Loop 289 Corridor Study - Phase II

TechMRT

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Loop 289 Corridor Study – Phase II

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1. INTRODUCTION

South Loop 289 stretching from the I-27 interchange to Spur 327 is one of the busiest corridors in Lubbock. It traverses the key business center of the city and includes four major interchanges connecting with local arterial streets. The majority of the trips made in both peak times of the day are short trips, which are less than the full length of the area between Slide Road and Interstate 27. The congestion is concentrated toward the center of this area and peaks at almost 100,000 vehicles per day.

This large traffic volume creates increased peak-hour congestion, traffic weaving, and safety concerns. A very pressing issue is traffic control during congestion as the interchanges and bridges are spaced within one mile of each other. This problem occurs at the grade for the bridge sections, as the sight distance might be too short in order for some drivers to anticipate the congestion ahead. When this occurs, accidents are often possible and might occur if drivers do not take proper precautions to prevent them. Other than safety, planners are concerned with the further increase in volumes and congestion in the area as the urban development of Lubbock is moving much faster toward the South than any other direction. This will cause an increase in volume for the South Loop 289 area far above what occurs in the present and will remain a concern and problem if steps are not taken to alleviate the congestion. Contributing to the operational problems are design deficiencies, such as the geometry and the type of the interchanges, length of weaving sections, ramp tapers, and unevenly distributed traffic volumes on main lanes. In addition, the closely spaced urban arterials intersecting with the loop system and intensive commercial development along the route contribute to the problem.

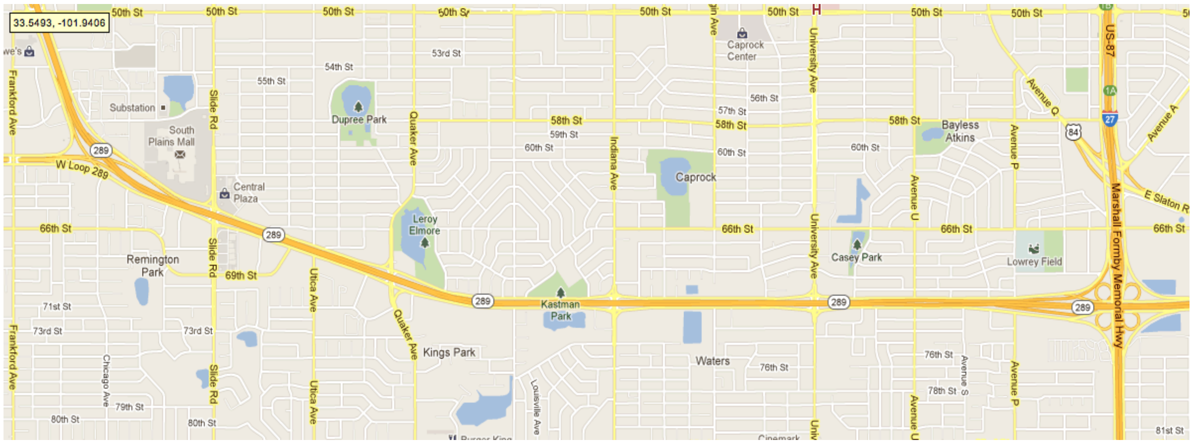


Figure 1-1: Map of the Study Area

1.1 Background and Literature Review

Traffic congestion has grown steadily in the United States. Several recent studies indicate that if trends do not change, most urban transportation networks will face frequent traffic congestion problems. It is also stated in some studies that views on the design of urban streets have been changing in response to economic, social, and environmental trends.

Among the ramp modification/reversal related research publications reviewed by the research group, the Federal Highway Administration (FHWA) report conducted by Scott et al. (2006) and publicized through the National Technical Information Service (NTIS) by the title "Ramp Reversal Projects: Guidelines for Successful Implementation" was a key research document because:

1) The study evaluated 15 ramp reversal projects on Texas freeways
2) The study investigated the benefit of ramp modification projects in many scenarios
3) The study provided 21 guidelines based on the evaluation conducted in the research.

The research project conducted by Nelson et al. on the "Lane Assignment Traffic Control Device on the Frontage Roads and Conventional Roads at Interchanges" was also an important case study under safe and efficient frontage road and intersection operation. The other study reviewed, in detail, was the research document published by Klaver et al., which was conducted on the "U.SOUTH 83 Main Lane, Ramp, and Cross-Street Interchange Operational Analysis" (1995). It addressed the impact of widening of the main lanes and converting all ramps along the study area to a uniform X-Ramp configuration. Other ramp modification related case study projects were also reviewed and discussed under their corresponding topic.

In general, it was found that all the reviewed studies support the benefits of ramp modification projects and addressed the X-Ramp pattern advantages under several viewpoints.

This literature review contains the findings of different studies on ramp modification projects and their impacts on the frontage roads and intersection. The first part illustrates the common motivations behind ramp modification projects as discussed in the reviewed studies. The second part focuses on the impact of X-Ramp configurations on frontage roads and intersections. The last part contains the challenges faced during ramp modification projects on past research projects.

- **Desires for Ramp Modification Projects**

Urban growth in general created the demand for the freeway system. The cost of constructing new facilities or of expanding the existing ones was determined uneconomical and as a last-case scenario in many recent projects. With main lane expansion becoming an ever-diminishing possibility, many TxDOT districts have modified various freeway elements to maximize efficiency and safety. In addition, it is crucial that the various improvement strategies should be prioritized according to their expected cost effectiveness. Ramp modification projects can also be categorized under those strategies of maximizing efficiency and safety.

Scott et al. (2006) discussed that ramp reversal or ramp modification projects become an important consideration, especially when the situation involves traffic spilling back from an exit ramp onto freeway main lanes. Congestion relief and improving traffic operations on freeway main lanes are also mentioned as benefits on many ramp modification projects. Moreover, improving access and traffic flow to the parks and malls was indicated as the driving force for ramp modification projects like the IH 20 ramp reversal project in the City of Arlington.

Safety considerations, particularly at the cross-street/frontage road intersections are also identified as primary factors for TxDOT to implement X-Ramp corridor projects at SH-358 in Corpus Christi. Frawley (2005) discussed that managing access points along any type of roads provides better mobility. In addition, Frawley illustrated how managing access points in state highways provide better traffic flow. Managing access points creates opportunities for through-traffic to brake and to accelerate in order to accommodate vehicles entering and exiting the highway. The desire to commercially develop areas along frontage roads is also mentioned as the main motivation behind to US 190 ramp reversal project in the City of Killeen.

- **Impact of X-Ramp Configuration on Frontage Roads and Intersections**

In most of the ramp modification project case studies, the area between the exit ramp and the upstream cross-street intersection is considered as the improved part of the frontage road. The X-Ramp pattern configuration solves the congestion issue between the exit ramp/frontage road intersection and the downstream cross-street. The improved segment on the frontage road due to ramp reversal projects also helps to provide for better traffic flow on the cross-street intersecting the frontage road.

In addition, Scott et al. (2006) discussed the advantage of an X-Ramp configuration on the IH 20 ramp reversal project due to its capability to increase green time for thru movements As stated by Scott et al, the TxDOT Roadway Design Manual offers guidance that the X-Ramp pattern encourages frontage road traffic to bypass the frontage road signal and weave with the main line traffic.

The ramp reversal project from Diamond to X-pattern is addressed in several reviewed studies. According to the research projects' results studied by Scott et al. (2006), The X-Ramp pattern configuration creates the following results:

- Increased development along frontage roads
- Reduced through demand on the frontage road approach to intersections
- Move the weaving area between an entrance ramp and exit ramp from the main lanes to the frontage road where speeds and volumes are lower, and
- Increased storage area for a cross-street's intersection queuing.

Having uniform X-Ramp patterns along the freeway creates uniform traffic flow and improves the level of service at the interchanges. The result of changing the mixture of Diamond and X-Ramp patterns to uniform X-Ramp patterns was also identified as the best recommendation to decrease the delay at interchanges.

Scott et al.(2006) addressed the information obtained from an official familiar with the US 190 ramp reversal project that revealed how the ramp reversal project had a positive impact on the operational performance of the westbound freeway mainlines and frontage roads. The results of the case studies in Scott et al. also showed that the volume on the frontage road at the cross street significantly decreased, producing one of the main benefits of ramp reversal projects.

- **Challenges and Countermeasures of Ramp Modification Projects**

One of the challenges discussed in ramp reversal case studies is drivers' inability to easily adopt the changed ramp configuration. Because the Diamond ramp pattern is the most common configuration, it was observed that drivers do not adjust to the changed ramp quickly. Scott et al. discussed the TxDOT Roadway Design Manual guidance which states that the X-Ramp pattern may cause some drivers to miss an exit located well in advance of the cross street .

Implementing appropriate traffic signs to show roadway widening on frontage roads is one of the important recommendations to protect drivers from making incorrect lane selections.

The SH114 ramp modification study in Grapevine also indicated that TxDOT maintenance staff ultimately moved the exit ramp warning sign farther east on SH 114 to allow motorists more time to react to the location of the new ramp. This may be a beneficial practice for similar projects.

Selecting an appropriate microscopic simulation model for a ramp reversal project is also a challenge and is one of the basic decision stages. Among the publicly or commercially available microscopic simulation models, which are also discussed in the report by Scott et al., VISSIM and CORISM are mentioned as the most appropriate models for ramp modification projects. Both models are considered practical candidates due to their route assignment features so that vehicles can be routed from the freeway to the frontage road, or vice-versa, in such a manner that unrealistic turning maneuvers are avoided.

The third challenge addressed in the reviewed case studies is the cost for the modification project. Scott et al. (2006) indicated that construction of auxiliary lanes may require major reconstruction at cross-streets. In addition, improving signal operations at the interchanges is also indicated as a challenge on the project cost. Most of the case studies discussed by Scott et al. indicated that signalized intersection operations must be adjusted in ramp reversal projects.

The road segment between the exit ramp and the subsequent entrance ramp was indicated as the most critical and challenging area that should be closely analyzed during ramp reversal projects. This area along the frontage road needs to be analyzed carefully because of the traffic volume increase due to the exit ramp. The addition of an auxiliary lane on the frontage road is considered the best option in most of the reviewed case studies and is an integral part of ramp reversal projects.

- **Summary**

The reviewed case studies indicated several motivations for implementing ramp reversal projects. Traffic spilling back from an exit ramp onto freeway main lanes, congestion relief, improved access and traffic flow to business centers, safety considerations (particularly at the cross-street/frontage road intersections), and the need to commercially develop the area along the frontage road are mentioned as the main reasons for ramp reversal projects.

The X-Ramp pattern interchange has been shown to be capable of solving the congestion problem between the exit ramp/frontage road intersection and the downstream cross-street.

Additionally, X-Ramp patterns provide increased green time to thru movements. Increasing development along a frontage road, reducing through demand on the frontage road approach to the intersection, and increasing the storage area for the cross-street's intersection queuing are also included under the benefit of the X-Ramp pattern.

Moreover, the result of changing the mixture of Diamond and X-Ramp patterns to uniform X-Ramp patterns was also identified as the best recommendation to decrease the delay at the interchanges. The results of several ramp reversal case studies also showed that volumes on the frontage road at the cross-street significantly decrease, leading to the other benefits of X-ramp patterns. The area between the exit ramp and entrance ramp along the frontage road is determined as the most vital area to be considered during a ramp reversal project. The addition of an auxiliary lane on the frontage road was determined as the best option in most of the reviewed case studies to overcome the increased volume from the entrance ramp.

Drivers' inability to easily adopt the changed ramp, selecting an appropriate microscopic simulation model, and project cost are mentioned as the main challenges for ramp modification projects. Implementing appropriate traffic signs to show roadway widening on frontage roads, using VISSIM and CORISM simulation models, and practicing cost effective construction strategies are indicated as counter measures to address these issues.

In general, the reviewed case studies recommended that ramp modification projects are worthwhile efforts. Moreover, the X-Ramp pattern was identified as the best scenario to provide a positive impact on the operational performance of the freeway mainlines and frontage roads.
Implementing appropriate traffic signs to indicate the new ramp was also found as one of the important recommendations to protect drivers from making an incorrect lane selection and to avoid complaints.

1.2 Phase I Study

The first part of the study regarding congestion for Loop 289 was completed in 2007. The study analyzed the level of service regarding the traffic volume in 2007 and modeled the following alternatives to the interchange designs:

1. Keeping the existing ramp configurations, add an auxiliary lane to the outside main lane between the entrance and exit ramps on the roadway segment between:
    - Slide Avenue and Quaker Avenue

  - Quaker Avenue and Indiana Avenue
  - Indiana Avenue and University Avenue and
  - University Avenue and I-27.
2. Convert the ramp configuration from diamond interchanges to X patterns along South Loop 289, both east and west bound between:
  - Quaker Avenue and Indiana Avenue
  - Indiana Avenue and University Avenue and
  - University Avenue and I-27

Depending on the simulation results, add a third lane on the frontage road connecting exit and entrance ramps.

3. Alternative (2) with an additional auxiliary lane on the main lanes going over the bridges.

These three alternative plans have advantages and disadvantages associated with cost, ease of construction, and a reduction or relocation of congestions. The LOS analysis for the current and forecasted traffic conditions were then conducted based on the simulation model developed in VISSIM. The analysis work was performed in the following steps:

1. Analysis of current level of service (LOS)

The level of service of the South Loop 289 was determined for the current traffic volumes. The LOS of the network was determined for five different sections, between the entrance and exit ramps along the network. The LOS of each section was determined using HCS 2000, a software package that follows the procedure defined in the Highway Capacity Manual 2000.

2. Analysis of LOS with proposed improvement alternatives

A set of simulation models representing the proposed improved alternative networks were developed on the basis of the basic calibrated network. All these networks, including basic networks, were modeled with the current traffic volumes, and the analysis of LOS was conducted on the output volumes from the simulation networks. These volumes were converted to density for the LOS analysis.

3. Analysis of LOS with the forecasted traffic volume

After the analysis of the alternatives with current traffic volumes, the current traffic volumes were forecasted for five years at an annual growth rate of 3%. Then, all the simulation networks were modeled with the forecasted volumes to analyze the traffic conditions that prevail after five years on each of the networks.

Phase I resulted in several conclusions. Firstly, lane usage was as expected in that drivers making short trips tended to travel in the outer lanes between ramps and only drivers traveling much farther utilized the middle and inner lanes. This resulted in the hypothesis that the alternatives including the auxiliary lane would help to reduce and alleviate some congestion due to the weaving movements. The second and more important result is that the combination of Alternatives 1 and 2 as presented in Alternative 3 helped to alleviate congestion the most.

The Phase I research revealed that the lane distribution on the main lanes is not evenly distributed for the existing network and the network is congested at certain sections. Adding an auxiliary lane to the main lanes, as in the case of Alternative 1, has provided better LOS than the existing network, but could not create an even distribution of traffic on the main lanes. The number of vehicles on the main lanes over the basic network and Alternative 1 is almost equal at every section, as there is no change in ramp configuration between the two networks. Changing the ramp configuration from Diamond to X, as in the case of Alternative 2, considerably reduced the volume of traffic on the main lanes because an X- pattern interchange will transfer the vehicles with shorter Origin-Destination trips (O-D) onto the frontage road, and this increased the traffic volume on the frontage roads. However, this change in ramp configuration increased the traffic volumes at the section between Slide and Quaker and at the Slide Road overpass. The X-pattern interchange has provided an entrance ramp onto the main lanes instead of an exit ramp at the section between Slide and Quaker. Alternative 3 provided better results compared to Basic Network and Alternative 1, but not better than Alternative 2. Although the ramp configuration is the same as Alternative 2 throughout the network, an auxiliary lane is provided on the main lanes over the bridges in Alternative 3. This encouraged the high volume traffic on the frontage roads to move onto the main lanes and hence the density on Alternative 3 is slightly higher than on Alternative 2. So, it is concluded that Alternative 2 is the best alternative network among all the three alternatives.

At the conclusion of this part of the study it was determined that to truly understand the impact of the alternatives for the interchange design it would be necessary to make a more detailed analysis of the frontage road segments. It was hypothesized that instead of using the main lanes, some traffic might be using the frontage road segments instead. This would mean that the reduction in congestion on the main lanes would then be moved to the frontage road segments and would therefore undo the good caused by the alternatives. Phase 2 was determined to be necessary to complete this analysis and further this conclusion by increasing its scope, making the result more accurate.

1.3 Objective of Phase II Project

This Phase II study was conducted based on the Phase I study recommendation and particularly focused on the impact of the ramp reversal strategy on frontage roads and intersections. The study mainly addressed the evaluation of the level of service on the frontage roads and intersections on the area of interest. It also identified best practices for frontage road and intersection operation while implementing ramp modification projects.

In order to complete the analysis of the improvement options for South Loop congestion issues, further literature review on X-pattern interchanges was performed. In this research, the three alternatives presented in Phase I were analyzed by taking into consideration the frontage road segments and the interchanges affected by the change in interchange design for both morning and afternoon peaks. This was done to prove or disprove the hypothesis that drivers were utilizing the frontage road segments for trips instead of the main lanes, reducing congestion on the main lanes but increasing the congestion on the frontage road. This was taken further by analyzing the impact to the South Loop and major arterial interchanges. It was determined analytically that the traffic from freeway main lanes to areas along frontage roads (or traffic in the opposite direction) will be re-routed. The traffic re-routing will cause a change in traffic volumes on some ramps, frontage road segments, and frontage road through-traffic volumes at interchanges. The changed traffic volumes were estimated according to traffic observations between Slide Road and Quaker Avenue, where the ramps are already X-patterns. In regards to these interchanges, optimized signal timing will also be analyzed and changed if needed. This will take full advantage of any volume changes created by interchange design changes.

1.4 Description of Alternatives and Model Modifications

The original tasks of this project included the addition of an outside auxiliary lane to the main lanes of South Loop 289 between each of the entrance and exit ramps from I-27 to Slide Road, the conversion of the ramp configuration from X to Diamond pattern between Slide Road and Quaker Avenue, as well as the conversion from Diamond to X pattern at the rest of the interchanges. Based on the simulation results from the first phase of the work, three alternatives were developed.

Alternative1 (A1): An auxiliary lane is added to the outside main lane between each entrance and exit ramp on both eastbound and westbound directions at:

- Slide Road and Quaker Avenue
- Quaker Avenue and Indiana Avenue
- Indiana Avenue and University Avenue
- University Avenue and IH-27

Alternative 2 (A2): The ramp configuration of the basic network is changed from Diamond to X pattern at:

- Quaker Avenue
- Indiana Avenue
- University Avenue

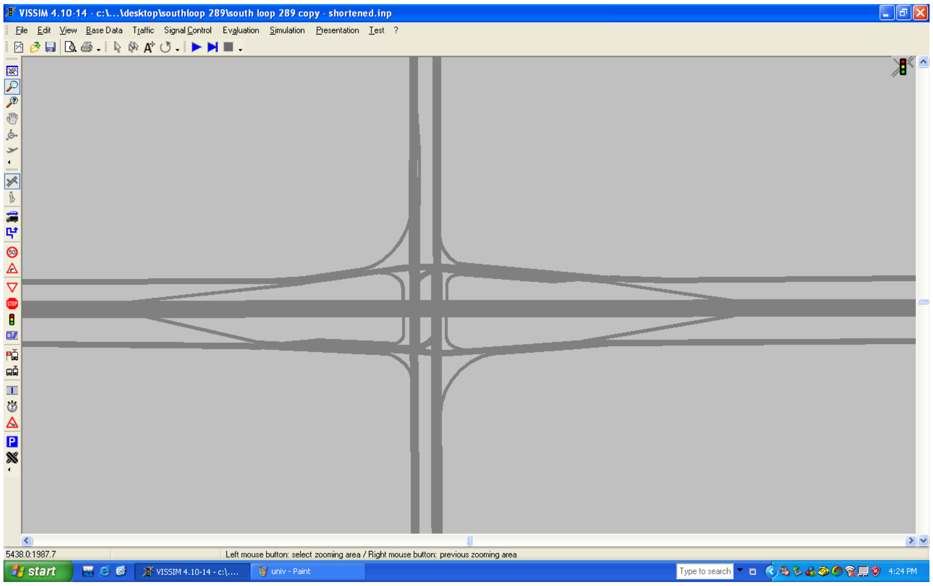
Considering that providing an X pattern interchange will increase traffic volume on the frontage road, an auxiliary lane is added on the frontage road between each exit and entrance ramp.

Alternative 3 (A3): This alternative is developed by providing an auxiliary lane on the main lanes to Alternative 2. The auxiliary lane is provided on the main lanes over the bridges for both eastbound and westbound directions.

Diamond and X Pattern Interchanges

The project area consists of four major interchanges, consisting of one X pattern interchange at the Slide Road overpass, two Diamond interchanges at University Avenue and Indiana Avenue, and a combination of X and Diamond interchanges at Quaker Avenue.

Diamond Interchange: A Diamond interchange is a common type of interchange; it is generally used when a freeway crosses a minor or major road. The freeway and the road are grade-separated. For a Diamond interchange on either direction, an off-ramp diverges slightly from the freeway and runs directly across the frontage road, becoming an on-ramp that returns to the freeway in a similar fashion. A typical layout of a Diamond interchange is shown in Figure 1-2.



Left mouse button: select zooming area / Right mouse button: previous zooming area

Figure 1-2: Diamond Pattern interchange at Indiana Avenue

X pattern Interchange: An X pattern interchange has a ramp configuration opposite to that of a Diamond interchange. In the case of Diamond interchanges, an exit ramp is provided while approaching the intersection and an entrance ramp following the intersection. In an X pattern interchange, the entrance ramp is provided before the intersection, and the exit ramp is provided after the interchange is crossed. A typical X interchange is shown in Figure 1-3:3.

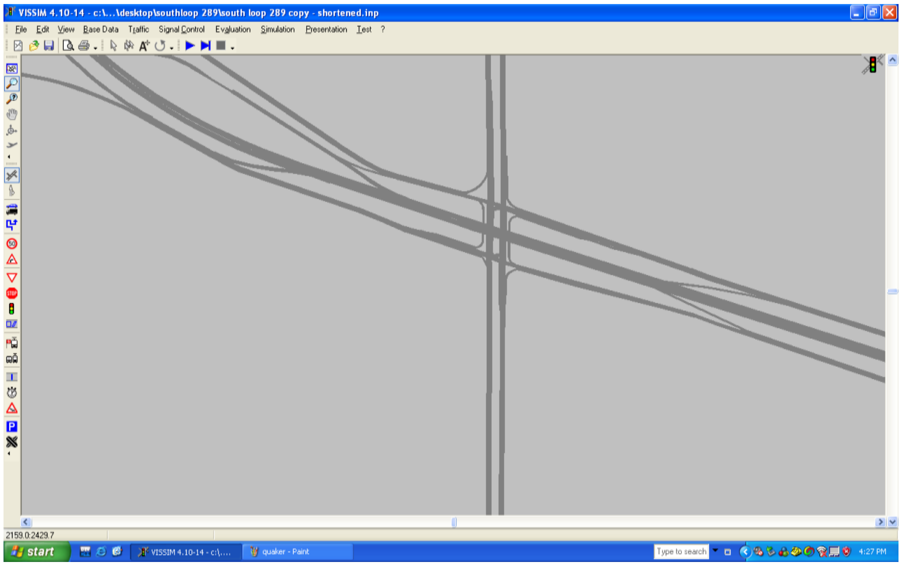


Figure 1-3: X pattern interchange at Slide Road Overpass

The following diagrams show, using an aerial view, the locations of changes made in each alternative. For each alternative the ramps that change direction (i.e. on to off or vice versa) or the additional auxiliary lane are highlighted. The auxiliary lanes are highlighted in red, and the ramps that changes are in green.

Figure 1-4: Alternative #1: Auxiliary Lane Addition

Figure 1-5: Alternative #2: Diamond to X Type Interchange Reconfiguration

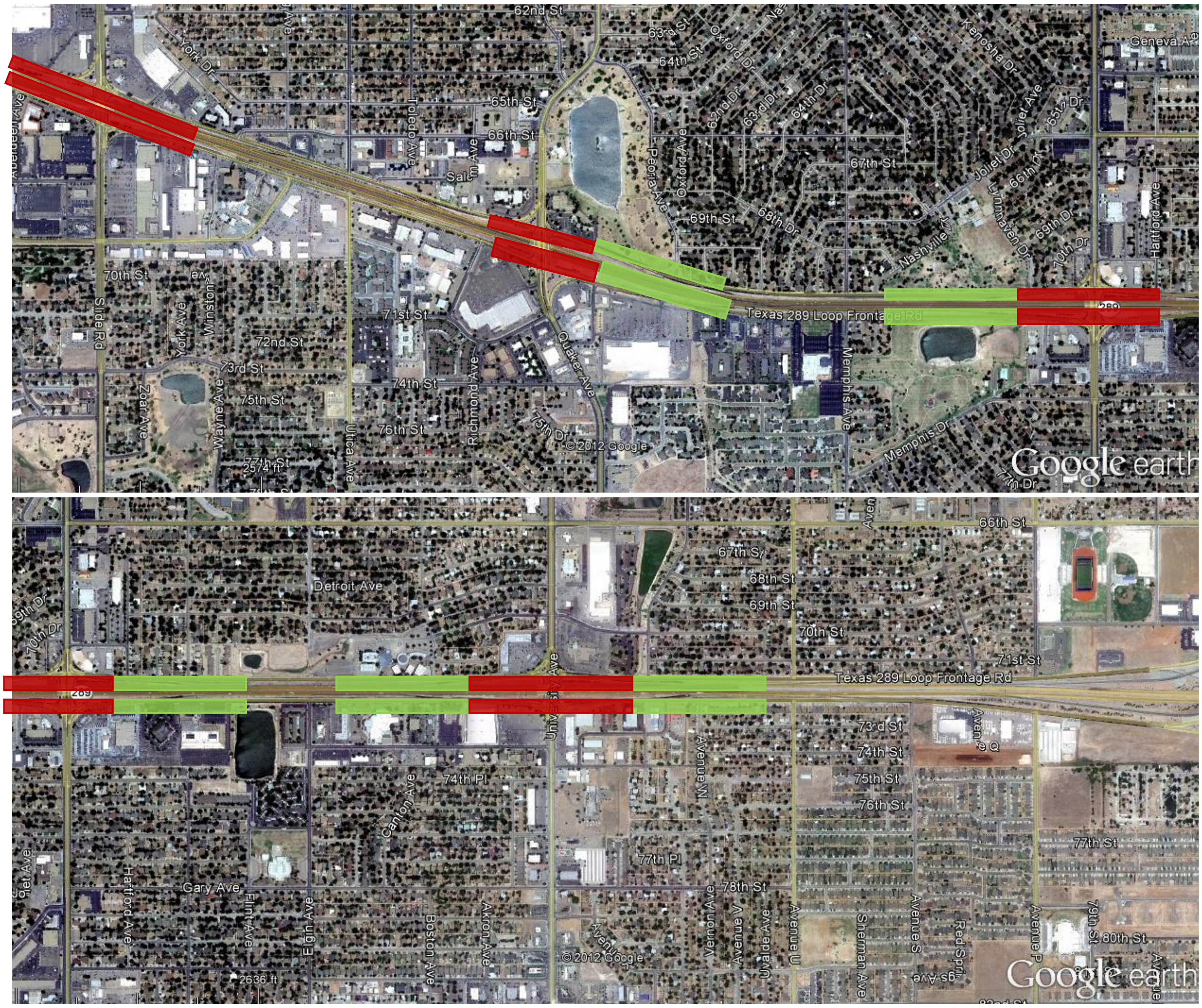


Figure 1-6: Alternative #3: Diamond to X Type Interchange and Auxiliary Lane Addition

1.5 Methodological Approach

To thoroughly evaluate the traffic performance on South Loop 289 including main lanes, frontage roads, intersections and weaving sections, both analytical and simulation approaches were applied.

The microscopic traffic simulation software VISSIM was used to model and analyze the traffic conditions on the main lane and frontage roads, while the Synchro software was employed to design traffic signal timing plans and evaluate the performance of the four major interchanges along South Loop 289.

- **Network Coding**

The basic geometry of the simulation networks were coded on aerial photographs of the study area from Google Earth. Links and nodes are the two design parameters which are used to develop a network in Synchro and VISSIM. Links are used to define the main lanes, frontage roads, and ramps while the nodes are used to connect all the necessary links in the network. Details such as speed limits and signal timing plans are coded in their respective ways for each program to match the real world conditions or modified if needed for the different configurations.

In order to analyze the LOS for the different segments in question, several different approaches were taken. Density was used as the measuring factor for the main lanes of Loop 289 and the volume to capacity (V/C) ratio was used for the frontage road segments. Specifically in Synchro, the intersection LOS was calculated using the average control delay per vehicle, which is widely used for evaluating intersection performance.

- **Modeling Control Devices**

After coding the geometry of the network, control devices are defined in the simulation model. They are the parameters which control the traffic flow in the simulation model. These control devices include a variety of parameters including Signal Controllers, Stop signs, Priority rules, Desired Speed Decisions, and Reduced Speed Decisions.

- **Calibration and Validation of the Simulation Model**

After all the features in the network are modeled, the model parameters are calibrated to make the simulation model replicate the real field conditions. The procedure by which the parameters of the model are adjusted so that the simulated response agrees with the measured field conditions is known as Model Calibration. Some of these parameters will have an effect on the driving behavior, and some of them will have an effect on the speed and acceleration of the vehicle. All these model parameters can be categorized into:

(1) Car following parameters
(2) Lane changing parameters
(3) Kinetic parameters
(4) Vehicle parameters

In order to gauge the accuracy of the simulation, validation and calibration needed to be done. Phase II simulations were calibrated in a similar manner as in Phase I. This method included taking cuts at sections, recording the traffic volumes in the simulation, and comparing the results to the measured field volumes to see if they were statistically accurate.

- **Signal Timing Design**

The research team designed signal timing phase orders based on the traditional TTI-4-Phase Diamond interchange operation, which is used at most Diamond interchanges in the City of Lubbock. The green time calculation method documented in Chapter 10 and Chapter 16 of the Highway Capacity Manual (HCM) 2000 was applied for obtaining equalizing saturation degrees of critical movements.

An Excel program was developed for calculating green time with the inputs of traffic volumes and lane configurations of interchanges. Calculated green time for each phase was adjusted based on minimum green time and pedestrian traveling time to get practical signal timing plans.

- **Weaving Analysis**

Analytical methods in HCM 2000 were used to evaluate the weaving performance along South Loop 289 as a supplement to the LOS analysis by simulation.

1.6 Summary of Results and Recommendations

The LOS analysis for the frontage road as well as the intersections was carried out for the basic network and the three alternative networks developed in the simulation arena. The basic network represents the existing condition, while Alternative 1 (A1) was developed by adding an auxiliary lane between each entrance and exit ramp on both Eastbound and Westbound directions; Alternative 2 (A2) was developed by changing the ramp configuration from Diamond to X- pattern and adding an additional lane on the frontage road between each exit and entrance ramp; and Alternative 3 (A3) was developed based on Alternative 2, by adding an auxiliary lane on the main lanes over the bridges.

Similarly to the Phase 1 study, the simulation analysis was conducted at five sections of the main lanes including the Slide Road overpass, Slide Road and Quaker Avenue, Quaker Avenue and Indiana Avenue, Indiana Avenue and University Avenue, and the section between University Avenue and IH27. The section by section level of service was first determined based on both the morning and afternoon peak traffic data on the basic network, which are shown in Table 1-1.

Table 1-1: Section by Section Level of Service of Main Lane Traffic under Current Condition

		*Section 1	*Section 2	*Section 3	*Section 4	*Section 5
AM	Westbound	C	B	C	C	B
	Eastbound	C	B	C	C	C
PM	Westbound	C	B	D	C	C
	Eastbound	C	B	C	C	B

*Section 1 - Slide Road overpass
*Section 2 – Between Slide Road and Quaker Avenue
*Section 3 – Between Quaker Avenue and Indiana Avenue
*Section 4 – Between Indiana Avenue and University Avenue
*Section 5 – Between University Avenue and IH27

The analysis of LOS on the frontage roads was carried out at four sections, including the frontage roads between Slide Road and Quaker Avenue (FS1), between Quaker and Indiana Avenue (FS2), between Indiana and University Avenue (FS3), and the section between University and IH27. The LOS for the morning and afternoon peak hours is summarized in Table 1-2: Section by Section Level of Service of Frontage Road under Current Condition.

Table 1-2: Section by Section Level of Service of Frontage Road under Current Condition

		Section 1	Section 2	Section 3	Section 4
AM	Westbound	C	C	B	C
	Eastbound	C	C	C	C
PM	Westbound	C	C	B	C
	Eastbound	C	C	C	C

*Section 1 – Between Slide Road and Quaker Avenue
*Section 2 – Between Quaker Avenue and Indiana Avenue
*Section 3 – Between Indiana Avenue and University Avenue
*Section 4 – Between University Avenue and IH27

As analyzed in Phase 1, the three improvement strategies impact the level of service of the network in different ways. Adding an auxiliary lane to the main lanes between entrance and exit ramps provides better LOS than the existing network because of the increased roadway capacity. However, it cannot result in a significant change in traffic distributions between frontage road and freeway simply because the auxiliary lane essentially does impact travelers' route choice behavior. It is easy to understand that though the LOS is improved in freeway segments, the performance of corresponding frontage roads remains almost unchanged in terms of V/C ratio.

Table 1-3: Section by Section Level of Service Main lane Traffic as a Result of Alternative 1

		Section 1	Section 2	Section 3	Section 4	Section 5
AM	Westbound	B	B	B	C	B
	Eastbound	B	B	C	C	C
PM	Westbound	B	B	C	C	B
	Eastbound	C	B	B	B	B

*Section 1 - Slide Road overpass
*Section 2 – Between Slide Road and Quaker Avenue
*Section 3 – Between Quaker Avenue and Indiana Avenue
*Section 4 – Between Indiana Avenue and University Avenue
*Section 5 – Between University Avenue and IH27

Table 1-4: Section by Section Level of Service of Frontage Roads as a Result of Alternative 1

		Section 1	Section 2	Section 3	Section 4
AM	Westbound	C	C	B	C
	Eastbound	C	C	C	C
PM	Westbound	B	C	B	C
	Eastbound	C	C	C	C

*Section 1 – Between Slide Road and Quaker Avenue
*Section 2 – Between Quaker Avenue and Indiana Avenue
*Section 3 – Between Indiana Avenue and University Avenue
*Section 4 – Between University Avenue and IH27

Changing the ramp configuration from a Diamond to X pattern as well as adding a lane on the frontage roads, as in the case of Alternative 2, essentially assigns a proportion of the traffic on the main lanes to the frontage road. Though it will improve the LOS on the main lane, traffic volumes on the frontage roads increased considerably. Additional lanes on the frontage road can in a certain degree accommodate and ease the increased traffic, which results in the LOS on the frontage road remaining at the level of Alternative 1.

Table 1-5: Section by Section Level of Service of Main lane Traffic as a Result of Alternative 2

		Section 1	Section 2	Section 3	Section 4	Section 5
AM	Westbound	C	B	C	B	B
	Eastbound	C	B	B	C	B
PM	Westbound	C	B	C	C	B
	Eastbound	C	B	C	B	B

*Section 1 - Slide Road overpass
*Section 2 – Between Slide Road and Quaker Avenue
*Section 3 – Between Quaker Avenue and Indiana Avenue
*Section 4 – Between Indiana Avenue and University Avenue
*Section 5 – Between University Avenue and IH27

Table 1-6: Section by Section Level of Service of Frontage Roads as a Result of Alternative 2

		Section 1	Section 2	Section 3	Section 4
AM	Westbound	C	C	B	C
	Eastbound	C	C	C	C
PM	Westbound	B	C	B	C
	Eastbound	C	C	C	C

*Section 1 – Between Slide Road and Quaker Avenue
*Section 2 – Between Quaker Avenue and Indiana Avenue
*Section 3 – Between Indiana Avenue and University Avenue
*Section 4 – Between University Avenue and IH27

In Alternative 3, the ramp configuration remains the same as in Alternative 2 throughout the network, and an auxiliary lane is provided on the main lanes over the bridges rather than in between the entrance and exit ramps. This alternative will improve the LOS on the overpass of the interchanges but have little impact on freeway segments between interchanges including Section 2, 3, 4 and 5.The pattern of traffic distribution between main lane and frontage roads almost remains unchanged and the V/C ratios of the frontage roads are also similar when compared with Alternative 2.

Table 1-7: Section by Section Level of Service of Main lane Traffic as a Result of Alternative 3

		Section 1	Section 2	Section 3	Section 4	Section 5
AM	Westbound	B	B	B	B	B
	Eastbound	B	B	B	B	B
PM	Westbound	B	B	C	B	B
	Eastbound	B	B	B	B	B

*Section 1 - Slide Road overpass
*Section 2 – Between Slide Road and Quaker Avenue
*Section 3 – Between Quaker Avenue and Indiana Avenue
*Section 4 – Between Indiana Avenue and University Avenue
*Section 5 – Between University Avenue and IH27

Table 1-8: Section by Section Level of Service of Frontage Roads as a Result of Alternative 3

		Section 1	Section 2	Section 3	Section 4
AM	Westbound	C	C	B	C
	Eastbound	C	C	C	C
PM	Westbound	B	C	B	C
	Eastbound	C	C	C	C

*Section 1 – Between Slide Road and Quaker Avenue
*Section 2 – Between Quaker Avenue and Indiana Avenue
*Section 3 – Between Indiana Avenue and University Avenue
*Section 4 – Between University Avenue and IH27

As analyzed in Phase 1, all three strategies will improve to varying degrees the level of service on the main lanes of the corridor. However, they will bring different impacts on the frontage roads.

Alternative 1 improves the level of service through added capacity on the main lanes of the corridor. It will not affect the trip distribution along South Loop 289, which results in similar traffic volumes and LOS on the frontage roads.

Alternative 2 alleviates the level of traffic density on the main lanes by converting the ramp configuration from a Diamond to an X pattern. However, a certain proportion of trips, particularly the short-distance trips, have been diverted to the frontage roads. Adding an auxiliary lane on the frontage roads can well accommodate the increased traffic. The performance of the frontage road segments is similar to the current network configuration.

Alternative 3 supplements Alternative 2 by adding an auxiliary lane on the bridges. The traffic distribution between the freeway segment and the frontage roads is similar to the traffic network under Alternative 2. So, the performance of the frontage roads also remains at the level of current traffic conditions.

According to interchange analysis by Synchro, the research team found that Alternative 2 and Alternative 3 could decrease control delays and provide better LOS for through movements on frontage roads at each interchange. Signal timing of interchanges was decided by the volume-to saturation flow ratio (V/S ratio) of the critical movement of each phase group. For frontage road green time at each interchange, the critical movement was left-turn, so the decreased frontage through traffic caused by interchange transformation would not change signal timing at interchanges. Therefore, traffic of other movements, including turning traffic on frontage roads and traffic on arterial roads will not benefit from an interchange transformation like Alternative 2 or Alternative 3 under both current traffic demands and future traffic demands.

In summary, the Phase 2 study approved the two basic conclusions resulting from the Phase 1 study:

1. Lane usage was as expected in that drivers making short trips tended to travel in the outer lanes between ramps and only drivers traveling much farther utilized the middle and inner lanes. Therefore, the alternatives including the auxiliary lane would help to reduce and alleviate some congestion due to the weaving movements.
2. The combination of Alternatives 1 and 2 presented in 3 helped to alleviate congestion the most.

Furthermore, the following conclusions can also be drawn based on the Phase 2 study:

1. Alternative 1 with an auxiliary lane provides better LOS on freeway main lanes than the existing network while not impacting LOS on frontage roads and intersections.
2. Alternative 2, changing the ramp configuration from Diamond to X and adding an auxiliary lane on frontage roads, considerably reduces traffic volume on freeway main lanes and increases traffic volumes on frontage roads. Because of the auxiliary lane added to frontage roads, frontage LOS would almost not be changed. This

improvement option decreases frontage road through traffic at interchanges and decreases control delay of this movement, but it has no effect on the other movements.

3. Alternative 3, with an auxiliary lane provided on freeway main lanes based on Alternative 2, has provided the same LOS on frontage roads and at interchanges. The auxiliary lane on the freeway benefited traffic from frontage roads to main lanes, while encouraging through traffic on frontage roads to move onto the auxiliary lane of main lanes. Alternative 3 provides better LOS on freeway main lanes and could further decrease the frontage road through traffic at interchanges, which means lower control delay and possibly better LOS for through traffic. However, the improvement option would not benefit the other movements at interchanges.
4. With limited construction funding, the research team suggests Alternative 1 to improve the traffic situation along South Loop 289.
5. With enough construction funding, the research team suggests Alternative 3, which provides better LOS on main lanes, longer weaving distances for weaving traffic, and better traffic safety at the joint points of on-ramps and main lanes.

1.7 Organization of the Report

This report contains eight sections. This section presents an overview of the project and provides a detailed summary of the findings. Section Two discusses the data collection and data analysis methods. Section Three presents an analytical discussion on the traffic redistribution after converting the interchanges from Diamond to X-type. In section Four, the Vissim and Synchro simulation tools used in the project are presented, as well as the description and modeling of the network, and the calibration and validation of the simulation model. Section Five presents the simulation results from Vissim and provides detailed LOS analysis of the proposed alternative strategies. Section Six presents the results of the signal timing design, the simulation results, and the LOS at the four major interchanges produced by Synchro. Section Seven presents the weaving analysis of the freeway segment between on- and off-ramps for current and future traffic volumes regarding the improved alternatives. Section Eight concludes this study.

2. TRAFFIC DATA AND DATA MINING

2.1. Data Collection

In order to analyze the complex traffic flow in the South Loop 289 area, detailed data needed to be collected. Traffic volumes needed to be collected at the following for all interchanges:

- Interchange Ramps
- Arterial Intersection Approaches
- Between Each Interchange Ramp and the Arterial Intersection Approach

Figures 2-1 through 2-5 show the locations where data was requested and received. For each diagram, a location or interchange area is listed. Also in each figure, highlighted red areas are frontage road data collection points, green areas are ramp locations, and blue areas are intersection approach locations.

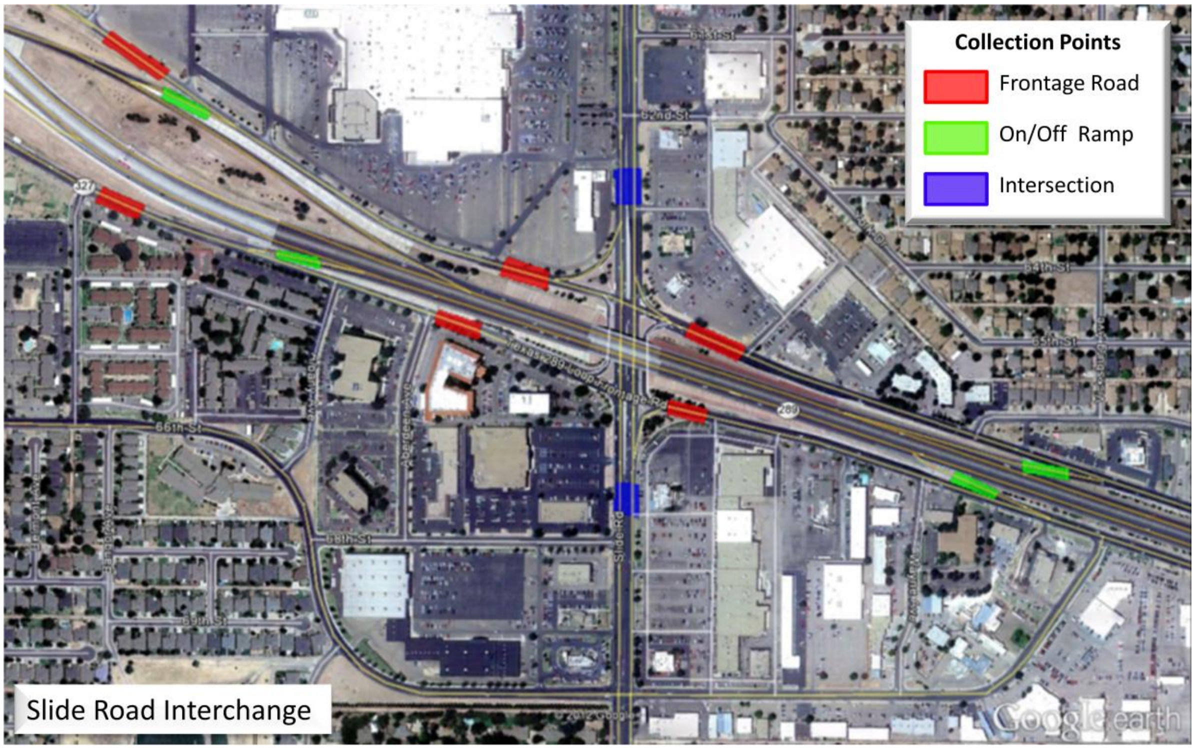


Figure 2-1: Data Collection Points at Slide Road Intersection

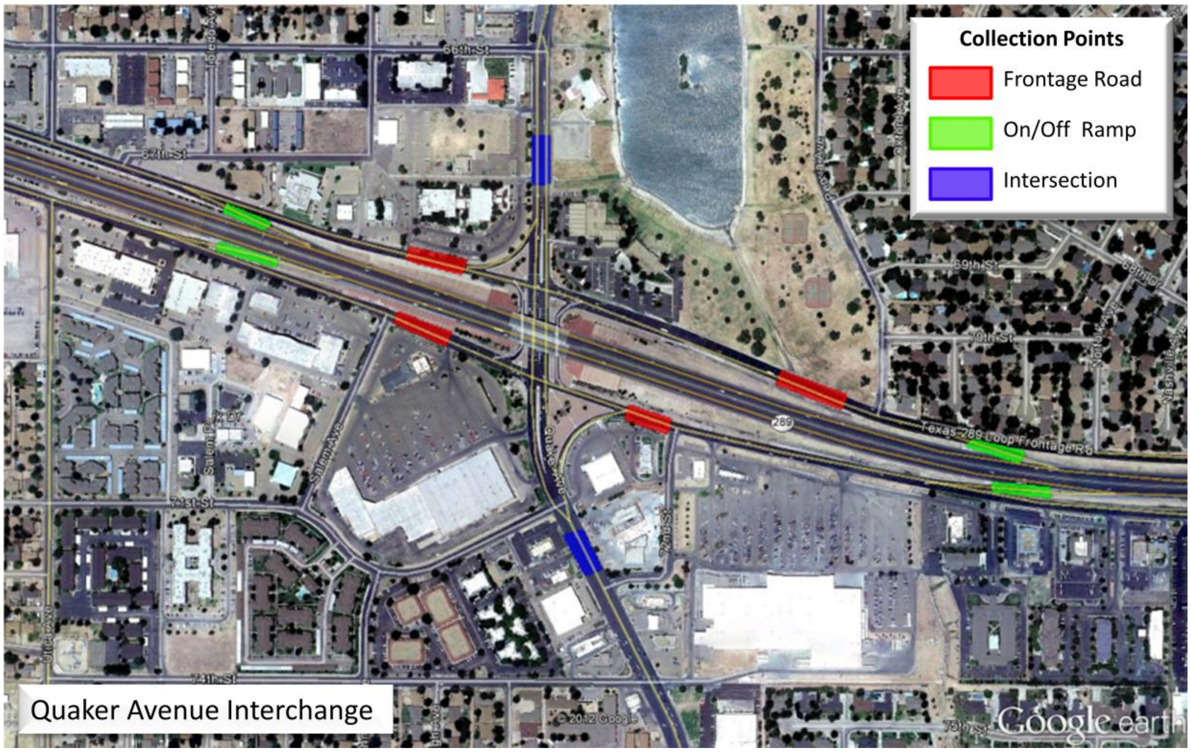


Figure 2-2: Data Collection Points at Quaker Avenue Intersection

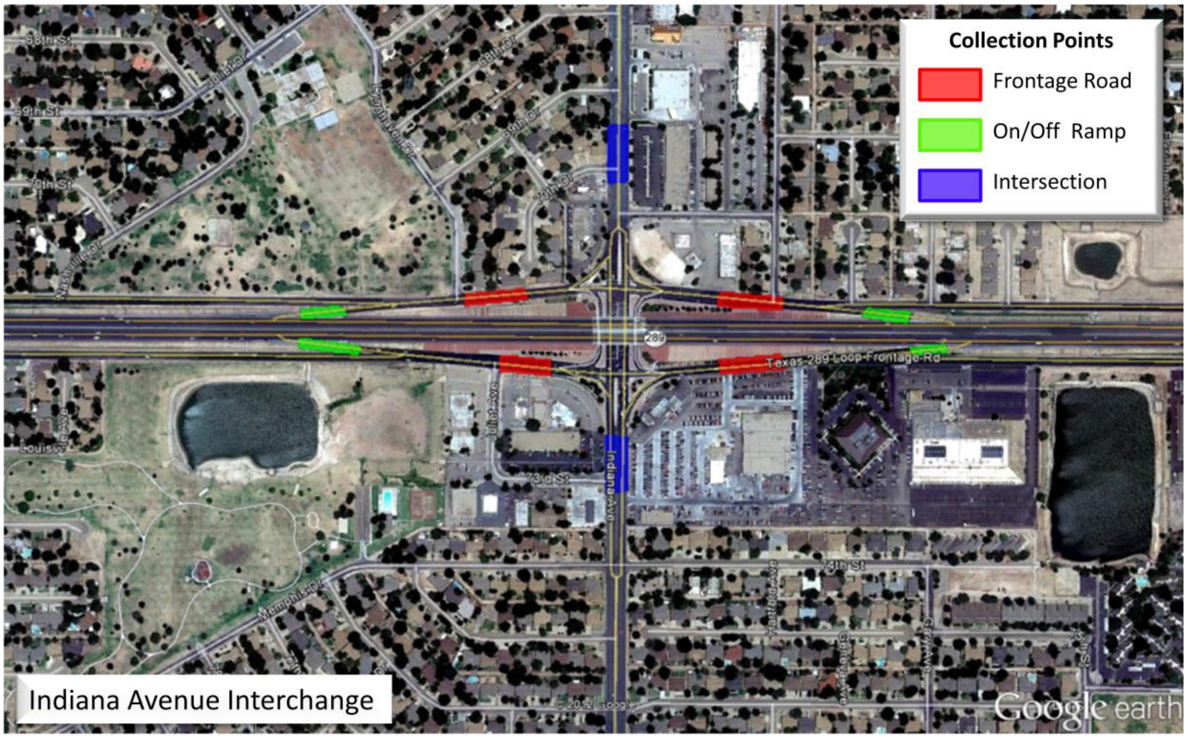


Figure 2-3: Data Collection Points at Indiana Avenue Intersection

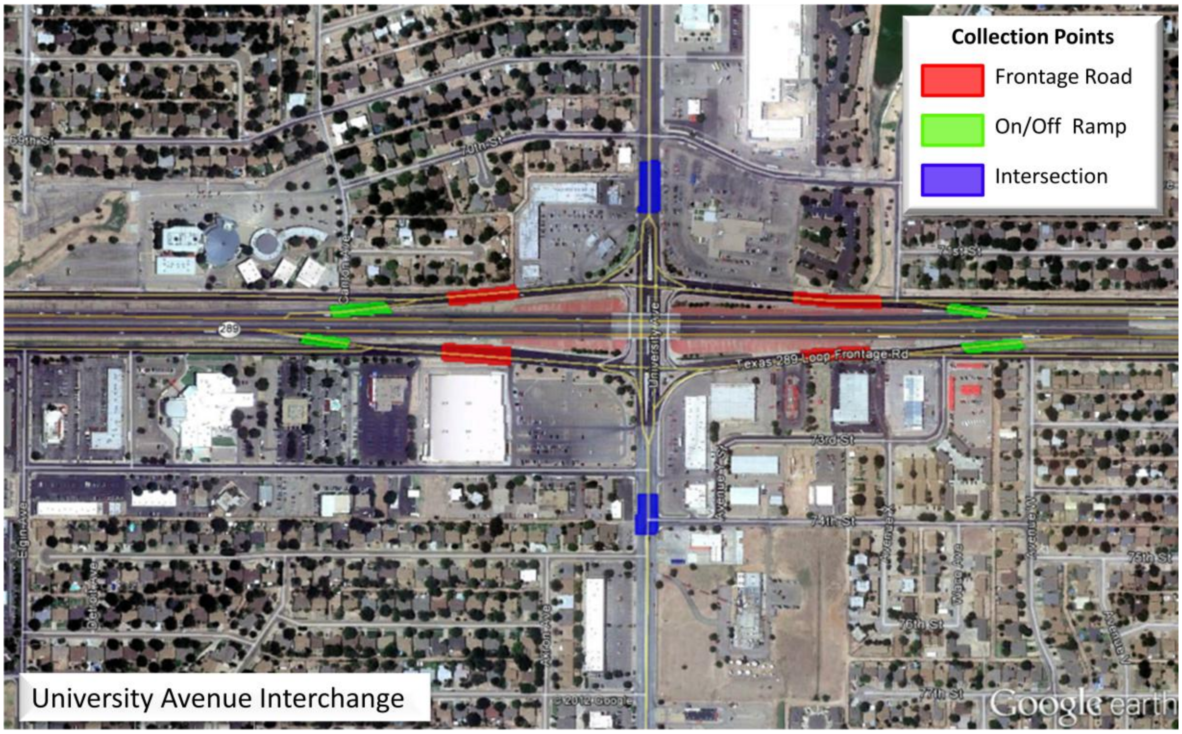


Figure 2-4: Data Collection Points at University Avenue Intersection

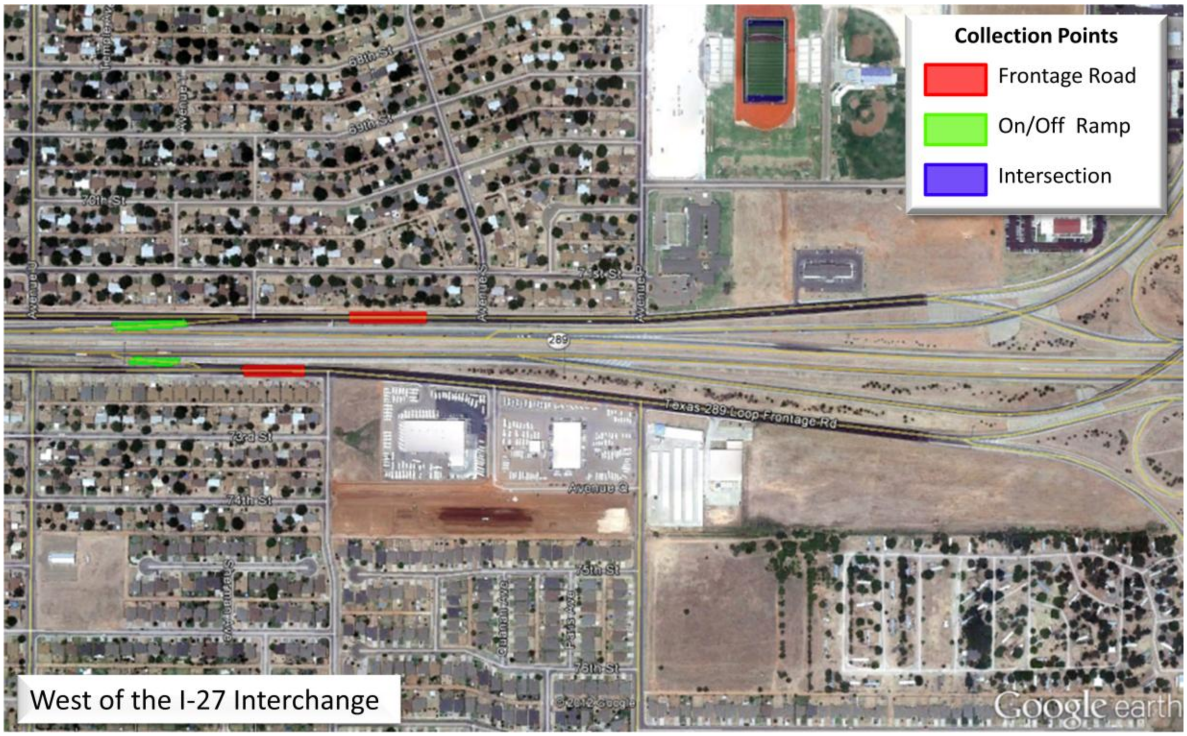


Figure 2-5: Data Collection Points West of the Interstate 27 Intersection

For each interchange related location, the volumes were provided in 15 minute intervals. They were provided for a couple of days of the week and the AM or PM peak was listed. For the Quaker and Indiana intersections, some of the existing data was missing or inaccurate, so this was supplemented by collecting new data for the turning movements by hand in the field. This new data was collected only at the peak times.

The collection of data for this analysis also provided easy access to detailed information of the traffic volume on the main lanes. This was seen as a better alternative than relying strictly on a growth factor for the current volume situation. The analysis used volumes collected at the three TxDOT detector points on the South Loop. Figures 2-6 through 2-8 show the location of the detectors and a description of the way in which the day is presented. Each lane is given a number as shown in the figures.

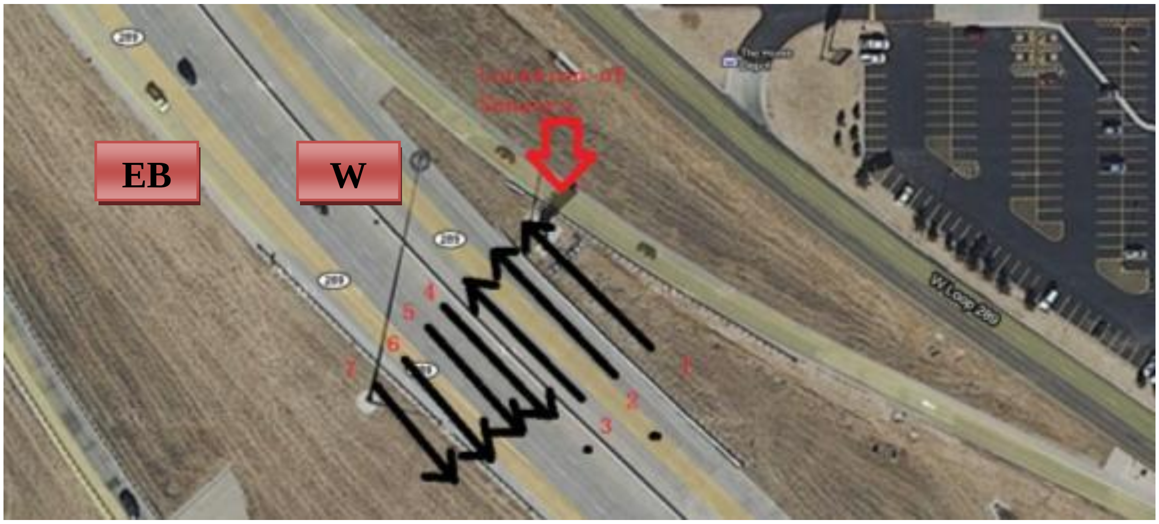


Figure 2-6: Main lane Data Collection Point at Spur 327

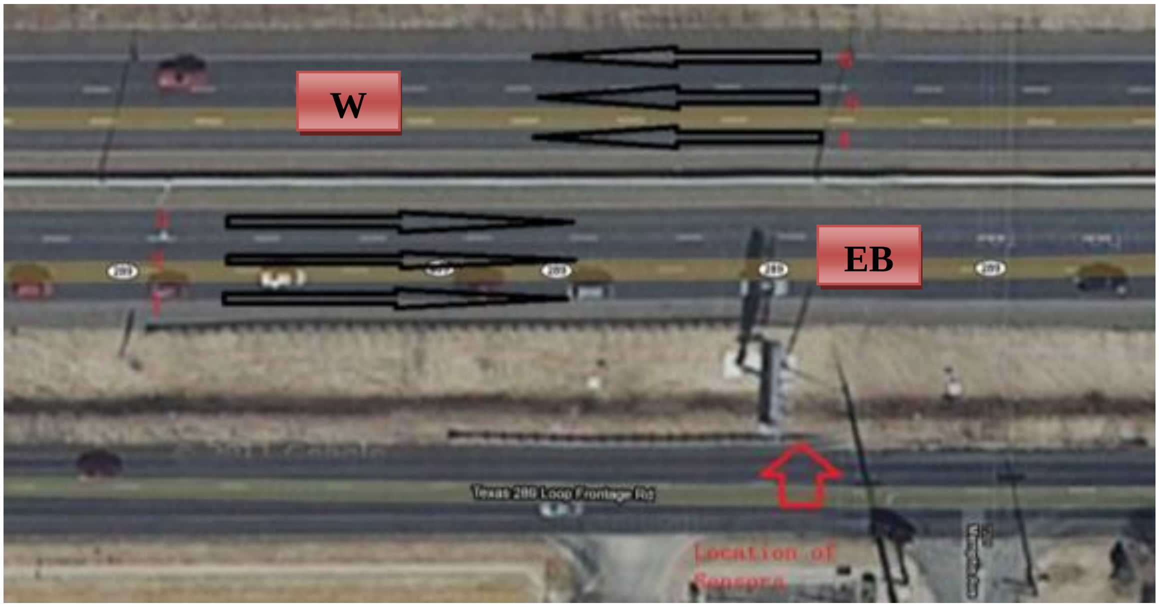


Figure 2-7: Main lane Data Collection Point at Memphis Avenue

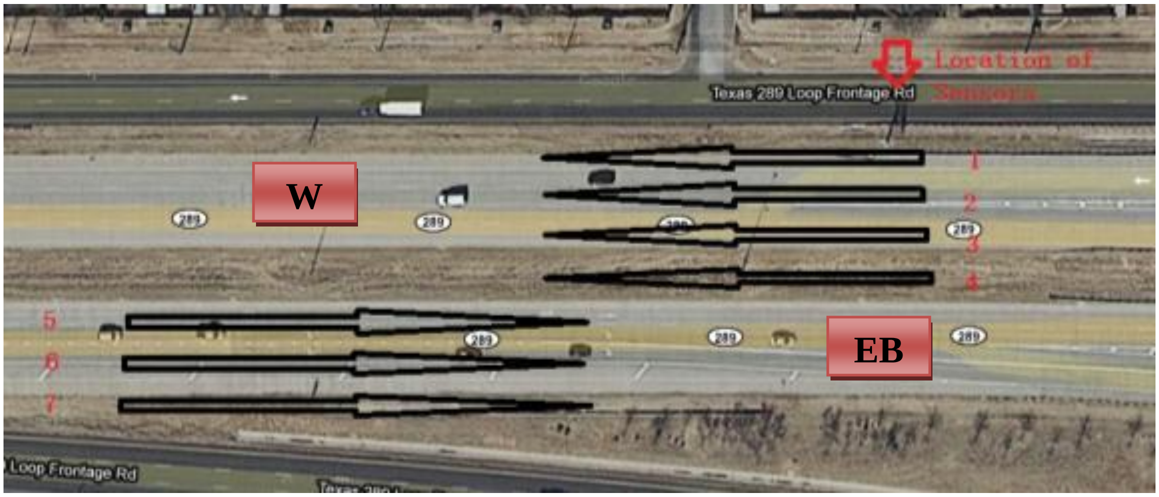


Figure 2-8: Main lane Data Collection Point at Avenue P

The TxDOT data from these detector locations were provided for three years in a volume per day measurement. Some data provided was erroneous and was listed as such in the information provided. Erroneous information was taken out of the data for the analysis.

The city's traffic volumes are presented in an interesting way. The traffic volumes from the City of Lubbock are plotted year versus year per lane in order to grasp a sense of increasing or decreasing traffic volume as presented in Figures 2-9 through 2-11.

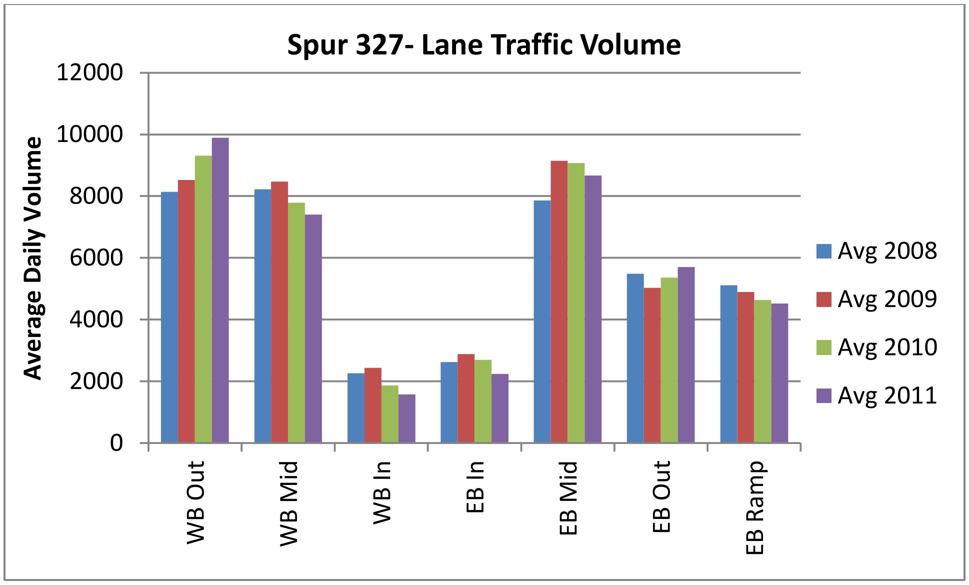


Figure 2-9: Daily Traffic Volumes at the Spur 327 Detector

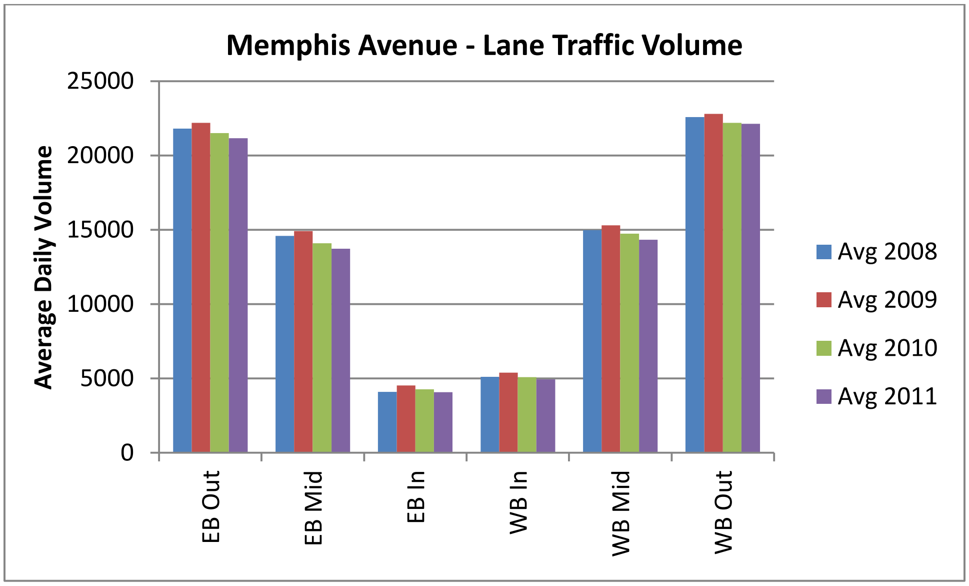


Figure 2-10: Daily Traffic Volumes at the Memphis Avenue Detector

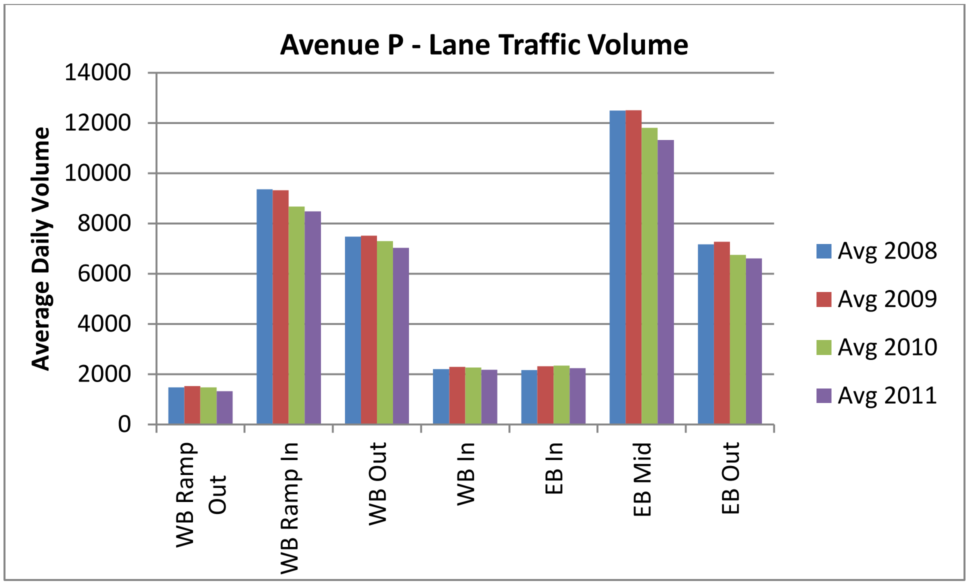


Figure 2-11: Daily Traffic Volumes at the Avenue P Detector

These charts highlight the idea that traffic is extremely unevenly distributed across the lanes for the main lanes. In fact, this trend remained remarkably constant throughout the last four years. It is also interesting to see that the volumes counted at these detectors do not necessarily always follow a strict growth rate. This could be seen as caused by various economic issues or rising gas prices.

The research team observed and counted traffic volumes of turning movements at two interchanges of the South Loop to verify the assumptions about the turning movement numbers (shown in Table 2-1).

Transformation of interchanges from Diamond-pattern to X-pattern is a key element considered in this research for improving the congested traffic along South Loop 289. It will cause traffic from freeway main lanes to be re-routed along frontage roads or in the opposite direction. Traffic volumes at ramps and frontage roads in the study area may change, and it is difficult to calculate the accurate re-routing numbers. Thus the research team took the traffic volumes and ramp designs between Slide Road and Quaker Avenue as references for estimating the locations of ramps in Alternative 2 and Alternative 3 and re-routing traffic volumes. Field observation and traffic counting was conducted on the frontage road segment between Slide Road and Quaker Avenue. Peak hour traffic volumes from freeway main lanes to areas along frontage roads (as shown in Figure 2-1:2Figure 1-1) (and traffic in the opposite direction) were recorded in Table 2-2.

Table 2-1: Recounted Turning Movements at Quaker Avenue and Indiana Avenue Interchanges

	Quaker Avenue & South Loop 289							
	North of Loop 289				South of Loop 289			
	SBR	WBR	WBL	NBL	NBR	EBR	EBL	SBL
AM Peak (7:15 - 8:15 AM)	55	58	39	107	105	56	44	83
	57	75	70	134	129	57	78	119
	86	126	113	161	139	139	91	128
	48	94	126	107	105	75	50	78
Total	246	353	348	509	478	327	263	408
PHF	0.715116	0.700397	0.690476	0.790373	0.859712	0.588129	0.722527	0.796875
PM Peak (5:15 - 6:15 PM)	66	86	185	178	118	123	73	95
	53	89	162	165	87	127	94	71
	59	79	140	169	86	144	76	109
	49	82	102	146	111	134	74	86
Total	227	336	589	658	402	528	317	361
PHF	0.859848	0.94382	0.795946	0.924157	0.851695	0.916667	0.843085	0.827982
	Indiana Avenue & South Loop 289							
	North of Loop 289				South of Loop 289			
	SBR	WBR	WBL	NBL	NBR	EBR	EBL	SBL
AM Peak (7:15 - 8:15 AM)	39	49	32	97	89	44	74	62
	94	77	51	176	113	99	158	109
	114	75	106	233	140	129	145	103
	91	88	74	151	94	76	135	94
Total	338	289	263	657	436	348	512	368
PHF	0.741228	0.821023	0.620283	0.704936	0.778571	0.674419	0.810127	0.844037
PM Peak (5:15 - 6:15 PM)	145	84	139	138	70	86	133	91
	135	76	116	105	52	198	158	66
	125	72	87	121	49	147	149	62
	120	61	64	127	49	101	103	51
Total	525	293	406	491	220	532	543	270
PHF	0.905172	0.872024	0.730216	0.889493	0.785714	0.671717	0.859177	0.741758

Figure 2-12: Areas along Frontage Roads Generating (and Attracting) Traffic to (or from) Freeway Main Lanes

Table 2-2: Observed Traffic Volumes between Freeway Main Lanes and Areas along Frontage Roads between Slide Road and Quaker Avenue

Eastbound S. Loop between Slide and Quaker					
Time		Offramp	hourly	Onramp	hourly
06/25/2012 AM	7:15 AM - 7:30 AM	12	48	13	52
	7:30 AM - 7:45 AM	18	72	23	92
	7:45 AM - 8:00 AM	22	88	25	100
	8:00 AM - 8:15 AM	20	80	13	52
	Hourly	72		74	
06/25/2012 PM	4:30 PM - 4:45 PM	24	96	21	84
	4:45 PM - 5:00 PM	29	116	19	76
	5:00 PM - 5:15 PM	40	160	17	68
	5:15 PM - 5:30 PM	31	124	15	60
	Hourly	124		72	
Westbound S. Loop between Slide and Quaker					
06/26/2012 AM	7:00 AM - 7:15 AM	2	8	12	48
	7:15 AM - 7:30 AM	3	12	24	96
	7:30 AM - 7:45 AM	8	32	18	72
	7:45 AM - 8:00 AM	13	52	34	136
	Hourly	26		88	
06/26/2012 PM	4:30 PM - 4:45 PM	9	36	4	16
	4:45 PM - 5:00 PM	15	60	8	32
	5:00 PM - 5:15 PM	20	80	8	32
	5:15 PM - 5:30 PM	10	40	4	16
	Hourly	54		24	

2.2. Data Analysis

Main Lanes Update

In order to create usable data for the main lanes, the given data had to go through several processes. First, any errors of data for each measurement point were removed. This left data with some holes but with enough information that an average daily volume could still be calculated. Second, an excel spreadsheet was used to isolate data for each day of the week, and an average amount was calculated for each. Last, the daily averages were compared to each other and it was found that Fridays posed the greatest stress on the system by having the greatest volumes for all measured sections (as shown in Figure 2-13). This Friday volume was used in the simulation by taking 10% of each lane volume and treating it as both the volume for morning and afternoon peak.

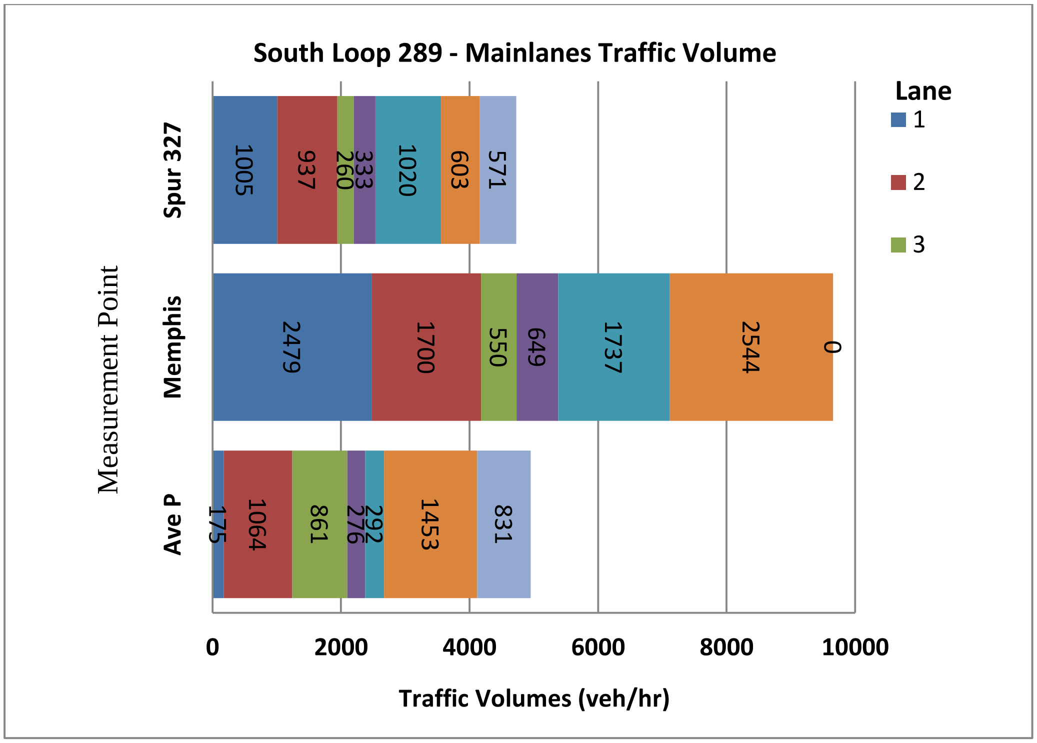


Figure 2-13: Main lane Traffic Volume Calculated at Each Collection Point

Frontage Road and Intersection Volumes

The provided data posed a substantial challenge due to the volumes that were recorded. For each study location, the volumes were recorded in 15 minute intervals. The peak hour volume was obtained from these counts. As Synchro takes hourly volumes as an input, it was necessary to further analyze the peak hourly volumes. The average of the daily peak hours was calculated for each movement of each location including interchange ramps.

Because Synchro uses a method where each link in the intersection must be provided with movement volumes, a type of conservation of volume method was used to determine each movement volume in the interchange. This is particularly important when considering the left movements on the north and south bound directions after they have passed the opposing frontage road intersection created at each intersection. It was used essentially to determine the amount of left turning cars that would balance the measured volumes with the provided through, right, and left turns from the other directions. This was done using diagrams and Excel spreadsheets to help with the complex task.

Missed volumes were analyzed by taking the 2008 data from the traffic counts on the website of the City of Lubbock (http://traffic.ci.lubbock.tx.us/TrafficData/trafficCounts.aspx) and amended using a percentage of the 2008 counts data. Because the northeast quadrant west bound data was missed at Quaker, the combined volume at another street along the route, Peoria, was used, and the percentage for the lanes was taken from the City of Lubbock frontage road data at the same location. Left turn volume and right turn volume for the south side of eastbound Indiana were not available. Therefore, the volumes from the 2008 data were referred.

3. ANALYSIS OF RAMP TRAFFIC REDISTRIBUTION

If the ramps along South Loop 289 are changed to X type, the traffic volume of each changed ramp will be changed because of relocation of the ramps. The changes in traffic volumes on the ramps of the study area are analyzed in this section using O-D analysis.

3.1 Ramp Design for Diamond to X

The ramps of South Loop 289 between Slide Road and Quaker Avenue are already in X type configurations, which means that the off ramp is before the on ramp along the direction of freeway traffic movement.

The ramps between Quaker Avenue and Indiana Avenue, Indiana Avenue and University Avenue, and East of University Avenue are proposed to be changed from Diamond pattern to X pattern.

The research team took the ramp design between Slide Road and Quaker Avenue as the reference to set the location and length of X pattern ramps for the proposed interchanges in this study. Between Slide Road and Quaker Avenue, the joint locations of off-ramp and freeway main lanes are separately 1200 feet (ft) and 1000 ft from the top of the adjacent bridge, and the off-ramp lengths are 660 ft and 600 ft, respectively. Between Slide Road and Quaker Avenue, the joint locations of on-ramp and freeway main lanes are separated 960 ft and 880 ft from the top of the adjacent bridge, and the on-ramp lengths are 1140 ft and 800 ft, respectively. In order to provide longer weaving distances for traffic on frontage roads with enough accelerating distance and decelerating distance, the following location and length of ramps are used for the proposed changed ramps in the study.

- On-ramp
    - 880 ft to the adjacent bridge top
    - 800 ft long
- Off-ramp
    - 1000 ft to the adjacent bridge top
    - 600 ft long

The proposed ramps for X type design are shown in Figures 3-1 through 3-4.

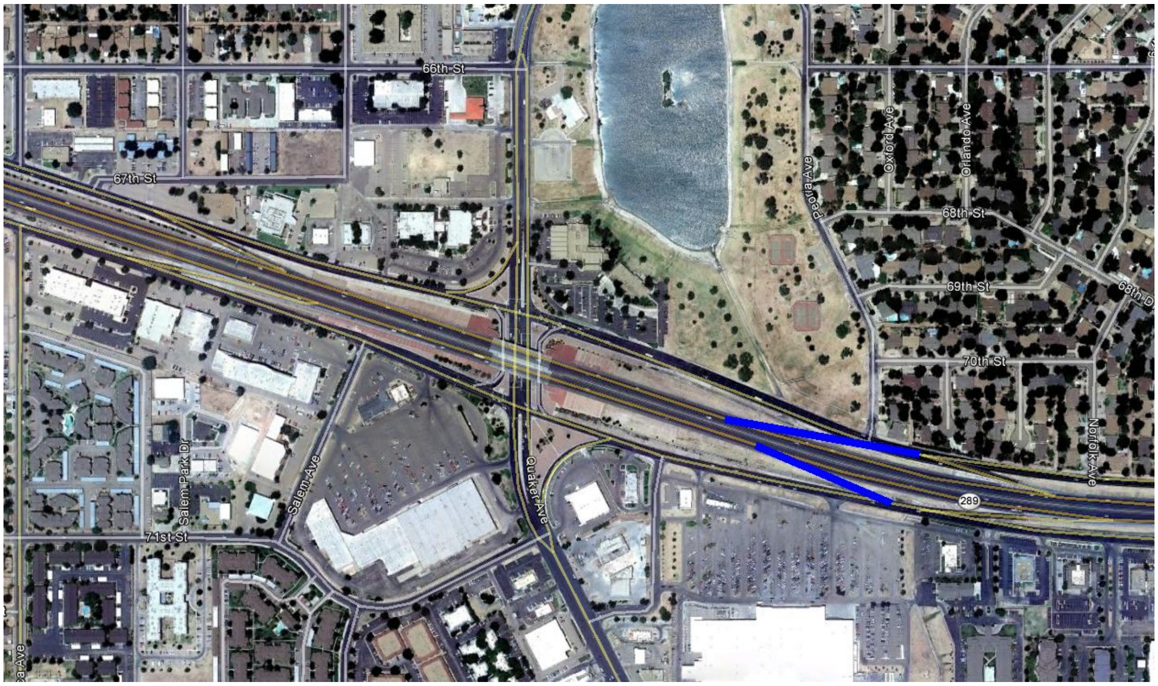


Figure 3-1: Proposed X Type Ramp Design at the Interchange of Quaker Avenue and South Loop 289

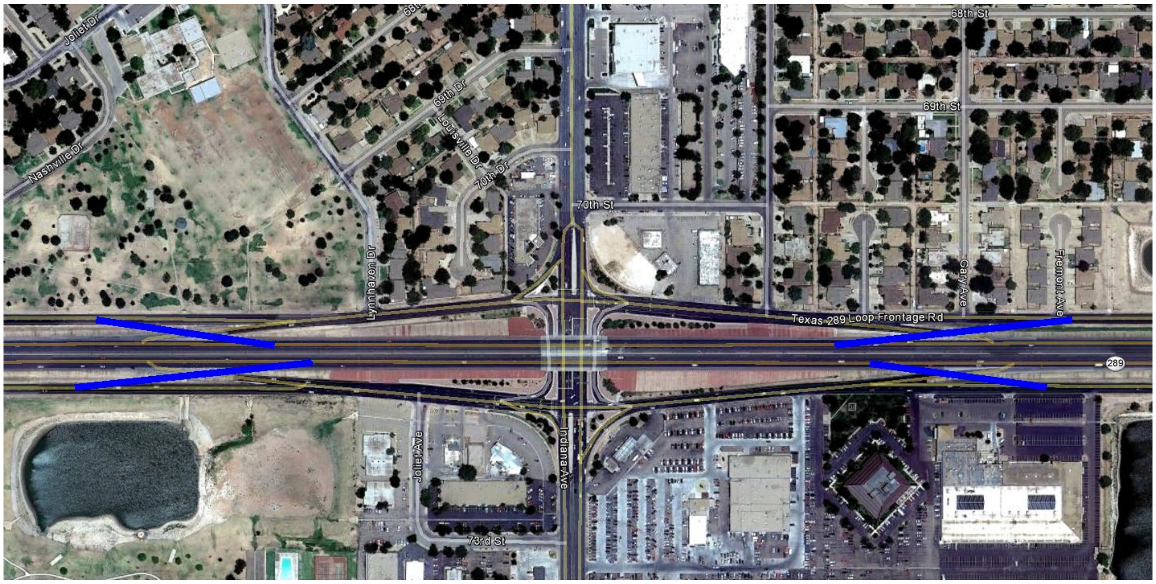


Figure 3-2: Proposed X Type Ramp Design at the Interchange of Indiana Avenue and South Loop 289

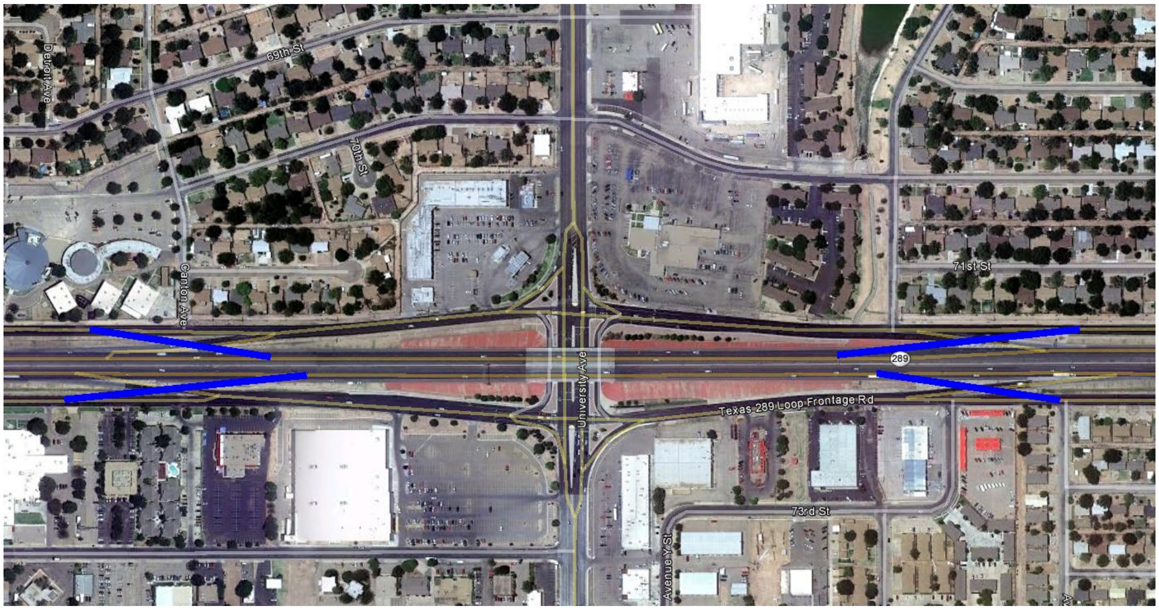


Figure 3-3: Proposed X Type Ramp Design at the Interchange of University Avenue and South Loop 289

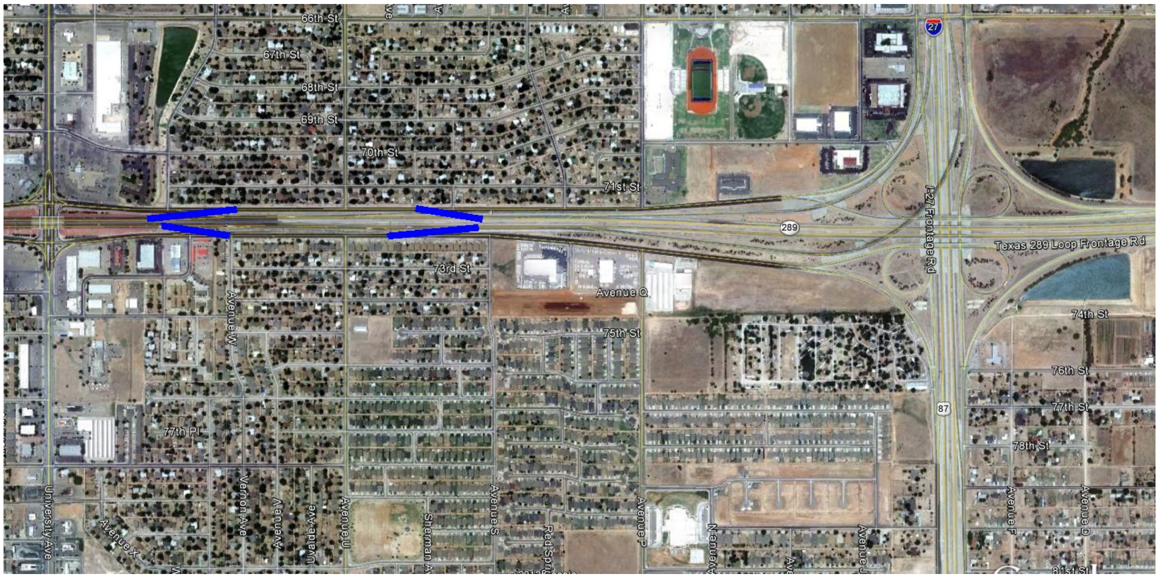


Figure 3-4: Proposed X Type Ramp Design on the East of the Interchange of University Avenue and South Loop 289

3.2 Eastbound On- and Off- Ramps

- **Eastbound Off-Ramp Between Slide Road and Quaker Avenue:**

The traffic from South Loop 289 eastbound main lanes to the business and residential area between Quaker Avenue and Indiana Avenue, shown as the blue polygon in Figure 3-5:, uses this off-ramp to exit the freeway under the current ramp configuration, shown as the red path in Figure 3-5:. If an X type ramp is used, traffic will exit using the blue path in Figure 3-5.The traffic volume on this ramp will be decreased.

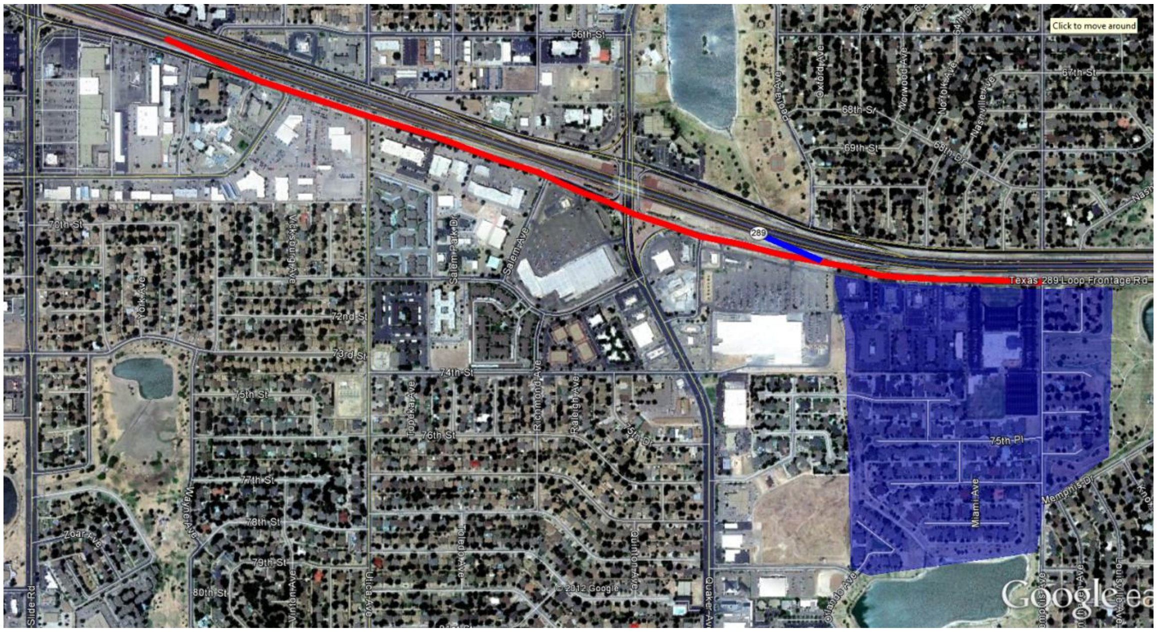


Figure 3-5: Traffic Re-Distribution of the Eastbound Off-Ramp Between Slide Road and Quaker Avenue

- **Eastbound Off-Ramp between Quaker Avenue and Indiana Avenue**

The traffic volume on this ramp will not change if the ramp design is altered. The traffic from the South Loop 289 eastbound main lanes to the business and residential area between Indiana Avenue and University Avenue, shown as the red area in Figure 3-6:, takes this off-ramp to exit the freeway under the current ramp configuration, but it will take the off-ramp between Indiana and University after the ramp configuration is changed. Therefore, the traffic volume using the ramp will decrease.

The traffic from the South Loop 289 eastbound main lanes to the business and residential area between Quaker Avenue and Indiana Avenue, shown as the blue area in Figure 3-6, takes the off-ramp between Slide Road and Quaker Avenue to exit the freeway under the current ramp configuration, but will take this ramp after the ramp configuration is changed. Therefore, this increased traffic will be added to the traffic volume of this ramp.

Due to these combined changes in traffic volume, the traffic volume using the off-ramp between Quaker Avenue and Indiana Avenue will remain unchanged.

Figure 3-6: Traffic Re-Distribution of the Eastbound Off-Ramp between Quaker Avenue and Indiana Avenue

- **Eastbound On-Ramp between Quaker Avenue and Indiana Avenue**

The traffic volume on this ramp will increase. The traffic from the business and residential area between Quaker Avenue and Indiana Avenue, shown as the blue area in Figure 3-7:, to the South Loop 289 eastbound main lanes takes the on-ramp between Indiana Avenue and University Avenue under the current ramp configuration, but normal traffic will take this ramp after the configuration is changed. Therefore, the traffic volume on this ramp will increase.

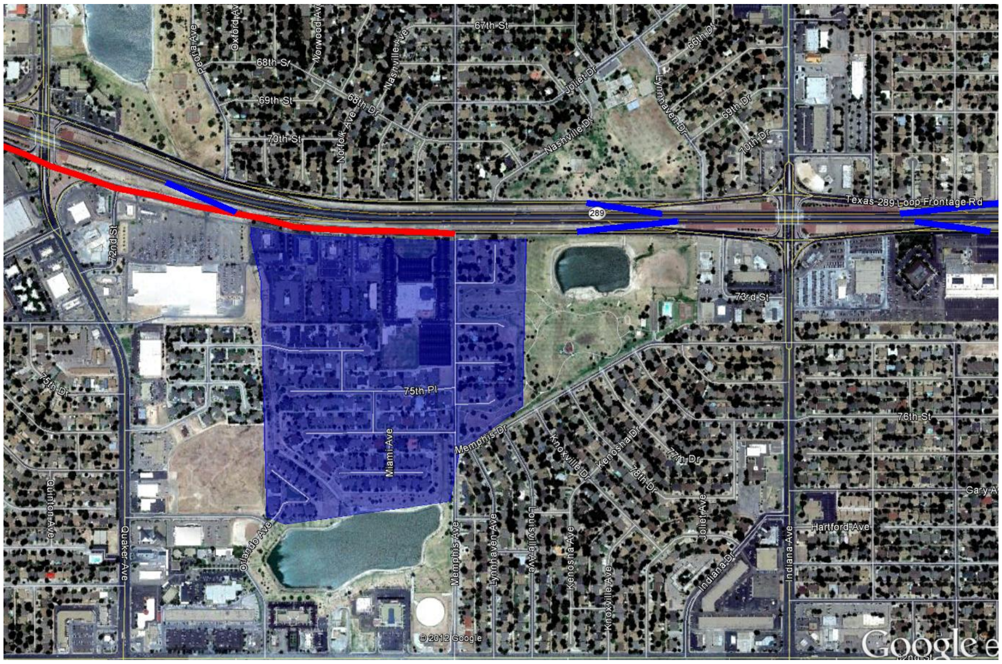


Figure 3-7: Traffic Re-Distribution of the Eastbound On-Ramp between Quaker Avenue and Indiana Avenue

- **Eastbound Off-Ramp between Indiana Avenue and University Avenue**

The traffic volume on this ramp will not change after a ramp design alteration. The traffic from the South Loop 289 eastbound main lanes to the business and residential area on the east of University, shown as the blue area in Figure 3-8:, takes this off-ramp to exit the freeway under the current ramp configuration, but will take the off-ramp on the east of University after the ramp configuration is changed. Therefore, this portion of traffic will be subtracted from the traffic volume on this ramp.

The traffic from the South Loop 289 eastbound main lanes to the business and residential area between Indiana Avenue and University Avenue, shown as the red area in Figure 3-8:, takes the off ramp between Quaker Avenue and Indiana Avenue to exit the freeway under the current ramp configuration but will take this ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume on this ramp.

These two changes to traffic will negate each other, resulting in a net balance of current traffic conditions.

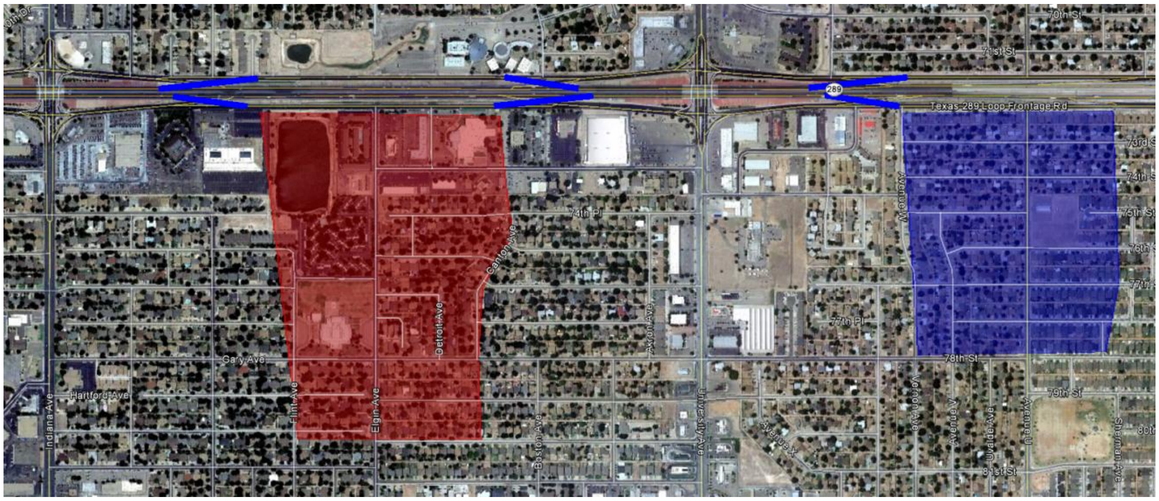


Figure 3-8: Traffic Re-Distribution of the Eastbound Off-Ramp between Indiana Avenue and University Avenue

- **Eastbound On-Ramp between Indiana Avenue and University Avenue**

The traffic volume on this ramp will not change after the ramp design is altered. The traffic from the business and residential area on the east of University Avenue, shown as the blue area in Figure 3-9, to the South Loop 289 eastbound main lanes takes this on-ramp to get onto the freeway under the current ramp configuration but will take the on-ramp between Quaker Avenue and Indiana Avenue after the ramp configuration is changed. Therefore, this portion of traffic will be subtracted from the traffic volume on this ramp.

The traffic from the business and residential area between Indiana Avenue and University Avenue, shown as the red area in Figure 3-9, takes the on-ramp on the east of University Avenue to get onto the freeway under the current ramp configuration but will take this ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume on this ramp.

These two changes in traffic flow result in a net balance of current traffic conditions, so the traffic at the ramp between Indiana Avenue and University Avenue will remain unchanged.

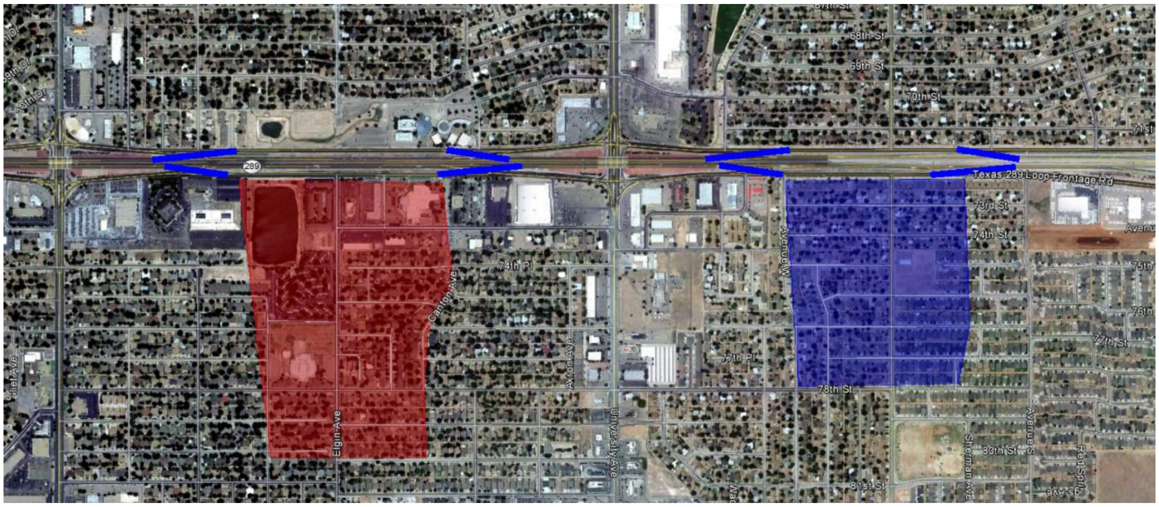


Figure 3-9: Traffic Re-Distribution of the Eastbound On-Ramp between Indiana Avenue and University Avenue

- **Eastbound Off-Ramp on the East of University Avenue**

The traffic volume on this ramp will increase after the ramp design is altered. The traffic from the business and residential area on the east of University Avenue, shown as the blue area in Figure 3-10, to the South Loop 289 eastbound main lanes takes the off-ramp between Indiana Avenue and University Avenue under the current ramp configuration but will take this ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume on this ramp.

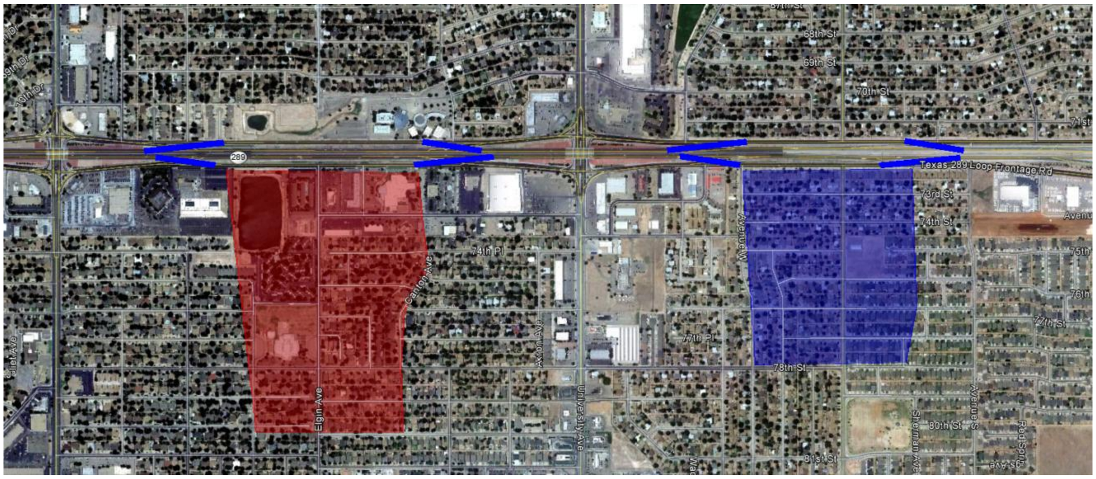


Figure 3-10: Traffic Re-Distribution of the Eastbound Off-Ramp on the East of University Avenue

- **Eastbound On-Ramp on the East of University Avenue**

The traffic volume on this ramp will increase. The traffic from the business and residential area on the east of University, shown as the blue area in Figure 3-11, takes the flyovers of the interchange of IH 27 and South Loop 289 onto IH 27 or South Loop 289 with the current ramp configuration, but will take this on-ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume of this ramp.

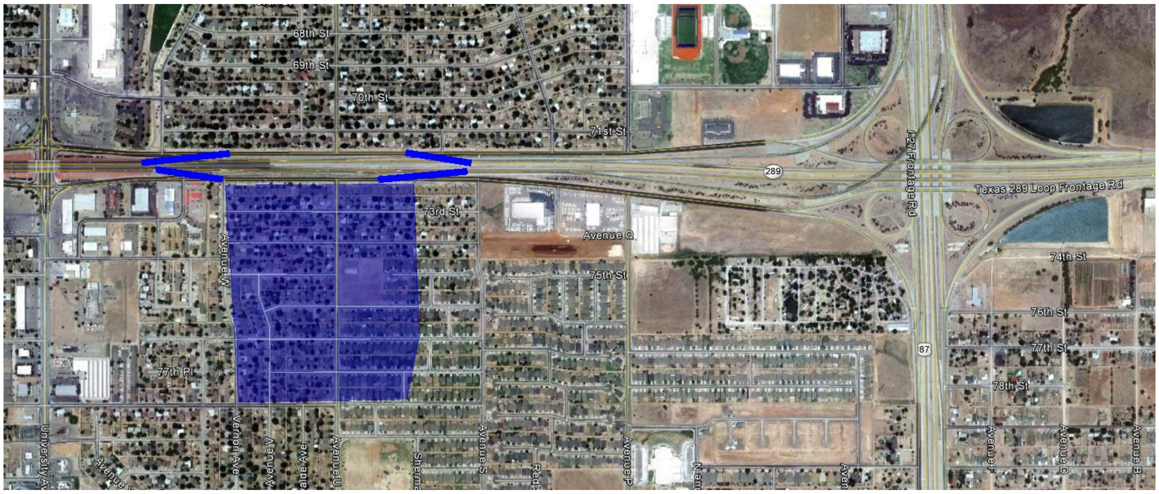


Figure 3-11: Traffic Re-Distribution of the Eastbound On-Ramp on the East of University Avenue

3.3 Westbound On- and Off- Ramps

- **Westbound Off-Ramp on the East of University Avenue**

The traffic volume on this ramp will decrease. The traffic from the South Loop 289 westbound main lanes to the business and residential area between University Avenue and Indiana Avenue, shown as the red area in Figure 3-12, takes this ramp under the current ramp configuration, but it will take the westbound off-ramp between University Avenue and Indiana Avenue under altered ramp conditions. Therefore, this portion of traffic will be subtracted from the traffic volume on this ramp.

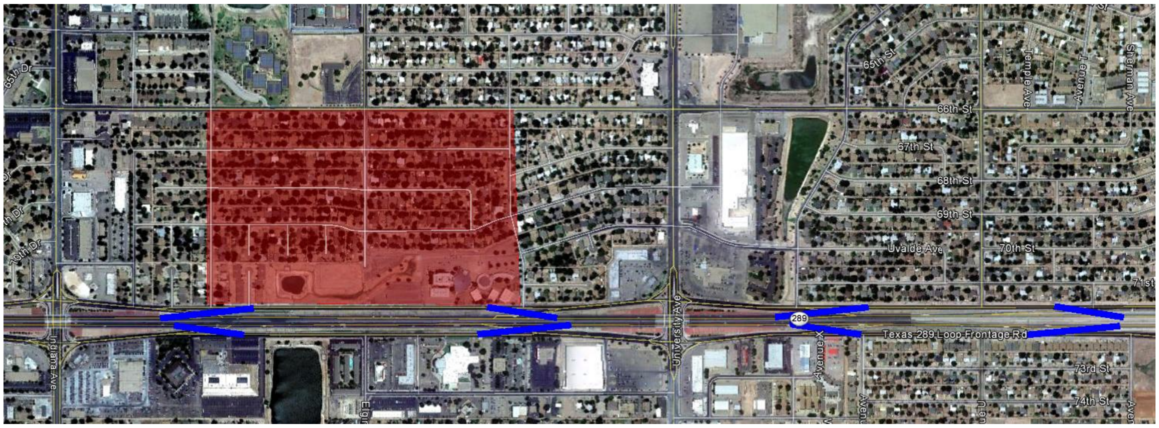


Figure 3-12: Traffic Re-Distribution of the Westbound Off-Ramp on the East of University Avenue

- **Westbound On-Ramp on the East of University Avenue**

The traffic volume on this ramp will increase. The traffic from the business and residential area on the east of University Avenue, shown as the blue area in Figure 3-13, takes the westbound on-ramp between University Avenue and Indiana Avenue onto South Loop 289 with current ramp configuration, but will take this on-ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume on this ramp.

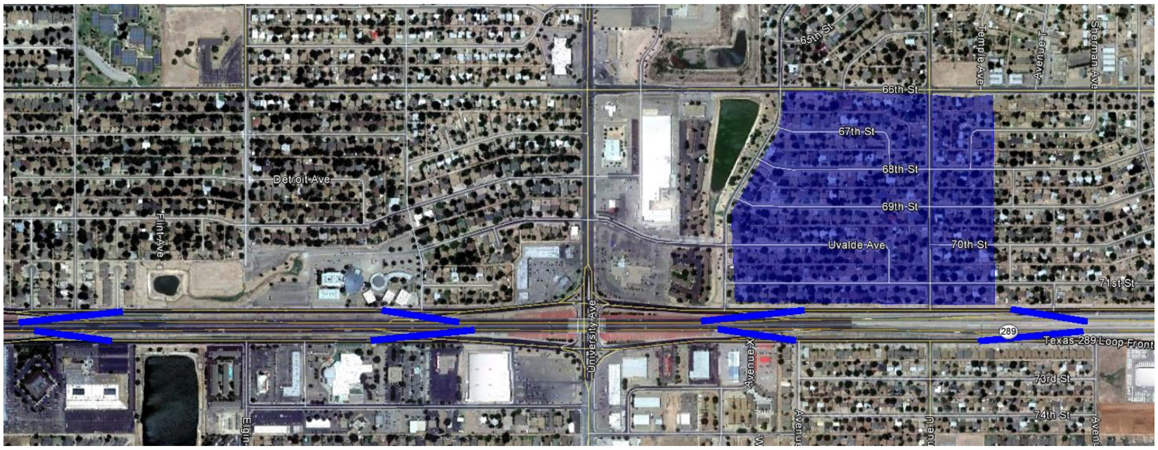


Figure 3-13: Traffic Re-Distribution of the Westbound On-Ramp on the East of University Avenue

- **Westbound Off-Ramp between University Avenue and Indiana Avenue**

The traffic volume on this ramp will not be changed after the ramp design is altered. The traffic from the South Loop 289 westbound main lanes to the business and residential area between Indiana Avenue and Quaker Avenue, shown as the blue area in Figure 3-14, takes this off ramp to exit the freeway under the current ramp configuration, but it will take the off-ramp between Indiana Avenue and Quaker Avenue after the ramp configuration is changed. Therefore, this portion of traffic will be subtracted from the traffic volume on this ramp.

The traffic from the South Loop 289 westbound main lanes to the business and residential area between University Avenue and Indiana Avenue, shown as the red area in Figure 3-14, takes the off ramp on the east of University Avenue to exit the freeway under the current ramp configuration, but will take this ramp after the ramp configuration is changed. Therefore, this traffic will be added to the traffic volume of this ramp.

Due to these counteracting changes in traffic volume, the traffic on the off-ramp between Indiana Avenue and University Avenue will remain unchanged.

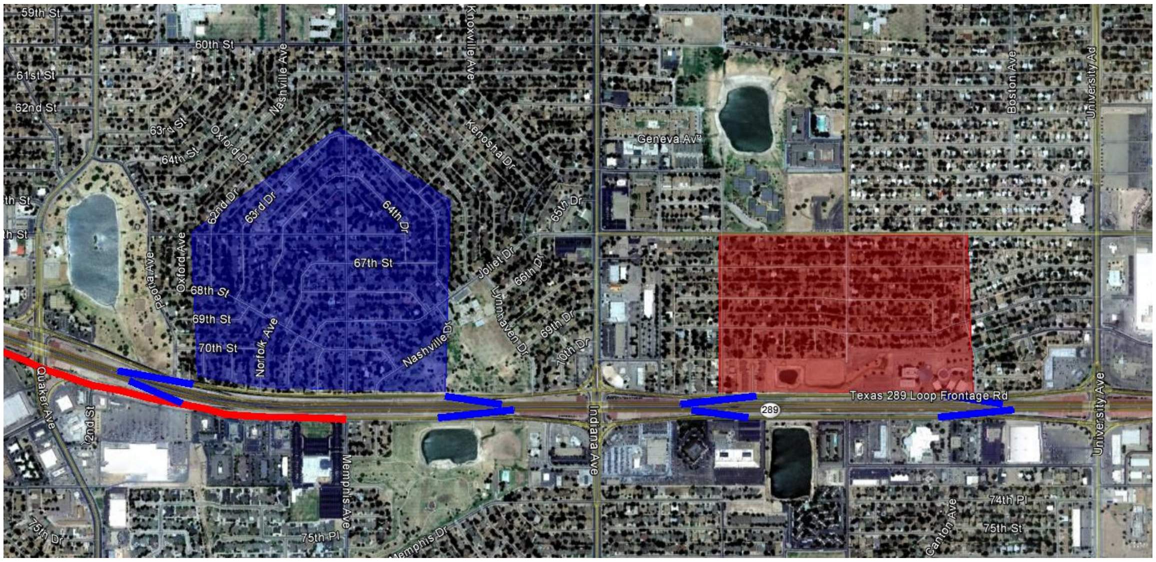


Figure 3-14: Traffic Re-Distribution of the Westbound Off-Ramp between University Avenue and Indiana Avenue

- **Westbound On-Ramp between University Avenue and Indiana Avenue**

The traffic volume on this ramp will not be changed after the ramp design is altered. The traffic from the business and residential area on the east of University Avenue, shown as the blue area in Figure 3-15, to the South Loop 289 westbound main lanes takes this on-ramp to get onto the freeway under the current ramp configuration, but will take the on-ramp on the east of University Avenue after the ramp configuration is changed. Therefore, this portion of traffic will be subtracted from the traffic volume on this ramp.

The traffic from the business and residential area between University Avenue and Indiana Avenue, shown as the red area in Figure 3-15, takes the on-ramp between Indiana Avenue and

Quaker Avenue to get onto the freeway under the current ramp configuration but will take this ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume of this ramp.

Due to these counteracting changes in traffic volume, the traffic on the off ramp between Indiana Avenue and University Avenue will remain unchanged.

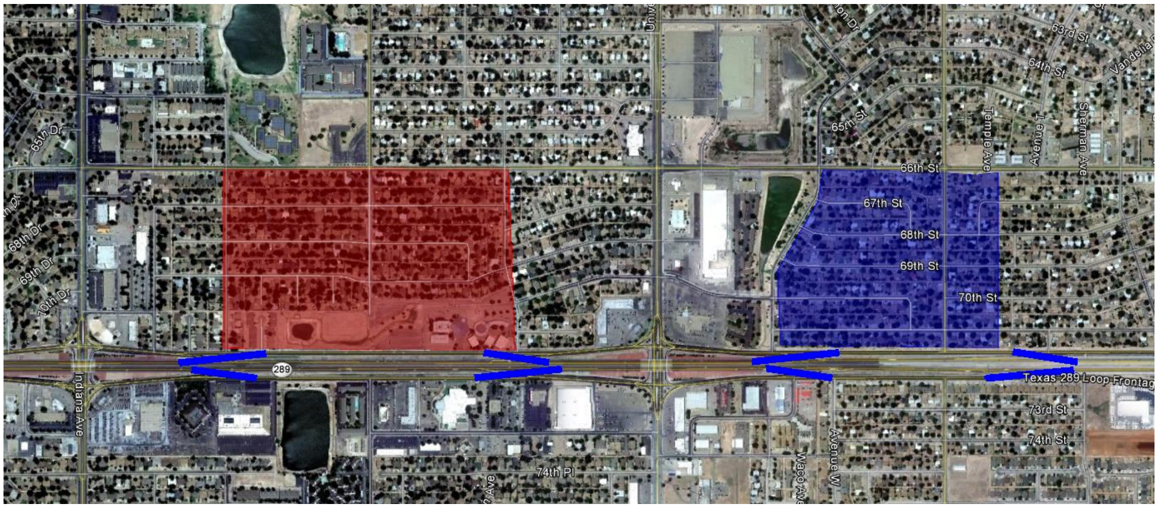


Figure 3-15: Traffic Re-Distribution of the Westbound On-Ramp between University Avenue and Indiana Avenue

- **Westbound Off-Ramp between Indiana Avenue and Quaker Avenue**

The traffic volume on this ramp will increase. The traffic from the South Loop 289 westbound main lanes to the business and residential area between Indiana Avenue and Quaker Avenue, shown as the blue area in Figure 3-16, takes the off-ramp between University Avenue and Indiana Avenue to exit the freeway with current ramp configuration, but it will take this ramp after the ramp configuration is changed. Therefore, this portion of traffic will be added to the traffic volume on this ramp.

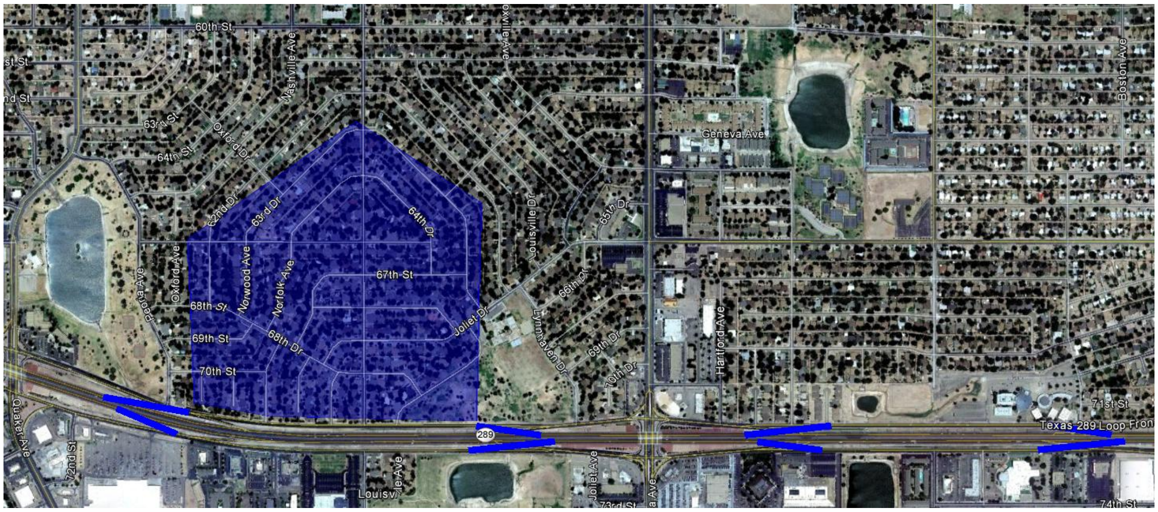


Figure 3-16: Traffic Re-Distribution of the Westbound Off-Ramp between Indiana Avenue and Quaker Avenue

- **Westbound On-Ramp between Quaker Avenue and Indiana Avenue**

The traffic volume on this ramp will remain unchanged. The traffic from the business and residential area between Indiana Avenue and Quaker Avenue, shown as the blue area in Figure 3-17, to the South Loop 289 westbound main lanes takes the on-ramp between Quaker Avenue and Slide Road under current ramp configuration, but the traffic will take this ramp after the configuration is changed. Therefore, this portion of traffic will be added to the traffic volume on this ramp.

The traffic from the business and residential area between University Avenue and Indiana Avenue, shown as the red area in Figure 3-17, takes this ramp onto the westbound main lanes of South Loop 289 with current ramp configuration, but it will take the on-ramp between University Avenue and Indiana Avenue under a different ramp configuration. The volume will be subtracted from the traffic volume on this ramp.

Due to these counteracting changes in traffic volume, the traffic on the off-ramp between Indiana Avenue and University Avenue will remain unchanged.

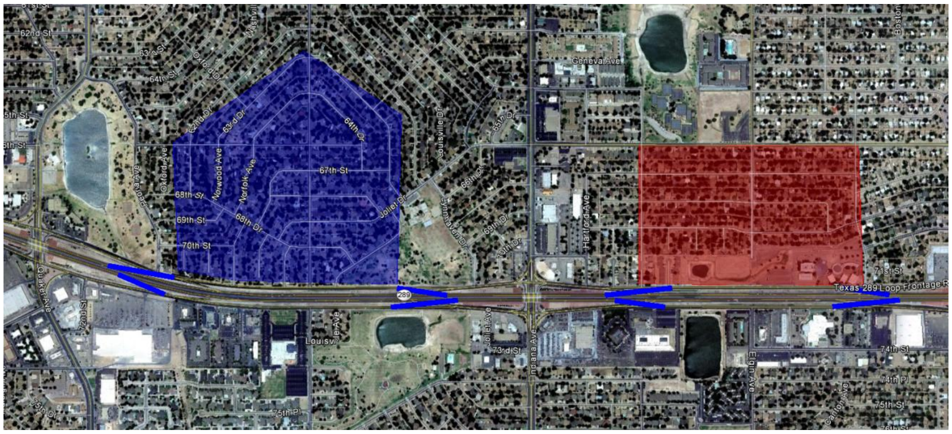


Figure 3-17: Traffic Re-Distribution of the Westbound On-Ramp between Indiana Avenue and Quaker Avenue

- **Westbound On-Ramp between Quaker Avenue and Slide Road**

The traffic volume on this ramp will decrease. The traffic from the business and residential area between Indiana Avenue and Quaker Avenue, shown as the blue area in Figure 3-18, takes this on-ramp with current ramp configuration, but the traffic will take the on-ramp between Indiana Avenue and Quaker Avenue after the configuration is changed. Therefore, the volume will be subtracted from the traffic volume on this ramp.

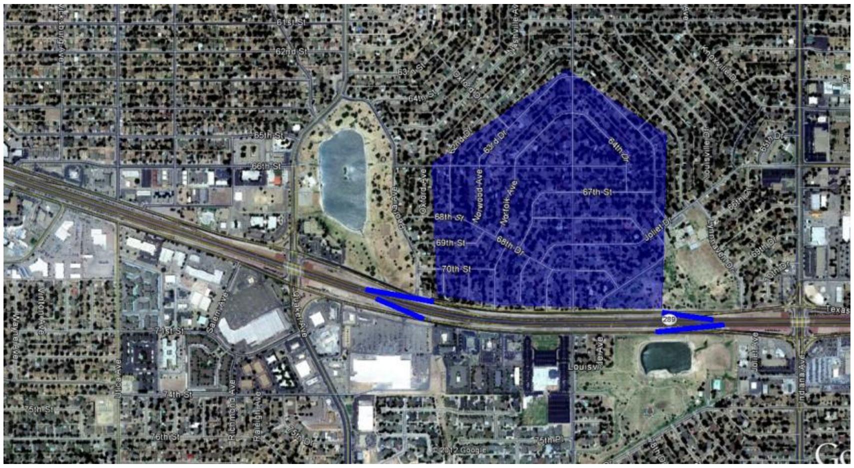


Figure 3-18: Traffic Re-Distribution of the Westbound On-Ramp between Quaker Avenue and Slide Road

3.4 Interchange Traffic Volume Changes

According to the O-D analysis and the ramp traffic distribution, the team concluded that the through traffic volumes on the frontage roads will decrease, as shown in Figure 3-19.

- **Decreased Eastbound Through Traffic**

For the intersection of Quaker Avenue and South Loop 289, the traffic from the eastbound main lanes of South Loop 289 to Area 1 is decreased.

For the intersection of Indiana Avenue and South Loop 289, the traffic from the eastbound main lanes of South Loop 289 to Area 2 and the traffic from Area 1 to the eastbound main lanes of South Loop 289 are decreased.

For the intersection of University Avenue and South Loop 289, the traffic from the eastbound main lanes of South Loop 289 to Area 3 and the traffic from Area 2 to the eastbound main lanes of South Loop 289 are decreased.

- **Decreased Westbound Through Traffic**

For the intersection of University Avenue and South Loop 289, the traffic from the westbound main lanes of South Loop 289 to Area 5 and the traffic from Area 6 to the westbound main lanes of South Loop 289 are decreased.

For the intersection of Indiana Avenue and South Loop 289, the traffic from the westbound main lanes of South Loop 289 to Area 4 and the traffic from Area 5 to the westbound main lanes of South Loop 289 are decreased.

For the intersection of Quaker Avenue and South Loop 289, the traffic from Area 4 to the westbound main lanes of South Loop 289 is decreased.

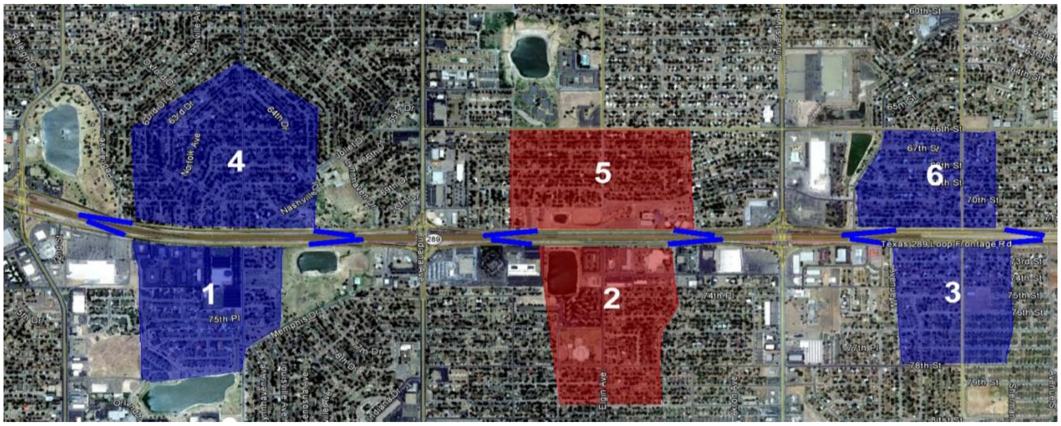
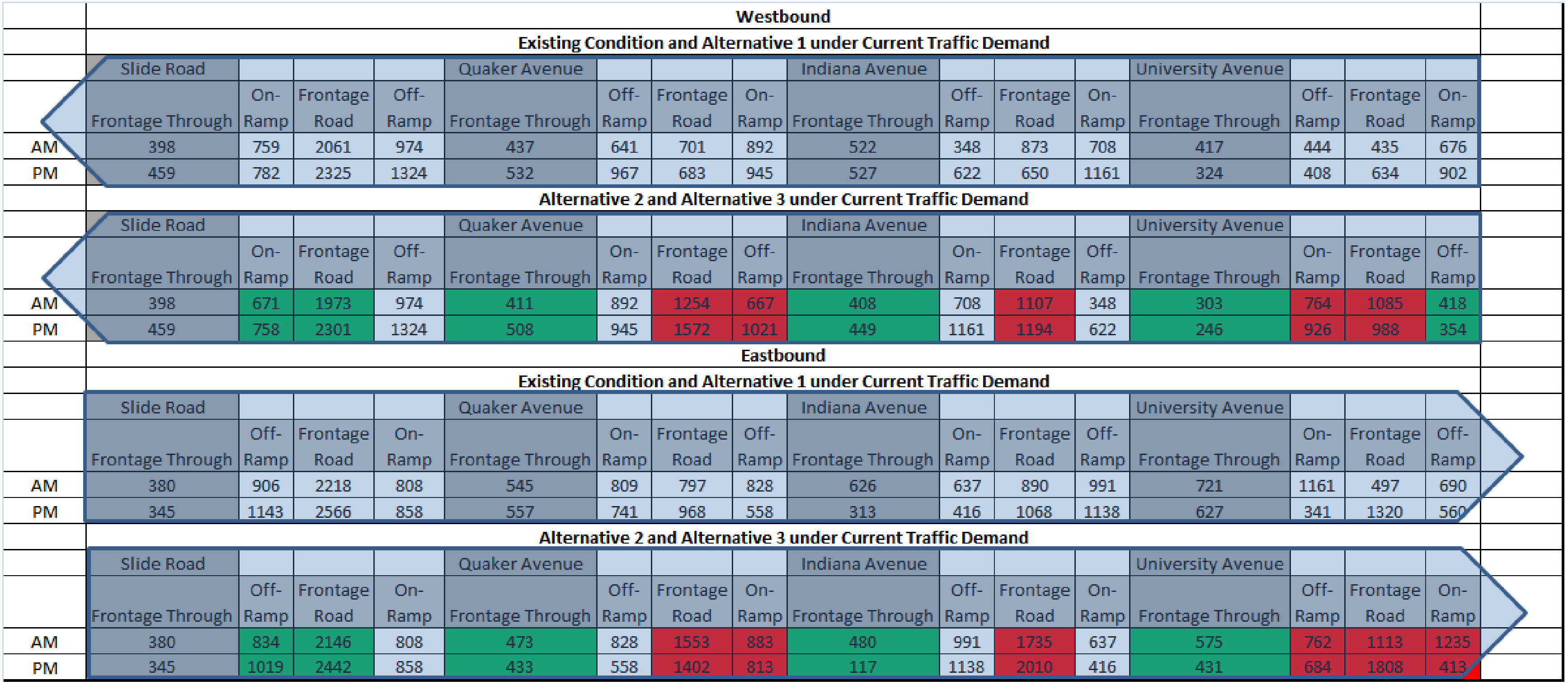


Figure 3-19: Business and Residential Areas Impacting Traffic Volumes of Through Movements

3.5 Traffic Re-Routing Results along Frontage Roads

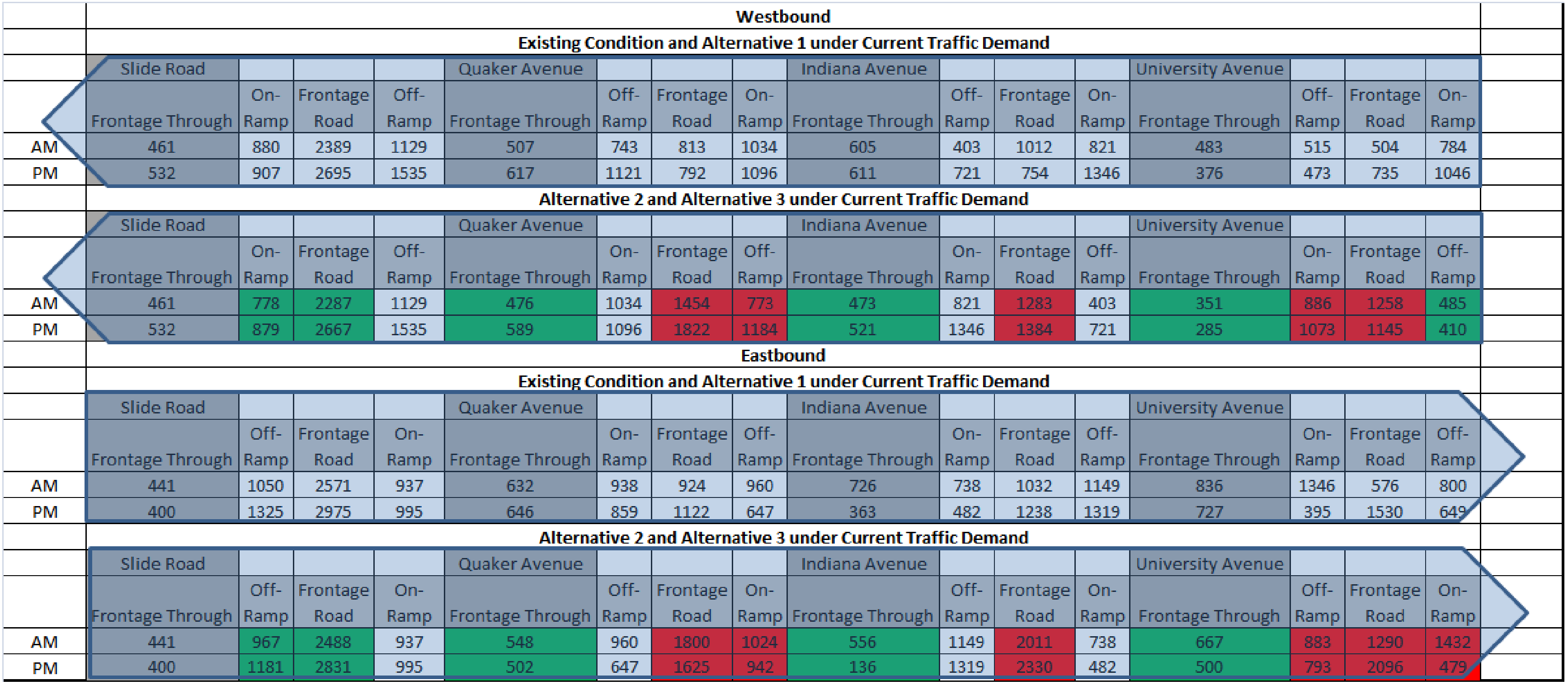
Table 3-1 and Table 3-2 demonstrate the current and forecasted traffic volume changes along the frontage roads of South Loop 289, when Diamond interchanges are changed to X-Type interchanges. The red-marked cells show the volumes increased by the transformation and the green-marked cells show the volumes decreased by the transformation.

Table 3-1: Traffic Re-Routing along Frontage Roads of South Loop 289 (Current Traffic Demand)



	Westbound															
	Existing Condition and Alternative 1 under Current Traffic Demand															
	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp
AM	398	759	2061	974	437	641	701	892	522	348	873	708	417	444	435	676
PM	459	782	2325	1324	532	967	683	945	527	622	650	1161	324	408	634	902
	Alternative 2 and Alternative 3 under Current Traffic Demand															
	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp
AM	398	671	1973	974	411	892	1254	667	408	708	1107	348	303	764	1085	418
PM	459	758	2301	1324	508	945	1572	1021	449	1161	1194	622	246	926	988	354
	Eastbound															
	Existing Condition and Alternative 1 under Current Traffic Demand															
	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp
AM	380	906	2218	808	545	809	797	828	626	637	890	991	721	1161	497	690
PM	345	1143	2566	858	557	741	968	558	313	416	1068	1138	627	341	1320	560
	Alternative 2 and Alternative 3 under Current Traffic Demand															
	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp
AM	380	834	2146	808	473	828	1553	883	480	991	1735	637	575	762	1113	1235
PM	345	1019	2442	858	433	558	1402	813	117	1138	2010	416	431	684	1808	413

Table 3-2: Traffic Re-Routing along Frontage Roads of South Loop 289 (Forecasted Future Traffic Demand)



Westbound

Existing Condition and Alternative 1 under Current Traffic Demand

	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp
AM	461	880	2389	1129	507	743	813	1034	605	403	1012	821	483	515	504	784
PM	532	907	2695	1535	617	1121	792	1096	611	721	754	1346	376	473	735	1046

Alternative 2 and Alternative 3 under Current Traffic Demand

	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp
AM	461	778	2287	1129	476	1034	1454	773	473	821	1283	403	351	886	1258	485
PM	532	879	2667	1535	589	1096	1822	1184	521	1346	1384	721	285	1073	1145	410

Eastbound

Existing Condition and Alternative 1 under Current Traffic Demand

	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp	Frontage Through	On-Ramp	Frontage Road	Off-Ramp
AM	441	1050	2571	937	632	938	924	960	726	738	1032	1149	836	1346	576	800
PM	400	1325	2975	995	646	859	1122	647	363	482	1238	1319	727	395	1530	649

Alternative 2 and Alternative 3 under Current Traffic Demand

	Slide Road				Quaker Avenue				Indiana Avenue				University Avenue			
	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp	Frontage Through	Off-Ramp	Frontage Road	On-Ramp
AM	441	967	2488	937	548	960	1800	1024	556	1149	2011	738	667	883	1290	1432
PM	400	1181	2831	995	502	647	1625	942	136	1319	2330	482	500	793	2096	479

4. MICROSCOPIC SIMULATION WITH VISSIM AND SYNCHRO

Simulation is a software tool used to replicate the real traffic conditions of the field, to evaluate operational conditions, and to investigate a transportation network. Microsimulation models are traffic models used to determine the driving behavior of individual vehicles traveling on the network. The microsimulation software tools have built-in traffic models for car-following, lane changing, and gap-acceptance. Microscopic simulation is mainly used for the evaluation and development of road traffic management and control systems.

Use of microsimulation models provide a better and clearer presentation of actual driver behavior inside the simulation network. These models are helpful to code complex traffic problems along with the implementation of intelligent transportation systems. Moreover, these software packages have an advantage – the ability to show the traffic flow traversing on the networks and various road and junction types (Bloomberg and Dale, 2000). This helps to represent the problem and solution in a format understandable to professionals and laymen alike.

VISSIM provides a discrete, stochastic, and time step based microscopic model. In VISSIM, the driver and the vehicle are modeled as single entities. The traffic flow model in VISSIM provides a psycho-physical car following model along with the rule-based algorithm for lane changing movements (Fellendorf and Vortisch, 2005).

VISSIM has a different microscopic simulation model compared to other models in terms of node-link structure. In VISSIM, networks are modeled based on links and connectors. In this model, the movement of vehicles is controlled by the node-link structure, in which the vehicle after arriving to the end of a link depends on the upstream or downstream node above or below to continue its trajectory (Gonzalez, 2006).

4.1 Network Coding

The study area consists of a freeway section with four major interchanges connected by frontage roads in both eastbound and westbound directions. The VISSIM microsimulation model was used for the development of the network of the corridor. The network was constructed using a 2D environment and then converted into 3D mode by assigning an elevation (arbitrary) to the links and connectors to provide a 3D view to the network.

VISSIM

The roadway network was designed in VISSIM using the details obtained from Google Earth. The network geometry was then checked against the “Sign and Striping Layout” provided by the Texas Department of Transportation (TxDOT) Lubbock District and also against the geometry observed in the field from the visits made to the project area. The network was designed on the background image, obtained from Google Earth, which had to be scaled to the real world dimensions. The area of interest is a five-mile portion, starting from IH-27 and extending to Spur 329 as shown in Figure 4-1.

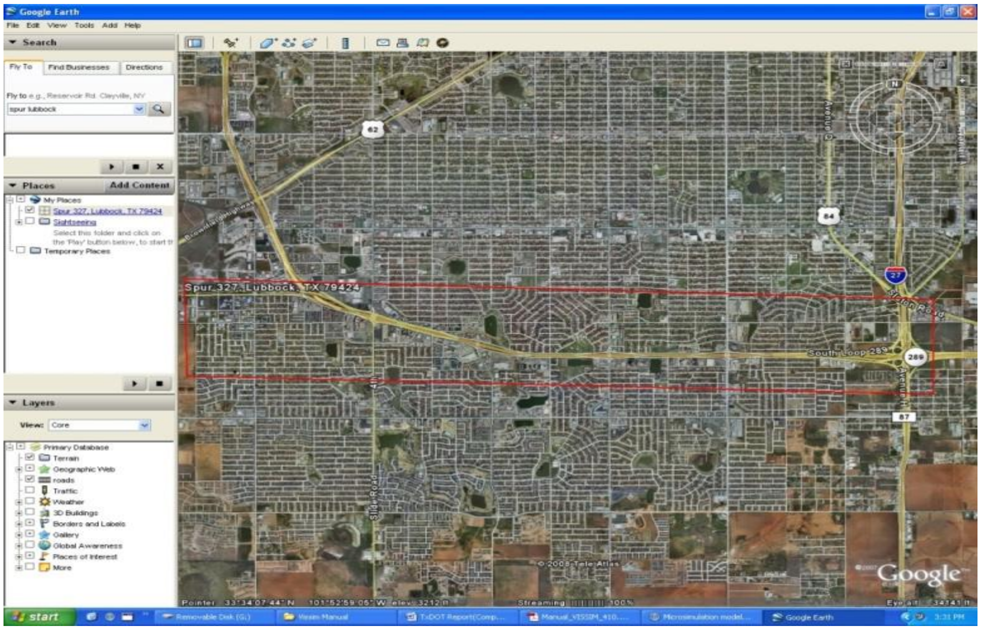


Figure 4-1: Google Earth Image of the Project Area

The network was developed using links and connectors. After the whole network had been modeled, the geometric design was checked to verify the accuracy of the length of the curves, ramps, distance between the two intersections of the interchange, number of lanes, width of the lanes, etc. After the roadway network was modeled, traffic control systems (e.g., signal, stop, and yield controls, etc.), and total volume inputs were coded throughout the network.

The signal controller was designed as a fixed time controller for all the intersections and the signal timing data was collected for all the intersections. The volume inputs were obtained from the raw data files provided by the Lubbock District TxDOT office. The simulation was run with the original volume and signal timing plan. The sample snapshots of the network coding and the simulations are shown in Figure 4-2 and in Figure 4-3.

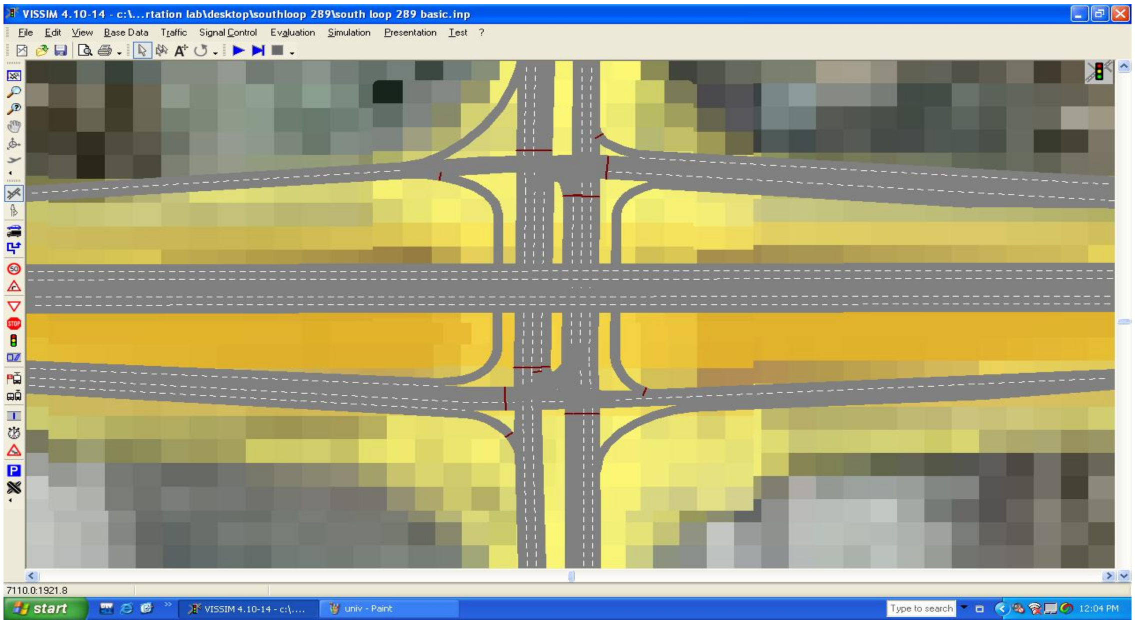


Figure 4-2: Coding of Traffic Control Systems at University Avenue

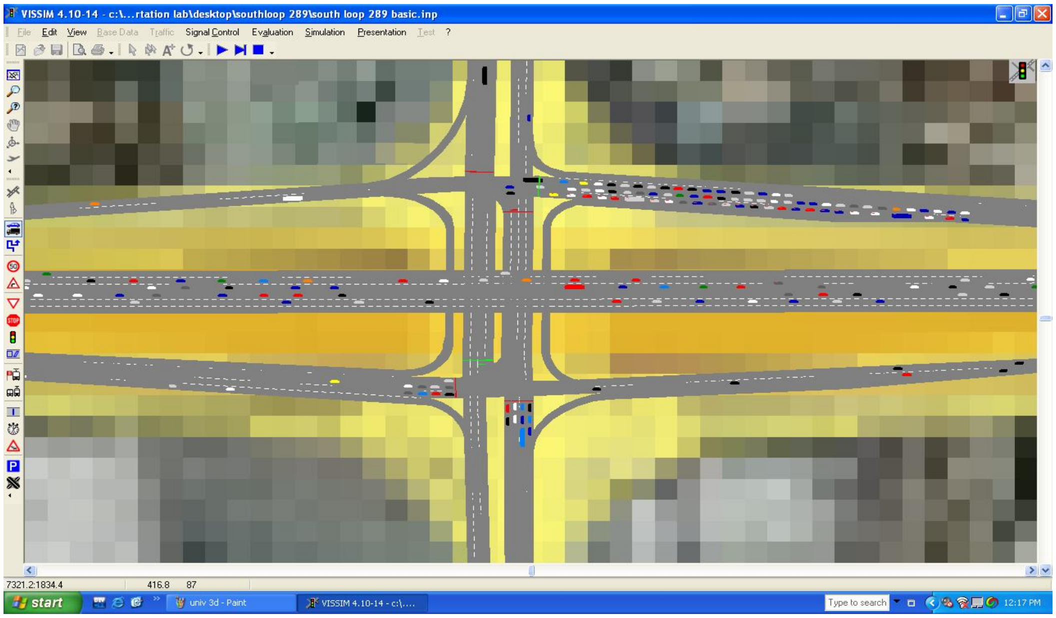


Figure 4-3: Snapshot of Simulation at University Avenue

Synchro

The Synchro simulation model was used for the development of the network. The network was designed on the background image, obtained from Google Earth, and scaled to the real world dimensions. The network was developed using links and nodes. After the roadway network, traffic volume inputs were coded throughout the network. This included main lanes, frontage roads, on-ramps and off-ramps, as well as intersection volumes.

Figure 4-4: Screen Shot of the Synchro Model

At all interchanges, volumes were taken at each movement on an individual lane basis for the major arterial and frontage road intersection. This resulted in a large amount of data being recorded in 15 minute intervals for several days. For each movement a Peak Hour Factor (PHF) was determined and then a conservative hourly volume was formed. This was also repeated for each ramp throughout the study area.

The signal phase orders, green times, and cycle lengths were adopted from the City of Lubbock Traffic Engineering Department designs for all the intersections, including Slide, Quaker, Indiana, and University. The design was performed as a traditional TTI-4-Phase operation. A 130-second cycle length was used as the coordination cycle length for peak hours in accordance with the City of Lubbock local traffic engineering department. An average four second yellow time and a two second all-red time were used for each phase

The volume inputs were obtained from the raw data files provided by the Lubbock District TxDOT office. The simulation was run with the current and forecasted volumes. The signal timing plan was adopted from the City of Lubbock traffic engineering department. The sample snapshots of the network coding and the simulations are shown in Figures 4-5 and 4-6.

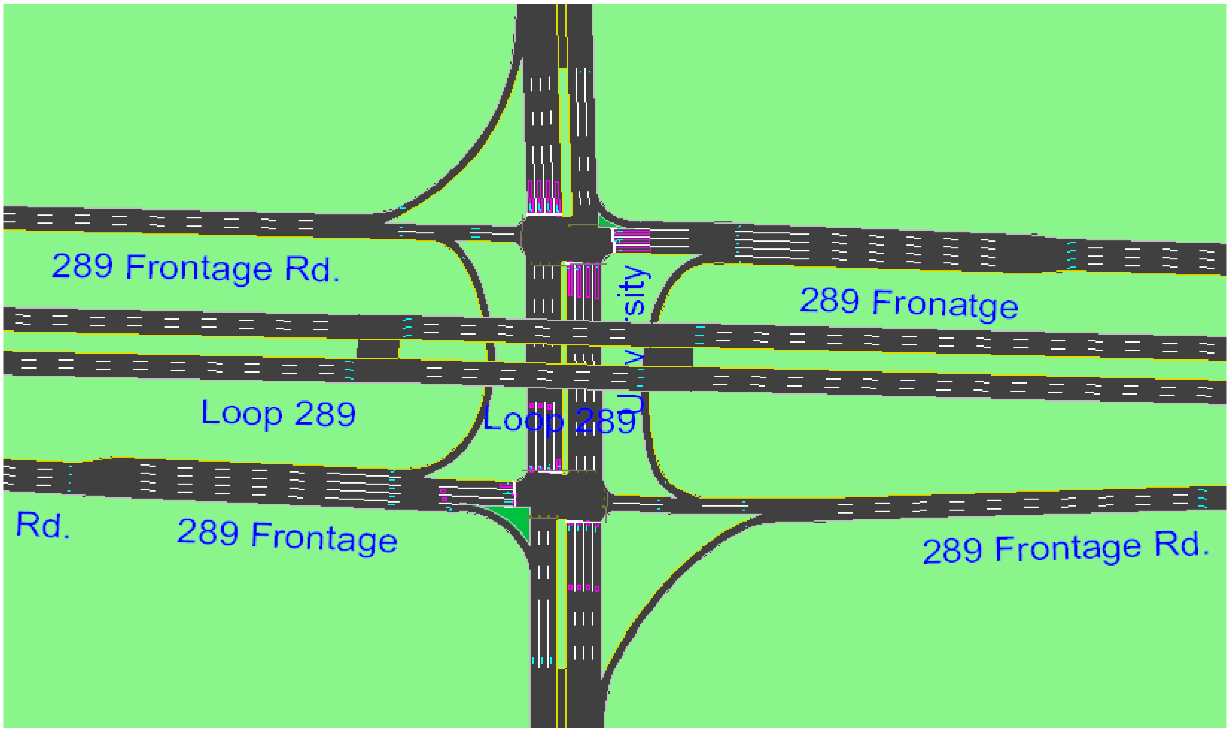


Figure 4-5: Coding of Traffic Control System at University Avenue

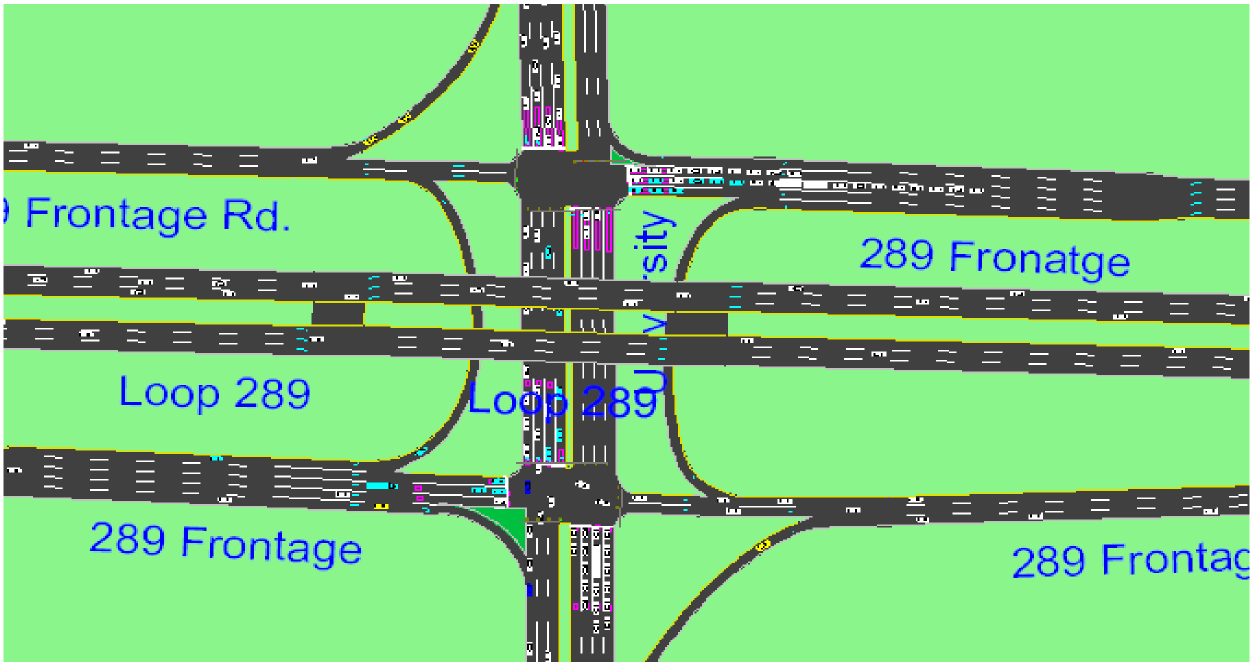


Figure 4-6: Snapshot of Simulation at University Avenue

4.2 Model Calibration and Validation

Validation and calibration were required to gauge the accuracy of the simulation. Phase II simulations were calibrated in a similar manner as done in Phase I. This method required taking cuts at sections, recording the traffic volumes in the simulation, and comparing the results to the measured field volumes to verify statistical accuracy.

The simulation model was validated after each pass of simulation and checked for validity using two statistic tests: Correlation Coefficient and Root Mean Squared-Error (RMSE). The two tests were conducted on the original traffic volume obtained from field observation and the volume obtained from the simulation output.

The correlation coefficient (r^2) indicates how closely the model-predicted data matches the observed data. Its value lies between 0 and 1. A correlation coefficient value closer to 1 is desirable. The formula for the term is (Ambadipudi and Dorothy, 2006):

$$r^2 = \left[\frac{n\sum_i (Count_i)(Volume_i) - \sum_i Count_i \sum_i Volume_i}{\sqrt{(n\sum_i Volume_i^2 - (\sum_i Volume_i)^2)(n\sum_i Count_i^2 - (\sum_i Count_i)^2)}} \right]^2$$

Where:

$Count_j$ is the observed ground count by direction for link j

$Volume_j$ is the estimated directional volume for link j

n_i is the number of directional counts in the volume group i such that j = 1, 2, 3,..ni

x_i is the average directional count for volume group i

n is the total number of links with a count

$Count_i$ is the observed volume (by direction) on $link_i$,

$Volume_i$ is the estimated volume (by direction) on $link_i$

The following figure shows a scatter plot between observed counts and VISSIM simulated volumes for the study network. To enhance the realism of the simulation, the model was calibrated based on traffic volume and the relative flows of the routing decisions on the main lanes and ramps.

Although the correlation coefficient of the model is acceptably high, this does not necessarily indicate that the model is accurate. Therefore a second statistic, RMSE, was used along with the correlation-coefficient. Conducting the RMSE test would reveal if the model had any systematic errors. The value of RMSE varies from 0 to 1 and a value closer to 0 is desirable. The percent RMSE formula is defined as (Ambadipudi and Dorothy, 2006):

:

$$\%RMSE_i = \frac{\sqrt{\dfrac{\sum_j (Count_j - Volume_j)^2}{n_i - 1}}}{\overline{x_i}}$$

Where:

$Count_j$ is the observed ground count by direction for link j

$Volume_j$ is the estimated directional volume for link j

n_i is the number of directional counts in the volume group i such that j = 1, 2, 3,... n_i

x_i is the average directional count for volume group i

The percent RMSE is calculated between the original volumes and the volumes collected from the simulation.

Table 4-1: Validation Calculation for AM Simulation and Main Lane Volume

		VISSIM	Actual				
Location	N	Count	Volume	(Count) (Volume)	Count^2	Volume^2	(Count - Volume)^2
Spur 327 WB	1	2859.52	2268	6484752.272	8176854.63	5142810.277	350160.3638
Spur 327 EB	2	2376.96	2643	6282058.463	5649938.842	6984900.128	70722.04273
Ave P WB	3	2402.56	2453	5894134.446	5772294.554	6018546.099	2571.76054
Ave P EB	4	2894.72	2369	6858188.203	8379403.878	5613137.415	276164.8878
Sums	4	10533.76	9733.15	25519133.38	27978491.9	23759393.92	699619.0549
						% RMSEi	**0.183377801**
						r^2 =	**0.700302876**

Table 4-2: Validation Calculation for PM Simulation and Main Lane Volume

		VISSIM	Actual				
Location	N	Count	Volume	(Count) (Volume)	Count^2	Volume^2	(Count - Volume)^2
Spur 327 WB	5	2147.2	2268	4869369.712	4610467.84	5142810.277	14538.69357
Spur 327 EB	6	2691.2	2643	7112562.154	7242557.44	6984900.128	2333.26068
Ave P WB	7	2551.68	2453	6259966.445	6511070.822	6018546.099	9684.030459
Ave P EB	8	2017.92	2369	4780868.318	4072001.126	5613137.415	123401.9049
Sums	4	9408	9733.151	23022766.63	22436097.23	23759393.92	149957.8896
						% RMSEi	**0.095057572**
						r^2 =	**0.726807624**

Analysis of the validation result shows that the simulation is valid. The percent RMSE obtained for the AM and PM simulations are 0.18 and 0.095, respectively. These are very promising as they are close to 0. Also the r^2 value is close to 1, showing that the correlation of the simulation to the actual volumes is high. The following graphs show the field-measured traffic volumes compared to the simulation volumes. They also show how closely the simulation matches the field-measured traffic volumes.

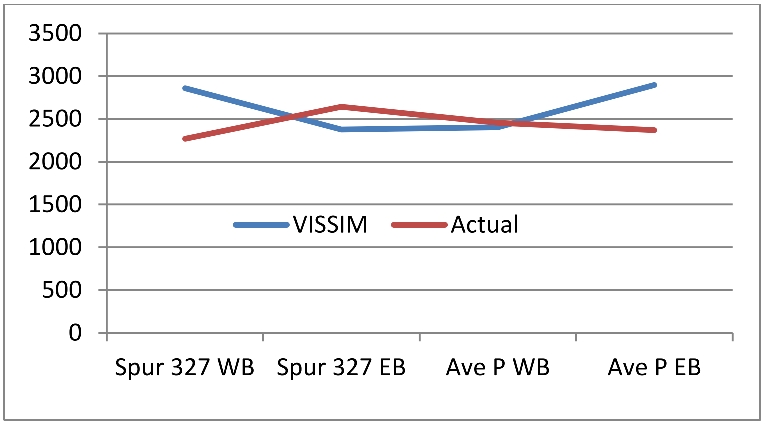


Figure 4-7: AM Comparison of Actual to Simulation Volumes

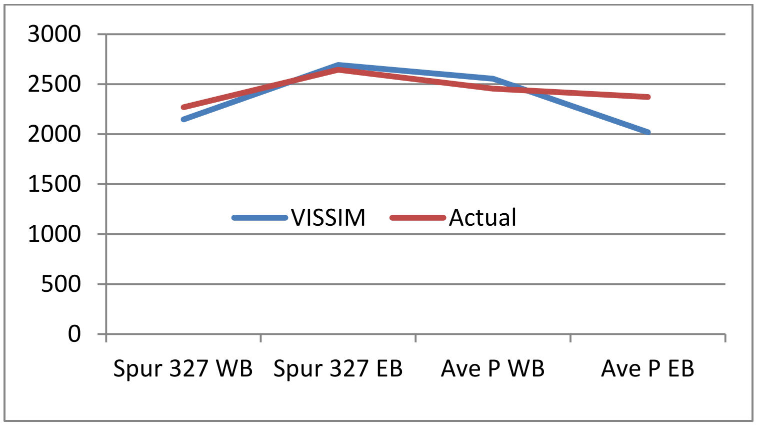


Figure 4-8: PM Comparison of Actual to Simulation Volumes

5. LEVEL OF SERVICE ANALYSIS OF MAIN LANES AND FRONTAGE ROADS

This section presents the analysis on the LOS on the main lanes and frontage roads of South Loop 289 for morning and afternoon peak hours regarding the current as well as future traffic conditions. The research area consists of five major interchanges: Slide Road, Quaker Avenue, Indiana Avenue, University Avenue and IH-27. At present, Indiana Avenue and University Avenue have Diamond interchanges, Slide Road has an X pattern interchange, and the ramp configuration changes from X to Diamond at Quaker Avenue.

For the frontage road, the analysis focuses on the sections between the five major intersections, particularly between the on- and off-ramp segments as shown in Figure 5.1. For main lane traffic, the analysis is conducted at five different sections in both eastbound and westbound directions as shown in Figure 5-2.

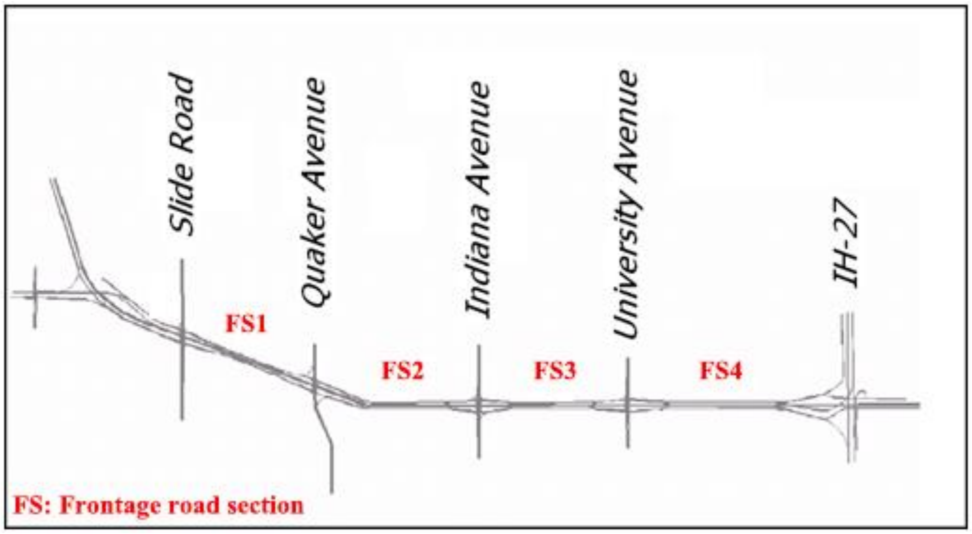


Figure 5-1: Four Frontage Road Sections on the Network where the LOS Analysis was Conducted

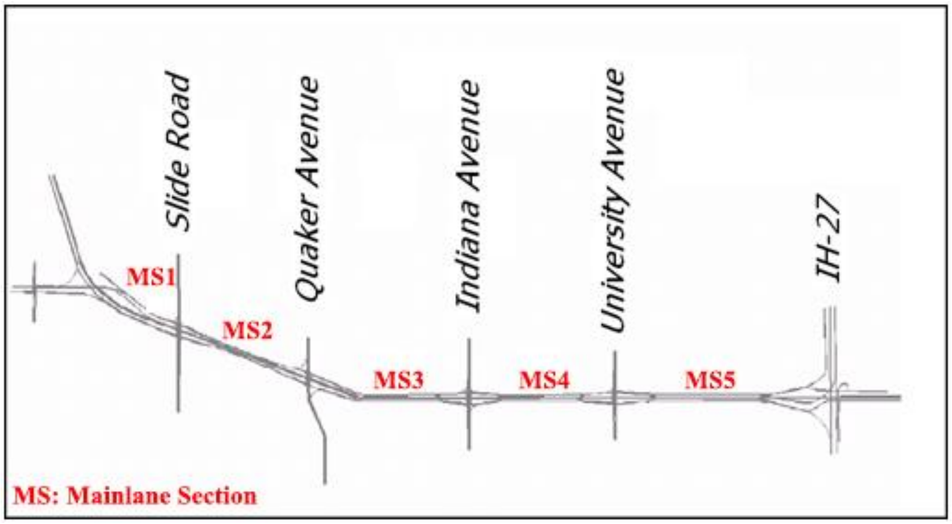


Figure 5-2: Five Main Lane Sections on the Network Where the LOS Analysis was Conducted

The analysis aims to evaluate the potential impacts of the improvement alternatives on both freeway main lanes and frontage roads. As the traffic on the frontage road is highly interrupted by the on- and off-ramps as well as the intersections, the profile of the speed and density along the frontage road is highly variable. The V/C ratio was thus selected as the performance indicator for evaluating the LOS on the frontage road. The detailed simulation results of the three improvement alternatives in terms of the traffic volume, V/C ratio, density, and LOS are presented section by section. Only the results from the westbound traffic are used for illustrative purposes, because the changes on the eastbound as a result of these improvement strategies are likely to be the same.

5.1 Current Condition

The current level of service (LOS) on the main lanes and frontage roads of the corridor were evaluated for both morning and afternoon peak hours. Simulation results revealed that the LOS for main lane traffic in both morning and afternoon peak hours ranges from ‘B’ to ‘D’, while the LOS for the frontage roads ranges from ‘B’ to ‘C’. For illustrative purposes, the effects of the improvement alternatives on the westbound direction of the corridor are presented in this section.

- Frontage road between Slide Road and Quaker Avenue (FS1)
- Frontage road between Quaker Avenue and Indiana Avenue (FS2)

- Frontage road between Indiana Avenue and University Avenue (FS3)
- Frontage road between University and IH-27 (FS4)

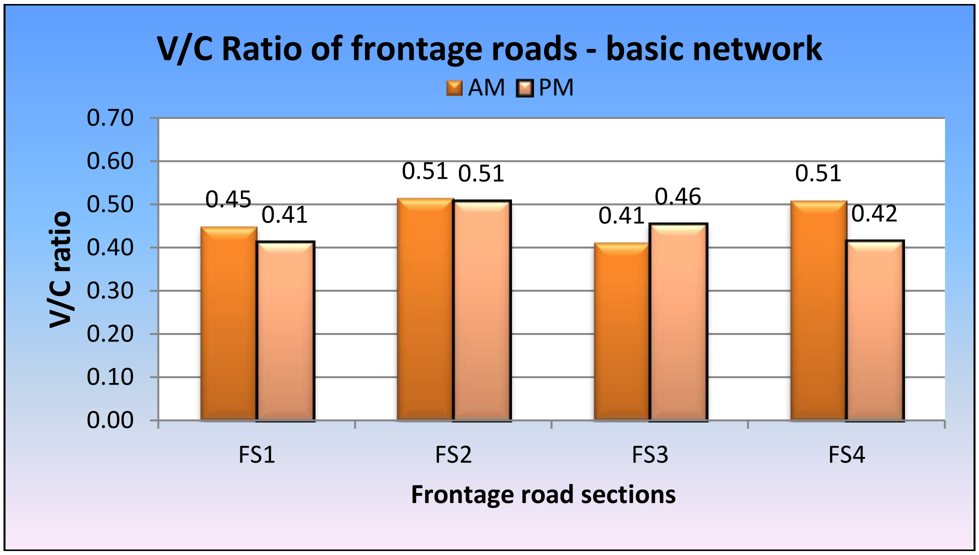


Figure 5-3: V/C Ratio of Frontage Roads on the Basic Network (Westbound)

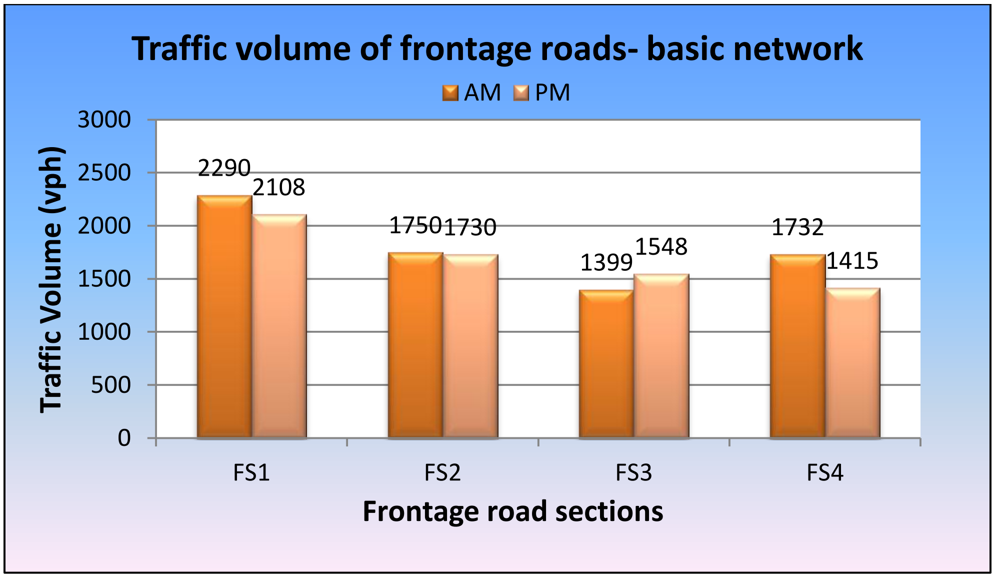


Figure 5-4: Traffic Flow of Frontage Roads on the Basic Network (Westbound)

Traffic volumes on the frontage road sections between Slide Road and Quaker Avenue are the highest along the westbound corridor, around 2290 vehicle per hour. Although most frontage roads have two lanes, this section has three lanes, so the V/C ratio is similar under this large volume to that of a two lane frontage road due to the larger capacity. All four analyzed frontage road sections are not at capacity. Except for the frontage road between Indiana and University Avenue, the traffic volumes are higher in the morning peak hours than the afternoon peak hours.

The current traffic condition on main lane traffic in terms of total traffic volume on the westbound is illustrated in Figure 5-5. The values on the Y-axis represent the traffic volume in vehicle per hour, while the labels on the X-axis represent the five sections of the network as follows:

- Slide Road overpass (S1)
- Slide Road and Quaker Avenue (S2)
- Quaker Avenue and Indiana Avenue (S3)
- Indiana Avenue and University Avenue (S4)
- University Avenue and IH-27 (S5).

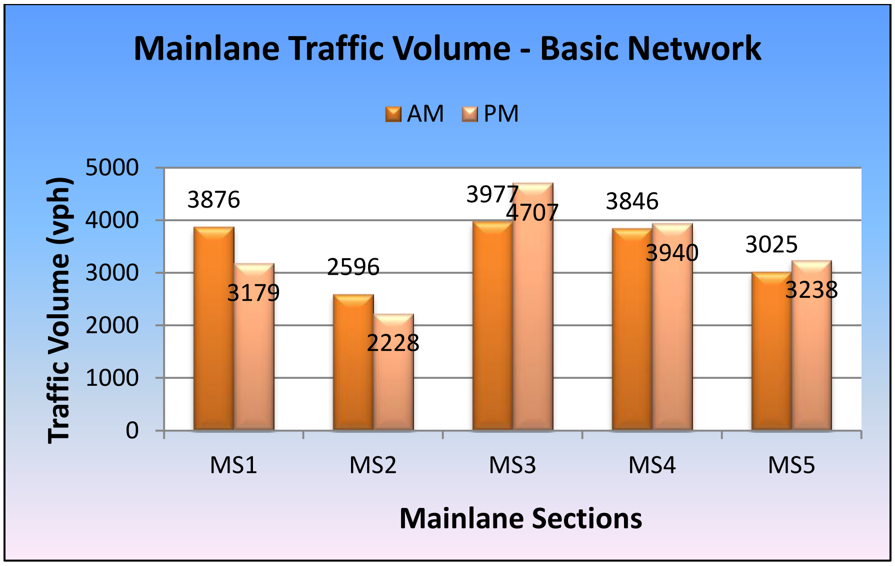


Figure 5-5: Traffic Volumes on Main Lane Segments on the Basic Network (Westbound)

The highest traffic volume along the westbound corridor occurs on the freeway section between Quaker Avenue and Indiana Avenue, amounting to 3977 and 4707 vehicle per hour for morning and afternoon peak hours, respectively. This is shown in the density profile of Figure 5-6. The most congested section lies between Quaker Avenue and Indiana Avenue, the density of which reaches 29 vehicles per mile per lane. However, with current traffic demand, none of the segments on the freeway and frontage roads has reached its capacity.

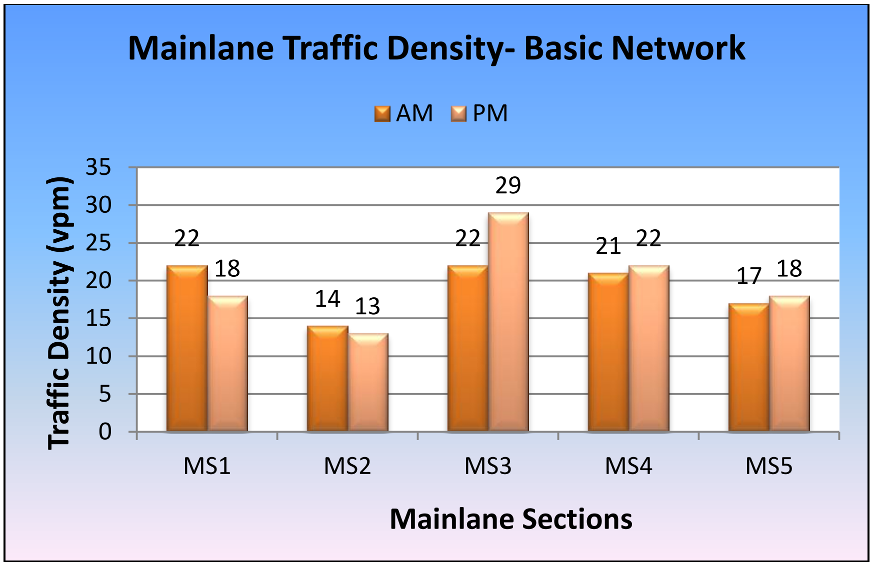


Figure 5-6: Traffic Densities of Main lane Segments on the Basic Network (Westbound)

5.2 Section by Section Evaluation on the Frontage Roads of the Improvement Alternatives

As implied in the Phase I study, though the alternatives to a certain degree improve the LOS on the freeway segments, they may impact the traffic distribution between the main lane and frontage roads. Particularly, with reconfiguration from Diamond to X type interchanges, a certain amount of traffic will be directed onto the frontage roads, which results in an increase of traffic volume and weaving behavior. In this section, LOS analysis was conducted to evaluate the impact the three alternatives have on the frontage roads. The corresponding traffic densities on the freeway main lanes are also presented to illustrate the traffic redistribution, as shown in the Phase I report.

Effects of Different Alternatives on Frontage Road Section 1: Between Slide Road and Quaker Avenue

The simulation results reflecting the effects of Alternative 1 (A1), Alternative 2 (A2), and Alternative 3 (A3) on traffic volumes on the frontage road between Slide Road and Quaker Avenue (FS1) is shown in Figure 5-7. The labels on the X-axis represent the alternative networks and each column on the X-axis shows the number of vehicles traveling on that frontage road segment for each alternative.

Since the interchange of Slide Road, as well as the westbound direction of the interchange of Quaker Avenue, was already an X-type interchange, Alternative 2 does not change the traffic distribution on this segment. Therefore, the traffic volumes for both AM and PM peak hours almost remain the same. Similar results were also obtained under Alternatives 1 and 3. The slight differences in the traffic volumes for these alternatives are mostly attributed to the stochastic traffic variations in VISSIM simulation.

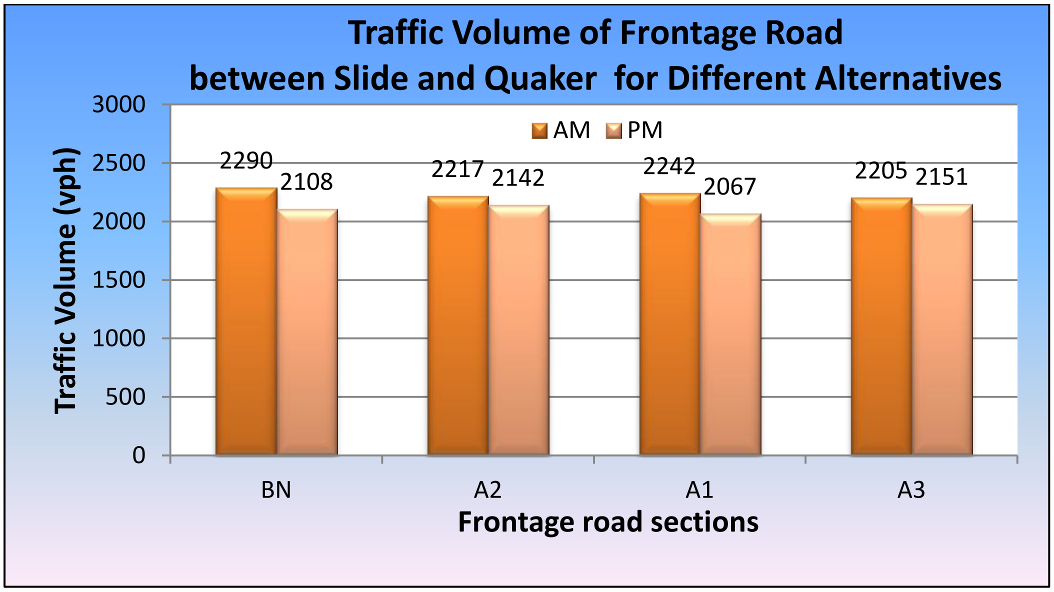


Figure 5-7: Traffic Volume on the Section FS1 for Differnet Alternatives

Figure 5-8 illustrates the changes in terms of the V/C ratio at the frontage road between Slide and Quaker regarding different improvement strategies. The results are easy to understand since the V/C ratio is proportional to the traffic volume. All three alternatives do not have notable impacts on this frontage road segment, thus the V/C ratio as well as the LOS remains unchanged.

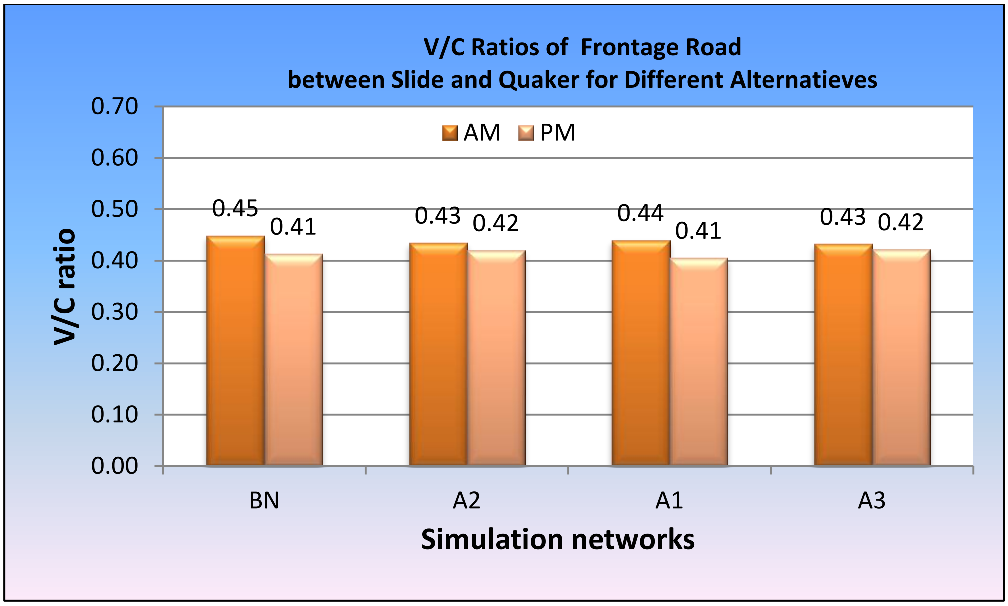


Figure 5-8: V/C Ratio on the Section FS1 for Different Alternatives

The following two figures present the main lane traffic densities on the Slide overpass and the segement between Slide Road and Quaker Avenue. Consistent conclusions with the Phase 1 study can be drawn. For the Slide overpass, adding an auxiluary lane in both Alternative 1 and Alternative 3 will decrease the density due to the increase in capacity. Alternative 2 does not change the interchange configuration of Slide Road, so it does not significantly reduce the traffic density on the Slide overpass. For the freeway segment between Slide Road and Quaker Avenue, none of the three alternatives will directly impact the traffic distribution or the segment capacity as analyzed in Phase 1; the density for this segment remains almost the same for each alternative.

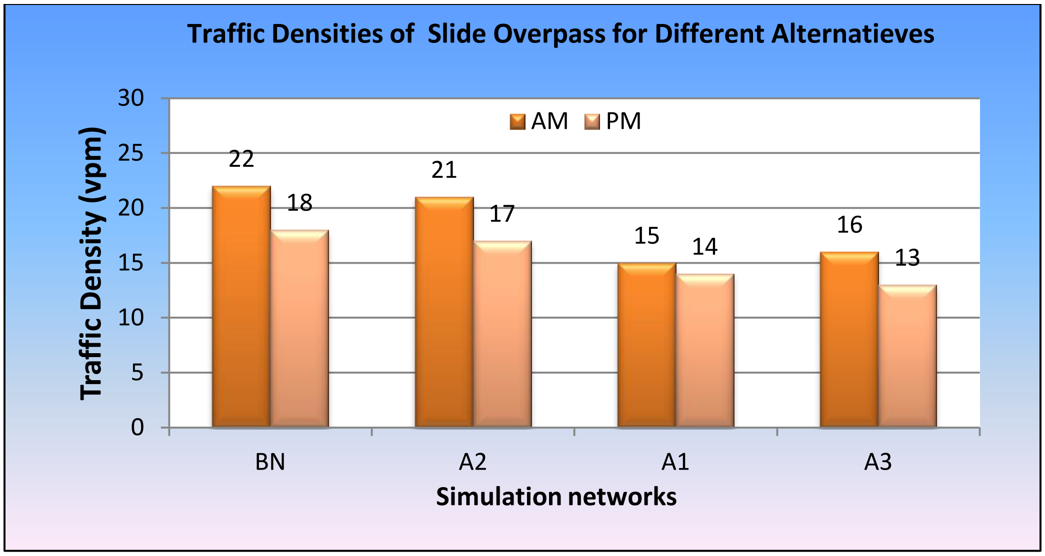


Figure 5-9: Traffic Density on the Freeway Section MS1 for Different Alternatives

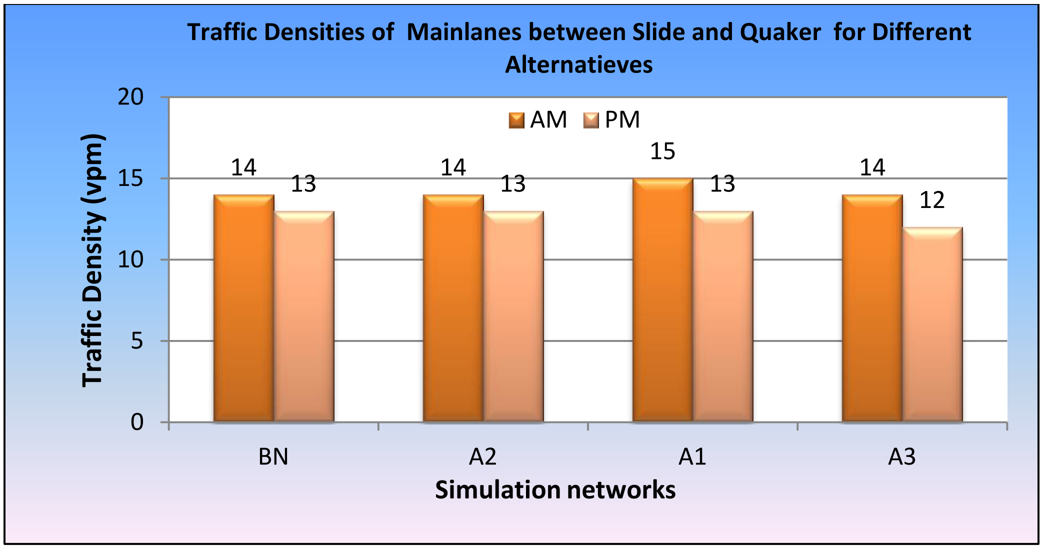


Figure 5-10: Traffic Density on the Freeway Section MS2 for Different Alternatives

Effects of the Alternatives on Frontage Road Section 2: Quaker Avenue and Indiana Avenue

The second analyzed frontage road section is between Quaker Avenue and Indiana Avenue. The conversion of Quaker Avenue and Indiana Avenue from Diamond to X type will change the traffic distribution between the main lane and frontage road. This is demonstrated by Figure 5-11, which shows traffic volumes on the frontage roads at this section.

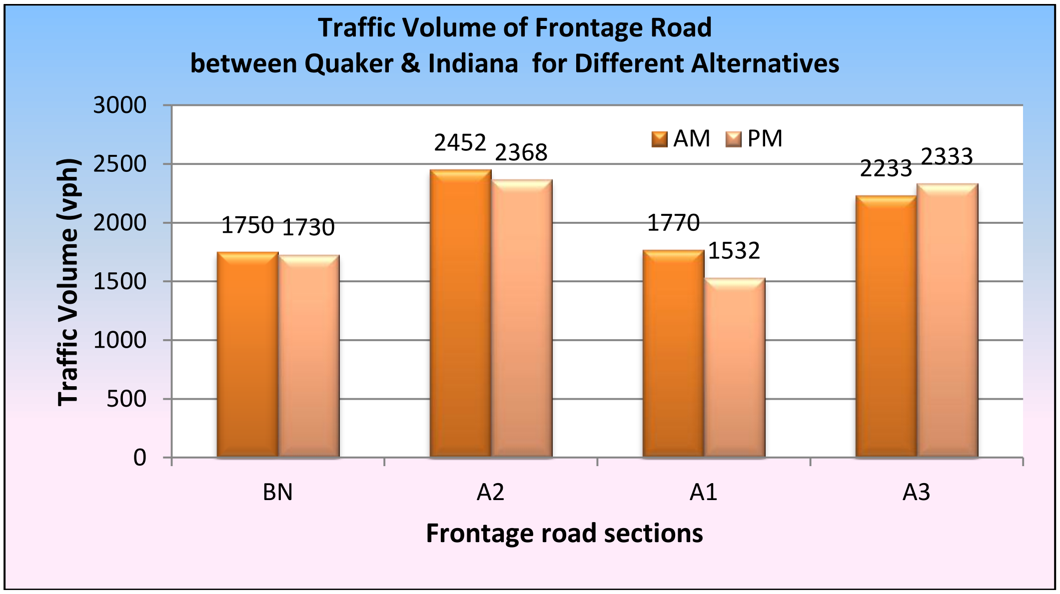


Figure 5-11: Traffic Volumes on the Frontage Road Section FS2 for Different Alternatives

It can be clearly seen from the figure that the traffic volumes on this frontage road segment are significantly increased under Alternative 2 and Alternative 3, in which the ramp reconfiguration is applied to the Indiana and Quaker interchanges. For example, after the interchange conversion, travelers from Indiana Avenue who intended to merge onto the freeway have to drive on the frontage road until arriving at the on-ramp near the interchange of Quaker Avenue. Conversely, travelers on the freeway heading towards Quaker Avenue have to take the off-ramp right after the interchange of Indiana Avenue and drive along the frontage road. These two changes on the travelling route result in a significant growth of the traffic volume on this frontage road segment. Note that in the AM and PM peak hours, the volume is increased by 700 vehicles per hour and 600 vehicles per hour, respectively.

Alternative 1 of adding an auxiliary lane on the freeway segment does not have a notable impact on the traffic volume of this frontage road segment since it will not essentially modify travelers' routing behavior and traffic distribution.

In terms of the V/C ratio, the increased traffic volume on the frontage road for A2 and A3 can be well accommodated by adding an auxiliary lane on the frontage road as shown in Figure 5-12. The highest V/C ratio of 0.51 occurs under Alternative 1 for the morning peak, which is almost the same as that in the basic network. All three alternatives enable the LOS on this frontage road segment to remain in an under-saturated category of ‘C’.

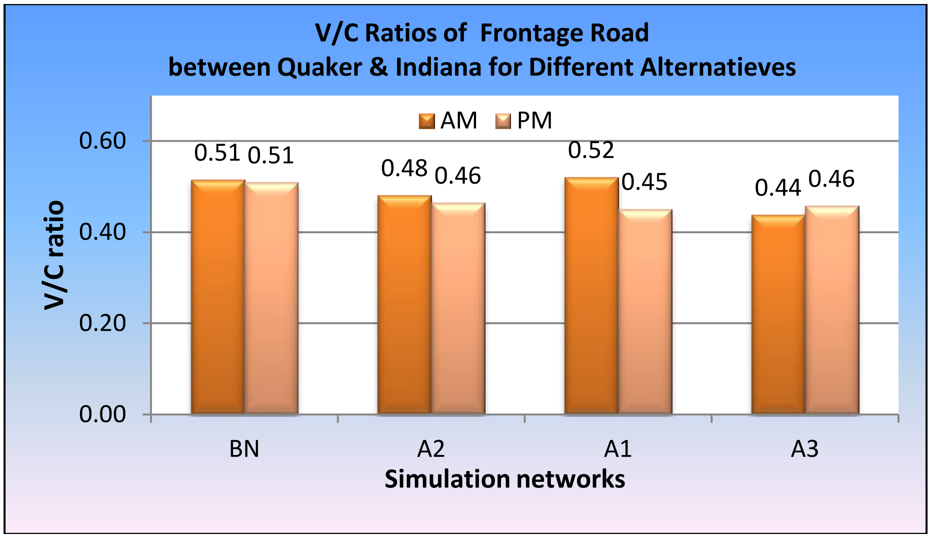


Figure 5-12: V/C Ratio on the Section FS2 for Different Alternatives

Figure 5-13 depicts the traffic densities on the corresponding main lane segment between Quaker Avenue and Indiana Aveue. This chart shows that traffic densities from all three alternatives are significantly reduced compared with the basic network. However, this reduction is achieved in different ways. Alternative 2 and Alternative 3 reduced the traffic on the freeway segment by diverting to a frontage road, while the improvement of Alternative 1 is achieved through increasing the capacity by adding an additional lane.

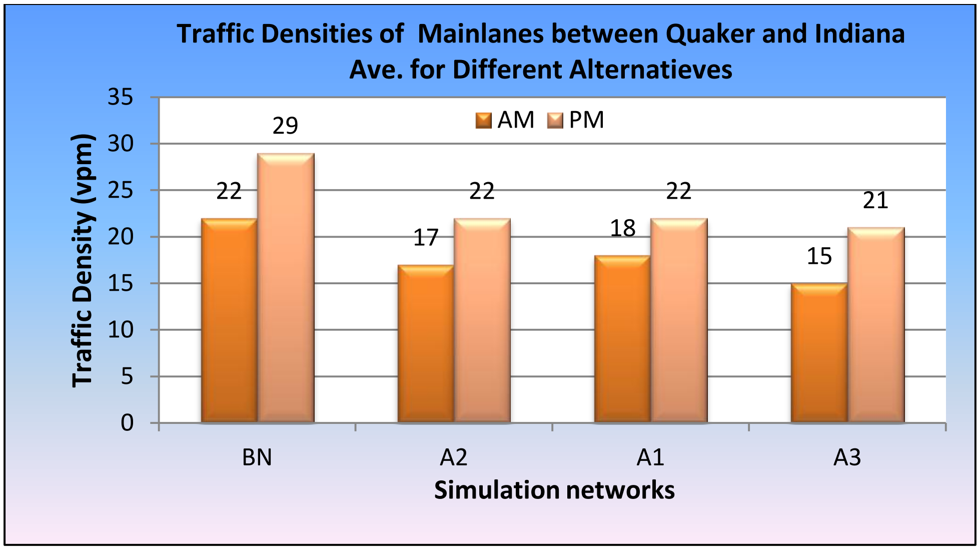


Figure 5-13: Traffic Densities on the Freeway Section MS3 for Different Alternatives

Effects of the Alternatives on Frontage Road Section 3: Indiana Avenue and University Avenue

Similar to the frontage road section between Quaker Avenue and Indiana Avenue, the conversion of interchanges on both Indiana Avenue and University Avenue will result in a redistribution of traffic between frontage roads and freeway main lanes. The traffic volumes on the frontage road are expected to increase, as illustrated by the simulation results in Figure 5-14.

It can be seen that both Alternative 2 and Alternative 3 will significantly increase the traffic volumes on the frontage roads. For example, the total traffic volume on the frontage road of the basic network during the morning peak hours is 1399 vehicles per hour. This is increased by almost 50%, to 2094, in the case of Alternative 2. The traffic volume caused by Alternative 3 is similar to that of Alternative 2, due to the similar trip distribution along the corridor.

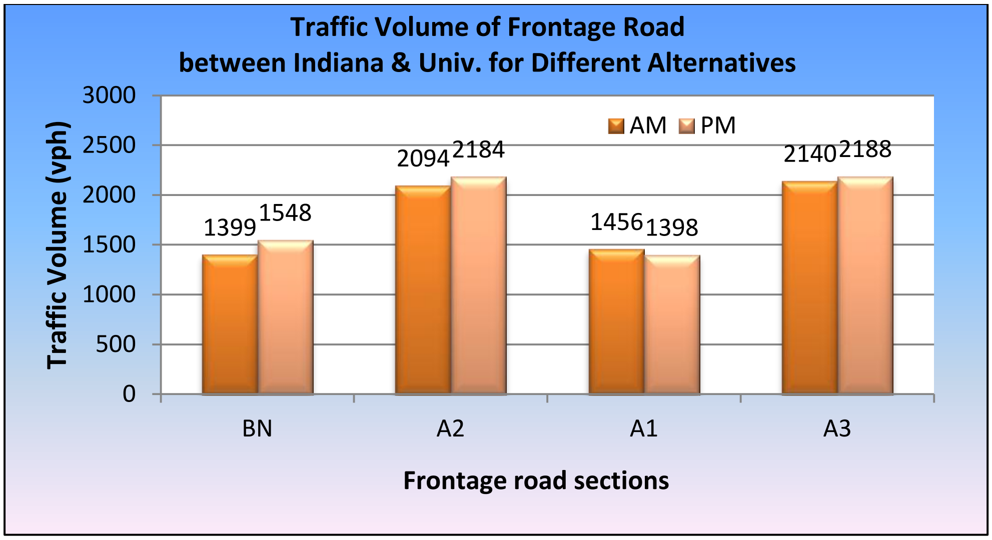


Figure 5-14: Traffic Volumes on the Frontage Road Section FS3 for Different Alternatives

In terms of V/C ratio, the three alternatives achieve very close peformances compared with the basic network. For alternatives A2 and A3, adding an auxiliary lane on the frontage road directly increased the capcity, which can well accomondate the increase in traffic volume. For A1, the result is also obvious since adding an auxiliary lane on the freeway segment will not significnatly change the traffic volume or the V/C ratio on the frontage road.

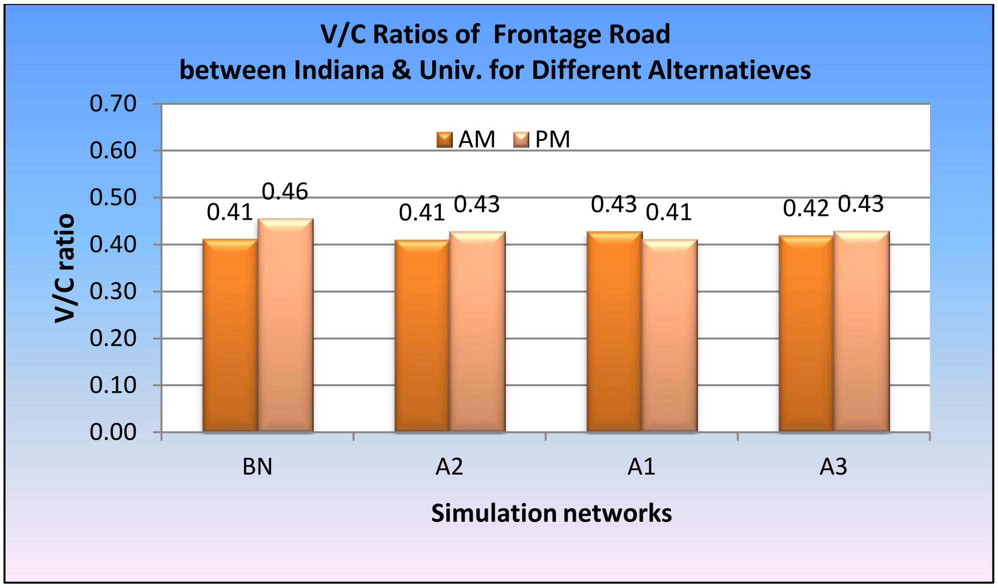


Figure 5-15: V/C Ratio on the Section FS3 for Different Alternatives

The increase of the traffic volume on the frontage road can be a result of a ‘late’ diverging and ‘early’ merging mechanism for the on- and off-ramp traffic. The increase of the volume on the frontage road results in the decrease of traffic volume on the freeway main lane. The densities for the three alternatives for the corresponding freeway main lane segments are illustrated in Figure 5-16. A significant reduction can be seen on this segment for the afternoon peak. The density on this freeway segment is decreased by 25%.

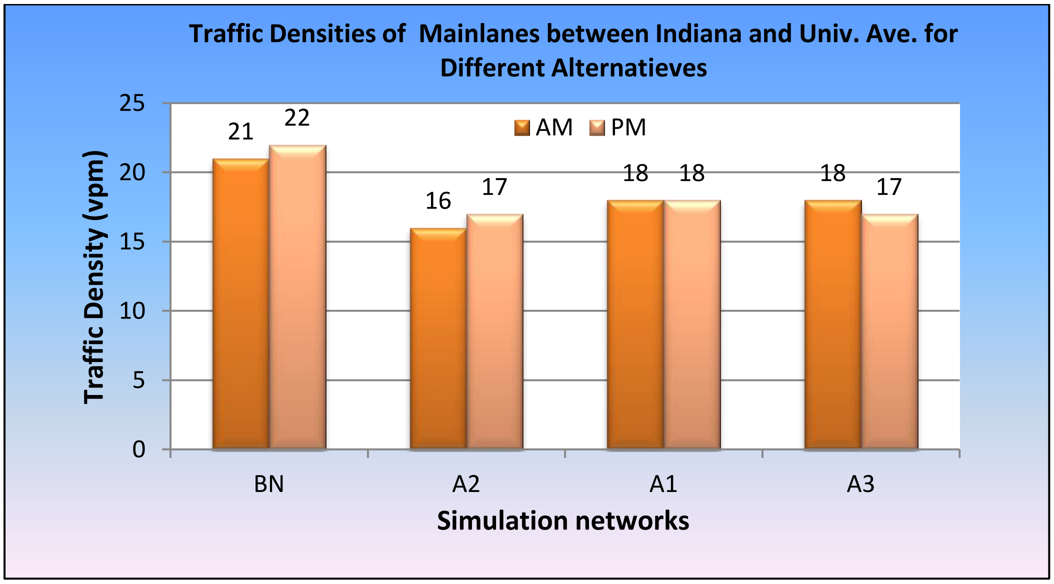


Figure 5-16: Traffic Densities on the Freeway Section MS4 for Different Alternatives

Effects of the Alternatives on Frontage Road Section 4: University Avenue and IH27

The conversion of the interchange on University Avenue from Diamond to X type will have a similar impact on the frontage road between University Avenue and IH-27. As discussed earlier, this configuration will increase the traffic volume on the frontage road. This increase is demonstrated in Figure 5-17 for this frontage road section.

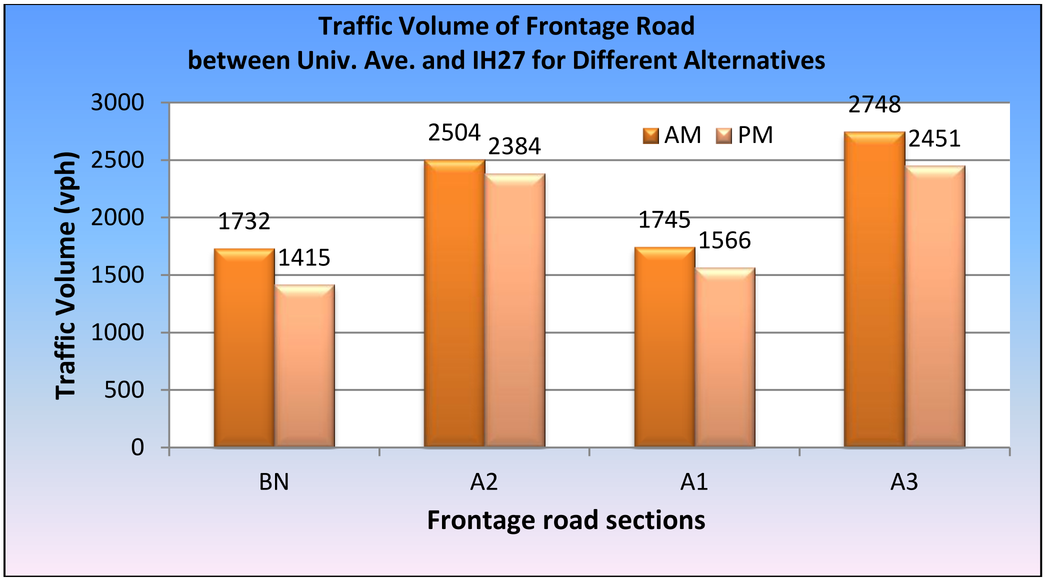


Figure 5-17: Traffic Volumes on the Frontage Road Section FS4 for Different Alternatives

As shown in Figure 5-17, the traffic volume on this frontage road segment is significantly increased by 800 vehicles per hour and 900 vehicles per hour for the morning and afternoon peak hours, respectively. However, the increased traffic volume is compensated by the auxiliary lane added onto the frontage road. So in terms of the V/C ratio, the performance does not have a significant growth, and remains at the level of ‘C’.

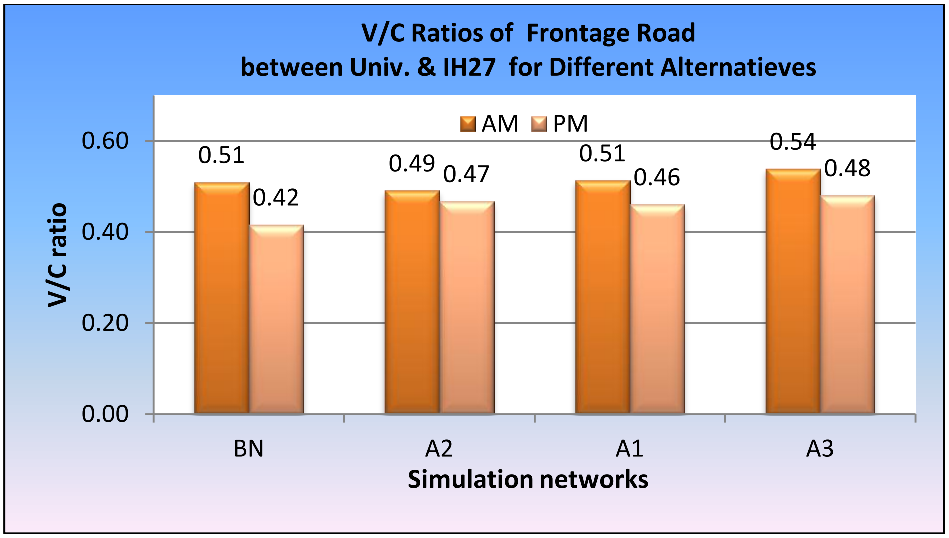


Figure 5-18: V/C Ratio on the Frontage Road Section FS4 for Different Alternatives

A similar impact on the main lane traffic for the three alternatives is also obtained as illustrated in Figure 5-19. The traffic density of the main lane traffic is improved by all three strategies. Alternative 1 achieves this by increasing the capacity. But for Alternatives 2 and 3, this improvement is due to distributing a certain amount of traffic onto the frontage roads.

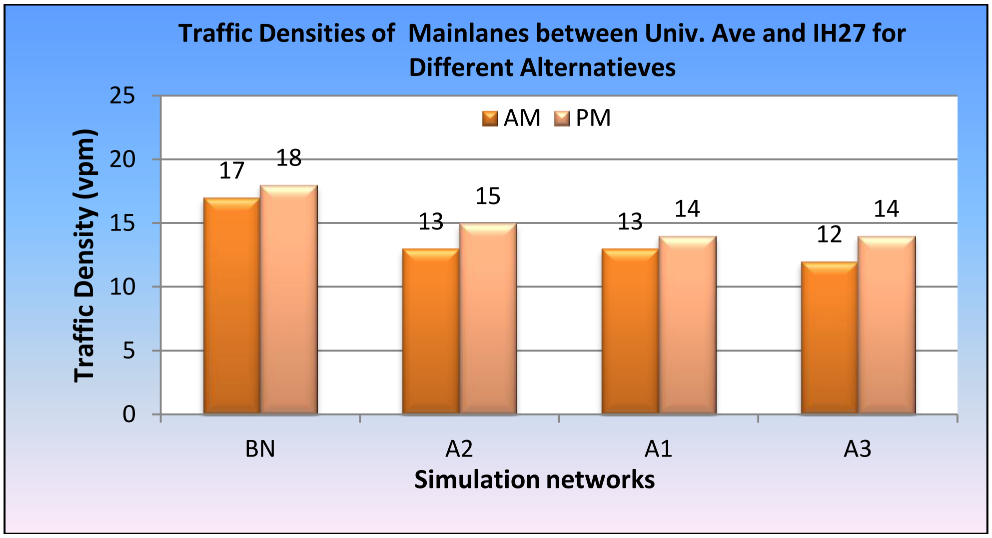


Figure 5-19: Traffic Densities on the Freeway Section MS5 for Different Alternatives

5.3 Summary for the Current Condition

In the previous section, the impact of the three alternatives was illustrated section by section along the westbound corridor of South Loop 289. This section summarizes the simulation results and LOS on both the east and westbound sections. The LOS for both frontage roads and mainlanes in the basic network is listed in Table 5-2.

Table 5-1: LOS of Traffic on Frontage Roads and Main Lanes of Basic Network

		Basic Network	
		AM	**PM**
Frontage Roads			
Slide Road & Quaker Ave.	*Westbound*	C	C
	Eastbound	C	C
Quaker & Indiana	*Westbound*	C	C
	Eastbound	C	C
Indiana & University	*Westbound*	B	B
	Eastbound	C	C
University & I-27	*Westbound*	C	C
	Eastbound	C	C
Main lanes			
Slide Road & Quaker Ave.	*Westbound*	B	B
	Eastbound	B	B
Quaker & Indiana	*Westbound*	C	D
	Eastbound	C	C
Indiana & University	*Westbound*	C	C
	Eastbound	C	C
University & I-27	*Westbound*	B	B
	Eastbound	C	B

For Alternative 1, adding an auxiliary lane does not have a direct impact on the LOS on the frontage roads. The only two changes of LOS on the frontage road sections (westbound between Indiana Avenue and University Avenue, westbound betweeen University and I-27) is due to the stochastic flutuation of traffic volume in the simualtion software and the V/C ratio is at the edge between grades ‘B’ and ‘C’. Consistent with the analysis using 2007 traffic volume, the LOS on the freeway main lanes is improved by adding an extra lane. However, the lane distirbution on the main lanes is uneven and results in high traffic volume on the outside lane, which still remains at a high level of traffic density, as well as producing weaving maneuvers.

Table 5-2: Comparison of LOS between Basic Network and Alternative 1

		AM		**PM**	
		Basic Network	**A1**	**Basic Network**	**A1**
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	B
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Indiana & University	*Westbound*	B	B	C	B
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Main laneMain lanes					
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B
Quaker & Indiana	*Westbound*	C	B	D	C
	Eastbound	C	C	C	B
Indiana & University	*Westbound*	C	B	C	C
	Eastbound	C	B	C	B
University & I-27	*Westbound*	B	B	B	B
	Eastbound	C	B	B	B

Alternative 2 converts interchanges along the corridor from Diamond to X type, which leads to a redistributed traffic pattern between frontage roads and main lanes. Specifically, a certain amount of travellers with short O-D trips will be shifted from the freeway to the frontage road. This results in an increase of traffic volume on the frontage road; however, this is compensated by adding an auxiliary lane on the frontage road between the on- and off-ramps. The changes of LOS on the frontage road are very limited as illustrated in Table 5-3.

Table 5-3: Comparison of LOS between Basic Network and Alternative 2

		AM		PM	
		Basic Network	**A2**	**Basic Network**	**A2**
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	B
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Indiana & University	*Westbound*	B	B	C	B
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Main lanes					
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B
Quaker & Indiana	*Westbound*	C	C	D	C
	Eastbound	C	B	C	C
Indiana & University	*Westbound*	C	B	C	C
	Eastbound	C	C	C	B
University & I-27	*Westbound*	B	B	B	B
	Eastbound	C	B	B	B

Alternative 3 further supplements Alternative 2 by adding an auxiliary lane on the overpass of each interchange (between on- and off-ramps) to further relieve the traffic on the freeway main lanes. It is easy to see that this auxiilary lane has little impact on the frontage roads or the freeway segments between the interchanges. However, it is expected that the traffic on the overpass of each interchange will be improved since the capacities are increased.

Table 5-4: Comparison of LOS between Basic Network and Alternative 3

		AM		PM	
		Basic Network	A3	Basic Network	A3
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	B
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Indiana & University	*Westbound*	B	B	C	B
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Main lanes					
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B
Quaker & Indiana	*Westbound*	C	B	D	C
	Eastbound	C	B	C	B
Indiana & University	*Westbound*	C	B	C	B
	Eastbound	C	B	C	B
University & I-27	*Westbound*	B	B	B	B
	Eastbound	C	B	B	B

In comparison, Alternative 2 achieves almost the same performance as Alternative 1 by converting the ramp configurations from Diamond to X pattern at interchanges. As demonstrated in the Phase 1 study, Alternative 2 also has an advantage that the traffic across different main lanes is more evenly distributed when compared to Alternative 1.

The results demonstrated that the traffic on the frontage roads is significantly increased under Alternative 2; however, this increase can be well accommodated by adding an auxiliary lane on the frontage road, allowing the LOS on the frontage road to remain almost unchanged.

Alternative 3 further supplements Alternative 2 by adding an auxiliary lane on the overpass of each interchange, which will increase the capacity of the main lane segments between on- and off-ramps. However, A3 does not create significant improvement compared to Alternative 2 and is not necessary at this stage. Hence Alternative 2, which changes the ramp configuration from Diamond to X type with an auxiliary lane added onto the frontage road, is recommended.

5.4 LOS Analysis for the Projected Traffic

The traffic projection is conducted on the basis of a 3% annual increase for five years for South Loop 289. This traffic growth rate was estimated by considering the actual traffic growth counted on the South Loop main lanes in 2008, 2009, and 2010 and verified by the transportation planning process calculations. The potential effects of the proposed improvement alternatives on LOS on the frontage roads are analyzed similarly to the analysis of current conditions.

Basic Network

The analysis was first conducted on the basic network without any modifications in roadway geometry. Changes in traffic density and volume on the main lanes along South Loop 289 are illustrated in Figure 5-20. As shown, the traffic volume was significantly increased by an amount ranging from 300 to 700 vehicles per hour. The densities were also higher compared to current traffic conditions. The most congested section appears to be the segment between Quaker Avenue and Indiana Avenue, for which the density reached 34 vehicles per mile per lane, which is very close to LOS 'E' (35 vehicles per mile per lane). The growth of traffic demand resulted in the LOS of some segments changing from 'C' to 'D' as listed in Table 5-5.

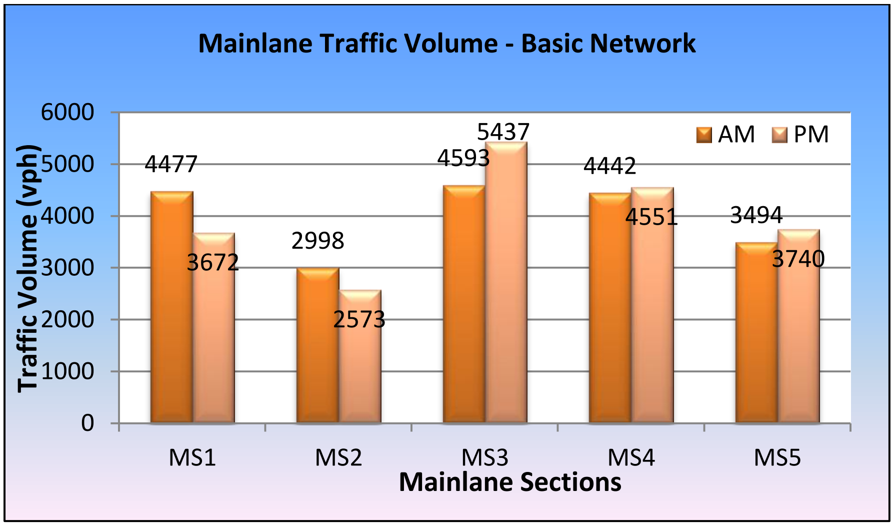


Figure 5-20: Traffic Volume on Main Lane Distribution on the Basic Network under Forecasted Traffic Conditions in 2016 (Westbound)

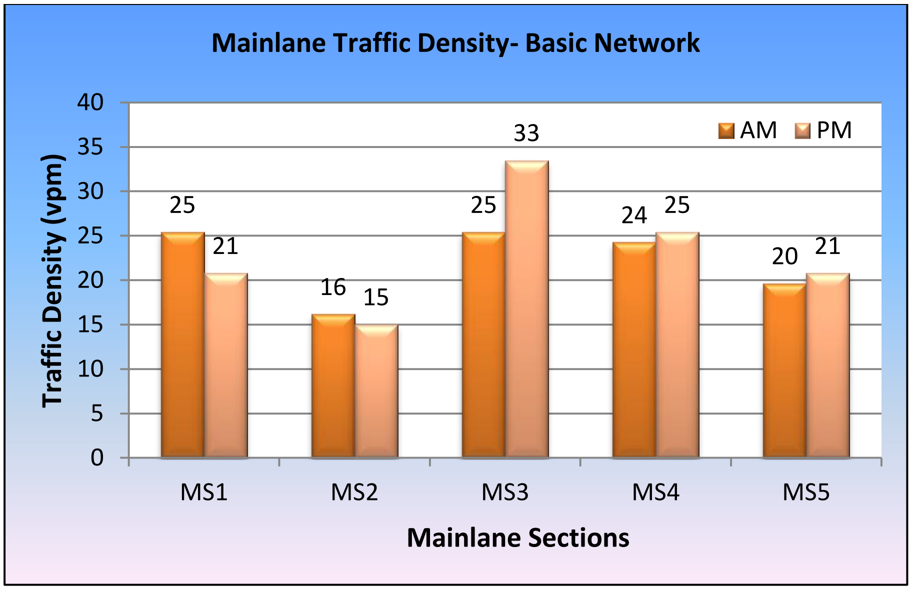


Figure 5-21: Traffic Densities on the Main Lanes of the Basic Network under Forecasted Traffic Conditions in 2016 (Westbound)

Similarly, for the current network configuration, the traffic flow as well as the V/C ratio will also significantly increase on the frontage roads. Several segments reached a V/C ratio of 0.59, which is very close to LOS ‘D’ (0.62). This increase results in the LOS on some segments of the frontage road, degrading from level ‘B’ to ‘C.’

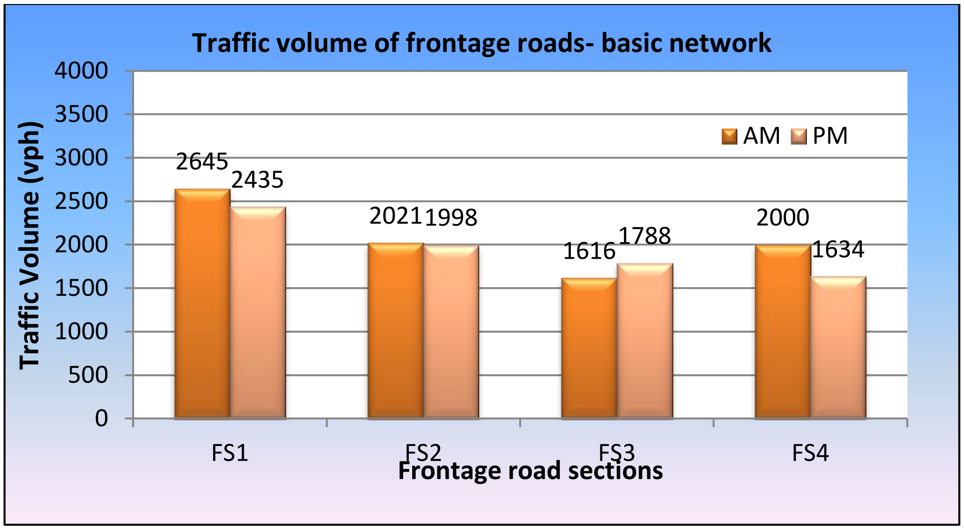


Figure 5-22: Traffic Volumes on Frontage Roads of the Basic Network under Forecasted Traffic Conditions in 2016 (Westbound)

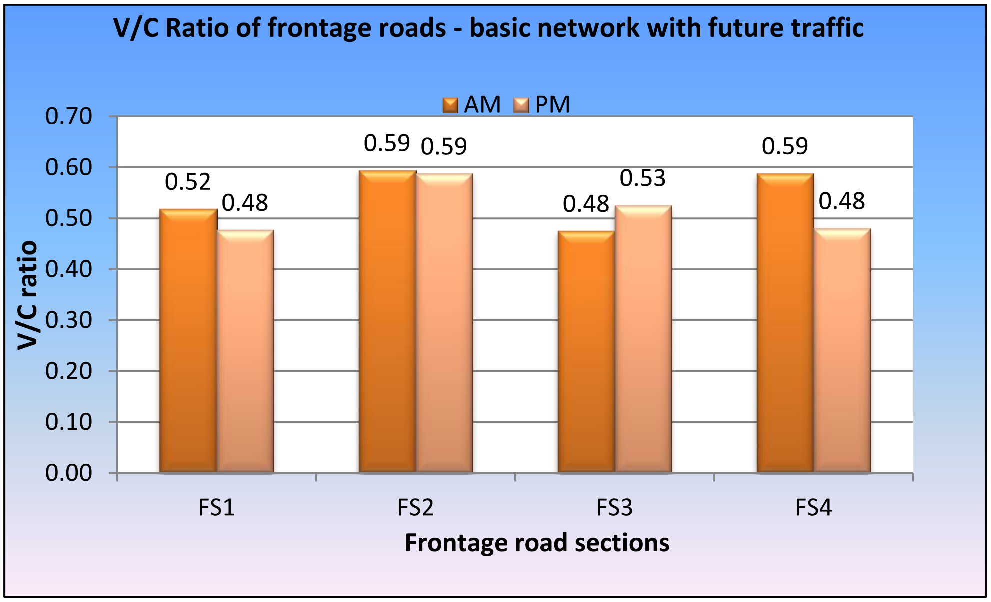


Figure 5-23: V/C Ratios on Frontage Roads of the Basic Network for Current and Forecasted Traffic Volumes (Westbound)

Table 5-5: Comparison of LOS in the Basic Network between Current and Future Traffic Conditions

		AM		PM	
		Current	Future	Current	Future
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	D	C	D
Indiana & University	*Westbound*	B	C	C	C
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Main lanes					
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	C	B	C
Quaker & Indiana	*Westbound*	C	C	D	D
	Eastbound	C	D	C	D
Indiana & University	*Westbound*	C	C	C	C
	Eastbound	C	D	C	D
University & I-27	*Westbound*	B	C	B	C
	Eastbound	C	C	B	C

Alternative 1

The V/C ratios of the frontage road sections with projected traffic volumes are illustrated in Figure 5-24. Compared with the current traffic conditions, the frontage road segment between Slide Road and Quaker Avenue and the segment between Indiana Avenue and University Avenue have been degraded from ‘B’ to ‘C’.

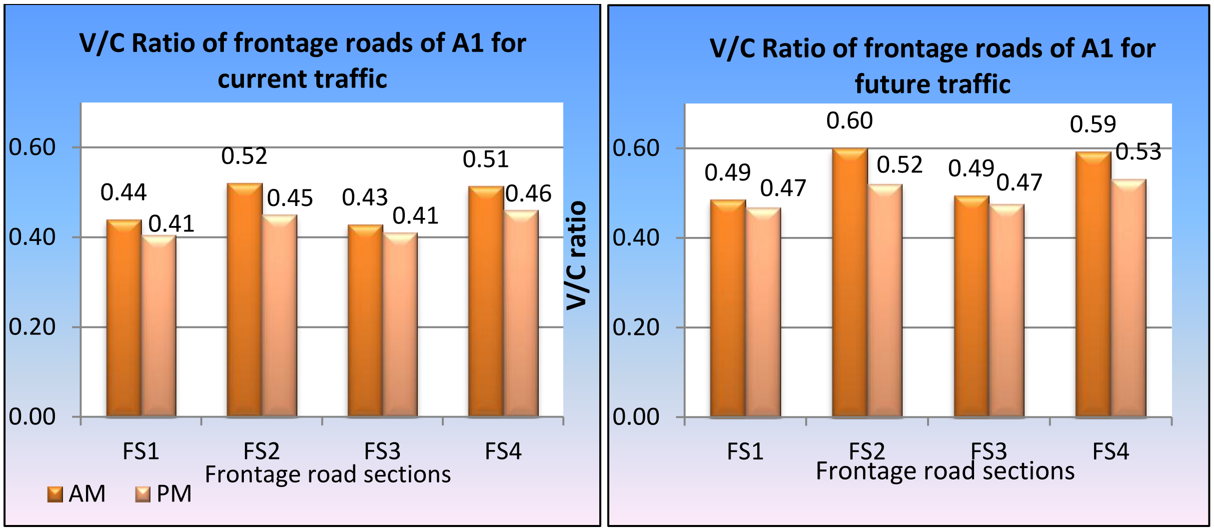


Figure 5-24: Effect of Alternative 1 on Frontage Roads with Current and Projected Traffic Data (Westbound)

Figure 5.25 further illustrates the LOS on the main lanes for the projected traffic conditions compared to the current situation. The densities of all the main lane traffic increase. For example, the freeway segment between Indiana Avenue and University Avenue degraded from ‘B’ to ‘C’ for both morning and afternoon peak hours.

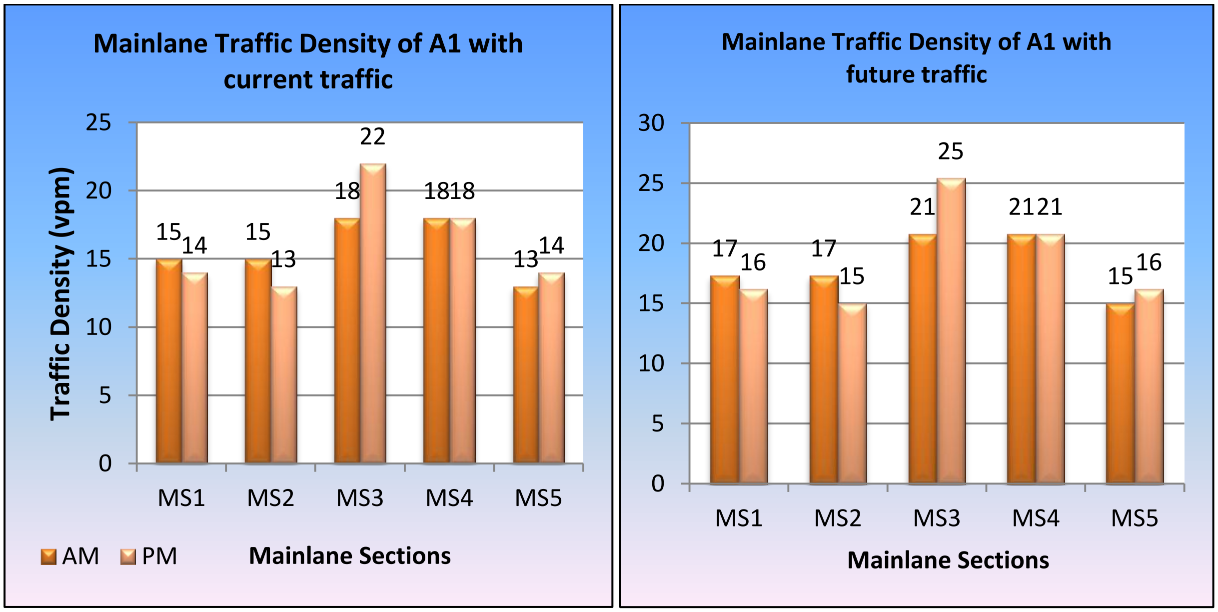


Figure 5-25: Effect of Alternative 1 on Main Lane with Current and Projected Traffic Data (Westbound)

The levels of service on both eastbound and southbound frontage roads as a result of Alternative 1 are summarized in Table 5-6. As can be seen, on the frontage roads, the LOS will be downgraded at three sections as a result of the increased traffic volumes. At the section of Slide Road and Quaker Avenue, the LOS is changed from ’B’ to ‘C’ for the westbound direction during the afternoon peak hours. On the westbound frontage road between Indiana Avenue and University Avenue, the LOS is degraded to ’C’ from ’B’ for both morning and afternoon peak hours. For the main lane traffic, as shown in Phase 1, four segments will be degraded from ‘B’ to ‘C.’ Generally, there will not be any significant changes of LOS for the frontage roads under Alternative 1.

Table 5-6: Comparison of LOS between the Basic Network and Alternative 1

		AM		**PM**	
		Current	**Future**	**Current**	**Future**
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Indiana & University	*Westbound*	B	C	B	C
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B
Quaker & Indiana	*Westbound*	B	C	C	C
	Eastbound	C	C	B	C
Indiana & University	*Westbound*	B	C	C	C
	Eastbound	B	B	B	C
University & I-27	*Westbound*	B	B	B	B
	Eastbound	B	B	B	C

Alternative 2

For Alternative 2, the flow pattern has been changed between the main lanes and frontage roads by converting the ramp configuration from a Diamond to an X pattern. Figure 5-26 and Figure 5-27 illustrate that the increase in traffic demand in five years will not cause significant changes in LOS for both frontage roads and freeway segments.

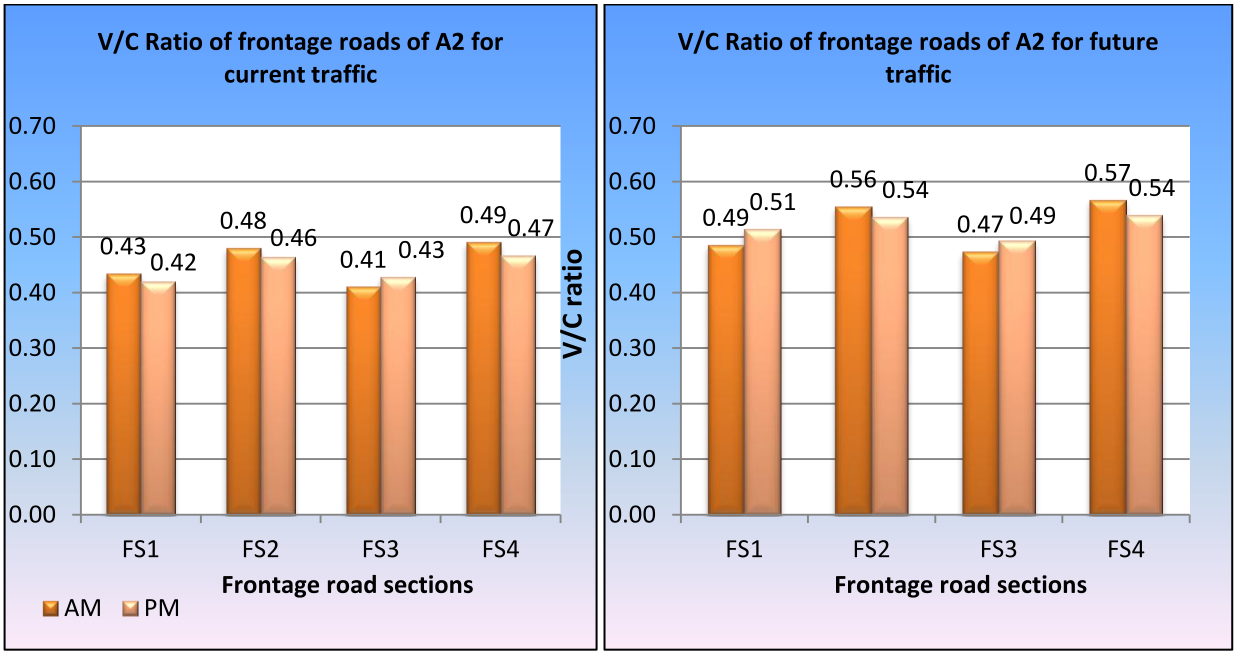


Figure 5-26: Effect of Alternative 2 on Frontage Roads with Current and Projected Traffic Data (Westbound)

As shown in Figure 5-27, the changes of the V/C ratio range from 0.06 to 0.09. The LOS on only two segements on the westbound corridor have degraded from ‘B’ to ‘C.’ Similar results are also obtained regarding the main lane traffic. Densities on the analyzed sections have changed by, at most, three vehicles per mile per lane. On the westbound corridor, four sections have degraded from ‘B’ to ‘C.’

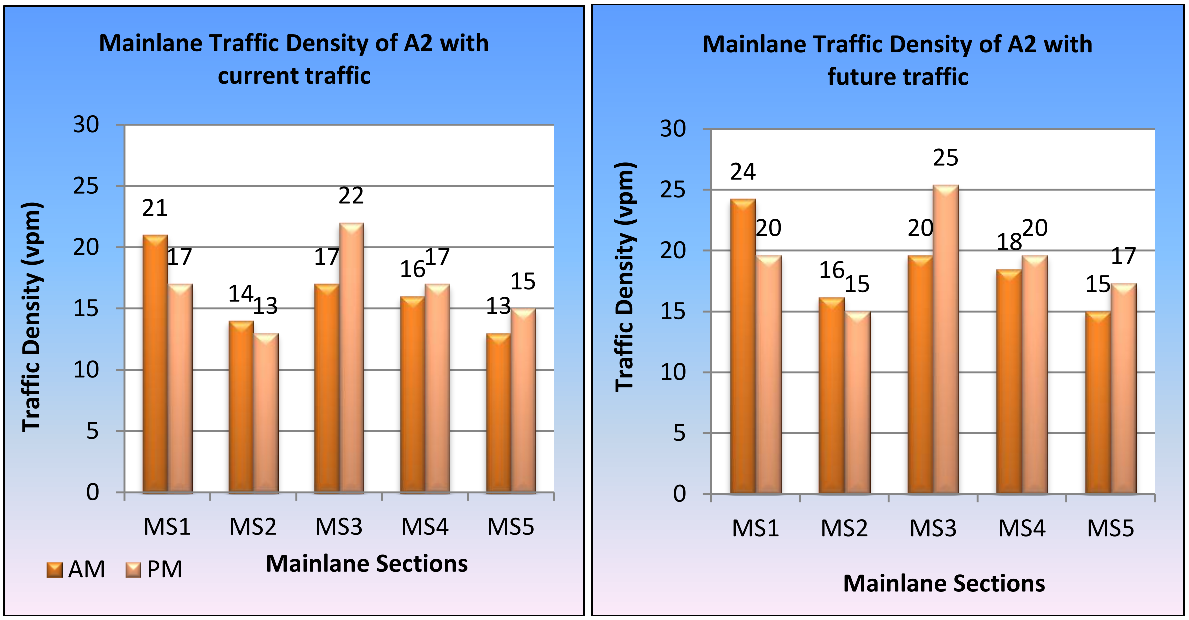


Figure 5-27: Effect of Alternative 2 on Main lane with Current and Projected Traffic Data (Westbound)

Accordingly, the level of service for current and future traffic demands on both the west and eastbound corridors are shown in Table 5-7. The changes in terms of LOS for both frontage roads and main lane traffic are shown to be limited.

Table 5-7: Comparison of LOS between the Basic Network and Alternative 2

		AM		PM	
		Current	**Future**	**Current**	**Future**
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Indiana & University	*Westbound*	B	C	B	C
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	B	C	C	C
Indiana & University	*Westbound*	B	B	C	C
	Eastbound	C	B	B	B
University & I-27	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B

Alternative 3

Alternative 3 supplements Alternative 2 by adding an auxiliary lane on the overpass of each interchange. Similarly to Alternatives 1 and 2, the traffic growth will not have a significant impact on the main lane traffic or on the frontage roads.

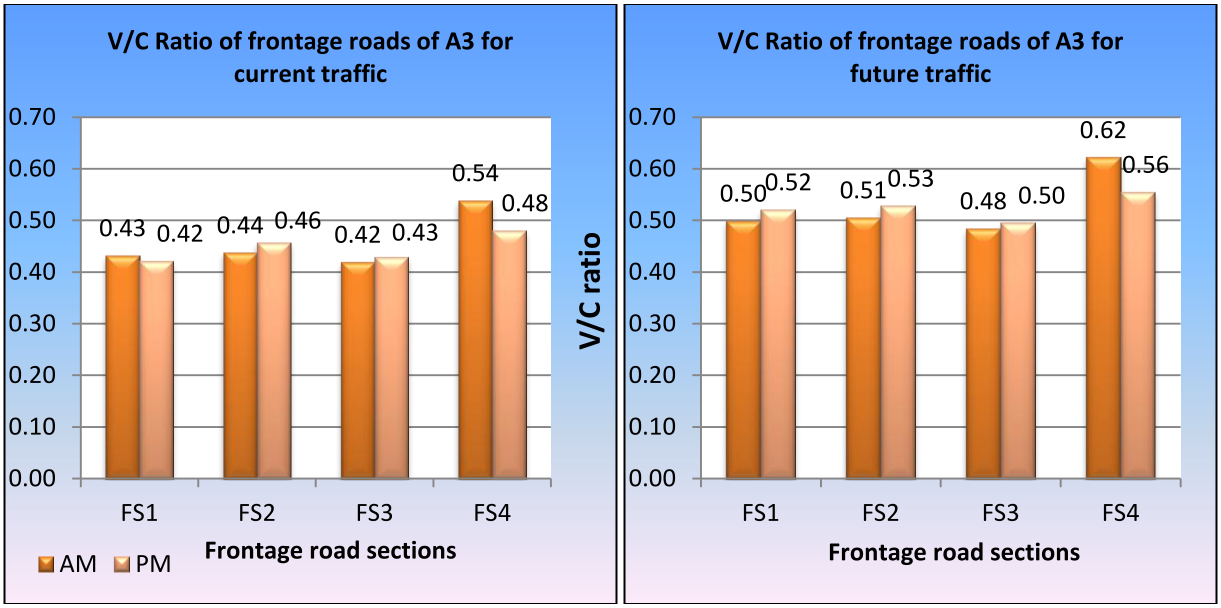


Figure 5-28: Effect of Alternative 3 on Traffic Volume and Lane Distribution with Current and Projected Traffic Data (Westbound)

On the frontage roads, the increases of the V/C ratios range from 0.6 to 1. On the westbound corridor, four segments will be degraded from ‘B’ to ‘C.’ In terms of the effects on traffic density on the main lanes, the difference between the current and the forecasted traffic demand is very limited, which can be observed from the density values illustrated in Figure 5-29.

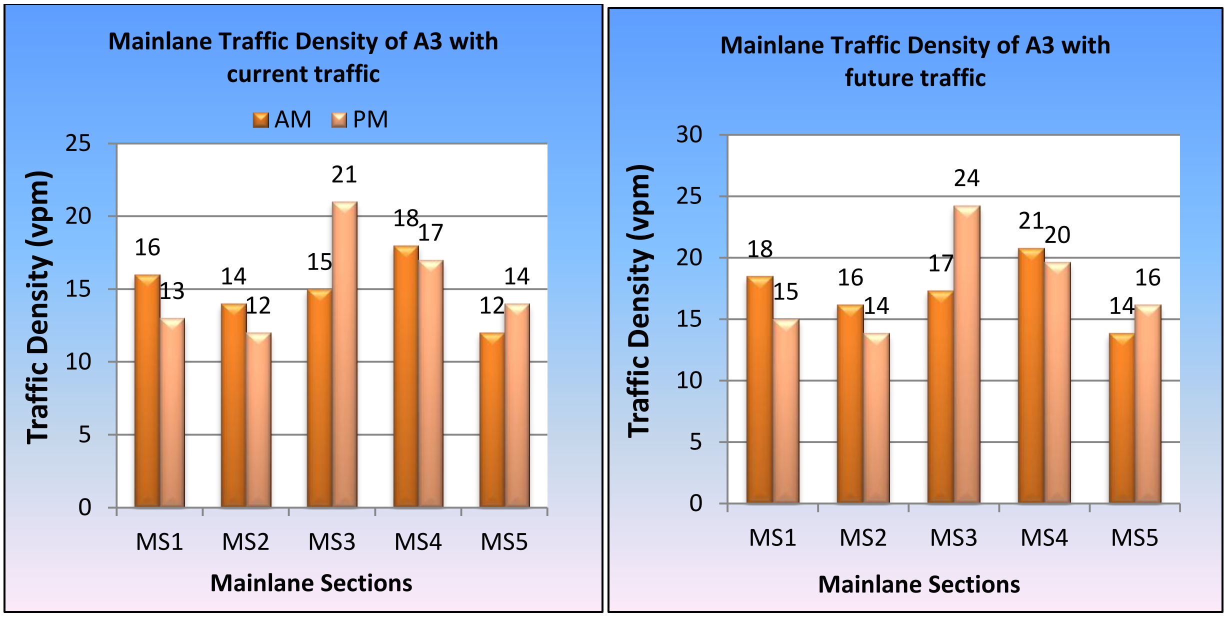


Figure 5-29: Effect of Alternative 3 on Traffic Volume and Lane Distribution with Current and Projected Traffic Data (Westbound)

The LOS for current and future traffc demands under Alternative 3 is shown in Table 5-8. Similarly, the changes in traffic demands will not have a significant impact on the performance of Alternative 3 within the next five years.

Table 5-8: Comparison of LOS between the Basic Network and Alternative 3

		AM		PM	
		Current	**Future**	**Current**	**Future**
Frontage Roads					
Slide Road & Quaker Ave.	*Westbound*	C	C	B	C
	Eastbound	C	C	C	C
Quaker & Indiana	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Indiana & University	*Westbound*	B	C	B	C
	Eastbound	C	C	C	C
University & I-27	*Westbound*	C	C	C	C
	Eastbound	C	C	C	C
Main lane					
Slide Road & Quaker Ave.	*Westbound*	B	B	B	B
	Eastbound	B	B	B	C
Quaker & Indiana	*Westbound*	B	B	C	B
	Eastbound	B	C	B	C
Indiana & University	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B
University & I-27	*Westbound*	B	B	B	B
	Eastbound	B	B	B	B

6. LEVEL OF SERVICE ANALYSIS OF INTERSECTIONS

The objective of this part of the project was to design the signal timing plans and perform LOS analysis for the four major interchanges in the study area, including Slide Road and South Loop 289, Quaker Avenue and South Loop 289, Indiana Avenue and South Loop 289, and University Avenue and South Loop 289. The design and analysis were performed for the existing situation and the three proposed alternative designs under current traffic demand and projected future traffic demand. Signal timing plans were first designed for each option with the current and forecasted future traffic volumes in the subject area. Then, the LOS of the interchanges were analyzed and compared. Synchro software with SimTraffic was used for the tasks, because it is efficient and widely used for traffic signal timing design and intersection analysis.

The major tasks of this part of the research project included:

- Analysis of collected traffic data
- Signal timing design
- Building the geometric and signal timing plans for all options in Synchro
- Calibrating the simulation models of SimTraffic using the observed traffic volumes
- Examining and comparing the performance of the alternatives

6.1 Data Analysis

As analyzed in the second section of this report, traffic volumes at Diamond interchanges will be changed by traffic re-routing when Diamond interchanges are changed to X type interchanges. The traffic volumes of existing Diamond interchange configurations (existing configuration and Alternative 1) were acquired from the counted traffic data, and the traffic volumes after interchange transformation (Alternative 2 and Alternative 3) were estimated based on counted traffic data and re-routing analysis documented in Section 2. The current and future interchange traffic volumes for Diamond interchange configurations and X pattern interchange configurations are listed in Table 6-1 through Table 6-4. The green-marked numbers are volumes decreased when Diamond interchanges were changed to X interchanges.

Table 6-1: Current AM Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		996	650	390	380	355		578	137	413	398	374
	D2X Ramp Config		996	650	390	380	355		578	137	413	398	374
Quaker Interchange	Existing Ramp Config		1160	478	263	545	327		1040	246	348	437	353
	D2X Ramp Config		1160	478	263	473	327		1040	246	348	411	353
Indiana Interchange	Existing Ramp Config		1148	436	512	626	348		884	338	263	522	289
	D2X Ramp Config		1148	436	512	480	348		884	338	263	408	289
University Interchange	Existing Ramp Config		1184	424	506	721	315		1125	458	255	417	207
	D2X Ramp Config		1184	424	506	575	315		1125	458	255	303	207

Table 6-2: Current PM Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		844	548	477	345	486		1020	205	471	459	463
	D2X Ramp Config		844	548	477	345	486		1020	205	471	459	463
Quaker Interchange	Existing Ramp Config		1256	402	317	557	528		1271	227	589	532	336
	D2X Ramp Config		1256	402	317	433	528		1271	227	589	508	336
Indiana Interchange	Existing Ramp Config		1123	220	543	313	532		1172	525	406	527	293
	D2X Ramp Config		1123	220	543	117	532		1172	525	406	449	293
University Interchange	Existing Ramp Config		1040	373	674	627	514		1232	701	450	324	187
	D2X Ramp Config		1040	373	674	431	514		1232	701	450	246	187

Table 6-3: Forecasted AM Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		1155	754	452	441	412		670	159	479	461	434
	D2X Ramp Config		1155	754	452	441	412		670	159	479	461	434
Quaker Interchange	Existing Ramp Config		1345	554	305	632	379		1206	285	403	507	409
	D2X Ramp Config		1345	554	305	548	379		1206	285	403	476	409
Indiana Interchange	Existing Ramp Config		1331	505	594	726	403		1025	392	305	605	335
	D2X Ramp Config		1331	505	594	556	403		1025	392	305	473	335
University Interchange	Existing Ramp Config		1373	492	587	836	365		1304	531	296	483	240
	D2X Ramp Config		1373	492	587	667	365		1304	531	296	351	240

Table 6-4: Forecasted PM Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		978	635	553	400	563		1182	238	546	532	537
	D2X Ramp Config		978	635	553	400	563		1182	238	546	532	537
Quaker Interchange	Existing Ramp Config		1456	466	367	646	612		1271	227	683	617	390
	D2X Ramp Config		1456	466	367	502	612		1271	227	683	589	390
Indiana Interchange	Existing Ramp Config		1123	220	629	363	617		1172	525	471	611	340
	D2X Ramp Config		1123	220	629	136	617		1172	525	471	521	340
University Interchange	Existing Ramp Config		1040	373	781	727	596		1232	701	522	376	217
	D2X Ramp Config		1040	373	781	500	596		1232	701	522	285	217

6.2 Signal Timing Design

The research team used the signal timing phase order of the traditional TTI-4-Phase Diamond interchange operation (as shown in Figure 6-1), which is used for operating most Diamond interchanges in the City of Lubbock. The green time calculation method documented in Chapter 10 and Chapter 16 of the HCM 2000 was applied for obtaining an equalizing saturation degree of critical movements.

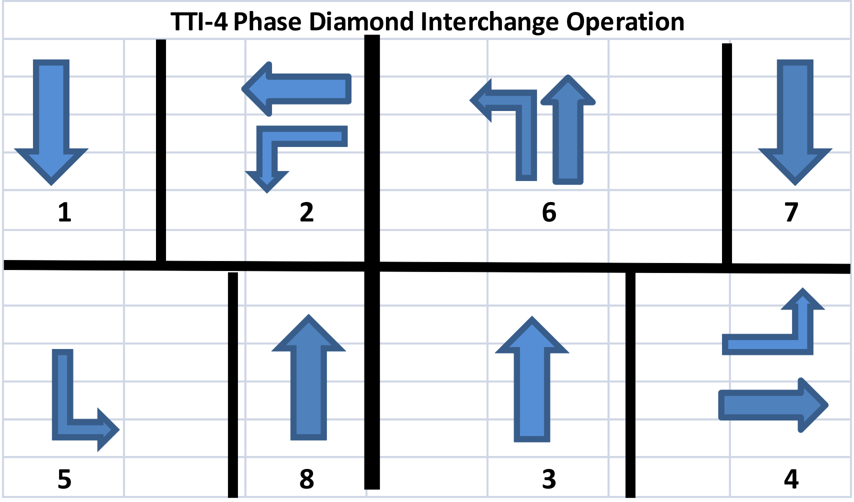


Figure 6-1: TTI-4-Phase Signal Timing Phase Design

An Excel program was developed for calculating green time with the inputs of traffic volumes and lane configurations at interchanges. The calculated green time of each phase was adjusted based on minimum green time and pedestrian traveling time to get practical signal timing plans (shown in Table 6-1 and Table 6-2). The signal timing plans in Table 6-1 and Table 6-2 were designed based on current traffic volumes and existing geometric designs. The future traffic was estimated by using a uniform traffic growth rate, 3%, in the study area, so traffic volumes of each movement were increased by the same percentage. Therefore, the calculated signal timing plans for future traffic were exactly the same as plans for current traffic. The only impact of the alternatives to interchanges was a decrease of through movement traffic on frontage roads, which was caused by the transformation from Diamond interchanges to X pattern interchanges. During the process of signal timing design, only the critical movement V/C ratio impacts affected green time. For frontage road traffic, the left turn traffic movement is the critical movement at each interchange of the study area. The transformation from Diamond interchanges to X type interchanges, therefore, would not change the calculated signal timing plans for existing Diamond interchanges. For this reason, signal timing plans for Diamond interchanges and X type interchanges with current and forecasted traffic volumes will be the same. During this research, the signal timing plans in Table 6-5 and Table 6-6 were employed for the analysis of the improvement options.

6.3 Analysis Results

Using the estimated traffic volumes, interchange lane configurations, and designed signal timing plans, Synchro models were built for the analysis of the three interchange operations under the existing and forecasted traffic demands. Alternative 1 has one additional lane on the freeway between each pair of on-ramps and off-ramps, so the traffic volumes at interchanges are the same as the volumes for existing configurations. Alternative 2 and Alternative 3 both have X type interchanges, which decrease through movement traffic volumes on frontage roads. The two alternatives have the same estimated traffic volumes and designed signal timing plans at interchanges. Thus, the team obtained the same analysis results for the existing design and Alternative 1 and the same analysis results for Alternative 2 and Alternative 3.

The research team ran simulations with SimTraffic in order to accurately evaluate control delay and LOS. The simulation results achieved are listed in Table 6-7 through Table 6-10.

The LOS values marked with green are the movements where LOS was improved after the transformation from a Diamond interchange to an X type interchange. In fact, all control delays of frontage road through movement at the Quaker Avenue interchange, Indiana Avenue interchange, and University Avenue interchange were decreased by the Diamond to X pattern change. However, only the improvements of the green-marked movements were enough to give better LOS values.

By comparing the analysis results, it was found that Alternative 2 and Alternative 3 decreased control delays and provided better LOS for through movements on frontage roads. The signal timing calculated by the equalizing V/C ratio method was not changed when Diamond interchanges were transformed to X type interchanges, because the traffic volumes of the critical movements would not be changed by the transformation. Therefore, the traffic of other movements, including turning traffic on frontage roads and traffic on arterial roads, was not benefitted by Alternative 2 and Alternative 3 under current traffic demand or future traffic demand.

Table 6-5: AM Signal Timing Plan

	Cycle Length	Yellow Time	All-Red Time	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
Slide Interchange	130	4	2	23	41	35	31	56	58	8	8
Quaker Interchange	130	4	2	28	34	30	38	54	60	8	8
Indiana Interchange	130	4	2	26	31	31	42	49	65	8	8
University Interchange	130	4	2	29	29	31	41	50	64	8	8

Table 6-6: PM Signal Timing Plan

	Cycle Length	Yellow Time	All-Red Time	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
Slide Interchange	130	4	2	32	35	28	35	59	55	8	8
Quaker Interchange	130	4	2	29	31	28	42	52	62	8	8
Indiana Interchange	130	4	2	32	26	31	40	50	63	8	8
University Interchange	130	4	2	33	29	29	39	54	60	8	8

Table 6-7: AM LOS with Current Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		C		D	E	A		D		D	D	A
	D2X Ramp Config		C		D	E	A		D		D	D	A
Quaker Interchange	Existing Ramp Config		D		D	D	A		D		D	D	A
	D2X Ramp Config		D		D	D	A		D		D	D	A
Indiana Interchange	Existing Ramp Config		D		D	C	A		E		D	E	A
	D2X Ramp Config		D		D	C	A		E		D	D	A
University Interchange	Existing Ramp Config		D		C	C	A		D		E	E	A
	D2X Ramp Config		D		C	C	A		D		E	D	A

Table 6-8: PM LOS with Current Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		D		D	D	A		D		D	D	A
	D2X Ramp Config		D		D	D	A		D		D	D	A
Quaker Interchange	Existing Ramp Config		D		D	D	A		D		E	D	A
	D2X Ramp Config		D		D	D	A		D		D	D	A
Indiana Interchange	Existing Ramp Config		D		D	D	A		E		E	E	A
	D2X Ramp Config		D		D	D	A		E		E	D	A
University Interchange	Existing Ramp Config		D		D	D	A		E		E	E	A
	D2X Ramp Config		D		D	D	A		E		E	D	A

Table 6-9: AM LOS with Forecasted Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		D		D	E	A		D		D	D	A
	D2X Ramp Config		D		E	E	A		D		D	D	A
Quaker Interchange	Existing Ramp Config		D		D	D	A		D		D	D	A
	D2X Ramp Config		D		D	D	A		D		D	D	A
Indiana Interchange	Existing Ramp Config		E		D	D	A		E		E	E	A
	D2X Ramp Config		E		D	C	A		E		E	D	A
University Interchange	Existing Ramp Config		D		D	C	A		D		E	E	A
	D2X Ramp Config		D		D	C	A		D		E	D	A

Table 6-10: PM LOS with Forecasted Traffic Volumes at Interchanges with Different Ramp Configurations

		South of S. Loop 289						North of S. Loop 289					
		Northbound			Eastbound			Southbound			Westbound		
			Through	Right	Left	Through	Right		Through	Right	Left	Through	Right
Slide Interchange	Existing Ramp Config		D		E	D	A		D		D	D	A
	D2X Ramp Config		D		E	D	A		D		D	D	A
Quaker Interchange	Existing Ramp Config		E		D	D	A		E		E	D	A
	D2X Ramp Config		E		D	D	A		E		D	D	A
Indiana Interchange	Existing Ramp Config		D		D	D	A		E		E	E	A
	D2X Ramp Config		D		D	D	A		E		E	D	A
University Interchange	Existing Ramp Config		E		D	D	A		E		E	E	A
	D2X Ramp Config		E		D	D	A		E		E	D	A

7. WEAVING AND RAMP ANALYSIS

Weaving is defined as the crossing of two or more traffic streams traveling in the same general direction along a significant length of highway without the aid of traffic control devices. When an on-ramp is closely followed by an off-ramp and the two are joined by an auxiliary lane, they form a weaving segment. If a one-lane on-ramp is closely followed by a one-lane off-ramp and the two are not connected by an auxiliary lane, the merge and diverge movements are considered separately using procedures for the analysis of ramp junctions (HCM2010). The impacts of the proposed and existing ramps of South Loop 289 to the traffic along the main lanes are caused by weaving, merging, and diverging movements at the junctions of the freeway and ramps. Therefore, this study analyzed each junction by using a weaving or ramp junction analysis procedure as necessary.

7.1 Rationale

Freeway weaving and ramp junction analysis is a very important aspect of this project. Changing the ramps from Diamond to X pattern will cause a change of traffic on frontage roads, freeway main lanes and ramps, especially around the junction areas of the main lanes and ramps. The micro simulation analysis gives a very good understanding of the density and LOS values for main lanes and frontage roads. The weaving and ramp analysis was specially studied for traffic movement at the ramps. This process identifies any possible problem at junction areas and helps the research group to provide a more effective recommendation.

7.2 Methodology

Chapter 24 and 25 of the HCM includes detailed information on how to determine to use either weaving or ramp junction analysis. For the existing ramp configuration and Alternative 2, ramps were directly connected to the outside lane of the main lanes, so the ramp analysis procedure was applied for evaluating the LOS of the ramps. For Alternative 1 and Alternative 2, an auxiliary lane was added to the freeway main lanes for connecting each pair of on ramp and off ramp. Therefore, the weaving analysis procedure was used for evaluating the performance of ramps and weaving segments.

For the weaving analysis, the essential data that were used were the main lane traffic volumes and detailed on- and off-ramp volumes. Other data that were used were for the determination of the lengths of the weaving segments and lengths of both acceleration and deceleration lanes. Finally, existing volumes were used to determine the projected traffic volumes for the next five years.

As presented in Tables 7-1 through 7-12, three ramp scenarios are detailed for both AM and PM peak hour volumes and for both existing (2011) to future (2016) traffic volumes. The four conditions are:

- Existing Geometric Condition
- Alternative 1: Weaving Analysis on Existing Condition
- Alternative 2: Ramp Junction Analysis on X Pattern
- Alternative 3: Weaving Analysis on X Pattern

First, the “Existing Geometric Condition” scenario represents the current geometric design of South Loop 289 with an X pattern west of Quaker Avenue and Diamond Intersections East of Quaker Avenue. Next, Alternative 1 uses the geometric conditions from the existing condition, but assumes the addition of an auxiliary lane to connect the on/off ramp pairs. Weaving analysis is used here. Next, Alternative 2 requires changing the existing geometric design to the X Pattern system with no auxiliary lane to connect the on/off ramp pairs. Ramp Junction Analysis is used here. Finally, Alternative 3 requires changing the existing geometric design of the X Pattern system, with the addition of the auxiliary lane to connect the on/off ramp pair.

7.3 Procedure

The method used to analyze the weaving segments and ramp junctions in this project was the methodology specified in the HCM 2000, specifically chapters 24 and 25. From there, Microsoft Excel was used to create spreadsheets to tabulate all the necessary information and finally determine the LOS of each existing or proposed ramp.

- **Ramp Junction Analysis**

The methodological process used to construct the ramp junction analysis is briefly summarized below:

The data for through traffic on the Loop 289 main lanes and the on/off ramp traffic in vehicles per hour were first determined to begin the analysis. Next, the proportion of approaching freeway flow remaining in Lanes 1, 2, and 3 immediately upstream of the merge point (P_{FM}) is calculated using the through and ramp traffic volumes. Then the flow rate in Lanes 1 and 2 of the freeway immediately upstream of the merge point (V_{12}) is calculated and measured in passenger cars per hour. Next, the capacity of the downstream segment (V_{FO}) is calculated and measured in passenger cars per hour. Next, the length of the acceleration and deceleration lanes, (L_A) and (L_D), respectively is calculated. These values were approximated using Google Earth and measured in feet. Then the density of the segment (D_R) is calculated. Finally, from the density the LOS is computed using the criteria shown in Table 7-13. These tables are detailed tables with density and LOS values as shown in Tables 7-1, 7-3, 7-5, and 7-7.

- **Weaving Analysis**

The methodological process used to construct the weaving analysis is identical to the ramp junction analysis; therefore, the detailed methodological process used to construct the spreadsheets for the weaving analysis is detailed below.

All weaving segments are considered to be “Type A” in which weaving vehicles in both directions must make one lane change to successfully complete a weaving maneuver (HCM2010). First, the data for the thru traffic and ramp traffic on the Loop 289 main lanes and the on/off ramp traffic in vehicles per hour is determined. Next, the total weaving flow rate in the weaving segment (V_M) is calculated, using the total ramp traffic volumes for the on/off ramp pair. Then the total non-weaving flow rate in the weaving segment (V_{NW}) is calculated. Next, the total flow rate in the weaving segment (V) is calculated and measured in passenger cars per hour. After this, the speed of weaving vehicles is determined by first assuming “unconstrained operation;” if the conditions for unconstrained operation are not met, then the “constrained operation” is assumed. For computation of the “unconstrained operation” first, the weaving intensity factor for the prediction of the weaving speed (W_W) and the weaving intensity factor for the prediction of the non-weaving speed (W_{NW}) are computed. Then both the weaving and non-weaving speeds are computed as (S_W) and (S_{NW}), respectively.

Next, the number of lanes used by non-weaving vehicles (N_W) is computed. If this value is less than 1.4 “unconstrained operation” is assumed; if not, the same process is done again using “constrained operation” parameters. Next, the saturation flow (S) is determined, followed by the distance of the auxiliary lane (L). These values were approximated using Google Earth and measured in feet. Then the density of the segment (D_R) is calculated. Finally, from the density the LOS is computed using the criteria shown in Table 7-13. These detailed tables show density and LOS values as shown in Tables 7-2, 7-4, 7-6, and 7-8.

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Table 7-1: Existing Geometric Conditions - 2011

AM/PM	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	23.2	C
		EB On	22.4	C
	East of Slide Rd.	WB On	24.8	C
		EB Off	23.6	C
	West of Quaker Ave.	WB Off	26.7	C
		EB On	23.0	C
	East of Quaker Ave.	WB Off	28.6	D
		EB On	27.5	D
	West of Indiana Ave.	WB On	27.6	D
		EB Off	28.0	D
	East of Indiana Ave.	WB Off	23.4	C
		EB On	26.2	C
	West of University Ave.	WB On	23.7	C
		EB Off	27.5	D
	East of University Ave.	WB Off	22.6	C
		EB On	23.5	C
	West of IH-27	WB On	19.5	C
		EB Off	24.1	C
PM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	23.9	C
		EB On	21.0	C
	East of Slide Rd.	WB On	25.0	C
		EB Off	23.8	C
	West of Quaker Ave.	WB Off	26.0	C
		EB On	21.9	C
	East of Quaker Ave.	WB Off	29.2	D
		EB On	25.7	C
	West of Indiana Ave.	WB On	29.3	D
		EB Off	29.3	D
	East of Indiana Ave.	WB Off	25.6	C
		EB On	27.2	C
	West of University Ave.	WB On	26.7	C
		EB Off	29.8	D
	East of University Ave.	WB Off	21.4	C
		EB On	23.4	C
	West of IH-27	WB On	21.6	C
		EB Off	24.6	C

Table 7-2: Alternative 1 - Weaving Analysis on Existing Condition - 2011

AM/PM	WEAVING SEGMENT	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	North of South Loop 289	East of Quaker Ave.	WB Off	22.5	C
		West of Indiana Ave.	WB On		
		East of Indiana Ave.	WB Off	17.0	B
		West of University Ave.	WB On		
		East of University Ave.	WB Off	16.1	B
		West of IH-27	WB On		
	South of South Loop 289	East of Quaker Ave.	EB On	23.5	C
		West of Indiana Ave.	EB Off		
		East of Indiana Ave.	EB On	24.5	C
		West of University Ave.	EB Off		
		East of University Ave.	EB On	20.3	C
		West of IH-27	EB Off		
PM PEAK HOUR VOLUME	North of South Loop 289	East of Quaker Ave.	WB Off	27.2	C
		West of Indiana Ave.	WB On		
		East of Indiana Ave.	WB Off	21.9	C
		West of University Ave.	WB On		
		East of University Ave.	WB Off	17.9	B
		West of IH-27	WB On		
	South of South Loop 289	East of Quaker Ave.	EB On	19.4	C
		West of Indiana Ave.	EB Off		
		East of Indiana Ave.	EB On	26.8	C
		West of University Ave.	EB Off		
		East of University Ave.	EB On	19.4	C
		West of IH-27	EB Off		

Table 7-3: Alternative 2 - Ramp Junction Analysis on X Pattern - 2011

AM/PM	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	23.2	C
		EB On	22.4	C
	East of Slide Rd.	WB On	24.0	C
		EB Off	18.8	B
	West of Quaker Ave.	WB Off	22.0	C
		EB On	23.0	C
	East of Quaker Ave.	WB On	21.8	C
		EB Off	27.7	D
	West of Indiana Ave.	WB Off	25.5	C
		EB On	19.8	C
	East of Indiana Ave.	WB On	18.7	B
		EB Off	29.5	D
	West of University Ave.	WB Off	18.9	B
		EB On	18.8	B
	East of University Ave.	WB On	16.9	B
		EB Off	25.9	C
	West of IH-27	WB Off	17.1	B
		EB On	15.4	B
PM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	23.8	C
		EB On	21.0	C
	East of Slide Rd.	WB On	25.0	C
		EB Off	17.9	B
	West of Quaker Ave.	WB Off	19.3	C
		EB On	21.9	C
	East of Quaker Ave.	WB On	20.0	C
		EB Off	24.0	C
	West of Indiana Ave.	WB Off	30.1	D
		EB On	23.4	C
	East of Indiana Ave.	WB On	17.8	B
		EB Off	33.7	D
	West of University Ave.	WB Off	21.7	C
		EB On	21.1	C
	East of University Ave.	WB On	15.4	B
		EB Off	26.5	C
	West of IH-27	WB Off	16.5	B
		EB On	19.5	C

Table 7-4: Alternative 3 - Weaving Analysis on X Pattern - 2011

AM/PM	WEAVING SEGMENT	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	North of South Loop 289	West of Slide Rd.	WB Off	14.9	B
		East of Slide Rd.	WB On		
		West of Quaker Ave.	WB Off	24.3	C
		East of Quaker Ave.	WB On		
		West of Indiana Ave.	WB Off	17.6	B
		East of Indiana Ave.	WB On		
		West of University Ave.	WB Off	14.2	B
		East of University Ave.	WB On		
	South of South Loop 289	West of Slide Rd.	EB On	19.9	C
		East of Slide Rd.	EB Off		
		West of Quaker Ave.	EB On	19.8	C
		East of Quaker Ave.	EB Off		
		West of Indiana Ave.	EB On	22.8	C
		East of Indiana Ave.	EB Off		
		West of University Ave.	EB On	18.1	B
		East of University Ave.	EB Off		
PM PEAK HOUR VOLUME	North of South Loop 289	West of Slide Rd.	WB Off	18.6	B
		East of Slide Rd.	WB On		
		West of Quaker Ave.	WB Off	26.6	C
		East of Quaker Ave.	WB On		
		West of Indiana Ave.	WB Off	23.3	C
		East of Indiana Ave.	WB On		
		West of University Ave.	WB Off	16.3	B
		East of University Ave.	WB On		
	South of South Loop 289	West of Slide Rd.	EB On	21.2	C
		East of Slide Rd.	EB Off		
		West of Quaker Ave.	EB On	16.6	B
		East of Quaker Ave.	EB Off		
		West of Indiana Ave.	EB On	26.8	C
		East of Indiana Ave.	EB Off		
		West of University Ave.	EB On	17.9	B
		East of University Ave.	EB Off		

Table 7-5: Existing Geometric Conditions - 2016

AM/PM	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	29.7	D
		EB On	25.6	C
	East of Slide Rd.	WB On	28.4	D
		EB Off	28.3	D
	West of Quaker Ave.	WB Off	32.4	D
		EB On	25.8	C
	East of Quaker Ave.	WB Off	36.3	E
		EB On	31.7	D
	West of Indiana Ave.	WB On	31.8	D
		EB Off	34.9	D
	East of Indiana Ave.	WB Off	29.1	D
		EB On	31.1	D
	West of University Ave.	WB On	26.8	C
		EB Off	33.8	D
	East of University Ave.	WB Off	27.7	D
		EB On	27.8	D
	West of IH-27	WB On	22.1	C
		EB Off	29.7	D
PM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	29.8	D
		EB On	24.6	C
	East of Slide Rd.	WB On	28.6	D
		EB Off	28.1	D
	West of Quaker Ave.	WB Off	30.7	D
		EB On	24.3	C
	East of Quaker Ave.	WB Off	36.3	E
		EB On	29.4	D
	West of Indiana Ave.	WB On	34.0	D
		EB Off	37.8	E
	East of Indiana Ave.	WB Off	31.7	D
		EB On	33.8	D
	West of University Ave.	WB On	29.8	D
		EB Off	36.9	E
	East of University Ave.	WB Off	26.1	C
		EB On	28.5	D
	West of IH-27	WB On	24.1	C
		EB Off	30.7	D

Table 7-6: Alternative 1 - Weaving Analysis on Existing Condition - 2016

AM/PM	WEAVING SEGMENT	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	North of South Loop 289	East of Quaker Ave.	WB Off	27.0	C
		West of Indiana Ave.	WB On		
		East of Indiana Ave.	WB Off	20.3	C
		West of University Ave.	WB On		
		East of University Ave.	WB Off	19.4	C
		West of IH-27	WB On		
	South of South Loop 289	East of Quaker Ave.	EB On	28.4	D
		West of Indiana Ave.	EB Off		
		East of Indiana Ave.	EB On	29.5	D
		West of University Ave.	EB Off		
		East of University Ave.	EB On	24.6	C
		West of IH-27	EB Off		
PM PEAK HOUR VOLUME	North of South Loop 289	East of Quaker Ave.	WB Off	32.9	D
		West of Indiana Ave.	WB On		
		East of Indiana Ave.	WB Off	26.5	C
		West of University Ave.	WB On		
		East of University Ave.	WB Off	21.6	C
		West of IH-27	WB On		
	South of South Loop 289	East of Quaker Ave.	EB On	23.3	C
		West of Indiana Ave.	EB Off		
		East of Indiana Ave.	EB On	32.3	D
		West of University Ave.	EB Off		
		East of University Ave.	EB On	23.4	C
		West of IH-27	EB Off		

Table 7-7: Alternative 2 - Ramp Junction Analysis on X Pattern - 2016

AM/PM	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	29.7	D
		EB On	25.6	C
	East of Slide Rd.	WB On	27.7	D
		EB Off	22.0	C
	West of Quaker Ave.	WB Off	25.8	C
		EB On	25.8	C
	East of Quaker Ave.	WB On	25.9	C
		EB Off	31.8	D
	West of Indiana Ave.	WB Off	29.9	D
		EB On	23.3	C
	East of Indiana Ave.	WB On	21.9	C
		EB Off	34.0	D
	West of University Ave.	WB Off	22.4	C
		EB On	22.2	C
	East of University Ave.	WB On	19.6	C
		EB Off	29.9	D
	West of IH-27	WB Off	19.8	C
		EB On	17.6	B
PM PEAK HOUR VOLUME	West of Slide Rd.	WB Off	29.7	D
		EB On	24.6	C
	East of Slide Rd.	WB On	28.6	D
		EB Off	20.5	C
	West of Quaker Ave.	WB Off	22.1	C
		EB On	24.3	C
	East of Quaker Ave.	WB On	23.4	C
		EB Off	27.9	D
	West of Indiana Ave.	WB Off	34.6	D
		EB On	28.3	D
	East of Indiana Ave.	WB On	20.3	C
		EB Off	39.3	E
	West of University Ave.	WB Off	25.1	C
		EB On	25.7	C
	East of University Ave.	WB On	17.6	B
		EB Off	31.2	D
	West of IH-27	WB Off	19.3	B
		EB On	23.6	C

Table 7-8: Alternative 3 - Weaving Analysis on X Pattern – 2016

AM/PM	WEAVING SEGMENT	FREEWAY SEGMENT/LOCATION	ON/OFF RAMP	D_R(pc/mi/ln)	LOS
AM PEAK HOUR VOLUME	North of South Loop 289	West of Slide Rd.	WB Off	17.7	B
		East of Slide Rd.	WB On		
		West of Quaker Ave.	WB Off	29.4	D
		East of Quaker Ave.	WB On		
		West of Indiana Ave.	WB Off	21.2	C
		East of Indiana Ave.	WB On		
		West of University Ave.	WB Off	17.0	B
		East of University Ave.	WB On		
	South of South Loop 289	West of Slide Rd.	EB On	24.0	C
		East of Slide Rd.	EB Off		
		West of Quaker Ave.	EB On	23.8	C
		East of Quaker Ave.	EB Off		
		West of Indiana Ave.	EB On	27.6	D
		East of Indiana Ave.	EB Off		
		West of University Ave.	EB On	21.8	C
		East of University Ave.	EB Off		
PM PEAK HOUR VOLUME	North of South Loop 289	West of Slide Rd.	WB Off	22.3	C
		East of Slide Rd.	WB On		
		West of Quaker Ave.	WB Off	32.3	D
		East of Quaker Ave.	WB On		
		West of Indiana Ave.	WB Off	28.3	D
		East of Indiana Ave.	WB On		
		West of University Ave.	WB Off	19.6	C
		East of University Ave.	WB On		
	South of South Loop 289	West of Slide Rd.	EB On	25.6	C
		East of Slide Rd.	EB Off		
		West of Quaker Ave.	EB On	19.9	C
		East of Quaker Ave.	EB Off		
		West of Indiana Ave.	EB On	32.5	D
		East of Indiana Ave.	EB Off		
		West of University Ave.	EB On	21.4	C
		East of University Ave.	EB Off		

7.4 Study Results

Table 7-9: Analysis Summary – 2011/AM Peak

YEAR 2011 - AM PEAK - EXISTING GEOMETRIC CONDTION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	24.8	23.6	26.7	23.0	28.6	27.5	27.6	28.0	23.4	26.2	23.7	27.5	22.6	23.5	19.5	24.1
LEVEL OF SERVICE (LOS)	C	C	C	C	D	D	D	D	C	C	C	D	C	C	C	C
YEAR 2011 - AM PEAK - ALTERNATIVE 1 - WEAVING ANALYSIS ON EXISTING CONDITION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	22.5	20.3	22.5	20.3	22.5	23.5	22.5	23.5	17.0	24.5	17.0	24.5	16.1	20.3	16.1	20.3
LEVEL OF SERVICE (LOS)	C	C	C	C	C	C	C	C	B	C	B	C	B	C	B	C
YEAR 2011 - AM PEAK - ALTERNATIVE 2 - RAMP JUNCTION ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	24.0	18.8	22.0	23.0	25.5	19.8	21.8	27.7	18.9	18.8	18.7	29.5	17.1	15.4	16.9	25.9
LEVEL OF SERVICE (LOS)	C	B	C	C	C	C	C	D	B	B	B	D	B	B	B	C
YEAR 2011 - AM PEAK - ALTERNATIVE 3 - WEAVING ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	14.9	19.9	24.3	19.8	17.6	22.8	24.3	19.8	14.2	18.1	17.6	22.8			14.2	18.1
LEVEL OF SERVICE (LOS)	B	C	C	C	B	C	C	C	B	B	B	C			B	B

Table 7-10: Analysis Summary – 2011/PM Peak

YEAR 2011 - PM PEAK - EXISTING GEOMETRIC CONDTION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	25.0	23.8	26.0	21.9	29.2	25.7	29.3	29.3	25.6	27.2	26.7	29.8	21.4	23.4	21.6	24.6
LEVEL OF SERVICE (LOS)	C	C	C	C	D	C	D	D	C	D	C	D	C	C	C	C
YEAR 2011 - PM PEAK - ALTERNATIVE 1 - WEAVING ANALYSIS ON EXISTING CONDITION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	25.9	21.6	25.9	21.6	27.2	19.4	27.2	19.4	21.9	26.8	21.9	26.8	17.9	19.4	17.9	19.4
LEVEL OF SERVICE (LOS)	C	C	C	C	D	C	D	C	C	C	C	C	B	C	B	C
YEAR 2011 - PM PEAK - ALTERNATIVE 2 - RAMP JUNCTION ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	25.0	17.9	19.3	21.9	30.1	23.4	20.0	24.0	21.7	21.1	17.8	33.7	16.5	19.5	15.4	26.5
LEVEL OF SERVICE (LOS)	C	B	C	C	D	C	C	C	C	C	B	D	B	C	B	C
YEAR 2011 - PM PEAK - ALTERNATIVE 3 - WEAVING ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	18.6	21.2	26.6	16.6	23.3	26.8	26.6	16.6	16.3	17.9	23.3	26.8			16.3	17.9
LEVEL OF SERVICE (LOS)	B	C	C	B	C	C	C	B	B	B	C	C			B	B

Table 7-11: Analysis Summary – 2016/AM Peak

YEAR 2016 - AM PEAK - EXISTING GEOMETRIC CONDTION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	28.4	28.3	32.4	25.8	36.3	31.7	31.8	34.9	29.1	31.1	26.8	33.8	27.7	27.8	22.1	29.7
LEVEL OF SERVICE (LOS)	D	D	D	C	E	D	D	D	D	D	C	D	D	D	C	D
YEAR 2016 - AM PEAK - ALTERNATIVE 1 - WEAVING ANALYSIS ON EXISTING CONDITION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	25.9	24.5	25.9	24.5	27.0	28.4	27.0	28.4	20.3	29.5	20.3	29.5	19.4	24.6	19.4	24.6
LEVEL OF SERVICE (LOS)	C	C	C	C	C	D	C	D	C	D	C	D	C	C	C	C
YEAR 2016 - AM PEAK - ALTERNATIVE 2 - RAMP JUNCTION ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	27.7	22.0	25.8	25.8	29.9	23.3	25.9	31.8	22.4	22.2	21.9	34.0	19.8	17.6	19.6	29.9
LEVEL OF SERVICE (LOS)	D	C	C	C	D	C	C	D	C	C	C	D	C	B	C	D
YEAR 2016 - AM PEAK - ALTERNATIVE 3 - WEAVING ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	17.7	24.0	29.4	23.8	21.2	27.6	29.4	23.8	17.0	21.8	21.2	27.6			17.0	21.8
LEVEL OF SERVICE (LOS)	B	C	D	C	C	D	D	C	B	C	C	D			B	C

Table 7-12: Analysis Summary – 2016/PM Peak

YEAR 2016 - PM PEAK - EXISTING GEOMETRIC CONDTION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	28.6	28.1	30.7	24.3	36.3	29.4	34.0	37.8	31.7	33.8	29.8	36.9	26.1	28.5	24.1	30.7
LEVEL OF SERVICE (LOS)	D	D	D	C	E	D	D	E	D	D	D	E	C	D	C	D
YEAR 2016 - PM PEAK - ALTERNATIVE 1 - WEAVING ANALYSIS ON EXISTING CONDITION																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	31.4	26.1	31.4	26.1	32.9	23.3	32.9	23.3	26.5	32.3	26.5	32.3	21.6	23.4	21.6	23.4
LEVEL OF SERVICE (LOS)	D	C	D	C	D	C	D	C	C	D	C	D	C	C	C	C
YEAR 2016 - PM PEAK - ALTERNATIVE 2 - RAMP JUNCTION ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	28.6	20.5	22.1	24.3	34.9	28.3	23.4	27.9	25.1	25.7	20.3	39.3	19.3	23.6	17.6	31.2
LEVEL OF SERVICE (LOS)	D	C	C	C	D	D	C	D	C	C	C	E	C	C	B	D
YEAR 2016 - PM PEAK - ALTERNATIVE 3 - WEAVING ANALYSIS ON X PATTERN																
RAMP DESCRIPTION	BETWEEN SLIDE AND QUAKER				BETWEEN QUAKER AND INDIANA				BETWEEN INDIANA AND UNIVERSITY				BETWEEN UNIVERSITY AND IH-27			
ON/OFF RAMP	WB ON	EB OFF	WB OFF	EB ON	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF	WB OFF	EB ON	WB ON	EB OFF
DENSITY IN THE MERGING INFLUENCE AREA (pc/mi/ln)	22.3	25.6	32.3	19.9	28.3	32.5	32.3	19.9	19.6	21.4	28.3	32.5			19.6	21.4
LEVEL OF SERVICE (LOS)	C	C	D	C	D	D	D	C	C	C	D	D			C	C

Table 7-13: LOS Criteria for Ramp Junctions

LOS	Mainlane Desnity pc/mi/ln
A	<= 10
B	> 10-19
C	> 19-27
D	> 27-35
E	> 35

The summary analyses of Tables 7-9 through 7-12 show several distinct patterns which are important to the analysis. When "*Existing Geometric Condition*," as the control, is compared to Alternatives 1-3, the densities and LOS values decrease the most with the implementation of Alternative 3. On the contrary, Alternative 1 and 2 have a more consistent variance, with Alternative 2 decreasing the density in several key intersections, such as between Quaker and Indiana, but the benefits appear to be less profound. All alternatives have better densities than the existing condition. Finally, these patterns reoccur through the AM and PM hours and the 2016 projections.

7.5 Conclusion

The weaving and ramp junction analyses presented in Tables 7-1 through 7-8 illustrate that the proposed re-design of the existing Diamond ramps to X pattern ramps have a significant impact on the mainlane traffic at ramp junctions. Furthermore, the analysis shows that X pattern ramps without the addition of the auxiliary lane will also help reduce congestion to a modest amount. Finally, the analysis shows that the use of Alternative 1, which results in the addition of only an auxiliary lane, will also have a moderate impact on the traffic density. Alternative 1 is a great option for a quick fix; however, Alternative 3, being the most costly option, would significantly alleviate the problem for many years to come.

8. CONCLUSIONS

Three capacity improvement strategies, namely Alternative 1 (A1), Alternative 2 (A2), and Alternative 3 (A3) were evaluated in this project, particularly focusing on the potential impact on the frontage roads and intersections along South Loop 289. Alternative 1 involves adding an auxiliary lane to the outside main lane between each entrance and exit ramps on both the eastbound and westbound directions of South Loop 289 at Slide Road and Quaker Avenue, Quaker Avenue and Indiana Avenue, Indiana Avenue and University Avenue, and University Avenue and IH-27. Alternative 2 changes the ramp configuration from a Diamond to an X pattern at Quaker Avenue, Indiana Avenue, and University Avenue. Considering that providing an X pattern interchange will increase traffic volume on the frontage road, an auxiliary lane is added to the frontage road between each exit and entrance ramp. Alternative 3 is developed on the basis of Alternative 2, but provides the auxiliary lanes over the bridges on both eastbound and westbound directions.

Traffic simulation models were developed in both VISSIM and Synchro to examine the effectiveness of the three alternative strategies with regard to both current and forecasted traffic demands.

Alternative 1 improves the level of service through added capacity on the main lanes of the corridor. This will not affect the traffic distribution between the main lane and the frontage roads, thus the LOS on the frontage road remains unchanged.

Alternative 2 alleviates the level of traffic density significantly on the main lanes by converting the ramp configuration from a Diamond to an X pattern. The auxiliary lane is necessary on the frontage to accommodate the increased traffic volumes diverted from the main lanes. However, Alternative 2 will significantly increase the traffic volume on the frontage roads. However, an auxiliary lane on the frontage road can effectively accomodate the increased traffic volume and the perfomance of the frontage roads will remain at the same level as the current network configuration.

Alternative 3 further supplements Alternative 2 by adding an auxiliary lane on the bridges. The resulting performance is almost the same as that of Alternative 2 for both frontage and main lane traffic segments.

For the analysis on the performance of intersections, it was revealed that Alternative 2 and Alternative 3 decreased control delays and provided better LOS for through movements on frontage roads. The signal timing calculated by the equalizing V/S ratio method was not changed when Diamond interchanges were transformed to X type interchanges, because the traffic volumes of the critical movements would not be changed by the transformation. Therefore, the traffic of other movements, including turning traffic on frontage roads and traffic on arterial roads was not benefited by Alternative 2 or Alternative 3 under current traffic demand and future traffic demand.

It was additionally found through weaving analysis that all three alternatives would lead to reduced weaving congestion. Even Alternative 1 would have a significant impact on the weaving congestion. Alternative 3 would have the most significant impact, but it is only recommended if a large amount of funding is available.

The findings from this research project lead to the following recommends:

With limited construction funding, the research team suggests Alternative 1 to alleviate traffic congestion along the main lanes of South Loop 289. LOS, traffic merging, and safety around joint points of on-ramps and main lanes will all be improved without impact to frontage roads and intersections.

With enough construction funding, the research team suggests Alternative 3, which provides better LOS on main lanes, longer weaving distances for weaving traffic and better traffic safety at the joint points of on-ramps and main lanes. Traffic volumes on frontage roads will be increased, but their LOS will be close to the existing situation because of the added auxiliary lane. The control delay of through movements on frontage roads at interchanges will be decreased. However, the whole interchange operation will not get much benefit from the interchange transformation from Diamond to X. Alternative 3 is the best improvement option.

Alternative 2 can improve the LOS of the freeway main lanes and alleviate congestion on the freeways, especially on the outside lanes. The impact to frontage roads and interchanges will be the same as with Alternative 3. Without an auxiliary lane for weaving traffic, temporary congestion may still happen at the joint points of on-ramps and main lanes because of limited space for traffic merging action.

9. REFERENCES

1. AASHTO. A Policy on Geometric Design of Highways and Streets. American Association of State Highway and Transportation Officials, Washington, D.C., 2004.
2. Dorothy, P. W., R. Ambadipudi, and R. M. Kill. Development and Validation of Large-Scale Microscopic Models. Presented at 85th Annual Meeting of the Transportation Research Board, Washington, D.C., 2006.
3. Chitturi, M. V., and R. F. Benekohal. Calibration of VISSIM for Freeways. Presented at 85th Annual Meeting of the Transportation Research Board, Washington, D.C., 2008.
4. Bloomberg, L., and J. Dale. A Comparison of the VISSIM and CORSIM Traffic Simulation Models on a Congested Network. Presented at 79th Annual Meeting of the Transportation Research Board, Washington, D.C., 2000.
5. Fellendorf M. VISSIM: A microscopic Simulation Tool to Evaluate Actuated Signal Control including Bus Priority. Presented at the 64th ITE Annual Meeting. 1994.
6. Frawley, W. E., and W. L. Eisele. Access management Guidebook for Texas. Publication FHWA/TX-05/0-4141-P3. Texas Transportation Institute, 2005.
7. Flynn, M., W. Feuer, E. Janoff, M. Newman, A. Wiley-Schwartz. A 21st – Century Vision of Street: Developing Street Design Guidelines as a Tool for Comprehensive Design. Presented at 89th Annual Meeting of the Transportation Research Board, Washington, D.C., 2010.
8. Fellendorf, M., and P. Vortisch. Validation of the Microscopic Traffic Flow Model
9. VISSIM in Different Real-World Situations. PTV America, 2005.
10. E. G. Velez. Adaptation of Vissim, A Dynamic Simulation Model, to the Traffic Behavior at Intersections in Mayaguez, Puerto Rico. University of Puerto Rico, Mayaguez, 2006.
11. Pecheux, K. K., K. E. Barns K, and R. H. Henk. U.S. 83 Mail Lane, Ramp, and Cross-Street Interchange Operational Analysis: McAllen, Texas. Publication TX-96/2903-4F. Texas Transportation Institute, 1995.
12. Nelson, A. A., J. M. Tydlacka, R. G. Stevens, S. T. Chrysler, and A. P. Voigt. Lane Assignment Traffic Control Devices on Frontage Roads and Conventional Roads at

Interchanges: Technical Report. Publication FHWA/TX-11/0-6106-1, Texas Transportation Institute, 2010.

13. ODOT. Network or Corridor Simulation Models, Chapter 8, Analysis Procedures Manual. Oregon Department of Transportation, Salem, OR, 2007.
14. PTV. VISSIM 4.10 User Manual. PTV AG, Karlsruhe, Germany, 2005.
15. PTV. VISSIM- State-of-the-Art Multi-Modal Simulation. PTV AG, Karlsruhe, Germany, 2005.
16. Cooner, S. A., S. Venglar, Y. Rathod, E. J. Pultorak, J. C. Williams, P. Vo, and S. P. Mattingly. Ramp Reversal Project: Guidelines for Successful Implementation. Publication FHWA/TX-07/0-5105-1, Texas Transportation Institute, 2007.
17. Trafficware. Synchro Studio 7 User Guide. Trafficware, Sugar Land, TX, 2006.