Technical Report Standard Title Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-92/1108-4		

4. Title and Subtitle	5. Report Date
Travel Impacts of the US-59 Southwest Freeway Reconstruction Project in Houston	September 1992
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Mark A. Shafer, Kevin D. Tyer, and Raymond A. Krammes	Research Report 1108-4
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843	11. Contract or Grant No. Study 2-8-87/1-1108
12. Sponsoring Agency and Address	13. Type of Report and Period Covered
Texas Department of Transportation Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Interim Report (July 1988-August 1992)
	14. Sponsoring Agency Code

15. Supplementary Notes

This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.
Study Title: Traffic Pattern Assessment and Road User Delay Costs Resulting from Roadway Construction Options

16. Abstract

This report documents the results and findings of a five-year study to monitor the travel impacts of the US-59 Southwest Freeway reconstruction project in Houston, Texas. The monitoring effort included screen line traffic volume counts and travel time runs on the freeway, frontage roads, and alternative routes. The results indicate drops in traffic volumes on the freeway primarily during the first phase of reconstruction and on the westbound frontage road throughout all three phases of recontruction. Only minor volume variations were observed on other routes in the corridor. Travel times and average speeds in the corridor did not change significantly during reconstruction. The impacts of the Southwest Freeway project were generally consistent with the impacts observed previously at other major urban freeway reconstruction projects in Texas.

17. Key Words	18. Distribution Statement
Freeway Reconstruction Corridor Analysis	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	43	

TRAVEL IMPACTS OF THE US-59 SOUTHWEST FREEWAY RECONSTRUCTION PROJECT IN HOUSTON

by

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and

Raymond A. Krammes

Research Report 1108-4
Research Study Number 2-8-87/1-1108

Sponsored by

Texas Department of Transportation
in cooperation with
U. S. Department of Transportation, Federal Highway Administration

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, TX 77843

September 1992

METRIC (SI*) CONVERSION FACTORS

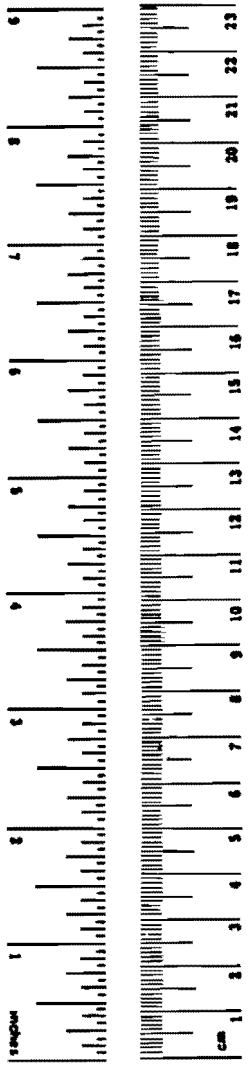
APPROXIMATE CONVERSIONS TO SI UNITS

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

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

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

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

TEMPERATURE (exact)

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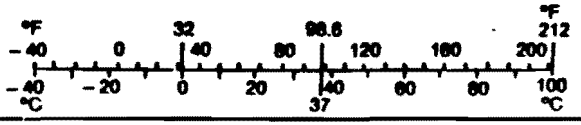

These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation and assistance of many Texas Department of Transportation personnel during the conduct of this study. Mark A. Marek (D-8) served as Technical Panel Chairperson. Lewis R. Rhodes, Jr. (D-18STO) and Steven Z. Levine (District 12) served as a Technical Panel Members. Numerous individuals in the Texas Department of Transportation District 12 office in Houston and the Texas Transportation Institute Houston office assisted in the study.

SUMMARY OF FINDINGS

This report is the fourth interim report prepared under Study No. 2-8-87/1-1108 "Traffic Pattern Assessment and Road User Delay Costs Resulting from Roadway Construction Options." Previous reports were:

- Report 1108-1 "Travel Impacts of Freeway Reconstruction: Synthesis of Previous Experience"
- Report 1108-2 "Analysis of Accidents at Long-Term Construction Projects in Texas"
- Report 1108-3 "Travel Impacts of Urban Freeway Reconstruction Projects in Texas"

This report presents the results and findings of a five-year study to monitor the travel impacts of the US-59 Southwest Freeway reconstruction project in Houston, Texas. The monitoring effort followed the data collection and statistical analysis methodology previously documented in Research Report 1108-3. Data collection included screen line traffic volume counts and travel time runs on the freeway, frontage roads, and alternative routes.

The results indicate drops in traffic volumes on the freeway primarily during the first phase of reconstruction and on the westbound frontage road throughout all three phases of recontruction. Only minor volume variations were observed on other routes in the corridor. Travel times and average speeds in the corridor did not change significantly during reconstruction. The impacts of the Southwest Freeway project were generally consistent with the impacts observed previously at other major urban freeway reconstruction projects in Texas.

IMPLEMENTATION STATEMENT

This study support the findings of Research Report 1108-3 and should be useful to the Texas Department of Transportation in its future corridor traffic management planning efforts for urban freeway reconstruction projects. The results for all of the reconstruction projects monitored suggest that the traffic control plans typically employed by the Department (which generally maintain the same number of freeway lanes as before reconstruction and involve only minor capacity reductions associated with narrowing lane and shoulder widths and detouring traffic within the right-of-way) are generally effective at minimizing the adverse travel impacts resulting from the projects. When access to the freeway is restricted due to ramp closures and/or frontage road lane closures, however, some diversion of traffic away from the freeway is likely to occur. Therefore, when considering traffic control options that would significantly reduce either the capacity of the freeway or access to the freeway, the Department should determine the availability of excess capacity on other routes in the corridor.

DISCLAIMER

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1. INTRODUCTION

This report documents the results and findings of a 5-year effort to monitor traffic conditions in the US-59 Southwest Freeway corridor in Houston. The purpose of the monitoring effort was to measure the traffic impacts of a major reconstruction project on the freeway.

The US-59 Southwest Freeway project is the sixth urban freeway reconstruction project in Texas that has been monitored as part of Study 1108 "Traffic Pattern Assessment and Road User Delay Costs Resulting from Roadway Construction Options." The monitoring efforts for the five previous projects were documented in Research Report 1108-3 "Travel Impacts of Urban Freeway Reconstruction Projects in Texas." The other projects included:

- I-35 in Austin,
- US-75 in Plano,
- I-45 North Freeway in Houston,
- I-35W in Fort Worth, and
- I-10 in El Paso.

Chapter 2 describes the US-59 Southwest Freeway project and the data collection and analysis methodology for the monitoring efforts. Chapter 3 summarizes the observed travel impacts with respect to changes in traffic volumes and travel times and speeds. Chapter 4 presents a summary and conclusions.

2. PROJECT DESCRIPTION

US-59 PROJECT

The US-59 Southwest Freeway is a major highway that connects southwest Houston to areas including the Galleria, the Summit, and the Central Business District. An 11.0-mile section from Shepherd Drive to Beltway 8 was reconstructed during the period 1989-1992. Figure 1 indicates the section of freeway that was reconstructed.

The preconstruction conditions for a typical freeway section on US-59 included a six-lane freeway with a median consisting of paved shoulders and concrete traffic barriers. The frontage roads consisted of two, one-way traffic lanes in each direction. The improvements to the freeway and frontage roads occurred in three phases. Phase I included frontage road reconstruction and intersection improvement. Phase II consisted of the addition of mainlanes between the existing lanes and the newly constructed frontage road lanes. Phase III construction added the High Occupancy Vehicle (HOV) lanes in the median of the freeway.

When construction is completed in late 1992, the typical cross section will be an eight-lane freeway with a median consisting of paved shoulders and a barrier-separated reversible HOV lane. The frontage road will typically consist of three, one-way traffic lanes in each direction.

DATA COLLECTION

The data collection efforts in the US-59 Southwest Freeway corridor in Houston included five annual field studies. Table 1 summarizes the construction status during each of the data collection periods. Traffic conditions were monitored before construction in July 1988 and May 1989 and during construction phases I, II, and III in May 1990, May 1991, and May 1992, respectively. The effort involved the collection of screen line traffic volumes and travel times.

Table 1. Construction Status During Traffic Data Collection Periods

Traffic Data Collection Period	Construction Status
July 1988	Before Construction
May 1989	Before Construction
May 1990	During Phase I
May 1991	During Phase II
May 1992	During Phase III

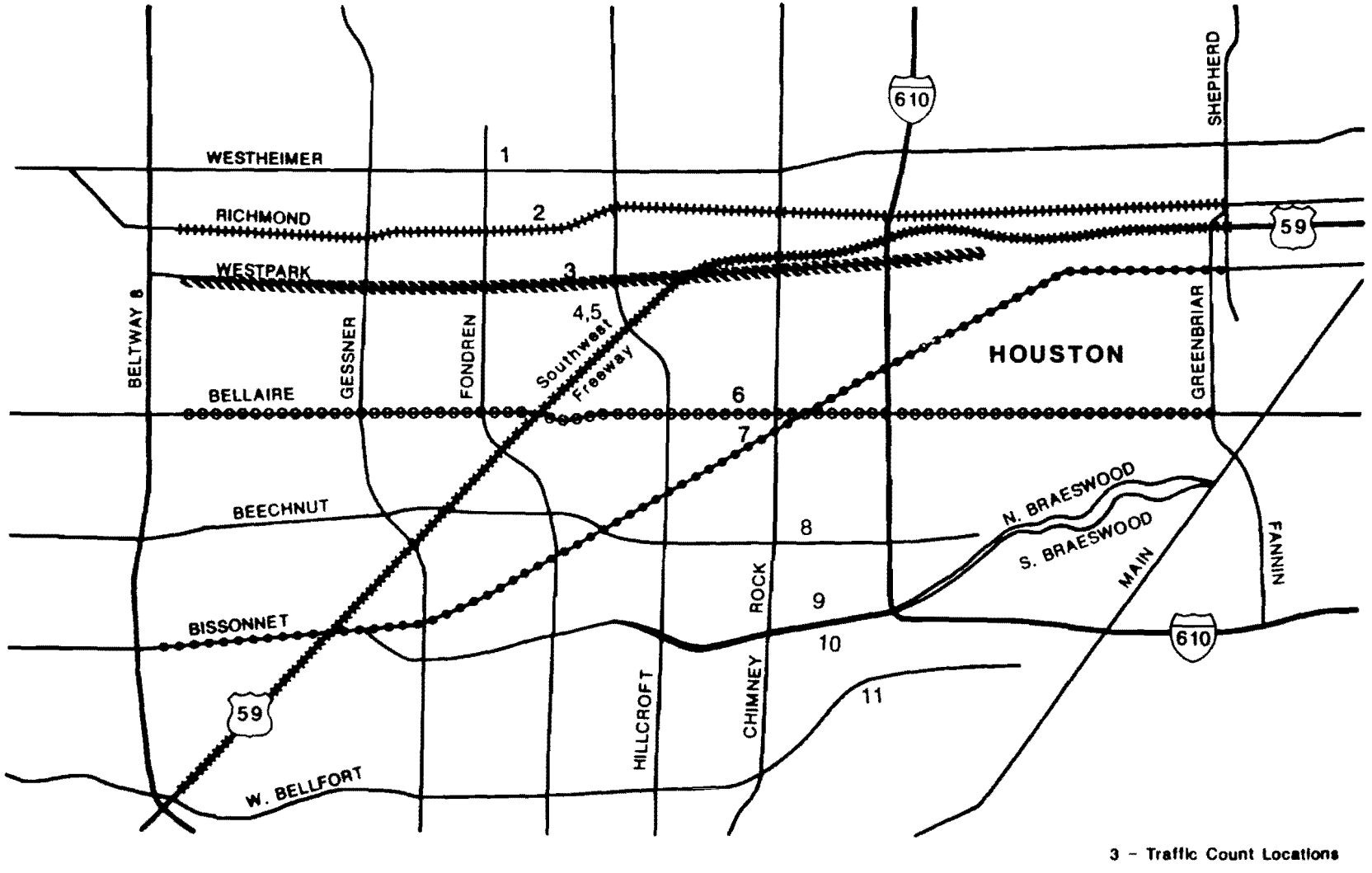


Figure 1. US-59 Southwest Freeway Study Corridor.

During the data collection in May 1990, phase I was in progress. Lanes were being added to both the northbound and southbound frontage roads. U-turn lanes were closed at most intersections, and left-turn lanes were reduced to minimum distances. At several locations, ramps were changed from a diamond to an "X" configuration.

During the May 1991 data collection, phase II was underway. Additional freeway mainlanes were being constructed between the existing mainlanes and the frontage road. Construction on the frontage roads caused intermittent lane closures in both directions and continued closure of most U-turn lanes. Night time closures of cross streets allowed work on the bridge structures for the outside freeway mainlanes. Off-peak lane closures occurred on Westpark at US-59, and lane closures occurred on Bellaire due to work by the city of Houston.

Construction on the inside mainlanes and transitway was in progress during the May 1992 data collection. Frontage road work continued on the northeastern part of the site causing lane closures. T-ramps connecting the transitway to the parking facilities were under construction. Night time closure of the freeway occurred to allow work on the bridge structures of the inside mainlanes and the transitway.

Traffic Volume Data

Traffic volume data were collected on the mainlanes, frontage roads, and major alternative routes at a single screen line which runs diagonally though the corridor. The screen line count locations are illustrated in Figure 1 and listed in Table 2. During each field study, data were collected on the same weekdays (Tuesday, Wednesday, Thursday).

Table 2. Traffic Volume Count Locations

Route	Count Location Number
US-59 Freeway	4
Frontage Road	5
Primary Alternative Routes:	
Westheimer	1
Richmond	2
Westpark	3
Bellaire	6
Bissonnet	7
Secondary Alternative Routes:	
Beechnut	8
North Braeswood	9
South Braeswood	10
West Bellfort	11

Average daily traffic volume data were collected from five Automatic Traffic Recorder (ATR) stations in the Houston area. The data from the ATR stations are used to adjust observed volumes by the seasonal variations in regional traffic patterns. These adjusted volumes are compared to observed volumes to determine the changes that are due to the reconstruction project. Averaged volumes from stations S-157 and S-182 were selected as the controls for this study. Stations S-157 and S-182 are located 11 miles from the study site on North Loop IH-610 and 15 miles from the study site on East Loop IH-610, respectively. These two stations were the only stations in the Houston area that remained in service throughout the study. This procedure was modeled after a statistical testing approach described by Griffin (1). Tyer (2) applied the procedure to screen line volumes at reconstruction projects. The methodology is summarized in Research Report 1108-3 (3). The z-test was used to determine whether the percentage change was significantly different from zero at a 0.05 significance level.

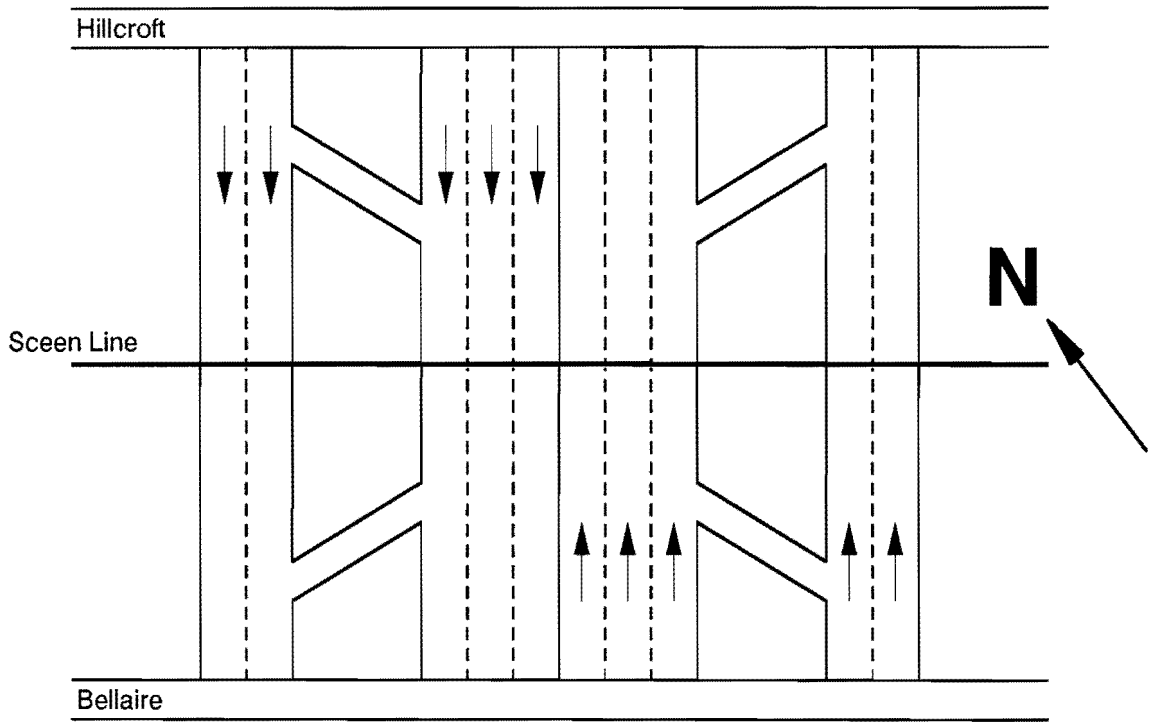
The traffic volume data collected during July 1988 were used to test the comparability of the ATR control locations to US-59 under before construction conditions. Through statistical testing, the traffic volume data on US-59 before construction were found to be comparable to the traffic volume data at the ATR stations. Therefore, the procedure should provide an objective basis for estimating the volume changes attributable to the reconstruction project.

The data from July 1988 were also used to examine the effects on secondary routes in the corridor. Table 3 shows the percent of traffic in the corridor on the secondary routes. Due to the small changes on these routes they were not included in further statistical testing.

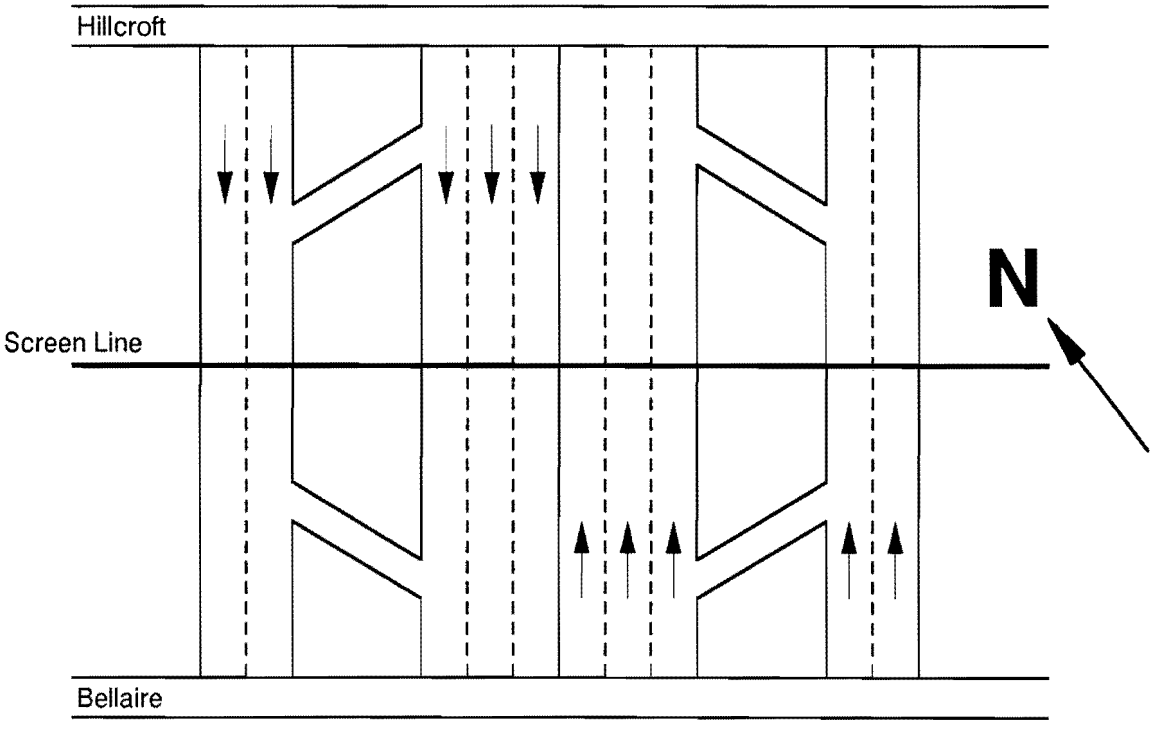
Table 3. Percentage of Traffic in the US-59 Southwest Freeway Corridor on Secondary Routes

Period	Before (July 1988)	During 1 (May 1990)	During 2 (May 1991)	During 3 (May 1992)
24 Hour	22%	23%	22%	21%
A.M. Peak	5%	5%	5%	4%
P.M. Peak	6%	5%	6%	5%

Between the 1990 field study and the 1991 field study, the ramp configuration changed between Hillcroft and Bellaire. The volume data from the freeway and frontage roads during the May 1991 and May 1992 field studies were adjusted to reflect this change. Figure 2 shows the conditions of the ramps before and after the changes were made. Ramp volumes collected in 1991 and 1992 were used to adjust the freeway and frontage road volumes so comparisons could be made to the May 1989 study. Tables 4 and 5 show the volumes on the freeway and frontage roads, respectively, before and after the adjustments.



a) Before May 1989 and During May 1990



b) During May 1991 and During May 1992

Figure 2. US-59 Ramp Configuration Before and During Construction at Screen Line Count Location.

Table 4. Freeway Volume Data Before and After Adjustments

Study	Period	Volume[a]		Adjusted Volume[b]	
		NB	SB	NB	SB
May 1991	24 Hour	48712	53488	72805	84489
	A.M. Peak	9702	6869	13386	10107
	Off Peak	19833	19832	31005	32896
	P.M. Peak	8223	12458	12257	19629
May 1992	24 Hour	47432	54356	83055	87197
	A.M. Peak	8938	7216	16131	10520
	Off Peak	18858	19597	34865	32510
	P.M. Peak	8328	12606	13475	20447

[a] "X" configuration

[b] Volume adjusted to reflect diamond configuration that existed in May 1989 and May 1990.

Table 5. Frontage Road Volume Data Before and After Adjustments

Study	Period	Volume[a]		Adjusted Volume[b]	
		NB	SB	NB	SB
May 1991	24 Hour	22253	22421	15269	7463
	A.M. Peak	5332	1771	3615	481
	Off Peak	9537	9666	6587	3382
	P.M. Peak	3612	5910	2521	1669
May 1992	24 Hour	30280	24630	16832	10853
	A.M. Peak	7018	1768	2228	516
	Off Peak	13976	9902	9098	4934
	P.M. Peak	4749	6969	3183	2635

[a] "X" configuration

[b] Volume adjusted to reflect diamond configuration that existed in May 1989 and May 1990.

Travel Time and Speed Data

Travel time data were collected on the mainlanes, frontage roads, and four major alternative routes. The floating car technique was used in which the driver of a test vehicle attempts to operate at the median speed on the route by passing as many vehicles as pass the test vehicle (4). Travel times were measured from Beltway 8 to N. Shepherd Drive, a distance of approximately 11 miles. The travel time routes are highlighted in Figure 1.

The frontage road is discontinuous in both directions between Hillcroft and Newcastle. Therefore, frontage road travel times include a short distance where data were collected on the freeway to bypass this discontinuity.

The major east-west alternative routes in the corridor are Richmond, Westpark, Bellaire, and Bissonnet. Richmond is primarily a six-lane signalized arterial with a 35 mph speed limit, although the east end of the route from Buffalo Speedway to Shepherd and west end of the route from Fondren to Beltway 8 are only four lanes. Westpark is also predominantly a six-lane signalized arterial with a continuous left-turn lane. The speed limit on Westpark is 35 mph. Westpark does not span the entire length of the study site. The route originally extended from Beltway 8 to Edloe but in 1990 the route was extended to Kirby. For travel times to reflect the entire study corridor, a detour was made at Kirby and the route was finished on the frontage road. Bellaire alternates between six and eight lanes throughout the corridor and has a speed limit of 35 mph. Bissonnet is predominantly a four-lane signalized arterial with a 35 mph speed limit. Between the Southwest Freeway and Beltway 8 the roadway is six lanes, and between Buffalo Speedway and Shepherd the roadway drops to two lanes.

The times at which travel time runs started are shown in Tables 6 and 7. Morning runs (A. M. Peak and Off-Peak) were performed in the inbound direction (Eastbound), and afternoon runs (P. M. Peak and Off-Peak) were performed in the outbound direction (Westbound). All runs were performed Tuesday through Thursday. Travel time runs on the alternative routes began every 1½ hours. Freeway travel time runs began each ½ hour and were repeated on a second day to improve the quality of the data and to ensure all times were covered. Travel time runs on the frontage road started every hour on the ½ hour throughout the peak and off-peak periods.

The paired t-test was used to determine whether the mean of the differences between the travel times at each start time was significantly different from zero at a 0.05 significance level or, in other words, whether the changes in travel times attributable to the reconstruction project were statistically significant. Travel time data from before and during reconstruction were paired by starting time to help separate the changes attributable to construction from changes due to hourly volume patterns. Data were eliminated from comparison if the travel time was affected by accidents or extreme weather conditions. This was done to further isolate the effects of reconstruction from normal travel patterns.

TABLE 6. Schedule of Travel Time Runs on the Expressway and Frontage Roads: US-59 Corridor in Houston

Direction	Beginning Times of Travel Time Runs		
	Tuesday	Wednesday	Thursday
Eastbound (Inbound)	6:00 A.M. 6:30 A.M. 7:00 A.M. 7:30 A.M. 8:00 A.M. 8:30 A.M. 9:00 A.M. 9:30 A.M. 10:00 A.M. 10:30 A.M. 11:00 A.M.	6:00 A.M. 6:30 A.M. 7:00 A.M. 7:30 A.M. 8:00 A.M. 8:30 A.M. 9:00 A.M. 9:30 A.M. 10:00 A.M. 10:30 A.M. 11:00 A.M.	6:30 A.M. 7:30 A.M. 8:30 A.M. 9:30 A.M. 10:30 A.M.
Westbound (Outbound)	2:00 P.M. 2:30 P.M. 3:00 P.M. 3:30 P.M. 4:00 P.M. 4:30 P.M. 5:00 P.M. 5:30 P.M. 6:00 P.M. 6:30 P.M. 7:00 P.M.	2:00 P.M. 2:30 P.M. 3:00 P.M. 3:30 P.M. 4:00 P.M. 4:30 P.M. 5:00 P.M. 5:30 P.M. 6:00 P.M. 6:30 P.M. 7:00 P.M.	2:30 P.M. 3:30 P.M. 4:30 P.M. 5:30 P.M. 6:30 P.M.

TABLE 7. Schedule of Travel Time Runs on the Alternative Routes: US-59 Corridor in Houston

Direction	Tuesday	Wednesday	Thursday	
	Bissonnet	Richmond	Westpark	Bellaire
Inbound	6:30 A.M. 7:30 A.M. 9:00 A.M. 10:30 A.M.	6:30 A.M. 7:30 A.M. 9:00 A.M. 10:30 A.M.	6:30 A.M. 7:30 A.M. 9:00 A.M. 10:30 A.M.	6:30 A.M. 7:30 A.M. 9:00 A.M. 10:30 A.M.
Outbound	2:00 P.M. 3:30 P.M. 5:00 P.M. 6:30 P.M.	2:00 P.M. 3:30 P.M. 5:00 P.M. 6:30 P.M.	2:00 P.M. 3:30 P.M. 5:00 P.M. 6:30 P.M.	2:00 P.M. 3:30 P.M. 5:00 P.M. 6:30 P.M.

3. OBSERVED TRAVEL IMPACTS

The analysis indicates that the reconstruction project on US-59 in Houston significantly affected traffic volumes through the corridor. Freeway traffic volumes were generally lower during the first two phases of reconstruction than the seasonally adjusted volumes that would have been expected if construction had not occurred. Volumes on the frontage roads experienced significant decreases throughout reconstruction. Alternative route volumes were also affected by the construction project. With only a few exceptions, there were no significant changes in travel times on the freeway, frontage roads, and alternative routes.

TRAFFIC VOLUMES

Volume data were divided into four time periods; twenty-four hour, A.M. peak, off peak, and P.M. peak. The A.M. peak is from 6:00 A.M. to 9:00 A.M., the off peak from 9:00 A.M. to 4:00 P.M., and the P.M. peak runs from 4:00 P.M. to 7:00 P.M. Comparisons were made by time period between before and during reconstruction data. The largest percentage changes occurred on the frontage roads.

Changes in Total Daily Screen Line Traffic Volumes

Table 8 summarizes the changes in the daily screen line traffic volumes during reconstruction. The volume of the corridor dropped below expected values in both directions. Expected values are determined by using the volumes from control locations to adjust screen line volumes to represent conditions without construction. A 16 percent drop occurred in the corridor during May 1990, a 14 percent drop in May 1991, and a 9 percent drop in May 1992. The eastbound direction showed the greatest drop in volume during the first two years of construction. In the final year of construction the reduction was about equal in both directions. The decrease in volume suggests that either trips in the corridor were canceled or that other forms of transportation were utilized.

Changes in Daily Traffic Volumes by Route

Eastbound (Inbound) Traffic

Table 9 presents the daily eastbound traffic volumes on each route before and during reconstruction. Table 10 summarizes the z-test statistics for each route. Similar tables for the A.M., Off, and P.M. peak periods are presented in Appendix A.

Freeway conditions appear to have improved as construction progressed. The freeway volume decreased 15 percent at the screen line in May 1990 and decreased 10 percent in May 1991. However, the volume of the freeway at the screen line increased only 2 percent in May 1992. These trends suggest that motorists changed their destinations, diverted to other routes, or canceled trips as construction began and returned to the freeway as construction continued.

Table 8. Total Daily Screen Line Traffic Volumes: US-59 Corridor in Houston

Direction	Before (May 1989)	During Reconstruction Volumes (May 1990)				During Reconstruction Volumes (May 1991)				During Reconstruction Volumes (May 1992)			
	Observed	Estimated[a]	Observed	Δ[b]	% Δ	Estimated[a]	Observed	Δ[b]	% Δ	Estimated[a]	Observed	Δ[b]	% Δ
EB	207618	229744	191443	-38301	-17	233057	195808	-37249	-16	233616	212723	-20893	-9
WB	204930	226770	192652	-34118	-15	230040	203298	-26742	-12	230592	208604	-21988	-10
Total	412548	456514	384095	-72419	-16	463097	399106	-63991	-14	464208	421327	-42881	-9

[a] Volumes were estimated by seasonally adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated.

Table 9. Eastbound Daily Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	72049	79727	67830	-11897	80877	72805	-8072	81071	83055	1984
Frontage Road	11451	12671	8258	-4413	12854	15269	2415	12885	16832	3947
Westheimer	52072	57621	34868	-22753	58452	34475	-23977	58593	38174	-20419
Richmond	15271	16898	19038	2140	17142	17824	682	17183	16392	-791
Westpark	26408	29222	24091	-5131	29644	24180	-5464	29715	25860	-3855
Bellaire	18751	20749	18382	-2367	21049	18247	-2802	21099	20395	-704
Bissonnet	11616	12854	18976	6122	13039	13008	-31	13071	12015	-1056

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table 10. Z-Test Statistics for Changes in Daily Traffic Volumes: US-59 Corridor in Houston

Route	During Reconstruction Volumes (May 1990)				During Reconstruction Volumes (May 1991)				During Reconstruction Volumes (May 1992)			
	Eastbound		Westbound		Eastbound		Westbound		Eastbound		Westbound	
	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]
Freeway	-15	-24.24	-9	-14.76	-10	-16.31	6	8.84	2	3.83	9	13.52
Frontage Road	-35	-28.71	-44	-47.13	19	13.33	-65	-74.14	31	21.08	-49	-53.81
Westheimer	-39	-63.83	-18	-23.18	-41	-66.97	-8	-9.73	-35	-55.62	-15	-19.12
Richmond	13	10.37	1	0.54	4	3.35	-5	-4.67	-5	-3.97	11	-10.41
Westpark	-18	-19.98	-35	-45.56	-18	-21.11	-32	-41.90	-13	-14.61	-28	-36.27
Bellaire	-11	-10.98	6	5.05	-13	-12.93	-5	-4.86	-3	-3.15	3	2.29
Bissonnet	48	31.51	6	4.36	0	-0.18	-4	-3.19	-8	-6.22	-4	-3.23

[a] Percentage change between the estimated and observed during volumes.

[b] Percentage change (%Δ) is significant at $\alpha = 0.05$ if $|z| > 1.96$

The largest percentage changes in traffic volume occurred on the frontage roads. The reductions in the eastbound direction were restricted to the May 1990 data, which coincides with the heavy phase I construction on the frontage roads during that year. Traffic volumes in the westbound direction of the frontage road were much lower than expected during all three phases of construction (May 1990, May 1991, and May 1992).

A large change in volume occurred on Westheimer between May 1989 and May 1990. The volume on the route stabilized for the remaining years of the study. The large volume in May 1989 may be attributed to a reconstruction project on Westheimer that concluded just before the May 1989 study occurred.

Richmond and Bissonnet received a majority of the diverted traffic during the first year of reconstruction. During the second year of the reconstruction project, both Richmond and Bellaire are very close to their expected volumes. This indicates that construction did not affect traffic on these two routes during May 1991. During the final year of reconstruction, the traffic appears to return to the freeway and frontage road. Westpark and Bellaire experienced a reduction in volume throughout the study.

Westbound (Outbound) Traffic

Table 11 summarizes the daily westbound traffic volumes on each route before and during reconstruction. Table 10 summarizes the z-test statistics for each route. Similar tables for the A.M., Off, and P.M. peak periods are presented in Appendix A. Freeway volumes decreased by 9 percent during the first year of construction. This change was followed by an increase of 6 percent in May 1991 and an increase of 9 percent in May 1992. This indicates that westbound (outbound) traffic was not adversely affected while the freeway was under construction. The frontage road experienced a heavy reduction during all three years of reconstruction at the screen line.

Summary

Combining eastbound and westbound directions, total volumes on the freeway during May 1990 (phase I) were 12 percent lower than would have been expected if normal regional volume patterns had prevailed. During May 1991 (phase II), total freeway volumes returned almost to normal (2 percent lower than expected). During May 1992 (phase III), total freeway volumes exceeded normally expected volumes by 6 percent.

TRAVEL TIMES AND SPEEDS

Travel times were measured on the freeway, frontage road, and on the alternative routes of Richmond, Westpark, Bellaire, and Bissonnet. Travel times were divided into four time periods: A.M. peak, A.M. off-peak, P.M. off-peak, and P.M. peak. The off-peak period was divided in half because data were collected in different directions during the A.M. and P.M. periods.

Table 11. Westbound Daily Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	71183	78769	71580	-7189	79905	84489	4584	80097	87197	7100
Frontage Road	18998	21023	11766	-9257	21326	7463	-13863	21377	10853	-10524
Westheimer	35488	39270	32203	-7067	39836	36735	-3101	39932	33970	-5962
Richmond	17623	19501	19618	117	19782	18781	-1001	19830	17632	-2198
Westpark	32907	36414	23843	-12571	36939	25154	-11785	37028	26672	-10356
Bellaire	17354	19203	20301	1098	19480	18446	-1034	19527	20026	499
Bissonnet	11377	12589	13341	752	12771	12230	-541	12802	12254	-548

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Tables 12 through 15 summarize the travel times and speeds before and during construction for the four time periods. Tables 16 and 17 summarize the paired t-test results.

A.M. Peak

The greatest change in travel time took place on the frontage road during the May 1990 study. This change may be attributed to the large amount of construction taking place on the frontage road at that time. The freeway maintained the highest average speed of all the routes throughout the study. The paired t-test indicates that the only significant change between before and during travel times occurred on Bissonnet between May 1989 and May 1990. This travel time increased by two minutes.

A.M. Off-Peak

Off-peak lane closures on the freeway increased the average travel time by three minutes during May 1992. The three-minute difference reduced the average travel speed by eleven miles per hour. The frontage road experienced little change in travel times during reconstruction. The only significant change on the alternative routes occurred on Westpark during May 1990. A 4.6-minute increase in travel time might have been caused by the expansion of Westpark from Edloe to Kirby between May 1989 and May 1990.

P.M. Off-Peak and P.M. Peak

No significant changes in travel times occurred during either the P.M. peak and the P.M. off-peak. The freeway retained the lowest average travel time and highest speed of any route in the corridor. Travel times on the frontage roads changed corresponding with the level of construction on the frontage roads. The longest travel times occurred during the heaviest period of reconstruction.

Table 12. A.M. Peak Period Eastbound Travel Times & Speeds: US-59 Corridor in Houston

Route	Distance	Sample Size[a]	Average Travel Time (min)				Average Travel Speed (mph)			
			Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)	Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)
US-59 Mainlanes	11.0	6	17.7	21.8	18.1	17.2	37	30	36	38
Frontage Road	10.8	3	25.9	37.4	32.0	22.8	25	17	20	28
Richmond	8.9	2	25.4	25.3	25.0	25.6	21	21	21	21
Westpark	9.0	2	24.8	21.5	20.4	26.0	22	25	26	21
Bellaire	8.7	2	24.7	24.1	22.7	25.4	21	22	23	21
Bissonnet	9.9	2	26.0	28.0	27.0	27.1	23	22	21	22

[a] Number of travel time runs during each study period.

Table 13. A.M. Off-Peak Period Eastbound Travel Times & Speeds: US-59 Corridor in Houston

Route	Distance	Sample Size[a]	Average Travel Time (min)				Average Travel Speed (mph)			
			Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)	Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)
US-59 Mainlanes	11.0	5	12.1	11.6	10.9	15.0	55	57	60	44
Frontage Road	10.8	2	23.3	23.2	24.6	23.9	27	27	26	27
Richmond	8.9	2	20.5	18.9	20.0	18.1	26	28	27	30
Westpark	9.0	2	18.2	22.8	21.0	22.5	35	24	26	24
Bellaire	8.7	2	22.0	20.3	19.9	18.1	24	26	26	29
Bissonnet	9.9	2	23.9	25.4	22.5	22.6	24	25	23	23

[a] Number of travel time runs during each study period.

Table 14. P.M. Off-Peak Period Westbound Travel Times & Speeds: US-59 Corridor in Houston

Route	Distance	Sample Size[a]	Average Travel Time (min)				Average Travel Speed (mph)			
			Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)	Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)
US-59 Mainlanes	10.8	4	11.6	11.5	11.3	12.4	56	57	58	53
Frontage Road	10.8	2	27.2[b]	31.8	24.3	22.7	24[b]	21	27	29
Richmond	8.9	2	21.9	20.5	22.1	21.9	25	26	24	25
Westpark	9.1	2	20.0	23.6	23.0	19.7	26	23	24	28
Bellaire	8.7	2	21.9[b]	24.1	21.9	22.4	24[b]	22	24	23
Bissonnet	9.9	2	26.7	25.0	25.9	26.6	22	24	23	22

[a] Number of travel time runs during each study period.

[b] Taken from July 1988 data.

Table 15. P.M. Peak Period Westbound Travel Times & Speeds: US-59 Corridor in Houston

Route	Distance	Sample Size[a]	Average Travel Time (min)				Average Travel Speed (mph)			
			Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)	Before (May 1989)	During (May 1990)	During (May 1991)	During (May 1992)
US-59 Mainlanes	10.8	5	21.0	20.3	25.0	18.6	31	31	26	35
Frontage Road	10.8	2	30.5[b]	39.1	41.5	32.5	21[b]	21	16	20
Richmond	8.9	2	30.6	23.3	27.5	28.4	18	18	19	19
Westpark	9.1	2	25.4	24.0	24.3	25.4	21	21	23	22
Bellaire	8.7	2	23.3[b]	29.9	29.5	24.2	23[b]	18	18	24
Bissonnet	9.9	2	31.8	31.6	26.0	27.4	19	19	23	22

[a] Number of travel time runs during each study period.

[b] Taken from July 1988 data.

Table 16. Paired t-Test Results for Changes in Travel Time During the Peak Period: US-59 Corridor in Houston

Route	A.M. Peak Period (Eastbound)									P.M. Peak Period (Westbound)								
	During[a] (May 1990)			During[a] (May 1991)			During[a] (May 1992)			During[a] (May 1990)			During[a] (May 1991)			During[a] (May 1992)		
	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value
US-59 Mainlanes	5	2.513	2.571	5	0.307	2.571	5	0.299	2.571	4	0.627	2.776	4	1.222	2.776	4	1.452	2.776
Frontage Road	2	2.775	4.303	2	0.848	4.303	2	3.184	4.303	1	1.441	12.706	1	1.599	12.706	1	1.727	12.706
Richmond	1	0.037	12.706	1	0.636	12.706	1	0.125	12.706	1	3.476	12.706	1	2.727	12.706	1	2.263	12.706
Westpark	1	3.526	12.706	1	3.214	12.706	1	0.343	12.706	1	2.051	12.706	1	2.200	12.706	1	2.200	12.706
Bellaire	1	1.444	12.706	1	0.911	12.706	1	1.500	12.706	1	1.928	12.706	1	5.952	12.706	1	0.500	12.706
Bissonnet	1	21.000	12.706	1	2.857	12.706	1	7.667	12.706	1	0.263	12.706	1	6.882	12.706	1	1.459	12.706

[a]Compared to before construction (May 1989) peak period travel times.

Note: Change in travel times is significant at $\alpha = 0.05$ if $|\text{calculated value}| >$ critical value

Table 17. Paired t-Test Results for Changes in Travel Time During the Off-Peak Period: US-59 Corridor in Houston

Route	A.M. Off-Peak Period (Eastbound)									P.M. Off-Peak Period (Westbound)								
	During[a] (May 1990)			During[a] (May 1991)			During[a] (May 1992)			During[a] (May 1990)			During[a] (May 1991)			During[a] (May 1992)		
	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value	df	Calculated t-value	Critical t-value
US-59 Mainlanes	4	0.645	2.776	4	1.789	2.776	4	1.411	2.776	2	0.000	4.303	2	0.846	4.303	2	1.789	4.303
Frontage Road	1	0.048	12.706	1	0.692	12.706	1	0.277	12.706	1	1.484	12.706	1	1.439	12.706	1	1.187	12.706
Richmond	1	1.737	12.706	1	0.360	12.706	1	1.786	12.706	1	0.871	12.706	1	0.091	12.706	1	0.000	12.706
Westpark	1	15.333	12.706	1	3.235	12.706	1	10.750	12.706	1	1.327	12.706	1	3.750	12.706	1	0.152	12.706
Bellaire	1	0.680	12.706	1	2.100	12.706	1	5.267	12.706	1	1.216	12.706	1	0.040	12.706	1	1.000	12.706
Bissonnet	1	1.381	12.706	1	1.074	12.706	1	0.659	12.706	1	4.250	12.706	1	0.714	12.706	1	0.000	12.706

[a]Compared to before construction (May 1989) peak period travel times.

Note: Change in travel times is significant at α =0.05 if $|\text{calculated value}|$ > critical value

4. SUMMARY AND CONCLUSIONS

Volumes in the Southwest Freeway corridor were lower than expected during the first phase of reconstruction. Motorists returned to the freeway and volumes returned to expected levels during phases II and III. Daily traffic volumes on US-59 were 12 percent lower during the first year of reconstruction than the volumes that would have been expected on the freeway if construction had not occurred. This decrease was probably due to restricted access from construction on the frontage roads and the reconfiguration of the entrance and exit ramps. During phase II volumes were only 2 percent lower than expected, and during phase III volumes were 6 percent higher.

Travel times and average speeds experienced only minor variations on the freeway, frontage roads, and alternative routes in the corridor during the US-59 reconstruction project. These changes in travel times and speeds were generally not statistically significant.

The traffic impacts of the US-59 Southwest Freeway reconstruction project are generally consistent with the impacts observed at five other urban freeway reconstruction projects in Texas. There were few significant changes in travel times or speeds at any of the projects, including the Southwest Freeway project. With respect to traffic volumes, the Southwest Freeway experienced a larger percentage decrease in volume during phase I (relative to regional volume patterns) than the other projects. Consistent with experience elsewhere in the state, however, the largest decreases were associated with construction phases that restricted access to the freeway due to reduced capacity on the frontage roads and/or ramp construction.

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APPENDIX A.

ANALYSIS OF A.M., OFF, AND P.M. PEAK PERIOD TRAFFIC VOLUMES

Table A-1. Eastbound A.M. Peak Period Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	14955	15292	12303	-2989	16133	13386	-2747	15920	16131	211
Frontage Road	2479	2535	2659	124	2674	3615	941	2639	2228	-411
Westheimer	14857	15192	9907	-5285	16028	9616	-6412	15816	11002	-4814
Richmond	5026	5139	6437	1298	5422	6648	1226	5350	4912	-438
Westpark	7246	7409	5983	-1426	7817	6097	-1720	7714	6193	-1521
Bellaire	4721	4827	4838	11	5093	4320	-773	5026	5036	10
Bissonnet	3827	3913	6914	3001	4129	3785	-344	4074	3318	-756

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table A-2. Westbound A.M. Peak Period Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	8930	9131	8857	-274	9634	10107	473	9506	10520	1014
Frontage Road	1388	1419	700	-719	1497	481	-1016	1478	516	-962
Westheimer	2542	2599	2208	-391	2742	2650	-92	2706	2570	-136
Richmond	1089	1114	1341	227	1175	1263	88	1159	1147	-12
Westpark	4899	5009	3535	-1474	5285	3793	-1492	5215	4108	-1107
Bellaire	1829	1870	2153	283	1973	1855	-118	1947	1983	36
Bissonnet	886	906	1353	447	956	1139	183	943	1098	155

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table A-3. Z-Test Statistics for Changes in A.M. Peak Period Traffic Volumes: US-59 Corridor in Houston

Route	During Reconstruction Volumes (May 1990)				During Reconstruction Volumes (May 1991)				During Reconstruction Volumes (May 1992)			
	Eastbound		Westbound		Eastbound		Westbound		Eastbound		Westbound	
	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]	% Δ[a]	z[b]
Freeway	-20	-14.90	-3	-1.79	-17	-13.05	5	2.90	1	0.95	11	6.16
Frontage Road	5	1.65	-51	-15.02	35	11.06	-68	-21.22	-16	-5.59	-65	-20.16
Westheimer	-35	-28.00	-15	-5.41	-40	-33.37	-3	-1.19	-30	-24.37	-5	-1.77
Richmond	25	11.00	20	4.47	23	10.04	8	1.72	-8	-3.96	-1	-0.25
Westpark	-19	-11.12	-29	-14.84	-22	-13.00	-28	-14.40	-20	-11.52	-21	-10.56
Bellaire	0	0.10	15	4.29	-15	-7.31	-6	-1.82	0	0.09	1	0.55
Bissonnet	77	26.23	49	9.12	-8	-3.58	19	3.85	-19	-8.20	16	3.31

[a] Percentage change between the estimated and observed during volumes.

[b] Percentage change (%Δ) is significant at $\alpha = 0.05$ if $|z| > 1.96$

Table A-4. Eastbound Off-Peak Period Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	30625	32543	23839	-8704	32723	31005	-1718	33204	34865	1661
Frontage Road	4629	4917	2359	-2558	4944	6587	1643	5017	9098	4081
Westheimer	20353	21620	12711	-8909	21740	13019	-8721	22060	14380	-7680
Richmond	5801	6162	6683	521	6196	6731	535	6288	6095	-193
Westpark	10237	10874	9376	-1498	10935	9570	-1365	11096	10124	-972
Bellaire	8133	8639	8036	-603	8687	7792	-895	8815	8578	-237
Bissonnet	4705	4998	3722	-1276	5026	5760	734	5100	5123	23

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table A-5. Westbound Off-Peak Period Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	28296	30058	23157	-6901	30224	32896	2672	30669	32510	1841
Frontage Road	8272	8787	4436	-4351	8836	3382	-5454	8966	4934	-4032
Westheimer	11704	12433	11834	-599	12502	14116	1614	12686	12257	-429
Richmond	6132	6514	6606	92	6550	6664	114	6646	6175	-471
Westpark	12403	13175	8977	-4198	13248	9620	-3628	13443	9845	-3598
Bellaire	7511	7979	8508	529	8023	8180	157	8141	8390	249
Bissonnet	4731	5026	5531	505	5053	5339	286	5128	5326	198

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table A-6. Z-Test Statistics for Changes in Off-Peak Period Traffic Volumes: US-59 Corridor in Houston

Route	During Reconstruction Volumes (May 1990)				During Reconstruction Volumes (May 1991)				During Reconstruction Volumes (May 1992)			
	Eastbound		Westbound		Eastbound		Westbound		Eastbound		Westbound	
	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]
Freeway	-27	-29.61	-23	-24.38	-5	-5.37	9	8.41	5	4.96	6	5.78
Frontage Road	-52	-28.25	-49	-34.96	33	14.28	-62	-45.15	81	31.30	-45	-31.52
Westheimer	-41	-41.51	-5	-3.44	-40	-40.32	13	8.76	-35	-34.46	-3	-2.42
Richmond	8	4.29	1	0.75	9	4.38	2	0.92	-3	-1.61	-7	-3.87
Westpark	-14	-9.57	-32	-25.41	-12	-8.64	-27	-21.56	-9	-6.02	-27	-21.11
Bellaire	-7	-4.30	7	3.79	-10	-6.42	2	1.14	-3	-1.64	3	1.78
Bissonnet	47	19.46	10	4.63	15	6.64	6	2.64	0	0.22	4	1.82

[a] Percentage change between the estimated and observed during volumes.

[b] Percentage change (%Δ) is significant at $\alpha = 0.05$ if $|z| > 1.96$

Table A-7. Eastbound P.M. Peak Period Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	12250	13831	11317	-2514	13995	12257	-1738	13827	13475	-352
Frontage Road	1977	2232	1237	-995	2259	2521	262	2232	3183	951
Westheimer	7526	8498	5973	-2525	8598	5489	-3109	8495	5781	-2714
Richmond	2419	2731	2962	231	2763	2752	-11	2730	2657	-73
Westpark	5116	5776	4642	-1134	5845	4658	-1187	5775	5115	-660
Bellaire	3332	3762	2815	-947	3807	2912	-895	3761	3469	-292
Bissonnet	1759	1986	2563	577	2010	1964	-46	1985	1929	-56

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table A-8. Westbound P.M. Peak Period Traffic Volumes by Route: US-59 Corridor in Houston

Route	Before May 1989	During Reconstruction Volumes (May 1990)			During Reconstruction Volumes (May 1991)			During Reconstruction Volumes (May 1992)		
	Observed	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]	Estimated[a]	Observed	Δ[b]
Freeway	15950	18009	14831	-3178	18221	19629	1408	18003	20447	2444
Frontage Road	4749	5362	3013	-2349	5425	1669	-3756	5360	2635	-2725
Westheimer	11467	12947	9583	-3364	13100	11077	-2023	12943	10323	-2620
Richmond	6814	7694	6759	-935	7784	6568	-1216	7691	5993	-1698
Westpark	8458	9550	5733	-3817	9663	5708	-3955	9547	6389	-3158
Bellaire	5272	5953	5937	-16	6023	5072	-951	5951	5898	-53
Bissonnet	4043	4565	4444	-121	4619	1934	-2685	4564	3807	-757

[a] Volumes were estimated by adjusting May 1989 before volumes according to the patterns observed at the control locations.

[b] Δ = Observed - Estimated

Table A-9. Z-Test Statistics for Changes in P.M. Peak Period Traffic Volumes: US-59 Corridor in Houston

Route	During Reconstruction Volumes (May 1990)				During Reconstruction Volumes (May 1991)				During Reconstruction Volumes (May 1992)			
	Eastbound		Westbound		Eastbound		Westbound		Eastbound		Westbound	
	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]	%Δ[a]	z[b]
Freeway	-18	-13.08	-18	-13.89	-12	-8.78	8	5.57	-3	-1.73	14	9.57
Frontage Road	-45	-15.89	-44	-23.38	12	3.53	-69	-39.86	43	11.94	-51	-27.74
Westheimer	-30	-18.44	-26	-18.76	-36	-23.02	-15	-10.77	-32	-19.98	-20	-14.33
Richmond	8	2.84	-12	-6.83	0	-0.14	-16	-8.98	-3	0.93	-22	-12.82
Westpark	-20	-10.02	-40	-26.97	-20	-10.41	-41	-27.81	-11	-5.68	-33	-21.78
Bellaire	-25	-10.80	0	-0.13	-24	-10.06	-16	-8.08	-8	-3.16	-1	-0.43
Bissonnet	29	7.97	-3	-1.16	-2	-0.68	-58	-30.23	-3	-0.85	-17	-7.56

[a] Percentage change between the estimated and observed during volumes.

[b] Percentage change (%Δ) is significant at $\alpha = 0.05$ if $|z| > 1.96$