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# 2000 Transportation Engineering Research Reports

## August 2000

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Program Coordinator: Tim Lomax

Mentors: Kevin Balke and Dennis Perkinson

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16. Abstract

The engineering research reports in this document resulted from the ninth year of the Undergraduate Transportation Engineering Fellows Program during the summer of 2000. The ten-week program, sponsored by the Advanced Institute program of the Southwest Region University Transportation Center (SWUTC), the Texas Transportation Institute (TTI), and the Civil Engineering Department at Texas A&M University, provides undergraduate students in Civil Engineering with the opportunity to learn more about transportation engineering through participation in a transportation research program. The program design allows the students to interact directly with a faculty member or TTI researcher in developing a research proposal, conducting appropriate research, and documenting the research results.

This compendium contains reports on two transportation research projects. One paper documents an evaluation of signal control strategies using data from Wellborn Road and the CORSIM simulation model. A few recommendations for additional studies were made based on the procedures developed in the project. No specific conclusions could be drawn concerning specific control strategy changes. The other paper compares the perception of the Houston Metro bus service and the bus volume and ridership. Past bus volumes and perception were compared and used with future scenarios. An all-bus plan and a projection of the light-rail operating condition were used as comparison cases. Several case-specific conclusions were drawn from the analysis, as well as some general conclusions concerning the methodology used.

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## Contents

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## Foreword

The Southwest Region University Transportation Center (SWUTC), through the Advanced Institute Program, the Texas Transportation Institute (TTI) and the Civil Engineering Department at Texas A&M University, established the Undergraduate Transportation Engineering Fellows Program in 1990. The program design allows undergraduate students in Civil Engineering to learn more about transportation engineering through participation in a transportation research program under the supervision of a faculty member or TTI researcher. The intent of the program is to introduce transportation engineering to students that have demonstrated outstanding academic performance, thus, developing a critical resource: capable and qualified future transportation officials.

In the summer of 2000, two students and faculty/staff mentors participated in the program:

| STUDENTS | MENTORS |
|---|---|
| Sean Merrell<br>Texas A&M University | Kevin Balke<br>Texas Transportation Institute |
| Miguel Vescovacci<br>University of Puerto Rico - Mayaguez | Dennis Perkinson<br>Texas Transportation Institute |

A special thanks is extended to the sponsors of this program—the U.S. Department of Transportation through the Advanced Institute Program of the Southwest Region University Transportation Center, the Texas Transportation Institute, and the Civil Engineering Department at Texas A&M University. Without their support and the contributions of the entire transportation engineering faculty and staff at Texas A&M University, this program could not have succeeded.

## Dedication

The 2000 Undergraduate Transportation Engineering Fellows Program was the first conducted without the care, guidance and effort of Dr. Dan Fambro. Dan's death not only left his many colleagues, students and friends sad, it deprived many others of the opportunity to learn from him. Throughout the growth of the program, Dan was involved in all aspects of recruiting students and mentors, as well as planning the other professional and social activities that accompany the summer experience. This edition is dedicated to Dan's memory. Future classes of students will miss a great opportunity.

# Evaluation of the Coordination Strategies of the Eagle Traffic Signal Controller

SEAN MERRELL

The coordination modes within the Eagle Traffic Signal Controller are very difficult to understand and use. This research was conducted to help traffic engineers get a better idea of how and when to use a certain coordination mode. The three coordination modes that were examined were the Permissive, Yield, and Permissive Yield modes. The Wellborn Road corridor in College Station, Texas including the intersections of Joe Routt Blvd., George Bush Drive and Holleman Ave. was the location that was analyzed. The A.M. peak traffic volumes were obtained along with the layout of the three intersections and coded into the CORSIM traffic simulation model. Using hardware-in-the-loop technology, three Eagle Traffic Signal Controllers were used to control the traffic signals within the simulation. The actual timing plans and offsets during the A.M. peak were programmed into the signal controllers.

The simulation was run three different times in each of the three coordination modes with the intersection delay times, total system delay and total travel time used as the measures of effectiveness. Although statistically there was no difference found between the coordination modes, the results showed that the best coordination mode to operate in at the George Bush Intersection was Permissive Yield mode. The other two intersections operated best in either Permissive or Yield mode.

## INTRODUCTION

It is common practice to coordinate traffic signals less than ½-mile apart on major streets and highways (*1*). It has also been observed that traffic flow on urban streets tend to flow in pulsed groups of vehicles, or platoons. Signal coordination simply attempts to make use of this flow characteristic and coordinate signal operation to accommodate platoons with minimal stops.[(2)] Without coordination of the traffic signals at these closely spaced intersections, vehicle delay and the number of vehicles stopped at red lights would increase.

Safety can be enhanced through progressive movement along thoroughfares where stops and delays are reduced. Driver comfort and satisfaction are influenced by the expectation of "system" operation where traffic moves smoothly with few stops, and trip times are generally repeatable along the same route. Motorists' view of good signal timing is where progression permits continuous movement with no random stops (*2*).

### *Problem Statement*

The Eagle traffic signal controller has six different coordination modes; however, the controller manual provides very little guidance on which coordination modes should be used under different traffic situations. The proper coordination of these signal controllers is critical to maintaining the proper progression of vehicles through the traffic network. By examining the different coordination modes, it is the goal of this research to make it easier to decide which coordination strategy the traffic engineer should use for a given traffic scenario.

*Research Objective*

By examining three of the coordination modes that are primarily used in College Station (Permissive, Yield and Permissive Yield Coordination) it is the objective of this research to determine which coordination strategy to use for a given traffic condition. This is important in order to effectively maintain the progression of traffic through a series of closely spaced intersections. The measures of performance that were used include the average intersection delay, the total system delay and the total travel time through the system.

*Scope*

This research was limited to evaluating only three of the six coordination modes present in the Eagle traffic signal controller. The traffic using three intersections along a linear arterial was counted along with the turning movements. These volumes, along with the layout and dimensions of these intersections, were entered into the traffic simulation program, CORSIM. The actual signal timing plans of these intersections were entered into three Eagle Traffic Signal Controllers. The main arterial under consideration for this research is Wellborn Road with the main intersections of interest being George Bush Drive, Holleman Ave. and Joe Routt Blvd. All work was simulation based. Other than collecting data to code in the simulation model, no other field data was collected. The strategies developed for this research were not tested in the field.

*Literature Review*

Prior to beginning this research, a number of different traffic control/coordination handbooks (*3*) along with previous research efforts (*4,5*) were reviewed in order to get a better understanding of signal coordination, progression, and how they relate to one another. These handbooks and previous research efforts did not have much in the way of explaining the impact the different coordination modes had on traffic or when to use a certain coordination mode. The Eagle Traffic Signal Controller Manual (*6*) was referenced many times in order to understand how the Eagle Controller operates the different coordination modes. But this manual also was unclear as to when one should use a certain coordination mode. The CORSIM User's Manual (*7*) was referenced numerous times in order to understand how to code the CORSIM simulation program properly.

## STUDY METHODOLOGY

*Intersection Layout*

A detailed mapping of the three intersections was conducted in order to obtain detailed information to code into the simulation program about these intersections. The equipment used for this task included a surveying wheel and drawing equipment. The primary information obtained included the number of lanes, the width of these lanes and details about the turning bays including whether a left or right turning bay was present and its length. The block length was also obtained to properly space these intersections in the simulation. All of this information was coded into the simulation program CORSIM. A layout of these intersections can be found in Figure 1.

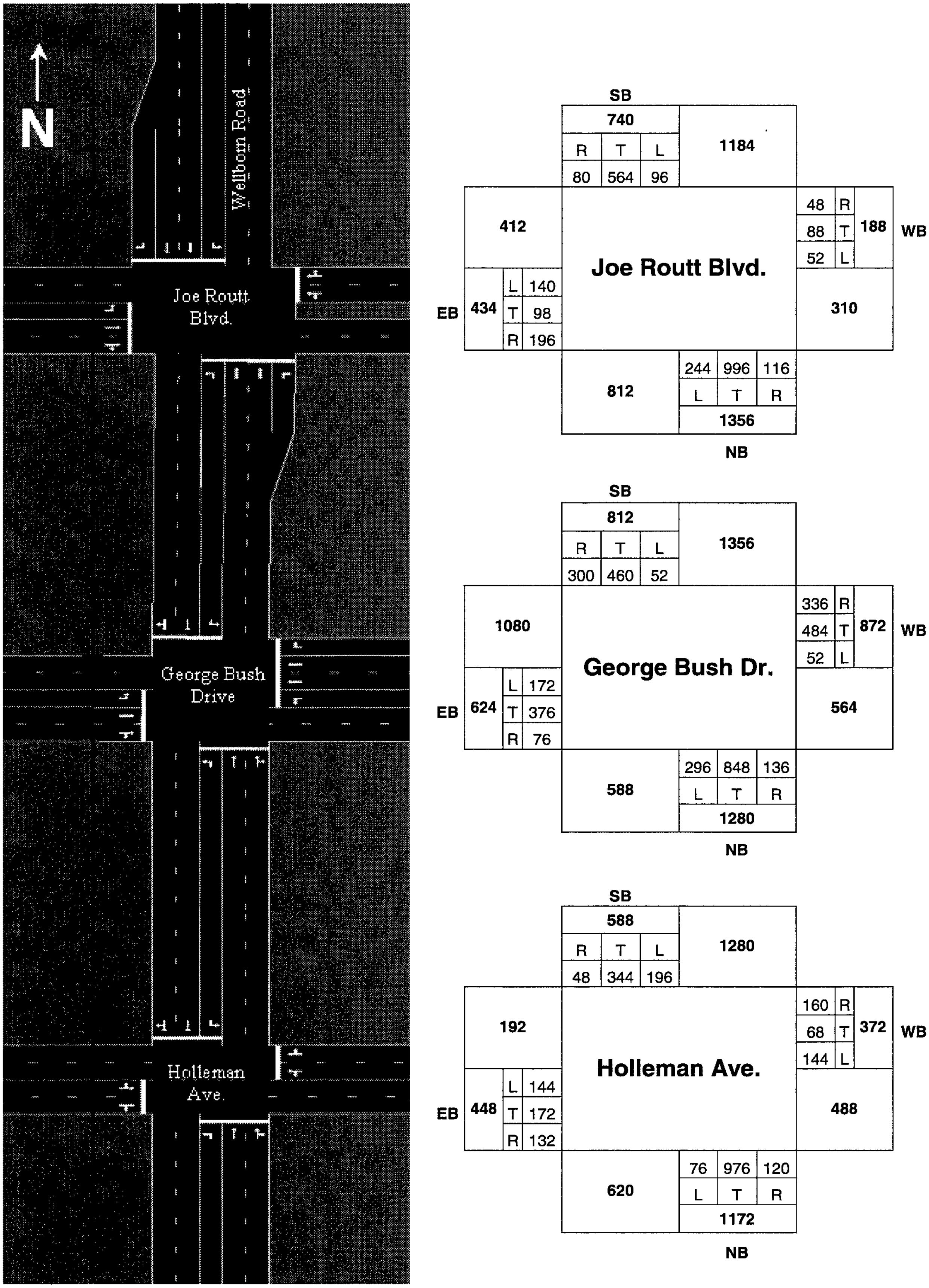


**Figure 1 – Intersection Diagrams and Morning Traffic Volumes (VPH)**

*Traffic Volumes*

The A.M.-peak vehicle volume data and the associated turning movements were obtained from a graduate student's previous research effort[8]. It was collected over a three-day period (Tuesday, Wednesday & Thursday) on November 8-10, 1999. This is an optimal period for data collecting since most students were in town at this point and it more accurately reflected the peak A.M. traffic conditions that Wellborn Drive normally experiences. This is the reasoning behind using data that was seven months old. The total traffic volumes that were collected can be found in Appendix A. A simplified figure of the traffic volumes used can be found in Figure 1.

*Signal Timing Plans*

Once the traffic volume data and intersection layouts were obtained, the last piece of field data that needed to be collected was the actual signal timing plans of the three intersections. These timing plans were obtained by downloading the signal timing plans from the controllers in the cabinets located at these intersections directly into a laptop computer. These signal timing plans were then loaded into the Eagle Traffic Signal Controllers in the lab. The controllers were programmed to always run the A.M.-peak timing plan instead of cycling through the other timing plans at different times during the day like controllers did in the field. All of the cycle lengths are 120 seconds. The signal timing plans and offsets are shown in Table 1. Once the controllers were in coordination with one another, it was then possible to start coding the simulation program.

**Table 1 – Signal Timing Plans**

| Intersection | Phase | | | | | | | | Offset |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| Joe Routt | 22 | 44 | 26 | 28 | 17 | 49 | 0 | 28 | 12 |
| George Bush | 27 | 38 | 29 | 26 | 20 | 45 | 0 | 26 | 49 |
| Holleman | 13 | 63 | 22 | 22 | 13 | 63 | 0 | 22 | 101 |

Phase seven is not used at these intersections and phase eight is only used during a train pre-emption event, which was ignored for this research.

*Coding Data into Simulation Program*

By far the most difficult and time-consuming part of this research project was figuring out how to code the intersections and traffic volume data into CORSIM. Once the basic syntax for each record type is understood, the hard part is making sure the data is in the correct columns. The intersection layout has to be broken down into links and nodes, with four links leaving each intersection (node), and four links entering each intersection. There also has to be beginning nodes at the end of all the streets in order provide a place for the vehicles to enter the simulation. The intersection timing plans did not have to be coded into CORSIM since the Eagle Traffic Signal Controllers themselves controlled them. Once all the necessary data was entered into CORSIM, Mr. Roelof Engelbrecht, a TTI researcher, enabled the hardware-in-the-loop technology so the traffic signal controllers were able to control the traffic signals in the simulation.

### *Collecting Data from CORSIM*

The three coordination modes that were being analyzed were each ran three different times in the simulation program. An initialization time of four minutes was needed at the beginning of each run in order for the simulation model to reach equilibrium. Each run lasted 20 minutes with no vehicles entering during the last five minutes to allow all the vehicles in the system to exit. After one coordination mode was run three different times and the data collected, the coordination mode in the traffic signal controller was changed to a different coordination mode. Although CORSIM collects a lot of different data during a simulation, the main data that was collected and used for the measure of effectiveness was average intersection delay, total system delay time and the average total travel time through the system.

## RESULTS

The measures of effectiveness that were be used to compare the different coordination modes included the average delay time of the vehicles that were stopped at the intersections, the total system delay and the average travel time for each vehicle through the three intersections. The data collected was then averaged for each of the three coordination modes. The data that was collected for each run can be found in Appendix B.

### *Travel Times*

The travel time through all three intersections is one of the measures of effectiveness that was used to evaluate each coordination mode. The runs for each coordination mode were averaged and resulted in the times shown in Table 2.

**Table 2 – Average Travel Times**

| Coordination Mode | Average Travel Time (seconds) | | |
|---|---|---|---|
| | Northbound | Southbound | Average |
| Permissive | 198.1 | 214.0 | 206.1 |
| Yield | 197.6 | 210.5 | 204.1 |
| Permissive Yield | 204.8 | 202.3 | 203.6 |

The travel times associated with the Permissive and Yield modes tend to favor the northbound direction, while the Permissive Yield mode tends to slightly favor the southbound direction. For the A.M.-peak period, the bulk of the traffic is traveling northbound. This is due to the fact of location of the college campus and other high employment areas North of these intersections. Figures 2 and 3 show the relationship between the coordination modes and the travel times for the North and Southbound traffic.

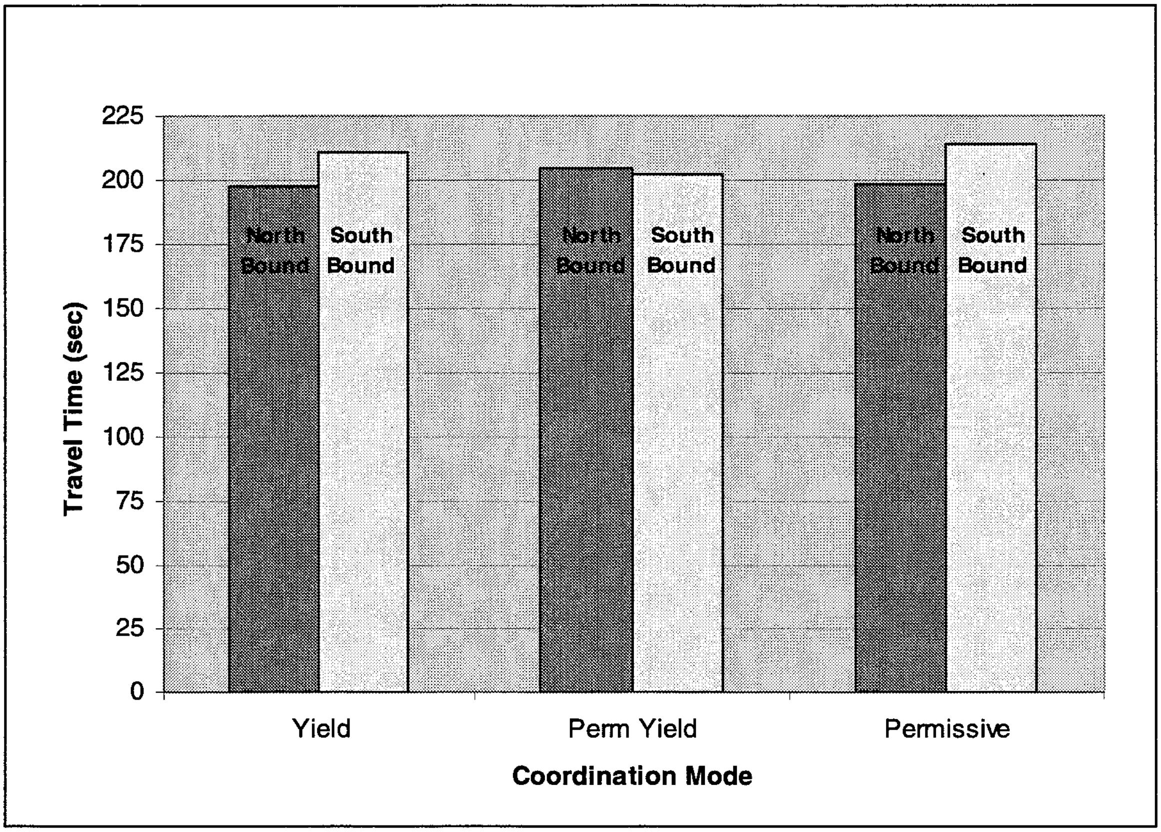


**Figure 2 – Comparison of Coordination Modes and Travel Times**

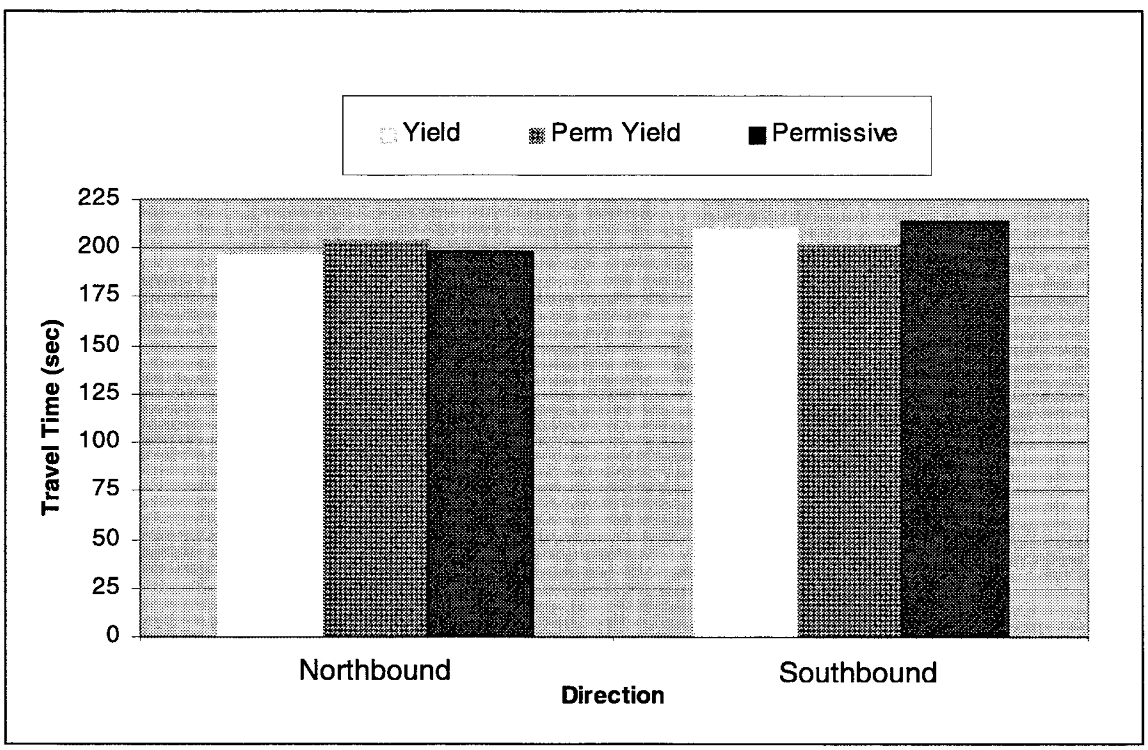


**Figure 3 – Comparison of Travel Direction and Travel Time**

*Intersection Delay*

Intersection Delay is the second measure of effectiveness used in this research. The total delay at each of the four entering links into each of the three intersections is the times that were used for this comparison. Each of the delay times for the three runs were averaged for the three intersections and for each coordination mode observed. The average intersection delay times are shown in Table 3.

**Table 3 – Average Intersection Delay Times (seconds)**

| Intersection | Permissive Yield | Permissive | Yield |
|---|---|---|---|
| George Bush Drive | 40.0 | 42.4 | 42.5 |
| Joe Routt Blvd. | 28.8 | 24.5 | 25.1 |
| Holleman Ave. | 48.2 | 43.9 | 46.1 |

Joe Routt Blvd. consistently had the lower delay times and Holleman Ave. consistently had the higher delay times. This can be seen in Figures 4 and 5.

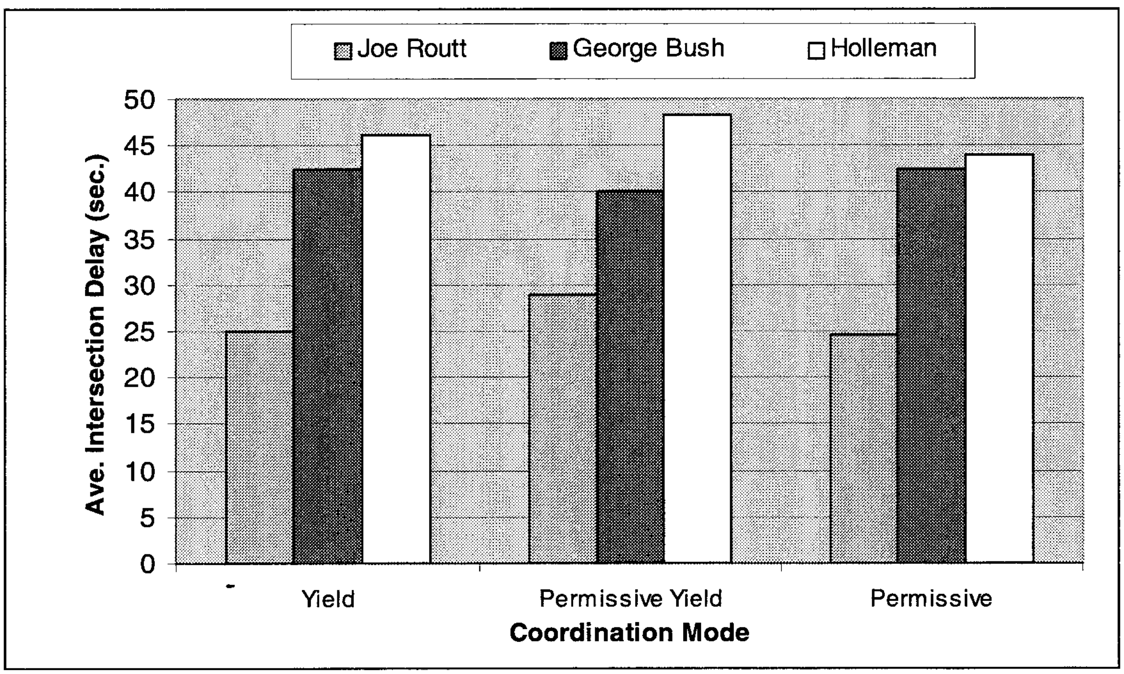


**Figure 4 – Comparison of Coordination Mode and Average Intersection Delay**

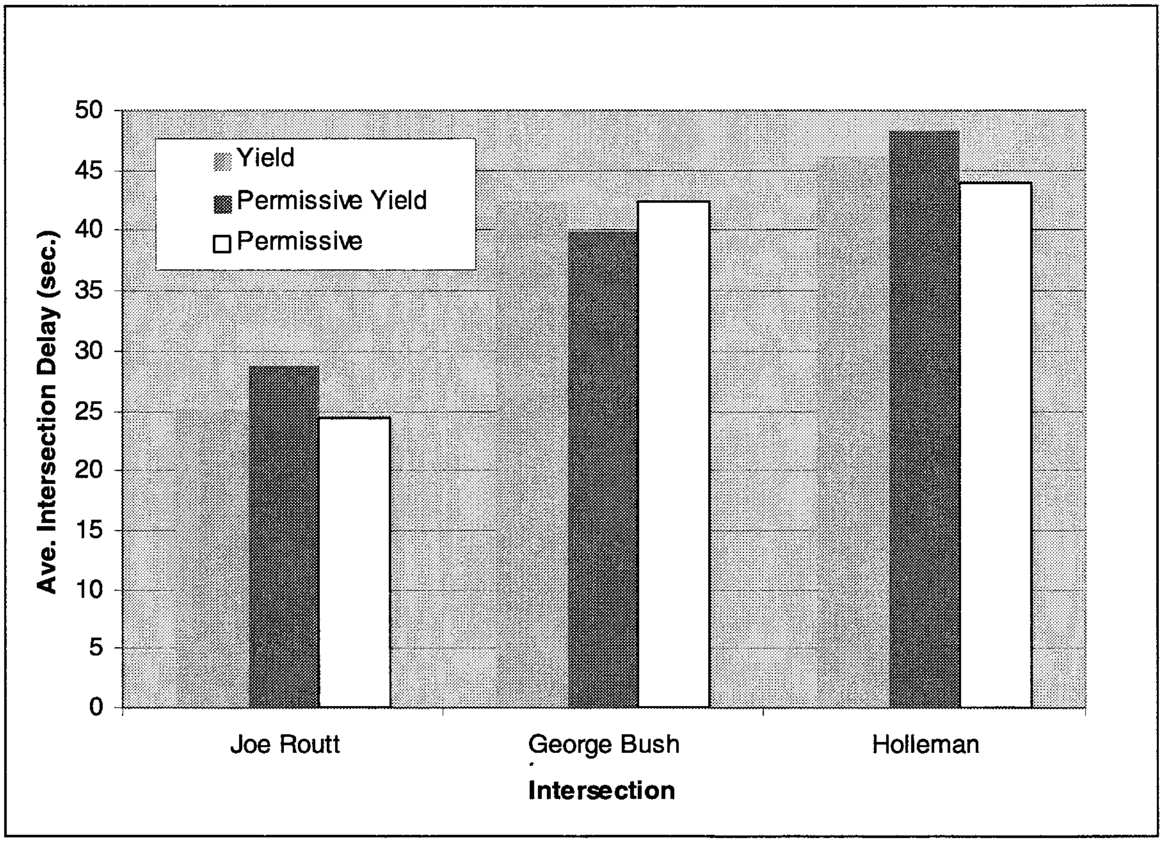


**Figure 5 – Comparison of Intersection and Average Intersection Delay**

*Total System Delay*

The last measure of effectiveness used in this research was the total system delay. This was measured by totaling the intersection delays for each coordination mode. Table 4 contains the total system delays for each coordination mode.

**Table 4 – Total System Delay (seconds)**

| | Permissive Yield | Yield | Permissive |
|---|---|---|---|
| **Run 1** | 41.1 | 36.1 | 36.8 |
| **Run 2** | 36.8 | 40.8 | 37.0 |
| **Run 3** | 39.3 | 38.4 | 38.8 |
| **Average** | 39.1 | 38.4 | 37.5 |

The total system delays are fairly similar for all the runs and all the coordination modes. This can be seen clearly in Figure 6.

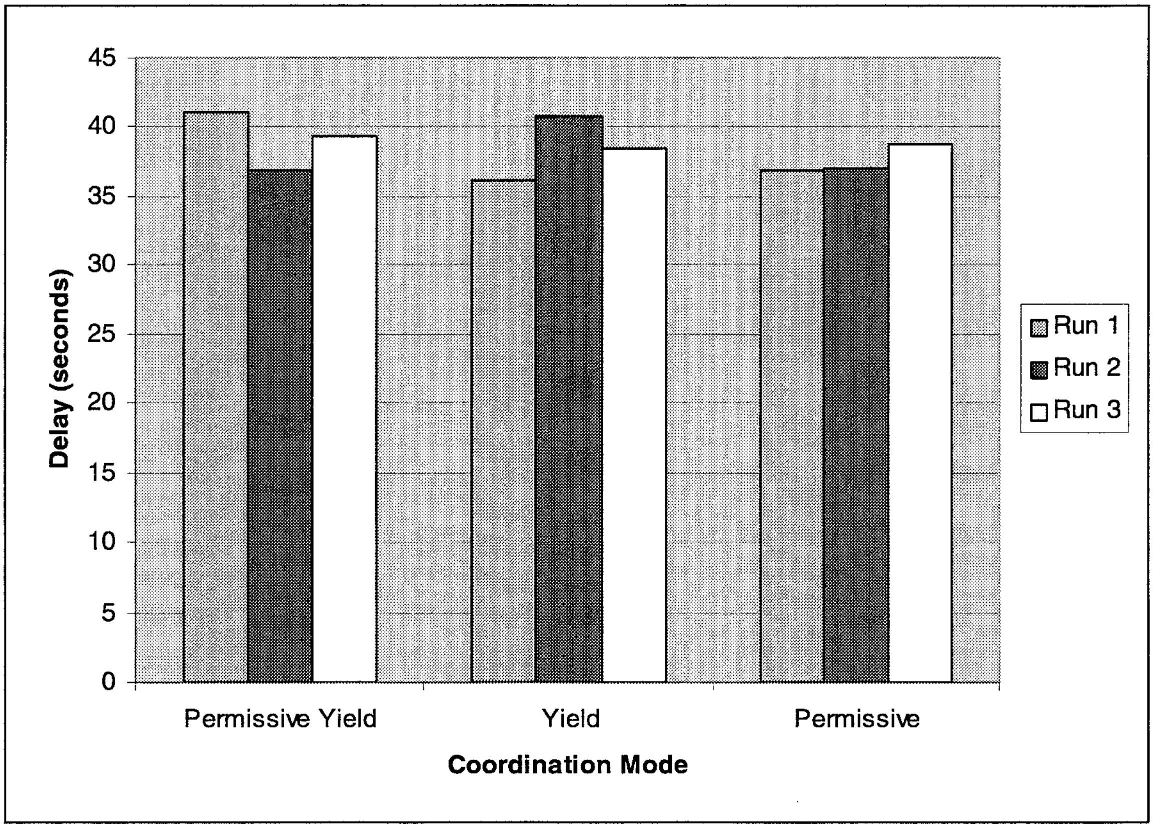


**Figure 6 – Total System Delay for Each Coordination Mode**

Although there appear to be differences in the simulation data, these differences have to be proven statistically. The next section contains a statistical evaluation of which coordination modes were statistically different when comparing the total system delay, average intersection delay and total travel times for each intersection, and which were not statistically different.

# CONCLUSIONS

When looking at the average travel time data, it appears that the Permissive and Yield modes would be the modes to use since the A.M. peak traffic direction is to the North. But the Permissive Yield mode presents a more balanced travel time for both directions. The intersection delay data shows the George Bush intersection tends to operate better under Permissive Yield mode and the other intersections operate better under the Permissive or Yield mode. The results from the total system delay data show that delay is very similar for each coordination mode and that there is not much difference which mode is used.

*Statistical Testing*

The measures of performance for the different coordination modes included the average travel time through the intersections being analyzed, and the average delay the vehicles experienced at each intersection and the total system delay. These results were tested using both a single- factor and a multi-factor analysis of variance statistical model[9] with a 95% significance level in order to determine if there is a true differences in the data for each coordination mode, as opposed to having random variations in the data. The statistical analysis can be found in Appendix C.

When looking at the single-factor ANOVA, it proves that statistically there is no difference in the coordination modes when looking at the average intersection delay or the total system delay. Since all of the computed F-values are less than the F-criticals, we can conclude there is no statistical difference between the coordination modes.

When looking at the multi-factor ANOVA, there is no statistical difference in either coordination modes or the interaction between intersections and coordination modes. Looking at the different travel times, there is no statistical difference between coordination modes, but there is a difference between the interaction of the travel direction and the coordination mode.

Taking all of this data analysis into consideration, it was found that for this particular traffic situation, that there is not any significant difference in delay or travel time between the different coordination modes that were analyzed.

*Recommendations*

The main recommendation for anyone continuing this research is to create intersections in CORSIM at the outer edges of the intersections being analyzed. This is necessary in order to more realistically simulate the traffic that approaches the intersections being analyzed. Once traffic leaves an upstream intersection, it tends to stay in a platoon when it reaches the next traffic signal. In the simulation that was run for this research, the upstream traffic was randomly created and did not represent actual traffic conditions of these platooning vehicles.

Another recommendation is to increase or decrease the amount of traffic in the simulation to see what effect this has on the intersection delays or travel time. The signal time plans and offsets could also be changed to create different scenarios. Since the George Bush intersection tended to operate better while in the Permissive Yield mode and the other intersections operated better in the Permissive and Yield modes, it may be best to try this order of coordination modes instead of having all intersections running on the same coordination mode.

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## APPENDIX A – Traffic Volume Data

| Joe Routt Blvd. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Southbound | | | | | | Northbound | | | | | |
| | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | |
| | R | T | L | R | T | L | R | T | L | R | T | L |
| | 8-Nov-99 | | | | | | 8-Nov-99 | | | | | |
| 7:00-7:15 | 19 | 130 | 19 | 11.3% | 77.4% | 11.3% | 21 | 240 | 46 | 6.8% | 78.2% | 15.0% |
| 7:15-7:30 | 15 | 136 | 20 | 8.8% | 79.5% | 11.7% | 23 | 254 | 55 | 6.9% | 76.5% | 16.6% |
| 7:30-7:45 | 18 | 144 | 22 | 9.8% | 78.3% | 12.0% | 33 | 245 | 65 | 9.6% | 71.4% | 19.0% |
| 7:45-8:00 | 25 | 155 | 25 | 12.2% | 75.6% | 12.2% | 29 | 248 | 77 | 8.2% | 70.1% | 21.8% |
| | 9-Nov-99 | | | | | | 9-Nov-99 | | | | | |
| 7:00-7:15 | 17 | 130 | 24 | 9.9% | 76.0% | 14.0% | 26 | 239 | 49 | 8.3% | 76.1% | 15.6% |
| 7:15-7:30 | 20 | 145 | 22 | 10.7% | 77.5% | 11.8% | 30 | 243 | 70 | 8.7% | 70.8% | 20.4% |
| 7:30-7:45 | 23 | 151 | 30 | 11.3% | 74.0% | 14.7% | 33 | 262 | 58 | 9.3% | 74.2% | 16.4% |
| 7:45-8:00 | 20 | 141 | 24 | 10.8% | 76.2% | 13.0% | 38 | 265 | 71 | 10.2% | 70.9% | 19.0% |
| | 10-Nov-99 | | | | | | 10-Nov-99 | | | | | |
| 7:00-7:15 | 20 | 122 | 20 | 12.3% | 75.3% | 12.3% | 19 | 237 | 61 | 6.0% | 74.8% | 19.2% |
| 7:15-7:30 | 24 | 148 | 25 | 12.2% | 75.1% | 12.7% | 26 | 229 | 45 | 8.7% | 76.3% | 15.0% |
| 7:30-7:45 | 18 | 146 | 23 | 9.6% | 78.1% | 12.3% | 36 | 255 | 68 | 10.0% | 71.0% | 18.9% |
| 7:45-8:00 | 22 | 144 | 33 | 11.1% | 72.4% | 16.6% | 35 | 270 | 66 | 9.4% | 72.8% | 17.8% |
| **AVERAGES** | **80** | **564** | **96** | **10.8%** | **76.3%** | **12.9%** | **116** | **996** | **244** | **8.5%** | **73.6%** | **17.9%** |

| Time | Eastbound | | | | | | Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | |
| | R | T | L | R | T | L | R | T | L | R | T | L |
| | 8-Nov-99 | | | | | | 8-Nov-99 | | | | | |
| 7:00-7:15 | 37 | 30 | 25 | 40.2% | 32.6% | 27.2% | 11 | 16 | 10 | 29.7% | 43.2% | 27.0% |
| 7:15-7:30 | 34 | 15 | 33 | 41.5% | 18.3% | 40.2% | 12 | 24 | 7 | 27.9% | 55.8% | 16.3% |
| 7:30-7:45 | 53 | 24 | 36 | 46.9% | 21.2% | 31.9% | 10 | 24 | 16 | 20.0% | 48.0% | 32.0% |
| 7:45-8:00 | 62 | 25 | 41 | 48.4% | 19.5% | 32.0% | 14 | 25 | 14 | 26.4% | 47.2% | 26.4% |
| | 9-Nov-99 | | | | | | 9-Nov-99 | | | | | |
| 7:00-7:15 | 46 | 17 | 35 | 46.9% | 17.3% | 35.7% | 8 | 15 | 9 | 25.0% | 46.9% | 28.1% |
| 7:15-7:30 | 50 | 20 | 32 | 49.0% | 19.6% | 31.4% | 9 | 22 | 16 | 19.1% | 46.8% | 34.0% |
| 7:30-7:45 | 53 | 19 | 36 | 49.1% | 17.6% | 33.3% | 14 | 26 | 13 | 26.4% | 49.1% | 24.5% |
| 7:45-8:00 | 57 | 30 | 36 | 46.3% | 24.4% | 29.3% | 11 | 27 | 13 | 21.6% | 52.9% | 25.5% |
| | 10-Nov-99 | | | | | | 10-Nov-99 | | | | | |
| 7:00-7:15 | 35 | 25 | 31 | 38.5% | 27.5% | 34.1% | 9 | 15 | 7 | 29.0% | 48.4% | 22.6% |
| 7:15-7:30 | 45 | 40 | 41 | 35.7% | 31.7% | 32.5% | 11 | 23 | 17 | 21.6% | 45.1% | 33.3% |
| 7:30-7:45 | 51 | 24 | 38 | 45.1% | 21.2% | 33.6% | 19 | 21 | 19 | 32.2% | 35.6% | 32.2% |
| 7:45-8:00 | 65 | 25 | 36 | 51.6% | 19.8% | 28.6% | 16 | 27 | 16 | 27.1% | 45.8% | 27.1% |
| **AVERAGES** | **196** | **98** | **140** | **44.9%** | **22.6%** | **32.5%** | **48** | **88** | **52** | **25.5%** | **47.1%** | **27.4%** |

| Holleman Ave. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Southbound | | | | | | Northbound | | | | | |
| | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | |
| | R | T | L | R | T | L | R | T | L | R | T | L |
| | 8-Nov-99 | | | | | | 8-Nov-99 | | | | | |
| 7:00-7:15 | 13 | 74 | 46 | 9.8% | 55.6% | 34.6% | 30 | 227 | 18 | 10.9% | 82.5% | 6.5% |
| 7:15-7:30 | 12 | 90 | 54 | 7.7% | 57.7% | 34.6% | 21 | 248 | 21 | 7.2% | 85.5% | 7.2% |
| 7:30-7:45 | 14 | 85 | 43 | 9.9% | 59.9% | 30.3% | 34 | 248 | 17 | 11.4% | 82.9% | 5.7% |
| 7:45-8:00 | 9 | 76 | 46 | 6.9% | 58.0% | 35.1% | 26 | 247 | 26 | 8.7% | 82.6% | 8.7% |
| | 9-Nov-99 | | | | | | 9-Nov-99 | | | | | |
| 7:00-7:15 | 11 | 73 | 49 | 8.3% | 54.9% | 36.8% | 25 | 236 | 21 | 8.9% | 83.7% | 7.4% |
| 7:15-7:30 | 14 | 102 | 56 | 8.1% | 59.3% | 32.6% | 30 | 240 | 20 | 10.3% | 82.8% | 6.9% |
| 7:30-7:45 | 13 | 79 | 50 | 9.2% | 55.6% | 35.2% | 32 | 261 | 24 | 10.1% | 82.3% | 7.6% |
| 7:45-8:00 | 14 | 102 | 53 | 8.3% | 60.4% | 31.4% | 39 | 268 | 11 | 12.3% | 84.3% | 3.5% |
| | 10-Nov-99 | | | | | | 10-Nov-99 | | | | | |
| 7:00-7:15 | 9 | 67 | 39 | 7.8% | 58.3% | 33.9% | 23 | 227 | 10 | 8.8% | 87.3% | 3.8% |
| 7:15-7:30 | 11 | 88 | 47 | 7.5% | 60.3% | 32.2% | 26 | 207 | 16 | 10.4% | 83.1% | 6.4% |
| 7:30-7:45 | 12 | 96 | 55 | 7.4% | 58.9% | 33.7% | 36 | 257 | 21 | 11.5% | 81.8% | 6.7% |
| 7:45-8:00 | 13 | 101 | 49 | 8.0% | 62.0% | 30.1% | 38 | 261 | 23 | 11.8% | 81.1% | 7.1% |
| **AVERAGES** | **48** | **344** | **196** | **8.2%** | **58.4%** | **33.4%** | **120** | **976** | **76** | **10.2%** | **83.3%** | **6.5%** |

| Time | Eastbound | | | | | | Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | |
| | R | T | L | R | T | L | R | T | L | R | T | L |
| | 8-Nov-99 | | | | | | 8-Nov-99 | | | | | |
| 7:00-7:15 | 33 | 35 | 35 | 32.0% | 34.0% | 34.0% | 35 | 13 | 32 | 43.8% | 16.3% | 40.0% |
| 7:15-7:30 | 31 | 42 | 31 | 29.8% | 40.4% | 29.8% | 37 | 15 | 39 | 40.7% | 16.5% | 42.9% |
| 7:30-7:45 | 29 | 51 | 44 | 23.4% | 41.1% | 35.5% | 43 | 16 | 37 | 44.8% | 16.7% | 38.5% |
| 7:45-8:00 | 39 | 53 | 34 | 31.0% | 42.1% | 27.0% | 31 | 12 | 28 | 43.7% | 16.9% | 39.4% |
| | 9-Nov-99 | | | | | | 9-Nov-99 | | | | | |
| 7:00-7:15 | 28 | 40 | 29 | 28.9% | 41.2% | 29.9% | 39 | 18 | 36 | 41.9% | 19.4% | 38.7% |
| 7:15-7:30 | 38 | 44 | 45 | 29.9% | 34.6% | 35.4% | 38 | 15 | 31 | 45.2% | 17.9% | 36.9% |
| 7:30-7:45 | 29 | 33 | 35 | 29.9% | 34.0% | 36.1% | 48 | 24 | 41 | 42.5% | 21.2% | 36.3% |
| 7:45-8:00 | 32 | 41 | 35 | 29.6% | 38.0% | 32.4% | 42 | 21 | 46 | 38.5% | 19.3% | 42.2% |
| | 10-Nov-99 | | | | | | 10-Nov-99 | | | | | |
| 7:00-7:15 | 31 | 37 | 35 | 30.1% | 35.9% | 34.0% | 43 | 21 | 39 | 41.7% | 20.4% | 37.9% |
| 7:15-7:30 | 33 | 42 | 33 | 30.6% | 38.9% | 30.6% | 37 | 17 | 37 | 40.7% | 18.7% | 40.7% |
| 7:30-7:45 | 37 | 51 | 29 | 31.6% | 43.6% | 24.8% | 45 | 18 | 31 | 47.9% | 19.1% | 33.0% |
| 7:45-8:00 | 36 | 47 | 46 | 27.9% | 36.4% | 35.7% | 41 | 15 | 34 | 45.6% | 16.7% | 37.8% |
| **AVERAGES** | **132** | **172** | **144** | **29.6%** | **38.4%** | **32.1%** | **160** | **68** | **144** | **43.1%** | **18.2%** | **38.7%** |

| George Bush Drive | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | Southbound | | | | | | Northbound | | | | | |
| | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | |
| | R | T | L | R | T | L | R | T | L | R | T | L |
| | 8-Nov-99 | | | | | | 8-Nov-99 | | | | | |
| 7:00-7:15 | 71 | 102 | 11 | 38.6% | 55.4% | 6.0% | 34 | 197 | 83 | 10.8% | 62.7% | 26.4% |
| 7:15-7:30 | 75 | 120 | 13 | 36.1% | 57.7% | 6.3% | 28 | 218 | 75 | 8.7% | 67.9% | 23.4% |
| 7:30-7:45 | 77 | 113 | 13 | 37.9% | 55.7% | 6.4% | 38 | 211 | 71 | 11.9% | 65.9% | 22.2% |
| 7:45-8:00 | 80 | 104 | 14 | 40.4% | 52.5% | 7.1% | 30 | 217 | 81 | 9.1% | 66.2% | 24.7% |
| | 9-Nov-99 | | | | | | 9-Nov-99 | | | | | |
| 7:00-7:15 | 69 | 103 | 10 | 37.9% | 56.6% | 5.5% | 29 | 206 | 76 | 9.3% | 66.2% | 24.4% |
| 7:15-7:30 | 74 | 129 | 20 | 33.2% | 57.8% | 9.0% | 28 | 201 | 75 | 9.2% | 66.1% | 24.7% |
| 7:30-7:45 | 73 | 109 | 11 | 37.8% | 56.5% | 5.7% | 36 | 231 | 79 | 10.4% | 66.8% | 22.8% |
| 7:45-8:00 | 76 | 132 | 10 | 34.9% | 60.6% | 4.6% | 43 | 228 | 63 | 12.9% | 68.3% | 18.9% |
| | 10-Nov-99 | | | | | | 10-Nov-99 | | | | | |
| 7:00-7:15 | 78 | 97 | 12 | 41.7% | 51.9% | 6.4% | 27 | 197 | 65 | 9.3% | 68.2% | 22.5% |
| 7:15-7:30 | 66 | 115 | 15 | 33.7% | 58.7% | 7.7% | 32 | 177 | 69 | 11.5% | 63.7% | 24.8% |
| 7:30-7:45 | 83 | 126 | 12 | 37.6% | 57.0% | 5.4% | 41 | 213 | 75 | 12.5% | 64.7% | 22.8% |
| 7:45-8:00 | 79 | 131 | 15 | 35.1% | 58.2% | 6.7% | 42 | 247 | 77 | 11.5% | 67.5% | 21.0% |
| **AVERAGES** | **300** | **460** | **52** | **37.1%** | **56.5%** | **6.4%** | **136** | **848** | **296** | **10.6%** | **66.2%** | **23.2%** |

| Time | Eastbound | | | | | | Westbound | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | | Traffic Volume Turning Movements (# of vehicles) | | | Percentage of each Movement (%) | | |
| | R | T | L | R | T | L | R | T | L | R | T | L |
| | 8-Nov-99 | | | | | | 8-Nov-99 | | | | | |
| 7:00-7:15 | 21 | 89 | 42 | 13.8% | 58.6% | 27.6% | 77 | 122 | 11 | 36.7% | 58.1% | 5.2% |
| 7:15-7:30 | 18 | 92 | 37 | 12.2% | 62.6% | 25.2% | 85 | 119 | 12 | 39.4% | 55.1% | 5.6% |
| 7:30-7:45 | 15 | 101 | 52 | 8.9% | 60.1% | 31.0% | 91 | 116 | 17 | 40.6% | 51.8% | 7.6% |
| 7:45-8:00 | 23 | 103 | 43 | 13.6% | 60.9% | 25.4% | 83 | 124 | 14 | 37.6% | 56.1% | 6.3% |
| | 9-Nov-99 | | | | | | 9-Nov-99 | | | | | |
| 7:00-7:15 | 12 | 90 | 38 | 8.6% | 64.3% | 27.1% | 78 | 118 | 11 | 37.7% | 57.0% | 5.3% |
| 7:15-7:30 | 14 | 94 | 47 | 9.0% | 60.6% | 30.3% | 90 | 115 | 16 | 40.7% | 52.0% | 7.2% |
| 7:30-7:45 | 26 | 88 | 39 | 17.0% | 57.5% | 25.5% | 82 | 132 | 10 | 36.6% | 58.9% | 4.5% |
| 7:45-8:00 | 20 | 91 | 44 | 12.9% | 58.7% | 28.4% | 81 | 121 | 11 | 38.0% | 56.8% | 5.2% |
| | 10-Nov-99 | | | | | | 10-Nov-99 | | | | | |
| 7:00-7:15 | 21 | 91 | 43 | 13.5% | 58.7% | 27.7% | 75 | 121 | 15 | 35.5% | 57.3% | 7.1% |
| 7:15-7:30 | 15 | 92 | 41 | 10.1% | 62.2% | 27.7% | 89 | 117 | 13 | 40.6% | 53.4% | 5.9% |
| 7:30-7:45 | 19 | 101 | 37 | 12.1% | 64.3% | 23.6% | 82 | 126 | 14 | 36.9% | 56.8% | 6.3% |
| 7:45-8:00 | 25 | 97 | 54 | 14.2% | 55.1% | 30.7% | 96 | 121 | 11 | 42.1% | 53.1% | 4.8% |
| **AVERAGES** | **76** | **376** | **172** | **12.2%** | **60.3%** | **27.5%** | **336** | **484** | **52** | **38.5%** | **55.5%** | **5.9%** |

# APPENDIX B – Data from Simulation Runs

## Coordination Mode ==> PERMISSIVE

| LINK | | RUN 1 | | | RUN 2 | | | RUN 3 | | | AVERAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH |
| FROM | TO | | | | | | | | | | | | |
| **George Bush Intersection** | | | | | | | | | | | | | |
| **30** | **10** | 229 | 125.5 | | 229 | 142.6 | | 224 | 116.9 | | 227 | 128.3 | |
| **50** | **10** | 372 | 214.3 | | 368 | 229.1 | | 353 | 253.1 | | 364 | 232.2 | |
| 20 | 10 | 179 | 145.7 | | 179 | 143.4 | | 185 | 136.3 | | 181 | 141.8 | |
| 40 | 10 | 235 | 175.9 | | 236 | 179.5 | | 237 | 276.9 | | 236 | 210.8 | |
| Total | | 1015 | 661.4 | **39.098** | 1012 | 694.6 | **41.182** | 999 | 783.2 | **47.039** | 1009 | 713.1 | **42.416** |
| **Joe Routt Intersection** | | | | | | | | | | | | | |
| **10** | **30** | 395 | 140.1 | | 391 | 119.8 | | 399 | 150.5 | | 395 | 136.8 | |
| **150** | **30** | 193 | 72.9 | | 193 | 61.9 | | 199 | 63.3 | | 195 | 66.0 | |
| 140 | 30 | 79 | 55.3 | | 79 | 53.4 | | 75 | 46.1 | | 78 | 51.6 | |
| 160 | 30 | 50 | 36.3 | | 51 | 35.9 | | 48 | 42.1 | | 50 | 38.1 | |
| Total | | 717 | 304.6 | **25.490** | 714 | 271.0 | **22.773** | 721 | 302.0 | **25.132** | 717 | 292.5 | **24.468** |
| **Holleman Intersection** | | | | | | | | | | | | | |
| **10** | **50** | 174 | 124.5 | | 174 | 126.4 | | 181 | 140.4 | | 176 | 130.4 | |
| **220** | **50** | 284 | 117.0 | | 284 | 109.8 | | 297 | 121.7 | | 288 | 116.2 | |
| 200 | 50 | 129 | 207.6 | | 128 | 214.2 | | 118 | 136.3 | | 125 | 186.0 | |
| 210 | 50 | 106 | 73.3 | | 106 | 74.6 | | 99 | 76.5 | | 104 | 74.8 | |
| Total | | 693 | 522.4 | **45.229** | 692 | 525.0 | **45.520** | 695 | 474.9 | **40.999** | 693 | 507.4 | **43.913** |
| Grand Total | | 2425 | 1488.4 | **36.826** | 2418 | 1490.6 | **36.988** | 2415 | 1560.1 | **38.760** | 2419 | 1513.0 | **37.524** |

| LINK | | RUN 1 | | | RUN 2 | | | RUN 3 | | | AVERAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TOTAL | AVERAGE | | TOTAL | AVERAGE | | TOTAL | AVERAGE | | TOTAL | AVERAGE | |
| | | TIME | STOPS | SPEED | TIME | STOPS | SPEED | TIME | STOPS | SPEED | TIME | STOPS | SPEED |
| FROM | TO | *SEC / VEH* | *(%)* | *MPH* | *SEC / VEH* | *(%)* | *MPH* | *SEC / VEH* | *(%)* | *MPH* | *SEC / VEH* | *(%)* | *MPH* |
| **Southbound** | | | | | | | | | | | | | |
| 150 | 30 | 30.5 | 63 | 8.9 | 27.1 | 56 | 10.1 | 26.9 | 56 | 10.1 | 28.17 | 58 | 9.7 |
| 30 | 10 | 78.3 | 78 | 20.2 | 82.8 | 88 | 19.1 | 76.8 | 70 | 20.6 | 79.30 | 79 | 20.0 |
| 10 | 50 | 98.8 | 51 | 25.5 | 99.5 | 56 | 25.3 | 102.5 | 56 | 24.6 | 100.27 | 54 | 25.1 |
| 50 | 220 | 6.2 | 0 | 32.7 | 6.3 | 0 | 31.9 | 6.4 | 0 | 31.5 | 6.30 | 0 | 32.0 |
| Total | | **213.8** | | | **215.7** | | | **212.6** | | | **214.03** | | |
| **Northbound** | | | | | | | | | | | | | |
| 220 | 50 | 29.3 | 59 | 7.0 | 27.8 | 57 | 7.4 | 29.1 | 59 | 7.0 | 28.73 | 58 | 7.1 |
| 50 | 10 | 90.5 | 48 | 27.8 | 93.3 | 51 | 27.0 | 99.0 | 59 | 25.4 | 94.27 | 53 | 26.7 |
| 10 | 30 | 66.6 | 44 | 23.7 | 63.7 | 40 | 24.7 | 68.0 | 55 | 23.2 | 66.10 | 46 | 23.9 |
| 30 | 150 | 9.1 | 0 | 30 | 8.9 | 0 | 30.4 | 9.2 | 0 | 29.4 | 9.07 | 0 | 29.9 |
| Total | | **195.5** | | | **193.7** | | | **205.3** | | | **198.17** | | |

## Coordination Mode ==> PERMISSIVE YIELD

| LINK | | RUN 1 | | | RUN 2 | | | RUN 3 | | | AVERAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FROM | TO | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH |
| **George Bush Intersection** | | | | | | | | | | | | | |
| **30** | **10** | 242 | 152.9 | | 243 | 138.1 | | 243 | 133.5 | | 243 | 141.5 | |
| **50** | **10** | 357 | 254.4 | | 347 | 240.9 | | 348 | 217.6 | | 351 | 237.6 | |
| 20 | 10 | 181 | 133.0 | | 182 | 128.1 | | 181 | 136.5 | | 181 | 132.5 | |
| 40 | 10 | 237 | 208.5 | | 234 | 96.1 | | 236 | 180.9 | | 236 | 161.8 | |
| **Total** | | 1017 | 748.8 | **44.177** | 1006 | 603.2 | **35.976** | 1008 | 668.5 | **39.792** | 1010 | 673.5 | **39.997** |
| **Joe Routt Intersection** | | | | | | | | | | | | | |
| **10** | **30** | 390 | 180.6 | | 398 | 179.9 | | 395 | 185.1 | | 394 | 181.9 | |
| **150** | **30** | 194 | 67.9 | | 196 | 70.0 | | 196 | 68.7 | | 195 | 68.9 | |
| 140 | 30 | 78 | 53.0 | | 74 | 53.2 | | 74 | 49.8 | | 75 | 52.0 | |
| 160 | 30 | 51 | 34.9 | | 52 | 45.2 | | 52 | 44.3 | | 52 | 41.5 | |
| **Total** | | 713 | 336.4 | **28.309** | 720 | 348.3 | **29.025** | 717 | 347.9 | **29.113** | 717 | 344.2 | **28.817** |
| **Holleman Intersection** | | | | | | | | | | | | | |
| **10** | **50** | 181 | 85.1 | | 181 | 94.5 | | 181 | 98.7 | | 181 | 92.8 | |
| **220** | **50** | 288 | 109.1 | | 291 | 102.1 | | 291 | 105.4 | | 290 | 105.5 | |
| 200 | 50 | 120 | 303.6 | | 117 | 257.6 | | 119 | 270.9 | | 119 | 277.4 | |
| 210 | 50 | 106 | 79.3 | | 107 | 78.0 | | 109 | 96.8 | | 107 | 84.7 | |
| **Total** | | 695 | 577.1 | **49.822** | 696 | 532.2 | **45.879** | 700 | 571.8 | **49.011** | 697 | 560.4 | **48.238** |
| **Grand Total** | | 2425 | 1662.3 | **41.129** | 2422 | 1483.7 | **36.756** | 2425 | 1588.2 | **39.296** | 2424 | 1578.067 | **39.061** |

| LINK | | RUN 1 | | | RUN 2 | | | RUN 3 | | | AVERAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TOTAL | AVERAGE | | TOTAL | AVERAGE | | TOTAL | AVERAGE | | TOTAL | AVERAGE | |
| FROM | TO | TIME *SEC / VEH* | STOPS *(%)* | SPEED *MPH* | TIME *SEC / VEH* | STOPS *(%)* | SPEED *MPH* | TIME *SEC / VEH* | STOPS *(%)* | SPEED *MPH* | TIME *SEC / VEH* | STOPS *(%)* | SPEED *MPH* |
| **Southbound** | | | | | | | | | | | | | |
| 150 | 30 | 28.8 | 60 | 9.5 | 29.3 | 60 | 9.3 | 28.9 | 60 | 9.4 | 29.00 | 60 | 9.4 |
| 30 | 10 | 83.4 | 90 | 19.0 | 79.6 | 82 | 19.9 | 78.4 | 80 | 20.2 | 80.47 | 84 | 19.7 |
| 10 | 50 | 84.1 | 46 | 29.9 | 87.3 | 47 | 28.8 | 88.6 | 47 | 28.4 | 86.67 | 47 | 29.0 |
| 50 | 220 | 6.1 | 0 | 33 | 6.3 | 0 | 32 | 6.2 | 0 | 32.7 | 6.20 | 0 | 32.6 |
| **Total** | | **202.4** | | | **202.5** | | | **202.1** | | | **202.33** | | |
| **Northbound** | | | | | | | | | | | | | |
| 220 | 50 | 27.3 | 55 | 7.5 | 25.6 | 53 | 8.0 | 26.3 | 55 | 7.8 | 26.40 | 54 | 7.8 |
| 50 | 10 | 98.3 | 51 | 25.5 | 97.2 | 55 | 25.8 | 93.1 | 50 | 26.9 | 96.20 | 52 | 26.1 |
| 10 | 30 | 73.0 | 53 | 21.6 | 72.5 | 58 | 21.8 | 73.4 | 59 | 21.5 | 72.97 | 57 | 21.6 |
| 30 | 150 | 9.3 | 0 | 29.1 | 9.2 | 0 | 29.4 | 9.2 | 0 | 29.6 | 9.23 | 0 | 29.4 |
| **Total** | | **207.9** | | | **204.5** | | | **202.0** | | | **204.80** | | |

## Coordination Mode ==> YIELD

| LINK | | RUN 1 | | | RUN 2 | | | RUN 3 | | | AVERAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FROM | TO | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH | # of VEHICLE TRIPS | DELAY TIME *VEH MIN* | AVERAGE DELAY PER VEH |
| George Bush Intersection | | | | | | | | | | | | | |
| **30** | **10** | 238 | 134.1 | | 239 | 146.3 | | 224 | 126.3 | | 234 | 135.6 | |
| **50** | **10** | 372 | 189.8 | | 365 | 257.7 | | 366 | 243.5 | | 368 | 230.3 | |
| 20 | 10 | 179 | 146.6 | | 180 | 148.3 | | 177 | 194.0 | | 179 | 163.0 | |
| 40 | 10 | 235 | 161.6 | | 236 | 161.8 | | 251 | 257.3 | | 241 | 193.6 | |
| Total | | 1024 | 632.1 | **37.037** | 1020 | 714.1 | **42.006** | 1018 | 821.1 | **48.395** | 1021 | 722.4 | **42.468** |
| Joe Routt Intersection | | | | | | | | | | | | | |
| **10** | **30** | 395 | 127.6 | | 390 | 161.2 | | 387 | 127.1 | | 391 | 138.6 | |
| **150** | **30** | 193 | 73.8 | | 193 | 59.8 | | 193 | 69.1 | | 193 | 67.6 | |
| 140 | 30 | 79 | 57.6 | | 79 | 53.0 | | 76 | 56.6 | | 78 | 55.7 | |
| 160 | 30 | 50 | 34.7 | | 50 | 37.1 | | 50 | 34.3 | | 50 | 35.4 | |
| Total | | 717 | 293.7 | **24.577** | 712 | 311.1 | **26.216** | 706 | 287.1 | **24.399** | 712 | 297.3 | **25.065** |
| Holleman Intersection | | | | | | | | | | | | | |
| **10** | **50** | 178 | 132.4 | | 178 | 98.3 | | 174 | 116.1 | | 177 | 115.6 | |
| **220** | **50** | 284 | 114.7 | | 284 | 108.6 | | 283 | 113.0 | | 284 | 112.1 | |
| 200 | 50 | 128 | 216.3 | | 126 | 324.8 | | 126 | 120.7 | | 127 | 220.6 | |
| 210 | 50 | 106 | 75.4 | | 106 | 92.8 | | 103 | 84.5 | | 105 | 84.2 | |
| Total | | 696 | 538.8 | **46.448** | 694 | 624.5 | **53.991** | 686 | 434.3 | **37.985** | 692 | 532.5 | **46.173** |
| Grand Total | | 2437 | 1464.6 | **36.059** | 2426 | 1649.7 | **40.800** | 2410 | 1542.5 | **38.402** | 2424.3333 | 1552.267 | **38.417** |

| LINK | | RUN 1 | | | RUN 2 | | | RUN 3 | | | AVERAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TOTAL TIME | AVERAGE | | TOTAL TIME | AVERAGE | | TOTAL TIME | AVERAGE | | TOTAL TIME | AVERAGE | |
| FROM | TO | *SEC / VEH* | STOPS *(%)* | SPEED *MPH* | *SEC / VEH* | STOPS *(%)* | SPEED *MPH* | *SEC / VEH* | STOPS *(%)* | SPEED *MPH* | *SEC / VEH* | STOPS *(%)* | SPEED *MPH* |
| Southbound | | | | | | | | | | | | | |
| 150 | 30 | 30.8 | 66 | 8.9 | 26.4 | 57 | 10.3 | 29.3 | 58 | 9.3 | 28.83 | 60 | 9.5 |
| 30 | 10 | 79.3 | 79 | 19.9 | 82.2 | 77 | 19.2 | 79.3 | 83 | 19.9 | 80.27 | 80 | 19.7 |
| 10 | 50 | 100.6 | 52 | 25.0 | 89.1 | 51 | 28.3 | 95.9 | 56 | 26.2 | 95.20 | 53 | 26.5 |
| 50 | 220 | 6.3 | 0 | 32 | 6.1 | 0 | 32.7 | 6.3 | 0 | 32 | 6.23 | 0 | 32.2 |
| Total | | **217.0** | | | **203.8** | | | **210.8** | | | **210.53** | | |
| Northbound | | | | | | | | | | | | | |
| 220 | 50 | 28.8 | 59 | 7.1 | 27.5 | 56 | 7.4 | 28.5 | 58 | 7.2 | 28.27 | 58 | 7.2 |
| 50 | 10 | 86.6 | 47 | 29.1 | 98.3 | 58 | 25.6 | 95.9 | 52 | 26.3 | 93.60 | 52 | 27.0 |
| 10 | 30 | 64.7 | 43 | 24.4 | 70.0 | 52 | 22.5 | 65.0 | 37 | 24.2 | 66.57 | 44 | 23.7 |
| 30 | 150 | 9.1 | 0 | 29.9 | 9.2 | 0 | 29.4 | 9.2 | 0 | 29.5 | 9.17 | 0 | 29.6 |
| Total | | **189.2** | | | **205.0** | | | **198.6** | | | **197.60** | | |

## APPENDIX C – Statistical Analysis

### Anova: Single Factor

Analysis of Total System Delay

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Permissive Yield | 3 | 117.2 | 39.0667 | 4.663333 |
| Yield | 3 | 115.3 | 38.4333 | 5.523333 |
| Permissive | 3 | 112.6 | 37.5333 | 1.213333 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 3.5622 | 2 | 1.78111 | 0.468713 | 0.646932 | 5.143249 |
| Within Groups | 22.8 | 6 | 3.8 | | | |
| | | | | | | |
| Total | 26.362 | 8 | | | | |

### Anova: Single Factor

Analysis of Intersection Delays

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Yield | 3 | 113.6847 | 37.89489 | 126.8263 |
| Permissive Yield | 3 | 117.0347 | 39.01156 | 95.00612 |
| Permissive | 3 | 110.8207 | 36.94022 | 117.2683 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 6.448755 | 2 | 3.224377 | 0.028526 | 0.972008 | 5.143249 |
| Within Groups | 678.2015 | 6 | 113.0336 | | | |
| | | | | | | |
| Total | 684.6502 | 8 | | | | |

## Anova: Two-Factor With Replication

Analysis of Intersection Delays and Coordination Modes

| SUMMARY | J.R. | G.B. | Holl. | Total |
|---|---|---|---|---|
| *Yield* | | | | |
| Count | 3 | 3 | 3 | 9 |
| Sum | 75.19 | 127.44 | 138.42 | 341.05 |
| Average | 25.06 | 42.48 | 46.14 | 37.89 |
| Variance | 1.00 | 32.42 | 64.12 | 119.50 |
| *Perm Yield* | | | | |
| Count | 3 | 3 | 3 | 9 |
| Sum | 86.45 | 119.95 | 144.71 | 351.10 |
| Average | 28.82 | 39.98 | 48.24 | 39.01 |
| Variance | 0.19 | 16.84 | 4.34 | 76.60 |
| *Permissive* | | | | |
| Count | 3 | 3 | 3 | 9 |
| Sum | 73.40 | 127.32 | 131.75 | 332.46 |
| Average | 24.47 | 42.44 | 43.92 | 36.94 |
| Variance | 2.18 | 16.95 | 6.40 | 94.33 |
| *Total* | | | | |
| Count | 9 | 9 | 9 | |
| Sum | 235.03 | 374.70 | 414.88 | |
| Average | 26.11 | 41.63 | 46.10 | |
| Variance | 5.01 | 18.09 | 22.22 | |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Sample | 19.35 | 2.00 | 9.67 | 0.60 | 0.56 | 3.55 |
| Columns | 1980.29 | 2.00 | 990.14 | 61.69 | 0.00 | 3.55 |
| Interaction | 54.32 | 4.00 | 13.58 | 0.85 | 0.51 | 2.93 |
| Within | 288.89 | 18.00 | 16.05 | | | |
| Total | 2342.84 | 26.00 | | | | |

**Anova: Two-Factor With Replication**

Analysis of Travel Times and Coordination Modes

| SUMMARY | NB | SB | Total |
|---|---|---|---|
| *Yield* | | | |
| Count | 3 | 3 | 6 |
| Sum | 592.80 | 631.70 | 1224.50 |
| Average | 197.60 | 210.57 | 204.08 |
| Variance | 63.16 | 42.94 | 92.88 |
| *Perm Yield* | | | |
| Count | 3 | 3 | 6 |
| Sum | 614.40 | 607.00 | 1221.40 |
| Average | 204.80 | 202.33 | 203.57 |
| Variance | 8.77 | 0.04 | 5.35 |
| *Permissive* | | | |
| Count | 3 | 3 | 6 |
| Sum | 594.50 | 642.10 | 1236.60 |
| Average | 198.17 | 214.03 | 206.10 |
| Variance | 38.97 | 2.44 | 92.09 |
| *Total* | | | |
| Count | 9 | 9 | |
| Sum | 1801.70 | 1880.80 | |
| Average | 200.19 | 208.98 | |
| Variance | 39.75 | 38.44 | |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Sample | 21.50 | 2.00 | 10.75 | 0.41 | 0.67 | 3.89 |
| Columns | 347.60 | 1.00 | 347.60 | 13.34 | 0.00 | 4.75 |
| Interaction | 291.35 | 2.00 | 145.68 | 5.59 | 0.02 | 3.89 |
| Within | 312.67 | 12.00 | 26.06 | | | |
| Total | 973.12 | 17.00 | | | | |

# EVALUATION OF THE PERCEPTION OF THE METRO BUS SYSTEM IN DOWNTOWN HOUSTON

MIGUEL VESCOVACCI

## Introduction

At the turn of the century in America, cities are growing at an increasing pace and as a result the needs of the population are increasing and are becoming more demanding. As major cities sprawl, government agencies have become more concerned about the consequences of this growth. The effectiveness of land use and development, and the transportation needs have become primary subjects of debate.

Downtown areas are being transformed dramatically as a result of this sprawl. Retail stores, as well as businesses and residents are moving out of the downtown areas and into suburbs. City planning boards and government agencies are attempting to reverse this trend and move the population back into the city centers and bring life back into the downtown districts.

Because of this, downtown areas must require an effective mobility scheme for the people and transit systems inside the city centers. There are many different transit modes used in downtown areas. The main modes used are:

- Heavy rail transit
- Light rail transit
- Buses and trolleys (includes paratransit)

All downtown areas in the major cities of America employ one or more of these modes. For example, New York City, the largest and most populated city in the U.S., has the largest network of heavy rail transit as well as the largest taxi fleet in the U.S. (although taxis don't classify as transit, they provide transportation). Boston, on the other hand, employs all of these modes, from heavy rail to light rail, and from buses to jitneys. Meanwhile Houston, which is the fourth largest city in the U.S. only employs the bus and trolley systems. Although the bus system in Houston provides a significant area of coverage, having only one alternative greatly affects the city's planning.

Buses are a good transit alternative because they are not tied to a fixed route or alignment. Buses have good maneuverability in downtown corridors and they have the ability of providing the service wherever the demand is acceptable. Also buses can be provided with exclusive lanes in downtown corridors in order to avoid the traffic congestion in the streets, thus providing a more reliable schedule and a better service. The mobility of these buses in large cities can provide a large area of coverage, as in the case of Houston, however, several factors also work against this system. Since buses are powered by gasoline or diesel fuel, they expel fumes into the atmosphere, accounting for pollution problems. In many cities the buses share the right-of-way with other vehicles, and sometimes this leads to schedule problems, even when the buses have exclusive lanes. Driving the buses also requires well trained personnel: responsible drivers capable of providing a safe ride and a safe atmosphere while maneuvering around the city, not only inside but outside the vehicle.

For the purpose of this research, our case study will be Houston and METRO's bus system in the downtown area.

## Background

Houston's bus system is operated by the Metropolitan Transit Authority of Harris County (METRO). METRO's headquarters are located at 1100 Louisiana at Louisiana Street, in downtown Houston. METRO is the entity responsible for operating the transit systems of the Houston metropolitan area. It is also responsible for transit planning in Houston. When METRO began operations in 1979, the result of a referendum held in the city, the transit system in Houston was very disorganized and was in a very poor status. METRO set about improving the transit system in order to meet the population's needs. METRO adopted the bus system to provide the citizens with a greater area of coverage and through the years the system has expanded.

As of 1998, the bus fleet that could operate and provide maximum service had increased almost to 1,500 vehicles. METRO has one of the largest bus networks in the U.S., providing a service area of 1,279 square miles in an urban area of 1,178 square miles. The fare revenues earned in 1998 totaled $46,510,131. Throughout the years METRO's bus system has become the first and only alternative for transit, along with METRO's downtown trolley system. As of today the major form of transit in downtown Houston is still the bus.

For the past 10 years, though, the bus system has been criticized by the downtown business community. METRO has made efforts to improve the bus system's quality of service; one of these efforts is the Negotiated Operating Plan (NOP) of 1993. Bus system conditions were deteriorating and METRO needed to make service improvements. The main objectives of the NOP were the following:

- maximize convenience, comfort and security associated with transit travel;
- provide a mix of local, express and park-and-ride service on streets with major bus volumes and to reduce the bus volume on Main Street where possible;
- minimize bus volumes (especially during midday) to the extent possible while providing the intended service to downtown;
- provide facilities for transfers which would offer patrons comfortable waiting areas, supportive amenities and sanitary facilities, while avoiding sidewalk congestion;
- strengthen the visual and pedestrian linkages connecting major downtown activity areas and to improve the overall quality of downtown sidewalks; and
- revitalize the retail environment on Main Street and to support and encourage planned development in the various sectors of downtown including the convention center area, the market square area, the Theater District, office areas, government facilities, and the St. Joseph Hospital complex.

To accomplish these objectives, METRO proposed several action plans. Although several changes were made to the system, there were many other measures that had to be also taken into consideration in order to reach some of the objectives. Some of these measures were never implemented and as a consequence, the conditions that prevail today are much the same as the prevailing conditions in 1993. Since then, many of the corridors have witnessed bus volume increases. Today, downtown construction has hampered the bus operations.

Another challenge facing METRO is public opinion; since the system is perceived to be used by poor people, although the ridership many times is otherwise. Even though the transit riders have good things to say about the bus system, the business community has some complaints. Although these sources are not experts in transit, they are influential and can affect the perception of METRO's image. Having a good image is beneficial for METRO and the downtown transit system, because it can lure new riders. Failure to completely implement the 1993 NOP has made METRO's primary objectives more difficult to accomplish. In spite of all this, METRO's staff has been hard at work to provide a more efficient transit scheme to improve its image and to relieve the traffic conditions in downtown.

## The Downtown District

The Downtown District comprises 35 corridors that are bordered in the north by the Buffalo Bayou, in the south by Interstate 45, in the east by US 59 and in the west by Interstate 45. It is located in the heart of Houston and employs a total workforce of 140,000 people, of which 7,000 are employed by Downtown retailers (source is Downtown District Community, April 1997). The demographics show that 58% of the workforce is male, while 42 % is female. 69% are white collar workers, while 18% are executives, administrators, or management officers. The office market has 24 Class A buildings from which 90.7% of the 25.2 million square footage available are currently leased, and 25 Class B buildings from which 73.65% of the total 9.3 million square footage are currently leased.

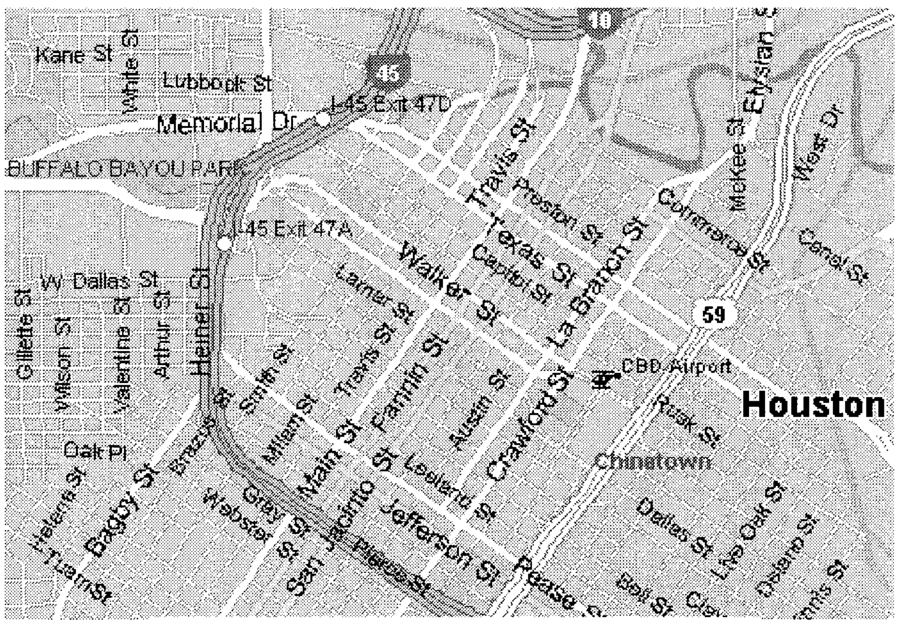



**Figure 1**

There are approximately 200 restaurants and close to 1.2 million square feet of retail shops. Retail sales in Downtown reach an approximate $509 million annually. Table 1 presents the numbers for leased areas in Downtown as of April 1997.

**Table 1 - Retail Facts of Downtown**

| | Leased (square feet) | Vacant (square feet) |
|---|---|---|
| Main Street | 441,2000 | 30,000 |
| Other streets | 230,000 | 95,000 |
| The Park Shops | 181,000 | 10,400 |
| Tunnel System | 250,000 | 50,000 |
| Total Leased | 1,102,200 | |
| Total Vacant | | 185,400 |
| Total square feet | 1,287,600 | |

Commuting to Downtown may seem hard because of the traffic, but 90% of the METRO buses run into Downtown. These include the Park & Ride shuttles, local and express routes. The Downtown District is also becoming more residential, as residential lofts are being built in the District. Approximately 22,000 students study in the different Downtown universities and visitors every year total 55 million.

For the past years, METRO has been recommending the construction of a light rail transit system that will help revitalize the downtown area and the corridor where the system will be built. This will bring changes in the downtown bus routes, an area which is already saturated with METRO buses. The following downtown corridors are considered the most important, because of the economic activity generated and because they provide the key access in and out of the downtown area.

*Smith*

Smith Street (southbound) is one of the seven main north-south corridors of activity in downtown Houston. It is adjacent to Bagby Street and Louisiana Street. The main buildings and complexes that are located on Smith Street are the Wortham Center, Bayou Place, Lyric Centre, Bob Casey Federal Court House, Bank of America Center, One Shell Plaza, Wells Fargo Plaza, One Allen Center, Hyatt Regency Hotel, YMCA building, and the unfinished Crowne Plaza Cullen Center and Enron Center. A series of tunnels also run underneath parts of Smith Street: N. Louisiana Tunnel, W. Walker Tunnel, and W. Dallas Tunnel. This network of buildings and tunnels make clear that the activity on Smith Street is enormous, therefore mobility around Smith and surrounding streets is essential. This may suggest that the bus system needs to provide frequent service along Smith Street.

The bus operating scheme for Smith Street is projected to increase during AM and PM peak hours with the street improvements in 2004. This presents a contrast of what the business community wants, which is lower bus volumes in the main north-south corridors. The bus stop activity on Smith Street suggests this increase. Ranked fifth in activity with 4,493 boardings and 6,051 alightings, Smith Street accounts for 8.6% of CBD total activity.

*Louisiana*

Like Smith Street, Louisiana (northbound) is another major corridor of downtown Houston. It crosses the Theater District and provides access to major buildings and centers of activity such as the Hogg Palace, Lancaster Hotel, Jones Hall and Plaza, Pennzoil Place, Two Shell Plaza and One Shell Plaza, El Paso Energy, Reliant Energy Plaza, Louisiana Place, Wedge International Tower and the Kellogg, Brown &

Root Tower. The N. Louisiana tunnel and S. Louisiana tunnel networks also connect major centers of economic and commercial activity. This important corridor must be met with adequate transportation facilities because of the great demand that is also generated. This is justified through the amount of bus stop activity generated in the corner of Louisiana and Lamar (1,497 boardings and alightings FY 2000). Louisiana Street is ranked sixth in the CBD's bus stop activity with 3,974 boardings and 5,571 alightings and that represents 7.8% of the total activity in the CBD.

*Milam*

Milam Street (southbound) crosses the Historic District in the northern part of downtown. This corridor is also dense in buildings and plazas, as it provides access to the Magnolia Ballroom, Market Square Park, Houston Chronicle Building, Chase Tower, Bank One Center, Louisiana Place, Americana Building, Houston Police Department Headquarters, and the Exxon Building. Milam is the third most active corridor for the METRO buses in the CBD, with 4,094 boardings and 6,729 alightings, accounting for 8.8% of all activity. In this corridor, the busiest stop is the McKinney Street corner (in front of Bank One Center and across from the tunnel loop) which has a total of 1,553 boardings and alightings. Another busy stop is the Rusk Street corner (in front of the Houston Club Building) which accounts for 927 alightings.

*Travis*

Travis Street runs northbound through downtown between Milam and Main. Like Milam, Travis Street crosses the Historic District and has a network of tunnels that provide access to numerous buildings. Some of these buildings are the Travis Tower, Foley's, HPD Headquarters, Commerce Building, Chase Bank Building, Chase Tower and Chase Center, Rice, Houston Chronicle Building, Market Square Park, Bayou Lofts and the Majestic Metro. Travis Street also provides direct access to I-45 North, so this corridor should have a considerable demand on PM peak hours.

By the activity generated at the bus stops in this corridor, Travis is classified as the second busiest corridor for METRO buses in the CBD. Throughout the corridor there are 7,946 boardings and 3,219 alightings that make up for 9.1% of the total activity in the CBD. The busiest stop in Travis is at the corner of Lamar Street with 2,615 boardings and alightings. Another busy stop for the METRO buses is at the corner of Walker Street with 904 boardings.

*Main*

Main Street is the largest corridor in downtown Houston, as well as the busiest in bus activity. Along with Bagby, Main Street is the only other corridor that has traffic northbound as well as southbound. There are many projects underway along Main Street that are expected to revitalize the economy in this corridor. Although it is the busiest corridor for activity it has poor economic activity. One of the main reasons that this corridor has the most bus activity is that it is used as a transfer point for most of the downtown commuters. Many people argue that the economy in Main Street is dead because there is no life in this corridor to attract businesses and retailing. Main Street provides access to the Historic District and places such as the State National Bank, Rice, Binz Building, Downtown District Operations Center, Palais Royal, One City Centre, etc. The plan to build a light rail transit system along Main Street is just one of the efforts being undertaken by the city to revitalize downtown and bring the people back into the city.

The bus volumes on Main Street are intended to meet the demand for the service. A total of 13,679 boardings are made each day on Main Street as well as 14,512 alightings. This accounts for 23% of the total activity generated in the CBD. The bus stop that generates the most activity in downtown is the

Lamar Street corner of northbound Main; it generates 2,787 boardings and alightings daily. The southbound Lamar Street stop is also very busy, generating a total of 1,545 boardings and alightings daily. This is the sixth busiest bus stop in downtown. The third busiest stop on Main Street and seventh busiest stop in downtown is the southbound route at the corner of Walker Street which generates 1,539 boardings and alightings daily. The eight busiest stop in the CBD is also on Main Street, the northbound route at the corner of Rusk Street with 1,504 boardings and alightings.

Bus volumes on Main Street have declined since 1993, and are projected to continue to drop even though the activity is so high on this street. Despite the drop, bus volumes remain constant almost throughout the CBD on Main Street. Because of this, METRO buses have a different role on Main Street than buses in the other corridors.

*Fannin*

Of the streets east of Main Street, Fannin Street is the busiest corridor in bus volumes and bus stop activity in downtown. Providing access to the downtown area through Interstate 10 East, this corridor reaches the Historic District where the federal and state buildings are located, the Binz building, Downtown District's Operation Center, Ritz Carlton Hotel, One City Centre and First City Tower, etc. It ranks fourth in the top 10 busiest streets of the CBD (8.8% of the CBD's total bus activity) with 5,962 boardings and 4,783 alightings daily.

*San Jacinto*

San Jacinto is the easternmost of the main north-south corridors in the downtown district. Having a northbound flow, it provides an exit from downtown through Interstate 10 East. Next to Fannin, it also provides access to most of the state and federal buildings and it borders the west part of the Historic District. It also provides access to many of the residential complexes in the downtown area. It ranks eighth in the busiest streets of downtown, having 2,996 boardings and 3,917 alightings daily to account for 5.6% of the total CBD's bus stop activity.

*Lamar*

Lamar is arguably the most important east-west corridor in downtown. It is the highest ranking east-west corridor in bus stop activity, seventh of all CBD streets with 5,206 boardings and 3,845 alightings which makes up for 7.4 % of the total CBD's bus stop activity. It provides access to the central part of downtown, the Park Shops, First City Tower, OneCity Centre, El Paso Energy, and Wells Fargo Plaza.

## The Perception

This section examines the main focus of the research: the business community's perception of METRO's bus system.

Bringing more people into downtown means providing more and better transportation facilities. The light rail system running through Main Street is one of these facilities that is expected to help attract retailing back into the downtown area. Having a light rail system running along Main Street should help improve the appearance and cleanliness of Main Street and surrounding areas. As seen in other cities with light rail systems, it could spur the retail economy inside the downtown area, attract more development and ultimately improve the quality of life in downtown, making it an attractive place to live. The alignment of the light rail is intended to reduce the number of bus transfers on Main Street and eliminate the bus system in this corridor. This plan creates a problem, though. Eliminating bus routes along Main Street means moving them onto surrounding streets to minimize the adverse effect on daily commuters. This increases bus volumes on many streets where the bus volumes are already high enough to consider it congestion.

Most of the economic activity in downtown occurs in the 7 main corridors: the Theater District and Historic District are also located within these corridors. As a result of the major activity that occurs on these streets, the bus system must provide adequate service based on the generated demand. However, the METRO bus system faces certain sociological and environmental issues that are not new to them, these issues have been around for more than eight years. Many of these problems are well based, however, some of these problems are related to class prejudice, misconceptions of who are the transit riders, the environmental impact of having buses traveling constantly near historic buildings, and the amount the bus lags behind the convenience and comfort of the private automobile.

A survey conducted in March 1993 by the METRO Market Research Section revealed several issues pertaining the downtown street level retailers and leasing agents. The most relevant findings were:

- Downtown retailers indicated vagrants/street people as the most important problem in the downtown area, followed by declining sales, no business during the evening, and lack of parking.
- Retailers cite METRO as having a positive effect on downtown retail because of the sidewalk activity, METRO riders are buyers, and because METRO brings people downtown.
- Retailers gave METRO a negative rating for contributing to problems of panhandling, crime and vagrants; however, a large portion of retailers report that METRO riders have no effect on these issues.
- The retailers (34 %) that can distinguish METRO riders from other people downtown indicated that METRO riders are likely to patronize their businesses and are much the same as their other customers.
- Retailers and leasing agents see the single transit center plan as a good compromise by both removing some of the transfer riders from downtown and ensuring downtown workers will not have to transfer.

Some of these findings are discussed below and related to the actual conditions.

*Vagrants*

Included in the 1993 findings, this problem still exists and it seems that any effort made by the city to address this problem has not produced the results desired. These people are also related to several other problems in which many parties are affected negatively; among these is METRO and the downtown community.

A survey was prepared by Telesurveys of Texas, Inc. in December 1992 to assess the image of downtown Houston. This survey was conducted with downtown employees, downtown employers and the general public. The purpose of the survey was to identify how these people felt about the downtown district regarding image, safety, work environment, recreational use, cultural and entertainment aspects, employment and residential use. The findings at the time of the survey included:

- The negative aspects of the district included the presence of homeless/vagrants, commute distance and traffic.

- More than half of the interviewed did not feel safe after dark (employers and employees attributed this perception to experience and the general public justified this perception based on crime reports from the media).

Even today many people perceive the downtown district as having the same image problems that it had in 1993, although the severity of some of these problems may have decreased. It is possible to identify a link between the opinion of the retail business representatives, the downtown employees and employers, and the general public. All identified the main problem in downtown to be the homeless/vagrant people.

*Declining Sales*

Declining sales was a problem identified in 1993 by the retailers. This was due in part to the amount of malls outside of the downtown district. This problem is different now because many of the retail centers in downtown have moved out, especially the ones located on Main Street, and as a consequence, the retail activity is minimal in downtown. There are hopes that the Light Rail Transit System will help reverse this trend, as other cities have benefited in this area.

*No Business During the Evening*

This problem resulted from several reasons, some that are related: declining sales, bad atmosphere in the downtown district after regular work hours due to crime, small amount of residences in the district, and very little nighttime activity. There is an effort currently underway by the City of Houston to revitalize the downtown area after work hours by bringing entertainment to the area with projects such as Enron Field, a proposed basketball arena in Downtown, the expansion of the George R. Brown Convention Center, and several hotels that are planning nighttime activity to restore Houston as one of the country's most attractive cities.

*Lack of Parking*

As mentioned earlier, these are the findings from a survey performed in 1993. The situation today has varied a little for some of these findings. For instance, several multi-story parking lots have been built in downtown, so parking space has actually increased. As of April 2000, out of 90,714 parking spaces in Downtown, 80,692 were public parking spaces, from which approximately 62% are located in major parking garages, 25% are surface parking lots, 10% are located in minor parking lots, and 3% are metered parking. By the year 2003 there will be 10,300 additional parking spaces available. There are a few variables that must be taken into account with these figures. The number of retail centers in downtown have decreased, since many businesses have moved out of downtown and into suburban areas or malls. The figures provided by the Downtown District show that there are 46 restaurants and retail stores currently and eight current projects in the Downtown Historic District. In the entire downtown area there is access to approximately 200 restaurants and retail shops. This might lead one to believe that the availability of parking space has increased, but actually the demand for parking space has decreased through the years.

*Overcrowded Sidewalks*

While some problems are being handled, others arise. Findings in the 1993 survey reveal that retailers give METRO a positive rating for promoting sidewalk activity because METRO riders are buyers.

Currently, it seems that too much sidewalk activity can be bad, at least near the bus stops. A large number of people on the sidewalks standing and waiting for the bus to arrive produces sidewalk congestion. This is perceived as bad by the retailers because it constrains the flow of people on the sidewalks and this reduces the amount of potential clients coming into the retail centers. Part of this problem is due to the people standing around at the bus stops that are not necessarily waiting for a ride, many are panhandlers, and this problem has been around for years.

*Crime*

Another problem identified was crime. Crime and vandalism are usually attributed to street people, and as a result the downtown district is perceived as an unsafe place after regular work hours. This is one reason why retailers mentioned the lack of business during the evening and declining sales as some of the main problems in downtown. The image of METRO is also affected due to this problem. In the 1993 survey, retailers gave METRO a bad rating because they believed it contributed to crime and vandalism, although most of them reported that METRO riders didn't participate in this type of activity. Although retailers recognize that METRO riders do not present a safety problem (because METRO riders are also clients) they still think that the presence of METRO buses are the reason panhandlers and vagrants wander around and provide an unsafe environment.

This perception continues. Today, the downtown district is still perceived to be unsafe in many areas, particularly in the southside. The METRO bus system in downtown is still perceived to contribute to the problem of vagrants and street people. This trend is being fought off through increased nighttime activity in this district. Currently, there is no information available on whether the downtown perception has changed, but many feel the perception will change in order to meet the goals for downtown Houston.

*Rider Profile*

Other problems that the retail representatives and leasing agents reported in the 1993 survey involve the image of METRO. For instance, only 34% of the retailers and leasing agents were able to distinguish METRO riders from other people, which means that the majority of the retailers were unable to identify METRO riders from "unwanted elements," which could also be a prejudicial issue because figures show that the METRO riders are daily commuters. This problem is one of the main reasons why it has been so difficult during the past eight years for METRO to establish a Downtown Transit Center for METRO buses.

*Downtown Transit Center*

For years METRO has been proposing the construction of a Transit Center in the downtown area to facilitate transfers and provide transit riders with comfortable and sheltered waiting areas, amenities, and sanitary facilities. The concept could ease the amount of transfer and bus activity on Main Street, however the downtown community has protested consistently wherever METRO has proposed a location. Many people believe that it will be a gathering place for vagrants and street people and therefore no one wants the center near their businesses or neighborhoods.

Several locations have been proposed during the years. In 1992, after proposing that the transit center be located in the southside of downtown, near Pierce Elevated and Main Street, officials from St. Joseph Hospital, Cullen Center, and Exxon raised concerns about the location. At that time, many people opposed the plan, arguing that they do not want the people using Main Street as transfer points to use their neighborhoods as transfer areas, and the debate was rooted with misconceptions about the people who used METRO. Then in 1995, another site was proposed in the block surrounded by Main, Travis, Calhoun, and Pierce Streets. Again the site was severely protested by neighbors from the First Church of

Christ and Beacons Field Apartments, arguing that the vibrations caused by the diesel motors, as well as the exhaust and noise would violate federal laws protecting historic buildings near the transit center. Many people argued that the site should be moved south of Pierce Street, however, this would make bus routes longer and deny patrons the ability to shop between bus stops in the northern part of downtown. The next section presents comparison process between the years 1993 and 2000 to determine how much has the bus volumes changed in the past 7 years, and how can we expect the perception to change in the most affected corridors.

## METRO Bus Volumes

This section presents a comparison of the years 1993 and 2000 to determine how much has the bus volumes changed in the past 7 years, and how can we expect the perception to change in the most affected corridors.

Throughout the years, one of the complaints of the business community has been the amount of buses running through downtown during different times of the day. The Negotiated Operating Plan of 1993 was created to address some of the business community's complaints, as well as provide better service for patrons. Given all the problems that the downtown business community faces, as pointed out in several surveys, it is likely that these same problems affect METRO and their operations in the downtown district. Main Street is the corridor that has the highest amount of buses, given that it has the most activity of boardings and alightings in downtown. During the years, retailers and the business community have complained that Main Street is very hard to access during morning and afternoon peak hours because of the traffic, the congested sidewalks, and the amount of METRO buses running on the streets. Although the following analysis concerns Main Street, it is fair to consider that the Light Rail Transit Line currently being planned for downtown will eliminate all the buses in this corridor. Because of this plan, the purpose of this analysis is to understand how bus volumes have changed and identify how has the downtown business community responded to these reductions since Main Street has been the corridor with the highest amount of bus activity and transfers. Figures 2 through 7 are graphs that detail the amount of buses running on Main Street during morning peak hours for the year 1993 and 2000.

For 1993, the bus volumes were higher than they are currently. Notice the peak in Figure 2 for AM northbound on Main Street. It is located in the street blocks between Walker and McKinney, and McKinney and Lamar. These two blocks represent the majority of bus activity on Main Street and also the turning point of many other buses that either get on or get off Main Street. The corridors of Walker, McKinney, and Lamar carry many vehicles also because downtown Houston was developed in a manner resembling a 'T,' with the base of the 'T' being these corridors that extend towards the George R. Brown Convention Center. This peak is not present in Figure 3 where the figures are compared between 1993 and 2000 for southbound buses. This is quite simple to explain. Buses heading southbound would have to make a left turn to access McKinney Street, which is the only street that has a westbound flow between Walker, McKinney, and Lamar. Making left turns can be challenging for buses, especially in areas of high traffic as the case with Main Street. Additionally there are delays caused by waiting for a protected phase on signalized intersections. Perhaps the most important reason why very few buses on Main Street make left turns is that the exclusive lane for the buses is on the right side of the street.

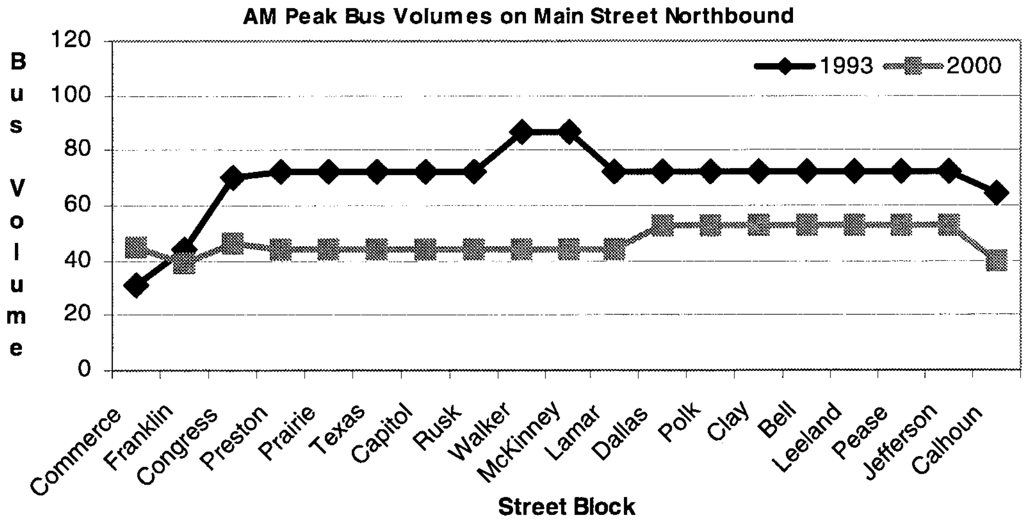



**Figure 2**

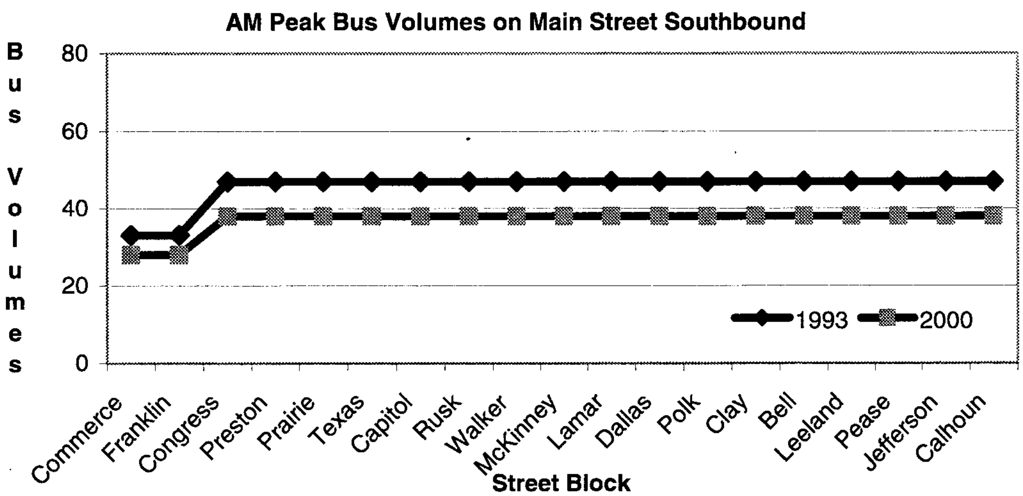



**Figure 3**

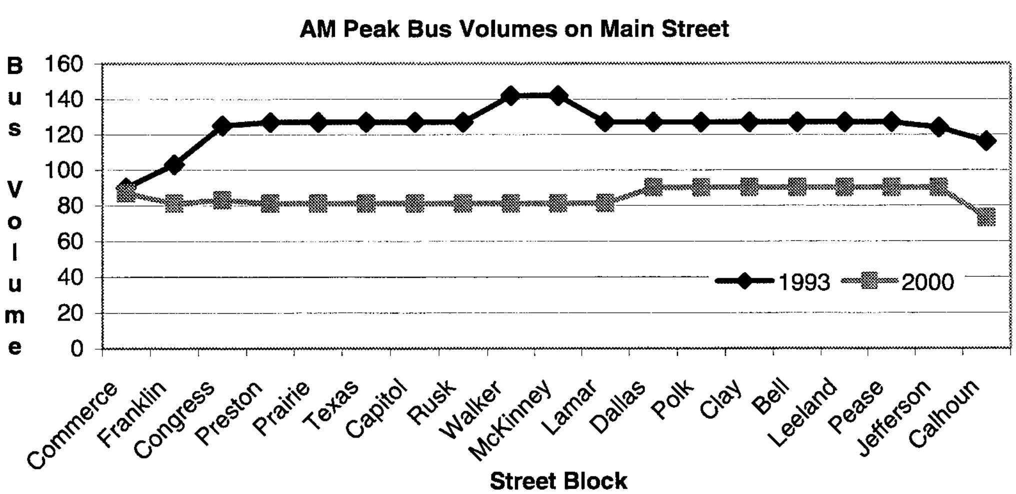



**Figure 4**

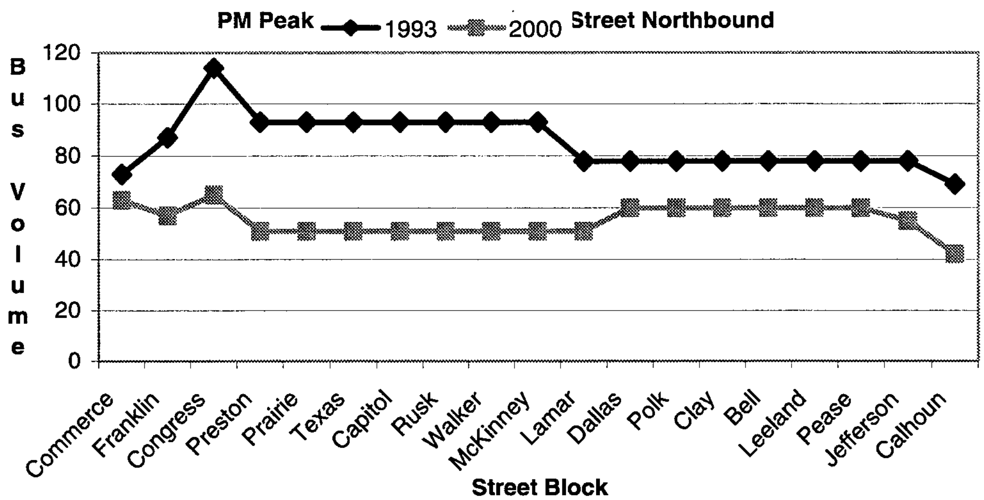



**Figure 5**

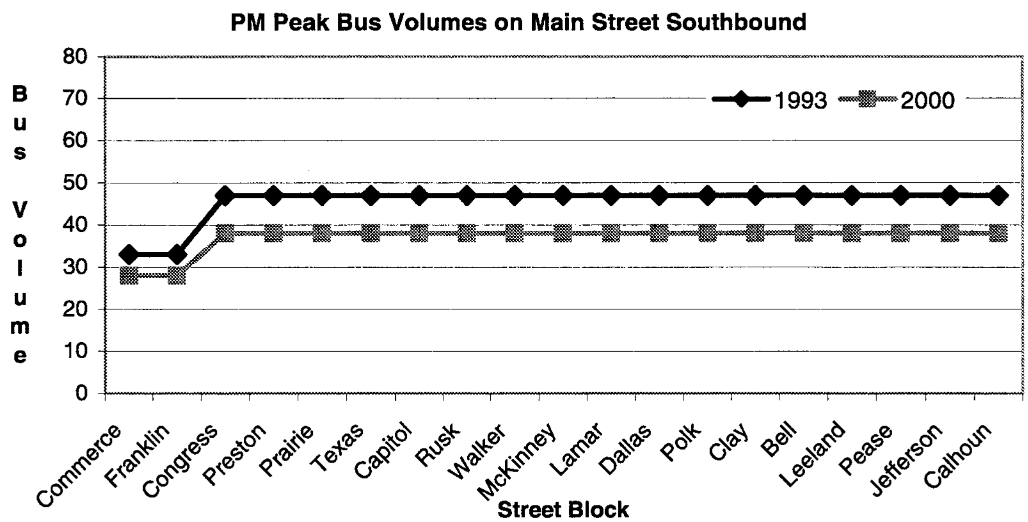



**Figure 6**

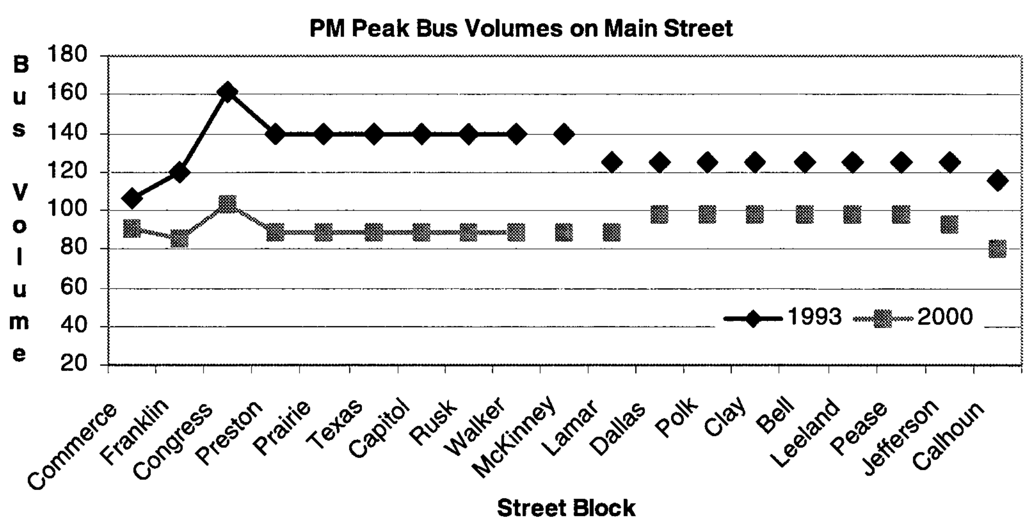



**Figure 7**

Also worth noting is that the amount of buses is lower when going southbound than going northbound. Data shows that the total amount of buses in downtown during the AM Peak periods for 1993 and 2000 show that there has been a reduction in bus volumes. Unfortunately, the Downtown business community still complains about the amount of buses running during peak hours not only through Main Street, but also on the parallel corridors. Figure 4 details how bus volumes have decreased on Main Street for every street block in the downtown area beginning in the northernmost street block of Commerce and Franklin southward to St. Joseph's (a.k.a Calhoun) and Pierce. Between Congress and Rusk streets, the volumes have decreased by more than 40 buses, where the biggest reduction has occurred between Rusk and Lamar with reductions of up to 60 buses, and in the southside of downtown bus volumes have decreased by more than 30. This shows that bus volumes have decreased during the AM peak hours, however, if there is no significant reduction during the PM peak hours then it is very likely that the business community's arguments will stand. For bus volumes on Main Street during PM peak hours, the general trend of declining volumes from the year 1993 to the year 2000 follows, however, the details are somewhat different. For example Figure 5 shows that, like AM peak conditions, PM peak conditions show the highest amount of buses running northbound are located in the northside of downtown along Franklin, Congress and Preston streets. The number of buses running northbound is also very high: up to 114 buses during the rush hour, and the lowest volume happens just entering downtown with 69 buses. A total of 93 buses run northbound on Main Street between Lamar and Preston, and in the southside as many as 78 buses run northbound.

The conditions for 2000 for the PM periods are similar to the AM periods when heading northbound, except that the volumes are uniformly slightly higher than the AM periods for the same year. However, what we must understand is how much have the bus volumes decreased. For the southside of Main Street, bus volumes have decreased by almost 20 buses whereas the busiest area of Main Street, from Lamar Street up to Preston Street, bus volumes have decreased by approximately 40 buses. The street block between Franklin and Congress had the highest level of bus activity for both 1993 and 2000.

The number of buses running southbound in Main Street during PM peak hours is expected to be different than the ones running northbound. One trend identified is that buses running southbound maintain a constant volume almost throughout the entire corridor, with the northernmost two street blocks having only slight variations. Because of this Figure 6 resembles Figure 4. Throughout most of the corridor, the bus volume has been reduced by nine buses and in the northernmost part by only five buses. As shown in the graph, volumes are currently under 40 buses, however what is important to note in this case, as in the case with the AM peak buses heading southbound, is that the reduction in bus volume is not that significant. This leads one to believe that buses heading southbound along Main Street are not the cause of the complaints and the ones causing all the activity in downtown, but rather these are the northbound buses and that's why there has been significant reductions. Figure 6 shows the net number of buses running through Main Street during PM peak hours for 1993 and 2000. Comparisons between both AM and PM net bus volumes for Main Street show that bus volumes are much higher during PM peak hours. Figures 4 and 6 are used for this comparison. Although the behavior is quite similar for the 2000 conditions, it is notable that the values of the PM peak volumes are higher than the AM peak volumes. By looking at both figures, it appears that the 2000 conditions seem to provide a more organized bus service on Main Street, compared to 1993 which is dominated by irregular patterns and very high volumes.

In summary, the following table presents the changes in bus volumes for Main Street. To accomplish this summary, Main Street was divided in three areas, northside, central and southside. Northside includes the blocks between Commerce and Prairie Streets, central includes the street blocks between Prairie and Dallas Streets, and the southside includes the street blocks between Dallas and Pierce Streets. This pattern can be followed for all streets running north-south, since the busiest corridors all run parallel from Smith Street to San Jacinto Street.

Tables 2 and 3 identify where the reductions have been most significant and shows that in both peak periods the reduction has been most dramatic on central Main Street. As mentioned before, central Main received a lot of bus activity due to the way the downtown area was developed (T-shaped) and a lot of bus activity came from Walker, McKinney, and Lamar streets, so we can expect a reduction in buses throughout these streets.

**Table 2 - Bus Volumes for AM Peak Conditions**

| Main Street | 1993 | 2000 | Margin of change | % Reduction |
|---|---|---|---|---|
| Northside | 127 | 81 | 46 | 36 |
| Central | 142 | 81 | 61 | 43 |
| Southside | 127 | 90 | 37 | 29 |

**Table 3 - Bus Volumes for PM Peak Conditions**

| Main Street | 1993 | 2000 | Margin of change | % Reduction |
|---|---|---|---|---|
| Northside | 161 | 103 | 58 | 36 |
| Central | 140 | 89 | 51 | 36 |
| Southside | 125 | 98 | 27 | 22 |

Similar figures for different corridors can be found in Appendix A. Although bus volumes on Main Street have actually decreased since 1993, other parallel streets have experienced increases in bus volumes in different areas. Smith Street has witnessed increases of as many as 12 buses on the northside during morning rush hour for a 16% increase, but also a decrease of as many as 14 buses during afternoon rush hour for a 16% decrease. Central Smith Street has witnessed increases of 8 and 10 buses at AM and PM peak hours corresponding to 10% and 12% respectively, while the southside has had a decrease during the morning and an increase during the afternoon.

Having significant percentages of change doesn't necessarily imply that the lowest or highest volume of buses will be found in that specific region of the corridor.

On Louisiana Street, increases in AM peak periods go unnoticed because the difference is only one bus, which means that there has been virtually no change in the corresponding regions of central Louisiana and the southside, but in the afternoon central Louisiana experiences a decrease of 26% (54 buses down from 73) and the southside of Louisiana has a decrease of 12% (7 bus decrease from 59 in the year 1993). On its northside, decreases of 10% are witnessed by a reduction from 70 buses to 63 buses during the morning rush hour, and during the afternoon peak hour there is a decrease of 36% (42 buses down from 66). In other words, while Smith experiences mixed results during the seven year span, Louisiana has decreases that can go noticed in the central region and the northside.

On Milam Street, the trends are opposite between the AM peak period and the PM peak period throughout the entire corridor. During the morning, decreases of as much as 39 buses (40% reduction) have been experienced on the southside, 27 buses (25% reduction) on the northside and 17 buses (15% reduction) on the central side. However, during the afternoon the northside experiences an increase of 100% (from 17 to 34 buses) and southside activity increases by 25% (from 47 buses to 59). So far, comparisons drawn between Smith, Louisiana, and Milam hold no similar pattern among them.

Travis Street, like Milam Street, witnesses decreases during one period and increases in the other period. Unlike Milam, though, the increases occurred during AM peak hours, with increases of as much as 12 buses (26% and 27% for central and the southside respectively) and decreases in the PM peak hours of as much as 37 buses (71 buses down from 108) in the southside, 36 buses (72 buses down from 108) on the northside and 34 buses (78 buses down from 112) on the central area. Milam flows southbound (into the district) and Travis flows northbound (out of the district), suggesting that the heavy flow in the city occurs around the northside and central during the morning and afternoon peak periods, where much of the activity is concentrated.

Although Fannin Street is also considered to be one of the main corridors in downtown, bus volumes are not as high as the previous discussed. Despite this, there are very high percentages of increase on Fannin. During the morning peak period the northside has an increase of 83% (44 buses up from 24), but the central and southside experience decreases of lesser magnitude but still significant (23% in central for a 13 bus decrease and 10 % in southside for a 5 bus decrease). In the afternoon peak hours there is a very substantial increase of 159% (44 buses up from 17) on the northside, while a decrease in central Fannin is experienced (45 buses down from 59 for a 24% decrease) and an insignificant southside increase of one bus is experienced.

San Jacinto Street, like Fannin Street, does not experience high volumes as Smith, Louisiana, or Milam Street, and on San Jacinto there are no decreases experienced, however, the percentage increases are very significant. The greatest increases occur during AM peak periods in the southside and during the PM peak periods on the northside and the southside again. These increases are of 36 buses up from 21 for a 76% change. The lowest percentage of increase experienced on San Jacinto occurs during the afternoon in the central region with 33%: 40 buses up from 30.

From these seven corridors we can conclude that they follow different patterns, which means that while the volumes in Main Street have lowered, the other corridors have not experienced the same amount of reduction. Because of this, some of the downtown retailers might not have noticed a reduction in bus volumes that others might have witnessed as conditions worsened. So as bus volumes in Main Street are lowered, it still accounts for 23% of the CBD's customer activity. Travis Street also holds a high amount of bus volume, as it places second to Main Street in the CBD's customer activity. It also accounts for significant reductions during the afternoons, which should satisfy the retail representatives. The third busiest corridor, Milam Street, also holds a high amount of buses. Since bus stop activity is related to the volume of buses, it is not a coincidence that these corridors have the highest amount of buses among the north-south corridors.

## High Sensitivity Analysis

To develop a well-founded comparison, there is a need to establish some parameters regarding what is considered high bus volumes and low bus volumes. Data collected from the actual conditions for the years 1993 and 2000 will help to determine what is considered high bus volumes and low bus volumes. There are geometric restrictions that are variables when determining these parameters, however, the streets of downtown provide adequate lane widths and number of lanes per corridor to minimize these geometric restrictions. The streets of downtown Houston currently have even more geometric restrictions due to the construction status, however, because this is temporary, it will be assumed that the impact of the construction will not affect the perception of the bus system on the medium run (during the construction phase, there have been some street narrowing, forcing METRO buses to share the public lanes with other traffic.) To determine where the bus volumes are high, we related the bus stop activity with the bus volumes in the main corridors of downtown, and we pinpointed the bus stops of major activity and analyzed the bus volumes around the bus stops.

With the data collected from the north-south corridors and from the east-west corridors, it is fair to consider that the parameters chosen to determine high bus volumes will be the same between the two different directional groups of corridors. To determine the parameters used to consider what is high bus volume and what is low bus volume, the data was collected from the actual conditions for the years 1993 and 2000. Upper and lower limits are considered on a base of what the capacity of the streets are given their geometric dimensions, how the bus system operates in downtown, and what is considered frequent service.

Most of the downtown corridors have three lanes and flow in only one direction, except for Main Street and Franklin Street. These three lanes are used by cars as well as trolleys or METRO buses. These downtown corridors also have another lane, considered as the bus lane, which METRO buses use as a semi-exclusive lane to avoid the traffic congestion during periods of heavy traffic. These bus lanes are semi-exclusive because cars and other forms of private transportation may use them to make right turns. METRO buses can also use the other lanes to pass another METRO bus. This occurs when METRO buses riding on the same street stop at different bus stops and the bus behind the one making the stop wishes to pass to avoid delays in its schedule. METRO buses running along a corridor usually make stops every two blocks. This allows METRO buses to move more freely through the corridors and not lose so much time when the bus must come to a complete stop, wait for passenger to get off and on, wait for passengers to accommodate themselves and afterwards accelerate the bus, a process that can take anywhere between 35 seconds to minutes.

The volume of buses in downtown is high in the main corridors most of the time, and low throughout most of the other corridors. An acceptable volume of buses per hour has an upper limit of 59 buses and a lower limit of 20 buses. Eighty or more buses is considered very high. Less than 20 buses per hour would be considered a low bus volume. For example, 20 buses per hour would be around one bus every three minutes, which would be like standing at a bus stop and perhaps not seeing the next bus come along. A volume of 60 buses per hour would be one bus every minute, except that the buses would stop alternatively every two minutes. Because of this, it would be possible to see the bus when it is about three or four blocks away. A rate of 80 buses per hour is close to saturation, where it is possible to see a bus picking up passengers and two or more buses may pass by it, or it might be possible to see two buses aligned in the same bus stop with very short waiting times and a large amount of sidewalk activity.

Bus stop activity is defined by riders getting on or off buses. As seen in many of the tables, the most active bus stops also have high or very high bus volumes.

*High Bus Volumes and High Bus Stop Activity*

Many street blocks currently contain a high amount of bus volume. Table 4 lists areas of downtown that have high bus volumes and high bus activity. Included in Appendix A are the indications of the 50 most active bus stops for the year 2000. High volumes are identified in bold numbering, very high volumes are identified in bold and italics and low volumes are identified by italics. Also included are the volume averages throughout each corridor.

The areas identified as having high bus volumes and high bus activity during AM peak periods and PM peak periods are presented in two different figures. Table 5 shows the blocks with high bus volumes during the AM peak period of the 50 most active downtown blocks. Table 6 shows the same high bus volume blocks for the same area but for the PM peak period. Notice in Table 5 that only 18 out of the 50 most active bus stops have either high or very high bus volumes, which indicates that many of the active bus stops in downtown have either medium (acceptable volume of buses) or low bus volumes, of which two scenarios can occur: transfers are occurring at a high rate in very few locations and/or buses are overflowing in the downtown area only in certain areas where there is not much bus activity during the morning. Notice that like the AM scenario, only 19 out of the top 50 bus activity stops have either high or very high bus volumes. Out of the locations identified, 12 had high or very high volumes on both periods. These locations are identified in Table 5.

**Table 4 - Year 2000 Bus Stop Activity and Volumes**

| Rank | Street | Block | Daily Bus Stop Activity | AM Volume | PM Volume |
|---|---|---|---|---|---|
| 1 | Main NB | Lamar & Dallas | 2,787 | Medium | Medium |
| 2 | Travis | Lamar & Dallas | 2,615 | Medium | High |
| 3 | Lamar | Main & Travis | 2,613 | High | High |
| 4 | Lamar | Fannin & Main | 1,742 | High | High |
| 5 | Milam | Walker & McKinney | 1,553 | Very High | Medium |
| 6 | Main SB | McKinney & Lamar | 1,545 | Medium | Medium |
| 7 | Main SB | Rusk & Walker | 1,539 | Medium | Medium |
| 8 | Main NB | Rusk & Walker | 1,504 | Medium | Medium |
| 9 | Dallas | Travis & Milam | 1,498 | Medium | Medium |
| 10 | Louisiana | McKinney & Lamar | 1,497 | Very High | High |
| 11 | Milam | Capitol & Rusk | 1,458 | Very High | Medium |
| 12 | Main NB | McKinney & Lamar | 1,373 | Medium | Medium |
| 13 | Main NB | Walker & McKinney | 1,365 | Medium | Medium |
| 14 | Fannin | McKinney & Lamar | 1,344 | Medium | Medium |
| 15 | Dallas | Main & Travis | 1,343 | Medium | Medium |

**Table 5 - High Bus Volume and High Bus Stop Activity for 2000 AM Peak Conditions**

| Street | Block | Rank | Daily Bus Stop Activity |
|---|---|---|---|
| Lamar | Main & Travis | 3 | 2,613 |
| Lamar | Fannin & Main | 4 | 1,742 |
| Milam | Walker & McKinney | 5 | 1,553 |
| Louisiana | McKinney & Lamar | 10 | 1,497 |
| Milam | Capitol & Rusk | 11 | 1,458 |
| Lamar | San Jacinto & Fannin | 17 | 1,317 |
| Milam | Dallas & Polk | 19 | 1,285 |
| Smith | Walker & McKinney | 21 | 1,260 |
| Smith | McKinney & Lamar | 22 | 1,240 |
| Fannin | Rusk & Walker | 23 | 1,200 |
| Milam | McKinney & Lamar | 25 | 1,182 |
| Louisiana | Dallas & Polk | 27 | 1,136 |
| Lamar | Travis & Milam | 28 | 1,135 |
| Smith | Lamar & Dallas | 30 | 1,106 |
| Smith | Capitol & Rusk | 33 | 986 |
| Louisiana | Lamar & Dallas | 38 | 882 |
| Milam | Rusk & Walker | 41 | 856 |
| Smith | Polk & Clay | 42 | 845 |

**Table 6 - High Bus Volume and High Bus Stop Activity for 2000 PM Peak Conditions**

| Street | Block | Rank | Daily Bus Stop Activity |
|---|---|---|---|
| Travis | Lamar & Dallas | 2 | 2,615 |
| Lamar | Main & Travis | 3 | 2,613 |
| Lamar | Fannin & Main | 4 | 1,742 |
| Louisiana | McKinney & Lamar | 10 | 1,497 |
| Travis | Rusk & Walker | 16 | 1,324 |
| Lamar | San Jacinto & Fannin | 17 | 1,317 |
| Milam | Dallas & Polk | 19 | 1,285 |
| Main NB | Dallas & Polk | 20 | 1,275 |
| Smith | Walker & McKinney | 21 | 1,260 |
| Smith | McKinney & Lamar | 22 | 1,240 |
| Fannin | Rusk & Walker | 23 | 1,200 |
| Main NB | Congress & Preston | 24 | 1,191 |
| Lamar | Travis & Milam | 28 | 1,135 |
| Smith | Lamar & Dallas | 30 | 1,106 |
| Smith | Capitol & Rusk | 33 | 986 |
| Travis | Capitol & Rusk | 34 | 967 |
| Smith | Polk & Clay | 42 | 845 |
| Travis | Polk & Clay | 47 | 786 |
| Travis | McKinney & Lamar | 49 | 757 |

Notice from Table 7 that the downtown locations that have high or very high bus volumes, as well as high activity, are concentrated on a few streets: Lamar, Smith, Louisiana, Milam and Fannin. Also notice that these locations are concentrated along the central part of downtown, which would be between Capitol Street and Dallas Street. This is the downtown area that could produce a negative perception of the transit system. Information provided by Mr. Guy Hagstette of the Downtown Business District confirms that the areas that have had a lot of complaints are between Capitol Street and Dallas Street; of these mainly Lamar, Smith, Louisiana, Milam, and each adjacent street to San Jacinto Street. But it is important to recognize that Lamar Street is not only the busiest east-west corridor regarding bus stop activity, but also the one with the most complaints by the business community.

As determined from Table 8, only one in the top fifty busiest corridors has low AM bus volumes. From Table 9 the same location also is found to have low PM bus volumes. This means that only one location in the top fifty busiest bus stops has low bus volumes at any time of the day, which suggests that the METRO service is reaching most areas of activity, because, 37 out of the 50 busiest bus stops have a medium amount of bus volume, between 20 and 60.

**Table 7 - Downtown Locations with High Bus Stop Volumes at AM and PM Peak Periods**

| Street | Block |
|---|---|
| Lamar | Main & Travis |
| Lamar | Fannin & Main |
| Louisiana | McKinney & Lamar |
| Lamar | San Jacinto & Fannin |
| Milam | Dallas & Polk |
| Smith | Walker & McKinney |
| Smith | McKinney & Lamar |
| Fannin | Rusk & Walker |
| Lamar | Travis & Milam |
| Smith | Lamar & Dallas |
| Smith | Capitol & Rusk |
| Smith | Polk & Clay |

**Table 8 - High Bus Stop Activity and Low Bus Volume for 2000 AM Peak Conditions**

| Street | Block | Rank | Daily Bus Stop Activity |
|---|---|---|---|
| McKinney | Main & Travis | 29 | 1,131 |

**Table 9 - High Bus Stop Activity and Low Bus Volume for 2000 PM Peak Conditions**

| Street | Block | Rank | Daily Bus Stop Activity |
|---|---|---|---|
| McKinney | Main & Travis | 29 | 1,131 |

*Low Bus Volumes and High Bus Activity*

The locations identified in the following tables will provide a clear view of where buses are low in the downtown area, allowing us to determine whether these areas need an increase in the bus activity to determine if the location is an area of priority that METRO must address. These locations need to be identified in order to determine if the perception is positive or negative and how it can affect METRO if bus volumes increase in these locations. Low bus volumes are determined to be 20 buses or less per hour. The following tables present the data collected for AM and PM peak periods.

This means that the service is adequate for these regions, whereas the block between Main and Travis on McKinney Street should have more buses running through it to provide a more frequent service that can satisfy the amount of bus activity being generated.

*High Bus Volume and Low Bus Stop Activity*

Areas of high bus volume and low bus stop activity might spur complaints about the noise and air pollution that the buses bring, as well as why are there so many buses around these areas when there is not much bus stop activity.

Table 10 details which street blocks in the downtown area are categorized under these conditions, providing a clearer picture of the areas that need to be addressed regarding bus volumes. There are several important trends identified from Table 10. First and foremost is that the majority of the street blocks identified are in the northside and southside of the main north-south corridors, especially from Smith Street to Travis Street. High volumes with low bus stop activity are found on Smith, Louisiana, Milam and Travis in the street blocks from Preston Street to Capitol Street, and from Clay Street to Jefferson Street. The southside of Main Street also has high bus volumes with low bus stop activity, unlike the central and northside, which means that most of the transfers are occurring in either the northside or central, especially in the street blocks between Congress and Preston, and Dallas and Polk. Other areas of high bus volumes and low bus activity are found in the central region of downtown, close to regions of high bus activity and high bus volumes.

Identifying the areas of high bus volumes with low bus stop activity, shows that these areas in the northside and the southside are bound together by the busy central region of downtown. Buses traveling to the central region must first enter through either the northside or the southside and make their exit in a similar fashion, unless their route configuration is different allowing them to run exclusively inside downtown or exit through Bagby Street.

**Table 10 - High Bus Volumes and Low Bus Stop Activity for 2000 AM & PM Peak Conditions**

| Street | Block | AM Volume | PM Volume |
|---|---|---|---|
| Smith | Franklin & Congress | High | Medium |
| Smith | From Congress to Capitol | Very High | High |
| Smith | Rusk & Walker | Very High | High |
| Smith | Dallas & Polk | High | High |
| Smith | From Clay to Calhoun | High | High |
| Smith | Calhoun & Pierce | Medium | High |
| Louisiana | From Preston to Rusk | High | Medium |
| Louisiana | From Rusk to McKinney | Very High | High |
| Louisiana | From Polk to Leeland | High | Medium |
| Louisiana | Leeland & Pease | High | High |
| Louisiana | Pease & Jefferson | High | Medium |
| Milam | From Congress to Capitol | Very High | Medium |
| Milam | Lamar & Dallas | Very High | High |
| Milam | Polk & Clay | Very High | High |
| Milam | From Clay to Calhoun | Very High | Medium |
| Milam | Calhoun & Pierce | High | Medium |
| Travis | From Preston to Capitol | Medium | High |
| Travis | Walker & McKinney | Medium | High |
| Travis | Dallas & Polk | Medium | High |
| Travis | From Clay to Jefferson | Medium | High |
| Main NB | Commerce & Franklin | Medium | High |
| Main NB | From Polk to Jefferson | Medium | High |
| Fannin | Walker & McKinney | High | High |
| Lamar | Milam & Louisiana | High | High |

## Expected Trends

The corridors that will be analyzed in this chapter are the ones identified as being highly sensitive to high bus volumes and have either a high bus stop activity or a low bus stop activity, but nevertheless high or very high bus volumes. The analysis will proceed by comparing how conditions for year 2000 compare with the conditions of 1993, given that areas of high sensitivity have not changed significantly over the seven year gap. Based on this real scenario comparison, projections for the years 2004 and 2020 will be integrated as future scenarios to predict changes in the perception of the bus system regarding the high bus volumes. The analysis will be divided by time of the day (AM and PM) and the perception will be evaluated as an integrated element. Having identified in the preceding chapters which areas are highly sensitive due to their conditions, the following corridors are vital in the role that perception plays in the bus system.

*Lamar Street*

Lamar Street is arguably the east-west backbone of downtown because of the way the downtown area was developed ('T' shaped). It is also one of the areas of highest sensitivity to bus stop activity as well as bus volumes. The four street blocks between Milam Street and San Jacinto Street have high amounts of bus stop activity, and three of these blocks are among the top four in high bus volumes and high bus stop activity.

AM Period: In 1993 the bus volumes on Lamar Street were considered fair, ranging from the mid 50s, which is considered a medium bus volume, to the 10s, a low amount of buses. However, bus volumes increased during the seven year span, and currently the bus volumes are high in the blocks between Fannin Street and Milam Street, otherwise the volumes are medium. However, the current conditions are as high as it is expected to be for the short and long run. For the year 2004, the behavior will be much the same as in the year 2000, that is low bus volumes at the northernmost and southernmost sides and higher bus volumes in the central region. The decrease from the year 2000 to the year 2004 will be about 15 to 17 buses throughout most of the corridor. In the year 2020 the volumes are expected to be similar to the 2004 projection with a very slight increase of two or three buses.

PM Period: Like the AM scenario, the pattern is pretty much the same. There was a medium amount of buses in 1993 followed by an increase in 2000, but greater decreases of as many as 22 to 25 buses are expected for 2004 and increases from 2004 to 2020.

Perception: Being one of the main east-west corridors, the projections are favorable for Lamar Street, since the numbers do not vary significantly between the AM and PM peak hours. If the perception has deteriorated from seven years ago, it is likely that it will improve in the next four years and remain that way for the next 20 years keeping in mind that the amount of people in the sidewalks should increase in the long run due to the Light Rail Transit Line on Main Street.

*Smith*

One of the north-south corridors, Smith Street is currently loaded with high bus volumes and high bus stop activity in the central region. Smith, which has a southbound flow, is also one of the main entrances to the downtown area, and therefore there are currently very high bus volumes in the northside during the AM peak period, when most of the inflow to downtown occurs.

AM Period: Bus volumes in 2000 have increased from the volumes in 1993. There are high bus volumes all throughout the corridor down to Jefferson Street and very high bus volumes between Franklin and Texas, and between Rusk and McKinney. The projections for 2004 show uniform increases from 2000 and the pattern throughout the corridor is the same as in the year 2000. The 2004 projection exhibits the highest amount of buses in the northside and central region, compared to the other scenarios. The projection for 2020 has lower bus volumes than the 2004 projection, although still higher than the 2000 conditions. This means that much of the northside and the central region in this corridor has very high bus volumes, and the southside has high volumes like the years 1993, 2000, and 2004 scenarios.

PM Period: For 1993, conditions are very similar to the AM conditions, except on the northside where bus volumes are slightly lower and the high volumes are found only in the street blocks between Rusk and McKinney. The 2000 conditions increase the bus volumes throughout the corridor, where high bus volumes are found from Congress Street and southward. Very high volumes are found in the blocks between Rusk and McKinney. Future projections expect slight reductions in bus volumes, not enough to bring the volumes in the central region to a medium level, but enough to bring down the bus volumes between Rusk and McKinney to a high level. The southside expects short term reductions to lower the volumes to a medium level, and long term projections to continue decreasing for 2020. However, projections for the year 2020 on the northside do not fare any better than the conditions for 1993.

Perception: Although PM bus volumes are generally lower than the AM bus volumes in every scenario, future scenarios do not lower bus volumes any further than what the 1993 conditions were. Reductions are expected based on the current conditions, but if activity increases for the next years in Smith Street, maintaining the expected level of bus volumes might prove to be favorable for business operators in this corridor. Otherwise the perception is not expected to improve.

*Milam*

Milam probably is the best example of how bus activity in a one-way corridor varies by time of the day. Like Smith Street, Milam Street has a southbound flow, which would suggest that it will also have the higher bus volumes on the northside and central in the AM peak periods when most of the flow of traffic is into the downtown area.

AM Period: Conditions showed very high bus volumes throughout most of the corridor. It covered the northside, the central region, and almost all of the southside. The conditions currently have resulted in a decrease of bus volumes on the northside and up to Rusk Street, and an increase from this same intersection and through the southside. Still, very high volumes prevail in the corridor from Preston to Jefferson, and the only acceptable area with a medium level of buses is on the northernmost block, which is Commerce and Franklin. This presents a scenario where the amount of buses making an entrance into downtown from this street are at an acceptable level, where most of the other buses are coming from the streets of Franklin, Congress, and the ones further south. Scenarios for 2004 and 2020 are very similar to each other, and both follow the same current pattern with a decrease of around 10 buses. Still, these scenarios account for very high bus volumes south of McKinney Street.

PM Period: Unlike the AM scenarios, the PM scenarios have the same pattern: low bus volumes in the northernmost part of downtown, followed by increases to medium levels throughout the remainder of the corridor. Although the current conditions show a slight increase in bus volumes, the result has the same effect as the volumes of the year 1993. However, the projections for 2004 and 2020 show increases at intervals of two blocks heading south. High volumes are expected around the blocks of Lamar and McKinney, and south of Clay, whereas very high bus volumes are expected south of Bell.

Perception: Although the past PM scenarios have had little effect on the way the buses are perceived in this corridor, it might change in the future along the southside, although currently this is not an area of high sensitivity. On the other hand, the patterns observed in the AM scenarios do not guarantee an improvement in the business community's perception of the bus system and METRO.

*Travis*

Travis Street, like Milam and Smith, is a one-way corridor, but has a northbound flow. Because of this, the trend is reversed, higher volumes occur during the PM peak periods.

AM Period: The past and current scenarios, years 1993 and 2000 respectively, operate with a medium level of buses almost through the entire corridor, except in the northernmost and southernmost ends where bus volumes are low. There are no significant changes in bus volumes, as they remain almost constant between Preston and Jefferson. This trend is expected to change in the short run, when bus volumes are expected to increase to the lower limits of high bus volumes in the street blocks south of Prairie. Long-term projections will not change from the projected bus volumes for 2004, except for a steep increase in bus volume to a very high level in the block between Pease and Jefferson.

PM Period: As anticipated for a northbound corridor, PM volumes are higher than their morning counterparts. Very high bus volumes in 1993 have been reduced by approximately 30 buses down to high volumes in the lower 70s and mid 60s during the seven year span, with medium levels of buses present north of Preston and south of Leeland. As in the AM scenarios, no dramatic changes are recorded between Preston and Leeland because the volumes remain fairly constant. Short-term projections do not anticipate significant increases or decreases from the current conditions, but the long-term conditions expect very high increases in the southside with small increases in the north and central side. High volumes dominate in all of the scenarios in the blocks between Congress and Leeland, and very high volumes are expected in the long run between Walker and Lamar and also south of Polk.

Perception: Although AM scenarios show increases in bus volumes, the afternoon peak hours are the scenarios with high sensitivity. Decreases in the past seven years might have helped improve the perception by the business district. Short-term projections do not present major changes in the volumes, and neither does the long-term projections in the north and central side which suggests that whether the perception is improving from the past seven years, it will not change much over the next years, and it might deteriorate in the long run unless the Light Rail Transit Line expected for Main Street enhances the bus system. As in the case of Milam, the southside could also become an area of high sensitivity in the long run.

*Louisiana*

This corridor has a northbound flow like Travis and San Jacinto. This may suggest that the patterns will be similar to the ones identified in Travis. The scenarios in this corridor behave alike each other, with the reductions and increases acting as the difference, which means that an increase in the northside is very likely to be accompanied by an increase of similar magnitude in the southside.

AM Period: The scenarios for 1993 and 2000 have similar bus volumes. Both have a medium level of buses north of Preston and south of McKinney, but the current scenario has an unusual peak of high volumes between Bell and Leeland, while both scenarios have very high volumes between Capitol and McKinney. The scenario projected for 2004 presents an increase of 20 buses on the northside. Higher volumes are included in this projection, as the volumes are at a high level everywhere. Very high volumes are found between Preston and McKinney. The long-term projection, however, expects a decrease from the high volumes projected for 2004. Since the decrease is only about five to eight buses, high volumes linger throughout the corridor and very high volumes are found between Rusk and McKinney.

PM Period: The behaviors are much the same as the AM scenarios, however, the increases are of greater magnitude. Volumes for 1993 are slightly higher than the volumes recorded for the same year during the morning period. The current conditions, however, present a decrease in the bus volumes. This decrease, of around 18 buses in the most notorious cases, helps bus volumes reach a medium level throughout most of the corridor except for the blocks between Capitol and McKinney where the bus volumes are high. This state of acceptable bus volumes currently experienced is expected to be short lived, especially with the dramatic increases projected in the short run. Increases for 2004 are as big as 37 buses in the northside between Congress and Capitol. Other areas such as the southside and the central region experience increases of as much as 32 and 34 buses respectively. The dramatic increases are constant in most areas of the corridor, and the behavior is similar to the current and past scenarios. The result of this projection is very high bus volumes from Congress all the way southbound. The long-term projection expects a decrease from the projections for 2004, however, it does not fare much better. Increases from the current conditions are as much as 26 buses on the northside and 25 on the southside, which results in very high bus volumes on the central region between Preston and McKinney, as well as high volumes in the northside and southside.

Perception: Louisiana Street is a corridor already bothered by the current morning bus volumes and is highly sensitive. The perception is expected to decline significantly, especially due to the impact that the afternoon bus increases will have on the corridor.

*Fannin*

Fannin Street has an area of high bus volumes in the central region. This corridor, which runs southbound, might be affected with bus volume increases depending on how the bus stop activity changes in the future. However, it currently has a very busy street block at Rusk and Walker.

AM Period: Bus volumes during 1993 and 2000 are very similar for most of the corridor except some variances on the northside where there is a 18-bus increase from 1993 to 2000 between Franklin and Congress. These volumes are still at an acceptable level. Currently there is a peak observed between Rusk and McKinney, but the volumes observed are at an acceptable level. The short-term projections expect a decrease to low levels of bus volume on the northside and maintain the same volumes throughout the central region. Long-term projections expect an increase in bus volumes throughout all the corridor, with high bus volumes expected from Congress and southward, peaking at very high levels between Jefferson and St. Joseph's Parkway.

PM Period: Unlike the other one-way corridors, Fannin Street has the same bus volumes during the AM peak period as well as the PM peak periods, for every scenario.

Perception: Bus volumes are at an acceptable level throughout most of the corridor, and areas of high bus volumes are fueled by the amount of bus stop activity generated. However, it is evident how the Light Rail Transit Line expected for the adjacent Main Street will affect the perception in this corridor by increasing the bus volumes to high levels through most of the corridor. Unless the corridor bus stop activity increases in the corridor in other blocks other than Rusk and Walker, the perception is very likely to deteriorate. The volumes around Jefferson and St. Joseph's Parkway are very high; meaning this area would probably become another area of high sensitivity in the long run.

*Main Northbound*

Main Street is the only north-south corridor in downtown that has traffic flowing in both directions. Because of this, the analysis will proceed first for the northbound bus volumes, and then for the southbound bus volumes, and the evaluation will be integrated. Since Main Street has been analyzed in a previous chapter, this analysis will focus on the future projections.

AM Period: The projections for 2004 present only slight increases from 2000 on the northside. As mentioned previously, the current conditions have significantly improved from past conditions, and the current conditions, as well as the short-term projections present a medium level of bus volumes, which is acceptable. This projection will continue until the Light Rail Transit Line begins operations, when the rail system will replace the buses in downtown and take care of most of the transfers occurring in the downtown area.

PM Period: The northbound flow in PM peak periods present slight increases from the morning volumes, but the behavior is similar. The only change occurs in the current scenario in the northernmost part of the corridor, where bus volumes are higher than in the AM periods, on the street block between Franklin and Congress. This margin of 19 buses is the most significant witnessed in this direction. The projection for 2004 is very similar to the one projected in the same year for the morning peak period.

*Main Southbound*

AM Period: Uniformly lowered from 1993 bus volumes, the 2000 current conditions provide a very acceptable level of bus volumes. Short-term projections expect an increase of as much as five buses, which is a slight increase. Only between Franklin and Congress are the volumes expected to decrease, and this decrease is insignificant (five buses). The bus volumes are still at a medium level.

PM Period: Since bus volumes have decreased in the past seven years, the current volumes are at a medium level where no block has more than 38 buses. But, short-term projections detail an increase in the bus volumes to raise the volumes to 46 buses during the peak hour. This is still an acceptable level. Note how the drop in bus volumes takes place on the same block, Franklin and Congress. This drop occurs where peaks are observed on Milam and Travis, and increases on Louisiana and Smith.

Perception: The volume changes on Main Street will affect the perception of the bus system from the business district point of view. However, knowing that in the future a Light Rail Transit Line will operate on Main Street accommodating the immense amount of transfers made everyday by the bus system in this corridor, the perception should improve dramatically, not only in Main Street, but possibly on adjacent streets such as those not affected by high bus volumes (e.g., McKinney and San Jacinto).

## Results

From the previous analysis these are the findings that satisfy the objectives of the research:
The perception was identified through the information gathered from the past surveys conducted by METRO and its clients. This information is available in the *Downtown Commuter Survey* prepared by METRO. Other information was obtained from articles in the *Houston Chronicle* and also information provided by the Downtown Business District. The problems affecting downtown include:

- vagrants;
- declining sales;
- no business during the evening;
- lack of parking (or at least knowledge of it);
- overcrowded sidewalks;
- crime; and
- commute distance.

The problems affecting METRO and the bus system include:

- vagrants;
- crime;
- rider profile; and
- location of transit center.

The findings are the result of data provided by a 1993 survey. Therefore some of these findings may be offset by some degree of magnitude, for instance, lack of parking may be the result of lack of information by the visitor, and low business activity during the evening may be more critical on the southside than on the northside where the Historic District, the Theater District, and Enron Field are located.

Low bus volumes were considered to be less than 20 buses per hour. A medium level of buses was considered to be between 20 and 59 buses per hour, a high level between 60 and 79, and any volume higher than that was considered to be very high. The findings resulted in five of the top ten busiest bus stops to have either high or very high bus volumes at any peak period. These bus stops are located in the following street blocks:

- Travis Street between Lamar and Dallas
- Lamar Street between Main and Travis
- Lamar Street between Fannin and Main
- Milam Street between Walker and McKinney
- Louisiana Street between McKinney and Lamar

These street blocks neighbor each other. This is the busiest area in downtown and it is in the central region. Out of the top 50 busiest bus stops, 18 have either high or very high bus volumes during the AM peak periods, and 19 satisfy the same conditions in the PM peak periods. All together, 25 of the top 50 satisfy these conditions at any peak period. Only one out of the top 50 busiest bus stops has low bus volumes at any peak period. This means that half of these busy bus stops have high volumes that can lead to a bad perception by the business operators, whereas the other half have medium bus volumes or lower, which should satisfy them. On the other hand, the critical areas also consist of street blocks with high bus volumes but low bus stop activity. The streets that are highly sensitive are included with the number of street blocks under these conditions:

- Smith Street: six blocks;
- Louisiana Street: five blocks;
- Milam Street: five blocks;
- Travis Street: four blocks;
- Main Street (northbound): two blocks;
- Fannin Street: one block; and
- Lamar Street: one block.

Much of the information collected for the database prepared with the different scenarios and projections for future years came from sources at Parsons Transportation Group, Inc., and LKC Consulting Services, Inc. Depending upon the source of the information gathered, the scenarios projected were based on different assumptions. Since some assumptions are not part of the current downtown plans and projects, or because the plan itself was not carried out completely, the numbers became obsolete. This was the case of the NOP projections for the year 2010. The information, although included in the graphs (see Appendix A), was discarded from the main analysis because it was misleading. The 1993 projections with NOP were considered for comparison with the current 2000 conditions to determine what goals of the NOP were achieved. Data for 2004 with a Light Rail scenario does not exist, and therefore it is not included. However, data for the same year with street improvements was considered, realizing that the Light Rail Line might begin operations after 2004. Data from the projections for the year 2025 was collected in a separate database because it is intended for presentation purposes only. This information is part of a project being prepared by TTI, Parsons Transportation Group, Inc., LKC Consulting Services, Inc., and METRO for the Downtown Business District to explain how bus volumes are expected to change with the Light Rail Transit Line operating on Main Street.

The comparison process between the bus volumes operating in 1993 and 2000 has resulted in some significant findings concerning perceptions related to the changes. Main Street has been the only benefactor in the past seven years, with decreases most significant in the northbound volumes in the central region. This is coupled with the fact that Main Street is the busiest street in downtown, with 23% of the total bus stop activity occurring in this corridor. The remainder of the north-south corridors have variations, but most importantly the volumes have increased in the different regions of these corridors. Table 11 summarizes which areas have experienced increases in bus volumes in the highly sensitive corridors.

**Table 11 - Increases in Highly Sensitive Corridors**

| Street | AM Peak | | | PM Peak | | |
|---|---|---|---|---|---|---|
| | Northside | Central | Southside | Northside | Central | South |
| Smith | ✔ | ✔ | | | ✔ | ✔ |
| Louisiana | | ✔ | ✔ | | | |
| Milam | | | | ✓ | ✓ | ✓ |
| Travis | ✓ | ✓ | ✓ | | | |
| Main | | | | | | |
| Fannin | ✓ | | | ✓ | | |
| San Jacinto | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

Note: The dark checkmarks (✔) denote an increase that resulted in high or very high bus volumes, and the light checkmarks (✓) denote an increase that resulted in a medium level of buses.

As seen, the most affected corridors are Smith and Louisiana, while increases in the other corridors had little effect on the volumes, or the perception. These are general remarks, and there might be single blocks in these regions that experienced a different pattern.

Identifying the areas where there is high sensitivity was essential to determine how these areas will behave in future projections. Also important was determining which regions could develop a high sensitivity in the future.

- Lamar Street had favorable projections (favorable refers to decreases in bus volumes), with no significant increases. The current conditions are expected to have the highest volumes, especially between Fannin and Milam, where most of the bus stop activity is concentrated. Short-term decreases, along with no significant long-term increases project an improvement in the perception in this important corridor of downtown.

- Smith Street currently has high and very high bus volumes, along with high bus stop activity in the central region: an increase from 1993. Projections for the short run expect the highest amounts of buses for the northside and central region, compared to other scenarios. The long-term projections do not show volumes as high as the 2004 scenario, nevertheless the projections are not any lower than the 1993 conditions. The perception is expected to deteriorate throughout the corridor as long as the bus stop activity does not increase on the northside.

- Milam Street could experience a deterioration in perception on the southside, although it has not been an area of high sensitivity in the past. Improvements in the perception are not expected to occur, especially south of McKinney and in the central region due to the inflow of buses coming from Franklin Street.

- Travis Street might experience perception improvements in the short run because of street improvements. Sidewalk activity on the northside might experience an increase, which in the case of Travis could prove beneficial. Long-term projections are delicate because although bus volumes are expected to increase, an increase in sidewalk activity could also be the result of having the Light Rail Transit Line on Main Street and this could possibly enhance the retail economy and the bus system in this corridor. As in the case of Milam Street, long-term projections could develop a highly sensitive area on the southside.

- Louisiana Street has projections in the short run that will very likely deteriorate the perception of the bus system, due to the increases expected by the year 2004 in the afternoon.

- Fannin Street should expect improvements in perception for the short run. However, since the Light Rail Transit Line on Main Street is expected to increase the bus volumes to high levels in this corridor, the perception should deteriorate unless the rail system helps increase bus stop activity and also enhances the retail environment. Like Milam and Travis, the southside could develop to a highly sensitive area with the increases in bus volumes to very high levels along Jefferson and St. Joseph's Parkway.

These are the most important findings from detailed analysis and work performed for each objective. The maps provide a user-friendly way of viewing the areas affected in downtown as the result of the increases and decreases in bus volumes.

### *Closing*

As determined through this research, it is important to understand how inner city planning is likely to affect the productivity of an area as important as the Downtown District. The perception that comes from the daily individual experiences of the transit riders and business operators is the result of the interpretation of these experiences by them. The reality that is lived everyday comes from the effort of the system to provide a frequent service wherever needed. When perception and reality come together it is easier to deal with, however, when they contradict, it is difficult to provide a solution. Houston experiences both cases: north-south corridors experience a link between perception and reality, and on the other hand many east-west streets have offset the perception and the reality. This nature might come from the amount of activity generated in the central region of downtown.

In downtown Houston, projections were made based on the objective of reducing bus volumes on Main Street, the area with most transfers in downtown. Giving too much priority to Main Street meant depreciating the impact that bus volumes were also having on the adjacent parallel streets, as well as how increases would affect the sensitivity of these corridors. Despite this, having a Light Rail Transit Line operating through downtown is positive for the transit environment in this district, as well as being the first stone of a master plan designed to make Houston a world class city. But to make Houston a world class city, Houstonians must first turn into world class citizens and this is possible if they are proud of their city. The deteriorating image of METRO's bus system is an obstacle in the road to achieving world class status, therefore, the findings of this research work present a long road ahead for Houston.

## Appendix A – Bus Volumes for 1993 and 2000

| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Smith Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 73 | 85 | 12 | **-16.44** |
| *Central* | 77 | 85 | 8 | **-10.39** |
| *Southside* | 70 | 65 | 5 | **7.14** |

| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Louisiana Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 70 | 63 | 7 | **10.00** |
| *Central* | 86 | 87 | 1 | **-1.16** |
| *Southside* | 59 | 60 | 1 | **-1.69** |

| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Milam Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 107 | 80 | 27 | **25.23** |
| *Central* | 111 | 94 | 17 | **15.32** |
| *Southside* | 98 | 59 | 39 | **39.80** |

| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Smith Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 89 | 75 | 14 | **15.73** |
| *Central* | 81 | 91 | 10 | **-12.35** |
| *Southside* | 56 | 66 | 10 | **-17.86** |

| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Louisiana Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 66 | 42 | 24 | **36.36** |
| *Central* | 73 | 54 | 19 | **26.03** |
| *Southside* | 59 | 52 | 7 | **11.86** |

| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Travis Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 22 | 25 | 3 | **-13.64** |
| *Central* | 47 | 59 | 12 | **-25.53** |
| *Southside* | 44 | 56 | 12 | **-27.27** |

| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Main Street NB* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 72 | 44 | 28 | **37.84** |
| *Central* | 87 | 44 | 43 | **49.43** |
| *Southside* | 72 | 53 | 19 | **26.39** |

| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Main Street SB* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northbound* | 59 | 42 | 17 | **28.81** |
| *Central* | 55 | 37 | 18 | **32.73** |
| *Southbound* | 55 | 37 | 18 | **32.73** |

| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Milam Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 17 | 34 | 17 | **-100.00** |
| *Central* | 47 | 49 | 2 | **-4.26** |
| *Southside* | 47 | 59 | 12 | **-25.53** |

| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Travis Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 108 | 72 | 36 | **33.33** |
| *Central* | 112 | 78 | 34 | **30.36** |
| *Southside* | 108 | 71 | 37 | **34.26** |

| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Main Street NB* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 114 | 65 | 49 | **42.98** |
| *Central* | 93 | 51 | 42 | **45.16** |
| *Southside* | 78 | 60 | 18 | **25.71** |

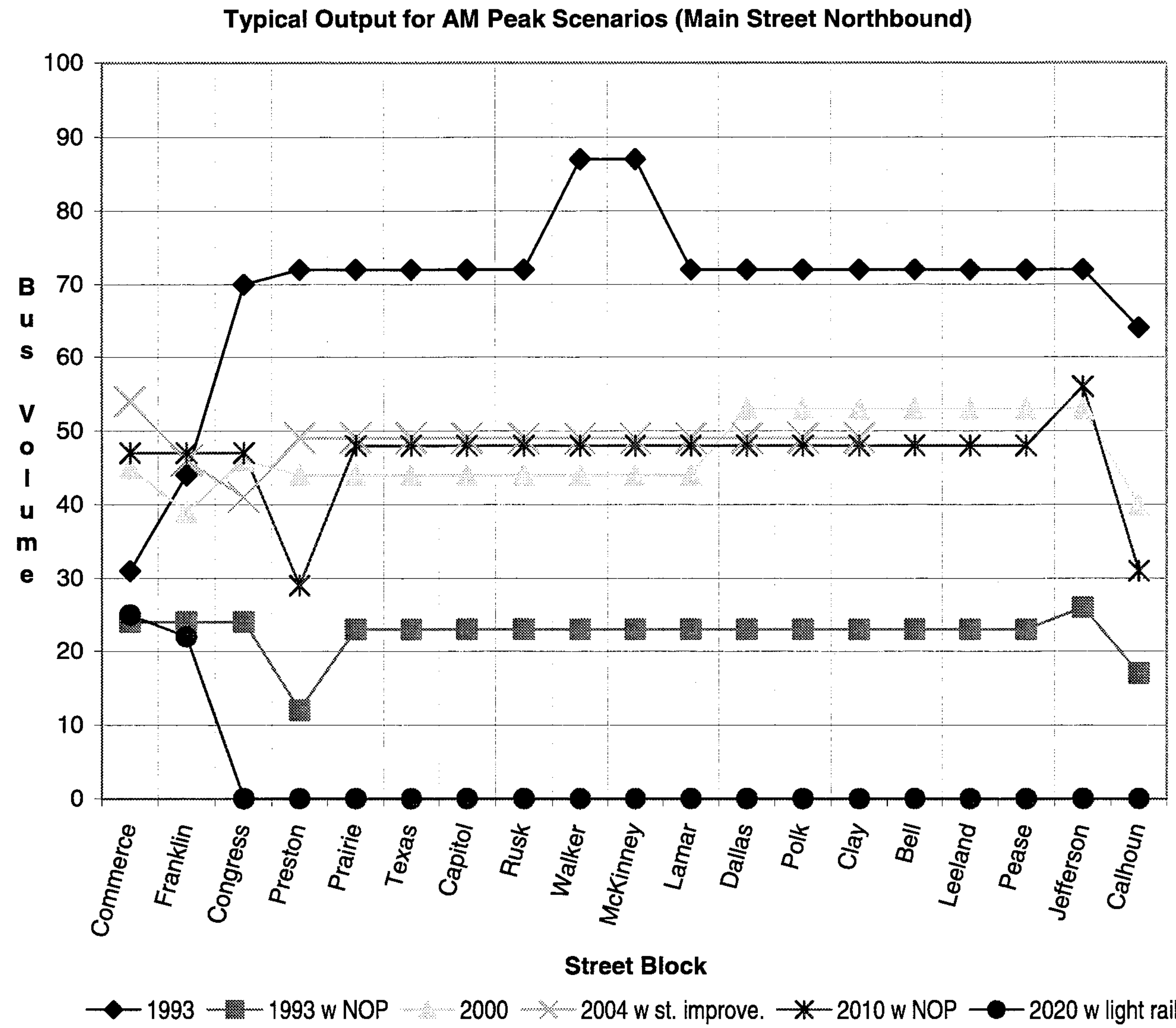
| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *Fannin Street* | *1993* | *2000* | *Margin of change* | *% Reduction* |
| *Northside* | 24 | 44 | 20 | **-83.33** |
| *Central* | 58 | 45 | 13 | **22.41** |
| *Southside* | 51 | 46 | 5 | **9.80** |

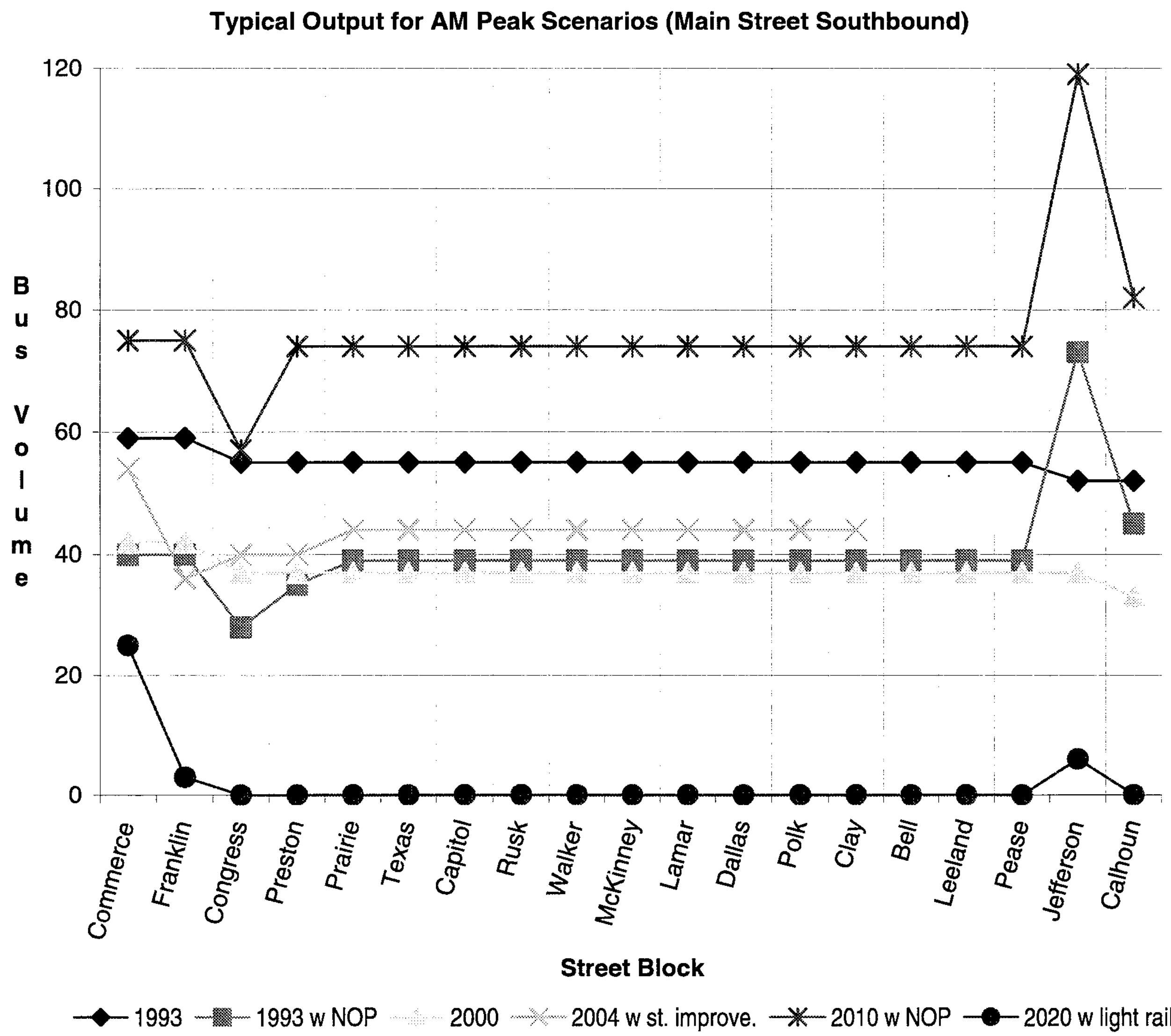
| Bus Volumes for AM Peak Conditions | | | | |
|---|---|---|---|---|
| *St. Jacinto Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 25 | 36 | 11 | **-44.00** |
| *Central* | 30 | 41 | 11 | **-36.67** |
| *Southside* | 21 | 36 | 15 | **-71.43** |

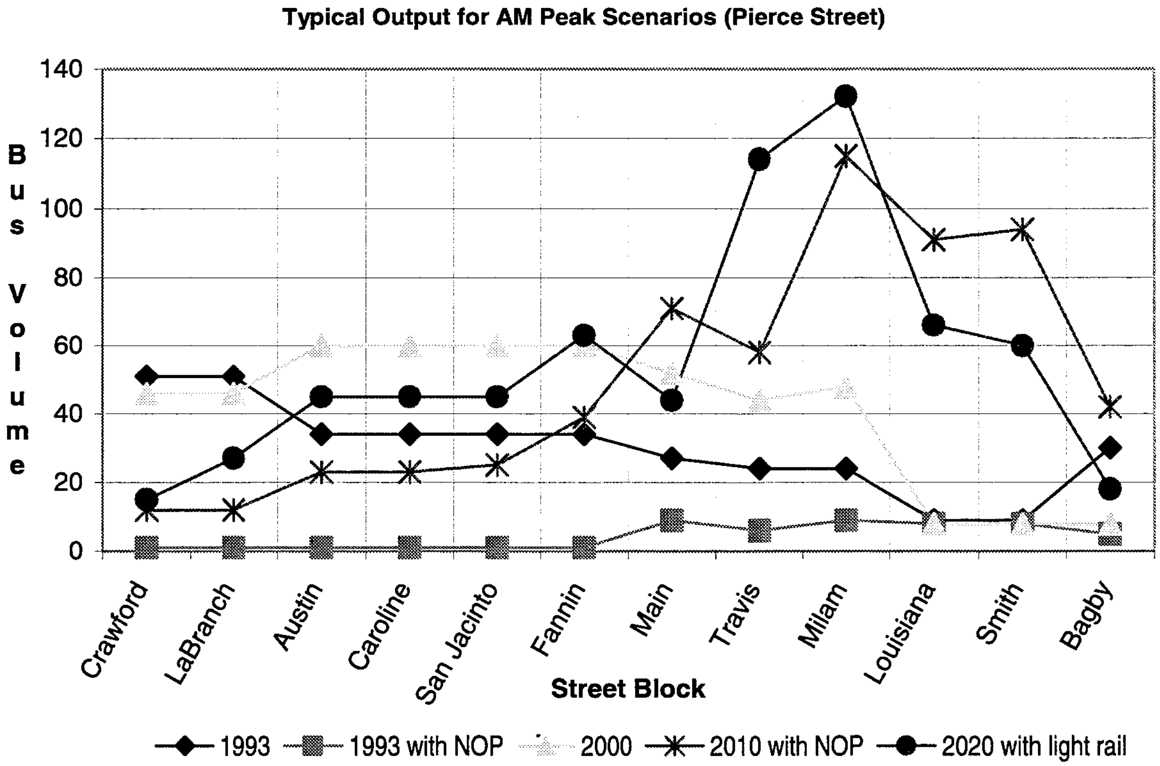
| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Main Street SB* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northbound* | 33 | 28 | 5 | **15.15** |
| *Central* | 47 | 38 | 9 | **19.15** |
| *Southbound* | 47 | 38 | 9 | **19.15** |

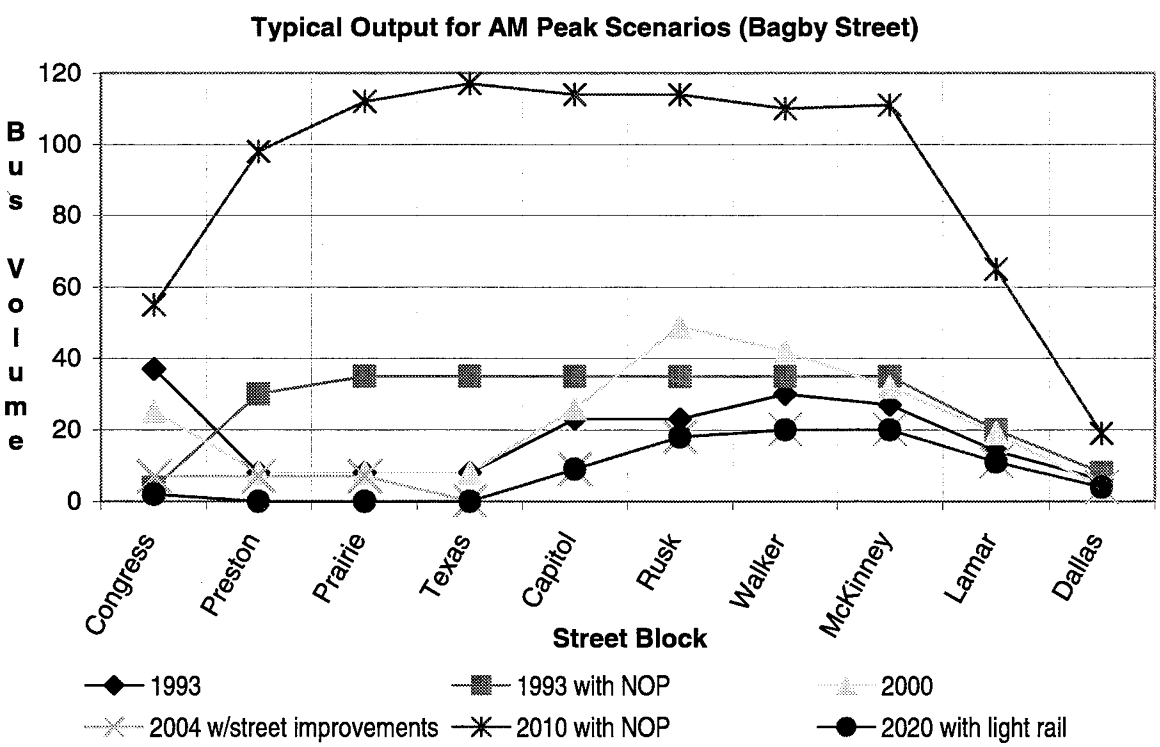
| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *Fannin Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 17 | 44 | 27 | **-158.82** |
| *Central* | 59 | 45 | 14 | **23.73** |
| *Southside* | 46 | 47 | 1 | **-2.17** |

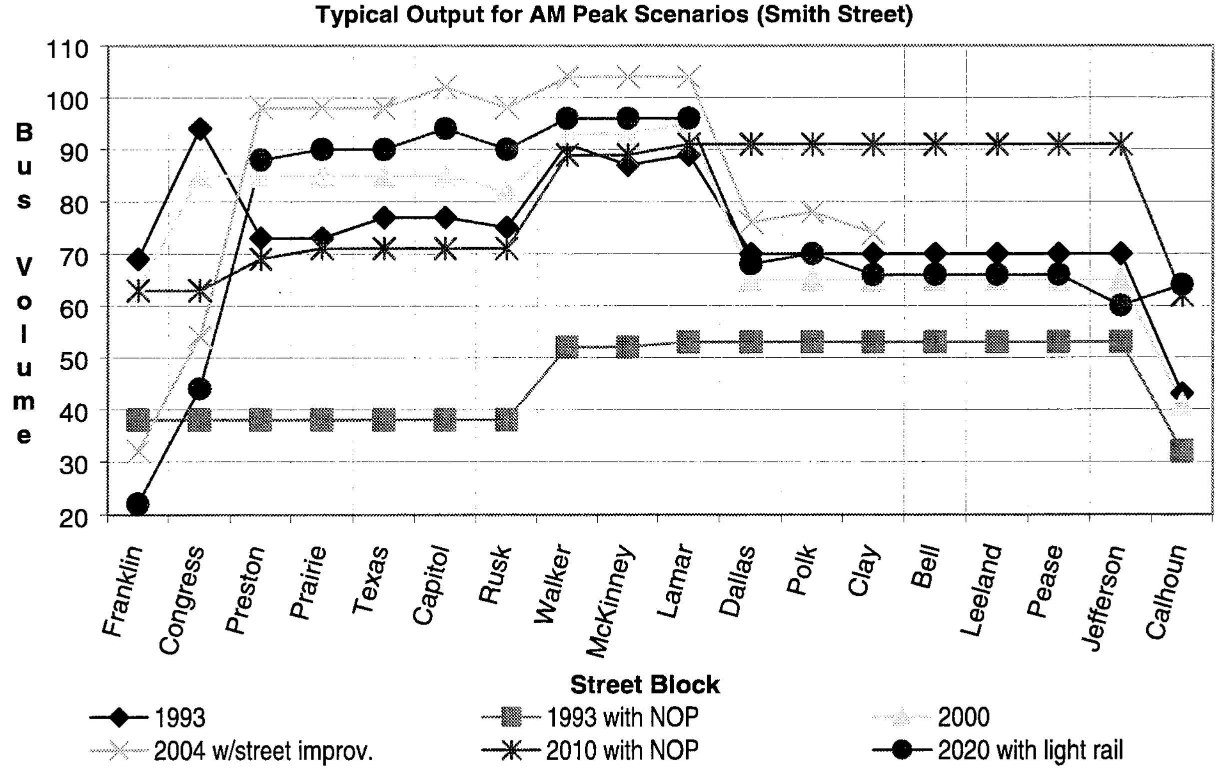
| Bus Volumes for PM Peak Conditions | | | | |
|---|---|---|---|---|
| *St. Jacinto Street* | *1993* | *2000* | *Margin of Change* | *% Reduction* |
| *Northside* | 21 | 36 | 15 | **-71.43** |
| *Central* | 30 | 40 | 10 | **-33.33** |
| *Southside* | 21 | 36 | 15 | **-71.43** |

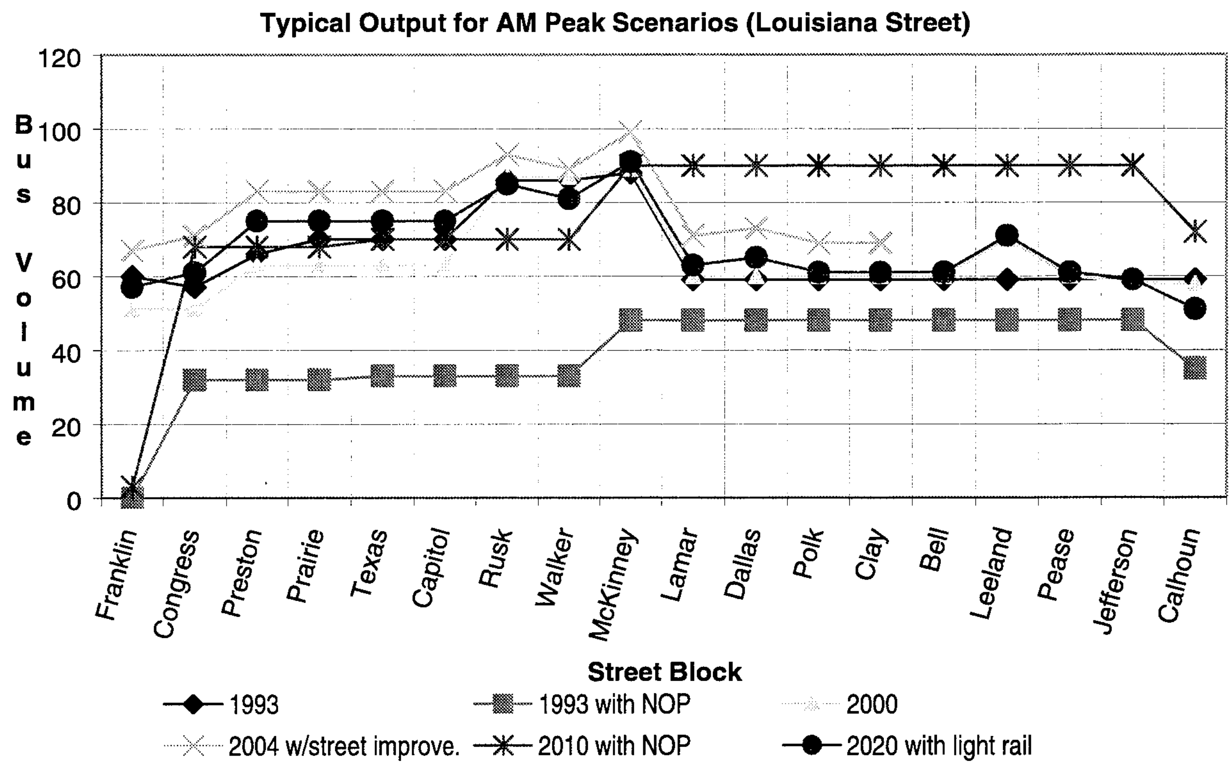

Typical Output for AM Peak Scenarios (Main Street Northbound)
Bus Volume
100
90
80
70
60
50
40
30
20
10
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 w NOP
2000
2004 w st. improve.
2010 w NOP
2020 w light rail

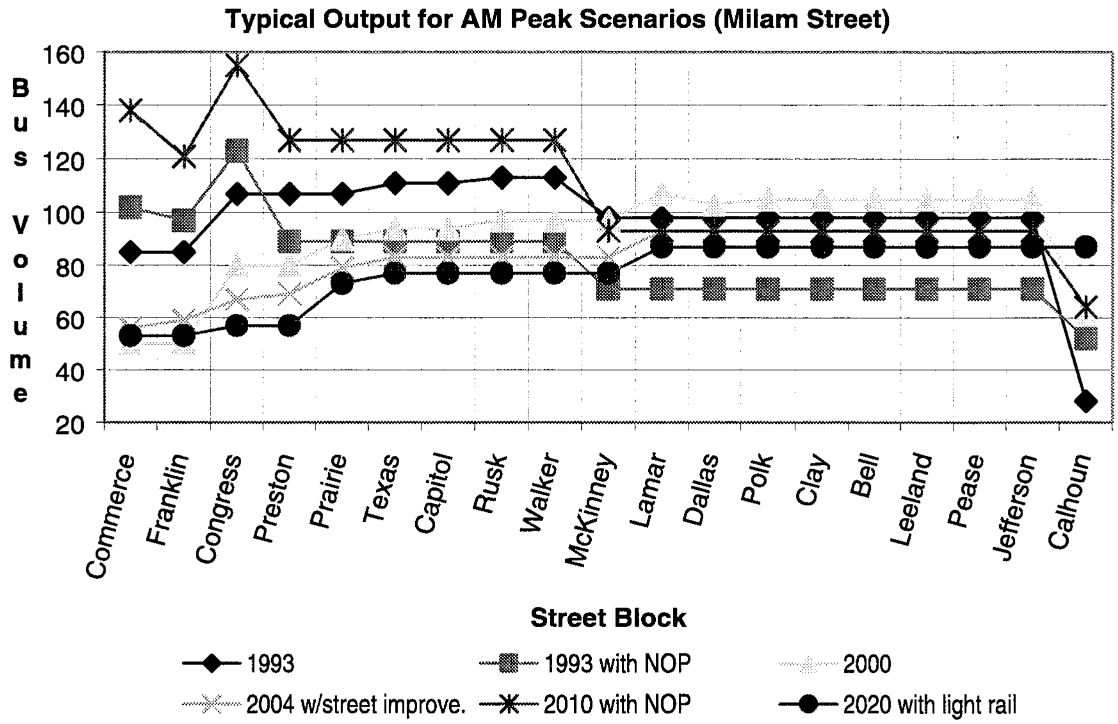

Typical Output for AM Peak Scenarios (Main Street Southbound)
Bus Volume
120
100
80
60
40
20
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 w NOP
2000
2004 w st. improve.
2010 w NOP
2020 w light rail

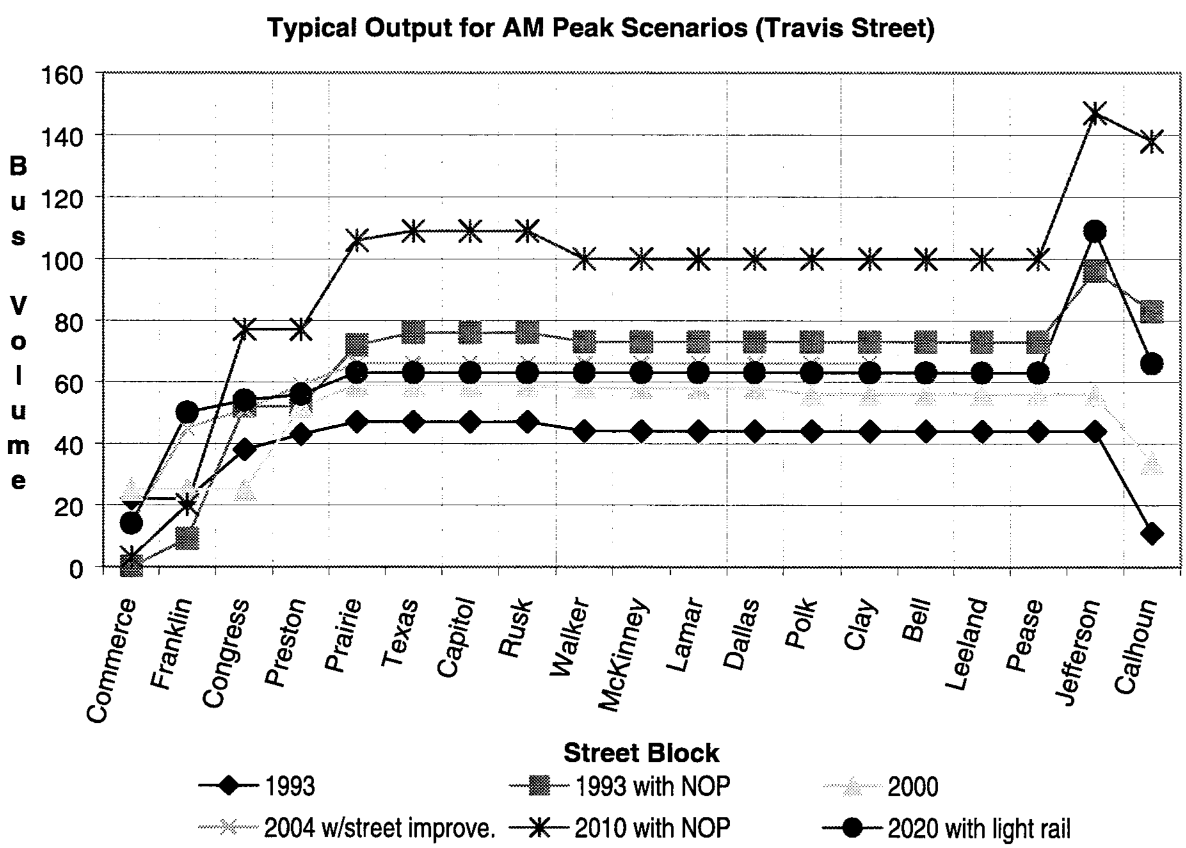

Typical Output for AM Peak Scenarios (Pierce Street)
Bus Volume
0
20
40
60
80
100
120
140
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2010 with NOP
2020 with light rail

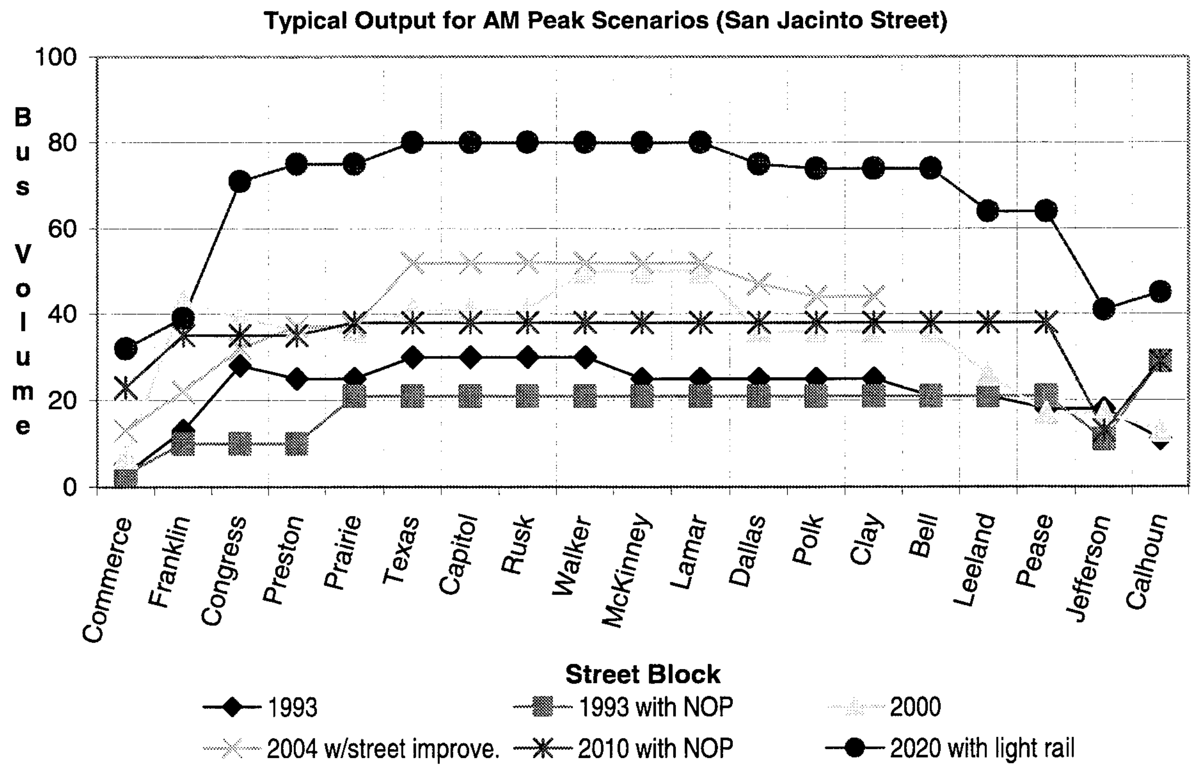

Typical Output for AM Peak Scenarios (Bagby Street)
Bus Volume
0
20
40
60
80
100
120
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Street Block
1993
1993 with NOP
2000
2004 w/street improvements
2010 with NOP
2020 with light rail

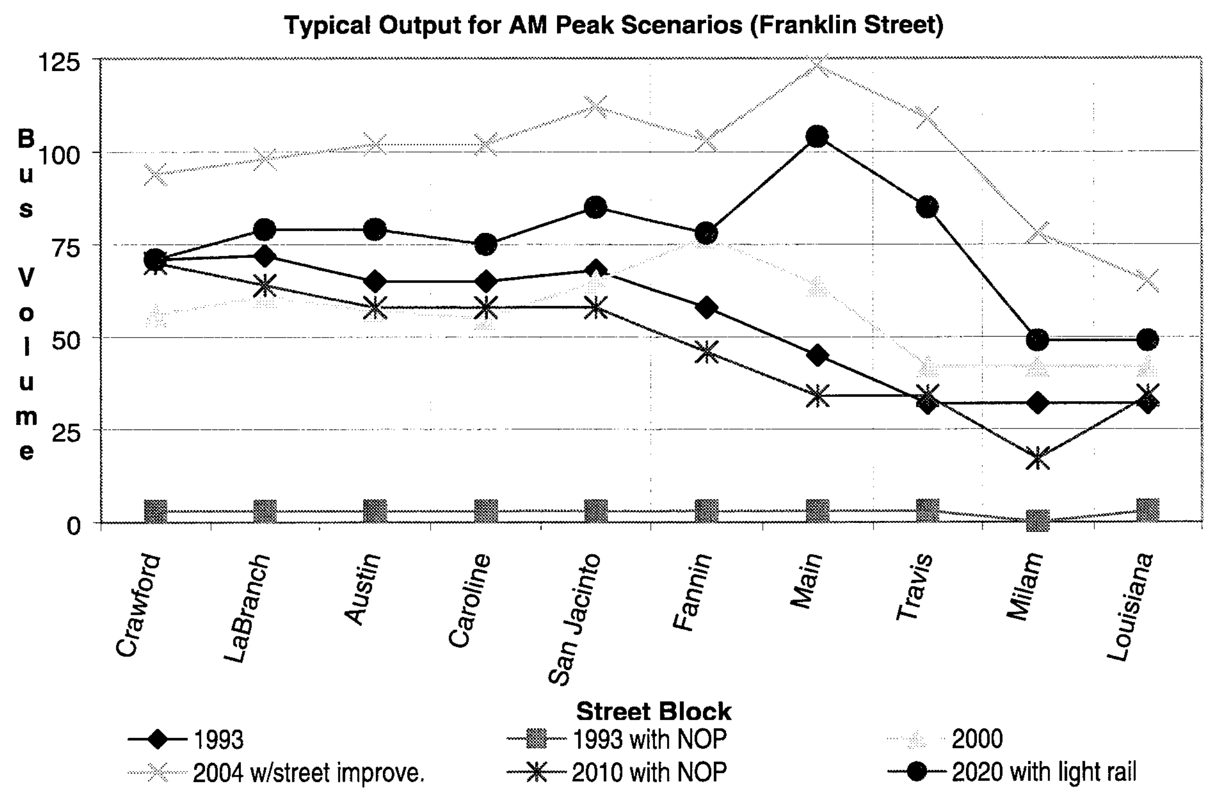

Typical Output for AM Peak Scenarios (Smith Street)
Bus Volume
110
100
90
80
70
60
50
40
30
20
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improv.
2010 with NOP
2020 with light rail

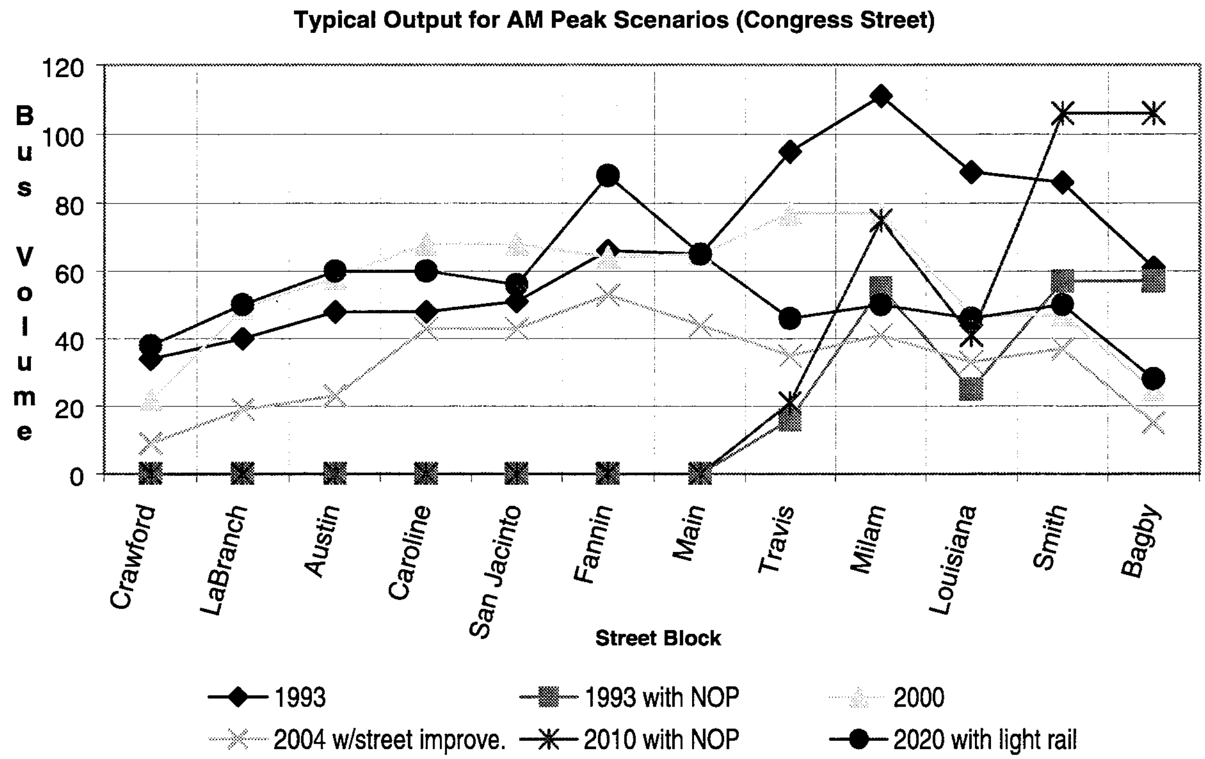

Typical Output for AM Peak Scenarios (Louisiana Street)
Bus Volume
120
100
80
60
40
20
0
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

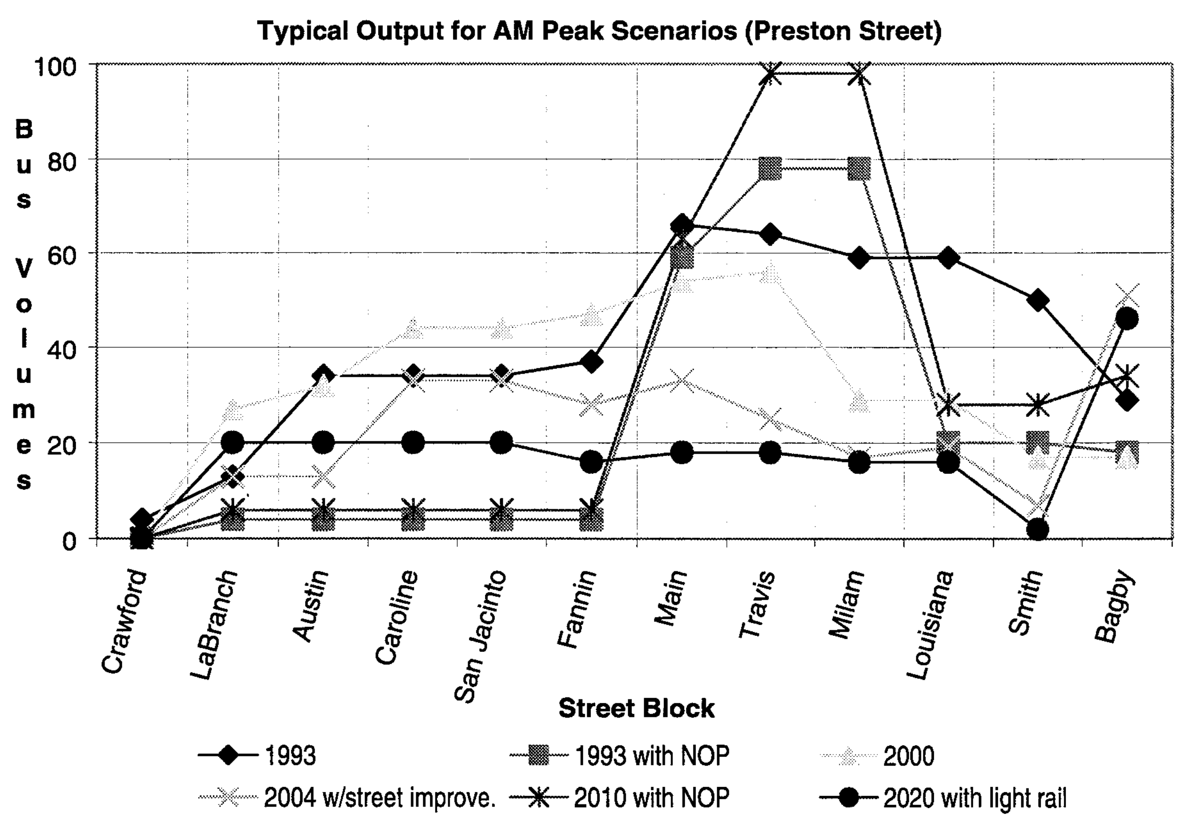

Typical Output for AM Peak Scenarios (Milam Street)
Bus Volume
160
140
120
100
80
60
40
20
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

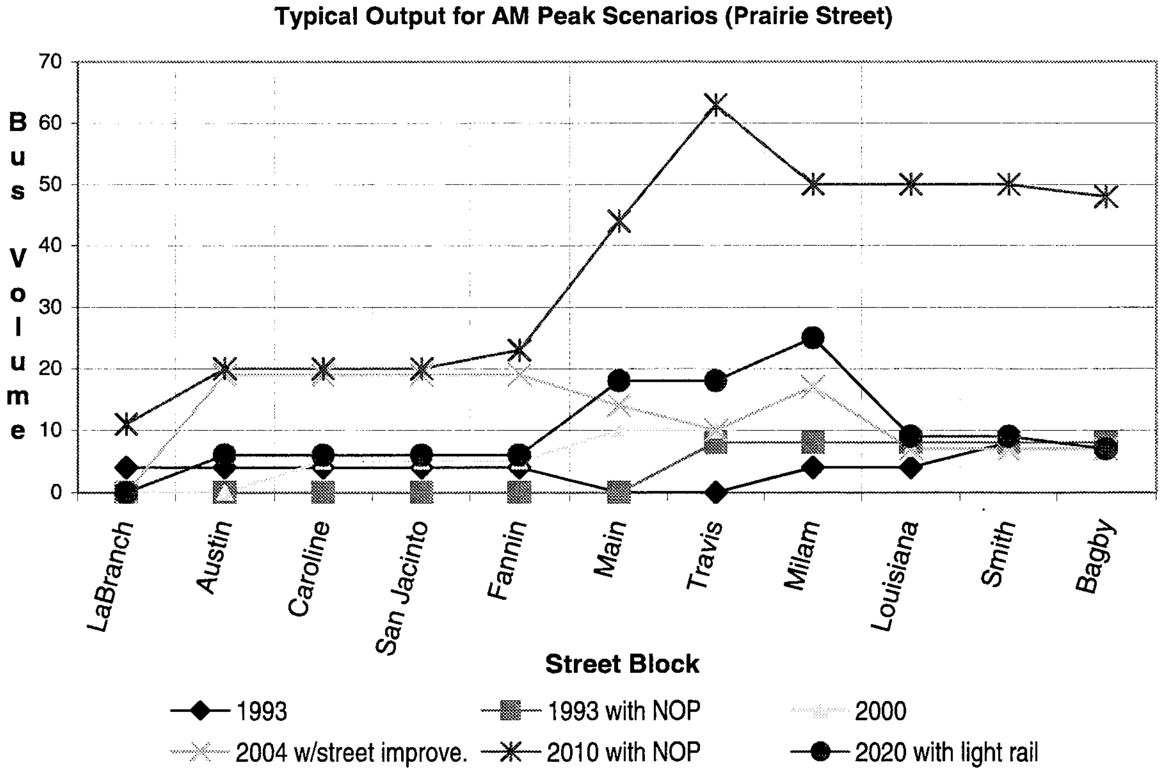

Typical Output for AM Peak Scenarios (Travis Street)
Bus Volume
160
140
120
100
80
60
40
20
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

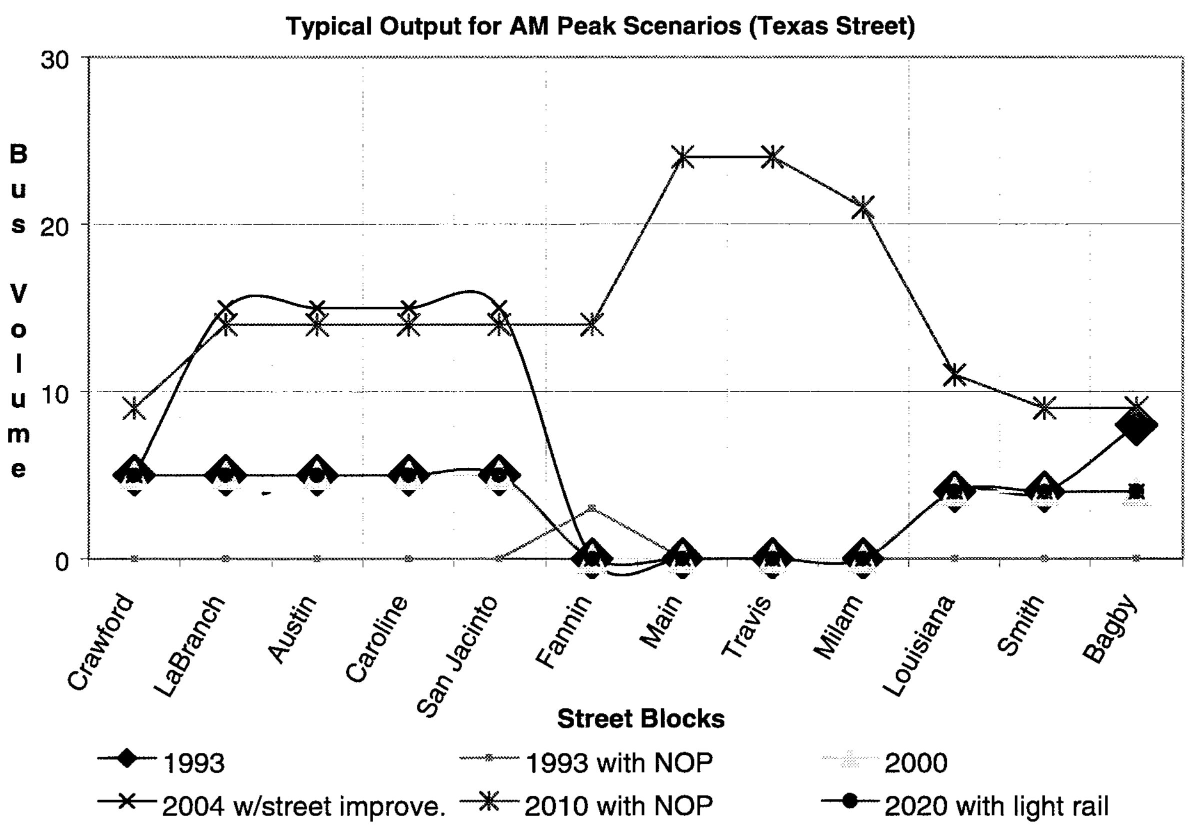

Typical Output for AM Peak Scenarios (San Jacinto Street)
Bus Volume
100
80
60
40
20
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

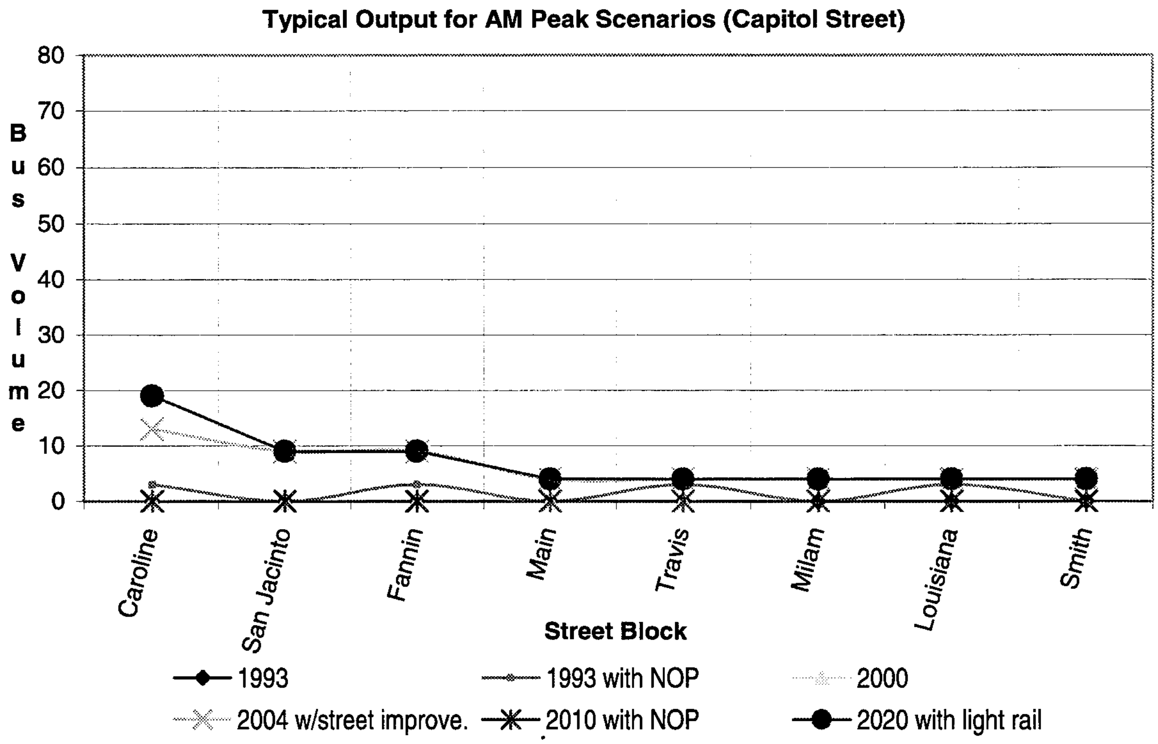

Typical Output for AM Peak Scenarios (Franklin Street)
Bus Volume
125
100
75
50
25
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

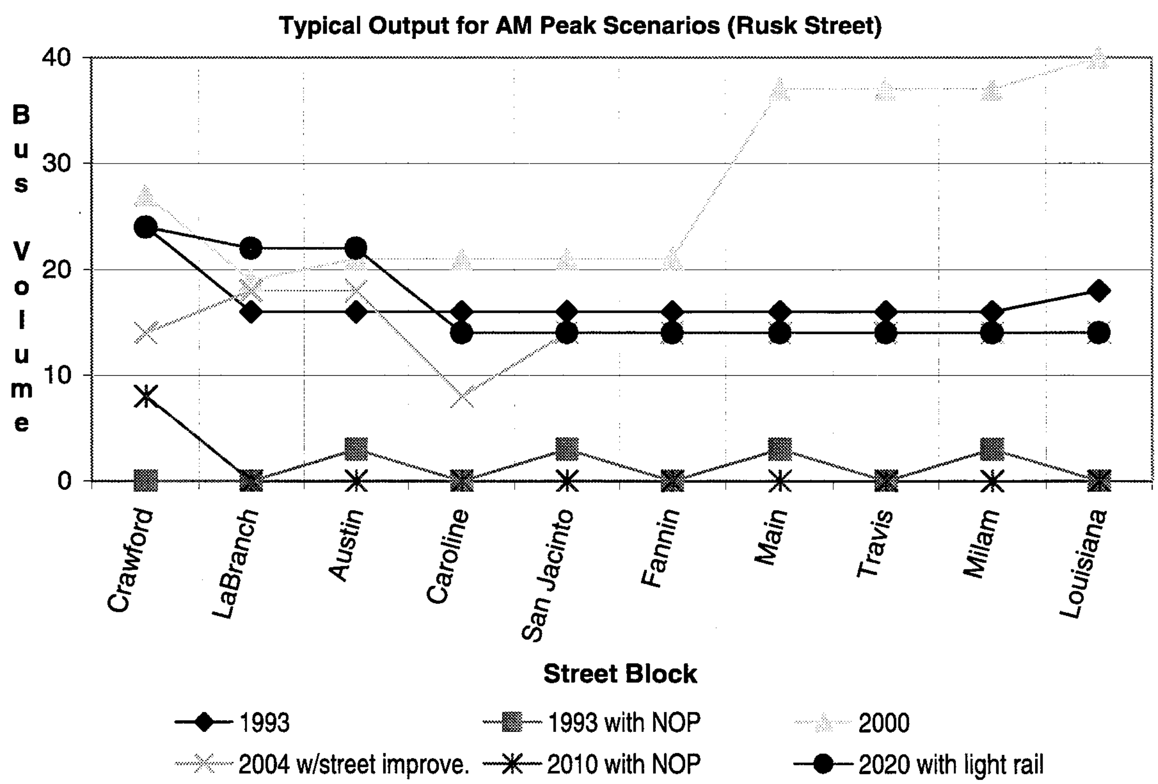

Typical Output for AM Peak Scenarios (Congress Street)
Bus Volume
120
100
80
60
40
20
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

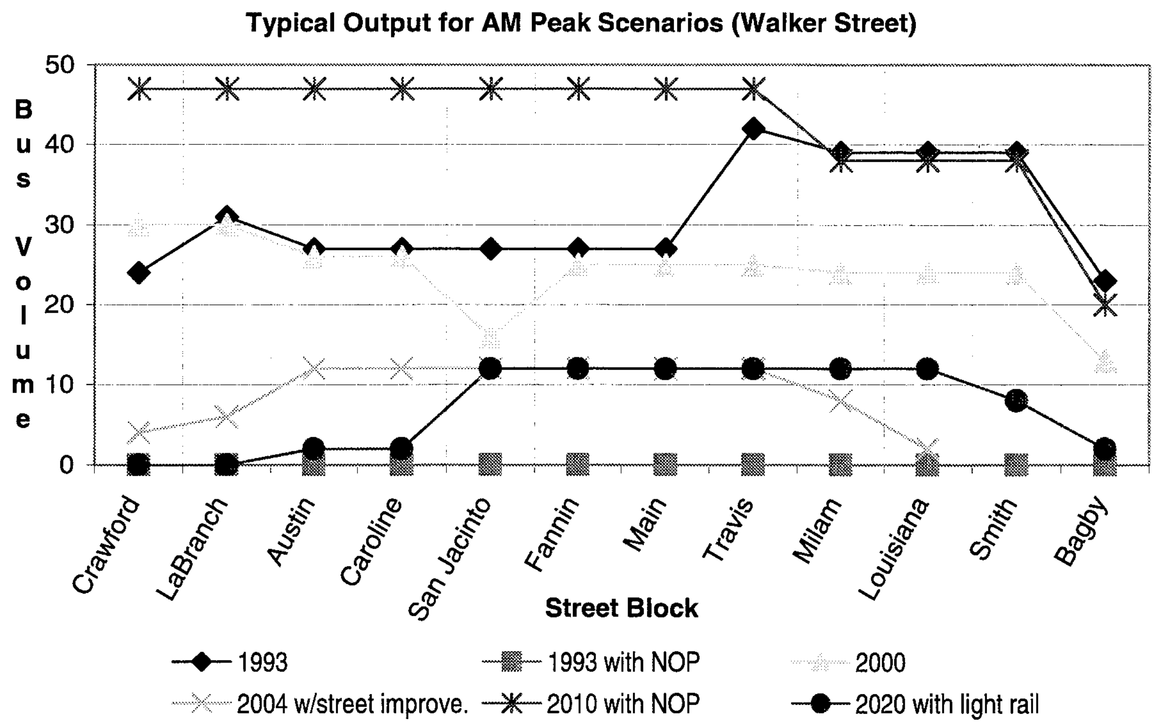

Typical Output for AM Peak Scenarios (Preston Street)
Bus Volumes
100
80
60
40
20
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

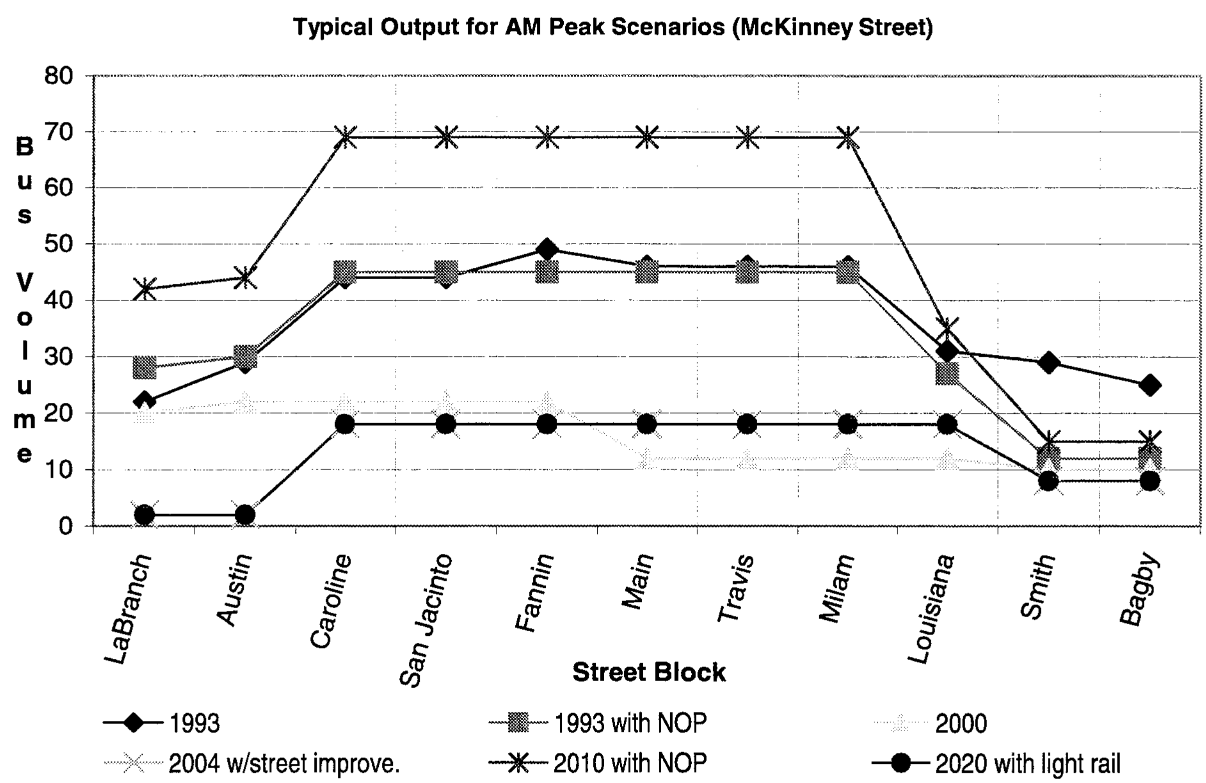

Typical Output for AM Peak Scenarios (Prairie Street)
Bus Volume
0
10
20
30
40
50
60
70
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

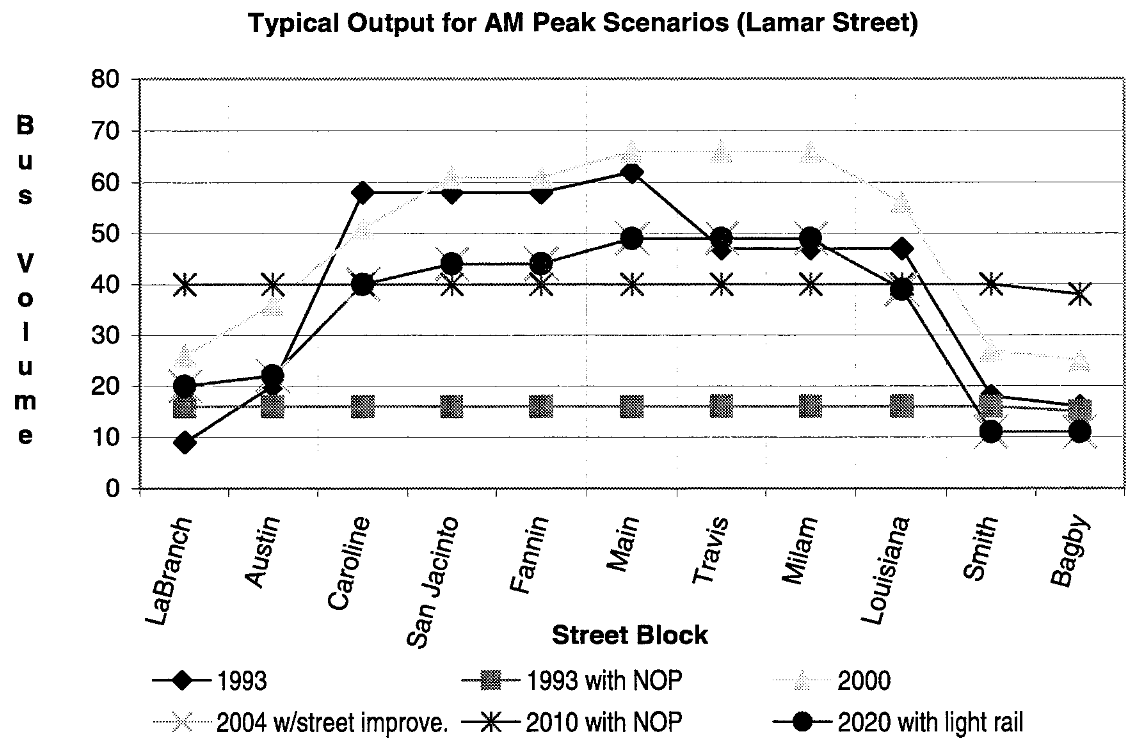

Typical Output for AM Peak Scenarios (Texas Street)
Bus Volume
0
10
20
30
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Blocks
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

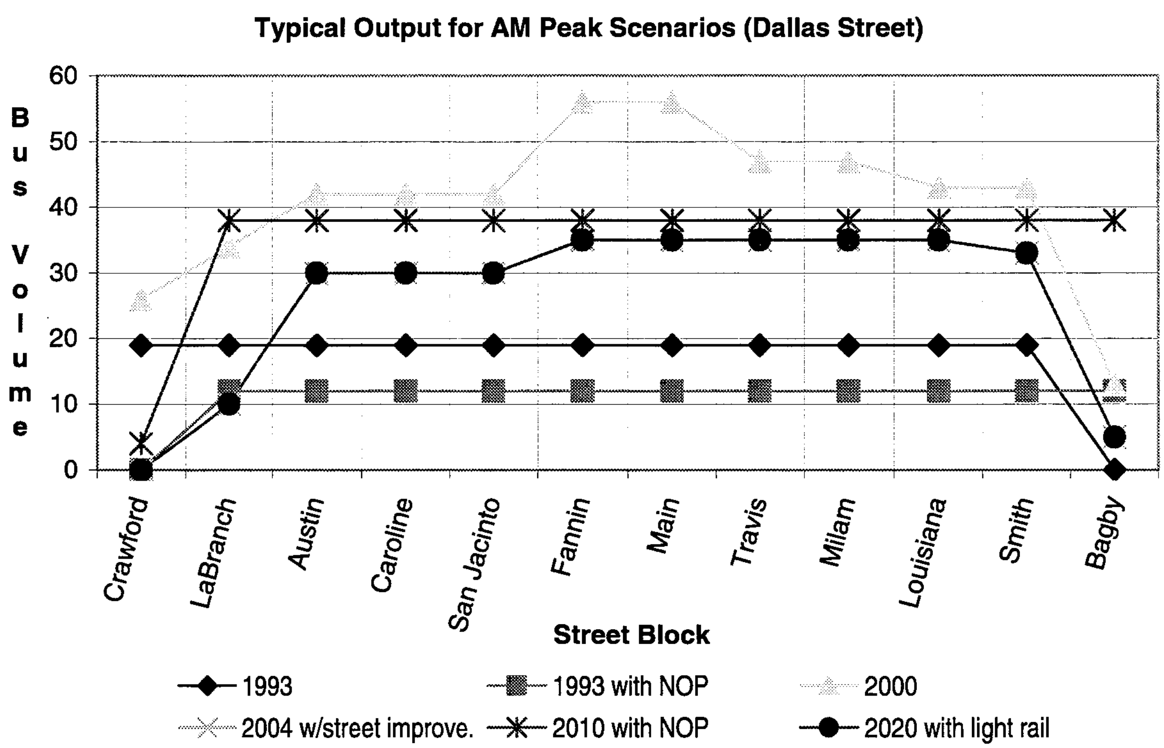

Typical Output for AM Peak Scenarios (Capitol Street)
Bus Volume
80
70
60
50
40
30
20
10
0
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

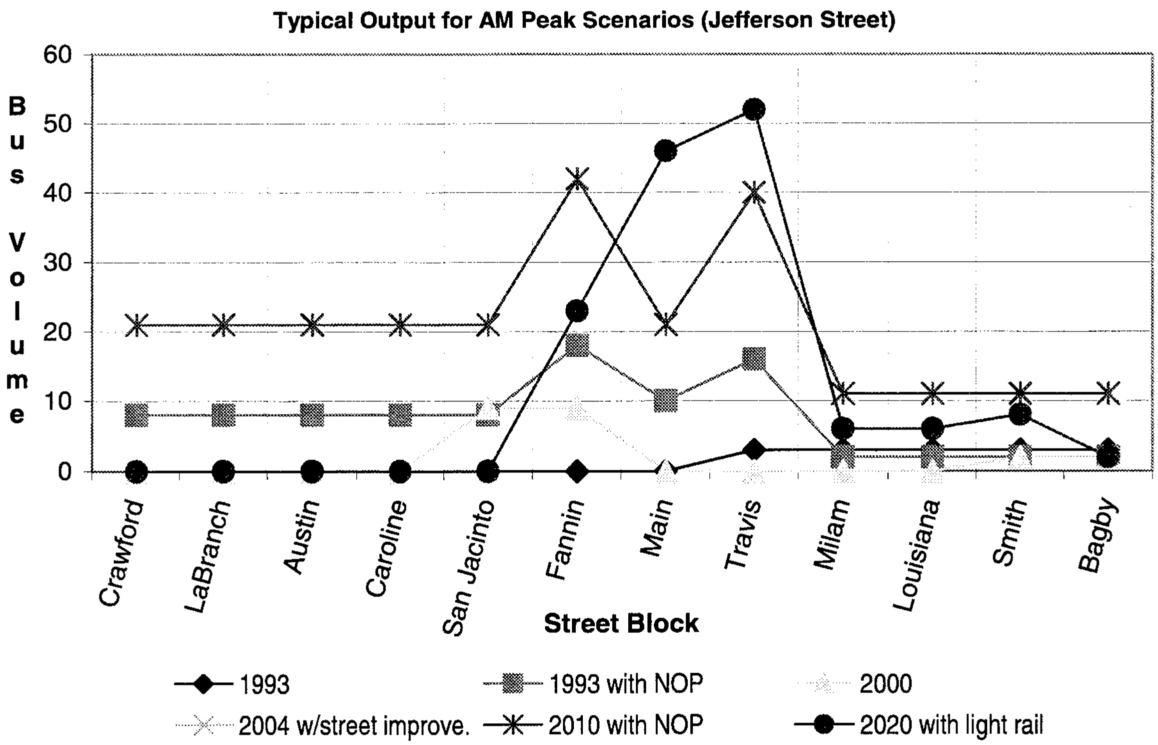

Typical Output for AM Peak Scenarios (Rusk Street)
Bus Volume
40
30
20
10
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

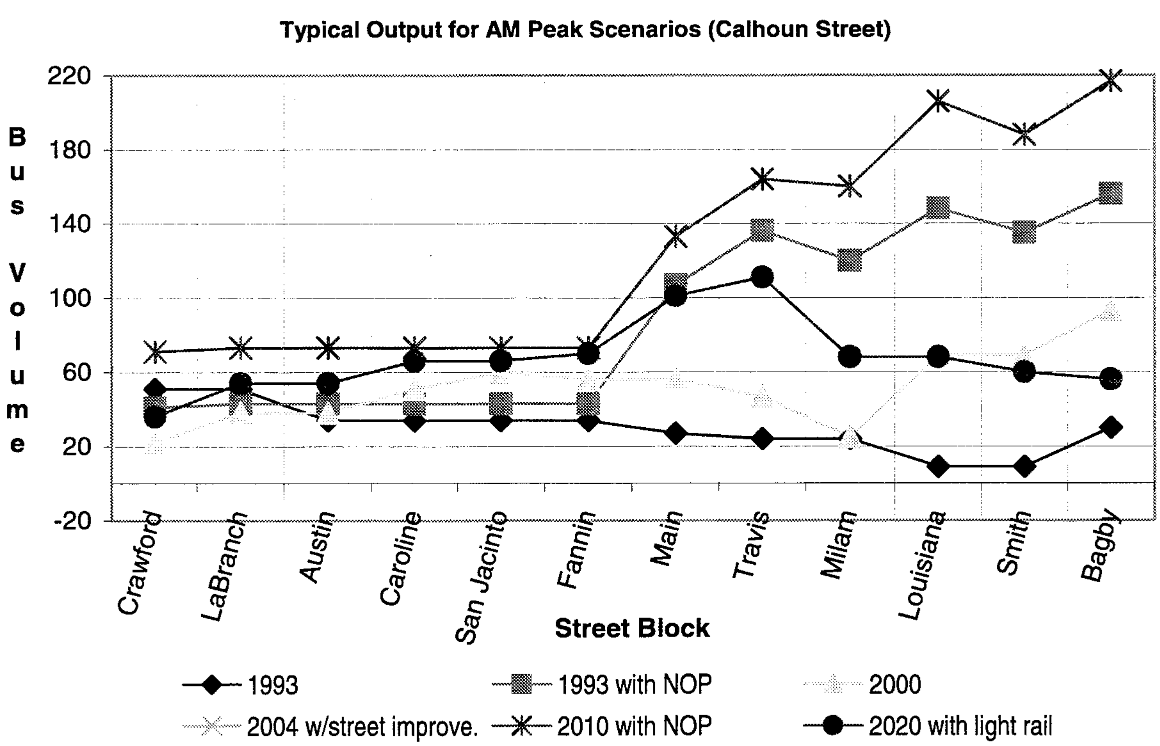

Typical Output for AM Peak Scenarios (Walker Street)
Bus Volume
0
10
20
30
40
50
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

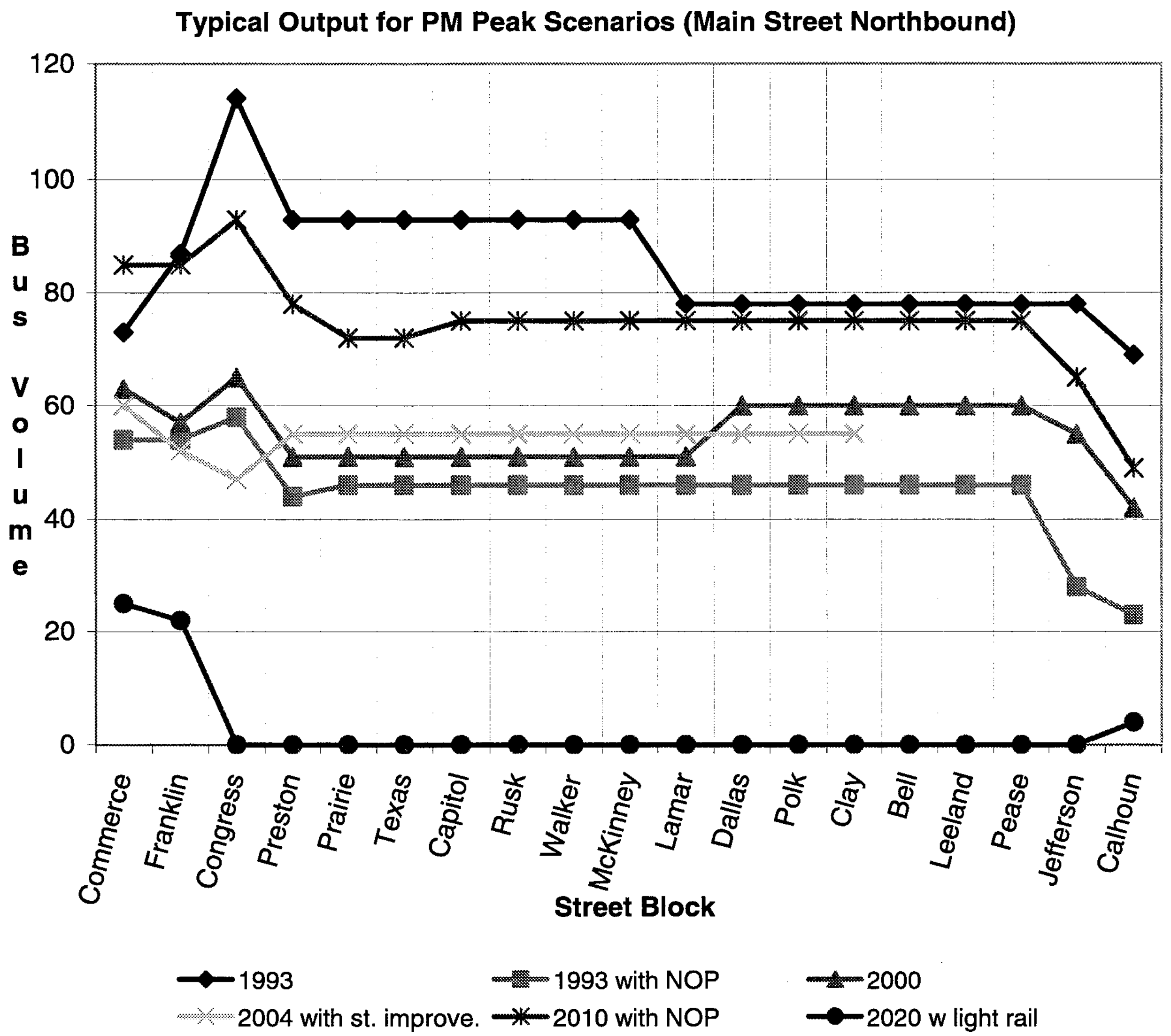

Typical Output for AM Peak Scenarios (McKinney Street)
Bus Volume
0
10
20
30
40
50
60
70
80
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail


Typical Output for AM Peak Scenarios (Lamar Street)
Bus Volume
0
10
20
30
40
50
60
70
80
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

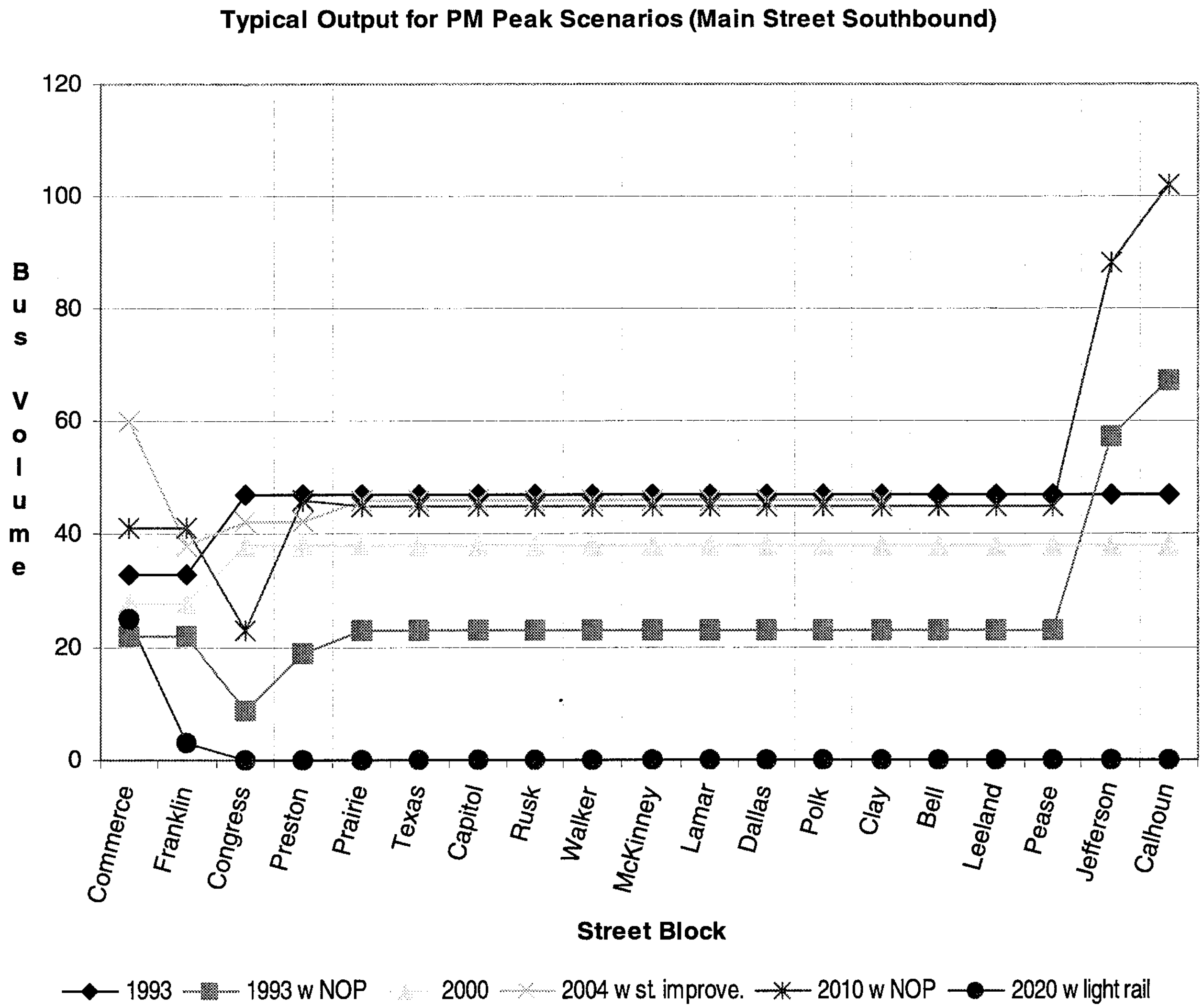

Typical Output for AM Peak Scenarios (Dallas Street)
Bus Volume
0
10
20
30
40
50
60
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

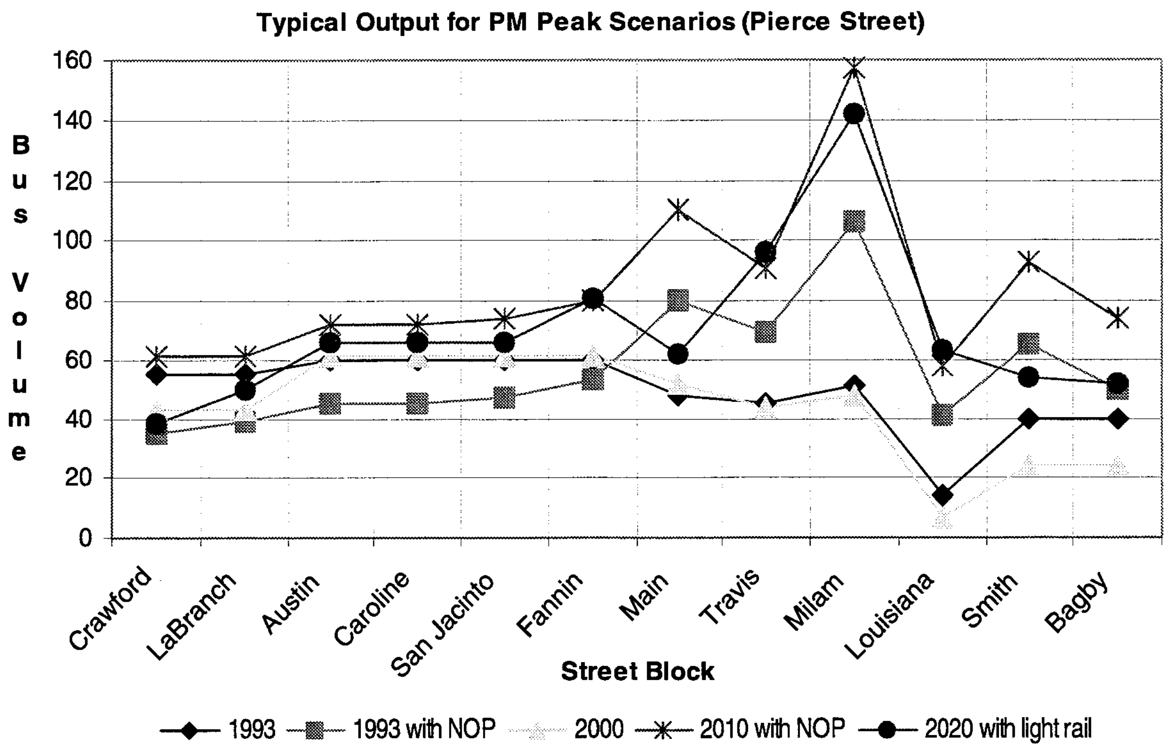

Typical Output for AM Peak Scenarios (Jefferson Street)
Bus Volume
60
50
40
30
20
10
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

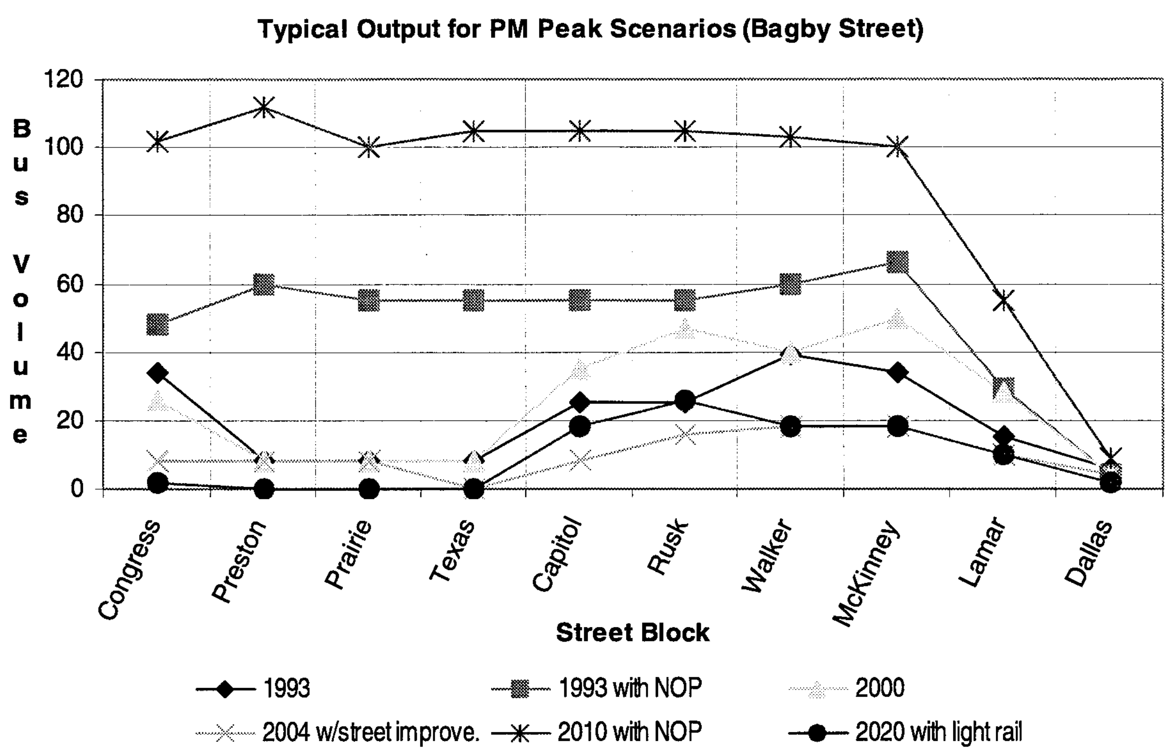

Typical Output for AM Peak Scenarios (Calhoun Street)
Bus Volume
220
180
140
100
60
20
-20
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

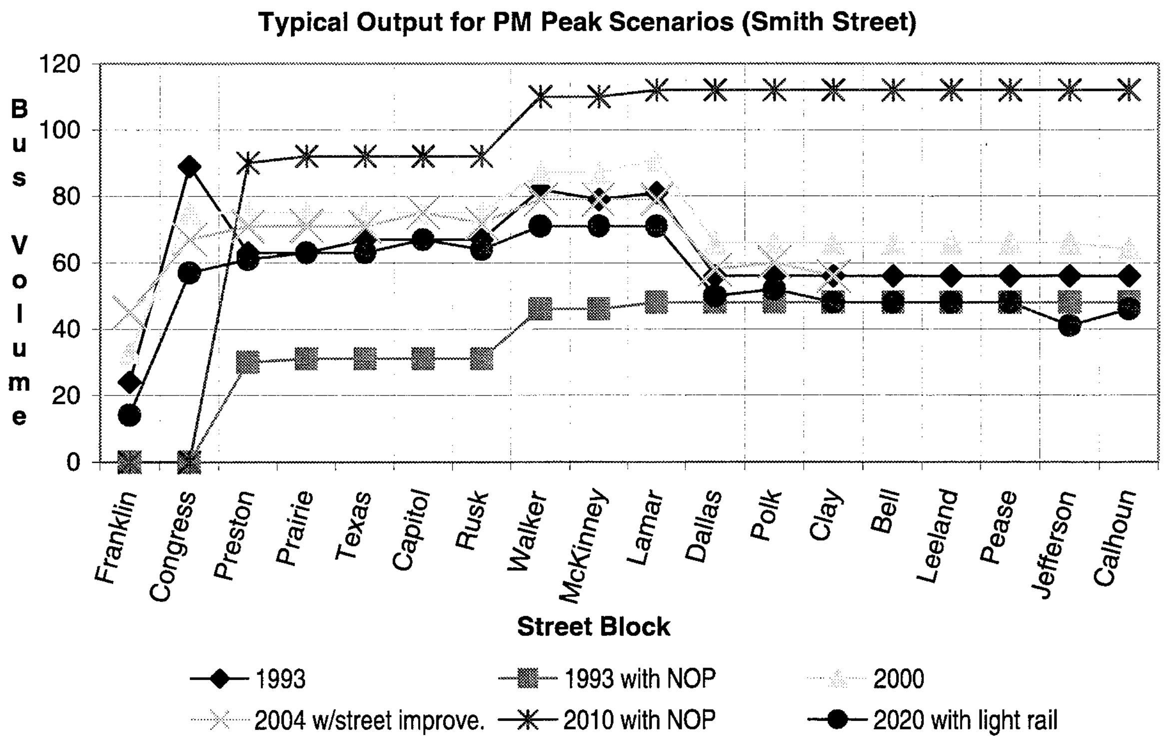


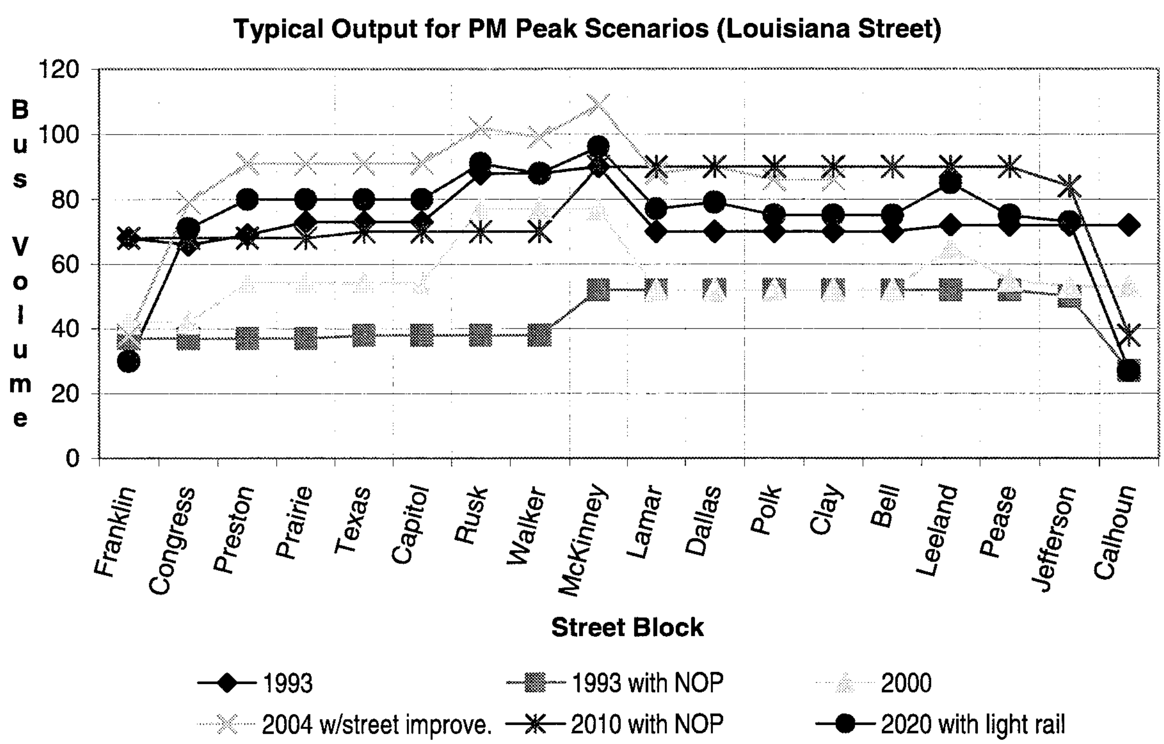
Typical Output for PM Peak Scenarios (Main Street Northbound)
Bus Volume
120
100
80
60
40
20
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 with st. improve.
2010 with NOP
2020 w light rail

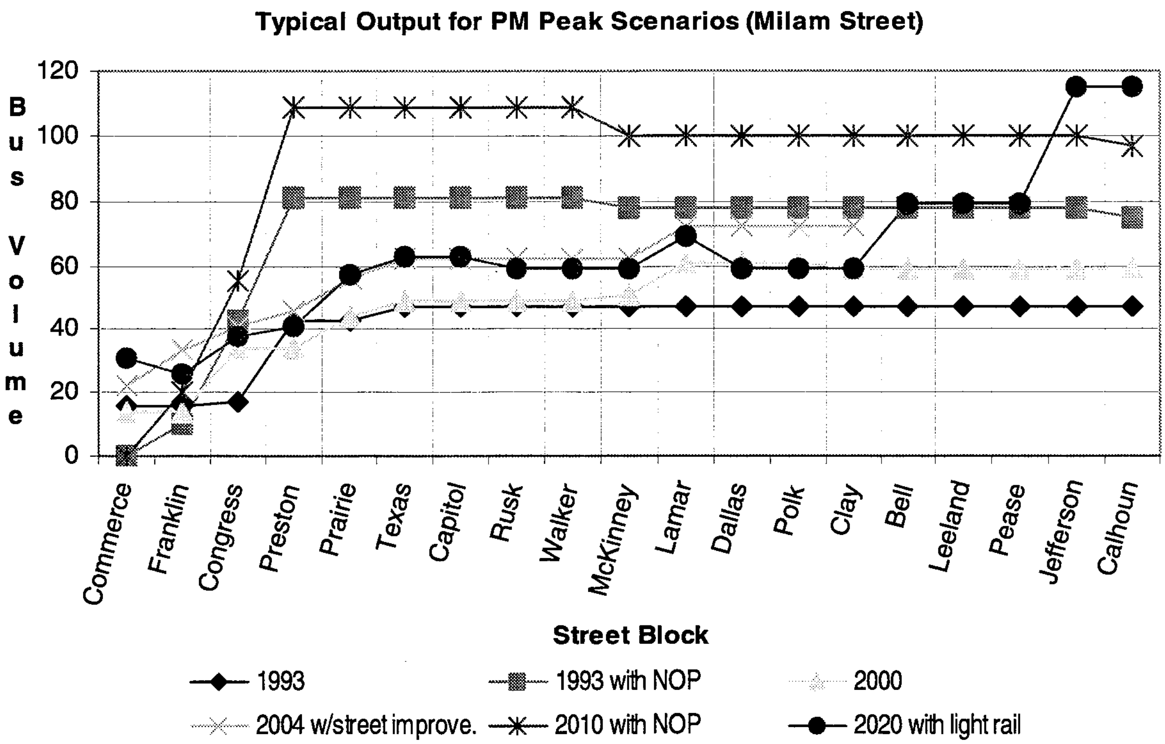

Typical Output for PM Peak Scenarios (Main Street Southbound)
Bus Volume
120
100
80
60
40
20
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 w NOP
2000
2004 w st. improve.
2010 w NOP
2020 w light rail

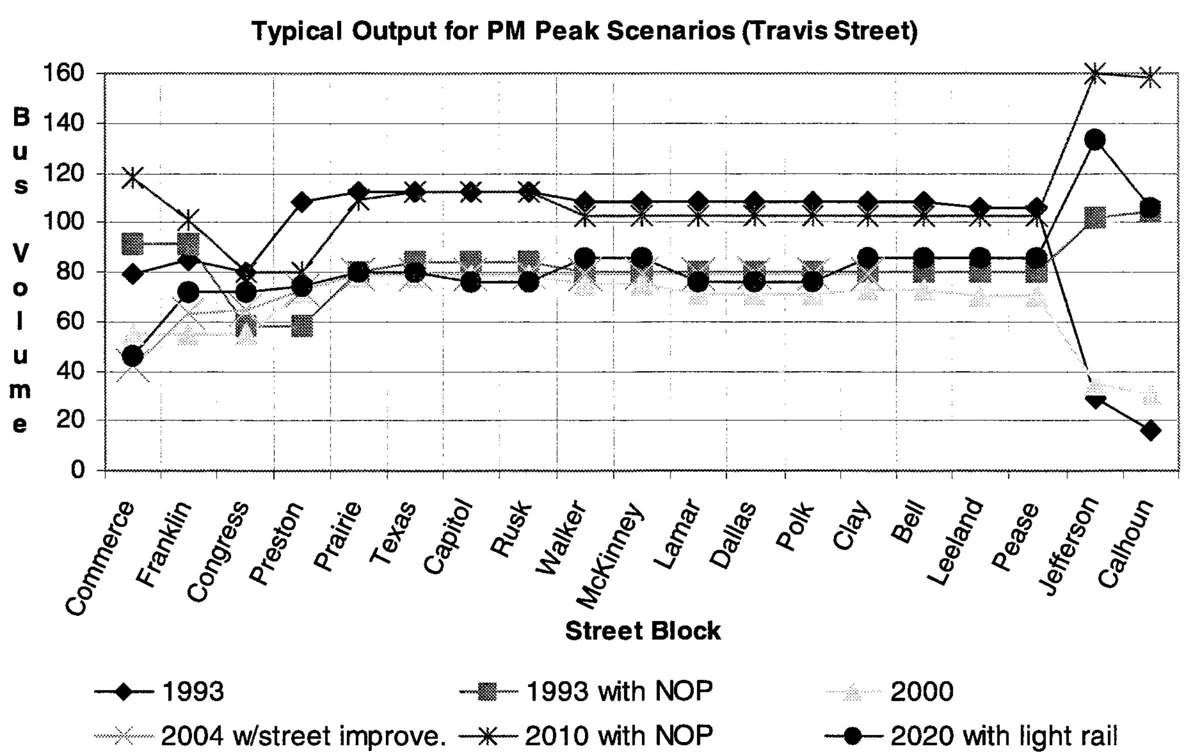

Typical Output for PM Peak Scenarios (Pierce Street)
Bus Volume
160
140
120
100
80
60
40
20
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2010 with NOP
2020 with light rail

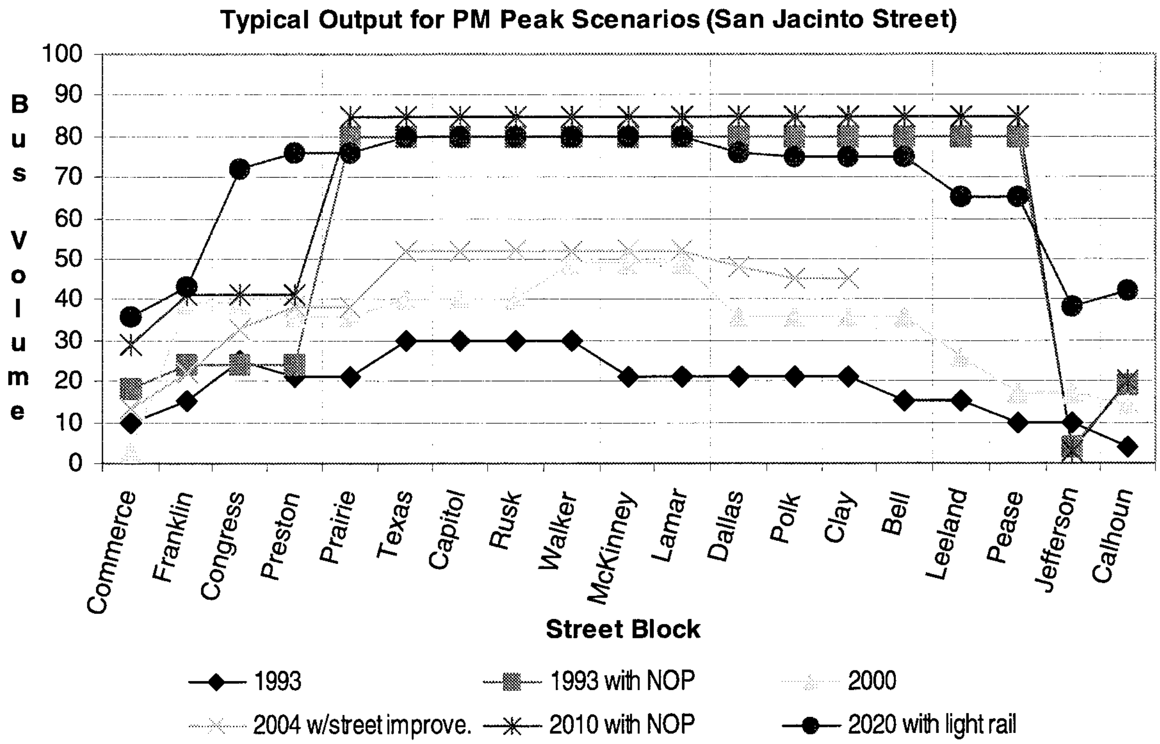

Typical Output for PM Peak Scenarios (Bagby Street)
Bus Volume
120
100
80
60
40
20
0
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

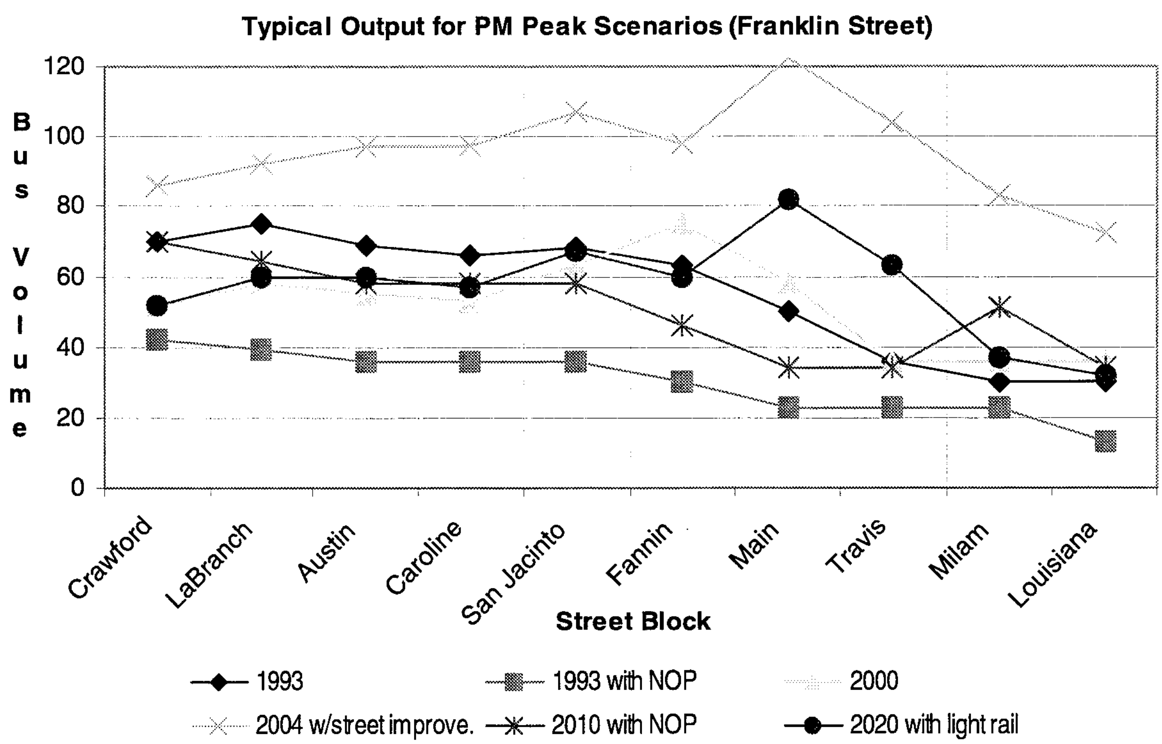

Typical Output for PM Peak Scenarios (Smith Street)
Bus Volume
120
100
80
60
40
20
0
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

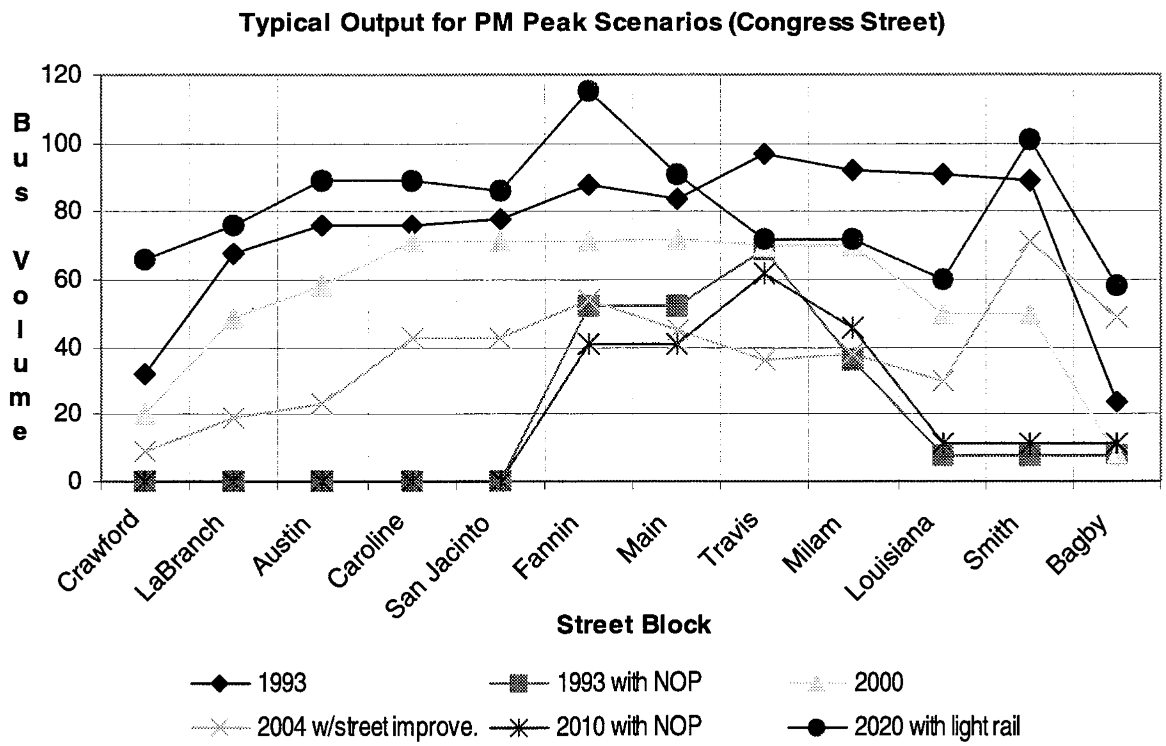

Typical Output for PM Peak Scenarios (Louisiana Street)
Bus Volume
120
100
80
60
40
20
0
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

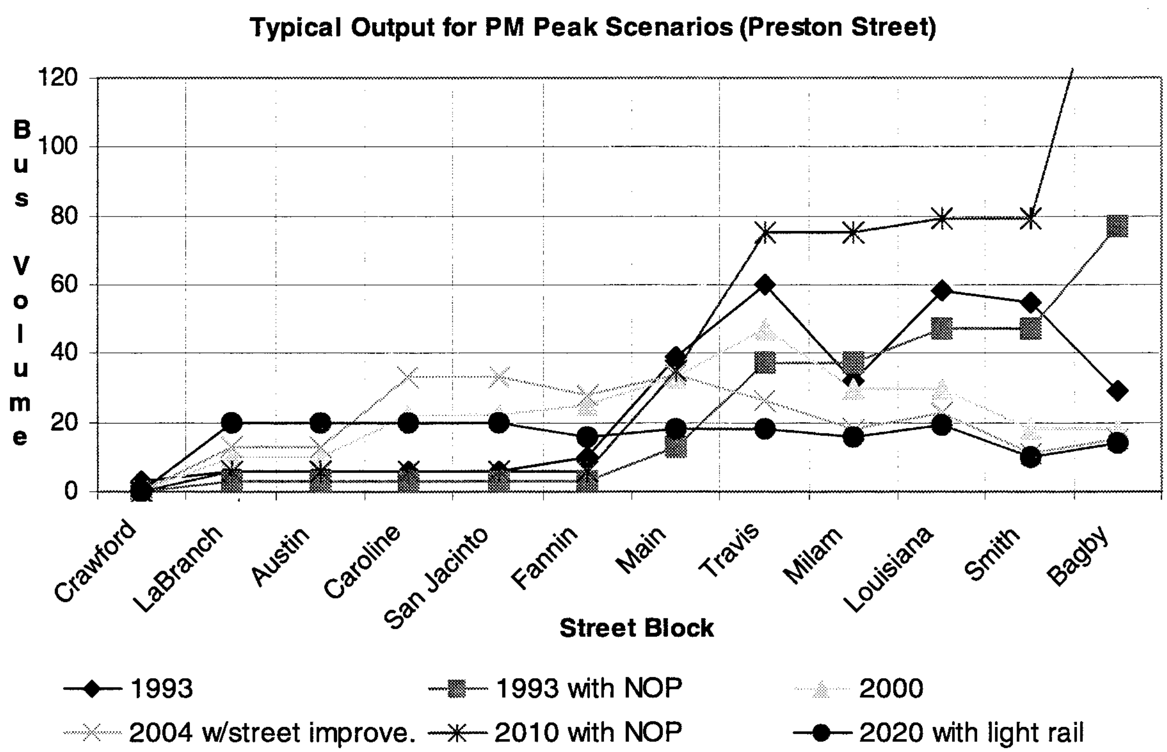

Typical Output for PM Peak Scenarios (Milam Street)
Bus Volume
0
20
40
60
80
100
120
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

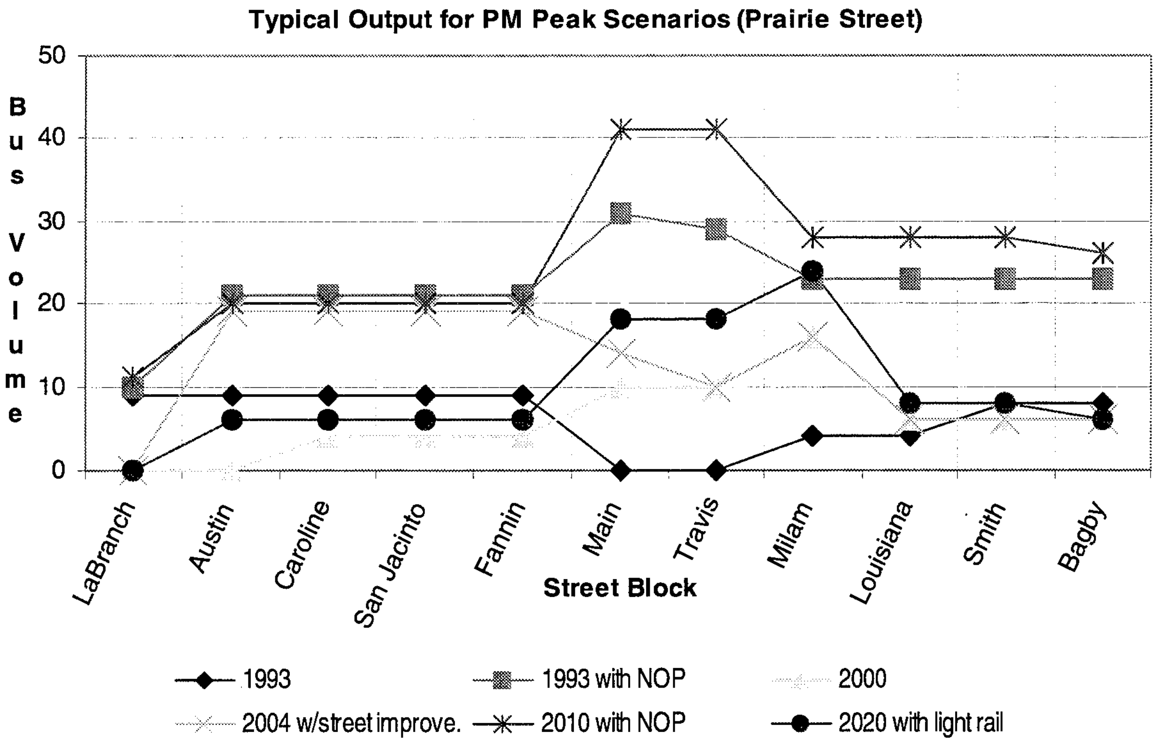

Typical Output for PM Peak Scenarios (Travis Street)
Bus Volume
0
20
40
60
80
100
120
140
160
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

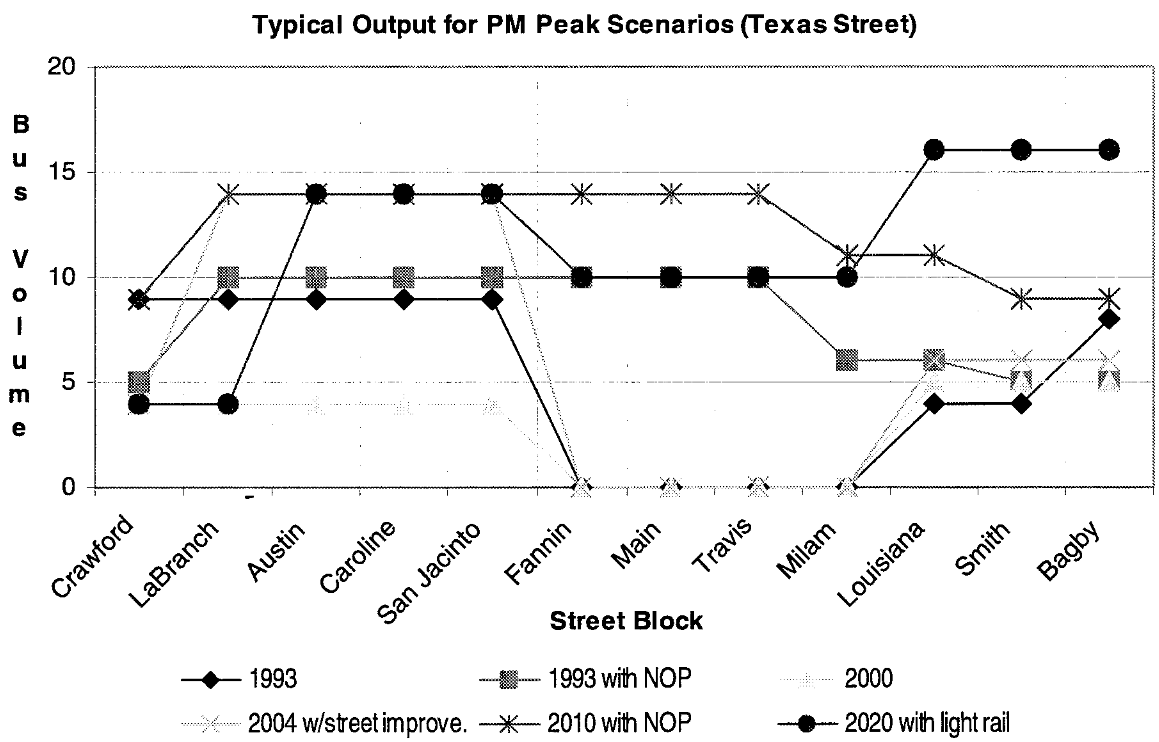

Typical Output for PM Peak Scenarios (San Jacinto Street)
Bus Volume
100
90
80
70
60
50
40
30
20
10
0
Commerce
Franklin
Congress
Preston
Prairie
Texas
Capitol
Rusk
Walker
McKinney
Lamar
Dallas
Polk
Clay
Bell
Leeland
Pease
Jefferson
Calhoun
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

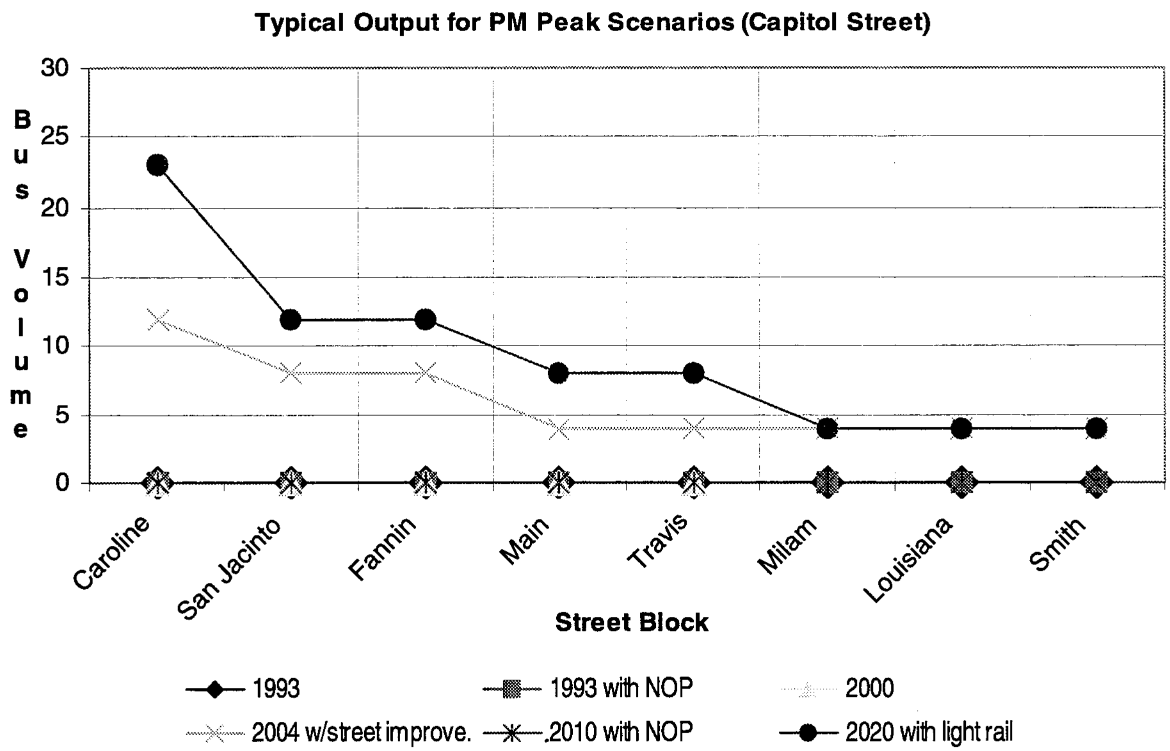

Typical Output for PM Peak Scenarios (Franklin Street)
Bus Volume
120
100
80
60
40
20
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

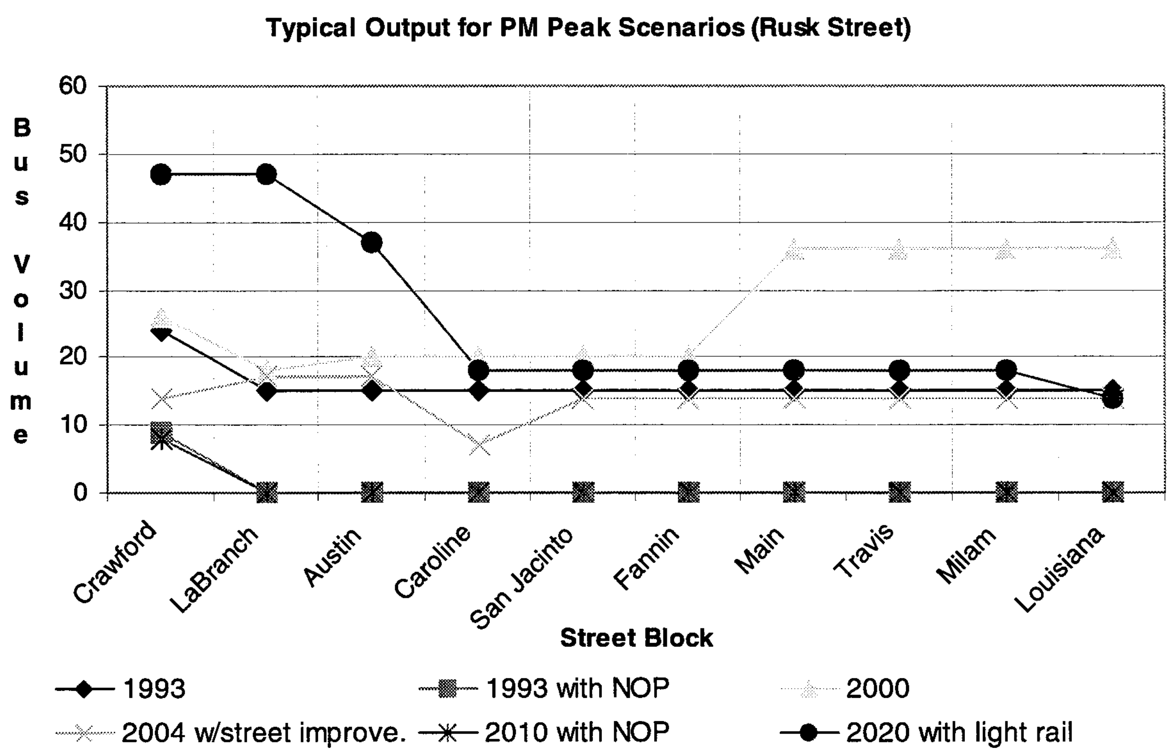

Typical Output for PM Peak Scenarios (Congress Street)
Bus Volume
120
100
80
60
40
20
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

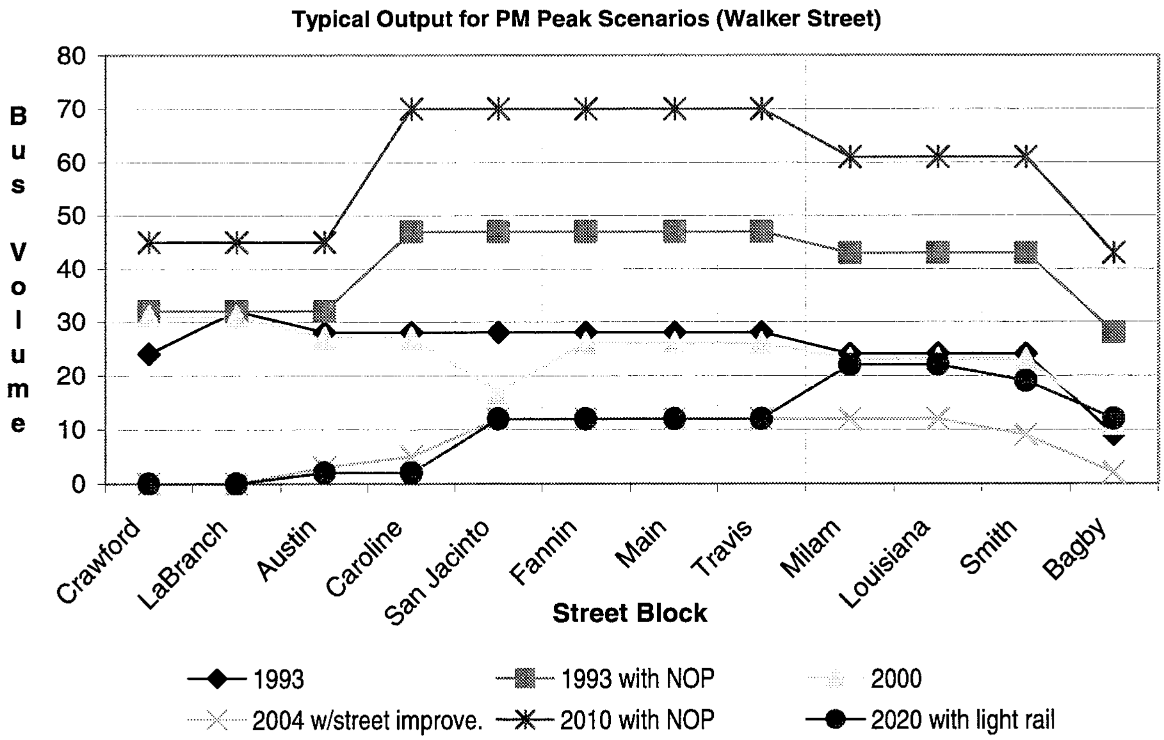

Typical Output for PM Peak Scenarios (Preston Street)
Bus Volume
120
100
80
60
40
20
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

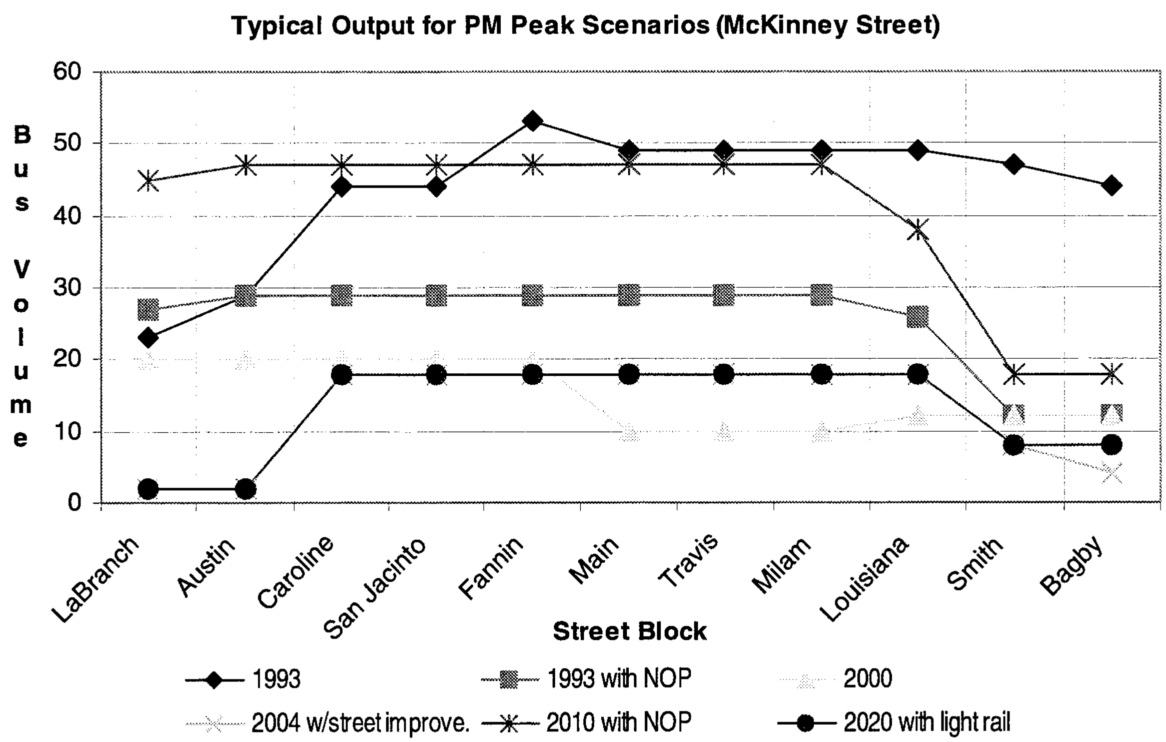

Typical Output for PM Peak Scenarios (Prairie Street)
Bus Volume
0
10
20
30
40
50
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

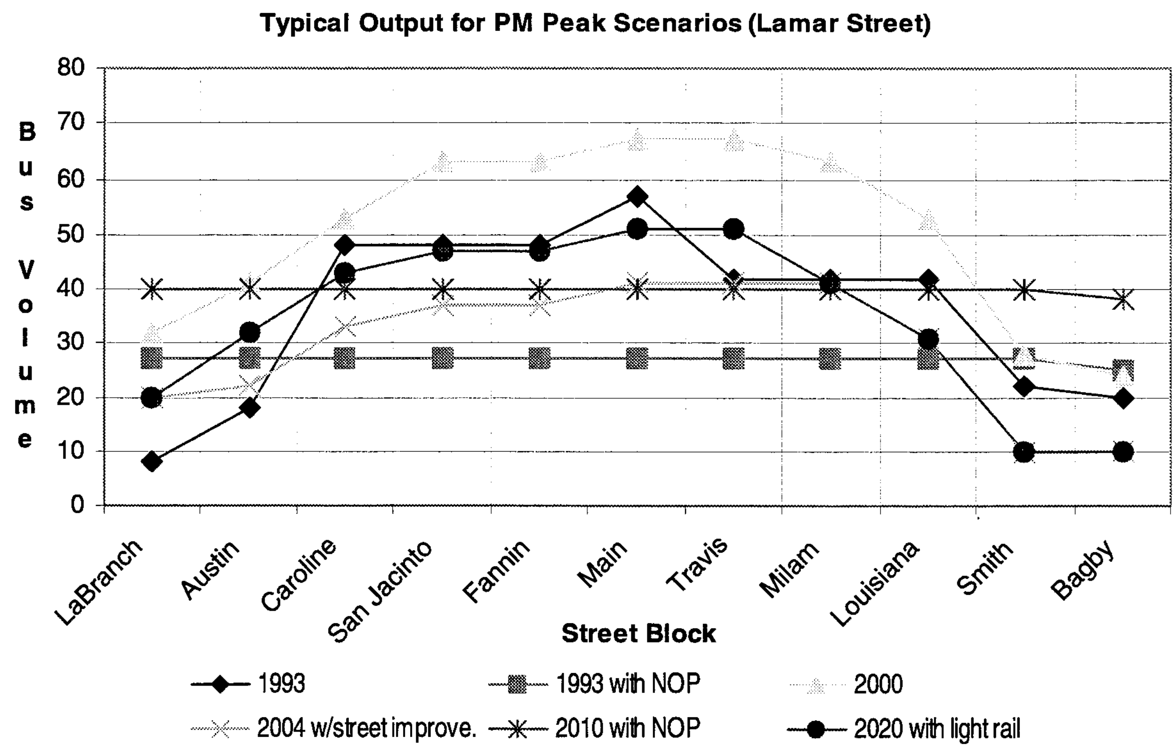

Typical Output for PM Peak Scenarios (Texas Street)
Bus Volume
0
5
10
15
20
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail


Typical Output for PM Peak Scenarios (Capitol Street)
Bus Volume
30
25
20
15
10
5
0
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
.2010 with NOP
2020 with light rail

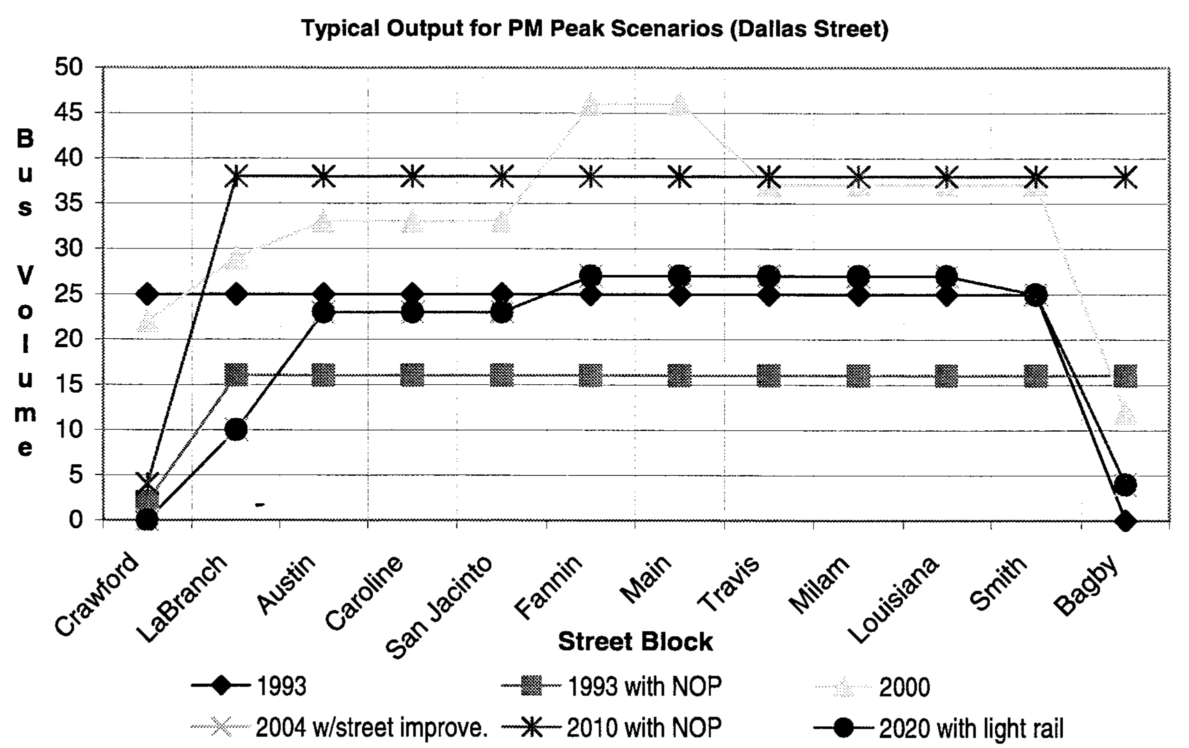

Typical Output for PM Peak Scenarios (Rusk Street)
Bus Volume
60
50
40
30
20
10
0
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail


Typical Output for PM Peak Scenarios (Walker Street)
Bus Volume
0
10
20
30
40
50
60
70
80
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

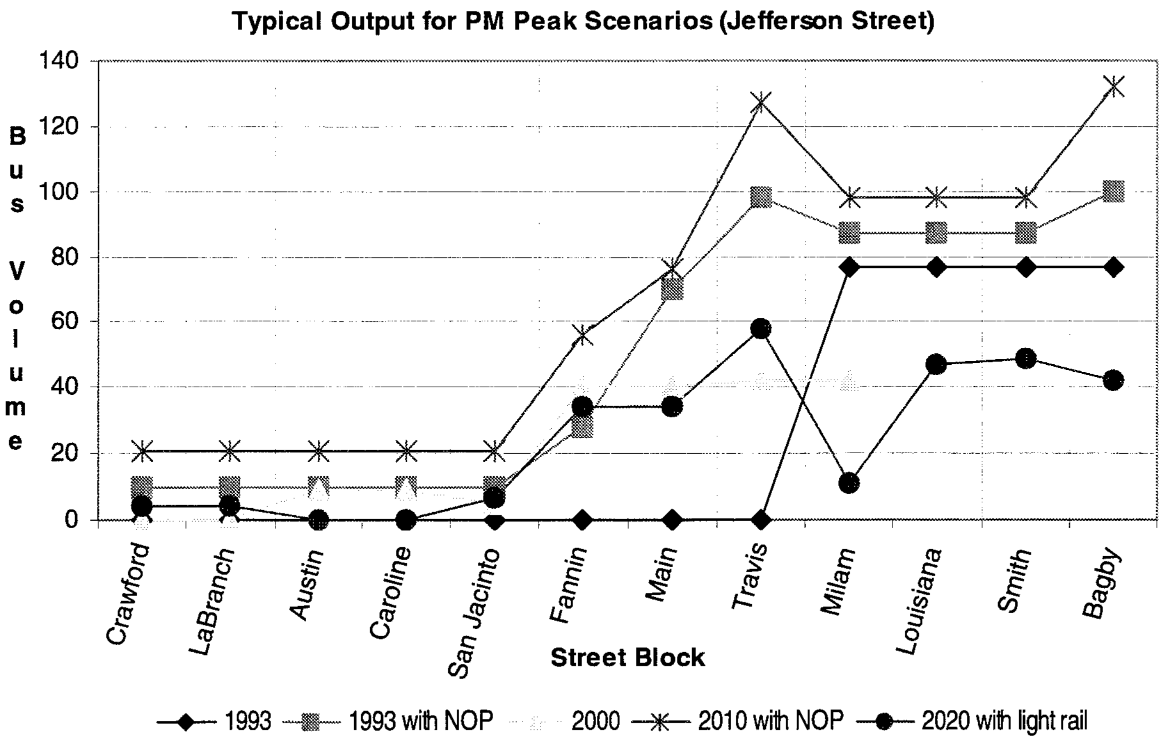

Typical Output for PM Peak Scenarios (McKinney Street)
Bus Volume
0
10
20
30
40
50
60
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

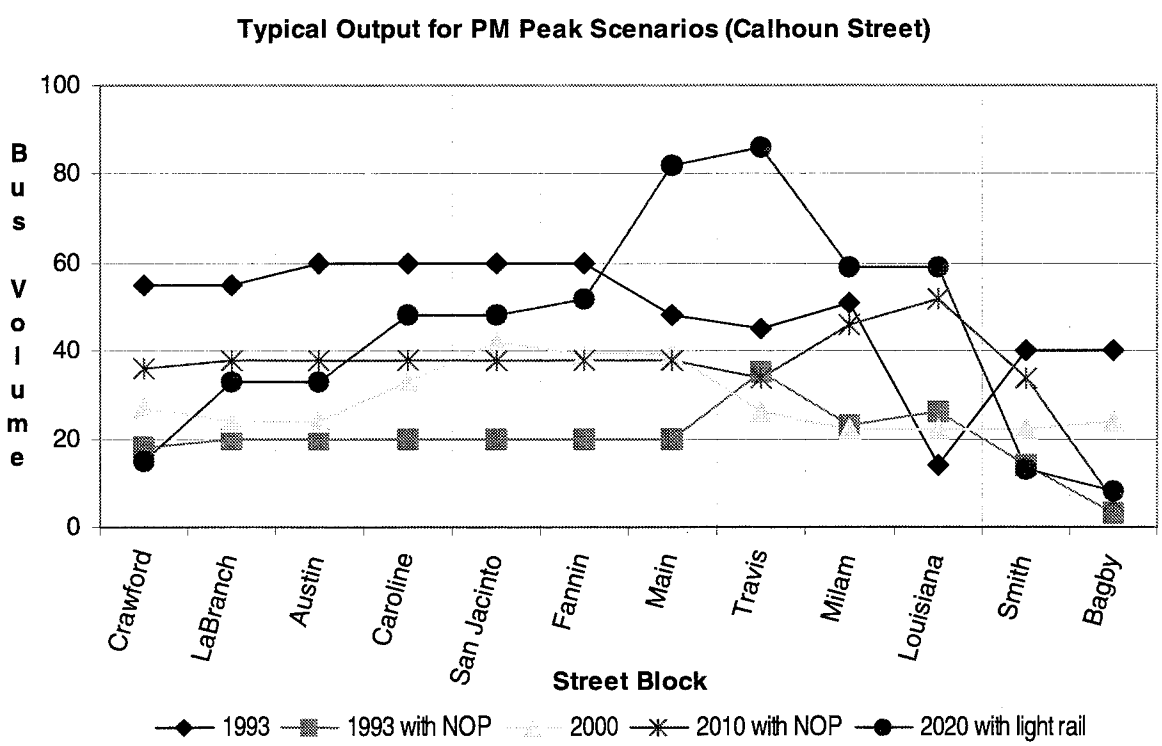


Typical Output for PM Peak Scenarios (Lamar Street)
80
70
60
50
40
30
20
10
0
Bus Volume
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail

Typical Output for PM Peak Scenarios (Dallas Street)
50
45
40
35
30
25
20
15
10
5
0
Bus Volume
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2004 w/street improve.
2010 with NOP
2020 with light rail


Typical Output for PM Peak Scenarios (Jefferson Street)
Bus Volume
0
20
40
60
80
100
120
140
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2010 with NOP
2020 with light rail


Typical Output for PM Peak Scenarios (Calhoun Street)
Bus Volume
0
20
40
60
80
100
Crawford
LaBranch
Austin
Caroline
San Jacinto
Fannin
Main
Travis
Milam
Louisiana
Smith
Bagby
Street Block
1993
1993 with NOP
2000
2010 with NOP
2020 with light rail