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16. Abstract

This report presents an analysis of accidents at five long-term freeway construction projects in Texas during 1984 - 1988. Data were collected from each project for two to three years prior to construction and for all years during construction through 1988. Total accidents on the mainlanes increased an average of 28.7 percent during construction. Severe accidents on the mainlanes increased by a greater percentage, on the average, than did PDO accidents (38.8 percent versus 24.9 percent). Nighttime accidents on the mainlanes increased by a greater proportion than did daytime accidents (37.4 percent versus 24.4). Frontage road accidents at the five projects increased by an average of only 2.4 percent during construction. The average changes in PDO and severe accidents, daytime and nighttime accidents, and in the various accident type categories on the frontage road were also found to be negligible.

A statistical test of homogeneity of the changes in accidents from project to project indicated that the average changes in total mainlane accidents, severe accidents, single vehicle, and multi-vehicle (excluding rear-end) accidents were consistent from project to project, and could be used as reasonable estimates of the expected impacts for future projects. Significant site-to-site variations in the other accident categories were detected, however.

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ANALYSIS OF ACCIDENTS AT LONG-TERM CONSTRUCTION PROJECTS IN TEXAS

by

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and

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Research Report 1108-2
Research Study Number 2-8-87-1108

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February 1990
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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.

	TEMPERATURE (exact)			
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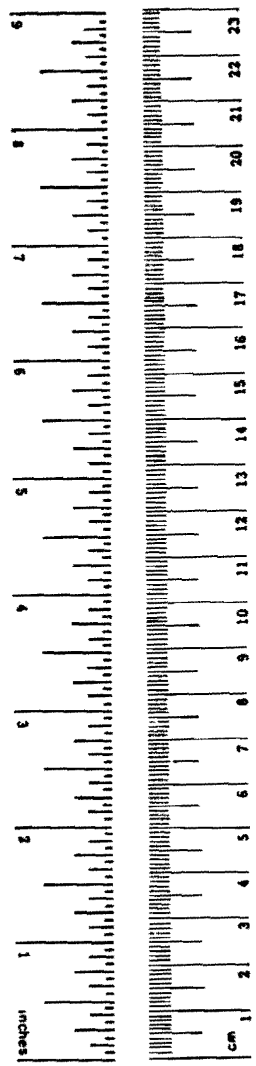

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
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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
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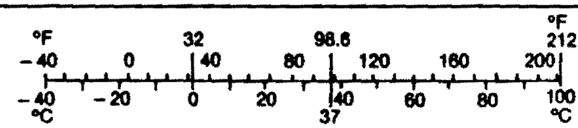

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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SUMMARY

This report presents an analysis of accidents at five long-term freeway construction projects in Texas during 1984 - 1988. Data for each project were obtained from the Master Accident File for two to three years prior to construction and for all years during construction through 1988.

Total accidents on the mainlanes increased by an average of 28.7 percent during construction across all five projects. Severe accidents on the mainlanes increased by a greater percentage, on the average, than did PDO accidents (38.8 percent versus 24.9 percent). These data suggest that the accidents during construction tended to be more severe than normal. Nighttime accidents on the mainlanes increased by a greater proportion than did daytime accidents (37.4 percent versus 24.4). The magnitude of the change in PDO, daytime, nighttime, and rear-end accidents due to construction varied considerably among the five projects. However, the changes in total accidents, severe accidents, single vehicle accidents, and multi-vehicle accidents (other than rear-end accidents) were found to be statistically consistent from project to project, indicating that the average changes in these measures could be used to predict the expected changes in accidents at similar types of future construction projects in Texas.

Frontage road accidents during construction at the five projects increased an average of only 2.4 percent, although one project experienced a 27.7 percent increase. The average changes in PDO and severe accidents, daytime and nighttime accidents, and in the various accident type categories were also found to be negligible.

IMPLEMENTATION STATEMENT

The results presented in this report add to the existing body of knowledge concerning the effects of roadway construction upon traffic safety. The report provides information that will be immediately useful in assessing the expected impacts of future construction projects in Texas upon traffic safety and accident costs. However, additional research is needed to further quantify the effects of construction upon accidents. More importantly, there is a need to develop a better understanding of how site-specific conditions at a construction project influence accidents. The Master Accident File does not include many important details about accidents occurring in a work zone. In particular, the details of the traffic control plan--including lane and shoulder widths, ramp geometry, advance signing, lighting, type and location of channelizing devices, and the nature of the work activity--are not included. More detailed studies will be needed in order to determine the effects of these specific traffic control and geometric design features on accidents in construction zones and, therefore, provide information that can be used to make more cost-effective decisions about those design features that affect safety.

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1. INTRODUCTION

Problem Statement

Texas is in the midst of an extended era of major freeway rehabilitation and reconstruction. A freeway construction project can have significant cost impacts upon the users of the facility. In general, these costs are due to increased motorist delays, vehicle operating costs, and accident costs. Road user costs incurred during roadway construction should be considered when selecting work zone traffic control for a project, as well as when selecting actions to mitigate the possible effects of traffic diversion to alternative routes and modes in the freeway corridor. In order to estimate these costs, data is needed as to the actual traffic operations and safety effects of freeway construction projects. Therefore, study 1108, "Traffic Pattern Assessment and Road User Delay Costs Resulting from Roadway Construction Options," sponsored by the Texas Department of Transportation (TxDOT), was initiated to develop a database on the effects of major freeway construction projects upon driver travel patterns, traffic operations, traffic accidents, and ultimately, road user costs.

Current information is especially needed concerning the impact of construction projects upon accidents. Texas is unique in that continuous frontage roads are typically provided adjacent to the freeway mainlanes. In many instances, both the mainlanes and the frontage roads are constructed, and the impacts of these construction projects upon accidents need to be quantified. Also, most urban freeway construction projects performed within the state do not involve long-term lane closures. Although temporary, off-peak closures may be allowed, most traffic control plans for urban freeway construction provide the same number of travel lanes as existed before construction for peak-period, peak-direction traffic. Previous work zone accident studies have shown relationships between the change in accidents and the number of freeway lanes closed (and the subsequent increase in volume per lane) during construction. Data is needed to determine the accident experience at urban freeway construction projects with the type of traffic control plan typically used in Texas. With an improved estimate of the impacts of construction upon accidents, highway officials can better assess the economic and safety trade-offs of alternative traffic control and construction methods.

Report Objectives

This report provides an assessment of the accident impacts of several long-term urban freeway construction projects in Texas. As background, past research concerning work zone traffic accidents is reviewed in Chapter 2. Chapter 3 presents the results of an accident analysis at five long-term urban freeway construction projects in Texas that were underway between 1984 and 1988. A summary of the major findings of this research is presented in Chapter 4 of the report. The intent of the report is to provide the Department with improved estimates of the changes in accidents during long-term urban freeway construction projects employing the most common traffic control plans and methods used in Texas.

2. BACKGROUND

Overview

The effects of maintenance and construction work zones upon accidents have been a topic of interest for a number of years. Several studies have evaluated accident characteristics in work zones. These studies have focused on one or more of the following basic questions:

1. How do accident frequencies (or rates) change at locations where work zones are established?

2. What effect do work zones have upon the specific types of accidents that occur?

3. What factors at work zones cause or at least contribute to increased accident frequency?

This chapter presents a review of the major research findings regarding work zone accidents during the past two decades. The intent of the review is to bring to the reader a synopsis of the work zone accident experience to date. Caution should be used when interpreting the actual numbers presented by the various studies. Work zone traffic control procedures have improved dramatically over the past two decades in response to the accident problems described by some of the early studies. Consequently, specific comparisons between studies may be somewhat misleading.

Changes in Accident Rates at Work Zones

Table 2-1 summarizes the changes in accident rates at work zones reported by a number of authors. The table is organized by date of study. A study by Doege and Levy (1) of accidents occurring on a section of the Illinois Tollway under repair showed that the accident rate increased 160 percent. Graham et al. (2) reported an average 7 percent increase at the nearly 80 work zones they examined, but the changes varied dramatically from site to site. In general, changes in accident rates were found to vary somewhat systematically depending on the road type and magnitude of the roadway capacity reductions employed during construction. For freeways with four to eight lanes, accident rate increases varied from 5 percent to nearly 150 percent. Changes reported by Graham for other roadway types are also shown in Table 2-1. Nemeth and Migletz (3), in their analysis of work zones on rural freeway sections in Ohio, found the accident rate during construction to increase an average of 29 percent. Lisle (4) estimated that accidents increased 119 percent at a construction zone in Virginia, and Paulsen et al. (5) reported that accidents increased 61 percent during resurfacing operations on two-lane highways in Georgia.

TABLE 2-1. CHANGES IN ACCIDENT RATES AT WORK ZONES

Study	Road Type	Change in Accident Rates During Construction
Doege and Levy (1) 1977	4-Lane Divided Highway 1 lane open per dir.	160% increase
Graham et al. (2) 1977	All Road Types Combined	7% increase
	6- or 8-Lane Interstates:	
	2 lanes open per dir.	5% increase
	1 lane open per dir.	115% increase
	4-Lane Interstates: 1 lane open per dir.	
	-no crossover-	69% increase
	-crossover-	147% increase
	4-Lane Divided Roadway: 1 lane open per dir.	
	-no crossover-	15% increase
	-crossover-	16% increase
	4-Lane Undivided Roadway: 1 lane open per dir.	5% decrease
	5-Lane Undivided Roadway: 1 lane open per dir.	59% increase
	2-Lane Roadway: 1 lane open (alternating flow)	31% increase
Nemeth and Migletz (3) 1978	Rural 4-Lane Freeway: 1 lane open per dir.	29% increase (comparing control and construction sections) 7% increase (comparing before-during accidents at construction zone only)
Lisle (4) 1978	Urban Freeway	119% increase in accident frequency (adjusted)
Paulsen et al. (5) 1978	2-Lane Highway (resurfacing)	61% increase

TABLE 2-1. (Cont'd)

Study	Road Type	Change in Accident Rates During Construction
Wang and Abrams (6) 1981	All Data Combined	28% increase
	Urban Freeway	33% increase
	Rural Freeway	34% increase
	Urban Multilane Divided Roadway	4% decrease
	Urban Multilane Undivided Roadway	21% increase
	Rural Multilane Undivided Roadway	46% increase
	Urban 2- or 3-Lane Roadway	12% decrease
	Rural 2-Lane Roadway	10% increase
Ziejewski (9) 1983	Urban 6-Lane Freeway: 2 lanes open per dir.	17% decrease in accident frequency reported estimated 19% increase in accident rate (based on reported change in traffic volumes during construction)
Kemper et al (10) 1985	Urban 4-Lane Divided Roadway with narrowed lanes (9-ft), reversible lanes, and off-peak lane closures	7% increase (comparing control and construction sections) 30% increase (comparing before-during accidents at construction zone only)
Kuo and Mounce (11) 1986	Urban Freeway with narrowed lanes (10-11 ft)	10% increase
Dudek et al (8) 1986	Rural 4-Lane Divided Roadway 1 lane open per direction	
	-no crossover-	53 to 60 % increase
	-crossover-	34% decrease to 64% increase
Sontagg (12) 1988	Urban 8-Lane Freeway: 2 lanes open per dir. with crossovers	10% increase in accident frequency reported estimated 95% increase in accident rate (based on reported change in traffic volumes during construction)

Data presented in 1981 by Abrams and Wang (6) indicated that accidents at work zone locations increased 28 percent, on the average. Again, systematic differences in accident rate changes were presented, based on roadway type. For example, work zone accidents on freeways (both urban and rural) were found to increase about 33 percent, while accidents at work zones on urban and rural multilane undivided roadways increased 21 and 46 percent, respectively. The technical report from that study and a subsequent implementation guide (7) presented empirical relationships to estimate accident rates during construction. The rate during construction was most strongly related to (1) the accident rate at the location prior to construction, and (2) the increase in volume per lane during construction (because the number of lanes available to traffic were reduced).

Dudek et al. (8) evaluated accident data from nine construction projects on rural four-lane divided roadways utilizing either single-lane closures (no crossovers) or two-lane, two-way operations (TLTWO) (with crossovers). The authors stated that the TLTWO sites had slightly better safety records overall, although there were significant differences in safety among the sites. Accident rates during construction for the single-lane closures increased between 53 and 60 percent. For the TLTWO sites, accident rates during construction ranged from a 34 percent decrease to a 64 percent increase.

More recent data from construction projects in a number of cities is also presented in Table 2-1 from Ziejewski (Chicago) (9), Kemper et al. (Washington, D.C.) (10), Kuo and Mounce (Houston) (11), and Sontagg (Milwaukee) (12). The traffic control plan for the projects discussed by Ziejewski and Sontagg involved long-term lane closures and crossovers to accommodate traffic during construction. Accident frequencies at these projects were reported to have decreased or have increased only slightly during construction. However, traffic volumes during construction at these projects also decreased due to the capacity restrictions imposed. Taking these changes in traffic volumes into consideration (by adjusting the accident frequencies according to the changes in traffic volumes that were reported), it appears that the accident rate at each project increased rather substantially during construction.

In some situations, it is necessary to maintain as much peak-period, peak-direction roadway capacity as possible during construction. In such cases, existing travel lanes are typically narrowed to provide space for the contractor to work while allowing traffic to move through the construction zone in the same number of lanes as existed before construction. Kemper et al. (10) and Kuo and Mounce (11) present data from two projects where this technique was used. Accidents at these projects increased approximately 7 to 10 percent, as shown in Table 2-1.

One of the more important considerations to keep in mind when evaluating the results of an accident investigation is the analysis method that was used. Different analysis methods, because they involve different assumptions, may provide different results when applied to the same data. For example, the analysis presented by both Nemeth and Migletz (3) and Kemper et al. (10) provides an opportunity to compute the effect of construction upon accidents using two standard analysis methods, (1) a before-and-during comparison of accident rates at the construction zone, and (2) a before-and-during comparison utilizing a comparison section as a control. In both studies, considerable differences exist between the changes in accidents during construction estimated using the two methods. Interestingly, the changes were not consistent between studies. Nemeth and Migletz showed a 7 percent increase in accidents based on a before-during comparison of accident rates at the construction site only, and a larger 29 percent increase when a comparison section was included as a control. Conversely, Kemper found a 30 percent increase in accidents when comparing before and during accidents at the construction zone only, but only a 7 percent increase in accidents when a comparison section was included as a control. Unfortunately, tests were not performed to determine whether or not the control sections were actually comparable to the construction zones in these studies. It is possible that one or both of the control sections were not similar to the corresponding construction zone with respect to accident history. It is clear, however, that the analysis method directly affects the results obtained in an accident evaluation.

Types of Accidents Occurring in Work Zones

The question of whether work zone accidents are more or less severe than other accidents continues to be debated, with evidence of both trends present in the literature. Graham et al. (2) found that, overall, neither injury nor fatal accidents increased substantially at the sample of work zones they studied. However, there was considerable variability in the change in severe accidents from site to site. Similarly, Richards and Faulkner (13), Nemeth and Migletz (3), Hargroves and Martin (14), Kemper et al. (10), Rouphail et al. (15), Hall (16), and Pigman and Agent (17) found no evidence of increased accident severity in work zones. In contrast, Flowers and Cook (18) and AASHTO (19) found that work zone accidents may be more severe. Part of the reason for these discrepancies could be due to different analysis methodologies and accident databases. Also, some studies examined all work zone accidents (construction, maintenance, and utility work zones), while others focused on construction zone accidents only.

A number of studies have concluded that work zones typically experience an increase in rear-end accidents. In fact, several studies found rear-end accidents to be the most common type of accident that occurs at work zones, accounting for more than 40 percent of all work zone accidents in some cases (3,13). These studies also report that the second-most common work zone accident is the single vehicle collision with a fixed object. According to the AASHTO study, fixed-object accidents account for approximately 20 percent of the work zone accidents in rural areas and about 14 percent in urban areas. Despite these consistent findings, it is important to realize that variations from these general trends are possible, depending on the work zone. As an example, Lisle (4) showed that the proportion of rear-end accidents at one particular work zone actually decreased from 51 percent before construction to 28 percent during construction. It was the fixed-object accidents that increased dramatically in this work zone, from 19 percent of accidents before construction to 52 percent during construction.

The effect of work zones upon large vehicle accidents has been another area of concern over the years. Richards and Faulkner (13) and Flowers and Cook (18) presented evidence suggesting that large trucks may be over-represented in work zone accidents. Ziejewski (9) reported that large trucks were involved in 38 percent of all accidents during the Edens Expressway reconstruction in Chicago, compared to only 13 percent of the accidents before reconstruction. AASHTO (19) found that combination trucks were involved in 34 percent of the fatal work zone accidents on Interstate highways, compared with a 10 percent involvement rate for other Interstate accidents. The AASHTO study also estimated that tractor-trailers were involved in 17 to 22 percent of all work zone accidents. In contrast, Hall (16) did not find an increase in the accident involvement rate of large trucks in his study of New Mexico construction zones.

Causes or Contributing Factors of Work Zone Accidents

Several studies have examined the possible causes or contributing factors to work zone accidents. Driver error is the most typical contributing factor cited in work zone accidents; Hargroves and Martin (14) estimated that driver error (such things as inattention, improper lane changing, following too closely, etc.) was a contributing factor in 80 percent of work zone accidents, whereas Nemeth and Migletz reported that number to be 86 percent (3). Lisle (4) examined work zone accidents on an Interstate highway in Virginia and found driver inattention contributed to over 48 percent of the accidents. It should be noted, however, that these numbers are not unlike those found for accidents on normal roadway sections. Oglesby and Hicks (20) report that "improper driving, often accompanied by law violations, is in the chain of events leading to 73 percent of the fatal and 83 percent of all highway accidents."

Speed is another factor commonly cited as contributing to work zone accidents. Both Richards and Faulkner (13) and Nemeth and Migletz (3) found that excessive speed was over-represented as a contributing factor in work zone accidents. Kemper et al. (10) found speeding to be a contributing factor in 17 percent of accidents occurring at the construction zones they examined, compared to 7 percent of the accidents occurring at the same locations before construction began. However, excessive speed was not over-represented in the work zone accidents Hargroves and Martin (14) examined; instead, the data indicated that slow-moving vehicles were involved in a greater proportion of work zone accidents than for accidents on normal roadway sections.

Several studies have attempted to determine whether specific work zone objects or features contribute excessively to accidents, but the evidence presented suggests that they do not. Nemeth and Migletz (3) found that work zone features were not often cited as contributing factors of the accident: road defects cited for 4 percent of the work zone accidents, the term "construction" cited in 8 percent of the accidents, and traffic control cited in 3 percent. Kemper et al. (10) reported that 12 percent of all accidents occurred with barricades, cones, machinery, or debris within the construction zone. Finally, Richards and Faulkner (13) indicated that 23 percent of the fixed-object work zone accidents that occurred involved barricades, cones, or warning signs. Another 8 percent of these accidents involved construction or maintenance machinery.

The reported effect of light conditions (daylight versus night or dusk or dawn) upon work zone accidents has also varied from study to study. Graham et al. (2), Richards and Faulkner (13), and Hall (16) found that the proportion of nighttime accidents to total accidents remained constant at the work zone locations examined. However, Lisle (4) reported a shift towards increased nighttime accidents in the work zone database he examined. With respect to accident severity, AASHTO (19) reports that nighttime accidents tended to be more severe at work zones, accounting for over half of the fatal work zone accidents, even though they made up only one-third of all work zone accidents which occurred. Nemeth and Migletz (3) reported that the proportion of tractor-trailer and bus accidents at night and at dawn or dusk were greater than the proportion of accidents during these time periods for other vehicles.

Summary

Although numerous studies have examined work zone accidents, there is little consensus regarding the quantitative implications of work zones upon safety. Tremendous site-to-site variation in work zone traffic control and other characteristics most likely is a chief cause of the widely differing results that have been obtained to date. In addition, different analysis methodologies and accident databases have been used in these studies. Consequently, it is difficult to draw any solid conclusions concerning work zone accidents. Nevertheless, a few trends do exist:

1. Accident rates do tend to increase at work zones. The magnitude of the increase depends on many factors, the most important of which appears to be the type of roadway and traffic control used at the work zone. Data from work zones on urban freeways (4- to 8-lane facilities) suggest that accidents increase approximately 30 percent during construction. Most of the data collected, however, have been for work zones where long-term lane closures were present.

2. Most studies suggest that work zone accidents tend to be less severe than normal accidents. However, at least two studies have presented data to refute this claim.

3. Rear-end accidents tend to increase at work zones. In some situations, single vehicle fixed-object accidents may also increase significantly.

4. Human error is the most frequently reported factor contributing to work zone accidents, as it is for accidents on normal sections of roadway. Excessive or unsafe speeds are also cited quite commonly as a contributing factor.

5. Objects within the work zone, such as channelizing devices, equipment, or debris, do not appear to be involved in an excessive number of work zone accidents.

6. A consensus has not been reached concerning the effect of light condition upon work zone accidents. Intuitively, such an effect would depend heavily on the complexity of the traffic control plan used and the adequacy of traffic control devices used to delineate the proper travel path.

3. ACCIDENTS AT FREEWAY CONSTRUCTION PROJECTS IN TEXAS

Introduction

This chapter presents an analysis of the safety impacts of five major freeway construction projects in Texas during the period 1984 through 1988. Table 3-1 presents a summary of the location, project length, and other salient features of each site. The number of travel lanes at the projects ranged from four to ten, the average daily traffic from 45,000 to 151,000 vehicles per day (vpd), and accident rates before construction from 1 to almost 3 accidents per million vehicle miles (mvm). Detailed descriptions and maps of each study site are presented in the appendices.

None of the projects required permanent lane closures on the freeway during construction. Instead, work areas were created in the median and between the freeway mainlanes and frontage road, and were separated from mainlane traffic with portable concrete barriers. Shoulders were narrowed or eliminated, lanes at some locations were narrowed, and lanes were shifted laterally within the right-of-way as the project progressed through the complex construction sequence. Temporary freeway lane closures were generally allowed during off-peak conditions (daylight and nighttime), although the frequency with which lanes were actually closed varied from project to project.

Two phases of the I-45 (North Freeway) project in Houston were examined. In the first phase, a barrier-separated interim high occupancy vehicle (HOV) lane was constructed in the freeway median, and work activities were limited to the median. During the second phase, the HOV lane was expanded in conjunction with freeway and frontage road widening and upgrading. During this phase, traffic on the freeway was disrupted more significantly due to lane closures, ramp closures, and lateral shifts in travel lanes. Consequently, the two phases were analyzed separately and then combined into an overall assessment. Similarly, the I-10 construction project in El Paso consisted of four discrete segments. Accidents were considered for each segment separately as well as for the project length as a whole.

The I-35W project in Ft. Worth was also divided into two distinct phases. During Phase I, traffic was maintained in the two existing travel lanes per direction (with little or no shoulders and portable concrete barrier on both sides) while work was performed in the median, between the freeway and frontage road, and along the frontage road. During Phase II, the traffic was moved onto two new freeway travel lanes in each direction while work progressed on rehabilitating the existing travel lanes. However, only six months of during construction data were available for Phase II at the time of this analysis, so only Phase I was examined.

The I-35 project in Austin and US-75 project in Plano also consisted of several construction phases. However, the traffic control plans for the phases and the resulting impacts on traffic were similar enough that separate analyses were not required.

TABLE 3-1. SUMMARY OF PROJECT LOCATIONS

			Conditions Before Construction			
Site	Location	Project Limits	Number of Lanes	Average Daily Traffic (VPD)	Accidents per MVM	Project Duration
1	I-45 Houston	North Shepard to Quitman (7.8 mi)	6- to 10-Lane Divided	151,000 (1984)	2.165	Jan 84 - Nov 84 (Ph. I) Mar 85 - May 87 (Ph. II)
2	I-10, El Paso	Seg. I: McRae to Lomaland (2.5 mi)	4-Lane Divided	68,500 (1984)	2.150	Jan 85 - Nov 86
		Seg. II: Ft Bliss RR to McRae(2.7 mi)	6-Lane Divided	126,500 (1985)	1.604	Jun 86 - Nov 89
		Seg. III: Chelsea St. to Ft Bliss RR (1.7 mi)	6-Lane Divided	135,000 (1985)	2.367	Nov 86 - Mar 90
		Seg. IV:Lomaland to Zaragosa (2.2 mi)	4-Lane Divided	45,000 (1986)	1.024	Aug 87 - Dec 89
		Seg. I-IV Average (9.1 mi)		92,500	1.855	
3	I-35, Austin	Yagar Ln to US 290 (5.9 mi)	4- to 6-Lane Divided	82,500 (1985)	1.295	Nov 86 - Aug 88
4	I-35W, Ft. Worth	I-20 to south of I-30 (6.4 mi)	4-Lane Divided	58,000 (1983)	2.919	Sep 84 - Jun 88 (Ph. I) Jun 88 - May 89 (Ph. II)
5	US-75, Plano	Plano Pkwy to Spring Creek Pkwy (3.4 mi)	4-Lane Divided	77,500 (1986)	1.303	Jun 87 - Sep 89

In addition to the mainlane construction work, the projects also included work on the frontage roads. The intensity of the work varied among projects. At the I-10 site in El Paso, frontage road work was limited primarily to turn-around lane construction at selected diamond interchanges and some intersection widening. In contrast, the US-75 project in Plano involved extensive drainage construction under the frontage roads as well as frontage road widening along a majority of the project.

Analysis Procedure

Accident data for each of the project locations were obtained from the Texas Department of Public Safety's Master Accident Files. Information about each reported accident occurring on the state highway system is maintained in the file. The limits of each construction project were located by control number, section number, and milepoint as designated by the TxDOT Roadway Inventory system; and all accidents (both directions of travel on the freeway and frontage roads) within those project limits were extracted from the Master Accident File. Some may argue that the analysis of all accidents within a given construction section is inappropriate because it will include those accidents not really due to the presence of construction. It is the opinion of the researchers, however, that one cannot ever be sure that an accident was or was not attributable to the presence of construction. Accidents coded as due to other factors may in fact been indirectly related to the presence of construction. Thus, the analysis of the changes in all accidents occurring within a given section of roadway undergoing construction is believed to be a stronger predictor of the true effect of construction. Furthermore, highway officials wishing to use the results of this study to predict accident impacts at future construction projects will have to base the analysis upon the historical data of all accidents for that roadway section.

A before-during comparison of accidents was performed for each project, utilizing comparison section and a check for comparability between the construction project and comparison section as specified by Griffin (20). For most of the projects, the comparison section was located immediately upstream or downstream of of the construction section. At projects where traffic and other conditions varied from one end to the other, however, sections on both ends of the construction section were used together to provide a composite comparison section. The use of comparison sections helps to factor out many of the extraneous factors (including year-to-year changes in traffic conditions, weather, and accident reporting procedures) that may influence the number of reported accidents at a location. It is assumed that the changes in year-to-year accident trends at the comparison section would also have occurred at the construction section if construction would not have been ongoing at the site. The differences in year-to-year trends between the construction project and the comparison section are then assumed to be due to the presence of construction.

Griffin recommends that multiple years of before data be collected and analyzed in order to maximize the strength of the study. Two or three years of before data at each construction project location (and corresponding comparison sections) were collected. The similarity of accident trends between the construction sections and comparison sections before construction were tested using the maximum-likelihood goodness-of-fit test presented by Griffin (20) to insure that the comparison sections selected for each site were comparable to the construction sections in terms of year-to-year accident trends. Data during construction at both the construction project location and the comparison sections were also obtained, and the comparability of year-to-year accident trends during construction was also checked. At the time of this analysis, data were available only through 1988. The I-10, I-35W, and US-75 projects continued beyond 1988, but only data through 1988 were analyzed.

Analyses were first performed separately for each project. The results from each project were also combined into a multiple before-during analysis with paired comparison ratios (21). The results of the combined analysis provide a proper overall estimate of the percentage change in accidents across all projects, along with a test of the statistical significance of the change. A detailed description of the statistical analysis procedures is provided in Appendix A. Data, statistical test results, and a discussion of the results for each individual project are provided in separate appendices (B through F).

The change in the total number of accidents at each site was of particular interest in this study. The effect of construction was also determined for accidents in each of the following categories:

1. Severity (property damage only, injuries plus fatalities),
2. Time of day (daytime, nighttime (including dusk and dawn)), and
3. Type (single-vehicle, multi-vehicle rear-end, other multi-vehicle).

Separate analyses were conducted for the freeway mainlanes and for the adjacent frontage roads because of their differences in geometry and traffic characteristics. The results confirm that construction has a somewhat different effect upon the two roadway types, and that separate analyses are appropriate.

Results

Mainlane Accidents

More than 21,000 accidents were examined before and during construction at the five construction projects and corresponding comparison sections. Table 3-2 summarizes the effects of construction upon mainlane accidents. The average increase in total accidents at the five construction projects was 28.7 percent. Furthermore, severe accidents (injuries plus fatalities) increased by a greater percentage (38.8 percent) than property damage only (PDO) accidents (24.9 percent). Daytime accidents increased 24.5 percent during construction, compared to a 37.4 percent increase in nighttime accidents. With respect to accident type, rear-end accidents increased an average of 45.7 percent during construction. This increase was greater than for either single vehicle accidents (13.9 percent) or other multi-vehicle (side-swipe, angular collisions, etc.) accidents (14.7

TABLE 3-2. EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS (ALL SITES COMBINED)

Accident Category	Change in Accidents During Construction	Significance of Change (Z-Statistic)	Chi-Square Value for Test of Homogeneity
All Accidents	+28.7%*	7.724	14.967
Accident Severity:			
PDO Accidents	+24.9%*	5.405	18.129**
Severe Accidents	+38.8%*	6.070	4.798
Time-of-Day Distribution:			
Daytime Accidents	+24.4%*	5.457	19.804**
Nighttime Accidents	+37.4%*	5.589	22.550**
Accident Type:			
Single Vehicle	+13.9%*	2.054	8.991
Rear-end Multi-Vehicle	+45.7%*	7.751	17.242**
Other Multi-Vehicle	+14.7%*	2.157	11.489

* Change is statistically significant at 0.05 level of significance

** The hypothesis that the data from the projects are homogenous is rejected because the observed X^2 value exceeds X^2_{crit} = 15.507 (0.05 level of significance, 8 degrees of freedom) percent). All of the changes were statistically significant at a 5 percent level of significance. That is, no more than a 5 percent chance exists that the changes observed were due to the random variability of the accidents and that no true change in accidents actually occurred.

The averages presented in Table 3-2 must be interpreted carefully, however, due to the considerable variability in results of some of the accident categories among the five projects. This variability is illustrated in Figures 3-1 through 3-4.

Figure 3-1 summarizes the effect of construction upon total accidents at each of the five projects. The increase in accidents ranged from 13.3 percent at the US-75 project in Plano, to 38.8 percent at the I-35 project in Austin.

The effect of construction upon accident severity is illustrated in Figure 3-2. The variation in the effects on PDO accidents is quite dramatic, ranging from a 2.8 percent decrease to a 45.6 percent increase. In comparison, the increase in severe accidents was somewhat more consistent, ranging from 31.2 to 62.7 percent.

Figure 3-3 illustrates the changes in daytime and nighttime accidents at each project. The changes in daytime accidents varied widely, with increases ranging from 2.3 percent to 52.4 percent. Nighttime accidents increased between 8.4 percent and 63.2 percent during construction. The increases in nighttime accidents were markedly higher than the increases in daytime accidents at four of the five projects. Unfortunately, the data from the Master Accident File are not sufficiently detailed to determine why nighttime accidents increased by a larger percentage than daytime accidents (i.e., whether it was due to the nature of the construction activity and/or traffic control during the evening hours, a visibility/delineation deficiency in the traffic control plan during twilight conditions, or some other factor). Although nighttime accidents make up only about one-third of the total accidents occurring at each site, the magnitude of the increases observed at these projects is reason for some concern.

A summary of the changes by accident type (single vehicle, rear-end, other multi-vehicle) is provided in Figure 3-4. No clear patterns are evident among the five projects. Single vehicle accidents fluctuated from a 4.1 percent decrease to a 54.3 percent increase. The effect of construction upon rear-end accidents ranged from a 14.1 percent decrease to a 74.9 percent increase. Likewise, the effect of construction upon other multi-vehicle accidents varied from a 22.8 percent decrease to a 42.2 percent increase.

A formal statistical test of the variability of the accident changes between projects is also presented in Table 3-2. The details of the procedure are included in Appendix A. A logit chi-square test was employed to test the degree of homogeneity, or similarity, of the results obtained from the five projects. If projects are determined to be homogenous in terms of their effects upon accidents, the overall average values presented in Table 3-2 can be considered to be good estimators of the effect of construction. However, if they are not homogenous, then the variability in effects between projects is too large for the overall values to be considered meaningful.

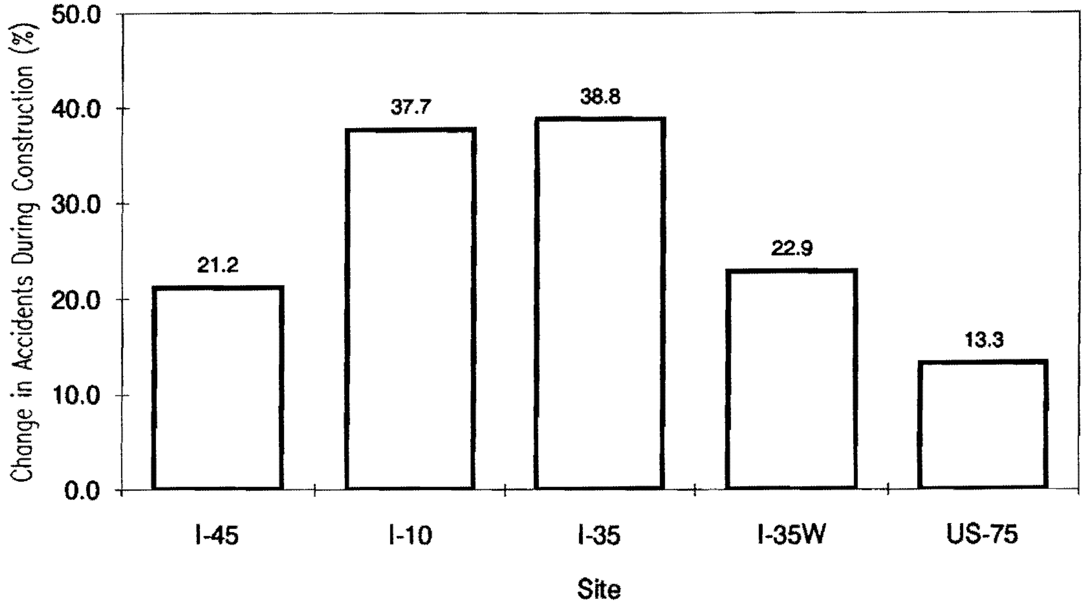

Figure 3-1. Effect of Construction upon Total Mainlane Accidents (Site-By-Site)

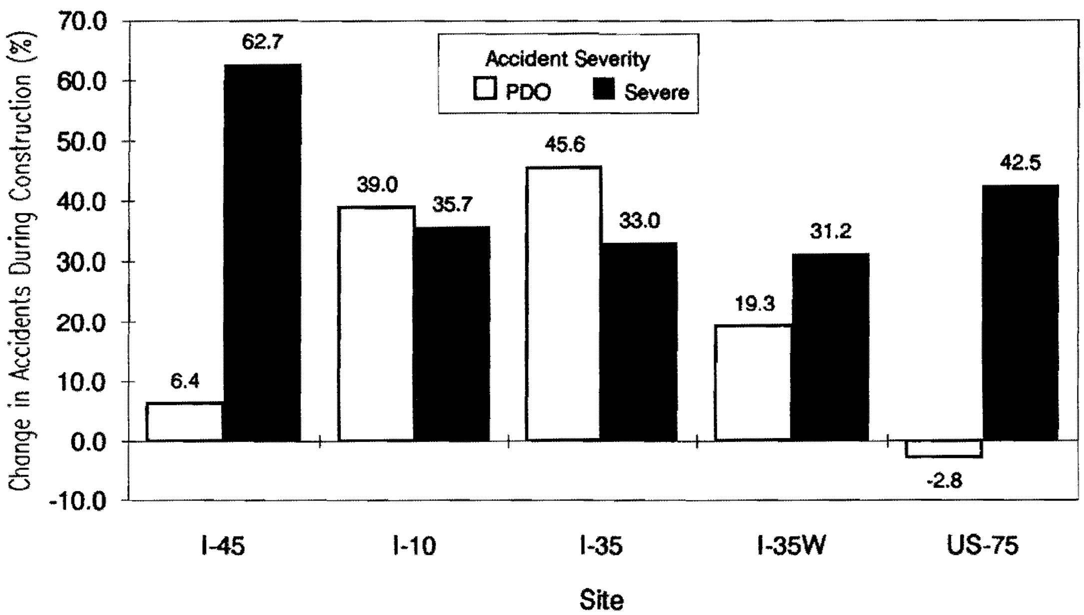

Figure 3-2. Effect of Construction Upon Mainlane Accident Severity (Site-By-Site)

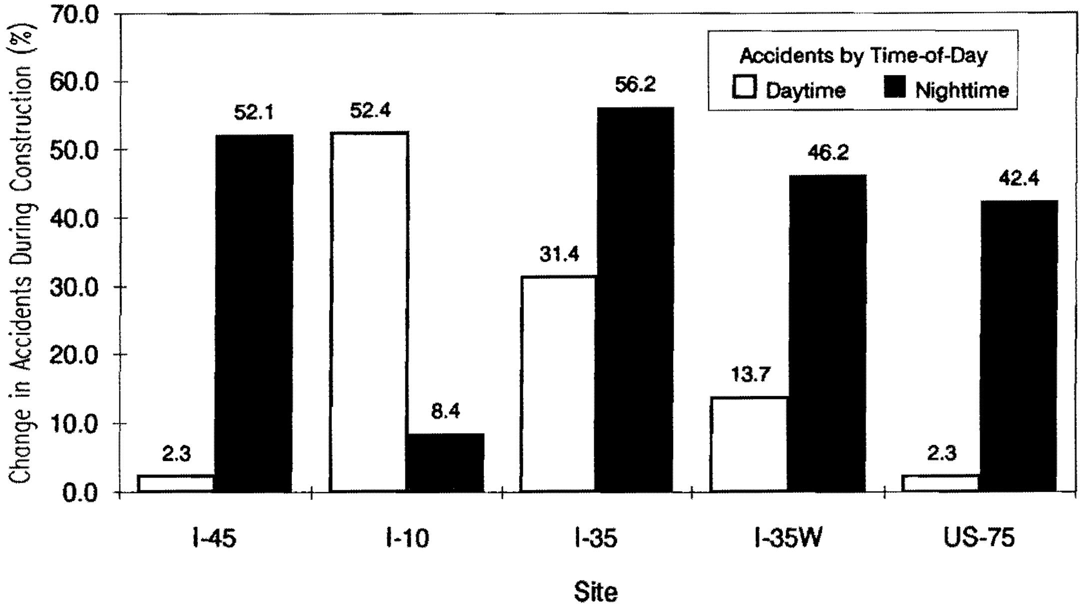

Figure 3-3. Effect of Construction Upon the Time-of-Day Distribution of Mainlane Accidents (Site-by-Site)

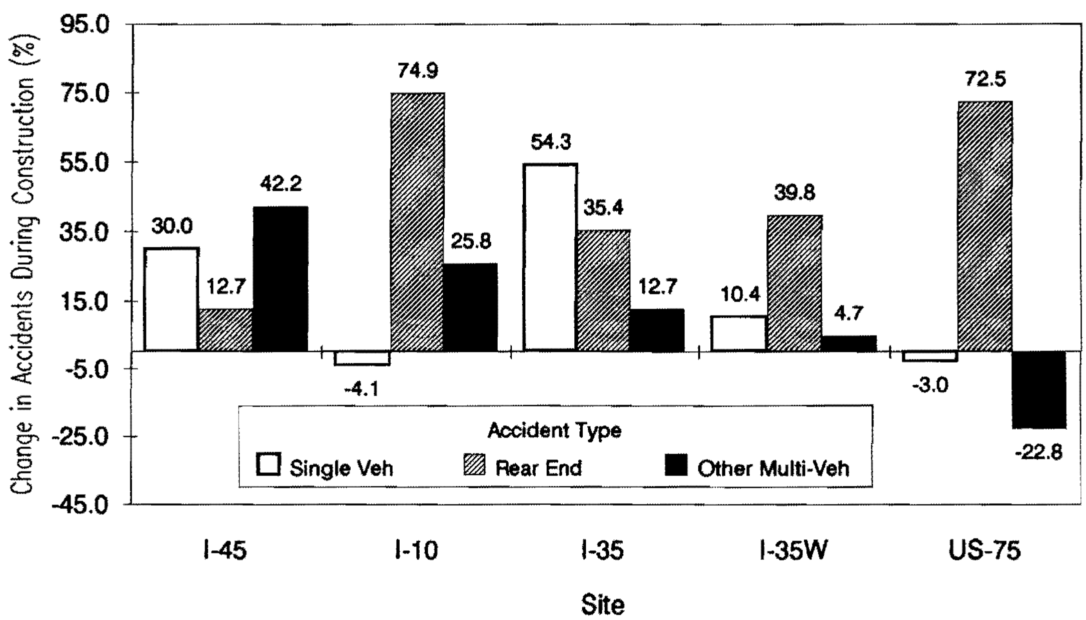

Figure 3-4. Effect of Construction Upon Mainlane Accident Type (Site-by Site)

A homogeneity statistic was calculated for the total accidents and for each accident category examined previously. These results, shown in Table 3-2, indicate that the five projects were reasonably similar in terms of changes in total accidents during construction. Likewise, the changes in severe accidents, single vehicle accidents, and other multi-vehicle accidents were found to be statistically similar. Conversely, the changes in PDO accidents were significantly dissimilar from project to project, as were changes in daytime and nighttime accidents, and the change in rear-end accidents. Caution should be exercised when drawing inferences or making predictions about these categories based on the overall changes reported.

Frontage Road Accidents

The frontage road analysis included more than 14,000 accidents at the construction projects and corresponding comparison sections. The effect of construction upon frontage road accidents is summarized in Table 3-3. Overall, construction had minimal effect upon accidents. On the average, total frontage road accidents increased only 2.4 percent during construction. PDO accidents also increased an average of 2.4 percent during construction, whereas severe accidents increased 3.8 percent. Nighttime accidents increased 2.8 percent during construction, compared to a 2.7 percent increase in daytime accidents. During construction, single vehicle accidents on the frontage road increased an average of 4.6 percent, and other multi-vehicle accidents increased 8.9 percent; whereas rear-end accidents decreased 6.1 percent. None of the changes reported in Table 3-3 were statistically significant at a 5 percent level of significance. Thus, one cannot conclude that frontage road accidents were truly affected by the presence of construction at these sites.

The variability among projects is perhaps more important than the overall accident changes reported for the frontage road. Project-by-project comparisons of the changes in frontage road accidents are presented in Figures 3-5 through 3-8.

Figure 3-5 shows the change in total frontage road accidents for each project. Changes ranged from a 6.3 percent decrease at the I-45 project to a 27.7 percent increase at the I-35W project. Four of the five projects experienced changes (increases or decreases) of less than 7 percent. Therefore, the large increase at the I-35W project was the exception rather than the rule. Unfortunately, the reason for the much larger increase in accidents at that location can not be determined conclusively from the data in the Master Accident File. Conversations with Department personnel involved in the project (22) suggest that increased traffic on the frontage road due to some ramp closures may have been partially responsible for the increase. Another partial explanation suggested was that, because of space limitations, certain entrance ramps had very short acceleration lanes during some steps in the construction process. A number of accidents occurred at these ramps, and some may have been coded as occurring on the frontage road. Also, merging onto the freeway was difficult at these ramps, sometimes causing traffic to back up the ramp onto the frontage road and causing accidents.

TABLE 3-3. EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS (ALL SITES COMBINED)

Accident Category	Change in Accidents During Construction	Significance of Change (Z-Statistic)	Chi-Square Value for Test of Homogeneity
All Accidents	+2.4%	0.607	13.240
Accident Severity:			
PDO Accidents	+2.4%	0.512	6.006
Severe Accidents	+3.8%	1.038	22.249**
Time-of-Day Distribution:			
Daytime Accidents	+2.7%	0.582	7.240
Nighttime Accidents	+2.8%	0.386	10.816
Accident Type:			
Single Vehicle	+4.6%	0.400	21.237**
Rear-end Multi-Vehicle	-6.1%	-0.843	12.536
Other Multi-Vehicle	+8.9%	1.699	8.982

* Change is statistically significant at 0.05 level of significance

** The hypothesis that the data from the projects are homogenous is rejected because the observed X^2 value exceeds X^2_{crit} = 15.507 (0.05 level of significance, 8 degrees of freedom)

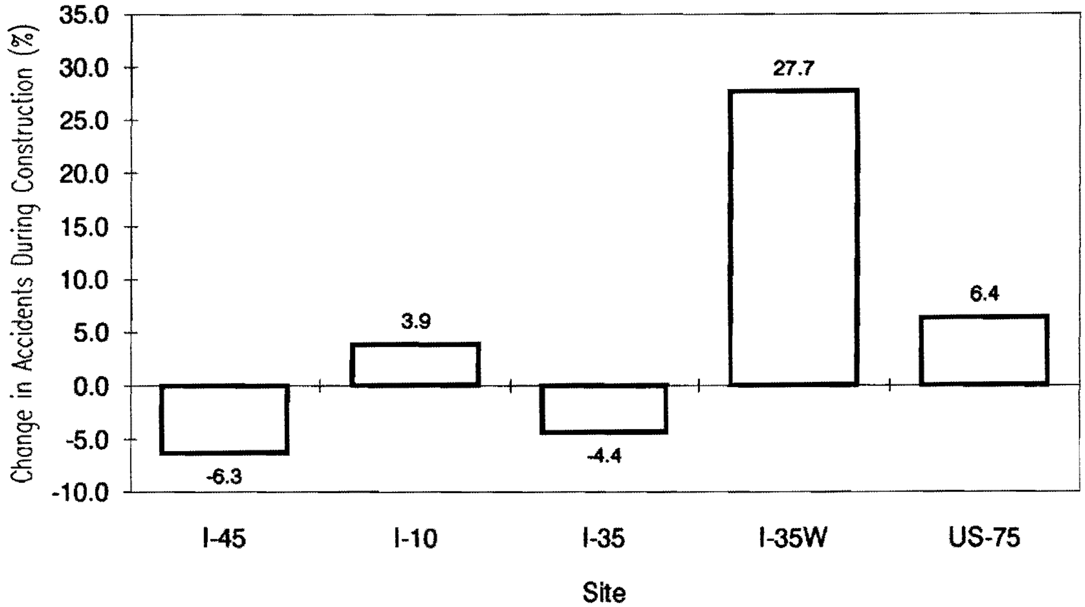

Figure 3-5. Effect of Construction Upon
Total Frontage Road Accidents (Site-By-Site)

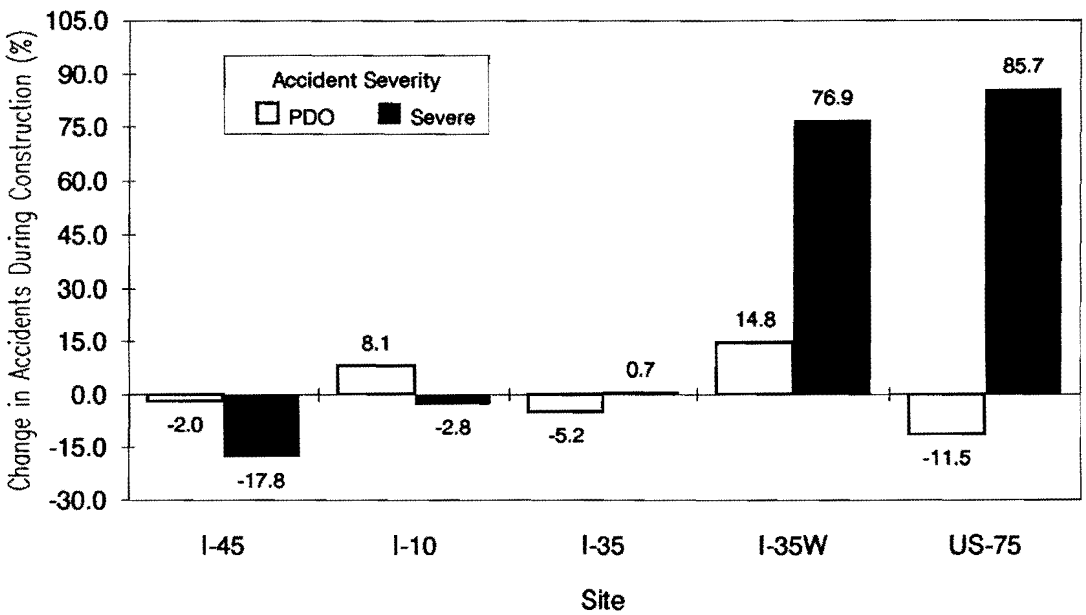

Figure 3-6. Effect of Construction Upon
Frontage Road Accident Severity (Site-By-Site)

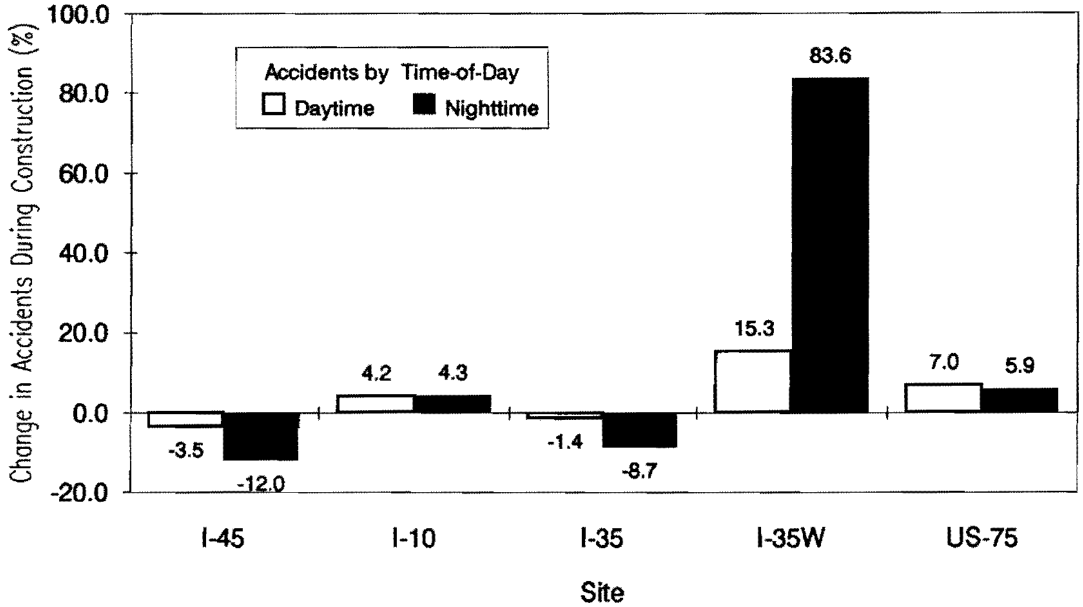

Figure 3-3. Effect of Construction Upon the Time-of-Day Distribution of Frontage Road Accidents (Site-by-Site)

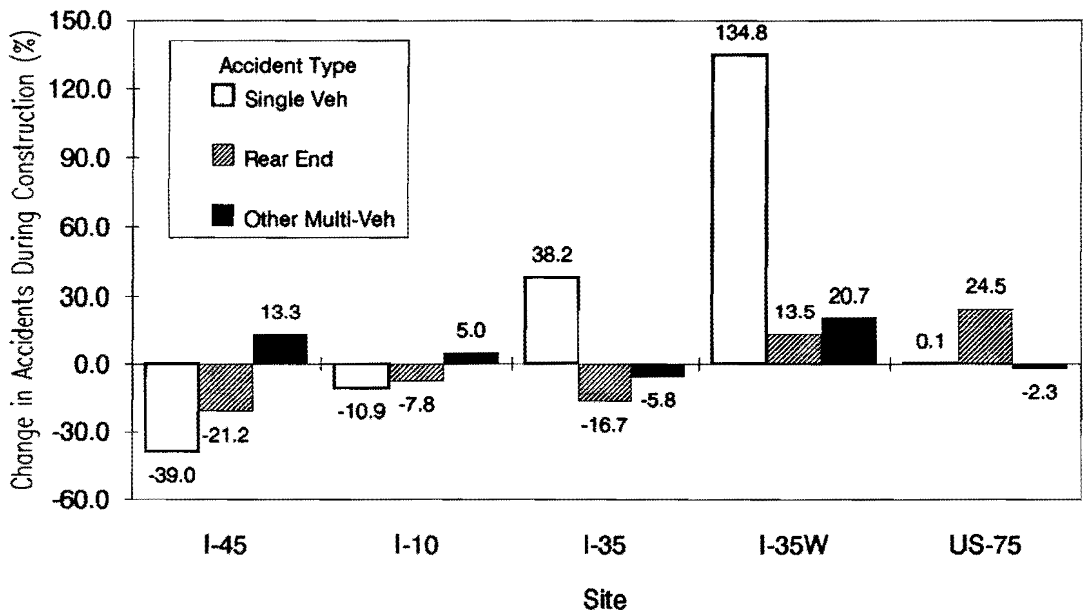

Figure 3-4. Effect of Construction Upon Frontage Road Accident Type (Site-by Site)

The effect of construction upon frontage road accident severity is displayed in Figure 3-6. Large increases in severe accidents were observed at the I-35W and US-75 projects (76.9 percent and 85.7 percent, respectively). The increases in total frontage road accidents at these two projects were primarily in the severe accident category. The change in severe accidents at the other three projects ranged from a 17.8 percent decrease to a 0.7 percent increase. The change in PDO accidents was fairly small at all of the projects, ranging from an 11.5 percent decrease to a 14.8 percent increase.

Figure 3-7 illustrates the change in frontage road accidents at each project by time-of-day. Nighttime accidents at the I-35W site increased 83.6 percent during construction. Conversely, nighttime accidents at the other projects increased less than 6 percent during construction. Daytime frontage road accidents were not significantly affected, with a 15.3 percent increase at the I-35W site the largest change observed.

Figure 3-8 summarizes the accident changes by type of accident that occurred at each project. No clear patterns are present in the data. However, the large 134.8 percent increase in single vehicle accidents at the I-35W project does stand out. This increase, together with the large increase in the severe and nighttime accident categories, suggests that the construction activities on the frontage roads during the I-35W project produced (by Texas standards) unusually large increases in severe, nighttime, single-vehicle accidents. As stated previously, changes in ramp locations and conditions during construction may be partially responsible for the increases, but this cannot be determined conclusively from the data in the Master Accident File.

The last column in Table 3-3 presents the results of the statistical tests of homogeneity between projects for the frontage road accidents. The results of the tests indicate that only the changes in severe accidents and single vehicle accidents were not similar from a statistical standpoint. Such a result was expected given the small changes at four of the five projects together with the large increases in these accidents at the I-35W project. The other accident categories, including total accidents, did not show evidence to reject the assumption of homogeneity.

Summary

This chapter has presented an evaluation of the accident experience at five long-term freeway construction projects in Texas during 1984 through 1988. The effects of construction upon both mainlane and frontage road accidents were analyzed. The major findings of the analysis are summarized below.

Mainlanes

1. Accidents increased an average of 28.7 percent during construction. Increases at individual projects ranged from 13.3 to 38.8 percent. The changes from project to project were found to be statistically similar, so that the average increase can be

considered a good predictor of the change in accidents expected at these types of construction projects.

2. Severe (injury or fatality) accidents increased an average of 38.8 percent, compared to an average 24.9 percent increase for PDO accidents. The results suggest that accidents during construction tended to be more severe than normal. The average change in severe accidents was statistically similar among the projects. However, the change in PDO accidents varied significantly from project to project. Therefore, caution must be used applying the average change in PDO accidents to other projects.

3. Nighttime accidents increased an average of 37.4 percent during construction, compared to a 24.4 percent increase in daytime accidents. Again, however, project-to-project variations in these changes are significant, and caution must be exercised when using the overall changes.

4. On the average, rear-end accidents increased more than single vehicle or other multi-vehicle accidents (45.7 percent compared to 13.9 and 14.7 percent increases, respectively). Significant project-to-project variation of the changes in rear-end accidents was detected with the homogeneity test. The variations of changes in single vehicle and other multi-vehicle accidents were not statistically significant.

Frontage Road

1. On the average, construction had a minimal effect upon frontage road accidents, with only an average 2.4 percent increase observed at the sites. This increase was not found to be statistically significant. On a project-project basis, two sites experienced slight decreases in accidents, two sites experienced increases of approximately 4 to 6 percent, and the remaining site experienced an almost 28 percent increase.

2. Severe frontage road accidents increased an average of 3.8 percent during construction, compared to a 2.4 percent increase in PDO accidents. The increase in severe accidents was influenced by large increases (76.9 percent and 85.7 percent) at two of the five sites. Consequently, the project-to-project variation of severe accident changes was found to be significant (based on the homogeneity test).

3. Nighttime accidents increased an average 2.8 percent during construction. Meanwhile, daytime accidents increased 2.7 percent.

4. Single vehicle and other multi-vehicle accidents increased 4.6 and 8.9 percent, respectively, during construction. In comparison, rear-end accidents decreased 6.1 percent overall. Significant project-to-project variation was detected for the changes in single vehicle accidents, however.

4. SUMMARY OF FINDINGS

This report has presented an analysis of accidents at five long-term freeway construction projects in Texas during 1984 - 1988. Data were collected from each project for two to three years prior to construction and for all years during construction through 1988. Mainlane and frontage road accidents were examined separately. The results of the analysis from each site were presented, and these data were also consolidated to determine the average effect of construction upon mainlane and frontage road accidents.

Overall, total accidents on the mainlanes increased 28.7 percent during construction. Severe accidents on the mainlanes increased by a greater percentage, on the average, than did PDO accidents (38.8 percent versus 24.9 percent). These data suggest that the accidents during construction tended to be more severe than normal. Nighttime accidents on the mainlanes increased by a greater proportion than did daytime accidents (37.4 percent versus 24.4). Unfortunately, the data from the Master Accident File is not sufficiently detailed to determine conclusively why nighttime accidents or severe accidents increased by a greater percentage during construction.

Overall, frontage road accidents at the five projects increased by only 2.4 percent during construction. The changes in PDO and severe accidents, daytime and nighttime accidents, and in the various accident type categories were also found to be negligible. However, one site experienced a 27.7 percent increase in frontage road accidents. Again, it was not possible to ascertain why frontage road accidents increased so much more at that site.

The results also suggest that the effect of construction varies to some degree from project to project, a result which has been demonstrated in numerous past studies documented in the literature. When averaged, accidents at the five projects were found to have increased almost 30 percent during construction. This figure is similar to that reported by Wang and Abrams (6) for urban freeway construction projects, but is larger than the 10 percent increase found by Kuo and Mounce (11) during the I-10 (Katy Freeway) construction project in Houston. The differences observed are likely to be due in part to differences in conditions among the projects and in part to differences in accident analysis procedures. Statistically speaking, however, the average changes in total accidents, severe accidents, single vehicle accidents, and multi-vehicle accidents (other than rear-end accidents) were consistent enough from project to project to be considered good estimates of the magnitude of changes expected at similar types of future construction projects in Texas.

The greater increase in severe accidents is somewhat contradictory to those of a number of researchers (2, 13-17) who found that accident severity decreased, or at least remained constant, at the work zones examined in their studies. However, the traffic control plan for the projects examined in this study did not require long-term lane closures. This allowed traffic speeds to remain fairly high during construction, which may be one reason for the increase in accident severity.

The results presented in this report add to the existing body of knowledge concerning the effects of roadway construction upon traffic safety. The report provides information that will be immediately useful in planning future construction projects in Texas. Specifically, the average changes in accidents during construction can be used to estimate the expected additional accident costs during a project. These additional accident costs are one component of the total cost of a project that should be considered in project planning.

Additional research is needed to further quantify the effects of construction upon accidents and, specifically, to develop a better understanding of how site-specific conditions at a construction project influence accidents. The projects used in this study were fairly uniform (five major construction projects on urban freeways with no long-term lane closures), yet the effect of construction varied from 13 percent to almost 40 percent, depending on the project. The Master Accident File does not include many important details about accidents occurring in a work zone. In particular, the details of the traffic control plan--including lane and shoulder widths, ramp geometry, advance signing, lighting, type and location of channelizing devices, and the nature of the work activity--are not included. More detailed studies will be needed in order to determine the effects of these specific traffic control and geometric design features on accidents in construction zones so that highway agencies can make more cost-effective decisions about those design features within construction zones that affect safety.

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APPENDIX A: STATISTICAL PROCEDURES

To compute the effect of construction upon accidents at one or more projects, it was necessary to isolate the effect of construction from the multitude of other factors that influence accidents and add to the typically substantial variation in accidents observed over time. The effect of construction at a project is computed as a proportional change between the number of accidents observed during construction and the number that would have been expected at that location during the same period of time if construction had not been present. In equation form, this is written as:

$$\frac{Accidents_{Observed} - Accidents_{Expected}}{Accidents_{Expected}}$$

or,

$$\frac{Accidents_{Observed}}{Accidents_{Expected}} - 1$$

In order to estimate the accidents that would have been expected at a project location during the construction period if no construction had occurred, a comparison section was selected immediately adjacent to each construction project. It is assumed that the accident trends over time at the comparison section would have been mimicked at the construction project location if no construction had occurred.

Two to three years of data before construction were collected for the construction project section and adjacent comparison section. In order to draw correct conclusions using a comparison section, it must be determined that the section is actually comparable to the construction project section in terms of accident trends. Griffin (20) has provided a method for checking the comparability of two sections using a likelihood ratio chi-square test. The comparability of the construction and comparison sections were tested for the years before construction as well as for the years during construction.

For a given time period (i.e., before construction or during construction), the comparability of sections was determined using the following equation (20):

$$G^2 = -2\sum_i \left(Comp_i * \ln\left(\frac{E[Comp_i]}{Comp_i}\right) + Cons_i * \ln\left(\frac{E[Cons_i]}{Cons_i}\right)\right)$$

where:

$Comp_i$ = Accidents in comparison section for year i of the period being analyzed (before-construction period or during-construction period)

$Cons_i$ = Accidents in construction section for year i of the period analyzed

E[ ] = Expected value of comparison or construction section during year i.

The expected value for each section for each year was computed as follows:

$$E\,[Comp_i] = \frac{\sum_i Comp_i}{\sum_i (Comp_i + Cons_i)} * (Comp_i + Cons_i)$$

The resulting G^2 statistic was compared to a chi-square distribution with the degrees of freedom equal to the number of years in analysis period minus 1. If the G^2 value did not exceed the critical value, then it was assumed that the construction section and comparison section were comparable in terms of accidents for that analysis period.

Once comparability between the construction and comparison sections was established, the ratio of the number of observed accidents at the construction section during construction to the expected number of accidents at the construction zone during construction was computed. The expected number of accidents during construction was computed as the number of accidents before construction at the construction zone times the ratio of accidents during construction to before construction at the comparison section, as illustrated below:

$$E\,[Cons_{During}] = Cons_{Before} \left(\frac{Comp_{During}}{Comp_{Before}} \right)$$

$Cons_{Before}$ = Number of accidents in the construction section in the before construction analysis period

$Cons_{During}$ = Number of accidents in the construction section in the during construction analysis period

$Comp_{Before}$ = Number of accidents in the comparison section in the before construction analysis period

$Comp_{During}$ = Number of accidents in the comparison section in the during construction analysis period

In order to test the statistical significance of the change in accidents at the construction zone, the ratio of observed accidents to expected accidents during construction was transformed by taking its natural logarithm. This transformed ratio has a normal distribution. The variance of this transformed ratio is estimated by the sum of the inverses of the sample sizes before and during construction at the construction and comparison sections.

$$Var\left(\frac{Cons_{During}}{E\,[Cons_{During}]}\right) = \frac{1}{Comp_{Before}} + \frac{1}{Comp_{During}} + \frac{1}{Cons_{Before}} + \frac{1}{Cons_{During}}$$

A Z-statistic to test the significance of the transformed ratio is computed as follows:

$$Z = \frac{\ln\left(\frac{Cons_{During}}{E\,[Cons_{During}]}\right)}{\sqrt{Var\left(\frac{Cons_{During}}{E\,[Cons_{During}]}\right)}} = \frac{\ln\left(\frac{Cons_{During} * Comp_{Before}}{Cons_{Before} * Comp_{During}}\right)}{\sqrt{\frac{1}{Comp_{Before}} + \frac{1}{Comp_{During}} + \frac{1}{Cons_{Before}} + \frac{1}{Cons_{During}}}}$$

This value was then compared to a critical value from a Normal distribution at a given level of significance. If the Z-statistic exceeded the critical value, then the change in accidents was statistically significant.

When analysis for each individual project was completed, the next step was to combine the data from each project so as to develop an estimate of the overall effect of construction. According to Griffin (21), the best estimate of the effect of a treatment (in this case, construction) at multiple locations is the weighted average of the estimated effect at each location, with the weights equal to the reciprocal of the variances of each estimate. In this way, the estimates from locations that have larger numbers of accidents before and during construction will carry more weight in the average than the locations with fewer accidents before and during construction. The computations of the average change (the subscripted n is used to designate a given project n) are:

$$T = \frac{\sum_n W_n \left(\frac{Observed_{During}}{Expected_{During}}\right)_n}{\sum_n W_n}$$

$$W_n = \frac{1}{Var\left(\ln\left(\frac{Observed_{During}}{Expected_{During}}\right)_n\right)} = \frac{1}{\left(\frac{1}{Comp_{before}} + \frac{1}{Comp_{during}} + \frac{1}{Cons_{before}} + \frac{1}{Cons_{during}}\right)_n}$$

T = Average change in accidents at the construction projects during construction

W_n = Weighting factor for change in accidents at project n

The variance of the average change is the reciprocal of the sum of the weights for each project:

$$Var(\bar{T}) = \frac{1}{\sum_n W_n}$$

A Z-Statistic is calculated based on the estimated average change and the estimated variance of the average change:

$$Z = \frac{\mathrm{T}}{\sqrt{Var\ (\bar{\mathrm{T}})}} = \frac{\mathrm{T}}{\sqrt{\frac{1}{\sum_n W_n}}}$$

The final set of computations was performed to test the homogeneity, or similarity, of the changes in accidents at each project. This test provided an indication of the validity of the overall changes estimated. If the changes from project to project are not homogeneous, then the overall changes estimated (using the weighted average procedure described above) must be used with caution, because considerable variability exists with respect to the effects of construction from project to project.

The test for homogeneity between sites was based on a logit chi-square test described by Griffin (21). A X^2_{Total} statistic was first calculated. This statistic represents the total deviation of the data from a no-change condition, summed over all sites.

$$X^2_{Total} = \sum_n W_n \left(\ln \left(\frac{Observed_{During}}{Expected_{During}} \right)_n \right)^2$$

This statistic can be thought of as similar to the total sum of the squares computed for typical analysis of variance. The degrees of freedom for this statistic is equal to the number of projects, n.

The chi-square total is divided into two components: chi-square association, representing the degree to which the average change over all projects is different from zero; and chi-square homogeneity, representing the deviation of the changes at each project about the overall average change. Chi-square association is simply the square of the Z-statistic for testing the significance of the average change as described previously, and can be thought of as similar to the treatment sum of the squares computed in a typical analysis of variance. One degree of freedom is associated with chi-square association. Chi-square homogeneity is the difference between chi-square total and chi-square association, and can be viewed as similar to the error sum of the squares in an analysis of variance.

$$X^2_{homogeneity} = X^2_{total} - X^2_{association} = \sum_n W_n \left(\frac{Observed_{during}}{Expected_{during}} \right)_n - \frac{T^2}{\frac{1}{\sum_n W_n}}$$

The degrees of freedom associated with the chi-square homogeneity are equal to the number of projects minus 1.

APPENDIX B: I-45, NORTH FREEWAY, HOUSTON

Introduction

The I-45 North Freeway serves the northern part of Houston and Harris County. In 1982, TxDOT and the Metropolitan Transit Authority of Harris County (METRO) agreed to develop a reversible HOV transitway in the median of the freeway to replace the contra-flow lane which had operated since 1979. The construction of the transitway occurred in conjunction with a general corridor-wide improvement project that included bridge widening, pavement improvements, better lighting and drainage, and capacity improvements on both the freeway and adjacent frontage road.

The project was divided into four phases. In the first phase, an interim transitway was established in the freeway median, separated from the mainlanes by concrete barrier. The transitway extended from downtown Houston to North Shepard drive (see Figure B-1). Phase II then improved the interim transitway and included the freeway/frontage road improvements from downtown to North Shepard. Phases III and IV continue the transitway and freeway corridor widening and improvements further north. A number of reports have been prepared documenting the experiences of the project on both mainlane and transitway traffic (23-25).

This accident analysis focuses on Phases I and II, the portion of the project from downtown Houston to North Shepard Drive. Work on Phase I began in January 1984 and ended in November 1984. Phase II then began in March 1985 and continued through May 1987. During Phase I, construction activity was limited primarily to the median of the freeway, placing concrete barrier and creating temporary pavements to accommodate traffic. During Phase II, construction included the existing freeway mainlanes and frontage roads as well as the median. In general, travel lanes through the project were narrowed, shoulders were narrowed or eliminated, and special traffic control features (such as splitting traffic flows around the middle freeway mainlanes when they were being rehabilitated) were implemented in some instances.

Data Collection and Analysis

The control-section and milepoints defining the limits of Phases I and II were as follows:

Control - Section	Milepoints	
0500-03	35.0-42.8	(1982-85)
	25.0-32.8	(1986-87)

A comparison section extending from Beltway 8 north for approximately 3 miles was selected for use in the analysis. Although it would have been desirable to use the

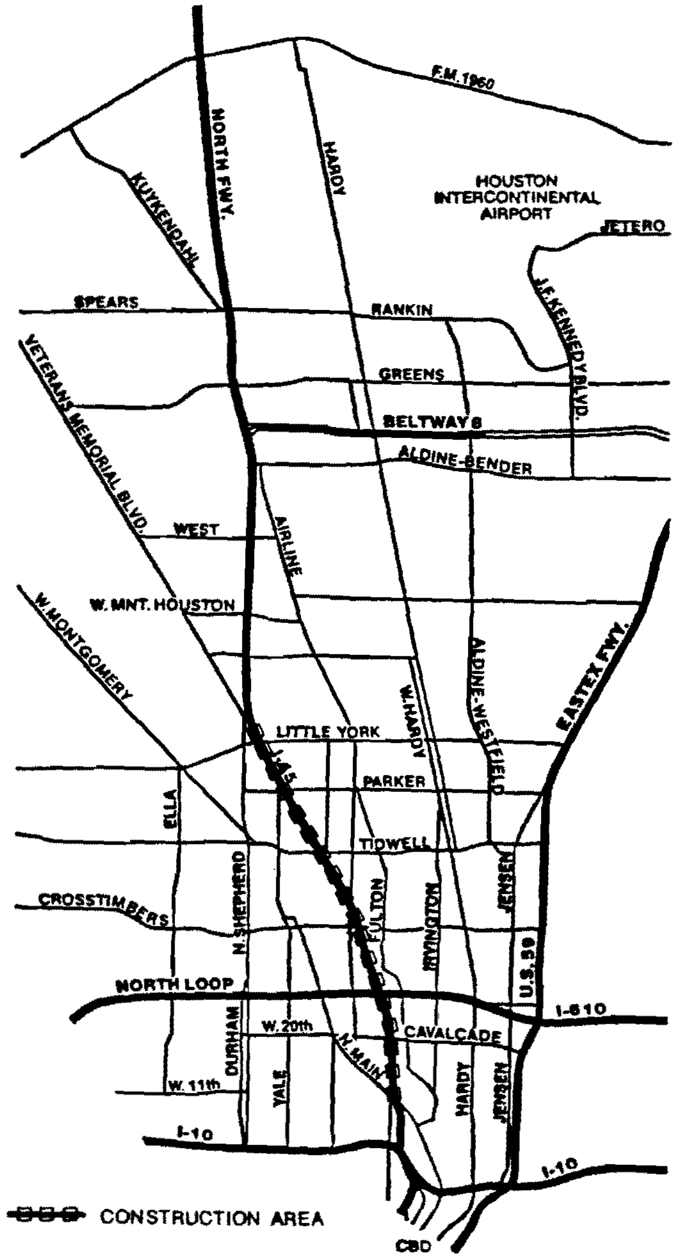

Figure B-1. The I-45, North Freeway, Project in Houston roadway section immediately north of North Shepard Drive, the initiation of Phase III construction in this segment precluded its use as a comparison. The control-section and milepoints of the comparison section are shown below.

Control - Section	Milepoints
0110-05	38.8-42.6

Data from the years 1982 and 1983 represented before construction conditions, whereas data from 1984 through May 1987 represented conditions during construction. The data were reduced and analyzed as specified by Griffin (21) for a before-during accident evaluation using a comparison section and a check for comparability between the construction section and comparison section. The total number of mainlane and frontage road accidents were evaluated, as well as specific accident categories. Separate analyses were performed for each phase, and then for both phases combined. Details concerning the statistical procedures used in the analysis are provided in Appendix A.

Results

Effect of Construction upon Mainlane Accidents

Table B-1 summarizes the impact of construction upon mainlane accidents during Phases I and II of the I-45 construction project. Total accidents during Phase I increased 13.5 percent. Severe accidents increased more dramatically than PDO accidents (42.9 percent increase compared to a 2.0 percent decrease), and daytime accidents increased a greater amount than did nighttime accidents (19.5 percent increase versus a 2.0 percent increase). With respect to accident type, single vehicle accidents increased 24.0 percent, rear-end accidents decreased 3.7 percent, and other multi-vehicle accidents (sideswipes, other angular collisions) increased 45.5 percent. None of the changes in accidents during Phase I was determined to be statistically significant, however.

Construction appeared to have a more significant impact upon accidents during Phase II. Total accidents increased 26.2 percent, nearly twice that observed during Phase I. Such a result would be expected, because construction during Phase I was limited to the median of the freeway, whereas work during Phase II occurred throughout the freeway right-of-way and involved periodic temporary freeway lane closures. Severe accidents increased 75.5 percent during Phase II construction, compared to a 12.3 percent increase in PDO accidents. Nighttime accidents increased dramatically (105.8 percent), whereas daytime accidents decreased slightly (6.6 percent). One possible explanation for this increase is that nighttime freeway lane closures were common during Phase II, but not for Phase I (Phase I did not involve work on the freeway mainlanes). Increases were also observed for all accident types during Phase II; 33.4 percent for single vehicle accidents, 25.1 percent for rear-end accidents, and 40.2 percent for other multi-vehicle accidents. As a final note, the increases in total accidents, severe accidents, and nighttime accidents were found to be statistically significant.

The final column in Table B-1 shows the combined effects of Phase I and II construction upon accidents. Overall, total accidents increased 21.2 percent during construction, an increase that was statistically significant. PDO accidents increased 6.4 percent, whereas severe accidents increased a significant 62.7 percent. Daytime accidents were only 2.3 percent greater during construction. In comparison, nighttime accidents increased 52.1 percent, also a statistically significant increase. Finally, single vehicle accidents increased 30.0 percent, rear-end accidents increased 12.7 percent, and other multi-vehicle accidents increased 42.2 percent during construction. Only the increase in other multi-vehicle accidents was statistically significant.

Effect of Construction upon Frontage Road Accidents

Table B-2 illustrates the effects of construction upon frontage road accidents. Phase II construction did involve some widening and rehabilitation work on the frontage road, whereas Phase I did not. However, frontage road accidents were not adversely affected during either phase of construction. Frontage road accidents actually decreased slightly during Phase I, and were essentially unchanged during Phase II. In general, no statistically or practically significant trends were evident with respect to the time-of-day distribution of accidents or the types of vehicle collisions that occurred.

Tables B-3 and B-4 present the data, the comparability statistics, estimated changes, and statistical test results for mainlane and frontage road accidents, respectively, during Phase I. Tables B-5 and B-6 provide the same information for Phase II. A G^2 value is presented next to each set of data. This statistic is the result of a test of comparability between the construction zone and comparison section both before and during construction. If the G^2 value is less than a critical X^2 value (based on the degrees of freedom in parentheses), then one would conclude that the two sections are comparable in terms of accident trends. In general, very few tests indicated non-comparability, suggesting that the comparison section was representative of the construction section in terms of accident trends. The Z-Statistic for each set of data represents the statistical significance of the percent change in accidents. This statistic is tested against a standard Normal distribution.

TABLE B-1. EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS: I-45, NORTH FREEWAY, HOUSTON, TX

	Percent Change Phase I	Percent Change Phase II	Phases I and II Combined
All Accidents	+13.5	+26.2 *	+21.2 *
Accident Severity:			
PDO Accidents	-2.0	+12.3	+6.4
Severe Accidents	+42.9	+75.5 *	+62.7 *
Time-of-Day Distribution:			
Daytime Accidents	+19.5	-6.2	+2.3
Nighttime Accidents	+2.0	+105.8 *	+52.1 *
Type of Vehicle Collision:			
Single-Vehicle Accidents	+24.0	+33.4	+30.0
Rear-End Accidents	-3.7	+25.1	+12.7
Other Multi-Vehicle Accidents	+45.5	+40.2	+42.2 *

* Statistically significant at a 0.05 level of significance

TABLE B-2. EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS I-45, NORTH FREEWAY, HOUSTON, TX

	Percent Change Phase I	Percent Change Phase II	Phases I and II Combined
All Accidents	-15.5	+0.8	-6.3
Accident Severity:			
PDO Accidents	-18.2	+13.2	-2.0
Severe Accidents	-3.1	-24.5	-17.8
Time-of-Day Distribution:			
Daytime Accidents	-14.8	+5.5	-3.5
Nighttime Accidents	-16.7	-8.6	-12.0
Type of Vehicle Collision:			
Single-Vehicle Accidents	-58.8 *	-29.5	-39.0
Rear-End Accidents	-7.0	-29.5	-21.2
Other Multi-Vehicle Accidents	-10.7	+36.7 *	+13.3

* Statistically significant at a 0.05 level of significance

TABLE B-3. I-45 MAINLANE ACCIDENT DATA (PHASE I)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	171	1866	1.716 (1)
During Construction	83	1028	N/A

Change in Accidents = +13.5%; Z-Statistic = 0.909

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	89	1356	0.196 (1)
During Construction	48	717	N/A

Change in Accidents = -2.0%; Z-Statistic = -0.109

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	82	510	1.037(1)
During Construction	35	311	N/A

Change in Accidents = +42.9%; Z-Statistic = 1.665

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics(d.f.)
Before Construction	92	1288	1.261 (1)
During Construction	44	736	N/A

Change in Accidents = +19.5%; Z-Statistic = 0.942

N/A Comparability statistic not available as less than one year's worth of during construction data were available

d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-3. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	79	578	1.210 (1)
During Construction	39	291	N/A

Change in Accidents = +2.0%; Z-Statistic = 0.094

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	42	271	1.048 (1)
During Construction	18	144	N/A

Change in Accidents = +24.0%; Z-Statistic = 0.717

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	76	1147	1.829 (1)
During Construction	38	552	N/A

Change in Accidents = -3.7%; Z-Statistic = -0.186

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	53	448	0.048 (1)
During Construction	27	332	N/A

Change in Accidents = +45.5%; Z-Statistic = 1.517

N/A Comparability statistic not available as less than one year's worth of during construction data were available
d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-4. I-45 FRONTAGE ROAD ACCIDENT DATA (PHASE I)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	221	726	0.375 (1)
During Construction	133	369	N/A

Change in Accidents = -15.5%; Z-Statistic = -1.330

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	175	538	0.211 (1)
During Construction	109	274	N/A

Change in Accidents = -18.2%; Z-Statistic = -1.410

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	46	188	0.216 (1)
During Construction	24	95	N/A

Change in Accidents = -3.1%; Z-Statistic = -0.114

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	153	519	0.001 (1)
During Construction	90	260	N/A

Change in Accidents = -14.8%; Z-Statistic = -1.049

N/A Comparability statistic not available as less than one year's worth of during construction data were available

d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-4. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	68	207	1.212 (1)
During Construction	43	109	N/A

Change in Accidents = -16.7%; Z-Statistic = -0.803

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	21	80	0.341 (1)
During Construction	14	22	N/A

Change in Accidents = -58.8%; Z-Statistic = -2.105

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	67	199	1.811 (1)
During Construction	42	116	N/A

Change in Accidents = -7.0%; Z-Statistic = -0.318

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	133	447	0.126 (1)
During Construction	77	231	N/A

Change in Accidents = -10.7%; Z-Statistic = -0.690

N/A Comparability statistic not available as less than one year's worth of during construction data were available

d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-5. I-45 MAINLANE ACCIDENT DATA (PHASE II)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	184	2034	1.672 (1)
During Construction	174	2429	5.454 (2)

Change in Accidents = +26.2%; Z-Statistic = 2.123

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	95	1471	0.430 (1)
During Construction	95	1652	0.156 (2)

Change in Accidents = +12.3%; Z-Statistic = 0.776

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	89	563	0.724 (1)
During Construction	79	877	16.410 (2)

Change in Accidents = +75.5%; Z-Statistic = 3.435

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	98	1390	0.786 (1)
During Construction	120	1597	3.466 (2)

Change in Accidents = -6.2%; Z-Statistic = -0.452

N/A Comparability statistic not available as less than one year's worth of during construction data were available
d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-5. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	86	644	1.872 (1)
During Construction	54	832	2.607 (2)

Change in Accidents = +105.8%; Z-Statistic = 3.978

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability: Statistics (d.f.)
Before Construction	45	296	0.631 (1)
During Construction	45	395	5.653 (2)

Change in Accidents = 33.4%; Z-Statistic = 1.286

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	85	1241	2.244 (1)
During Construction	69	1260	6.863 (2)

Change in Accidents = +25.1%; Z-Statistic = 1.341

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	54	497	0.038 (1)
During Construction	60	774	0.721 (2)

Change in Accidents = +40.2%; Z-Statistic = 1.721

N/A Comparability statistic not available as less than one year's worth of during construction data were available

d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-6. I-45 FRONTAGE ROAD ACCIDENT DATA (PHASE II)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	232	799	0.479 (1)
During Construction	221	767	1.422 (2)

Change in Accidents = +0.8%; Z-Statistic = 0.072

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	181	592	1.150 (1)
During Construction	141	522	1.060 (2)

Change in Accidents = +13.2%; Z-Statistic = 0.903

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	51	207	0.519 (1)
During Construction	80	245	1.124 (2)

Change in Accidents = -24.5%; Z-Statistic = -1.391

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	162	561	0.010 (1)
During Construction	147	537	2.489 (2)

Change in Accidents = +5.5%; Z-Statistic = 0.415

N/A Comparability statistic not available as less than one year's worth of during construction data were available
d.f. degrees of freedom = no. years in analysis period - 1

TABLE B-6. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	70	238	1.227 (1)
During Construction	74	230	0.037 (2)

Change in Accidents = -8.6%; Z-Statistic = -0.471

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	23	87	0.496 (1)
During Construction	33	88	0.145 (2)

Change in Accidents = -29.5%; Z-Statistic = -1.125

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	70	221	1.767 (1)
During Construction	88	196	0.080 (2)

Change in Accidents = -29.5%; Z-Statistic = -1.858

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	139	491	0.093 (1)
During Construction	100	483	1.403 (2)

Change in Accidents = +36.7%; Z-Statistic = 2.144

N/A Comparability statistic not available as less than one year's worth of during construction data were available

d.f. degrees of freedom = no. years in analysis period - 1

APPENDIX C: I-10, EL PASO

Introduction

In January 1985, work began on the reconstruction of an 8.6 mile section of I-10 in El Paso, TX. The project limits extended from Chelsea St. in downtown El Paso eastward to Zaragosa Rd., as illustrated in Figure C-1. The construction project was divided into four separate segments, with control-section and milepoint limits as defined below.

Segment	Control - Section	Milepoints
I	2121-03	28.7-31.2
II	2121-03	26.0-28.7
III	2121-02	24.3-26.0
IV	2121-03	30.7-32.9

Segment IV was the easternmost segment of the project, followed sequentially by Segments I, II, and III. Normal 12-ft travel lanes and a partial inside shoulder were maintained in each direction within Segments I and IV, with construction work performed adjacent to the travel lanes. Due to space limitations in Segments II and III, the shoulders were converted to temporary travel lanes in order to maintain three 10.5-ft lanes during construction. Construction began on Segment I in January 1985. Segment I was completed in December 1986. Segments II and III began in June and October 1986, respectively. Segment II was completed in November 1989, and Segment III was scheduled to be finished in March 1990. Work on Segment IV was initiated in August 1987 and was completed in December 1989.

Data Collection and Reduction

Different comparison sections were used for each segment in the accident analysis. For Segment I, Segment IV was used as a comparison section, as construction in Segment IV did not begin until Segment I was completed. A two-mile segment immediately west of Segment III served as a comparison section for both Segment II and III. The control-section and milepoint limits of this comparison section were as follows:

Control - Section	Milepoints
2121-02	22.3-24.3

For Segment IV, a three-mile section immediately east of the project was used as a comparison. The limits of this section were:

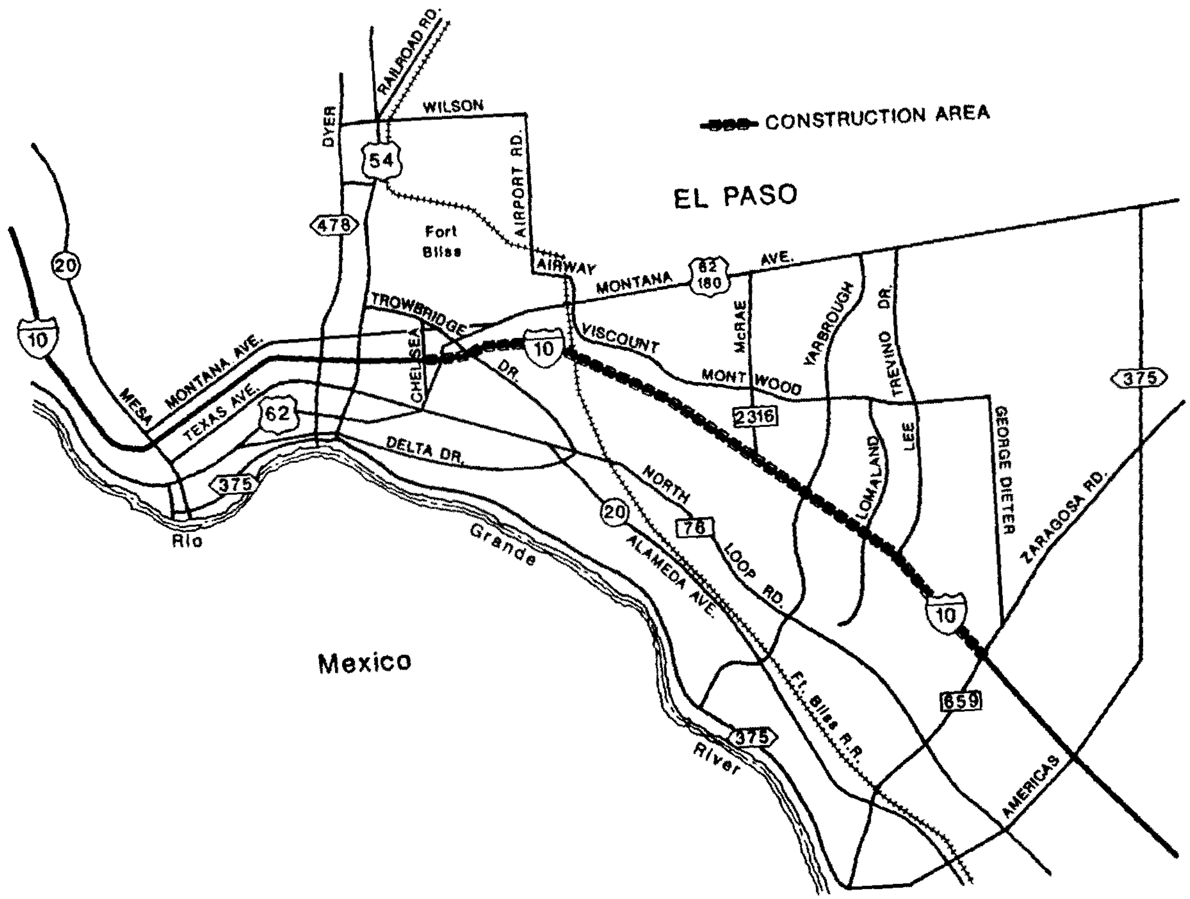

Figure C-1. The I-10 Project in El Paso

Control - Section	Milepoints
2121-04	32.9-35.9

For each construction segment and comparison section, accident data were collected for three years prior to construction and for the duration of construction (through 1988). The data were reduced and analyzed as specified by Griffin (20) for a before-during accident evaluation using a comparison section and a check for comparability between the construction section and comparison section. The total number of mainlane and frontage road accidents were evaluated, as well as specific accident categories. Details of the statistical procedures used in the analysis are provided in Appendix A.

Results

Effect of Construction upon Mainlane Accidents

A summary of the effects of construction upon mainlane accidents at the I-10 construction project is shown in Table C-1. Information is provided separately for each of the four segments of the construction project, as well as for all four segments combined. Overall, the effect of construction varied dramatically from segment to segment. Total accident increases during construction ranged from 13.5 percent within segment III to 117.2 percent in segment IV. Considering all segments together, total accidents increased 37.8 percent.

Table C-1 also presents a summary of the effect of construction upon accident severity. PDO accidents at segments I, II, and IV increased by greater amount than severe accidents. Consolidating all segments, PDO accidents increased 39.0 percent, compared to a 35.7 percent increase in severe accidents.

Daytime accidents increased much more than did nighttime accidents during construction. Overall, daytime accidents were 52.4 percent higher during construction, whereas nighttime accidents increased only 8.4 percent. On a segment by segment basis, segments II and IV experienced more substantial increases in nighttime accidents. The nighttime accident increase at segment IV was actually greater than the daytime accident increase (173.9 percent versus 63.3 percent). However, the basic trend evident at this project was that construction had the most effect upon daytime accidents.

As illustrated in Table C-1, single vehicle accidents overall were not significantly affected. Segment IV experienced a sizeable increase in single-vehicle accidents (56.6 percent), but the other segments experienced slight decreases in this type of accidents during construction. Construction did have a dramatic impact upon rear-end accidents. Increases in rear-end accidents among the various segments ranged from 35.8 percent in segment III to 124.1 percent in segment IV. The increase for the entire project averaged 74.9 percent. For the most part, other multi-vehicle accidents also increased, although not to the same degree as rear-end accidents. These accidents increased 25.8 percent during construction.

Effect of Construction upon Frontage Road Accidents

A summary of the effects of I-10 construction upon frontage road accidents is presented in Table C-2. Work activities during construction were concentrated primarily on the freeway mainlanes, with only isolated sections of frontage road affected by turn-around lane construction and diamond intersection improvements. Total frontage road accidents over the entire project increased 3.9 percent during construction. Two of the four segments experienced decreases in accidents, whereas accidents increased at the two others. With respect to accident severity, PDO accidents increased an average of 8.1 percent during construction, compared to a 2.8 percent decrease in severe accidents. Two sites experienced decreases in severe accidents, and severe accidents increased at the two others. On the average, daytime accidents increased 4.2 percent during construction, compared to a 4.3 percent increase in nighttime accidents. On a segment by segment basis, the effect of construction upon daytime accidents ranged from a 16.8 percent decrease to a 24.7 percent increase. For nighttime accidents, one segment experienced a 14.6 percent decrease, whereas another experienced a 31.2 percent increase in these accidents. Single-vehicle accidents on the frontage road decreased 10.9 percent during construction. Rear-end accidents also decreased a smaller amount, 7.8 percent. Other multi-vehicle accidents increased 5.0 percent during construction.

Tables C-3 and C-4 present the data, the comparability statistics, estimated changes, and statistical test results for mainlane and frontage road accidents, repspectively, within Segment I. Tables C-5 through C-10 present similar information for Segments II through IV. A G^2 value is presented next to each set of data. This statistic is the result of a test of comparability between the construction zone and comparison section. If the G^2 value is less than the critical value in parentheses, there is no reason to reject the hypothesis that the two sections are comparable in terms of accident trends. The Z-statistic is the computed significance of the estimated change in accidents during construction. This statistic was compared to a critical Z-value from a standard normal distribution at a 0.05 level of significance.

In addition, statistics from combining the four segments into an overall assessment of the construction project are presented in Tables C-11 and C-12. A Z-statistic is also presented to test the significance of the overall percent changes computed, along with a homogeneity statistic that represents the degree of similarity between segments in terms of accident changes observed. This statistic is compared to a standard Chi-Square distribution with the specified degrees of freedom. If the computed statistic exceeds the critical value, it can be assumed that construction had a significantly different effect upon accidents from segment to segment. If this occurs, the overall changes computed during construction must be interpreted with caution.

TABLE C-1. EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS I-10, EL PASO

	Segment I	Segment II	Segment III	Segment IV	All Segments Combined
All Accidents	+22.5 %	+62.2 %*	+13.5 %	+117.2 %*	+37.8 %
Accident Severity:					
PDO Accidents	+31.3 %	+67.5 %*	+8.9 %	+161.5 %*	+39.0 %
Severe Accidents	+11.3 %	+54.5 %*	+21.5 %	+45.2 %	+35.7 %
Time-of-Day Distribution:					
Daytime Accidents	+32.3 %	+80.1 %*	+31.3 %*	+63.3 %	+52.4 %
Nighttime Accidents	+0.5 %	+26.3 %	-21.5 %	+173.9 %*	+8.4 %
Type of Vehicle Collision:					
Single Vehicle Accidents	-7.6 %	-8.3 %	-7.7 %	+56.6 %	-4.1 %
Rear-End Accidents	+67.1 %	+121.0 %*	+35.8 %*	+124.1 %	+74.9 %
Other Multi-Vehicle Accidents	+22.0 %	+44.3 %	-1.6 %	+217.5 %*	+25.8 %

TABLE C-2. EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS I-10, EL PASO

	Segment I	Segment II	Segment III	Segment IV	All Segments Combined
All Accidents	+19.4 %	-3.0 %	-16.4 %	+26.0 %	+3.9 %
Accident Severity:					
PDO Accidents	+14.5 %	+10.3 %	+0.1 %	+3.1 %	+8.1 %
Severe Accidents	+29.6 %	-23.6 %	-41.0 %	+85.9 %	-2.8 %
Time-of-Day Distribution:					
Daytime Accidents	+24.7 %	-3.3 %	-16.8 %	+23.6 %	+4.2 %
Nighttime Accidents	+6.5 %	+2.9 %	-14.6 %	+31.2 %	+4.3 %
Type of Vehicle Collision:					
Single Vehicle Accidents	+35.3 %	-17.9 %	-64.5 %*	+15.7 %	-10.9 %
Rear-End Accidents	+63.7 %*	-23.3 %	-15.7 %	-9.0 %	-7.8 %
Other Multi-Vehicle Accidents	-5.0 %	+9.8 %	-4.7 %	+85.9 %	+5.0 %

TABLE C-3. I-10 MAINLANE ACCIDENT DATA (SEGMENT I)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	75	329	2.851 (2)
During Construction	59	317	0.007 (1)

Change in Accidents = +22.5%; Z-Statistic = 1.062

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	36	190	2.545 (2)
During Construction	28	194	0.656 (1)

Change in Accidents = +31.3%; Z-Statistic = 1.001

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	39	139	1.389 (2)
During Construction	31	123	0.888 (1)

Change in Accidents = +11.3%; Z-Statistic = 0.396

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	43	195	2.655 (2)
During Construction	36	216	0.096 (1)

Change in Accidents = +32.3%; Z-Statistic = 1.135

d.f. degrees of freedom

TABLE C-3. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	32	134	0.412 (2)
During Construction	24	101	0.231 (1)

Change in Accidents = +0.5%; Z-Statistic = 0.017

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	38	122	0.732 (2)
During Construction	31	92	2.283 (1)

Change in Accidents = -7.6%; Z-Statistic = -0.282

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	22	142	0.386 (2)
During Construction	14	151	2.190 (1)

Change in Accidents = +67.1%; Z-Statistic = 1.421

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	15	65	9.148 (2)
During Construction	14	74	0.004 (1)

Change in Accidents = +22.0%; Z-Statistic = 0.486

d.f. degrees of freedom

TABLE C-4. I-10 FRONTAGE ROAD ACCIDENT DATA (SEGMENT I)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	252	586	2.874 (2)
During Construction	174	483	1.121 (1)

Change in Accidents = +19.4%; Z-Statistic = 1.524

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	163	401	2.347 (2)
During Construction	115	324	0.698 (1)

Change in Accidents = +14.5%; Z-Statistic = 0.949

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	89	185	0.558 (2)
During Construction	59	159	0.455 (1)

Change in Accidents = +29.6%; Z-Statistic = 1.300

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	171	409	1.855 (2)
During Construction	119	355	0.344 (1)

Change in Accidents = +24.7%; Z-Statistic = 1.582

d.f. degrees of freedom

TABLE C-4. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	81	177	1.071 (2)
During Construction	55	128	0.849 (1)

Change in Accidents = +6.5%; Z-Statistic = 0.300

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	39	51	0.151 (2)
During Construction	26	46	1.347 (1)

Change in Accidents = +35.3%; Z-Statistic = 0.931

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	86	194	0.322 (2)
During Construction	52	192	0.312 (1)

Change in Accidents = +63.7%; Z-Statistic =2.427

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	127	341	4.602 (2)
During Construction	96	245	1.787 (1)

Change in Accidents = -5.0%; Z-Statistic = -0.319

d.f. degrees of freedom

TABLE C-5. I-10 MAINLANE ACCIDENT DATA (SEGMENT II)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	312	494	2.964 (2)
During Construction	414	1063	6.993 (2)

Change in Accidents = 62.2%; Z-Statistic = 5.218

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	186	297	3.476 (2)
During Construction	243	650	4.697 (2)

Change in Accidents = +67.5%; Z-Statistic = 4.300

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	126	197	3.164 (2)
During Construction	171	413	2.499 (2)

Change in Accidents = +54.5%; Z-Statistic = 2.981

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	230	330	3.794 (2)
During Construction	298	770	13.643 (2)

Change in Accidents = +80.1%; Z-Statistic = 5.363

d.f. degrees of freedom

TABLE C-5. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	82	164	0.992 (2)
During Construction	116	293	1.131 (2)

Change in Accidents = +26.3%; Z-Statistic = 1.340

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	83	152	1.628 (2)
During Construction	100	168	0.791 (2)

Change in Accidents = -8.3%; Z-Statistic = -0.464

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents Construction Section	Comparability Statistics (d.f.)
Before Construction	155	239	0.440 (2)
During Construction	189	644	5.050 (2)

Change in Accidents = +121.0%; Z-Statistic = 5.997

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	74	103	1.935 (2)
During Construction	125	251	4.297 (2)

Change in Accidents = +44.3%; Z-Statistic = 1.953

d.f. degrees of freedom

TABLE C-6. I-10 FRONTAGE ROAD ACCIDENT DATA (SEGMENT II)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	137	615	2.980 (2)
During Construction	175	762	3.054 (2)

Change in Accidents = -3.0%; Z-Statistic = -0.241

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	98	465	2.814 (2)
During Construction	108	565	1.491 (2)

Change in Accidents = +10.3%; Z-Statistic = 0.638

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	39	150	0.905 (2)
During Construction	67	197	5.112 (2)

Change in Accidents = -23.6%; Z-Statistic = -1.174

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	103	496	3.954 (2)
During Construction	125	582	4.005 (2)

Change in Accidents = -3.3%; Z-Statistic = -0.230

d.f. degrees of freedom

TABLE C-6. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	34	119	0.504 (2)
During Construction	50	180	1.741 (2)

Change in Accidents = +2.9%; Z-Statistic = 0.112

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	16	36	0.400 (2)
During Construction	26	48	2.056 (2)

Change in Accidents = -17.9%; Z-Statistic = -0.512

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	28	202	1.700 (2)
During Construction	47	260	0.825 (2)

Change in Accidents = -23.3%; Z-Statistic = -1.035

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	93	377	4.578 (2)
During Construction	102	454	1.203 (2)

Change in Accidents = +9.8%; Z-Statistic = 0.319

d.f. degrees of freedom

TABLE C-7. I-10 MAINLANE ACCIDENT DATA (SEGMENT III)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	377	570	6.002 (2)
During Construction	349	599	1.136 (2)

Change in Accidents = +13.5%; Z-Statistic = 1.341

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	223	359	4.157 (2)
During Construction	206	361	0.355 (2)

Change in Accidents = +8.9%; Z-Statistic = 0.695

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	154	211	8.682 (2)
During Construction	143	238	1.013 (2)

Change in Accidents = +21.5%; Z-Statistic = 1.299

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	286	388	6.537 (2)
During Construction	242	431	3.200 (2)

Change in Accidents = +31.3%; Z-Statistic = 2.432

d.f. degrees of freedom

TABLE C-7. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	91	182	0.315 (2)
During Construction	107	168	6.443 (2)

Change in Accidents = -21.5%; Z-Statistic = -1.356

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	96	156	0.495 (2)
During Construction	84	126	0.549 (2)

Change in Accidents = -7.7%; Z-Statistic = -0.418

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	184	277	1.881 (2)
During Construction	160	327	0.122 (2)

Change in Accidents = +35.8%; Z-Statistic = 2.257

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	97	137	8.018 (2)
During Construction	105	146	2.127 (2)

Change in Accidents = -1.6%; Z-Statistic = -0.085

d.f. degrees of freedom

TABLE C-8. I-10 FRONTAGE ROAD ACCIDENT DATA (SEGMENT III)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	161	389	5.082 (2)
During Construction	151	305	2.896 (2)

Change in Accidents = -16.4%; Z-Statistic = -1.311

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	116	264	3.535 (2)
During Construction	90	205	1.043 (2)

Change in Accidents = +0.1%; Z-Statistic = 0.005

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	45	125	1.765 (2)
During Construction	61	100	2.374 (2)

Change in Accidents = -41.0%; Z-Statistic = -2.216

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	118	303	4.774 (2)
During Construction	110	235	1.978 (2)

Change in Accidents = -16.8%; Z-Statistic = -1.161

d.f. degrees of freedom

TABLE C-8. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	43	86	3.056 (2)
During Construction	41	70	1.452 (2)

Change in Accidents = -14.6%; Z-Statistic = -0.563

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	18	38	0.726 (2)
During Construction	24	18	1.185 (2)

Change in Accidents = -64.5%; Z-Statistic = -2.445

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	36	92	1.130 (2)
During Construction	39	84	1.344 (2)

Change in Accidents = -15.7%; Z-Statistic = -0.620

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	107	259	5.315 (2)
During Construction	88	203	0.923 (2)

Change in Accidents = -4.7%; Z-Statistic = -0.280

d.f. degrees of freedom

TABLE C-9. I-10 MAINLANE ACCIDENT DATA (SEGMENT IV)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	63	110	5.801 (3)
During Construction	24	91	4.039 (1)

Change in Accidents = +117.2%; Z-Statistic = 2.783

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	35	58	3.260 (3)
During Construction	12	52	2.487 (1)

Change in Accidents = +161.5%; Z-Statistic = 2.495

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	28	52	4.014 (3)
During Construction	12	39	1.443 (1)

Change in Accidents = +75.0%; Z-Statistic = 1.382

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	22	55	2.924 (3)
During Construction	122	49	2.103 (1)

Change in Accidents = +63.3%; Z-Statistic = 1.119

d.f. degrees of freedom

TABLE C-9. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	36	46	5.127 (3)
During Construction	12	42	1.861 (1)

Change in Accidents = +173.9%; Z-Statistic = 2.546

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	30	54	4.537 (3)
During Construction	11	31	2.683 (1)

Change in Accidents = +56.6%; Z-Statistic = 1.072

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	13	29	6.169 (3)
During Construction	6	30	0.477 (1)

Change in Accidents = +124.1%; Z-Statistic = 1.446

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	20	27	3.882 (3)
During Construction	7	30	0.863 (1)

Change in Accidents = +217.5%; Z-Statistic = 2.252

d.f. degrees of freedom

TABLE C-10. I-10 FRONTAGE ROAD ACCIDENT DATA (SEGMENT IV)

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	148	346	0.839 (3)
During Construction	56	165	2.790 (1)

Change in Accidents = +26.0%; Z-Statistic = 1.263

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	94	228	1.877 (3)
During Construction	40	100	2.116 (1)

Change in Accidents = +3.1%; Z-Statistic = 0.135

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	54	118	0.058 (3)
During Construction	16	65	0.720 (1)

Change in Accidents = +85.9%; Z-Statistic = 1.915

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	100	238	2.046 (3)
During Construction	35	103	0.990 (1)

Change in Accidents = +23.6%; Z-Statistic = 0.927

d.f. degrees of freedom

TABLE C-10. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	48	108	1.403 (3)
During Construction	21	62	1.965 (1)

Change in Accidents = +31.2%; Z-Statistic = 0.887

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	43	57	2.210 (3)
During Construction	15	23	0.441 (1)

Change in Accidents = +15.7%; Z-Statistic = 0.374

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	34	116	3.170 (3)
During Construction	19	59	0.280 (1)

Change in Accidents = -9.0%; Z-Statistic = -0.287

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	54	118	0.058 (3)
During Construction	16	65	0.720 (1)

Change in Accidents = +85.9%; Z-Statistic = 1.915

d.f. degrees of freedom

TABLE C-11. COMBINED EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS: I-10, EL PASO, TX

	Overall Percent Change	Z Statistic	Homogeneity Statistic (d.f.)
All Accidents	+37.8	5.250	10.366
Accident Severity:			
PDO Accidents	+39.0	4.127	9.167
Severe Accidents	+35.7	3.221	2.267
Time-of-Day Distribution:			
Daytime Accidents	+52.4	5.740	4.450
Nighttime Accidents	+8.4	0.726	9.594
Type of Vehicle Collision:			
Single-Vehicle Accidents	-4.1	-0.362	1.487
Rear-End Accidents	+74.9	6.191	6.840
Other Multi-Vehicle Accidents	+25.8	1.888	5.562

* Statistically significant at a 0.05 level of significance

TABLE C-12. COMBINED EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS: I-10, EL PASO, TX

	Overall Percent Change	Z Statistic	Homogeneity Statistic (d.f.)
All Accidents	+3.9	0.574	5.365 (3)
Accident Severity:			
PDO Accidents	+8.1	0.945	0.434 (3)
Severe Accidents	-2.8	-0.240	11.590 (3)
Time-of-Day Distribution:			
Daytime Accidents	+4.2	0.517	4.493 (3)
Nighttime Accidents	+4.2	0.331	1.120 (3)
Type of Vehicle Collision:			
Single-Vehicle Accidents	-10.9	-0.614	6.872 (3)
Rear-End Accidents	-7.8	-0.546	2.772 (3)
Other Multi-Vehicle Accidents	+5.0	0.538	3.901 (3)

* Statistically significant at a 0.05 level of significance

APPENDIX D: I-35, AUSTIN, TX

Introduction

In November 1986, TxDOT initiated a project to widen and rehabilitate a 5.7 mile section of I-35 in Austin, TX. The limits of the project extended from Yagar Ln. on the north to US 290 on the south, as shown in Figure D-1. The project also involved drainage and lighting improvements, replacement of turnaround lanes, bridge repairs, and ramp reconstruction.

The project lasted approximately 19 months, from November 1986 to August 1988. The control-section and milepoint limits of the project are as follows:

Control - Section	Milepoints
0015-13	21.9-27.8

Data Collection and Reduction

There was considerable variation in land use patterns and traffic volumes from one end of the project to the other. Consequently, comparison sections on both ends of the project were selected and pooled in order to provide a strong basis for comparison. Unfortunately, these sections were not found to replicate accident trends in the construction zone very well. An attempt was made to use either the sections on one end of the site or the other, but neither fit the accident trends in the construction zone any closer. A comparison section on another roadway was considered, but a suitable alternative could not be found. Finally, it was decided to perform the analysis with the comparison sections originally selected, but with extra caution taken when interpreting the results. The control-section and milepoint limits of the comparison sections were as shown below.

Control - Section	Milepoints
0015-13	17.9-21.9
0015-03	27.8-30.2

Accident data from 1984, 1985, and 1986 (through November) were used as before data. Data from November 1986 through August 1988 represented during construction conditions.

The data were reduced and analyzed as specified by Griffin (20) for a before-during accident comparison using a control section and a check for comparability between the construction section and comparison section. The total number of mainlane and frontage road accidents were evaluated, as well as specific accident categories.

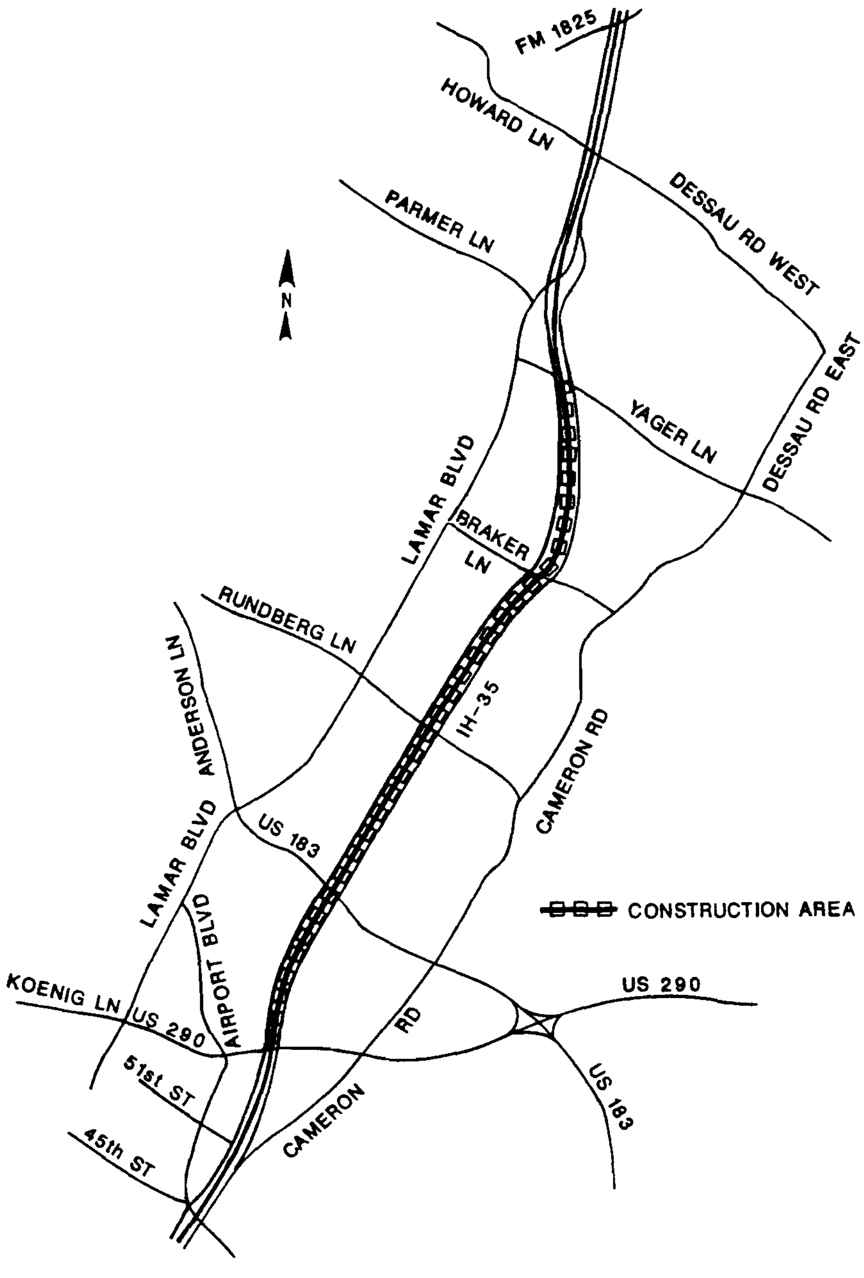

Figure D-1. The I-35 Project in Austin

Results

Effect of Construction upon Mainlane Accidents

Table D-1 summarizes the effects of construction upon mainlane accidents. The presence of construction resulted in a 38.8 percent increase in total mainlane accidents. With respect to accident severity, PDO accidents increased by a greater percentage (45.6 percent) than did severe accidents (33.0 percent). At this location, nighttime accidents increased a greater amount (56.2 percent) than did daytime accidents (31.4 percent). Both single-vehicle and rear-end accidents increased substantially during construction (54.3 percent and 35.4 percent, respectively), while other multi-vehicle accidents increased less dramatically (12.7 percent).

Effect of Construction upon Frontage Road Accidents

The effect of construction upon frontage road accidents is summarized in Table D-2. Based on the data collected, total frontage road accidents decreased 4.4 percent during construction. PDO accidents decreased 5.1 percent, whereas severe accidents increased a very small (0.7 percent) amount. Although daytime accidents were slightly lower (1.4 percent), nighttime accidents were slightly higher (8.7 percent). Single-vehicle accidents on the frontage road increased the most dramatically during construction (38.2 percent), whereas rear-end and other multi-vehicle accidents decreased 16.7 and 5.8 percent, respectively.

Tables D-3 and D-4 present the data, the comparability statistics, estimated changes, and statistical test results for the accident analysis. A G^2 value is presented next to each set of data. This statistic is the result of a test of comparability between the construction zone and comparison section. The G^2 value is compared to a standard Chi-Square distribution with the appropriate degrees of freedom. If the value does not exceed the critical value, then the two sections are comparable in terms of accident trends. A Z-statistic is also presented in the tables which represents the statistical significance of the percent change in accidents. This statistic is compared to a standard Normal distribution.

TABLE D-1. EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS: I-35, AUSTIN, TX

	Change in Accidents During Construction
All Accidents	+38.8 %*
Accident Severity:	
PDO Accidents	+45.6 %*
Severe Accidents	+33.0 %*
Time-of-Day Distribution:	
Daytime Accidents	+31.4 %*
Nighttime Accidents	+56.2 %*
Type of Vehicle Collision:	
Single-Vehicle Accidents	+54.3 %*
Rear-End Accidents	+35.4 %*
Other Multi-Vehicle Accidents	+12.7 %

TABLE D-2. EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS: I-35, AUSTIN, TX

	Change in Accidents During Construction
All Accidents	-4.4 %
Accident Severity:	
PDO Accidents	-5.1 %
Severe Accidents	+0.7 %
Time-of-Day Distribution:	
Daytime Accidents	-1.4 %
Nighttime Accidents	-8.7 %
Type of Vehicle Collision:	
Single-Vehicle Accidents	+38.2 %
Rear-End Accidents	-16.7 %
Other Multi-Vehicle Accidents	-5.8 %

* Change is statistically significant at 0.05 level of significance

TABLE D-3. I-35 MAINLANE ACCIDENT DATA

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	1236	654	13.482 (2)
During Construction	595	437	0.742 (1)

Change in Accidents = +38.8%; Z-Statistic = 4.129

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	757	425	12.927 (2)
During Construction	323	264	0.719 (1)

Change in Accidents = +45.6%; Z-Statistic = 3.656

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	479	229	1.422 (2)
During Construction	272	173	0.126 (1)

Change in Accidents = +33.0%; Z-Statistic = 2.263

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	804	454	8.869 (2)
During Construction	364	270	1.595 (1)

Change in Accidents = +31.4%; Z-Statistic = 2.741

TABLE D-3. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	432	200	5.440 (2)
During Construction	231	167	0.045 (1)

Change in Accidents = +56.2%; Z-Statistic = 3.356

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	283	180	1.094 (2)
During Construction	159	156	0.021 (1)

Change in Accidents = +54.3%; Z-Statistic = 2.936

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	635	334	9.439 (2)
During Construction	299	213	3.349 (1)

Change in Accidents = +35.4%; Z-Statistic = 2.701

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	318	140	5.889 (2)
During Construction	137	68	0.001 (1)

Change in Accidents = +12.7%; Z-Statistic = 0.667

TABLE D-4. I-35 FRONTAGE ROAD ACCIDENT DATA

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	1180	1310	33.008 (2)
During Construction	476	505	0.034 (1)

Change in Accidents = -4.4%; Z-Statistic = -0.601

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	752	893	29.468 (2)
During Construction	262	295	0.000 (1)

Change in Accidents = -5.1%; Z-Statistic = -0.542

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	428	417	4.805 (2)
During Construction	214	210	0.122 (1)

Change in Accidents = +0.7%; Z-Statistic = 0.060

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	840	899	29.487 (2)
During Construction	309	326	0.970 (1)

Change in Accidents = -1.4%; Z-Statistic = -0.154

TABLE D-4. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	350	411	8.662 (2)
During Construction	167	179	1.068 (1)

Change in Accidents = -8.7%; Z-Statistic = -0.703

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	125	116	3.000 (2)
During Construction	46	59	3.551 (1)

Change in Accidents = +38.2%; Z-Statistic = 1.376

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	256	427	29.442 (2)
During Construction	118	164	1.417 (1)

Change in Accidents = -16.7%; Z-Statistic = -1.264

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	889	767	4.298 (2)
During Construction	312	282	0.000 (1)

Change in Accidents = +4.8%; Z-Statistic = 0.485

APPENDIX E: I-35W, FT. WORTH, TX

Introduction

An extensive construction effort to rebuild a 6.4 mile portion of I-35W in Ft. Worth, TX was initiated in September 1984. The capacity of that portion of the freeway was expanded from its original four lanes (two per direction) to a final eight-lane configuration. Other improvements were made in ramp geometry, acceleration and deceleration lanes, and frontage roads. The limits of the project extended from I-20 to just south of the interchange of I-35W and I-30. Figure E-1 illustrates the location of the construction zone in Ft. Worth. The control-section and milepoint limits of the project are documented below.

Control - Section	Milepoints
0014-16	0.0-6.4

The project involved two major phases. During the first phase, traffic was maintained on the existing travel lanes as two new travel lanes were constructed immediately adjacent. When Phase I was completed, the traffic was shifted onto the new pavement and the existing lanes were constructed during Phase II. Phase I was completed in June 1988, followed immediately by the initiation of Phase II. Only Phase I was evaluated in conjunction with this accident analysis.

Data Collection and Analysis

Roadway segments at both ends of the construction zone were selected for use as comparison sections for the accident analysis. The control-section and milepoint limits of the comparison sections are as follows:

Control - Section	Milepoints
0014-16	6.4-9.4
0014-02	4.9-6.9

Accident data from the years 1982 and 1983 were used to represent accident conditions before construction, whereas data from 1984 through June 1988 represented conditions during construction. The data were reduced and analyzed as specified by Griffin (20) for a before-during accident comparison using a control section and a check for comparability between the construction section and comparison section. The total number of mainlane and frontage road accidents were evaluated, as well as specific accident categories.

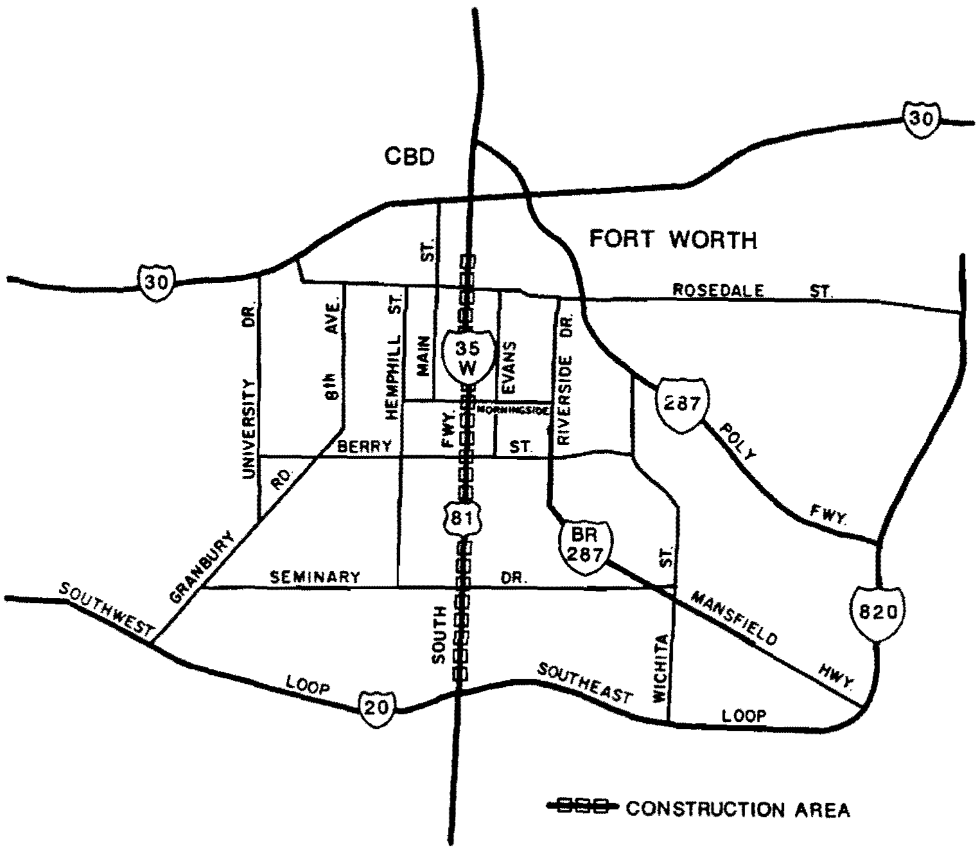

Figure E-1. The I-35W Project in Fort Worth

Results

Effect of Construction upon Mainlane Accidents

Table E-1 presents the results of the analysis of accidents during I-35W reconstruction in Ft. Worth. Total mainlane accidents were 22.9 percent higher during construction. Severe accidents increased by a greater percentage during construction than did PDO accidents (31.2 percent versus 19.3 percent, respectively). Nighttime accidents on the mainlanes increased 46.2 percent, whereas daytime accidents increased 13.7 percent. With respect to the type of vehicle collisions occurring, rear-end accidents increased by the greatest amount, 39.8 percent. In contrast, single-vehicle and other multi-vehicle accidents increased 10.4 and 4.7 percent, respectively.

Effect of Construction Upon Frontage Road Accidents

A summary of the changes in frontage road accidents during I-35W construction is provided in Table E-2. During this project, frontage road accidents were significantly affected, as total accidents increased 27.7 percent. Even more dramatic, the data show that severe accidents increased 76.9 percent, compared to a 14.8 percent increase in PDO accidents. Most of the accident increase appeared to occur at night, with nighttime accidents increasing 83.6 percent. In contrast, daytime accidents during construction increased 15.3 percent. It was also found that single-vehicle accidents increased 134.8 percent during construction, compared to a 13.5 percent increase in rear-end accidents and a 20.7 percent increase in other multi-vehicle accidents. Unfortunately, the data from the Master Accident File are not sufficiently detailed to determine why these dramatic changes in accidents occurred. Conversations with TxDOT personnel (22) involved with the project that increased travel on the frontage road due to ramp closures may have been partially responsible for the increase. Another partial explanation suggested was that, because of space limitations, some entrance ramps had very short acceleration lanes during some steps in the construction process. A number of accidents occurred at these ramps, and some may have been coded as occurring on the frontage road. Also, merging onto the freeway was difficult at these ramps, sometimes causing traffic to back up the ramp onto the frontage road and causing accidents.

Tables E-3 and E-4 present the data, the comparability statistics, estimated changes, and statistical test results for the accident analysis during Phase I construction. A G^2 value is presented next to each set of data. This statistic is a test of comparability between the construction zone and comparison section, and is compared to a standard Chi-Square distribution with the appropriate degrees of freedom. If the G^2 value does not exceed the critical value, the two sections appear to be comparable in terms of accident trends. A Z-Statistic is also presented that represents the statistical significance of the percent change in accidents computed. This statistic is compared to a standard Normal distribution.

TABLE E-1. EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS: I-35W, FT. WORTH, TX

Accident Category	Change in Accidents During Construction
All Accidents	+22.9 %*
Accident Severity:	
PDO Accidents	+19.3 %*
Severe Accidents	+31.2 %*
Time-of-Day Distribution:	
Daytime Accidents	+13.7 %
Nighttime Accidents	+46.2 %*
Type of Vehicle Collision:	
Single-Vehicle Accidents	+10.4 %
Rear-End Accidents	+39.8 %*
Other Multi-Vehicle Accidents	+4.7 %

TABLE E-2. EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS: I-35W, FT. WORTH, TX

Accident Category	Change in Accidents During Construction
All Accidents	+27.7 %*
Accident Severity:	
PDO Accidents	+14.8 %
Severe Accidents	+76.9 %*
Time-of-Day Distribution:	
Daytime Accidents	+15.3 %
Nighttime Accidents	+83.6 %*
Type of Vehicle Collision:	
Single-Vehicle Accidents	+134.8 %*
Rear-End Accidents	+13.5 %
Other Multi-Vehicle Accidents	+20.7 %

TABLE E-3. I-35W MAINLANE ACCIDENT DATA

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	832	1337	1.955 (2)
During Construction	1236	2441	48.38 (4)

Change in Accidents = +22.9%; Z-Statistic = 3.662

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	621	998	2.599 (2)
During Construction	863	1655	44.254 (4)

Change in Accidents = +19.3%; Z-Statistic = 2.672

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	211	339	0.031 (2)
During Construction	373	786	7.494 (4)

Change in Accidents = +31.2%; Z-Statistic = 2.514

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	559	954	5.565 (2)
During Construction	848	1645	34.011 (4)

Change in Accidents = +13.7%; Z-Statistic = 1.884

d.f. degrees of freedom

TABLE E-3. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	273	383	3.269 (2)
During Construction	388	796	17.482 (4)

Change in Accidents = +46.2%; Z-Statistic = 3.780

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	232	294	3.155 (2)
During Construction	366	512	2.683 (4)

Change in Accidents = +10.4%; Z-Statistic = 0.888

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	331	710	0.220 (2)
During Construction	471	1412	45.022 (4)

Change in Accidents = +39.8%; Z-Statistic = 3.929

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	269	333	2.452 (2)
During Construction	399	517	7.401 (4)

Change in Accidents = +4.7%; Z-Statistic = 0.432

d.f. degrees of freedom

TABLE E-4. I-35W FRONTAGE ROAD ACCIDENT DATA

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	208	610	3.302 (2)
During Construction	307	1150	2.749 (4)

Change in Accidents = +27.7%; Z-Statistic = 2.380

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	158	470	1.053 (2)
During Construction	241	823	3.273 (4)

Change in Accidents = +14.8%; Z-Statistic = 1.174

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	50	140	3.779 (2)
During Construction	66	327	0.976 (4)

Change in Accidents = +76.9%; Z-Statistic = 2.680

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	155	407	2.222 (2)
During Construction	251	760	1.477 (4)

Change in Accidents = +15.3%; Z-Statistic = 1.195

d.f. degrees of freedom

TABLE E-4. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	53	201	1.661 (2)
During Construction	56	390	3.174 (4)

Change in Accidents = +83.6%; Z-Statistic = 2.889

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	27	105	5.020 (2)
During Construction	23	210	2.003 (4)

Change in Accidents = +134.8%; Z-Statistic = 2.772

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	31	136	3.112 (2)
During Construction	48	239	44.397 (4)

Change in Accidents = +13.5%; Z-Statistic = 0.498

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	150	369	0.807 (2)
During Construction	236	701	0.508 (4)

Change in Accidents = +20.7%; Z-Statistic = 1.537

d.f. degrees of freedom

APPENDIX F: US-75, PLANO, TX

Introduction

The North Central Expressway north of I-610 in Dallas is undergoing extensive reconstruction from I-610 north to Spring Creek Parkway. Work will begin in 1990 on the section south of I-610 to downtown Dallas and the section north of Spring Creek Parkway to McKinney. The construction effort between I-610 and Spring Creek Parkway is divided into five segments. One of those segments, a 3.3-mi section in Plano from F.M. 544 to Spring Creek Parkway, was selected for monitoring and analysis by TTI as part of Study 1108. The location of this project is shown in Figure F-1. Prior to construction, this section was a four-lane freeway with two-lane, one-way frontage roads. Additional freeway and frontage road lanes are being added as part of the project, so that in its final configuration both the freeway and frontage road will consist of three lanes per direction. For purposes of the accident analysis, the project limits were identified by control-section and milepoints and are documented below.

Control - Section	Milepoints
0047-06	9.3-12.7

Data Collection and Reduction

Segments located on each end of the construction zone were selected as comparison sections for the accident analysis. The control-section and milepoint limits of these comparison sections were:

Control - Section	Milepoints
0047-06	7.4-9.3
0047-06	12.7-14.6

Data from the years 1984 through May 1987 represented before construction conditions, whereas data from June 1987 through December 1988 represented conditions during construction. The data were reduced and analyzed as specified by Griffin (20) for a before-during accident analysis using a comparison section and a check for comparability between the construction section and comparison section. The total number of mainlane and frontage road accidents were evaluated, as well as specific accident categories.

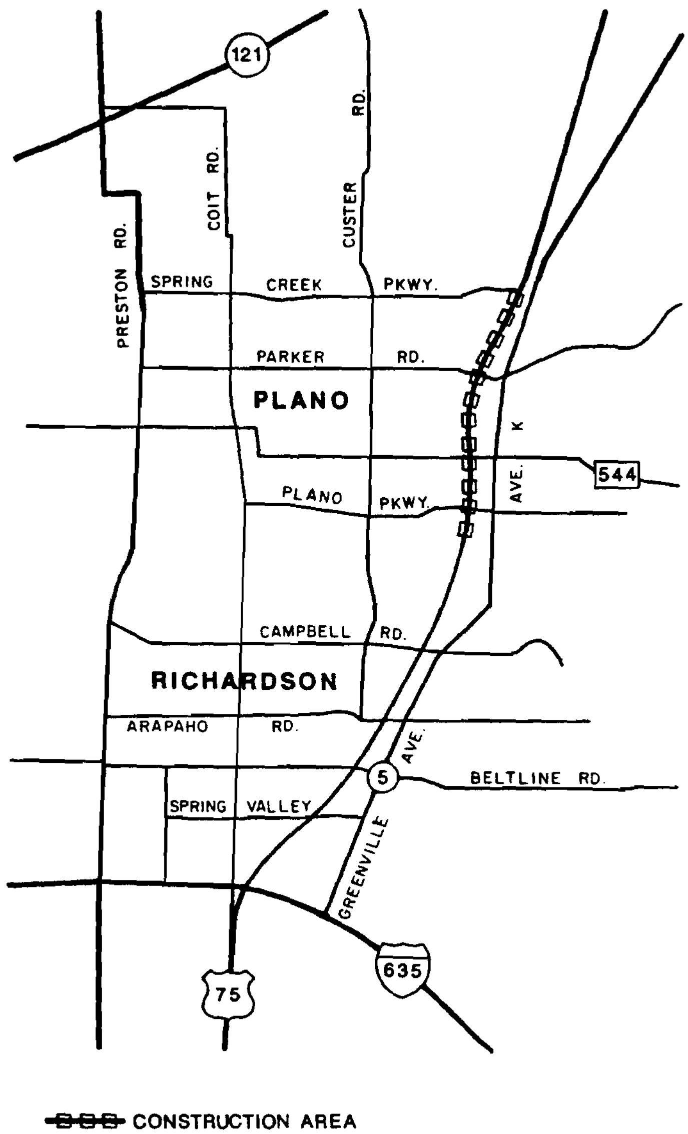

Figure F-1. The US-75 project in Plano

Results

Effect of Construction Upon Mainlane Accidents

Table F-1 summarizes the effect that construction had upon mainlane accidents on US-75 in Plano. Total accidents increased 13.3 percent during construction. In general, the increased accidents tended to be more severe. Severe accidents increased 42.5 percent, compared to PDO accidents which decreased 2.8 percent during construction. Nighttime accidents during the US-75 project increased 42.4 percent, whereas daytime accidents increased only 2.3 percent. Data from this site also show that rear-end accidents increased the most during construction, 72.5 percent. In contrast, single vehicle accidents decreased 3.0 percent during construction, and other multi-vehicle accidents decreased 22.8 percent.

Effect of Construction Upon Frontage Road Accidents

A summary of the effect of US-75 construction upon frontage road accidents is provided in Table F-2. Total frontage road accidents increased 6.4 percent during construction. This total increase was found to be due primarily to a dramatic 85.7 percent increase in severe accidents on the frontage road. PDO accidents decreased 11.5 percent during construction. The increased accidents were distributed fairly evenly throughout the day. Daytime accidents increased 7.0 percent during construction, and nighttime accidents increased 5.9 percent. With respect to the type of vehicle collisions which occurred during construction, rear-end accidents increased the greatest amount, 24.5 percent. Single-vehicle and other multi-vehicle accidents on the frontage road were generally unaffected by construction, with these types of accidents showing a 0.1 percent increase and a 2.3 percent decrease, respectively.

Tables F-3 and F-4 present the data, the comparability statistics, estimated changes, and statistical test results for the accident analysis. A G^2 value is presented next to each set of data. This statistic is used to test the comparability between the construction section and comparison section in terms of accident trends. The computed statistic is tested against a standard Chi-Square distribution with the appropriate degrees of freedom. If the computed G^2 value is less than the critical Chi-Square value, the two sections are assumed to be comparable in terms of accident trends. A Z-statistic is presented to test the significance of the percent change in accidents during construction. This statistic is tested against a standard Normal distribution.

TABLE F-1. EFFECT OF CONSTRUCTION UPON MAINLANE ACCIDENTS: US-75, PLANO, TX

Accident Category	Change in Accidents During Construction
All Accidents	+13.3 %
Accident Severity:	
PDO Accidents	-2.8 %
Severe Accidents	+42.5 %
Time-of-Day Distribution:	
Daytime Accidents	+2.3 %
Nighttime Accidents	+42.4 %
Type of Vehicle Collision:	
Single-Vehicle Accidents	-3.0 %
Rear-End Accidents	+72.5 %*
Other Multi-Vehicle Accidents	-22.8 %

* Statistically significant at 0.05 level of significance

TABLE F-2. EFFECT OF CONSTRUCTION UPON FRONTAGE ROAD ACCIDENTS: US-75, PLANO, TX

	Change in Accidents During Construction
All Accidents	+6.4 %
Accident Severity:	
PDO Accidents	-11.5 %
Severe Accidents	+85.7 %
Time-of-Day Distribution:	
Daytime Accidents	+7.0 %
Nighttime Accidents	+5.9 %
Type of Vehicle Collision:	
Single-Vehicle Accidents	+0.1 %
Rear-End Accidents	+24.5 %
Other Multi-Vehicle Accidents	-2.3 %

* Statistically significant at 0.05 level of significance

TABLE F-3. US-75 MAINLANE ACCIDENT DATA

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	371	354	1.051 (3)
During Construction	172	186	0.365 (1)

Change in Accidents = +13.3%; Z-Statistic = 0.968

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	218	212	7.081 (3)
During Construction	110	104	0.053 (1)

Change in Accidents = -2.8%; Z-Statistic = -0.168

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	153	142	5.805 (3)
During Construction	62	82	1.637 (1)

Change in Accidents = +42.5%; Z-Statistic = 1.730

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	234	256	0.265 (3)
During Construction	118	132	0.055 (1)

Change in Accidents = +2.3%; Z-Statistic = 0.413

d.f. degrees of freedom

TABLE F-3. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	137	98	1.719 (3)
During Construction	53	54	0.353 (1)

Change in Accidents = +42.4%; Z-Statistic = 1.510

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	106	77	1.259 (3)
During Construction	61	43	1.140 (1)

Change in Accidents = -3.0%; Z-Statistic = -0.121

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	163	136	0.663 (3)
During Construction	66	95	0.108 (1)

Change in Accidents = +72.5%; Z-Statistic = 2.755

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	102	141	0.618 (3)
During Construction	45	48	0.366 (1)

Change in Accidents = -22.8%; Z-Statistic = -1.059

d.f. degrees of freedom

TABLE F-4. US-75 FRONTAGE ROAD ACCIDENT DATA

TOTAL ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	154	400	1.144 (3)
During Construction	55	152	4.930 (1)

Change in Accidents = +6.4%; Z-Statistic = 0.338

PDO ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	104	295	1.323 (3)
During Construction	45	113	3.913 (1)

Change in Accidents = -11.5%; Z-Statistic = -0.580

SEVERE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	50	105	0.221 (3)
During Construction	10	39	0.873 (1)

Change in Accidents = +85.7%; Z-Statistic = 1.572

DAYTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	109	289	1.670 (3)
During Construction	37	105	4.503 (1)

Change in Accidents = +7.0%; Z-Statistic = 0.306

d.f. degrees of freedom

TABLE F-4. (CONT'D)

NIGHTTIME ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	45	111	3.273 (3)
During Construction	18	47	0.646 (1)

Change in Accidents = 5.9%; Z-Statistic = 0.173

SINGLE VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	39	55	3.732 (3)
During Construction	17	24	8.629 (1)

Change in Accidents = +0.1%; Z-Statistic = .003

REAR END ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	39	142	0.350 (3)
During Construction	15	68	0.449 (1)

Change in Accidents = +24.5%; Z-Statistic = 0.649

OTHER MULTI-VEHICLE ACCIDENTS

	No. Accidents in Comparison Section	No. Accidents in Construction Section	Comparability Statistics (d.f.)
Before Construction	76	203	3.851 (3)
During Construction	23	60	0.457 (1)

Change in Accidents = -2.3%; Z-Statistic = -0.084

d.f. degrees of freedom