Methodology for Estimating Urban Roadway System Congestion

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The major urban areas in Texas have experienced a period of unprecedented growth. Along with that growth came significant increases in traffic congestion with corresponding declines in urban mobility. A procedure was developed to estimate the relative traffic congestion levels on urban-area roadway systems. The data elements of the methodology are available from planning agencies and are based on an urban-area designation rather than specific political boundaries. The methodology can be utilized by agencies in urban areas that rely on the freeway and street system to provide person movement. The methodology was illustrated using 1975–1984 data from Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, and San Antonio. An estimate of the number of years before congestion reaches an undesirable level was generated for each major urban area.

Economic growth in major Texas urban areas since the decade of the 1960s has been widely reported, along with the factors that facilitated that growth. Among other factors, the perceived quality of life enjoyed by residents of large Texas cities in the 1960s led to an increase in major business relocation and new business formation in Texas and throughout the Sun Belt. Good transportation and desirable single-family dwellings in suburban areas within relatively short commuting distances to employment centers were important factors, along with the increase in economic activity, in the expansion of major Texas cities. Freeway, expressway, and arterial street systems were expanded or constructed during the initial years of this growth. Inexpensive land and increasing levels of mobility provided by freeways resulted in residential, commercial, and office-space construction at increasing distances from the traditional city centers. Urban Texans have shown that they will locate 20 mi or more from downtown in order to obtain a single-family house on an individual lot.

This choice of residential development has not been without its costs, however, as an analysis of traffic volume demand and roadway capacity indicates. The decade of the 1970s saw a decline in the rate of new freeway and major street construction and a rapid increase in traffic volume due to economic growth. Although lack of funding and concern about available rights-of-way and the environment slowed new freeway construction in many large cities, traffic volume growth rates much greater than those projected produced congested roadways much sooner than had been expected. The promise of near-optimal mobility with the automobile was broken with the rapid rise of congestion.

The mobility decline detailed in the second part of this paper helped to prompt increases in federal, state, and local funding for transportation improvement projects. Expenditures and project justifications are determined on an individual basis, but the condition of the transportation system as a whole is indicative of overall urban mobility. The manner in which projects are chosen, the economic resources expended in their construction, and their impact on reducing commuter travel delay are important factors in determining the amount of support that urban residents will have for new projects.

In the initial section of this paper the development of a procedure used to rank relative mobility in major urban areas is detailed. The data used are generally available from federal, state, and local sources. The general approach is that of a planning-level analysis, which should not require a significant amount of new data collection. No attempt was made in this study to estimate future mobility levels, but rather to illustrate and quantify historical changes in traffic volumes and congestion.

CONGESTION MEASUREMENT METHODOLOGY

Previous research (*1*) into mobility levels in Texas resulted in a methodology to compare urban roadway congestion levels. In this section the purpose, data base, analysis procedure, and major findings of that research effort are summarized.

Purpose

Transportation professionals and the general public are becoming increasingly aware of the traffic congestion levels experienced in major cities. This interest has resulted in research on a procedure that would allow quantitative comparisons of urban areawide traffic volumes and roadway mileage. Obviously, a procedure that could be used by transportation planning agencies with generally available data would be more accessible than one that required new or more extensive data collection.

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Data Base

In the initial relative mobility study, available data proved to be the largest problem. Consistent data that allowed an accurate comparative assessment of urban congestion are not available from any agency or group of agencies. Data collected in several ways by many sources were acquired. In the opinion of the research staff and reviewers of the research report, however, the quantitative measures used in the study did provide a reasonably accurate measure of overall urban mobility. The general nature of the mobility assessment and the variety of data sources as well as the experience of the reviewing agencies combined to provide analysis results consistent with the accuracy level desired. Comparability of the measures was achieved by using several estimates of both travel and area statistics. For example, in defining an urban area, it was not always possible to use jurisdictional limits as the boundaries because of either lack of data on related travel measures or noncomparability of information. County boundaries may appear to provide consistency, but variations in county size as well as percentage of urbanization significantly impaired the utility of county-based data.

Houston's Experience with Declining Mobility

The Houston data detailing the increase in congestion were analyzed to provide a basis for quantitative indicators of mobility decline. The rapid increase in congestion on Houston-area freeways and arterial streets during the 1970s emphasized the need for actions to restore and maintain good mobility.

The disparity between increases in freeway lane miles and in freeway travel during the 1970s in Houston is quantified in Table 1 and Figure 1. The rate of new freeway construction in the 1970s was one-sixth that of the 1960s, whereas daily freeway vehicle miles of travel (VMT) increased at approximately the same rate throughout the 20-year period (*2*). Vehicle registration, population, and traffic volume counts were thoroughly analyzed and also demonstrated the shift from relatively good mobility to relatively poor mobility in only a few years.

Congestion increases were also apparent in the travel delay estimates. Peak-period volume and travel-time information was used to generate the data in Table 2 and Figure 2. Six major radial freeways were evaluated in each of four travel studies conducted by the Houston-Galveston

TABLE 1 GROWTH TRENDS, CITY OF HOUSTON, 1950 TO 1980 (*1, 3*)

Year	Annual Average Population (1000)	Annual Average Vehicles (1000)	Freeway Travel in VMT Per Day[1] (1000)	Freeway Capacity (Lane-Miles)	Daily VMT Per Freeway Lane-Mile (1000)
1950	596[2]	240	201	24	8.4
1955	692[2]	375	620	100	6.2
1960	938[2]	480	1,044	187	5.6
1965	1,084	625	3,425	456	7.5
1970	1,240	777	7,320	761	9.6
1975	1,440	1,000	11,366	898	12.7
1980	1,604	1,272	16,308	959	17.0
Percent Increase Per Year					
1960-70	2.8	4.9	19.6	15.1	5.5
1970-80	2.6	5.1	8.4	2.4	5.9

[1]VMT--Vehicle-Miles of Travel

[2]As of April 1

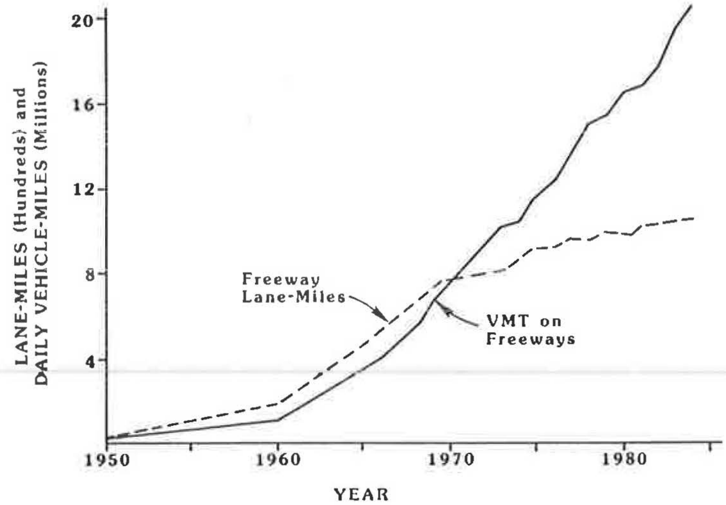
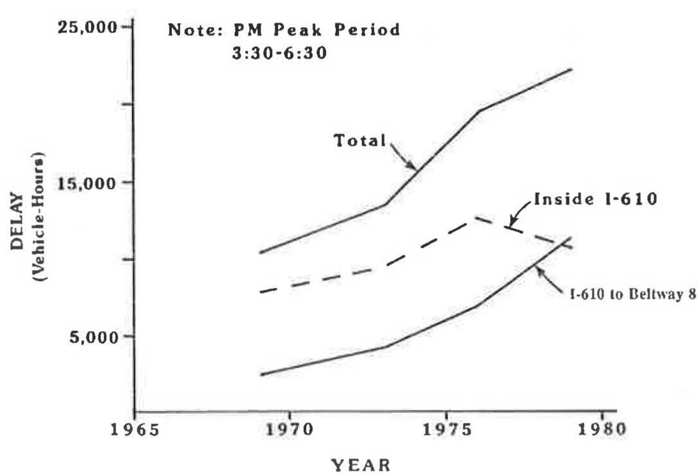


FIGURE 1 Freeway capacity and travel in Houston, 1950 to 1984.

TABLE 2 AVERAGE PEAK-PERIOD DELAY BY FREEWAY SEGMENT FOR SIX MAJOR RADIAL FREEWAYS (*1, 2, 4–6*)

Year	Inside I-610 (Veh-Hours)	I-610 to Beltway 8 (Veh-Hours)	Total (Veh-Hours)
1969	7,880	2,330	10,210
1973	9,370	4,120	13,490
1976	12,650	6,990	19,640
1979	10,970	11,170	22,150



Note: The values presented are total delay for the six freeways studied (I-10W, I-10E, US 59S, US 59N, I-45S, I-45N).

FIGURE 2 Delay by segment for Houston freeways, afternoon peak period (*1, 2, 4–6*).

Regional Transportation Study (HGRTS) (*4*). The dramatic (380 percent) increase in delay in the area from I-610 to Beltway 8 (Figure 2) from 1969 to 1979 indicates the decline in mobility outside the central city area. The decrease in delay inside I-610 (a major circumferential freeway approximately 5 mi from downtown) may be attributable to several factors, including the completion of certain freeway sections and the traffic-metering effect of I-610. On most radial freeways the number of lanes outside Loop 610 is less than that inside the loop. Volumes, however, are not significantly lower, which results in greater congestion outside I-610.

The decline in mobility carries with it a substantial cost. A study performed in Houston (*7*) estimated that in 1981 congestion cost Houstonians $1.9 billion. By most standards, the level of congestion that existed in Houston during the early 1980s would not be acceptable.

The maximum freeway service flow rate for level-of-service C (LOS C) is 1,550 passenger cars per hour per lane (volume/capacity ratio equal to 0.77) for a 70-mph design speed facility (*8*). Using average values for *k*-factor and directional distribution and including some adjustment for trucks and lateral obstructions, these values can be interpreted to indicate that 15,000 vehicles per day (vpd) per lane is an estimate of the beginning of LOS D operation. The development of this value is consistent with the planning-level analysis methodology presented in this paper.

The use of the boundary between LOS C and D as the beginning of congestion is consistent with reports by the U.S. Department of Transportation to Congress on the status of highways in the United States (*9*) (congestion begins at a *v/c* ratio of 0.8) and the AASHTO Policy on Geometric Design of Highways and Streets (*10*) (urban freeways and streets should be designed for LOS C). Although the use of a single number tends to mask the myriad factors used in roadway capacity analyses, the level of accuracy of the data base and the planning nature of the ultimate use of the results of this methodology are compatible with this approach.

Figure 3 quantifies the increase in congested freeway lane miles in Harris County between 1970 and 1985. Although it is not known what percentage of the freeway system exceeding 15,000 vpd per lane (operating at LOS D or worse in the peak hour) is acceptable, it can be assumed that the 10 percent value in 1970 did not suggest countywide deficiencies; however, the 45 percent in 1980 would appear to suggest that such deficiencies did exist.

The data available to the study team did not allow the determination of a specific date at which Houston's traffic problems became critical. For purposes of the overall analysis, however, this was not required. Mobility in Houston could be characterized as "reasonably good" beyond 1970. Peak-period speeds on freeways and major arterials were fairly high, and traffic delay was not a major concern. By the late 1970s, however, peak-period travel delay had doubled from 1970 levels, and volume-per-lane values reflected 2 hr or more of congested operation during both

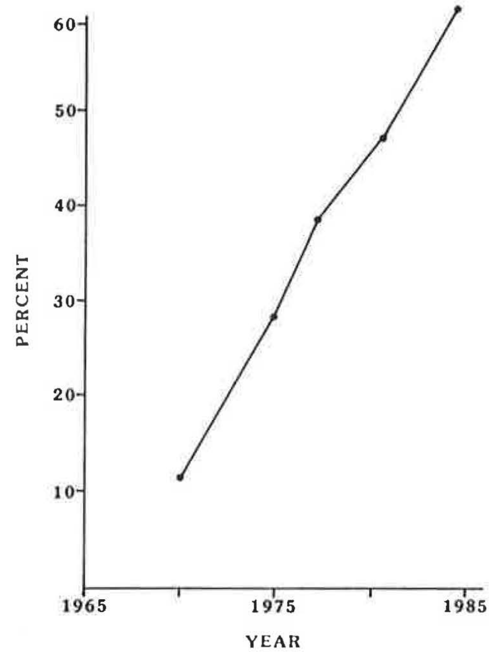


FIGURE 3 Percent of freeway lane miles with more than 15,000 ADT for Harris County (Houston), 1970 to 1985.

the morning and evening peak periods. Congested freeway lane miles in Harris County (Figure 3) increased from 10 percent in 1970 to 40 percent in 1978. When data for rural areas of Harris County were subtracted from the analysis, the 1978 congested urban freeway mileage approached 50 percent.

Congestion Indicator Determination

The data on mobility decline for Houston indicated that an unacceptable level of transportation service was reached somewhere in the 1975–1976 time frame. That assumption allowed quantitative measures of impending congestion problems to be developed and compared for the major urban areas of Texas. The following measures, listed in apparent order of reliability and usefulness, can be used as guidelines to determine whether congestion in an urban area is becoming critical.

Traffic per Lane

As shown previously, 15,000 vpd per lane for freeways can be interpreted to represent the beginning of LOS D operation. Once traffic has entered that range, congestion is becoming critical. As a measure of approaching congestion, the value of 13,000 vpd per lane used by the Federal Highway Administration in their highway needs estimate (*11*) and by the Texas State Department of Highways and Public Transportation in their project development process (*12*) would appear to represent a more appropriate value.

That standard was also attained on the basis of average urban area in Houston during the period when the degree of mobility was becoming unacceptable (1976–1977).

The corresponding measure for urban arterial streets would appear to be approximately 4,500 vpd per lane. This value occurred in Houston about the mid-1970s and is in general agreement with accepted traffic engineering standards for arterial street operations.

In summary, the following guidelines can be used to mark the point at which urban-area average traffic volumes become critical:

- Freeways: 13,000 vpd per lane,
- Principal arterials: 4,500 vpd per lane.

Percentage of Congested Freeway

The percentage of the freeway system operating under congested conditions (15,000 vpd per lane or more) was determined to be another descriptor of congestion and mobility levels. The relevant data for the Houston area have been presented (Figure 3). From that information, using the 1976–1977 time frame, it appears that once 30 percent of the lane miles is operating at or above 15,000 vpd, mobility has become significantly impaired.

- If the proportion of the county freeway system operating with average daily traffic (ADT) greater than 15,000 vpd per lane is 30 percent, that constitutes congested conditions.

k-*Factor*

As congestion increases, the peak hour begins to spread into a peak period, and congestion exists for longer periods of time. The result is that the percentage of daily traffic that occurs in the peak hour, or the *k*-factor, declines. Decreasing *k*-factor values are thus indicative of the rising off-peak traffic volumes and the lengthening of the peak period. Both of these occurrences are associated with increasing freeway congestion.

Using the *k*-factor as a measure is complicated because of data availability; *k*-factors are readily available only at a limited number of locations, which may or may not be where intense congestion occurs. For example, many sections of roadway in Houston have *k*-factors in the range of 7 percent.

- The systemwide freeway *k*-factor (percentage of ADT in the peak hour) that indicates congested conditions is 9.2 percent.

Summary

These measures are only some of the variables examined during the assessment of possible mobility indicators (*1*). Although all of the measures are limited by the reliability and accuracy of the data base, they are illustrative of urban travel conditions. They are also available without any new data collection requirements, which allows the use of historical traffic data collected during the usual urban planning process. A single variable may not be indicative of the traffic congestion in an urban area, but if all the measures are examined, the relative mobility levels should become apparent.

APPLICATION OF MOBILITY INDICATORS TO TEXAS CITIES, 1975 TO 1984

Urban-Area Definition

Data presented for the various urban areas were derived from several sources, only some of which make a distinction between urban and rural. Many data summaries are for city or county boundaries. This study uses a population density of more than 1,000 persons per square mile as the criterion for urban-area delineation. Data sources with urban and rural classifications for facility mileage and travel volume were used to estimate the quantitative values presented subsequently. It appears that inconsistencies in the data are present to the same degree for all urban areas.

Freeway and Principal Arterial Travel per Lane

Tables 3 and 4 give estimates of lane miles and VMT for freeways and principal arterials in seven urban areas. These were combined into VMT per lane mile of freeway and principal arterials in Table 5 and Figures 4 and 5.

The freeway values in Tables 3 and 5 and Figure 4 are some of the more reliable data used in this study. Figure 4 indicates the critical freeway congestion measure derived from the 1975–1976 Houston value. The volume in the Houston urban area has remained significantly higher than that in other urban areas throughout the study period. Dallas and San Antonio freeway volumes steadily increased during the mid- to late 1970s and increased at a faster rate during the early 1980s. Austin remained at a fairly constant level of freeway traffic volume per lane until about 1981, when freeway congestion began increasing at a rate comparable with that of Dallas and San Antonio. These three urban areas, on the basis of historical growth trends, should hit the critical freeway congestion point well before 1990. Although the Fort Worth freeway travel per lane was not increasing as rapidly as that of Dallas, Austin, or San Antonio, its 1984 value of 10,000 VMT per lane mile has been exceeded by each of those areas since 1980. El Paso and Corpus Christi are characterized by lower, but increasing, values of VMT per lane mile.

The data for VMT per principal arterial lane mile are shown in Tables 4 and 5 and Figure 5. As was the case with the freeway measure, Houston's principal arterials handle more traffic volume per lane than is served in the

TABLE 3 FREEWAY CAPACITY AND TRAVEL IN MAJOR URBAN AREAS (*2, 5, 6, 13–22*)

Year	Houston		Dallas		El Paso		Ft. Worth		San Antonio		Austin		Corpus Christi	
	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)
1984	1,460	23,615	1,620	19,925	345	2,800	965	9,685	785	8,450	290	3,300	165	1,360
1983	1,410	22,555	1,580	18,400	335	2,690	935	9,230	775	7,965	280	2,970	165	1,370
1982	1,375	21,080	1,550	16,870	325	2,560	905	8,625	760	7,600	265	2,530	160	1,300
1981	1,330	19,800	1,515	15,750	310	2,325	880	8,140	760	7,500	250	2,275	160	1,270
1980	1,255	18,405	1,485	15,015	295	2,155	855	7,535	750	7,115	240	2,130	160	1,190
1979	1,265	17,950	1,465	14,620	275	1,975	825	7,145	735	6,680	240	2,100	155	1,235
1978	1,180	16,405	1,450	13,695	275	1,790	795	6,660	685	5,880	240	2,050	155	1,200
1977	1,175	15,650	1,430	12,840	260	1,665	755	6,100	675	5,475	235	2,000	155	1,100
1976	1,210	14,405	1,395	11,555	260	1,545	730	5,670	670	5,080	230	1,900	150	1,070
1975	1,145	13,190	1,350	10,445	260	1,415	720	5,275	660	4,755	215	1,780	150	1,020

TABLE 4 PRINCIPAL ARTERIAL CAPACITY AND TRAVEL IN MAJOR URBAN AREAS (*2, 5, 6, 13–22*)

Year	Houston		Dallas		El Paso		Ft. Worth		San Antonio		Austin		Corpus Christi	
	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)	Lane Miles	Daily VMT (1000)
1984	1,920	10,860	1,650	7,640	800	2,820	825	4,015	980	3,920	380	1,825	320	1,350
1983	1,845	10,350	1,595	7,035	780	2,705	800	3,845	965	3,685	360	1,710	315	1,300
1982	1,785	9,725	1,555	6,440	760	2,600	785	3,660	940	3,525	340	1,595	310	1,250
1981	1,715	9,165	1,510	6,010	740	2,525	760	3,450	890	3,295	325	1,535	305	1,220
1980	1,655	8,565	1,475	5,730	725	2,470	745	3,255	870	3,090	310	1,460	300	1,185
1979	1,585	7,690	1,435	5,400	715	2,410	740	3,150	840	3,000	300	1,410	295	1,150
1978	1,520	7,230	1,395	5,080	710	2,300	725	3,000	805	2,775	280	1,310	295	1,110
1977	1,450	6,925	1,375	4,840	695	2,170	710	2,870	765	2,555	280	1,300	290	1,040
1976	1,380	6,345	1,350	4,490	685	2,070	690	2,725	760	2,470	260	1,210	285	1,000
1975	1,310	5,875	1,320	4,150	675	1,945	665	2,560	740	2,350	245	1,120	285	960

TABLE 5 DAILY VMT PER LANE MILE ON FREEWAYS AND PRINCIPAL ARTERIALS IN MAJOR URBAN AREAS (*2, 5, 6, 13–22*)

Year	Houston		Dallas		El Paso		Ft. Worth		San Antonio		Austin		Corpus Christi	
	Freeway	Prin. Art.	Freeway	Prin. Art.	Freeway	Prin. Art.	Freeway	Prin. Art.	Freeway	Prin. Art.	Freeway	Prin. Art.	Freeway	Prin. Art.
1984	16,175	5.655	12,300	4,630	8,110	3,525	10,035	4,865	10,760	4,000	11,380	4,805	8,240	4,220
1983	15,995	5,610	11,645	4,410	8,030	3,470	9,870	4,805	10,280	3,820	10,605	4,750	8,305	4,125
1982	15,330	5,450	10,885	4,140	7,875	3.420	9.530	4,660	10.000	3,750	9,545	4,690	8,125	4,030
1981	14,885	5,345	10,395	3,980	7,500	3,410	9,250	4,540	9,870	3,700	9,100	4,725	7,940	4,000
1980	14,665	5,175	10,110	3,885	7,305	3,405	8,815	4,370	9,490	3,550	8,875	4,710	7,440	3,950
1979	14,190	4,850	9,980	3,765	7,180	3,370	8,660	4,255	9,090	3,570	8,750	4,700	7,970	3,900
1978	13,905	4,755	9,445	3,640	6,510	3,240	8,375	4,140	8,585	3,450	8,540	4,680	7,740	3,765
1977	13,320	4,775	8,980	3,520	6,405	3,120	8,080	4,040	8,110	3,340	8,510	4,645	7,095	3,585
1976	11,905	4,600	8,285	3,325	5,940	3,020	7,765	3,950	7,580	3,250	8,260	4,655	7,135	3,510
1975	11,520	4,485	7,735	3,145	5,440	2,880	7,325	3,850	7,205	3,175	8,280	4,570	6,800	3,370

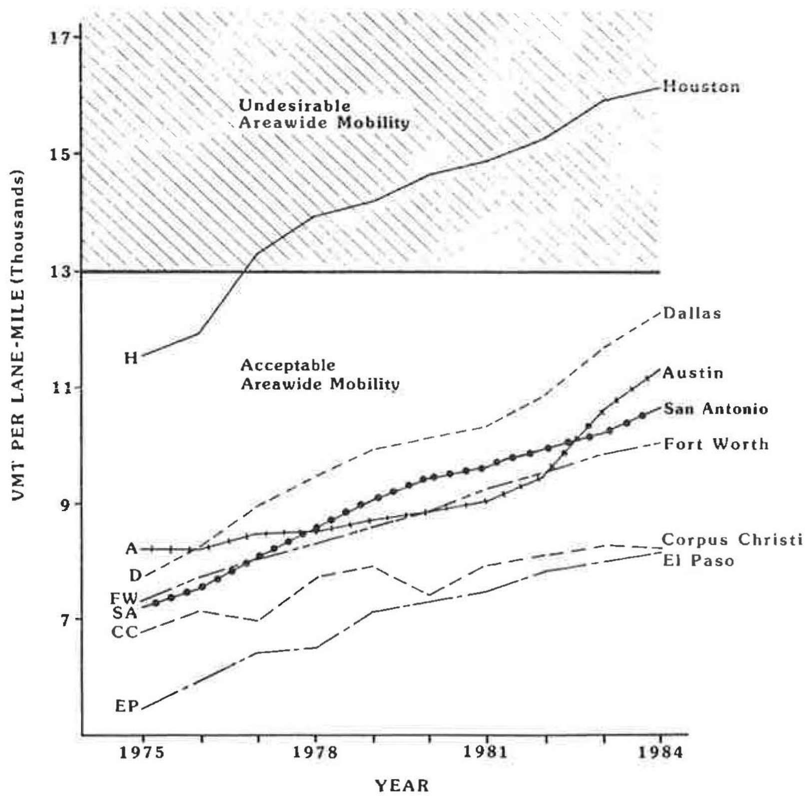


FIGURE 4 Daily travel per freeway lane mile for major Texas urban areas, 1975 to 1984.

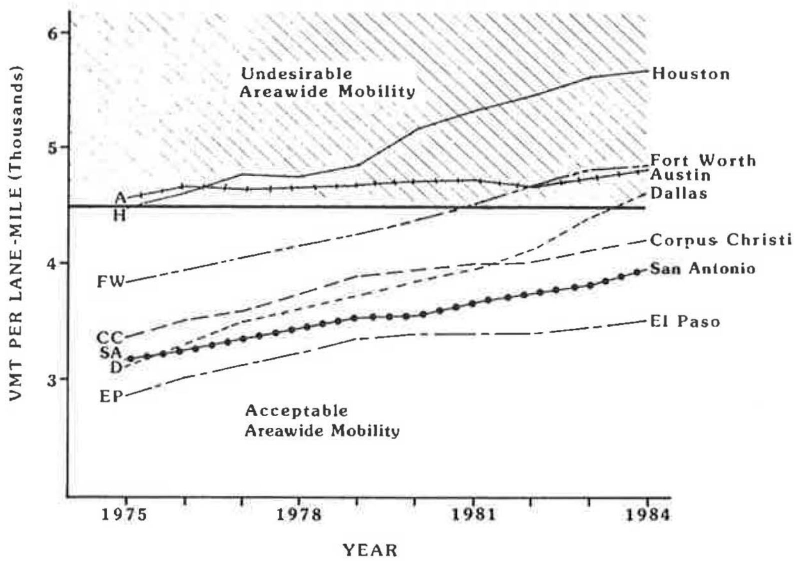


FIGURE 5 Daily travel per principal arterial lane mile for major Texas urban areas, 1975 to 1984.

other areas. The San Antonio, Fort Worth, and Austin arterials, however, are estimated to operate with higher volumes than those in Dallas, which was second to Houston in the freeway rankings. The five highest levels of major urban-area arterial VMT per lane mile exceeded the critical congestion measure in 1984; only Houston exceeded the freeway measure.

The freeway and principal arterial roadway systems were chosen for this analysis because of the availability of data and their importance to areawide mobility. In a subsequent section these two classifications are combined into a single indicator of relative mobility.

Percentage of Congested Freeway

Figure 6 shows the percentage of freeway lane miles in each major urbanized county with ADT volumes in excess of 15,000. Harris County (Houston) reached a congested freeway mileage level more than twice that of the critical measure in 1984. The Dallas freeway system was also beyond the congestion measure in 1984 after a decade of growth that paralleled that of Harris County. Travis (Austin) and Bexar (San Antonio) counties have exceeded 20 percent and have congestion growth trends that nearly parallel those of Dallas and Harris. Based on historic growth trends, Travis, Bexar, and Tarrant (Fort Worth) counties should exceed the 30 percent level before 1990. Although below 15 percent, the El Paso and Nueces County (Corpus Christi) growth rates were fairly high between 1980 and 1984.

The difficulty with urban-area boundary definition and the readily available traffic and roadway link data for counties resulted in the use of county boundaries for this indicator. Some allowance should be made for the differences in county land use patterns and their effect on traffic volumes. Dallas County has a smaller percentage of rural area than the other counties; the percentage of congested freeway lane miles is therefore slightly higher for Dallas County in relation to that for the urban area. Similarly, the percentage of congested miles would be higher for the other six counties if the indicator were calculated for those urban-area (rather than county) boundaries.

k-Factor and ADT per Lane

Automatic traffic recorder (ATR) stations in Texas cities do not provide a statistically accurate sample of urban-area travel. The number of stations is too low, and the locations are not similar in relation to congested freeway segments in every urban area. New ATR stations opened in relatively new and lower-volume freeway sections and older stations taken out of service during freeway reconstruction projects further disrupt the consistency of the data. (These stations were included on the premise that more data were better than consistent data when the latter are not statistically representative of actual conditions.) The percentage of daily traffic that occurs in the peak hour (*k*-factor) and the ADT per lane at these ATR stations are, however, at least somewhat indicative of the growth in freeway congestion.

The peak-hour capacity of a freeway section is relatively constant, and therefore during periods of increasing traffic demand, the traffic volume during the hours adjacent to the peak increases. The trend of increasing freeway volume accompanies a decline in the *k*-factor (Figure 7). Houston, Austin, Dallas, and Fort Worth are at or below the 9.2 percent level determined to indicate impending congestion. San Antonio is somewhat higher than the other areas

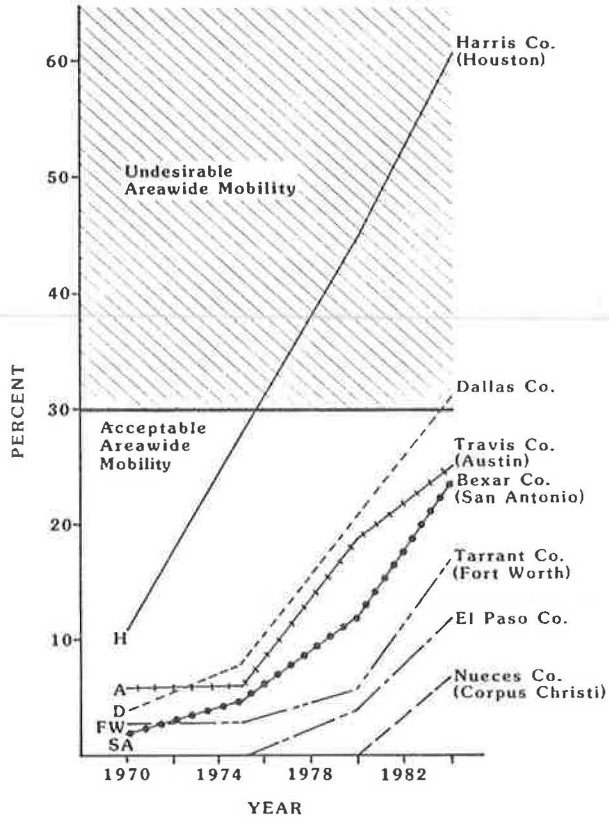


FIGURE 6 Percent of freeway lane miles with more than 15,000 ADT for urbanized Texas counties, 1970 to 1984 (*2, 5, 6, 13, 15, 16, 18, 20*).

because of several new traffic counting stations installed on relatively uncongested roadways in 1976. The El Paso and Corpus Christi data do not currently indicate significant freeway problems.

Daily freeway volume per lane can be calculated from the ATR station data. Figure 8 shows how the cities relate to the 15,000-vpd-per-lane critical value (maximum volume for LOS C) used in Figure 6. Again, the lack of comparability in ATR data reduces the usefulness of this measure, but Figure 8 reveals the same trends noted in other data. Austin, Dallas, Fort Worth, Houston, and San Antonio are above the 15,000-ADT-per-lane level. Austin and Dallas have had significant increases in traffic per lane since 1982.

RELATIVE MOBILITY IN TEXAS CITIES, 1975 TO 1984

The data presented in this paper indicate that varying levels of congestion exist in the large urban areas of Texas. Those areas that do not have severe areawide congestion nevertheless experience traffic problems at specific locations within the urban area.

A 1982 report (*1*) details the analysis technique used in this paper. A relative congestion index was generated by combining freeway and principal arterial VMT per lane (Table 5) for each major urban area. Freeways in most of the large Texas cities carry approximately twice the VMT of the principal arterials (Tables 3 and 4). The value for freeway VMT per lane was doubled to account for this

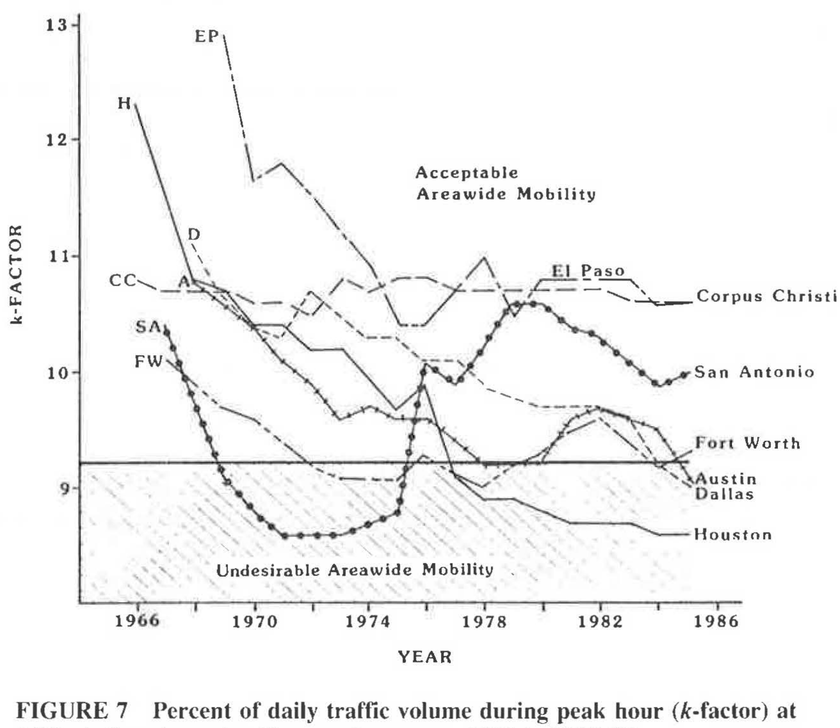


FIGURE 7 Percent of daily traffic volume during peak hour (*k*-factor) at ATR stations in major Texas urban areas, 1966 to 1985 (*5*).

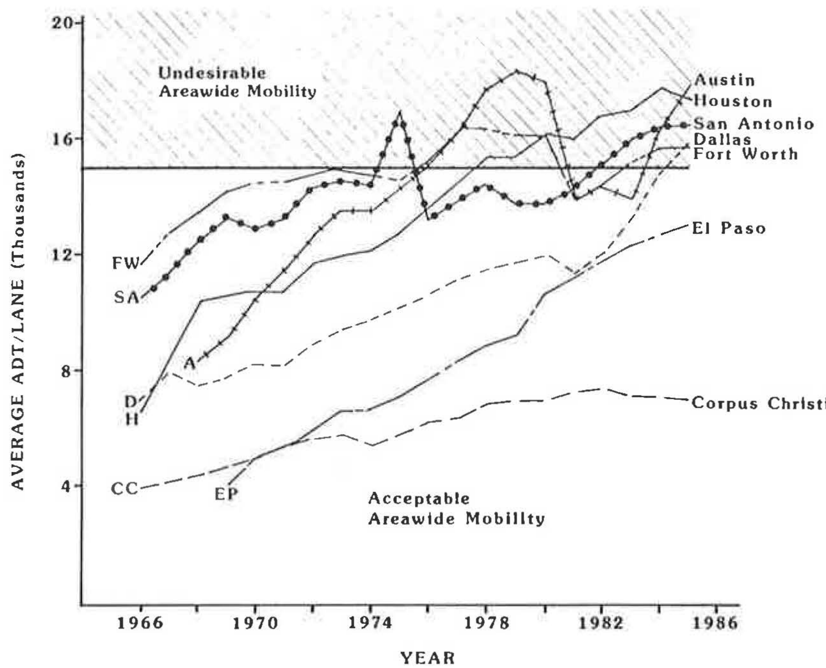


FIGURE 8 Average daily traffic per lane at ATR stations in major Texas urban areas, 1966 to 1985 (*5*).

TABLE 6 AREAWIDE RELATIVE CONGESTION LEVELS

Year	Houston	Dallas	El Paso	Ft. Worth	San Antonio	Austin	Corpus Christi
1984	1.25	0.96	0.65	0.82	0.84	0.90	0.68
1983	1.23	0.91	0.64	0.81	0.80	0.85	0.68
1982	1.18	0.85	0.63	0.78	0.78	0.78	0.66
1981	1.15	0.81	0.60	0.76	0.77	0.75	0.65
1980	1.13	0.79	0.59	0.72	0.74	0.74	0.62
1979	1.09	0.78	0.58	0.71	0.73	0.73	0.65
1978	1.07	0.74	0.53	0.68	0.70	0.71	0.63
1977	1.03	0.70	0.52	0.66	0.66	0.71	0.58
1976	0.93	0.65	0.49	0.64	0.62	0.69	0.58
1975	0.90	0.61	0.45	0.61	0.59	0.69	0.56
Congestion Increase 1975 to 1984	39%	57%	44%	34%	42%	30%	21%

Note: A congestion level higher than 1.00 is considered undesirable.

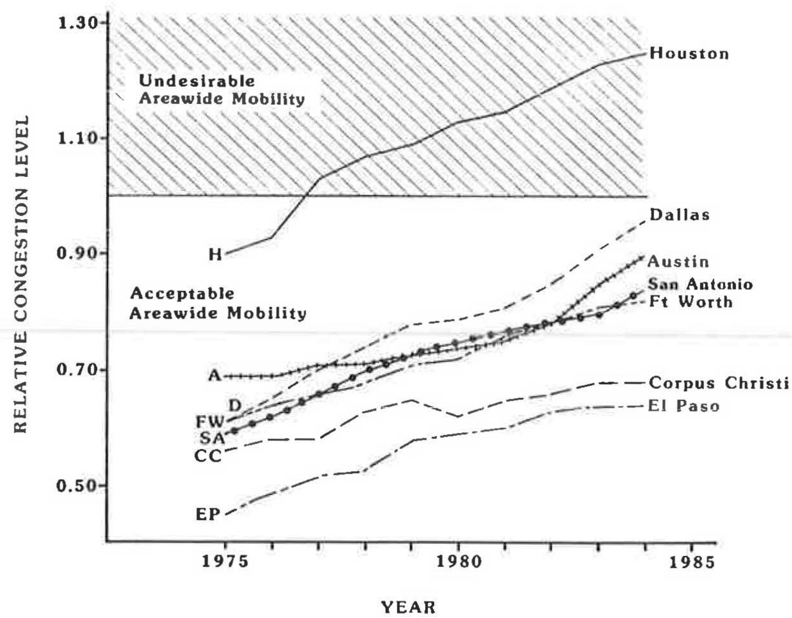


FIGURE 9 Relative congestion levels in major Texas urban areas, 1975 to 1984.

increased importance and added to the arterial VMT per lane. The congestion levels were then normalized, with the critical congestion indicator set equal to 1.0 (*3*):

Congestion index level

$$= \frac{2\ (\text{fwy. VMT/lane}) + \text{princ. art. VMT/lane}}{2\ (\text{fwy. standard}) + \text{princ. art. standard}} \qquad (1)$$

For example,

$$\text{Houston (1984)} = \frac{2(16{,}175) + 5{,}655}{2(13{,}000) + 4{,}500} = 1.25$$

The relative congestion levels in Table 6 are shown along with the urban-area congestion indicator in Figure 9. Houston exceeded the critical level in 1977 and was 25 percent above that level in 1984. Dallas and Austin were within 10 percent of the critical level, and their congestion levels increased at almost twice the rate of Houston between 1980 and 1984. The congestion levels for Fort Worth and San Antonio were approximately equal to those of Houston, Dallas, and Austin in 1980, but have not increased at the same rate as those of Dallas and Austin. The mobility levels for Corpus Christi and El Paso (the inverse of the

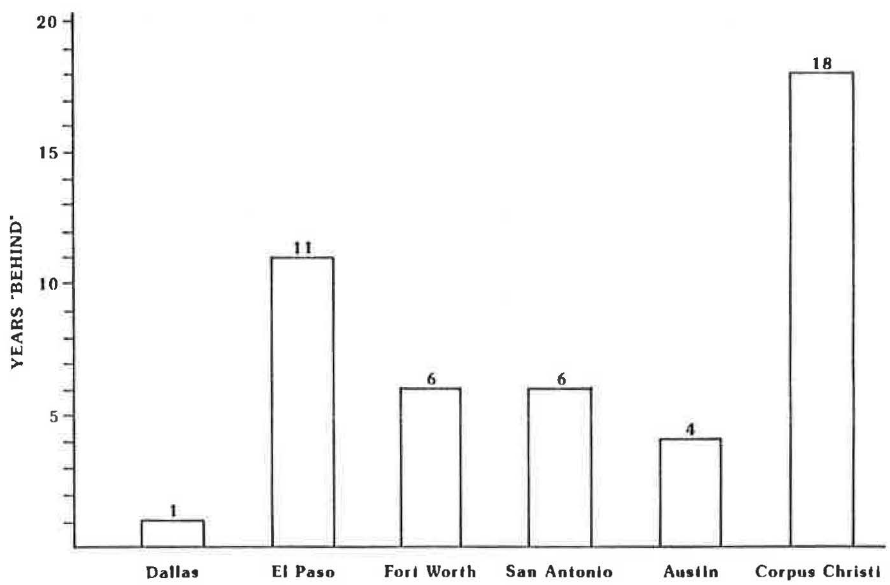


FIGURE 10 Time until attainment of congestion indicator level (extrapolation of 1975 to 1984 data).

congestion levels) have remained generally high, although there has been some decline.

The relationship between freeway and arterial operating conditions should also be examined. The data showed Houston as the only urban area with freeway conditions worse than the congestion indicator, but four areas exceeded the critical arterial value. Greater emphasis is placed on freeway operations, but the important role of principal arterials as alternative routes for freeway trips and as major collection-distribution roadways for freeway access should not be overlooked. A transportation improvement plan that coordinates the use of all roadway resources is more efficient and better able to meet the needs of an automobile-oriented society.

Figure 10 is a summary of the growth trends in the freeway and arterial congestion index between 1975 and 1984. Dallas is estimated to be 1 year from the congestion-indicator level. Austin, San Antonio, and Fort Worth appear to be approximately 5 years away from attainment of the congestion indicator. Austin, however, has had a significantly higher growth rate since 1980, and if that were considered, its estimate of years to attainment would resemble that of Dallas. El Paso is not expected to reach the critical congestion level until the mid-1990s, and Corpus Christi is not expected to have a significant areawide congestion problem before 2000.

It should be noted that the data used in this paper end in 1984. Any assessment of years to attainment of the critical level must be examined with an additional 3 years of mobility decline in mind. Dallas and San Antonio, therefore, may have already exceeded the critical-indicator values, with Austin very near that undesirable congestion level.

REFERENCES

1. *Estimates of Relative Mobility in Major Texas Cities.* Research Report 323-1F. Texas Transportation Institute, Texas A&M University System, College Station, 1982.
2. *Various Houston/Harris County Data.* Houston-Galveston Regional Transportation Study, n.d.
3. *Houston Facts 1981.* Houston Chamber of Commerce, April 1981.
4. *Travel Time and Speed Survey—1969, 1973, 1976 and 1979.* Houston-Galveston Regional Transportation Study, n.d.
5. *Permanent Automatic Traffic Recorder Data—1950–1984.* State Department of Highways and Public Transportation, Austin, Tex., n.d.
6. *Texas Traffic Map—1950–1985.* State Department of Highways and Public Transportation, Austin, Tex., n.d.
7. *Houston Regional Mobility Plan.* Houston Chamber of Commerce, 1982.
8. *Special Report 209: Highway Capacity Manual.* TRB, National Research Council, Washington, D.C., 1985.
9. *The Status of the Nation's Highways: Condition and Performance.* FHWA, U.S. Department of Transportation, June 1985.
10. *A Policy on the Geometric Design of Highways and Streets.* American Association of State Highway and Transportation Officials, Washington, D.C., 1984.
11. *1980—3R Study.* FHWA, U.S. Department of Transportation, 1980.
12. *Ten-Year Project Development Plan Documentation and Support Data.* State Department of Highways and Public Transportation, Austin, Tex., 1986.
13. *Major Thoroughfare Link File—1977, 1979, 1980 and 1983.* North Central Texas Council of Governments, Arlington, n.d.
14. *1984 Vehicle-Miles of Travel Estimates.* North Central Texas Council of Governments, Arlington, Dec. 1985.
15. *Roadway and Population Estimates for the Dallas/Fort Worth Intensive Study Area.* State Department of Highways and Public Transportation, Regional Planning Office, Arlington, Tex., n.d.
16. *Various El Paso County Data.* Planning Office, District 24, State Department of Highways and Public Transportation, Austin, Tex., n.d.
17. *El Paso Urban Transportation Study.* State Department of Highways and Public Transportation, Planning and Research Division, n.d.
18. *Various Bexar County Data.* Planning Office, District 15, State Department of Highways and Public Transportation, Austin, Tex., n.d.
19. *1984 Traffic Volumes.* Austin Transportation Study, 1985.
20. *Roadway Inventory (RI2-TLOG) Tables.* State Department of Highways and Public Transportation, Planning and Research Division, Austin, Tex., n.d.
21. *Form TT Tables.* State Department of Highways and Public Transportation, Planning and Research Division, Austin, Tex., n.d.
22. *Highway Performance Monitoring System.* State Department of Highways and Public Transportation, Planning and Research Division, Austin, Tex., n.d.

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