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16. Abstract

This product provides usable information yielded from researching access management benefits. The product describes the findings of micro-simulation performed on real and theoretical corridors. The micro-simulation resulted in impacts that can be anticipated if certain access management techniques are implemented on arterial streets, given certain conditions. In addition, the product provides findings from crash analyses performed on case study corridors in Texas and Oklahoma. The case studies include corridors with and without raised medians, before and after raised median presence, and varying access point densities.

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INVESTIGATION OF ACCESS POINT DENSITY AND RAISED MEDIANS:

CRASH ANALYSIS AND MICRO-SIMULATION

by

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KEY FINDINGS

Crash Analysis

- Correlation exists between access point density and crash rates
    - Corridors with higher access point densities tend to have higher crash rates (crashes per million vehicle miles traveled)
- Correlation exists between presence of raised median and crash rates and severities
    - Corridors with raised medians tend to have lower crash rates
    - Corridors with raised medians tend to have less severe crashes (in terms of injuries/fatalities)
    - Corridors with raised medians tend to have fewer head-on and sideswipe crashes
- Texas Department of Public Safety crash reports provided more useful data than crash listings provided by cities
- Crash analysis requires study of injuries and fatalities
    - Some injuries and/or fatalities are caused by something other than crash (e.g., a driver may have a fatal heart attack causing a crash that is not related to access density or presence of a raised median)
- Significant percentages of crashes at signalized intersections are caused by red-light-running incidents
- 11 case studies (10 in Texas and 1 in Oklahoma)

Micro-simulation

- Three case study locations in Texas and three theoretical corridors
    - analyzed impacts of raised medians and access point density using VISSIM
- VISSIM is a valuable micro-simulation tool and is a sophisticated program with a steep learning curve for a new user. It should be noted that other software packages may be equally useful—VISSIM was investigated for this study due to the researcher's experience with this model.
- Results of the percent difference in travel time, speed, and delay varied for each corridor for the ranges of operational and geometric conditions investigated.
    - For example, on corridors with raised medians, up to a 7 mph increase in speeds on the Bryan corridor; up to a 6 mph decrease in speed along the Tyler corridor
- Investigated various traffic volume ranges and geometric conditions with the theoretical scenarios. On average, theoretical corridors experienced a 3 mph decrease in speeds (using a consistent median opening spacing of 660 feet).
- Found that more circuitous travel and increased U-turn traffic can cause the raised median treatment to have slightly longer travel times (slower speeds). However, increases in travel time, and subsequent delay, are likely offset by the reduction in the number of conflict points and increased safety provided by a raised median.
- It is important to understand that numerous operational and geometric assumptions were made to perform the micro-simulation; the authors encourage the reader to review and understand these assumptions and limitations prior to transferring results.

METHODOLOGY FOR CRASH ANALYSIS

The research team studied 11 corridors to determine 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 (TWLTSs). 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.

Researchers calculated crash rates (crashes per million vehicle miles traveled [VMT]) for each of the corridor segments studied. Crash rates were determined using average daily traffic (ADT) volumes for each corridor segment provided by state, regional, and local agencies; the distances of each corridor segment; and the numbers of crashes reported. Annual traffic volumes were available for most of the corridor segments; however, in some cases missing years' data had to be interpolated.

Case Study Summaries

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

- Texas Avenue (SH Business 6) in College Station;
- Loop 281 in Longview;
- Grant Avenue (US 385) in Odessa;
- Camp Bowie Road (US 377) in Fort Worth;
- University Drive (US 380) in McKinney;
- Preston Road (SH 289) in Plano;
- 31st Street (FM 1741) in Temple;
- Broadway (US 69) in Tyler;
- 42nd Street (SH 191) in Odessa;
- Park Boulevard in Plano; and
- 71st Street in Tulsa, Oklahoma.

Crash Study Findings

Through the crash analyses, the research team found that there is a correlation between access point densities and crash rates on the case study corridors. Table 1 presents each of the corridor segments, along with their respective crash rates and other related information.

Table 1. 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")	5.2
Loop 281, Longview, TX	20,000 – 27,000	53	Raised ("After")	4.3
US 385, Odessa, TX	9,500 – 11,700	50	Undivided ("Before")	19.6
US 385, Odessa, TX	9,500 – 11,700	50	Raised ("After")	15.4
71st Street (west), Tulsa, OK	20,000 – 24,000	27	Undivided ("Before")	3.8
71st Street (west), Tulsa, OK	28,000 – 33,000	27	Raised ("After")	2.5
71st Street (west-central), Tulsa, OK	20,000 – 21,000	20	Undivided ("Before")	3.8
71st Street (west-central), Tulsa, OK	22,000 – 37,000	20	Raised ("After")	1.8
US 380 (west), McKinney, TX	14,700 – 29,000	56	Raised	3.1
US 380 (east), McKinney, TX	13,500 – 24,000	99	Raised	7.3
US 377 (west), Fort Worth, TX	18,200 – 21,000	50	Raised	5.9
US 377 (east), Fort Worth, TX	18,200 – 21,000	110	Raised	8.8
SH 289, Plano, TX	44,000 – 53,000	30	Raised	4.2
Park Blvd (west), Plano, TX	28,000 – 37,000	10	Raised	1.7
Park Blvd (central), Plano, TX	33,000 – 36,000	39	Raised	6.6
Park Blvd (east), Plano, TX	34,000 – 35,000	16	Raised	2.2
71st Street (east-central), Tulsa, OK	27,000 – 47,000	33	Raised	3.2
71st Street (east), Tulsa, OK	25,000 – 51,000	42	Raised	5.2
FM 1741, Temple, TX	26,000 – 31,000	39	TWLTL	2.7
US 69 (north), Tyler, TX	30,000 – 39,000	38	TWLTL	8.6
US 69 (south), Tyler, TX	27,000 – 40,000	85	TWLTL	12.9
SH 191 (west), Odessa, TX	29,000 – 36,000	56	TWLTL	6.6
SH 191 (east), Odessa, TX	16,500 – 24,000	28	TWLTL	4.0

Figure 1 provides evidence of the relationship observed between access point density on arterial streets and crash rates on those streets. These data indicate that one can expect an increase in crashes per million vehicle miles traveled as the access point density on a street increases.
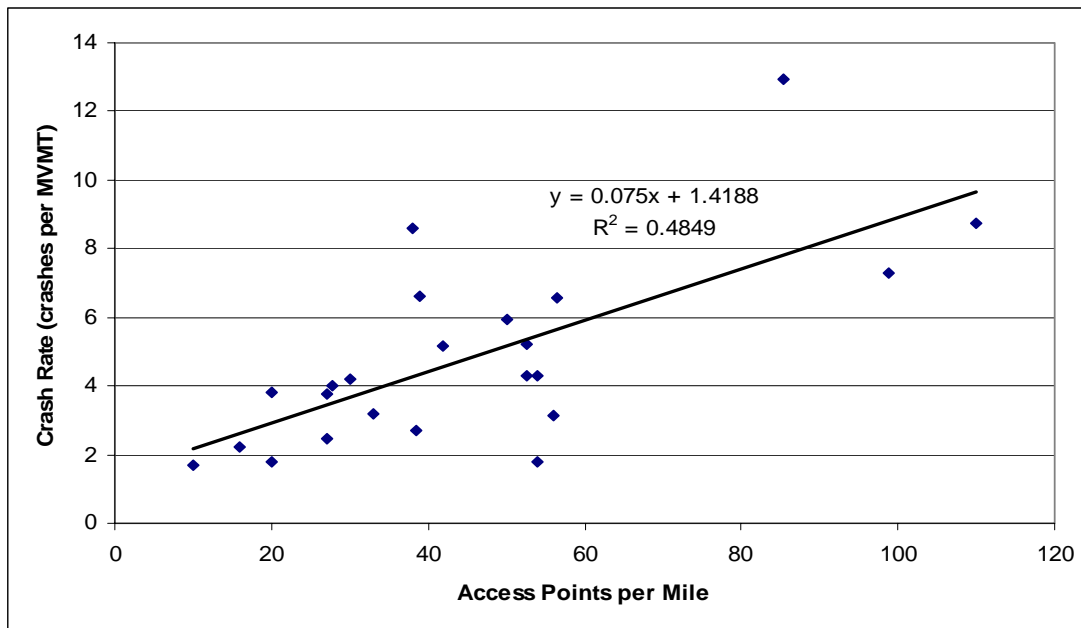

The chart shows: $y = 0.075x + 1.4188$, $R^2 = 0.4849$

Figure 1. Relationship between Access Point Density and Crash Rate.

The research also showed that there is a correlation between the presence of a raised median and crash rates, and that the presence of a raised median impacts the types and severity of crashes. Table 2 provides percentage reductions in crash rates observed after raised medians were installed on arterial streets. When raised medians are present, there are typically fewer head-on and swideswipe crashes that cause more severe injuries and property damage. Furthermore, head-on crashes appear to most often occur at intersections, involving turning vehicles and/or red-light-running.

Table 2. 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[2]	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 1).

Crash Data Availability and Reliability

This project identified the differences in quality of crash information provided by different agencies. The crash reports provided by DPS are typically very accurate, with occasional errors in block numbers indicating where the crash occurred. The diagrams on the reports help pinpoint the exact locations of the crashes for mapping purposes. Cities and ODOT provided summary crash information, usually listing the crashes, the types of impacts, and block number locations. Some city lists had numbers of injuries, while others did not. The best case studies were performed when using roads that are on Texas' state-maintained system.

The investigations of this research project demonstrate that crash data format and availability vary among agencies. The Texas Department of Transportation (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. 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.

METHODOLOGY FOR MICRO-SIMULATION ANALYSIS

The research team identified three case study locations in Texas for micro-simulation analysis. The geometric characteristics of these test corridors are shown in Table 3. Theoretical corridors were also created for further analysis. Table 4 contains the geometric characteristics for the theoretical corridors. Traffic performance (travel time, speed, and delay) was simulated before and after raised medians were implemented. In the "before" period, each corridor was a TWLTL. The conflict points, travel time, and speed differences shown in Table 3 and Table 4 are discussed in the findings below. VISSIM was used for the micro-simulation analysis.

The VISSIM Micro-simulation Model

VISSIM is a microscopic, time step, and behavior-based model developed to simulate urban traffic and transit operations *(1)*. The research team chose this micro-simulation tool for its unique ability to simulate multiple-conflict points and dynamics associated with a 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. 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 raised 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 visual 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 signalized intersection. Signal optimization was performed in SYNCHRO for this analysis and incorporated into VISSIM. Comparing the incremental benefits of various alternatives is more accurate when all the scenarios have optimized signal timing. Three micro-simulation runs were performed for each case study and each theoretical corridor, and the results were averaged for a given ADT volume and corridor.

Inputs and Coding in VISSIM

The first step in creating the micro-simulation model was gathering the necessary data. Generally, the research team obtained an aerial photograph of the case study for use as the background in VISSIM. 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 typically taken during the noon and evening peak periods. Researchers also obtained signal timing for the signalized intersections on the corridor. Finally, the team completed travel time runs using the floating-car method in both directions on the corridor during the peak hour *(2)*. 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 floating-car travel time 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 described in detail in the report titled "Estimating the Impacts of Access Management Techniques: Final Results" (3).

Table 3. Characteristics and Results of Case Study Corridors.

Case Study	Corridor Length (miles)	Signals per Mile / Access Points per Mile[1]	Median Opening Spacing (feet)[2]	Number of Lanes Each Direction[3]	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)	0.66	3.0 / 91	690 to 1,320	2	-60	18,200	21,800	-11	2 (increase)
							48,000	-38	7 (increase)
31st Street (Temple)	0.71	5.6 / 66	350 to 850	2	-56	13,300	16,000	3	1 (decrease)
Broadway Avenue (Tyler)	1.47	4.1 / 46	500 to 1,500	3	-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. See Report 0-4221-2 for more details.

[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 when daily counts were not available.

[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.

Testing and Calibrating VISSIM

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 analyst then viewed the on-screen animation to check the realism of queue lengths. The researchers then compared the travel time outputs to those collected with the field travel time runs. Speed distributions were altered 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.

Table 4. 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	NA	18	660	660	18,000 to 28,000	NA	NA
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.

NA = Not Applicable.

Theoretical Corridors

Table 4 provides the geometric characteristics of the theoretical corridors. The percent differences in the conflict points and travel time columns shown in Table 4 are discussed in the findings section of this report. 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 design of the theoretical corridors began with identifying typical land uses for the 1.0-mile corridor with one set of signals separated by 0.5 mile. 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 equal numbers of driveways on the north and south sides along the corridor, and the driveways lined up across the road (see Table 4 for scenario characteristics). 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 (4). 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.

Scenarios 1 and 2 evaluated ADT volumes at 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 directional design hour volume (DDHV), which was accomplished by multiplying the ADT by the K factor (0.135) and the D factor (0.5). The K factor was estimated for a suburban area (5), 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 its 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.

FINDINGS OF THE TEST CORRIDORS AND THEORETICAL CORRIDORS

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. Travel time and speed results are the focus in the discussion here; however, the results for delay can be found

in the full report (*3*). The results for delay are similar to those described here for travel time. VISSIM allows the user to choose the duration 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 for design hour analysis.

Micro-simulation tools allow for detailed analysis of traffic systems and have great potential for analyzing access management strategies. They implicitly account for the stochastic nature of the transportation system and can provide both temporal and spatial information down to the individual vehicle level. The research team has prepared a conference paper that documents some of the lessons learned while assessing the impacts of access management using micro-simulation (*6*). The conference paper describes the desirable input and output characteristics of a micro-simulation tool for possible use in investigating access management alternatives. One input characteristic is that the micro-simulation tool includes the opportunity to input the complex conditions that must be considered when evaluating access management improvements. The ability for the micro-simulation model to manage geometric inputs is clearly important when evaluating access management techniques because access management strategies often include changes in roadway geometry. It is imperative that the model allow for locating driveways in a scaled environment. There must also be the ability to include acceleration or deceleration lanes (common access management techniques) in combination with these driveways. Turning radii and lane width are also important geometric factors that are necessary in the roadway network.

The micro-simulation tool must also have the ability to handle numerous operational inputs that affect traffic flow. These include gap acceptance, speed, and acceleration characteristics. Accurate traffic signal simulation is also an essential element for a micro-simulation tool because signal spacing is an important access management treatment. In addition, accurate traffic signal operations and traffic progression are required if micro-simulation tools are to be used successfully. Because the success of traffic signal treatments depend on proper timings, it is vital that the simulation package (1) have traffic signal optimization routines, or (2) allow for the importation of traffic signal data to be input from external traffic signal software.

It is important that traffic operation effects (i.e., reduction in delay and/or travel time) can be solely attributed to the transportation improvements made to a given corridor, and not due to changes in traffic operations along the corridor (i.e., weaving). Therefore, it is imperative that users have complete control of the network demand. This control can be accomplished by providing a method to input origin-destination pairs and paths or exclusively handle routing decisions of vehicles so that changes between simulation runs and alternatives do not include the influences of weaving maneuvers.

Finally, the analyst must understand the underlying theory behind the micro-simulation model, and the model must also be calibrated to field conditions. The underlying theory will affect driver behavior, vehicle type characteristics, and traffic flow within the context of the other input parameters. Generally, there are input parameters within the model that can be adjusted to better reflect field conditions.

Considering the output characteristics necessary for a micro-simulation tool used for evaluating access management techniques is also important. For access management applications, the

analysis requires the ability to study the system at any level of spatial or temporal detail. In particular, this is required at the individual level to provide for both disaggregate and aggregate analyses. Output is necessary for different locations (spatially) along the corridor where access management treatments are being evaluated. For example, signalized and unsignalized intersections and/or raised median openings may be locations where traffic operations are of particular interest. Temporal output that allows investigation of traffic operations through time is also necessary as it allows the analyst to investigate platooning, queuing, and other time-based operations. Micro-simulation allows for this investigation at the individual vehicle level.

It is beneficial if the micro-simulation software provides an animation feature to allow the analyst to watch the simulation run to provide a visual check of consistency and to ensure there are no suspicious movements in the network (e.g., vehicles colliding). Further, animation abilities are valuable for graphically illustrating the operation and impacts of corridors after access management techniques have been implemented.

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 *ITE Journal* article (*7*).

The next alternative or alternatives included the proposed condition of a raised median along the corridor with existing traffic volumes. In some cases, there were raised median alternatives to better serve specific origin-destination patterns for the driveways and streets in a specific corridor. The final alternatives always included the future conditions with the TWLTL and with the raised median alternatives that were investigated for the particular corridor. The results shown in Tables 3 and 4 compare the TWLTL with the raised median alternative with the most median openings—the most likely alternative to be implemented. The additional alternatives analyses can be found elsewhere (*3*). When the average daily traffic was not readily available from 24-hour loop counts, it was estimated by dividing the directional design hour volume by an assumed K factor of 0.135 for suburban areas (*5*) 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 3 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 (*8*).

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 3 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. Figure 2 graphically displays that as volume increases, speed decreases for both the raised median and TWLTL alternatives along Texas Avenue.

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. Figure 3 illustrates the decreased speed with the implementation of the raised median at various ADT levels. 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 found that an additional median opening(s) could reduce the percent differences between the TWLTL and raised median even further.

The reduction in travel time on Texas Avenue with the raised median treatment is likely attributed to prohibiting U-turns at a major signalized intersection. This change forced vehicles to make U-turns at locations farther along the corridor—allowing more through-movement green time at the signals. The increase in travel time with the installation of a raised median in Temple and Tyler is likely due to the median opening spacings and an overall increase in traffic on the corridor because some U-turning vehicles must travel farther to reach their destinations. Increased travel time is also caused by U-turning vehicles that must weave across lanes to reach turn bays. This 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 VMT are likely causing travel time and delay increases. Delay may also increase slightly at the signalized intersections.
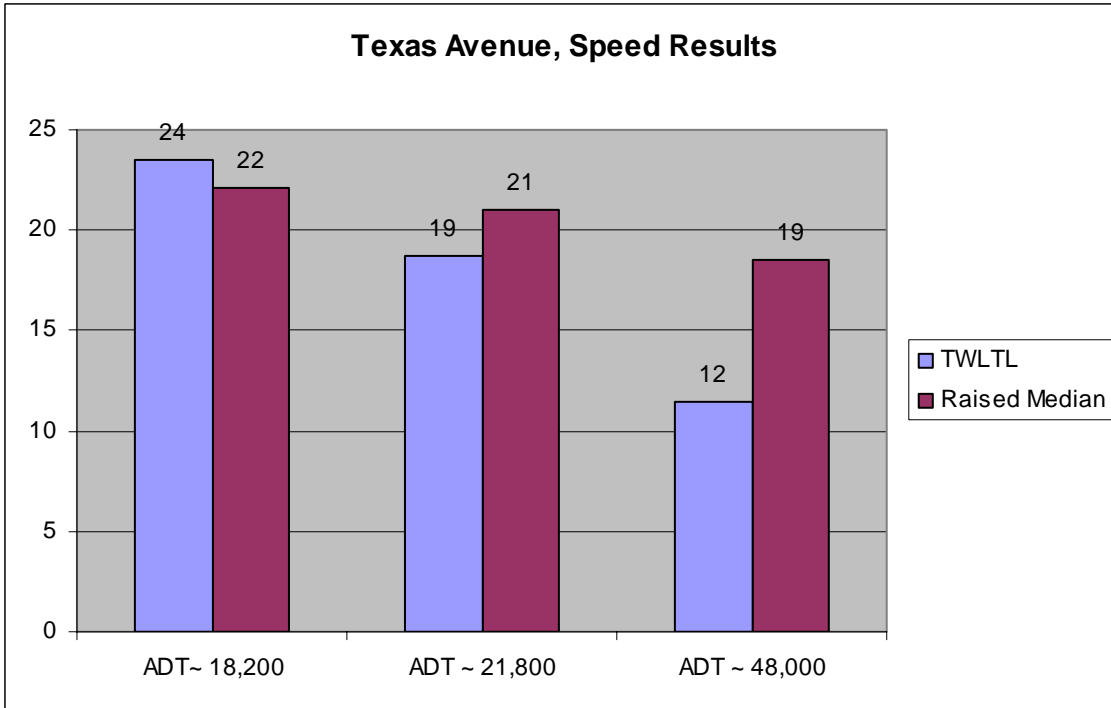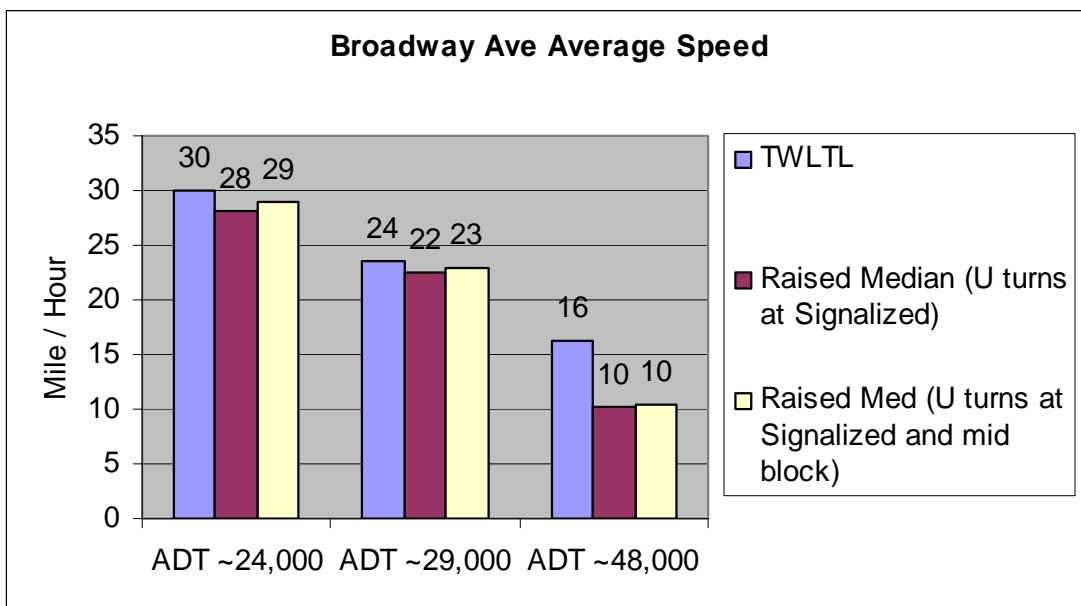
Figure 2. Texas Avenue Speed Results.

Figure 3. Broadway Avenue Speed Results.

Quantitative Findings of Theoretical Corridors

While the actual case study locations presented here are valuable in assessing the impacts of access management treatments, additional theoretical scenarios were analyzed. These additional scenarios were developed for TxDOT staff members for alternatives analysis. Researchers met with TxDOT in the first year of this project to identify the most useful scenarios for 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. The design of the theoretical corridors and the travel demand used for the analyses were described previously. Analysis of the theoretical corridors 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 TWLTLs and altering driveway density.

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 demonstrated in Scenario 3. When a raised median is added to the corridor, the number of conflict points decreases from 1220 to 300, a decline of approximately 75 percent (see Table 4). 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 4 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 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. Figure 4 shows the relatively similar speed results for Scenario 2 and 3 for three lanes in each direction. 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 which might lead to better management of traffic circulation.
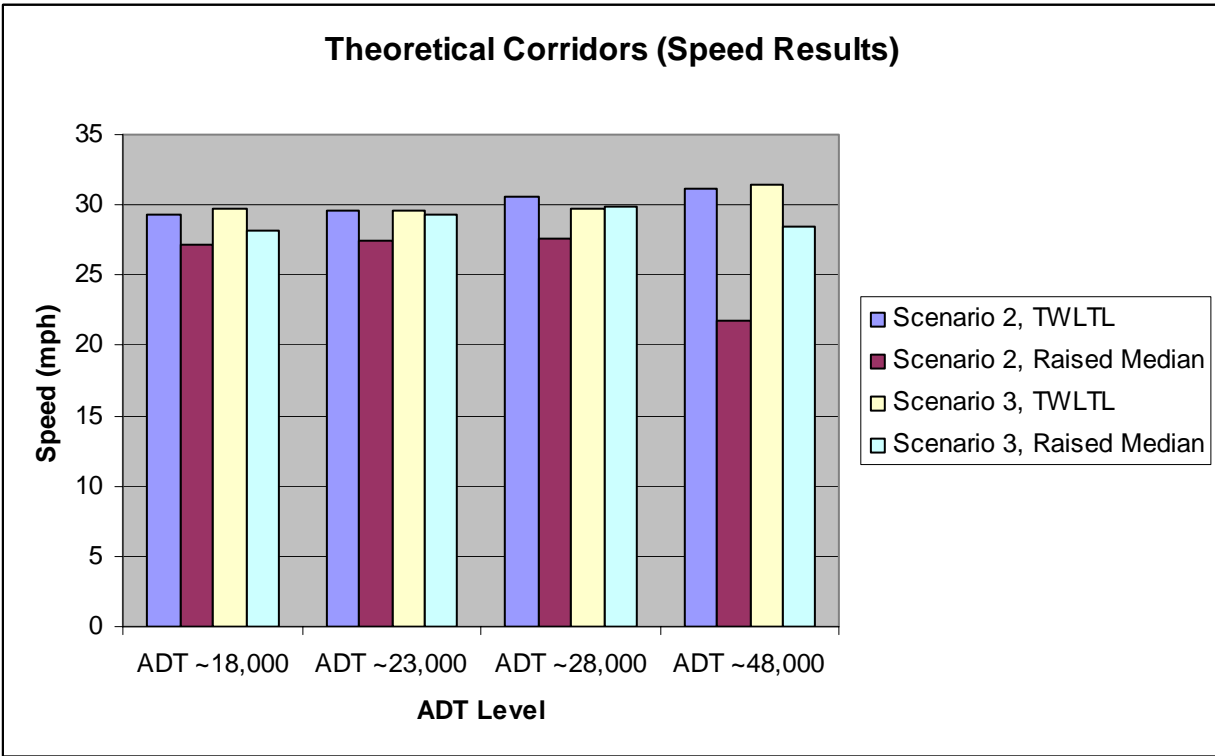
Figure 4. Scenario 2 and 3 Speed Results (3 Lanes in Each Direction).

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

In recent years, there has been increased interest in access management principles and techniques in Texas. This document highlighted the findings of a recent research effort sponsored by TxDOT and performed by the Texas Transportation Institute that estimated the operational impacts of access management in Texas.

The VISSIM Micro-simulation Tool Conclusions

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

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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 project, 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 project.

Operational Performance Conculsions

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 3.

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 4. 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. These results are summarized in Table 2. More details on these comparisons can be found in the final report (3). 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 averaged 3mph. 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.

In general, the more circuitous travel and increased U-turn traffic can cause the raised median treatment to have slightly longer travel times. However, it is likely that these increases in travel time, and subsequent delay, are offset by the reduction in the number of conflict points and increased safety. The safety advantages of raised median treatments were also highlighted in this research project.

Crash Analysis Conclusions

The crash analyses performed in this project indicate that there is a relationship between crash rates and access point density. Corridors with higher access point densities had higher crash rates in terms of crashes per million vehicle miles traveled. The increased crash rates on corridors with a TWLTL compared to those with a raised median were also noted – corridors and that had raised medians experienced lower crash rates. In addition, the corridors with raised medians also typically had less severe crashes in terms of numbers of fatalities and incapacitating injuries. It should be noted for future research efforts that historical crash data are typically available for a period of no more than 10 years.

Future Research Needs for Operational Analysis

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 (O-D) study to identify vehicle patterns both within and through the study corridor.

Implementing an 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.

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.

The theoretical corridors could also use additional research on the effects of travel time, speed, and delay as a consequence of higher traffic volumes. It should be noted that turn bays were on the order of 100 feet in the theoretical scenarios and closer to 250 feet for the case studies. Altering these distances would reduce the queuing into the through lanes. Adding a "dummy" signal to the endpoints of the corridors and theoretical scenarios might also replicate expected field conditions by providing for gaps in the traffic stream that might be observed in the arterial

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environment. These minor changes could affect the simulation results, and would be useful items to further investigate in future research.

Though not analyzed, it is hypothesized that further analysis would find that additional median opening(s) could reduce the percent differences between the TWLTL and raised median even further. The research found that the results of access management treatments can be very corridor-specific. The results are a function of traffic volumes, driveway density, weaving and associated origin-destination patterns, median opening location and density, deceleration lane length, signal coordination, operating speed distribution, driver behavior, and other elements. These numerous interactions can be investigated in a micro-simulation tool that allows for analysis of these elements.

It should be noted that the results of this analysis are from a limited number of test corridors and simulation runs. The results should not be taken as representative for other areas as detailed micro-simulation is often necessary at each site-specific location. 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.

Future Research Needs for Crash Analysis

The research identified potential problems with various sources of traffic volume and crash data. Additional research on other corridors will provide a greater amount of data from which to draw conclusions regarding the safety impacts of the presence of raised medians and lower access point densities on arterial streets. The best results will come from researching corridors for which reliable crash data are available, as discussed earlier in this document.

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