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16. Abstract

This research report summarizes the research activities and findings of the 2.5-year research project to investigate the impacts of access management treatments. The first objective of the project was to estimate the impacts of access management techniques through field data collection at selected sites in Texas and to perform simulation of traffic performance. Findings related to travel time and delay from three case studies are provided in this report. Theoretical corridors were also created and analyzed to provide further insight into corridor performance with changes in median type, driveway density, and traffic volume. The researchers identify key considerations for using micro-simulation (VISSIM) for investigating access management treatments. Generally, the research identified a range of differences in travel time (and relatively small changes in speed) when comparing a corridor with a two-way left-turn lane (TWLTL) with the installation of a raised median along the three case study corridors and three theoretical corridors. The reduction in the number of conflict points along the corridors with access management was large (up to 60 percent for the case studies and up to 75 percent for the theoretical corridors). The reduction in conflict points illustrates the potential safety impacts of access management.

The second objective of the research was to estimate the safety benefits of access management treatments by investigating crash data from select corridors where access management treatments have been installed. A key part of this analysis is the assessment of the crash information used in the analysis. The research identified a relationship between increasing access point density and increasing crash rates. It also identified a reduction in crashes when comparing corridors with a TWLTL with those with a raised median. Crash severity was also reduced with the raised median.

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DISCLAIMER

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- Ms. Claire Roth: VISSIM programming and data collection;
- Ms. Pam Rowe: report preparation;
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SUMMARY

PROJECT OBJECTIVES

This section provides a summary of the research results. Greater detail on all aspects of the research can be found in this report. The two primary objectives of the research were to:

1. Estimate the impacts of access management techniques through field data collection at three selected sites in Texas and micro-simulation of traffic performance. Micro-simulation was also performed on three theoretical scenarios to evaluate different geometric conditions (driveway consolidation and median type) and varying traffic levels.
2. Estimate the safety impacts of access management treatments by investigating crash data from 10 selected sites in Texas and one in Oklahoma where access management treatments (driveway consolidation and raised medians) are installed. A key part of the crash analysis was assessing the quality of the crash information used in the analysis.

METHODOLOGY FOR ANALYSES

Researchers satisfied the first objective by performing micro-simulation in Verkehr in Städten Simulation (Traffic in Cities-Simulation) (VISSIM) along three test corridors and three theoretical corridors created to investigate the impacts on operations (travel time, speed, and delay) with different driveway spacings, median treatments, and traffic volumes. The second objective was satisfied by investigating 11 corridors to estimate relationships between crash rates and access point (driveways and public street intersections) densities, as well as the presence of raised medians or two-way left-turn lanes (TWLTLs).

Estimating Operational Impacts

The research team identified three case study locations for micro-simulation analysis in Texas. The characteristics of these test corridors are shown in Table S-1. Traffic performance (travel time, speed, and delay) was simulated before and after raised medians were implemented. Further, Table S-2 provides the characteristics of the theoretical corridors. The theoretical corridors were investigated to cover a broader range of traffic volume ranges and geometric characteristics (raised medians and driveway consolidation) than evaluated with the field test corridors. The later columns showing the travel time and speed results in Tables S-1 and S-2 will be described in a later section. The reader is encouraged to review the report for more details on the case study corridors, theoretical corridors, and the VISSIM model.

Estimating Safety Impacts

The research team studied 11 corridors to determine relationships between crash rates and access point densities (driveways and public street intersections), as well as the presence of raised medians or two-way left-turn lanes (TWLTLs). Some corridors had two or more distinct segments, each with varying access point densities. Researchers obtained crash history and traffic volumes for each of the corridor segments. The Texas Department of Public Safety (DPS) provided crash reports for each of the corridors that are state-maintained roads. For the other corridors in Texas, city police departments provided crash information. The Oklahoma Department of Transportation (ODOT) provided crash information for the Tulsa corridor.

Table S-1. Characteristics and Results of Case Study Corridors.

Case Study	Location	Corridor Length (miles)	Signals per Mile / Access Points per Mile[1]	Median Opening Spacing (feet)[2]	Number of Lanes Each Direction[3]	Land Uses	Percent Difference in Conflict Points[4]	Estimated Existing ADT[5]	Estimated Future ADT[6]	Future Percent Difference in Travel	Future Actual Difference in Speed (mph)
Texas Avenue	Bryan, Texas	0.66	3.0 / 91	690 to 1,320	2	Retail, University	-60	18,200	21,800	-11	2 (increase)
									48,000	-38	7 (increase)
31st Street	Temple, Texas	0.71	5.6 / 66	350 to 850	2	Retail, Some Residential	-56	13,300	16,000	3	1 (decrease)
Broadway Avenue	Tyler, Texas	1.47	4.1 / 46	500 to 1,500	3	Commercial, Retail	-60	24,400	29,300	2	<1 (decrease)
									48,000	57	6 (decrease)

[1]Access point density includes both directions and includes driveways, streets, and signalized intersections.

[2]Median opening spacing is the range for the raised median alternative with the most openings. Five alternatives were investigated along 31st Street and two alternatives along Broadway.

[3]The Texas Avenue and 31st Street corridors were not widened in the micro-simulation because VISSIM allows vehicles to perform U-turns with two lanes, and this study was intended to investigate the differences between the TWLTL and the raised median. From a practical perspective, flared intersections and slightly widened mid-block location(s) would facilitate the U-turns.

[4]The percent difference values are from the conversion from a TWLTL to a raised median. Negative values imply a decrease when converting to the raised median. These differences are based upon the weighted average of three micro-simulation runs.

[5]Estimated from road tubes or videotapes. The average daily traffic (ADTs) are estimated by assuming a K and D factor to apply to the observed peak-hour volume.

[6]The lower ADT value is a 20 percent increase over existing conditions. This represents an approximately 2 percent increase over 10 years. The higher ADT value was run to estimate higher-volume conditions. The ADTs are estimated by assuming a K and D factor to apply to the observed peak hour volume.

Table S-2. Theoretical Corridor Characteristics and Results.

Theoretical Corridor	Median Treatment[1]	Number of Lanes in Each Direction	Percent Difference in Conflict Points[2]	Number of Driveways	Driveway Spacing (feet)	Raised Median Opening Spacing (feet)	Estimated Future ADT[3]	Future Percent Difference in Travel Time[2]	Future Actual Difference in Speed (mph)
Scenario 1	TWLTL and Raised	2	Not Applicable	18	660	660	18,000 to 28,000	Not Applicable	Not Applicable
Scenario 2	TWLTL	2	-70	42	330	660	18,000	2	<1 (decrease)
							23,000	6	2 (decrease)
	Raised						28,000	31	8 (decrease)
	TWLTL	3	-70	42	330	660	18,000	8	2 (decrease)
							23,000	8	2 (decrease)
	Raised						28,000	11	3 (decrease)
							48,000	44	9 (decrease)
Scenario 3	TWLTL	3	-75	84	165	660	18,000	6	2 (decrease)
							23,000	1	<1 (decrease)
							28,000	2	<1 (decrease)
	Raised						33,000	7	2 (decrease)
							38,000	22	6 (decrease)
							48,000	10	3 (decrease)

[1] Scenario 1 can be considered as both a TWLTL and a raised median because, due to the driveway spacing, there is no change in the conflict points and turning locations.

[2] The percent difference values are from the conversion from a TWLTL to a raised median. Negative values imply a decrease when converting to the raised median. These differences are based upon the weighted average of three micro-simulation runs.

[3] The ADTs are estimated by assuming a K and D factor to apply to the observed peak-hour volume.

This paper describes the crash analysis performed along 10 case study locations in Texas and one in Oklahoma. This analysis provides a safety estimate on corridors after installation of access management techniques—comparisons of corridors with and without raised medians and varying access point densities. Researchers investigated before and after conditions at two locations where a raised median was installed to replace TWLTLs (Longview and College Station) and at two locations where raised medians were added to undivided roads (US 382 in Odessa and 71st Street in Tulsa). Table S-3 provides a summary of the characteristics of each study corridor investigated in the crash analysis. The directions (e.g., west) on each study corridor indicate the section of the corridor (i.e., "west" indicates the "west" end of the corridor). As with the micro-simulation, Table S-3 indicates a broad range of operating conditions that were investigated. The crash rate results shown in Table S-3 will be described in detail in the next section of this summary.

Table S-3. Characteristics and Crash Rate Results for Safety Analysis Case Studies.

Corridor Segment	ADT Range	Access Points/Mile	Median Type	Average Crashes per Million VMT
Texas Avenue, College Station, TX	40,000 – 42,000	60	TWLTL (“Before”)	4.3
Texas Avenue, College Station, TX	38,500 – 43,000	57	Raised (“After”)	1.8
Loop 281, Longview, TX	20,000 – 27,000	53	TWLTL (“Before”)	5.21
Loop 281, Longview, TX	20,000 – 27,000	53	Raised (“After”)	4.29
US 385, Odessa, TX	9,500 – 11,700	50	Undivided (“Before”)	19.57
US 385, Odessa, TX	9,500 – 11,700	50	Raised (“After”)	15.39
71st Street (west), Tulsa, OK	20,000 – 24,000	27	Undivided (“Before”)	3.76
71st Street (west), Tulsa, OK	28,000 – 33,000	27	Raised (“After”)	2.48
71st Street (west-central), Tulsa, OK	20,000 – 21,000	20	Undivided (“Before”)	3.82
71st Street (west-central), Tulsa, OK	22,000 – 37,000	20	Raised (“After”)	1.78
US 380 (west), McKinney, TX	14,700 – 29,000	56	Raised	3.12
US 380 (east), McKinney, TX	13,500 – 24,000	99	Raised	7.29
US 377 (west), Fort Worth, TX	18,200 – 21,000	50	Raised	5.92
US 377 (east), Fort Worth, TX	18,200 – 21,000	110	Raised	8.76
SH 289, Plano, TX	44,000 – 53,000	30	Raised	4.21
Park Blvd (west), Plano, TX	28,000 – 37,000	10	Raised	1.71
Park Blvd (central), Plano, TX	33,000 – 36,000	39	Raised	6.59
Park Blvd (east), Plano, TX	34,000 – 35,000	16	Raised	2.23
71st Street (east-central), Tulsa, OK	27,000 – 47,000	33	Raised	3.20
71st Street (east), Tulsa, OK	25,000 – 51,000	42	Raised	5.17
FM 1741, Temple, TX	26,000 – 31,000	39	TWLTL	2.71
US 69 (north), Tyler, TX	30,000 – 39,000	38	TWLTL	8.60
US 69 (south), Tyler, TX	27,000 – 40,000	85	TWLTL	12.92
SH 191 (west), Odessa, TX	29,000 – 36,000	56	TWLTL	6.55
SH 191 (east), Odessa, TX	16,500 – 24,000	28	TWLTL	4.00

VMT – vehicle-miles of travel

TEST CORRIDOR FINDINGS

Micro-simulation Test Corridor Results

Qualitative Findings of Test Corridors

While the VISSIM model appears to be a very promising micro-simulation tool for simulating access management treatments, there is a steep learning curve for analysts. Throughout the research project, the research team continued to learn more about the VISSIM model and received frequent software updates for VISSIM from the developers.

One specific consideration with micro-simulation is that the results should be based on numerous runs of the same conditions along a corridor. This is because VISSIM is a stochastic model in which the numerous input variables are modeled—often according to distributions (e.g., speed, acceleration characteristics, vehicle types, and motorist behavior). Therefore, each run of the simulation provides one estimate of the performance measure. The results of this research generally required three runs to get results that appeared to converge on an acceptable average value for the performance measures.

VISSIM has outstanding output abilities that allow the user to analyze many aspects of the corridor. For this project, the researchers analyzed travel time, speed, and delay. VISSIM allows the user to choose the duration for the analysis. Researchers selected the peak hour for analysis. This time limit also facilitated the analysis by narrowing the results to those that will be most useful for design hour analysis.

The research team has prepared conference papers that document some of the lessons learned while assessing the impacts of access management using micro-simulation (*1,2*). The papers describe the desirable input and output characteristics of a micro-simulation tool for possible use in investigating access management alternatives. These characteristics are also described in this report.

Quantitative Findings of Test Corridors

Each micro-simulation corridor was investigated with numerous alternatives. Each corridor began with a TWLTL as the existing condition. Therefore, the first step was to optimize the traffic signals. This always resulted in at least some improvement in travel times—indicating the tremendous benefit of this relatively simple operational change. For the interested reader, the benefits of signal optimization are further described in a recent Institute of Transportation Engineers (ITE) Journal article (*3*). The next alternative or alternatives included the proposed condition of a raised median along the corridor with existing traffic volumes. There were then raised median alternatives to better serve specific origin-destination patterns of each specific corridor's driveways and streets. The final alternatives always included the future conditions with the TWLTL and with the raised median alternatives that were investigated for the particular corridor. When the average daily traffic (ADT) was not readily available from 24-hour loop counts, estimations divided the directional design hour volume (DDHV) by an assumed K factor of 0.135 for suburban areas (*4*) and a D factor of 50 percent. The DDHV was the volume "entering" each end of the corridor for the VISSIM micro-simulation during the peak (design) hour.

Table S-1 shows the percent reduction in vehicular conflict points when going from a TWLTL to a raised median treatment for the three case study locations. The percent reduction varies from 56 to 60 percent. Research performed through the National Cooperative Highway Research Program (NCHRP) has shown that reduced conflict (access) points are related to a reduction in crashes along arterials (*5*).

While the three corridors show nearly the same percent reduction in conflict points, the percent difference in travel time varies for each corridor. This difference is between a TWLTL and the raised median in the future traffic volume conditions. Existing condition traffic volumes were increased 20 percent to obtain the future traffic volumes. This equates to approximately 2 percent per year for 10 years. A negative travel time value in Table S-1 indicates that the raised median had a shorter travel time for vehicles traversing the corridor. On the Texas Avenue corridor (ADT ~21,800), travel time decreased 11 percent with the raised median compared to the TWLTL. For Texas Avenue at an ADT of approximately 48,000, travel time decreased 38 percent with the raised median installation. The speed increased by 2 mph at the ADT of approximately 21,800, and it increased by 7 mph at an ADT of approximately 48,000.

The travel time along 31st Street in Temple increased 3 percent (approximately 1 mph decrease at the only ADT level of 16,000 that was investigated). Along Broadway Avenue in Tyler, the travel times increased 2 percent (<1 mph decrease) when the raised median was installed at the lower ADT level (29,300). At the higher ADT level of 48,000, there was a 57 percent increase in travel times with the raised median. This equates to a 6 mph decrease in speed. It should be noted that generally the more circuitous travel and increased U-turn traffic can cause the raised median treatment to have slightly longer travel times. However, it is hypothesized that these increases in travel time, and subsequent delay, are offset by the reduction in the number of conflict points and increased safety. Though not performed, it is also hypothesized that further analysis could have found that an additional median opening(s) could reduce the percent differences between the TWLTL and raised median even further.

Quantitative Findings of Theoretical Corridors

Analysis of the theoretical corridors also addressed the number of conflict points, travel time, speed, and delay. These results help researchers begin to identify operational characteristics resulting from changing to raised medians from TWLTL lanes and altering driveway density. It is anticipated that adding additional traffic volume, beyond that experienced in the field case studies, may result in even larger differences in these four parameters among median types.

Safety is an important aspect of access management. A reduction in the number of conflict points within a corridor will likely reduce the number of crashes within that corridor. Installing a raised median is an excellent way to reduce the number of conflict points. This is illustrated the most in Scenario 3 (see Table S-2). When a raised median is added to the corridor, the number of conflict points decreases from 1220 to 300, a decline of roughly 75 percent. The report contains more details on the reduction in the number of conflict points. Scenario 2 also showed a large decrease in the number of conflict points after the addition of a raised median. Another way to reduce the number of conflict points is to reduce the number of driveways along the corridor. When the number of driveways increased from 18 to 42, the total conflict points for the scenarios with a TWLTL increased from 338 to 650 (five lanes) and 674 (seven lanes), an increase of approximately 50 percent.

Table S-2 illustrates all the theoretical scenarios and their results. As in the case studies, the number of conflict points decreases with the installation of a raised median. This decrease occurs even when the number of driveways increases from 18 in Scenario 1 to 84 in Scenario 2, an increase of approximately 460 percent. The number of conflict points for both the five- and seven-lane options for Scenario 2 was reduced by 70 percent with the installation of a raised median. This large reduction is accompanied by an increase in travel times with the raised median by from 2 to 31 percent for the five-lane option and from 8 to 44 percent for the seven-lane option. The Scenario 3 results show a 75 percent reduction in the number of conflict points with the installation of a raised median, along with a 1 to 22 percent increase in travel time.

These results generally demonstrate an increase in travel time along the corridor for through-moving vehicles due to the circuitous travel of U-turning traffic and the associated weaving of these maneuvers. The actual reduction in speed is, on average, approximately 3 mph when a raised median replaces a TWLTL. It is hypothesized that these relatively small differences would likely be justified with the associated reduction in conflict points and potential safety increase along such corridors. These analyses also make assumptions about traffic patterns entering and exiting the corridors. Along and around an actual corridor, observation rather than simulation would allow a better understanding of the origin-destination patterns that might lead to better management of traffic circulation.

Future research in this area should continue investigating the relationship between median type, driveway density, and traffic volume. In the theoretical corridors, the median opening spacings were set at 1/8 mile (660 feet), and it would be interesting to investigate the potential changes in travel time with different median opening spacings. It would also be interesting to investigate these parameters over longer corridors to gain insight into potential changes over longer distances. It is preferable that such analyses be conducted on actual field sites, along with an associated crash analysis, though finding such a site and performing such data collection could be difficult and costly.

Safety Analysis Case Study Results

Qualitative Findings

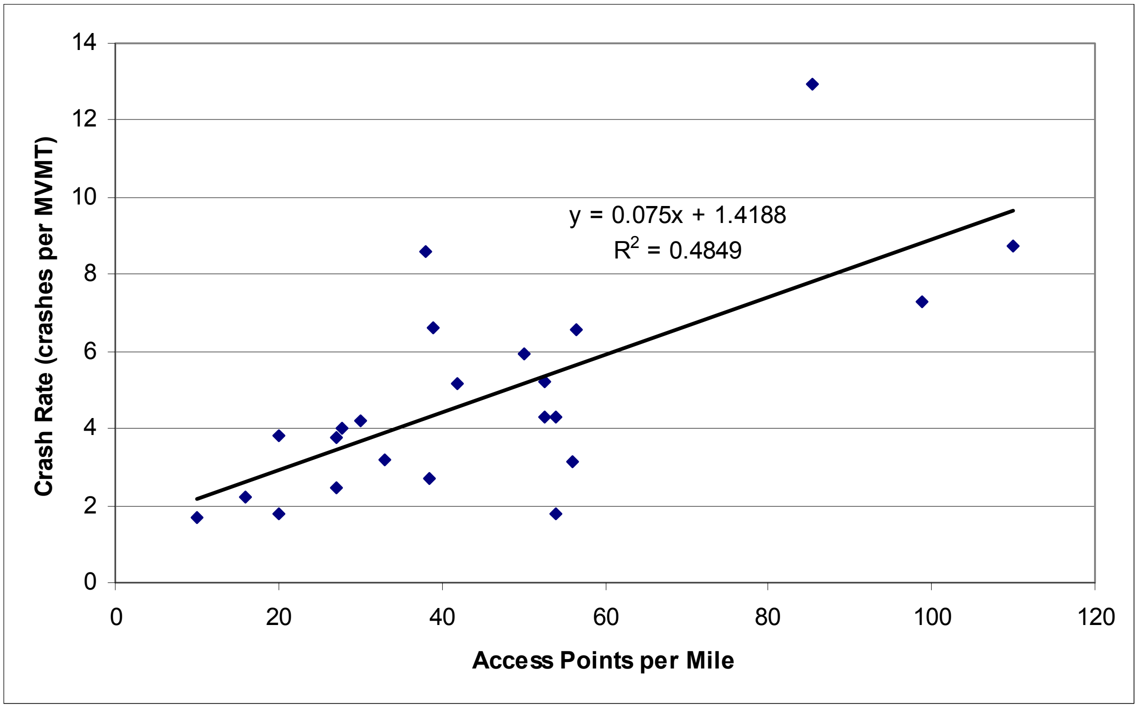
Crash records were individually investigated for each corridor to identify the number and type of crashes. Traffic volume data were collected for the computation of crash rates. One beneficial illustrative tool was the development of graphics which contained the location and type of crash for a given corridor. The type of crash was shown with the standard ITE crash diagram icons (*6*) in these crash spot maps.

The investigations of this research project demonstrate that crash data format and availability vary among agencies. TxDOT provides relatively consistent crash reports and summaries, from which much useful information can be obtained. When working with off-state-system roads, however, one must usually rely on a local city or other entity to provide crash data. The total number of crashes and types of crashes will always provide insightful and fundamental information about the safety of a corridor. However, the consistency and usefulness of locally provided data details will make some data more useful than others for analysis. Of course, the authors recognize the typical limitations of crash data (i.e., unreported crashes, erroneous data from processing, possible limitations of the report form, and causes of the crashes as described in reference 6); however, the results appear to demonstrate some useful relationships regarding access point density and crash rates described below.

Quantitative Findings

In the first year of this 2-year project, the most in-depth crash analysis and methodology development was performed on the Texas Avenue corridor in College Station, Texas. Researchers found that crash rates and severity decreased after the raised median was installed. Crash rates reduced from 4.3 to 1.8 crashes per million vehicle-miles of travel (as shown in Table S-3). Crashes were reduced by nearly 60 percent after the installation of the raised median, and the severity of crashes also were reduced. Conflict points along the corridor were reduced 26 percent. More details can be found in the report.

Figure S-1 shows the relationship between the number of access points per mile and the associated crash rates along the corridors and/or partial segments of the corridors investigated in this study (see Table S-3). Figure S-1 includes all of the test corridors in Table S-3 except US 385 in Odessa (Grant Avenue), which was located in a downtown area and subsequently had a distinctly different operational characteristic than the other arterial corridors. The relationship in Figure S-1 clearly indicates that there is an upward relationship in the crash rate as the number of access points per mile increases—irrespective of the median treatment (undivided, TWLTL, or raised). A regression line is shown in Figure S-1 that yielded an R-squared value of 0.48. The regression line only explains about half of the variability in the data; however, the relationship is clearly upward. This upward trend is similar to what was found in national research in NCHRP Report 420 (*5*). The researchers also investigated the relationship between the number of access points per mile and crash rate for the raised median projects and for the non-raised median corridors separately. The relationship was still upward, but it was slightly steeper with the non-raised median corridors (slope = 0.1225) compared to the raised median corridors (slope = 0.0618). It is intuitive that when the number of conflict points are reduced through turn restrictions along a raised median that there is a reduced slope in the relationship (i.e., relatively lower crash rates).



MVMT = Million vehicle-miles of travel

Figure S-1. Relationship between Access Point Density and Crash Rates.

Table S-4 shows a comparison of the crash rates along the corridors where there was a "before" and "after" analysis of the crash records performed. Table S-4 includes the corridor name, ADT after the raised median was installed, the "before" median condition, crash rates before and after the median installation, difference in the crash rates, percent difference in the crash rates, and the number of access points per mile. There were five specific corridors, or segments of the corridors, studied before and after the raised median installation. The final row of the table compares the average crash rate before and after the raised median installation on all of the remaining study corridors shown in Table S-1. The result is that there is always a reduction in the crash rate due to the installation of the raised median. The percent reduction ranges from 17 to 58 percent. This occurs over a range of access point densities from 20 to 53. The two corridors that went from a TWLTL to a raised median experienced 17 and 58 percent reductions, while the two corridors that were previously undivided experienced 34 to 53 percent reductions. Finally, the average of all corridors together (final row of Table S-4) shows an average reduction of 31 percent going from either a TWLTL or undivided roadway to a raised median. The increased safety of the raised median has also been documented in NCHRP Report 395 (*7*) and NCHRP Report 420 (*5*).

Table S-4. Crash Rate Comparison of Corridors "Before" and "After" the Installation of a Raised Median.

Corridor(s)	ADT[1]	"Before" Median Type	Crash Rate				Access Points/Mile
			"Before" Condition	Raised Median	Absolute Difference	Percent Difference	
College Station (Texas Avenue)	41,000	TWLTL	4.3	1.8	-2.5	-58	54
Longview (Loop 281)	23,500	TWLTL	5.2	4.3	-0.9	-17	53
Tulsa (west) (71st Street)	30,500	Undivided	3.8	2.5	-1.3	-34	27
Tulsa (west-central) (71st Street)	29,500	Undivided	3.8	1.8	-2.0	-53	20
Odessa (US 385)	10,600	Undivided	19.6	15.4	-4.2	-21	50
All Remaining	30,600	Varies	7.0	4.8	-2.2	-31	49

[1]ADT is the traffic volume in the "after" condition that has the raised median present.
[2]This is a comparison of the average crash rate for all the corridors "before" and "after" the raised median was installed. Note that the "before" condition was typically a TWLTL (refer to Table S-3).

The researchers recognize that oftentimes there are other improvements performed to a corridor that can increase their safety in addition to the raised median. When the raised median was installed, there was often a roadway widening. This can improve safety along the corridor; however, the crash rate indicates that for the increased level of travel along the corridor, there appears to be an improvement in safety for the corridors studied here.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Operational Impacts Assessed through Micro-simulation

Although it is a valuable micro-simulation tool, VISSIM is a sophisticated program with a steep learning curve for a new user. Any initial difficulty is primarily due to VISSIM's numerous sophisticated input and output capabilities. The process of inputting the different types of data into the micro-simulation was difficult and time-consuming. Further, each alternative was run several times with visual examination to ensure the corridor was running correctly.

VISSIM allows the user to change numerous model inputs and to input the necessary available field data, which are both important aspects of the program. Users can adjust design elements such as driveway spacing, number of lanes, speed limits, and right-turn-on-red. VISSIM also allows the user to input signal timing and phases after they are optimized in a separate program such as SYNCHRO, which was used in this project. The optimized timings and phases were entered into VISSIM from SYNCHRO, another time-consuming process in alternatives where multiple scenarios have multiple signals. The most time-consuming portion of the process is entering all the data into VISSIM and ensuring the corridor is calibrated to field conditions.

VISSIM's output abilities are just as impressive as the input characteristics. For this study, travel time, speed, and delay were analyzed in the case studies and the theoretical corridors. For this project, the research team simulated the peak hour. This research found that VISSIM was useful for studying the effects of access management. It should be noted that other software packages may be equally useful—only VISSIM was investigated for this study.

The analysis results for the three case study corridors revealed small differences in travel time and delay between the existing (TWLTL) and proposed (raised median) conditions. The proposed future conditions (approximately a 20 percent increase in traffic) resulted in a small percent increase in the overall travel time and delay. The percentage difference in travel time, speed, and delay varied for each corridor. Travel time on the Texas Avenue (Bryan, Texas) corridor decreased 11 to 38 percent with the raised median compared to the TWLTL in the future condition. Travel time on the 31st Street (Temple, Texas) corridor increased 3 percent with a raised median compared to a TWLTL in the future condition, and on Broadway Avenue (Tyler, Texas) travel time increased 2 to 57 percent with the raised median treatment compared to a TWLTL in the future. This resulted in a maximum of a 6 mph decrease in speed due to the raised median installation (Tyler) and as much as a 7 mph increase in speed with the raised median (Bryan). These results are summarized in Table S-1.

The reduction in travel time on Texas Avenue from the future TWLTL to the future raised median treatment might be attributed to prohibiting U-turns at a high-volume signalized intersection. This forces vehicles to make U-turns at locations farther along the corridor, at uncongested locations. In effect, this takes less time than waiting for turning traffic in the more congested portions of the corridor. This also allows for more through-movement green time, which can be reduced on corridors with high left-turn and U-turn movements. The increased travel times from the future TWLTL to the future installation of raised medians in Temple and Tyler are likely due to overall increases in traffic on the corridor, as some U-turning vehicles must travel farther to reach their destination. Increased travel time is also caused by U-turning vehicles that must weave across lanes to reach turn bays, which can cause traffic queues. The U-turning vehicles are also adding additional traffic on the roadways in the opposite direction of their origin. The additional vehicle-miles of travel (VMT) likely causes travel time and delay to increase. Delay may also increase slightly at the signalized intersections. As noted previously, the percent difference in travel time along the Temple corridor was only about 3 percent when comparing the raised median alternative with the most median openings—the alternative most effectively handling the corridor turning movements. It is hypothesized that increasing the number of median opening locations could have reduced the percent difference between the TWLTL and raised median alternatives to less than 3 percent.

The theoretical corridor results also indicate small increases in travel time with the raised median treatment compared to the future TWLTL conditions. The results are presented in Table S-2. Scenario 1 did not have a comparison between a TWLTL and a raised median because the driveway spacing was 660 feet, similar to the median openings, so it was essentially the same for both median treatments. Travel time for Scenario 2 (five lane) increased 2 to 31 percent for the raised median compared to the TWLTL, while that for Scenario 2 (seven lane) increased 8 to 44 percent with a raised median compared to the TWLTL. The travel time increase with the raised median ranged from 1 to 22 percent in Scenario 3 when compared to the TWLTL. More details on these comparisons can be found in the final report. The reasons given for increases in travel time for the case studies are hypothesized for the theoretical corridors as well. While the percent differences are large in some scenarios, the actual speed reduction averages 3 mph. These small increases in travel time, and subsequent delay, appear to be outweighed by the reduction in the number of conflict points and increased safety—another impact analyzed in this study on additional test corridors.

Safety Impacts Assessed through Crash Analyses

The investigations of this research project demonstrate that crash data format and availability vary among agencies. TxDOT provides relatively consistent crash reports and summaries, from which much useful information can be obtained. When working with off-state-system roads, however, one must usually rely on a local city or other entity to provide crash data. The total number of crashes and types of crashes will always provide insightful and fundamental information about the safety of a corridor. However, it was found that crash data accuracy, availability, and usefulness vary greatly among agencies. For instance, it can be quite difficult, if not impossible, to obtain crash data dated more than 10 years ago.

Detailed crash analysis on 11 test corridors indicated that as access point density increases, there is an increase in crash rates (Figure S-1). This trend is irrespective of the median type, though the research team found that the relationship is steeper (increases slightly more) on roadways without raised medians. For test corridors where crash data were investigated before and after the raised median installation, a reduction in the crash rate was always found (Table S-4). It should be noted that the widening of the roadway and other roadway improvements typical when a raised median is installed can also improve the safety of the roadway. However, crash rates are normalized by the increased traffic and appear to indicate that the roadway is improved with raised medians, and associated geometric changes, which reduces the number of conflict points.

Future Research Needs

Operational Impacts and Micro-simulation Analyses

More research is needed to further identify the impact of access management treatments over a range of traffic volumes. Although this project identified many valuable findings, primarily related to the potential implementation of raised medians, combinations of access management treatments along a corridor could be further investigated. For example, the presence of acceleration and/or deceleration lanes at heavy driveway or cross-street locations could facilitate traffic movement. Further, along the actual test corridors it is difficult to identify the precise origin-destination patterns of vehicles without a costly origin-destination study to identify vehicle patterns both within and through the study corridor. Although costly, it would also be valuable to investigate longer corridors with combinations of access management techniques, as those provided here were relatively short (0.5 to 1.5 miles).

Implementing an origin-destination (O-D) matrix for vehicle trips is another topic that could be further researched. In the case studies for this project, vehicle origin was used to determine likely destinations through assumptions, which were consistent across scenarios. A matrix was designed in which the vehicle entrance location determined where the vehicle would exit the system; however, due to budgetary limitations, the research team did not automate the O-D matrix. Therefore, ensuring the number of vehicles in the corridor was relatively consistent with field observations required numerous checks.

The theoretical corridors could also use additional research on the effects of travel time, speed, and delay as a consequence of higher traffic volumes. In the theoretical corridors, the spacing of median openings remained constant. The results of varying the distance of the openings would also be of interest.

Finally, it would be preferable if such further analyses could be performed on actual field sites, along with a crash analysis on the same site, though finding such sites and performing such data collection can be difficult and costly.

Safety Analyses

While this project was able to consider several years of data on each of the case study corridors, additional studies on these (and other) corridors will provide additional confidence in the findings. It will be useful to identify additional corridors where raised medians are planned or where there are plans to change access point densities and begin collecting crash and traffic volume data from years prior to the changes. The access point density changes may come from increases due to land development or from decreases due to driveway consolidations or land redevelopment.

To date, analysts have had to review crash reports (if available) for corridors to investigate the safety of installed treatments and operational improvements (travel time, speed, and delay) that may eventually be investigated through micro-simulation. Recent research sponsored by the Federal Highway Administration (FHWA) has investigated the inclusion of surrogate safety measures into micro-simulation (*8*). Ultimately, such methods would allow the analyst to obtain estimates of safety impacts from transportation alternatives in the same micro-simulation model that provides operational performance data. The FHWA work describes surrogate safety measures such as the time-to-collision (TTC) concept. TTC considers two vehicles with eventually crossing trajectories and computes the time that the two vehicles would collide if they maintained their current vectors at each time step of the micro-simulation. A percentage of the TTCs under a certain time in seconds for the micro-simulation can be used as a surrogate for safety. The intent is that the TTC would identify the stop-and-go acceleration characteristics that might be present for different transportation alternatives—allowing them to be compared from a safety perspective. TTI is in the process of investigating the use of the TTC in the VISSIM environment with the micro-simulation test corridors described in this paper. Proof-of-concept and early results of this work are published in two available conference papers (*1,2*).

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CHAPTER 1

INTRODUCTION

Traffic volumes and congestion have increased in recent years, particularly on arterial streets. The primary purpose of arterial streets is to move vehicles while providing necessary access to residential and commercial developments. Unlimited access directly from businesses and/or residences to arterial streets causes average speeds to decrease and diminishes the capacity of the arterial. Frequent access also presents safety concerns by providing more locations for potential conflicts of vehicles' paths. Past solutions have involved building relief routes to the arterial; however, it is very common for the same problems to eventually occur on the relief route. In some cases, tertiary relief routes have also been built.

A better, more cost-efficient alternative to building relief routes is incorporating access management techniques into the design of arterials. This practice is most successful when included in the original design of the arterial, but can also be applied through retrofit projects on existing roads. Access management techniques such as raised medians, turn lanes, auxiliary lanes, median opening spacing, and driveway spacing protect public investment in the arterial by preserving its function of moving vehicles. Such design methods also provide a safer street for the motoring public by decreasing the potential number of conflict points occurring at intersections.

In recent years, there has been increased interest in access management principles and techniques in Texas. Several Texas Department of Transportation (TxDOT) district and division staff members have expressed a desire to have access management guidelines in place to help them design arterial facilities and to help manage access locations. TxDOT recently published the *Access Management Manual* at http://manuals.dot.state.tx.us/dynaweb/coldesig/acm. Texas Transportation Institute (TTI) assisted the TxDOT Design Division in the development of the *Access Management Manual*. This research project estimates the impacts of access management techniques.

1.1 PROJECT OBJECTIVES

The primary objectives of this research effort are to:

1. Estimate the impacts of access management techniques through field data collection at three selected sites in Texas and simulation of traffic performance. Simulation will also be performed on three theoretical scenarios to evaluate different geometric and traffic conditions.

2. Estimate the safety benefits of access management treatments by investigating crash data from selected sites in Texas and Oklahoma where access management treatments are installed. A key part of the crash analysis will be assessing the quality of the crash information used in the analysis.

Both objectives focus on estimating the impacts of access management treatments—either by simulation of traffic performance or by investigating crash data. In the first year of the research project, the research team focused on portions of both objectives. Simulation of one corridor along Texas Avenue in Bryan, Texas, was performed, and findings were included in Report 0-4221-1 (*9*). Since the publication of Report 0-4221-1, the research team has discovered more about the abilities and limitations of the micro-simulation package Verkehr in Städten Simulation (Traffic in Cities-Simulation) (VISSIM). The research team re-evaluated the Texas Avenue corridor in the second year of the study, and the results are provided in this report. Section 2.3 of this report provides more information regarding the use of micro-simulation of access management treatments. The research team also performed micro-simulation along two additional corridors in the second year of the study. Finally, the research team developed theoretical scenarios that TxDOT can use in alternatives analysis of various arterial street configurations with access management treatments.

The second objective was also addressed in the first year of the study. Extensive quality assurance of the crash data along one study corridor in College Station, Texas (Texas Avenue), was performed, and the findings related to summarizing the crash data are presented in this report. Findings of crash trends are also reported for this location, where a raised median replaced a two-way left-turn lane (TWLTL). Discussion is provided about other locations where crash data were collected as well.

In the second year and one-half of the study, the research team obtained, analyzed, and summarized crash and traffic volume data for 11 other corridors. These corridors had four or six lanes, some with continuous TWLTLs and others with raised medians. The corridors also had varying access point densities.

1.2 WORK PLAN

Researchers identified and performed the tasks listed and described below to complete the project. The research team completed several portions of the tasks in the first year of the research project, and then completed the remaining tasks in the subsequent year and a half of the research project.

1.2.1 Identify Relevant Literature

The task to review state-of-the-practice was removed from the original work proposal due to a reduction in the project budget. However, the research team needed to review some literature related to crash studies. The research team was also familiar with references on the subject necessary for the analysis due to their involvement in other state and national access management activities.

1.2.2 Identify Analysis Tools and Prioritize Access Management Techniques

This second task in the original proposal was also removed due to budget reductions. The literature review was intended to identify many different simulation models and/or procedures for use in quantifying the benefits of access management techniques. The research team chose to use the VISSIM microscopic simulation software package based on its ability to model median treatments along arterial streets. The research team also investigated relevant literature on the VISSIM model.

This task was intended to determine which access management techniques would be investigated in the research project. This was achieved through project advisory group meetings. The primary access management treatments investigated in the project were the installation of raised medians and driveway consolidation.

1.2.3 Identify Study Corridors and Perform Data Collection

Case study locations were identified for both the simulation and crash studies. Researchers collected field data at the case study locations to simulate the operational improvement alternatives due to access management techniques. Crash data were collected at several study locations for the crash analysis.

1.2.4 Analyze and Summarize Case Study Data

Coding and operating the VISSIM software is quite complex. This report documents some aspects to look for in seeking an appropriate simulation model for investigating the impacts of access management (see Section 2.3). Simulation findings are provided for the case study corridors investigated. The researchers also performed quality assurance of the crash data at several case study locations, and these procedures and experiences are documented in this report. Access management-related safety results are included where raised medians have been installed and where there have been changes in driveway density.

1.2.5 Perform Sensitivity Analysis

The intent of this task was to perform sensitivity analysis for varying traffic conditions and access management treatments for which field case study locations could not be identified. Because not all access management treatments and differing traffic conditions could be found in the case studies, this analysis “fills the gaps” between conditions that could be analyzed directly from the actual case study locations and other situations of interest. The research team met with TxDOT staff members to identify the most useful scenarios to create in a VISSIM environment for TxDOT's future use with alternatives analysis.

Finally, many detailed steps are required for the operation of VISSIM. The research team developed a simplified list of steps for VISSIM use with accompanying default values and necessary inputs for application of the scenarios by TxDOT (see Appendix A).

1.3 REPORT ORGANIZATION

This report is organized into a summary, four chapters, and three appendices, as described below:

- **Executive Summary**. The summary provides an overview of the research and results.
- **Chapter 1, Introduction.** This chapter presents an introduction to the research topic, objectives, and procedures.
- **Chapter 2, Micro-simulation Methodology and Findings.** This chapter discusses the VISSIM model used for simulation of traffic performance with access management treatments. This chapter also presents the findings of the case study analysis and the theoretical corridors.
- **Chapter 3, Crash Analysis Methodology and Findings.** This chapter discusses the quality assurance researchers performed on the crash data obtained for the sites they selected for estimating safety benefits of access management treatments. Safety impacts related to installing raised medians or variations in driveway density at the case study locations are also included.
- **Chapter 4, Recommendations and Discussion.** This chapter describes the recommendations and discussion related to the findings in the report.
- **References.** This section lists the references used in this report.
- **Appendix A**. This section includes a simplified VISSIM procedure.

- **Appendix B**. This section describes the DPS crash-reporting process and appropriate forms.
- **Appendix C**. This section includes summary crash data for the Texas Avenue study corridor.

CHAPTER 2

MICRO-SIMULATION METHODOLOGY AND FINDINGS

This chapter describes the simulation performed in VISSIM to evaluate traffic operations along select corridors in Texas before-and-after implementation of access management treatments. Three case studies are described along with simulation findings. The Texas Avenue (Bryan, Texas) case study location was completed in the first year of the study, and findings of the analysis were included in Report 0-4221-1. That corridor was reanalyzed for this report to benefit from new information about the VISSIM model and its operation. Results of the subsequent analyses are described in this chapter of the report. This chapter also includes findings from two other case study corridors.

In addition to the three case study locations simulated in VISSIM, theoretical corridors were developed to assess the impacts of different access management treatments. Both the study corridors and theoretical corridors provide insight into the operational impacts of different driveway densities and converting from a TWLTL to a raised median.

2.1 SIMULATION CASE STUDY LOCATIONS

Researchers identified three case study locations for simulation analysis in Texas. Traffic performance was simulated before and after access management alternatives were implemented. The three case study locations are:

- Texas Avenue in Bryan,
- 31st Street in Temple, and
- Broadway Avenue in Tyler.

These case study locations and summaries of the findings are described in further detail in the sections that follow the description of the VISSIM model.

2.2 VISSIM MODEL

VISSIM is a microscopic, time step, and behavior-based model developed to simulate urban traffic and transit operations (*10*). Researchers chose this modeling tool for its unique ability to simulate specific complex multiple-conflict points and dynamics associated with the TWLTL arterial environment. The research team used the model to quantify the performance measures of travel time, speed, and delay along the study corridors.

VISSIM is an ideal tool for modeling changes from a TWLTL to a raised median because of its dynamic routing system, unique to VISSIM. When a route is removed (i.e., a left-turn movement is eliminated when a raised median is installed), VISSIM causes the vehicle to automatically find the next shortest route, which is the next median opening. VISSIM can also animate the simulation. Therefore, the user can visually identify any problems occurring in the model and check the model for accuracy. This visual animation is also an informative tool that the public can easily see and understand.

Although VISSIM is a good modeling tool, it cannot optimize signal timing. Whenever traffic volumes or roadway geometrics change, the user must optimize the signal timing, allowing maximum flow of vehicles through the intersection. Comparing the incremental benefits of various alternatives is more accurate when all the scenarios have optimized signal timing.

2.2.1 Inputs and Coding

The first step in creating the model was gathering the necessary data. Generally, the research team obtained an aerial photograph of the site for use as the background in VISSIM. The research team found that opening VISSIM with the background in place slowed the simulation. Researchers manually collected the necessary geometrics such as lane configurations, lane widths, driveway widths, distance between driveways, and lengths of dedicated lanes. They also collected traffic volumes on the mainlanes and turning movement counts at signalized intersections and driveways along the corridor. These counts were taken during the noon and evening peak hours. Researchers also obtained signal timing for the signalized intersections on the corridor. Finally, the team completed travel time runs using the floating-car method (*11*) in both directions on the corridor during the peak hour. The data collected during the travel time runs were used in the calibration process to ensure that the VISSIM model was operating in a similar manner to the travel time run data collected in the field.

Research team members input the gathered information into VISSIM, which was a tedious task. For a new user, entering these data can be a very time-consuming process. However, as the user becomes more familiar with the software, this stage of the modeling procedure becomes easier and less time consuming. For a more detailed description of the input and coding processes, refer to the VISSIM procedure in Appendix A.

2.2.2 Testing and Calibration

Once the VISSIM model was completed, it was tested and calibrated. Researchers reviewed the on-screen animation and model outputs to determine the model's accuracy in simulating field operations. The user then viewed the on-screen animation to check the realism of queue lengths. Computer operators then compared the travel time outputs to those collected with the field travel time runs. Speed distributions were calibrated slightly (when necessary) to ensure that the VISSIM model's travel times were similar to the floating-car travel time data collected in the field.

2.3 DISCUSSION OF MICRO-SIMULATION FINDINGS

While the VISSIM model appears to be a very promising micro-simulation tool for simulating access management treatments, there is a steep learning curve for analysts. Throughout the research project, the research team continued to learn more about the VISSIM model and received frequent software updates from VISSIM.

One specific consideration with VISSIM is that micro-simulation results should be based on numerous runs of the same conditions along a corridor. This is because VISSIM is a stochastic model in which the numerous input variables are modeled—often according to distributions (e.g., speed, acceleration characteristics, vehicle types, and motorist behavior). Therefore, each run of the simulation provides one estimate of the performance measure. The travel time and delay findings provided in Report 0-4221-1 for Texas Avenue are the result of one simulation run. The results shown in this report are based on three simulation runs, after which the results were similar enough to average their results.

The research team prepared conference papers that document some of the lessons learned while assessing the impacts of access management using micro-simulation (*1,2*). The papers describe using the input and output characteristics of a tool to simulate access management alternatives. One key input characteristic is the ability to insert geometric conditions to scale (e.g., lane width and turning radii). Also key are the operational inputs that affect traffic flow, including gap acceptance, speed, and acceleration characteristics. The model should allow inputting traffic signal information. It is also important that users have full control of the network demand and motorist origin-destination routes to ensure that changes in the performance measures between alternatives are really due to the geometric changes between alternatives rather than difficult weaving caused by inconsistent handling of origin-destination patterns between alternatives. Finally, the micro-simulation user must understand the underlying theory behind the micro-simulation model and the model must be calibrated to field conditions.

The conference papers also describe necessary output characteristics for a simulation model. One vital output characteristic is the ability to analyze the system or corridor at any level of spatial or temporal detail. Spatial analysis allows for specific analysis at a certain location(s) along the study corridor, while temporal flexibility allows for an evaluation of the corridor, or specific segments of the corridor, over time. It is also beneficial if the simulation model incorporates an animation feature to watch a simulation run. This feature allows a visual check of the successful operation of the program and is an informative visual tool for displaying different alternatives. The VISSIM micro-simulation tool satisfies these preferred input and output characteristics.

2.4 TEXAS AVENUE (BRYAN) CASE STUDY LOCATION

2.4.1 General Description

The Texas Avenue study corridor is a five-lane major arterial with a continuous two-way left-turn lane. The major traffic generators along this section of Texas Avenue include fast-food restaurants, a drug store, a bank, office buildings, and a shopping center anchored by a large video store. Various retail and commercial developments also exist along this section. Currently, a TWLTL serves as the median treatment along this section of Texas Avenue. This corridor has a signal density of 3.0 signals per mile. Figure 2-1 shows the Texas Avenue study site between the two arrows. The northbound view of the Texas Avenue corridor is shown in Figure 2-2 from the Villa Maria signalized intersection. Figure 2-3 shows the TWLTL along Texas Avenue with the Villa Maria intersection in the background.

2.4.2 Traffic Operations Analysis

Data Collection

Researchers collected traffic volume data on Texas Avenue between Dunn Street and Dellwood Street in March and April of 2002. They also collected average daily traffic (ADT) data on Texas Avenue at two locations using tube counters south of Dunn Street and north of Dellwood Street. The estimated ADT from loop counts at two locations on Texas Avenue north and south of Villa Maria was approximately 18,200 and 16,600, respectively. Researchers collected noon and evening turning movement counts at the intersections of Texas Avenue and Villa Maria Road and Texas Avenue and Sulphur Springs/Eagle Pass Road. They also collected turning movement counts at all of the driveways between Dunn Street and Dellwood Street. The team videotaped traffic on the corridor and later reduced the data to obtain specific counts.

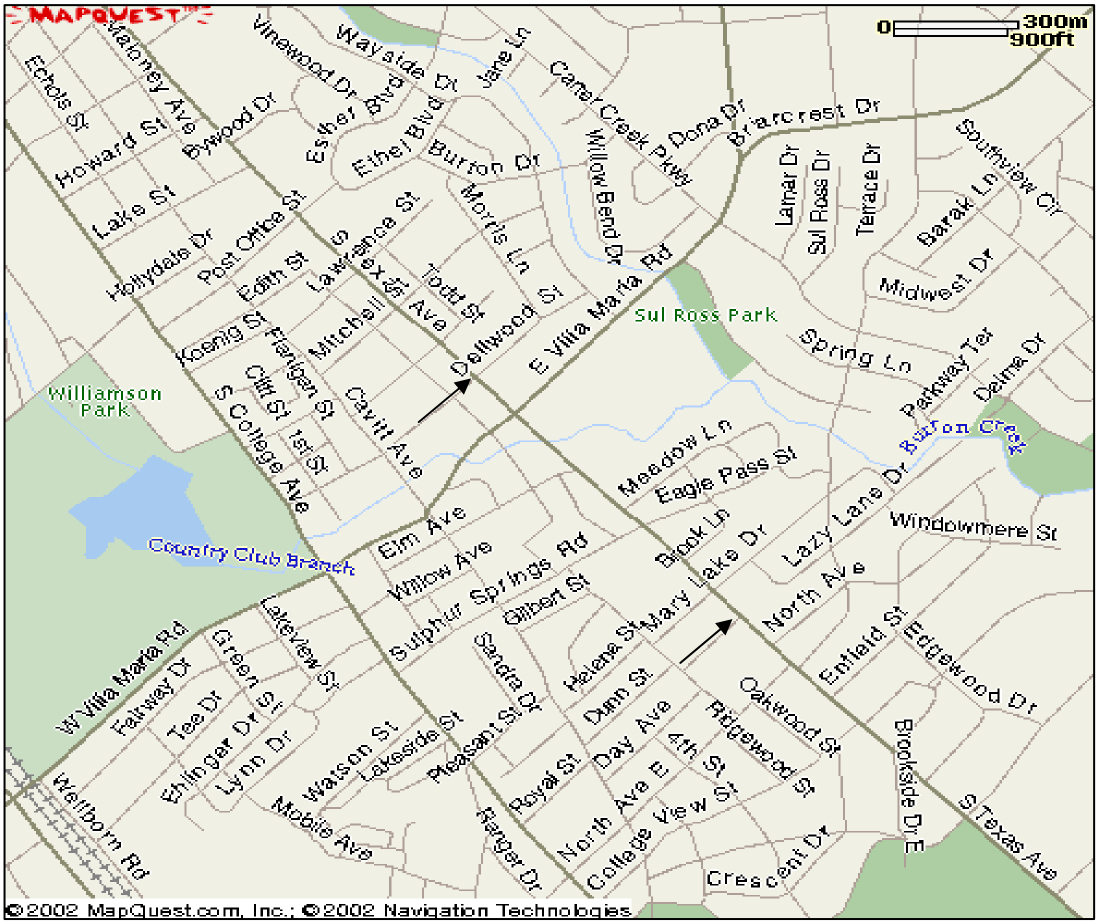


Figure 2-1. Texas Avenue Study Site in Bryan, Texas, Used for Operational Analysis (Map Provided by MapQuest.com, Inc.).

Figure 2-2. Texas Avenue Facing North from Villa Maria.

Figure 2-3. Texas Avenue Facing North with Villa Maria in the Background.

Traffic Demand

Researchers evaluated existing and proposed conditions using existing traffic volumes. The noon peak hour consisted of the highest mainlane and driveway traffic volumes; therefore, the team used the noon peak-hour volumes for the operational analysis.

For the raised median condition, VISSIM automatically rerouted existing traffic volumes to alternate routes to their destinations. For example, a left-turning motorist from a driveway that was prohibited by the installation of the raised median would turn right and make a U-turn at the first median opening.

Vehicle Conflict Points

As part of this study, researchers conducted an evaluation of vehicle conflict points for existing and proposed conditions. The existing condition on Texas Avenue consists of a five-lane arterial with a TWLTL. At the intersections of Texas Avenue with Villa Maria Road and Eagle Pass/ Sulphur Springs Road, the TWLTL transitions to a conventional left-turn lane.

Previous national research suggests that a TWLTL providing access to numerous driveways can be a safety problem due to the numerous conflict points (7). Table 2-1 presents an estimate of the number of existing conflict points based on the type and number of intersections and driveways on Texas Avenue between Dunn Street and Dellwood Street.

Table 2-1. Texas Avenue Existing Condition Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersection (TWLTL)	40	13	5	520
T-Intersection (RM)	0	2	5	0
T-Intersection (RMO)	0	11	5	0
RMO only	0	5	5	0
Dellwood Intersection	1	46	5	46
Villa Maria Intersection	1	52	5	52
Sulphur Springs Intersection	1	46	5	46
Mary Lake Intersection	1	46	5	46
Dunn Intersection	1	46	5	46
Total				756

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The proposed condition consists of a raised median between Dunn Street and Dellwood Street with full median openings north of Dellwood Street, between Villa Maria Road and Sulphur Springs Road, at Sulphur Springs Road, and at Dunn Street. Table 2-2 summarizes the estimated number of conflict points for the proposed condition. The proposed condition reduces the number of potential conflicts from 756 to 297, a reduction of approximately 60 percent.

Table 2-2. Texas Avenue Proposed Condition Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersection (TWLTL)	0	13	5	0
T-Intersection (RM)	38	2	5	76
T-Intersection (RMO)	4	11	5	44
RMO only	1	5	5	5
Dellwood Intersection	1	4	5	4
Villa Maria Intersection	1	52	5	52
Sulphur Springs Intersection	1	56	5	56
Mary Lake Intersection	1	4	5	4
Dunn Intersection	1	56	5	56
Total				297

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Analysis Conditions

Researchers used VISSIM to model the following: (1) existing condition, (2) optimized existing condition, (3) proposed condition with a raised median, (4) proposed future (higher volume) condition with a raised median, (5) future condition (higher volume) with the current TWLTL along Texas Avenue (6) proposed future with a raised median and (7) future TWLTL at 48,000 ADT. The following sections describe the details of the seven conditions. The VISSIM model evaluated travel time and delay along the Texas Avenue corridor under each of the seven conditions.

1. Existing Condition. Texas Avenue is a five-lane arterial roadway with a TWLTL as the center lane. The corridor is 0.66 miles in length with an ADT of approximately 18,200 north of Villa Maria and approximately 16,600 south of Villa Maria. The driveway density is 40 and 50

driveways per mile on the east and west side of Texas Avenue, respectively. The current signal timings were collected from the City of Bryan and used in this model. Figure 2-4 shows the approximate location of streets and driveways.

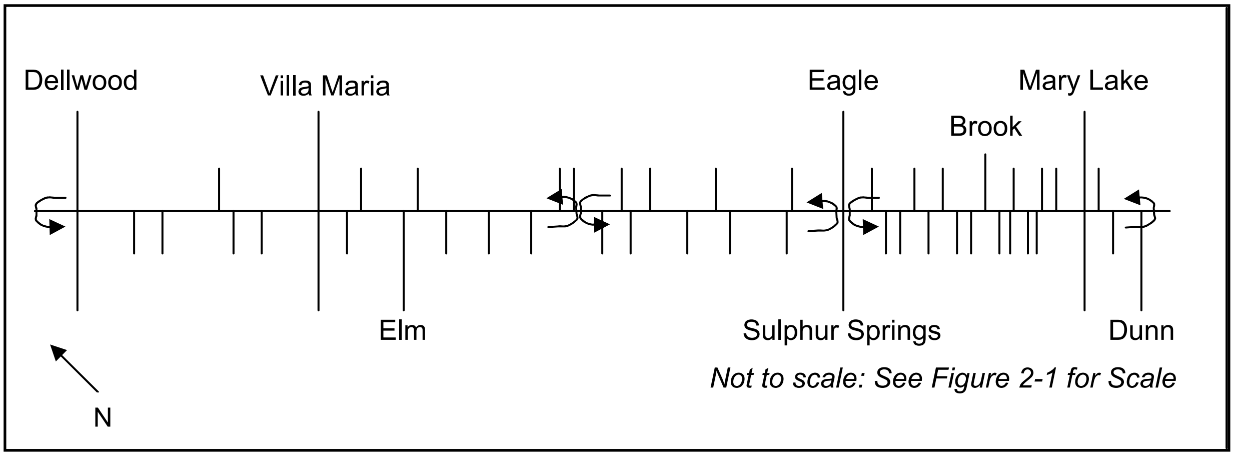


Figure 2-4. Schematic to Illustrate Approximate Driveway, Street, and U-turn Locations for Operational Scenarios.

2. Optimized Existing Condition. In the optimized condition, the existing geometry on Texas Avenue remains the same, but signal timing at the two signalized intersections on the corridor was optimized using SYNCHRO, a signal optimization software.

3. Proposed Condition with a Raised Median. In this proposed condition, a raised median replaces the TWLTL. U-turn median openings range in spacing from 690 to 1,320 feet. U-turns are allowed at the median openings north and south of Villa Maria Road and at the intersection of Texas Avenue and Sulphur Springs Road. The U-turn locations are approximated in Figure 2-4. Because of the existing high traffic volumes at the intersection of Texas Avenue and Villa Maria Road, U-turns are not allowed at this intersection. U-turns are rerouted to median openings located north and south of Villa Maria Road. Signal timing was also optimized in the proposed condition.

4. Proposed Future Condition with a Raised Median. Researchers increased the traffic volume along Texas Avenue to analyze how Texas Avenue may operate in the future. Traffic volume was increased by 20 percent, which equates to approximately 2 percent per year for 10 years to

yield 21,800 vehicles per day north of Villa Maria and 19,900 vehicles per day south of Villa Maria. The increase resulted in approximately 400 additional vehicles on Texas Avenue during the peak hour. The future condition was analyzed for the five-lane cross section with a center raised median. The high traffic volume at the intersection of Texas Avenue and Villa Maria Road required mitigation to allow traffic flow through the intersection. Therefore, dual left-turn lanes were added on the south, east, and west approaches to the intersection. Dual left-turn lanes are currently present on the north approach. Signal timing was also optimized in both of the future conditions. Median spacing is the same as for the proposed condition (#3).

5. Future Condition with a TWLTL. This condition is the same as #4 above except that a TWLTL replaces the raised median.

6. Proposed Future with a Raised Median. This condition is the same as option #4 at approximately 48,000 ADT.

7. Future TWLTL. This condition is the same as option #5 at approximately 48,000 ADT.

Analysis Procedure

The research team conducted travel time and delay analyses to create the existing and proposed conditions along Texas Avenue. The VISSIM model then evaluated travel time and delay along the Texas Avenue corridor under each of the seven conditions listed above. Three simulations of each scenario were performed, each using a different random number seed. The random number seed was constant for a given replication across each of the alternatives. The random number seed was varied across replications to randomize the micro-simulation. VISSIM generated three travel time and delay estimates for each corridor scenario.

VISSIM allows for evaluation or analysis of different performance measures. Travel time and delay were two measures analyzed in this study. Travel time estimates were generated for both northbound and southbound vehicles for the entire corridor, by placing a travel time measurement location where the analysis started and stopped as vehicles crossed these points.

Traveling northbound, a beginning travel time measurement "bar" was placed before the Dunn Street intersection and an ending travel time measurement bar was placed after the Dellwood Street intersection. This distance of 0.66 mile is somewhat longer than the study corridor length. The bars were located to ensure that vehicles were created upstream prior to reaching the analysis zone of the corridor. The travel time measurement bars were placed in the same locations in the southbound direction, with the start before the Dellwood Street intersection and the end after the Dunn Street intersection. Floating-car travel time runs during the noon peak hour provided data to compare with VISSIM for calibration purposes. During this time, research team members traveled the corridor six times in each direction. The average travel times from the floating-car runs were comparable to the VISSIM travel times; however, the speed distributions in VISSIM were calibrated to match the field travel time data.

Findings

Table 2-3 summarizes the findings of the travel time analysis. From the existing condition to the optimized existing condition, the travel time decreases 8 seconds (approximately 7 percent). Therefore, optimizing signal timing does lower the travel time on the corridor. This result illustrates the importance of signal optimization as a low-cost improvement. Travel time increases approximately 12 percent in the proposed future condition with the raised median compared to the optimized condition. This phenomenon can be attributed to an overall increase in traffic on the corridor, as some U-turning vehicles must travel farther to reach their destination. The increased traffic can also increase delay at the intersections. Increased delay is expected at the Texas Avenue and Eagle Pass/Sulphur Springs signalized intersection because of additional U-turning traffic. Additional delay is also expected at the Texas Avenue and Villa Maria signalized intersection, due to a greater number of vehicles traveling through the intersection to reach median openings located north and south of the intersection.

Because mitigation was necessary at the intersection of Texas Avenue and Villa Maria, it is difficult to compare the existing condition to the future conditions. Therefore, the proposed future condition with a raised median is compared to the future condition with a TWLTL. Travel times are lower overall in the proposed future condition with a raised median than those in the future condition with a TWLTL. On Texas Avenue, the weighted average travel time is 26.0 seconds longer (an increase of approximately 26 percent) for the proposed future condition with a TWLTL than the optimized existing condition. Placing a raised median along the corridor increases the travel time over the existing condition. The weighted average travel time increases by 12.2 seconds (12 percent) from the optimized existing condition to the existing proposed condition with a raised median. However, future travel times are shorter when the TWLTL is replaced by a raised median relative to a TWLTL. Overall, comparing the TWLTL to the raised median alternative, travel times decrease on the corridor by 13.8 seconds (a reduction of approximately 11 percent) in the future condition (volumes at existing plus 20 percent) when the raised median is present, and at an ADT of approximately 48,000 they decrease by 79 seconds (38 percent). This analysis indicates a travel time benefit with the raised median installation.

Table 2-3. Texas Avenue Travel Time Analysis Findings.

Scenario	Eastbound Travel Time (seconds)	Westbound Travel Time (seconds)	Weighted Average Travel Time (seconds)
1. Existing (TWLTL)	122.8	96.4	109.4
2. Optimized Existing (TWLTL)	107.9	97.1	101.2
3. Proposed (RM)	105.0	109.9	107.7
4. Proposed Future (RM)[1]	115.4	111.3	113.4
5. Future (TWLTL)[1]	130.2	124.1	127.2
6. Proposed Future (RM)[2]	125.9	129.5	128.1
7. Future (TWLTL)[2]	179.6	220.2	207.1

[1]Future traffic volume at existing plus 20 percent.
[2]Future traffic volume at approximately 48,000 ADT.
Note: Travel times are reported for all vehicles that travel in a given direction through the entire corridor.

VISSIM uses node evaluations to analyze delay. This was done by tracing the four approaching legs of the intersection and the intersection itself and drawing a node around each signalized intersection (Villa Maria and Sulphur Springs/Eagle Pass). The lengths of the node legs along the corridor extend to the next signalized intersection on one end and past the time travel measurement location in the other direction. The length of the node legs on the cross streets varies to include the most representative portion of the roadway. Table 2-4 presents the delay analysis findings. As expected, the delay results follow a trend similar to that of the travel time results shown in Table 2-3. From the existing condition to the optimized existing condition, the average delay decreases approximately 23 percent. Therefore, optimizing signal timing does reduce delay along the corridor. On Texas Avenue, the proposed future condition with raised median results in 2.3 seconds less delay than the future condition with the TWLTL. This equates to an approximate 8 percent decrease in delay with the raised median.

At approximately 48,000 ADT, there is more than a 30 seconds per vehicle difference between the TWLTL and raised median alternative. These delay and travel time results appear to indicate that installation of a raised median along this corridor would be beneficial.

Table 2-4. Texas Avenue Average Delay Analysis Findings.

Scenario	Average Delay (seconds per vehicle)
1. Existing (TWLTL)	23.8
2. Optimized Existing (TWLTL)	18.4
3. Proposed (RM)	24.1
4. Proposed Future (RM)[1]	27.5
5. Future (TWLTL)[1]	29.8
6. Proposed Future (RM)[2]	49.6
7. Future (TWLTL)	82.9

[1]Future traffic volume at existing plus 20 percent.
[2]Future traffic volume at approximately 48,000 ADT.

2.4.3 Discussion

Managing left-turn movements with the proposed median can reduce the number of potential conflict points by approximately 60 percent and possibly reduce angular and head-on crash potential along the Texas Avenue case study corridor. The proposed raised median, however, limits access and results in more traffic at the signalized intersections due to rerouting U-turn traffic. The increase in traffic may also require additional capacity at the intersection along with optimized signal timing.

The analysis of this corridor shows differences in travel time and delay between the existing and proposed conditions. The proposed condition with raised median present reveals a slight increase in overall travel time and delay due to an overall increase in traffic on the corridor, as some U-turning vehicles must travel farther to reach their destination. Delay is likely to increase at the intersections as well, particularly at the signalized intersections of Villa Maria and Sulphur Springs/Eagle Pass, because of additional U-turning traffic.

Adding approximately 20 percent to the traffic volume, equating to approximately 2 percent growth per year over 10 years, requires mitigation at the intersection of Texas Avenue and Villa Maria. Based on the analysis, the installation of a raised median on Texas Avenue would result in travel times 13.8 seconds (11 percent) shorter and delays 2.3 seconds (8 percent) shorter than if a TWLTL was present along the corridor with an increase in traffic volumes of 20 percent. It appears that a raised median would handle the increased traffic volumes more efficiently. When traffic volumes are increased to approximately 48,000 ADT, the installation of a raised median results in a travel time 79 seconds (38 percent) shorter and delays more than 30 seconds per vehicle (40 percent) shorter.

2.5 31ST STREET (FM 1741) (TEMPLE) CASE STUDY LOCATION

2.5.1 General Description

The second case study corridor is in Temple, Texas, on 31st Street, from Canyon Creek Road to the Colonial Mall entrance. This road segment, a five-lane arterial, includes a TWLTL with a signal density of 5.6 signals per mile. A wide variety of land uses abut 31st Street, including single-family residences, apartment complexes, stand-alone retail stores, shopping centers, and office buildings. The study site is shown between the arrows in Figure 2-5. Figure 2-6 depicts the northern end of the corridor, where most of the retail establishments are located. Figure 2-7 shows the southern end of the corridor, characterized by single-family residences with driveways intersecting 31st Street, as well as apartment complexes.

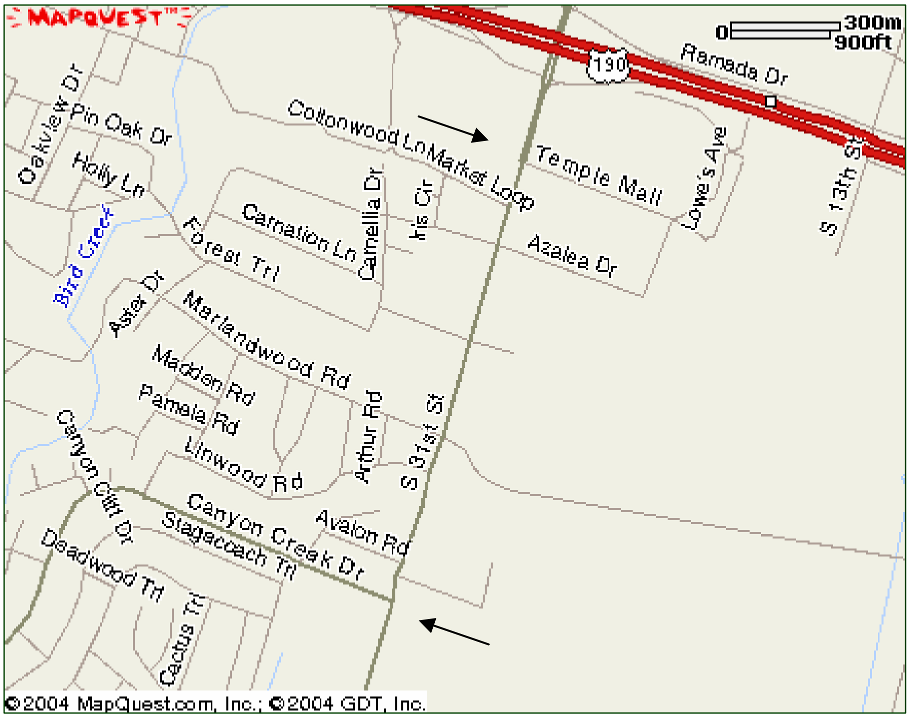


Figure 2-5. 31st Street Study Site in Temple, Texas, Used for Operational Analysis (Map Provided by MapQuest.com, Inc.).

Figure 2-6. Southbound 31st Street at Colonial Mall Entrance.

Figure 2-7. Northbound 31st Street, North of Canyon Creek Road.

2.5.2 Traffic Operations Analysis

The research team performed a traffic operations analysis along a 0.71-mile section of 31st Street between Canyon Creek Drive and the Colonial Mall entrance. Researchers analyzed the current condition, optimized current condition, five different proposed median opening options (Options A, B, C, D, and E), and future traffic volumes of each of the options. The subsequent sections describe the data collection, traffic demand, analysis procedures, and findings.

Data Collection

The research team collected traffic volume data on 31st Street from Canyon Creek Drive to the Colonial Mall entrance using on-site data collection and video cameras; data were reduced at the College Station office. The actual counting and videotaping included all turning and through movements at every cross street and driveway intersection occurring from 11:30 a.m. to 1:30 p.m. (noon peak period) and from 4:30 p.m. to 6:00 p.m. (evening peak period). Researchers collected data from every driveway over a 3-day period. Signal timing obtained from the video tapes was also compared to the signal timing from the City of Temple. For ease of data analysis and for input to VISSIM, researchers arranged the data to turning movements at each driveway and through and turning movements at every signalized and un-signalized intersection. Because of time limitations, the floating-car method was used to obtain field travel time data during peak hours approximately 2 months after the traffic volume data collection.

Traffic Demand

The traffic volume data indicated that the peak hour was from 4:45 p.m. to 5:45 p.m. Therefore, researchers used this time period for the VISSIM analysis.

For the raised median conditions, VISSIM automatically rerouted existing traffic volume to reach their destination. For example, a left-turning motorist prohibited by the installation of the raised median would turn right and then make a U-turn at the first median opening. In instances where corner lots consisted of large left-turning volumes, traffic was rerouted to a side street to replicate field conditions. This allowed vehicles to make a left turn instead of a U-turn at the first median opening in the opposite direction of desired travel. For signalized intersections with a left-turning volume of approximately 250 or more, a second turn lane was installed for the proposed condition. Due to the high southbound U-turn volume at the Marlandwood intersection, a dual left-turn lane was installed, and the innermost lane could make U-turns and left turns.

The ADT for the 31st Street corridor is approximately 13,300. The future condition with a 20 percent increase in traffic volume has an ADT of approximately 16,000. The ADT for the existing condition was estimated by dividing the directional design hour volume (DDHV) for each direction by the estimated K-factor (peak-hour proportion of daily traffic) of 0.135 and D-factor (directional distribution). The K-factor value was estimated for a suburban area (*4*). Researchers estimated DDHV for the volume of vehicles entering the corridor from both ends. The D-factor for northbound traffic was 0.4, and for southbound traffic it was 0.6. The ADT for both directions was averaged, giving the overall ADT.

Vehicle Conflict Points

Vehicle conflict points are any location where two vehicles can potentially cross paths. Conflict points occur with crossing through movements, turning across lanes, or merging or diverging maneuvers from an intersection or driveway. An example of a diverging conflict point would be a location where a lead vehicle maneuvers into a turn lane and the following vehicle brakes as the lead vehicle slows. As previously indicated, reducing conflict points reduces the number of crashes along corridors. As part of this study, researchers conducted an evaluation of vehicle conflict points for the existing condition and the five proposed raised median conditions.

The existing condition of 31st Street consists of a five-lane arterial with a TWLTL from Canyon Creek Drive to the Colonial Mall entrance. Table 2-5 presents an estimate of the existing conflict points based on the type and number of intersections and driveways on 31st Street between Canyon Creek Drive and the Colonial Mall entrance. The existing condition contains 698 total conflict points.

The proposed Option A condition consists of a raised median between Canyon Creek Drive and the Colonial Mall entrance with full median openings at the signalized intersections—Canyon Creek, Marlandwood, Azalea, and the Colonial Mall entrance. Table 2-6 summarizes the estimated conflict points for the proposed condition. The proposed condition reduces the number of potential conflicts from 698 to 257, a reduction of approximately 63 percent.

Table 2-5. 31st Street (FM 1741) Existing Condition Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	37	13	5	481
T-Intersections RM (Driveways)	0	2	5	0
T-Intersections RMO (Driveways)	0	11	5	0
RMO Only	0	6	5	0
Directional RMO (Left in Only)	0	6	5	0
Canyon Creek Drive Intersection	1	44	5	44
Marlandwood Intersection	1	37	5	37
Forest Trail Intersection	1	38	5	38
Colonial Mall Entrance Intersection	1	52	5	52
Total				698

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Table 2-6. 31st Street (FM 1741) Proposed Condition Option A Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	5	0
T-Intersections RM (Driveways)	37	2	5	74
T-Intersections RMO (Driveways)	0	11	5	0
RMO Only	0	6	5	0
Directional RMO (Left in Only)	0	6	5	0
Canyon Creek Drive Intersection	1	44	5	44
Marlandwood Intersection	1	37	5	37
Forest Trail Intersection	1	4	5	4
Azalea Intersection	1	46	5	46
Colonial Mall Entrance Intersection	1	52	5	52
Total				257

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The proposed Option B condition consists of a raised median between Canyon Creek Drive and the Colonial Mall entrance with full median openings at the signalized intersections and a directional left-in raised median opening at Market. Table 2-7 summarizes the estimated conflict points for the proposed condition. The proposed condition reduces the number of potential conflicts from 698 to 261, a reduction of approximately 63 percent.

The proposed Option C condition consists of a raised median between Canyon Creek Drive and the Colonial Mall entrance with full median openings at the signalized intersections and the un-signalized intersection with Forest Trail and a directional left-in raised median opening at Market. Table 2-8 summarizes the estimated conflict points for the proposed condition. The proposed condition reduces the number of potential conflicts from 698 to 295, a reduction of approximately 57 percent.

Table 2-7. 31st (FM 1741) Street Proposed Condition Option B Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	5	0
T-Intersections RM (Driveways)	36	2	5	72
T-Intersections RMO (Driveways)	0	11	5	0
RMO Only	0	6	5	0
Directional RMO (Left in Only) Market	1	6	5	6
Canyon Creek Drive Intersection	1	44	5	44
Marlandwood Intersection	1	37	5	37
Forest Trail Intersection	1	4	5	4
Azalea Intersection	1	46	5	46
Colonial Mall Entrance Intersection	1	52	5	52
Total				261

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The proposed Option D condition consists of a raised median between Canyon Creek Drive and the Colonial Mall entrance with full median openings at the signalized intersections and Forest Trail. Table 2-9 summarizes the estimated conflict points for the proposed condition. The proposed condition reduces the number of potential conflicts from 698 to 291, a reduction of approximately 58 percent.

Table 2-8. 31st Street (FM 1741) Proposed Condition Option C Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points Per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	5	0
T-Intersections RM (Driveways)	36	2	5	72
T-Intersections RMO (Driveways)	0	11	5	0
RMO Only	0	6	5	0
Directional RMO (Left in Only) Market	1	6	5	6
Canyon Creek Drive Intersection	1	44	5	44
Marlandwood Intersection	1	37	5	37
Forest Trail Intersection	1	38	5	38
Azalea Intersection	1	46	5	46
Colonial Mall Entrance Intersection	1	52	5	52
Total				295

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The proposed Option E condition consists of a raised median between Canyon Creek Drive and the Colonial Mall entrance with full median openings at the signalized intersections and Forest Trail, a directional left-in raised median opening at Market, and a full median opening between Canyon Creek Drive and Marlandwood. Table 2-10 summarizes the estimated conflict points for the proposed condition. The proposed condition reduces the number of potential conflicts from 698 to 304, a reduction of approximately 56 percent.

Table 2-9. 31st Street (FM 1741) Proposed Condition Option D Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points Per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	5	0
T-Intersections RM (Driveways)	37	2	5	74
T-Intersections RMO (Driveways)	0	11	5	0
RMO Only	0	6	5	0
Directional RMO (Left in Only) Market	0	6	5	0
Canyon Creek Drive Intersection	1	44	5	44
Marlandwood Intersection	1	37	5	37
Forest Trail Intersection	1	38	5	38
Azalea Intersection	1	46	5	46
Colonial Mall Entrance Intersection	1	52	5	52
Total				291

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The five different proposed condition options reduce conflict points relative to the existing condition from 56 to 63 percent. The average conflict reduction is 59 percent, which is similar to the conflict point reduction found along the Texas Avenue corridor.

Table 2-10. 31st (FM 1741) Street Proposed Condition Option E Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points Per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	5	0
T-Intersections RM (Driveways)	35	2	5	70
T-Intersections RMO (Driveways)	1	11	5	11
RMO Only	0	6	5	0
Directional RMO (Left in Only) Market	1	6	5	6
Canyon Creek Drive Intersection	1	44	5	44
Marlandwood Intersection	1	37	5	37
Forest Trail Intersection	1	38	5	38
Azalea Intersection	1	46	5	46
Colonial Mall Entrance Intersection	1	52	5	52
Total				304

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Analysis Conditions

After completing the conflict analysis, the research team used VISSIM to model the different alternatives introduced above. The team modeled the existing condition, optimized existing condition, proposed raised median conditions with varying raised median opening options, and proposed future (higher volume) conditions. The future conditions are based on a 2 percent increase in traffic volumes each year for 10 years, which equates to an approximate 20 percent increase. The following sections describe the details of the different conditions. Researchers used the VISSIM model to evaluate travel time and delay along the 31st Street corridor under each of the 13 conditions.

1. Existing Condition. 31st Street is a five-lane arterial roadway with a TWLTL as the center lane. The corridor is 0.71 miles in length with a driveway density consisting of 23 driveways on the west side and 14 on the east side. The driveway density remains the same throughout the proposed conditions below. The approximate ADT for the existing condition is 13,300. Researchers compared the existing signal timing collected by video to the signal timing received from the City of Temple. Figure 2-8 shows the approximate location of streets and driveways.

2. Optimized Existing Condition. The optimized condition remains the same as the existing, but signal timing and phasing at the four signalized intersections on the corridor were optimized using SYNCHRO.

3. Proposed Condition with a Raised Median (Option A). In the proposed conditions, a raised median replaces the TWLTL. In Option A, full-median openings are located at the signalized intersections only, to allow U-turns. The median opening spaces range from 1,000 to 1,600 feet, depending on the distance between the signalized intersections. The signalized intersections include the intersections of 31st Street with Canyon Creek Drive, Marlandwood, Azalea, and the Colonial Mall entrance.

4. Proposed Condition with a Raised Median (Option B). Option B includes full median openings at signalized intersections and a left-in only directional median opening at Market to allow U-turns. Market is a roadway that T-intersects with 31st Street. Median openings are spaced approximately 350 to 1,600 feet apart, depending on the opening.

5. Proposed Condition with a Raised Median (Option C). Option C includes full median openings at signalized intersections, the un-signalized intersection at Forest Trail, and a left-in only directional median opening at Market to allow U-turns. Median opening spacings range from 350 to 1,400 feet.

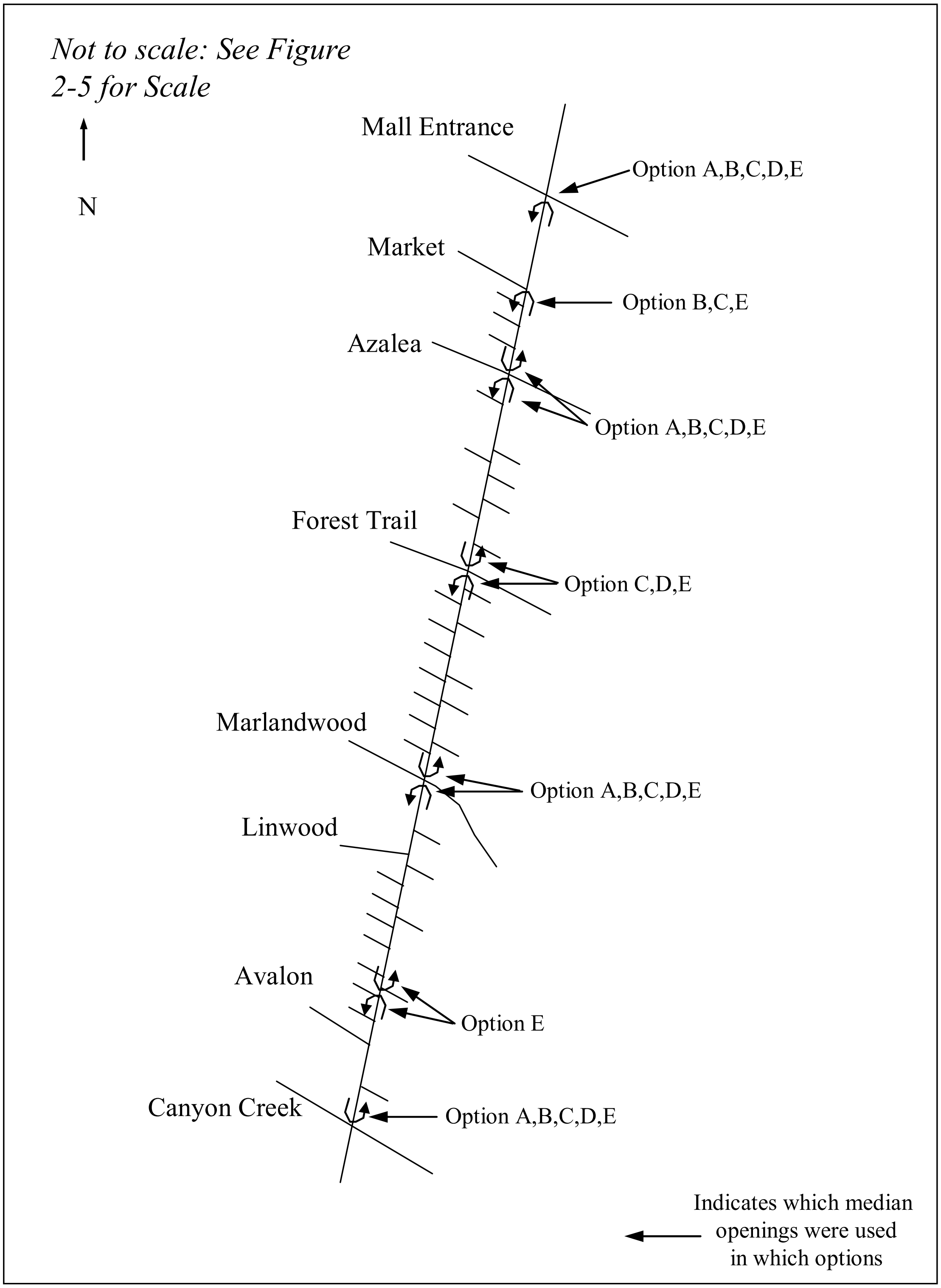


Figure 2-8. Schematic to Illustrate Approximate Driveway, Street, and U-turn Locations for Operational Scenarios.

6. Proposed Condition with a Raised Median (Option D). Option D includes full median openings at signalized intersections and at Forest Trail to allow U-turns. Median opening spacings range from 700 to 1,400 feet.

7. Proposed Condition with a Raised Median (Option E). Option E includes full median openings at signalized intersections, Forest Trail, and between Canyon Creek Drive and Marlandwood at the northern driveway of the Meadow Village Apartments. Also, a left-in only directional median opening is located at Market. These median openings allow for U-turns. Median opening spacings range from 350 to 850 feet.

8. Proposed Future Condition with a Raised Median (Option A). In the proposed future conditions, the driveway locations and density and roadway geometry do not change from the proposed conditions listed above. For the future conditions, an approximate 20 percent increase in traffic volume was applied, representing a 2 percent increase in traffic volume over 10 years. The approximate ADT for the corridor in future conditions is 16,000. As for the proposed condition, full median openings located at the signalized intersections allow U-turns.

9. Proposed Future Condition with a Raised Median (Option B). Future Option B is the same as proposed Option B with full median openings at signalized intersections and a left-in only directional median opening at Market allowing U-turns.

10. Proposed Future Condition with a Raised Median (Option C). Future Option C is the same as proposed Option C with full median openings at signalized intersections, the un-signalized intersection at Forest Trail, and a left-in only directional median opening at Market allowing U-turns.

11. Proposed Future Condition with a Raised Median (Option D). Future Option D is the same as proposed Option D with full median openings at signalized intersections and Forest Trail to allow U-turns.

12. Proposed Future Condition with a Raised Median (Option E). Future Option E is the same as proposed Option E with full median openings at signalized intersections, Forest Trail, and between Canyon Creek Drive and Marlandwood at the northern driveway of the Meadow Village Apartments. Also, a left-in only directional median opening is located at Market. These median openings allow U-turns.

13. Future Condition with a TWLTL. The future existing condition is the same as the existing condition with a TWLTL only with the 20 percent increase in vehicle traffic volume.

Findings

Researchers conducted analysis for travel time and delay along the 31st Street corridor, running three simulations for each scenario, similar to the Texas Avenue corridor study. The research team collected travel time data along 31st Street, using travel time measurement bars in VISSIM, as for the Texas Avenue corridor. In this case study, a beginning travel time measurement "bar" was placed at the first northbound intersection (Canyon Creek Drive), and an ending travel time measurement "bar" was placed at the next signalized intersection (Marlandwood). This process continued for every signalized intersection, and then it was repeated in the southbound direction. Northbound travel time for the entire corridor was obtained by placing a beginning bar at the Canyon Creek Drive intersection and an ending bar at the Colonial Mall entrance intersection. Southbound travel time for the entire corridor was computed from a beginning bar at the Colonial Mall entrance intersection to an ending bar at Canyon Creek Drive. Travel times for each smaller link were only used to test the simulation results against the floating-car field travel time runs. The travel times for the entire distance of the corridor are presented in the analysis. Table 2-11 shows the travel time results for the northbound and southbound directions as well as the total weighted average travel time from Canyon Creek Drive to the Colonial Mall entrance intersection—a distance of 0.71 miles. The travel time values were weighted by traffic volume in each direction. Each scenario was run and analyzed three times using different random seeds, similar to that conducted in the Texas Avenue corridor. The three runs then created the weighted average for travel time.

To verify the accuracy of VISSIM's weighted average travel time analysis, the team conducted its own travel time floating-car runs along the corridor. For 1 hour, researchers collected the floating-car travel time runs over the entire corridor length, consisting of five runs in each direction. The research team used the same method to collect travel time in VISSIM as Texas Avenue. The travel times analyzed in VISSIM were slightly shorter than the floating-car method used in the field. The most congested portion of the corridor is located around the Colonial Mall entrance intersection. This isolated location created a 58 percent increase in travel time going northbound for that segment. There was a 42 percent increase in travel time going southbound for that segment. Travel times are anticipated to be higher in this segment because of interrupted facilities and the proximity of the signalized intersection. It is also possible that this difference was caused by the time elapsed (several months) between the travel time runs and the actual data collection. Due to the nature of interrupted facilities and the limited number of floating cars through this section during the peak period, the research team did not alter this congested portion of the corridor. It is possible such an adjustment could have also contributed error to the final results. There was no difference between the floating-car travel time runs and VISSIM for the other segments.

Table 2-11 shows northbound and southbound travel times and the weighted average of the travel time from Canyon Creek Drive to the Colonial Mall entrance, a distance of 0.71 miles. The weighted average travel time for the existing condition was 84.4 seconds. After optimizing the signal timing, travel time decreased by 2.8 seconds. Option C had the shortest weighted average travel time in the proposed scenario (63.7 seconds), while Option E had the shortest in the proposed future scenario (88.4 seconds). Generally, overall travel times for proposed future scenarios reflecting an approximate 20 percent increase in traffic did not dramatically increase from proposed scenarios since most turning movements along the corridor already occur at signalized intersections, and future conditions did not increase U-turning vehicles to a large degree. The 31st Street corridor was also relatively uncongested and there were fewer driveway movements. Therefore, the few driveway movements that did occur did not substantially increase the travel time in the proposed future scenarios where left-turning traffic is rerouted to median opening locations.

Table 2-11. 31st Street (FM 1741) Travel Time Analysis Findings.

Scenario	Northbound Travel Time (seconds)	Southbound Travel Time (seconds)	Weighted Average Travel Time (seconds)
1. Existing (TWLTL)	94.1	79.2	84.4
2. Optimized Existing (TWLTL)	85.7	79.2	81.6
3. Proposed RM (Option A)	95.0	95.0	95.0
4. Proposed RM (Option B)	114.8	96.7	102.7
5. Proposed RM (Option C)	81.6	84.8	83.7
6. Proposed RM (Option D)	79.5	85.6	83.4
7. Proposed RM (Option E)	93.7	90.3	91.6
8. Proposed Future RM (Option A)	99.5	104.6	102.7
9. Proposed Future RM (Option B)	118.9	104.6	110.0
10. Proposed Future RM (Option C)	112.1	82.4	93.4
11. Proposed Future RM (Option D)	95.2	103.2	100.3
12. Proposed Future RM (Option E)	96.3	82.5	88.4
13. Future Condition (TWLTL)	104.9	74.8	85.5

Note: Travel times are reported for all vehicles that travel in a given direction through the entire corridor.

When comparing the proposed conditions to the proposed future conditions, travel time increased by a few seconds for most of the conditions. For example, the optimized existing condition has a weighted average of 81.6 seconds while the future condition has a weighted average of 85.5 seconds, an increase of 3.9 seconds. Option D, however, increased 16.9 seconds in the future condition. This may result from not having a median opening at Market, a large left-turning driveway volume, causing an increased volume of vehicles to make U-turns at the Colonial Mall entrance. Increasing the traffic volume by 20 percent for the future conditions impacts the weighted average travel times. Option E travel time actually decreases 3.2 seconds in the future condition. Although this decrease is very small, it may be attributed to having seven median openings and the resulting ability to handle the higher traffic volumes. Finally, it should be noted that travel time in the future condition with a TWLTL was 2.9 seconds (3 percent) shorter than proposed future Option E and 24.5 seconds (29 percent) shorter than Option B. This increase in time can be attributed to cars weaving across traffic to reach the turn bay in order to make a U-turn.

Average delay from the three runs along the 31St Street corridor was collected in VISSIM using node evaluations as discussed in the Texas Avenue analysis. Nodes were drawn in the same manner as in the Texas Avenue case study. Average delay was analyzed for the existing, optimized, and proposed (current and future) conditions. Nodes were placed at Canyon Creek Drive, Marlandwood, Azalea, and the Colonial Mall entrance. Delay nodes include delay along the corridor and inbound legs of the cross-street signalized intersections along 31st Street. The total delay along the corridor also includes delay from the signalized cross streets, which may alter the total. Like weighted average travel times, there was no significant change in average delay between the existing, optimized, and proposed (current and future) conditions, as shown in Table 2-12. The greatest change in delay time occurred between the optimized existing TWLTL of 10.0 seconds per vehicle and the proposed future Option B at 19.1 seconds per vehicle—a 9.1-second per vehicle increase. Option C had the shortest average delay time in both the proposed and proposed future conditions. This is because Option C contains median openings at locations with high left-turning volumes, reducing the number of U-turns at intersection median openings. The distribution of U-turning movements to different locations along the corridor reduces the number of U-turns at one location and decreases overall delay.

Table 2-12. 31st Street (FM 1741) Average Delay Analysis Findings.

Scenario	Average Delay (seconds per vehicle)
1. Existing (TWLTL)	15.8
2. Optimized Existing (TWLTL)	10.0
3. Proposed RM (Option A)	13.5
4. Proposed RM (Option B)	15.7
5. Proposed RM (Option C)	10.2
6. Proposed RM (Option D)	11.5
7. Proposed RM (Option E)	11.6
8. Proposed Future RM (Option A)	15.5
9. Proposed Future RM (Option B)	19.1
10. Proposed Future RM (Option C)	13.1
11. Proposed Future RM (Option D)	15.3
12. Proposed Future RM (Option E)	13.3
13. Future Condition (TWLTL)	13.4

2.5.3 Discussion and Conclusions

Analyses of the 31st Street corridor in Temple provided information about conflict points, travel time, and delay along the corridor that is very important when examining median alternatives. Due to the relatively uncongested nature of the corridor, any differences found were very small between micro-simulation estimates of travel time and delay of TWLTL alternatives and raised median alternatives.

The existing corridor with a TWLTL contains 698 potential conflict points. This number is greatly reduced with the addition of a raised median. When comparing the existing condition with Option E, the option with the most median openings, the number of conflict points decreases to 304—a reduction of approximately 56 percent. The other proposed conditions reduce the number of conflict points even further. This great reduction in the number of conflict points would likely improve safety along the corridor—particularly as traffic volumes increase and congestion begins to occur.

As it was analyzed in this case study, the 31st Street corridor was relatively uncongested for the VISSIM. The travel time analysis for this case study indicates only a 28.4-second difference when comparing the optimized existing condition, the shortest travel time, with proposed future Option B, the longest travel time. Further, this corridor does not have a large number of driveway turning movements. Most turning movements occur at intersections not affected by the installation of the raised median. Compared to the existing condition, travel times in the proposed future conditions increase very slightly, all of which can be attributed to the 20 percent increase in traffic volumes.

As with the travel time analysis, the delay analysis also reveals only a small change in delay of 9.1 seconds per vehicle at the most. The analysis indicates that optimizing the existing signal timing can decrease the average delay by 37 percent.

Clearly, the 31st Street corridor is not too congested. The estimated ADT along the corridor is approximately 13,300. The future conditions have an ADT of approximately 16,000. The analysis predicts only small changes between the current and future traffic volumes. Researchers anticipate that as congestion grows along the corridor, travel time and delay differences might become larger as vehicles travel around the raised median to make U-turns. However, from a safety perspective, the conflict point analysis clearly shows that the reduction in opportunities for conflict with the raised median treatment would likely offset additional circuitous travel caused by the raised median.

2.6 BROADWAY AVENUE (US 69) (TYLER) CASE STUDY LOCATION

2.6.1 General Description

The third case study corridor is along Broadway Avenue (US 69) between Loop 323 and Chimney Rock Drive in Tyler, Texas. This road currently has three through lanes in each direction, a TWLTL, and a signal density of 4.1 signals per mile. Adjacent land uses include residential, office, commercial, and retail; however, there are no single-family residential driveways intersecting Broadway Avenue. The study site is shown between the arrows in Figure 2-9. Figures 2-10 and 2-11 show the three lanes in each direction and the TWLTL along with the mix of land uses along the corridor.

2.6.2 Traffic Operations Analysis

The third study corridor for traffic operations analysis is a 1.47-mile section on Broadway Avenue from Grande Boulevard to Loop 323. In a similar manner as the previous two study corridors, the existing condition, optimized existing condition, two different proposed median opening options, and future proposed traffic volumes were investigated. The subsequent sections describe the data collection, traffic demand, analysis procedures, and findings.

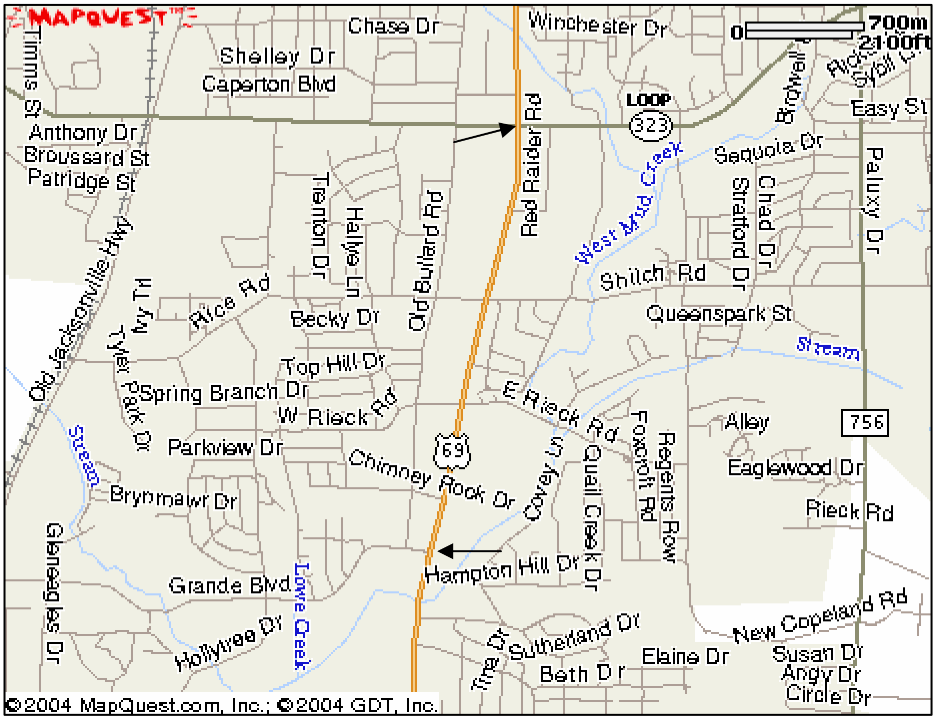


Figure 2-9. Broadway Avenue Study Site in Tyler, Texas, Used for Operational Analysis (Map Provided by MapQuest.com, Inc.).

Figure 2-10. Broadway Avenue Facing North to Chimney Rock Signalized Intersection.

Figure 2-11. Broadway Avenue Facing South at Chimney Rock Signalized Intersection.

Data Collection

The research team collected traffic volume data on Broadway Avenue from Grande Boulevard to Loop 323 using videotapes from a 1999 project. The videotapes included all turning and through movements at every street and driveway intersection from 12:00 p.m. to 1:00 p.m. (noon peak period) and from 5:00 p.m. to 6:00 p.m. (evening peak period). To assist in the analysis, researchers organized the data into turning movement counts at each driveway and through and turning movement counts at each signalized and un-signalized intersection. Corridor geometrics were recently collected.

Traffic Demand

The traffic volume data revealed that the evening peak hour (5:00 p.m. to 6:00 p.m.) was the daily peak hour; therefore, this time period was used for the subsequent analysis.

For the proposed raised median conditions, existing traffic volumes were rerouted to alternative routes to reach their ultimate destination. For example, a left-turning motorist entering the corridor from a driveway or side street that was prohibited by the installation of the raised median would turn right and then make a U-turn at the first median opening. In some instances, where corner lots consisted of large left-turning volumes, traffic was rerouted to the side street, allowing vehicles to make a left turn at the signal instead of a U-turn at the first median opening in the direction opposite of desired travel. Like the Temple case study, signalized intersections with a left-turning volume of roughly 250 or greater received a second turn lane. Due to high southbound left-turning volumes at the Rieck Road signalized intersection, a dual turn-lane was installed, allowing two lanes for left turns and U-turns from the inside lane.

The ADT was also estimated for Broadway Avenue using the same method as for 31st Street, by dividing the DDHV for each direction by an assumed K-factor (peak-hour proportion of daily traffic) of 0.135 and D-factor (directional distribution) (*4*). The D-factor for northbound traffic was 0.46, while for southbound traffic it was 0.54. The directional ADT was averaged to get the total ADT for the corridor. ADT for the current condition was approximately 24,000. The future condition contained a relatively higher ADT of approximately 29,400. When the videotaped data were collected in 1999, there was no signal at the Chimney Rock intersection. However, when the research team returned to the corridor to collect roadway geometrics such as lane widths and distance between driveways, a signal had been installed at Chimney Rock. For analysis proposes, the signal was omitted from the existing condition and the optimized existing condition. The signal was included for the proposed, future existing, and proposed future conditions.

Further, in 1999 and currently, Broadway Avenue northbound at Loop 323 has only two through lanes. Initial VISSIM runs showed bottlenecking at this intersection as vehicles merged into two lanes from three lanes. The resulting congestion backed up the rest of the corridor. For analysis purposes, researchers extended the third lane through the intersection for all scenarios, allowing traffic to run more smoothly and the analysis to focus on the raised median treatments.

Vehicle Conflict Points

A conflict point analysis was performed in a similar manner as the previous case studies. Researchers conducted an evaluation of vehicle conflict points for the existing condition compared to the two proposed raised median conditions.

The existing condition on Broadway Avenue consists of a seven-lane arterial with a TWLTL from Grande Boulevard to Loop 323. Table 2-13 presents an estimate of the existing conflict points based on the type and number of intersections and driveways on Broadway Avenue between Grande Boulevard and Loop 323. The existing condition contains 974 total conflict points.

Table 2-13. Broadway Avenue (US 69) Existing Condition Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points Per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	56	13	7	728
T-Intersections RM (Driveways)	0	2	7	0
T-Intersections RMO (Driveways)	0	11	7	0
RMO Only	0	6	7	0
Directional RMO (Left in Only)	0	6	7	0
Grande Blvd Intersection	1	46	7	46
Chimney Rock Intersection	1	46	7	46
Rieck Intersection	1	46	7	46
Rice/Shiloh Intersection	1	62	7	62
Independence Intersection	1	46	7	46
Loop 323 Intersection	1	116	7	116
Total				974

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The proposed Option A condition consists of a raised median between Grande Boulevard and Loop 323 with full median openings at the signalized intersections—Grande Boulevard, Chimney Rock, Rieck, Rice/Shiloh, Independence, and Loop 323. Table 2-14 summarizes the estimated number of conflict points for the proposed Option A condition. The proposed condition reduces the number of potential conflicts from 974 to 358, a reduction of approximately 63 percent. The substantial decrease in the number of conflict points can be seen by comparing the first two rows of data in Table 2-13 with those in Table 2-14. The predominant change in the total number of conflict points is a result of eliminating the numerous conflict points at the TWLTL driveways and replacing those with the raised median.

Table 2-14. Broadway Avenue (US 69) Proposed Condition Option A Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points Per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	7	0
T-Intersections RM (Driveways)	56	2	7	112
T-Intersections RMO (Driveways)	0	11	7	0
RMO Only	0	6	7	0
Directional RMO (Left in Only)	0	6	7	0
Grande Boulevard Intersection	1	46	7	46
Chimney Rock Intersection	1	46	7	46
Rieck Intersection	1	46	7	46
Rice/Shiloh Intersection	1	62	7	62
Independence Intersection	1	46	7	46
Loop 323 Intersection	1	116	7	116
Total				358

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The proposed Option B condition consists of a raised median between Grande Boulevard and Loop 323 with full median openings at signalized intersections and at three mid-block locations. The first mid-block opening is located between Chimney Rock and Rieck; the second between Rieck and Rice/Shiloh at Mobile, a T-intersection; and the third between Independence and Loop 323 at the Broadway Square Mall main entrance. Table 2-15 summarizes the estimated number of conflict points for the proposed Option B condition. The proposed condition reduces the number of potential conflicts from 974 to 385, a reduction of approximately 60 percent.

Table 2-15. Broadway Avenue (US 69) Proposed Condition Option B Conflict Points.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points Per Intersection	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	7	0
T-Intersections RM (Driveways)	53	2	7	106
T-Intersections RMO (Driveways)	3	11	7	33
RMO Only	0	6	7	0
Directional RMO (Left in Only)	0	6	7	0
Grande Boulevard Intersection	1	46	7	46
Chimney Rock Intersection	1	46	7	46
Rieck Intersection	1	46	7	46
Rice/Shiloh Intersection	1	62	7	62
Independence Intersection	1	46	7	46
Loop 323 Intersection	1	116	7	116
Total				385

[1]TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening.
[2]Intersections include both public streets and private driveways.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Analysis Procedure

The research team again used VISSIM to model several conditions. The team modeled the existing condition, optimized existing condition, proposed raised median conditions with different raised median opening options, and proposed future conditions with an increased volume. The future conditions are based on an approximate 2 percent increase in traffic volumes each year for 10 years. This equated to an estimated "future" volume of approximately 29,300. A future volume of 48,000 was also investigated in the study. The following sections describe the 10 conditions. VISSIM also evaluated the travel time and delay along the Broadway Avenue corridor under each of the seven conditions.

<u>1. Existing Condition</u>. Broadway Avenue is a seven-lane arterial roadway with a TWLTL as the center lane. The corridor is 1.47 miles in length with a driveway density consisting of 32 driveways on the west side and 24 on the east side. The driveway density remains the same throughout the proposed conditions where the raised median is added and when traffic volumes are increased. The existing signal timings were collected from the City of Tyler. Figure 2-12 shows the approximate location of streets and driveways.

<u>2. Optimized Existing Condition</u>. The optimized condition is the same as the existing condition, but the signal timing at the two signalized intersections on the corridor was optimized using SYNCHRO.

<u>3. Proposed Condition with a Raised Median (Option A)</u>. In each of the proposed conditions (Option A and Option B), a raised median replaces the TWLTL. In Option A, full-median openings are located at the signalized intersections only to facilitate U-turns. The signalized intersections include Grande Boulevard, Chimney Rock (not included in existing condition), Rieck, Shiloh/Rice, Independence, and Loop 323.

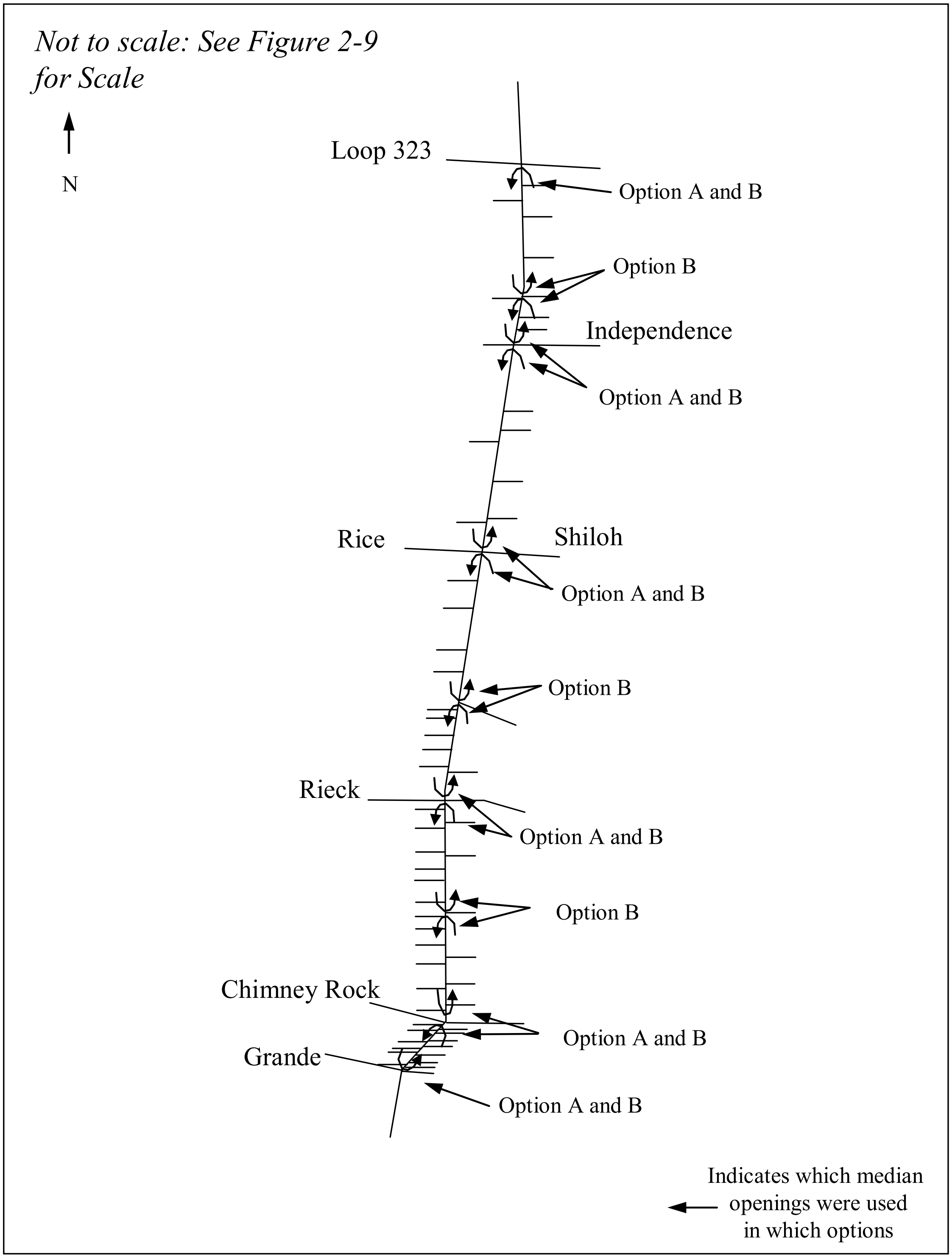


Figure 2-12. Schematic to Illustrate Approximate Driveway, Street, and U-turn Locations for Operational Scenarios.

4. Proposed Condition with a Raised Median (Option B). In Option B, full median openings are located at the signalized intersections and three median openings are located at mid-block locations. The first mid-block opening is located at the Broadway Square Mall main entrance, which is also the south driveway for the French Quarter Shopping Center between Loop 323 and Independence. The second mid-block median opening is located at Mobile between Rice/Shiloh and Rieck Road, and the third is located at the driveway for Outback Steakhouse between Rieck Road and Chimney Rock.

5. Proposed Future Condition with a Raised Median (Option A). In the proposed future conditions the roadway geometry, driveway locations, and intersection locations do not change from the proposed conditions. For the future conditions, traffic volumes are increased by 20 percent, representing an approximate 2 percent per year increase over 10 years. The future Option A condition is similar to the proposed condition; full median openings are located at signalized intersections to allow U-turns.

6. Proposed Future Condition with a Raised Median (Option B). The future Option B condition is similar to the proposed Option B with full median openings at signalized intersections and also includes the 20 percent increase in traffic volume.

7. Future Condition with a TWLTL. This condition has the same roadway geometry as the existing condition with a 20 percent increase in vehicle traffic volume.

8. The same as option #5 but at approximately 48,000 ADT.

9. The same as option #6 but at approximately 48,000 ADT.

10. The same as option #7 but at approximately 48,000 ADT.

Findings

Researchers conducted analyses for travel time and delay for the existing and proposed conditions along the corridor. Three simulations were run for each scenario, similar to the previous two case studies. To verify the accuracy of the simulated travel time findings, the team conducted its own travel time runs along the corridor, collecting 1 hour of floating-car travel time estimates between the signalized intersections along the corridor as well as the travel time along the entire length of the corridor. One hour provided adequate time for six runs in each direction. The travel time in the field was more than a minute longer than the existing condition travel time in VISSIM. However, the field travel time was within 5 percent of the simulation travel time along the corridor after the signal timing and phasing were optimized. Installing the signal at Chimney Rock after the initial data was collected most likely involved optimizing the signals in the field; therefore, researchers made no calibration adjustments to the VISSIM model.

The research team used travel time measurement "bars" in VISSIM in the same manner as the Temple case study. A beginning travel time measurement bar was placed at the first northbound intersection (Grande Boulevard), and an ending travel time measurement bar was placed at the next signalized intersection (Rieck). This process continued for every signalized intersection and was then repeated in the southbound direction. For vehicles traversing the entire corridor in the northbound direction, researchers placed a beginning bar at Grande Boulevard and an ending bar at Loop 323. Travel times for vehicles traversing the entire corridor in the southbound direction were computed from a beginning bar at Loop 323 to an ending bar at Grande Boulevard. The travel times for each intersection segment were only used to compare simulation results with the floating-car field travel time runs. The analysis used the travel times for the entire distance of the corridor. Table 2-16 shows the travel time results for the northbound and southbound directions as well as the total weighted average travel time from Grande Boulevard to Loop 323—a distance of 1.47 miles. The travel time values were weighted by traffic volume in each direction.

Table 2-16. Broadway Avenue (US 69) Travel Time Analysis Findings.

Scenario	Northbound Travel Time (seconds)	Southbound Travel Time (seconds)	Weighted Average Travel Time (seconds)
1. Existing (TWLTL)	266.2	264.7	263.6
2. Optimized Existing (TWLTL)	190.4	164.0	176.2
3. Proposed RM (Option A)	223.5	157.2	188.3
4. Proposed RM (Option B)	207.9	162.3	182.5
5. Proposed Future RM (Option A)[1]	239.8	233.6	236.7
6. Proposed Future RM (Option B)[1]	216.6	242.2	230.6
7. Future Condition (TWLTL)[1]	229.9	222.1	225.6
8. Proposed Future RM (Option A)[2]	381.7	662.1	515.1
9. Proposed Future RM (Option B)[2]	434.5	591.6	509.0
10. Future Condition (TWLTL)[2]	222.2	403.4	325.1

[1]Future traffic volume at existing plus 20 percent.
[2]Future traffic volume at approximately 48,000 ADT.

Operating the traffic signals reduces the travel time from 263.6 seconds (existing condition with the TWLTL) to 176.2 seconds (optimized existing condition), a difference of 87.4 seconds (32 percent reduction). This analysis demonstrates that traffic flow along this corridor would be greatly improved by simply optimizing the signals as done when the Chimney Rock signal was installed. The proposed raised median Option B has the shortest weighted average travel time in both the current and future proposed conditions. Travel times for Option B are shorter than those for Option A because there are more opportunities to make U-turns in Option B. More U-turn locations means motorists travel a shorter distance to a U-turn location; therefore, the travel time of vehicles traversing the corridor is not influenced as greatly by U-turning vehicles. The proposed future condition with a TWLTL had a longer travel time compared to the optimized existing and proposed conditions because of the 20 percent increase in vehicles. It is also interesting to note that the future condition (TWLTL) travel time is slightly shorter than those of Option A with a raised median (11.1 seconds) and Option B with a raised median (5.0 seconds). At approximately 48,000 ADT, the differences between the TWLTL and raised median are more substantial. The raised median (Option B) has an increased travel time of 184 seconds (57 percent) over the TWLTL. These results are due to the small increase in circuitous travel the raised median creates.

Average delay was also analyzed using VISSIM for the existing, optimized existing, and proposed current and future conditions (see Table 2-17). Delay was measured using node evaluations in the same manner as Texas Avenue. Nodes were drawn around the signalized intersections of Grande Boulevard, Rieck, Shiloh/Rice, Independence, and Loop 323. Unlike the earlier travel time estimates, delay also includes the cross streets. A long delay or no delay on the cross street may affect the overall average delay. The average delay after optimizing the existing condition drops by 44 percent. Further, both Option A and Option B proposed conditions show a small decrease in delay compared to the optimized existing condition. At an ADT of approximately 48,000, Option B has a slightly higher delay time than the future condition with a TWLTL (approximately 18 seconds per vehicle). These results are relatively similar to the travel time results.

Table 2-17. Broadway Avenue (US 69) Average Delay Analysis Findings.

Scenario	Average Delay (seconds per vehicle)
1. Existing (TWLTL)	31.5
2. Optimized Existing (TWLTL)	17.7
3. Proposed RM (Option A)	17.6
4. Proposed RM (Option B)	16.1
5. Proposed Future RM (Option A)[1]	28.7
6. Proposed Future RM (Option B)[1]	24.3
7. Future Condition (TWLTL)[1]	25.0
8. Proposed Future RM (Option A)[2]	84.7
9. Proposed Future RM (Option B)[2]	81.7
10. Future Condition (TWLTL)[2]	63.8

[1]Future traffic volume at existing plus 20 percent.
[2]Future traffic volume at approximately 48,000 ADT.

2.6.3 Discussion and Conclusions

The analyses of the Broadway Avenue corridor in Tyler produced information related to conflict points, travel time, and delay. For this corridor, small differences were found between the TWLTL and the raised median.

The existing corridor with a TWLTL contains 974 conflict points. Addition of a median greatly reduces the number of conflict points. When comparing the number of conflict points in the exiting condition to that in Option B, the option with the most conflict points, the number of conflict points drops to 385—a 60 percent reduction. This large reduction in the number of conflict points can reduce the potential number of crashes along a corridor such as this.

Travel time analysis in this case study showed that simply optimizing the signal timing can make a great difference and can provide great benefit for small cost. The optimized existing condition had a weighted average travel time of 176.2 seconds, compared to 263.6 seconds for the existing condition (33 percent reduction). In both the proposed existing and future conditions, travel times with the raised median installation options were slightly longer than those with the TWLTL. These differences in travel time equated to an increase of, at most, 6 mph for the raised median at approximately 48,000 ADT. This small difference is likely due to the added turning volumes at median openings, which can disrupt traffic by creating a circuitous flow.

The delay analysis, like travel time, also showed that simply optimizing the signal timing reduces the delay by 44 percent (13.8 seconds per vehicle). Delays for Option B in both the proposed and future conditions were slightly shorter than those of Option A. Option B had an even shorter delay for the optimized existing condition with a TWLTL and the future condition (volume increased 20 percent over existing) with a TWLTL. The delays are shorter because the raised median properly stores and routes vehicles. At 48,000 ADT, the differences between the raised median and TWLTL alternatives are more substantial.

There are several key conclusions that can be drawn from this case study:

- Corridor operations can benefit from signal timing optimization.
- The reduction of approximately 60 percent in the number of conflict points with the raised median compared to the TWLTL indicates a safety advantage.
- The raised median may cause vehicles to travel a slightly more circuitous route, as indicated by the slightly longer travel times with the raised median compared to the TWLTL,

particularly in the future conditions. The increase in travel time equated to an increase in speed of, at most, 6 mph.

This case study analysis suggests that raised median treatments provide a safer environment by reducing the number of conflict points even though there might be small increases in the total travel time and delay of vehicles traversing the corridor.

2.7 SUMMARY AND DISCUSSION OF CASE STUDY RESULTS

VISSIM Experiences

The VISSIM model has a steep learning curve. There are many details to learn when considering what and how to input data into the model. There are often numerous runs and repeated visual inspections to ensure the corridor is running correctly. Appendix A contains a list of generalized steps for using the VISSIM model. Even in the first step, the researchers identified valuable experiences. The first step is to import an aerial photograph into VISSIM as a background and as a tool for scaling the corridor. However, once the scale was set, researchers learned to remove the background because it slowed the program. With the background it became almost impossible to make changes or move the view without the program locking up (as per Appendix A).

VISSIM allows adjustment of corridor characteristics such as driveway spacing, number of lanes, speed limits, and right-turn-on-red. Signal timing and phases can also be input into VISSIM, although VISSIM cannot perform signal optimization. This must be done using a signal optimization program such as SYNCHRO, which was used in this project. The optimized timing and phases from SYNCHRO are then entered into VISSIM. This process can be time consuming when there are multiple scenarios with more than one signal. Entering all the data into the model is the most time-consuming portion of the process.

VISSIM has outstanding output abilities that allow the user to analyze many aspects of the corridor. For this study, the researchers analyzed travel time and delay. VISSIM allows the user to choose the duration and location for the analysis. Researchers selected an hour as the peak time for analysis. This time limit also facilitated the analysis by narrowing the results to those that will be most useful.

Operational Results

Table 2-18 illustrates the characteristics and results for each of the three study corridors. It provides a comparison among the different geometric characteristics, conflict point reductions, and changes in travel time and speed along the corridor. The percent reduction in conflict points is calculated from the difference in the number of conflict points on corridors after replacing a TWTLT with a raised median.

While the three corridors show nearly the same percent reduction in conflict points, the percent difference in travel time varies for each corridor. This difference is between a TWLTL and the raised median in the future traffic volume conditions. Existing condition traffic volumes were increased 20 percent to obtain the future traffic volumes. This equates to approximately 2 percent per year for 10 years. A negative travel time value in Table 2-18 indicates that the raised median had a shorter travel time for vehicles traversing the corridor. On the Texas Avenue corridor (ADT ~21,800), travel time decreased 11 percent with the raised median compared to the TWLTL. For Texas Avenue at an ADT of approximately 48,000, travel time decreased 38 percent with the raised median installation. The speed increased by 2 mph at the ADT of approximately 21,800, and it increased by 7 mph at an ADT of approximately 48,000.

Table 2-18. Characteristics and Results of Case Study Corridors.

Case Study	Location	Corridor Length (miles)	Signals per Mile / Access Points per Mile[1]	Median Opening Spacing (feet)[2]	Number of Lanes Each Direction[3]	Land Uses	Percent Difference in Conflict Points[4]	Estimated Existing ADT[5]	Estimated Future ADT[6]	Future Percent Difference in Travel Time[4]	Future Actual Difference in Speed (mph)
Texas Avenue	Bryan, Texas	0.66	3.0 / 91	690 to 1,320	2	Retail, University	-60	18,200	21,800	-11	2 (increase)
									48,000	-38	7 (increase
31st Street	Temple, Texas	0.71	5.6 / 66	350 to 850	2	Retail, Some Residential	-56	13,300	16,000	3	1 (decrease)
Broadway Avenue	Tyler, Texas	1.47	4.1 / 46	500 to 1,500	3	Commercial, Retail	-60	24,400	29,300	2	<1 (decrease)
									48,000	57	6 (decrease)

[1]Access point density includes both directions and includes driveways, streets, and signalized intersections.

[2]Median opening spacing is the range for the raised median alternative with the most openings. Five alternatives were investigated along 31st Street and two alternatives along Broadway.

[3]The Texas Avenue and 31st Street corridors were not widened in the micro-simulation because VISSIM allows vehicles to perform U-turns with two lanes, and this study was intended to investigate the differences between the TWLTL and the raised median. From a practical perspective, flared intersections and slightly widened mid-block location(s) would facilitate the U-turns.

[4]The percent difference values are from the conversion from a TWLTL to a raised median. Negative values imply a decrease when converting to the raised median. These differences are based upon the weighted average of three micro-simulation runs.

[5]Estimated from road tubes or videotapes. The ADTs are estimated by assuming a K and D factor to apply to the observed peak-hour volume.

[6]The lower ADT value is a 20 percent increase over existing conditions. This represents an approximately 2 percent increase per year over 10 years. The higher ADT value was run to estimate higher-volume conditions. The ADTs are estimated by assuming a K and D factor to apply to the observed peak-hour volume.

The travel time along 31st Street in Temple increased 3 percent (approximately 1 mph decrease at the only ADT level of 16,000 that was investigated). Along Broadway Avenue in Tyler, the travel time increased 2 percent (<1 mph decrease) when the raised median was installed at the lower ADT level (29,300). At the higher ADT level of 48,000, there was a 57 percent increase in travel time with the raised median. This equates to a 6 mph decrease in speed. It should be noted that generally the more circuitous travel and increased U-turn traffic can cause the raised median treatment to have slightly longer travel times. However, it is hypothesized that these increases in travel time, and subsequent delay, are offset by the reduction in the number of conflict points and increased safety. Though not tested, it is also hypothesized that further analysis could have determined that an additional median opening(s) could reduce the percent differences between the TWLTL and raised median even further.

The analysis results for the three case study corridors revealed small differences in travel time and delay between the existing (TWLTL) and proposed (raised median) conditions. The proposed future conditions (approximately a 20 percent increase in traffic) resulted in a small percent increase in the overall travel time and delay. The percentage difference in travel time, speed, and delay varied for each corridor. Travel time on the Texas Avenue (Bryan, Texas) corridor decreased 11 to 38 percent with the raised median compared to the TWLTL in the future condition. Travel time on the 31st Street (Temple, Texas) corridor increased 3 percent with a raised median compared to a TWLTL in the future condition, and on Broadway Avenue (Tyler, Texas) travel time increased 2 to 57 percent with the raised median treatment compared to a TWLTL in the future. This resulted in a maximum of a 6 mph decrease in speed due to the raised median installation (Tyler) and as much as a 7 mph increase in speed with the raised median (Bryan).

The reduction in travel time on Texas Avenue from the future TWLTL to the future raised median treatment might be attributed to prohibiting U-turns at a high-volume signalized intersection. This forces vehicles to make U-turns at locations farther along the corridor, at uncongested locations. In effect, this takes less time than waiting for turning traffic in the more congested portions of the corridor. This also allows for more through-movement green time, which can be reduced on corridors with high left-turn and U-turn movements. The increased travel times from the future TWLTL to the future installation of raised medians in Temple and Tyler are likely due to overall increases in traffic on the corridor, as some U-turning vehicles must travel farther to reach their destination. Increased travel time is also caused by U-turning vehicles that must weave across lanes to reach turn bays, which can cause traffic queues. The U-turning vehicles are also adding additional traffic on the roadways in the opposite direction of their origin. The additional vehicle-miles of travel (VMT) likely causes travel time and delay to increase. Delay may also increase slightly at the signalized intersections. As noted previously, the percent difference in travel time along the Temple corridor was only about 3 percent when comparing the raised median alternative with the most median openings—the alternative most effectively handling the corridor turning movements. It is hypothesized that increasing the number of median opening locations along any of the corridors could have increased speeds with the raised median alternative.

Future Research

The following items need to be researched further:

- the relationship between safety and time changes with increasing congestion levels and changing driveway density;
- the relationship between the length of the corridor and its effects on travel time and delay, as this project addressed relatively short corridors; and
- using an origin-destination (O-D) matrix to map vehicle turning movements.

2.8 THEORETICAL CORRIDORS

While the actual case study locations presented here are valuable in assessing the impacts of access management treatments, additional theoretical scenarios were also simulated. These additional scenarios will be useful to TxDOT staff members for alternatives analysis. Researchers met with TxDOT in the first year of this project to identify the most useful scenarios for their typical needs. Three theoretical corridors incorporating access management treatments such as raised median installation and driveway consolidation were investigated for different traffic volumes as a result of that meeting.

2.8.1 General Description

The three theoretical corridors range from Scenario 1 with a TWLTL and very few driveways to Scenario 3 with a raised median and several driveways. The three scenarios were analyzed using differing ADTs, varying numbers of lanes and driveways, and differing median treatments. All three scenarios have a signal density of 2.0 signals per mile.

2.8.2 Traffic Operations Analysis

The research team performed a traffic operations analysis on each theoretical corridor similar to the previous three case studies. Each theoretical corridor is 1 mile long. The following sections describe the data configuration, analysis procedures, and findings.

Data Configuration

The design of a theoretical corridor began with identifying typical land uses for the 1-mile corridor. The goal of the researchers was to design a realistic representation of a typical corridor. Some of the land uses included a drive-in bank, pharmacy/drugstore, fast-food with drive-through, and gas station. In Scenario 1, 18 driveways represented 18 parcels with varying land use types; some were used more than once. In Scenario 2, 42 driveways represented 42 parcels with repeating land uses. While Scenario 3 contained the same number of parcels as Scenario 2, with the same land uses, each parcel in Scenario 3 had two driveways, making a total of 84 driveways. In all scenarios there are an equal number of driveways on the north and south sides along the corridor, and the driveways lined up across the road. Once the land uses were identified, the researchers used the Institute of Transportation Engineers (ITE) *Trip Generation* manual to estimate the number of trips generated and the directional distribution (entering/exiting) of each particular land use (*12*). In Scenario 3, the trips generated were divided equally between the two driveways. The vehicles exiting all driveways in all scenarios were divided equally—50 percent left turning and 50 percent right turning. This was also true for all vehicles entering the driveways—50 percent enter from one direction and the other 50 percent enter from the other direction.

Traffic Demand

Scenarios 1 and 2 evaluated ADT volumes of 18,000, 23,000, 28,000, and 48,000. The research team added ADTs of 33,000 and 38,000 to Scenario 3's evaluation. For a given ADT level and simulation run, the same number of vehicles entered the corridor from each end. The actual number of entering vehicles was calculated by estimating the DDHV, which was accomplished by multiplying the ADT by the K-factor (0.135) and the D-factor (0.5). The K-factor value was estimated for a suburban area (*4*), and the D-factor assumed an equal split of traffic from each direction.

For the raised median conditions, VISSIM automatically rerouted the existing traffic to their final destination using the shortest route. For example, a left-turning motorist that was prohibited by the installation of the raised median would turn right and then make a U-turn at the first median opening.

Vehicle Conflict Points

Similar to the preceding case studies, researchers evaluated conflict points for Scenario 1 (with a TWLTL) and Scenarios 2 and 3 (with raised medians). The number of conflict points is based on the number of driveways and types of intersections.

Table 2-19 summarizes the number of conflict points for Scenario 1, which contains 18 driveways and two cross streets, with a driveway spacing of 660 feet. This distance is the same as the median opening spacings in the raised median options. For this reason, Scenario 1 can be interpreted as a TWLTL or a raised median. The total number of conflict points is 338.

Table 2-19. Theoretical Corridor Scenario 1 (with a Five-lane TWLTL/RM) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	18	13	5	234
T-Intersections RM (Driveways)	0	2	5	0
Cross Street 1 Intersection	1	52	5	52
Cross Street 2 Intersection	1	52	5	52
Total				338

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The total number of conflict points for Scenario 2 with a five-lane TWLTL cross section is shown in Table 2-20. The total number of conflict points increased from Scenario 1 because the number of driveways increased from 18 to 42. The number of conflict points increased from 338 to 650, approximately 48 percent.

Table 2-20. Theoretical Corridor Scenario 2 (with a Five-lane TWLTL) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	42	13	5	546
T-Intersections RM (Driveways)	0	2	5	0
Cross Street 1	1	52	5	52
Cross Street 2	1	52	5	52
Total				650

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Table 2-21 presents Scenario 2 with a seven-lane TWLTL. The addition of one lane in each direction increased the number of conflict points even more than adding more driveways. The number of conflict points increased from 338 in Scenario 1 to 674, approximately 50 percent.

Table 2-21. Theoretical Corridor Scenario 2 (with a Seven-lane TWLTL) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	42	13	7	546
T-Intersections RM (Driveways)	0	2	7	0
Cross Street 1	1	64	7	64
Cross Street 2	1	64	7	64
Total				674

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The theoretical corridor in Scenario 2 with a five-lane RM is shown in Table 2-22. The number of conflict points dramatically decreased after the installation of a raised median, from 338 in Scenario 1 to 196, approximately 42 percent.

Table 2-22. Theoretical Corridor Scenario 2 (with a Five-lane RM) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	5	0
T-Intersections RM (Driveways)	42	2	5	84
Cross Street 1	1	56	5	56
Cross Street 2	1	56	5	56
Total				196

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

The number of conflict points for Scenario 2 with a seven-lane RM is summarized in Table 2-23. The addition of one lane in each direction adds conflict points at the intersections, but installation of the raised median reduces the number of conflict points at driveways. The decrease in driveway conflict points decreases the total number of conflict points for the corridor from 338 in Scenario 1 to 216, approximately 36 percent.

Table 2-23. Theoretical Corridor Scenario 2 (with a Seven-lane RM) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	7	0
T-Intersections RM (Driveways)	42	2	7	84
Cross Street 1	1	66	7	66
Cross Street 2	1	66	7	66
Total				216

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Table 2-24 presents the number of conflict points for Scenario 3 with a seven-lane TWLTL. Doubling the number of driveways along the corridor doubles the number of driveway conflict points. The total number of conflict points increased significantly from 338 in Scenario 1 to 1220, approximately 70 percent.

Table 2-24. Theoretical Corridor Scenario 3 (with a Seven-lane TWLTL) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	84	13	7	1,092
T-Intersections RM (Driveways)	0	2	7	0
Cross Street 1	1	64	7	64
Cross Street 2	1	64	7	64
Total				1,220

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Table 2-25 indicates the number of conflict points for Scenario 3 with a seven-lane RM. This scenario is an excellent example of how simply installing a raised median will dramatically decrease the number of conflict points. The number of conflict points decreased from 1120 in Scenario 3 without a raised median to 300 with a raised median, a reduction of approximately 75 percent. The number of conflict points decreased from 338 in Scenario 1 to 300, approximately 11 percent.

Table 2-25. Theoretical Corridor Scenario 3 (with a Seven-lane RM) Conflict Points.

Roadway Section Type[1]	Number of Intersection Types along Study Corridor	Conflict Points per Intersection[2]	Number of Lanes[3]	Total Conflict Points
T-Intersections TWLTL (Driveways)	0	13	7	0
T-Intersections RM (Driveways)	84	2	7	168
Cross Street 1	1	66	7	66
Cross Street 2	1	66	7	66
Total				300

[1]TWLTL = two-way left-turn lane. RM = raised median.
[2]It is assumed that even though the driveways are directly across from one another, vehicles will not go straight from one driveway to the other.
[3]Number of lanes includes through lanes with a TWLTL or RM depending on the option.
Note: Some rows were kept at zero for consistency and comparison across similar tables.

Analysis Procedure

The researchers used VISSIM to model three scenarios, each having a few different options related to traffic volume and median treatment. The corridor's length and two cross streets remain the same throughout each scenario, and the signalized cross streets are placed 0.5 miles apart. The subsequent sections detail the three different scenarios and their varying options. The VISSIM model evaluated travel time and delay along the corridor under each of the scenarios.

<u>Scenario 1.</u> Scenario 1 consists of a five-lane TWLTL (or raised median). The driveways are spaced 660 feet apart, the same distance as the median openings. This spacing provides the same benefits of having a raised median. The 1.0-mile long corridor contains two cross streets (0.5 miles apart) and 18 driveways (660 feet apart), nine on each side directly across from one

another (see Figure 2-13). This scenario was analyzed using ADTs of 18,000, 23,000, and 28,000. Signal timing was optimized for every option using the different ADTs.

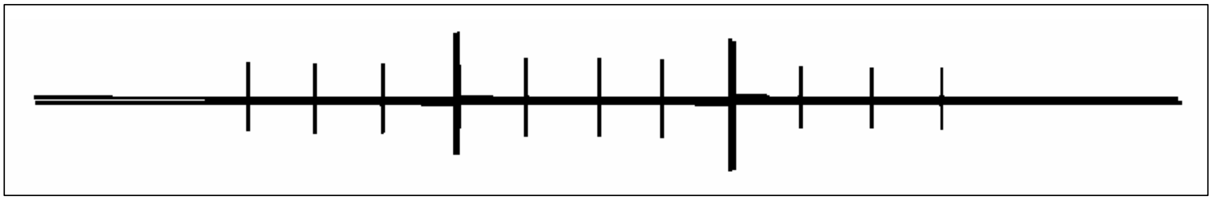


Figure 2-13. Schematic of Cross Streets and Driveway Locations for Scenario 1.

Scenario 2. Scenario 2 consists of four different options: a five-lane TWLTL and raised median and a seven-lane TWLTL and raised median. The geometry of Scenario 2 is similar to that of Scenario 1. However, in this scenario 24 driveways were added to the original 18, making a total of 42 driveways spaced 330 feet apart (see Figure 2-14). This scenario was analyzed using ADTs of 18,000, 23,000, 28,000, and 48,000.

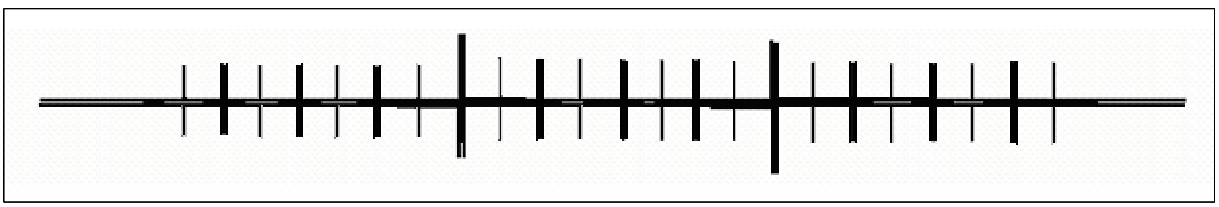


Figure 2-14. Schematic of Cross Streets and Driveway Locations for Scenario 2.

Scenario 3. This scenario is a seven-lane corridor with a TWLTL in one option and a raised median in another option. The driveway density increases once again in this scenario, doubling from 42 to 84 and creating a driveway spacing of 165 feet (see Figure 2-15). For this scenario, the research team analyzed ADTs of 18,000, 23,000, 28,000, 33,000, 38,000, and 48,000.

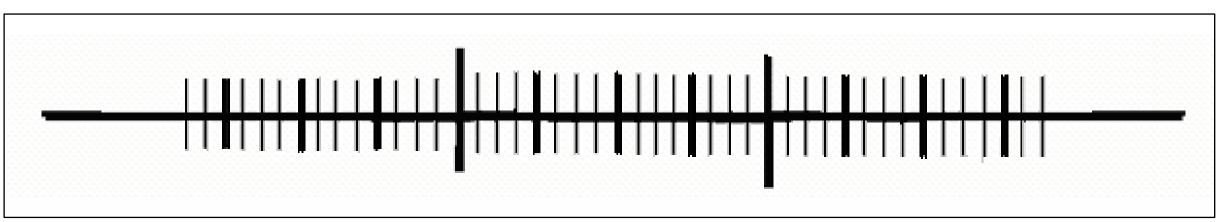


Figure 2-15. Schematic of Cross Streets and Driveway Locations for Scenario 3.

Findings

The research team analyzed travel time, vehicle speed, and delay at three locations along each corridor. Figure 2-16 shows the locations of data collection points (CPs) or travel time measurement "bars." For example, CP 1's beginning travel time measurement "bar" is on the west side, and the ending travel time measurement bar is on the east side. Collection points 1, 2, and 3 collect data in one direction, while CPs 4, 5, and 6 collect data at the same location but in the opposite direction. Collection points 1 and 4; 2 and 5; and 3 and 6 coincide, respectively, for opposite directions. Note that CPs 1 and 4 are located 0.25 miles from the end at the points where traffic enters the corridor. The distance between CP 1 and CP 4 is 1 mile. Collection points 2 and 5 are located just outside the cross-street intersection and before a driveway. They are 0.55 mile (2,900 feet) apart. This placement focuses on signal effects on vehicle travel when compared to CPs 3 and 6, located just inside the cross-street intersection and before a driveway. CPs 3 and 6 are 0.47 mile (2,500 feet) apart. Each scenario was run five times using different random seeds, then analyzed and compared to similar options to ensure they were similar enough to average and to estimate the performance measures. Tables in the following sections summarize the averages of the five runs.

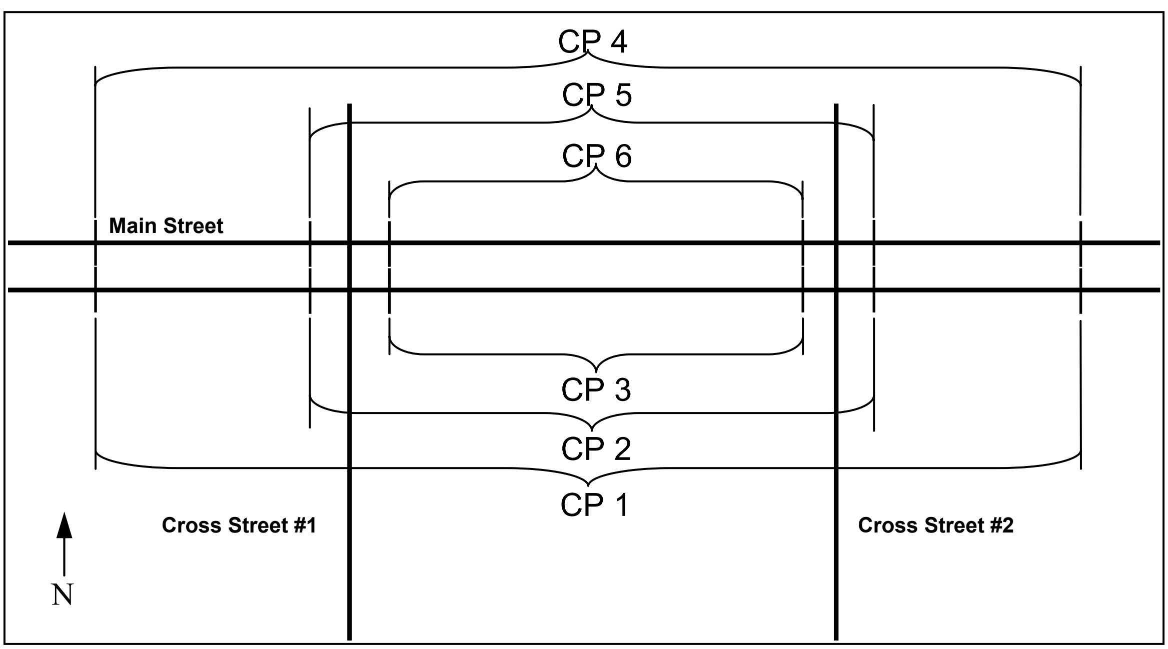


Figure 2-16. Collection Point Locations in VISSIM.

Table 2-26 presents travel times for Scenario 1. As would be expected, CPs 1 and 4 have the longest travel time while CPs 3 and 6 have the shortest. This is consistent in all analyses. Compared to Scenario 1, Scenario 2 (five-lane with TWLTL) travel times increased only slightly. The greatest increase, occurring at CPs 3 and 6 with an ADT of 18,000, is only 5.8 seconds (approximately 11 percent). There is less similarity between Scenario 1 and Scenario 2 (five lane with RM). The increase in travel time is greatest at CPs 1 and 4. As the collection points move farther out along the corridor, the travel time increase becomes greater. Travel time decreases from Scenario 2 (five-lane TWLTL and RM—see Table 2-27) to Scenario 2 (seven-lane TWLTL and RM—see Table 2-28). This decrease is intuitive and occurs because of the additional capacity of the corridor. There is very little difference between Scenario 2 (seven-lane with TWLTL and RM) and Scenario 3 (seven-lane TWLTL and RM) except at 48,000 ADT. The raised median did result in a 50.2 seconds (44 percent) increase over the TWLTL for Scenario 2.

The raised median generally has a higher travel time than the TWLTL in Scenario 3. At 48,000 ADT, the raised median increased travel time by 11.9 second (10 percent—see Table 2-29).

Table 2-26. Theoretical Corridor Scenario 1 (Five-lane) Travel Time Analysis Findings.

Option[1]	Weighted Average Travel Time (seconds)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL/RM	119.0	68.7	48.8
2. 23,000 TWLTL/RM	117.8	65.5	49.7
3. 28,000 TWLTL/RM	119.0	64.8	50.5

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-27. Theoretical Corridor Scenario 2 (Five-lane) Travel Time Analysis Findings.

Option[1]	Weighted Average Travel Time (seconds)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	127.7	77.0	55.0
2. 23,000 TWLTL	123.5	69.6	51.9
3. 28,000 TWLTL	116.8	66.9	50.8
4. 18,000 RM	130.8	80.6	53.7
5. 23,000 RM	131.5	77.0	54.4
6. 28,000 RM	152.9	76.9	58.5

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-28. Theoretical Corridor Scenario 2 (Seven-lane) Travel Time Analysis Findings.

Option[1]	Weighted Average Travel Time (seconds)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	122.9	75.6	49.0
2. 23,000 TWLTL	121.6	73.1	49.2
3. 28,000 TWLTL	117.6	70.9	47.8
4. 48,000 TWLTL	115.3	65.2	50.2
5. 18,000 RM	132.4	84.8	50.6
6. 23,000 RM	131.5	80.0	51.9
7. 28,000 RM	130.6	85.5	51.2
8. 48,000 RM	165.5	100.8	59.4

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-29. Theoretical Corridor Scenario 3 (Seven-lane) Travel Time Analysis Findings.

Option[1]	Weighted Average Travel Time (seconds)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	120.6	74.2	48.1
2. 23,000 TWLTL	121.7	73.4	48.8
3. 28,000 TWLTL	121.4	71.7	50.2
4. 33,000 TWLTL	114.5	64.9	50.8
5. 38,000 TWLTL	114.4	64.5	49.4
6. 48,000 TWLTL	114.5	63.0	50.0
7. 18,000 RM	128.4	80.2	49.4
8. 23,000 RM	123.0	73.8	49.2
9. 28,000 RM	123.4	73.6	49.6
10. 33,000 RM	122.4	66.7	48.7
11. 38,000 RM	139.8	67.9	49.6
12. 48,000 RM	126.4	65.9	50.9

[1]TWLTL = two-way left-turn lane. RM = raised median.

Speed was also analyzed along the corridor based on the travel time data. The speed distribution used in VISSIM was from 28.4 and 51.7 mph. In all scenarios, speeds between CPs 3 and 6 (within the signalized intersections) are fastest overall. Between CPs 2 and 5 (right outside the intersection) speeds decrease. This is due to vehicles slowing or stopping at the signals. The overall speeds generally decrease from Scenario 1 to Scenario 2 (five-lane TWLTL and RM) (comparing Tables 2-30 and 2-31). When lanes are added to Scenario 2 (see Table 2-32), the speeds generally increase slightly, as expected. There is a slight decrease in speed when a raised median is introduced to the corridor for both Scenario 2 (Tables 2-31 and 2-32) and Scenario 3 (Table 2-33). There are small differences in speeds between Scenario 2 (seven-lane TWLTL and RM—Table 2-32) and Scenario 3 (TWLTL and RM—Table 2-33). Also, there is little change in speed between median treatments. At Scenario 3 CPs 1 and 4, the speed decreases from 31.5 miles per hour with a TWLTL to 25.8 miles per hour with a raised median at 38,000 ADT (Table 2-33). This difference is only approximately 10 percent reduction in speed.

Table 2-30. Theoretical Corridor Scenario 1 (Five-lane) Average Speed Analysis Findings.

Option[1]	Average Speed (miles/hour)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL/RM	30.2	28.8	34.9
2. 23,000 TWLTL/RM	30.6	30.2	34.3
3. 28,000 TWLTL/RM	30.2	30.5	33.8

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-31. Theoretical Corridor Scenario 2 (Five-lane) Average Speed Analysis Findings.

Option[1]	Average Speed (miles/hour)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	28.4	25.7	30.8
2. 23,000 TWLTL	29.1	28.5	32.6
3. 28,000 TWLTL	31.1	29.6	33.3
4. 18,000 RM	27.5	24.6	31.7
5. 23,000 RM	27.4	25.7	31.3
6. 28,000 RM	23.6	25.9	29.2

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-32. Theoretical Corridor Scenario 2 (Seven-lane) Average Speed Analysis Findings.

Option[1]	Average Speed (miles/hour)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	29.4	26.2	34.5
2. 23,000 TWLTL	29.6	27.1	34.4
3. 28,000 TWLTL	30.7	27.9	35.4
4. 48,000 TWLTL	31.2	30.4	33.7
5. 18,000 RM	27.2	23.3	33.4
6. 23,000 RM	27.4	24.7	32.6
7. 28,000 RM	27.6	23.1	33.0
8. 48,000 RM	21.8	19.6	28.5

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-33. Theoretical Corridor Scenario 3 (Seven-lane) Average Speed Analysis Findings.

Option[1]	Average Speed (miles/hour)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	29.8	26.7	35.2
2. 23,000 TWLTL	29.9	27.0	34.7
3. 28,000 TWLTL	29.8	27.7	33.7
4. 33,000 TWLTL	31.4	30.5	33.3
5. 38,000 TWLTL	31.5	30.7	34.3
6. 48,000 TWLTL	31.4	31.4	33.8
7. 18,000 RM	28.1	24.6	34.5
8. 23,000 RM	29.3	26.8	34.6
9. 28,000 RM	29.2	26.9	34.3
10. 33,000 RM	29.4	29.7	35.0
11. 38,000 RM	25.8	29.1	34.4
12. 48,000 RM	28.5	30.1	33.2

[1]TWLTL = two-way left-turn lane. RM = raised median.

Delay was not collected using nodes on the theoretical corridor as it was in the three case studies (Tables 2-34 to 2-37). VISSIM estimated delay from the collection points or travel time measurement "bars." This estimation provides average delays for vehicles traversing from one CP to the next. Average delay data collection was changed to the node method for the case studies for more understandable results. Average delay for all the scenarios is shortest at CPs 3 and 6 and longest at CPs 1 and 4. This difference is due to the greater number of obstacles like signals and driveways for collection points farther apart on the corridor. There is a great difference in delay between CPs 2 and 5 and 3 and 6. This difference suggests that the main delay factor is the signalized intersection. A comparison between Scenario 1 (Table 2-34) and Scenario 2 (with a TWLTL—Tables 2-35 and 2-36) shows little change in delay. However, when a raised median is installed the delay increases, likely because of the more circuitous travel required to reach U-turn locations. For example, in Scenario 3 at an ADT of approximately 48,000 (Table 2-37), CPs 1 and 4, delay increases 12.0 seconds per vehicle, an increase of approximately 55 percent.

Table 2-34. Theoretical Corridor Scenario 1 (Five-lane) Average Delay Analysis Findings.

Option[1]	Average Delay (seconds per vehicle)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL/RM	26.7	17.9	5.2
2. 23,000 TWLTL/RM	25.4	14.8	6.1
3. 28,000 TWLTL/RM	26.5	15.2	6.8

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-35. Theoretical Corridor Scenario 2 (Five-lane) Average Delay Analysis Findings.

Option[1]	Average Delay (seconds per vehicle)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	34.6	25.9	11.3
2. 23,000 TWLTL	30.7	18.7	8.3
3. 28,000 TWLTL	24.3	16.2	7.3
4. 18,000 RM	37.7	29.5	10.0
5. 23,000 RM	38.5	26.1	10.7
6. 28,000 RM	60.1	29.1	14.9

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-36. Theoretical Corridor Scenario 2 (Seven-lane) Average Delay Analysis Findings.

Option[1]	Average Delay (seconds per vehicle)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	30.0	24.7	5.4
2. 23,000 TWLTL	29.1	22.2	5.6
3. 28,000 TWLTL	24.7	19.9	4.6
4. 48,000 TWLTL	22.4	12.8	6.9
5. 18,000 RM	39.8	34.0	7.1
6. 23,000 RM	38.6	28.9	8.3
7. 28,000 RM	37.5	27.2	7.5
8. 48,000 RM	72.3	43.1	15.6

[1]TWLTL = two-way left-turn lane. RM = raised median.

Table 2-37. Theoretical Corridor Scenario 3 (Seven-lane) Average Delay Analysis Findings.

Option[1]	Average Delay (seconds per vehicle)		
	1 & 4	2 & 5	3 & 6
1. 18,000 TWLTL	28.1	23.2	4.5
2. 23,000 TWLTL	28.8	22.6	5.2
3. 28,000 TWLTL	28.4	17.8	6.6
4. 33,000 TWLTL	22.0	14.1	4.7
5. 38,000 TWLTL	20.3	13.7	5.8
6. 48,000 TWLTL	21.9	12.3	6.4
7. 18,000 RM	35.7	29.2	5.7
8. 23,000 RM	30.2	22.9	5.6
9. 28,000 RM	31.0	22.7	6.1
10. 33,000 RM	29.8	15.9	5.1
11. 38,000 RM	47.2	17.0	5.9
12. 48,000 RM	33.9	15.0	7.3

[1]TWLTL = two-way left-turn lane. RM = raised median.

2.8.3 Discussion and Conclusions

Analysis of the theoretical corridors also addressed the number of conflict points, travel time, speed, and delay. These results help researchers begin to identify operational characteristics resulting from changing to raised medians from TWLTL lanes and altering driveway density. It is anticipated that adding additional traffic volume, beyond that experienced in the field case studies, may result in even larger differences in these four parameters between median types.

Safety is an important aspect of access management. A reduction in the number of conflict points within a corridor will likely reduce the number of crashes within that corridor. Installing a raised median is an excellent way to reduce the number of conflict points. This is illustrated the most in Scenario 3 (see Table 2-38). When a raised median is added to the corridor, the number of conflict points decreases from 1,220 to 300, a decline of roughly 75 percent. Scenario 2 also showed a large decrease in the number of conflict points after the addition of a raised median. Another way to reduce the number of conflict points is to reduce the number of driveways along the corridor. When the number of driveways increased from 18 to 42, the total conflict points for the scenarios with a TWLTL increased from 338 to 650 (five lanes) and 674 (seven lanes), an increase of approximately 50 percent.

Table 2-38. Theoretical Corridor Characteristics and Results.

Theoretical Corridor	Median Treatment[1]	Number of Lanes in Each Direction	Percent Difference in Conflict Points[2]	Number of Driveways	Driveway Spacing (feet)	Raised Median Opening Spacing (feet)	Estimated Future ADT[3]	Future Percent Difference in Travel Time[2]	Future Actual Difference in Speed (mph)
Scenario 1	TWLTL and Raised	2	Not Applicable	18	660	660	18,000 to 28,000	Not Applicable	Not Applicable
Scenario 2	TWLTL	2	-70	42	330	660	18,000	2	<1 (decrease)
							23,000	6	2 (decrease)
	Raised						28,000	31	8 (decrease)
	TWLTL	3	-70	42	330	660	18,000	8	2 (decrease)
							23,000	8	2 (decrease)
	Raised						28,000	11	3 (decrease)
							48,000	44	9 (decrease)
Scenario 3	TWLTL	3	-75	84	165	660	18,000	6	2 (decrease)
							23,000	1	<1 (decrease)
							28,000	2	<1 (decrease)
	Raised						33,000	7	2 (decrease)
							38,000	22	6 (decrease)
							48,000	10	3 (decrease)

[1] Scenario 1 can be considered as both a TWLTL and a raised median because, due to the driveway spacing, there is no change in the conflict points and turning locations.

[2] The percent difference values are from the conversion from a TWLTL to a raised median. Negative values imply a decrease when converting to the raised median. These differences are based upon the weighted average of three micro-simulation runs.

[3] The ADTs are estimated by assuming a K and D factor to apply to the observed peak-hour volume.

Table 2-38 illustrates all the theoretical scenarios and their results. As in the case studies, the number of conflict points decreases with the installation of a raised median. This decrease occurs even when the number of driveways increases from 18 in Scenario 1 to 84 in Scenario 2, an increase of approximately 460 percent. The number of conflict points for both the five- and seven-lane options for Scenario 2 was reduced by 70 percent with the installation of a raised median. This large reduction is accompanied by an increase in travel times with the raised median by from 2 to 31 percent for the five-lane option and from 8 to 44 percent for the seven-lane option. The Scenario 3 results show a 75 percent reduction in the number of conflict points with the installation of a raised median, along with a 1 to 22 percent increase in travel time.

These results generally demonstrate an increase in travel time along the corridor for through-moving vehicles due to the circuitous travel of U-turning traffic and the associated weaving of these maneuvers. The actual reduction in speed is, on average, approximately 3 mph when a raised median replaces a TWLTL. It is hypothesized that these relatively small differences would likely be justified by the associated reduction in conflict points and potential safety increase along such corridors. These analyses also make assumptions about traffic patterns entering and exiting the corridors. Along and around an actual corridor, observation rather than simulation would allow a better understanding of the origin-destination patterns which might lead to better management of traffic circulation.

Future research in this area should continue investigating the relationship between median type, driveway density, and traffic volume. In the theoretical corridors, the median opening spacings were set at 1/8 mile (660 feet), and it would be interesting to investigate the potential changes in travel time with different median opening spacings. It would also be interesting to investigate these parameters over longer corridors to gain insight into potential changes over longer distances. It is preferable that such analyses be conducted on actual field sites, along with an associated crash analysis, though finding such a site and performing such data collection could be difficult and costly.

CHAPTER 3

CRASH ANALYSIS METHODOLOGY AND FINDINGS

This chapter describes the crash analysis performed along 11 case study locations in Texas and one in Oklahoma. This analysis provides a safety estimate on corridors after installation of access management techniques. Researchers investigated three locations where a raised median was installed to replace TWLTLs and two locations where raised medians were added to undivided roads. One notable finding of this part of the project is that crash data accuracy, availability, and usefulness vary greatly among agencies. For instance, it can be quite difficult, if not impossible, to obtain crash data dated more than 10 years ago. Further details are provided in each case study discussion.

3.1 CRASH ANALYSIS CASE STUDY LOCATIONS

The 11 case study locations for crash analysis identified in Texas, as well as the one in Oklahoma are listed below:

- Texas Avenue in College Station;
- Loop 281 in Longview;
- Call Field Road in Wichita Falls;
- Grant Avenue (US 385) in Odessa;
- 71^{st} Street in Tulsa, Oklahoma;
- Camp Bowie Boulevard (US 377) in Fort Worth;
- University Drive (US 380) in McKinney;
- Preston Road (SH 289) in Plano;
- 31^{st} Street (FM 1741) in Temple;
- Broadway Avenue (US 69) in Tyler;

- 42^{nd} Street (SH 191) in Odessa; and,
- Park Boulevard in Plano.

Researchers studied the Texas Avenue corridor first, in order to develop and refine the analysis process for all case study corridors. Therefore, this report includes more detailed information about the Texas Avenue corridor, and the reader is referred to Report 0-4221-1 for more information where applicable. Case study locations are described in further detail in the sections that follow.

3.2 TEXAS AVENUE (COLLEGE STATION) CASE STUDY LOCATION

3.2.1 General Description

The first case study corridor is along Texas Avenue in College Station, Texas. Researchers investigated changes in crash characteristics along Texas Avenue from 0.2 miles south of George Bush Drive to 0.2 miles north of University Drive. Before the retrofit, Texas Avenue was a five-lane roadway with a TWLTL. In 1996, TxDOT widened Texas Avenue to six lanes and converted the TWLTL to a raised median. The land use on the east side of Texas Avenue is mainly commercial. There are many traffic generators such as a large home electronics store, a bookstore, restaurants, and retail shops. Figure 3-1 shows the study site between the two arrows along Texas Avenue. The campus of Texas A&M University borders the west side of Texas Avenue. Figure 3-2 and Figure 3-3 show the raised median treatment along this portion of Texas Avenue, which has only one main entrance to the campus.

Researchers gathered crash data for the time period from January 1993 to June 2000 for the study site. Crash data were examined both for the entire corridor and at specific locations. The subsequent sections describe data collection, traffic demand, analysis procedures, and preliminary results. Portions of the Texas Avenue case study location discussion are excerpted from references (*9*) and (*13*).

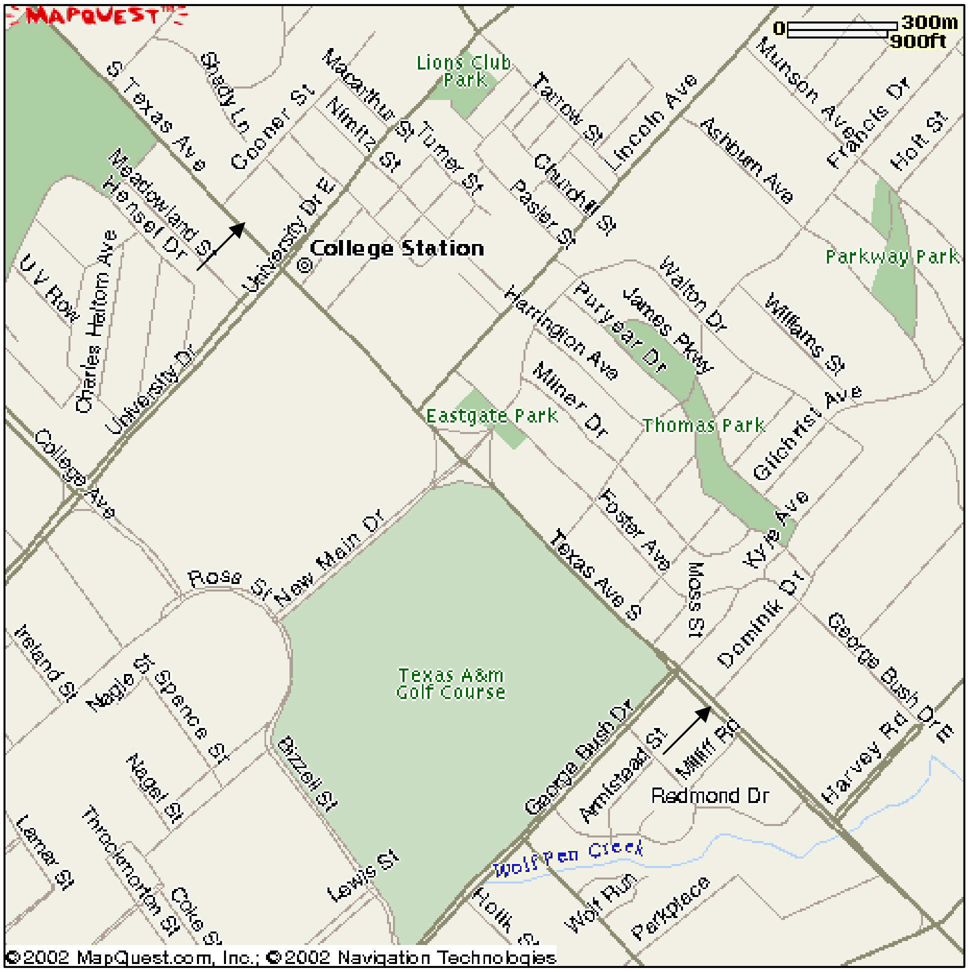


Figure 3-1. Texas Avenue Study Site in College Station, Texas, Used for Crash Analysis (Map Provided by MapQuest.com, Inc.).

Figure 3-2. Raised Median Treatment on Texas Avenue Showing Cross Section.

Figure 3-3. Raised Median Treatment on Texas Avenue Showing Median Openings.

3.2.2 Data Collection

Crash data were obtained from the Accident Records Bureau (ARB) of the Texas Department of Public Safety (DPS) in Austin. "Coded crash data" refers to crash information contained in the DPS mainframe database. Currently, this information consists of all the data from the original crash reports, with the exception of crash sketches and the exact wording of narratives, for the most recently processed 10-year time frame. For quality assurance purposes, original crash reports retained by DPS were also collected and compared to the coded crash data, allowing researchers to investigate the accuracy of the crash-reporting process in the State of Texas. The authors will take the readers step by step through the crash-reporting process, summarize the quality of the process, and describe the specifics of the data collection.

Crash-Reporting Process

Completing a crash report is the beginning of the crash-reporting process. In the State of Texas, a crash report is submitted on one of two forms, the ST-2 or the ST-3 (see Appendix B, Figures B-1 through B-4).

The ST-2 is used less often and is sent directly to the ARB by one or more of the crash participants. This form is used when there is no police involvement or when the police do not plan to report the crash and the motorists involved still desire an official record. The ST-2 is more commonly referred to as the "blue form," due only to the color of the form. The form contains all the applicable information for the crash including location, vehicle identification, damage, and casualties.

When local agency police do not report a crash, drivers have the right and responsibility to report their traffic incident to the DPS with a blue form. State law places the onus on the driver, not the policing authority, to report a crash on a public roadway. In most cases, if the police stop at the crash scene they will submit a report. In property damage only (PDO) cases where the total property damage is estimated at less than $1,000 and no injuries were involved, the drivers may request that police not fill out a crash report because the drivers intend to report the incident and are peaceably exchanging insurance and contact information. To clarify, PDO means no injuries occurred, and there was only vehicular and/or roadway facility damage. In some cases, researchers use equivalent property damage only (EPDO) to include injuries by adding the associated costs from the injuries to the PDO for comparison and estimating purposes. The authors of this report did not use EPDOs. If the police are not involved at the crash scene, the drivers may file a crash report either directly through the local police or through the DPS. If the crash is a PDO not exceeding $1,000 and no traffic citations or criminal proceedings are warranted, it is highly unlikely the police will report the crash, even if the drivers involved try to report it. In that specific instance, the police will suggest that the drivers submit a blue form to DPS for reporting purposes.

Crash-reporting trends are the common reason behind the fewer number of blue form crash reports. Regardless of the legal responsibility of drivers to report crashes, the current tendency of motorists is to not report crashes not involving injuries, criminal charges, and/or property damage exceeding $1,000 because drivers wish to avoid higher insurance rates (*14*,*15*).

In the State of Texas, police use the ST-3 to report crashes. The ST-3 contains all the same information as the blue form, except in more detail. This form has a location for the reporting officer to sketch the crash and write summary comments. These comments are based on statements of individuals involved and the officer's professional assessment of the crash scene. One benefit of the ST-3 is that the officer's comments should offer a more accurate and unbiased point of view of the incident. The police form also includes citation, weather, and road data. Weather conditions, road data, and crash sketches may be submitted on the blue form in the driver narrative section; however, the ST-3 offers a less biased crash assessment because drivers invariably will report in their own favor for insurance purposes. Once the officer's crash investigation is complete, the crash record is submitted to the local police department.

Crash information retained by local authorities varies in length and detail based on the needs and goals of the local policing authority. In College Station, Texas, the local police store certain data from the crash report in a local database. The database contains information such as the crash location and the overall severity of the crash. Overall crash severity is one way that crashes are categorized.

Disposition of individuals involved in a crash is associated with the overall crash severity. For instance, in a crash with four possible injuries and one incapacitating injury, the crash has an overall severity of incapacitating injury. An example of a possible injury is when a person complains of a sore neck. Non-incapacitating injuries consist of obvious scrapes and bruises that do not physically disable a person at the scene, while incapacitating include broken limbs or excessive bleeding requiring minimal movement and a pressure bandage (e.g., a tourniquet). Crash data retained by the College Station Police Department (CSPD) are shown in Appendix B. After the data are input, the records are stored on file in the CSPD Records Department and a copy is shipped to the ARB. The local recording process usually takes about 10 business days.

When the ST-2 and ST-3 reports arrive at the ARB, the files are immediately sorted and state processing begins. The process is similar to an assembly line. Incoming files are date stamped and sorted by county. In the next stage, the records are separated into three categories, referred to as Groups I, II, and III for the Texas Avenue case study.

The crash reports are placed in the different groups based on cause of crash, location of crash, estimated replacement/repair costs involved, and overall crash severity. Group I includes PDO crashes less than $1,000 and crashes that do not occur on a roadway (i.e., crashes in a private parking lot). Group II includes PDO crashes equal to or in excess of $1,000 in which the vehicles were not towed from the scene. Group III includes all crashes that take place on a public roadway that include injuries and/or PDOs equal to or in excess of $1,000 in which the vehicles were towed. Group I crashes are the least likely to be reported.

During the grouping stage, certain information is marked on the records for later coding to an individual's traffic history/driving record. All traffic violations are coded to a driver's traffic history for state and insurance reasons. The crash is coded into the at-fault driver's record for state purposes, but the crash is not coded into the not-at-fault driver's record. An example of a not-at-fault driver is a driver of a vehicle that is rear-ended at a stop light. Only the rear-end motorist has the crash coded to his/her personal driving record. Another example of a not-at-fault driver is one who crashed while evading an animal on the roadway. It is possible to be at fault in a crash and not receive a traffic citation, for example, when the crash does not occur on a roadway but on private property instead, such as a parking lot.

The state and insurance agencies use a driver's personal driving record for different purposes. The state uses this information to suspend a driver's license or to aid in criminal proceedings. Insurance agencies use the information to analyze their client's policy to validate premium changes or policy cancellation. However, insurance agencies have only limited access to the data. They can only retrieve the last three years of data and only those data including traffic citations. The only crash data insurance agencies can access is what a driver submits in an insurance claim.

Coding Group II and III crash data into a DPS mainframe is the next step in the state crash-reporting process. Group I records are not included because they are the least likely to be reported and the least severe.

The first and longest step in the coding process is handwritten coding. During this phase, the coding of records is broken down into different stages. The reports are coded in an assembly-line fashion with ARB staff coding only certain information as the record passes through. For instance, a specific person's task would be to code only the driver data onto a hard-copy sheet.

Once the hard-copy coding phase is complete, the data are input using a dual data entry method. While in the earlier stages, data entry is checked on varying levels to minimize errors, the dual data entry method is one of the best ways to reduce mistakes. Two different people input the same data into a computer; the computers compare the records; matching records are approved for final mainframe upload; and records that do not match are set aside for checking.

One further note, the ARB is working to further improve the crash-reporting system with the Crash Record Information System (CRIS). DPS is working with TxDOT to fund this new system which will help automate the reporting process and make the information more accessible in a timely manner. ARB staff members are assisting in transportation engineering and planning by supplying crash data to different agencies that try to make informed infrastructure safety improvements. CRIS will further enhance the abilities of the ARB and any other agency requiring such information. A copy of a CRIS newsletter is located in Appendix B.

There is a more in-depth description of the crash-reporting process in outline format in Appendix B. Figure 3-4 is a flowchart representation of the above crash-reporting process.

Data Collection Efforts

The authors retrieved crash data from various resources. They obtained primary data, the coded and original crash reports, from the ARB. After defining the study corridor, the researchers compiled the coded crash data using a TTI CD-ROM supplied by the ARB. To collect the original crash reports, the applicable reference information, such as the date of the crash and the county where the crash occurred, were submitted directly to the ARB. Other data collected from TxDOT were the annual average daily traffic (AADT) counts and the roadway layout before and after the retrofit. AADT values will be discussed later in Section 3.2.3, "Traffic Demand," and roadway layout will be discussed in Section 3.2.4, "Crash Analysis Procedure."

Crash data used for the before-construction analysis covered January 1993 to December 1994. The data used for the after-construction period covered July 1998 to June 2000. Researchers selected the before time frame because starting in July 1995, PDO records contained only PDO crashes where the vehicle had to be towed from the scene. If there was no injury or the vehicle was not towed, then there was not a crash record after July 1995. The before data were filtered as appropriate to ensure that comparisons to the after-construction data were consistent. Researchers selected the after time frame because June 2000 were the most recent data available and construction of the raised median concluded in June 1998.

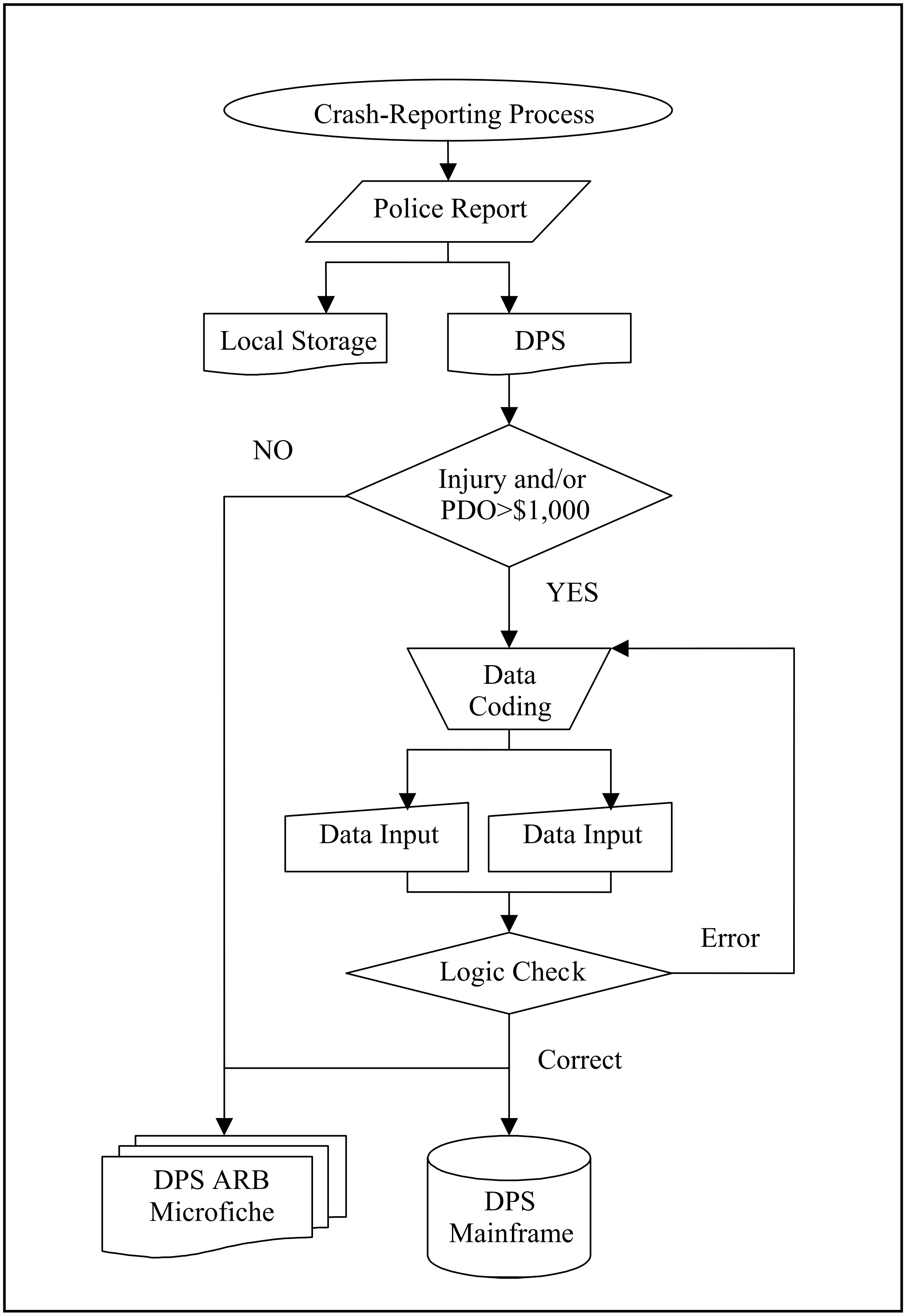


Figure 3-4. Crash-Reporting Process Flowchart.

Summary of Crash-Reporting Errors

Most crash-reporting errors were found in the location, orientation, crash type, or severity of the incident. After carefully looking through more than 1,014 individual crash reports, the researchers feel confident that location inaccuracies are the most prevalent. In some instances, both law enforcement personnel and ARB coding staff made data entry errors. The mistakes were minor and not attributable to negligence. The authors assess that, through comparison with original crash reports, they can identify and correct the few crash reporting errors.

Researchers first looked for coding errors made during ARB data entry. Of 1,014 records studied, they found only 29 errors (3 percent) in the DPS mainframe after comparison with the data provided in the original police reports. Of the 29 coding mistakes, eight resulted during hard-copy coding stage by someone who was unfamiliar with the peculiarities of College Station. For example, SH 30 is Harvey Road, and FM 2818 is Harvey Mitchell Parkway. One crash that occurred at Harvey Mitchell Parkway was coded for Harvey Road. For someone from College Station, the error is obvious; however, it is far more probable that someone who is unfamiliar with the area may unknowingly code the information incorrectly. For the errors found, the original crash report removed any doubt as to the location of the crash.

Of the remaining errors, 20 were related to coding the incorrect primary road at an intersection crash, and only one was related to the crash type. Coding mistakes for the primary roadway are the least significant because the discrepancies are based on the authors' interpretation of the data and not on the ARB coding rules. The ARB defines the primary roadway as the one that has designation seniority. In other words, in a crash at the intersection of Texas Avenue and University Drive, the primary roadway is Texas Avenue because it is a state highway and University Drive is a farm-to-market road. The researchers believe if the crash does not occur in the intersection (i.e., an off-setting reference distance is supplied that places the crash outside of the intersection), then the crash should be coded to the roadway on which it occurs. Hence, the crash reports were modified accordingly.

The other source of error in crash reporting originates with the crash report submitted by the police. The police reports studied for this project contained more than enough additional information to enable the researchers to clarify and verify any perceived discrepancies in the reporting of location, orientation, crash type, or severity of a crash. In their investigation, the researchers did find erroneous reference distances used by the reporting officer(s). For example, one police officer recorded a crash 100 feet south of Dominik Drive. After further investigation, the researchers were able to determine through other reported information that the crash occurred 600 feet south of Dominik Drive. The reported orientation, crash type, and crash severity data overall appeared contain no errors. Researchers looked for errors of this type from the perspective of internal discrepancies within the report itself. For instance, it would be considered an error if a police officer coded the crash severity with a death but did not record the death of any of the drivers or non-drivers.

The milepost position of a crash along the main roadway, as coded by DPS, is another potential error related to crash location. This error also occurs in the handwritten coding stage; however, this fault cannot be solely attributed to the ARB, nor is it considered a significant problem. Because driveway openings can be approximately 40 feet wide, accuracy within 0.01 or 0.001 miles (53 or 5 feet) is desirable. In the field, it would be a daunting, if not impossible, task for officers to determine that level of accuracy by current manual methods for the entire State of Texas. Technologies such as the Global Positioning System (GPS) might be used in the future to identify the crash location relative to known objects (e.g., traffic signs or center of curve radius). Police report locations for all crashes were compared to milepost locations from the TxDOT location map and were adjusted to within 5 feet to ensure the location accuracy.

Common errors that were expected but could not be verified were those related to: the exact number of vehicles involved, the true intentions of the at-fault driver, and compounding causes attributing to the crash. In one instance, the driver of a vehicle in the southbound outside lane approaching traffic congestion at the Texas Avenue and George Bush Drive signal attempted to move into the adjacent lane to avoid the longer queue of cars and sideswiped another vehicle. None of the other drivers or the reporting officer made any comment or inference regarding the at-fault driver's intention. Answers to questions such as "did the driver miss his/her blind spot," "was the other driver speeding or changing lanes," and "did either party have additional stimuli distracting him/her from driving" are typically unknown, due to inaccurate eyewitness reporting and drivers providing false information to avoid incrimination (*6*).

To summarize the quality assurance aspect of the study, error calculations were limited to the milepost locations of crashes along the main roadway.

In the above calculations, the revised data section refers to the reduction of original raw data. This reduction includes removing all data records containing errors not attributable to the DPS such as data input errors in the original police report and data the DPS coded for the wrong roadway due to lack of familiarity with the crash location. Cases where the DPS coded the wrong roadway, which occurred approximately 3 percent of the time, were not included because it was difficult to ascertain the intent of the coding officer.

Overall, the low percentage of errors in the state crash record data is promising and indicates a robust data set for crash analysis along Texas Avenue. The authors looked at coded data collected locally by the College Station Police Department, but chose not to use them because the information was not detailed enough for this study's purposes.

3.2.3 Traffic Demand

Traffic volumes were retrieved from TxDOT to generate the section and intersection crash rates for Texas Avenue addressed in this section. Table 3-1 presents the AADT values used for the rate calculations. Values for the entering volumes listed in Table 3-2 were calculated assuming a 50/50 directional split, and were then used to formulate total entering volumes for the intersection rate calculations.

Table 3-1. Texas Avenue AADT Counts.

Year	AADT (vehicles/day)					
	Texas Avenue North of University Drive	University Drive West of Texas Avenue	University Drive East of Texas Avenue	Texas Avenue from University Drive to George Bush Drive	George Bush Drive West of Texas Avenue	Texas Avenue South of George Bush Drive
	MP 4.950[1]	MP 6.621[1]	MP 6.716[1]	MP 5.700[1]	MP 3.232[1]	MP 6.056[1]
1993	26,000	34,000	31,000	40,000	22,000	39,000
1994	25,000	34,000	29,000	42,000	22,000	41,000
1998[2]	22,500	35,500	32,000	38,500	26,500	42,000
1999[2]	25,500	38,500	34,500	43,000	28,000	46,500
Before	25,500	34,000	30,000	41,000	22,000	40,000
After	24,000	37,000	33,250	40,750	27,250	44,250

[1] MP = milepost referring to a location along a roadway as used by TxDOT in Roadway Inventory (RI) logbooks.
[2] Time frame is from July of that year through June of the next.

Table 3-2. Traffic Volumes Entering Texas Avenue.

Year	Entering Traffic Volumes (vehicles/day)							
	Vehicles Entering the Intersection of Texas Avenue and George Bush Drive				Vehicles Entering the Intersection of Texas Avenue and University Drive			
	EB[1]	WB[1]	NB[1]	SB[1]	EB[1]	WB[1]	NB[1]	SB[1]
1993	11,000	11,000	19,500	20,000	17,000	15,500	20,000	13,000
1994	11,000	11,000	20,500	21,000	17,000	14,500	21,000	12,500
1998[2]	13,250	13,250	21,000	19,250	17,750	16,000	19,250	11,250
1999[2]	14,000	14,000	23,250	21,500	19,250	17,250	21,500	12,750
Before	11,000	11,000	20,000	20,500	17,000	15,000	20,500	12,750
After	13,625	13,625	22,125	20,375	18,500	16,625	20,375	12,000

[1] EB = eastbound; WB = westbound; NB = northbound; and SB = southbound.
[2] Indicates that the time frame goes from July of that year through June of the next.

3.2.4 Crash Analysis Procedure

This section discusses the use of crash diagrams, crash rates, and the various calculations that were performed in the crash analysis.

Crash Diagrams

Crash diagrams are an integral part of conducting a crash analysis. Crash diagramming is a standard technique that enables researchers to pinpoint locations with high crash volumes and to visually associate the representative crash types with their location. Researchers generate crash diagrams by placing each individual crash on a plane-view schematic of the study location according to the crash type, location, and whether there was an injury involved. Figure 3-5 below, from the "Traffic Accident Studies" chapter in the ITE *Manual of Transportation Engineering Studies*, was used by the authors to produce the crash diagrams. This figure was essential in the diagramming process.

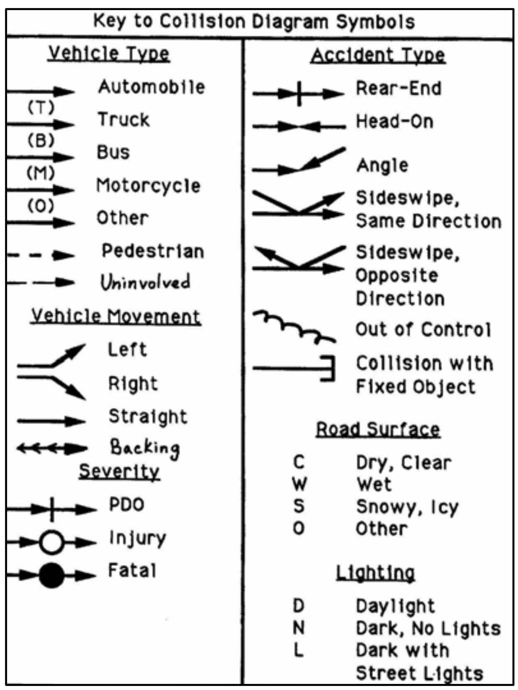


Figure 3-5. Crash Diagram Symbols (*6*).

Figures 3-6 and 3-7 show two examples of the researcher's crash diagrams for this study. Each tally mark represents one crash.

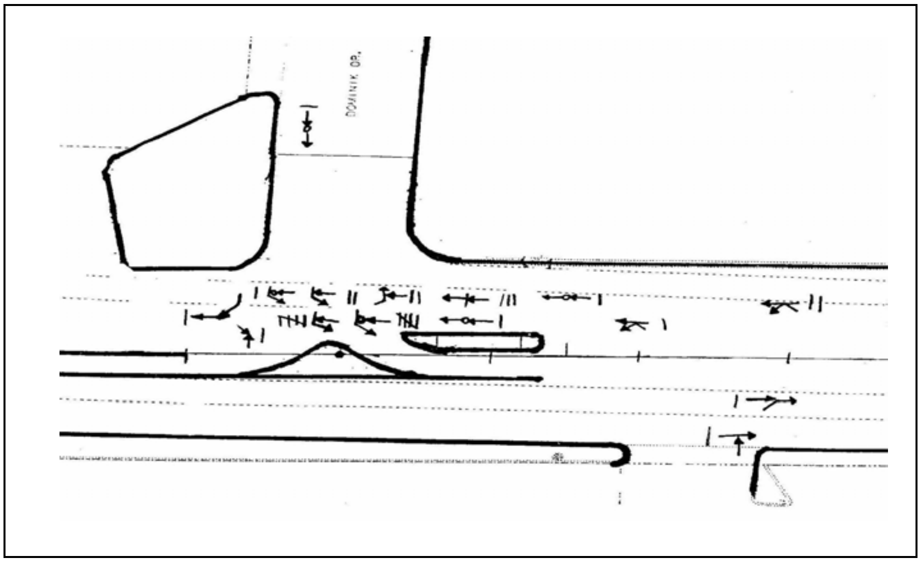


Figure 3-6. Before Period at Texas Avenue (left to right) and Dominik Drive (up and down).

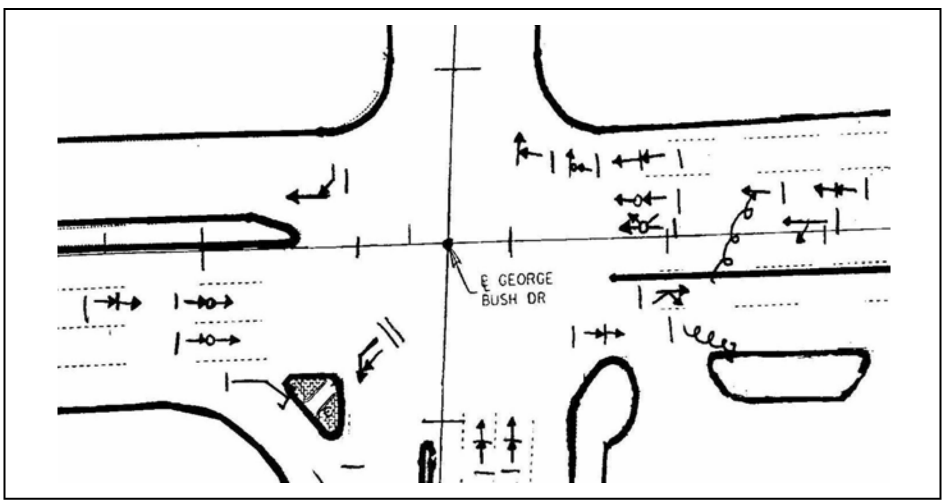


Figure 3-7. Before Period at Texas Avenue (left to right) and George Bush Drive (up and down).

Crash Rates

Crash rates were used to describe the change in crash impacts from the "before" period to the "after" period. Using crash rates equalizes the calculated values between before and after periods by normalizing the data to traffic volumes and time frames of before and after periods. The intersection crash rates were calculated for the intersections of Texas Avenue and University

Drive as well as Texas Avenue and George Bush Drive. Researchers selected these intersections because they are the two intersections with the highest traffic volumes along the corridor. The following filtering process was used to determine which crashes should be attributed to the intersections. All crash reports for crashes that occurred within 0.2 miles north, south, east, and west of the center of the intersection were collected and analyzed in detail to determine if the cause of the crash could be attributed to the intersection. For example, a rear-end crash that occurred because a driver stopped for the signal was attributed to the intersection; however, a sideswipe crash that occurred after the vehicles passed through the intersection was not attributed to the intersection. Only crashes whose causes were attributed to the intersection were included in the calculation of the intersection crash rates. The other type of crash rate that was calculated was a section rate. The section consisted of the 0.7-mile section of Texas Avenue between the intersections of University Drive and George Bush Drive. Table 3-3 summarizes the locations of the intersections and sections that were used to calculate crash rates.

Table 3-3. Milepost Locations Used to Calculate the Intersection and Section Crash Rates.

Location	**Texas Avenue and University Drive**	**Section**	**Texas Avenue and George Bush Drive**
Milepost	5.85-6.25	5.2-5.9	4.92-5.32

The "before" period was a 2-year period from January 1993 to December 1994, because of the change in the crash-reporting threshold that occurred in 1995. The "after" period was the 2-year period from July 1998 to June 2000. Equations 3-1, 3-2, and 3-3 were used to calculate the crash rates and percent change values *(6)*. Statistical analyses were performed for the Texas Avenue, corridor and they are contained in reference *(9)*.

$$RSP = \frac{1{,}000{,}000C}{365TV} \tag{3-1}$$

$$RSEC = \frac{100{,}000{,}000C}{365TVL} \tag{3-2}$$

$$\%\ Change = \frac{A - B}{B} \times 100 \tag{3-3}$$

Where:

- RSP = spot crash rate (intersection);
- $RSEC$ = section crash rate;
- C = total number of crashes for the associated location and time frame;
- T = time frame in years;
- V = annual average daily traffic counts entering study location (vehicles per day);
- L = length of roadway section under investigation (miles);
- A = absolute value of the after rate; and
- B = absolute value of the before rate.

3.2.5 Crash Analysis Results

This section presents summaries of the data and findings and describes the results of the crash study as a whole. This discussion also covers the Texas Avenue/University Drive and Texas Avenue/George Bush Drive intersections and, finally, the effect of the closure of access to Dominik Drive.

Vehicle Conflict Points

As part of this study, researchers conducted an evaluation of vehicle conflict points for the existing and proposed conditions. Before installation of the raised median, the condition on Texas Avenue was a five-lane arterial with a TWLTL. At the intersections of Texas Avenue with George Bush Drive and University Drive, the TWLTL transitioned to a conventional left-turn lane.

Previous research suggests that a TWLTL providing access to numerous driveways can be a safety problem because of the numerous conflict points. Table 3-4 presents an estimation of the number of conflict points based on the type and number of intersections and driveways along the study corridor.

Table 3-4. Total Conflict Points along Texas Avenue for the Before Period.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes	Total Conflict Points
T-Intersection (TWLTL)	42	13	5	546
T-Intersection (RM)	9	2	5	18
T-Intersection (RMO)	0	11	5	0
T-Intersection (C)	1	11	5	11
RMO only	4	5	5	20
4-Way Intersection (Mi)	1	46	5	46
4-Way Intersection (GB)	1	40	5	40
4-Way Intersection (NM)	1	46	5	46
4-Way Intersection (U)	1	85	5	85
Total				812

[1] TWLTL = two-way left-turn lane. RM = raised median. RMO = raised median opening. C = channelized raised median treatment. Mi, GB, NM, and U = Miliff Road, George Bush Drive, New Main, and University Drive, respectively.

[2] Intersections include both public streets and private driveways.

The "after" geometry consists of a raised median between University Drive and George Bush Drive, with median openings at 10 locations. Table 3-5 summarizes the estimated number of conflict points for the "after" condition. The "after" condition reduces the number of potential conflicts from 812 to 602, a reduction of approximately 26 percent.

Findings of Summary Statistics and Analyses

<u>Crashes</u>. Table 3-6 shows the reduction in the total number of crashes, comparing all crashes reported in the "after" period to the same types of crashes in the "before" period. An approximately 59 percent reduction in crashes occurred over the entire Texas Avenue corridor.

Table 3-5. Total Conflict Points along Texas Avenue for the After Period.

Roadway Section Type[1]	Number of Intersection[2] Types along Study Corridor	Conflict Points per Intersection	Number of Lanes	Total Conflict Points
T-Intersection (TWLTL)	7	13	5	91
T-Intersection (TWLTL)	4	15	7	60
T-Intersection (RM)	27	2	7	54
T-Intersection (RMO)	7	13	7	91
T-Intersection (C)	0	11	7	0
RMO only	1	5	7	5
RMO only	7	7	7	49
4-Way Intersection (Mi)	1	54	7	54
4-Way Intersection (GB)	1	64	7	64
4-Way Intersection (NM)	1	59	7	59
4-Way Intersection (U)	1	75	7	75
Total				602

[1] TWLTL = two-way left turn-lane. RM = raised median. RMO = raised median opening. C is a channelized raised median treatment. Mi, GB, NM and U stand for Miliff Road, George Bush Drive, New Main and University Drive, respectively.
[2] Intersections include both public streets and private driveways.

It should be noted in Table 3-6 that the sum of the crashes in the "before" period for the two signalized intersections and from milepost 5.200 to 5.900 is 403 (102+194+107), and this is not equal to the 435 reported in the "Texas Avenue Corridor" column. This is because the individual crash reports were investigated along the corridor, and if the crash was outside of the milepost 5.200 to 5.900 segment and it could not be directly attributed to the intersection, it was not included in the intersection tally. Therefore, there were 32 crashes (435-402) that were outside of mileposts 5.200 and 5.900 and not attributable to the signalized intersection in the "before" period.

In the "after" period, the two signalized intersections and mileposts 5.200 to 5.900 sum to 181 (35+93+53) rather than the 178 indicated in the "Texas Avenue Corridor" column. This is because the signalized intersections overlap with the milepost 5.200 to 5.900 segment (see Table 3-3); therefore, if a crash occurs along that segment and is attributed to a signalized intersection it would be included in both places. In this case, the "Texas Avenue Corridor" value of 178 is lower than the 181 crashes to ensure there is no double-counting of crashes along the corridor.

Table 3-6. Summary of Crash Reduction on the Texas Avenue Corridor.

Time Period	Texas Avenue Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900[1]	Intersection of Texas Avenue & University Drive
Before	435	102	194	107
After	178	35	93	53
Percent Change	-59.1	-65.7	-52.1	-50.5

[1] MP = milepost referring to a location along a roadway as used by TxDOT in Roadway Inventory (RI) logbooks. MP 5.200 to MP 5.900 refers to the roadway section from approximately 500 feet north of George Bush Drive to 300 feet south of University Drive along Texas Avenue. This section of the roadway was used for the section crash rates discussed later in the report.

When a raised median is installed, one can expect reductions in head-on and angular crashes. This reduction is due to the physical separation of opposing traffic that the raised median provides and the resulting prohibition of left-turn movements. It is possible that when a raised median is installed, other types of crashes, such as rear-ends and sideswipes, may increase. These types of crashes can be attributed to vehicles stopping near a median opening or vehicles changing lanes to get to a median opening. This is particularly likely if the median opening was not adequately designed. For instance, if the length of the median opening is not long enough to accommodate the number of vehicles using it, this may result in rear-end crashes. Sideswipe crashes could occur if the median opening is located too close to an intersection. Figure 3-8 shows the number of crashes in the before and after periods along the corridor.

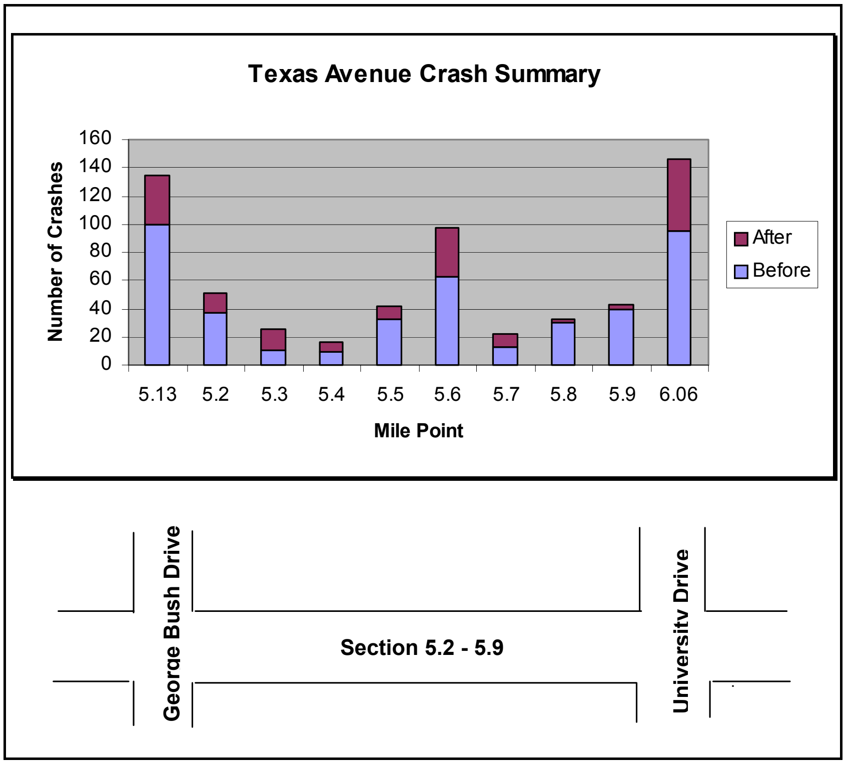


Figure 3-8. Total Before and After Crashes by Milepost for Texas Avenue.

Table 3-7 and Figure 3-9 display the number of crashes by crash type. All crash types were lower in the after period than in the before period, with the exception of single-vehicle crashes. Each single-vehicle crash record for the after period was investigated, and researchers determined that these crashes were not caused by the raised median.

Table 3-7. Summary of Crashes by Crash Type.

Time Period	Rear-End	Sideswipe	Right-Angle	Head-On	Single-Vehicle	Other
Before	282	27	107	4	7	8
After	113	9	42	1	13	0
Percent Change	-59.9	-66.7	-60.7	-75.0	85.7	-100.0

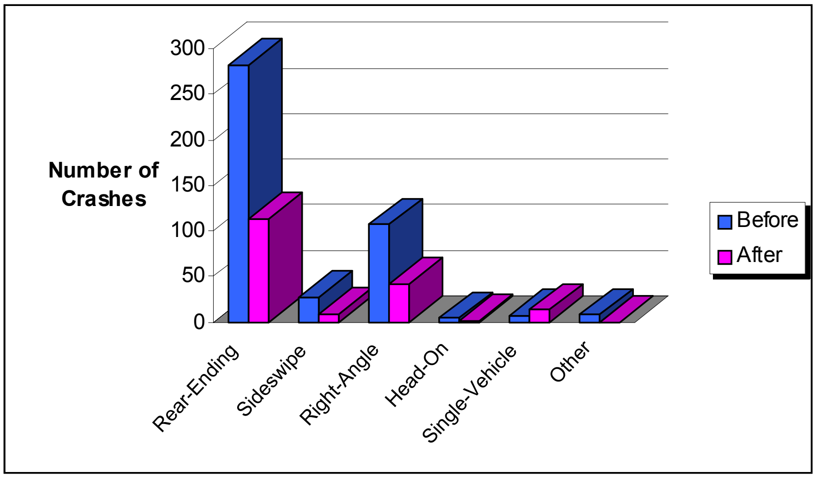


Figure 3-9. Texas Avenue Crash Type Summary.

The authors also studied the effects of the closure of left-in-left-out traffic at a T-intersection along the study corridor. The closure was at Dominik Drive, a local road intersecting the east side of Texas Avenue approximately 300 feet south of George Bush Drive. Figure 3-10 is a photograph taken from Dominik Drive approaching Texas Avenue, showing the raised median and sign restricting left turns. While the authors expected to find rear-end, sideswipe, right-angle, and head-on crashes for this intersection in both the "before" and "after" periods, the data revealed only right-angle crashes. There were sideswipes associated with the TWLTL along the study corridor, but none occurred at the intersection of Dominik Drive and Texas Avenue (see Table 3-8).

In one case, a motorist exited a private drive south of Miliff Road and proceeded to use the TWLTL to travel northbound on Texas Avenue. Using the TWLTL, the driver gained speed to enter the main inside lane and sideswiped another vehicle. This specific location was not included in the raised median retrofit, and a virtually identical crash occurred in both the before and after study time frames. Sideswipes decreased by 67 percent for the entire corridor.

Figure 3-10. Raised Median Restricting Left Turns at Dominik Drive.

Table 3-8. Sideswipe Crashes.

Time Period	Texas Avenue Corridor	Intersection of Texas Avenue & Dominik Drive
Before	27	0
After	9	0
Percent Change	-66.7	0

Dominik Drive at Texas Avenue was channelized for left-turn traffic in the before period; hence, the chance for a head-on crash was minimal. The authors reiterate that a raised median removes the chance of a head-on crash in the center lane, while a TWLTL does not physically reduce the opportunity for a head-on crash.

The authors also investigated crashes related to the proximity of Dominik Drive and the adjacent signalized intersection of Texas Avenue and George Bush Drive (see Figure 3-11). Authors initially researched rear-end crashes at this location. While TWLTLs decrease the number of roadway conflict points by removing turning traffic from the mainlanes, some motorists take advantage of the traversable TWLTL. For example, drivers have unprohibited access to private driveways and public streets and may drive into the TWLTL immediately following a signalized intersection. As previously indicated, Dominik Drive is approximately 300 feet south of George Bush Drive. Because dual left-turn lanes on northbound Texas Avenue take up approximately 150 feet, only about 150 feet remains for traffic waiting to turn left onto Dominik Drive to queue in the TWLTL prior to the raised median installation. Therefore, traffic could queue into the George Bush Drive intersection, causing a rear-end crash. A rear-end crash could also occur as a result of a motorist on George Bush Drive turning right onto southbound onto Texas Avenue and trying to weave across traffic when southbound Texas Avenue has the right-of-way. Another rear-end crash could occur when southbound left-turning George Bush Drive vehicles attempt to access Dominik Drive. While these weaving maneuvers more than likely have occurred, there were no crashes attributed to such scenarios.

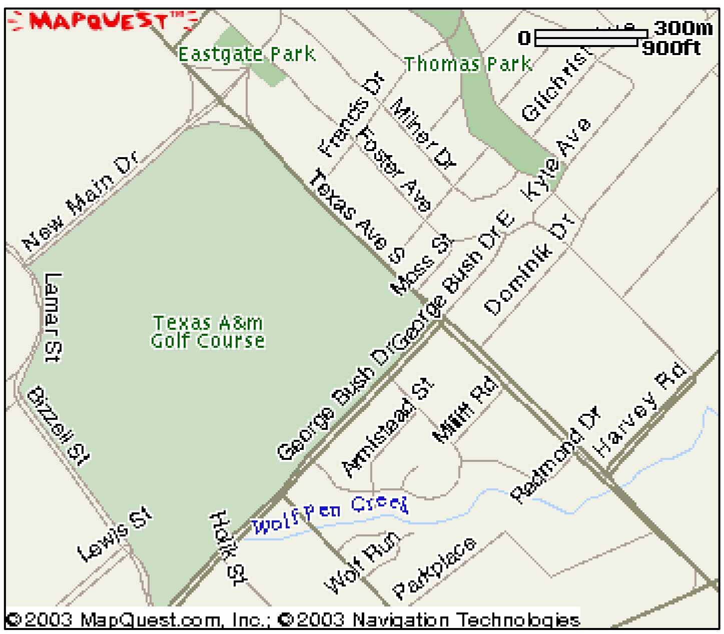


Figure 3-11. Map Showing Dominik Drive and Surrounding Street Network (Map Provided by MapQuest.com, Inc.).

In some instances, when turning maneuvers are prohibited at one intersection due to crashes, the crash rate increases at adjacent intersections where turning maneuvers are allowed. Therefore, the authors investigated whether such crash migration had occurred due to the closure of left-turn lanes at Dominik (see Figure 3-11). In the before condition, motorists turning left onto Dominik Drive from the southbound lanes of Texas Avenue would have performed one of the following:

(1) traveled south down Texas Avenue, (2) turned right onto Texas Avenue from the eastbound traffic on George Bush Drive, or (3) turned left onto Texas Avenue from the westbound traffic on George Bush Drive. The third scenario is the least likely, because an alternate route is available to avoid backtracking after going through the signalized intersection. The two entry routes onto Dominik offered after the retrofit are (1) eastbound George Bush Drive through the Texas Avenue intersection or (2) U-turn at the end of the raised median and the beginning of the TWLTL south of Dominik Drive.

The next set of drivers to consider are those turning left onto Texas Avenue southbound from Dominik Drive. Their rerouting paths are (1) westbound on George Bush Drive to Texas Avenue or (2) eastbound/southbound on George Bush Drive as it turns to intersect Harvey Road, which runs east and west and intersects Texas Avenue south of the study corridor.

Both left-in and left-out motorists had to reroute, but the authors did not observe corresponding increases in crashes north or south of Dominik Drive along Texas Avenue. Right-angle crashes decreased by 56 percent south of Dominik Drive, and there was the expected 100 percent reduction at Dominik Drive (see Table 3-9). At the adjacent signalized intersection of George Bush Drive and Texas Avenue, total crashes and crash rates dropped by 66 and 70 percent, respectively. These findings indicate that crashes did not migrate, and the raised median has reduced crashes at this intersection.

Table 3-9. Right-Angle Crashes.

Time Period	Texas Avenue Corridor	Intersection of Texas Avenue & Dominik Drive	MP 6.190 to MP 6.255[1]
Before	107	16	16
After	42	0	7
Percent Change	-60.7	-100	-56

[1] MP = milepost referring to a location along a roadway as used by TxDOT in Roadway Inventory (RI) logbooks. MP 6.190 to MP 6.255 refers to the roadway section from approximately 600 feet south of George Bush Drive to 1,100 feet south of George Bush Drive along Texas Avenue.

Crash Rates. As indicated earlier, the authors studied the before-and-after crash rates calculated using Equations 3-1 and 3-2. Table 3-10 contains a summary of the crash rates and associated percent changes. There was an overall reduction in the crash rates at the two major intersections along the study corridor and for the section of roadway between the intersections.

Table 3-10. Summary Crash Rates[1].

Time frame	Texas Avenue & George Bush Drive	Texas Avenue & University Drive	MP 5.200 to MP 5.900[2]
Before	2.2	21.0	4.3
After	0.7	11.0	1.8
Percent Change	-69.5	-46.0	-57.0

[1] Equations 3-1 and 3-2 were used to determine crash rates at an intersection and roadway section, respectively.
[2] MP = milepost referring to a location along a roadway as used by TxDOT in Roadway Inventory (RI) logbooks. MP 5.200 to MP 5.900 refers to the roadway section from approximately 500 feet north of George Bush Drive to 300 feet south of University Drive along Texas Avenue.

Injuries. Another common effect of the installation of a raised median is a reduction in crash severity. This reduction is due to the decrease in head-on collisions and right-angle crashes, which are typically the most severe types of crashes. Table 3-11 displays a summary of the numbers of injuries by severity level in the before and after periods. The number of possible injuries reduced from 206 to 141 (32 percent reduction). The number of incapacitating injuries dropped significantly from 14 in the before period to 1 in the after period, a reduction of approximately 93 percent reduction. There was a small increase in the number of non-incapacitating injuries, but this shift in injury type may be due to the reduction in overall severity.

Table 3-11. Summary of Injuries.

Time Period	Possible Injury[1]	Non-Incapacitating Injury[1]	Incapacitating Injury[1]
Before	206	48	14
After	141	50	1
Percent Change	-31.6	4.2	-92.9

[1] The various injury classifications were defined in “Crash-Reporting Process” in Section 3.2.2 of this chapter.

Figures 3-12 and 3-13 graphically represent injury classes as a percentage of total injuries. Table 3-11, Figure 3-12, and Figure 3-13 illustrate a reduction in crash severity.

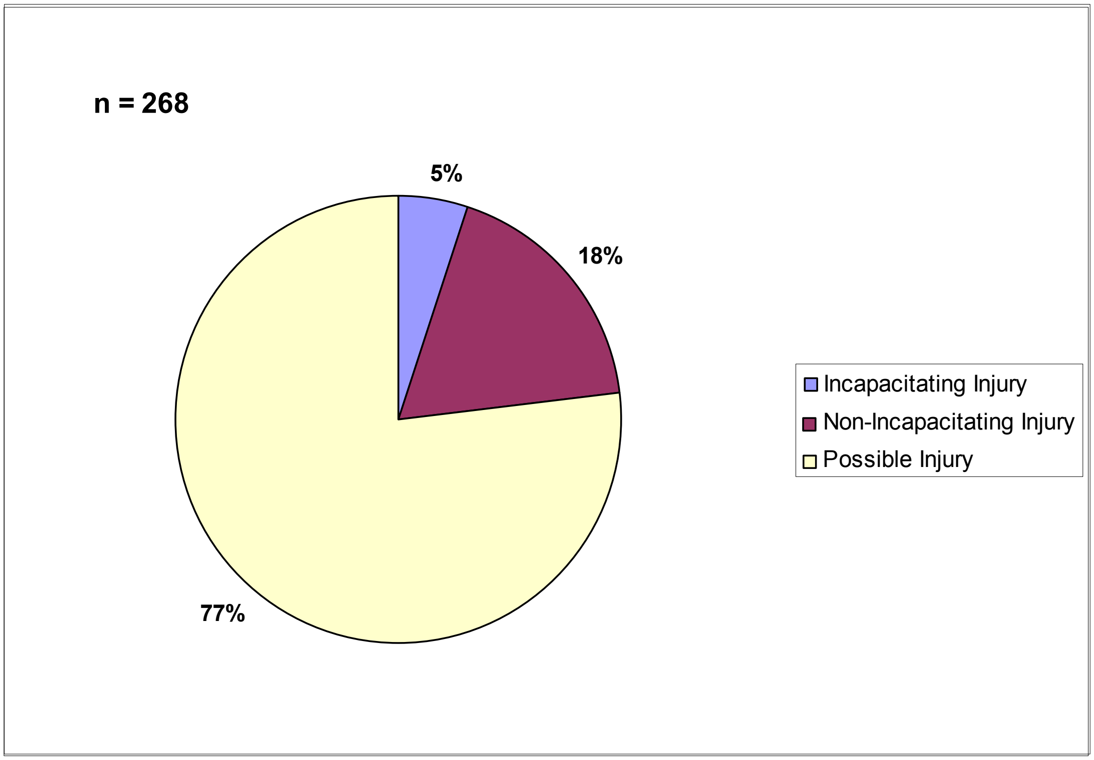


Figure 3-12. Summary of Injuries in the Before Period for the Texas Avenue Corridor.

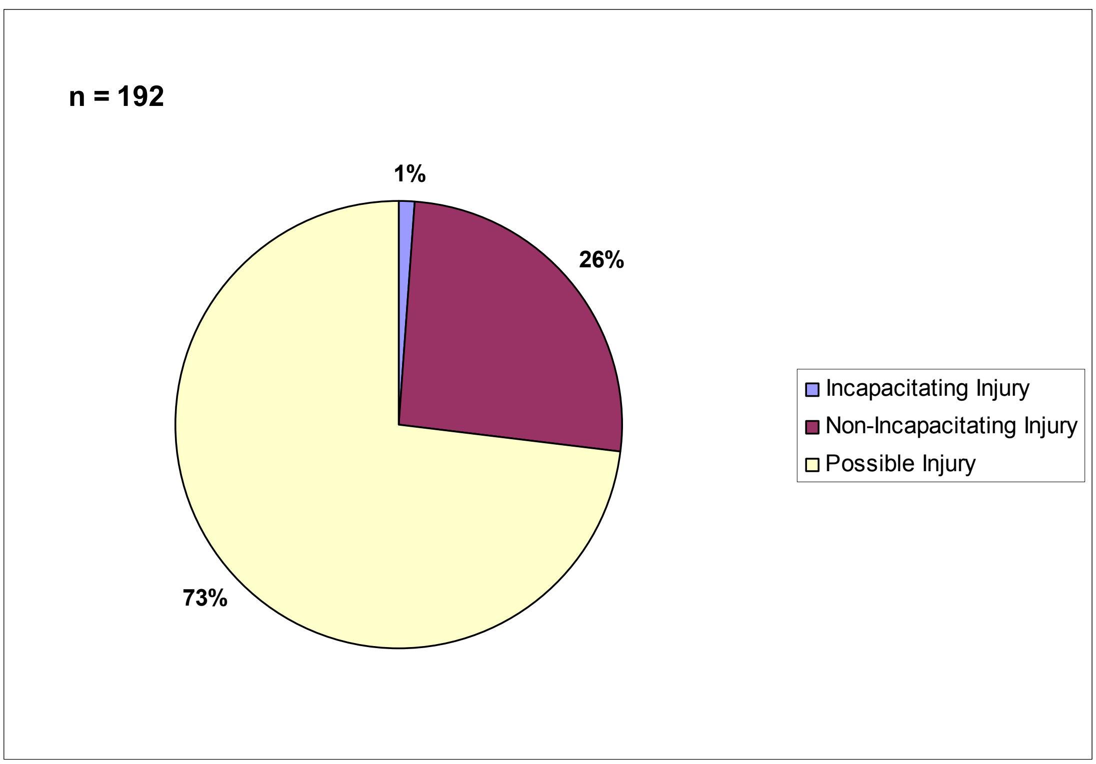


Figure 3-13. Summary of Injuries in the After Period for the Texas Avenue Corridor.

3.2.6 Comparison Group

Many different factors can influence a simple before-and-after study. The biggest factor is the inability to control potentially confounding factors (*14*). The underlying assumption behind a before-and-after study is that the reduction in crashes from the "before" period to the "after" period can be attributed to the treatments. The following list describes confounding factors that, if not accounted for, may invalidate the results of a before-and-after study (*14*).

Traffic, weather, road user behavior, vehicle fleet, and other factors change over time. Therefore, the reduction in crashes or severity of crashes may be due to the change in these factors rather than the traffic management treatment. These factors include the following:

- In addition to the treatment in question, other treatments or programs may have been implemented during either of the study periods.
- The number of PDO crashes is affected by the cost of repairs, which will gradually change over time.
- The probability of reportable crashes being reported may change over time, possibly due to changes in insurance rates.
- The roadway section may have been chosen for treatment because of an unusually high crash history. However, since such a crash history is "unusual," the location may not be the best comparison of "after" period data.

Using a comparison group to control all the confounding factors not easily estimated, researchers eliminated some factors that could make the underlying assumption in the "before-and-after" study questionable. One study asserts that it is reasonable to assume a large comparison group (i.e., one in which the annual crash count is at least several hundred) will encompass all factors that may affect the long-term expected number of crashes (*15*).

The total number of reported crashes in College Station, Texas was chosen as the comparison group for this study. Since the study site is located in College Station, any confounding factors affecting the study site would be encompassed in the comparison group. Figure 3-14 displays a summary of crashes for the comparison group.

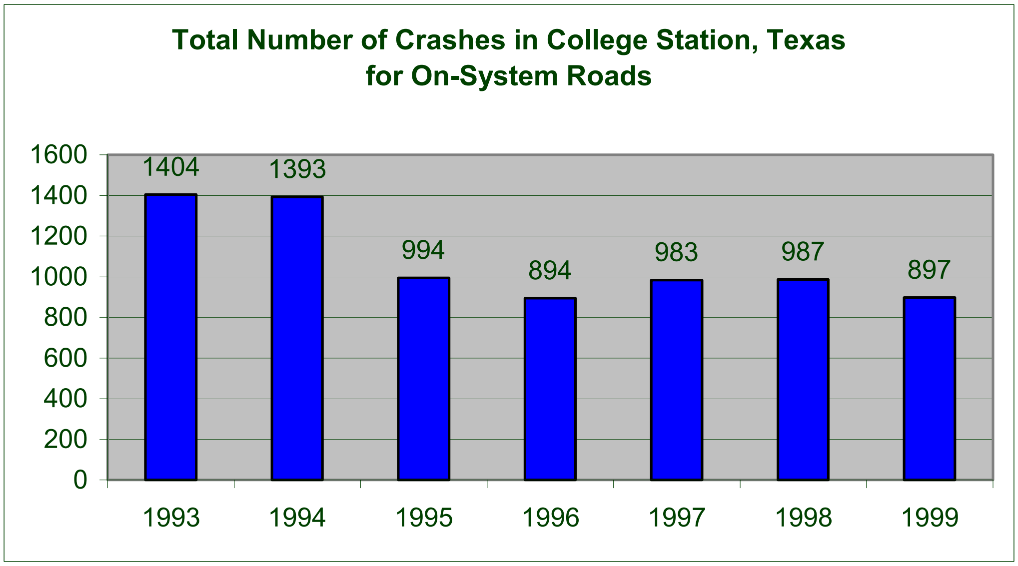


Figure 3-14. Summary of Crashes in the Comparison Group.

As mentioned previously, the crash-reporting threshold changed in June 1995, so that only crashes resulting in injury, or PDO crashes over $1,000 were reported. Because of this, when comparing the total number of crashes in a 2-year period prior to 1995 (1993-1994) with a 2-year period after 1995 (1996-1997), approximately 33 percent fewer crashes were reported in the latter period. Therefore, researchers reduced the total number of crashes for the comparison group in the "before" period by 33 percent prior to comparing it to the number of crashes in the "after" period. Crashes that occurred on the studied section of Texas Avenue were removed from the comparison group. A summary of this comparison is shown in Table 3-12.

Table 3-12. Summary of Comparison of Texas Avenue Corridor to Comparison Group.

	Texas Avenue Corridor	Comparison Group
Crashes in the Before Period	435	2,362
Reduced Crashes in the Before Period	435[1]	1,582 (33% decrease)
Expected Crashes in the After Period[2]	470 (8% increase)	-
Actual Crashes in the After Period	178 (59% decrease)	1,706 (8% increase)

[1] Crashes in the "before" period for the Texas Avenue were previously filtered to reflect the change in the crash-reporting threshold.
[2] Expected crashes as found in the comparison group.

The crashes in the comparison group increased by approximately 8 percent from the “before” period to the “after” period; therefore, an 8 percent increase in crashes along the Texas Avenue corridor could have been expected had there been no mitigation. However, since the total crashes on the Texas Avenue corridor actually decreased by approximately 60 percent from the “before” to the “after” period, confounding factors do not appear to be responsible. The reduction in crashes might be attributed to the raised median treatment and not to other confounding factors such as weather, vehicle fleet, driver behavior, cost of car repairs, inclination to report crashes, etc. Further research is needed to determine why there was an overall increase in crashes in College Station as a whole. This could be due to the population increase and/or to younger drivers, though the research team did not investigate this possibility.

3.2.7 Recommendations and Discussion

According to the study results, the raised median reduced crashes and crash severity along the Texas Avenue corridor, which suggests that the overall roadway safety was improved.

Closing left-turn access reduces the number of conflict points and virtually removes the opportunity for right-angle and head-on crashes. The removal of left-turn possibilities into and out of Dominik Drive eliminated right-angle crashes completely at that location. Left-turning traffic was redirected and gained access through other means. Redirected traffic flows may result in crash migration; however, there is no evidence of this phenomenon along the study corridor.

Consequently, researchers studied the crash characteristics of the whole corridor and, in particular, right-angle crashes and crashes at the adjacent controlled intersection, George Bush Drive at Texas Avenue. They investigated the adjacent signal because motorists may reroute eastbound on George Bush Drive east of Texas Avenue to gain access to Dominik Drive. The number of crashes for the whole corridor decreased by 59 percent and at the adjacent signal by 50 percent. Right-angle crashes south of Dominik Drive (a location that would offer a driver the opportunity to make a U-turn and then a right-turn to gain access to Dominik Drive) decreased by 56 percent. It appears from these findings that crash migration did not occur and that the rerouted paths forced by the use of a raised median resulted in crash reduction and a safer roadway.

3.3 LOOP 281 (LONGVIEW) CASE STUDY LOCATION

3.3.1 General Description

Another case study corridor is Loop 281 in Longview, Texas, between FM 63 (McCann Road) and Spur 502 (Judson Road). In the before condition, this road segment comprised three through-lanes in each direction as well as a flush median that varied in width from a typical TWLTL to more than 30 feet. In the widest parts, vehicles pulled out from driveways and lined up several abreast, waiting for traffic gaps through which to complete left-turn movements. The raised median project developed turn bays for full and directional turning movements (see Figure 3-15). In addition, the raised median closed numerous previous left-turn opportunities.

3.3.2 Crash Analysis

The Texas Department of Public Safety provided crash reports for this case study location dating back to 1992, approximately 4 years before the median was built in late 1996. This data set allowed the research team to conduct a before-and-after crash analysis of the corridor. The reports include details about the number, severity, and locations of crashes on Loop 281.

3.3.3 Traffic Demand

Traffic volumes on the Loop 281 corridor were relatively constant throughout the study years, ranging from 20,000 to 27,000 vehicles per day. The volume peaked in 1996, prior to the median installation. Table 3-13 displays traffic volumes recorded at one point on the study segment for each of the study years.

Figure 3-15. Loop 281 in Longview.

Table 3-13. Loop 281 (Longview) AADT Counts.

Year	AADT (vehicles/day)
1992	23,000
1993	25,000
1994	26,000
1995	24,000
1996	27,000
1997	20,000
1998	24,000
1999	23,000

3.3.4 Crash Analysis Results

The results of the crash analysis for the Loop 281 corridor are summarized in the following sections.

Crashes. Table 3-14 shows the number of crashes along the corridor during the study period. Note that construction of the median occurred in 1996. Crashes per million vehicle miles of travel (VMT) peaked in 1995, the year before the raised median was installed. Crashes per million VMT dropped significantly after the median construction was completed, though there was another peak in 1998, decreasing again the following year. The post-construction peak was lower than all but one of the pre-construction study years.

Table 3-14. Loop 281 (Longview) Corridor Summary of Crashes.

Year	Number of Crashes	Crashes per Million VMT
1992	44	4.03
1993	62	5.23
1994	66	5.21
1995	71	6.23
1996	42	3.28
1997	38	4.04
1998	57	5.01
1999	42	3.85

Loop 281 crash data available for the entire years of 1992 through 1999 are shown in Figures 3-16 through 3-23, with the locations and types of crashes that occurred during the study years. It should be noted that each of these figures is based on the most recent aerial photograph, which includes the raised median.

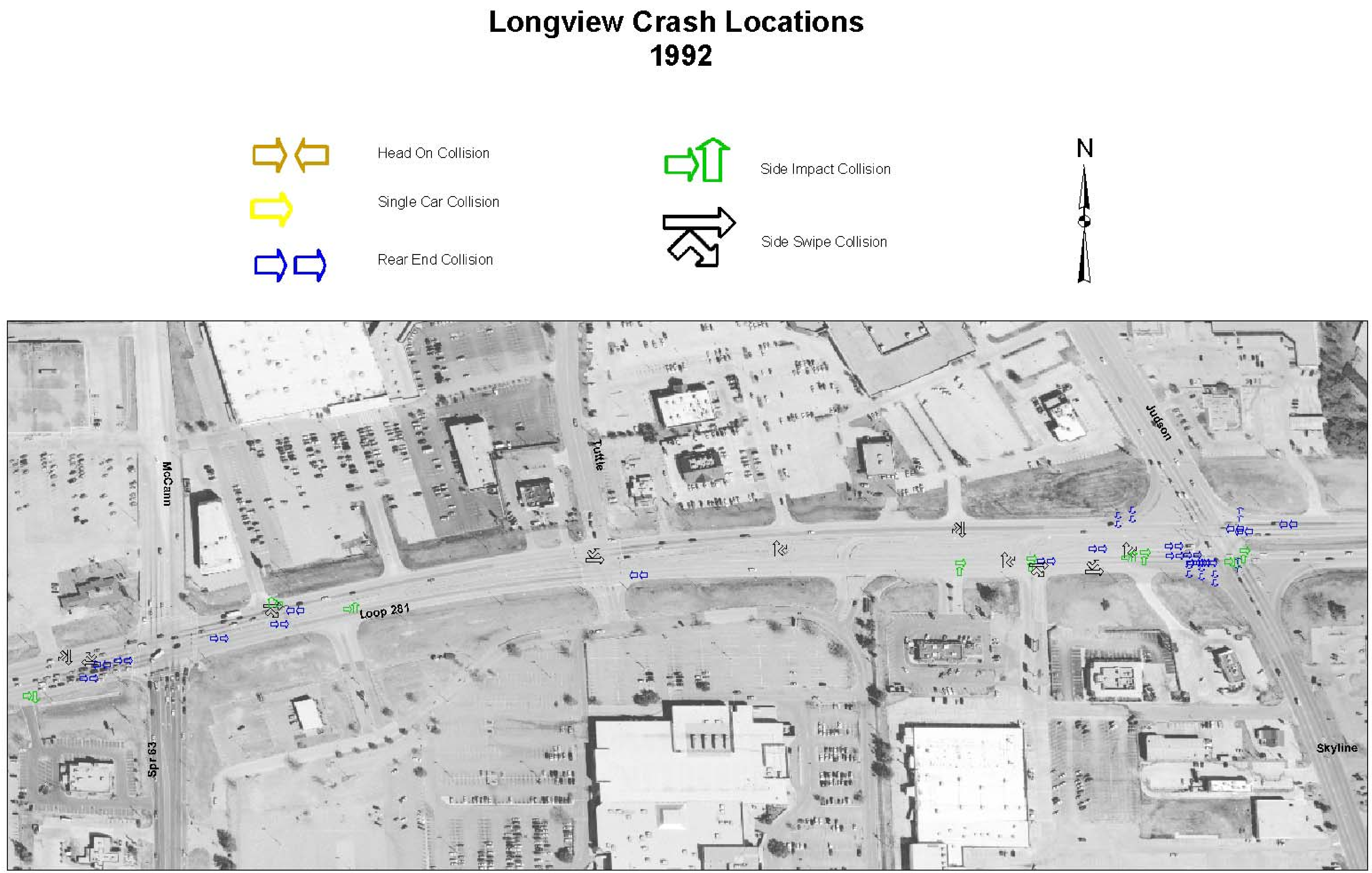


Figure 3-16. Longview (Loop 281) Crash Locations 1992.

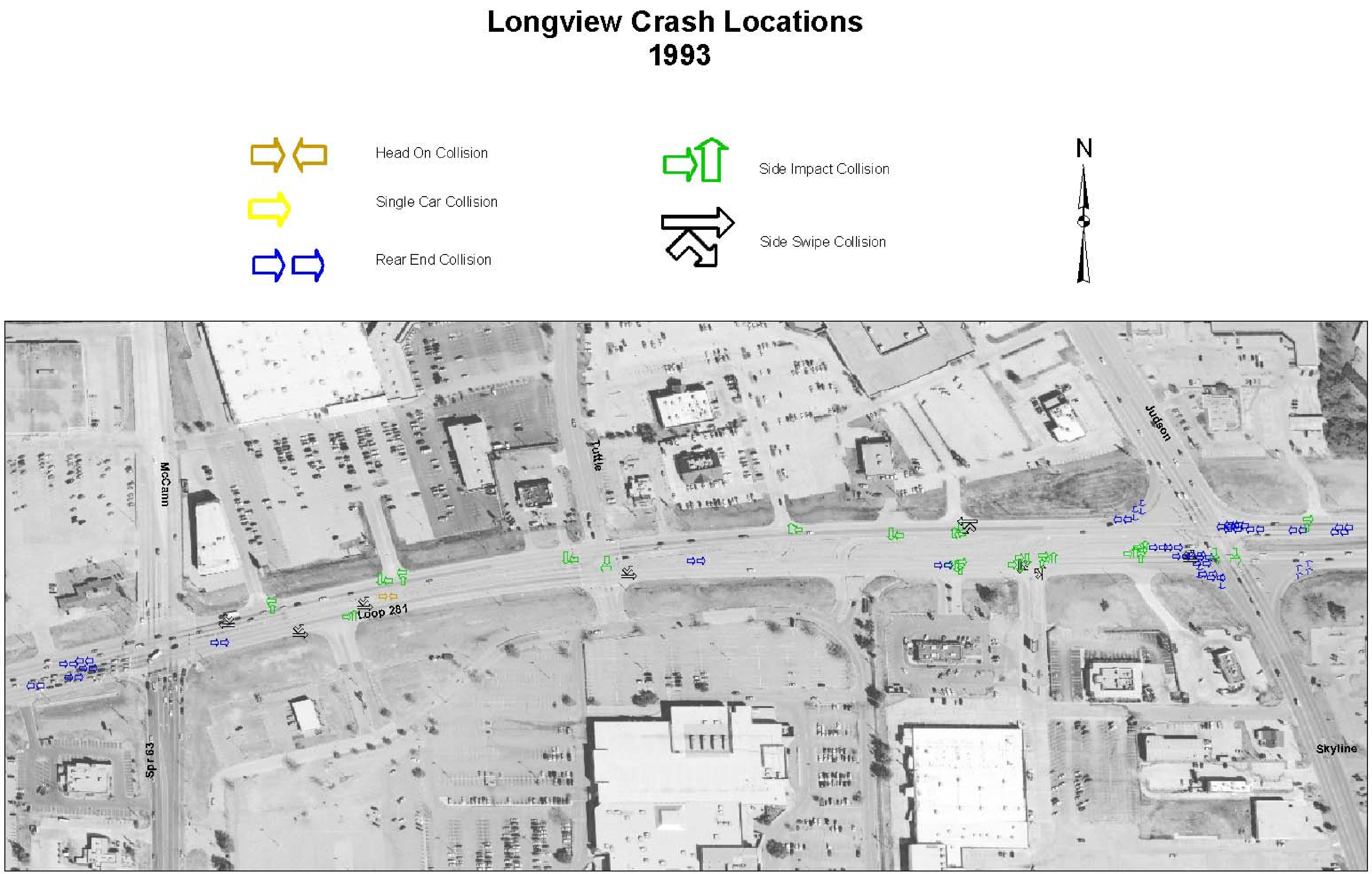


Figure 3-17. Longview (Loop 281) Crash Locations 1993.

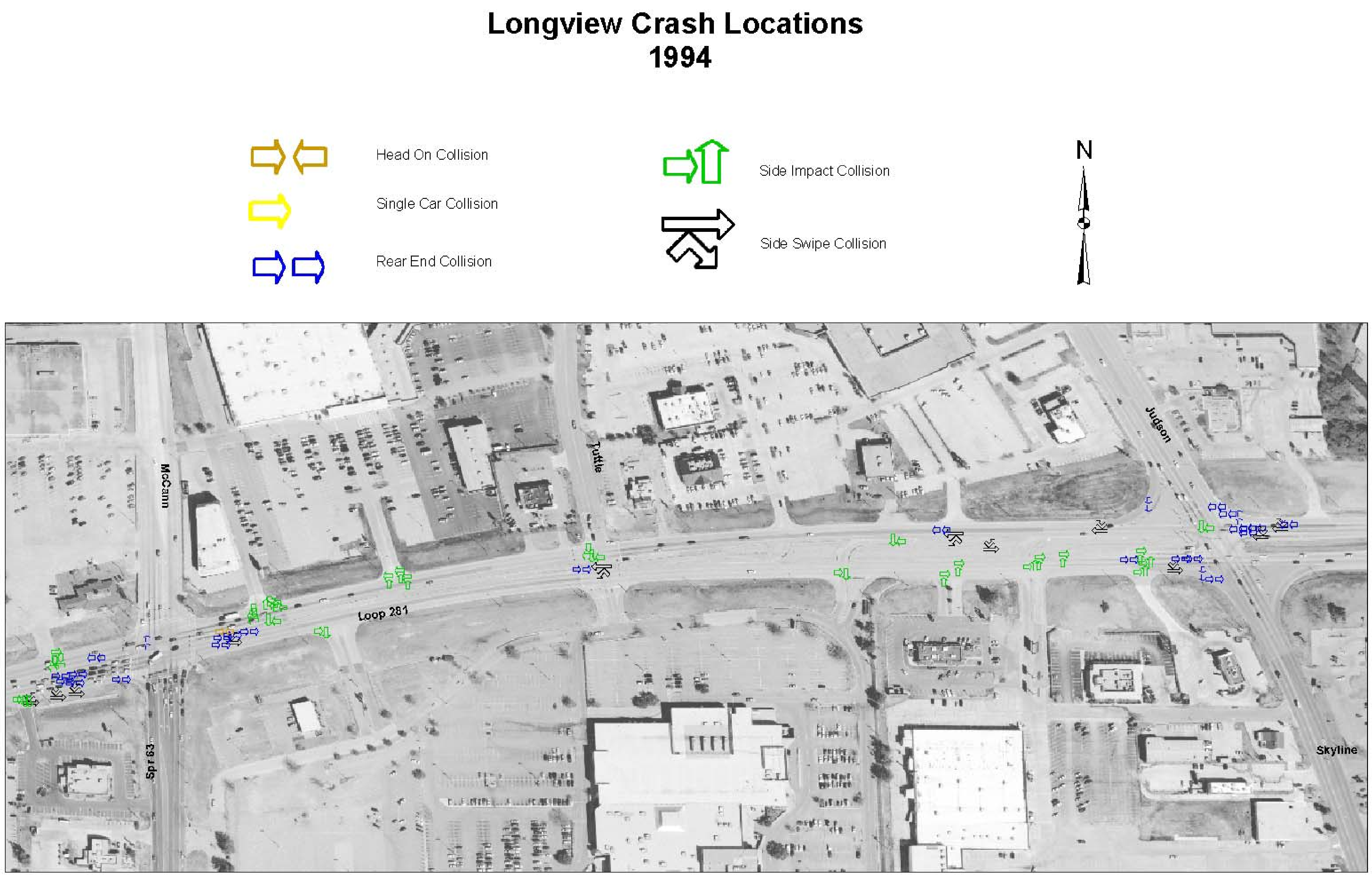


Figure 3-18. Longview (Loop 281) Crash Locations 1994.

Longview Crash Locations
1995

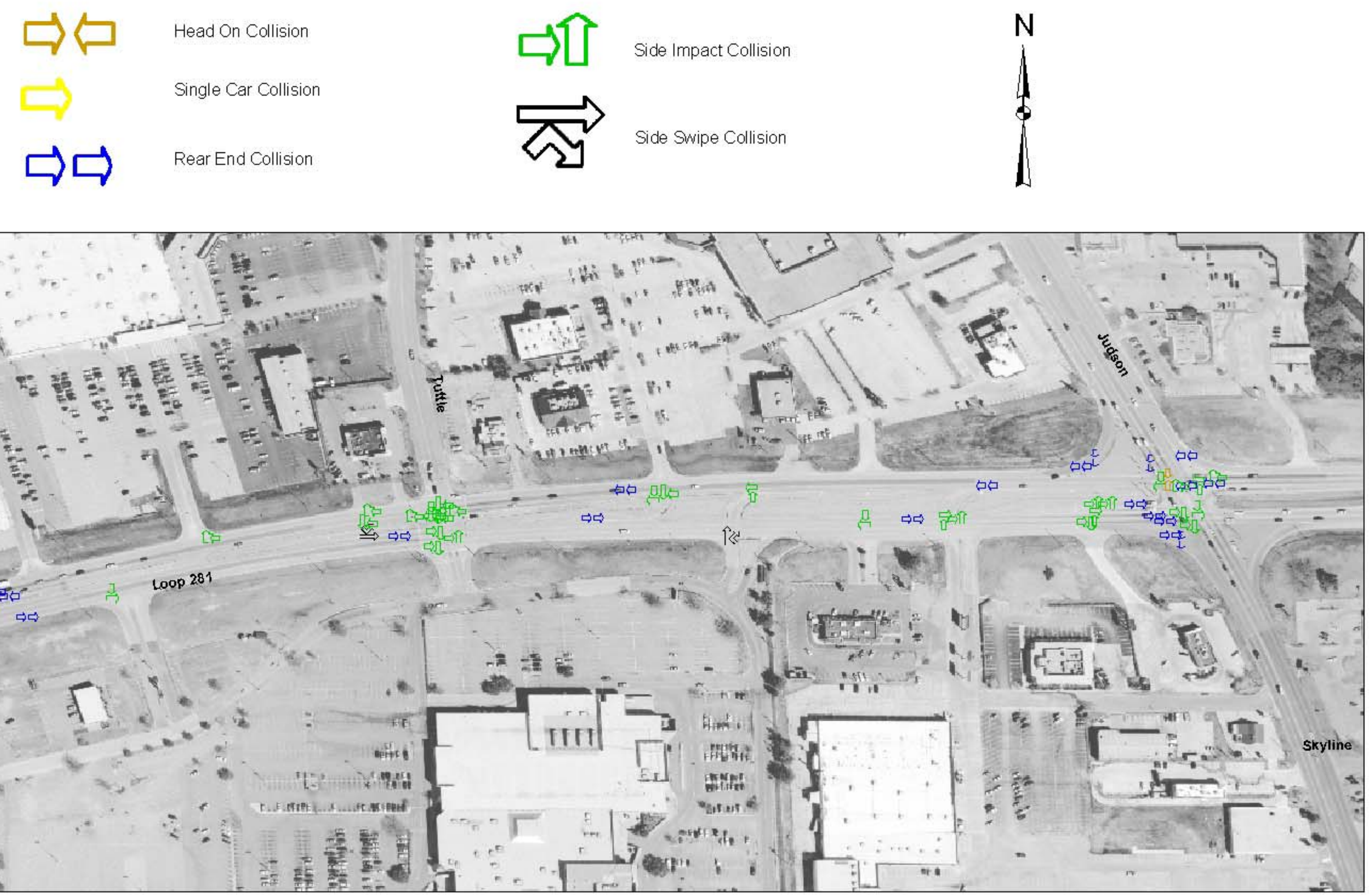


Figure 3-19. Longview (Loop 281) Crash Locations 1995.

Longview Crash Locations
1996

Figure 3-20. Longview (Loop 281) Crash Locations 1996.

Longview Crash Locations
1997

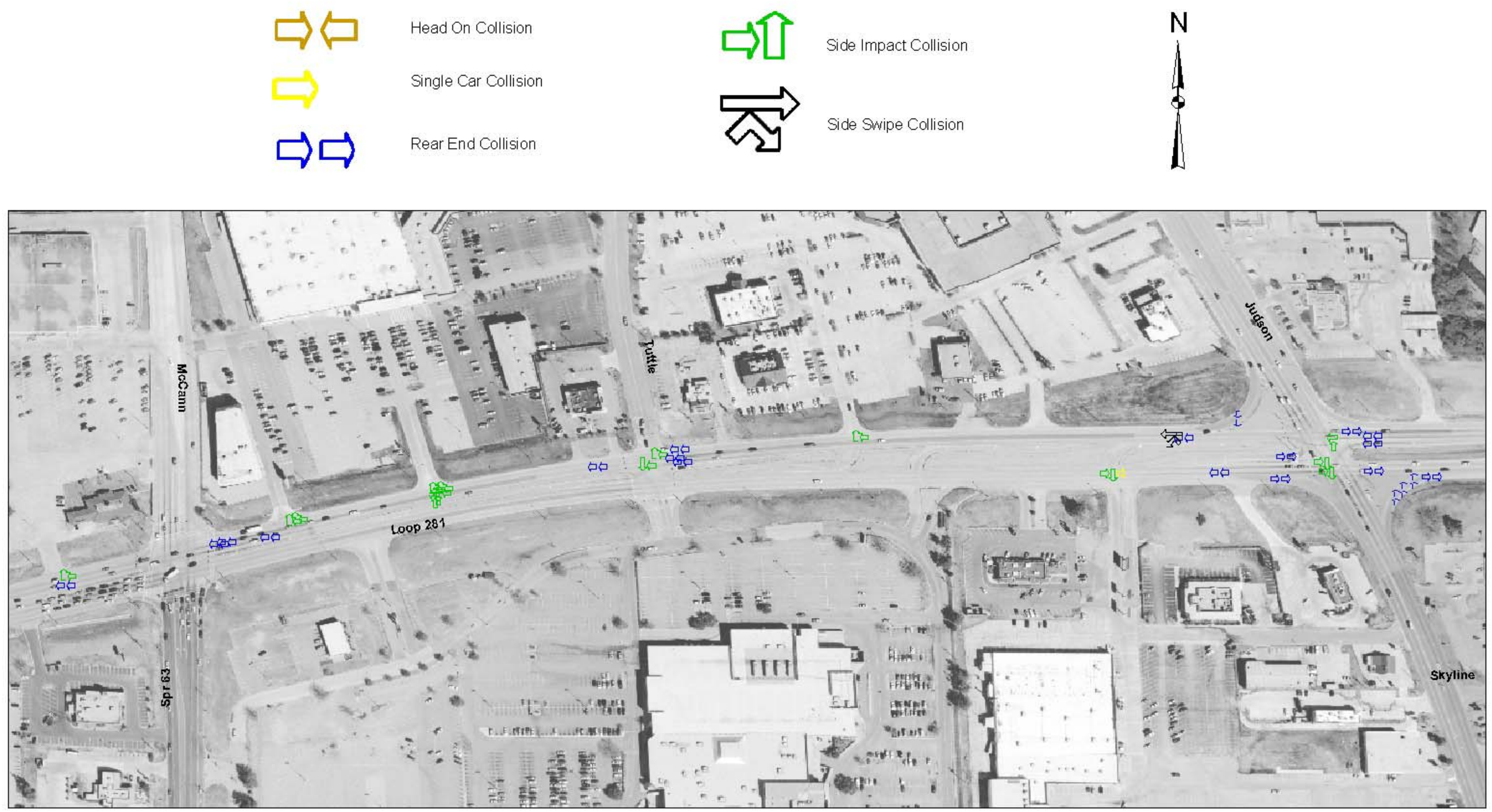


Figure 3-21. Longview (Loop 281) Crash Locations 1997.

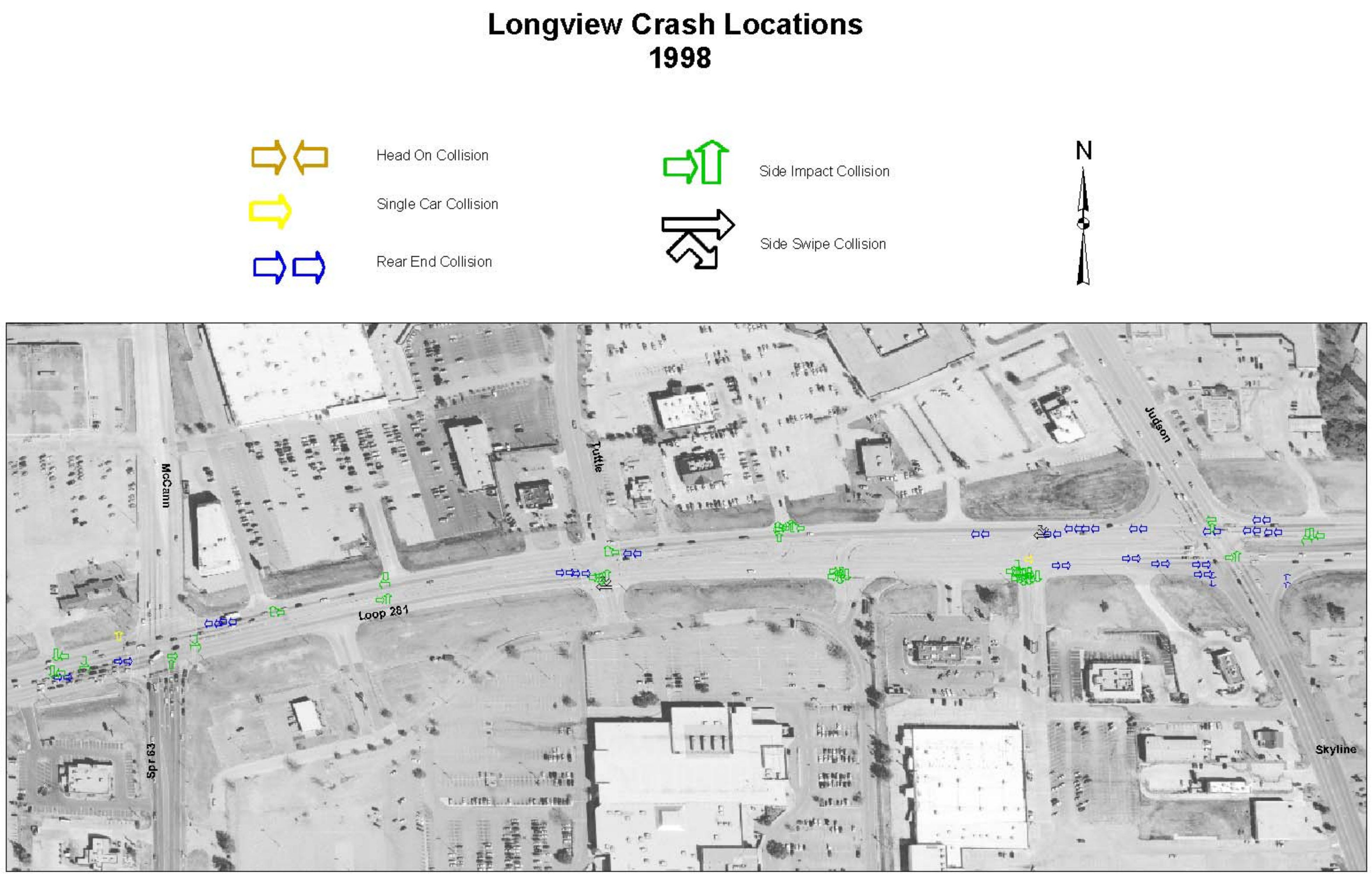


Figure 3-22. Longview (Loop 281) Crash Locations 1998.

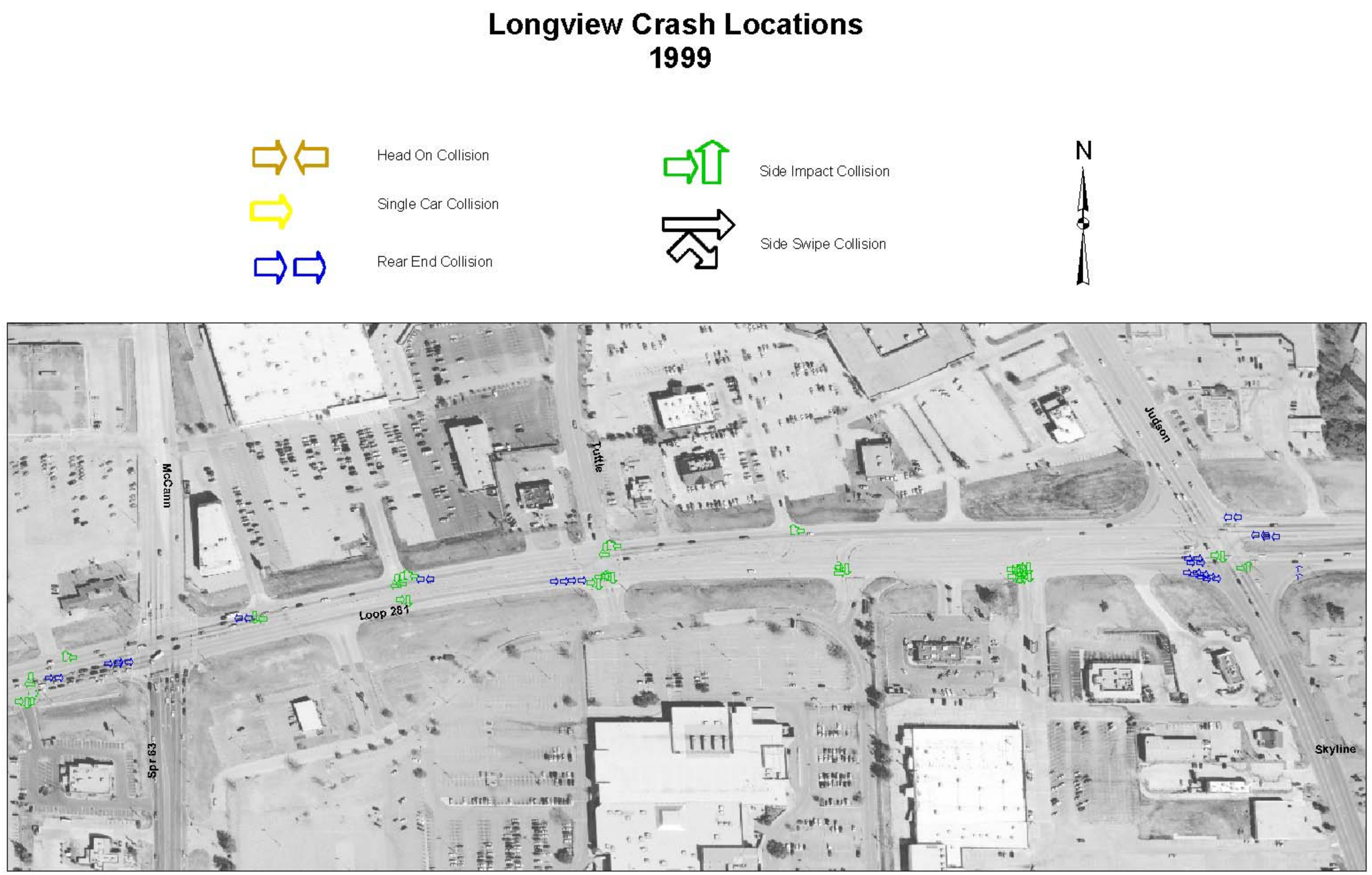


Figure 3-23. Longview (Loop 281) Crash Locations 1999.

Table 3-15 provides the number of injuries by type for each of the study years. The most significant observation from this figure is that there were five incapacitating injuries prior to raised median installation, with only one occurring in the years after the installation. Though the incapacitating injury in 1993 was the result of a red-light running crash, this information indicates that the presence of the raised median affects the severity of crashes and injuries on this corridor. The only fatality occurred as a result of a driver heart attack and ensuing single-vehicle collision.

Table 3-15. Loop 281 (Longview) Injury Type by Year.

Year	1992	1993	1994	1995	1996	1997	1998	1999
None	112	125	186	155	80	114	119	85
Possible	28	54	51	50	45	45	64	52
Non-incapacitating	0	4	8	18	15	7	12	11
Incapacitating	1	1	0	3	0	0	0	1
Fatality	0	0	0	1	0	0	0	0

Table 3-16 presents the crash impacts types by year on the Loop 281 corridor. It is notable that there were no head-on crashes in the three years after the raised median was installed, while there was an average of one per year prior to installation. Furthermore, side-swipe crashes decreased significantly in these years, as well, from an average of eight per year to an average of one per year.

Table 3-16. Loop 281 (Longview) Crash Impact Types by Year.

Year	1992	1993	1994	1995	1996	1997	1998	1999
Rear-End	25	31	27	20	18	21	23	17
Side-Impact	10	22	27	44	18	15	30	25
Side-Swipe	9	8	11	4	3	1	2	0
Single	0	0	0	2	1	1	2	0
Head-On	0	1	1	1	2	0	0	0

3.4 CALL FIELD ROAD (WICHITA FALLS) CASE STUDY LOCATION

3.4.1 General Description

Another case study corridor is along Call Field Road in Wichita Falls, Texas. Less than 0.5 mile, this segment of Call Field Road had a five-lane cross section including a TWLTL prior to improvements. The adjacent land uses are primarily strip shopping centers with a few stand-alone businesses. There are several driveways and two side streets intersecting Call Field Road between the two end points of the segment (Kemp Boulevard and Lawrence Road). One of the side streets, Faith Road, is an unsignalized intersection, while the other one, Rhea Road, is signalized. The raised median closed left-turn opportunities at Faith Road as well as some driveways, as shown in Figure 3-24.

Figure 3-24. Call Field Road in Wichita Falls.

3.4.2 Crash Analysis

Since Call Field Road is not a state-maintained road, the research team obtained crash data from the Wichita Falls Police Department. The data were received in two sets, neither of which contained detailed crash reports. Therefore, the research team was not able to perform analysis consistent with that performed on the other corridors. However, this corridor remains a candidate for future studies if appropriate data can be obtained.

3.5 GRANT AVENUE (US 385) (ODESSA) CASE STUDY LOCATION

3.5.1 General Description

Another case study corridor is along Grant Avenue (US 385) in Odessa, Texas. Before installation of the raised median, this road segment was undivided with two lanes of traffic in both directions of travel, as well as angle-in parking for adjacent buildings. The abutting land uses include retail stores and office buildings. The 1992 road improvements changed the parking to parallel and separated the directions of travel with a raised median that features left-turn bays at each street intersection (see Figure 3-25). As a result, mid-block left-turns into parking spaces or driveways were no longer possible.

Figure 3-25. Grant Avenue (US 385) in Odessa.

3.5.2 Crash Analysis

Data Collection

Texas DPS provided crash reports dating back to 1991, the year prior to median construction. Table 3-17 contains the traffic volumes that were provided to the research team.

Table 3-17. Grant Avenue (US 385) AADT Counts.

Year	AADT (vehicles/day)
1991	10,500
1992	9,700
1993	9,500
1994	10,000
1995	10,000
1996	10,500
1997	10,200
1998	10,100
1999	11,700

Traffic volumes experienced an overall upward trend during the study years, all but two of which are post-construction of the median. The central business district in Odessa has seen continued growth and redevelopment since the early 1990s, primarily due to expansions of hospitals and the health-care related industry.

Table 3-18 presents numbers of crashes and crashes per million VMT for each of the study years on the Grant Avenue corridor. Crashes per million VMT dropped considerably (from an average of more than 20 crashes per million VMT to an average of less than 15 crashes per million VMT) approximately 1 year after the median was opened. It is important to keep in mind that during the median installation project, the on-street angle-in parking was converted to parallel.

Table 3-18. Grant Avenue (US 385) Corridor Summary of Crashes and Crash Rates.

Year	Number of Crashes	Crashes per Million VMT
1991	30	19.57
1992	39	27.54
1993	31	22.35
1994	23	15.75
1995	22	15.07
1996	16	10.44
1997	23	15.44
1998	19	12.88
1999	27	15.81

The data also indicate that this conversion led to a decrease in mid-block crashes, as shown in Table 3-19.

Table 3-19. Grant Avenue (US 385) Corridor Summary of Crashes by Location.

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Intersection	22	29	22	18	18	10	20	18	26	8
Mid-Block	8	10	9	5	4	6	3	1	1	2

The research also discovered that a high percentage of the crashes on the Grant Avenue corridor were caused by red-light running events. As Table 3-20 shows, there was an average of approximately 36 crashes per year caused by a driver running a red light. The percentages per year ranged from a low of 18 in 1995 to a high of 68 in 1998.

Table 3-20. Grant Avenue (US 385) Corridor Summary of Red-Light Running Crashes.

Year	Red-Light Crashes	Total Crashes	Percent Red-Light
1991	10	33	30
1992	12	39	31
1993	10	31	32
1994	5	23	22
1995	4	22	18
1996	4	16	25
1997	9	23	39
1998	13	19	68
1999	17	27	63

Figure 3-26 depicts the locations and types of crashes that occurred on the Grant Avenue corridor during the study years. This figure illustrates that fact that the vast majority of crashes on this corridor occurred at intersections with other public streets.

3.6 71st STREET (TULSA) CASE STUDY LOCATION

3.6.1 General Description

This study also includes an analysis of 71st Street, between Lewis and Memorial, in Tulsa, Oklahoma. This 4-mile corridor was widened to 6 lanes from 2 lanes over several years. The road improvements included adding two through-lanes in each direction, as well as a raised median. The eastern 2 miles of the corridor were improved in 1991. The west-central segment (the second mile of road from the west) was completed in 1994 and the westernmost segment was completed in 1996. Figure 3-27 shows 71st Street at Memorial.

3.6.2 Crash Analysis

Data Collection

The Oklahoma Department of Transportation provided relatively detailed crash data for this corridor. Again, the research team discovered differences in format and detail among various agencies providing crash data. Individual crash reports were not available for this corridor; therefore, exact crash locations could not be plotted. However, researchers used the information available to produce summaries of accidents (by type) for each section of the corridor.

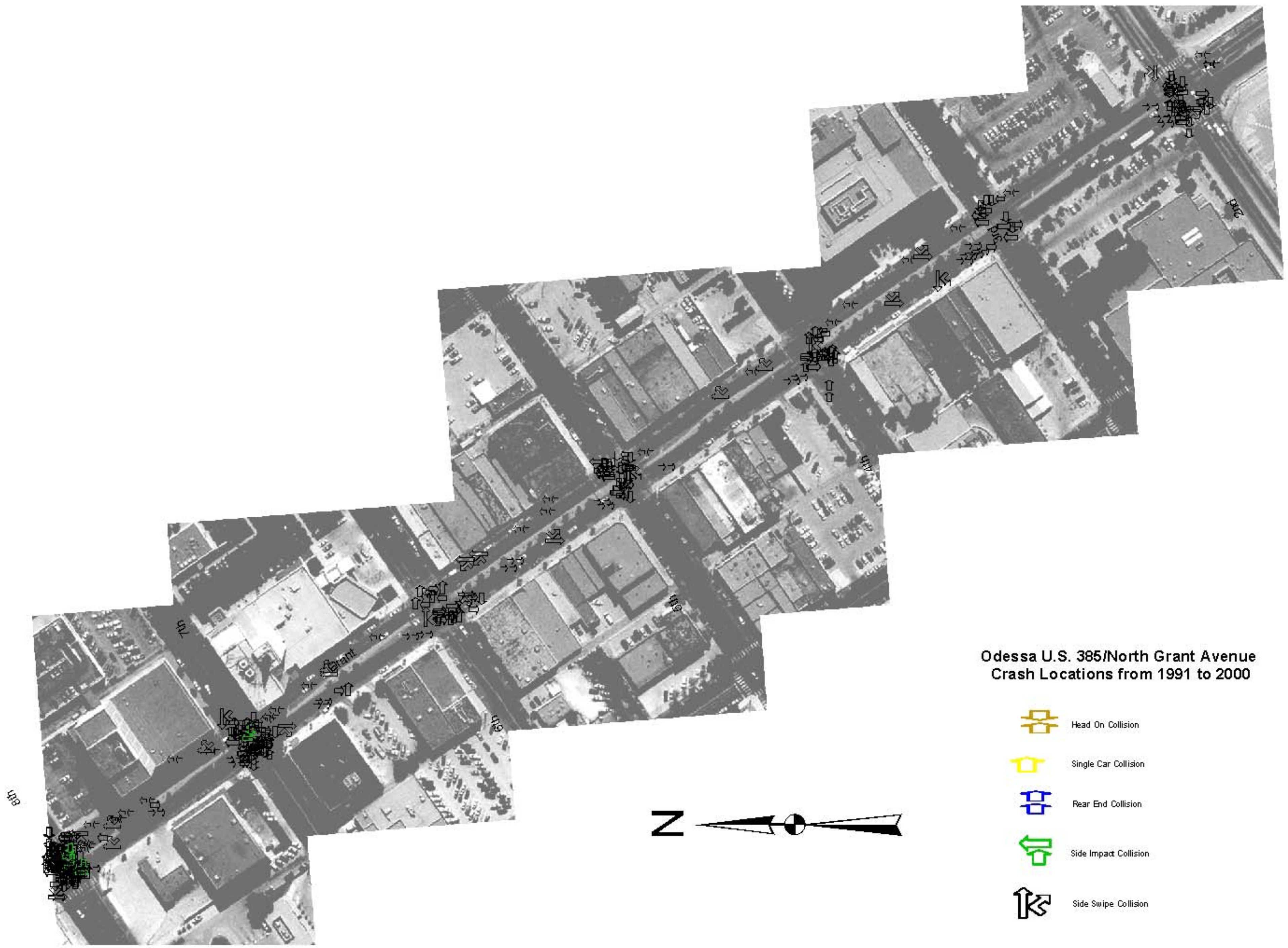


Figure 3-26. Grant Avenue (US 385) Crash Locations 1991-2000.

Figure 3-27. 71st Street at Memorial Drive in Tulsa, Oklahoma.

3.6.3 Traffic Demand

While traffic counts were available for each of the four major segments of the corridor in various years of the study, only 2 counts per segment were available in some years, while in other years there were counts for only some of the segments. When 2 counts were available for one segment, the average of the 2 volumes was used. For those years in which no counts were available for a given segment, the research team estimated volumes by using straight-line projections between known counts. Table 3-21 contains the traffic volumes provided to the research team.

Traffic volumes increased significantly after the road-widening and median installation project. Such increases are not surprising, given that the capacity of the road was greatly increased when expanded from two lanes to six lanes.

Table 3-21. 71st Street (Tulsa) AADT Counts.

Year	Segment	AADT (vehicles per day)
1993	West	20,000
	West-Central	20,100
	East-Central	27,300*
	East	25,500
1994	West	22,180*
	West-Central	20,497
	East-Central	27,924*
	East	28,153*
1995	West	24,234
	West-Central	22,600
	East-Central	28,950*
	East	28,340*
1999	West	33,300
	East	51,000
2001	West	29,100
	West-Central	31,200
	East-Central	39,850*
	East	41,700

Note: * = estimated by interpolation.

Table 3-22 shows the crash rates per million VMT for each of the major segments on the 71st Street corridor. Crash rates per million VMT are estimated for the years in which traffic volumes were estimated.

Table 3-22. 71st Street (Tulsa) Summary of Crashes.

Year	Segment	Number of Crashes	Crashes per Million VMT
1993	West	39	5.34
	West-Central	28	3.82
	East-Central	33	3.31
	East	85	9.13
1994	West	28	3.46
	West-Central	15	2.00
	East-Central	27	2.65
	East	61	5.94
1995	West	22	2.49
	West-Central	20	2.42
	East-Central	36	3.41
	East	75	7.25

Table 3-22. 71st Street (Tulsa) Summary of Crashes (continued).

Year	Segment	Number of Crashes	Crashes per Million VMT
1996	West	29	3.13
	West-Central	27	2.83
	East-Central	58	4.73
	East	77	6.28
1997	West	20	1.95
	West-Central	11	1.01
	East-Central	26	1.85
	East	78	5.42
1998	West	32	2.86
	West-Central	16	1.32
	East-Central	39	2.45
	East	71	4.30
1999	West	20	1.65
	West-Central	22	1.63
	East-Central	87	5.06
	East	61	3.28
2000	West	29	2.55
	West-Central	18	1.45
	East-Central	54	3.40
	East	53	3.13
2001	West	36	3.39
	West-Central	21	1.84
	East-Central	29	1.99
	East	27	1.77

It is very clear that once the road was widened and the raised median installed, the crash rate dropped significantly. Segments of this corridor experienced some of the lowest crash rates of the entire project. Some of the 71st Street segments also have the lowest access point densities of the project.

3.7 CAMP BOWIE BOULEVARD (US 377) (FORT WORTH) CASE STUDY LOCATION

3.7.1 General Description

The case study section of Camp Bowie Boulevard located between Hilldale and Horne, just southwest of the I-30/Camp Bowie interchange, is approximately 0.9 miles in length and is abutted by commercial development. This corridor contains two distinct segments, each with different types of development and access densities. The east segment is characterized by businesses built on individual lots and an access density of 110 access points per mile. This high density is partly due to Camp Bowie, which cuts through the area at a diagonal to the local street layout, creating several five- and six-leg intersections along this corridor. The west segment has larger-scale shopping center style development, allowing businesses to share access points. There are also no intersections with more than four legs along this segment. This segment of Camp Bowie Boulevard has an access density of 50 access points per mile, less than half the density of the east segment. The entire corridor has a raised median that was in place prior to the study years.

3.7.2 Crash Analysis

Crash data were available in the form of individual crash reports from the Texas Department of Public Safety for the years 1993 through 2001.

3.7.3 Traffic Demand

Traffic counts, taken at one location on this corridor for each of the study years, are shown in Table 3-23. Volumes on Camp Bowie Boulevard were relatively constant during the study years, though a downward trend exists.

Table 3-23. Camp Bowie Boulevard (US 377) AADT Counts.

Year	AADT (vehicles/day)
1993	20,000
1994	20,000
1995	21,000
1996	21,000
1997	19,300
1998	19,300
1999	18,400
2000	18,300
2001	18,000

3.7.4 Crash Analysis Results

Obvious differences exist in crash rates between the two segments of this corridor. In any given year, the east segment typically had higher numbers of crashes per million VMT than the west segment, which has the lower access point density. Table 3-24 shows the crash rates of each segment for the years that traffic volume and crash report data were available.

Without exception, the east segment had a higher crash rate per million VMT than the west segment for each year of the project. The differences between segments each year ranged from small fractions to factors of approximately three. These crash rates support the theory that road segments with higher access point densities have higher crash rates.

Table 3-24. Camp Bowie Boulevard (US 377) Corridor Summary of Crashes.

Year	Segment	Access Density (points/mile)	Number of Crashes	Crashes per Million VMT
1993	East	110	28	9.59
	West	50	27	7.40
1994	East	110	27	9.25
	West	50	22	6.03
1995	East	110	29	9.46
	West	50	16	4.17
1996	East	110	24	7.83
	West	50	26	6.78
1997	East	110	24	8.52
	West	50	25	7.10
1998	East	110	17	6.40
	West	50	14	4.21
1999	East	110	22	8.19
	West	50	26	7.74
2000	East	110	29	10.85
	West	50	13	3.89

Figures 3-28 and 3-29 show the difference in the distribution of crashes on each segment of this corridor. Figure 3-28 illustrates the west segment, which has a much lower access point density. Review of this figure reveals that the crashes are concentrated at major intersections more than the on the east segment (Figure 3-29). It is important to note that not only are the crashes concentrated more on the segment with a lower access point density, but there is also a much lower crash rate per million VMT on that segment.

3.8 UNIVERSITY DRIVE (US 380) (MCKINNEY) CASE STUDY LOCATION

3.8.1 General Description

This corridor, located between US 75 and SH 5 in McKinney, Texas, is approximately 1.3 miles long, with two distinct segments. The east segment is abutted by smaller businesses on single lots, including some in houses transitioning from residential use. This segment, between SH 5 and Sharon Street, is approximately 0.8 miles long and has an access density of 98.75 access points per mile. The west segment, located between US 75 and Sharon Street, has 56 access points per mile and is abutted by larger-scale developments with shared access points for multiple businesses.

In 1992 a road widening project completed on University Drive increased the number of lanes from two to six and included installation of a raised median. All the data used to study this corridor are post-construction (keeping in mind that construction was completed during 1992).

3.8.2 Crash Analysis

Texas DPS provided the research team with crash reports for the years 1992 through 2000.

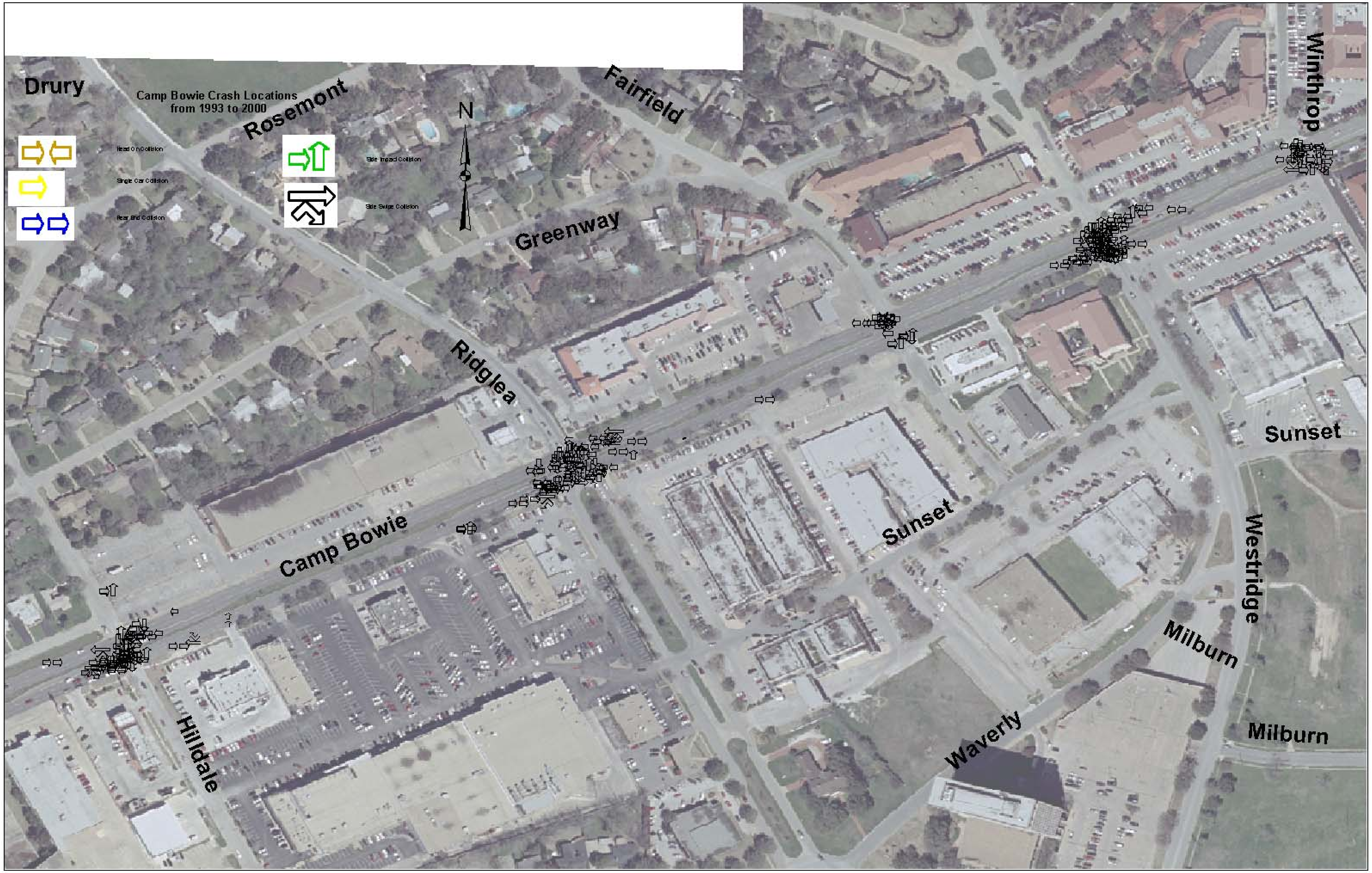


Figure 3-28. Camp Bowie Boulevard (US 377) Crash Locations (West Segment) 1993-2000.

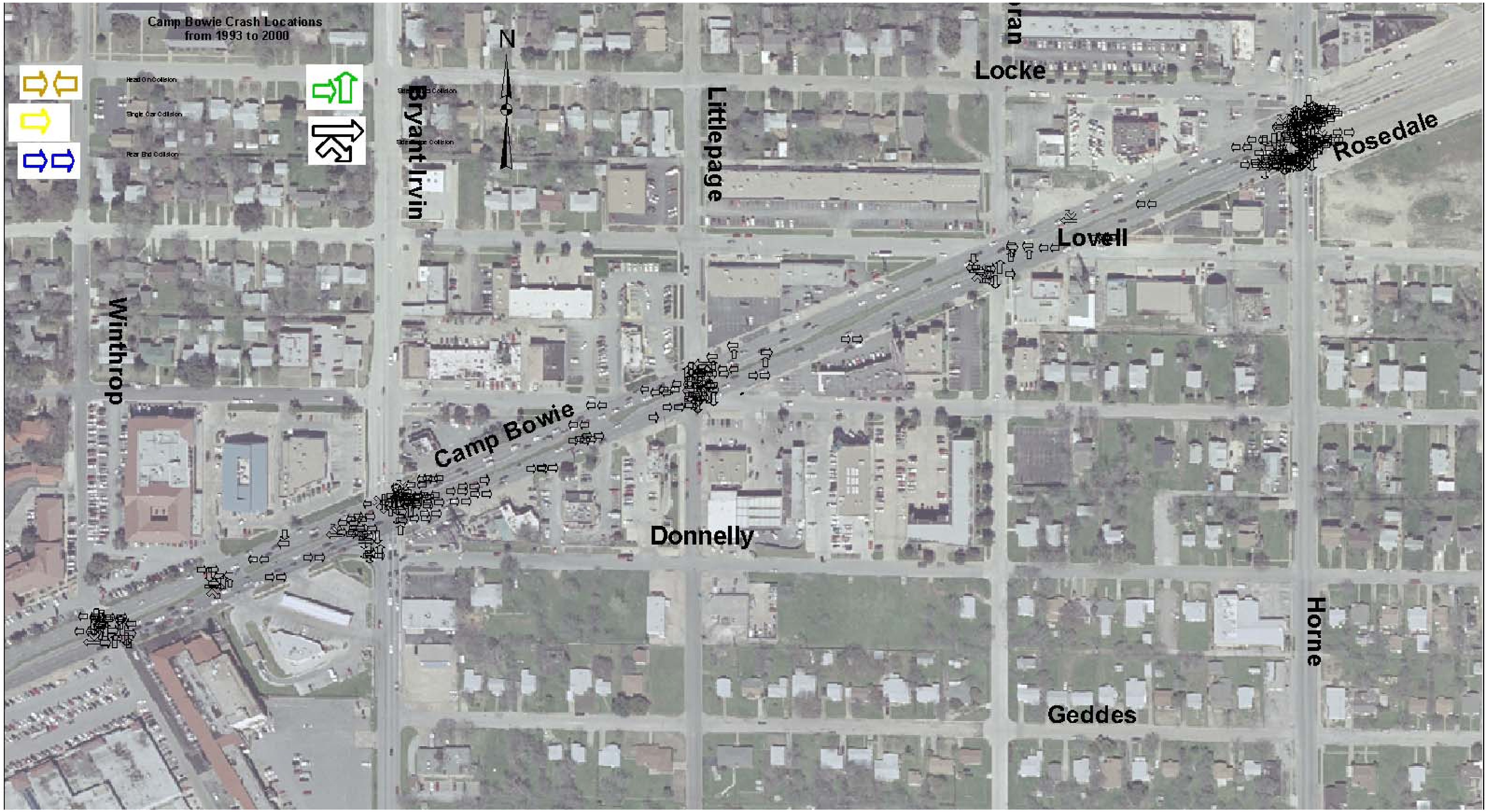


Figure 3-29. Camp Bowie Boulevard (US 377) Crash Locations (East Segment) 1993-2000.

3.8.3 Traffic Demand

Traffic volumes have continually increased on University Drive since completion of the road widening and raised median project in 1992. The west segment has consistently had higher volumes than the east segment, though both have increased at similar rates. As seen in Table 3-25, traffic volumes have grown from approximately 14,000 to 24,000 vehicles per day on the east segment and 15,000 to 29,000 vehicles per day on the west segment.

Table 3-25. University Drive (US 380) AADT Counts.

Year	East Segment AADT (vehicles/day)	West Segment AADT (vehicles/day)
1992	13,500	14,700
1993	17,400	18,600
1994	19,800	21,000
1995	19,400	21,000
1996	19,800	21,000
1997	21,000	23,000
1998	22,000	24,000
1999	23,000	28,000
2000	24,000	29,000

3.8.4 Crash Analysis Results

As with the other case study corridors and segments, the west segment, which has a lower access density, experienced considerably lower crash rates than the east segment. Other than in 1994, when the numbers of crashes per million VMT was almost the same for both segments, the east segment had from two to three times the crash rate of the west segment. Table 3-26 displays the crash rates for each segment during the study period.

Table 3-26. University Drive (US 380) Corridor Summary of Crashes.

Year	Segment	Access Density (points/mile)	Number of Crashes	Crashes per Million VMT
1992	East	98.75	27	10.96
	West	56	9	2.10
1993	East	98.75	17	5.35
	West	56	13	2.39
1994	East	98.75	15	4.15
	West	56	25	4.08
1995	East	98.75	17	4.80
	West	56	21	3.42
1996	East	98.75	24	6.64
	West	56	15	2.45
1997	East	98.75	20	5.22
	West	56	25	3.72
1998	East	98.75	26	6.48
	West	56	22	3.14
1999	East	98.75	37	8.81
	West	56	27	3.30
2000	East	98.75	38	8.68
	West	56	27	3.19

This case study yields another example of higher crash rates on road segments with higher access point densities than road segments with lower access densities. Figures 3-30 and 3-31 display the locations of crashes on the University Drive corridor for the study years. They show how the majority of crashes on this corridor are concentrated at intersections with public streets.

3.9 PRESTON ROAD (SH 289) (PLANO) CASE STUDY LOCATION

3.9.1 General Description

The Preston Road case study corridor is located between Plano Parkway and Ventura in Plano, Texas. It has six lanes and a raised median throughout the corridor, which is the case for each of the study years. The study section of Preston Road is abutted by large-scale shopping center type development, characterized by shared access points.

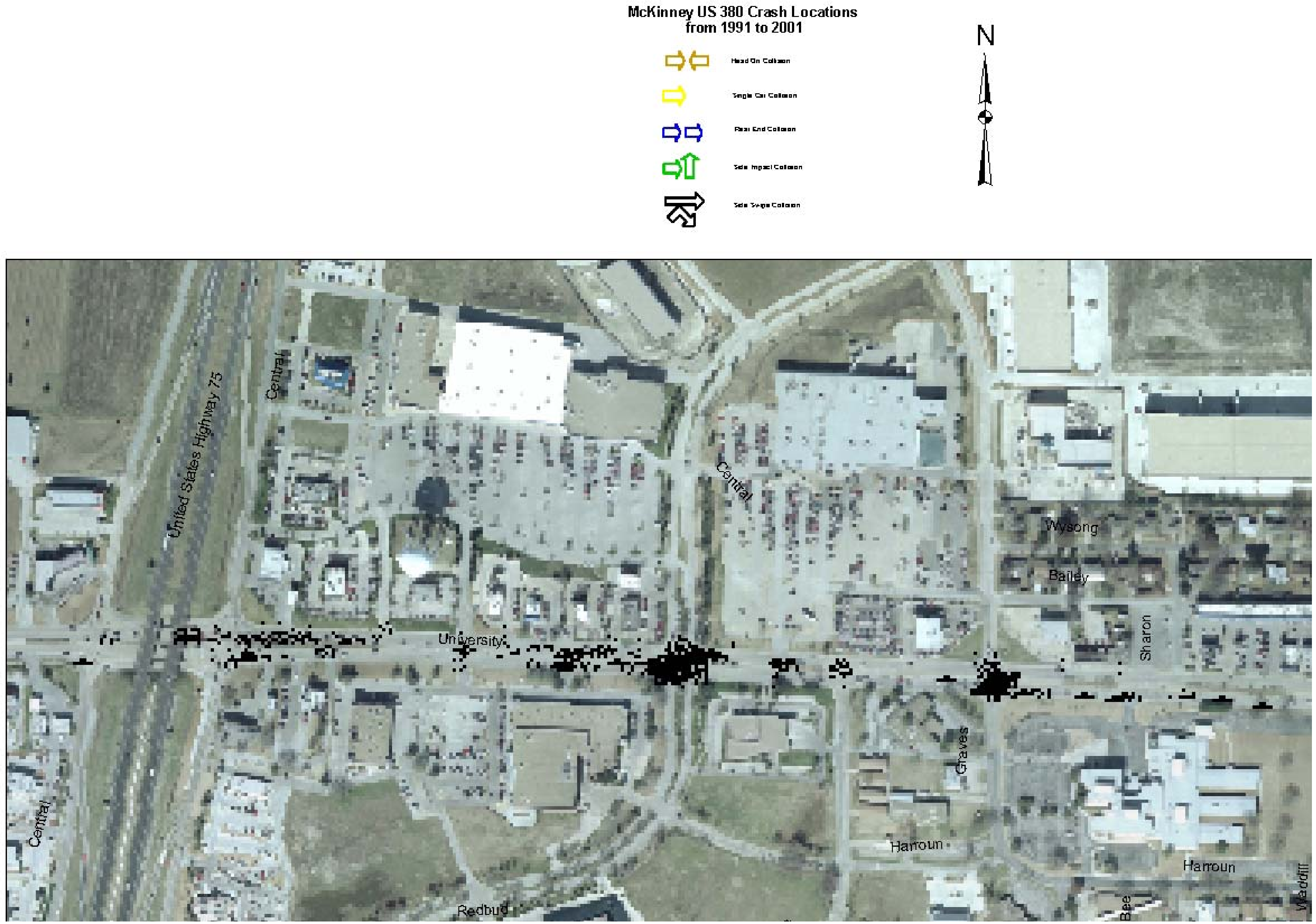


Figure 3-30. University Drive (US 380) Crash Locations (West Segment) 1991-2001.

Figure 3-31. University Drive (US 380) Crash Locations (East Segment) 1991-2001.

3.9.2 Crash Analysis

At the time of this report preparation, Texas DPS was not able to provide crash reports for Preston Road. For this report, the research team used summary crash data provided by the City of Plano. These summary data do not include specific crash locations, which would allow plotting the crashes on maps or aerial photographs. These data do provide enough information to prepare summaries of crash types and numbers for each major segment of the corridor.

3.9.3 Traffic Demand

Traffic volumes were available for each year of the study at one location on the corridor. Volumes ranged from 44,000 vehicles per day in 1995 to a high of 53,000 vehicles per day in 2001. Table 3-27 shows the traffic volumes for each study year for this corridor.

3.9.4 Crash Analysis Results

Table 3-28 shows the numbers of crashes per million VMT for each year of the study.

Table 3-27. Preston Road (SH 289) AADT.

Year	AADT (vehicles/day)
1993	38,000
1994	41,000
1995	44,000
1996	49,000
1997	47,000
1998	46,000
1999	45,000
2000	53,000

Table 3-28. Preston Road (SH 289) Crashes per Million VMT.

Year	Number of Crashes	Crashes per Million VMT
1993	71	3.94
1994	113	5.81
1995	78	3.74
1996	94	4.04
1997	88	3.95
1998	91	4.17
1999	120	5.62
2000	103	4.10

The low crash rates on the Preston Road corridor are typical of corridors with raised medians and low driveway densities. The access density of the Preston Road corridor is 30 access points per mile, which is lower than most of the corridors and corridor segments studied in this research project.

Figures 3-32 through 3-34 show the locations of crashes on Preston Road for the study years (numbers next to icons represent the number of each crash type that occurred in each block).

3.10 31ST STREET (FM 1741) (TEMPLE) CASE STUDY LOCATION

3.10.1 General Description

The 31st Street corridor in Temple, Texas, contains a mix of land uses, ranging from single- and multi-family residential to retail and office buildings. The study section is approximately 1.3 miles long and has an access density of 38.5 access points per mile. The southern portion of the corridor has the highest concentration of access points, due to single-family houses with driveways fronting 31st Street. However, that is a relatively short section of road and the number of crashes at the residential driveways was not high; therefore, this corridor is not divided into two segments. The 31st Street corridor is characterized by a low access point density and a continuous TWLTL.

Figure 3-32. Preston Road (SH 289) Crash Locations (Segment-A).

Figure 3-33. Preston Road (SH 289) Crash Locations (Segment-B).

Figure 3-34. Preston Road (SH 289) Crash Locations (Segment-C).

3.10.2 Crash Analysis

Texas DPS provided the research team with crash reports for the study years on this corridor.

3.10.3 Traffic Demand

The traffic volumes on 31st Street shown in Table 3-29 range from 26,000 to 31,000 vehicles, with no upward or downward trend.

Table 3-29. 31st Street (FM 1741) AADT Counts.

Year	AADT (vehicles/day)
1993	30,000
1994	29,000
1995	31,000
1996	30,000
1997	29,000
1998	31,000
1999	26,000
2000	30,000

3.10.4 Crash Analysis Results

The crash rates on 31st Street, listed by year in Table 3-30, are relatively low, ranging from 1.78 to 4.07 crashes per million VMT. There was no upward or downward trend in the crash rates through the years of the study period, consistent with the fact that no change to the cross section or access density occurred during this time.

Table 3-30. 31st Street Corridor (FM 1741) Summary of Crashes.

Year	Number of Crashes	Crashes per Million VMT	Access Density
1993	49	3.44	38.5
1994	56	4.07	38.5
1995	51	3.47	38.5
1996	27	1.90	38.5
1997	36	2.62	38.5
1998	36	2.45	38.5
1999	22	1.78	38.5
2000	28	1.97	38.5

The crash analysis results from the 31st Street corridor illustrate the impact of low access point density on crash rates, since the corridor has a low access density and there is no raised median.

Figure 3-35 shows the location and type of crashes on the 31st Street corridor.

3.11 BROADWAY AVENUE (US 69) (TYLER) CASE STUDY LOCATION

3.11.1 General Description

The Broadway corridor study section is located between Loop 323 and Chimney Rock Road in Tyler, Texas. It is abutted primarily by commercial (retail and office building) development, with some single-family residential development backing up to the corridor (but with no driveway access). There is a mix of large-scale and stand-alone retail development on the corridor. The corridor has two distinct segments, the north with a driveway density of 38.1 access points per mile and the south with a density of 85.37 access points per mile. Broadway currently has three lanes in each direction with a continuous TWLTL, though a raised median installation is planned for fiscal year 2005.

Figure 3-35. 31st Street (FM 1741) Crash Locations.

3.11.2 Crash Analysis

Texas DPS provided the research team with crash reports for each year of the study period. Because the two segments have significantly different access densities, the research team performed two analyses on this corridor.

3.11.3 Traffic Demand

The overall corridor experienced growth in traffic volumes during the study period. The south segment, between Rieck and Chimney Rock, experienced a higher traffic growth rate than the north segment, located between Loop 323 and Rieck. This situation is likely due to commercial growth along the corridor during these years, as well as an overall growth trend in the southern Tyler area. Table 3-31 displays the traffic volumes on each of these two segments for each of the study years.

Table 3-31. Broadway Avenue (US 69) AADT Counts.

Year	Segment	AADT (vehicles/day)
1993	North	30,000
	South	27,000
1994	North	30,000
	South	28,000
1995	North	35,000
	South	30,000
1996	North	32,000
	South	32,000
1997	North	33,000
	South	31,000
1998	North	39,000
	South	34,000
1999	North	39,000
	South	40,000
2000	North	39,000
	South	40,000

3.11.4 Crash Analysis Results

The findings on the Broadway corridor were interesting, since the two segments had very similar crash rates for most of the study years, as shown in Table 3-32. This situation exists even though the north segment has an access density that is less than half that of the south segment. The overall corridor, a continuous TWLTL, had a higher access density than other similar corridors with raised medians.

Table 3-32. Broadway Avenue (US 69) Corridor Crash Summary.

Year	Segment	Number of Crashes	Crashes per Million VMT	Access Density (points/mile)
1993	North	121	13.16	38.10
	South	36	8.91	85.37
1994	North	98	10.65	38.10
	South	53	12.65	85.37
1995	North	93	8.67	38.10
	South	38	8.46	85.37
1996	North	60	6.12	38.10
	South	36	7.52	85.37
1997	North	88	8.70	38.10
	South	46	9.92	85.37
1998	North	93	7.78	38.10
	South	41	8.06	85.37
1999	North	81	6.77	38.10
	South	38	6.35	85.37
2000	North	74	6.19	38.10
	South	37	6.18	85.37

It is noteworthy that the crash rate on the north segment of the Broadway corridor dropped by approximately 50 percent (from 13.16 in 1993 to 6.19 in 2000) during the study years. There were no street improvements made; therefore, there is no clear explanation of the reduction in the crash rate.

Figure 3-36 shows the locations and types of crashes on the Broadway corridor.

Figure 3-36. Broadway Avenue (US 69) Crash Locations 1993-2000.

3.12 42nd STREET (SH 191) (ODESSA) CASE STUDY LOCATION

3.12.1 General Description

The 42nd Street corridor is located in northeast Odessa, Texas, between Dawn Street and East Loop 338. This 2.4-mile corridor is abutted primarily by commercial/retail land uses, with some office buildings and a university. The overall access density for this section of 42nd Street is 40 access points per mile, but, like several other case studies, it can be divided into two segments. The west segment, between Dawn and Tanglewood Lane, is approximately 1.1 miles long and is surrounded by fully developed land. There are some residential streets intersecting this portion of the corridor, but very few residential driveways intersect 42nd Street. There is also a high school and a mix of single-lot and large-scale retail development, as well as some office buildings.

The east segment, between Tanglewood Lane and East Loop 338, is approximately 1.3 miles long and is not completely surrounded by developed land. Some residential streets intersect 42nd Street; however, there are no intersecting residential driveways. The commercial development on this segment is primarily large-scale, including a regional shopping mall and some office buildings. The easternmost portion of this segment is bordered by the University of Texas of the Permian Basin on the south side and by undeveloped land partially on the north side.

3.12.2 Crash Analysis

Texas DPS provided the research team with crash reports for the years 1993-2000.

3.12.3 Traffic Demand

As shown in Table 3-33, traffic volumes on the 42nd Street corridor increased during the study years. The eastern segment experienced commercial development and redevelopment during this time period, which likely caused the increased volumes.

Table 3-33. 42nd Street (SH 191) AADT Counts.

Year	Segment	AADT (vehicles/day)
1993	East	17,600
	West	30,000
1994	East	16,500
	West	29,000
1995	East	20,000
	West	29,000
1996	East	23,000
	West	32,000
1997	East	24,000
	West	35,000
1998	East	21,000
	West	34,000
1999	East	24,000
	West	36,000
2000	East	23,000
	West	36,000

3.12.4 Crash Analysis Results

Crash rates on the two segments of this corridor, as in the other multiple-segment case studies, show that one can expect fewer crashes per million VMT when roads have lower access point densities. The eastern portion of the 42nd Street corridor, which has an access density of 27.69 access points per mile, had consistently lower crash rates for each year of the study period than the western portion, which has an access density of 56.36 access points per mile. For most years, the differences in crash rates on the two segments were quite notable. Table 3-34 displays the numbers of crashes and crash rates for both segments of the 42nd Street corridor.

Table 3-34. 42nd Street (SH 191) Corridor Crash Summary.

Year	Segment	Number of Crashes	Crashes per Million VMT	Access Density (points/mile)
1993	East	43	5.15	27.69
	West	139	11.54	56.36
1994	East	47	6.00	27.69
	West	94	8.07	56.36
1995	East	35	3.69	27.69
	West	72	6.18	56.36
1996	East	30	2.75	27.69
	West	39	3.04	56.36
1997	East	40	3.51	27.69
	West	75	5.34	56.36
1998	East	38	3.81	27.69
	West	102	7.47	56.36
1999	East	34	2.99	27.69
	West	88	6.09	56.36
2000	East	45	4.12	27.69
	West	68	4.70	56.36

Figures 3-37 and 3-38 show the locations and types of crashes for the 42nd Street corridor.

3.13 PARK BOULEVARD (PLANO) CASE STUDY LOCATION

3.13.1 General Description

The Park Boulevard corridor is located in Plano, Texas, between Mira Vista on the west and Travis on the east, for a length of approximately 2.4 miles. It has two lanes in each direction, with a continuous TWLTL. The corridor can be divided into three segments, two of which are primarily residential, and a third segment, which is primarily commercial. The westernmost segment, between Mira Vista and just west of Ventura, is a 1.0-mile segment surrounded by a golf course and residential development, with no driveways intersecting Park Boulevard and an access density of 10.00 access points per mile. The 0.9-mile central segment passes through commercial/retail development from just west of Ventura to Ohio Street. This segment has an access density of 38.89 access points per mile, which is the highest of the three Park Boulevard segments but is relatively low compared to other roads abutted by commercial development.

The east segment is 0.5 miles long and surrounded by residential development, like the west segment, also with no driveway intersections on Park Boulevard.

3.13.2 Crash Analysis

Because this road is not on the state-maintained system, Texas DPS did not have crash reports available. The City of Plano provided the research team with summaries of crashes for the study years, which included types of crashes and the blocks of Park Boulevard in which they occurred. Exact locations were not included; therefore, it was not possible to plot exact crash locations on aerial photographs.

3.13.3 Traffic Demand

The research team did not have annual traffic volumes for Park Boulevard, since it is not on the state-maintained system and does not have annual counts performed. Counts on various segments of the study section for various years were provided by TxDOT and the City of Plano. By studying other traffic counts in the area, researchers estimated AADT for missing years in order to ultimately estimate crashes per million VMT. Traffic volumes did increase on the west segment during the study years but was somewhat consistent on the other two segments. The traffic volumes provided, as well as those estimated, are shown in Table 3-35.

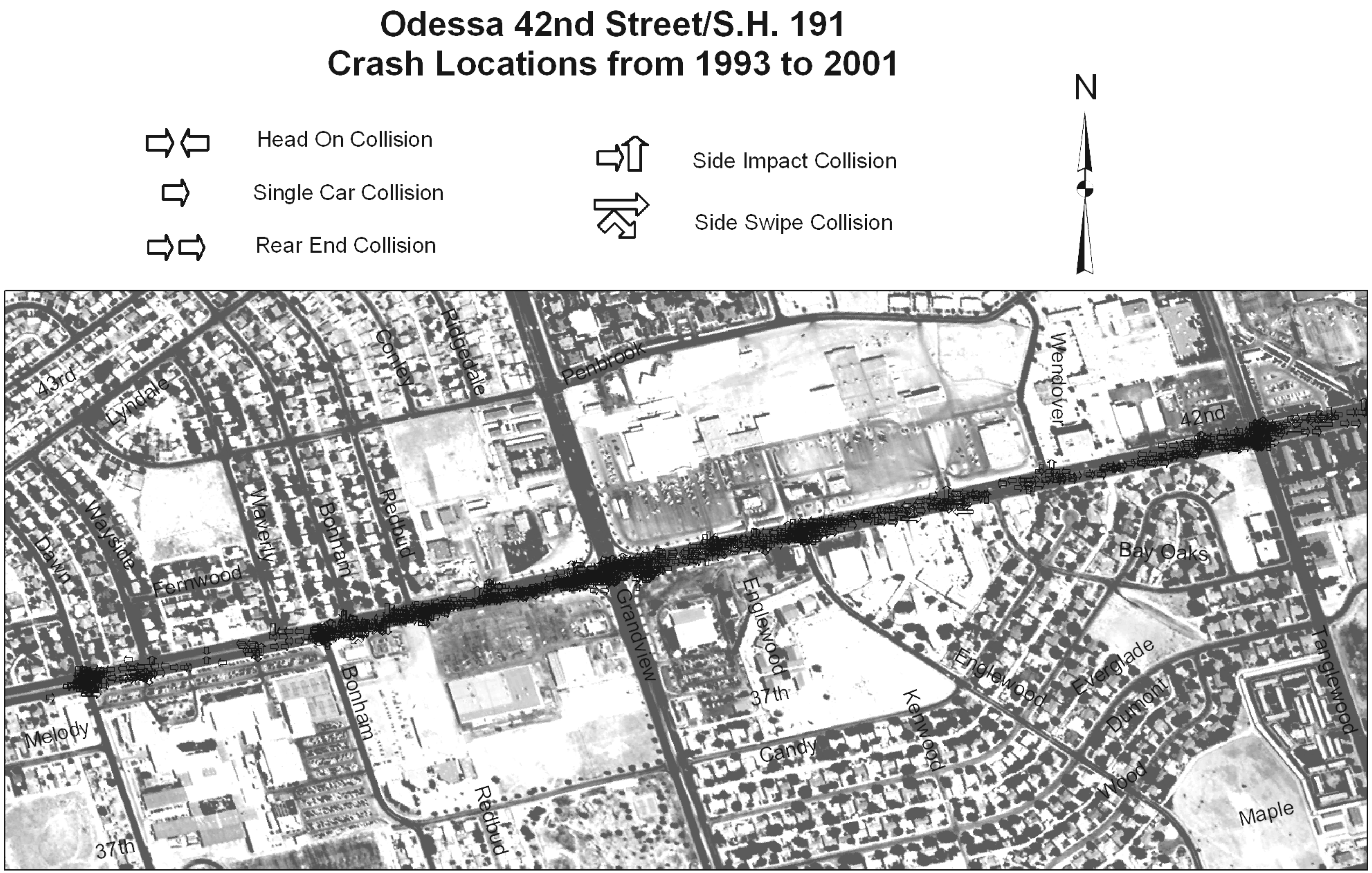


Figure 3-37. 42nd Street (SH 191) Crash Locations (Western Segment - A) 1993-2001.

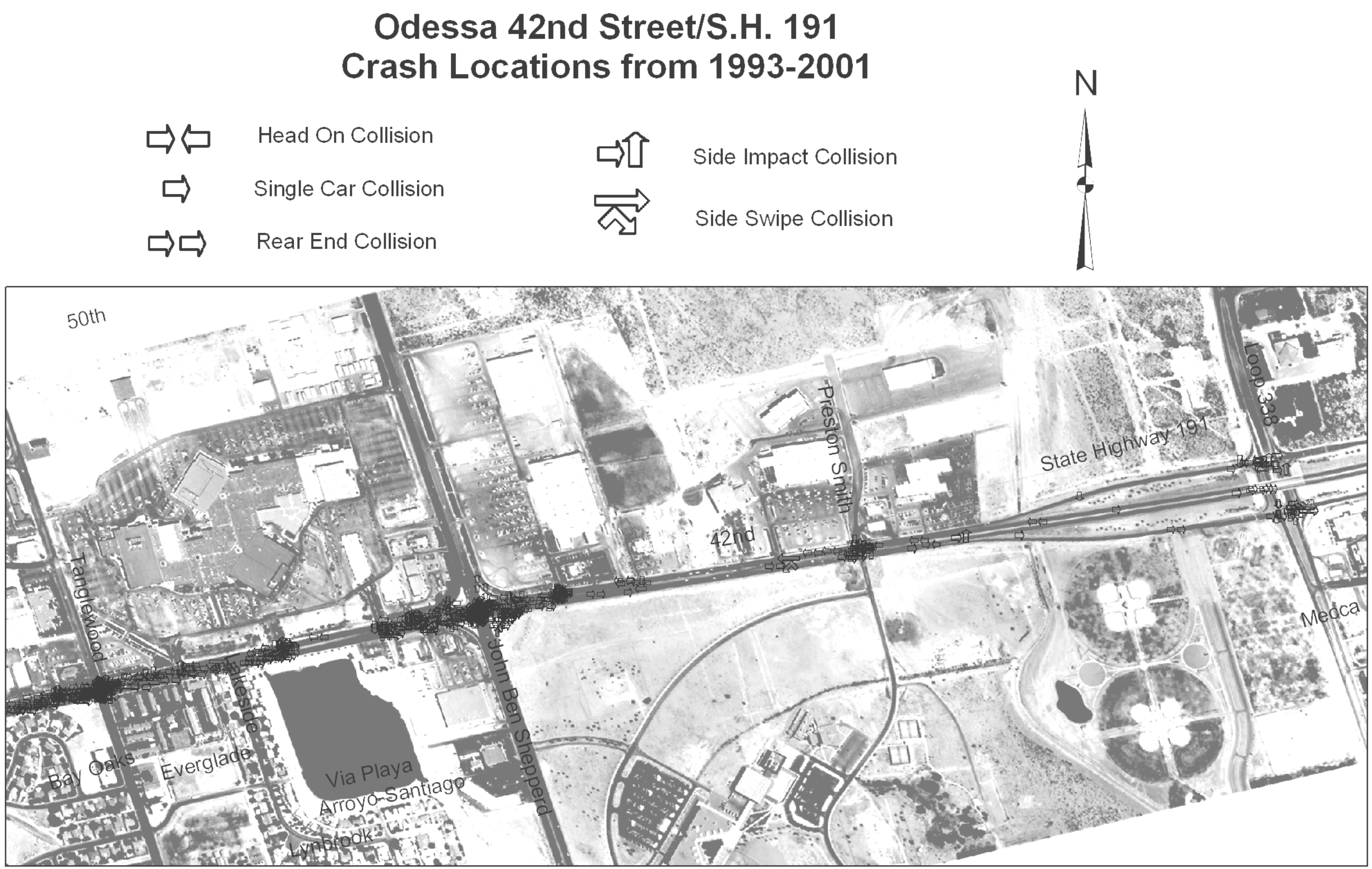


Figure 3-38. 42nd Street (SH 191) Crash Locations (Western Segment - B) 1993-2001.

Table 3-35. Park Boulevard (Plano) AADT Counts.

Year	Segment	AADT (vehicles/day)
1995	West	28,324
	Central	33,651
	East	34,337
1996	West	30,273
	Central	34,031
	East	34,337
1997	West	32,222
	Central	34,411
	East	34,337
1998	West	34,171
	Central	34,791
	East	34,337
1999	West	36,120
	Central	35,171
	East	34,337
2000	West	36,372
	Central	35,551
	East	34,337
2001	West	36,372
	Central	35,551
	East	34,337
2002	West	36,876
	Central	36,311
	East	34,337

3.13.4 Crash Analysis Results

As shown in Table 3-36, The Park Boulevard corridor contains segments with the lowest access densities of the entire research project. The west segment has 10.00 access points per mile and the east segment has 16.0 access points per mile. These two segments also have the lowest overall crash rates, which follows the findings from other case study corridor segments where there are very few access points. The central segment has a relatively low access density, considering it is surrounded by retail development, at 38.89 access points per mile. While the central segment has crash rates that are consistently higher than the other two segments on this corridor, its crash rates are lower than most of the retail corridors that have higher access densities.

Since specific crash locations were not available to the research team, it was not possible to plot them in an aerial photograph figure.

Table 3-36. Park Boulevard (Plano) Crash Summaries.

Year	Segment	Number of Crashes	Crashes per Million VMT	Access Density (points/mile)
1995	West	26	2.51	10.0
	Central	88	7.96	38.9
	East	18	2.87	16.0
1996	West	23	2.08	10.0
	Central	79	7.07	38.9
	East	11	1.76	16.0
1997	West	21	1.79	10.0
	Central	83	7.34	38.9
	East	6	0.96	16.0
1998	West	17	1.36	10.0
	Central	92	8.05	38.9
	East	19	3.03	16.0
1999	West	21	1.59	10.0
	Central	79	6.84	38.9
	East	26	4.15	16.0
2000	West	22	1.66	10.0
	Central	60	5.14	38.9
	East	13	2.07	16.0
2001	West	14	1.05	10.0
	Central	68	5.76	38.9
	East	7	1.12	16.0
2002	West	22	1.63	10.0
	Central	54	4.53	38.9
	East	12	1.91	16.0

3.14 CRASH ANALYSIS SUMMARY AND CONCLUSIONS

The research team studied 11 corridors to determine relationships between crash rates and access point densities (driveways and public street intersections), as well as the presence of raised medians or two-way left-turn lanes (TWLTLs). Some corridors had two or more distinct segments, each with varying access point densities. Researchers obtained crash history and traffic volumes for each of the corridor segments. The Texas Department of Public Safety (DPS) provided crash reports for each of the corridors that are state-maintained roads. For the other corridors in Texas, city police departments provided crash information. The Oklahoma Department of Transportation (ODOT) provided crash information for the Tulsa corridor.

3.14.1 Safety Analysis Case Study Results

Qualitative Findings

Crash records were individually investigated for each corridor to identify the number and type of crashes. Traffic volume data were collected for the computation of crash rates. One beneficial illustrative tool was the development of graphics which contained the location and type of crash for a given corridor. The type of crash was shown with the standard ITE crash diagram icons (*6*) in these crash spot maps.

The investigations of this research project demonstrate that crash data format and availability vary among agencies. TxDOT provides relatively consistent crash reports and summaries, from which much useful information can be obtained. When working with off-state-system roads, however, one must usually rely on a local city or other entity to provide crash data. The total number of crashes and types of crashes will always provide insightful and fundamental information about the safety of a corridor. However, the consistency and usefulness of locally provided data details will make some data more useful than others for analysis. Of course, the authors recognize the typical limitations of crash data (i.e., unreported crashes, erroneous data from processing, possible limitations of the report form, and causes of the crashes as described in reference 6); however, the results appear to demonstrate some useful relationships regarding access point density and crash rates described below.

Quantitative Findings

In the first year of this 2-year project, the most in-depth crash analysis and methodology development was performed on the Texas Avenue corridor in College Station, Texas. Researchers found that crash rates and severity decreased after the raised median was installed. Crash rates reduced from 4.3 to 1.8 crashes per million vehicle-miles of travel (as shown in

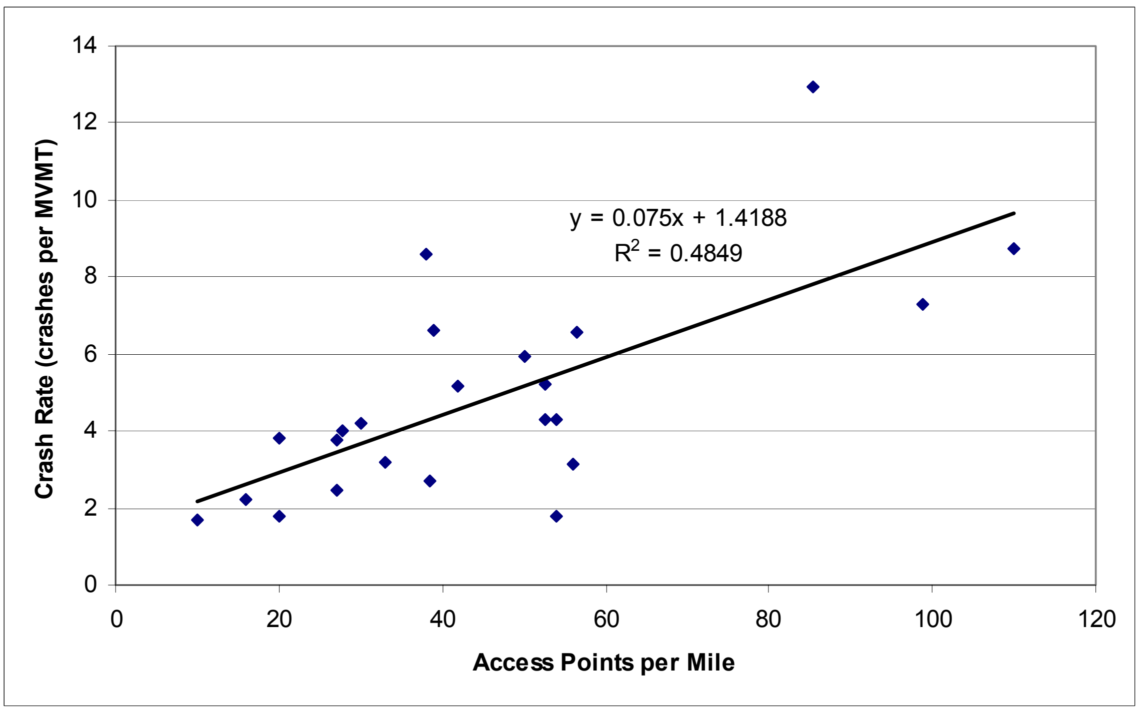
Table 3-37). Crashes were reduced by nearly 60 percent after the installation of the raised median, and the severity of crashes also were reduced. Conflict points along the corridor were reduced 26 percent.

Table 3-37. Characteristics and Crash Rate Results for Safety Analysis Case Studies.

Corridor Segment	ADT Range	Access Points/Mile	Median Type	Average Crashes per Million VMT
Texas Avenue, College Station, TX	40,000 – 42,000	60	TWLTL ("Before")	4.3
Texas Avenue, College Station, TX	38,500 – 43,000	57	Raised ("After")	1.8
Loop 281, Longview, TX	20,000 – 27,000	53	TWLTL ("Before")	5.21
Loop 281, Longview, TX	20,000 – 27,000	53	Raised ("After")	4.29
US 385, Odessa, TX	9,500 – 11,700	50	Undivided ("Before")	19.57
US 385, Odessa, TX	9,500 – 11,700	50	Raised ("After")	15.39
71st Street (west), Tulsa, OK	20,000 – 24,000	27	Undivided ("Before")	3.76
71st Street (west), Tulsa, OK	28,000 – 33,000	27	Raised ("After")	2.48
71st Street (west-central), Tulsa, OK	20,000 – 21,000	20	Undivided ("Before")	3.82
71st Street (west-central), Tulsa, OK	22,000 – 37,000	20	Raised ("After")	1.78
US 380 (west), McKinney, TX	14,700 – 29,000	56	Raised	3.12
US 380 (east), McKinney, TX	13,500 – 24,000	99	Raised	7.29
US 377 (west), Fort Worth, TX	18,200 – 21,000	50	Raised	5.92
US 377 (east), Fort Worth, TX	18,200 – 21,000	110	Raised	8.76
SH 289, Plano, TX	44,000 – 53,000	30	Raised	4.21
Park Blvd (west), Plano, TX	28,000 – 37,000	10	Raised	1.71
Park Blvd (central), Plano, TX	33,000 – 36,000	39	Raised	6.59
Park Blvd (east), Plano, TX	34,000 – 35,000	16	Raised	2.23
71st Street (east-central), Tulsa, OK	27,000 – 47,000	33	Raised	3.20
71st Street (east), Tulsa, OK	25,000 – 51,000	42	Raised	5.17
FM 1741, Temple, TX	26,000 – 31,000	39	TWLTL	2.71
US 69 (north), Tyler, TX	30,000 – 39,000	38	TWLTL	8.60
US 69 (south), Tyler, TX	27,000 – 40,000	85	TWLTL	12.92
SH 191 (west), Odessa, TX	29,000 – 36,000	56	TWLTL	6.55
SH 191 (east), Odessa, TX	16,500 – 24,000	28	TWLTL	4.00

VMT – vehicle-miles of travel

Figure 3-39 shows the relationship between the number of access points per mile and the associated crash rates along the corridors and/or partial segments of the corridors investigated in this study (see Table 3-37). Figure 3-39 includes all of the test corridors in Table 3-37 except US 385 in Odessa (Grant Avenue), which was located in a downtown area and subsequently had a distinctly different operational characteristic than the other arterial corridors. The relationship in Figure 3-39 clearly indicates that there is an upward relationship in the crash rate as the number of access points per mile increases—irrespective of the median treatment (undivided, TWLTL, or raised). A regression line is shown in Figure 3-39 that yielded an R-squared value of 0.48. The regression line only explains about half of the variability in the data; however, the relationship is clearly upward. This upward trend is similar to what was found in national research in NCHRP Report 420 (*5*). The researchers also investigated the relationship between the number of access points per mile and crash rate for the raised median projects and for the non-raised median corridors separately. The relationship was still upward, but it was slightly steeper with the non-raised median corridors (slope = 0.1225) compared to the raised median corridors (slope = 0.0618). It is intuitive that when the number of conflict points are reduced through turn restrictions along a raised median that there is a reduced slope in the relationship (i.e., relatively lower crash rates).



MVMT = Million vehicle-miles of travel

Figure 3-39. Relationship between Access Point Density and Crash Rates.

Table 3-38 shows a comparison of the crash rates along the corridors where there was a "before" and "after" analysis of the crash records performed. Table 3-38 includes the corridor name, ADT after the raised median was installed, the "before" median condition, crash rates before and after the median installation, difference in the crash rates, percent difference in the crash rates, and the number of access points per mile. There were five specific corridors, or segments of the corridors, studied before and after the raised median installation. The final row of the table compares the average crash rate before and after the raised median installation on all of the remaining study corridors shown in Table 3-37. The result is that there is always a reduction in the crash rate due to the installation of the raised median. The percent reduction ranges from 17 to 58 percent. This occurs over a range of access point densities from 20 to 53. The two corridors that went from a TWLTL to a raised median experienced 17 and 58 percent reductions, while the two corridors that were previously undivided experienced 34 to 53 percent reductions. Finally, the average of all corridors together (final row of Table 3-38) shows an average reduction of 31 percent going from either a TWLTL or undivided roadway to a raised median. The increased safety of the raised median has also been documented in NCHRP Report 395 (*7*) and NCHRP Report 420 (*5*).

Table 3-38. Crash Rate Comparison of Corridors "Before" and "After" the Installation of a Raised Median.

Corridor(s)	ADT[1]	"Before" Median Type	Crash Rate				Access Points/Mile
			"Before" Condition	Raised Median	Absolute Difference	Percent Difference	
College Station (Texas Avenue)	41,000	TWLTL	4.3	1.8	-2.5	-58	54
Longview (Loop 281)	23,500	TWLTL	5.2	4.3	-0.9	-17	53
Tulsa (west) (71st Street)	30,500	Undivided	3.8	2.5	-1.3	-34	27
Tulsa (west-central) (71st Street)	29,500	Undivided	3.8	1.8	-2.0	-53	20
Odessa (US 385)	10,600	Undivided	19.6	15.4	-4.2	-21	50
All Remaining	30,600	Varies	7.0	4.8	-2.2	-31	49

[1]ADT is the traffic volume in the "after" condition that has the raised median present.
[2]This is a comparison of the average crash rate for all the corridors "before" and "after" the raised median was installed. Note that the "before" condition was typically a TWLTL (refer to Table 3-37).

The researchers recognize that oftentimes there are other improvements performed to a corridor that can increase their safety in addition to the raised median. When the raised median was installed, there was often a roadway widening. This can improve safety along the corridor; however, the crash rate indicates that for the increased level of travel along the corridor, there appears to be an improvement in safety for the corridors studied here.

3.14.2 Safety Analyses

While this project was able to consider several years of data on each of the case study corridors, additional studies on these (and other) corridors will provide additional confidence in the findings. It will be useful to identify additional corridors where raised medians are planned or where there are plans to change access point densities and begin collecting crash and traffic volume data from years prior to the changes. The access point density changes may come from increases due to land development or from decreases due to driveway consolidations or land redevelopment.

CHAPTER 4

FINDINGS AND DISCUSSION

4.1 OPERATIONAL IMPACTS

Although it is a valuable micro-simulation tool, VISSIM is a complicated program with a steep learning curve for a new user. This initial difficulty is primarily due to VISSIM's numerous sophisticated input and output capabilities. The process of inputting the different types of data into the micro-simulation was difficult and time-consuming. Further, each alternative was run several times with visual examination to ensure the corridor was running correctly. One practical observation made by researchers was to remove the background aerial photograph once the scale was obtained in the corridor because when running the simulations, it caused the model to lock-up numerous times.

VISSIM allows the user to change numerous model inputs and to input the necessary available field data, which are both important aspects of the program. Users can adjust design elements such as driveway spacing, number of lanes, speed limits, and right-turn-on-red. VISSIM also allows the user to input signal timing and phases after they are optimized in a separate program such as SYNCHRO, which was used in this project. The optimized timings and phases were entered into VISSIM from SYNCHRO, another time-consuming process in alternatives where multiple scenarios have multiple signals. The most time-consuming portion of the process is entering all the data into VISSIM and ensuring the corridor is calibrated to field conditions.

VISSIM's output abilities are just as impressive as the input characteristics. For this study, travel time and delay were analyzed in the case studies and the theoretical corridors. Researchers were able to enter the length of time for analysis and the location. For this project, the research team selected a 1-hour time length to symbolize the peak hour.

The analysis results for the three case study corridors revealed small differences in travel time and delay between the existing (TWLTL) and proposed (raised median) conditions. The proposed future conditions (approximately a 20 percent increase in traffic) resulted in a small percent increase in the overall travel time and delay. The percentage difference in travel time, speed, and delay varied for each corridor. Travel time on the Texas Avenue (Bryan, Texas) corridor decreased 11 to 38 percent with the raised median compared to the TWLTL in the future condition. Travel time on the 31st Street (Temple, Texas) corridor increased 3 percent with a raised median compared to a TWLTL in the future condition, and on Broadway Avenue (Tyler, Texas) travel time increased 2 to 57 percent with the raised median treatment compared to a TWLTL in the future. This resulted in a maximum of a 6 mph decrease in speed due to the raised median installation (Tyler) and as much as a 7 mph increase in speed with the raised median (Bryan). These results are summarized in Table 2-18.

The reduction in travel time on Texas Avenue from the future TWLTL to the future raised median treatment might be attributed to prohibiting U-turns at a high-volume signalized intersection. This forces vehicles to make U-turns at locations farther along the corridor, at uncongested locations. In effect, this takes less time than waiting for turning traffic in the more congested portions of the corridor. This also allows for more through-movement green time, which can be reduced on corridors with high left-turn and U-turn movements. The increased travel times from the future TWLTL to the future installation of raised medians in Temple and Tyler are likely due to overall increases in traffic on the corridor, as some U-turning vehicles must travel farther to reach their destination. Increased travel time is also caused by U-turning vehicles that must weave across lanes to reach turn bays, which can cause traffic queues. The U-turning vehicles are also adding additional traffic on the roadways in the opposite direction of their origin. The additional vehicle-miles of travel (VMT) likely causes travel time and delay to increase. Delay may also increase slightly at the signalized intersections. As noted previously, the percent difference in travel time along the Temple corridor was only about 3 percent when comparing the raised median alternative with the most median openings—the alternative most effectively handling the corridor turning movements. It is hypothesized that increasing the number of median opening locations could have reduced the percent difference between the TWLTL and raised median alternatives to less than 3 percent.

The theoretical corridor results also indicate small increases in travel time with the raised median treatment compared to the future TWLTL conditions. The results are presented in Table 2-38. Scenario 1 did not have a comparison between a TWLTL and a raised median because the driveway spacing was 660 feet, similar to the median openings, so it was essentially the same for both median treatments. Travel time for Scenario 2 (five-lane) increased 2 to 31 percent for the raised median compared to the TWLTL, while that for Scenario 2 (seven-lane) increased 8 to 44 percent with a raised median compared to the TWLTL. The travel time increase with the raised median ranged from 1 to 22 percent in Scenario 3 when compared to the TWLTL. The reasons given for increases in travel time for the case studies are also hypothesized for the theoretical corridors as well. While the percent differences are large in some scenarios, the actual speed reduction averages 3 mph across all scenarios and traffic volumes. These small increases in travel time, and subsequent delay, appear to be outweighed by the reduction in the number of conflict points and increased safety—another impact analyzed in this study on additional test corridors.

4.2 SAFETY IMPACTS

The research team studied 11 corridors to determine relationships between crash rates and access point densities (driveways and public street intersections), as well as the presence of raised medians or two-way left-turn lanes (TWLTLs). Crash records were individually investigated for each corridor to identify the number and type of crashes. Traffic volume data were collected for the computation of crash rates. The investigations of this research project demonstrate that crash data format and availability vary among agencies. TxDOT provides relatively consistent crash reports and summaries, from which much useful information can be obtained. When working with off-state-system roads, however, one must usually rely on a local city or other entity to provide crash data. The total number of crashes and types of crashes will always provide insightful and fundamental information about the safety of a corridor. However, the consistency and usefulness of locally provided data details will make some data more useful than others for analysis. Of course, the authors recognize the typical limitations of crash data (i.e., unreported crashes, erroneous data from processing, possible limitations of the report form, and causes of the crashes as described in reference 6); however, the results appear to demonstrate some useful relationships regarding access point density and crash rates described below.

Researchers found a relationship between the number of access points per mile and the associated crash rates along the corridors and/or partial segments of the corridors investigated in this study (see Table 3-38). The relationship in Figure 3-39 clearly indicates that there is an upward relationship in the crash rate as the number of access points per mile increases—irrespective of the median treatment (undivided, TWLTL, or raised). The researchers also investigated the relationship between the number of access points per mile and crash rate for the raised median projects and for the non-raised median corridors separately. The relationship was still upward, but it was slightly steeper with the non-raised median corridors (slope = 0.1225) compared to the raised median corridors (slope = 0.0618). It is intuitive that when the number of conflict points are reduced through turn restrictions along a raised median that there is a reduced slope in the relationship (i.e., relatively lower crash rates).

Researchers also performed a comparison of the crash rates along the corridors where there was a "before" and "after" analysis of the crash records performed. Table 3-38 shows the results of this analysis. It was found that there is always a reduction in the crash rate due to the installation of the raised median. The percent reduction ranges from 17 to 58 percent. This occurs over a range of access point densities from 20 to 53. The two corridors that went from a TWLTL to a raised median experienced 17 and 58 percent reductions, while the two corridors that were previously undivided experienced 34 to 53 percent reductions. Finally, the average of all corridors together (final row of Table 3-38) shows an average reduction of 31 percent going from either a TWLTL or undivided roadway to a raised median. The increased safety of the raised median has also been documented in NCHRP Report 395 (*7*) and NCHRP Report 420 (*5*).

The researchers recognize that oftentimes there are other improvements performed to a corridor that can increase their safety in addition to the raised median. When the raised median was installed, there was often a roadway widening. This can improve safety along the corridor; however, the crash rate indicates that for the increased level of travel along the corridor, there appears to be an improvement in safety for the corridors studied here.

4.2.1 Crash Data Availability and Reliability

The investigations of this research project demonstrate that crash data format and availability vary among agencies. The Texas Department of Transportation provides relatively consistent crash reports and summaries, from which much useful information can be obtained. When working with off-state-system roads, however, one must usually rely on a local city or other entity to provide crash data. The total number of crashes and types of crashes will always provide insightful and fundamental information about the safety of a corridor. However, the consistency and usefulness of locally provided data details will make some data more useful than others for analysis. Data provided by other states will vary, as was experienced with the Tulsa, Oklahoma, case study. However, even the basic numbers and types of crashes can provide useful information, in addition to the details included in crash reports and summaries.

4.3 FUTURE RESEARCH

4.3.1 Operational Impacts and Micro-simulation Analyses

More research is needed to further identify the impact of access management treatments over a range of traffic volumes. Although this project identified many valuable findings, primarily related to the potential implementation of raised medians, combinations of access management treatments along a corridor could be further investigated. For example, the presence of acceleration and/or deceleration lanes at heavy driveway or cross-street locations could facilitate traffic movement. Further, along the actual test corridors it is difficult to identify the precise origin-destination patterns of vehicles without a costly origin-destination study to identify vehicle patterns both within and through the study corridor. Although costly, it would also be valuable to investigate longer corridors with combinations of access management techniques, as those provided here were relatively short (0.5 to 1.5 miles).

Implementing an origin-destination (O-D) matrix for vehicle trips is another topic that could be further researched. In the case studies for this project, vehicle origin was used to determine likely destinations through assumptions, which were consistent across scenarios. A matrix was designed in which the vehicle entrance location determined where the vehicle would exit the system; however, due to budgetary limitations, the research team did not automate the O-D matrix. Therefore, ensuring the number of vehicles in the corridor was relatively consistent with field observations required numerous checks.

The theoretical corridors could also use additional research on the effects of travel time, speed, and delay as a consequence of higher traffic volumes. In the theoretical corridors, the spacing of median openings remained constant. The results of varying the distance of the openings would also be of interest.

Finally, it would be preferable if such further analyses could be performed on actual field sites, along with a crash analysis on the same site, though finding such sites and performing such data collection can be difficult and costly.

4.3.2 Safety Analyses

While this project was able to consider several years of data on each of the case study corridors, additional studies on these (and other) corridors will provide additional confidence in the findings. It will be useful to identify additional corridors where raised medians are planned or where there are plans to change access point densities and begin collecting crash and traffic volume data from years prior to the changes. The access point density changes may come from increases due to land development or from decreases due to driveway consolidations or land redevelopment.

4.3.3 Combining Micro-simulation and Safety Analyses

To date, analysts have had to review crash reports (if available) for corridors to investigate the safety of installed treatments and operational improvements (travel time, speed, and delay) that may eventually be investigated through micro-simulation. Recent research sponsored by the Federal Highway Administration (FHWA) has investigated the inclusion of surrogate safety measures into micro-simulation (*8*). Ultimately, such methods would allow the analyst to obtain estimates of safety impacts from transportation alternatives in the same micro-simulation model that provides operational performance data. The FHWA work describes surrogate safety measures such as the time-to-collision (TTC) concept. TTC considers two vehicles with eventually crossing trajectories and computes the time that the two vehicles would collide if they maintained their current vectors at each time step of the micro-simulation. A percentage of the TTCs under a certain time in seconds for the micro-simulation can be used as a surrogate for safety. The intent is that the TTC would identify the stop-and-go acceleration characteristics that might be present for different transportation alternatives—allowing them to be compared from a safety perspective. TTI is in the process of investigating the use of the TTC in the VISSIM environment with the micro-simulation test corridors described in this paper. Proof-of-concept and early results of this work are published in two available conference papers (*1,2*).

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APPENDIX A

VISSIM

VISSIM PROCEDURE

General Process

1. Obtain an aerial photograph of the roadway for use as the background in VISSIM.
2. Obtain roadway geometrics such as the number of lanes, lane widths and driveway widths, distance between driveways, length of dedicated turn lanes, etc.
3. Collect traffic volumes such as mainlane counts, intersection turning movements, and driveway volumes and turning movements.
4. Obtain any intersection signal timings.
5. Perform floating-car travel time runs from the beginning to the end of the corridor during the peak hour. This information will be used later to calibrate the model.
   a) The peak hour was selected as the hour with the combination of the highest mainlanes, intersection, and driveway traffic volumes.

Creating the Network

1. Input the background into VISSIM.
   a) Scale the drawing using a measurement taken in the field, and save the scale.
2. Draw links for main roads and driveways.
   a) Make separate links for each segment of roadway.
   b) Do not draw links across intersections—you will connect these with connectors in the next step.
   c) Space driveways according to the aerial photograph, if possible. If not, the distances can be scaled off of the field measurements.
3. Draw connectors.
   a) Connect each of the links across the intersection with connectors.
   b) Connect all right and left turns onto and off of the main road with connectors.
   c) For left-turn connectors onto a multi-lane road, connect the left-turn in the leftmost lane.

The following steps should be completed for one driveway at a time until that driveway is operating well.

4. Enter stop signs.
   a) Place stop signs before any connectors.
5. Enter priority rules.
   a) Use gap times of 3.0 – 4.0 seconds for right-turn movements.
   b) Use gap times of 4.5 – 5.5 seconds for left-turn movements.
   c) Note: You may have to vary these depending on the roadway widths.
6. Enter mock traffic volumes.
   a) It is recommended to enter a high volume such as 100 vehicles per hour at each driveway so you can see any potential conflicts.
7. Simulate.
   a) Watch for any collisions.
   b) Update priority rules until there are no collisions.
8. Move on to the next driveway.
9. Complete steps 4-7 again.

After all of the driveways are operating without collisions, move on to the following steps.

Change the traffic volumes to the actual volumes.

1. Use the routing decision tool to direct the vehicles where to go.

   Be careful of putting a routing decision too close to a connector; the vehicle may miss the connector and you will receive an error message.

2. Input traffic signals.

   The traffic signals in VISSIM use National Electrical Manufacturers Association (NEMA) phasing. VISSIM does not have the capability to optimize signal timing. To optimize the signals, you will need to use software such as SYNCHRO, if you have more than one signal.

Highway capacity software could also be used if there is only one signal or there is no coordination between the signals.

3. Evaluations

   VISSIM has the capability to collect data such as average delay, stopped delay, number of stops, queue length, travel time, emissions, intersection delay, etc. You must set up parameters during which you want to collect data. If you want to collect an hour of data, researchers recommend simulating from 0-4,500 seconds and collecting from 900-4,500 seconds. This will allow time for the network to become saturated with vehicles before the data collection begins. The first case study, Texas Avenue, had a simulation time of 0-3,900 seconds and collected data from 300 to 3,900 seconds. It was found that allowing VISSIM to saturate for 900 seconds (15 minutes) instead of 300 seconds (5 minutes) created a more realistic situation.

4. Output.

   VISSIM has the capability to determine the following values during simulation—travel time, total delay, intersection delay, queue length, number of stops, etc. See the VISSIM manual for a complete description of outputs. The user must designate what values he/she wants as output. The output is separated into text files that can be easily placed into a spreadsheet to evaluate.

5. Calibration.

   After obtaining the initial output from the model, it is necessary to calibrate the model to adequately predict the traffic conditions in the field. In this step, the floating-car travel time data are used. Compare the average travel times to the travel times output by VISSIM. If there are significant differences in the travel times, changes to the speed distributions in VISSIM can be made until the travel times are similar.

APPENDIX B

Crash-Reporting Process

POLICE CRASH REPORT DOCUMENTS

TEXAS PEACE OFFICER'S ACCIDENT REPORT ST-3 (Eff. 9/1/01)   MAIL TO: ACCIDENT RECORDS, TEXAS DEPARTMENT OF PUBLIC SAFETY, PO BOX 4087, AUSTIN, TX 78773-035)

PLACE WHERE ACCIDENT OCCURRED   LOC. ________

COUNTY ________ CITY OR TOWN ________

IF ACCIDENT WAS OUTSIDE CITY LIMITS, INDICATE DISTANCE FROM NEAREST TOWN ________ MILES NORTH S E W OF ________ SHOW ONLY IF INSIDE CITY LIMITS / CITY OR TOWN

DO NOT WRITE IN THIS SPACE — LOC. ____ CODE ____ SEVERITY ____ FAT. REC. ____ DR. REC. ____ — DPS NO.

ROAD ON WHICH ACCIDENT OCCURRED ________ BLOCK NUMBER / STREET OR ROAD NAME / ROUTE NUMBER OR STREET CODE — CONSTR. ZONE ☐ YES ☐ NO SPEED LIMIT ____

INTERSECTING STREET OR RR X'ING NUMBER ________ BLOCK NUMBER / STREET OR ROAD NAME / ROUTE NUMBER OR STREET CODE — CONSTR. ZONE ☐ YES ☐ NO SPEED LIMIT ____

NOT AT INTERSECTION ________ ☐ FT. ☐ MI. ☐ N ☐ S ☐ E ☐ W OF ________ SHOW MILEPOST OR NEAREST INTERSECTING NUMBERED HIGHWAY. IF NONE, SHOW NEAREST INTERSECTING STREET OR REFERENCE POINT.

DATE OF ACCIDENT ________ 20____ DAY OF WEEK ________ HOUR ____ ☐ A.M. ☐ P.M. IF EXACTLY NOON OR MIDNIGHT, SO STATE

UNIT NO. 1 - MOTOR VEHICLE   VEHICLE IDENT. NO. ________   IF BODY STYLE = VAN OR BUS, INDICATE SEATING CAPACITY ____

YEAR MODEL ____ COLOR & MAKE ____ MODEL NAME ____ BODY STYLE ____ LICENSE PLATE ____ YEAR / STATE / NUMBER

DRIVER'S NAME ________ LAST / FIRST / MIDDLE / ADDRESS (STREET, CITY, STATE, ZIP)   PHONE NUMBER ____

DRIVER'S LICENSE ________ STATE / NUMBER / CLASS/TYPE   DOB ____ MO DAY YEAR   RACE ____ SEX ____ OCCUPATION ____

SPECIMEN TAKEN (ALCOHOL/DRUG ANALYSIS) 1-BREATH 2-BLOOD 3-OTHER 4-NONE 5-REFUSED ☐ ALCOHOL/DRUG ANALYSIS RESULT ____   PEACE OFFICER, EMS DRIVER, FIRE FIGHTER ON EMERGENCY? ☐ YES ☐ NO

LESSEE ☐ OWNER ☐ ________ NAME (ALWAYS SHOW LESSEE IF LEASED, OTHERWISE SHOW OWNER) / ADDRESS (STREET, CITY, STATE, ZIP)

LIABILITY INSURANCE ☐ YES ☐ NO ________ INSURANCE COMPANY NAME / POLICY NUMBER   VEHICLE DAMAGE RATING ____

UNIT NO. 2 - MOTOR VEHICLE ☐ TRAIN ☐ PEDALCYCLIST ☐ TOWED ☐ PEDESTRIAN ☐ OTHER ☐   VEHICLE IDENT. NO. ________   IF BODY STYLE = VAN OR BUS, INDICATE SEATING CAPACITY ____

YEAR MODEL ____ COLOR & MAKE ____ MODEL NAME ____ BODY STYLE ____ LICENSE PLATE ____ YEAR / STATE / NUMBER

DRIVER'S NAME ________ LAST / FIRST / MIDDLE / ADDRESS (STREET, CITY, STATE, ZIP)   PHONE NUMBER ____

DRIVER'S LICENSE ________ STATE / NUMBER / CLASS/TYPE   DOB ____ MO DAY YEAR   RACE ____ SEX ____ OCCUPATION ____

SPECIMEN TAKEN (ALCOHOL/DRUG ANALYSIS) 1-BREATH 2-BLOOD 3-OTHER 4-NONE 5-REFUSED ☐ ALCOHOL/DRUG ANALYSIS RESULT ____   PEACE OFFICER, EMS DRIVER, FIRE FIGHTER ON EMERGENCY? ☐ YES ☐ NO

LESSEE ☐ OWNER ☐ ________ NAME (ALWAYS SHOW LESSEE IF LEASED, OTHERWISE SHOW OWNER) / ADDRESS (STREET, CITY, STATE, ZIP)

LIABILITY INSURANCE ☐ YES ☐ NO ________ INSURANCE COMPANY NAME / POLICY NUMBER   VEHICLE DAMAGE RATING ____

DAMAGE TO PROPERTY OTHER THAN VEHICLES

________ OBJECT / NAME AND ADDRESS (STREET, CITY, STATE, ZIP) OF OWNER / FEET FROM CURB / $ ____ DAMAGE ESTIMATE

LIGHT CONDITION ☐	WEATHER ☐☐		SURFACE CONDITION ☐	TYPE ROAD SURFACE ☐	DESCRIBE ROAD CONDITIONS (INVESTIGATOR'S OPINION)
1-DAYLIGHT	1-CLEAR/CLOUDY	6-SMOKE	1-DRY	1-BLACKTOP	
2-DAWN	2-RAINING	7-SLEETING	2-WET	2-CONCRETE	
3-DARK-NOT LIGHTED	3-SNOWING	8-HIGH WINDS	3-MUDDY	3-GRAVEL	
4-DARK-LIGHTED	4-FOG	9-OTHER	4-SNOWY/ICY	4-SHELL	
5-DUSK	5-BLOWING DUST		5-OTHER ____	5-DIRT	
				6-OTHER ____	

IN YOUR OPINION, DID THIS ACCIDENT RESULT IN AT LEAST $1,000.00 DAMAGE TO ANY ONE PERSON'S PROPERTY? ☐ YES ☐ NO

CHARGES FILED

NAME ________ CHARGE ________ CITATION NUMBER ____

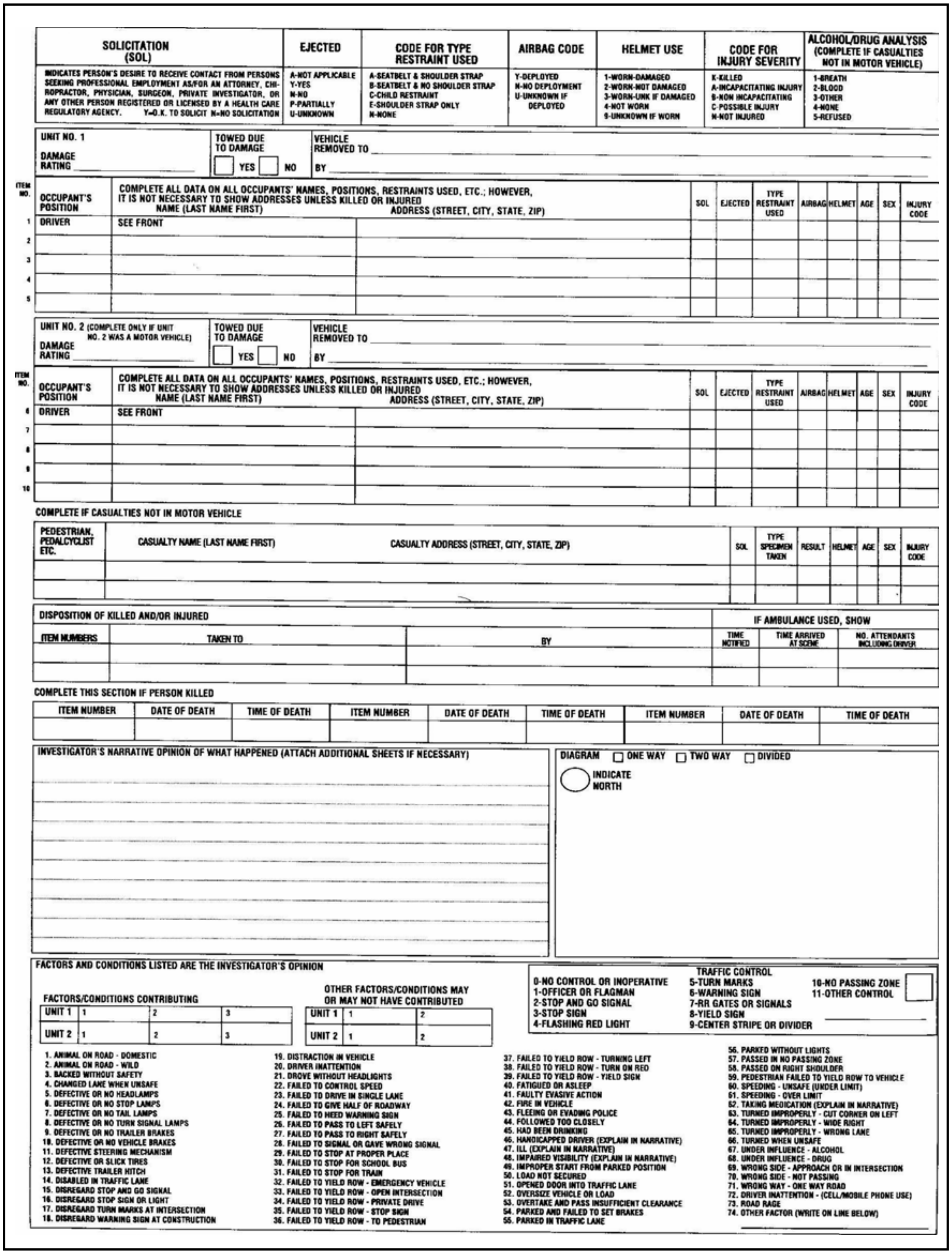
NAME ________ CHARGE ________ CITATION NUMBER ____

TIME NOTIFIED OF ACCIDENT ________ M DATE / HOUR   HOW ________   TIME ARRIVED AT SCENE OF ACCIDENT ________ M DATE / HOUR

TYPED OR PRINTED NAME OF INVESTIGATOR ________ DATE REPORT MADE ________ IS REPORT COMPLETE ☐ YES ☐ NO

SIGNATURE OF INVESTIGATOR ________ ID NO. ____ DEPARTMENT ________ DIST/AREA ____

Figure B-1. Page 1 of a ST-3, Police Crash Report.



SOLICITATION (SOL)	EJECTED	CODE FOR TYPE RESTRAINT USED	AIRBAG CODE	HELMET USE	CODE FOR INJURY SEVERITY	ALCOHOL/DRUG ANALYSIS (COMPLETE IF CASUALTIES NOT IN MOTOR VEHICLE)
INDICATES PERSON'S DESIRE TO RECEIVE CONTACT FROM PERSONS SEEKING PROFESSIONAL EMPLOYMENT AS/FOR AN ATTORNEY, CHIROPRACTOR, PHYSICIAN, SURGEON, PRIVATE INVESTIGATOR, OR ANY OTHER PERSON REGISTERED OR LICENSED BY A HEALTH CARE REGULATORY AGENCY. Y=O.K. TO SOLICIT N=NO SOLICITATION	A-NOT APPLICABLE Y-YES N-NO P-PARTIALLY U-UNKNOWN	A-SEATBELT & SHOULDER STRAP B-SEATBELT & NO SHOULDER STRAP C-CHILD RESTRAINT E-SHOULDER STRAP ONLY N-NONE	Y-DEPLOYED N-NO DEPLOYMENT U-UNKNOWN IF DEPLOYED	1-WORN-DAMAGED 2-WORN-NOT DAMAGED 3-WORN-UNK IF DAMAGED 4-NOT WORN 9-UNKNOWN IF WORN	K-KILLED A-INCAPACITATING INJURY B-NON INCAPACITATING C-POSSIBLE INJURY N-NOT INJURED	1-BREATH 2-BLOOD 3-OTHER 4-NONE 5-REFUSED

UNIT NO. 1 DAMAGE RATING ______ TOWED DUE TO DAMAGE [ ] YES [ ] NO VEHICLE REMOVED TO ______ BY ______

ITEM NO.	OCCUPANT'S POSITION	COMPLETE ALL DATA ON ALL OCCUPANTS' NAMES, POSITIONS, RESTRAINTS USED, ETC.; HOWEVER, IT IS NOT NECESSARY TO SHOW ADDRESSES UNLESS KILLED OR INJURED NAME (LAST NAME FIRST)	ADDRESS (STREET, CITY, STATE, ZIP)	SOL	EJECTED	TYPE RESTRAINT USED	AIRBAG	HELMET	AGE	SEX	INJURY CODE
1	DRIVER	SEE FRONT									
2											
3											
4											
5											

UNIT NO. 2 (COMPLETE ONLY IF UNIT NO. 2 WAS A MOTOR VEHICLE) DAMAGE RATING ______ TOWED DUE TO DAMAGE [ ] YES [ ] NO VEHICLE REMOVED TO ______ BY ______

ITEM NO.	OCCUPANT'S POSITION	COMPLETE ALL DATA ON ALL OCCUPANTS' NAMES, POSITIONS, RESTRAINTS USED, ETC.; HOWEVER, IT IS NOT NECESSARY TO SHOW ADDRESSES UNLESS KILLED OR INJURED NAME (LAST NAME FIRST)	ADDRESS (STREET, CITY, STATE, ZIP)	SOL	EJECTED	TYPE RESTRAINT USED	AIRBAG	HELMET	AGE	SEX	INJURY CODE
6	DRIVER	SEE FRONT									
7											
8											
9											
10											

COMPLETE IF CASUALTIES NOT IN MOTOR VEHICLE

PEDESTRIAN, PEDALCYCLIST ETC.	CASUALTY NAME (LAST NAME FIRST)	CASUALTY ADDRESS (STREET, CITY, STATE, ZIP)	SOL	TYPE SPECIMEN TAKEN	RESULT	HELMET	AGE	SEX	INJURY CODE

DISPOSITION OF KILLED AND/OR INJURED

ITEM NUMBERS	TAKEN TO	BY	IF AMBULANCE USED, SHOW: TIME NOTIFIED	TIME ARRIVED AT SCENE	NO. ATTENDANTS INCLUDING DRIVER

COMPLETE THIS SECTION IF PERSON KILLED

ITEM NUMBER	DATE OF DEATH	TIME OF DEATH	ITEM NUMBER	DATE OF DEATH	TIME OF DEATH	ITEM NUMBER	DATE OF DEATH	TIME OF DEATH

INVESTIGATOR'S NARRATIVE OPINION OF WHAT HAPPENED (ATTACH ADDITIONAL SHEETS IF NECESSARY)

DIAGRAM [ ] ONE WAY [ ] TWO WAY [ ] DIVIDED

INDICATE NORTH

FACTORS AND CONDITIONS LISTED ARE THE INVESTIGATOR'S OPINION

FACTORS/CONDITIONS CONTRIBUTING

UNIT 1	1	2	3
UNIT 2	1	2	3

OTHER FACTORS/CONDITIONS MAY OR MAY NOT HAVE CONTRIBUTED

UNIT 1	1	2
UNIT 2	1	2

TRAFFIC CONTROL

0-NO CONTROL OR INOPERATIVE
1-OFFICER OR FLAGMAN
2-STOP AND GO SIGNAL
3-STOP SIGN
4-FLASHING RED LIGHT
5-TURN MARKS
6-WARNING SIGN
7-RR GATES OR SIGNALS
8-YIELD SIGN
9-CENTER STRIPE OR DIVIDER
10-NO PASSING ZONE
11-OTHER CONTROL

1. ANIMAL ON ROAD - DOMESTIC
2. ANIMAL ON ROAD - WILD
3. BACKED WITHOUT SAFETY
4. CHANGED LANE WHEN UNSAFE
5. DEFECTIVE OR NO HEADLAMPS
6. DEFECTIVE OR NO STOP LAMPS
7. DEFECTIVE OR NO TAIL LAMPS
8. DEFECTIVE OR NO TURN SIGNAL LAMPS
9. DEFECTIVE OR NO TRAILER BRAKES
10. DEFECTIVE OR NO VEHICLE BRAKES
11. DEFECTIVE STEERING MECHANISM
12. DEFECTIVE OR SLICK TIRES
13. DEFECTIVE TRAILER HITCH
14. DISABLED IN TRAFFIC LANE
15. DISREGARD STOP AND GO SIGNAL
16. DISREGARD STOP SIGN OR LIGHT
17. DISREGARD TURN MARKS AT INTERSECTION
18. DISREGARD WARNING SIGN AT CONSTRUCTION
19. DISTRACTION IN VEHICLE
20. DRIVER INATTENTION
21. DROVE WITHOUT HEADLIGHTS
22. FAILED TO CONTROL SPEED
23. FAILED TO DRIVE IN SINGLE LANE
24. FAILED TO GIVE HALF OF ROADWAY
25. FAILED TO HEED WARNING SIGN
26. FAILED TO PASS TO LEFT SAFELY
27. FAILED TO PASS TO RIGHT SAFELY
28. FAILED TO SIGNAL OR GAVE WRONG SIGNAL
29. FAILED TO STOP AT PROPER PLACE
30. FAILED TO STOP FOR SCHOOL BUS
31. FAILED TO STOP FOR TRAIN
32. FAILED TO YIELD ROW - EMERGENCY VEHICLE
33. FAILED TO YIELD ROW - OPEN INTERSECTION
34. FAILED TO YIELD ROW - PRIVATE DRIVE
35. FAILED TO YIELD ROW - STOP SIGN
36. FAILED TO YIELD ROW - TO PEDESTRIAN
37. FAILED TO YIELD ROW - TURNING LEFT
38. FAILED TO YIELD ROW - TURN ON RED
39. FAILED TO YIELD ROW - YIELD SIGN
40. FATIGUED OR ASLEEP
41. FAULTY EVASIVE ACTION
42. FIRE IN VEHICLE
43. FLEEING OR EVADING POLICE
44. FOLLOWED TOO CLOSELY
45. HAD BEEN DRINKING
46. HANDICAPPED DRIVER (EXPLAIN IN NARRATIVE)
47. ILL (EXPLAIN IN NARRATIVE)
48. IMPAIRED VISIBILITY (EXPLAIN IN NARRATIVE)
49. IMPROPER START FROM PARKED POSITION
50. LOAD NOT SECURED
51. OPENED DOOR INTO TRAFFIC LANE
52. OVERSIZE VEHICLE OR LOAD
53. OVERTAKE AND PASS INSUFFICIENT CLEARANCE
54. PARKED AND FAILED TO SET BRAKES
55. PARKED IN TRAFFIC LANE
56. PARKED WITHOUT LIGHTS
57. PASSED IN NO PASSING ZONE
58. PASSED ON RIGHT SHOULDER
59. PEDESTRIAN FAILED TO YIELD ROW TO VEHICLE
60. SPEEDING - UNSAFE (UNDER LIMIT)
61. SPEEDING - OVER LIMIT
62. TAKING MEDICATION (EXPLAIN IN NARRATIVE)
63. TURNED IMPROPERLY - CUT CORNER ON LEFT
64. TURNED IMPROPERLY - WIDE RIGHT
65. TURNED IMPROPERLY - WRONG LANE
66. TURNED WHEN UNSAFE
67. UNDER INFLUENCE - ALCOHOL
68. UNDER INFLUENCE - DRUG
69. WRONG SIDE - APPROACH OR IN INTERSECTION
70. WRONG SIDE - NOT PASSING
71. WRONG WAY - ONE WAY ROAD
72. DRIVER INATTENTION - (CELL/MOBILE PHONE USE)
73. ROAD RAGE
74. OTHER FACTOR (WRITE ON LINE BELOW)

Figure B-2. Page 2 of a ST-3, Police Crash Report.

DRIVER'S CONFIDENTIAL ACCIDENT REPORT
FORM ST-2 (Rev. 1/1/90)

PLEASE READ INSTRUCTIONS ON REVERSE SIDE

TEXAS DEPARTMENT OF PUBLIC SAFETY

LOCATION

PLACE WHERE ACCIDENT OCCURRED COUNTY ______ CITY OR TOWN ______

IF ACCIDENT WAS OUTSIDE CITY LIMITS, INDICATE DISTANCE FROM NEAREST TOWN ______ MILES ☐ NORTH ☐ S ☐ E ☐ W OF ______ CITY OR TOWN

ROAD ON WHICH ACCIDENT OCCURRED ______ BLOCK NUMBER ______ STREET OR ROAD NAME ______ ROUTE NUMBER

CONSTR. ZONE ☐ YES ☐ NO SPEED LIMIT ______

COMPLETE ONE
- INTERSECTING STREET ______ BLOCK NUMBER ______ STREET OR ROAD NAME ______ ROUTE NUMBER — CONSTR. ZONE ☐ YES ☐ NO SPEED LIMIT ______
- NOT AT INTERSECTION ______ FEET ☐ NORTH ☐ S ☐ E ☐ W OF ______ SHOW MILEPOST OR NEAREST INTERSECTING NUMBERED HIGHWAY. IF URBAN, SHOW NEAREST INTERSECTING STREET OR REFERENCE POINT.

DO NOT WRITE IN THIS SPACE

DPS NO. ______
LOC ______
CODE ______
SEVERITY ______
TYPE ______

TIME

DATE OF ACCIDENT ______ 19 ______ DAY OF WEEK ______ HOUR ______ ☐ A.M. ☐ P.M. IF EXACTLY NOON OR MIDNIGHT, SO STATE

VEHICLES

YOUR VEHICLE

YEAR MODEL ______ MAKE ______ (FORD, CHEV., ETC.) TYPE OF VEHICLE ______ (SEDAN, PICKUP, TRUCK, ETC.) LICENSE PLATE ______ YEAR ______ STATE ______ NUMBER

OWNER ______ NAME ______ MAIL ADDRESS ______ CITY AND STATE ______ ZIP

DRIVER ______ NAME ______ MAIL ADDRESS ______ CITY AND STATE ______ ZIP

DRIVER'S LICENSE ______ STATE ______ NUMBER DATE OF BIRTH ______ SEX ______ RACE ______

APPROX. COST TO REPAIR YOUR VEHICLE $ ______

FOR OTHER VEHICLES USE ANOTHER FORM

TOTAL VEHICLES INVOLVED

OTHER UNIT - MOTOR VEHICLE, TRAIN, PEDESTRIAN, BICYCLIST, ETC. - INDICATE WHICH (COMPLETE INFORMATION YOU HAVE AVAILABLE - IF UNKNOWN, MARK "NOT KNOWN") ______

YEAR MODEL ______ MAKE ______ (FORD, CHEV., ETC.) TYPE OF VEHICLE ______ (SEDAN, PICKUP, TRUCK, ETC.) LICENSE PLATE ______ YEAR ______ STATE ______ NUMBER

OWNER ______ NAME ______ MAIL ADDRESS ______ CITY AND STATE ______ ZIP

DRIVER ______ NAME ______ MAIL ADDRESS ______ CITY AND STATE ______ ZIP

APPROX. COST TO REPAIR THIS VEHICLE $ ______

DAMAGE TO PROPERTY OTHER THAN VEHICLES ______ NAME OBJECT, SHOW OWNERSHIP, AND STATE NATURE OF DAMAGE

APPROXIMATE COST TO REPAIR $ ______

CASUALTIES

NO. 1 (SHOW ONLY PEDESTRIANS OR PERSONS INJURED IN YOUR VEHICLE)

NAME ______ ADDRESS ______

AGE ______ SEX ______ RACE ______ WAS PERSON KILLED? ______ DATE OF DEATH ______

DESCRIBE INJURY ______

☐ DRIVER ☐ PASSENGER ☐ PEDESTRIAN ☐ RIGHT FRONT ☐ RIGHT REAR ☐ CENTER REAR ☐ LEFT REAR

SEAT BELT ☐ USED ☐ NOT USED

NO. 2

NAME ______ ADDRESS ______

AGE ______ SEX ______ RACE ______ WAS PERSON KILLED? ______ DATE OF DEATH ______

DESCRIBE INJURY ______

☐ DRIVER ☐ PASSENGER ☐ PEDESTRIAN ☐ RIGHT FRONT ☐ RIGHT REAR ☐ CENTER REAR ☐ LEFT REAR

SEAT BELT ☐ USED ☐ NOT USED

STATE BRIEFLY WHAT HAPPENED (IF SPACE IS INSUFFICIENT CONTINUE ON ANOTHER PAGE)

★ DRIVER'S SIGNATURE ______ DATE OF REPORT ______

IMPORTANT! COMPLETE REQUIRED INSURANCE INFORMATION ON OTHER SIDE

Figure B-3. Page 1 of a ST-2, DPS "Blue Form."

PLEASE READ ALL INSTRUCTIONS CAREFULLY

THIS FORM CONTAINS TWO SEPARATE REPORTS WHICH WILL BE DESTROYED AFTER COMPLETION OF ALL PROCESSING

The driver of a motor vehicle involved in an accident not investigated by a law enforcement officer and resulting in injury to or death of any person, or damage to the property of any one person, including himself, to an apparent extent of at least Five Hundred Dollars ($500), shall within ten (10) days after such accident complete and forward these reports in accordance with the instructions below. These reports are not required when an accident is investigated by a law enforcement officer unless specifically requested by authority of Section 4, Texas Motor Vehicle Safety-Responsibility Act (Article 6701h, Vernon's Texas Civil Statutes).

INSTRUCTIONS FOR COMPLETING DRIVER'S CONFIDENTIAL ACCIDENT REPORT (FORM ST-2)
(On other side of this form)

NOTE: The Driver's Confidential Accident Report (Form ST-2) is classified by law as privileged and for confidential use in accident prevention purposes.

1. The report on the other side of this sheet should be prepared and signed by the driver; however, if the driver is unable to make the report for some valid reason, the report may be submitted by another person with a notation as to the reason the driver could not report.

2. Print all names and addresses. Include sufficient information for "Location" and "Time" so that exact date and place of accident may be determined. Answer all questions to the best of your knowledge. If unable to answer any question, mark "not known."

3. If the "other unit" is a pedestrian, bicycle, train or other non-motor vehicle, please specify and show the name of pedestrian, bicyclist, etc. on line labeled "Driver."

4. If accident involved a fixed object, describe it fully, show its exact location and state whether it was protected by flags, painting and/or lights.

5. The narrative description of the accident should contain a brief statement of the facts regarding the accident. If additional space is needed, use a full size sheet of paper for continuation.

6. An accurate original signed report will avoid the necessity for a supplemental report.

TEXAS MOTOR VEHICLE ACCIDENT INSURANCE INFORMATION (FORM SR-21) Rev. 4-88

IMPORTANT

Note: Under certain conditions, Section 5 of the Texas Motor Vehicle Safety-Responsibility Act (V.T.C.S. 6701h) requires suspension of driver's license, registration receipts and license plates of uninsured motorists involved in motor vehicle accidents resulting in bodily injury or death, or damages to the property of any one person of at least $1,000.00. The Accident Insurance Information (Form SR-21) is a public document.

1. This report may be prepared and signed by **either** the driver or owner of the involved vehicle.

2. Accurate, complete reporting of at least minimum liability insurance coverage will avoid additional correspondence and prevent possible suspension of your driving and registration privileges.

3. If garage estimates are attached to non-injury accidents, processing will be expedited.

DID YOU HAVE AT LEAST $20,000/40,000 BODILY INJURY AND $15,000 PROPERTY DAMAGE LIABILITY INSURANCE IN EFFECT ON THE DATE OF THE ACCIDENT? ☐ YES ☐ NO

If the above is answered "Yes" answer all the items in the box below.

Date of Accident ______ Place of Accident ______ City or Town ______ County

Make of Vehicle Involved in Accident ______ Year ______ Type ______ Vehicle Identification No. ______

______ Name of Your Liability Insurance Co. (Not the Agent)

Owner's Name ______

Owner's Address ______

Policy No. ______

Driver's Name ______

______ Usual Signature ☐ Owner ☐ Driver

Driver's Address ______

If your vehicle was operating under Texas Railroad Commission Carrier Authority, give No. ______

When completed, mail this form to: STATISTICAL SERVICES BUREAU
TEXAS DEPARTMENT OF PUBLIC SAFETY
BOX 4087. AUSTIN. TEXAS 78773-0001

Figure B-4. Page 2 of a ST-2, DPS "Blue Form."

OUTLINE OF THE CRASH-REPORTING PROCESS

1. The police file a report (a blank version of the most recent format of a police crash report, ST-3, for the State of Texas is shown in Figures B-1 and B-2).

2. Local Records
   a) Hard copies are kept on file for approximately two to five years (three years for the College Station Police Department; see Figure B-5).
   b) Depending on the size of the police department and the internal desires of the department to computerize their crash-reporting system, some departments will code some of the information from the crash reports into their own internal database.

3. The report is shipped within approximately 10 days to the ARB of the DPS. The sending of the records may vary based on the severity of the crash, the investigation required, any coding and/or logging filed within the local police department, and any backlogs in the overall process at that department.

4. The ARB receives the crash reports directly from the police department through the federal mail system.
   a) In 1997, the DPS began to improve the antiquated crash report filing process. Currently, DPS and TxDOT are combining their efforts to create and fund a new, more automated crash-reporting system: the Crash Records Information System. Ms. Cathy Cioffi is the project manager (Figures B-6 and B-7 are a copy of a CRIS newsletter).

5. The records are processed in an assembly line fashion, with specific people focusing on particular sections.
   a) The initial decision is made about whether or not to code a crash to a particular person's driving history (i.e., rear-end = yes, hitting a tree while swerving from an animal = no).
   b) The files are then sorted for further coding/processing.
      i. Before July 1995, all crashes were coded. Not all crashes are reported. Hence, only reported crashes may be coded, and this limitation should be expressed and understood in any study.

College Station Police Department
Texas Accidents

ID	K1	C2	C3	C4	C5	C6	C7	C8
1	01/07/1998	1300	900	TEXAS	WALTON DR	North	Clear	Possible Injury
2	01/14/1998	1540	700	TEXAS	WALTON DR	North	Clear	Non-Injury
3	01/17/1998	0834	0	TEXAS	BRENTWOOD DR	*missing*	Clear	Non-Incapacitating
4	01/18/1998	1742	0	TEXAS	VALLEY VIEW DR-CS	*missing*	Clear	Non-Injury
5	01/19/1998	1826	1500	TEXAS	MILLIFF RD	South	Clear	Non-Injury
6	01/22/1998	2238	800	TEXAS	UNIVERSITY DR	South	Clear	Non-Injury
7	01/23/1998	2120	0	TEXAS	RICHARDS ST	*missing*	Clear	Non-Injury
8	01/23/1998	2310	700	TEXAS	LIVE OAK ST-CS	South	Clear	Non-Injury
9	01/23/1998	1714	700	TEXAS	LIVE OAK ST-CS	South	Clear	Possible Injury
10	01/28/1998	1655	0	TEXAS	GEORGE BUSH DR	*missing*	Clear	Non-Injury
11	01/29/1998	1620	0	TEXAS	HARVEY MITCHELL PW S	*missing*	Clear	Possible Injury
12	01/30/1998	1226	900	TEXAS	LINCOLN AV	South	Clear	Non-Injury
13	01/30/1998	1015	1300	TEXAS	MOSS ST-CS	North	Clear	Non-Injury
14	02/05/1998	0641	1000	TEXAS	*missing*	*missing*	Clear	Non-Injury
15	02/06/1998	1735	1000	TEXAS	WALTON DR	South	Clear	Non-Injury
16	02/08/1998	1438	1300	TEXAS	GILCHRIST AV	*missing*	Clear	Possible Injury
17	02/10/1998	1410	1050	TEXAS	WALTON DR	*missing*	Clear	Non-Incapacitating
18	02/16/1998	0958	1500	TEXAS	MILLIFF RD	*missing*	Raining	Non-Injury
19	02/18/1998	1440	1000	TEXAS	WALTON DR	South	Raining	Non-Incapacitating
20	02/19/1998	2220	500	TEXAS	UNIVERSITY DR	*missing*	Clear	Non-Injury
21	02/19/1998	2100	500	TEXAS	UNIVERSITY DR	*missing*	Clear	Non-Injury
22	02/23/1998	0856	700	TEXAS	UNIVERSITY DR	South	Clear	Possible Injury
23	02/25/1998	1335	700	TEXAS	LONE STAR DR	South	Clear	Non-Injury
24	02/27/1998	1615	800	TEXAS	LIVE OAK ST-CS	South	Clear	Non-Injury
25	02/28/1998	1430	1080	TEXAS	WALTON DR	*missing*	Clear	Non-Injury
26	02/28/1998	2202	700	TEXAS	LIVE OAK ST-CS	South	Clear	Non-Injury
27	03/03/1998	0752	1400	TEXAS	GEORGE BUSH DR	North	Clear	Non-Injury
28	03/05/1998	2130	800	TEXAS	LIVE OAK ST-CS	*missing*	Clear	Non-Injury
29	03/06/1998	2257	500	TEXAS	UNIVERSITY DR	*missing*	Clear	Incapacitating
30	03/06/1998	1509	0	TEXAS	REDMOND DR	*missing*	Clear	Non-Injury
31	03/07/1998	1629	600	TEXAS	LIVE OAK ST-CS	South	Clear	Possible Injury
32	03/07/1998	2140	1400	TEXAS	GEORGE BUSH DR	South	Clear	Non-Injury
33	03/09/1998	1411	500	TEXAS	UNIVERSITY DR	South	Clear	Non-Incapacitating
34	03/12/1998	2120	700	TEXAS	*missing*	*missing*	Raining	Non-Injury
35	03/12/1998	2158	700	TEXAS	UNIVERSITY DR	South	Raining	Non-Injury
36	03/13/1998	1310	1500	TEXAS	HARVEY	North	Clear	Possible Injury
37	03/14/1998	1320	1000	TEXAS	WALTON DR	South	Raining	Non-Injury
38	03/16/1998	1229	1500	TEXAS	REDMOND DR	South	Clear	Possible Injury
39	03/18/1998	1239	1000	TEXAS	WALTON DR	South	Clear	Possible Injury
40	03/21/1998	0112	1000	TEXAS	WALTON DR	*missing*	Clear	Possible Injury
41	03/24/1998	1135	500	TEXAS	UNIVERSITY DR	*missing*	Clear	Non-Injury
42	03/25/1998	2303	1400	TEXAS	GEORGE BUSH DR	*missing*	Clear	Possible Injury
43	03/25/1998	1705	1500	TEXAS	HARVEY	North	Clear	Non-Injury

Date Printed May 20, 2002 10:09:04 AM

Page 1 of 1

Figure B-5. College Station Police Department (CSPD) Crash Data File.

CRIS Project Newsletter

Volume 1, Issue 1

What is CRIS?

Crash Records Information System

The crash records information system (CRIS) project is a joint initiative between the Department of Public Safety (DPS) and the Texas Department of Transportation (TxDOT). The vision of the project is to implement a new crash records information system that will provide enhanced efficiencies to capture, manage and disseminate timely and accurate data to parties who need it to improve the safety of the Texas roadways.

Accident data is used to evaluate the effectiveness of safety programs and obtain funding to support traffic safety. This data is also critical for state and local transportation project planning and prioritization, highway and railroad crossing safety evaluation, identification of target areas for enhanced law enforcement, and for traffic safety studies.

The system in use today was designed in the 1970's using technologies available at that time that do not meet the needs of DPS, TxDOT or other local and state agencies in 2002. The result is a system that is manually intensive and untimely in it's reporting capabilities.

The CRIS Project includes the redesign of the current accident /crash records system resulting in the creation of a new crash records information system. This may include designing linkages to other components of the traffic records system and other systems.

The CRIS project is utilizing the DPS Concurrent Engineering Methodology (CEM) to manage and document the project. A steering committee comprised of DPS and TxDOT stakeholders provide guidance. Sponsors for the project are Frank Elder, Assistant Chief-Driver License Division, Carol Rawson, Deputy Director-Traffic Operations and Bob Burroughs, Major-Traffic Law Enforcement.

CRIS Project Steering Committee

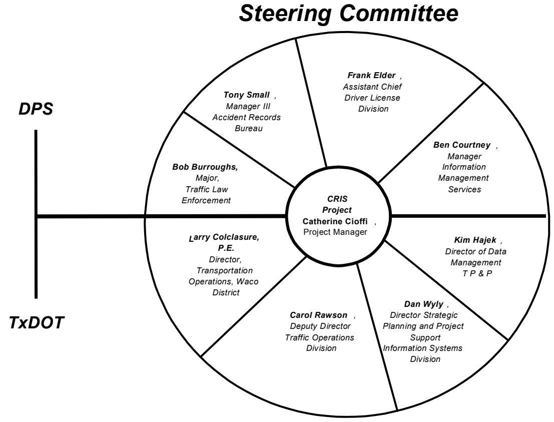
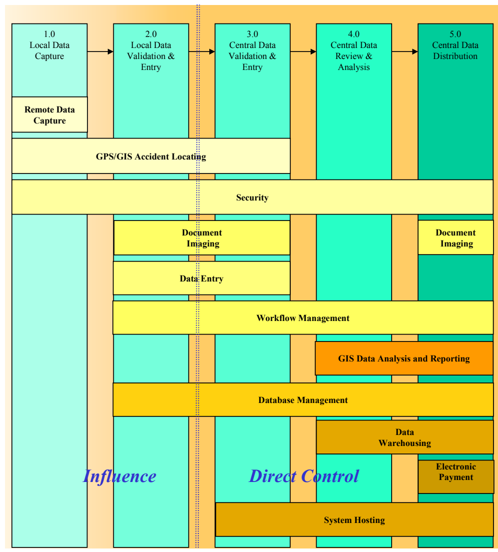


Figure B-6. Page 1 of a Crash Records Information System (CRIS) Newsletter.

Currently, we have a vendor conducting a Study & Recommend assisting the CRIS Steering Committee in making a solution approach decision. The vendor will deliver a Findings and Recommendation Report in August that will include a recommended solution approach and a cost benefit analysis.

The project will take a phased approach to implementation. A Request for Offer (RFO) for the next phase of the project is expected to go out by the end of the 4th quarter 2002. The project is expected to move into the design and implementation phase by the end of the 1st quarter 2003.

The five CRIS process areas and potential technologies are graphically depicted below:



Special thanks to Rick Pearson and Tony Zamarripa of the Accident Records Bureau for their imagination and creativity in the design of the CRIS project logo.

If you are interested in receiving quarterly CRIS updates or have questions about the project, please contact:

Cathy Cioffi
CRIS Project Manager
(512) 424-5436
Catherine.cioffi@txdps.state.tx.us

Figure B-7. Page 2 of a Crash Records Information System (CRIS) Newsletter.

ii. As of July 1995, non-injury crashes that do not result in property damage of greater than $1,000 (i.e., tow-away crashes will exceed this and are the usual criteria for coding property damage only crashes) are no longer coded. Also, only injured passengers are coded. Before, all passengers were coded.

iii. Both coded and non-coded records are stored on microfilm at the same time. They are transferred to microfilm after the coding process is complete, and the records are uploaded into the DPS mainframe.

c) Files to be coded will be further classified and numbered.

i. The coding process is completed using in-house written documents.

ii. These documents will be sent to another department for input into the DPS mainframe database. CD-ROMs may be made for a particular county for use outside of the DPS.

(1) These CDs are made on request. The CDs contain the data in a data stream format. This format is impossible to read without the appropriate codebook. Furthermore, it is still difficult to read without the proper formatting software. Texas Transportation Institute uses a statistical analysis software package, called SAS. This program converts the data stream into a user-friendlier format that may be imported into spreadsheet software such as Microsoft Excel.

(2) The format contains column headers, and virtually all of the data are in numeric coding that is fairly easy to understand by anyone who has a copy of the coding sheets.

iii. The applicable information is also coded to the driving records of the motorists involved in a crash. A crash is only coded to someone's personal driving record if he/she is at fault and/or that person received a traffic citation.

d) The coding process is filled with checks and editing.

i. A double input method is used, whereby two individuals enter the same information, and a computer compares the records to find possible errors.

ii. The computer will only allow certain ranges of information to be entered in certain fields to reduce errors. For example, some entries may only allow text while some may only allow numbers and other entries may only allow one number while others allow up to three digits.

e) Record A contains the summarized crash report information including the location, number of vehicles involved, type of crash, orientation, and other information.

f) Record B contains the driver's and the vehicle's descriptive information.

   i. This includes whether the drivers were injured, drunk, and/or considered at-fault.

   ii. The vehicle description comprises vehicle make and model information and whether a vehicle defect could be attributed to the crash.

g) Record C contains only the information for the passengers in the vehicles involved and any pedestrians, cyclists, or additional people involved (non-injured passengers are not coded, but the total number of people inside each vehicle is listed).

h) All of the records are kept in the mainframe database, and hard copies of the reports are kept on file and organized by county and date in the ARB.

   i. Paper hard copies are transferred to microfilm hard copies and held for 10 years. The records are destroyed after 10 years.

   ii. DPS has an internal seven-digit coding system for referencing within the data in the mainframe or on CD.

      (1) The DPS coding is reused at the beginning of every new 10-year period.

      (2) The seven-digit code is not used in pulling actual records from the stored microfilm filing system.

      (3) The seven-digit code is also coded with the driver's individual traffic record for referencing purposes.

i) Comments:

   i. The whole process takes approximately 18 months.

   ii. The actual milepost locations are accessed by the use of the roadway inventory logbook sheets generated by TxDOT. The logbook shows the mileposts of cross streets and important curb cuts (e.g., a fire station) along a particular roadway.

   iii. The mainframe information is updated when the coding process is complete. In particular, the ARB uses a 13-month system to assess any editing issues discovered through the data entry process and to address any additional unforeseen delays.

iv. There is another form, known as the "blue form," that may be submitted directly to DPS by individuals who were in a crash that was not reported by local law enforcement. A copy of the blue form is shown in Figure B-3. Depending on the crash location, severity, and whether there were any violations involved (i.e., hit-and-run violation), the local police department may or may not record the crash in their own database. State law puts the responsibility on the drivers involved to report the crash and not the police department. Only crashes on public roadways must be reported (e.g., parking lot crashes are not recorded) by motorists.

v. The information in the database has been used in the past to better plan police officer route scheduling to ensure timely response to crash-prone areas.

APPENDIX C

Crash Analysis Data

SUMMARY CRASH DATA FOR THE TEXAS AVENUE STUDY CORRIDOR

Tables C-1 through C-10 contain the summary of the data collected for the Texas Avenue study corridor. Some clarifying notes for all of the tables are listed below.

1. The data for 2000 include only crashes through June.
2. (*) Indicates that the exact time frame for the year in question started in July of that year and ran through June of the following year. Consequently, 1998* actually stands for the time frame of July 1998 to June of 1999.
3. The Before category covers January 1993 through December of 1994.
4. The After category covers July 1998 through June of 2000.
5. The data for 1993-95 reflect the changes in July 1995, in which the state no longer requires PDOs less than $1,000.
6. The Texas Avenue corridor category indicates the study area from roughly 0.2 miles north and south of George Bush Drive along Texas Avenue and includes crashes along George Bush Drive that are attributed to the signalized intersection.
7. Milepost 5.200 to MP 5.900 refers to the roadway section from approximately 500 feet north of George Bush Drive to 300 feet south of University Drive along Texas Avenue.
8. % Change B-C indicates the change from the before period to the construction period.
9. % Change C-A indicates the change from the construction period to the after period.
10. % Change B-A indicates the change from the before period to the after period.

Table C-1. Total Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	1,006	228	469	271
1993	220	42	98	57
1994	215	60	96	50
1995	125	40	54	25
1996	109	23	47	34
1997	116	22	62	31
1998	98	16	52	35
1999	87	20	43	25
2000	36	5	17	14
1998*	88	15	48	26
1999*	90	20	45	27
Before	435	102	194	107
Construction	264	50	127	85
After	178	35	93	53
%Change B-C	-39.3	-51.0	-34.5	-20.6
%Change C-A	-32.6	-30.0	-26.8	-37.6
%Change B-A	-59.1	-65.7	-52.1	-50.5

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-2. Total People.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	3,303	843	1,533	890
1993	740	140	345	205
1994	500	286	345	169
1995	416	143	186	82
1996	403	92	68	128
1997	319	68	181	89
1998	267	44	137	104
1999	231	58	113	70
2000	107	12	56	43
1998*	221	38	126	67
1999*	259	60	130	85
Before	1,240	426	690	374
Construction	838	175	399	280
After	480	98	256	152
%Change B-C	-32.4	-58.9	-42.2	-25.1
%Change C-A	-42.7	-44.0	-35.8	-45.7
%Change B-A	-61.3	-77.0	-62.9	-59.4

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-3. Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	2300	541	1097	636
1993	490	94	225	128
1994	500	145	229	111
1995	276	94	120	56
1996	261	57	115	85
1997	261	52	146	74
1998	232	40	121	92
1999	191	48	94	55
2000	89	11	47	35
1998*	194	35	110	58
1999*	210	49	107	66
Before	990	239	454	239
Construction	624	123	305	215
After	404	84	217	124
%Change B-C	-37.0	-48.5	-32.8	-10.0
%Change C-A	-35.3	-31.7	-28.9	-42.3
%Change B-A	-59.2	-64.9	-52.2	-48.1

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-4. Non-Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	1003	302	436	254
1993	250	46	120	77
1994	320	141	116	58
1995	140	49	66	26
1996	142	35	55	43
1997	58	16	35	15
1998	35	4	16	12
1999	40	10	19	15
2000	18	1	9	8
1998*	27	3	16	9
1999*	49	11	23	19
Before	570	187	236	135
Construction	214	52	94	65
After	76	14	39	28
%Change B-C	-62.5	-72.2	-60.2	-51.9
%Change C-A	-64.5	-73.1	-58.5	-56.9
%Change B-A	-86.7	-92.5	-83.5	-79.3

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-5. Fatalities.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	0	0	0	0
1993	0	0	0	0
1994	0	0	0	0
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
1998*	0	0	0	0
1999*	0	0	0	0
Before	0	0	0	0
Construction	0	0	0	0
After	0	0	0	0
%Change B-C	N/A	N/A	N/A	N/A
%Change C-A	N/A	N/A	N/A	N/A
%Change B-A	N/A	N/A	N/A	N/A

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-6a. Non-Injured Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	1782	425	835	496
1993	399	76	176	107
1994	421	126	187	92
1995	225	78	96	43
1996	188	40	84	62
1997	186	37	102	62
1998	167	27	88	70
1999	126	33	62	36
2000	70	8	40	24
1998*	137	24	82	40
1999*	151	33	78	48
Before	820	202	363	199
Construction	445	88	215	165
After	288	57	160	88
%Change B-C	-45.7	-56.4	-40.8	-17.1
%Change C-A	-35.3	-35.2	-25.6	-46.7
%Change B-A	-64.9	-71.8	-55.9	-55.8

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-6b. Possibly Injured Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	368	84	190	102
1993	69	16	34	19
1994	58	13	32	16
1995	37	11	19	9
1996	52	14	24	14
1997	49	6	30	10
1998	43	8	24	13
1999	48	14	23	14
2000	12	2	4	7
1998*	40	8	18	12
1999*	42	14	21	12
Before	127	29	66	35
Construction	121	22	66	33
After	82	22	39	24
%Change B-C	-4.7	-24.1	0.0	-5.7
%Change C-A	-32.2	0.0	-40.9	-27.3
%Change B-A	-35.4	-24.1	-40.9	-31.4

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-6c. Non-Incapacitated Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	130	31	61	32
1993	16	2	10	2
1994	16	6	8	2
1995	11	5	3	2
1996	19	2	6	9
1997	25	9	13	2
1998	19	5	9	6
1999	17	1	9	5
2000	7	1	3	4
1998*	17	3	10	6
1999*	17	2	8	6
Before	32	8	18	4
Construction	53	13	22	14
After	34	5	18	12
%Change B-C	65.6	62.5	22.2	250.0
%Change C-A	-35.8	-61.5	-18.2	-14.3
%Change B-A	6.3	-37.5	0.0	200.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-6d. Incapacitated Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	20	1	11	6
1993	6	0	5	0
1994	5	0	2	1
1995	3	0	2	2
1996	2	1	1	0
1997	1	0	1	0
1998	3	0	0	3
1999	0	0	0	0
2000	0	0	0	0
1998*	0	0	0	0
1999*	0	0	0	0
Before	11	0	7	1
Construction	5	0	2	3
After	0	0	0	0
%Change B-C	-54.5	N/A	-71.4	200.0
%Change C-A	-100.0	N/A	-100.0	-100.0
%Change B-A	-100.0	N/A	-100.0	-100.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-7a. Non-Injured Non-Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	703	230	294	159
1993	204	35	97	64
1994	268	124	94	43
1995	110	38	52	18
1996	94	23	38	27
1997	27	10	13	7
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
1998*	0	0	0	0
1999*	0	0	0	0
Before	472	159	191	107
Construction	119	33	51	34
After	0	0	0	0
%Change B-C	-74.8	-79.2	-73.3	-68.2
%Change C-A	-100.0	-100.0	-100.0	-100.0
%Change B-A	-100.0	-100.0	-100.0	-100.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-7b. Possibly Injured Non-Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	234	61	109	75
1993	36	10	18	10
1994	43	13	18	13
1995	24	10	10	7
1996	34	9	12	12
1997	26	5	17	7
1998	26	4	12	8
1999	31	9	16	11
2000	14	1	6	7
1998*	20	3	12	7
1999*	39	10	18	15
Before	79	23	36	23
Construction	71	15	32	23
After	59	13	30	22
%Change B-C	-10.1	-34.8	-11.1	0.0
%Change C-A	-16.9	-13.3	-6.3	-4.3
%Change B-A	-25.3	-43.5	-16.7	-4.3

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-7c. Non-Incapacitated Non-Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	56	9	27	17
1993	9	1	4	3
1994	7	3	3	1
1995	2	0	2	0
1996	14	3	5	4
1997	4	1	4	1
1998	8	0	4	3
1999	8	1	2	4
2000	4	0	3	1
1998*	7	0	4	2
1999*	9	1	4	4
Before	16	4	7	4
Construction	22	4	10	7
After	16	1	8	6
%Change B-C	37.5	0.0	42.9	75.0
%Change C-A	-27.3	-75.0	-20.0	-14.3
%Change B-A	0.0	-75.0	14.3	50.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-7d. Incapacitated Non-Drivers.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	10	2	6	3
1993	1	0	1	0
1994	2	1	1	1
1995	4	1	2	1
1996	0	0	0	0
1997	1	0	1	0
1998	1	0	0	1
1999	1	0	1	0
2000	0	0	0	0
1998*	0	0	0	0
1999*	1	0	1	0
Before	3	1	2	1
Construction	2	0	1	1
After	1	0	1	0
%Change B-C	-33.3	-100.0	-50.0	0.0
%Change C-A	-50.0	N/A	0.0	-100.0
%Change B-A	-66.7	-100.0	-50.0	-100.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

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Table C-8a. Rear-End Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	631	181	315	198
1993	137	37	68	37
1994	145	49	70	39
1995	73	32	31	17
1996	64	18	28	25
1997	69	15	39	24
1998	60	11	34	25
1999	58	17	31	18
2000	25	2	14	13
1998*	55	10	32	19
1999*	58	15	33	22
Before	282	86	138	76
Construction	162	38	81	63
After	113	25	65	41
%Change B-C	-42.6	-55.8	-41.3	-17.1
%Change C-A	-30.2	-34.2	-19.8	-34.9
%Change B-A	-59.9	-70.9	-52.9	-46.1

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-8b. Sideswipe Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	44	6	13	14
1993	17	1	1	8
1994	10	2	5	3
1995	5	2	1	0
1996	2	1	1	0
1997	1	0	0	0
1998	4	0	2	1
1999	5	0	3	2
2000	0	0	0	0
1998*	7	0	4	2
1999*	2	0	1	1
Before	27	3	6	11
Construction	3	1	1	0
After	9	0	5	3
%Change B-C	-88.9	-66.7	-83.3	-100.0
%Change C-A	200.0	-100.0	400.0	N/A
%Change B-A	-66.7	-100.0	-16.7	-72.7

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-8c. Right-Angle Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	268	25	115	48
1993	58	2	25	11
1994	49	5	17	6
1995	35	3	17	6
1996	37	1	16	8
1997	35	5	19	6
1998	28	4	13	8
1999	17	2	6	3
2000	9	3	2	0
1998*	20	4	9	4
1999*	22	4	7	2
Before	107	7	42	17
Construction	83	7	40	19
After	42	8	16	6
%Change B-C	-22.4	0.0	-4.8	11.8
%Change C-A	-49.4	14.3	-60.0	-68.4
%Change B-A	-60.7	14.3	-61.9	-64.7

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-8d. Head-On Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	9	2	5	1
1993	0	0	0	0
1994	4	2	2	0
1995	1	0	0	0
1996	0	0	0	0
1997	3	0	3	0
1998	0	0	0	0
1999	0	0	0	0
2000	1	0	0	1
1998*	0	0	0	0
1999*	1	0	0	1
Before	4	2	2	0
Construction	3	0	3	0
After	1	0	0	1
%Change B-C	-25.0	-100.0	50.0	N/A
%Change C-A	-66.7	N/A	-100.0	N/A
%Change B-A	-75.0	-100.0	-100.0	N/A

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-8e. Single-Vehicle Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	42	12	17	7
1993	3	1	2	0
1994	4	2	1	1
1995	8	2	4	1
1996	6	3	2	1
1997	7	2	1	1
1998	6	1	3	1
1999	7	1	3	2
2000	1	0	1	0
1998*	6	1	3	1
1999*	7	1	4	1
Before	7	3	3	1
Construction	12	4	2	3
After	13	2	7	2
%Change B-C	71.4	33.3	-33.3	200.0
%Change C-A	8.3	-50.0	250.0	-33.3
%Change B-A	85.7	-33.3	133.3	100.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-8f. Other Crashes.

Time Period	Texas Corridor	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
Total	12	2	4	3
1993	5	1	2	1
1994	3	0	1	1
1995	3	1	1	1
1996	0	0	0	0
1997	1	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	0	0	0	0
1998*	0	0	0	0
1999*	0	0	0	0
Before	8	1	3	2
Construction	1	0	0	0
After	0	0	0	0
%Change B-C	-87.5	-100.0	-100.0	-100.0
%Change C-A	-100.0	N/A	N/A	N/A
%Change B-A	-100.0	-100.0	-100.0	-100.0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-9. Injuries with Respect to Restraint Use for Drivers.

Time Period	Injury Category	Lap & Shoulder	Lap Only	Shoulder Only	Airbag	None
Before	Total	919	10	4	7	50
	Non-injury	773	10	1	2	34
	Possible	122	0	1	1	3
	Non-Incapacitating	20	0	1	4	7
	Incapacitating	4	0	1	0	6
After	Total	351	0	0	35	18
	Non-injury	263	0	0	13	12
	Possible	69	0	0	10	3
	Non-Incapacitating	19	0	0	12	3
	Incapacitating	0	0	0	0	0

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.

Table C-10. Crash Rates.

Time frame	Intersection of Texas Avenue & George Bush Drive	MP 5.200 to MP 5.900	Intersection of Texas Avenue & University Drive
1993	1.9	4,475	2.5
1994	2.6	4,175	2.2
1995	1.6	2,192	1.0
1996	0.9	1,908	1.4
1997	0.9	2,634	1.3
1998	0.7	2,499	1.5
1999	0.8	2,014	1.0
2000	0.4	1,321	1.0
1998*	1.2	4,554	2.1
1999*	1.5	3,823	2.0
Before	2.2	4,321	2.3
Construction	1.0	2,693	1.8
After	0.7	2,084	1.0
%Change B-C	-53.7	-37.7	-25.0
%Change C-A	-33.5	-22.6	-40.8
%Change B-A	-69.3	-51.8	-55.6

See the other notes at the beginning of this appendix to clarify any of the abbreviations or other marks that are not defined here.