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16. Abstract

Vehicular traffic moving through rural sections of Interstate 35 in Texas is growing at a dramatic rate. For example, in the rural areas between San Antonio and Dallas, traffic grew between 4 and 8 percent annually between 1983 and 1992. Some rural sections exhibited traffic growth rates as high as 10 percent between 1970 and 1993. And as traffic grows, so does travel time — an inevitable consequence of congestion. Thus, a trip from San Antonio to Dallas, which took approximately 4.5 hours in 1972, will require 8 hours by the year 2006, given a modest 4 percent traffic growth annually. Other disturbing, congestion-related consequences include rising pollution levels and greater operating costs for passenger cars and trucks, not to mention more accidents. If the problems associated with increasing traffic demand in the state are not resolved, Texans can expect higher costs of living and greater losses in productivity.

The primary objective of this report is to demonstrate the future loss of personal mobility by the highway user on rural sections of the Interstate. A second primary objective is to lay the groundwork for a comprehensive economic analysis of the problems associated with large traffic flows by using rural IH-35 as an example of a high-traffic corridor. Additionally, this report will provide a foundation for suggesting alternative solutions to the problem of traffic congestion on high-traffic corridors.

By demonstrating the problems of growing traffic demand on rural high-traffic corridors in Texas, and by building on the findings of an earlier study, we suggest that a supercorridor — also known as a managed transportation system (MTS) — continues to be a feasible option for mitigating the growing traffic congestion problems on rural corridors.

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# HISTORIC TRENDS AND FUTURE CONSEQUENCES OF PROJECTED TRAFFIC ALONG RURAL INTERSTATE 35

Salvador Gonzalez-Ayala
Mark Euritt
Rob Harrison
Clay Koontz
B. F. McCullough
Roberto Macias-Mohr

Research Report Number 1326-1

Research Project 0-1326
*Economic Feasibility of a Managed Transportation System*

conducted for the

**TEXAS DEPARTMENT OF TRANSPORTATION**

in cooperation with the

**U.S. DEPARTMENT OF TRANSPORTATION**
**Federal Highway Administration**

by the

**CENTER FOR TRANSPORTATION RESEARCH**
**Bureau of Engineering Research**
**THE UNIVERSITY OF TEXAS AT AUSTIN**

May 1996

## IMPLEMENTATION RECOMMENDATIONS

This report presents a method for assessing the loss of mobility on rural highways — a method that can be applied to any corridor in the state. In a specific case study, this report examines traffic trends on rural sections of Interstate 35 between San Antonio and Dallas. For this case study, we recorded average daily traffic data and then forecast traffic patterns for the locations along the Interstate. Using the *Highway Capacity Manual* and the forecast average daily traffic data, we made predictions as to when flow capacity would be reached. Overall, this report is intended to illustrate the problems associated with growing traffic congestion on rural corridors; it also serves as the basis for later reports that specifically discuss corridor solutions.

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

## DISCLAIMERS



B. F. McCullough, P.E. (Texas No. 19914)
*Research Supervisor*

## TABLE OF CONTENTS

## SUMMARY

Vehicular traffic moving through rural sections of Interstate 35 in Texas is growing at a dramatic rate. For example, in the rural areas between San Antonio and Dallas, traffic grew between 4 and 8 percent annually between 1983 and 1992. Some rural sections exhibited traffic growth rates as high as 10 percent between 1970 and 1993. And as traffic grows, so does travel time — an inevitable consequence of congestion. Thus, a trip from San Antonio to Dallas, which took approximately 4.5 hours in 1972, will require 8 hours by the year 2006, given a modest 4 percent traffic growth annually. Other disturbing, congestion-related consequences include rising pollution levels and greater operating costs for passenger cars and trucks, not to mention more accidents. If the problems associated with increasing traffic demand in the state are not resolved, Texans can expect higher costs of living and greater losses in productivity.

The primary objective of this report is to demonstrate the future loss of personal mobility by the highway user on rural sections of the Interstate in Texas. A second primary objective is to lay the groundwork for a comprehensive economic analysis of the problems associated with large traffic flows by using rural IH-35 as an example of a high-traffic corridor. Additionally, this report will provide a foundation for suggesting alternative solutions to the problem of traffic congestion on high-traffic corridors.

By demonstrating the problems of growing traffic demand on rural high-traffic corridors in Texas, and by building on the findings of an earlier study, we suggest that a supercorridor — also known as a managed transportation system (MTS) — continues to be a feasible option for mitigating the growing traffic congestion problems on rural corridors.

# CHAPTER 1. INTRODUCTION

## BACKGROUND

In Texas, as in the rest of the U.S., highway travelers are finding their mobility increasingly compromised by growing vehicular congestion. This congestion, the result of trends that date back to the 1980s, comes after almost 25 years of progressively better personal mobility. And it's not just in urban areas: Increasingly, there is a concern among Texans that this mobility loss is now also extending into the rural segments of our key intercity links. Thus it is essential that the nature and extent of the problem be identified so that it may be properly addressed (while it still can). Accordingly, this report first describes a method for analyzing the problem, and then presents a scheme for applying the method to a specific corridor in the state for demonstration purposes.

The present study builds on the findings and recommendations of the "Texas 2020" study conducted by the Center for Transportation Research (CTR) of The University of Texas at Austin in the early 1990s. The Texas 2020 reports concluded that a high-speed ground transportation system (also known as a supercorridor) was feasible from an engineering standpoint (Refs 1 and 2). The supercorridor proposed as part of that study was to be a multimodal facility consisting of separate highway and rail components, and was to be located within the so-called Texas Triangle, an area bounded by Dallas/Ft. Worth, Houston, and San Antonio.

By demonstrating the problems of growing traffic demand on rural high-traffic corridors in Texas (Fig 1.1), and by building on the findings of the initial Texas 2020 study, we suggest that a supercorridor — also known as a managed transportation system (MTS) — continues to be a feasible option for mitigating the growing traffic congestion on rural corridors.

## OBJECTIVES

The primary objective of this report is to demonstrate the future loss of personal mobility on rural sections of the Interstate within Texas. A second primary objective is to lay the groundwork for a comprehensive economic analysis of the problems associated with large traffic flows by using rural IH-35 as an example of a high-traffic corridor. Additionally, this report will provide a foundation for suggesting alternative solutions to the problem of traffic congestion on high-traffic corridors.

## METHODOLOGY

The overall methodology of this project is presented in Figure 1.2. Note that the methodology is divided into the two areas distinguished by the shaded and non-shaded parts on the chart. The top of the chart relates to identifying the extent of personal mobility loss on a specific corridor through a series of logical steps. Interstate Highway-35 from Dallas to San Antonio (i.e., the lightly shaded line in Figure 1.1) will be used as an example to illustrate the concept. The primary objective will be accomplished by illustrating the problem of growing traffic demand and by predicting the point at which segments of rural IH-35 between Dallas and San Antonio will reach traffic flow capacity, using the 1985 Highway Capacity Manual (HCM) as a reference guide. After plotting historical average daily traffic (ADT) from 1983–1992 for sections in each of the counties between San Antonio and Dallas (excluding Bexar, Ellis, and Dallas Counties), we analyze the traffic growth rates occurring during this period. Following a comprehensive analysis of traffic growth rates, we suggest acceptable growth rates for projecting future traffic.

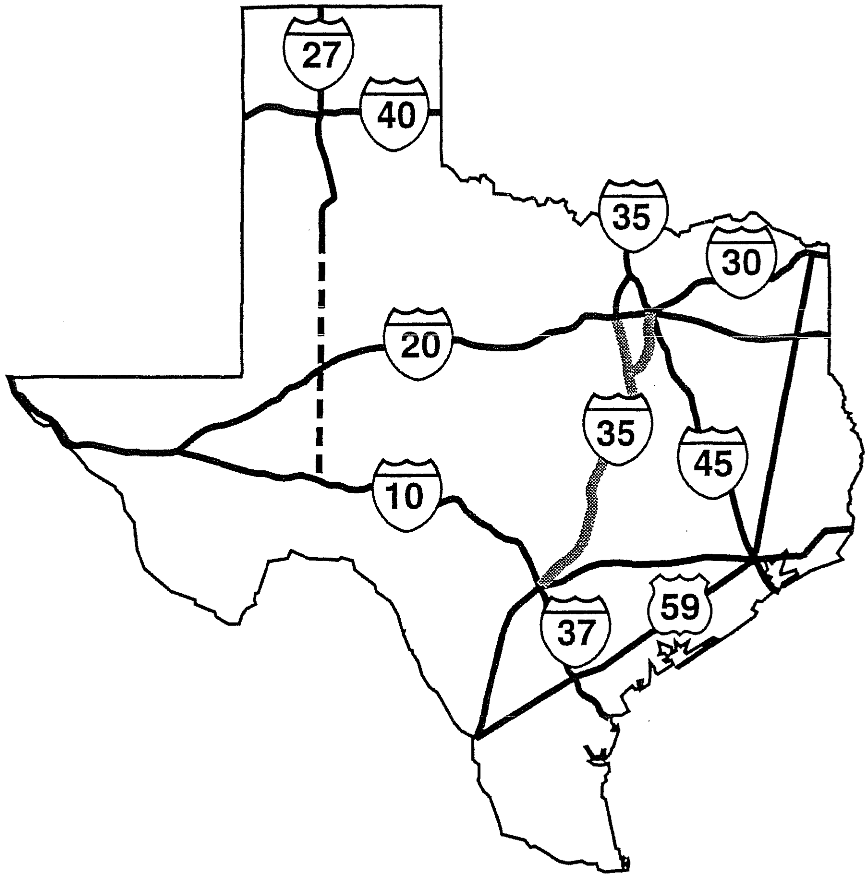


*Figure 1.1 High-traffic corridors in Texas*

Thus, the primary objective will be accomplished by illustrating the problem of growing traffic demand by predicting the years in which segments of rural IH-35 between Dallas and San Antonio will reach traffic flow capacity, using the 1985 Highway Capacity Manual (HCM) as a reference guide. After plotting historical Average Daily Traffic (ADT) from 1983-1992 for sections in each of the counties between San Antonio and Dallas, except Bexar, Ellis, and Dallas Counties, an analysis of the traffic growth rates during this period is to be conducted. Following a comprehensive analysis of traffic growth rates, a decision regarding acceptable growth rates for projecting future traffic is to be made and carried out.

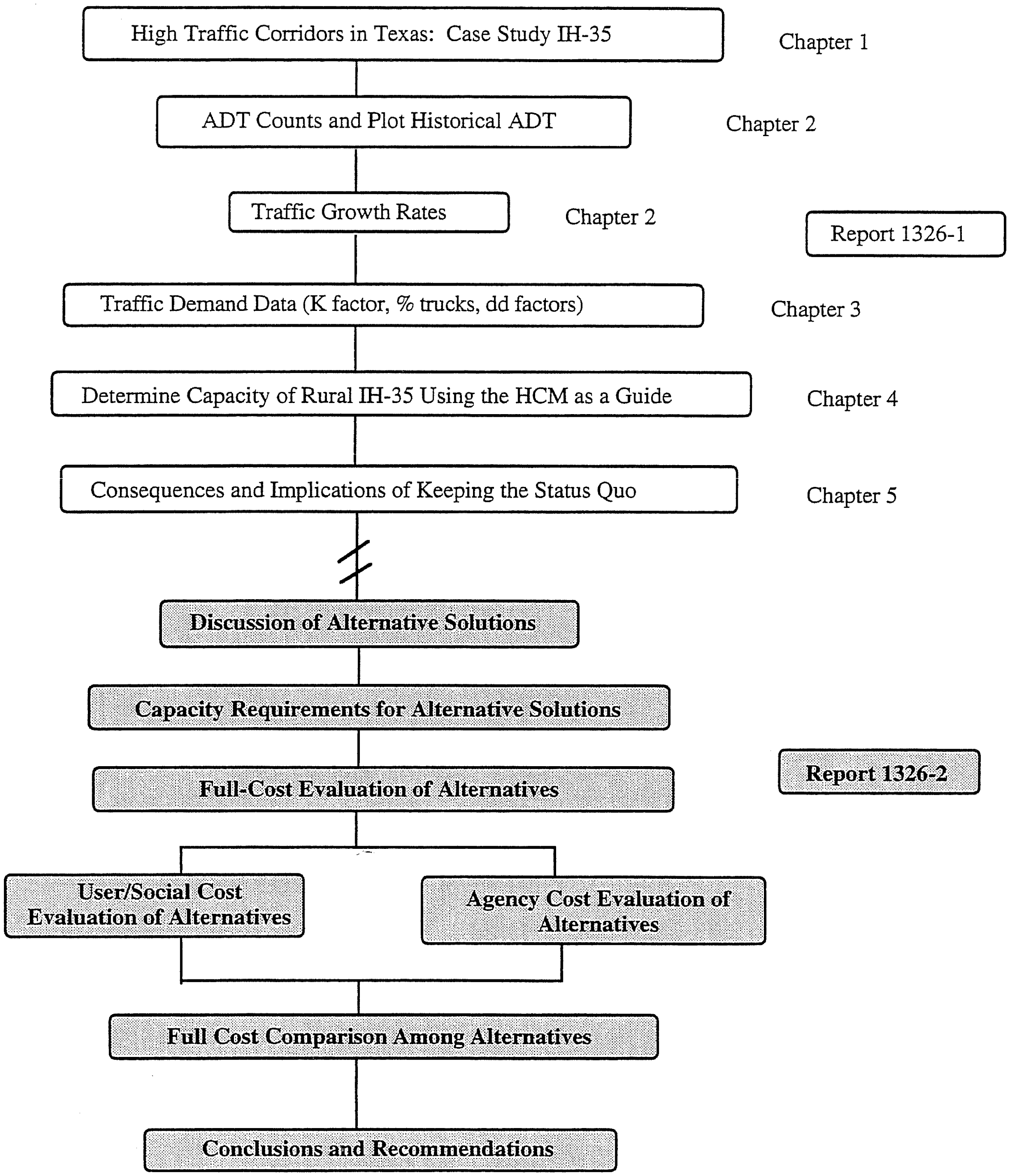


*Figure 1.2 Methodology and work areas for Project 1326*

## ORGANIZATION OF REPORT

Figure 1.3 shows the sequence of detailed steps required to accomplish the tasks specified in shaded areas of Figure 1.2. The chapters where the material is covered are shown on the left side of Figure 1.3.

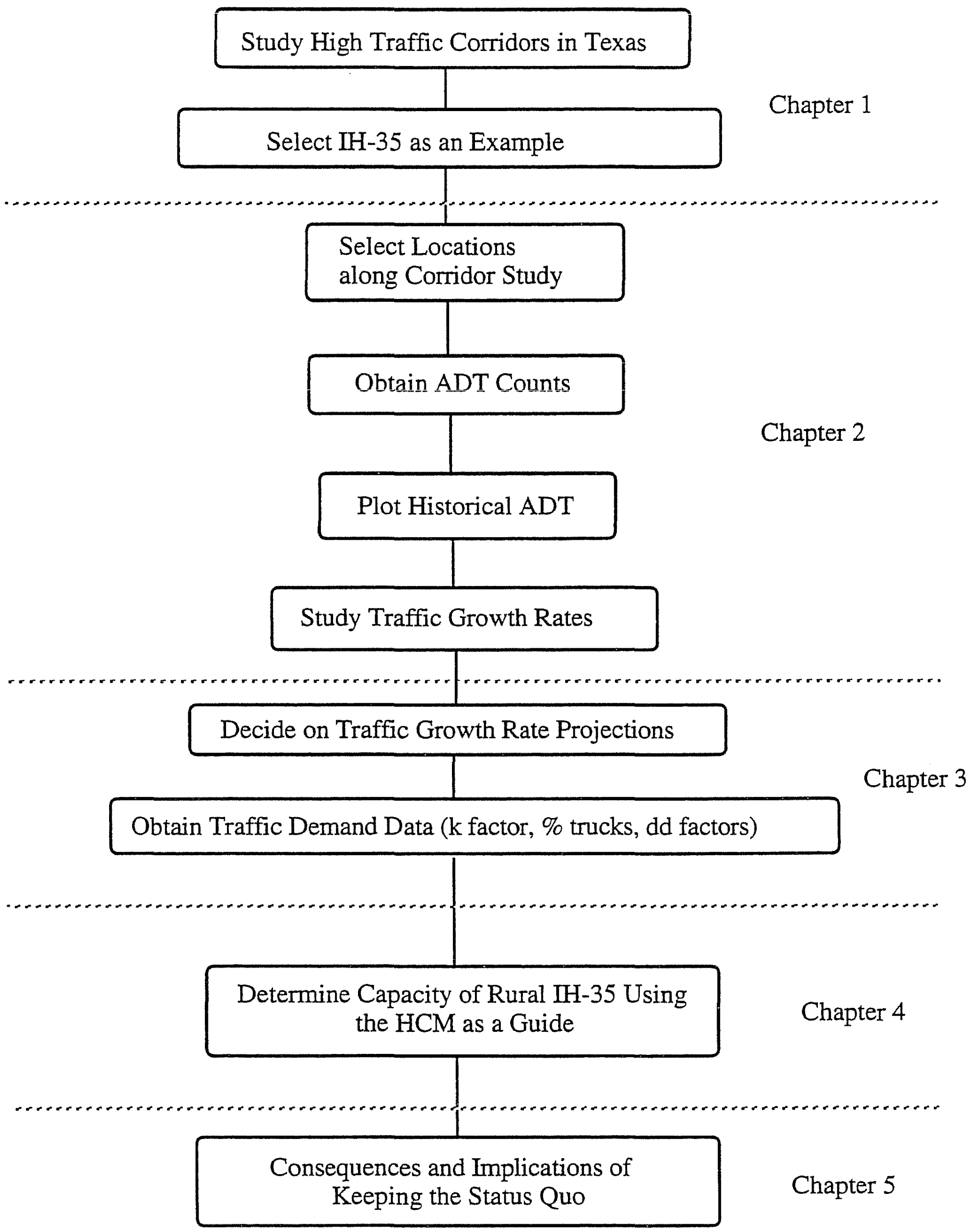


*Figure 1.3 Methodology for study with emphasis on the traffic analysis*

Chapter 2 analyzes recent traffic patterns within rural sections of IH-35, with traffic flows recorded in terms of average daily traffic (ADT). Counties studied include Frio, Comal, Hays, Travis, Williamson, Bell, Falls, McLennan, and Hill. For each of the counties, we plot the ADT between the years 1983 and 1992 and then compute traffic growth rates during the period. After plotting and analyzing traffic patterns, we eliminate, based on low traffic tendencies, Frio and other counties south of San Antonio. Analyzing the remaining counties for growth trends, we then determine an acceptable range of growth rates for projecting future traffic. Traffic growth rates from the remaining locations studied ranged between 4 percent and 8 percent between 1983 and 1992. Using the lower limit of 4 percent and the upper limit of 8 percent, we project traffic growth to the year 2020. To supplement the 10-year ADT analysis period from 1983 to 1992, ADT is plotted for McLennan, Bell, and Hill Counties for the years between 1970 and 1993. (Traffic projections are not performed using these data.)

Chapter 3 discusses traffic demand characteristics for locations along IH-35. After obtaining the necessary demand factors, we convert ADT to hourly flows.

Chapter 4 analyzes the traffic flow capacity of rural IH-35 using the 1985 *Highway Capacity Manual* (HCM) as a guide. We performed a capacity analysis for two different scenarios. The first scenario assumes IH-35 can be upgraded to six lanes (three lanes each direction). In the second scenario, the present configuration is analyzed. Once the traffic is converted to an hourly flow, it is then corrected for the percentage of trucks on the highway by reducing the capacity as suggested by the HCM. The hourly flows are then compared with the level of service guidelines outlined in the HCM to determine the point at which different operating levels of service will occur; we also present a series of maps depicting the progressive worsening of traffic flows.

Chapter 5 illustrates the consequences of maintaining the status quo on IH-35. An example depicts the intercity travel times between San Antonio and Dallas for the years 1950–2020. The travel times are computed based on the speeds associated with the operational levels of service determined in the previous chapter. Other consequences that will occur as a result of the projected congestion include pollution problems and increasing environmental costs, which result in higher operating costs. Other consequences, such as loss of productivity and increased cost of living, are also discussed.

Finally, Chapter 6 presents the conclusions of the capacity analysis. Several recommendations are made for further continuation of the study.

# CHAPTER 2. TRAFFIC GROWTH TRENDS

## GENERAL

Among all states, Texas has the second largest population in the nation (behind California). And as its population increases, so does its number of licensed drivers. As a consequence, the mobility that travelers once enjoyed becomes increasingly compromised.

Figure 1.1 in Chapter 1 shows some of the many high-traffic corridors in Texas. Of these corridors, IH-10, IH-45, and IH-35, which link the Texas Triangle, represent three key high-traffic corridors. In this report, the IH-35 leg of the Texas Triangle is specifically studied for traffic patterns.

Average daily traffic (ADT) is defined as the total number of vehicles that pass over a given section of roadway in one day, averaged over one year and including both directions. This chapter analyzes the ADT for IH-35 according to whether the traffic on a particular segment is heavy or light. Representing the lighter traffic section is that link between Laredo and San Antonio; representing the heavier traffic section is that link between San Antonio and Dallas.

### *Locations of ADT Counts*

Traffic counts are recorded by the Texas Department of Transportation (TxDOT) throughout the state, and by other agencies throughout the nation. Along IH-35, many counts are taken by Automatic Traffic Recording (ATR) stations. Count locations for each of the three counties in which traffic data from 1970–1993 were plotted are indicated on each of the figures. ADT data for each of the three counties were obtained from a series of ADT maps maintained by TxDOT. ADT data for the counties analyzed from 1983–1992 were obtained from serial numbers on the TxDOT traffic log sheets.

### *Low-Traffic Sections*

With the passage of the North American Free Trade Agreement (NAFTA), the Laredo-to-San-Antonio section of IH-35 has played an enormous role in efficiently transporting commodities to and from Mexico. Yet traffic between Laredo and San Antonio is considered relatively light in comparison with traffic between San Antonio and Dallas. Figure 2.1 depicts the ADT of a section of IH-35 in rural Frio County for the years 1983-1992. During this 10-year period, traffic along rural Frio County grew at an enormous rate. In 1983, approximately 4,000 vehicles per day were recorded in this county. Frio County traffic grew at a relatively modest rate through about 1987, at which time traffic began to grow at a more dramatic rate. By 1992, Frio County averaged approximately 9,000 vehicles per day along the rural interstate. Thus, over the entire 10-year period, traffic more than doubled.

### *High-Traffic Sections (1970-1993)*

Traffic between San Antonio and Dallas has been growing rapidly since the completion of the Interstate. In 1990, Dallas had a population of over 3.8 million, while San Antonio had a population of 1.3 million (Ref 8). IH-35 is the most popular corridor linking the two cities. Between Austin and San Antonio, an additional lane (making six lanes) is being built in both directions to accommodate some of the traffic. Between Austin and Dallas, IH-35 is currently four lanes (with the exception of two locations). TxDOT has plans to upgrade IH-35 to six lanes on a section between Austin and Georgetown and also on a section in McLennan County.

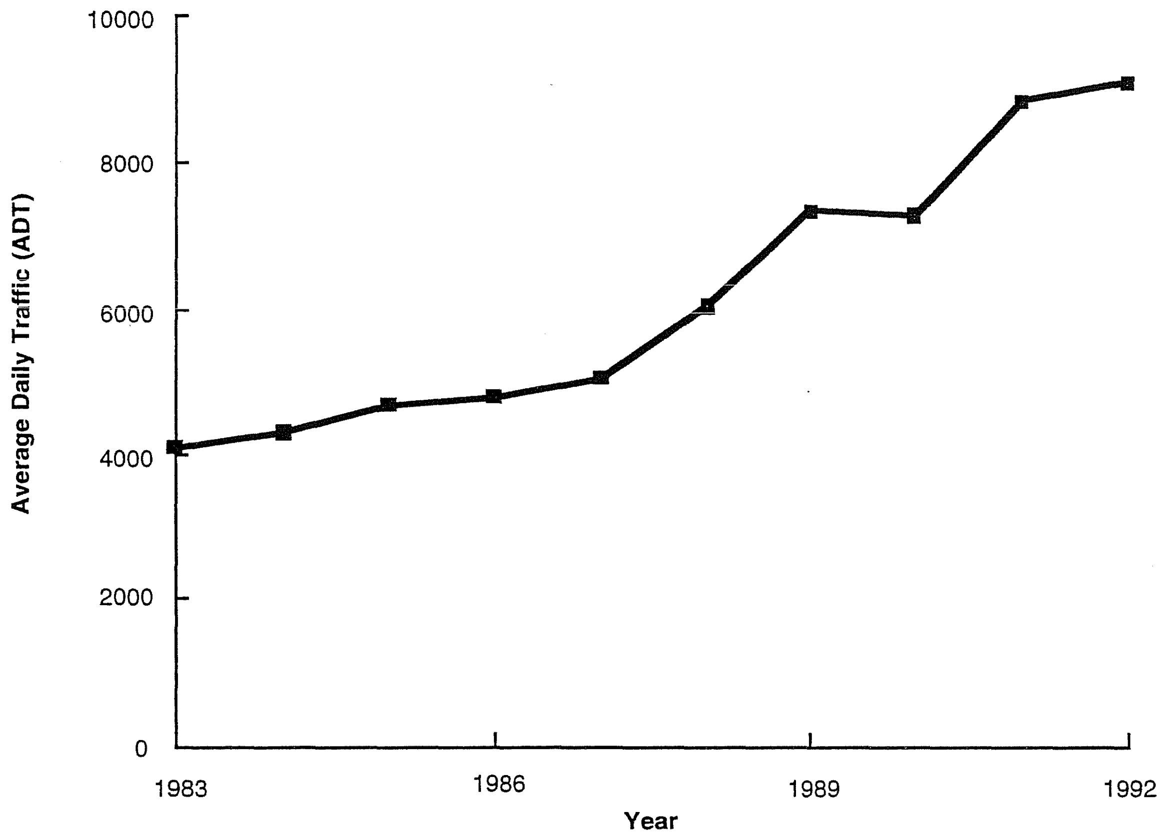


*Figure 2.1 Historical ADT for rural IH-35 in Frio County*

Figure 2.2 depicts the ADT for a section of rural IH-35 in Bell County, just north of the Williamson County line. Historical ADT taken from 1970 through 1993 for this section indicates that traffic volume in 1970, at approximately 10,000 vehicles per day, was relatively light. Traffic continued to grow at a modest rate until about the mid-1980s, when ADT began nearing 20,000 vehicles per day. Since the mid-1980s, traffic flows have been steadily increasing, such that by the early 1990s the ADT was exceeding 30,000.

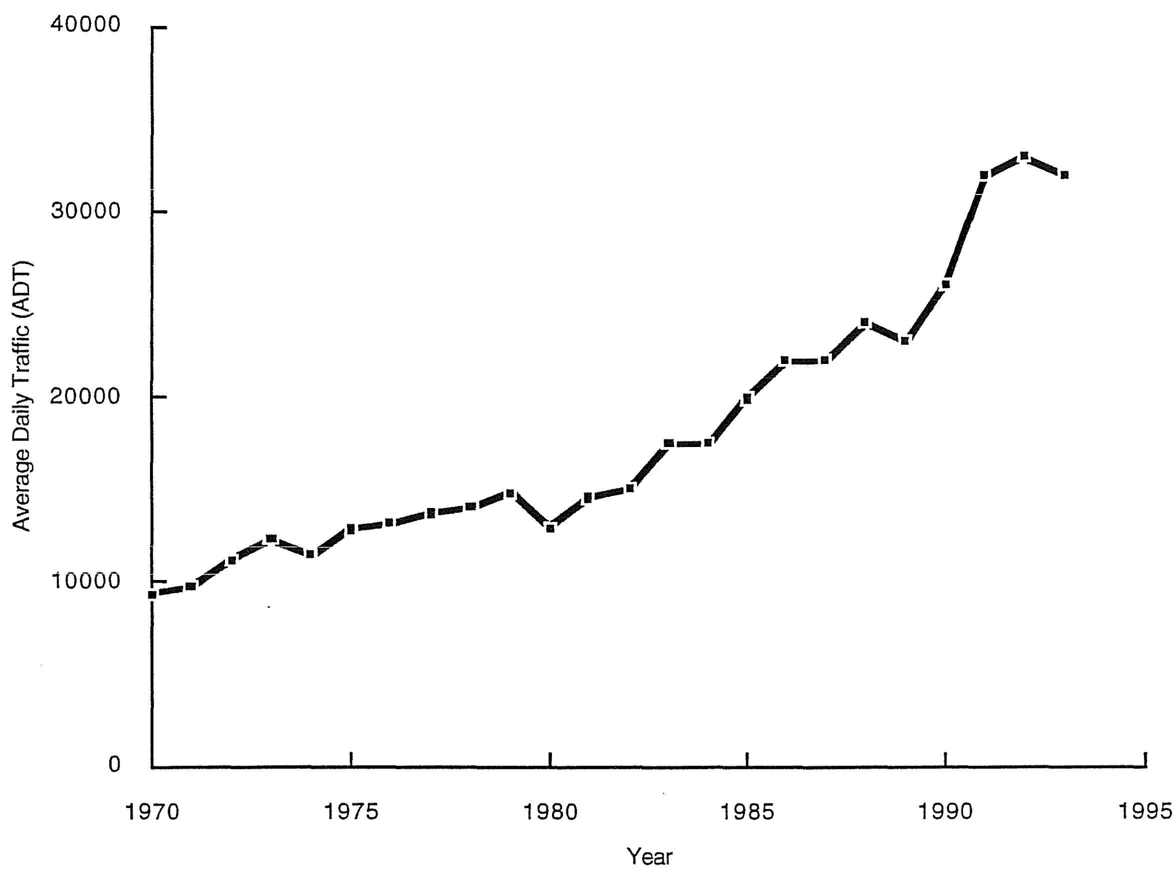


*Figure 2.2 Historical ADT for rural IH-35 in Bell County (north of Williamson Co. line)*

### *High-Traffic Sections (1983-1992)*

In addition to traffic data obtained for 1970 through 1993, we also collected traffic figures from 1983 through 1992. ADT data were taken for each of the rural counties between San Antonio and Dallas — excluding Bexar, Ellis, and Dallas Counties. (Ellis and Dallas Counties were excluded from the analysis because IH-35 splits into an east and west route, causing an anomaly in the analysis. Bexar County was not considered in the analysis because results would be distorted owing to the large amount of urban traffic surrounding San Antonio.) Figure 2.3 illustrates the ADT for McLennan County for the 10-year period from 1983 through 1992. In 1983, daily traffic was just under 30,000 vehicles per day; it has steadily grown at a 4.73 percent rate through 1992. In 1992, daily traffic at a selected location in McLennan County totaled approximately 40,000 vehicles.

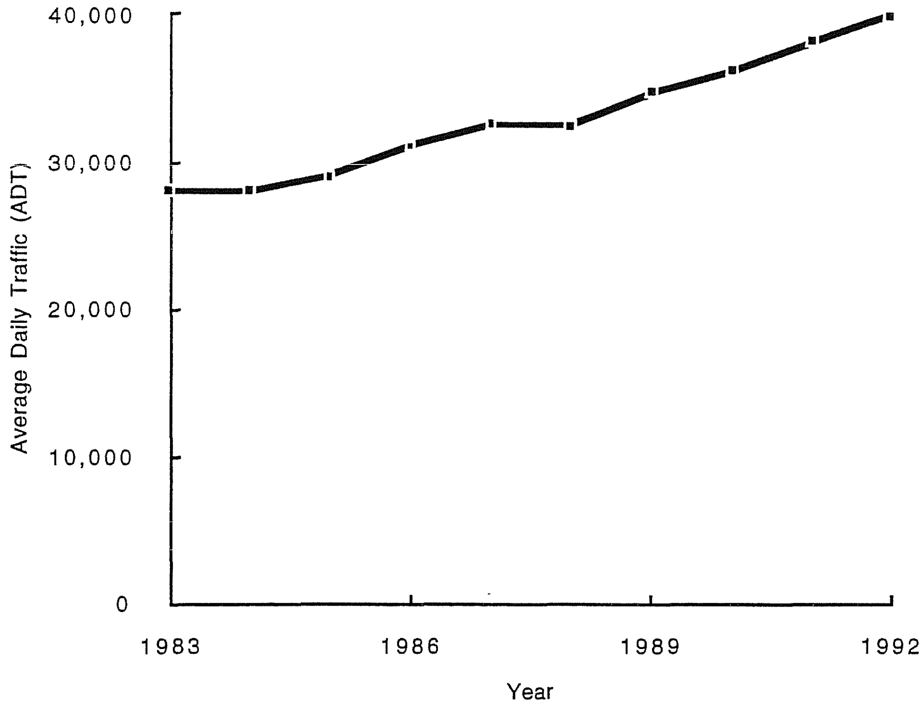


*Figure 2.3 Historical ADT for rural IH-35 in McLennan County (1983-1992)*

During the same 10-year period at a selected location in Comal County, traffic grew at a rate of 7.41 percent, the largest growth rate for the locations studied. Figure 2.4 depicts the traffic trends for Comal County. In 1983, daily traffic was approximately 24,000 vehicles. By 1992, daily traffic had grown to nearly 40,000 vehicles. Other counties ranging between McLennan and Comal County showed similar growth rates during this period. Other counties can be seen in Appendices A and B.

### *Traffic Growth Rates*

Clearly, IH-35 is a heavily traveled corridor. Table 2.1 shows the annual traffic growth rates for Bell, McLennan, and Hill Counties between 1970 and 1993. Table 2.2 shows the growth rates for counties studied from 1983 through 1992. Please note that the locations for the 1970-1993 data differ from those used for the 1983-1992 data. Also, for some counties only historical data dating back to 1983 were obtained.

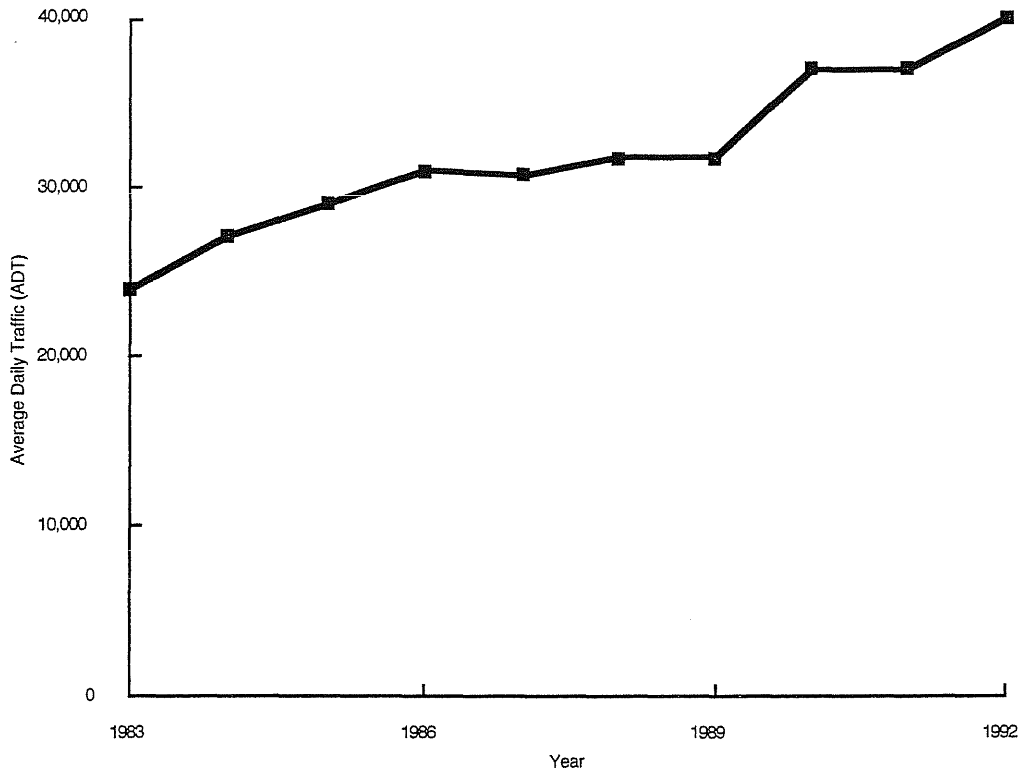


*Figure 2.4 ADT for rural IH-35 in Comal County (1983-1992)*

*Table 2.1 Average annual daily traffic growth rates along rural IH-35, 1970–1993*

| County | Annual Growth Rate (%) |
|---|---|
| Bell | 10.69 |
| McLennan | 5.20 |
| Hill | 9.44 |

*Table 2.2 Average annual daily traffic growth rates along rural IH-35, 1983–1992*

| County | Annual Growth Rate (%) |
|---|---|
| Comal | 7.41 |
| Hays | 7.41 |
| Travis | 6.21 |
| Williamson | 7.29 |
| Bell | 5.23 |
| Falls | 5.56 |
| McLennan | 4.73 |
| Hill | 5.04 |

## TRAFFIC GROWTH PROJECTIONS

Given that from 1983 through 1992 annual traffic growth rates on rural IH-35 varied from 4.73 to 7.41 percent for the locations studied, we used a growth rate of 4 and 8 percent in determining appropriate traffic growth rates for the analysis. A projection of a linear 4 percent captures the lower limit of growth rates along the corridor, while a linear 8 percent captures the upper limit. Thus, 4 and 8 percent are perhaps conservative, considering the long-term trends and other factors (e.g., the long-term effects of NAFTA on traffic growth remain unknown).

Traffic projections for McLennan County resemble traffic projections for both Hays and Comal Counties. Figure 2.5 depicts predicted traffic using both scenarios. In 1992, ADT totaled nearly 40,000. Projecting the numbers to the year 2020, there will be an average of approximately 80,000 vehicles and 130,000 vehicles a day according to our 4 and 8 percent growth rates, respectively.

Likewise, traffic growth projections in Hill County resemble traffic in McLennan County. Using a 4-percent growth scenario, Hill County can expect approximately 65,000 vehicles per day by the year 2020. Using an 8-percent scenario, Hill County can expect approximately 105,000 vehicles a day by the year 2020. Traffic growth projections for Hill County and other counties are listed in Appendix C.

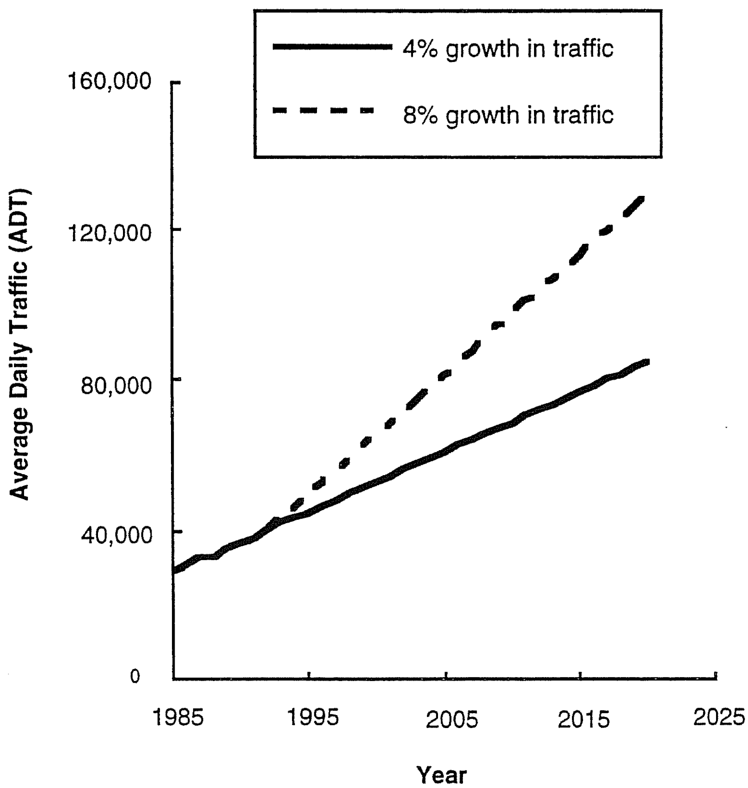


*Figure 2.5 Future traffic projections along rural IH-35 in McLennan County*

## SUMMARY

This chapter has focused on IH-35 as a high-traffic corridor, with the Dallas-to-San-Antonio segment specifically reviewed. Rural locations in nine counties along IH-35 were selected and analyzed for traffic patterns. Traffic flow data from 1983–1992 were plotted and trends were examined. Our traffic analyses indicate that flows in Frio County (located south of San Antonio) are much less severe then those in counties north of San Antonio. However, the traffic growth rate from 1983–1992 was 13.7 percent annually. Other counties studied between San Antonio and Dallas included Hill, McLennan, Bell, Falls, Williamson, Travis, Hays, and Comal. The analyses indicated traffic growth rates between 4 percent and 8 percent annually for each of these counties. In addition to reviewing traffic from 1983–1992, we analyzed the traffic for McLennan, Hill, and Bell Counties for the period 1970–1993. Our analysis indicated an even higher traffic growth during the period. For McLennan County, growth during this 23-year period was 10.69 percent; similarly, Hill County experienced a growth rate of 9.44 percent.

The lower growth rates for 1983–1992 reflect the slowdown of the Texas economy during the period. Thus, the findings obtained from an analysis of this period are probably conservative and may in fact represent an underestimate of conditions.

We next projected the traffic growth for each of the counties studied. Scenarios of 4 percent and 8 percent were selected to encompass the traffic growth rates for each county during the period from 1982–1993. Traffic was projected from 1993 through 2020 based on the historical data obtained for 1983–1992; thus the traffic from 1970–1993 was not used for projections. These traffic growth projections are used in the capacity analysis presented in Chapter 4.

# CHAPTER 3. TRAFFIC DEMAND

## GENERAL

Traffic demand represents the composition and distribution of traffic on a highway. Such traffic demand on the highway system can be characterized by taking into account several "demand" factors for peak and off-peak travel periods. Typically, rural peak conditions occur during daylight hours, while rural off-peak conditions occur at night. As highways become more congested, however, trucking companies are beginning to schedule truck travel more during the late night and early morning hours. Thus, one may expect the gap between peak and off-peak periods to narrow in the future.

In this chapter, we define demand terms that will later be used for the capacity analysis. Characteristic traffic demand factors for IH-35 are obtained from ATR stations, while the percentage of trucks is obtained from vehicle classification stations located along IH-35. Finally, using the necessary demand factors, we convert ADT to hourly flow.

### *Demand Terms*

To study the demand cycle of a system, it is necessary to convert ADT to hourly traffic. One can then study "peak" conditions separately from "off-peak" conditions by defining a "k factor." The k factor is a factor less than 1 that, when multiplied by the ADT, yields hourly flows. For example, on a given section of roadway, assume that there were 20,000 vehicles on the highway during the day and, during the peak hour of the day, that 2,000 vehicles were recorded. The relevant k factor in such an example would be .10, or 10 percent, which indicates that 10 percent of the ADT occurred during the peak hour.

Another term used to identify demand is the directional distribution factor "dd." The dd factor converts ADT from both directions on the roadway to traffic in one direction. A highway that has half of the traffic going each direction would have a dd factor of .50, or 50 percent. When ADT is multiplied by the k factor and the dd factor, traffic is converted to hourly flows in one direction. One must divide by the number of lanes in one direction to obtain the hourly flow per lane. Depending on the k and dd factors used, one may obtain peak or off-peak flows.

### *Peak Conditions*

Over the course of one year, a highway can experience seasonal, monthly, weekly, or daily cycles in traffic. If one defines the high travel periods as peak flow, then in urban areas there are normally two large peak traffic flows occurring daily, one during the morning rush hour (typically from 6:30 a.m. to 8:30 a.m.) and one in the afternoon (normally occurring from 4:30-6:30 p.m.). Figure 3.1 illustrates the typical daily trends occurring in an urban area, with this information taken from permanent recording station s210 located 2.9 km north of Atascosa in Bexar County. The illustration shows only the trends associated with urban traffic.

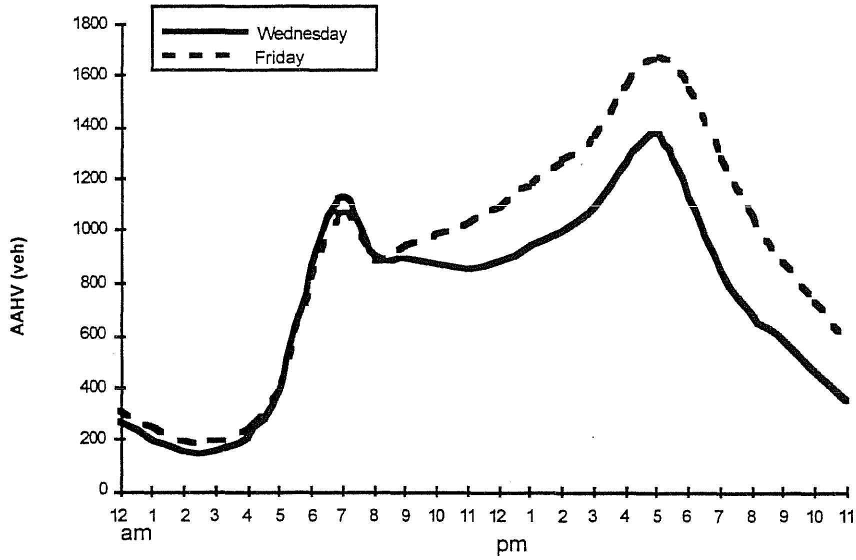


*Figure 3.1 1993 daily traffic distribution resembling urban traffic characteristics (Ref 5)*

For rural sections, there is generally one less severe peak per day, occurring during the afternoon at around 5:00 p.m. Figure 3.2 illustrates the daily cycle of traffic recorded at station s215 located 5 km north of FM 487 in Bell County. In this way, one can use the daily cycle data to obtain a k factor for any hour of the day.

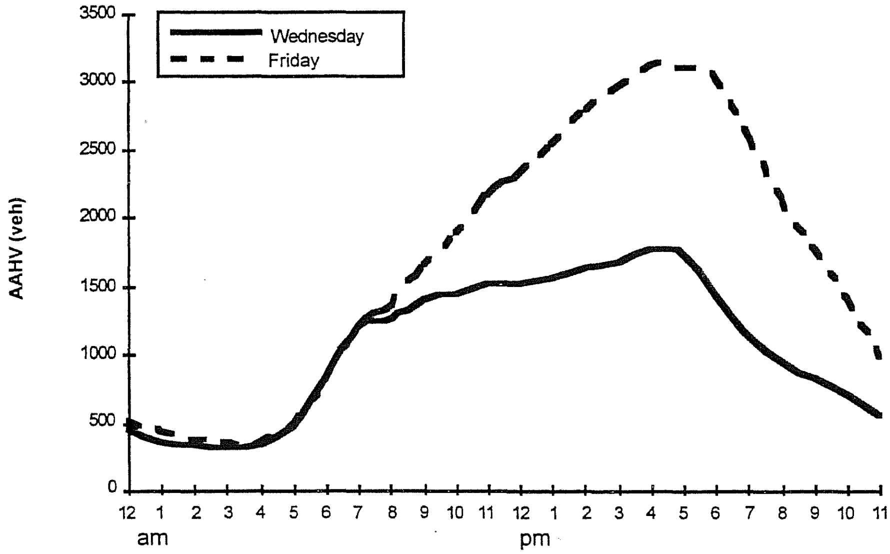


*Figure 3.2 1993 daily traffic distribution for a typical rural location (Ref 5)*

### *Off-Peak Conditions*

In urban areas, off-peak conditions typically occur at night, during mid-morning, and at mid-afternoon. In rural areas, one off-peak period normally occurs during the late night and early morning hours (whereas off-peak conditions are ignored in this analysis).

## TRAFFIC DEMAND FACTORS

K factors, the percentage of trucks, and dd factors were obtained from six stations located along IH-35. It must be noted that the six stations used for determining the three factors are not the locations from which ADT figures were obtained. Additionally, vehicle classification counts (percent trucks) were not taken from the ATR stations. The location of each station used is indicated in Appendix D.

### *K factor Determination*

Selecting a k factor for design and analysis can be difficult. For example, if a new facility is being built, there are no historical data to use as a guide. For IH-35, there are sufficient data to analyze, but for the analysis, we used a k factor equal to the 30th highest hour for the year — based on the fact that the driving public will tolerate no more than 30 hours of adverse driving conditions per year (Ref 7). Table 3.1 summarizes the k factors for each of the ATR stations selected. An average k factor of 11 percent was selected for the analysis, based on the data shown in Table 3.1.

*Table 3.1 1993 K factor for the 30th highest hour (Ref 6)*

| Station | K factor (%) |
|---|---|
| S004 | 9.5 |
| S118 | 12.5 |
| S132 | 8 |
| S190 | 10 |
| S197 | 13.2 |
| S210 | 9.4 |
| S215 | 14.1 |
| Average | 10.96 |

### *DD factor Determination*

Similar to the k factor, the dd factor is also taken from each of the same seven sites. And again, the dd factor is taken from the 30th highest hour data and averaged for the seven sites; these figures are presented in Table 3.2. Because the average dd factor for the seven locations is 56.3, we used 56 percent in the analysis.

*Table 3.2 1993 DD factor for the 30th highest hour (Ref 6)*

| Station | DD Factor (%) |
|---|---|
| S004 | 58 |
| S118 | 50 |
| S132 | 54 |
| S190 | 64 |
| S197 | 51 |
| S210 | 64 |
| S215 | 53 |
| Average | 56.3 |

### *Percentage of Trucks*

Given that trucks are large and cause most of the damage to pavement structures, one must therefore consider the percentage of trucks in analyzing traffic. The larger the percentage of trucks, the smaller the number of passenger cars that can fit on the roadway.

Six vehicle classification stations were used to determine the percentage of trucks. For the analysis, only five axle tractor-trailers ("18-wheelers") and buses were considered. This approach is somewhat conservative in that when the total number of trucks (including single-unit trucks, single-axle trucks, and single-axle trailers) are considered, the percentage of trucks increases substantially. For the six locations, trucks and buses average 14.90 percent. If you exclude station MS 219, which is located near Laredo, the figure drops to 13.80 percent. For the analysis, the Laredo station is excluded, as the data are atypical of the others. We thus used 14 percent for the analysis. Table 3.3 summarizes the vehicle classification data. For a more comprehensive set of data and for the location of each station, see Appendix D.

*Table 3.3 Vehicle classification data for selected locations**

| Station | % Trucks |
|---|---|
| LW 513 | 20.97 |
| M 1072 | 21.21 |
| MS 1315 | 11.75 |
| MS 4 | 9.04 |
| MS 210 | 17.14 |
| MS 219 | 40.41 |
| Average | 14.90 |

* Truck counts were obtained from Ref 9

## CONVERSION OF ADT TO HOURLY TRAFFIC

The demand factors defined above allow us to convert ADT to hourly traffic, which is required to determine system capacity. To obtain hourly flow, one multiplies the ADT by the k factor and the dd factor. In this case, the k and dd factors correspond to the 30th highest hour volume for the year 1993. Once the hourly traffic volume is computed, it can then be compared with values obtained from the *Highway Capacity Manual.*

Table 3.4 shows the ADT converted to hourly traffic for McLennan County using ADT data recorded from 1983 through 1992. Hourly volumes for the years 1993 through 2020 are predicted values estimated at a 4 percent annual rate and in terms of vehicles per hour for one direction of traffic. Service flows for the remaining counties are listed in Appendix E.

*Table 3.4 Hourly service flow in one direction for McLennan County**

| Year | Hourly Flow (vph) |
|---|---|
| 1985 | 1786 |
| 1990 | 2226 |
| 1995 | 2753 |
| 2000 | 3245 |
| 2005 | 3737 |
| 2010 | 4229 |
| 2015 | 4720 |
| 2020 | 5212 |

*Not corrected for the percentage of trucks

The values in Table 3.4 show the traffic in one direction only. To obtain hourly flow per lane, divide by the number of lanes. In the case of McLennan County, there are three lanes in each direction. In 1985, McLennan County recorded 1,786 vehicles per direction per hour, or nearly 600 vehicles per hour per lane. In 2020, there will be just over 5,200 vehicles per hour per direction, or just over 1,700 vehicles per hour per lane. The hourly volume data for each of the counties can be compared with guideline values presented in the *Highway Capacity Manual.*

## SUMMARY

This chapter has described the demand characteristics of IH-35 in Texas. The k factor, used to convert ADT to hourly traffic in both directions, corresponds to the 30th highest hour for the year. A value of 11 percent, obtained from the average of the seven locations, was used throughout the traffic analysis. The dd factor converts the hourly traffic in both directions to the hourly traffic in one direction. Like the k factor, the dd factor was obtained for IH-35 in the same manner. The dd factor corresponding to the 30th highest hour was 56 percent for the locations studied. Vehicle classification data were also collected. Six vehicle classification stations (different from those stations used to determine the k and dd factors) were used to obtain an average truck percentage of 14. Finally, using McLennan County as a example, ADT was converted to hourly traffic using the demand factors described above. The hourly volumes will help in analyzing capacity in the next chapter.

# CHAPTER 4. TRAFFIC FLOW CAPACITY

## GENERAL

The traffic demand information presented in Chapter 3 and the traffic growth trend data provided in Chapter 2 are used in this chapter to determine the "capacity" of IH-35. The capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions (Ref 3). Accordingly, capacity analysis is based on freeway segments of uniform traffic and roadway conditions. If any of these prevailing conditions change significantly, segment capacity and operating conditions change as well (Ref 4).

The point at which a highway is no longer able to perform its intended function represents the point at which a highway fails. A highway can fail for two possible reasons: First, failure can be represented by pavement deterioration that impedes vehicular mobility. Second, a highway can become so congested that speeds drop to an unacceptable level. When this occurs, the highway system has failed in providing the public with an acceptable "level of service."

In this chapter, rural IH-35 traffic is studied in terms of capacity. For each county studied, ADT was plotted and projected to the year 2020. From the ADT data, hourly traffic flows were determined using the AASHTO criteria (Ref 7) introduced in the previous chapter. Finally, this chapter determines the year in which traffic flow capacity will be reached for each location.

## CAPACITY CRITERIA

As a guide to analyzing capacity, we used both the 1985 and the 1994 *Highway Capacity Manual* (with definitions borrowed from the 1985 edition). The two are very similar, with only a few minor changes occurring in the later chapter on freeway flow. The following section describes definitions, capacity expressions, and key assumptions.

### *Definitions*

A principal objective of capacity analysis is the estimation of the maximum amount of traffic that can be accommodated by a given facility. Capacity analysis would, however, be of limited utility if this were its only focus. Traffic facilities generally operate poorly at or near capacity, and, consequently, facilities are rarely designed or planned to operate in this range. Therefore, capacity analysis is also intended to estimate the maximum amount of traffic that can be accommodated by a facility while maintaining prescribed operational qualities (Ref 3).

To determine the operational quality of a facility, one uses the concept of *level of service,* which categorizes traffic according to six levels of service. Level of Service (LOS) A is the best operation, while Level of Service F is the worst. These levels are defined below (Ref 3).

Level of Service A represents free flow, with individual motorists virtually unaffected by the presence of others in the traffic stream. The freedom to select desired speeds and to maneuver within the traffic stream is extremely high; also exemplary is the general level of comfort and convenience provided to the motorist, passenger, or pedestrian. This condition is illustrated in Figure 4.1.

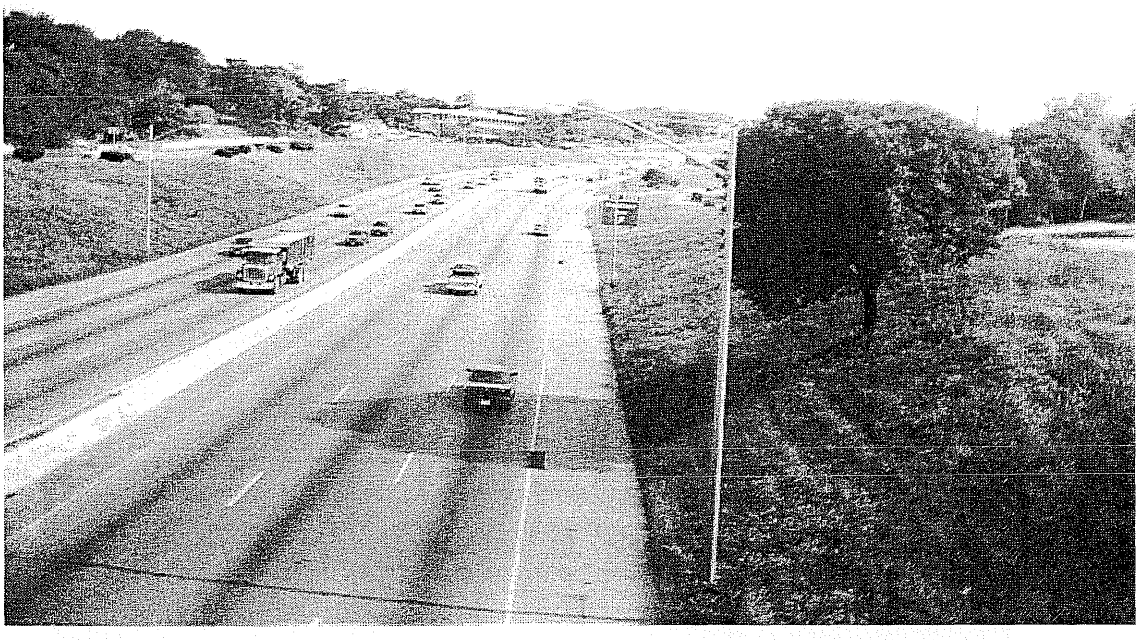

*Figure 4.1 IH-35 exhibiting LOS A flow conditions*

Level of Service B is in the range of stable flow, though the presence of other users in the traffic stream begins to be noticeable. The freedom to select desired speeds is relatively unaffected, but, compared with LOS A, there is a slight decline in the freedom to maneuver within the traffic stream. The level of comfort and convenience provided is somewhat less than that provided at LOS A, and the presence of others in the traffic stream begins to affect individual behavior, as illustrated in Figure 4.2.

While Level of Service C is in the range of stable flow, it marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by interactions with others in the traffic stream. The selection of speed is compromised, and maneuvering within the traffic stream requires substantial regard for others. As illustrated in Figure 4.3, the general level of comfort and convenience declines noticeably at this level.

Level of Service D represents high-density, but stable, flow. Speed and freedom to maneuver are severely restricted, and the driver (or pedestrian) experiences a generally poor level of comfort and convenience, as illustrated in Figure 4.4. Small increases in traffic flow will generally cause operational problems at this level.

Level of Service E represents conditions at or near the capacity level. All speeds are reduced to a low, but relatively uniform, value. Freedom to maneuver within the traffic stream is extremely difficult, and is generally accomplished only by forcing a vehicle or pedestrian to "give way" to accommodate such maneuvers. Comfort and convenience levels are extremely poor, with driver or pedestrian frustration generally high. Operations at this level are usually unstable, given that small increases in flow or minor incidents within the traffic stream will cause breakdowns. Figure 4.5 illustrates the general condition of LOS E traffic flows.

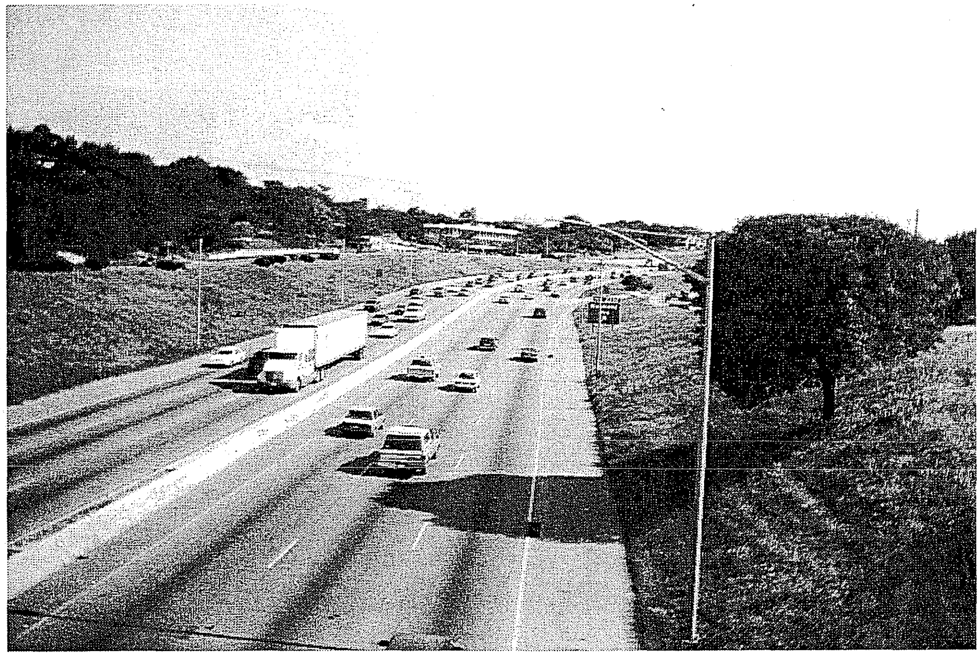

*Figure 4.2. IH-35 exhibiting LOS B flow conditions*

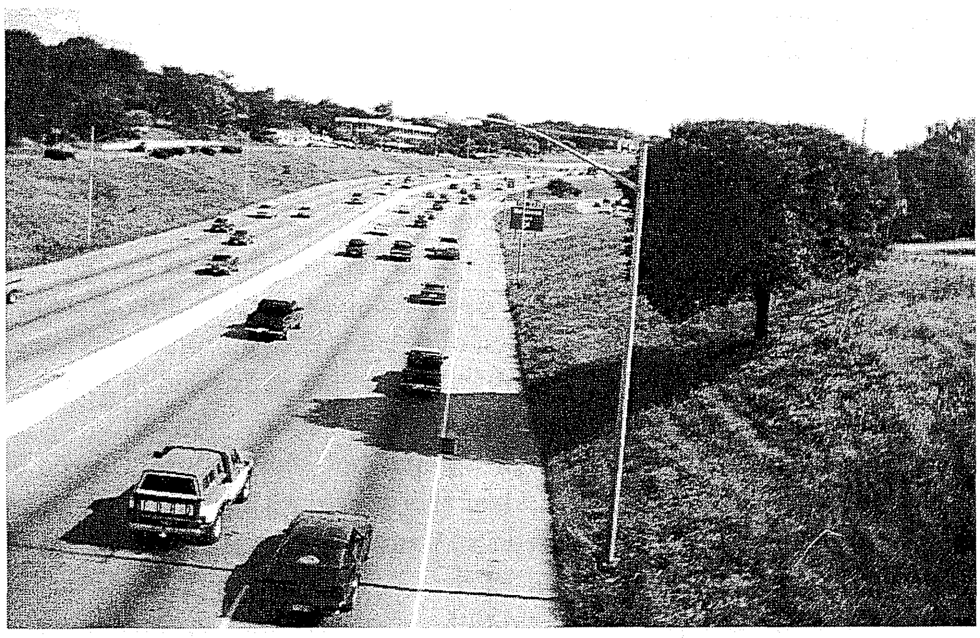

*Figure 4.3 IH-35 exhibiting LOS C flow conditions*

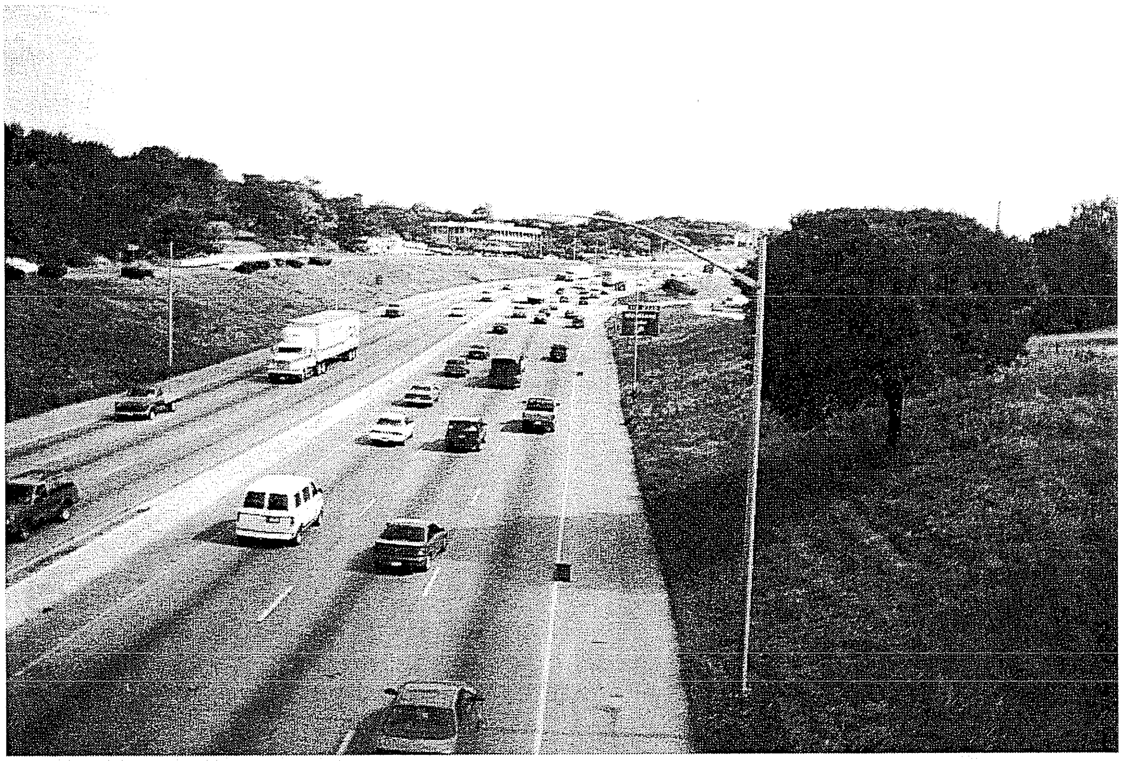

*Figure 4.4 IH-35 exhibiting LOS D flow conditions*

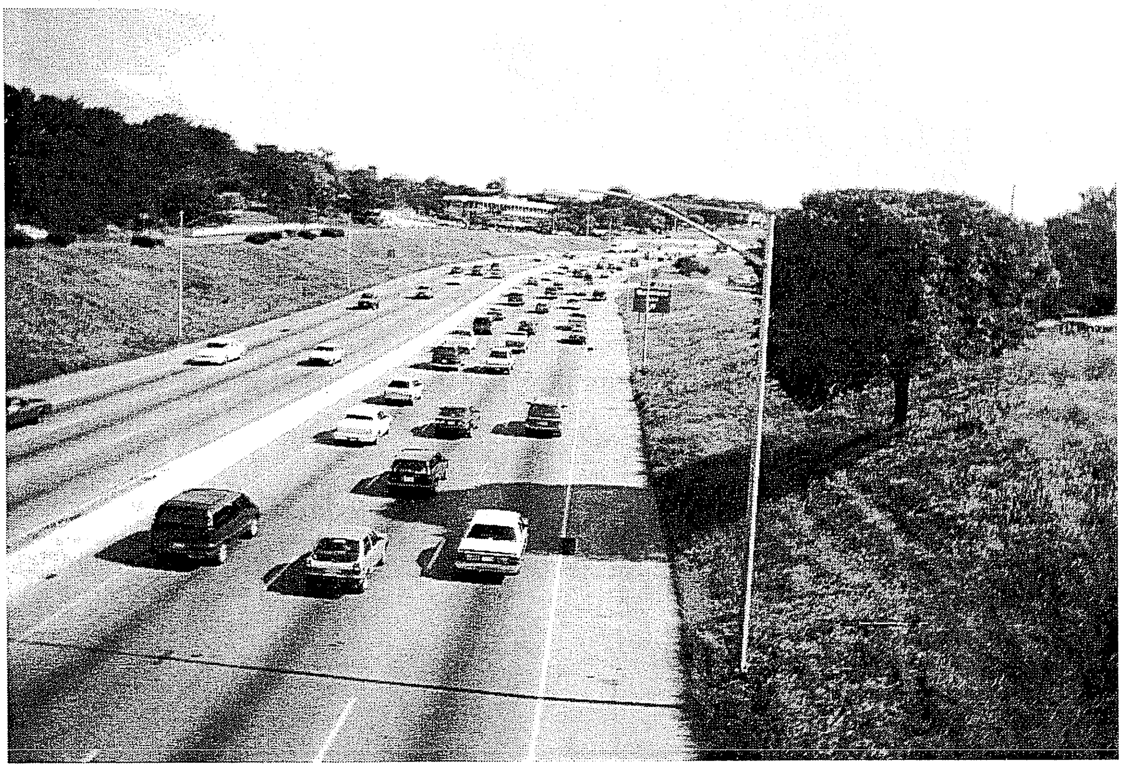

*Figure 4.5 IH-35 exhibiting LOS E flow conditions*

Level of Service F is used to define "forced" or "breakdown" flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount that can traverse the point, as shown in Figure 4.6. Queues form behind such locations, and operations within the queue are characterized by extremely unstable stop-and-go waves. Vehicles may progress at reasonable speeds over distances of 60–80 m or more, then be required to stop in a cyclic fashion. LOS F is used to describe the operating conditions within the queue, as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge flow, which causes the queue to form; LOS F is an appropriate designation for such points.

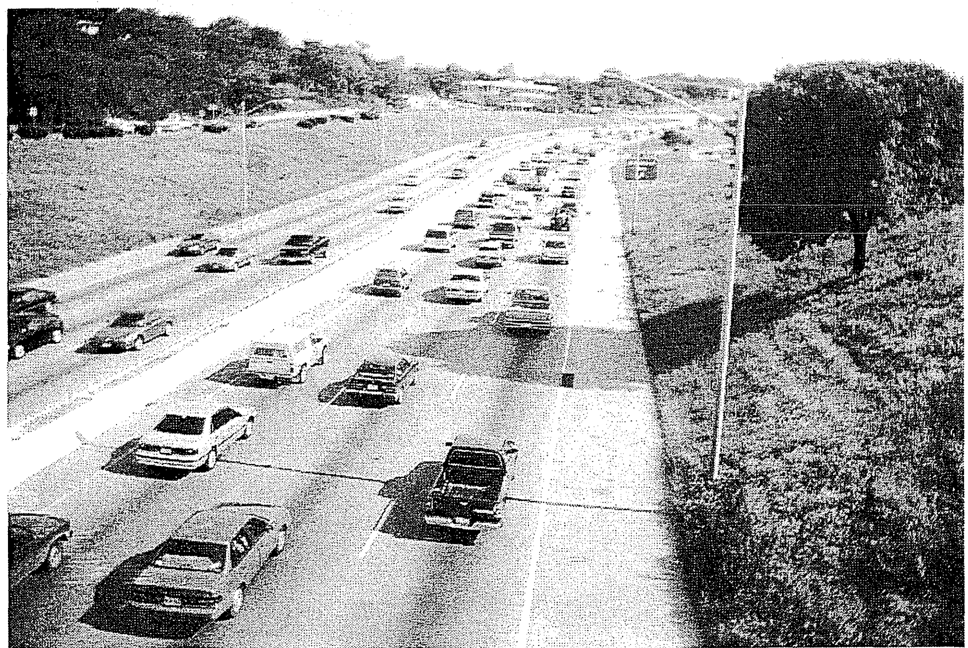

*Figure 4.6 IH-35 exhibiting LOS F flow conditions*

For each LOS, a given speed and flow rate are associated with it, as summarized in Table 4.1 (Ref 3).

*Table 4.1 Speed and flow relationships*

| Level of Service | Average Travel Speed (mph) | Max. Service Flow (pcphpl*) |
|---|---|---|
| A | >60 | 700 |
| B | >57 | 1100 |
| C | >54 | 1500 |
| D | >46 | 1800 |
| E | >30 | 2000 |
| F | <30 | unstable |

* passenger cars per hour per lane

### *Capacity Expression*

The following expression is used for the capacity analysis:

$$SF = MSF*N*fw*fhv*fp$$

where:

SF is the service flow,
MSF is the maximum service flow,
fw is the factor to adjust for the effects of restricted lane widths and/or lateral clearances,
fhv is the factor to adjust for the effect of heavy vehicles in the traffic stream, and
fp is the factor to adjust for the effect of driver population.

SF is the flow obtained by multiplying the ADT by the k factor and using the dd factor as vehicles per hour per direction. MSF is the maximum service flow. MSF is the unknown value in the expression. One solves for the MSF and then compares the value for the analysis condition with the values in Table 4.1 to determine the level of service of the facility. The term *fw* assumes a value of 1 when standard 3.6-m lanes exist (thus dropping out of the expression). The term *fhv* is the factor that accounts for heavy vehicles on the highway. The more trucks there are, the fewer the number of cars that can drive on the highway. Figure 4.7 illustrates the effect trucks have on the SF for Level of Service B and Level of Service C conditions.

As the percentage of trucks increases, the capacity of a system is hindered. For a three-lane highway (one direction), the MSF is the capacity of the system, assuming ideal conditions. With 0 trucks the capacity would be 4,500 vehicles per hour for a LOS C, and 3,300 vehicles per hour for service level B. The MSF continues to drop as the percentage of trucks increases. For 40 percent trucks, the MSF is approximately 2,000 and 1,500 vehicles per hour per direction for service level C and B conditions, respectively.

### *Key Assumptions in the Analysis*

The use of the *Highway Capacity Manual* expression for capacity involves a few assumptions to simplify the analysis. In the expression are the factors *fp* and *fw*. Both are assumed to have a value of 1, thus having no effect on the expression. The fw term is taken to be 1 because lane widths are a standard 3.6 m for the interstate. For lanes widths less than 3.6 m, fw would be less than 1, and for lane widths greater than 3.6 m, fw would have a value greater than 1. Fp is taken to be 1 because the driver population characteristics are not known in this case. Fp would have a value less than 1 when there is a mix of drivers. For example, some drivers are weekday commuters while others are recreational; accordingly, the *Highway Capacity Manual* suggests a value of 1.0.

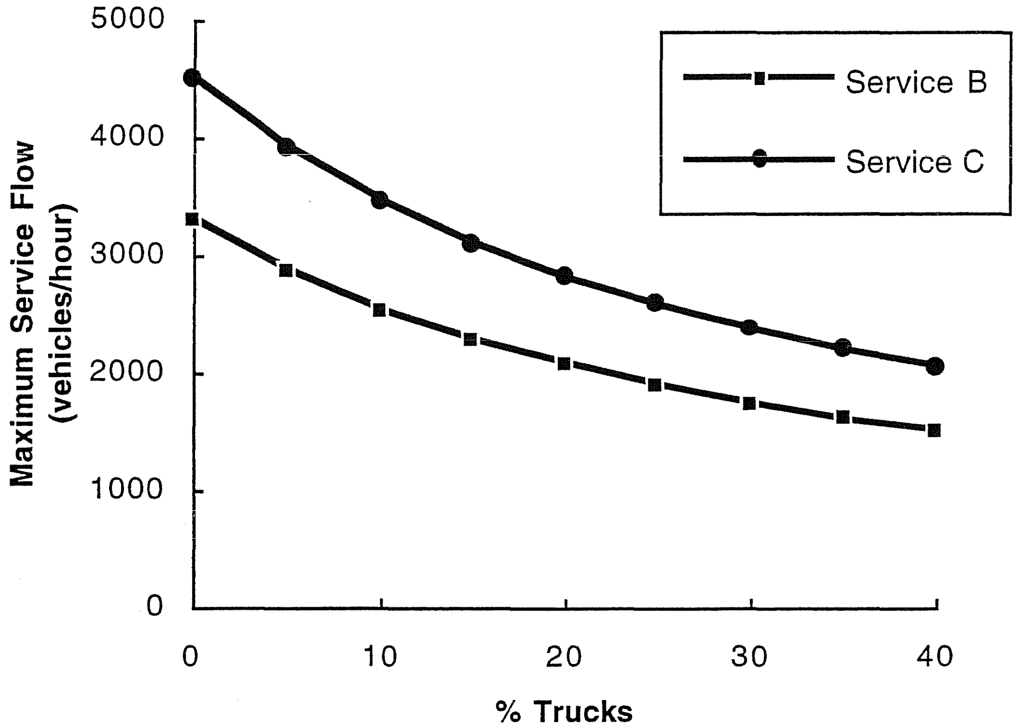


*Figure 4.7 Relationship between MSF and % trucks for LOS B and LOS C*

Another important factor is that which accounts for heavy vehicles. As seen in the previous section, the percentage of trucks plays a large role in capacity. Using 14 percent trucks, a fhv factor can be computed. Only 18-wheelers and buses are considered for the analysis (a somewhat conservative approach). When considering single-unit trucks, the percentage is much higher. The expression used to obtain fhv (Ref 3) is:

$$fhv = 1/(1+p(Et-1))$$

where:

fhv is the factor for heavy vehicles, and

p is the fraction of trucks (14%);

Et takes into account the type of terrain ( Et = 4 for rolling terrain).

Substituting values into the expression, fhv = .70 for the analysis.

## CAPACITY ANALYSIS

Using the 1985 *Highway Capacity Manual* as a guide, we next identified the year in which rural IH-35 will reach certain levels of service. For the initial scenario, we assumed that the Interstate is or will soon be a six-lane highway from San Antonio to Dallas. This is actually not the case, since there are no plans to upgrade IH-35 to six lanes other than on an Austin to Georgetown segment (where there are not already six lanes) and on a segment in McLennan County. This assumption tends to lean toward the conservative side. In addition to the six-lane scenario, a "present configuration" scenario was considered. The present configuration is six lanes in Travis, Comal, Hays, and McLennan Counties, and four lanes in the remaining counties.

### *Six-Lane Scenario*

For IH-35, we developed a series of corridor maps indicating the level of service each of the counties is experiencing for a given year using the projected traffic growth rates of 4 percent and 8 percent annually. One key assumption is that the ADT and the traffic growth for all sections within a county will be the same, which in reality is not true. Another important assumption is that traffic for Bexar County is assigned the same ADT as Comal County for the purpose of developing the maps shown below; in other cases, ADT in Bexar County is not used. Similarly, ADT for Johnson, Ellis, Dallas, and Tarrant Counties are assigned the same ADT as Hill County, which is south of the IH-35 east-west split. Again, this is only an assumption used for the purpose of developing maps. The assumptions are conservative, as more traffic can be expected in Bexar County than in Comal County (as it is closer to San Antonio). The assumption for Hill County is deemed valid since more traffic is expected in Ellis, Tarrant, Dallas, and Johnson Counties than in Hill County; the increased traffic expected in Hill County is divided in half because of the IH-35 split.

When analyzing levels of service, it is convenient to combine them into three groups, namely, good, fair, and poor, with LOS A and B considered good, LOS C and D considered fair, and LOS E and F considered poor. Figure 4.8 shows the 1984 traffic LOS for each county along the IH-35 corridor from Dallas to San Antonio. Note that the entire rural distance between the two cities was either LOS A or LOS B in 1984, which is good, uninterrupted flow.

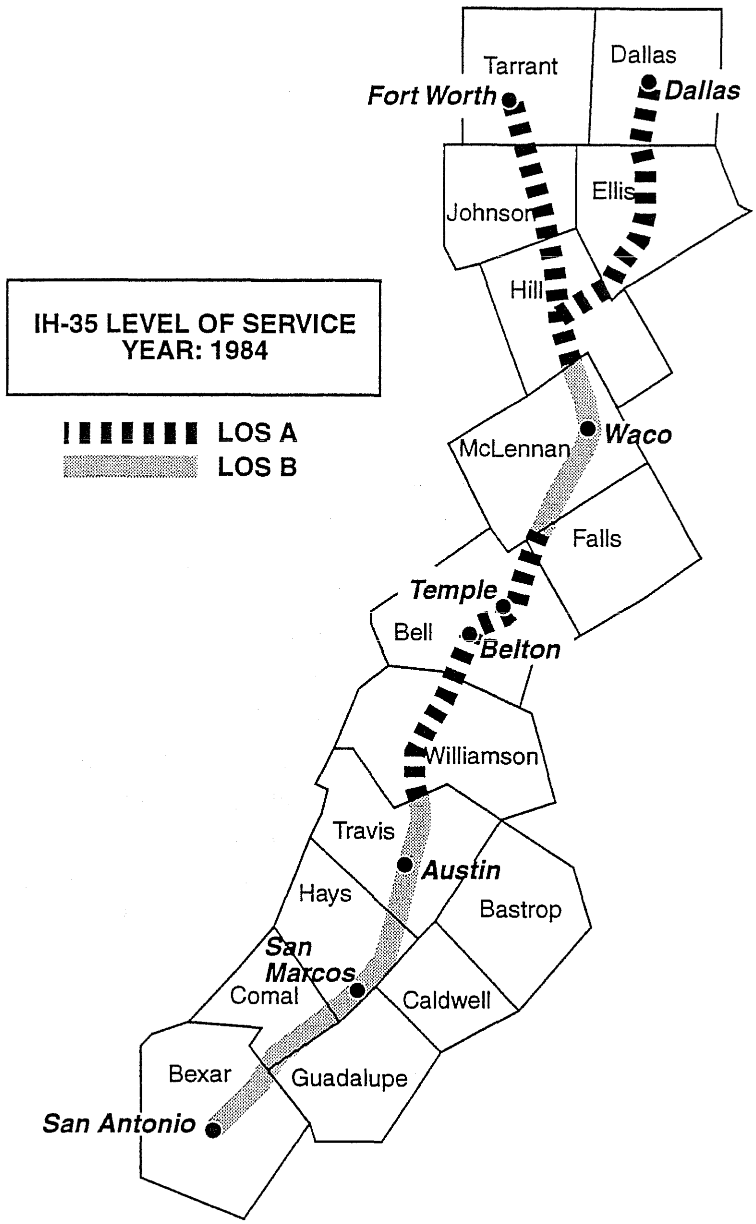


*Figure 4.8 Illustration of traffic flow conditions for rural IH-35 for the year 1984*

Figure 4.9 illustrates the traffic LOS conditions for the year 1992, when all rural sections were either in the LOS C or the LOS D range. Flow is categorized as "fair." Based on Table 4.1, the average speeds range from 46 to 56 mph.

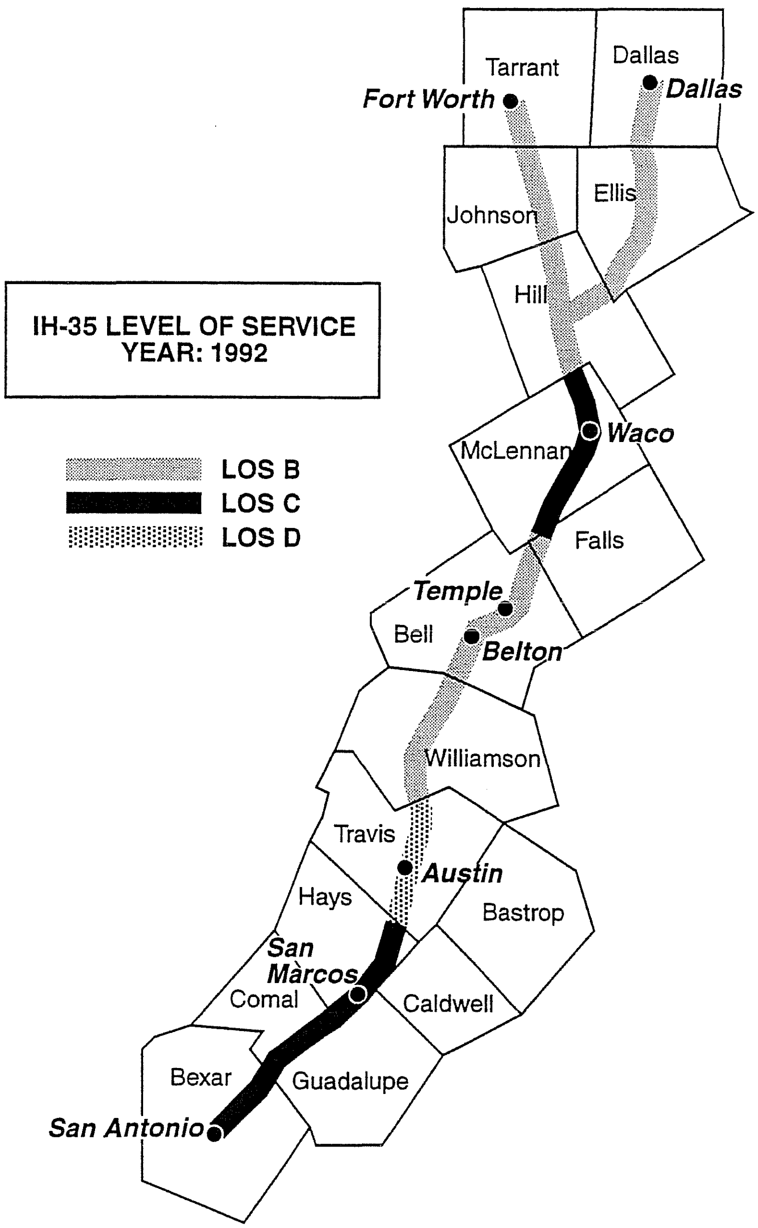


*Figure 4.9 Illustration of traffic flow conditions for rural IH-35 for the year 1992*

Figure 4.10 illustrates the traffic LOS conditions for the year 2016. The entire 454-km distance between Dallas and San Antonio will reach LOS E or F by this time, which is categorized as a poor flow rate. Again, this is for rural IH-35 given a 4-percent growth rate and six lanes (three each direction). For intermediate years, please refer to Appendix F.

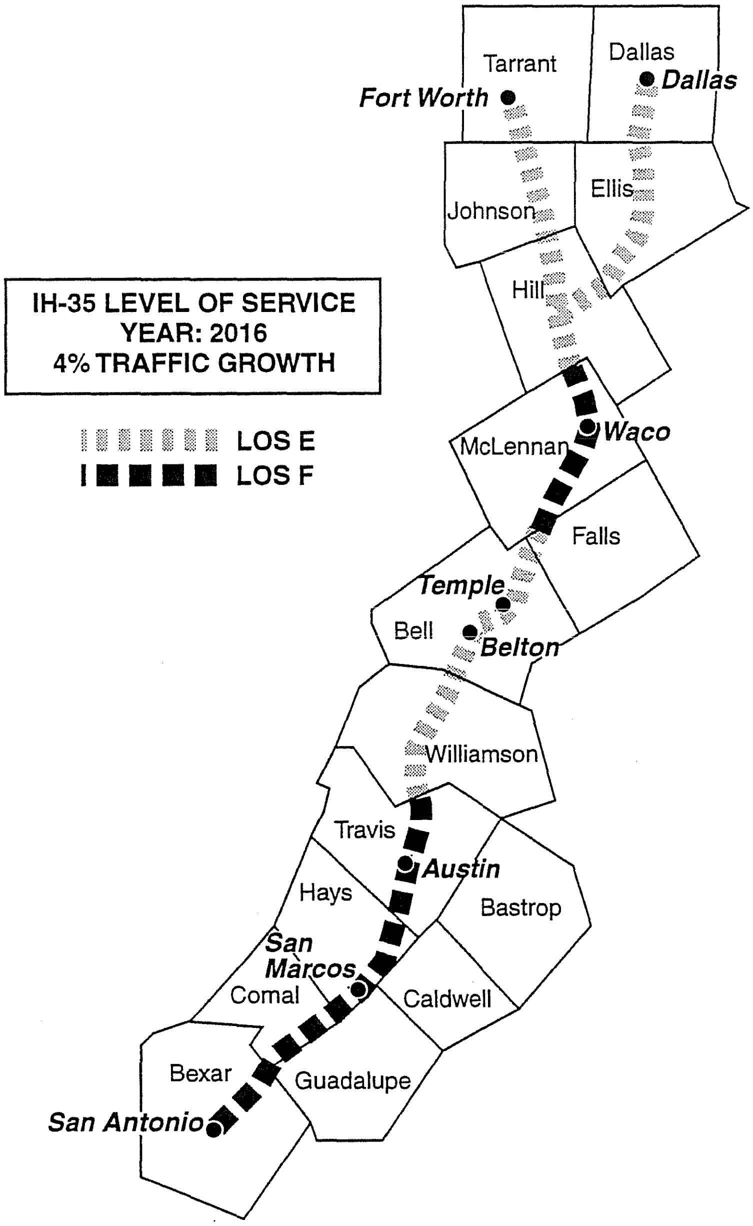


*Figure 4.10 Illustration of traffic flow conditions for rural IH-35 for the year 2016*

For the 8-percent growth rate, the capacity date is even more dramatic, as illustrated in Figure 4.11. Assuming that, aside from the growth rate doubling, everything remains the same, LOS E and F will occur by the year 1999 in all of the counties.

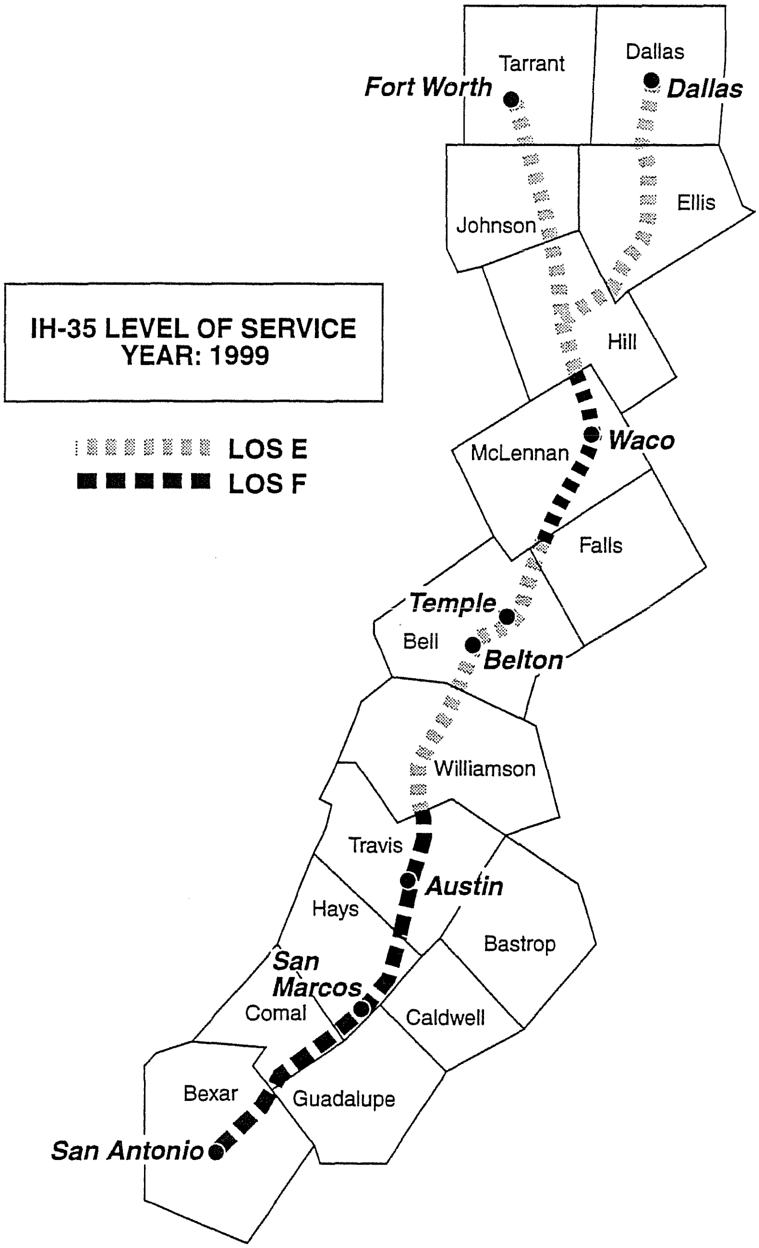


*Figure 4.11 Illustration of traffic flow conditions for rural IH-35 for the year 1999*

### *Present Configuration*

We also analyzed the present configuration as we did the more conservative six-lane scenario. Again, the present configuration consists of six lanes in each of the counties, excluding Hill, Bell, and Falls Counties, which are four lanes. Traffic flows are predicted values beginning in 1993, the same as those used in the six-lane scenario.

The entire 454-km stretch between San Antonio and Dallas will experience a poor level of service (LOS E) by the year 2006 given a 4-percent growth rate. For the 8-percent growth rate, poor level of service will be reached 6 years sooner, by the year 1999.

## CAPACITY RESULTS

Based on the above analysis, it can be predicted that IH-35 capacity will be reached in the not too distant future, meaning that levels of service will continue to drop as the number of vehicles continue to rise. Four different scenarios were studied. The first two involved assuming that six lanes exist over the entire distance from San Antonio to Dallas, while in the last two scenarios, the existing configuration was studied. For each configuration, linear growth rates of 4 percent and 8 percent were used.

Table 4.2 summarizes the capacity analysis results by presenting the year in which a "fair" level of service (LOS C) and the year in which a "poor" level of service (LOS E) will be reached, for 4 percent and 8 percent growth rates. LOS E will be reached 9 years later if another lane is built for a 4 percent growth rate, and 5 years later for an 8 percent growth rate. Using the table, it may be assumed that we have a 3- to 10-year window for constructing the additional lanes before a poor level of service is reached.

*Table 4.2 Year entire 454 km distance between Dallas and San Antonio will reach LOS C (fair) and LOS E (poor) conditions*

| Configuration | Growth Rate | LOS C | LOS E |
|---|---|---|---|
| 6 lanes | 4% | 1997 | 2015 |
| 6 lanes | 8% | 1995 | 2004 |
| Present Conf. | 4% | 1992* | 2006 |
| Present Conf | 8% | 1992* | 1999 |

*Values are based on actual data; projected values begin in 1993

Ultimate capacity is reached when the total number of cars wanting to use the system (demand) exceed the number of cars that can fit in the system — in other words, when Level of Service F is reached. The ultimate capacity of a freeway is 2,000 vehicles per hour per lane (vphpl), assuming ideal conditions. Table 4.3 summarizes the ultimate capacity for each county.

The year each county will reach capacity ranges from 1995 for Travis County, with an 8 percent growth rate, to the year 2020 for Bell County, with a 4 percent growth rate. One possible explanation for Travis County's rapid attainment of capacity is that actual traffic grew more dramatically than predicted traffic growth rates in 1994 and in 1995.

*Table 4.3 Year ultimate capacity (LOS F) for each county will be reached*

| **Config.**<br>Growth** | **6 lanes**<br>4% | **6 lanes**<br>8% | **PC***<br>4% | **PC***<br>8% |
|---|---|---|---|---|
| Hill | 2019*** | 2006 | 2002 | 1997 |
| McLenn | 2010 | 2001 | 2010 | 2001 |
| Falls | 2019 | 2006 | 2002 | 1997 |
| Bell | 2020 | 2006 | 2003 | 1998 |
| William | 2017 | 2005 | 2001 | 1997 |
| Travis | 1997 | 1995 | 1997 | 1995 |
| Hays | 2010 | 2001 | 2010 | 2001 |
| Comal | 2010 | 2001 | 2010 | 2001* |

* Present configuration
** Projections begin in 1993
*** The projected year ultimate capacity will be reached

## SUMMARY

This chapter presented a capacity analysis of rural IH-35 using capacity criteria obtained from the 1985 *Highway Capacity Manual.* The term *level of service,* which is a measuring tool for determining a highway's operational characteristics, was introduced. The demand factors obtained in the last chapter were used to convert ADT to hourly traffic, which could then be compared with figures reported in the *Highway Capacity Manual.* Two different scenarios were analyzed: In the first scenario, IH-35 was assumed to have six lanes from Dallas to San Antonio. In the second scenario, the capacity analysis used the present configuration. A series of maps were shown depicting the years various operating levels of service would occur.

The capacity analysis indicates that there is a 3- to 10-year window available before the entire route reaches a poor LOS condition. Furthermore, only a 2- to 10-year window exists before several counties along the route reach ultimate LOS F capacity.

# CHAPTER 5. CONSEQUENCES AND IMPLICATIONS OF THE STATUS QUO

## GENERAL

Continued traffic growth on IH-35, one of the most important trade corridors in Texas, will lead to a transportation crisis in the very near future. Not only does the corridor carry commuter traffic between two of the three most populous cities in Texas; it must also convey substantial freight traffic between these cities as well as to and from Mexico. This chapter examines the consequences and implications of continued traffic growth.

Obviously, there are many problems that result from high traffic within corridors. As highways begin reaching capacity, there are greater risks of sustained congestion and more frequent accidents. As operating levels of service decline, intercity travel times rise and pollution increases. Vehicles involved in stop-and-go traffic run less efficiently and, consequently, burn more fuel. In addition to the bad fuel efficiency associated with poor levels of service, travel times rise, which again requires vehicles to consume more fuel to travel the same distance.

## CONSEQUENCES

As shown in the previous chapter, rural segments of IH-35 will soon begin reaching capacity, with one of the consequences being an increase in travel times. As the operating level of service drops, speeds drop as well and, consequently, intercity travel times rise. Other problems associated with traffic congestion begin well before capacity is reached (e.g., pollution and accidents).

### *Travel Times*

Prior to the opening of the Interstate system, highway travel was a tedious and time-consuming experience. One drove on narrow and winding roads at an average speed of no more than 60 mph. Motorists would have to drive through, rather than around, communities on an extended trip, slowing down and stopping for each signalized intersection within the small towns. As an example, a trip from Dallas to San Antonio took approximately 8 hours prior to the opening of Interstate 35.

As the Interstate was being constructed, intercity travel times began to drop considerably as more and more sections of the highway were completed. By 1972, when the final section of IH-35 between San Antonio and Dallas was completed, travel times were nearly cut in half (abetted by a legal speed limit of 70 mph). Given the distance between Dallas and San Antonio of approximately 454 km (282 miles), it took approximately 4 hours to travel between the two cities, assuming one drove at 70 mph in rural areas and 55 mph in urban areas. In 1973, Congress passed legislation lowering the speed limit to 55 mph, where it remained until 1989. During this period travel time increased to approximately 5 hours, as traffic continued to operate at high levels of service.

Since 1989, traffic — along with required travel times — has been increasing rather dramatically. For example, for the 4-percent annual traffic growth rate, we project that pre-Interstate travel times will be reached by the year 2017. For the 8-percent annual traffic growth rate, the time required to travel between Dallas and San Antonio will once again reach 8 hours (i.e., pre-Interstate travel time) by the year 2005. These travel time trends are highlighted in Figure 5.1.

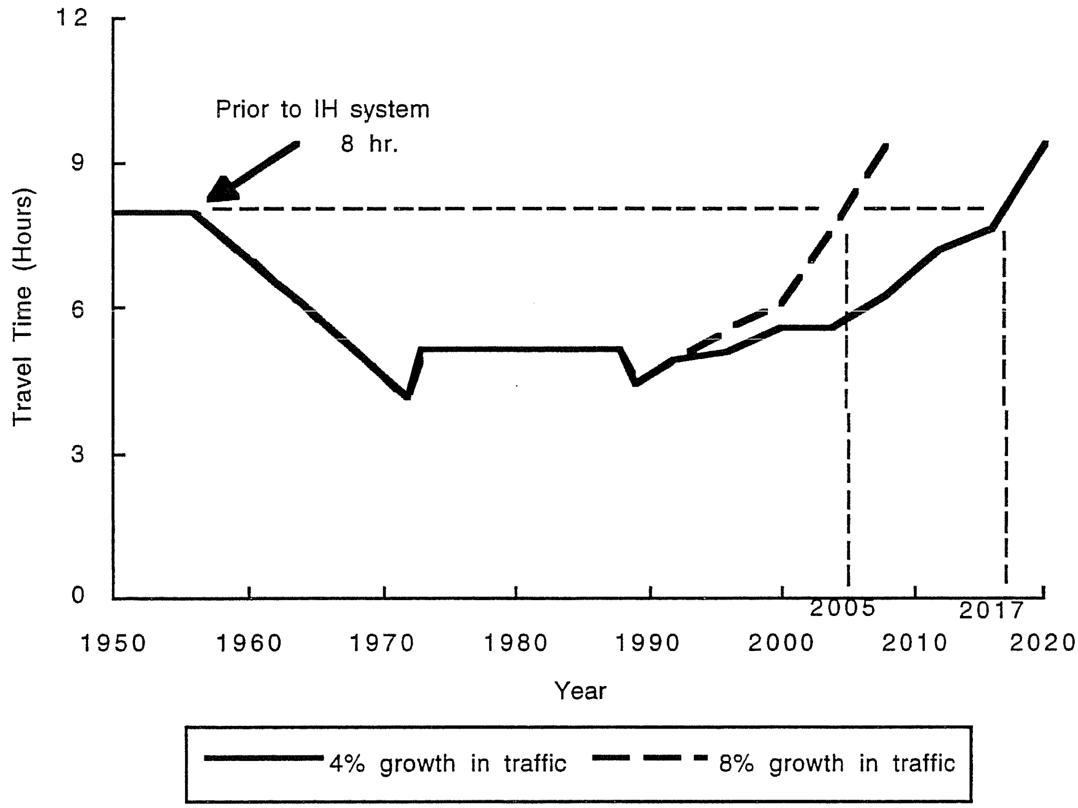


*Figure 5.1 Travel time from San Antonio to Dallas (1950-2020)*

### *Pollution*

Pollution is another important consequence of high traffic. The traffic increases of the last several years have created large amounts of pollution in some rural areas. As speeds drop, the efficiency of the engine is reduced and, with stop-and-go traffic (i.e., LOS F conditions), engines become highly inefficient. As average speeds drop, not only does a decline in engine efficiency cause more emissions, but the simple fact that it will take longer to travel the same distance contributes even more pollution. Table 5.1 illustrates the emissions produced by passenger cars and trucks for different operating speeds. (MOBILE4.1 was the model used to determine emissions.)

*Table 5.1 CO, HC, and NOx emissions (gm/mile) ( Ref 5)*

| | Level of Service | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LOS A | | LOS B | | LOS C | | LOS D | | LOS E | | LOS F | |
| Emission | Car | Truck | Car | Truck | Car | Truck | Car | Truck | Car | Truck | Car | Truck |
| CO | 7.03 | 5.42 | 6.85 | 5.27 | 6.77 | 5.22 | 6.71 | 5.17 | 9.88 | 2.94 | 13.64 | 3.59 |
| HC | 0.37 | 0.27 | 0.41 | 0.29 | 0.43 | 0.31 | 0.46 | 0.33 | 0.45 | 0.30 | 0.66 | 0.45 |
| NOx | 0.04 | 0.34 | 0.05 | 0.38 | 0.05 | 0.40 | 0.05 | 0.42 | 0.06 | 0.42 | 0.07 | 0.55 |

### *Accidents*

Finally, increased traffic jeopardizes vehicular and pedestrian safety. As traffic increases, the headway between vehicles on the roadway shrinks, causing the available driver reaction time to be reduced.

## IMPLICATIONS

The implications of poor operating conditions on the Interstate system are all too obvious. Overall, we can expect our present quality of life to decline as a result of the eminent mobility loss. With more drivers on the highway traveling farther distances today than in the past, and with NAFTA-driven freight traffic climbing to increasing levels, we can expect both passenger vehicle operating costs and truck freight costs to increase as a result of congestion. More time will be spent traveling, leading to an overall loss in national and state productivity.

### *Operating Costs*

Operating costs for both trucks and cars rise as speeds decrease. Operating costs for a truck consist of driver salary, depreciation of the truck, fuel, tire wear, maintenance, and overhead. For the passenger vehicle, operating costs consist of travel time, depreciation of the vehicle, fuel, tire wear, maintenance, and insurance. Table 5.2 shows the operating costs for automobiles for each level of service, while Table 5.3 shows the figures associated with trucks.

*Table 5.2 Travel time and vehicle operating costs for cars ($/mile)(Ref 5)*

| Item | Level of Service | | | | | |
|---|---|---|---|---|---|---|
| | LOS A | LOS B | LOS C | LOS D | LOS E | LOS F |
| Speed (mph) | 65 | 59 | 56 | 53 | 45 | 30 |
| Travel Time | 0.221 | 0.244 | 0.257 | 0.271 | 0.378 | 0.799 |
| Depreciation | 0.094 | 0.095 | 0.099 | 0.099 | 0.104 | 0.127 |
| Fuel | 0.033 | 0.029 | 0.028 | 0.026 | 0.039 | 0.055 |
| Tire Wear | 0.002 | 0.002 | 0.001 | 0.001 | 0.008 | 0.014 |
| Maintenance & Repair | 0.035 | 0.033 | 0.032 | 0.031 | 0.031 | 0.027 |
| Insurance | 0.060 | 0.066 | 0.070 | 0.074 | 0.103 | 0.218 |
| Total Cost, $/mile | 0.445 | 0.469 | 0.486 | 0.502 | 0.662 | 1.240 |

*Table 5.3 Vehicle operating costs for trucks ($/mile)(Ref 5)*

| **Item** | **Level of Service** | | | | | |
|---|---|---|---|---|---|---|
| | LOS A | LOS B | LOS C | LOS D | LOS E | LOS F |
| Speed (mph) | 65 | 59 | 56 | 53 | 45 | 30 |
| Driver | 0.254 | 0.280 | 0.295 | 0.311 | 0.434 | 0.917 |
| Depreciation | 0.128 | 0.128 | 0.144 | 0.144 | 0.167 | 0.225 |
| Fuel | 0.109 | 0.100 | 0.094 | 0.090 | 0.181 | 0.273 |
| Tire Wear | 0.041 | 0.036 | 0.031 | 0.029 | 0.260 | 0.519 |
| Maintenance & Repair | 0.221 | 0.207 | 0.192 | 0.185 | 0.179 | 0.147 |
| Overhead | 0.190 | 0.209 | 0.220 | 0.232 | 0.324 | 0.684 |
| Total Cost, $/mile | 0.943 | 0.959 | 0.976 | 0.992 | 1.545 | 2.765 |

### *Loss of Productivity*

A direct implication of increased travel time is loss of productivity. Since more of a person's time must be devoted to traveling, less time will be available for work. Using the travel time illustration from Figure 4.10 (Chapter 4) as an example, loss of productivity can easily be seen as travel times increase. Assume the average traveler earns $20/hr, and that a trip from San Antonio to Dallas in 1972 took approximately 4 hours: The operating expense to a company for such a trip was $80. However, if the same trip took 8 hours, the operating expense would be $160, a difference of $80 for a one-way trip. The loss in productivity would be much greater, because the loss in productivity to the company would equal the increased operating expense of the wage earner plus the loss in sales.

### *Cost of Living*

Each negative factor associated with congestion will eventually lead to an increase in cost of living. Increases in travel times will lead to higher operating costs for trucks, making commodities more expensive. Because more time will be devoted to traveling, a company's operating expenses will increase while its productivity decreases. Because a company must cover its expenses, these costs will be passed on to the consumer; thus an overall increase in the price level could occur, leading to inflation.

## SUMMARY

In this chapter, we discussed consequences and implications of maintaining the status quo. Longer travel times are beginning to occur, such that travel times between San Antonio and Dallas will eventually approach pre-Interstate travel times. Another consequence associated with higher traffic flows and congestion is higher emissions. As speeds reduce, engine efficiency is also greatly reduced, contributing in the process unacceptable levels of pollution to the environment.

And once a corridor reaches capacity, accidents will become an increasing problem as driver mobility diminishes.

The consequences described in this chapter have many serious implications. Longer travel times will lead to higher operating costs. Within the trucking industry, these higher operating costs will lead to higher prices for goods and services. While operating costs for trucks are very crucial, operating costs for passenger vehicles are also important and become more apparent with longer travel times. An 8-hour trip from San Antonio to Dallas via IH-35 will take its toll on the vehicle. Fuel efficiency declines as speeds become more unstable. Braking and engine-related problems will arise, all leading to higher operating costs. Finally, the higher costs associated with poor operational LOS will lead to an overall cost-of-living increase. Companies that have higher operating expenses must cover themselves by passing on the cost to the consumer.

# CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

## CONCLUSIONS

Based on the findings documented in this report, we offer the following conclusions from both a general (or statewide) viewpoint, and then with respect to a very specific application to a major corridor in Texas.

### *General*

This report described a method for exploring loss of mobility on rural highways that can be applied to any major corridor in the state. Furthermore, the application of the method to a specific corridor demonstrates that the present loss of mobility being experienced on urban highway sections will eventually expand to the rural sections of key intercity links. Unfortunately, the timing of these events will be much sooner than presently perceived. These results suggest a need in the very near future to initiate a major study aimed at identifying the extent of the statewide problem by applying the method on the major trade corridors in Texas. The definition of the problem will provide an opportunity for mobilizing public support and resources needed to address the problem. Otherwise, the public will be faced with a loss of personal mobility with a consequent steady erosion of the quality of life in Texas. Thus, industries that would normally be attracted to the state and which could provide job opportunities for Texas citizens will seek other areas of the country for their relocations.

### *Specific Observations*

Assuming a conservative 4- to 8-percent annual growth, the specific application of this method to the Interstate Highway 35 corridor from Dallas to San Antonio (approximately 454 km, or 282 miles) demonstrates the following:

1. Between the years 2005 and 2017, the travel time for trips from Dallas to San Antonio will increase from the present 4 hours to a pre-Interstate time of 8 hours.
2. Vehicle operating costs for cars and trucks will increase by 2.5 to 3 times the present values in segments of the roadway over the next 5 years and on the entire 454 km segment over the next 10 years.
3. Within 5 years, congestion caused by the increased travel demands will result in pollution levels that are 1.5 to 2 times higher than present levels on segments of the roadway, and over the entire 454 km segment in 10 years.
4. Although not quantified, the increased congestion will result in a serious increase of the accident rates, since the entire 454-km trip will occur under driving conditions equivalent to rush-hour traffic levels of service on freeways in major cities at the present time.
5. The capacity analysis indicates that there is only a 3- to 10-year window available before a poor level of service (LOS D) characterizes the entire route. Furthermore, only a 2- to 10-year window exists before several counties along the route will be at ultimate capacity (given present lane configurations).

## RECOMMENDATIONS

In general, we recommend that the method developed in this report be applied to all major transportation corridors in Texas, in order to identify the extent of the problem and its timing. In this analysis, we recommend that the following be developed:

1. A priority listing of corridors on which to apply an economic analysis for feasible alternative solutions to alleviate rural intercity traffic congestion.
2. A policy that evolves from the implementation of Item 1 to develop solutions.
3. The proposed solution should consider multimodal transportation, such as adding passenger rail, intermodal combinations of trucks and trains, and special lanes for cars and trucks. In addition, other transmission agencies, such as those associated with oil, gas, electricity, and fiber optics, could be enlisted as partners in sharing the use of new corridor links.

## REFERENCES


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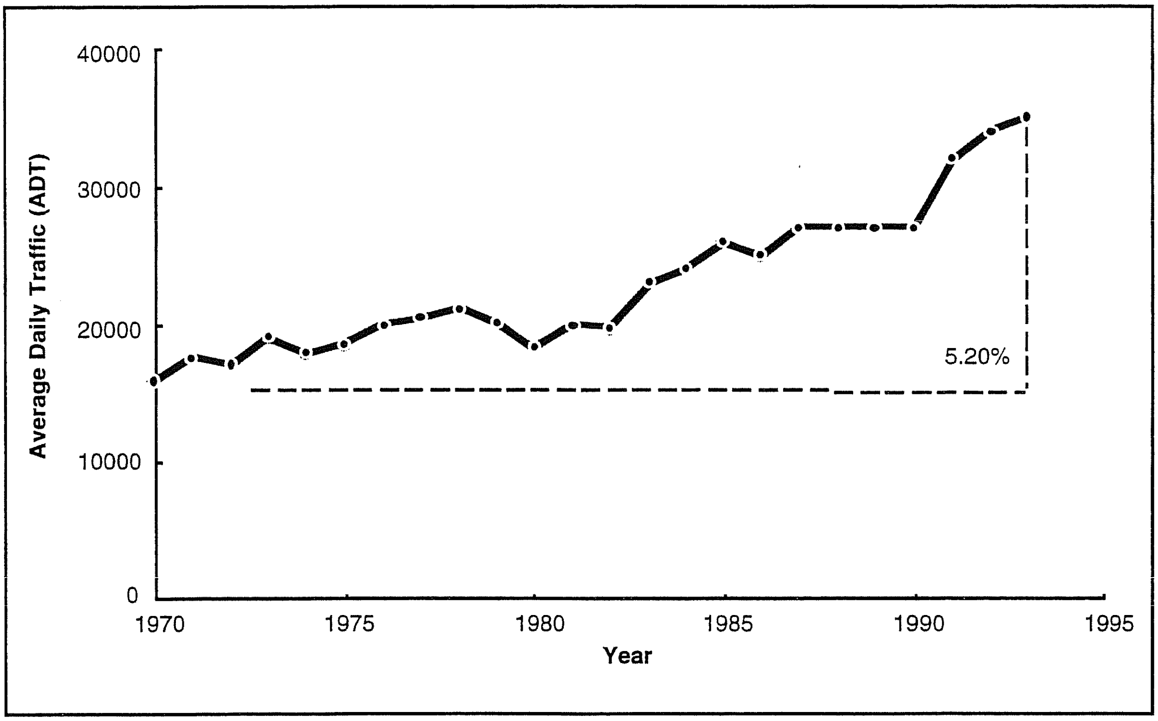
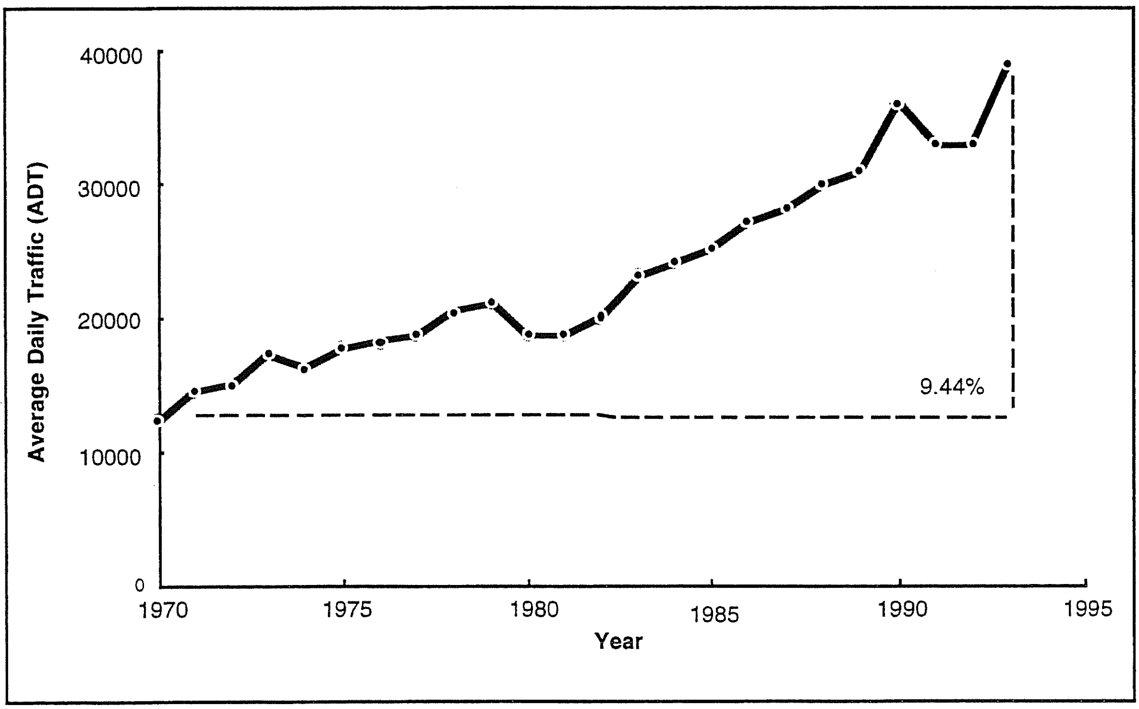
2. Harrison, R., Moh'd Suliman, and B. F. McCullough, *The Technical, Engineering, and Economic Feasibility of a High-Speed Ground Corridor,* Southwest Region University Transportation Center, Center for Transportation Research, The University of Texas at Austin, May 1993.
3. Transportation Research Board, *Highway Capacity Manual,* Special Report 209, Transportation Research Board, 1985.
4. Transportation Research Board, *Highway Capacity Manual,* Special Report 209, Transportation Research Board, 1994.
5. Macias-Mohr, R., Rob Harrison, Mark Euritt, and B. F. McCullough, *Preliminary Economic Evaluation of Alternatives for Reducing Congestion Problems in Texas,* Report 1326-2, Center For Transportation Research, The University of Texas at Austin (forthcoming).
6. Texas Department of Transportation, Permanent Automatic Traffic Recording Report, Texas Department of Transportation, 1993.
7. AASHTO, *A Policy on Geometric Design of Highways and Streets,* AASHTO, 1984.
8. The Dallas Morning News, *1992-1993 Texas Almanac,* The Dallas Morning News, 1991.
9. Texas Department of Transportation, *Vehicle Classification Report,* Texas Department of Transportation, 1993.

## APPENDIX A:

## 1970-1993 RURAL ADT HISTORY FOR SELECTED COUNTIES



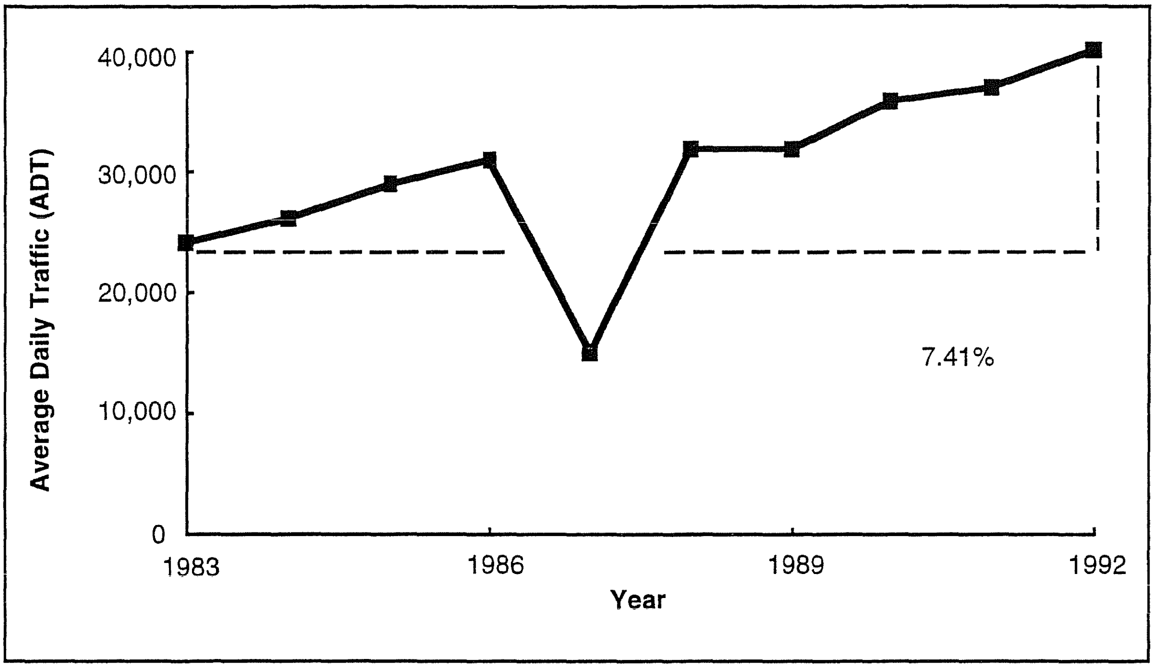

*1970–1993 traffic data for rural Hill County*



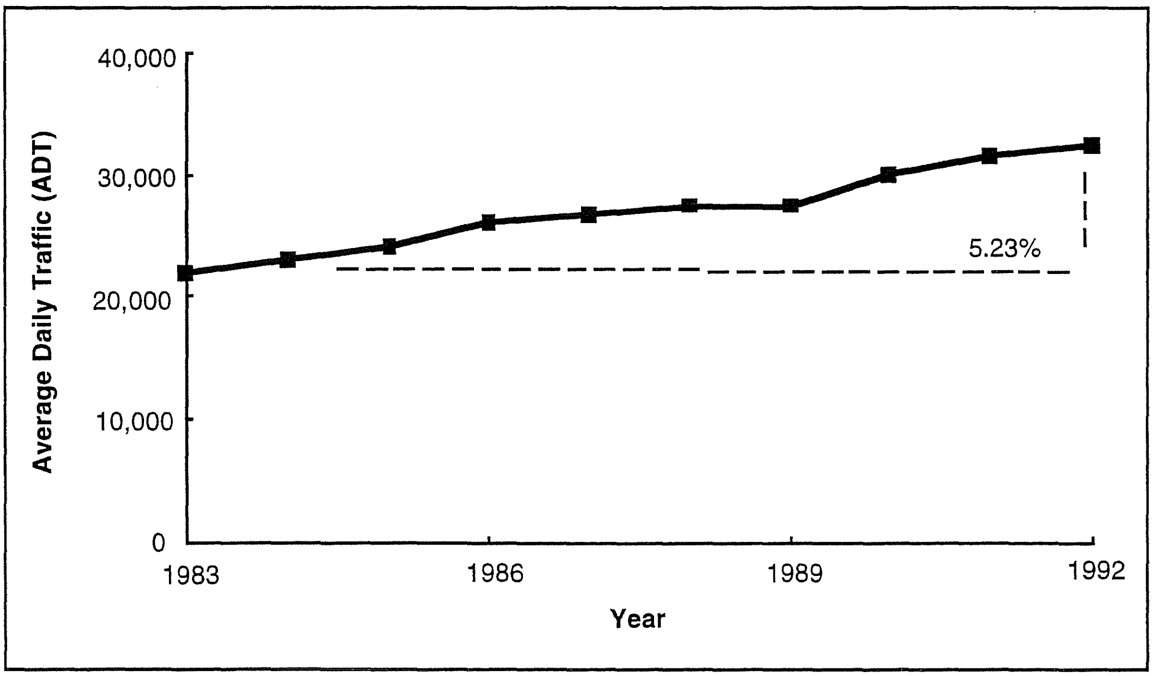

*1970–1993 traffic data for rural McLennan County*

# APPENDIX B:

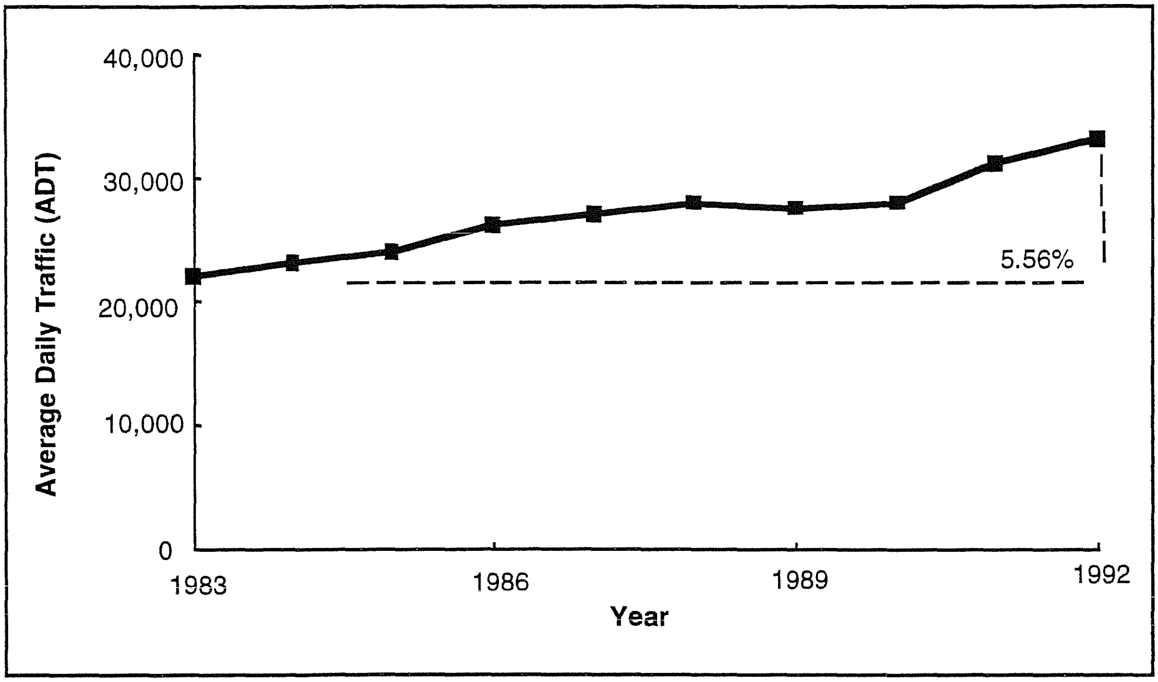
# 1983-1992 RURAL ADT HISTORY FOR SELECTED COUNTIES



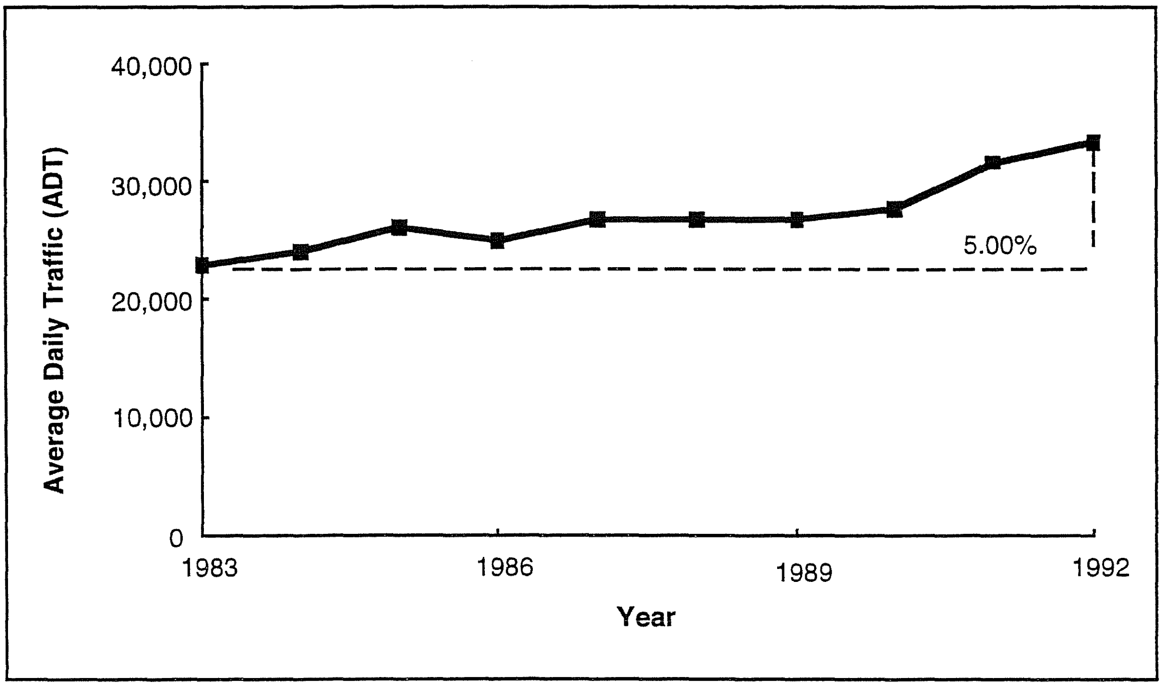

*1983–1992 historical traffic data for rural Hays County*



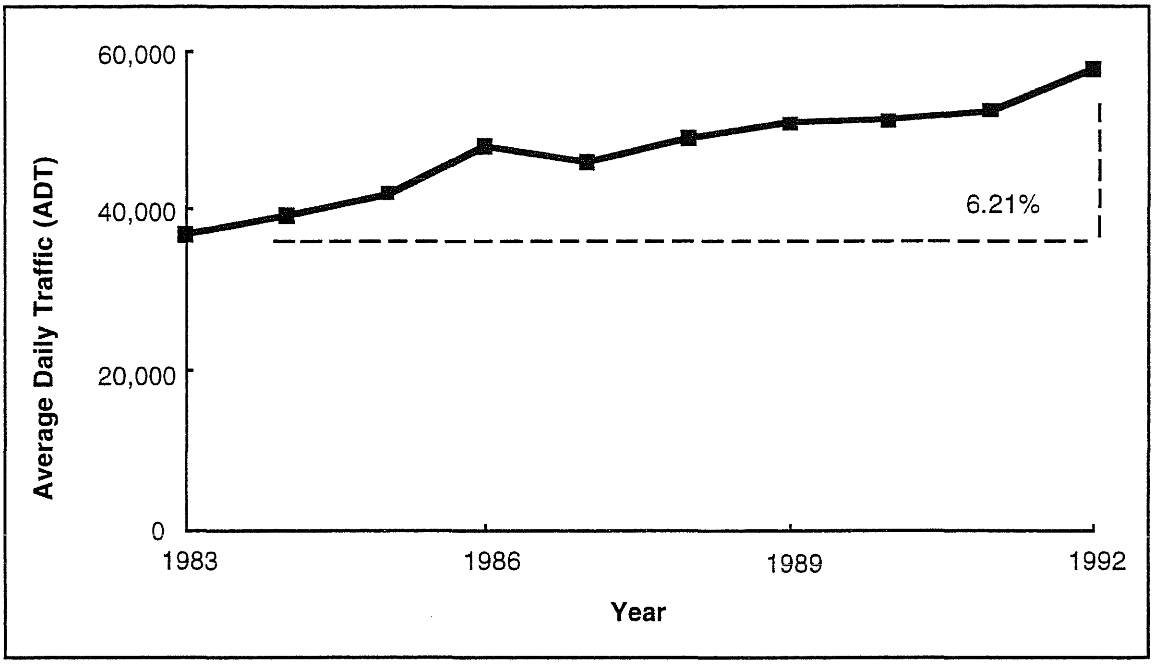

*1983–1992 historical traffic data for Bell County*




*1983–1992 historical traffic data for rural Falls County*



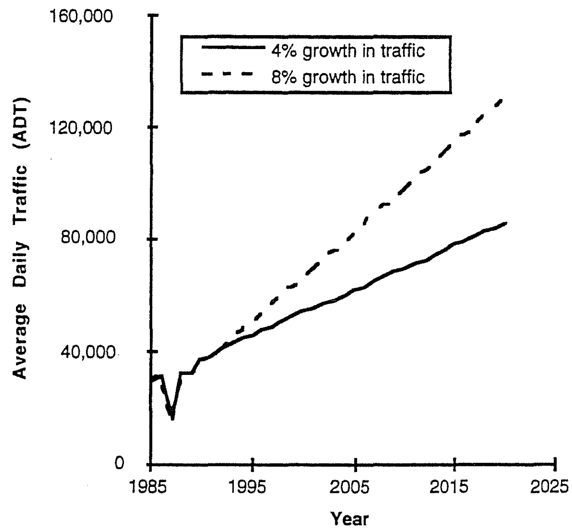

*1983–1992 historical traffic data for rural Hill County*



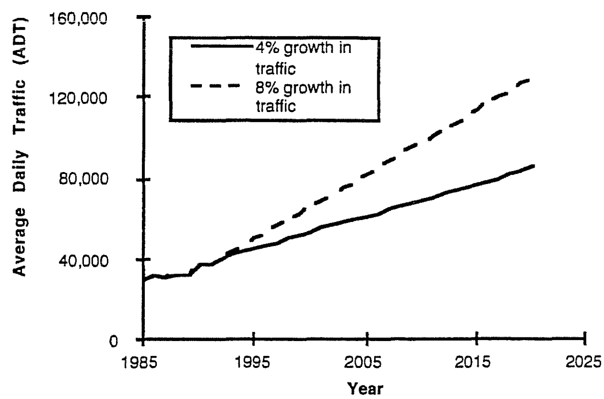

*1983–1992 historical traffic data for rural Travis County*

# APPENDIX C:

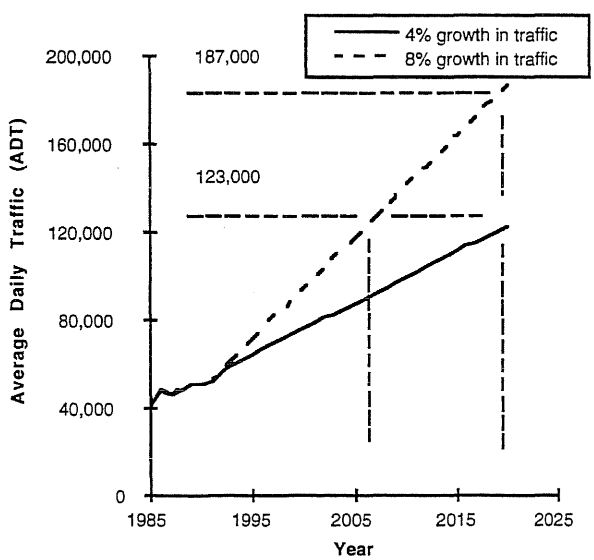
# RURAL TRAFFIC GROWTH PROJECTIONS



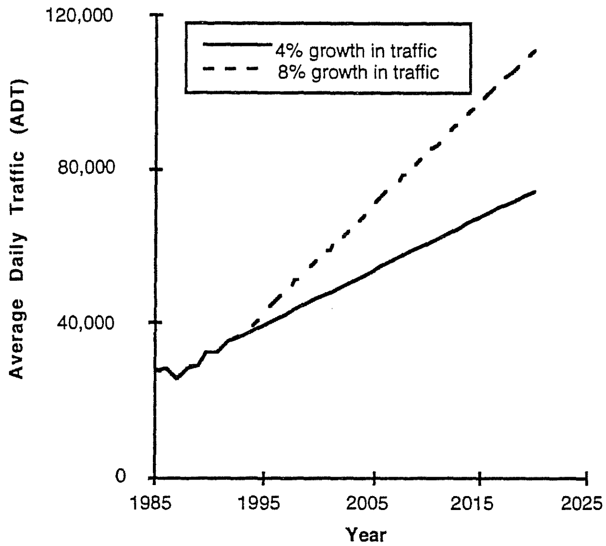

*Traffic growth patterns for rural Hays County*



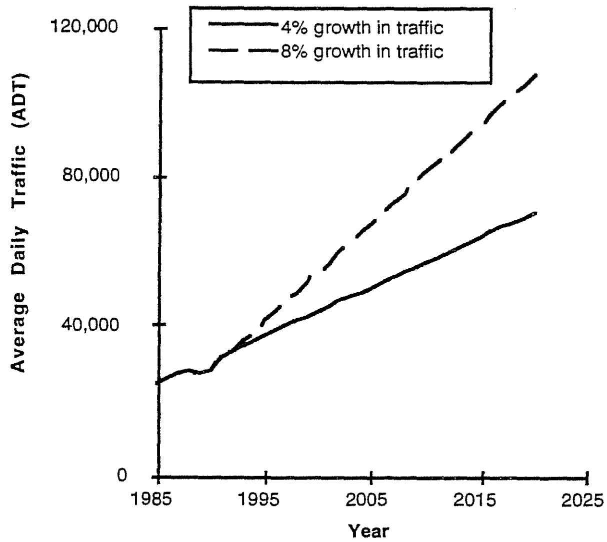

*Traffic growth patterns for rural Comal County*



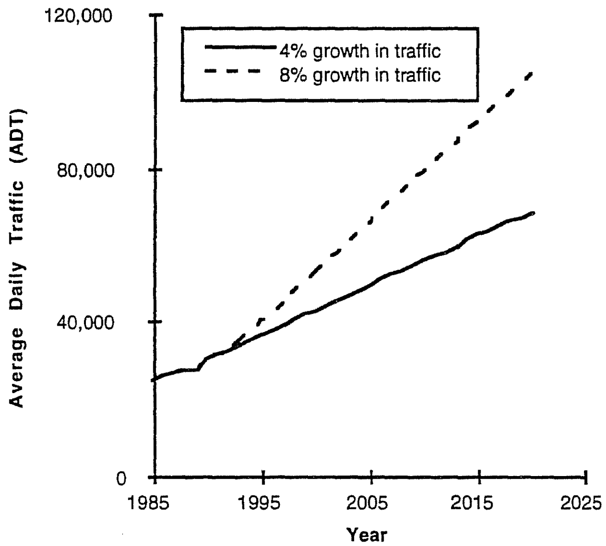

*Traffic growth patterns for rural Travis County*



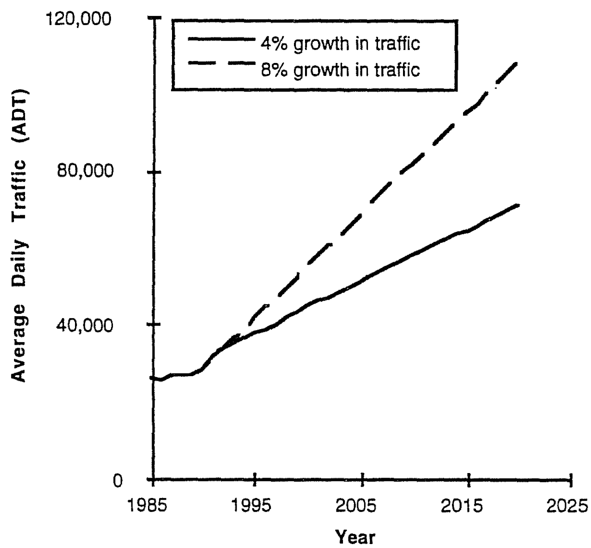

*Traffic growth patterns for rural Williamson County*




*Traffic growth patterns for rural Falls County*




*Traffic growth patterns for rural Bell County*




*Traffic growth patterns for rural Hill County*

# APPENDIX D:

# TRAFFIC DEMAND FACTOR WORKSHEETS

## Worksheet for Determining k and dd Factors

Directional Distribution Factors (D) and (K) factors for I-35 at 7 different locations
Reference: TxDOT Permanent Automatic Traffic Recorders Report 1993
AADT 30th Highest Hour data is used (1993)

| | STATION | | | | | | |
|---|---|---|---|---|---|---|---|
| FACTOR | S004 | S118 | S132 | S190 | S197 | S210 | S215 |
| dd factor | 58 | 50 | 54 | 64 | 51 | 64 | 53 |
| k factor | 9.5 | 12.5 | 8 | 10 | 13.2 | 9.4 | 14.1 |
| D AVERAGE | 56.2857143 | D=56 | | | | | |
| K AVERAGE | 10.9571429 | K=11 | | | | | |

LOCATION
S004 - .3 MI S OF FM 1626 AUSTIN
S118 -1.1 MI N. OF BU 77, N. WACO
S132 - N. OF TOWN LAKE BRIDGE AUSTIN
S190 - 1.9 MI. S OF FM 1825, N. AUSTIN
S197 - S. OF BELL-FALLS CO. L., TEMPLE
S210 - 1.8 MI. N OF ATASCOSA CO. L., SAN ANTONIO
S215 - 3.2 MI. N OF FM 487, BELTON

# Worksheet for Calculating the Percentage of Trucks

Reference: TxDOT 1993 Vehicle Classification Report

| | Station number and Location LW 513 | M 1072 | MS 1315 | MS 4 | MS 210 | MS 219 |
|---|---|---|---|---|---|---|
| No. buses | 88 | 23 | 69 | 111 | 70 | 78 |
| No. Trucks (All semis) | 5249 | 3937 | 5307 | 5291 | 2836 | 2841 |
| Tot. Veh. | 25445 | 18673 | 45744 | 59765 | 16957 | 7223 |
| Fract. trucks | 0.20974651 | 0.2120709 | 0.11752361 | 0.09038735 | 0.17137465 | 0.40412571 |
| % Trucks | 20.97% | 21.21% | 11.75% | 9.04% | 17.14% | 40.41% |

LW 513-Bell County, South of Salado perc. trucks 14.90% exc. Laredo 13.80%
M 1072 Cooke County, North of Gainesville
MS 1315 Guadalupe County @ Comal County Line
MS 4 Travis County So. of Austin
MS 210 Bexar County SW of San Antonio
MS219 Webb County North of Laredo
Note: Truck count is only tractor trailer combinations (no single units)

# APPENDIX E:

# HOURLY SERVICE FLOWS

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Hourly Service Volumes for the 6 Lane Scenario | | | | | |
| | | | Vehicles per hour per lane (4% growth rate) | | | | | |
| | | | | | | | | |
| Year | Hill | McLennan | Falls | Bell | Williamson | Travis | Hays | Comal |
| 1983 | 671 | 816 | 641 | 641 | 504 | 1079 | 700 | 700 |
| 1984 | 700 | 816 | 671 | 671 | 531 | 1137 | 758 | 787 |
| 1985 | 758 | 846 | 700 | 700 | 641 | 1225 | 846 | 846 |
| 1986 | 729 | 904 | 758 | 758 | 700 | 1400 | 904 | 904 |
| 1987 | 779 | 948 | 781 | 773 | 675 | 1345 | 437 | 897 |
| 1988 | 779 | 948 | 813 | 799 | 704 | 1429 | 926 | 926 |
| 1989 | 779 | 1011 | 803 | 799 | 704 | 1486 | 926 | 926 |
| 1990 | 804 | 1053 | 816 | 878 | 758 | 1489 | 1050 | 1079 |
| 1991 | 923 | 1113 | 907 | 916 | 962 | 1527 | 1079 | 1079 |
| 1992 | 975 | 1164 | 962 | 944 | 991 | 1682 | 1166 | 1166 |
| 1993 | 1014 | 1210 | 1001 | 981 | 1031 | 1749 | 1213 | 1213 |
| 1994 | 1053 | 1257 | 1039 | 1019 | 1071 | 1816 | 1260 | 1260 |
| 1995 | 1092 | 1303 | 1078 | 1057 | 1110 | 1883 | 1306 | 1306 |
| 1996 | 1131 | 1350 | 1116 | 1094 | 1150 | 1951 | 1353 | 1353 |
| 1997 | 1170 | 1396 | 1155 | 1132 | 1190 | 2018 | 1400 | 1400 |
| 1998 | 1209 | 1443 | 1193 | 1170 | 1229 | 2085 | 1446 | 1446 |
| 1999 | 1248 | 1489 | 1232 | 1208 | 1269 | 2152 | 1493 | 1493 |
| 2000 | 1287 | 1536 | 1270 | 1245 | 1309 | 2220 | 1540 | 1540 |
| 2001 | 1326 | 1583 | 1309 | 1283 | 1348 | 2287 | 1586 | 1586 |
| 2002 | 1365 | 1629 | 1347 | 1321 | 1388 | 2354 | 1633 | 1633 |
| 2003 | 1404 | 1676 | 1386 | 1359 | 1428 | 2421 | 1679 | 1679 |
| 2004 | 1443 | 1722 | 1424 | 1396 | 1467 | 2489 | 1726 | 1726 |
| 2005 | 1482 | 1769 | 1463 | 1434 | 1507 | 2556 | 1773 | 1773 |
| 2006 | 1521 | 1815 | 1501 | 1472 | 1547 | 2623 | 1819 | 1819 |
| 2007 | 1560 | 1862 | 1540 | 1510 | 1586 | 2690 | 1866 | 1866 |
| 2008 | 1599 | 1908 | 1578 | 1547 | 1626 | 2758 | 1913 | 1913 |
| 2009 | 1638 | 1955 | 1616 | 1585 | 1665 | 2825 | 1959 | 1959 |
| 2010 | 1677 | 2002 | 1655 | 1623 | 1705 | 2892 | 2006 | 2006 |
| 2011 | 1716 | 2048 | 1693 | 1661 | 1745 | 2959 | 2053 | 2053 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2012 | 1755 | 2095 | 1732 | 1698 | 1784 | 3027 | 2099 | 2099 |
| 2013 | 1794 | 2141 | 1770 | 1736 | 1824 | 3094 | 2146 | 2146 |
| 2014 | 1833 | 2188 | 1809 | 1774 | 1864 | 3161 | 2193 | 2193 |
| 2015 | 1872 | 2234 | 1847 | 1812 | 1903 | 3228 | 2239 | 2239 |
| 2016 | 1911 | 2281 | 1886 | 1849 | 1943 | 3296 | 2286 | 2286 |
| 2017 | 1950 | 2327 | 1924 | 1887 | 1983 | 3363 | 2333 | 2333 |
| 2018 | 1989 | 2374 | 1963 | 1925 | 2022 | 3430 | 2379 | 2379 |
| 2019 | 2028 | 2420 | 2001 | 1963 | 2062 | 3498 | 2426 | 2426 |
| 2020 | 2067 | 2467 | 2040 | 2000 | 2102 | 3565 | 2473 | 2473 |
| 2021 | 2106 | 2514 | 2078 | 2038 | 2141 | 3632 | 2519 | 2519 |

| | | | Hourly Service Volumes for the 6 Lane Scenario | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Vehicles per hour per lane (8% growth rate) | | | | | |
| Year | Hill | McLennan | Falls | Bell | Williamson | Travis | Hays | Comal |
| 1983 | 671 | 816 | 641 | 641 | 504 | 1079 | 700 | 700 |
| 1984 | 700 | 816 | 671 | 671 | 531 | 1137 | 758 | 787 |
| 1985 | 758 | 846 | 700 | 700 | 641 | 1225 | 846 | 846 |
| 1986 | 729 | 904 | 758 | 758 | 700 | 1400 | 904 | 904 |
| 1987 | 779 | 948 | 781 | 773 | 675 | 1345 | 437 | 897 |
| 1988 | 779 | 948 | 813 | 799 | 704 | 1429 | 926 | 926 |
| 1989 | 779 | 1011 | 803 | 799 | 704 | 1486 | 926 | 926 |
| 1990 | 804 | 1053 | 816 | 878 | 758 | 1489 | 1050 | 1079 |
| 1991 | 923 | 1113 | 907 | 916 | 962 | 1527 | 1079 | 1079 |
| 1992 | 975 | 1164 | 962 | 944 | 991 | 1682 | 1166 | 1166 |
| 1993 | 1053 | 1257 | 1039 | 1019 | 1071 | 1816 | 1260 | 1260 |
| 1994 | 1131 | 1350 | 1116 | 1094 | 1150 | 1951 | 1353 | 1353 |
| 1995 | 1209 | 1443 | 1193 | 1170 | 1229 | 2085 | 1446 | 1446 |
| 1996 | 1287 | 1536 | 1270 | 1245 | 1309 | 2220 | 1540 | 1540 |
| 1997 | 1365 | 1629 | 1347 | 1321 | 1388 | 2354 | 1633 | 1633 |
| 1998 | 1443 | 1722 | 1424 | 1396 | 1467 | 2489 | 1726 | 1726 |
| 1999 | 1521 | 1815 | 1501 | 1472 | 1547 | 2623 | 1819 | 1819 |
| 2000 | 1599 | 1908 | 1578 | 1547 | 1626 | 2758 | 1913 | 1913 |
| 2001 | 1677 | 2002 | 1655 | 1623 | 1705 | 2892 | 2006 | 2006 |
| 2002 | 1755 | 2095 | 1732 | 1698 | 1784 | 3027 | 2099 | 2099 |
| 2003 | 1833 | 2188 | 1809 | 1774 | 1864 | 3161 | 2193 | 2193 |
| 2004 | 1911 | 2281 | 1886 | 1849 | 1943 | 3296 | 2286 | 2286 |
| 2005 | 1989 | 2374 | 1963 | 1925 | 2022 | 3430 | 2379 | 2379 |
| 2006 | 2067 | 2467 | 2040 | 2000 | 2102 | 3565 | 2473 | 2473 |
| 2007 | 2145 | 2560 | 2117 | 2076 | 2181 | 3699 | 2566 | 2566 |
| 2008 | 2223 | 2653 | 2194 | 2151 | 2260 | 3834 | 2659 | 2659 |
| 2009 | 2301 | 2746 | 2271 | 2227 | 2340 | 3968 | 2752 | 2752 |
| 2010 | 2379 | 2839 | 2348 | 2302 | 2419 | 4103 | 2846 | 2846 |
| 2011 | 2457 | 2932 | 2425 | 2378 | 2498 | 4237 | 2939 | 2939 |
| 2012 | 2535 | 3026 | 2502 | 2453 | 2578 | 4372 | 3032 | 3032 |

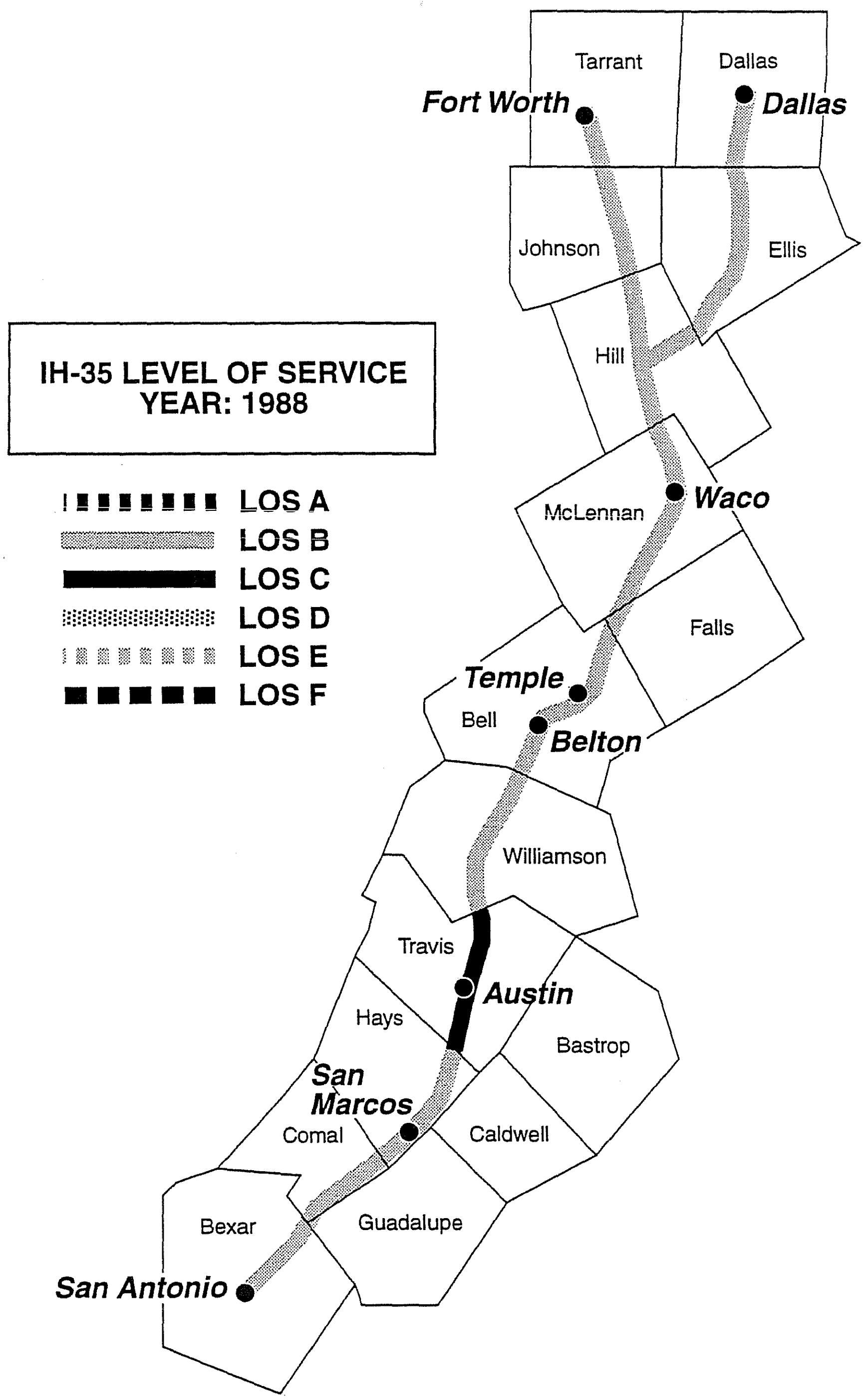
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2013 | 2613 | 3119 | 2579 | 2529 | 2657 | 4506 | 3126 | 3126 |
| 2014 | 2691 | 3212 | 2656 | 2604 | 2736 | 4641 | 3219 | 3219 |
| 2015 | 2769 | 3305 | 2733 | 2680 | 2815 | 4775 | 3312 | 3312 |
| 2016 | 2847 | 3398 | 2810 | 2755 | 2895 | 4910 | 3406 | 3406 |
| 2017 | 2925 | 3491 | 2887 | 2831 | 2974 | 5045 | 3499 | 3499 |
| 2018 | 3003 | 3584 | 2964 | 2906 | 3053 | 5179 | 3592 | 3592 |
| 2019 | 3081 | 3677 | 3041 | 2982 | 3133 | 5314 | 3685 | 3685 |
| 2020 | 3159 | 3770 | 3118 | 3057 | 3212 | 5448 | 3779 | 3779 |
| 2021 | 3237 | 3863 | 3194 | 3133 | 3291 | 5583 | 3872 | 3872 |

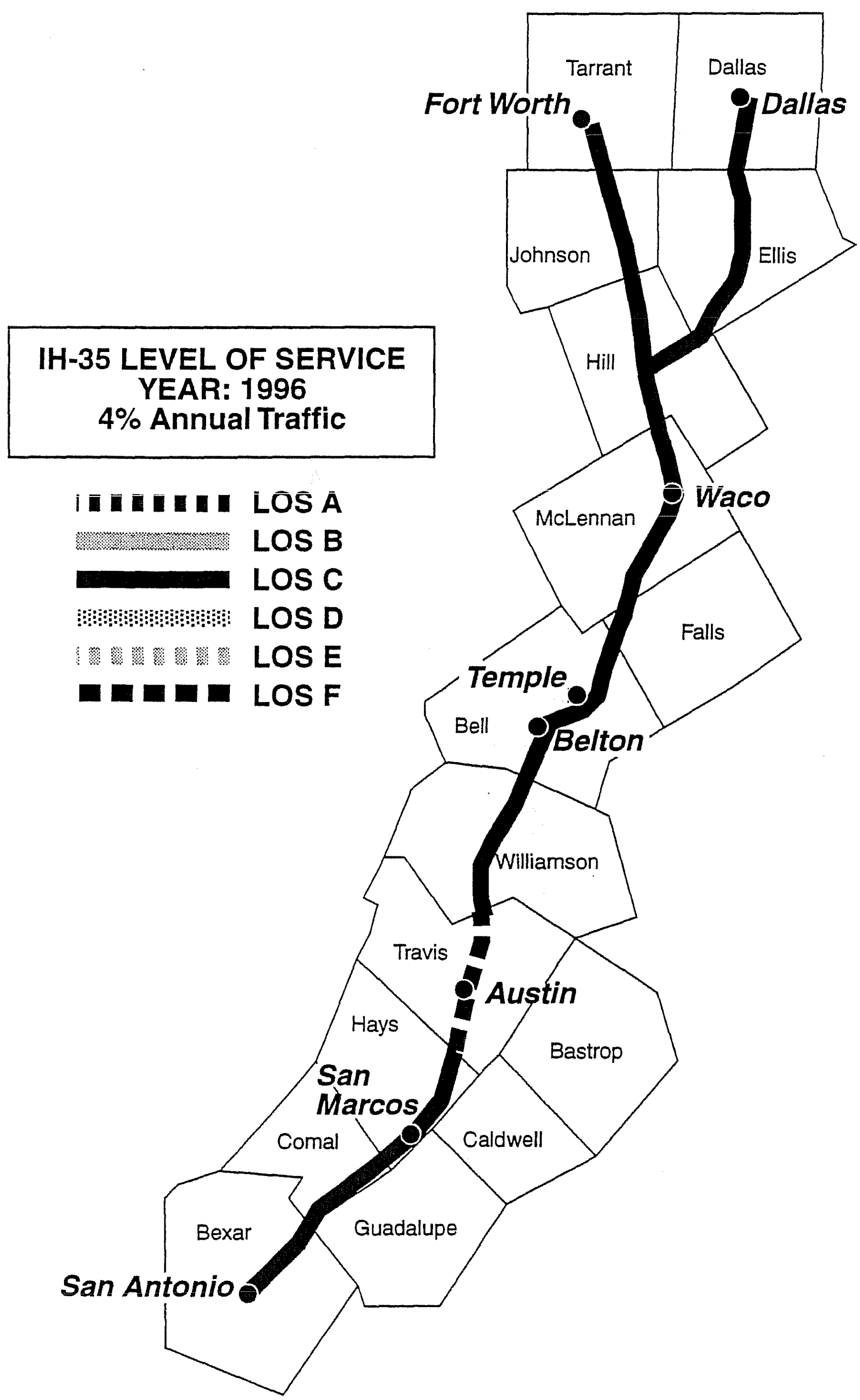
| | Hourly Service Volumes for the Present Configuration* | | | |
|---|---|---|---|---|
| | Vehicles per hour per lane (4% growth rate) | | | |
| | | | | |
| Year | Hill | Falls | Bell | Williamson |
| 1983 | 1006 | 962 | 962 | 757 |
| 1984 | 1050 | 1006 | 1006 | 796 |
| 1985 | 1137 | 1050 | 1050 | 962 |
| 1986 | 1093 | 1137 | 1137 | 1050 |
| 1987 | 1168 | 1172 | 1160 | 1012 |
| 1988 | 1168 | 1219 | 1199 | 1056 |
| 1989 | 1168 | 1205 | 1199 | 1056 |
| 1990 | 1205 | 1224 | 1316 | 1137 |
| 1991 | 1384 | 1361 | 1374 | 1443 |
| 1992 | 1463 | 1443 | 1415 | 1487 |
| 1993 | 1521 | 1501 | 1472 | 1547 |
| 1994 | 1580 | 1559 | 1529 | 1606 |
| 1995 | 1638 | 1616 | 1585 | 1665 |
| 1996 | 1697 | 1674 | 1642 | 1725 |
| 1997 | 1755 | 1732 | 1698 | 1784 |
| 1998 | 1814 | 1790 | 1755 | 1844 |
| 1999 | 1872 | 1847 | 1812 | 1903 |
| 2000 | 1931 | 1905 | 1868 | 1963 |
| 2001 | 1989 | 1963 | 1925 | 2022 |
| 2002 | 2048 | 2021 | 1981 | 2082 |
| 2003 | 2106 | 2078 | 2038 | 2141 |
| 2004 | 2165 | 2136 | 2095 | 2201 |
| 2005 | 2223 | 2194 | 2151 | 2260 |
| 2006 | 2282 | 2252 | 2208 | 2320 |
| 2007 | 2340 | 2309 | 2264 | 2379 |
| 2008 | 2399 | 2367 | 2321 | 2439 |
| 2009 | 2457 | 2425 | 2378 | 2498 |
| 2010 | 2516 | 2482 | 2434 | 2558 |
| 2011 | 2574 | 2540 | 2491 | 2617 |
| 2012 | 2633 | 2598 | 2548 | 2677 |
| 2013 | 2691 | 2656 | 2604 | 2736 |
| 2014 | 2750 | 2713 | 2661 | 2796 |
| 2015 | 2808 | 2771 | 2717 | 2855 |
| 2016 | 2867 | 2829 | 2774 | 2915 |
| 2017 | 2925 | 2887 | 2831 | 2974 |
| 2018 | 2984 | 2944 | 2887 | 3034 |
| 2019 | 3042 | 3002 | 2944 | 3093 |
| 2020 | 3101 | 3060 | 3000 | 3152 |
| 2021 | 3159 | 3118 | 3057 | 3212 |
| | | | | |
| *Present Configuration consists of 6 lanes in McLennan, Travis, | | | | |
| Hays, & Comal counties and 4 lanes in the counties listed above | | | | |

| | Hourly Service Volumes for the Present Configuration* | | | |
|---|---|---|---|---|
| | Vehicles per hour per lane (8% growth rate) | | | |
| | | | | |
| Year | Hill | Falls | Bell | Williamson |
| 1983 | 1006 | 962 | 962 | 757 |
| 1984 | 1050 | 1006 | 1006 | 796 |
| 1985 | 1137 | 1050 | 1050 | 962 |
| 1986 | 1093 | 1137 | 1137 | 1050 |
| 1987 | 1168 | 1172 | 1160 | 1012 |
| 1988 | 1168 | 1219 | 1199 | 1056 |
| 1989 | 1168 | 1205 | 1199 | 1056 |
| 1990 | 1205 | 1224 | 1316 | 1137 |
| 1991 | 1384 | 1361 | 1374 | 1443 |
| 1992 | 1463 | 1443 | 1415 | 1487 |
| 1993 | 1580 | 1559 | 1529 | 1606 |
| 1994 | 1697 | 1674 | 1642 | 1725 |
| 1995 | 1814 | 1790 | 1755 | 1844 |
| 1996 | 1931 | 1905 | 1868 | 1963 |
| 1997 | 2048 | 2021 | 1981 | 2082 |
| 1998 | 2165 | 2136 | 2095 | 2201 |
| 1999 | 2282 | 2252 | 2208 | 2320 |
| 2000 | 2399 | 2367 | 2321 | 2439 |
| 2001 | 2516 | 2482 | 2434 | 2558 |
| 2002 | 2633 | 2598 | 2548 | 2677 |
| 2003 | 2750 | 2713 | 2661 | 2796 |
| 2004 | 2867 | 2829 | 2774 | 2915 |
| 2005 | 2984 | 2944 | 2887 | 3034 |
| 2006 | 3101 | 3060 | 3000 | 3152 |
| 2007 | 3218 | 3175 | 3114 | 3271 |
| 2008 | 3335 | 3291 | 3227 | 3390 |
| 2009 | 3452 | 3406 | 3340 | 3509 |
| 2010 | 3569 | 3522 | 3453 | 3628 |
| 2011 | 3686 | 3637 | 3567 | 3747 |
| 2012 | 3803 | 3753 | 3680 | 3866 |
| 2013 | 3920 | 3868 | 3793 | 3985 |
| 2014 | 4037 | 3983 | 3906 | 4104 |
| 2015 | 4154 | 4099 | 4019 | 4223 |
| 2016 | 4271 | 4214 | 4133 | 4342 |
| 2017 | 4388 | 4330 | 4246 | 4461 |
| 2018 | 4505 | 4445 | 4359 | 4580 |
| 2019 | 4622 | 4561 | 4472 | 4699 |
| 2020 | 4739 | 4676 | 4586 | 4818 |
| 2021 | 4856 | 4792 | 4699 | 4937 |
| | | | | |
| *Present Configuration consists of 6 lanes in McLennan, Travis, | | | | |
| Hays, & Comal counties and 4 lanes in the counties listed above | | | | |

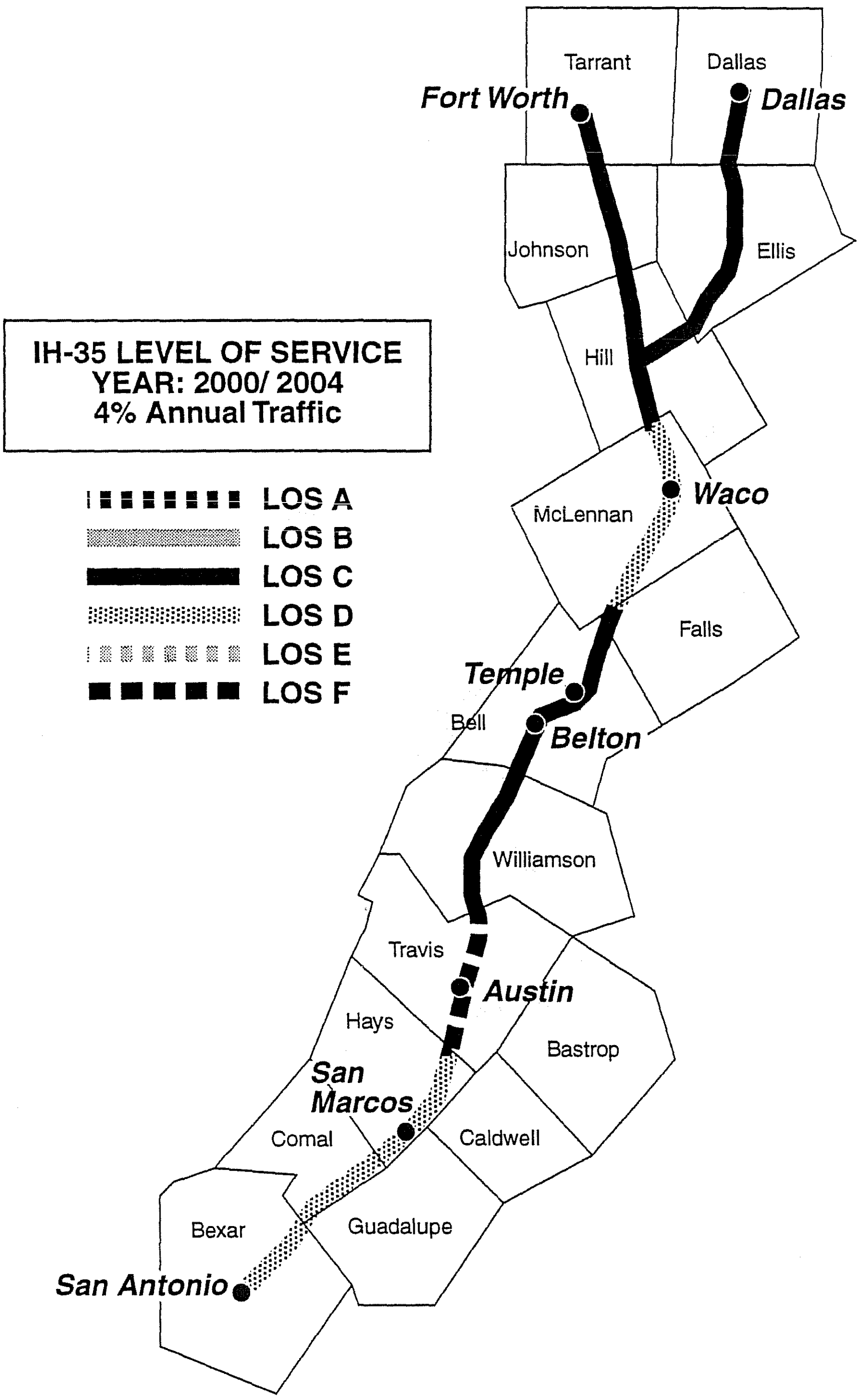
# APPENDIX F:

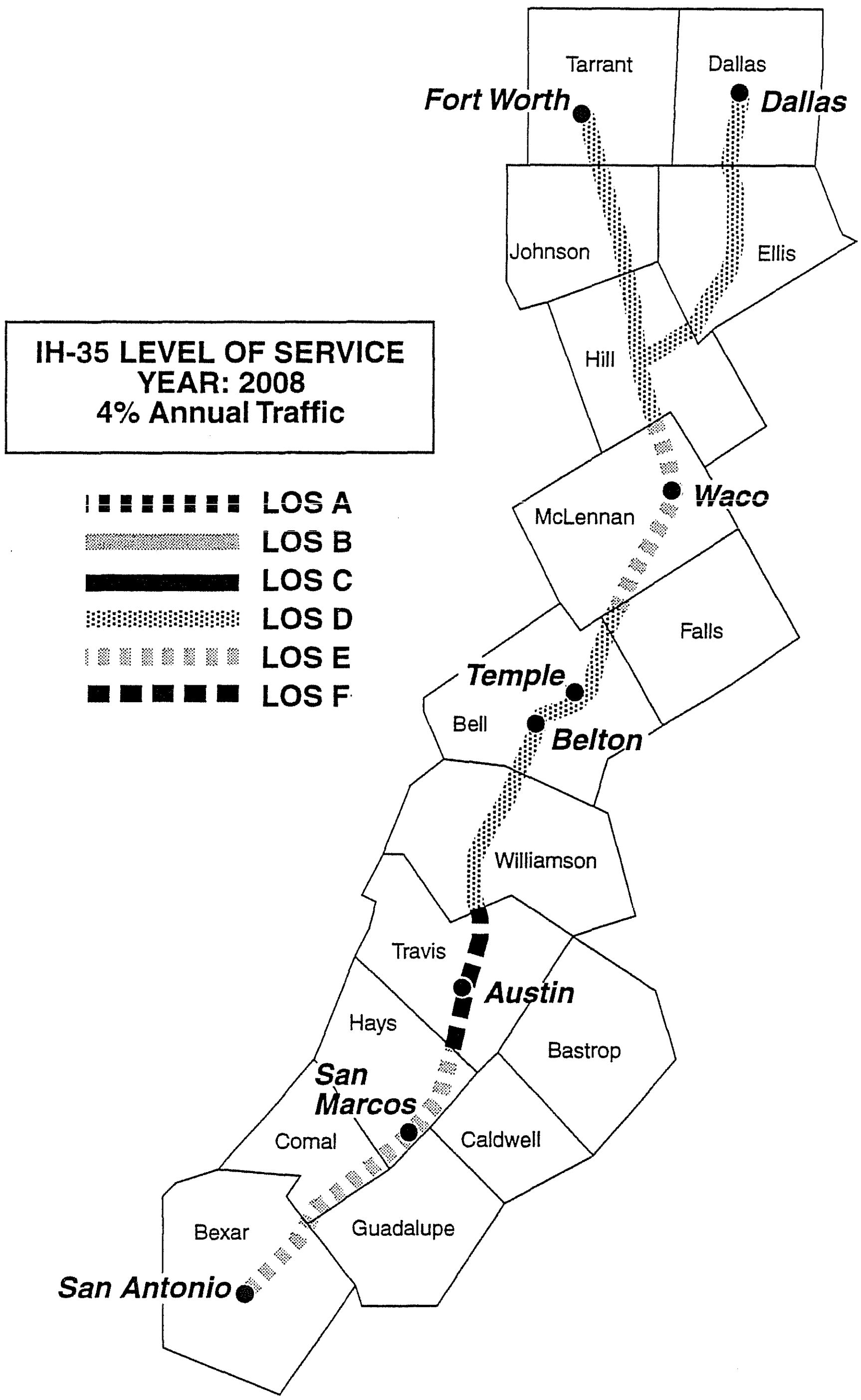
# CAPACITY MAPS

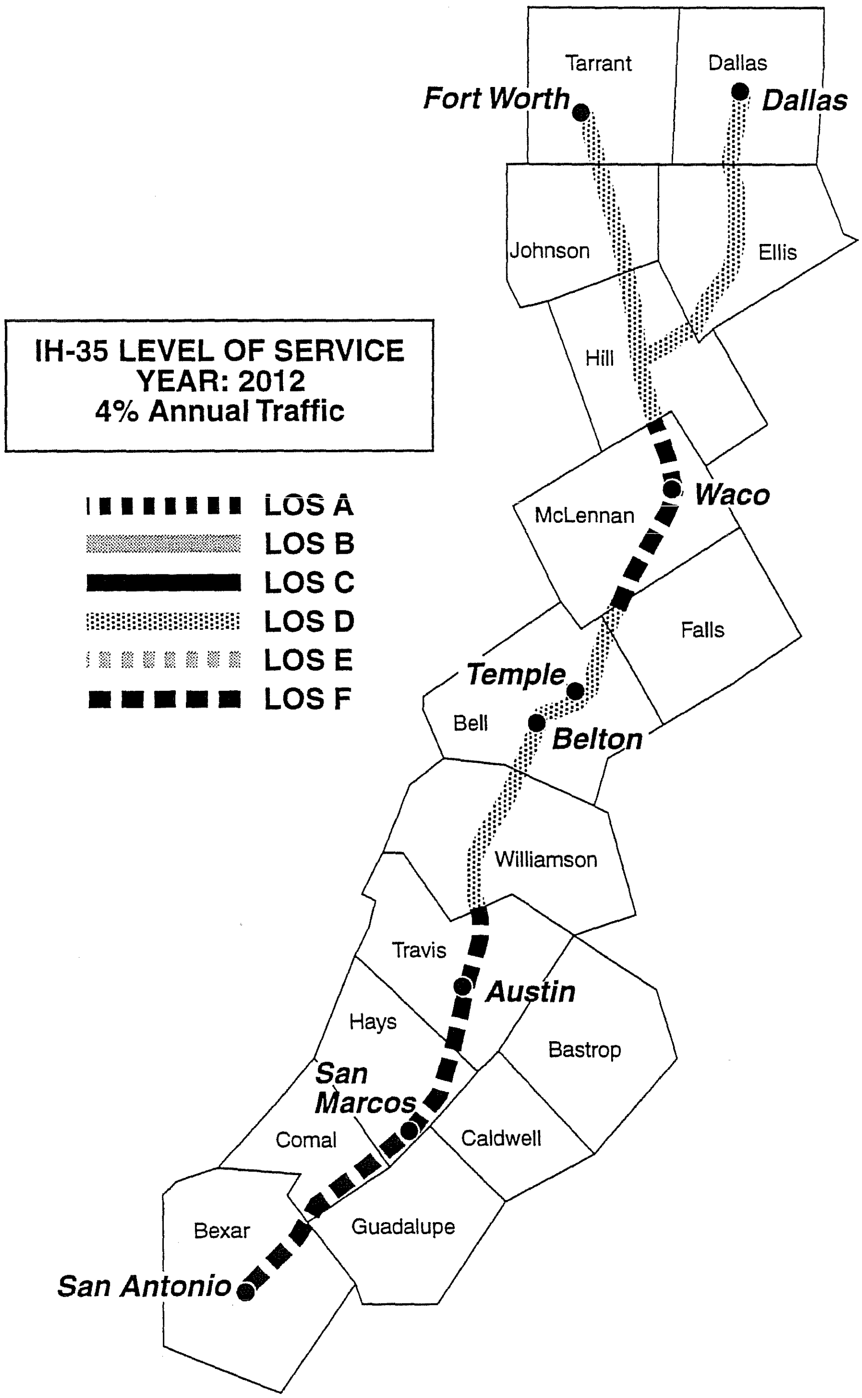

IH-35 LEVEL OF SERVICE
YEAR: 1988
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio

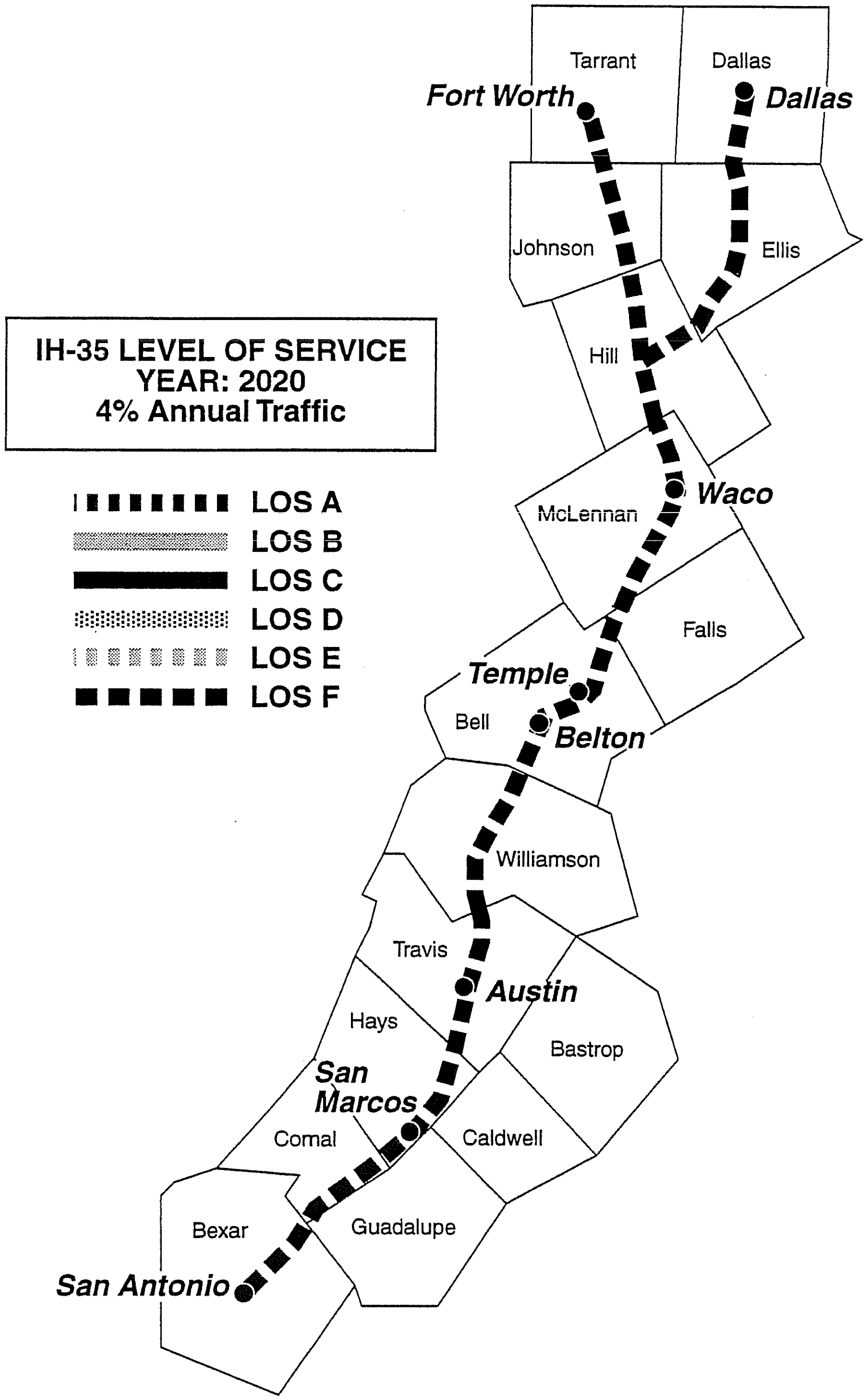


IH-35 LEVEL OF SERVICE
YEAR: 1996
4% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio

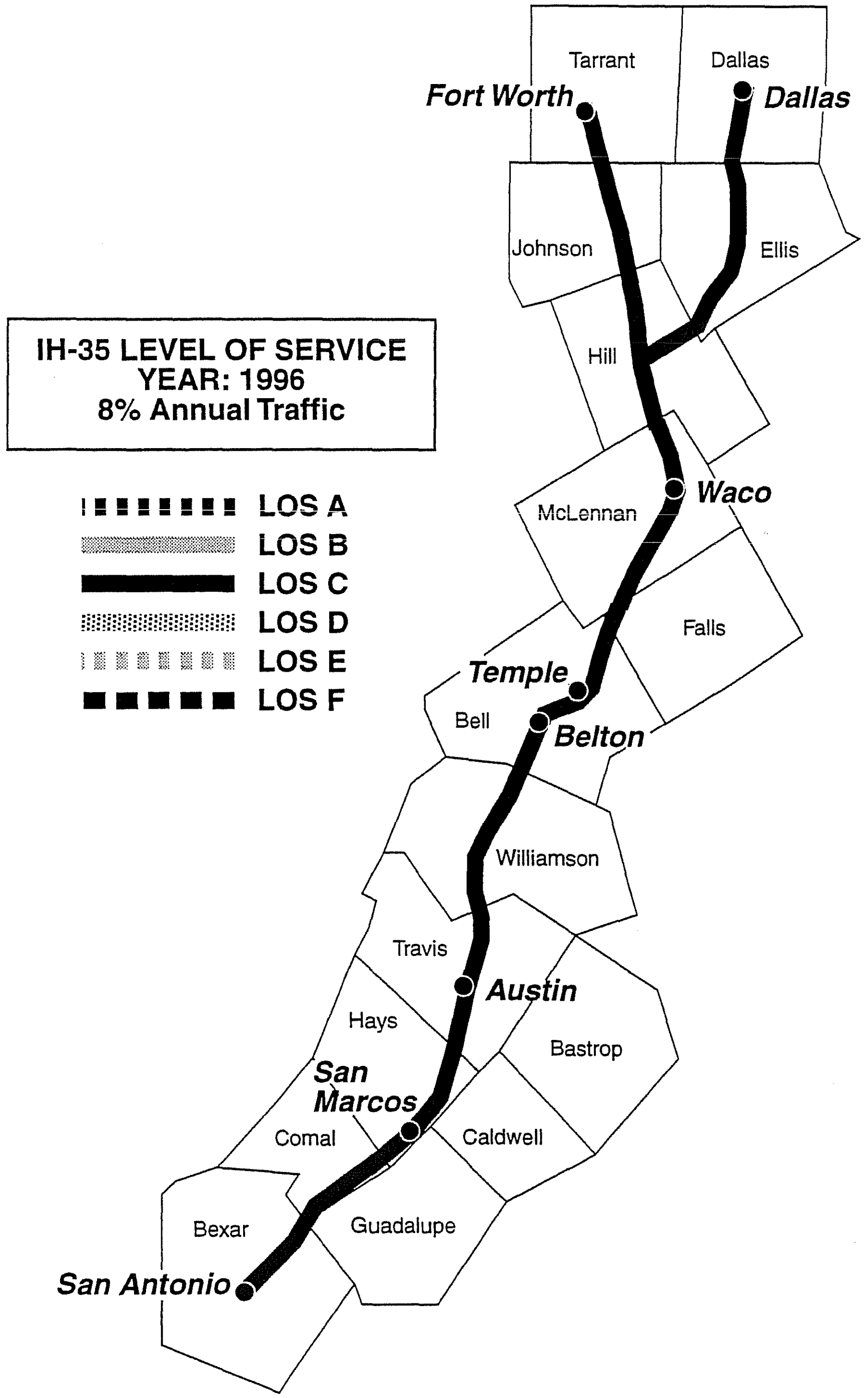

IH-35 LEVEL OF SERVICE
YEAR: 2000/ 2004
4% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio

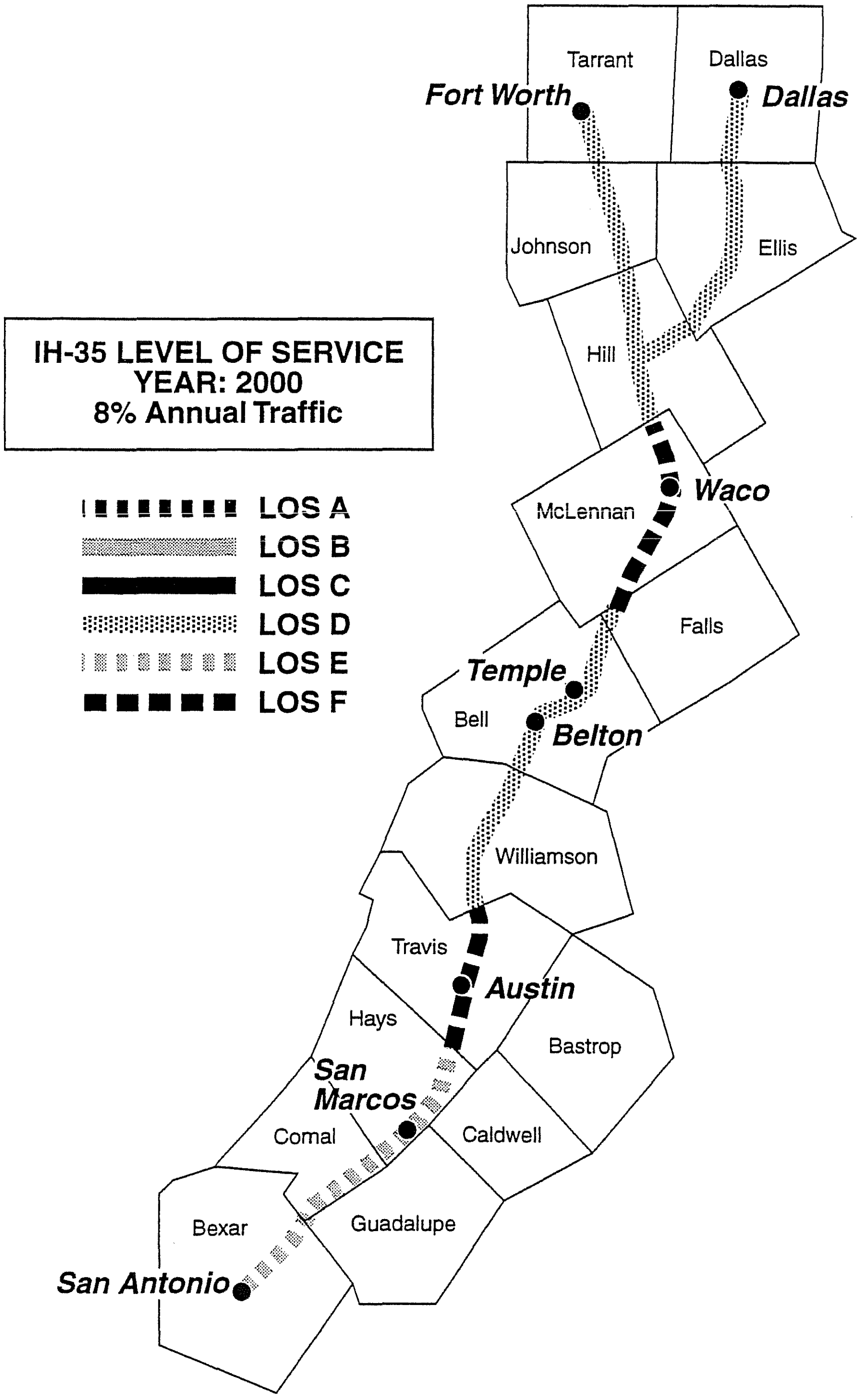

IH-35 LEVEL OF SERVICE
YEAR: 2008
4% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio


IH-35 LEVEL OF SERVICE
YEAR: 2012
4% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio



IH-35 LEVEL OF SERVICE
YEAR: 2020
4% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio


IH-35 LEVEL OF SERVICE
YEAR: 1996
8% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
Waco
McLennan
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Hays
Bastrop
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio


IH-35 LEVEL OF SERVICE
YEAR: 2000
8% Annual Traffic
LOS A
LOS B
LOS C
LOS D
LOS E
LOS F
Tarrant
Dallas
Fort Worth
Dallas
Johnson
Ellis
Hill
McLennan
Waco
Falls
Temple
Bell
Belton
Williamson
Travis
Austin
Bastrop
Hays
San Marcos
Comal
Caldwell
Bexar
Guadalupe
San Antonio