will have you sign for your payment.

APPENDIX E. TASK 7 DEMOGRAPHIC QUESTIONNAIRE

The demographic questionnaire was included at the end of the response booklet to gather additional information about the participants.

1) Age: _____
2) Gender (circle one): Male Female
3) How many years have you been a licensed driver? _____
4) How many years have you lived in an urban area? _____
5) How many hours do you drive per week (on average)? _____
6) How frequently do you drive through major interchanges (like those seen today)?
   a) Never
   b) About once per year
   c) About once per month
   d) Weekly
   e) Daily
   f) Multiple times per day
7) Have you ever been any type of professional driver (e.g., truck driver, delivery driver, etc)?
   Yes No

APPENDIX F. TASK 7 SIGNIFICANCE TEST TABLES

The following tables include the *t*-test results for all of the comparisons between and within sign sets that were discussed in chapter 4 (see task 7).

TOPIC 1: OPTION LANE ARROW TYPES AND DRIVER LANE PREFERENCE

Table 19 and table 20 show the *p*-values for the comparisons between sign sets for topic 1. Table 19 shows the comparisons between sign sets by movement from the starting lane to the desired destination.

Table 19. Topic 1 comparisons between sign sets by movement.

Sign Set Comparison	Movement		
	Option to Exit	Through to Exit	Option to Through
A to B	0.6069	0.0000	0.2063
A to C	0.7191	0.0386	0.1448
B to C	0.3334	0.0000	0.7530

Table 20 shows the comparisons between the option lane start and the through lane start within each sign set. The destination was the exit.

Table 20. Topic 1 comparisons within sign sets by movement.

Sign Set Comparison	*p*-Value
A to A	0.0430
B to B	0.0000
C to C	0.4674

TOPIC 2: OPTION LANE ARROW TYPE AND SEPARATION

Table 21 shows the comparisons between sign sets to determine the significance of both the arrow type (up versus down) and option lane arrow configuration (separated versus integrated).

Table 21. Topic 2 comparisons between sign sets.

Sign Set Comparison	*p*-Value
A to B	0.1456
A to C	0.0000
B to D	0.0000
C to D	0.1385

TOPIC 3: LEFT EXIT NOTATION

Table 22 and table 23 show the comparisons for topic 3. Table 22 shows the *p*-values for the comparisons between sign sets for each question.

Table 22. Topic 3 comparisons between sign sets by question.

Sign Set Comparison	Question 1	Question 2	Question 3
A to B	0.0604	0.0002	0.0015
A to C	0.0036	0.0017	0.0014
B to C	0.0002	0.7747	0.0000

Table 23 shows the *p*-values for comparisons between questions 2 and 3.

Table 23. Topic 3 comparisons between Questions 2 and 3.

Sign Set Comparison	*p*-Value
A to A	0.0000
B to B	0.0000
C to C	0.0000

TOPIC 4: TWO-LANE EXIT WITH TWO DESTINATIONS

Table 24 shows the *p*-values for comparisons between sign sets to determine the difference between multiline and hyphen separators for destination names.

Table 24. Topic 4 comparisons between sign sets.

Sign Set Comparison	*p*-Value
A to B	0.0000
C to D	0.0000

TOPIC 5: SIGNING A TWO-LANE EXIT WITH A DOWNSTREAM SPLIT

Table 25 shows the *p*-values for the comparisons between the three sign sets examined in topic 5. Each sign used a different method to separate the two signed destinations: multiline, vertical line, or hyphen separators. Sign set A used a multiline separator; therefore, the top and bottom exits are separate entries.

Table 25. Topic 5 comparisons between sign sets.

Sign Set Comparison	*p*-Value
A (top exit) to A (bottom exit)	0.0007
A (top exit) to B	0.0000
A (bottom exit) to B	0.0000
B to C	0.0000

TOPIC 6: MULTILANE DIAGRAMMATIC SIGNS

Table 26 shows the comparisons between the easy and hard task difficulty conditions for diagrammatic signs.

Table 26. Topic 6 comparisons between easy and hard conditions within sign sets.

Number of Lanes	*p*-Value
4	0.0000
5	0.0004
6	0.0000
7	0.0000
8	0.0000
9	0.0000

TOPIC 7: SIGNING TWO FREEWAY EXITS IN CLOSE PROXIMITY

Table 27 through table 29 show the *p*-values for the comparisons examined in topic 7. Table 27 shows the comparisons for the through movement condition.

Table 27. Topic 7 comparisons for through movement condition between sign sets.

Sign Set Comparison	*p*-Value
A to B	0.0001
A to C	0.0447
A to D	0.0038
A to E	0.0190

Table 28 shows the *p*-values for select comparisons for the first (rightmost) exit movement. Since sign sets A2, B, and C all had the same percentage correct, sign set A2 was used to test for significance.

Table 28. Topic 7 comparisons for the first exit movement condition between sign sets.

Sign Set Comparison	*p*-Value
A to B2	0.0582
A2 to A	0.3209
A2 to B2	0.4684

Table 29 shows the *p*-values for the comparisons between sign sets for the second exit movement condition.

Table 29. Topic 7 comparisons for second exit movement condition between sign sets.

Sign Set Comparison	*p*-Value
A to A2	0.0000
A to B	0.0000
A to B2	0.0000
A to C	0.0000
A2 to B	0.0832
A2 to B2	0.0491
A2 to C	0.0001
B to B2	0.7655
B to C	0.0000
B2 to C	0.0000

ACKNOWLEDGEMENTS

The original maps are the copyright property of Google Maps® and others and can be accessed from http://maps.google.com. The map overlays were developed as a result of this research project. The overlays include lines, instructions, etc.

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