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16. Abstract

This report describes the results of laboratory experiments performed to assess whether certain freeway corridor attributes specified in a real-time motorist information display affect motorists' expected responses to travel time information. Specifically, the study was designed to determine whether (1) the recommended alternative route, (2) the location where motorists were told to divert from the freeway, or (3) the location of the reported onset of congestion relative to where motorists were told to divert influenced motorist diversion threshold values to time saved travel time information. The procedures and results of the studies are described, and recommendations are presented for application of the results to the design and operation of freeway corridor motorist information displays.

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EFFECT OF FREEWAY CORRIDOR ATTRIBUTES UPON MOTORIST DIVERSION RESPONSES TO REAL-TIME TRAVEL TIME INFORMATION

by

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and

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Research Report 1232-13
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sponsored by

Texas Department of Transportation
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TEXAS TRANSPORTATION INSTITUTE
Texas A&M University System
College Station, TX 77843

October 1992

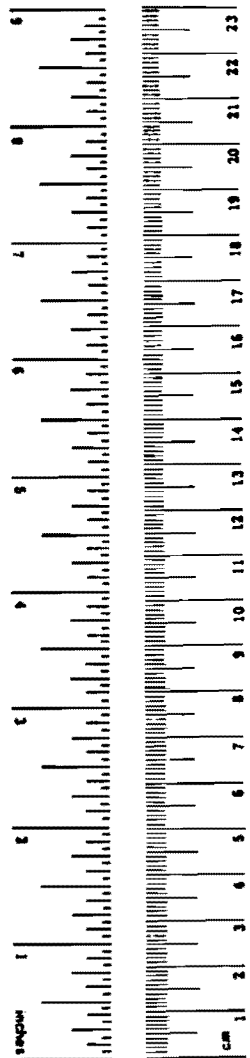
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

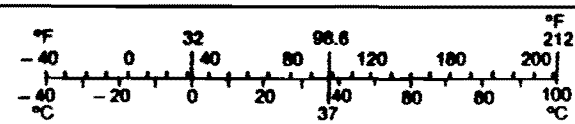
NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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DISCLAIMER

SUMMARY

This report presents the results of laboratory experiments conducted to assess the effects of selected freeway corridor attributes specified in a real-time traffic message upon motorist time-saved threshold values. The corridor attributes evaluated in this research were as follows:

- the recommended alternative route,
- the location where motorists would be advised to divert to the recommended alternative route, and
- the location where congestion was said to begin relative to the location where motorists were advised to divert.

The laboratory experiments used subjects who regularly drove on the North Central Expressway in Dallas, TX for their daily home-to-work trip to the Dallas CBD. Evaluating the responses of all subjects together, it was found that none of the corridor attributes significantly affected the cumulative time saved threshold distributions of motorists. The data was found to differ significantly from that reported by Huchingson et al. several years prior, with more motorists in the current study requiring greater time-saved values before diversion would be considered. However, it was noted that the earlier Huchingson et. al. research focused on motorist diversion enroute to a special event during off-peak travel conditions, whereas the current study addressed diversion during the morning peak-period home-to-work trip.

Analysis-of-variance procedures were employed to examine the effect of the corridor attributes specified above upon motorist time-saved threshold values for different subgroups of the study sample (i.e., those arriving early, those older than 45 years old, etc.). Of the various subgroupings tested, the only one found to be significant was the importance the subject placed on arriving to work on time. Specifically, subjects indicating that it was not important for them to arrive to work on time had a much higher time saved threshold value to consider diverting to Greenville Avenue than they did to divert to the Dallas North Tollway. These particular subjects indicated that they have a strong aversion to using Greenville Avenue because of a large number of traffic signals present on that route.

The lack of statistical significant differences between corridor attributes should not be interpreted to mean that individual motorists respond identically regardless of the recommended route or location when they are told to divert. In fact, it was found that

some subjects had much higher threshold values for considering diversion to one alternative route over the other. However, these preferences on an individual basis tended to cancel each other out in the analyses performed for this study.

IMPLEMENTATION STATEMENT

The results of this study have direct bearing upon the design and operation of motorist information systems in several ways. Comparing the results of the current study with those of previous research, it appears that motorists may be more sensitive to travel time information during the off-peak travel periods than during peak periods. Consequently, it appears justifiable to present small (i.e., 5-minute) differences in travel time between the freeway and an alternative route to motorists in off-peak conditions, whereas more significant differences in travel time may be necessary during peak conditions.

Second, the data indicated that roads used to access the actual alternative routes in a corridor may affect motorists acceptance of real-time travel time information. The conditions on the various access roads in the corridor should be considered when plans for locating motorist information displays within the corridor are being made, as well as in the design of the displays themselves.

Finally, the results of the study suggest that a given motorist's likelihood of diverting in response to a time-saved traffic message will depend on the individual's preference for, or aversion against, the alternative route being recommended in the message. As in-vehicle navigation systems gain traffic-responsive capabilities, the in-vehicle units may need to allow each motorist to program their preferences and aversions into the system in order to "fine-tune" the routing algorithms generating diversion recommendations to the motorist.

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1. INTRODUCTION

As traffic demands in urban areas continue to grow, transportation agencies are looking for ways to better manage existing roadway facilities so as to minimize traffic congestion and maintain mobility within the region. Advanced Transportation Management Systems (ATMS), part of the Intelligent Vehicle Highway System (IVHS), offer potential for helping to improve the management and control of urban transportation facilities. ATMS encompasses many elements now being used for freeway and arterial street surveillance and control, including electronic surveillance, ramp metering, computerized coordination of arterial street signal timings, incident management, and dissemination of real-time information to motorists about roadway and traffic conditions.

Research indicates that motorists desire accurate and current information about unusual roadway and traffic conditions, and are willing to react to this information by altering their departure time, route, and, to a small degree, mode of travel (1,2,3). Various technologies have been used for many years to provide motorists with real-time information, including changeable message signs, highway advisory radio, telephone hotlines, and commercial radio and television traffic reports. This dissemination process will be enhanced as Advanced Traveler Information Systems (ATIS) are implemented. With this new technology, drivers will be able to receive traffic information and navigational assistance, both tailored to the individual needs of the driver. However, not all motorists are anticipated to have ATIS technology in their vehicles. Consequently, the integration of traditional driver information dissemination and ATIS technologies will be extremely important to the successful management of an urban transportation system (4).

Also important will be the type and amount of traffic information that is disseminated to motorists. Previous human factors research (5,6) has generated basic design guidelines for the traditional forms of real-time motorist information displays. For instance, the dissemination of real-time travel time information has been demonstrated to have an influence upon motorist diversion decisions. Unfortunately, actual travel times have been very difficult to measure and even more difficult to predict, so that only a few transportation agencies have even attempted to offer real-time travel time information to motorists. Fortunately, advances in ATMS technology are expected to make travel time estimation and prediction more possible.

With the prospect of providing real-time travel time information to motorists, however, there is a need for a more thorough understanding of how the provision of this type of information will affect motorists' diversion decisions and travel patterns. The literature indicates that the diversion decision-making process is complex, and that the availability of real-time travel times is but one bit of information the motorist must consider when deciding whether or not to divert. Thus, the response to real-time travel time information in an urban freeway corridor is likely to depend on specific characteristics of that corridor. However, there is presently little guidance available as to what characteristics may affect motorist perceptions and responses to real-time travel time information, or what the magnitude of those responses might be.

This report presents the results of research conducted to investigate how freeway corridor characteristics influence motorist responses to real-time travel time information. This research consisted of laboratory studies of motorists who regularly make home-to-work trips in a specific urban freeway corridor. In this way, the influence of specific freeway corridor attributes upon motorist responses could be investigated.

The remainder of this report consists of four additional chapters. Chapter 2 provides a review of background research regarding motorist diversion decision-making and responses. Chapters 3 and 4 describe the study procedures and results of laboratory experiments conducted to investigate the effect of selected corridor characteristics upon motorist perceptions of real-time travel time information messages. Chapter 5 summarizes the findings of the research, and provides interpretations of the study results with respect to their application in the future design and operation of motorist information displays.

2. BACKGROUND

As already stated, it is a well-established fact that motorists desire real-time traffic information. Presumably, arming motorists with such information allows them to make better choices about when to depart, what routes to take, and whether to alter their routes in response to unexpected traffic conditions downstream. However, real-time traffic information must be packaged and presented to motorists in the proper manner in order to facilitate quick, easy, and correct comprehension. Consequently, extensive human factors research was performed in the 1970s to develop comprehensive guidelines for designing real-time traffic information messages (5,6). According to these guidelines, motorists desire answers to the following questions when unexpected traffic conditions occur:

- What has happened to cause the unexpected conditions?
- Where did the event happen?
- What is the effect on traffic?
- Who is the information intended for?
- What action is advised?

Of these, describing the effect of an unexpected incident upon traffic is one of the more difficult tasks. Evidence suggests that travel time is one of the most important considerations in motorist's long term route choices as well as in decisions to divert to alternative routes (7-10). Although research suggests that certain generic descriptors (e.g., the terms "major" or "minor" accident) have an inherent meaning to motorists as to the impact of an incident upon travel (11,12), it is believed that providing motorists more objective and quantitative travel time or speed information about the impacts allows better decisions to be made by motorists.

Unfortunately, the majority of transportation agencies with operational motorist information systems tend to avoid using travel time in real-time traffic messages. This is primarily because of a lack of adequate surveillance capabilities over the entire roadway network in an area, and the difficulty in estimating travel times in congestion. However, emphasis now exists nationwide for expanded surveillance systems through the implementation of Advanced Traffic Management Systems (ATMS). In addition, research is underway to improve the understanding of congested traffic phenomena, leading to improved travel time prediction models. Hence, there is renewed interest in the dissemination of real-time travel time information to motorists, particularly enroute travel times.

Human Factors Research of Real-Time Travel Time Messages

Travel time information can be presented to motorists in a variety of formats. These include the following:

- An absolute travel time value between points on a given route,
- The delay to be encountered between two points,
- The time to be saved between two points by diverting to a specified alternative route,
- The delay to be avoided between two points by diverting to an alternative route, and
- The presentation of travel times for both the given route and a specified alternative route.

Human factors studies have been conducted to assess motorist sensitivity to the delay and time saved formats. In one study, Huchingson et. al. asked motorists whether they would consider diverting from a freeway in response to a message indicating that a certain amount of delay would be experienced on the freeway, or that a certain amount of time could be saved by using an alternative route while enroute to a special event (11). Researchers found that motorists were more likely to consider diverting when higher values of delay were presented. Similarly, displaying a greater time savings value in a message increased the percentage of motorists who would consider diverting.

When comparing motorist's interpretations of delay and time savings values, researchers found that motorists were more likely to consider diverting to a given time savings value than to the identical value reported in terms of delay. One hypothesis for the difference is that a time savings value already considers the travel time on the alternative route, whereas motorists considering delay values must estimate how much longer it will take them to bypass the congestion via an alternative route, and whether the increased travel time is offset by the delay expected on the primary route. In the Huchingson et. al. study, the average motorist considered diverting if a delay of 15-20 minutes or greater were indicated, whereas the average motorist would consider diverting if a time saved value of 5-10 minutes or greater was displayed.

A subsequent study (12), also by Huchingson et. al. performed in Houston, found motorists more inclined to divert to given delay value messages than in the earlier study. In this study, the average motorist considered diverting if a message indicating 5-10 minutes or more of delay at a highway workzone was presented to them (as compared to the 15-20 minutes found in the earlier study). Figure 2-1 presents the cumulative percentage distributions at various delay and time savings values for the two Huchingson studies. As can be seen, the delay value distributions for the two studies are very different. Furthermore, the distribution for time saved values from the first study and the distribution for delay values from the second study were most similar. It must be noted that there were several differences in the way the two surveys were administered that may account for some of the differences in the distributions (12), including:

- The messages tested in the first study did not identify a specific alternative route as being available to motorists for diverting, whereas subjects in the second study were told that the frontage road could be used as an alternative route;
- Only subjects known to drive freeways were used in the second study, whereas the first study did not check whether the subjects typically used the freeways when driving; and
- Subjects in the second study were told that the delays were due to roadway maintenance work (rather than an accident or other incident specified in the first study).

Regardless of the actual reasons for the differences, it appears that motorist sensitivity to real-time travel time information may be influenced by factors in addition to the magnitude of delay (or time saved, delay avoided, etc.) to be encountered, or the format in which information concerning travel times is displayed. As described below, results of other studies which have examined the diversion characteristics and propensities of motorists provide an indication of some of these factors.

Factors Likely Affecting Motorist Sensitivity to Real-Time Travel Time Information

Alternative Route Characteristics

One of the more prominent types of characteristics believed to play a major role in motorist diversion decisions (and thus likely to influence motorist sensitivity to real-time

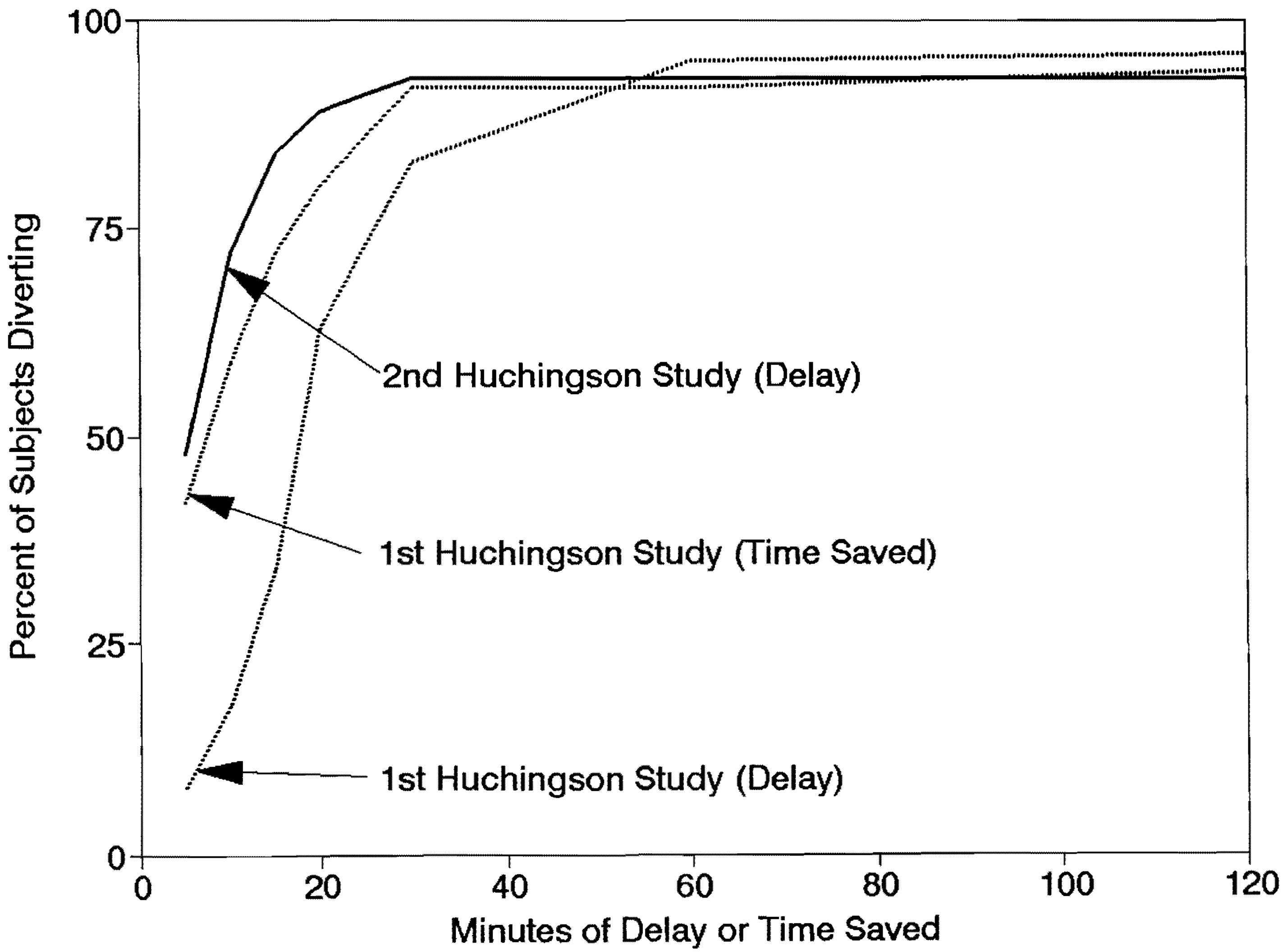


Figure 2-1. Results from Previous Research by Huchingson et. al. (11,12).

travel time information) are those relating to the alternative routes available and/or being recommended as diversion routes by real-time traffic messages. For example, in a study of traffic diversion for special events in Dallas by Richards et. al., anticipated dissatisfaction with a recommended alternative route was the most frequently cited reason for not diverting (13). Likewise, Roper et. al. found that motorists in Los Angeles were more reluctant to divert to surface streets from a freeway facility undergoing maintenance work than they were to divert to other freeways nearby (14). Motorists surveyed by Huchingson et. al. cited unfamiliarity and anticipated dissatisfaction with an alternative route (in terms of congestion, additional travel distance, etc.) as the most common reasons they had for not diverting in response to incident congestion they had encountered in their previous driving experiences (15).

Unfortunately, there have been only a few attempts to relate more objective measures of the characteristics of a route to motorist diversion propensity. Of course, real-time travel time information is, indirectly, one such route measure. However, measures such as the number of traffic signals per mile or the expected number of stops per mile may also be related to motorist diversion decisions (such as suggested by Stephandes et. al. (10)). Another potential route characteristic that may affect motorist diversion decisions is the consistency of travel times on a given route. Routes with higher travel time variability may be less desirable to motorists, even if the average travel times tend to be lower. Additional research will be necessary to further explore the possibility of these relationships.

Trip and Roadway Network Characteristics

Another set of factors believed to affect motorist sensitivity to real-time travel time are those defining the type of trip which the motorist is making. Research by Mahmassani et. al. (16) and by Barfield et. al (3) showed motorists had higher diversion propensities for trips they were making from work to home than from home to work. Unfortunately, it is not known whether this difference was because the penalty for arriving late to work was considered more severe than arriving late at home, or that motorists were not as likely to adjust their work-to-home departure times as they were to adjust their home-to-work departure times to circumvent potential delays.

Researchers (Shirazi et. al. (7), Mahmassani et. al. (16),) have also found that reported diversion behavior depends on the number of alternative routes available and known to the motorists making diversion decisions. In general, larger numbers of alternatives have been associated with greater propensities for diversion. However, this does not necessarily mean that each motorist utilizes a number of different alternative routes. Research by Stephanedes et. al. (10) indicates that motorists generally choose between their primary route and one alternative route when making a diversion decision.

A key issue that has not been resolved is exactly what constitutes a reasonable "alternative" route. For motorists making longer trips (such as suburban to CBD commuters), reasonable alternatives may be limited to freeways, thoroughfares or major arterials. For motorists with shorter trips, minor arterials and even collector streets may serve as alternative routes. Following this same line of reasoning, the location within the freeway corridor motorists receive real-time traffic information may influence the number of alternatives available to them, and hence, their response to that information. Research by Dudek et. al. tends to support this contention. Their work showed that motorists preferred to receive real-time information prior to entering the freeway (when they presumably have more opportunities to divert) rather than after they were already on the freeway (and their diversion opportunities were limited to downstream exit ramps) (1).

Motorist Demographics

The available research is unclear as to whether or not motorist diversion decisions (and the sensitivity of these decisions to real-time travel time information) depend on basic motorist demographic characteristics. Studies by Heathington et. al. (9), Huchingson et. al. (11), Stephanedes et. al. (10), and Mahmassani et. al. (16) suggest that motorist diversion decisions or behavior cannot be explained by socioeconomic attributes. However, other studies have shown that some socioeconomic attributes influence motorist's diversion decisions. For example, older drivers and female drivers have been shown to be less likely to divert under certain conditions (Allen et. al. (17), Mannering (18), and Barfield et. al. (3)). One reason for the discrepancies is the difficulty in isolating the effect of any one factor. Depending on the study design and administration procedures, it appears that demographic effects may or may not be evident in an analysis of motorists' diversion decision-making process.

Although it cannot be said for certain whether standard demographic measures can be used as a predictor of motorist diversion, it is apparent that there are individual differences in motorist perceptions and diversion responses. Huchingson et. al. (11,12) and Allen et. al (17) have shown, for example, that a small proportion of motorists will not consider diverting to traffic information or navigational recommendations regardless of the traffic situation they may encounter.

Closing Remarks

The literature presents a strong argument supporting the contention that motorist diversion decisions are not solely dependent upon the magnitude of delay, time saved, etc., presented in real-time information displays. Rather, real-time information is only one factor contributing to the overall decision-making process drivers must go through when they encounter unexpected traffic conditions. Several corridor characteristics and individual differences also appear to impact motorist diversion decisions. An understanding of the degree to which these characteristics interact with motorist information displays is needed in order to design and operate these displays most effectively. To date, however, there have not been any studies to directly assess the impact of corridor characteristics upon motorist sensitivity to real-time travel time information. Consequently, the remainder of this report summarizes the procedures and results of laboratory studies conducted to directly evaluate how different corridor characteristics may alter the perceptions and anticipated diversion decisions of motorists presented with real-time travel time information.

3. STUDY PROCEDURES

An understanding of the corridor characteristics affecting motorists perceptions and reactions to real-time travel time information will be useful in the design and operation of the real-time motorist information systems in Texas. Although previous research suggests that corridor characteristics and individual motorist attributes may influence motorist sensitivity to real-time travel time information, there have been few studies which have attempted to verify this directly. In this chapter, laboratory studies are described that were used to investigate the interrelationship between selected freeway corridor characteristics and real-time travel time messages that may be disseminated within a corridor.

The laboratory studies were patterned after those conducted by Huchingson et. al. in the 1970s. In that earlier work, motorists were asked to imagine themselves on a freeway enroute to a special event when they encountered a changeable message sign which advised them of downstream congestion. The motorists were asked to select the minimum amount of delay or time saved the message would have to display in order to get them to consider diverting from their normal freeway route. The minimum value at which they would consider diverting was termed their delay (or time saved) threshold.

In this latest research effort, motorist thresholds to travel time information were again investigated. However, each subject was asked to consider several different candidate real-time traffic messages for a given trip in a given corridor. For each message, one component of the message was altered. In that way, motorists' assessments of the threshold value needed before they would consider diverting in response to each message provided an indication of the effect of each component. Also, the subjects were asked to consider the messages as being received over their automobile radio, as opposed to viewing the message on a changeable message sign.

Study Objectives

Based on the review of literature regarding motorist information systems and diversion behavior, three particular corridor characteristics were identified for inclusion in the laboratory studies. The goal of this research was to determine whether differences in each of these characteristics affected the travel time threshold values reported by motorists. Specifically, the objectives of this research were to:

1. Determine whether motorist-reported time saved threshold values for diversion depend on the alternative route specified in the traffic message;

2. Determine whether the threshold values depend on the location within the corridor where motorists are presented the message; and

3. Determine whether the threshold values depend on how far upstream from the source of congestion on the primary route the message is presented to motorists.

Description of the Studies

The laboratory experiments were accomplished through a series of short telephone surveys of a tightly-defined group of subjects who were known to travel a specific urban freeway corridor in Texas and therefore presumably quite familiar with the roadway and traffic characteristics of that corridor. After research personnel evaluated several potential candidate corridors, the North Central Expressway corridor in Dallas, Texas was selected. Subjects were recruited with assistance of two major employers located in the Dallas central business district. Subject selection was designed to yield employees who drove their own automobiles to work daily, lived in a specific region of the Dallas metropolitan area, and normally used the North Central Expressway for their home-to-work trip. By doing this, it was possible to limit the study population to a single type of trip with nearly identical origin-destination characteristics, reducing the possibility of these factors confounding with the effects of the corridor characteristics of interest in the laboratory studies.

With approval of each of the employers, subjects were contacted on two weekday mornings to participate in a five- to ten-minute survey administered over the telephone. The reason for doing this was to facilitate each subjects recall of travel on the North Central Expressway during their normal trip to work. On each day, subjects were read a series of four traffic messages, and asked to envision themselves receiving these messages over the radio as a traffic advisory broadcast. The subjects were asked how they might react to these different messages. Afterwards, they were questioned about the responses they gave to gain insight into the reasons for any differences in time saved threshold values provided from one message to the next.

The following sections provide a more detailed description of the freeway corridor, the traffic messages presented to the subjects, the subject selection process, the experimental study design, and the data collection and data analysis procedures used in the study.

The North Central Expressway Corridor

The North Central Expressway (US-75) extends from the eastern side of the Dallas central business district through north Dallas. The Expressway borders the small cities of Highland Park and University Park, and passes through the satellite communities of Richardson and Plano (see Figure 3-1). Built in the 1940s, the four-lane divided facility currently carries approximately 130,000 vehicles per day and experiences severe congestion during much of the day over the 9.25 miles between the Lyndon Baines Johnson (LBJ) freeway (I-635) and the central business district (CBD).

Two major interchanges are located on the Expressway within the study corridor. On the northern end of the section is a fully directional freeway-to-freeway interchange with I-635. Unfortunately, the design of the interchange is insufficient to accommodate traffic demands so that the interchange itself is usually a cause of congestion on the Expressway. Approximately midway between LBJ freeway and the CBD, a second interchange provides cloverleaf connections between the Expressway and Northwest Highway (Loop 12). In the vicinity of the Expressway, Northwest Highway is a six-lane divided arterial street with closely-spaced traffic signals. Frontage roads which run alongside a portion of the Expressway are discontinued through the interchange. In addition to these major interchanges, diamond interchanges spaced at approximately one-mile intervals provide ingress and egress to other major east-west arterials.

To the north of Northwest Highway, the freeway and arterial street system follows a basic grid pattern. Several north-south arterials parallel the Expressway in this part of Dallas, and then turn in towards the CBD further south. Of these, Greenville Avenue is the most highly utilized arterial in the corridor (19). Its close proximity and easy access to the east side of the Expressway (less than one-block separation in some locations) also makes it a prime alternative route for Expressway motorists during incident conditions. To the west, the Dallas North Tollway (a controlled-access toll facility) is located approximately 2.5 to 3 miles from the Expressway, providing the fastest means of north-south travel in the corridor during peak periods (19). It is also a viable alternative route to the Expressway for some motorists in the north Dallas area.

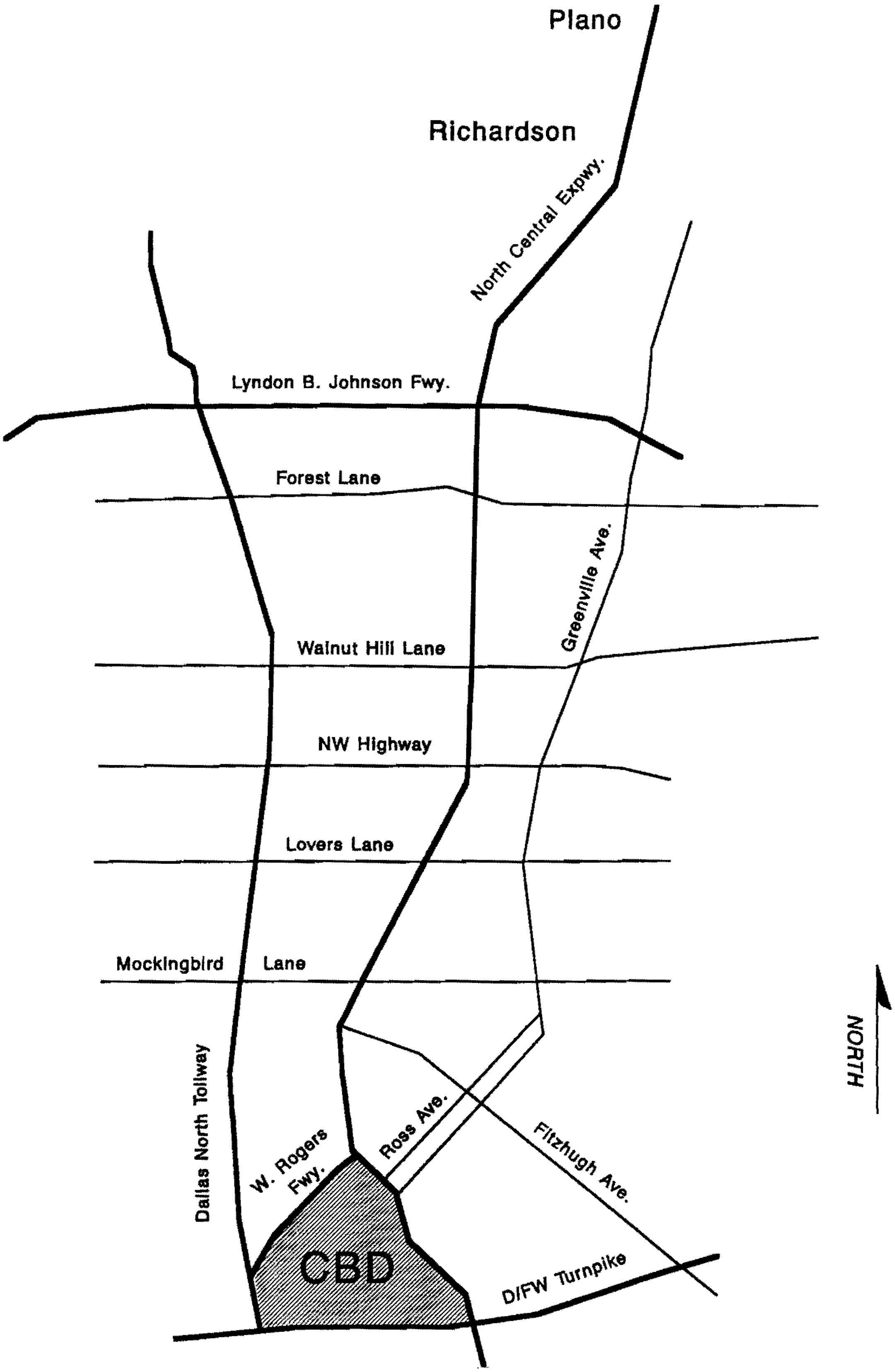


Figure 3-1. Study Site.

Table 3-1 summarizes average am peak period and peak hour travel times on the Expressway, the Tollway, and Greenville Avenue between LBJ Freeway and the CBD. As stated previously, the Tollway provides the quickest travel to downtown during these periods. However, there is a fee for using the facility, which apparently discourages some motorists from utilizing it and thus preserving its higher speed operation. Meanwhile, travel times are somewhat higher on the Expressway, and even higher on Greenville Avenue. During the peak hour, however, the difference between these two routes is only 4 minutes. Consequently, any additional disruption to traffic on the Expressway would likely cause travel times to exceed those normally occurring on Greenville Avenue.

TABLE 3-1. NORTH CENTRAL EXPRESSWAY CORRIDOR TRAVEL TIMES

	North Central Expressway	Dallas North Tollway	Greenville Avenue
Average AM Peak Period Travel Times (LBJ to CBD)	14.3 Minutes	12.5 Minutes	21.4 Minutes
AM Peak Hour Travel Times (LBJ to CBD)	18.1 Minutes	13.1 Minutes	22.4 Minutes

<u>Description of the Real-Time Traffic Messages</u>

As described in Chapter 2, design guidelines for real-time traffic messages indicate the following information is desired by the motorist:

- What has happened?
- Where did it happen?
- What is the effect on traffic?
- Who should be concerned?
- What should they do?

Using these guidelines, eight different traffic messages were developed which varied three corridor factors selected for evaluation in this research. The three factors that were varied in this study were as follows:

1. The location where the traffic message was to be presented to the motorist (and thus where they were told to divert),
2. The location where the problem was said to exist, and
3. The alternative route to be recommended in order to save time.

For example, Greenville Avenue was specified as the alternative route in one-half of the messages, whereas the Dallas North Tollway was recommended in the remaining messages. Likewise, subjects were told to divert either at the LBJ freeway interchange, or at the interchange of the Expressway with Northwest Highway. Finally, the location of congestion in the messages was specified as either immediately downstream of the location where diversion to the alternative route was recommended, at a cross-street approximately 1 mile downstream of the recommended point of diversion, or at a cross-street approximately 4 miles downstream.

The remaining components of the traffic message were kept constant. The type of incident creating congestion was always specified as an accident. In addition, information as to the length of congestion provided in the messages was kept constant (approximately 1 mile), using major cross-streets as reference points.

The time saved approach to displaying travel time information was used in this research. This approach was chosen because it provides the most direct means of presenting the temporal benefits of diverting to a recommended route. Earlier research (11) also found motorists to be more sensitive to time saved values in a real-time message than they were to an identical value displayed in terms of delay.

Table 3-2 summarizes the key features of each of the traffic messages used in the laboratory experiments.

TABLE 3-2. TRAFFIC MESSAGES EVALUATED IN LABORATORY STUDIES

Message Number	Corridor Characteristic			Message
	Alternative Route	Diversion Location	Congestion Location	
1	Greenville Avenue	LBJ Freeway	LBJ Freeway	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT WALNUT HILL LANE CONGESTION BEGINS AT LBJ FREEWAY EXIT LBJ FREEWAY EASTBOUND TAKE GREENVILLE AVENUE TO DOWNTOWN SAVE -- MINUTES
2	Dallas North Tollway	LBJ Freeway	LBJ Freeway	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT WALNUT HILL LANE CONGESTION BEGINS AT LBJ FREEWAY EXIT LBJ FREEWAY WESTBOUND TAKE DALLAS NORTH TOLLWAY TO DOWNTOWN SAVE -- MINUTES
3	Greenville Avenue	Northwest Highway	Northwest Highway	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT FITZHUGH AVENUE CONGESTION BEGINS AT NORTHWEST HWY EXIT NORTHWEST HIGHWAY EASTBOUND TAKE GREENVILLE AVENUE TO DOWNTOWN SAVE -- MINUTES
4	Dallas North Tollway	Northwest Highway	Northwest Highway	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT FITZHUGH AVENUE CONGESTION BEGINS AT NORTHWEST HWY EXIT NORTHWEST HIGHWAY WESTBOUND TAKE DALLAS NORTH TOLLWAY TO DOWNTOWN SAVE -- MINUTES

Message Number	Corridor Characteristic			Message
	Alternative Route	Diversion Location	Congestion Location	
5	Dallas North Tollway	LBJ Freeway	Forest Lane	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT NORTHWEST HWY CONGESTION BEGINS AT FOREST LANE EXIT LBJ FREEWAY WESTBOUND TAKE DALLAS NORTH TOLLWAY TO DOWNTOWN SAVE -- MINUTES
6	Greenville Avenue	LBJ Freeway	Forest Lane	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT NORTHWEST HWY CONGESTION BEGINS AT FOREST LANE EXIT LBJ FREEWAY EASTBOUND TAKE GREENVILLE AVENUE TO DOWNTOWN SAVE -- MINUTES
7	Dallas North Tollway	LBJ Freeway	Northwest Highway	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT FITZHUGH AVENUE CONGESTION BEGINS AT NORTHWEST HWY EXIT LBJ FREEWAY WESTBOUND TAKE DALLAS NORTH TOLLWAY TO DOWNTOWN SAVE -- MINUTES
8	Greenville Avenue	LBJ Freeway	Northwest Highway	ATTENTION SOUTHBOUND TRAFFIC ACCIDENT AT FITZHUGH AVENUE CONGESTION BEGINS AT NORTHWEST HWY EXIT LBJ FREEWAY EASTBOUND TAKE GREENVILLE AVENUE TO DOWNTOWN SAVE -- MINUTES

Subject Selection Process

The focus of the selection process was to obtain a homogenous group of subjects to participate in the surveys, so as to minimize the influence of other factors (such as type of trip, trip length, origin-destination patterns, etc.) which could possibly affect motorist sensitivity to real-time travel time information. Major employers located in the Dallas CBD were contacted with the assistance of the North Central Mobility Task Force. Employers were asked to help identify employees who met the following criteria:

- Worked at a downtown location,
- Lived north of the LBJ freeway and in close proximity to the North Central Expressway, and
- Normally drove their own vehicles to work using the Expressway.

Next, the employers sent out internal memorandums to those individuals fitting the above criteria. The memorandum outlined the general purpose of the research being performed, and asked for volunteers. The employers were asked to allow the researchers to contact the employees while at work. Consequently, no monetary incentives were offered subjects to encourage them to participate.

Three corporations agreed to assist in the study. These were Nations Bank (formerly NCNB), MOBIL Oil Corporation, and ARCO Oil and Gas Company. Initially, a total of 67 subjects expressed interest in participating. However, scheduling difficulties and other problems eventually limited the sample to 44 participants from the Nations Bank and the MOBIL Oil Corporations.

Experimental Study Design

Given the number of messages which were developed for study, it was decided that two separate experiments would be performed. The same subjects were used in both experiments. On one day, researchers queried subjects as to their interpretations and expected responses to the first four messages (experiment 1), whereas a call on a subsequent day addressed the final four messages (experiment 2). For either experiment, the messages presented on that day were randomized so as to counterbalance any ordering effects present.

Because the study was divided into two separate experiments, each experiment addressed only two of the three corridor factors at a time. In the first experiment, the recommended route and the location where subjects were said to receive the real-time traffic message were varied, and the distance from the recommended diversion location to the beginning of congestion was held constant (said to be immediately downstream of the diversion location). In the second experiment, the location where the traffic message was to be received (and where it was recommended that subjects divert) was kept constant at LBJ freeway, and the recommended route and distance from the diversion location to the location of congestion were varied.

Data Collection and Analysis Procedures

Appendix A contains the script of the introductory statements made to each subject when contacted by study personnel via telephone. Each telephone conversation was recorded (with permission of the subject) for post-hoc review, if needed. As part of each call, subjects were told to imagine themselves driving to work during their normal daily commute to work, and to imagine that they received a traffic advisory alert over their automobile radio. The researcher would then recite one of the four traffic messages scheduled for that day (depending on the order required by the statistical design). At the end of the message, the researcher asked the subject whether he or she would consider diverting in response to the message if the amount of time saved was said to be 5 minutes. If the subject said yes, the researcher moved to the next message. If the subject responded negatively, the researcher repeated the last part of the question, asking the subject if he or she would divert if the time saved value was said to be 10 minutes. Each time the subject said no, the time saved value was increased. Once the subject said yes, the researcher recorded that particular time saved value, then moved to the next traffic message and repeated the sequence.

Once time saved values to the different messages were obtained, subjects were asked to provide explanations for any differences in time saved values they gave for the various messages, and to describe, in their own words, why they would require a greater time saved value for one message than they would for another. Presumably, these reasons would relate to the differences between the messages (different recommended routes, diversion points, or locations of congestion), and would provide insight into how neach of these corridor characteristics may influence motorist perceptions and decisions. Study personnel used an open-ended question format in this phase of the experiment, recording subject responses verbatim on the data forms.

At the conclusion of the second experiment, data were collected regarding each subject's normal work trip travel habits. These data included an estimate of their normal arrival time at work, the time they are expected to be at work, the level of importance the subject placed upon arriving at work on time, and average trip duration under normal conditions. However, no attempt was made to counterbalance any of these data in the study design.

Analysis of the data began with a comparison of the cumulative time saved distributions for each message with the results of the earlier Huchingson et. al. work (11). Next, analysis-of-variance procedures were employed to determine whether statistically significant differences existed in the average time saved threshold values between messages, taking into consideration the demographic and normal trip characteristic data collected from the subjects at the end of the second experiment. Finally, the explanations provided by the subjects for differences in their time saved thresholds between the various messages were collated and interpreted.

4. RESULTS

Subject Demographics

Table 4-1 summarizes the basic demographic characteristics of the subjects participating in the two experiments. Generally speaking, males were slightly overrepresented in the sample (57 percent). With respect to age, most subjects (93 percent) were between the ages of 25 and 54 years. Only two percent were younger than 25 years of age, and only five percent were older than 55 years.

TABLE 4-1. SUBJECT DEMOGRAPHICS

Category	Distribution of Subjects
Gender:	
males	57%
females	43%
Age:	
less than 25	2%
25 to 39	43%
40 to 54	50%
greater than 54	5%

Data regarding the subjects' normal home-to-work trip characteristics are presented in Table 4-2. As shown in the table, the majority of the subjects normally arrive at work between 7:00 and 8:30 am. However, approximately one-third (32 percent) indicated that they arrived prior to 7:00 am. In comparison, over one-half of the subjects (62 percent) indicated that they were required to be at work by 7:30 to 8:30 am. Although not asked directly, it was assumed that at least one of the employers maintained a flextime policy for its employees (although only one subject explicitly stated that he was on a flextime schedule).

TABLE 4-2. SUBJECT HOME-TO-WORK TRAVEL CHARACTERISTICS

	Percent of Subjects Travelling in Each Time Period						
	Before 6:30 am	6:30 - 6:59 am	7:00 - 7:29 am	7:30 - 7:59 am	8:00 - 8:29 am	8:30 or later	Flex-time
Usual Arrival Time	16%	16%	23%	23%	18%	2%	2%
Time Required at Work	5%	2%	27%	14%	48%	2%	2%
Average Travel Time to Work	25.8 Minutes			48.6 Minutes			50.0 Minutes

The distribution of arrival times over the morning peak period resulted in a wider range of travel times than had originally been hoped for in the subject selection process. Table 4-2 also shows the average reported travel times for subjects arriving at work prior to 7:30 am, and at 7:30 am or later. For the former group, average travel times were less than 26 minutes, whereas they were almost 49 minutes for the latter group (even though both groups travel the same approximate distances). Thus, although the employer-based selection process did yield subjects with homogenous origin-destination patterns, there were some differences between subjects in terms of the time when they travelled each day and the traffic conditions they normally encountered when travelling at those times.

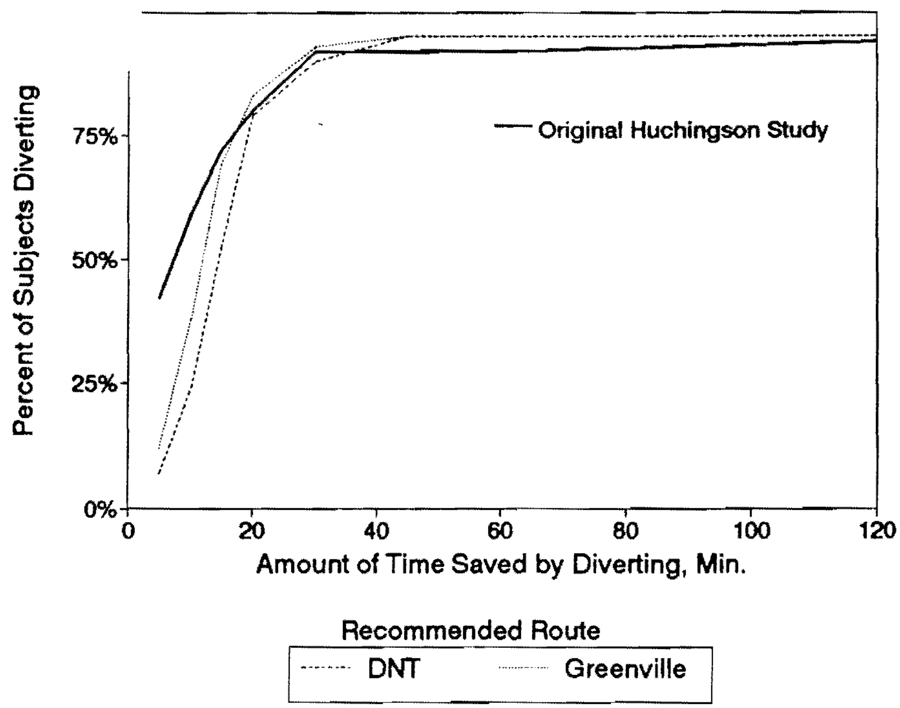
Cumulative Distributions of Time Saved Threshold Values

Evaluation of the responses obtained from the subjects began with an assessment of the distributions of time saved values by message. The time saved threshold value represents the minimum amount of time savings a subject would require before considering diversion to the recommended alternative route. It was assumed that a subject would also consider diverting at any time saved value that was larger than the "threshold" value. Consequently, the number of subjects that would consider diverting at a given time saved value would be the sum of those reporting that given threshold value plus all subjects having a smaller threshold value as well. Graphical representations of the data are discussed in the following two sections.

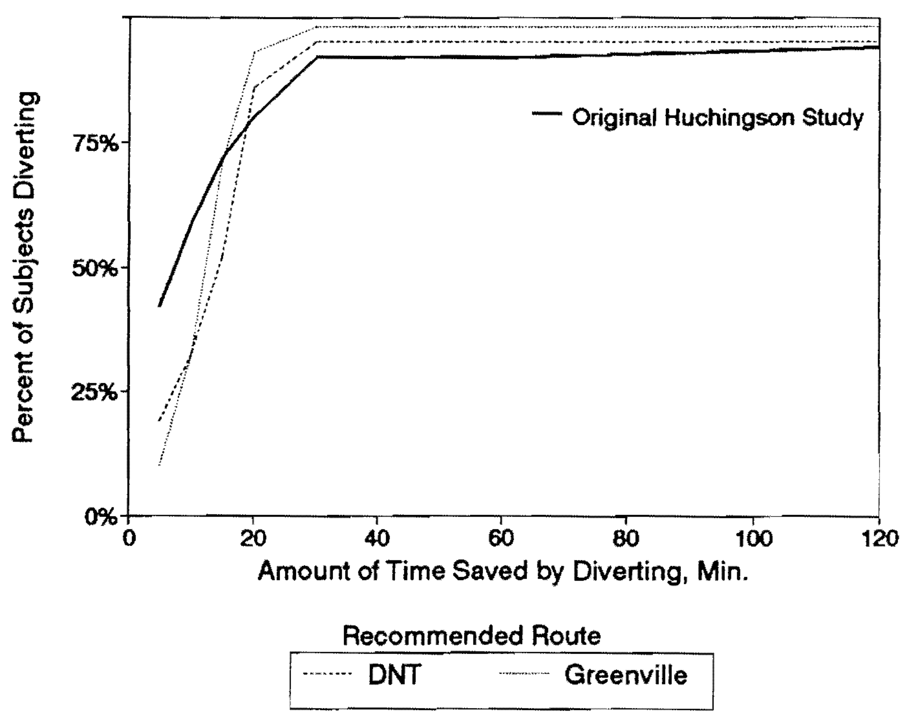
Experiment 1 -- Effect of Different Recommended Routes and Different Recommended Diversion Locations

Figure 4-1 presents graphs showing the percent of subjects who would consider diverting when presented time saved values ranging from five minutes to two hours. Also shown in the graphs are the results of the original Huchingson et. al. study of time saved messages (11). The top portion of Figure 4-1 illustrates subject responses when the messages instructed them to divert at the LBJ Freeway and to use Greenville Avenue or the Dallas North Tollway (messages 1 and 2, respectively). The bottom portion of Figure 4-1 displays similar information when subjects were instructed to divert at Northwest Highway, again either to Greenville Avenue or to the Dallas North Tollway (messages 3 and 4, respectively). In both cases, the percent of subjects indicating they would consider diverting to a given time saved value when Greenville Avenue was the recommended route was slightly greater than that when the Dallas North Tollway was recommended. Numerically, the percentages are most divergent at a time saved value of 15 minutes. When the LBJ Freeway was recommended as the diversion location, approximately 17 percent more subjects would consider diverting to Greenville than would consider diverting to the Tollway. When Northwest Highway was recommended as the diversion location, 19 percent more subjects would consider diverting to Greenville than would consider diverting to the Tollway at a time saved value of 15 minutes. Because of the fairly small sample size available for this analysis, however, these differences were not found to be statistically significant using a Kolmogorov-Smirnov goodness-of-fit test (20).

Although the curves representing the current study data are not significantly different from each other, it is obvious that they do not replicate the data obtained in the Huchingson et. al. study (11). Subjects in the Huchingson study demonstrated a high sensitivity to very small time saved values, with the 50th-percentile subject considering diversion when a time saved value between 5 and 10 minutes was presented. The current data from all four messages show the 50th-percentile subject required 10 to 15 minutes before considering diversion. The results of all four messages evaluated were found to be statistically different from the Huchingson study, again based on the Kolmogorov-Smirnov test at a 0.05 level of significance. It must be remembered that subjects in the current study were responding to a scenario where they were considering peak-period traffic conditions, whereas the subjects in the Huchingson study were responding to a scenario involving travel to a special event during off-peak periods (when the potential for better travel on alternative routes is greater).



(a) Recommended Diversion Location: LBJ Freeway



(b) Recommended Diversion Location: Northwest Highway

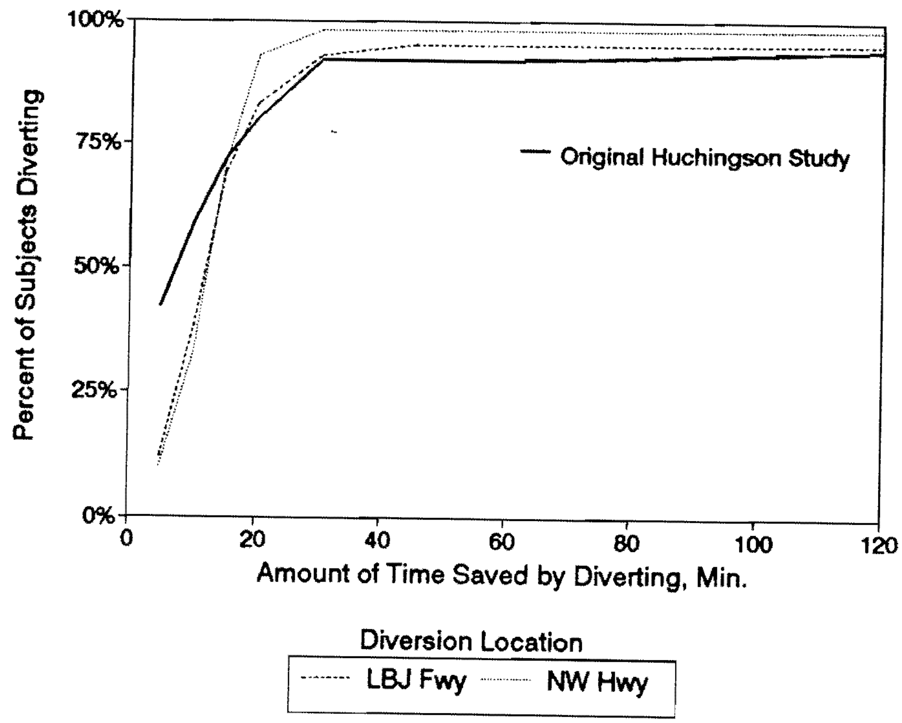
Figure 4-1. Effect of Recommended Route on Percent of Subjects Considering Diversion at a Given Time Shared Value: Experiment 1.

Reorganizing the cumulative responses to the four messages provides insight into the effect of the recommended diversion location (LBJ Freeway or Northwest Highway) upon subject diversion considerations. Figure 4-2 presents two graphs illustrating the percent of subjects who would consider diverting at either LBJ Freeway or at Northwest Highway, when the subject was advised to use either Greenville Avenue (top graph) or the Dallas North Tollway (bottom graph). The data presented in this manner indicates that the location where subjects were advised to divert had only a minor effect on the cumulative distribution of time saved values. If Greenville was specified as the recommended alternative route, the maximum difference in the percent of subjects considering diverting at LBJ Freeway versus diverting at Northwest Highway was less than 10 percent; if the Dallas North Tollway was specified as the alternative route, the maximum difference was 9 percent.

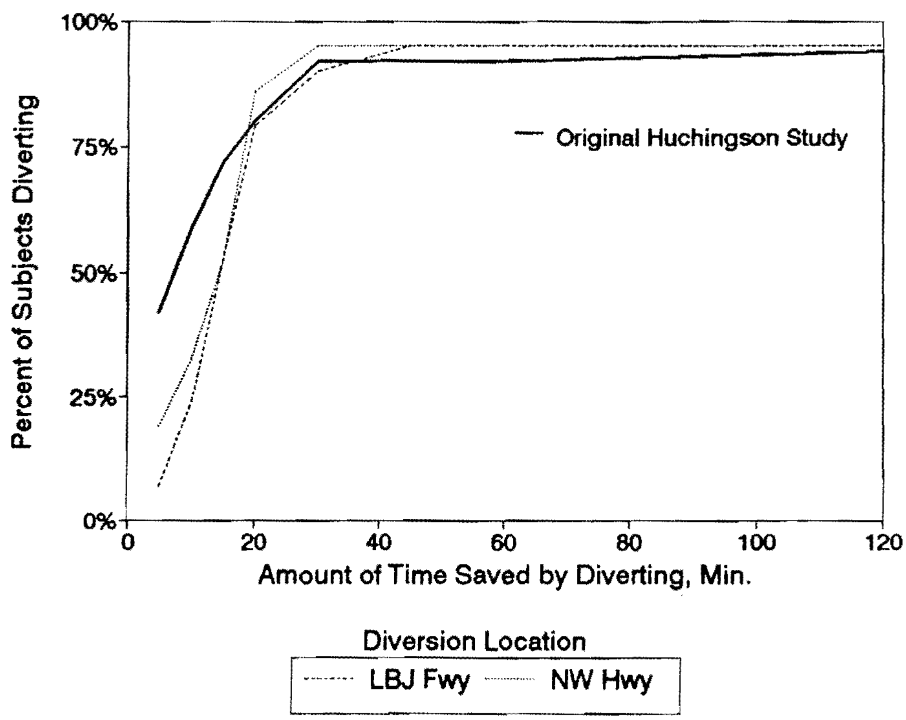
Experiment 2 -- Effect of Different Recommended Routes and Different Locations of Reported Congestion Relative to the Recommended Diversion Point

In the second experiment, the subjects were presented similar traffic messages as in the first experiment with one notable exception: in all four messages, the recommended diversion point was kept stationary at LBJ Freeway, and congestion was reported to begin at points farther downstream than in the first experiment. As in the first experiment, cumulative distribution curves were plotted relating the percent of subjects considering diversion to the time saved value reported in a traffic message. The effect of the recommended route at each reported congestion location is shown in Figure 4-3 and the effect of the different congestion locations for each recommended alternative route is shown in Figure 4-4.

Comparisons presented in both figures mimic those found in the first experiment; namely, the percentages for each message did not differ significantly from one another. The graphs in Figure 4-3 show a slightly greater percentage of subjects considering diversion to Greenville Avenue as compared to the Dallas North Tollway, regardless of the reported location where congestion was said to begin. Thus, the data from this experiment were consistent to the results of the first experiment in that regard. Likewise, the data showed significantly lower percentages of diversion at small time saved values than were reported from the Huchingson et. al. study (11), again supporting the results of the first experiment.

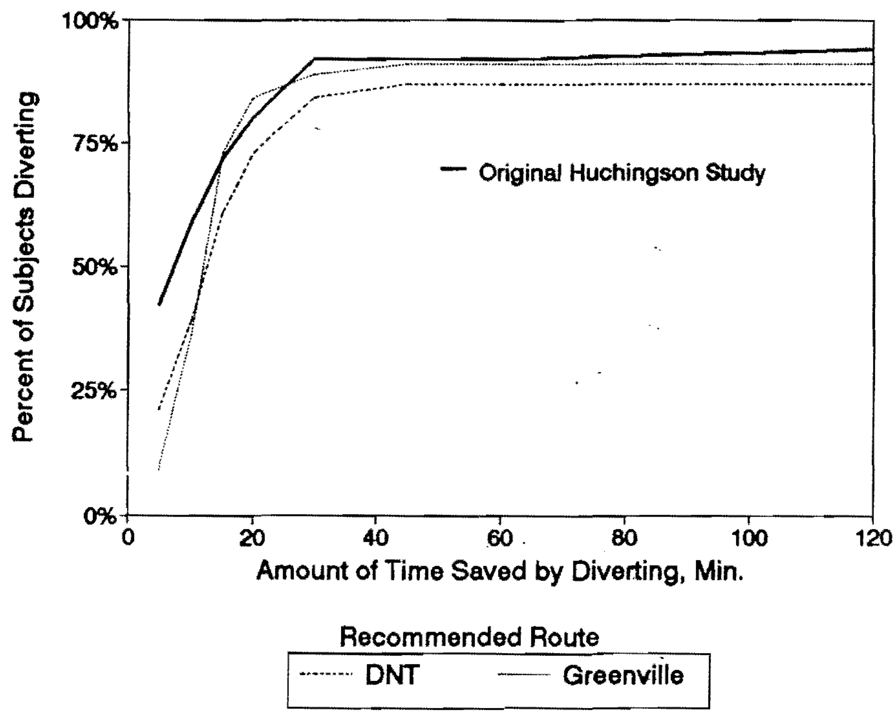


(a) Recommended Route: Greenville Avenue

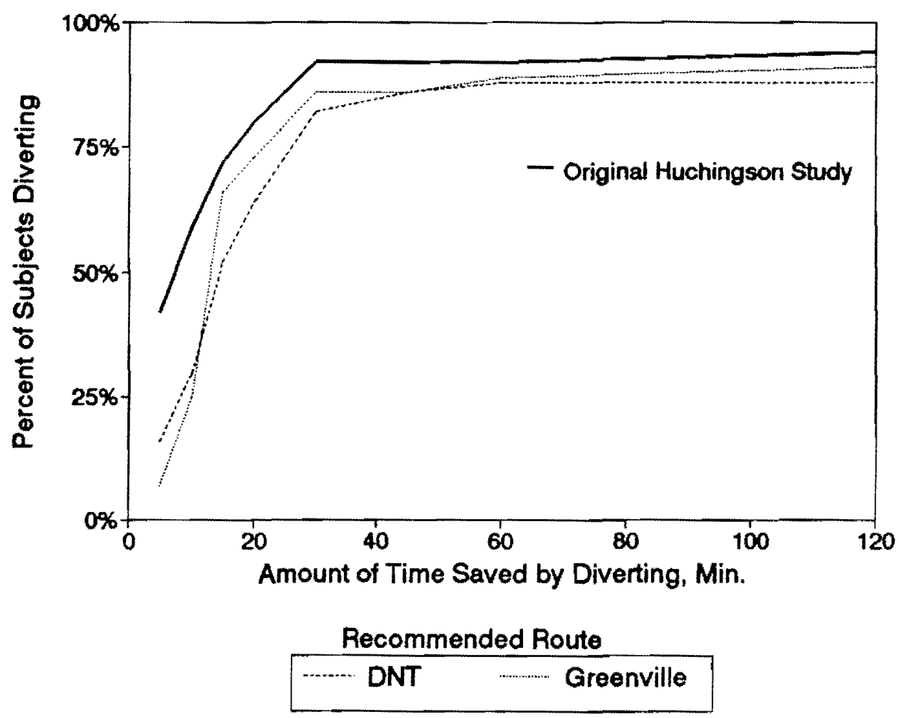


(b) Recommended Route: Dallas North Tollway

Figure 4-2. Effect of Recommended Diversion Location Upon Percent of Subjects Considering Diversion to a Given Time Saved Value: Experiment 1.

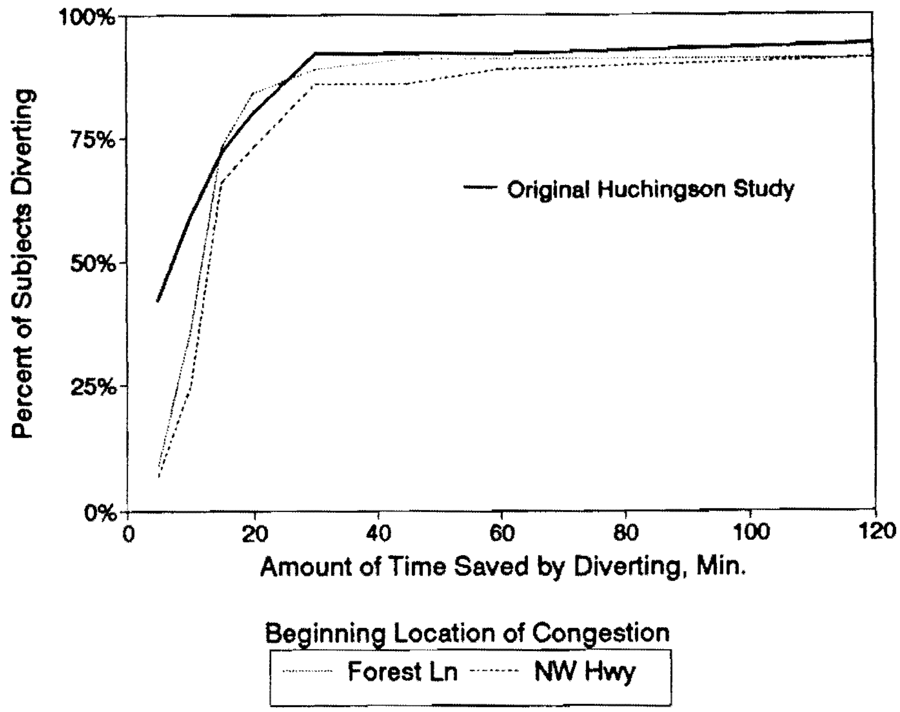


(a) Beginning of Congestion: Forest Lane

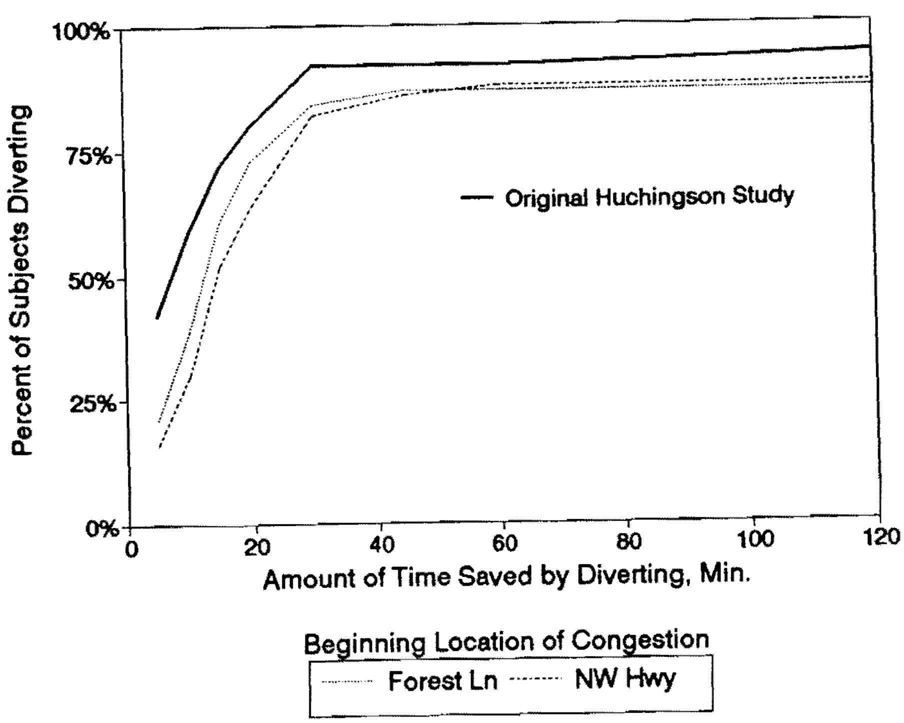


(b) Beginning of Congestion: Northwest Highway

Figure 4-3. Effect of Recommended Rate Upon Percent of Subjects Considering Diversion to a Given Time Saved Message: Experiment 2.



(a) Recommended Route: Greenville Avenue

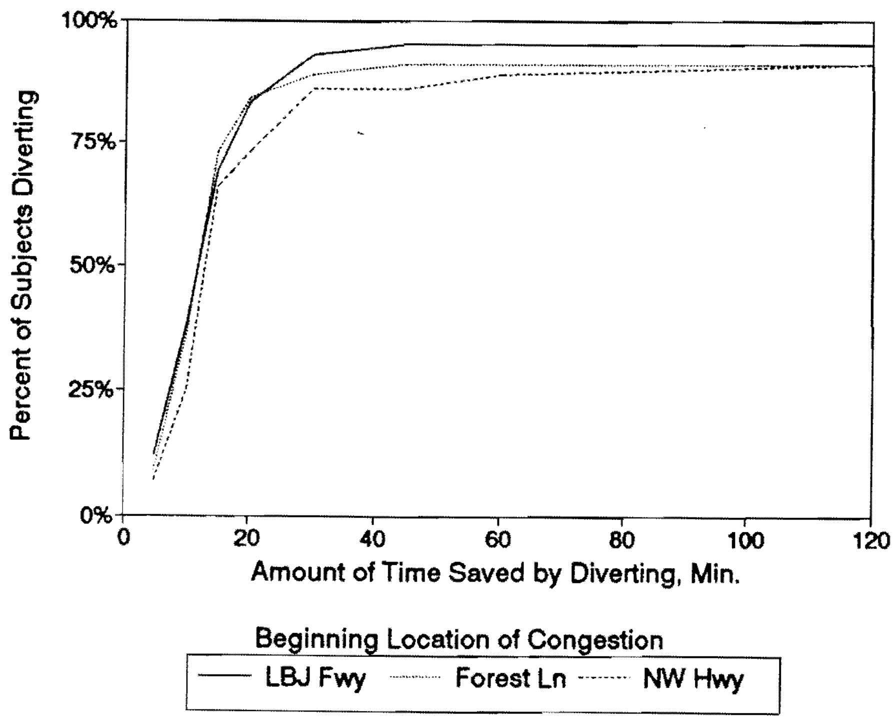


(b) Recommended Route: Dallas North Tollway

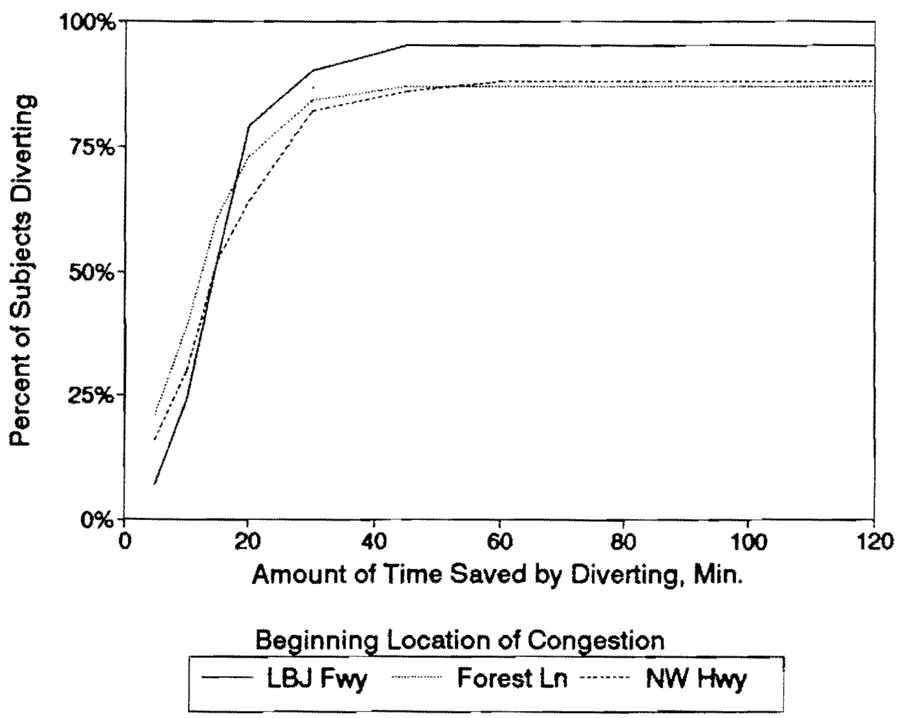
Figure 4-4. Effect of Reported Beginning Location of Congestion Upon Percent of Subjects Considering Diversion to a Given Time Saved Message: Experiment 2.

In Figure 4-4, it appears that the percent of subjects considering diversion was slightly higher when the congestion was said to be a short distance downstream (at Forest Lane) rather than a greater distance downstream (at Northwest Highway). This result was consistent when either Greenville Avenue or the Dallas North Tollway was the recommended alternative route. These data suggest a trend in terms of slightly greater diversion propensity the closer congestion is to the point of diversion. Combining these data with those of the first experiment when LBJ Freeway was specified as the diversion location, the diversion percentage at each time saved value was the greatest when congestion was reported to begin at LBJ Freeway, second highest when it is reported to begin at Forest Lane, and smallest when it was reported to begin at Northwest Highway (the most downstream congestion point tested) (see Figure 4-5). However, the differences were not substantial enough to be considered statistically significant, given the available sample size.

In summary, the distributions of subject responses did not indicate any statistically significant differences that could be attributed to the differences in recommended route, diversion location, or location of congestion. However, these results are based on an assumption that subject responses can be considered as a single homogenous group. Recent research (3) suggests that there are numerous subgroups within the driving population each having distinct attitudes, perceptions, and behavioral tendencies with respect to diversion. Despite the steps that were taken to single out a uniform sample population for testing purposes, differences within the sample may exist with respect to their sensitivity to real-time travel time information. To investigate this possibility, the demographic and travel characteristic data collected from each subject were combined with the recommended route, diversion location, and point of congestion variables of the original study design in an analysis-of-variance (ANOVA) evaluation. In this way, effects of the message variables upon average time saved thresholds could be systematically assessed for different subgroups of the sample. The results of that analysis are described in the next section.



(a) Recommended Route: Greenville Avenue



(b) Recommended Route: Dallas North Tollway

Figure 4-5. Effect of Reported Beginning Location of Congestion Upon Percent of Subjects Considering Diversion to a Given Time Saved Value: Experiments 1 and 2 Combined.

Analysis-of-Variance Evaluation

Because of the study design, separate ANOVA evaluations were performed on the data from each experiment. Furthermore, because the study was not designed to completely counterbalance the subject demographic and travel characteristics, only one subject variable at a time was combined with the corridor characteristic variables in the analysis. Hence, the analysis for each experiment tested several three-factor models, all of which included: (1) a subject variable (demographic or travel characteristic), (2) the recommended route variable, and (3) the recommended diversion location or the location of the beginning of congestion variable (representing experiments 1 or 2, respectively).

The subject variables were defined identically for each experiment. Table 4-3 describes these variables, and how they were divided into categories for analysis purposes. The limited amount of data necessitated that the number of categories for each variable be kept to two or three. Both age and gender were included as demographic variables, as was the employer for whom the subject worked (since the companies used in the survey employed very different types of people). Both the subject's usual arrival time at work and the required work start time were considered in the analysis (although a distinction was not made between the time which the subject wanted to start work or the time the company itself identified as the start time). Each of these variables were divided into two categories, separating the off-peak and peak period travel conditions.

Another variable of interest in the analysis was the difference between the subject's reported time of arrival and the time they are required to be at work. Recent research suggests that motorist route choice and departure time selections are related to the amount of "arrival time cushion" the motorist gives himself or herself prior to starting work. Three categories were defined for this variable: (1) those arriving early, (2) those reportedly arriving exactly at the required start time, and (3) those arriving later. Subject rating of the importance of arriving to work on time (not important, important, or very important) was also considered in the ANOVA analyses. Finally, the normal home-to-work travel time of the subjects were divided into three categories (30 minutes or less, 31 to 45 minutes, and greater than 45 minutes) for inclusion into the pool of variables evaluated.

Subject time saved thresholds were modelled as a function of the recommended route, diversion location or congestion location, and one of the subject variables listed in Table 4-3. Thus, for experiment 1:

TABLE 4-3. DEFINITION OF SUBJECT VARIABLES IN ANOVA EVALUATION

Variables	Categories
Age	less than 40 years (n=20)
	40 years or more (n=24)
Gender	male (n=25)
	female (n=19)
Employer	Nations Bank (n=23)
	MOBIL Oil Corporation (n=21)
Usual Work Arrival Time	earlier than 7:30 am (n=28)
	7:30 am or later (n=16)
Required Work Start Time	earlier than 7:30 am (n=25)
	7:30 am or later (n=19)
Arrival Time Cushion (Schedule Delay)	early arrivers (n=29)
	on-time arrivers (n=10)
	later arrivers (n=5)
Importance of Arriving to Work on Time	not important (n=22)
	important (n=16)
	very important (n=6)
Normal Home-to-Work Travel Time	30 minutes or less (n=20)
	31 to 45 minutes (n=16)
	greater than 45 minutes (n=8)

n=sample size

Time Saved Threshold = *f*(route, diversion location, subject characteristic)

Likewise, the model for experiment 2 was:

Time Saved Threshold = *f*(route, congestion location, subject characteristic)

ANOVA procedures were then employed to determine which subject characteristics, in conjunction with the route and diversion or congestion variables, yielded the most significant models. The results of the evaluation for each experiment are presented in the following sections.

Experiment 1 -- Recommended Route and Diversion Location

The time saved threshold values obtained from each subject for each message were limited to the range from 0 to 120 minutes (although a "never divert" answer was also possible). Furthermore, it was anticipated that the responses might be heavily skewed to the lower values, resulting in data which would not strictly follow a normal distribution. Unfortunately, ANOVA procedures are based on assumptions that the data is normally distributed and displays uniform variability over the different variable combinations possible in the analysis. The Bartlett's test for equal variances and Shapiro-Wilks test for the normality of the data (21,22) were performed on each of the candidate models evaluated, and verified both a lack of homogeneity of the variances and non-normality of the data. Retesting a logarithmic transformation of the data essentially eliminated the variance homogeneity problems, but the data remained slightly non-normal. However, subsequent discussions were held with TTI statisticians who judged that the slight non-normality would not seriously affect the results of an ANOVA evaluation.

Table 4-4 presents a summary of the results of the ANOVA evaluations of each of the candidate models for experiment 1. As the table indicates, none of the eight models tested were found to be statistically significant. The implication of these results are that the other individual variabilities in time saved threshold values overshadowed any systematic differences in average threshold values categorized according to the recommended route, recommended diversion location, and the subject characteristics tested. The models which included the subject variables gender, employer, and arrival time importance resulted in lower levels of significance than the remaining variables, but were still much higher than the 0.1 level that was selected for establishing statistical significance in this phase of the analysis.

TABLE 4-4. ANOVA RESULTS FOR EXPERIMENT 1

Model	Subject Variable Included in the Model	Level of Significance*	Significant Variables
1	Age	0.562	None
2	Gender	0.240	None
3	Employer	0.179	None
4	Usual Work Arrival Time	0.690	None
5	Required Work Start Time	0.557	None
6	Arrival Time Cushion	0.856	None
7	Arrival Time Importance	0.266	None
8	Normal Travel Time	0.875	None

* A level of significance of 0.1 was judged to be statistically significant

Experiment 2 -- Recommended Route and Location of Beginning of Congestion

The results of the ANOVA evaluation for the data collected in the second experiment are presented in Table 4-5. As in the first experiment, a logarithmic transformation of the data was required to stabilize the variances and to reduce the non-normality of the data. Unlike the first experiment, though, the results of the second experiment yielded two models which were judged to be statistically significant. One of the models incorporated the employer variable with the route and congestion location variables (model 3), and the other included the subject rankings of arrival time importance (model 7). The ANOVA results of model 3 showed that the average time savings thresholds were significantly different for employees of the two companies. However, for each group of employees considered separately, there were no differences attributable to the recommended route or the location where congestion was reported to begin.

TABLE 4-5. ANOVA RESULTS FOR EXPERIMENT 2

Model	Subject Variable Included in the Model	Level of Significance	Significant Variables
1	Age	0.776	None
2	Gender	0.121	None
3	Employer	0.094	Employer
4	Usual Work Arrival Time	0.690	None
5	Required Work Start Time	0.764	None
6	Arrival Time Cushion	0.856	None
7	Arrival Time Importance	0.091	Route, Congestion Location, and Importance
8	Normal Travel Time	0.723	None

* A level of significance of 0.1 was judged to be statistically significant

On the other hand, the ANOVA results of model 7 indicated that Arrival Time Importance, recommended route, and reported location of congestion were all significant variables in the model. To further investigate the interactions between these three variables, a second ANOVA evaluation was performed. In this second analysis, the arrival time importance variable was used to divide the subjects into subgroups, and the ANOVA procedure then performed on the time saved threshold values of each subgroup. Table 4-6 presents the result of that analysis.

The results of that analysis indicated that there were no differences in average threshold values for subjects who felt that arriving on time at work was either important or very important. However, those subjects indicating that it was not important for them to arrive to work on time showed significant differences in average time saved threshold values depending on the alternative route that was recommended. Specifically, those subjects reported significantly higher time saved thresholds (over 20 minutes higher) when Greenville Avenue was specified as the alternative route than when the Dallas North

Tollway was specified. In other words, this particular group of subjects had a strong aversion to diverting to Greenville Avenue.

TABLE 4-6. RESULTS OF ANOVA ANALYSIS BASED ON CATEGORIES OF ARRIVAL TIME IMPORTANCE: EXPERIMENT 2

Arrival Time Importance Category	Level of Significance	Significant Variables
Not Important	0.066	Route (Avg. Greenville Threshold = 34.5 min., Avg. DNT Threshold = 13.3 min.)
Important	0.487	None
Very Important	0.779	None

Interestingly, all but one of the subjects in the "not important" category stated that they disliked the large number of traffic lights on Greenville Avenue, and that it would require a promise of a much greater time savings to that route to get them to consider diverting. A description of other subject reasons for the time saved threshold values selected is provided in the next section.

Individual Subject Variations in Time Saved Thresholds by Message

Whereas ANOVA evaluations did not identify many subgroups of the sample population which had consistent differences in time saved threshold values for the various messages that were tested, this does not mean that all subjects reported identical time saved threshold values for all messages. In fact, the majority of subjects selected least one threshold value for a message that was different from the thresholds from the other messages. As shown in Table 4-7, only 9 percent of the subjects responded with the same threshold value to all eight messages they were asked to consider. Considering experiments 1 and 2 independently, the percentage of subjects selecting identical time saved threshold values to each message was 24 and 25 percent, respectively.

To gain additional insight into those subjects who selected different threshold values for one or more messages, subgroups were again created, this time by grouping those who selected lower threshold values for one message over another. For example, all subjects selecting a lower threshold value for the message recommending Greenville Avenue (diverting at LBJ Freeway) than the message recommending the Dallas North Tollway were placed into one subgroup. Likewise, those with a lower threshold value when the Tollway was recommended than when Greenville was recommended were placed in another subgroup, and so on. For each subgroup, the average threshold values for each message was then computed.

Table 4-8 summarizes the average values of these new subgroups for the messages evaluated in experiment 1, where the effects of the recommended alternative route and recommended diversion location were considered. The average threshold values were substantially different. For the subgroup selecting lower threshold values when Greenville was recommended, they indicated that it would require an additional 7 minutes (19 minutes - 12 minutes), on the average, to get them to use the Tollway if it was recommended. On the other hand, those subjects selecting lower threshold values when the Tollway was recommended would require an average of 12 more minutes (21 minutes - 9 minutes) of time savings before they would consider diverting to Greenville Avenue.

A similar distinction can be made with respect to the location where diversion was recommended. The subgroup selecting lower thresholds to divert at LBJ Freeway would require 10 (23 minutes - 13 minutes) more minutes of time savings before considering diverting at Northwest Highway, whereas those selecting a lower threshold to divert at Northwest Highway would require an additional 6 minutes (18 minutes - 12 minutes) before diversion at LBJ Freeway would be considered. Overall, it can be seen how these differences would cancel out when combined, leading to a somewhat misleading conclusion that there are no differences in motorist time saved thresholds when different routes or diversion locations are recommended. In actuality, the difficulty is in determining what individual attributes can be used to predict which of the subgroups a given motorist might align him or herself with.

TABLE 4-7. PERCENTAGE OF IDENTICAL TIME SAVED THRESHOLDS

	Percent of Subjects with Identical Time Saved Threshold Values
All Messages	9
By Experiment:	
Experiment 1	24
Experiment 2	25
By Corridor Characteristic:	
Experiment 1	
Recommended Route	
Diverting at LBJ Freeway	34
Diverting at NW Highway	49
Recommended Diversion Location	
Diverting to Greenville Avenue	49
Diverting to Dallas North Tollway	49
Experiment 2	
Recommended Route	
Congestion beginning at Forest Lane	41
Congestion beginning at NW Highway	48
Beginning Location of Congestion	
Diverting to Greenville Avenue	70
Diverting to Dallas North Tollway	70

TABLE 4-8. AVERAGE TIME SAVED THRESHOLD VALUES BY SUBGROUP: EXPERIMENT 1

	Average Time Saved Threshold Value, Minutes	
	Subgroup with Lower Values for Greenville	Subgroup with Lower Values for DNT
Messages Recommending Use of Greenville	12	21
Messages Recommending Use of DNT	19	9
	Subgroup with Lower Values for LBJ Fwy	Subgroup with Lower Values for Northwest Hwy
Messages Recommending Diverting at LBJ Fwy	13	18
Messages Recommending Diverting at Northwest Hwy	23	12

A summary of the reasons as to why the subjects reported a higher time saved threshold for one route or diversion location over the other is provided in Table 4-9. One of the more surprising findings from this part of the analysis was the high percentage of subjects who cited anticipated congestion on the roadways to be used to access the Tollway (either LBJ Freeway or Northwest Highway) as the reason why they would require a greater time savings before considering diverting to the Tollway than they would for a message recommending Greenville Avenue as the alternative route. Reasons which were originally expected to be significant in their decisions regarding the use of the Tollway, such as the farther distance to the Tollway or the fee required for its use, were cited only a few times. Meanwhile, the most common reason cited by those subjects requiring a greater time savings before considering diverting to Greenville was the presence of traffic lights and stop signs on that route, and poor past experiences with using that route. Judging from these reasons, it appears that the subjects were basing their time saved thresholds on how bad they disliked one or the other of the recommended routes.

Differences in time saved thresholds according to the recommended diversion location also suggest that subjects disliked diverting at one location over the other. For those subjects selecting lower time saved thresholds for diverting at LBJ freeway, the most frequent reason cited was that access to either Greenville Avenue or the Tollway would be more difficult via Northwest Highway. Another common reason cited was that the network south of Northwest Highway did not allow for an easy return to the Expressway beyond the point of congestion. Thus, those subjects needed a bigger incentive before attempting to follow any recommended diversion advice at Northwest Highway.

For those subjects selecting lower time saved thresholds for diverting at Northwest Highway, the most common reason was that diverting so far away from their destination (at LBJ freeway) was perceived to pose a greater risk (ie. they were more likely to encounter a problem on the alternative route). Another common reason cited was the poor travel conditions on LBJ Freeway which made it difficult to access the alternative routes at that point.

Table 4-10 summarizes the average time saved threshold values for the various subgroups for experiment 2. The results of the second experiment yielded only two subjects who selected lower threshold values to messages stating congestion began at Northwest Highway (farther downstream of the diversion location) in comparison to messages stating congestion began at Forest Lane (closer to the diversion location). Thus, it was not necessary to compare those subgroups. The remainder of the analysis focused on the threshold values of subgroups having different threshold values for each of the recommended alternative routes.

TABLE 4-9. REASONS GIVEN FOR SELECTING DIFFERENT TIME SAVED THRESHOLD VALUES: EXPERIMENT 1

Reasons	Percent of Subgroup
For Higher Threshold Values to Divert to the DNT:	
• Roads accessing DNT (LBJ Freeway, Northwest Hwy) are too congested	75%
• The Tollway is farther away from the Expressway	8%
• It is difficult to return to the Expressway once at the Tollway	8%
• The Tollway requires a fee to use	9%
For Higher Threshold Values to Divert to Greenville:	
• Too many traffic lights, stop signs on Greenville	58%
• Had poor experience with Greenville in the past	42%
For Higher Threshold Values to Divert at LBJ Freeway:	
• Diverting farther away from their destination increases risk of encountering problems on alternative routes	50%
• Had poor experience with LBJ Freeway congestion in the past	31%
For Higher Threshold Values to Divert at Northwest Hwy:	
• More difficult to access alternative routes at Northwest Hwy	36%
• Difficult to return to the Expressway from either alternative route south of Northwest Hwy	14%

For the subgroup selecting lower threshold values when Greenville was recommended, an additional 17 minutes (28 minutes - 11 minutes) in time savings would need to be promised to get them to use the Tollway if it was recommended. On the other hand, those subjects selecting lower threshold values when the Tollway was recommended would require an average of 15 more minutes (25 minutes - 10 minutes) of time savings before they would consider diverting to Greenville Avenue.

TABLE 4-10. AVERAGE TIME SAVED THRESHOLD VALUES BY SUBGROUP: EXPERIMENT 2

	Average Time Saved Threshold Value, Minutes	
	Subgroup with Lower Values for Greenville	Subgroup with Lower Values for DNT
Messages Recommending Use of Greenville	11	25
Messages Recommending Use of DNT	28	10

The data from the two experiments do indicate that many subjects have specific preferences about routes and diversion locations that will likely affect their acceptance of real-time travel time information. However, these preferences are highly individualistic and are not apparently dependant upon socioeconomic or trip characteristics commonly used to predict motorist route choice behavior.

5. SUMMARY AND APPLICATION OF STUDY FINDINGS

Summary

This report has presented the results of laboratory experiments conducted to assess the effects of different corridor characteristics upon motorist time saved threshold values. The corridor characteristics evaluated in this research were as follows:

- the recommended alternative route,
- the location where motorists would be advised to divert to the recommended alternative route, and
- the location where congestion was said to begin relative to the location where motorists were advised to divert.

The laboratory experiments used subjects who regularly drove on the North Central Expressway in Dallas, TX for their daily home-to-work trip to the Dallas CBD. The basic study procedures used in the experiments were similar to those employed by Huchingson et. al. in previous research.

Below is a summary of the findings from the laboratory experiments:

1. Cumulative percentages of subjects considering diversion at various time saved values did not show any statistically significant differences as a function of the recommended route, diversion location, or location where congestion was said to begin. However, there were consistent trends in the data in that slightly higher percentages of subjects would consider diverting to Greenville Avenue at a given time saved value than they would if the Dallas North Tollway was recommended. Likewise, the percentage of subjects who would consider diverting to either route tended to decrease slightly as the reported location of the beginning of congestion was placed farther and farther downstream of the recommended diversion point.

2. Although the cumulative percentages for the different messages were not found to differ significantly (statistically speaking) from one another, all were found to differ significantly from those obtained from Huchingson et. al. in earlier research. Whereas the 50th percentile subject in the Huchingson reportedly considered diversion if the time save value was between 5 and 10 minutes, the 50th percentile subject in the experiments reported in this report required nearly a 15-minute time

savings before he or she would consider diverting. The traffic scenarios presented to subjects in the two studies were dissimilar, however, and could be the reason for the significant differences. For example, the Huchingson study tested a scenario involving travel to a special event during the off-peak period (when travel on alternative routes may be quite good), whereas the current study tested a scenario involving home-to-work trips being made throughout the morning peak period (when congestion is likely on alternative routes). Another possible explanation for the difference in threshold values between studies is that congestion levels in Dallas (as well as nationally) have increased dramatically over the past 20 years, such that a 5 or 10-minute savings in travel time is no longer considered as significant as it once was.

3. ANOVA procedures were employed to examine the effect of the corridor features upon motorist time saved threshold values for different subgroups of the study sample. Of the various subgroupings tested, the only one found to be significant was dependent upon the importance the subject placed on arriving to work on time. Specifically, subjects indicating that it was not important for them to arrive to work on time had a much higher time saved threshold value when considering diverting to Greenville Avenue than they did when diverting to the Dallas North Tollway. In other words, it would take a much higher savings in travel time before they would consider diverting to Greenville Avenue in comparison to the Dallas North Tollway. Statistically, this difference was significant only for the second experiment, although a similar trend was evident in the data collected from the first experiment. Reasons for these time saved values indicate that subjects have a strong aversion to using Greenville Avenue because of a large number of traffic signals present on that route.

4. Comparision of individual subject responses to the traffic messages suggest that corridor characteristics do have a significant influence on time saved threshold values for some of the subjects. It was found, for example, that some subjects had much higher threshold values for considering diversion to Greenville Avenue (as opposed to the Dallas North Tollway), whereas other subjects had higher threshold values for the Tollway. Similarly, separate groupings were evident when considering the different diversion locations examined in the experiments.

5. Explanations provided by the subjects for these different threshold values generally indicate that they had an aversion to one or the other of the alternatives which then resulted in a higher threshold value to justify using that alternative. For instance,

some subjects disliked the large number of signals on Greenville Avenue (as indicated previously), whereas other subjects did not want to pay the fee to use the Tollway. Other reasons offered for disliking one route over the other included having to travel a farther distance to the Tollway (relative to Greenville Avenue), or previously having an unpleasant trip on one of the routes. Another reason cited numerous times was that the roads accessing the alternative routes were too congested or difficult to use. This further emphasizes the need to consider conditions not only on the parallel alternative routes recommended in real-time traffic messages, but the connecting roadways to be used to access those alternative routes as well.

Application of Results to the Design and Operation of Real-Time Motorist Information Systems in Urban Freeway Corridors

The results of this study have direct bearing upon the design and operation of motorist information systems in several ways. First, by comparing the current study results with those of Huchingson et. al., it appears that motorists may be less sensitive to time savings information during the peak travel periods than during the off-peak periods. The increased congestion levels present throughout an urban freeway corridor in peak periods may make motorists less confident of estimates of travel time savings via alternative routes. Consequently, significant differences in travel time (ie. 10-15 minutes in time saved) may be necessary before most motorists may be willing to divert from their primary route during peak periods.

Second, subject responses suggest that connecting roads used to access various alternative routes in a corridor may affect motorists time saved thresholds. Thus, conditions on the various connecting roadway in the corridor should be considered when plans for locating motorist information displays within the corridor are being made, with preferences given to those providing better access to alternative routes.

Finally, the results of the study suggest that not all motorists will prefer to utilize a given alternative route, even for those making the same type of trip and having similar origin-destination patterns. Considering motorists on an individual basis, the likelihood of their diverting in response to time saved information may change dramatically depending on the route being recommended. This finding will be particularly important to the design and operation of systems providing real-time travel time information to in-vehicle navigation systems (i.e., ATIS). It may become necessary to allow drivers to program their in-vehicle units with their individual route preferences or aversions in order to fine-tune the routing algorithms used to make diversion recommendations to the motorist. In this way, information credibility and usefulness to the motorist could be maximized, and the ability to predict the motorist's response enhanced.

Recommendations for Future Research

The findings of this research represent a limited perspective of the very complex and dynamic process motorists must go through in making diversion decisions. Additional research is warranted into other factors (such as the number of reasonable alternative routes in the corridor) that may interact with real-time traffic information to induce motorist diversion. Also, it must be remembered that the data come from hypothetical traffic scenarios presented in a laboratory environment. Field studies are needed to correlate the results of this study (representing motorists perceptions and interpretations) to actual traffic conditions (representing actual motorist behavior).

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Appendix A:

Laboratory Equipment Script

Date: ______________ Surveyor: ________

Project 1232
TIME SAVED SURVEY -- Part I

Subjects Name: ______________________ Time Called: __________

"Good Morning. My name is *[Insert Your Name]* with the Texas Transportation Institute at Texas A&M University. Recently, you expressed a willingness to participate in a survey to help us better manage traffic on North Central Expressway. It is a two part survey that we will conduct on two separate days. Are you still interested in participating in this survey?"

IF SUBJECT SAYS NO: "OK. Thank you for your time." *[Quit]*
IF SUBJECT SAYS YES: Would now be a convenient time for you to answer the first part of the survey questions? The survey should take about 10 to 15 minutes to complete."

IF SUBJECT SAYS NO: "What would be a convenient time?" ________ "O.K. I'll try to call you back then."
IF SUBJECT SAYS YES: "I am required to inform you that we would like to tape record your responses to make it easier for us to analyze the information that we receive. If you do not wish our conversation be recorded, you may still participate in the survey. Do you have any objections to tape recording this conversation?"

IF SUBJECT SAYS NO: "I am turning on the tape recorder now." *[turn on tape recorder]*

Before we begin, I would like to explain the purpose of the survey and the manner in which it will be conducted. During your drives to work you have undoubtedly been delayed by traffic congestion or accidents. The purpose of this part of the survey is to help us determine how much time individuals needs to save before they will exit North Central and use either the Dallas North Tollway or Greenville Avenue. You will be presented four hypothetical messages that will describe a different traffic situation. Each message will give you information about the location of an accident and the location of the congestion. The message will also tell you which exit and alternative route to take to avoid the congestion. At the end of each message, I will ask you how much time you need to save under the conditions that I have described before you would consider it to be practical and economical to use the recommended alternate route.

Let me give you an example. You are traveling inbound on North Central Expressway during a normal morning commute and you receive a message via the radio that there is an accident ahead of you. The message tells you that there is a delay on North Central from your current location. You are advised in the message to take a specific exit, for example LBJ Westbound, and use an alternative route, say the Dallas North Tollway. I will then ask you how much time will you need to save in order for you to divert to the recommended alternate route.

I will be prompting you with time saving values ranging from 5 minutes to 2 hours. You will need to stop me when I give the time saving value that most closely represents the amount of savings that you would need to use the recommended route. I will give you an opportunity at the end of the survey to change any of your answers if you so desire.

Do you have any questions on how the survey will be conducted or what you will be doing before we begin?"

IF SUBJECT SAYS YES: *[Field Questions]*
IF SUBJECT SAYS NO: "O.K. I will now begin the survey."

ORDER A

MESSAGE #1

OPERATOR: You are driving to work on North Central Expressway. You are about one mile north of the LBJ Interchange when you hear the following message on the radio:

ATTENTION SOUTHBOUND TRAFFIC
ACCIDENT AT WALNUT HILL LANE
CONGESTION BEGINS AT LBJ FREEWAY
EXIT LBJ FREEWAY EASTBOUND
TAKE GREENVILLE AVENUE TO DOWNTOWN
SAVE X MINUTES

The actual value of X could vary between 5 minutes and 2 hours. As a commuter on North Central Expressway, would you then exit to LBJ eastbound and take Greenville Avenue to work under the conditions that I have just described:

if you could save 5 minutes?
10 minutes?
15 minutes?
20 minutes?
25 minutes?
30 minutes?
45 minutes?
60 minutes?
2 hours?

MESSAGE #2

OPERATOR: Now, assume the message is the same except that you are advised to take Dallas North Tollway instead of Greenville Avenue to downtown.

As a commuter on North Central Expressway, would you exit LBJ westbound and take the Dallas North Tollway to work:

if you could save 5 minutes?
10 minutes?
15 minutes?
20 minutes?
25 minutes?
30 minutes?
45 minutes?
60 minutes?
2 hours?

ORDER A

MESSAGE #3

OPERATOR: You are driving to work on the North Central Expressway. You are about one mile north of the Northwest Highway exit when you hear the following message on the radio:

ATTENTION SOUTHBOUND TRAFFIC
ACCIDENT AT FITZHUGH AVENUE
CONGESTION BEGINS AT NORTHWEST HIGHWAY
EXIT NORTHWEST HIGHWAY EASTBOUND
TAKE GREENVILLE AVENUE TO DOWNTOWN
SAVE X MINUTES

Again, the actual value of X could vary between 5 minutes and 2 hours. As a commuter on North Central Expressway, would you then exit to Northwest Highway eastbound and take Greenville Avenue to work under the conditions that I have just described:

if you could save 5 minutes?
10 minutes?
15 minutes?
20 minutes?
25 minutes?
30 minutes?
45 minutes?
60 minutes?
2 hours?

MESSAGE #4

OPERATOR: Now, assume the message is the same except that you are advised to take Dallas North Tollway instead of Greenville Avenue to downtown.

As a commuter on North Central Expressway, would you exit to Northwest Highway Westbound and take the Dallas North Tollway to work:

if you could save 5 minutes?
10 minutes?
15 minutes?
20 minutes?
25 minutes?
30 minutes?
45 minutes?
60 minutes?
2 hours?