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16. Abstract

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An analysis of the cost of this congestion was performed using travel delay, increased fuel consumption and increased auto insurance premiums as the economic analysis factors. The economic cost to the urban area, and to the individual resident, was estimated.

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THE IMPACT OF DECLINING MOBILITY IN MAJOR TEXAS AND OTHER U.S. CITIES

by

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Final Research Report 431-1F

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Texas Department of Highways and Public Transportation
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Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in²	square inches	645.2	millimetres squared	mm²
ft²	square feet	0.0929	metres squared	m²
yd²	square yards	0.836	metres squared	m²
mi²	square miles	2.59	kilometres squared	km²
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft³	cubic feet	0.0328	metres cubed	m³
yd³	cubic yards	0.0765	metres cubed	m³

NOTE: Volumes greater than 1000 L shall be shown in m³.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm²	millimetres squared	0.0016	square inches	in²
m²	metres squared	10.764	square feet	ft²
km²	kilometres squared	0.39	square miles	mi²
ha	hectores (10 000 m²)	2.53	acres	ac

MASS (weight)

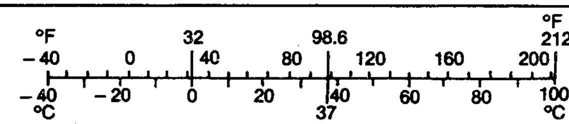
Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m³	metres cubed	35.315	cubic feet	ft³
m³	metres cubed	1.308	cubic yards	yd³

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

ABSTRACT

An assessment of the freeway and major street operating conditions was performed in seven Texas cities and 22 other urban areas in the U.S. for the period 1982 to 1986. Vehicle-miles of travel and lane-miles of roadway data were collected from a variety of sources to estimate congestion on the freeway/expressway and principal arterial street systems. The values for each system were combined into a congestion index used to rank the urban areas on a relative scale.

An analysis of the cost of this congestion was performed using travel delay, increased fuel consumption and increased auto insurance premiums as the economic analysis factors. The economic cost to the urban area, and to the individual resident, was estimated.

An investigation of business attitudes toward urban area traffic congestion was performed in 13 of the study cities. The construction and widening of freeways and major streets in the urban areas were the most frequently mentioned improvements that would enhance business activity.

Key Words: Mobility, Congestion, Economic Analysis, Business Attitudes, Transportation Planning

IMPLEMENTATION STATEMENT

As a means of assisting the Texas Department of Highways and Public Transportation in planning future highway needs and identifying funding requirements, it is desirable to have a measure of the seriousness of the congestion and mobility problem in major Texas cities and how those cities compare with other major U.S. cities. The report provides a quantification of those mobility levels and the economic impact of congested roadways on urban motorists. A survey of the business community estimated the role of transportation in business planning and decision-making activities. The information in this report should be of value in identifying and prioritizing transportation facility and program needs.

DISCLAIMER

SUMMARY

Roadway system traffic congestion increased over the past decade in most large U.S. urban areas as transportation facility construction did not keep pace with population and travel demand growth. The low to moderate population density urban areas, like those in Texas, depend on the freeway and major street systems to handle almost all of the urban person movement requirements. The importance of traffic congestion measurement methodologies is related to this reliance on transportation infrastructure and the support of economic growth.

This report estimated traffic congestion levels in the seven largest Texas urban areas and 22 similar large U.S. urban areas. The economic impact of roadway congestion on travel time, fuel consumption and automobile insurance premiums was also estimated to determine the cost of adverse travel conditions. The attitudes of local business leaders toward transportation problems and solutions in several of the study cities were analyzed with a survey.

Freeway and Principal Arterial Street Traffic Condition

The freeway and principal arterial street systems were chosen for inclusion due to their importance in urban mobility and generally good data availability. Table S-1 presents the 1986 estimates of daily vehicle-miles of travel (DVMT) per lane-mile of freeway and principal arterial. The congestion index (CI) value for each urban area was developed by combining the DVMT per lane-mile data for each type of roadway in a ratio defined by the amount of daily vehicle-miles of travel (e.g., the Phoenix principal arterial DVMT per lane-mile value would be weighted 3.4 times greater than the freeway value -- 15,840,000 - 4,620,000). A CI greater than 1.0 indicates an undesirable mobility level for the urban area major roadway system. Urban areas with CIs less than 1.0 may have areas of intense traffic congestion, but the average mobility level of the region could be described as good.

The average congestion index value for the five most congested Texas cities was five percent above the average of the study cities outside Texas, with three Texas urban areas

ranking in the eleven most congested study areas. Analysis of the congestion growth patterns indicated congestion in the Texas urban areas increased at a faster rate than the areas outside Texas for the period 1982 to 1986, concurrent with an economic downturn in Texas.

Table S-1. 1986 Congestion Index Value

Urban Area	Freeway/Expway		Principal Arterials		Congestion	Rank
	DVMT[1] (1000)	DVMT[2] Ln-Mile	DVMT[1] (1000)	DVMT[2] Ln-Mile	Index[3]	
Phoenix AZ	4,620	14,665	15,840	6,105	1.18	4
Los Angeles CA	92,100	19,190	70,410	6,065	1.42	1
Sacramento CA	7,400	11,385	5,885	6,065	.95	18
San Diego CA	21,020	12,935	7,850	5,130	1.00	10
San Fran-Oakland CA	36,925	16,160	12,000	6,075	1.24	2
Denver CO	9,290	12,470	10,680	5,560	1.01	9
Miami FL	6,975	12,915	12,300	6,225	1.10	6
Tampa FL	2,940	10,890	3,650	6,080	.96	13
Atlanta GA	21,530	14,795	9,055	6,115	1.15	5
Indianapolis IN	6,910	10,015	3,950	4,730	.80	28
Louisville KY	4,785	9,475	2,735	5,695	.80	22
Minn-St Paul MN	14,560	12,235	5,100	4,435	.93	15
Kansas City MO	10,905	7,735	4,385	4,820	.64	29
St Louis MO	15,620	11,320	10,765	6,220	.95	14
Albuquerque NM	1,930	9,650	3,250	5,285	.87	20
Oklahoma City OK	5,780	8,375	3,310	5,130	.71	26
Portland OR	6,325	12,045	3,140	5,980	.97	12
Memphis TN	3,110	8,520	3,760	5,010	.77	23
Nashville TN	4,250	10,625	4,805	5,340	.89	19
Salt Lake City UT	3,450	9,080	1,825	5,530	.77	23
Seattle-Everett WA	15,500	13,965	8,325	5,740	1.09	7
Milwaukee WI	6,315	11,375	4,700	5,055	.91	16
Austin TX	5,300	12,620	2,190	5,340	.98	11
Corpus Christi TX	1,420	8,350	1,400	4,375	.71	26
Dallas TX	22,575	13,765	8,230	4,900	1.05	8
El Paso TX	3,420	9,910	2,915	3,620	.75	25
Fort Worth TX	10,725	11,000	4,250	5,060	.87	20
Houston TX	24,115	15,970	10,810	5,530	1.21	3
San Antonio TX	9,450	11,665	4,585	4,450	.91	16
Outside Texas Avg.	13,740	11,810	9,440	5,565	.96	
Texas Avg.	11,000	11,900	4,910	4,755	.92	
Congested Texas Avg.	14,435	13,005	6,010	5,055	1.00	
Total Avg.	13,080	11,830	8,350	5,370	.95	
Maximum Value	92,110	19,190	70,410	6,225	1.42	
Minimum Value	1,420	7,735	1,400	3,620	.64	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile
[3] See Equation 1

Source: Equation 1 and Tables 3 and 5

Cost of Congestion on Urban Roadway Systems

The economic effect of traffic congestion was estimated in the cost of travel delay, excess fuel consumed by motorists and higher auto insurance premiums paid by residents of large, congested urban areas. Travel delay was estimated as both regular, recurring delay and congestion related to incidents. Table S-2 illustrates the estimated cost components for

Table S-2. Component and Total Congestion Costs By Urban Area

Urban Area	Annual Cost Due to Congestion ($ Million)						Total Delay/Fuel Cost ($ Millions)
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Insurance	Total	
Phoenix AZ	360	365	55	55	90	920	830
Los Angeles CA	2,320	2,785	365	440	3,525	9,440	5,915
Sacramento CA	105	60	15	10	185	375	190
San Diego CA	210	125	35	20	195	585	390
San Fran-Oakland CA	675	875	110	140	885	2,685	1,795
Denver CO	230	230	35	35	35	565	525
Miami FL	300	450	40	65	460	1,310	850
Tampa FL	75	115	10	15	15	230	215
Atlanta GA	350	385	50	50	140	975	835
Indianapolis IN	15	25	0	5	20	65	45
Louisville KY	40	45	5	5	10	110	100
Minn-St Paul MN	120	110	20	15	70	330	260
Kansas City MO	35	105	5	15	55	210	155
St Louis MO	250	295	30	35	195	805	610
Albuquerque NM	40	45	5	5	10	105	95
Oklahoma City OK	35	40	5	5	30	120	90
Portland OR	85	170	10	25	50	335	290
Memphis TN	40	45	5	5	40	135	100
Nashville TN	65	70	10	10	10	165	155
Salt Lake City UT	30	15	5	0	20	70	50
Seattle-Everett WA	275	385	40	60	20	780	755
Milwaukee WI	75	75	10	10	65	230	165
Austin TX	75	85	10	10	25	210	185
Corpus Christi TX	5	5	0	0	5	20	15
Dallas TX	280	505	40	75	210	1,110	900
El Paso TX	15	15	0	5	5	40	40
Fort Worth TX	110	195	15	30	65	410	350
Houston TX	475	665	70	95	360	1,665	1,305
San Antonio TX	85	95	10	15	30	235	205
Outside Texas Avg.	260	310	40	45	280	935	655
Texas Avg.	150	225	20	30	100	525	430
Congested Texas Avg.	205	310	30	45	140	725	590
Total Avg.	235	290	35	45	235	835	600
Maximum Value	2,320	2,785	365	440	3,525	9,440	5,915
Minimum Value	5	5	0	0	5	20	15

Note: Congested Texas cities average includes Austin, Dallas, Fort Worth, Houston, and San Antonio

Source: TTI Analysis Tools and Local Transportation Agency References

each study area and 1986 urban area population. The two congestion cost impacts per capita values presented in Table S-3 are provided to separate the direct effects of congestion (delay and fuel cost) from the less direct (auto insurance premiums are also related to property crime rates). The per capita cost values are the most comparable to the congestion index indicator, while the total urban area cost is representative of the annual societal cost of congestion.

Table S-3. Estimated Economic Impact of Congestion in 1986

Urban Area	Congestion Cost Per Capita (Dollars)	Delay/Fuel Cost Per Capita (Dollars)	Congestion Cost Per Reg. Veh. (Dollars)	Delay/Fuel Cost Per Reg. Veh. (Dollars)
Phoenix AZ	550	495	830	750
Los Angeles CA	880	550	1,230	770
Sacramento CA	395	200	345	175
San Diego CA	295	195	535	355
San Fran-Oakland CA	775	520	1,000	670
Denver CO	380	355	450	420
Miami FL	730	475	915	595
Tampa FL	380	360	335	315
Atlanta GA	525	450	690	590
Indianapolis IN	70	50	130	90
Louisville KY	40	125	245	225
Minn-St Paul MN	170	135	290	230
Kansas City MO	185	140	340	250
St Louis MO	420	320	585	445
Albuquerque NM	230	205	275	245
Oklahoma City OK	165	120	265	195
Portland OR	325	280	565	485
Memphis TN	160	115	290	210
Nashville TN	295	280	460	430
Salt Lake City UT	95	70	115	85
Seattle-Everett WA	495	485	740	720
Milwaukee WI	190	140	285	205
Austin TX	445	395	460	410
Corpus Christi TX	65	55	65	55
Dallas TX	585	475	685	555
El Paso TX	85	75	120	110
Fort Worth TX	370	310	455	385
Houston TX	595	465	875	685
San Antonio TX	225	195	295	255
Outside Texas Avg.	355	275	495	385
Texas Avg.	340	280	420	350
Congested Texas Avg.	445	370	555	460
Total Avg.	350	275	480	375
Maximum Value	880	550	1,230	770
Miminum Value	65	50	65	55

Five urban areas were estimated to have total 1986 congestion cost values in excess of $1 billion. The total estimated economic impact in the 29 study areas was more than $24 billion, or $835 million per city. The study average per capita congestion cost was approximately $350.

The seven Texas urban areas were estimated to have approximately $3.7 billion associated with the adverse impacts of congestion; almost half of that in Houston. Dallas ranked fifth among the 29 study areas with a total 1986 economic impact in excess of $1.1 billion. On a congestion cost per capita basis, Houston, Dallas and Austin rank in the ten highest of 29 areas studied. Houston and Dallas remain in the ten highest ranked areas when comparing congestion impacts on a per registered vehicle basis.

Local Business Leader Opinion Survey

A limited sample of the opinions of leaders of major businesses located in 13 of the study areas was conducted to assess the impact of transportation issues on daily business activities and the business decision-making process. More than one-third of the responding organizations were in service industries with another third in manufacturing and construction.

Land cost, access to highway facilities, physical environment, proximity to markets, and availability of parking were ranked as the most important factors considered in the decision to locate the company at its present site. The quality of transportation facilities and services was ranked ahead of access for personnel and the transport of materials and supplies in an assessment of the relative importance of transportation factors to the current business activities of their firm.

Urban areas with the highest congestion index were also among those with the highest percentage of business leaders listing the peak-hour traffic situation as severely congested. The data suggest that opinions concerning traffic congestion are more closely related to experience with local conditions in previous years (than to the quantitative estimates of roadway operating condition). More than half of the responding companies had been at their location for more than 10 years; compared to a decade earlier, traffic in the areas surveyed is more congested today.

The most frequently listed transportation system improvement projects were the construction of more capacity on arterial streets and freeways. Approximately half of the responding companies inside and outside Texas listed these improvements as necessary to enhance business. Other suggestions that were included by more than 25 percent of the respondents related to upgrading public transportation and construction/expansion of a rail transit system. These last two suggestions were less endorsed (by 8 to 15 percentage points) in the four Texas cities than in the other nine study areas.

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CHAPTER 1
INTRODUCTION

Mobility, for almost all Americans, is defined by the automobile. In many cities with significant population growth since 1950, Interstate freeway construction and other federal and state projects provided excellent urban mobility during the 1960s and 1970s. Many urban areas can attribute the rapid increase in population and economic development, in part, to the good transportation system provided for persons and goods in newer, less dense cities. The relative slowdown in roadway construction activity in Texas, and other states, during the 1970s, however, did not allow street and freeway supply to keep pace with increasing demand.

Traffic congestion, expected during the "rush" hour, can now be encountered much of the day on one or more major freeways in almost all large urban areas. To the extent that service, retail, commercial or manufacturing businesses change location or alter expansion or new development plans due to traffic congestion, the condition of a transportation system can impact urban development.

Since the mid-1970s, the negative perception of transportation mobility levels in many major cities has motivated federal, state and local agencies to increase roadway construction projects. Traffic congestion has emerged as an important urban issue at a time when varying amounts of funds are available to address the need for expanded transportation infrastructure. Construction projects in major Texas cities will result in significant peak-period travel improvements; many cities in other states are also constructing rail and highway facilities that will provide more person movement capacity.

Relative Mobility Levels

Quantitative estimates of mobility levels in various cities that would allow comparisons of transportation systems have been difficult to obtain. Several different data bases and methodologies have been used to illustrate the impact of traffic congestion, traffic volume growth and facility construction on the mobility provided by major urban roadway systems. This research report uses existing data from federal, state and local agencies to develop planning-level estimates of traffic conditions on freeways and principal arterial streets in 29 low to moderate population density urban areas between 1982 and 1986. This list includes the seven large urban areas in Texas (population greater than 250,000) and 22 urban areas of comparable density outside Texas which rely on the street and highway system to provide urban mobility.

Economic Impact

While traffic congestion is frustrating to motorists, perhaps a more important measure is the cost of congestion. Three factors were analyzed for their economic impact on the residents of large urban areas. Travel delay is a major element in an assessment of cost of inadequate transportation systems. Motor vehicles consume more fuel in congested situations than during free-flow operation. Congested traffic operation also results in higher accident rates, which may explain a portion of the higher insurance costs paid by urban vehicle owners.

Calculations of travel delay, excess fuel consumed and increased insurance costs are displayed on an areawide and per capita basis. The latter value illustrates what might be termed the "congestion tax" paid by urban residents.

Transportation as a Business Concern

A survey of major businesses was conducted in 13 of the study areas to determine how business activities and the decision-making process are influenced by traffic congestion. The businesses were asked to rank transportation issues with various economic, social, political and environmental factors to determine the relative importance of transportation facilities on business location and expansion decisions. The survey results can provide information to agencies concerned with economic development issues.

CHAPTER 2
URBAN AREAWIDE CONGESTION MEASUREMENT METHODOLOGY DEVELOPMENT

Previous research (1,2)[1] on areawide mobility levels in Texas resulted in a methodology to compare urban roadway congestion levels. This section summarizes the purpose, data base, analysis procedure and major findings of that research effort and an FHWA research report on urban freeway congestion.

Purpose of Congestion Measurement Techniques

Transportation professionals and the general public are increasingly aware of the traffic congestion levels experienced in major cities. This interest resulted in research to develop a procedure that would allow quantitative comparisons of urban areawide traffic volumes and roadway mileage. Obviously, a procedure that utilizes generally available data would be more desirable than one which required new or more extensive data collection.

Previous Urban Mobility Comparison Studies

Lack of comparable and significant urban travel data has hampered the analysis of congestion levels on a national basis. The amount of roadway system performance statistics collected and reported by local and state agencies varies significantly across the nation. Differences in roadway functional classification terminology have resulted in significant variations between major and minor arterial street mileage. The Highway Performance Monitoring System (HPMS) data base (3) compiled by FHWA since 1980 was used as the basic source of data for this analysis. Local planning and transportation agencies and state departments of transportation (DOT) were also contacted to obtain relevant data and provide local review.

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[1]Numbers in parentheses denote references listed at the end of the report.

HPMS data is submitted to FHWA by state DOTs and includes information on state and locally maintained roadway systems. This should give a more accurate representation of the urban area roadway condition than information that could be developed from a single organization. The differences in functional classification and the amount of data used to update the database each year varies in each state. Locally developed planning data were, therefore, used to provide another source of information concerning the urban roadway system.

The boundary chosen for inclusion in a mobility analysis is also significant. City or county jurisdictions vary in the percentage of urban area included and the density of development. State laws pertaining to municipal incorporation, and the time and manner in which the area developed also have a substantial impact on land use patterns.

In conducting the initial relative mobility studies, data availability 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 studies (1,2) 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 using several estimates of both travel and area statistics. For example, in defining urban area, it was not always possible to use jurisdictional limits as the defining boundaries due to either lack of data on related travel measures or non-comparability 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. This study uses a population density of more than 1000 persons per square mile as the criterion for urban area delineation.

A 1986 FHWA research report entitled, "Quantification of Urban Freeway Congestion and Analysis of Remedial Measures" (4) utilized the HPMS data base to develop detailed estimates of congestion due to recurring delay (usual, high traffic volumes) and incident delay. Freeway systems in the 37 Metropolitan Statistical Areas (MSAs) with populations greater than one million were analyzed for travel delay and excess fuel consumption. The study ranked the urban areas according to a congestion severity index (total delay per million vehicle-miles of travel) for 1984 and 2005. The future values were derived from the traffic volume growth estimates in HPMS and applied to the existing roadway system to illustrate the effect a construction moratorium would have on the systems.

The 1984 FHWA rankings are compared to those developed within this report. It should be noted that the FHWA report (4) focused on relatively detailed estimates of urban area freeway delay for large MSAs, while this project analyzed planning level estimates of delay, fuel and insurance costs for freeways and principal arterial streets in low to moderate population density urban areas. While not directly comparable, these studies should illustrate areas of concern to transportation planners.

Study Design

The urban area traffic volume level that was consistent with desirable overall mobility was determined using data derived from the Houston area. During the late 1960s and early 1970s, citizens in Houston enjoyed one of the best transportation systems in the nation. Peak-hour speed on most facilities was reasonable, and congestion did not extend for a significant period beyond either peak hour. By 1980, however, Houston had acquired, and probably deserved, a reputation as one of the most congested cities in the country. At some point, transportation mobility had declined from desirable to undesirable.

The initial focus of the 1982 research effort (1) was to develop an estimate of the initial point at which mobility levels could be described as undesirable. Having estimated this point, the measures of mobility levels associated with that time could be assumed to be representative of undesirable congestion levels.

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 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, while daily freeway VMT increased at approximately the same rate throughout the 20-year period (1). Vehicle registration, population, and traffic volume counts were thoroughly analyzed and also indicated the shift from relatively good mobility to relatively poor mobility in only a few years.

Table 1. City of Houston Growth Trends, 1950 to 1985

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
1950	595[2]	240	200	25	8,400
1955	690[2]	375	620	100	6,200
1960	940[2]	480	1,045	185	5,600
1965	1,085	625	3,425	455	7,500
1970	1,235	775	7,320	760	9,600
1975	1,440	1,000	11,365	900	12,700
1980	1,610	1,270	16,310	960	17,000
1985	1,730	1,450	20,600	1,100	18,700
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

Source: References 1, 2, 5, 6

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

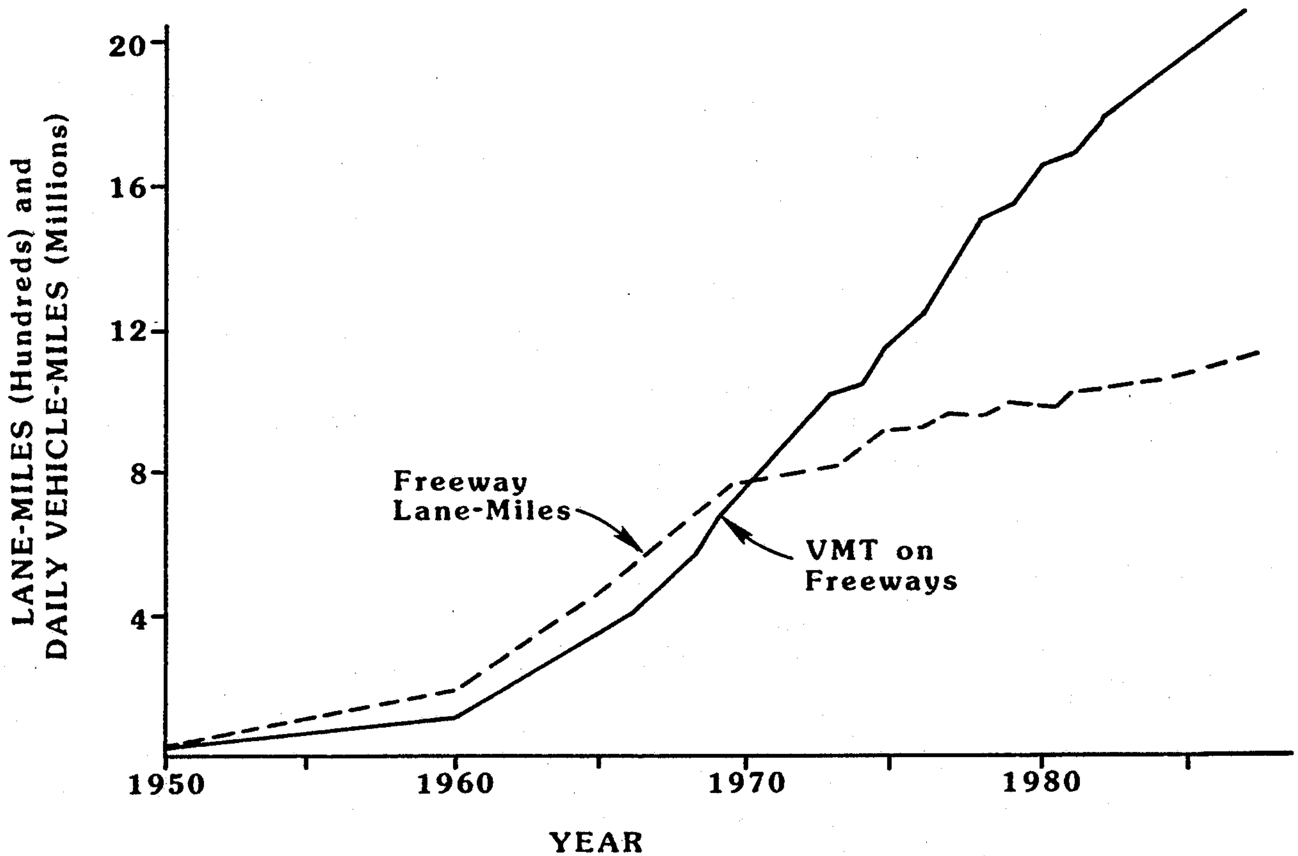


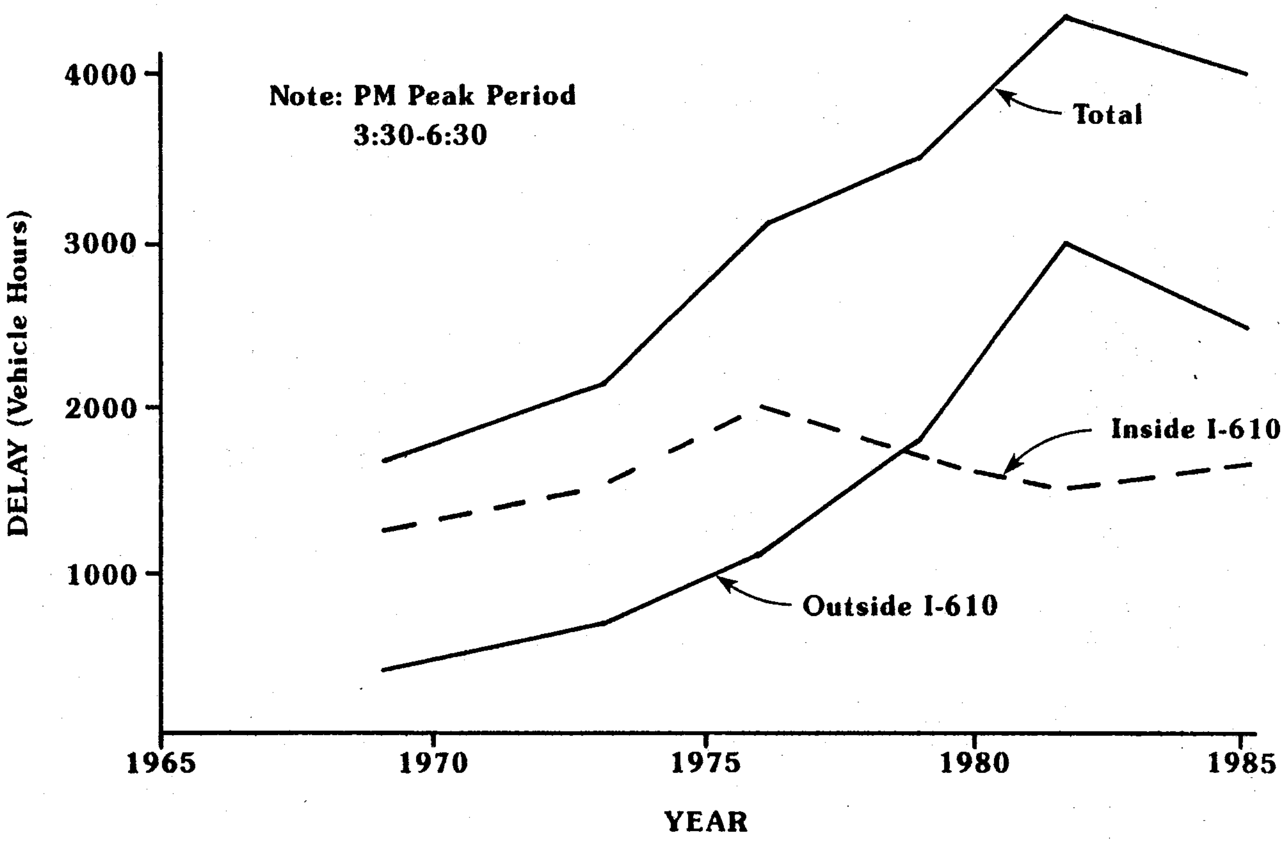
Figure 1. Freeway Capacity and Travel in Houston, 1950 to 1986

Table 2. Average Evening Peak-Period Delay By Freeway Segment Per Major Radial Freeway

Year	Inside I-610 (Veh-Hours)	I-610 to Beltway 8 (Veh-Hours)	Total (Veh-Hours)
1969	1,315	390	1,705
1973	1,560	685	2,245
1976	2,110	1,165	3,275
1979	1,830	1,860	3,690
1982	1,480	3,000	4,480
1985	1,615	2,565	4,180

Source: References 1, 2, 7, 8, 9

Note: Evening peak period used for analysis was 3:30 to 6:30 p.m.



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

Source: References 1, 2, 7, 8, 9

Figure 2: Delay by Segments for Houston Freeways, P.M. Peak Period

by the Houston-Galveston Regional Transportation Study (HGRTS) (7). The dramatic (380 percent) increase in delay between I-610 and 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 five miles 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, resulting in greater congestion outside I-610.

The maximum freeway service flow rate for level-of-service C (LOS C) is 1,550 passenger cars per lane per hour (volume/capacity ratio equal to 0.77) for a 70 mph design speed facility (10). Using average values for k-factor (the percentage of daily traffic volume during the peak hour) and directional distribution, and including some adjustment for trucks, these values can be interpreted to indicate that 15,000 vehicles per lane per day is an estimate of the beginning of level-of-service D operation. (The development of this value is consistent with the planning level analysis methodology presented in this report).

The use of the boundary between level-of-service C and D as the beginning of congestion is consistent with reports by the Department of Transportation to Congress on the status of highways in the United States (11) (congestion begins at a volume/capacity ratio of 0.8) and the AASHTO Policy on Geometric Design of Highways and Streets (12) (urban freeways and streets should be designed for level-of-service C). While the use of a single number tends to mask the myriad of 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 1965 and 1985. Although it is not known what percentage of the freeway system exceeding 15,000 vehicles per lane per day (operating at LOS D or worse in the peak hour) is an "acceptable" measure, it can be assumed that the 10 percent value in 1970 did not suggest county-wide deficiencies; however, the 45 percent in 1980 would appear to suggest 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. Prior to 1975, mobility in Houston could be characterized as "reasonably good." 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 two or more hours of congested operation during both the morning and evening peak periods. Congested freeway lane-miles in Harris County (Figure 2) increased from 10 percent in 1970 to 40 percent in 1978. When 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 factors, listed in apparent order of reliability and usefulness, represent guidelines that can be used to determine if congestion in an urban area is becoming critical.

Traffic Per Lane

As shown previously, 15,000 vehicles per lane per day for freeways can be interpreted to represent the beginning of LOS D operation. Once traffic volume has entered that range, congestion is becoming critical. As a measure of approaching congestion, the 13,000 vehicles per lane per day value used by the Federal Highway Administration in the highway needs estimate (13) and by the Texas Department of Highways and Public Transportation in their Project Development Process (14) would appear to represent a more appropriate value. That standard also was attained on an average urban area basis in Houston during the period (1976-77) when mobility was becoming unacceptable.

The corresponding measure for urban arterial streets would appear to be approximately 5,000 vehicles per lane per day. This value was not reached in Houston until 1979-80, but the design of the Houston area principal arterial street system would not accommodate traffic volumes representative of congestion in other urban areas. An inconsistent arterial system with respect to both the number of lanes and continuous roadway length, reduced the levels of traffic volume necessary to cause undesirable congestion. This value is also in general agreement with values presented in the Highway Capacity Manual (10).

- Urban Area Average Traffic Volume
  - Freeway: 13,000 daily vehicle-miles of travel per lane-mile
  - Principal Arterial: 5,000 daily vehicle-miles of travel per lane-mile

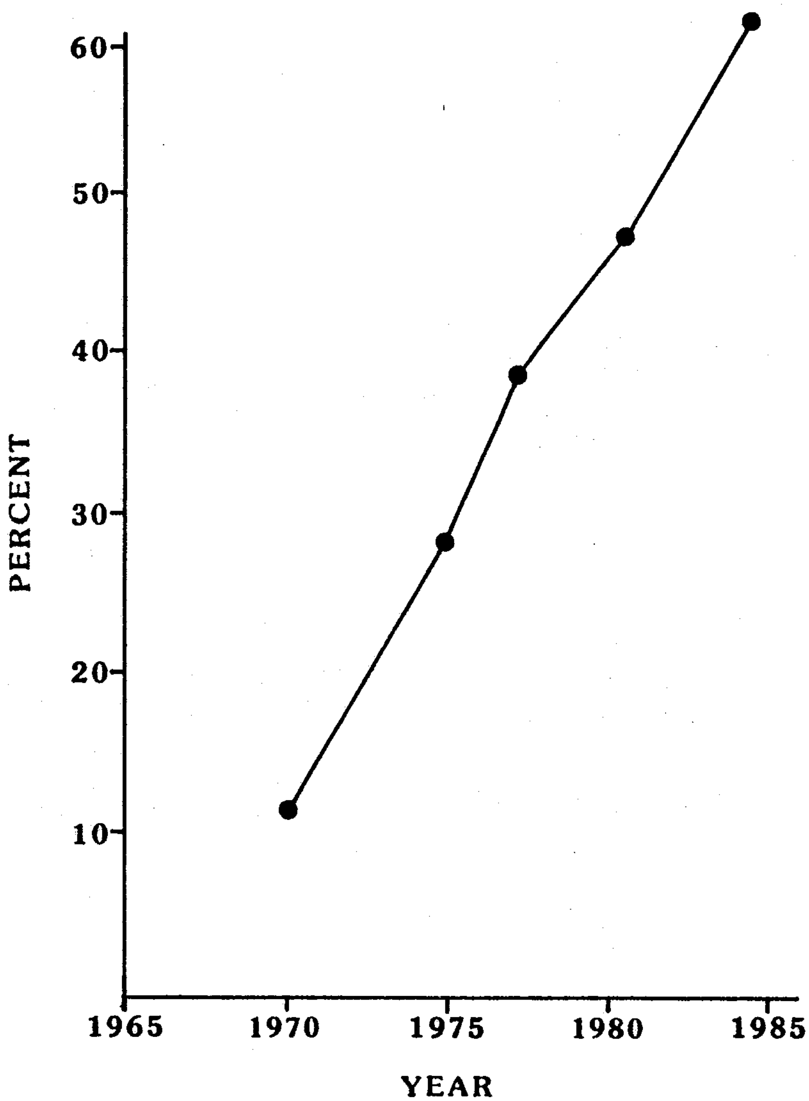
Congestion Index

Combining the freeway and principal arterial traffic volume per lane values into one indicator (Equation 1) generates a value to compare the major mobility providing roadways of each urban area. Weighing the vehicle-miles of travel (VMT) per lane values by the amount of VMT in each functional class provides flexibility in applying the formula to areas with very different freeway and street travel characteristics. The congestion levels are normalized, with a value of 1.0 representing the beginning of undesirable mobility levels.

$$\text{Congestion Index} = \frac{\text{Freeway VMT/Lane-mile} \times \text{Freeway VMT} + \text{Prin. Art. VMT/Lane-Mile} \times \text{Prin. Art. VMT}}{13{,}000 \times \text{Freeway VMT} + 5{,}000 \times \text{Prin. Art. VMT}} \qquad \text{Equation 1}$$

Percentage of Congested Freeway

The percentage of the freeway system operating under congested conditions (15,000 vehicles per lane per day or more) was determined to be another description of congestion and mobility levels. Those data for the Houston area were presented previously (Figure 3). From that information, using the 1976-77 time frame, it appears that once 30 percent



Source: 1, 2, 8

Figure 3. Percent of Freeway Lane-Miles With More Than 15,000 ADT for Harris County (Houston), 1970 to 1985

of the lane-miles are operating at or above 15,000 vehicles per day, mobility has become significantly impaired.

- Percentage of Freeway System with ADT Greater than 15,000 Per Lane: 30 percent.

Summary

These measures are only some of the variables examined during the assessment of possible mobility indicators (1). While all of the measures have limitations due to the reliability and accuracy of the data base, the three indicators below are illustrative of urban travel conditions.

- Urban area traffic volumes
- Congestion Index
- Percentage of freeway system with ADT per lane greater than 15,000

These factors 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 of the measures are examined, the relative mobility levels should become apparent. The analysis in the following chapter used the indicators to assess relative mobility levels in the study areas.

CHAPTER 3
RELATIVE MOBILITY LEVELS ON MAJOR URBAN ROADWAY SYSTEMS

The urban area travel volume and capacity statistics developed from federal, state and local sources for the 29 study areas are summarized in this chapter. The major indicators of daily vehicle-miles of travel (DVMT) per lane-mile for freeways and principal arterials are combined in a congestion index to rank the relative mobility levels. Travel volume and facility supply are combined with population and urban area size to produce frequency and density ratios for urban area comparison.

Freeway/Expressway Travel and Mileage Statistics

Table 3 illustrates the study results concerning freeway operating condition in 1986. Daily vehicle-miles of travel (DVMT), lane-miles of freeway, average number of lanes on the freeway system and DVMT per lane-mile are included. A ranking based on travel per lane-mile is also presented. A summary group of statistics at the bottom of Table 3 compares the averages for urban areas outside and within Texas.

Los Angeles, San Francisco, Houston, Atlanta, Phoenix, Seattle-Everett and Dallas were estimated to have the seven most congested freeway systems in 1986. These freeway systems exceeded the desirable level of 13,000 DVMT per lane-mile. Of the ten most congested systems, Phoenix would appear to be the one which is congested due to both inadequate length and width. Phoenix has only 4.8 lanes per freeway mile (ranked 25th of 29) and 315 lane-miles of freeway (ranked 26th of 29). In contrast, seven of the ten systems estimated to be greater than 1,000 lane-miles in length are among the eight most congested systems. These seven systems have a higher-than-average 6.5 lanes per freeway. These large urban area systems would appear to be congested due to very high demand, rather than only because of inadequate facilities.

Three Texas areas rank in the ten most congested freeway systems and the five most congested Texas cities carry 10 percent more vehicle-miles per lane-mile than the study average for cities outside Texas. The number of freeway lanes in Texas is only slightly higher than the average outside Texas. Texas and California are the only states with study cities reporting system averages of greater than six lanes.

Table 3. 1986 Freeway Mileage and Travel Volume

Urban Area	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	Rank[3] DVMT/LM
Phoenix AZ	4,620	315	4.8	14,665	5
Los Angeles CA	92,110	4,800	8.2	19,190	1
Sacramento CA	7,400	650	6.9	11,385	15
San Diego CA	21,020	1,625	7.4	12,935	8
San Fran-Oak CA	36,925	2,285	6.8	16,160	2
Denver CO	9,290	745	5.0	12,470	11
Miami FL	6,975	540	5.3	12,915	9
Tampa FL	2,940	270	4.9	10,890	19
Atlanta GA	21,530	1,455	5.8	14,795	4
Indianapolis IN	6,910	690	5.0	10,015	21
Louisville KY	4,785	505	4.4	9,475	24
Minn-St Paul MN	14,560	1,190	4.8	12,235	12
Kansas City MO	10,905	1,410	4.6	7,735	29
St. Louis MO	15,620	1,380	5.5	11,320	17
Albuquerque NM	1,930	200	5.0	9,650	23
Oklahoma City OK	5,780	690	5.0	8,375	27
Portland OR	6,325	525	5.0	12,045	13
Memphis TN	3,110	365	5.1	8,520	26
Nashville TN	4,250	400	4.4	10,625	20
Salt Lake City UT	3,450	380	5.5	9,080	25
Seattle-Everett WA	15,500	1,110	5.8	13,965	6
Milwaukee WI	6,315	555	5.1	11,375	16
Austin TX	5,300	420	5.5	12,620	10
Corpus Christi TX	1,420	170	5.2	8,350	28
Dallas TX	22,575	1,640	5.3	13,765	7
El Paso TX	3,420	345	5.0	9,910	22
Fort Worth TX	10,725	975	5.4	11,000	18
Houston TX	24,115	1,510	6.1	15,970	3
San Antonio TX	9,450	810	5.0	11,665	14
Outside Texas Avg	13,325	1,000	5.4	11,675	
Texas Avg	11,015	840	5.5	11,915	
Congested Texas Avg	14,455	1,070	5.6	13,030	
Total Avg	12,765	960	5.4	11,735	
Maximum Value	84,710	4,720	7.9	17,945	
Minimum Value	1,420	170	4.4	7,735	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of freeway
[3] Rank value of 1 associated with most congested condition

Source: TTI Analysis and Local Transportation Agency References

Table 4 presents freeway statistics derived from 1986 urban area size and population estimates. Any comparison of the ratios must include consideration of the population density of each urban area. Most of the study cities could be characterized as relatively low density; all the areas except Los Angeles, San Francisco-Oakland and Miami have densities less than 3,000 persons per square mile. As a group, however, the cities outside Texas have a population density almost 50 percent greater than the five most congested Texas cities. If the three relatively dense cities are removed from the calculation, the other U.S. cities are more than 25 percent more dense. The following discussion should be viewed with the expectation that the facility mileage ratios for the other U.S. cities would nominally be 25 percent greater than the congested Texas cities.

The lack of freeway mileage in Phoenix is apparent in the values in Table 4; they are the lowest in all four ratios. San Diego, San Francisco-Oakland, Atlanta, Austin and Dallas have relatively high (greater than 10.0) levels of freeway travel per capita. Phoenix, Miami and Memphis are at the low end of the list of study cities, with travel rates under 4.0. The five most congested Texas cities average 45 percent more travel on freeways than the other U.S. cities.

Three California areas (Los Angeles, San Diego and San Francisco-Oakland) have freeway travel per square mile estimates greater than 30,000, 40 to 100 percent greater than the next most densely travelled area. This indicates either dense development and/or heavier than average reliance on the freeway system.

If the freeway statistics in Table 4 are divided by population density, the variability due to development patterns can be controlled (Table A-1 in Appendix A). The lower density cities such as Atlanta, Kansas City, Austin and Dallas are ranked significantly higher in both travel and facility frequency per capita and per square-mile when normalized by population density.

<u>Principal Arterial Street Travel and Mileage Statistics</u>

The 1986 estimate of principal arterial street travel and mileage are presented in Table 5. The format is identical to that of Table 3, although the interpretation of the values is somewhat different. In relating urban area traffic volume per lane values to

Table 4. Summary of Freeway Travel Frequency and Density Statistics for 1986

Urban Area	Popn. (1000) (Sq Mi)	Urban Area Per/SqMi	Popn Density Person	DVMT[1] Per Person	Rank[5]	DVMT[2] Per Sq.Mi.	Rank[5]	Ln Mi[3] Per 1000	Rank	Ln Mi[4] Per 1000	Rank[5]
Phoenix AZ	1,735	855	2,030	2.66	29	5,405	29	.18	1	.37	1
Los Angeles CA	10,710	2,050	5,225	8.60	11	44,930	2	.45	5	2.34	27
Sacramento CA	955	330	2,894	7.75	16	22,425	3	.68	16	1.97	25
San Diego CA	1,980	965	2,050	10.62	5	21,780	6	.82	23	1.68	22
San Fran-Oak CA	3,435	810	4,240	10.75	4	45,585	1	.67	15	2.82	29
Denver CO	1,500	865	1,735	6.19	19	10,740	22	.50	8	.86	4
Miami FL	1,780	450	3,955	3.92	27	15,500	14	.30	2	1.20	14
Tampa FL	615	410	1,500	4.78	24	7,170	28	.44	3	.66	2
Atlanta GA	1,695	1,500	1,130	12.70	1	14,355	17	.86	24	.97	8
Indianapolis IN	895	425	2,105	7.72	17	16,260	10	.77	20	1.62	21
Louisville KY	785	360	2,180	6.10	20	13,290	18	.64	13	1.40	19
Minn-St Paul MN	1,845	960	1,920	7.89	15	15,165	15	.64	14	1.24	15
Kansas City MO	1,135	575	1,975	9.61	7	18,965	8	1.24	29	2.45	28
St. Louis MO	1,930	700	2,755	8.09	13	22,315	4	.72	18	1.97	26
Albuquerque NM	455	250	1,820	4.24	26	7,720	27	.44	4	.80	3
Oklahoma City OK	730	500	1,460	7.92	14	11,560	20	.95	28	1.38	18
Portland OR	1,040	400	2,600	6.08	21	15,815	13	.50	10	1.31	17
Memphis TN	800	380	2,105	3.89	28	8,185	25	.46	6	.96	7
Nashville TN	500	455	1,100	8.50	12	9,340	23	.80	21	.88	5
Salt Lake City UT	760	375	2,025	4.54	25	9,200	24	.50	9	1.01	11
Seattle-Everett WA	1,565	695	2,250	9.90	6	22,300	5	.71	17	1.60	20
Milwaukee WI	1,210	550	2,200	5.22	23	11,480	21	.46	7	1.01	10
Austin TX	465	335	1,390	11.40	3	15,820	12	.90	27	1.25	16
Corpus Christi TX	270	175	1,540	5.26	22	8,115	26	.63	12	.97	9
Dallas TX	1,890	1,410	1,340	11.94	2	16,010	11	.87	25	1.16	12
El Paso TX	480	190	2,525	7.13	18	18,000	9	.72	19	1.82	24
Fort Worth TX	1,120	825	1,360	9.58	8	13,000	19	.87	26	1.18	13
Houston TX	2,790	1,600	1,745	8.64	10	15,070	16	.54	11	.94	6
San Antonio TX	1,000	460	2,175	9.45	9	20,545	7	.81	22	1.76	23
Outside Texas Avg	1,730	675	2,330	7.17		16,795		.62		1.39	
Texas Avg	1,145	715	1,725	9.06		15,225		.76		1.30	
Congested Texas Avg	1,455	925	1,600	10.20		16,090		.80		1.26	
Total Avg	1,590	685	2,185	7.62		16,415		.66		1.37	
Maximum Value	10,730	2,100	5,110	11.91		44,495		1.25		2.73	
Minimum Value	270	175	1,170	2.76		5,435		.19		.37	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1] Daily vehicle-miles of travel per person.
[2] Daily vehicle-miles of travel per square mile of urban area.
[3] Lane-miles per 1000 persons.
[4] Lane-miles per square mile of urban area.
[5] Rank value of 1 associated with most congested condition.

Source: TTI Analysis and Local Transportation Agency References.

congestion levels, some consideration should be given to system continuity. A principal arterial street network defined by a one-mile grid such as that in Phoenix or the southern Los Angeles urban area is capable of providing a higher level-of-service than a network with discontinuous streets or streets with two-lane cross sections between lengths of four or six-lane sections. The aggregate statistics in this report do not recognize any difference in system continuity. At a planning level of analysis, system continuity would not appear to be a concern on the freeway systems in the study areas.

Five urban areas listed in Table 5 have DVMT per lane-mile values in excess of 6,000, 20 percent greater than the recommended urban area indicator of 5,000 DVMT per lane-mile. This would indicate a significant level of congestion on the principal arterial street systems in Miami, St. Louis, Atlanta, Phoenix and Tampa. A freeway system operating 20 percent greater than the highest desirable level would have an average of 15,600 DVMT per lane-mile, a value exceeded only by the very congested systems in Los Angeles, San Francisco-Oakland and Houston. The variability of arterial street data and the lack of adjustment for system continuity may indicate that some of the 22 urban areas with values in excess of 5,000 DVMT per lane-mile did not have undesirable systemwide levels of congestion. The data may also indicate that the congestion indicator level (5,000) should be higher. The congestion index calculation presented subsequently will use 5,000 DVMT per lane-mile as the congestion criteria; the value may be too low, but this should not significantly alter the relative ranking of mobility levels estimated in the procedure.

Table 5 illustrates that most of the mobility provided in Phoenix is on principal arterial streets. The principal arterial street system had more than eight times as many lane-miles as the freeway system (Table 3) and more than three times the DVMT, in 1986. The system had a lower than study average number of lanes per street and a relatively high volume per lane value. While the freeway system volume was 13 percent greater than the desirable congestion indicator, the principal arterial street system volume was estimated to be 22 percent higher than desirable.

Table 5. 1986 Principal Arterial Street Mileage Travel Volume

Urban Area	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	Rank[3] DVMT/LM
Phoenix AZ	15,840	2,595	3.2	6,105	4
Los Angeles CA	70,410	11,610	4.0	6,065	7
Sacramento CA	5,885	970	4.0	6,065	7
San Diego CA	7,850	1,530	3.4	5,130	18
San Fran-Oak CA	12,000	1,975	3.8	6,075	6
Denver CO	10,680	1,920	3.8	5,560	12
Miami FL	12,300	1,975	4.3	6,225	1
Tampa FL	3,650	600	3.8	6,080	5
Atlanta GA	9,055	1,480	3.6	6,115	3
Indianapolis IN	3,950	835	3.7	4,730	25
Louisville KY	2,735	480	3.6	5,695	11
Minn-St Paul MN	5,100	1,150	3.5	4,435	27
Kansas City MO	4,385	910	3.4	4,820	24
St. Louis MO	10,765	1,730	3.2	6,220	2
Albuquerque NM	3,250	615	3.5	5,285	17
Oklahoma City OK	3,310	645	3.1	5,130	18
Portland OR	3,140	525	3.3	5,980	9
Memphis TN	3,760	750	4.0	5,010	22
Nashville TN	4,805	900	3.4	5,340	15
Salt Lake City UT	1,825	330	3.3	5,530	13
Seattle-Everett WA	8,325	1,450	3.3	5,740	10
Milwaukee WI	4,700	930	3.0	5,055	21
Austin TX	2,190	410	4.1	5,340	15
Corpus Christi TX	1,400	320	3.5	4,375	28
Dallas TX	8,230	1,680	4.5	4,900	23
El Paso TX	2,915	805	3.6	3,620	29
Fort Worth TX	4,250	840	3.9	5,060	20
Houston TX	10,810	1,955	3.9	5,530	13
San Antonio TX	4,585	1,030	3.3	4,450	26
Outside Texas Avg	8,945	1,155[4]	3.5	5,480	
Texas Avg	4,910	1,005	3.8	4,755	
Congested Texas Avg	6,010	1,180	3.9	5,055	
Total Avg	7,970	1,120[4]	3.6	5,305	
Maximum Value	62,170	11,180	4.5	6,225	
Minimum Value	1,400	320	3.0	3,620	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of principal arterial
[3] Rank value of 1 associated with most congested condition
[4] Average without Los Angeles data included

Source: TTI Analysis and Local Transportation Agency References

San Francisco-Oakland, Miami, and Tampa also have relatively high volume per lane values, but have systems with a lower proportion of two-lane roadways, as evidenced by the higher than average number of lanes per facility. Eight of the 11 most congested principal arterial street networks have systems of more than 1,400 lane-miles with an average width of 3.6 lanes. There are also several relatively narrow street systems (low average number of lanes) that were estimated to operate near or below the recommended volume per lane (e.g., San Diego, Milwaukee, San Antonio).

The Texas urban areas averaged wider, less travelled facilities than the other U.S. cities in the study. Volumes were eight to 13 percent less than the other cities average. If the Los Angeles system is removed from the data base, the arterial street lane-miles for the other U.S. cities is comparable to the five most congested Texas cities.

Table 6 presents the travel volume and principal arterial street system mileage values on a per capita and square mile basis. The rankings for each of the columns also appears in the Table; a comparison of the rankings for DVMT and lane-miles per square mile (and per person) would provide information concerning the relative position of each area in terms of roadway travel and supply. Atlanta is ranked lower in DVMT per capita than in lane-miles per 1000 persons (indicating a system that should be congested); Indianapolis, Corpus Christi and San Antonio exhibit the opposite tendency.

The two facility mileage ratios would seem to be more useful in interpreting the transportation system condition. DVMT is dependent on facility mileage and population density, while lane-miles of facility is a more independent quantity. With a few exceptions, however, the relative rankings for the two facility mileage ratios are approximately equal to the companion travel ratio.

Table A-2 in Appendix A presents the four ratios in Table 6 divided by the population density for each urban area. This calculation reduced the impact of developmental differences on the factors, while providing a method to compare the relative rankings of the urban areas. The facility provision ratio per area (lane-miles per square mile), adjusted for population density, indicated the congested Texas cities were only 10 percent less than the outside Texas average, compared with a 55 percent lower estimate without the population density adjustment. The congested Texas facility per capita (lane-miles per 1000 persons) value was altered from 10 percent below to 15 percent above the other U.S. cities. The lane-miles present in Texas urban principal arterial street systems would, therefore, seem to be comparable to the other U.S. cities when adjusted for the significantly lower population density in Texas cities.

Table 6. Summary of Principal Arterial Streets Travel Frequency and Density Statistics for 1986

Urban Area	1986 Popn. (1000)	Urban Area (Sq Mi)	Popn Density Per/Sq Mi	DVMT[1] Per Person	Rank[5]	DVMT[2] Per Sq Mi	Rank[5]	Ln Mi[3] Per 1000 Pers	Rank[5]	Ln Mi[4] Per Sq Mi	Rank[5]
Phoenix AZ	1,735	855	2,030	9.13	2	18,525	3	1.50	27	3.04	26
Los Angeles CA	10,710	2,050	5,225	6.57	6	34,345	1	1.08	22	5.66	29
Sacramento CA	955	330	2,895	6.16	7	17,835	4	1.02	20	2.94	25
San Diego CA	1,980	965	2,050	3.96	20	8,135	17	.77	8	1.59	13
San Fran-Oak CA	3,435	810	4,240	3.49	25	14,815	7	.57	3	2.44	22
Denver CO	1,500	865	1,735	7.12	4	12,345	9	1.28	25	2.22	20
Miami FL	1,780	450	3,955	6.91	9	27,335	2	1.11	23	4.39	28
Tampa FL	615	410	1,500	5.93	6	8,900	15	.98	19	1.46	11
Atlanta GA	1,695	1,500	1,130	5.34	11	6,035	25	.87	11	.99	2
Indianapolis IN	895	425	2,105	4.41	18	9,295	14	.93	16	1.96	16
Louisville KY	785	360	2,180	3.48	26	7,595	21	.61	4	1.33	10
Minn-St Paul MN	1,845	960	1,920	2.76	28	5,315	27	.62	5	1.20	5
Kansas City MO	1,135	575	1,975	3.86	23	7,625	20	.80	10	1.58	12
St. Louis MO	1,930	700	2,755	5.58	10	15,380	5	.90	15	2.47	24
Albuquerque NM	455	250	1,820	7.14	3	13,000	8	1.35	26	2.46	23
Oklahoma City OK	730	500	1,460	4.53	17	6,620	23	.88	12	1.29	8
Portland OR	1,040	400	2,600	3.02	27	7,850	19	.50	2	1.31	9
Memphis TN	800	380	2,105	4.70	15	9,895	13	.94	18	1.97	17
Nashville TN	500	455	1,100	9.61	1	10,560	11	1.80	29	1.98	18
Salt Lake City UT	760	375	2,025	2.40	29	4,865	29	.43	1	.88	1
Seattle-Everett WA	1,565	695	2,250	5.32	12	11,980	10	.93	16	2.09	19
Milwaukee WI	1,210	550	2,200	3.88	21	8,545	16	.77	8	1.69	14
Austin TX	465	335	1,390	4.71	14	6,535	24	.88	12	1.22	6
Corpus Christi TX	270	175	1,540	5.19	13	8,000	18	1.19	24	1.83	15
Dallas TX	1,890	1,410	1,340	4.35	19	5,835	26	.89	14	1.19	4
El Paso TX	480	190	2,525	6.07	8	15,340	6	1.68	28	4.24	27
Fort Worth TX	1,120	825	1,360	3.79	24	5,150	28	.75	7	1.02	3
Houston TX	2,790	1,600	1,745	3.87	22	6,755	22	.70	6	1.22	6
San Antonio TX	1,000	460	2,175	4.59	16	9,965	12	1.03	21	2.24	21
Outside Texas Avg	1,730	675	2,330	5.24		12,125		.94		2.13	
Texas Avg	1,145	715	1,725	4.65		8,225		1.02		1.85	
Congested Texas Avg	1,455	925	1,600	4.26		6,850		.85		1.38	
Total Avg	1,590	685	2,185	5.10		11,185		.96		2.07	
Maximum Value	10,710	2,050	5,225	9.61		34,345		1.80		5.66	
Minimum Value	270	175	1,100	2.40		4,865		.43		.88	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1] Daily vehicle-miles of travel per person
[2] Daily vehicle-miles of travel per square mile of urban area
[3] Lane-miles per 1000 persons
[4] Lane-miles per square mile of urban area
[5] Rank value of 1 associated with most congested condition

Source: TTI Analysis and Local Transportation Agency References

1986 Congestion Index Values

Freeway and principal arterial street travel statistics in Tables 3 and 5 are presented in Table 7 to calculate the congestion index values for 1986. The formula, as derived in a TTI research report (1) and summarized in the previous chapter (Equation 1), utilized volume per lane values weighted by the daily vehicle-miles of travel on both functional classes. This weighting allows the individual roadway mileage and travel characteristics of each urban area to be included.

Table 7. 1986 Congestion Index Values

Urban Area	Freeway/Expressway		Principal Arterial Streets		Congestion[3] Index	Rank
	DVMT[1] (1000)	DVMT Per[2] Ln-Mile	DVMT[1] (1000)	DVMT Per[2] Ln-Mile		
Phoenix AZ	4,620	14,665	15,840	6,105	1.18	4
Los Angeles CA	92,110	19,190	70,410	6,065	1.42	1
Sacramento CA	7,400	11,385	5,885	6,065	.95	14
San Diego CA	21,020	12,935	7,850	5,130	1.00	10
San Fran-Oak CA	36,925	16,160	12,000	6,075	1.24	2
Denver CO	9,290	12,470	10,680	5,560	1.01	9
Miami FL	6,970	12,915	12,300	6,225	1.10	6
Tampa FL	2,940	10,890	3,650	6,080	.96	13
Atlanta GA	21,530	14,795	9,055	6,115	1.15	5
Indianapolis IN	5,800	10,015	3,950	4,730	.80	22
Louisville KY	4,785	9,475	2,735	5,695	.80	22
Minn-St Paul MN	14,560	12,235	5,100	4,435	.93	16
Kansas City MO	10,905	7,735	4,385	4,820	.64	29
St. Louis MO	15,620	11,320	10,765	6,220	.95	15
Albuquerque NM	1,930	9,650	3,250	5,285	.87	20
Oklahoma City OK	5,780	8,375	3,310	5,130	.71	27
Portland OR	6,325	12,045	3,140	5,980	.97	12
Memphis TN	3,110	8,520	3,760	5,010	.77	24
Nashville TN	4,250	10,625	4,805	5,340	.89	19
Salt Lake City UT	3,450	9,080	1,825	5,530	.77	24
Seattle-Everett WA	15,500	13,765	8,325	5,740	1.09	7
Milwaukee WI	6,315	11,375	4,700	5,055	.91	17
Austin TX	5,300	12,620	2,190	5,340	.98	11
Corpus Christi TX	1,420	8,350	1,400	4,375	.71	27
Dallas TX	22,575	13,765	8,230	4,900	1.05	8
El Paso TX	3,420	9,910	2,915	3,620	.75	26
Fort Worth TX	10,725	11,000	4,250	5,060	.87	20
Houston TX	24,115	15,970	10,810	5,530	1.21	3
San Antonio TX	9,560	11,665	4,585	4,450	.91	17
Outside Texas Avg	13,688	11,810	9,440	5,565	.96	
Texas Avg	11,015	11,900	4,910	4,755	.92	
Congested Texas Avg	14,455	13,005	6,010	5,055	1.00	
Total Avg	13,043	11,830	8,350	5,370	.95	
Maximum Value	92,110	19,190	70,410	6,225	1.42	
Minimum Value	1,420	7,735	1,400	3,620	.64	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

Source: TTI Analysis and Local Transportation Agency References

The ten highest congestion index values were equal to or greater than 1.0, indicating an undesirable level of urban areawide congestion. Los Angeles, San Francisco-Oakland, Houston, Phoenix and Atlanta were the most severely congested, with values 15 percent or more above the maximum desirable congestion level. Nine other urban areas had congestion indices greater than 0.90, indicating a major roadway system that could become congested in the near future. The data are for 1986 and more than one additional year of traffic volume growth has occurred at the time of this report.

The seven Texas cities were estimated to have approximately the same average congestion index as the other major U.S. cities selected for this study. The average of the 5 most congested Texas cities, however, was at the undesirable congestion level. The averages for other states with more than one urban area in this study include: California-1.15; Florida -- 1:03; Missouri -- 0.80; and Tennessee -- 0.83.

Of the urban areas with index values greater than 1.0, Phoenix, Miami and Denver were the only study cities estimated to have more travel on the principal arterial system than the freeways. Table 8 provides an estimate of the daily vehicle-miles of travel on the freeway, principal arterial streets and total roadway system. The most congested Texas cities were estimated to rely much more heavily on the freeway system to provide mobility than the average of the study cities outside Texas. While both sets of roadway systems derive approximately 60 percent of total daily VMT from the freeway and principal arterial street systems, the percentage of freeway DVMT in the five most congested Texas cities is 20 percent greater than the average of the study cities outside Texas.

Table 8. Summary of Freeway/Principal Arterial Street VMT Relationship -- 1986

Urban Area	Freeway DVMT (1000)	Principal Arterial Street DVMT (1000)	Total DVMT (1000)	Fwy DVMT[1] % of Total	Prin Art[2] % of Total	Fwy/PA[3] VMT % of Total
Phoenix AZ	4,620	15,840	29,960	15	53	68
Los Angeles CA	92,110	70,410	210,925	44	33	77
Sacramento CA	7,400	5,885	20,215	37	29	60
San Diego CA	21,020	7,850	44,640	47	18	65
San Fran-Oak CA	36,925	12,000	70,540	52	17	69
Denver CO	9,290	10,680	29,020	32	37	69
Miami FL	6,970	12,300	31,965	22	38	60
Tampa FL	2,940	3,650	12,355	24	30	53
Atlanta GA	21,530	9,055	53,070	41	17	58
Indianapolis IN	6,910	3,950	15,775	44	25	69
Louisville KY	4,785	2,735	15,295	31	18	49
Minn-St Paul MN	14,560	5,100	39,870	37	13	49
Kansas City MO	10,905	4,385	23,435	47	19	65
St. Louis MO	15,620	10,765	37,190	42	29	71
Albuquerque NM	1,930	3,250	8,080	24	40	64
Oklahoma City OK	5,780	3,310	16,780	34	20	54
Portland OR	6,325	3,140	16,265	39	19	58
Memphis TN	3,110	3,760	13,240	23	28	52
Nashville TN	4,250	4,805	12,795	33	38	71
Salt Lake City UT	3,450	1,825	12,380	28	15	43
Seattle-Everett WA	15,500	8,325	35,975	43	23	66
Milwaukee WI	6,315	4,700	23,065	27	20	48
Austin TX	5,300	2,190	12,125	44	18	62
Corpus Christi TX	1,420	1,400	5,965	24	23	47
Dallas TX	22,575	8,230	49,050	46	17	63
El Paso TX	3,420	2,915	9,415	36	31	67
Fort Worth TX	10,725	4,250	29,285	37	15	51
Houston TX	24,115	10,810	61,660	39	18	57
San Antonio TX	9,560	4,585	22,240	42	21	64
Outside Texas Avg	13,740	9,440	35,130	35	26	61
Texas Avg	11,000	4,915	27,105	38	20	59
Congested Texas Avg	14,435	6,010	34,870	42	18	59
Total Avg	13,080	8,350	33,190	36	25	60
Maximum Value	92,110	70,410	210,925	52	53	77
Minimum Value	1,420	1,400	5,965	15	13	43

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1]Percent of total daily vehicle-miles of travel on the freeway system
[2]Percent of total daily vehicle-miles of travel on the principal arterial system
[3]Percent of total daily vehicle-miles of travel on the urban area major roadway system

Source: TTI Analysis and Local Transportation Agency References

Traffic Congestion Growth, 1982 to 1986

The congestion indices for each study area between 1982 and 1986 are presented in Table 9 (Tables A-3 to A-6 in Appendix A provide more detailed information for each study area). Atlanta, San Diego, Austin and Dallas were estimated to have the fastest congestion growth rate, in excess of an annual average of five percent. Each of these areas was over, or very near, the undesirable congestion index levels of 1.0. Six other urban areas (San Francisco-Oakland, Minneapolis-St. Paul, Kansas City, Nashville, El Paso and San Antonio) had annual average growth rates in excess of four percent. Minneapolis-St. Paul, Nashville and San Antonio had congestion index values that increased from relatively low levels to a position that (in 1986) at the 1982 to 1986 growth rate, traffic volumes would exceed the desirable level in two to three years. If the 1982 to 1986 annual growth rates are sustained, by 1990 five to ten additional urban areas will have congestion index values in excess of 1.0.

Table 9. Congestion Index Values, 1982 to 1986

Urban Area	1982	1983	1984	1985	1986	Percent Change (82-86)
Phoenix AZ	1.16	1.15	1.17	1.20	1.18	2
Los Angeles CA	1.24	1.26	1.26	1.30	1.32	6
Sacramento CA	.80	.83	.86	.89	.90	13
San Diego CA	.78	.83	.91	.95	1.00	28
San Fran-Oak CA	1.06	1.05	1.15	1.20	1.24	17
Denver CO	.88	.90	.96	.99	1.01	15
Miami FL	1.05	1.09	1.07	1.13	1.10	5
Tampa FL	.94	.91	1.03	1.00	.96	2
Atlanta GA	.89	.94	.99	1.05	1.15	29
Indianapolis IN	.73	.69	.74	.76	.80	10
Louisville KY	.85	.83	.83	.82	.80	-6
Minn-St Paul MN	.78	.82	.86	.88	.93	19
Kansas City MO	.55	.56	.57	.61	.64	16
St. Louis MO	.83	.87	.90	.91	.95	14
Albuquerque NM	.76	.81	.87	.92	.87	14
Oklahoma City OK	.72	.72	.75	.74	.71	-1
Portland OR	.87	.86	.88	.93	.97	11
Memphis TN	.76	.78	.72	.73	.77	1
Nashville TN	.75	.77	.85	.86	.89	19
Salt Lake City UT	.73	.73	.75	.76	.77	5
Seattle-Everett WA	.95	.99	1.02	1.05	1.09	15
Milwaukee WI	.85	.86	.89	.90	.91	7
Austin TX	.77	.84	.89	.91	.98	27
Corpus Christi TX	.67	.69	.69	.71	.71	6
Dallas TX	.84	.89	.94	.98	1.05	25
El Paso TX	.63	.64	.65	.70	.75	19
Fort Worth TX	.76	.79	.80	.82	.87	14
Houston TX	1.17	1.21	1.25	1.23	1.21	3
San Antonio TX	.77	.79	.82	.87	.91	18
Outside Texas Avg	.86	.88	.91	.94	.95	10
Texas Avg	.80	.84	.86	.89	.93	16
Congested Texas Avg	.86	.90	.94	.96	1.00	18
Total Avg	.85	.87	.90	.92	.94	12
Maximum Value	1.24	1.26	1.26	1.30	1.32	29
Minimum Value	.55	.56	.57	.61	.64	-6

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

Source: Equation 1 and Tables 3, 5, and A-3 to A-6

The congestion indices for the five most congested Texas cities were approximately equal to the average of the study areas outside Texas until 1986. Significant index increases were registered in Austin, Dallas, El Paso and Fort Worth between 1985 and 1986, increasing both Texas averages. The economic recession in Texas during this time does not seem to be reflected in traffic volume data. A similar economic downturn experienced in the early-80s in Houston was not apparent in the data until 1985.

Percentage of Congested Freeway Lane-Miles

Table A-6 lists the estimate of percentage of freeway capacity that operates at undesirable traffic volume levels. These values generally agree with the urban area freeway DVMT per mile rankings. The most heavily travelled systems (Los Angeles, San Francisco-Oakland, Houston and Phoenix) have more than 50 percent of the freeway system that could be characterized as congested. Seven other urban areas (Miami, Seattle-Everett, Dallas, San Diego, Denver, Atlanta and Austin) have 30 percent or more of the freeway system estimated to have more than 15,000 ADT per lane, exceeding the congestion indicator level.

CHAPTER 4
ECONOMIC IMPACT OF CONGESTION IN URBAN AREAS

The economic impact of congestion was analyzed in 29 urban areas in 17 states included in this study. These locations represent low to moderate population density similar to those of Texas cities. The study includes seven urban areas within Texas: Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, and San Antonio. This chapter will be devoted to the analysis and discussion of the economic impact of congestion. The analysis procedure was based on a methodology developed for the Houston Regional Mobility Plan (15) and is further documented in Appendix B.

Daily Vehicle-Miles of Travel and Population Estimates

The basic unit of input used in the congestion cost estimates was daily vehicle-miles of travel (DVMT). Population provided a base on which to evaluate cost of congestion in the areas studied. Table 10 is a summary of DVMT and population in the cities selected for study.

The DVMT values (Table 10) used throughout this study were obtained from a combination of sources. Data were obtained from the Federal Highway Administration's Highway Performance Monitoring System (HPMS) (3) and various local and state transportation planning agencies and were illustrated in Tables. The 1986 population values were estimated using U.S. Census Bureau and HPMS data.

Definition of Congestion for Individual Roadway Sections

Prior to calculating congestion cost, the congested peak-period VMT for both freeways/expressways and principal arterial streets within the study areas was estimated. The congested peak-period VMT consists of the percentage of total vehicle travel operating in congested conditions during the morning and evening peak periods. For this study, congested conditions were estimated to begin at the transition from level-of-service (LOS)

C to D (as discussed in Chapter 2 in the section titled, "Houston's Experience With Declining Mobility"). The traffic volumes representative of the beginning of congestion on an individual section of freeway was estimated as 15,000 ADT per lane.

Table 10. Summary of DVMT Values and Population For Congestion Cost Estimates

Urban Area	Daily Vehicle-Miles of Travel (1000s)			1986 Population (1000s)
	Freeway/ Expressway	Principal Arterial	Freeway and Arterial	
Phoenix AZ	4,620	15,840	20,460	1,675
Los Angeles CA	84,710	62,170	146,880	10,730
Sacramento CA	7,240	4,925	12,165	960
San Diego CA	21,020	7,720	28,740	2,000
San Fran-Oak CA	36,485	10,555	47,040	3,470
Denver CO	9,290	10,680	19,970	1,485
Miami FL	6,970	12,300	19,270	1,795
Tampa FL	2,940	3,650	6,590	600
Atlanta GA	21,530	9,055	30,585	1,855
Indianapolis IN	5,800	3,790	9,590	910
Louisville KY	4,785	2,735	7,520	785
Minn-St Paul MN	14,560	5,100	19,660	1,950
Kansas City MO	10,905	4,385	15,290	1,130
St. Louis MO	15,620	10,765	26,385	1,925
Albuquerque NM	1,930	3,250	5,180	455
Oklahoma City OK	5,780	3,310	9,090	730
Portland OR	6,325	3,140	9,465	1,040
Memphis TN	3,110	3,760	6,870	850
Nashville TN	4,250	4,805	9,055	550
Salt Lake City UT	3,450	1,825	5,275	760
Seattle-Everett WA	15,500	8,325	23,825	1,565
Milwaukee WI	6,315	4,700	11,015	1,210
Austin TX	5,300	2,190	7,490	470
Corpus Christi TX	1,420	1,400	2,820	270
Dallas TX	22,575	8,230	30,805	1,895
El Paso TX	3,420	2,915	6,335	490
Fort Worth TX	10,725	4,250	14,975	1,120
Houston TX	24,115	10,810	34,925	2,800
San Antonio TX	9,560	4,585	14,145	1,050
Outside Texas Avg	13,325	8,945	22,270	1,745
Texas Avg	11,015	4,910	15,925	1,155
Congested Texas Avg	14,455	6,010	20,465	1,465
Total Avg	12,765	7,970	20,735	1,605

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

Source: TTI Analysis and Local Transportation Agency References

Principal arterial street operation analyses consider the volume of traffic and intersection signal timings. Therefore, a range of cycle lengths from 60 to 120 seconds was considered, with the principal arterial street receiving 50 percent of the green signal time. (The limiting condition for principal arterial street condition would be at the intersection of two principal arterial streets). These calculations resulted in an estimate of 5,750 vehicles per day per lane as the beginning of LOS D on a section of principal arterial street. This volume is also in general agreement with a value that could be derived by applying the ratio of undesirable urban area traffic volume per lane (5,000 for principal arterials and 13,000 for freeways/expressways) to the value for congestion on an individual section of freeway (15,000 ADT per lane).

HPMS sample data were utilized to estimate the percentage of urban area DVMT occurring on facilities with traffic volume per lane values in excess of the congestion levels (15,000 vehicles per day per lane for freeways/expressways and 5,750 vehicles per day per lane for principal arterial streets). Congested urban area DVMT estimates are presented in Appendix B.

Economic Impact Estimate

The methodology used in this study includes traffic delay and excess fuel cost caused by both incident and recurring type events encountered by the motorist. Recurring congestion results from normal daily facility operations, while incident congestion occurs as a result of an accident or vehicle breakdown. The calculations also identify additional insurance premium cost within an urban area. The congestion cost calculations are discussed in detail in Appendix B of this report. Therefore, this section only briefly covers the constants, variables, and measures of effectiveness (MOEs) used in this portion of the analysis.

Study Constants

The methodology of the congestion cost analysis utilized six independent variables. These constant values were applied to the calculations for each study area considered.

1. Average vehicle occupancy -- 1.25 persons.
2. Working days per year -- 250.
3. Average cost of time (16) -- $8.20 per person-hour.[1]

4. Commercial vehicle operating cost (17) -- $1.65 per mile.

5. Vehicle mix -- 95 percent passenger and 5 percent commercial.

6. Vehicular speeds: (7)

   Freeway/Expressway peak: 35mph, off-peak: 55mph

   Principal Arterial Street peak: 20mph, off-peak: 35mph

Urban Area Travel Variables

The congestion cost estimates also included five site-specific variables which were dependent on the urban area being analyzed. These variables are discussed in detail in Appendix B of this report; this section briefly describes each variable used in the calculations. The five dependent variables include:

1. Daily Vehicle-Miles of Travel (DVMT) -- the average daily traffic of a section of roadway multiplied by the length (in miles) of that section of roadway.
2. Insurance rates -- the state and urban area insurance rates for the state-required minimum coverage.
3. Fuel cost -- the state average fuel cost per gallon for 1986.
4. Registered vehicles -- the number of registered vehicles as reported by county tax offices.
5. Population -- estimated by 1985 U.S. Census Bureau and 1986 HPMS data.

Measures of Effectiveness

The economic impact of congestion resulting from the calculations detailed in Appendix B were stated in terms of annual urban area congestion cost and cost per capita.

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[1]The referenced value of $8.00 per hour in 1985 was adjusted using the 1986 Consumer Price Index (CPI) ratio compared to the 1985 CPI.

This study utilized these cost values (delay, fuel, and insurance) to analyze the effect of congestion within each study area.

Estimates of traffic delay and fuel cost were calculated for both incident and recurring events. The excess insurance premium cost for each area was also determined. The total cost (delay, fuel, and insurance) for each study area was then tabulated.

Delay due to congested traffic operation is the most expensive type of congestion related cost. As estimated in this study, delay is defined as the total vehicle-hours per day spent by motorist operating vehicles on facilities under congested conditions. Delay is the most noticeable impact of congestion to motorists because it directly impacts the travel time of their commute.

Fuel cost represents the excess fuel consumed by vehicles operating in congested conditions. This type of congestion related cost is relativity small when compared to delay. However, should fuel be in short supply, excess fuel consumption could become a substantial commuter issue.

Another congestion related cost estimated in this study was increased insurance premiums. Vehicles operating in congested conditions generally have a greater risk of being involved in an accident. Usually higher urban area accident rates equate to higher insurance premiums for motorists operating vehicles in this urban area. Insurance premiums are not only affected by accident rates, however, these premiums are also affected by the crime rates within each urban area.

Presenting cost values on a per capita basis allowed traffic congestion to be evaluated for individual residents of an urban area. The excess insurance premium cost is, however, somewhat independent of traffic congestion. For that reason, the congestion cost per capita was calculated with and without the estimated urban area insurance cost.

Results of Economic Analysis

Congestion costs shown in Table 11 are the result of converting the congested peak-period VMT into vehicle-hours of delay for congestion resulting from recurring and non-recurring (incident) events using the procedure outlined in Appendix B.

Both fuel and delay costs were, in general, greater for incidents than for recurring events. Incident events resulted in varying amounts of increased delay than events that are recurring in nature. These incident delay values were determined by reviewing data presented in the report by Lindley ("Quantification of Urban Freeway Congestion and Analysis of Remedial Measures" (4)), for urban areas included in this study. This increase in delay may be a result of the timing of incidents; many occur during congested operations and are more than likely to result in the closing of one or more lanes of traffic. The closing of traffic lanes further intensifies the congested situation and causes greater delay and higher fuel consumption.

Individual motorist congestion cost is also presented in Table 11. The impact of excess insurance can be illustrated by comparing the delay and fuel cost estimates with the total cost estimate and total per capita. Insurance costs ranged from a maximum of 49 percent of total congestion cost in Sacramento, to a minimum of three percent in Seattle-Everett. Table 12 illustrates the ranking of the study areas with respect to congestion cost with and without excess insurance cost.

Table 11. Estimated Economic Impact of Congestion in 1986

Urban Area	Annual Cost Due to Congestion ($ million)						Total Delay/Fuel Cost ($ Million)	Congestion Cost Per Capita (Dollars)	Delay/Fuel Cost Per Capita (Dollars)	Congestion Cost Per Reg. Veh. (Dollars)	Delay/Fuel Cost Per Reg. Veh. (Dollars)
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Insurance	Total					
Phoenix AZ	360	365	55	55	90	920	830	550	495	830	750
Los Angeles CA	2,320	2,785	365	440	3,525	9,440	5,915	880	550	1,230	770
Sacramento CA	105	60	15	10	185	375	190	395	200	345	175
San Diego CA	210	125	35	20	195	585	390	295	195	535	355
San Fran-Oak CA	675	875	110	140	885	2,685	1,795	775	520	1,000	670
Denver CO	230	230	35	35	35	565	525	380	355	450	420
Miami FL	300	450	40	65	460	1,310	850	730	475	915	595
Tampa FL	75	115	10	15	15	230	215	380	360	335	315
Atlanta GA	350	385	50	55	140	975	835	525	450	690	590
Indianapolis IN	15	25	0	5	20	65	45	70	50	130	90
Louisville KY	40	45	5	5	10	110	100	140	125	245	225
Minn-St Paul MN	120	110	20	15	70	330	260	170	135	290	230
Kansas City MO	35	105	5	15	55	210	155	185	140	340	250
St Louis MO	250	295	30	35	195	805	610	420	315	585	445
Albuquerque NM	40	45	5	5	10	105	95	230	205	275	245
Oklahoma City OK	35	40	5	5	30	120	90	165	120	265	195
Portland OR	85	170	10	25	50	335	290	325	280	565	485
Memphis TN	40	45	5	5	40	135	100	160	115	290	210
Nashville TN	65	70	10	10	10	165	155	295	280	460	430
Salt Lake City UT	30	15	5	0	20	70	50	95	70	115	85
Seattle-Everett WA	275	385	40	60	20	780	755	495	485	740	720
Milwaukee WI	75	75	10	10	65	230	165	190	140	285	205
Austin TX	75	85	10	10	25	210	185	445	395	460	410
Corpus Christi TX	5	5	0	0	5	20	15	65	55	65	55
Dallas TX	280	505	40	75	210	1,110	900	585	475	685	555
El Paso TX	15	15	0	5	5	40	40	85	75	120	110
Fort Worth TX	110	195	15	30	65	410	350	370	310	455	385
Houston TX	475	665	70	95	360	1,665	1,305	595	465	875	685
San Antonio TX	85	95	10	15	30	235	205	225	195	295	255
Outside Texas Avg.	260	310	40	45	280	935	655	355	275	495	385
Texas Avg.	150	225	20	30	100	525	430	340	280	420	350
Congested Texas Avg.	205	310	30	45	140	725	590	445	370	555	460
Total Avg.	235	290	35	45	235	835	600	350	275	480	375
Maximum Value	2,320	2,785	365	440	3,525	9,440	5,915	880	550	1,230	770
Minimum Value	5	5	0	0	5	20	15	65	50	65	55

Source: TTI Analysis

Table 12. 1986 Rankings of Urban Area By Estimated Economic Impact of Congestion

Urban Area	Annual Congestion Impact		Annual Per Capita Impact		Annual Per Reg. Vehicle Impact	
	Rank Incl Delay, Fuel, & Ins. Cost[1]	Rank Incl Delay & Fuel Cost[2]	Rank Incl Delay, Fuel, & Ins. Cost[1]	Rank Incl Delay & Fuel Cost[2]	Rank Incl Delay, Fuel, & Ins. Cost[1]	Rank Incl Delay & Fuel Cost[2]
Phoenix AZ	7	7	6	3	5	2
Los Angeles CA	1	1	1	1	1	1
Sacramento CA	13	17	11	17	16	25
San Diego CA	10	11	17	18	11	15
San Fran-Oak CA	2	2	2	2	2	5
Denver CO	11	10	13	11	15	12
Miami FL	4	5	3	5	3	6
Tampa FL	18	15	12	10	18	16
Atlanta GA	6	6	7	8	7	7
Indianapolis IN	27	27	28	29	26	27
Louisville KY	24	22	25	23	25	21
Minn-St Paul MN	15	14	22	22	21	20
Kansas City MO	19	20	21	20	17	18
St Louis MO	8	9	10	12	9	10
Albuquerque NM	25	24	18	16	23	19
Oklahoma City OK	23	25	23	24	24	24
Portland OR	14	13	15	15	10	9
Memphis TN	22	23	24	25	20	22
Nashville TN	21	21	16	14	12	11
Salt Lake City UT	26	26	26	27	28	28
Seattle-Everett WA	9	8	8	4	6	3
Milwaukee WI	17	19	20	21	22	23
Austin TX	20	18	9	9	13	13
Corpus Christi TX	29	29	29	28	29	29
Dallas TX	5	4	5	6	8	8
El Paso TX	28	28	27	26	27	26
Fort Worth TX	12	12	14	13	14	14
Houston TX	3	3	4	7	4	4
San Antonio TX	16	16	19	19	19	17

[1]Rank results from the combined estimated cost of delay (recurring and incident), excess fuel, and excess insurance premiums due to congested traffic operation.
[2]Ranked by combining estimated cost for delay (recurring and incident) and excess fuel resulting from congested traffic conditions on freeways/expressways and principal arterial streets.

Source: TTI Analysis

Geographic Impact on Congestion Values

The summary information in Table 11 illustrates that urban areas located within Texas tend to have lower average values in all annual congestion cost categories than urban areas outside Texas. The per capita congestion cost values for congested Texas urban areas, however, exceeds those outside Texas by 24 percent, Texas statewide by 31 percent, and the total urban area average by 25 percent. Evaluating cost per capita excluding additional insurance premiums also indicates that congested Texas areas were the most impacted by congestion; the average cost per capita was 29 percent higher than the study areas outside Texas. Excluding insurance premiums lowered the average per capita cost by approximately 16 percent for all geographic areas while reducing per capita cost 14 percent statewide in Texas and 15 percent for congested Texas areas. Figure 4 illustrates the annual cost of congestion per capita in graphic form.

Urban Area Ranking

Table 12 presents the ranking of the urban areas for annual and per capita congestion cost, including and excluding excess insurance premiums, for 1986. The overall rank of urban areas, with few exceptions, does not seem to be affected by either normalizing with population or by insurance premiums.

The urban area ranking for total congestion cost and congestion cost per capita generally concur with one another, but there are some significant changes between annual and per capita rankings. Examples of these variations include Austin and Minneapolis-St Paul. Austin ranks in the lower half of urban areas (17th and 18th in annual congestion cost categories) when analyzed with respect to annual estimated congestion cost; however, Austin ranks in the top ten with the per capita analyses. The change in ranking of Minneapolis-St Paul is the reverse that of Austin. Minneapolis-St Paul ranks 12th in annual impact (including and excluding insurance premiums) in corresponding cost per capita categories 20th and 19th.

Comparison of Urban Mobility Levels

A relatively good correlation exists between the ranking of urban areas based on estimated economic impact of congestion (Table 12) and the rankings based on congestion index values (Table 7). All of the top ten ranked urban areas by congestion index (Table 7) are included in the top ten of one or more categories illustrated in Table 12. Overall, variations between the ranking systems are relatively minor.

It should be noted that the basic input for all ranking schemes mentioned is daily vehicle-miles of travel. While the focus of the economic and congestion index analyses differ, the same sources of data were used in both analyses. The rankings (Tables 7 and

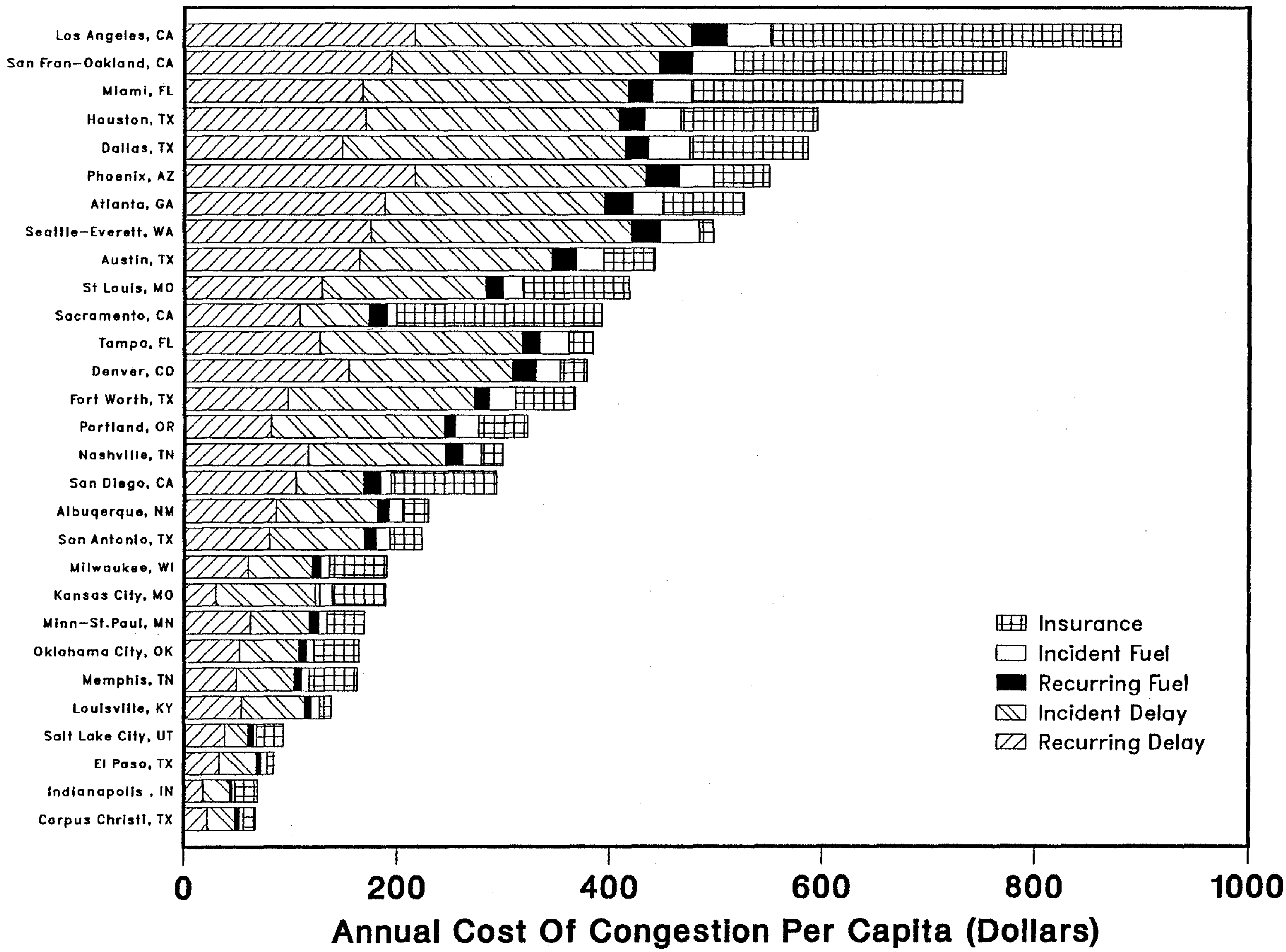

Figure 4. Urban Area Annual Congestion Cost Per Capita

12) may represent some repetition of identical information, but traffic congestion and economic impact are different concepts.

Conclusions

The economic analysis presented in this Chapter estimated costs due to congestion (time, fuel, and insurance) in an urban area. In general, the less congested urban areas with larger populations exhibit higher total congestion costs than smaller urban areas. Estimating the severity of traffic congestion, however, requires that some normalizing device be used to distinguish between large areas and severely congested areas. The cost per capita values represent a better tool for comparison with the Congestion Index estimated in Chapter 3, and urban mobility studies performed by FHWA and others. Total urban area congestion cost estimates are important in developing support for transportation system improvement programs requiring increased state and local funding.

Of the three types of cost considered to be affected by congestion (time, fuel, and insurance), insurance premiums are the most difficult to apply to congestion cost estimates and not as closely associated with congestion as delay and fuel. The excess insurance premium cost represents a widely varying portion of the total congestion cost, but only small differences were found in rankings including and excluding insurance cost.

The economic analysis calculations are most sensitive to changes in daily vehicle miles of travel (DVMT) and incident delay. Varying DVMT by 10 percent (Appendix B) resulted in an average increase or decrease in estimated congestion cost of eight percent. Varying incident vehicle-hours of delay by 10 percent had approximately half that effect (five percent) on congestion cost. This analysis indicates that to significantly reduce congestion cost, congested conditions or system demand must be reduced.

CHAPTER 5
TRANSPORTATION AS A BUSINESS CONCERN

To better understand the relative impact of traffic congestion/loss of mobility on daily business activities and the business decision-making process, surveys of local leaders of major businesses were performed. Business leaders in the following 13 cities were surveyed.

- Phoenix AZ
- San Diego CA
- Denver CO
- Atlanta GA
- Minneapolis MN
- Albuquerque NM
- Portland OR
- Salt Lake City UT
- Seattle WA
- Austin TX
- Dallas TX
- Houston TX
- San Antonio TX

In most of the study cities, TTI obtained a list of local leaders of major businesses (those with 100 or more employees) from the Chamber of Commerce or similar economic development organization. A systematic sample (not to exceed 300) of these leaders was mailed a survey. In those cases where segregation of the member organization by size was not possible (such as in San Diego, Atlanta and Albuquerque), a systematic sample of 300 businesses was selected from the total membership.

Survey efforts concentrated on the large businesses in each city under the assumption that larger firms would be more likely to feel the effects of traffic congestion/loss of mobility than smaller firms. Because the survey focused on leaders of larger businesses and because only businesses which belong to local chambers of commerce (or similar economic development organization) were included in the survey, the responses may not be representative of the total business population in each city surveyed. However, the mechanics associated with surveying an adequate sample of leaders from the total business population in each urban area were beyond the scope of this project.

A total of 3,554 surveys were mailed. Approximately 933 surveys were returned for a 26 percent response rate. Survey response rates by city are summarized in Table 13. An example of the survey instrument used is included in Appendix C.

Table 13. Business Leader Survey Distribution

City	Number of Surveys Mailed	Number of Surveys Returned	Response Rate
Phoenix AZ	300	79	26%
San Diego CA	206	103	50%
Denver CO	300	94	31%
Atlanta GA	300	40	13%
Minneapolis MN	300	57	19%
Albuquerque NM	300	80	27%
Portland OR	234	54	23%
Salt Lake City UT	300	71	24%
Seattle WA	300	72	24%
Austin TX	220	56	25%
Dallas TX	194	43	22%
Houston TX	300	100	33%
San Antonio TX	300	84	28%
Total	3554	933	26%

The questions contained on the business leader surveys generally fall into 4 categories:

- Characteristics of businesses;
- Reasons for locating business at present site;
- Perceptions of traffic congestion; and
- Impact of traffic conditions on business activities.

Characteristics of Businesses Responding to the Survey

Type of Business

As indicated in Table 14 on the following page, the largest percentage of businesses responding to the survey can be classified as service industries.

Table 14. Types of Businesses Responding to Survey

Type of Business	Percent of Total Sample
Service industries[1]	37%
Manufacturing	17%
Construction, transportation and related industries	14%
Retail trade	7%
Wholesale trade	5%
Public utilities, communications	5%
Federal, state, local government agencies	4%
Other	11%

[1]Includes finance, insurance, real estate, health, education, business, law.

Two cities with significantly different averages in this category are Dallas and Austin. Twenty-six percent of the businesses from Dallas and 23 percent of those from Austin are classified as government agencies (federal, state or local).

Number of Employees

The median number of persons employed at businesses ranged from lows of 60 in San Diego and 85 in Albuquerque to a high of 1,050 in Dallas. These figures are not surprising as the segregation of major businesses was not possible in either San Diego or Albuquerque. Dallas was also unique in that TTI was provided with a list of the largest 200 businesses in that city. The median number of employees at businesses from all 13 cities surveyed is 190.

Gross Annual Income

As to be expected from large firms, approximately 60 percent of the businesses reported gross annual incomes of $10 million or greater.

Length of Time at Present Address

Seventy percent of the companies surveyed have been at their present location for more than 5 years; more than half have been at their present site for more than 10 years. The median number of years businesses have been at their present location ranged from lows of 6 years in San Diego and 7 years in Albuquerque and Atlanta to a high of 25 years in Portland. The median number for companies from all 13 cities surveyed is 12 years.

Before selecting their present site, at least 80 percent of the firms from each city did not consider locating in a different city.

Important/Unimportant Factors in Decision to Locate at Present Site

Business leaders in each city were asked to identify which factors were most important in their company's decision to locate at its present site. A list of 15 factors was provided and each factor was rated on a scale of one (not important) to five (very important). The total responses to this question are summarized in Table 15.

Table 15. Relative Importance of Various Factors in Company's Decision to Locate at Present Site

Factor	Rating[1] Mean Total Sample	Rating[1] Significance Level[2] Total Sample
Land ownership or leasing costs	4.02	Most Significant
Convenient access to highway facilities	3.90	
Physical environment	3.88	
Proximity to markets	3.81	
Availability of parking	3.74	
Uncongested highway facilities	3.53	Intermediate Significance
Availability of trained labor force	3.30	
Convenient access to airport	3.13	
Local government attitudes or incentives	3.09	
Existing residential location of professional/managerial staff	2.95	Least Significant
Local taxes	2.92	
Existing residential locations of support/technical staff	2.92	
Proximity to public transportation	2.87	
Cost of living	2.84	
Availability of good housing nearby	2.80	

[1]Each factor was rated on a scale of one (not important) to five (very important).
[2]To assess statistically significant differences in the responses, a Duncan's multiple range test for variable rank was performed.

Very little difference exists between the survey responses in the different cities. In general, land ownership/leasing costs, convenient access to highway facilities, and physical environment are among the most important factors considered, followed by proximity to markets and availability of parking.

Uncongested highway facilities ranked 6th among the 15 factors provided for consideration. This response may be due, in part, to the fact that more than half of the businesses surveyed have been at their present location for more than 10 years; highway congestion may not have been perceived as a serious problem (and therefore not an important consideration) during the time many of these companies were selecting sites for their businesses.

In a subsequent question, business leaders were asked to rank the relative importance of several transportation factors to the current business activities of their firm. A list of three factors was provided and each was rated on a scale of one (not important) to five (very important). The total responses from all 13 cities surveyed are presented in Table 16. In each city survey surveyed, the quality of transportation facilities and services in making their city a pleasant place to live and work ranked highest followed by access for personnel to others in the industry.

Table 16. Relative Importance of Various Factors to Current Business Activities of Firm

Factor	Rating[1]	
	Mean Total Sample	Significance Level[2] Total Sample
The quality of transportation facilities and services in making your city a pleasant place to live and work	3.86	Most Significant
Access for your personnel to others in your industry	3.63	Intermediate Significance
Transport of materials and products to and from markets and suppliers	3.04	Least Significant

[1]Each factor was rated on a scale of one (not important) to five (very important).
[2]To assess statistically significant differences in the responses, a Duncan's multiple range test for variable rank was performed.

Perceptions of Traffic Congestion

Weekday Peak Travel Hours

Overall, almost 60 percent of the business leaders surveyed reported the roadway network that serves their firm is severely congested during weekday peak travel hours

(Table 17). In fact, 80 percent of those from Phoenix reported severe congestion. In addition, 73 percent from Seattle, 69 percent from Dallas, 67 percent from Houston, 65 percent from Atlanta, and 61 percent from Denver also reported severe congestion during weekday peak travel hours. In a previous chapter, all 6 of these cities were estimated to have congestion indices in excess of 1.00, indicating an undesirable level of urban area congestion.

In Albuquerque and San Diego, on the other hand, approximately half of those surveyed perceived roadway conditions as only slightly congested.

Table 17. Perceptions of Traffic Conditions on Roadway Network that Serves Business

City	Weekday Peak Travel Hours				Weekday Off-Peak Travel Hours		
	Congestion Index	Not Congested	Slightly Congested	Severely Congested	Not Congested	Slightly Congested	Severely Congested
Phoenix AZ (n=79)	1.18	--	20%	80%	20%	66%	14%
San Diego CA (n=103)	1.00	3%	53%	44%	68%	29%	3%
Denver CO (n=93)	1.01	1%	38%	61%	41%	57%	2%
Atlanta GA (n=40)	1.15	2%	33%	65%	38%	60%	2%
Minneapolis MN (n=57)	.93	--	51%	49%	47%	49%	4%
Albuquerque NM (n=79)	.87	4%	51%	45%	57%	38%	5%
Portland OR (n=54)	.97	6%	61%	33%	65%	35%	--
Salt Lake City UT (n=70)	.77	1%	40%	59%	53%	44%	3%
Seattle WA (n=71)	1.09	--	27%	73%	25%	71%	4%
Austin TX (n=55)	.98	4%	38%	58%	40%	51%	9%
Dallas TX (n=42)	1.05	--	31%	69%	29%	59%	12%
Houston TX (n=99)	1.21	4%	29%	67%	39%	51%	10%
San Antonio TX (n=83)	.91	4%	36%	60%	48%	51%	1%
Outside Texas Avg	1.00	2%	40%	58%	45%	51%	4%
Texas Avg	1.04	3%	34%	63%	40%	52%	8%
Total Avg	1.01	2%	39%	59%	43%	52%	5%

Weekday Off-Peak Travel Hours

During off-peak travel hours, slightly more than half of the respondents indicated that roadway conditions were slightly congested; an additional 43 percent indicated that roadways were not congested (Table 17).

In Phoenix, however, 66 percent of the business leaders reported slight congestion and 14 percent reported severe congestion during off-peak travel hours. Dallas business leaders also perceived more congestion than the average with 59 percent reporting slight congestion and 12 percent reporting severe congestion.

Impact of Traffic Conditions on Business Activities

Impact on Current Business Activities

In general, half of the business leaders felt that area traffic conditions have had an impact on their business; 88 percent of those stated that the impact was negative (Table 18).

Table 18. Have Traffic Conditions in Local Area Had an Impact on Business Activities

City	Con-gestion Index	Impact on Business			If "Yes," Type of Impact	
		Yes	No	Not Sure	Positive	Negative
Phoenix AZ (n=79)	1.18	53%	27%	20%	10%	90%
San Diego CA (n=103)	1.00	39%	52%	9%	11%	89%
Denver CO (n=92)	1.01	48%	37%	15%	10%	90%
Atlanta GA (n=40)	1.15	53%	35%	12%	10%	90%
Minneapolis MN (n=57)	.93	37%	49%	14%	21%	79%
Albuquerque NM (n=70)	.87	41%	49%	10%	16%	84%
Portland OR (n=54)	.97	32%	59%	9%	14%	86%
Salt Lake City UT (n=71)	.77	44%	45%	11%	7%	93%
Seattle WA (n=72)	1.09	72%	21%	7%	10%	90%
Austin TX (n=54)	.98	67%	20%	13%	9%	91%
Dallas TX (n=42)	1.05	51%	37%	12%	5%	95%
Houston TX (n=99)	1.21	62%	28%	10%	10%	90%
San Antonio TX (n=84)	.91	58%	25%	17%	20%	80%
Outside Texas Avg	1.00	47%	41%	12%	11%	89%
Texas Avg	1.04	60%	27%	13%	12%	88%
Total Avg	1.01	51%	37%	12%	12%	88%

Most frequently listed negative impacts include:

- Long travel times resulting in reduced productivity/efficiency (34 percent);
- Poor employee punctuality (17 percent); and
- Poor employee morale/increased stress (11 percent).

Impact on Recent or Future Development

About one-third of those responding to the survey stated that the traffic conditions have had an influence on recent or future plans for development or expansion in terms of where to develop or expand (Table 19). About 19 percent further stated that traffic conditions have influenced recent or future plans in terms of when, how much and what to develop or expand. Specifically:

- 45 percent of the businesses plan to move (or have just recently moved to locations with good access to freeways and major arterials.

- 13 percent stated that branch offices will be (or have been) opened to reduce customer/client travel times.

- 10 percent stated that area traffic congestion may force them to relocate their place of business in the near future.

Also of interest is that 13 percent of the leaders in Phoenix and 5 percent in Albuquerque stated that traffic is good for their company's growth. In addition, 20 percent from Albuquerque, 13 percent from Denver and San Antonio, and 11 percent from Houston and Salt Lake City indicated that certain sites are not developed unless there is sufficient traffic.

Table 19. Influence of Traffic Conditions on Development/Expansion Plans

Have Traffic Conditions Had Any Influence on Firm's Current or Future Plans for Development or Expansion in Terms of:

City	Where to Develop/Expand		When to Develop/Expand		How Much to Develop/Expand		What to Develop/Expand	
	Yes	No	Yes	No	Yes	No	Yes	No
Phoenix AZ (n=78)	37%	63%	24%	76%	23%	77%	21%	79%
San Diego CA (n=100)	41%	59%	23%	77%	24%	76%	23%	77%
Denver CO (n=90)	22%	78%	9%	91%	15%	85%	13%	87%
Atlanta GA (n=40)	38%	62%	24%	76%	19%	81%	19%	81%
Minneapolis MN (n=56)	20%	80%	13%	87%	11%	89%	11%	89%
Albuquerque NM (n=77)	26%	74%	17%	83%	15%	85%	16%	84%
Portland OR (n=54)	31%	69%	17%	83%	17%	83%	13%	87%
Salt Lake City UT (n=70)	33%	67%	19%	81%	20%	80%	20%	80%
Seattle WA (n=72)	43%	57%	25%	75%	26%	74%	28%	72%
Austin TX (n=51)	33%	67%	14%	86%	14%	86%	22%	78%
Dallas TX (n=40)	37%	63%	26%	74%	26%	74%	32%	68%
Houston TX (n=97)	34%	66%	22%	78%	16%	84%	14%	86%
San Antonio TX (n=82)	32%	68%	17%	83%	19%	81%	22%	78%
Outside Texas Avg	32%	68%	19%	81%	19%	81%	18%	82%
Texas Avg	34%	66%	19%	81%	18%	82%	21%	79%
Total Avg	33%	67%	19%	81%	19%	81%	19%	81%

Transportation Improvements Needed to Enhance Business

A subsequent question asked what specific transportation improvements are needed to enhance business in their area. A total of 9 improvements were listed and respondents could check as many improvements as appropriate. Responses to this question are presented in Table 20.

In general, highway improvements (construction of additional freeway lanes and widening/upgrading major surface streets) were listed more frequently than public transportation improvements. In fact, the construction of additional freeway lanes was listed by 78 percent of the business leaders from Phoenix and 70 percent of those from San Diego; widening and upgrading major surface streets was cited by 60 percent of the business leaders from Atlanta, 57 percent of those from San Antonio and 55 percent of those from Phoenix and San Diego.

Table 20. Transportation Improvements Needed to Enhance Business

City	Widen/upgrade major surface streets	Resurface urban freeway system	Construct additional freeway lanes	Grade separations for railroads & roads	Construct special bus/carpool/vanpool lanes	Upgrade existing public transit system	Construct/expand rail transit system	Promote flextime & ridesharing	Other
Phoenix AZ (n=79)	55%	17%	78%	19%	22%	44%	18%	19%	20%
San Diego CA (n=103)	55%	8%	70%	15%	23%	37%	35%	25%	18%
Denver CO (n=94)	40%	20%	47%	16%	18%	44%	46%	14%	13%
Atlanta GA (n=40)	60%	8%	30%	8%	13%	15%	60%	8%	15%
Minneapolis MN (n=57)	25%	18%	49%	9%	19%	32%	30%	28%	9%
Albuquerque NM (n=80)	51%	23%	45%	16%	8%	28%	11%	18%	21%
Portland OR (n=54)	43%	9%	39%	6%	---	26%	43%	17%	17%
Salt Lake City UT (n=71)	38%	7%	56%	9%	7%	18%	16%	10%	14%
Seattle WA (n=72)	38%	4%	51%	6%	21%	46%	38%	21%	15%
Austin TX (n=56)	46%	20%	46%	14%	13%	16%	16%	5%	29%
Dallas TX (n=43)	37%	26%	58%	23%	26%	37%	30%	16%	5%
Houston TX (n=100)	51%	20%	50%	26%	21%	30%	22%	10%	16%
San Antonio TX (n=84)	57%	12%	45%	6%	8%	14%	5%	12%	19%
Outside Texas Avg	45%	13%	51%	11%	15%	32%	32%	17%	16%
Texas Avg	49%	19%	49%	17%	16%	24%	17%	11%	19%
Total Avg	46%	14%	51%	13%	15%	30%	28%	15%	16%

Note: Respondents were able to check more than one improvement. Therefore, the percentages do not add up to 100%.

By contrast, the construction of a (or expansion of the) rail transit system was listed by 60 percent of the businesses in Atlanta, 46 percent of those in Denver and 43 percent of those in Portland.

In addition, 46 percent from Seattle and 44 percent from Phoenix and Denver cited upgrading the existing public transportation system as an important improvement to enhance business in their public.

Impact of Roadway Construction

When asked if the roadway/freeway reconstruction activities currently underway in their city have had an adverse effect on business activities, the majority of business leaders from all cities surveyed responded "no."

Those cities in which the highest percentages of businesses are adversely affected include San Antonio (33 percent), Seattle (25 percent) and Minneapolis (23 percent). For those cities adversely affected, 47 percent experienced increased travel times and lengthy delays due to construction and 28 percent indicated that the construction activities hampered access to their place of business. Most business leaders went on to say, however, that the resulting improvements will be well worth the inconveniences experienced during the construction activities.

Rating of Highway Transportation

When asked to rate the highway transportation in their city relative to other cities of similar size, slightly less than half of all business leaders surveyed indicated that their city was average (Table 21).

Looking at individual cities, however, reveals that 63 percent of those responding from San Diego, 48 percent from Atlanta, 46 percent from Minneapolis, and 40 percent from San Antonio perceive highway transportation in their respective cities to be above average. On the other hand, 87 percent of those from Phoenix and 48 percent from Austin rated their city as below average.

Table 21. How Business Leaders Rated the Highway Transportation in Their City Relative to Other Cities of Similar Size

City	Congestion Index	Above Average	Average	Below Average
Phoenix AZ (n=79)	1.18	5%	8%	87%
San Diego CA (n=102)	1.00	63%	34%	3%
Denver CO (n=94)	1.01	5%	54%	41%
Atlanta GA (n=40)	1.15	48%	35%	17%
Minneapolis MN (n=57)	.93	46%	47%	7%
Albuquerque NM (n=78)	.87	18%	56%	26%
Portland OR (n=53)	.97	36%	62%	2%
Salt Lake City UT (n=70)	.77	6%	71%	23%
Seattle WA (n=70)	1.09	11%	60%	29%
Austin TX (n=52)	.98	6%	46%	48%
Dallas TX (n=42)	1.05	19%	71%	10%
Houston TX (n=99)	1.21	12%	51%	37%
San Antonio TX (n=83)	.91	40%	51%	9%
Outside Texas Avg	1.00	25%	47%	28%
Texas Avg	1.04	20%	54%	26%
Total Avg	1.01	24%	49%	27%

Additional Comments

Business leaders were encouraged to offer additional comments or suggestions regarding traffic conditions or improving urban mobility in their city. Slightly less than half of the business leaders did provide additional comments. In general, the most frequently listed comments can be categorized as follows.

- Need mass transportation improvements (17 percent).
- Complete roadway construction as soon as possible (15 percent).
- Need traffic engineering improvements at various locations (15 percent).
- Need better transportation system planning and management (10 percent).

Summary

Overall, almost 60 percent of the business leaders surveyed reported that the roadway network that serves their firm is severely congested during weekday peak travel hours. In addition, half also felt that area traffic conditions have had an impact on the current business activities of their firms; 88 percent of those stated that the impact was negative (long travel times resulting in reduced productivity/efficiency, poor employee punctuality, poor employee morale/increased stress). Furthermore, about one-third stated that local traffic conditions have had an influence on recent or future plans for development or expansion in terms of where to develop or expand; about 19 percent also reported that traffic conditions have influenced recent or future plans in terms of when, how much, and what to develop or expand. Thus, it appears that traffic congestion/declining mobility can and does have an impact on the business community and the business decision-making process.

CHAPTER 6
CONCLUSIONS

Roadway travel mobility in 29 large urban areas with moderate to low population densities was examined in this report. These areas rely on the freeway and principal arterial street system to handle most of the peak-period and daily person-trips; the travel and development patterns of the seven large Texas urban areas are similar to the 22 areas outside Texas.

Urban Area Roadway Congestion

The freeway and principal arterial street systems were chosen for inclusion due to their importance in urban mobility and generally good data availability. Comparison of the 1986 freeway (Table 3) and principal arterial (Table 5) data indicate the five most congested Texas cities have ten percent more freeway vehicle-miles of travel per lane-mile (VMT/LM) and eight percent less principal arterial VMT/LM than the study cities outside Texas. The Texas areas also relied more heavily on the freeway systems to handle urban vehicle travel than the study areas outside the state. Table 8 indicates a freeway/principal arterial travel ratio of 42/18 percent of total urban area VMT in the most congested Texas areas, with a 34/26 ratio estimated for the areas outside Texas.

The congested nature of the Texas urban freeway systems has led the Texas Department of Highways and Public Transportation (TDHPT) and local agencies to increase construction on new and widened limited-access highway projects. Fuel tax increases by the U.S. and state legislatures have provided funding for the capacity increases estimated in Table 10. The comparative imbalance in freeway and principal arterial travel miles would also suggest that some emphasis on continuous, arterial street systems could relieve some freeway congestion and/or handle future traffic growth in Texas.

Data collected for 1982 through 1986 indicate that urban roadway congestion in Texas increased approximately twice as fast as the average of the 22 urban areas outside Texas (Table 9). That this increase came during a statewide economic recession should give further support to the roadway construction plans by TDHPT and other agencies. These data are also more than one year old; the values and conclusions should be viewed with traffic growth since 1986 in mind.

Economic Impact of Urban Roadway Congestion

Three factors were used to estimate the cost of congestion to urban residents in the 29 study areas:

- Travel delay due to congested peak-period roadways and due to incidents which temporarily reduce capacity;
- Increased fuel consumption due to traffic operating in congested situations; and
- Increased insurance premiums paid by motorists in urban area due to increased accident rates associated with congested roadways.

For comparative purposes, the annual estimated congestion cost represents the economic impact on society of an inadequate roadway transportation system. Large urban areas will have significant congestion cost values by virtue of their population. Normalizing the areawide economic impact with urban population estimates, however, provides a comparison of the congestion experienced by individual motorists in different urban areas. The distinction between these two concepts should be realized during the following discussion.

Five urban areas were estimated to have total 1986 congestion cost values in excess of $1 billion. The total estimated value in the 29 study cities was more than $24 billion, or $835 million per study area (Table 11). The 29 city average congestion cost was approximately $350 per capita (Table 11). If the insurance premium cost calculation is eliminated (high premiums are also related to, among other things, increased property crime rates) the delay and fuel cost were estimated at more than $275 per capita. There were, however, only four urban areas that changed as many as four ranking positions when the per capita insurance calculation was eliminated (Table 12).

The seven Texas urban areas were estimated to have approximately $3.7 billion associated with adverse impacts of congestion; almost half of that in Houston. Dallas ranked fifth among the 29 study areas with a total 1986 economic impact in excess of $1.1 billion. On a cost per capita basis, however, Houston, Dallas and Austin rank in the top ten of 29 areas studied. Houston and Dallas remain in the ten highest ranked areas when comparing area congestion impacts on a per registered vehicle basis. The cost per capita rankings, thus, closely agree with the congestion index rankings in Table 7. A summary of this information is included in Table 22.

Local Business Leader Opinion Survey

A limited sample of the opinions of leaders of major businesses located in 13 of the study areas was conducted to assess the impact of transportation issues on daily business activities and the business decision-making process. More than one-third of the responding organizations were in service industries with another third in manufacturing and construction (Table 14).

Business mobility appeared to be relatively low, with more than 50 percent of the firms located at their present site for more than 10 years. At the time of the last major location decision, at least 80 percent of the firms did not consider locating in a different city. Land cost, access to highway facilities, physical environment, proximity to markets, and availability of parking were ranked as the most important factors considered in the decision to locate the company at its present site. The quality of transportation facilities and services as they relate to the condition of the city was ranked ahead of access to other industry personnel and the transport of materials and supplies in an assessment of the relative importance of transportation factors to the current business activities of their firm (Table 16).

Table 22. Summary of 1986 Major Texas and Other U.S. Cities Urban Area Major Roadway Condition and Economic Impact of Traffic Congestion

Urban Area	DVMT/Ln-Mi Per Lane Mile		Congestion Index[1]	Annual Cost Due to Congestion ($ million)				1986 Popn. (1000)	Congestion Cost Per Capita (Dollars)
	Freeway	Principal Arterial		Delay	Fuel	Insurance	Total		
Austin TX	12,620	5,340	.98	160	20	25	210	470	445
Corpus Christi TX	8,350	4,375	.71	10	0	5	20	270	65
Dallas TX	13,765	4,900	1.05	785	115	210	1,110	1,895	585
El Paso TX	9,910	3,620	.75	30	5	5	40	490	85
Fort Worth TX	11,000	5,060	.87	305	45	65	410	1,120	370
Houston TX	15,970	5,530	1.21	1,140	165	360	1,665	2,800	595
San Antonio TX	11,800	4,450	.91	170	25	30	235	1,050	225
Outside Texas Avg[2]	11,675	5,565	.96	570	85	280	935	1,745	355
Texas Avg	11,915	4,755	.92	375	55	100	525	1,155	340
Congested Texas Avg[3]	13,030	5,055	1.00	515	75	140	725	1,465	445
Total Avg[4]	11,735	5,305	.95	520	80	235	835	1,605	350
Maximum Value[5]	17,945	6,225	1.42	5,110	805	3,525	9,440	10,730	880
Minimum Value[5]	7,735	3,620	.64	10	0	5	20	270	65

[1] See Equation 1
[2] Includes 22 major U.S. urban areas outside of Texas
[3] Includes Austin, Dallas, Fort Worth, Houston and San Antonio
[4] Average values for 29 study urban areas
[5] Maximum or minimum value for 29 study urban areas

Source: Tables 3, 5, 7 and 11

Perceptions of peak and off-peak traffic conditions do not exactly match the quantitative estimate of congestion (Table 17). The urban areas with the highest congestion index, however, also were among those with the highest percentage of business leaders listing the peak-hour traffic situation as severely congested. The data in Table 17 suggest that traffic congestion is closely related to experience with local conditions in previous years. More than half of the responding companies had been at their location for more than 10 years; compared to a decade earlier, traffic in the areas surveyed was more congested. A small percentage (5 percent) of the total respondents described the off-peak period roadway network as severely congested, but approximately half listed the system as slightly congested.

Sixty percent of the Texas organizations responding felt that congestion had an impact on business activities, while less than 50 percent of those outside Texas replied affirmatively (Table 18). Reduced productivity resulting from lengthy travel times and decreased employee punctuality were the most frequently cited negative impacts.

The most frequently listed transportation system improvement projects were the construction of more capacity on arterial streets and freeways. Approximately half of the responding companies inside and outside Texas listed these improvements as necessary to enhance business (Table 20). Other suggestions that were included by more than 25 percent of the respondents related to upgrading public transportation and construction/expansion of a rail transit system. These last two suggestions were less endorsed (by 8 to 15 percentage points) in the four Texas cities than in the other nine study areas.

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APPENDIX A

FREEWAY AND PRINCIPAL ARTERIAL STREET TRAVEL AND MILEAGE STATISTICS

1982 To 1986

Table A-1. Summary of Normalized Freeway Travel and Mileage Statistics for 1986

Urban Area	Normalized For Population Density[1]							
	VMT Per Person	Rank	VMT Per Sq Mi	Rank	Ln Mi Per 1000 Pers	Rank	Ln Mi Per Sq Mi	Rank
Phoenix AZ	1.40	28	2,760	29	.10	27	.19	29
Los Angeles CA	1.55	27	7,895	13	.09	28	.44	25
Sacramento CA	2.67	20	7,540	15	.24	21	.68	14
San Diego CA	3.57	12	10,510	5	.28	16	.81	6
San Fran-Oak CA	2.48	21	10,515	4	.15	26	.65	15
Denver CO	3.60	11	6,255	19	.29	15	.50	20
Miami FL	.95	29	3,885	27	.07	29	.30	28
Tampa FL	3.35	15	4,900	24	.31	12	.45	24
Atlanta GA	9.57	1	11,605	2	.65	1	.78	7
Indianapolis IN	3.15	17	6,375	18	.37	9	.76	9
Louisville KY	2.80	18	6,095	20	.30	14	.64	16
Minn-St Paul MN	3.45	13	7,465	16	.28	16	.61	18
Kansas City MO	4.83	8	9,650	7	.62	6	1.25	1
St. Louis MO	3.16	16	8,115	11	.28	16	.72	11
Albuquerque NM	2.33	24	4,240	26	.24	21	.44	25
Oklahoma City OK	5.42	6	7,920	12	.65	1	.95	2
Portland OR	2.34	23	6,080	21	.19	25	.50	20
Memphis TN	1.72	26	3,660	28	.20	24	.43	27
Nashville TN	6.60	5	7,725	14	.62	6	.73	10
Salt Lake City UT	2.27	25	4,540	25	.25	20	.50	20
Seattle-Everett WA	4.43	9	9,905	6	.32	11	.71	12
Milwaukee WI	2.37	22	5,220	23	.21	23	.46	23
Austin TX	8.04	3	11,275	3	.64	4	.89	3
Corpus Christi TX	3.41	14	5,260	22	.41	8	.63	17
Dallas TX	8.86	2	11,915	1	.64	4	.87	4
El Paso TX	2.71	19	6,980	17	.27	19	.70	13
Fort Worth TX	7.10	4	9,575	8	.65	1	.87	4
Houston TX	4.92	7	8,615	10	.31	12	.54	19
San Antonio TX	4.25	10	9,105	9	.36	10	.77	8
Outside Texas Avg	3.36		6,950		.30		.61	
Texas Avg	5.61		8,960		.47		.75	
Congested Texas Avg	6.63		10,095		.52		.79	
Total Avg	3.91		7,435		.34		.65	
Maximum Value	9.57		11,915		.65		1.25	
Minimum Value	.95		2,760		.07		.19	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1]Ratio values in Table 4 divided by population density

Source: TTI Analysis and Local Transportation Agency References

Table A-2. Summary of Normalized Principal Arterial Travel and Mileage Statistics for 1986

Urban Area	Normalized For Population Density[1]							
	VMT Per Person	Rank	VMT Per Sq Mi	Rank	Ln Mi Per 1000 Pers	Rank	Ln Mi Per Sq Mi	Rank
Phoenix AZ	4.80	2	9,455	1	.79	2	1.55	3
Los Angeles CA	1.13	28	5,795	8	.20	27	1.04	8
Sacramento CA	1.82	20	5,130	12	.34	21	.96	11
San Diego CA	1.31	24	3,860	23	.26	25	.77	21
San Fran-Oak CA	.72	29	3,040	26	.12	29	.53	27
Denver CO	4.14	4	7,190	3	.74	4	1.29	5
Miami FL	1.68	22	6,850	5	.27	23	1.10	7
Tampa FL	4.16	3	6,085	6	.68	6	1.00	9
Atlanta GA	4.03	5	4,880	13	.66	7	.80	20
Indianapolis IN	2.06	17	4,165	19	.45	14	.92	13
Louisville KY	1.60	23	3,485	25	.28	22	.61	25
Minn-St Paul MN	1.21	25	2,615	28	.27	23	.59	26
Kansas City MO	1.94	19	3,880	21	.40	17	.81	19
St. Louis MO	2.18	15	5,590	9	.35	19	.90	14
Albuquerque NM	3.92	6	7,140	4	.74	4	1.35	4
Oklahoma City OK	3.11	10	4,535	15	.61	11	.88	16
Portland OR	1.16	27	3,020	27	.19	28	.50	28
Memphis TN	2.08	16	4,425	16	.42	15	.88	16
Nashville TN	7.47	1	8,735	2	1.40	1	1.64	1
Salt Lake City UT	1.20	26	2,400	29	.22	26	.43	29
Seattle-Everett WA	2.38	12	5,320	10	.41	16	.93	12
Milwaukee WI	1.77	21	3,885	20	.35	19	.77	21
Austin TX	3.32	8	4,660	14	.62	10	.87	18
Corpus Christi TX	3.36	7	5,185	11	.77	3	1.19	6
Dallas TX	3.23	9	4,345	18	.66	7	.89	15
El Paso TX	2.31	13	5,950	7	.64	9	1.64	1
Fort Worth TX	2.81	11	3,795	24	.56	12	.75	23
Houston TX	2.21	14	3,860	22	.40	17	.70	24
San Antonio TX	2.04	18	4,365	17	.46	13	.98	10
Outside Texas Avg	2.54		5,070		.46		.92	
Texas Avg	2.75		4,595		.59		1.00	
Congested Texas Avg	2.72		4,205		.54		.84	
Total Avg	2.59		4,955		.49		.94	
Maximum Value	7.47		9,460		1.40		1.64	
Minimum Value	.72		2,400		.12		.43	

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1]Ratio values in Table 6 divided by population density

Source: TTI Analysis and Local Transportation Agency References

Table A-3. Summary of Relative Mobility Values For 1982

Urban Area	Freeway/Expressway				Principal Arterial Streets				Congestion Index
	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	
Phoenix AZ	2,850	210	4.9	13,570	14,930	2,460	3.1	6,070	1.16
Los Angeles CA	72,905	4,350	7.8	16,760	55,050	10,185	3.6	5,405	1.24
Sacramento CA	5,300	630	7.0	8,415	4,995	830	3.6	6,015	.80
San Diego CA	15,075	1,520	7.0	9,915	6,130	1,430	3.0	4,285	.78
San Fran-Oak CA	28,865	2,105	6.3	13,715	9,685	1,725	3.5	5,615	1.06
Denver CO	7,900	745	4.9	10,605	9,160	1,800	3.6	5,090	.88
Miami FL	5,950	515	5.2	11,555	11,870	1,875	4.2	6,330	1.05
Tampa FL	1,980	190	4.7	10,420	3,190	545	3.8	5,855	.94
Atlanta GA	15,765	1,365	5.6	11,550	5,740	1,320	3.6	4,350	.89
Indianapolis IN	5,730	650	5.0	8,815	3,770	795	3.6	4,740	.73
Louisville KY	3,915	410	4.3	9,550	2,925	465	3.6	6,290	.85
Minn-St Paul MN	11,200	1,100	4.8	10,180	4,300	1,110	3.3	3,875	.78
Kansas City MO	8,900	1,350	4.5	6,590	3,805	940	3.4	4,050	.55
St. Louis MO	12,035	1,210	5.3	9,945	8,955	1,670	3.1	5,360	.83
Albuquerque NM	1,535	200	5.0	7,675	2,860	570	3.4	5,020	.76
Oklahoma City OK	5,825	665	4.9	8,760	2,750	575	3.0	4,785	.72
Portland OR	4,740	440	4.9	10,770	2,775	515	3.1	5,390	.87
Memphis TN	3,050	355	5.0	8,590	3,500	720	4.0	4,860	.76
Nashville TN	3,250	345	4.3	9,420	3,250	790	3.3	4,115	.75
Salt Lake City UT	2,870	325	5.4	8,830	1,455	300	3.4	4,850	.73
Seattle-Everett WA	12,270	1,005	5.7	12,210	6,835	1,340	3.2	5,100	.95
Milwaukee WI	5,600	525	4.9	10,665	4,290	915	2.9	4,690	.85
Austin TX	2,530	265	5.3	9,545	1,595	340	4.3	4,690	.77
Corpus Christi TX	1,300	160	5.2	8,125	1,250	310	3.5	4,030	.67
Dallas TX	16,870	1,550	6.1	10,885	6,440	1,555	4.4	4,140	.84
El Paso TX	2,560	325	5.0	7,875	2,600	760	3.5	3,420	.63
Fort Worth TX	8,625	905	5.3	9,530	3,660	785	4.0	4,660	.76
Houston TX	21,080	1,375	6.1	15,330	9,725	1,785	4.0	5,450	1.17
San Antonio TX	7,600	760	4.9	10,000	3,525	940	3.4	3,750	.77
Outside Texas Avg	10,795	920	5.3	10,385	7,830	1,495	3.4	5,095	.86
Texas Avg	8,650	760	5.4	10,185	4,114	925	3.9	4,305	.80
Congested Texas Avg	11,340	970	5.5	11,060	4,990	1,080	4.0	4,540	.86
Total Avg	10,275	880	5.4	10,340	6,930	1,355	3.5	4,905	.85
Maximum Value	72,905	4,350	7.8	16,760	55,050	10,185	4.4	6,330	1.24
Minimum Value	1,300	160	4.3	6,595	1,250	300	2.9	3,280	.55

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1] Daily vehicle-miles of travel
[2] Daily vehicle-miles of travel per lane-mile of roadway

Source: TTI Analysis and Local Transportation Agency References

Table A-4. Summary of Relative Mobility Values For 1983

Urban Area	Freeway/Expressway				Principal Arterial Streets				Congestion Index	Percent of Congested Freeway Ln-Miles
	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT[2] Ln-Mile		
Phoenix AZ	2,910	215	4.9	13,535	14,965	2,490	3.2	6,010	1.15	50
Los Angeles CA	75,070	4,415	7.8	17,005	57,105	10,280	3.7	5,555	1.26	65
Sacramento CA	5,800	630	7.0	9,205	5,020	850	3.6	5,905	.83	5
San Diego CA	16,475	1,550	7.1	10,625	6,490	1,450	3.0	4,475	.83	25
San Fran-Oak CA	29,090	2,145	6.4	13,560	9,735	1,725	3.5	5,645	1.05	60
Denver CO	8,240	745	5.0	11,060	9,400	1,830	3.7	5,135	.90	25
Miami FL	6,265	515	5.2	12,165	12,300	1,900	4.2	6,475	1.09	35
Tampa FL	1,945	190	4.7	10,235	3,065	545	3.8	5,625	.91	15
Atlanta GA	17,005	1,400	5.6	12,145	6,540	1,375	3.6	4,755	.94	20
Indianapolis IN	5,260	650	5.0	8,090	3,720	810	3.6	4,595	.69	0
Louisville KY	4,435	450	4.4	9,855	2,720	470	3.6	5,785	.83	10
Minn-St Paul MN	12,165	1,130	4.8	10,765	4,450	1,120	3.4	3,975	.82	15
Kansas City MO	8,985	1,350	4.5	6,655	3,855	940	3.4	4,100	.56	0
St. Louis MO	13,035	1,245	5.3	10,470	9,285	1,680	3.1	5,525	.87	15
Albuquerque NM	1,615	200	5.0	8,075	3,080	575	3.5	5,355	.81	5
Oklahoma City OK	5,940	675	4.9	8,800	2,900	605	3.0	4,795	.72	5
Portland OR	5,375	500	4.9	10,750	2,725	515	3.1	5,290	.86	20
Memphis TN	3,300	355	5.1	9,295	3,400	720	4.0	4,720	.78	10
Nashville TN	3,255	340	4.3	9,575	3,395	810	3.3	4,190	.77	10
Salt Lake City UT	2,975	340	5.5	8,750	1,525	300	3.4	5,085	.73	5
Seattle-Everett WA	13,095	1,035	5.7	12,650	7,320	1,365	3.2	5,365	.99	25
Milwaukee WI	5,800	530	4.9	10,945	4,280	920	2.9	4,650	.86	10
Austin TX	2,970	280	5.4	10,605	1,710	360	4.2	4,750	.84	20
Corpus Christi TX	1,370	165	5.2	8,305	1,300	315	3.5	4,125	.69	0
Dallas TX	18,400	1,580	6.1	11,645	7,035	1,595	4.4	4,410	.89	25
El Paso TX	2,690	335	5.0	8,030	2,705	780	3.5	3,465	.64	15
Fort Worth TX	9,230	935	5.3	9,870	3,845	800	3.9	4,805	.79	15
Houston TX	22,555	1,410	6.1	15,995	10,350	1,845	3.9	5,610	1.21	50
San Antonio TX	7,965	775	4.9	10,275	3,685	965	3.3	3,820	.79	15
Outside Texas Avg	11,275	935	5.4	10,645	8,055	1,515	3.4	5,135	.88	20
Texas Avg	9,310	785	5.4	10,675	4,375	950	3.8	4,425	.84	20
Congested Texas Avg	12,225	995	5.6	11,680	5,325	1,115	3.9	4,675	.90	25
Total Avg	10,800	900	5.4	10,655	7,170	1,375	3.5	4,965	.87	20
Maximum Value	75,070	4,415	7.8	17,005	57,105	10,280	4.4	6,475	1.26	65
Minimum Value	1,370	165	4.3	6,655	1,300	300	2.9	3,465	.56	0

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1]Daily vehicle-miles of travel
[2]Daily vehicle-miles of travel per lane-mile of roadway

Source: TTI Analysis and Local Transportation Agency References

Table A-5. Summary of Relative Mobility Values For 1984

Urban Area	Freeway/Expressway				Principal Arterial Streets				Congestion
	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	Index
Phoenix AZ	3,150	220	4.9	14,315	15,305	2,530	3.2	6,050	1.17
Los Angeles CA	77,265	4,515	7.9	17,110	57,700	10,750	3.8	5,365	1.26
Sacramento CA	6,480	640	6.9	10,125	5,030	890	3.7	5,650	.86
San Diego CA	18,480	1,575	7.2	11,735	7,085	1,480	3.1	4,785	.91
San Fran-Oak CA	32,215	2,155	6.5	14,950	9,880	1,745	3.6	5,660	1.15
Denver CO	8,740	745	5.0	11,730	10,105	1,860	3.8	5,430	.96
Miami FL	6,470	525	5.3	12,325	12,000	1,925	4.3	6,235	1.07
Tampa FL	2,540	220	4.7	11,545	3,655	570	3.7	6,410	1.03
Atlanta GA	18,105	1,430	5.7	12,660	7,460	1,405	3.6	5,310	.99
Indianapolis IN	6,090	690	5.0	8,825	4,060	825	3.6	4,920	.74
Louisville KY	4,600	460	4.4	10,000	2,645	480	3.6	5,510	.83
Minn-St Paul MN	13,000	1,155	4.8	11,255	4,650	1,130	3.4	4,115	.86
Kansas City MO	9,380	1,360	4.5	6,895	3,910	950	3.5	4,115	.57
St. Louis MO	14,410	1,315	5.4	10,955	9,745	1,710	3.2	5,700	.90
Albuquerque NM	1,710	200	5.0	8,550	3,370	585	3.5	5,760	.87
Oklahoma City OK	6,060	680	5.0	8,910	3,330	630	3.0	5,285	.75
Portland OR	5,570	510	4.9	10,920	2,795	515	3.2	5,425	.88
Memphis TN	3,015	360	5.1	8,375	3,315	730	4.0	4,540	.72
Nashville TN	3,645	360	4.3	10,125	4,295	850	3.4	5,050	.85
Salt Lake City UT	3,020	340	5.5	8,880	1,675	310	3.4	5,400	.75
Seattle-Everett WA	13,915	1,065	5.8	13,065	7,790	1,410	3.3	5,525	1.02
Milwaukee WI	5,880	530	5.0	11,095	4,655	930	2.9	5,005	.89
Austin TX	3,300	290	5.4	11,380	1,825	380	4.1	4,800	.89
Corpus Christi TX	1,360	165	5.2	8,240	1,350	320	3.5	4,220	.69
Dallas TX	19,925	1,620	6.1	12,300	7,640	1,650	4.5	4,630	.94
El Paso TX	2,800	345	5.0	8,115	2,820	800	3.5	3,525	.65
Fort Worth TX	9,685	965	5.4	10,035	4,015	825	3.9	4,865	.80
Houston TX	24,380	1,480	6.1	16,475	10,860	1,920	3.9	5,655	1.25
San Antonio TX	8,450	785	4.9	10,765	3,920	980	3.3	4,000	.82
Outside Texas Avg	11,985	955	5.4	11,105	8,385	1,555	3.5	5,330	.91
Texas Avg	9,985	805	5.4	11,045	4,635	980	3.8	4,530	.86
Congested Texas Avg	13,145	1,025	5.6	12,190	5,650	1,150	3.9	4,790	.94
Total Avg	11,505	920	5.4	11,090	7,480	1,415	3.6	5,135	.90
Maximum Value	77,265	4,515	7.9	17,115	57,700	10,750	4.5	6,410	1.26
Minimum Value	1,360	165	4.6	6,895	1,350	310	2.9	3,525	.57

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1]Daily vehicle-miles of travel
[2]Daily vehicle-miles of travel per lane-mile of roadway

Source: TTI Analysis and Local Transportation Agency References

Table A-6. Summary of Relative Mobility Values For 1985

Urban Area	Freeway/Expressway				Principal Arterial Streets				Congestion Index	Percent of Congested Freeway Ln-Miles
	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile	DVMT[1] (1000)	Lane-Miles	Avg No. Lanes	DVMT/[2] Ln-Mile		
Phoenix AZ	3,530	235	4.8	15,020	15,705	2,570	3.2	6,110	1.20	60
Los Angeles CA	82,125	4,670	7.9	17,585	60,360	11,050	3.8	5,460	1.30	70
Sacramento CA	6,900	640	6.9	10,780	5,045	920	3.8	5,485	.89	15
San Diego CA	19,650	1,595	7.2	12,320	7,500	1,500	3.1	5,000	.95	30
San Fran-Oak CA	34,665	2,205	6.5	15,720	10,355	1,805	3.6	5,735	1.20	65
Denver CO	9,050	745	5.0	12,145	10,470	1,890	3.8	5,540	.99	30
Miami FL	7,110	540	5.3	13,165	12,700	1,960	4.3	6,480	1.13	45
Tampa FL	2,845	260	4.9	10,940	3,840	595	3.8	6,455	1.00	20
Atlanta GA	19,430	1,455	5.8	13,355	8,365	1,440	3.6	5,810	1.05	30
Indianapolis IN	6,280	690	5.0	9,100	4,100	835	3.7	4,910	.76	0
Louisville KY	4,450	460	4.4	9,675	2,755	480	3.6	5,740	.82	10
Minn-St Paul MN	13,685	1,190	4.8	11,500	4,890	1,135	3.5	4,305	.88	20
Kansas City MO	10,190	1,380	4.6	7,385	4,250	950	3.5	4,475	.61	5
St. Louis MO	14,815	1,355	5.4	10,935	10,260	1,730	3.2	5,930	.91	15
Albuquerque NM	1,820	200	5.0	9,100	3,600	600	3.5	6,000	.92	10
Oklahoma City OK	5,975	685	5.0	8,720	3,350	645	3.0	5,195	.74	5
Portland OR	5,925	515	4.9	11,505	2,965	520	3.3	5,700	.93	25
Memphis TN	3,050	365	5.1	8,355	3,520	750	4.0	4,690	.73	10
Nashville TN	3,915	385	4.4	10,170	4,585	880	3.4	5,210	.86	10
Salt Lake City UT	3,220	360	5.5	8,945	1,795	330	3.3	5,440	.76	10
Seattle-Everett WA	14,850	1,100	5.8	13,500	8,060	1,440	3.3	5,595	1.05	35
Milwaukee WI	6,065	540	5.1	11,230	4,820	930	3.0	5,180	.90	20
Austin TX	4,890	420	5.5	11,640	2,000	400	4.1	5,000	.91	30
Corpus Christi TX	1,400	165	5.2	8,485	1,370	320	3.5	4,280	.71	5
Dallas TX	21,100	1,640	6.2	12,865	7,950	1,675	4.5	4,745	.98	35
El Paso TX	3,120	345	5.0	9,040	2,880	800	3.6	3,600	.70	20
Fort Worth TX	10,070	975	5.4	10,325	4,140	840	3.9	4,930	.82	20
Houston TX	24,115	1,480	6.1	16,295	10,850	1,930	3.9	5,620	1.23	60
San Antonio TX	9,080	800	5.0	11,350	4,285	1,020	3.3	4,200	.87	20
Outside Texas Avg	12,705	980	5.4	11,415	8,785	1,590	3.5	5,475	.94	25
Texas Avg	10,540	830	5.5	11,430	4,780	1,000	3.8	4,625	.89	27
Congested Texas Avg	13,850	1,065	5.6	12,495	5,845	1,170	3.9	4,900	.96	33
Total Avg	12,185	945	5.4	11,420	7,820	1,445	3.6	5,270	.92	25
Maximum Value	82,125	4,670	7.9	17,585	60,360	11,050	4.5	6,480	1.30	70
Minimum Value	1,400	165	4.4	7,385	1,370	320	3.0	3,600	.61	0

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston and San Antonio

[1]Daily vehicle-miles of travel
[2]Daily vehicle-miles of travel per lane-mile of roadway

Source: TTI Analysis and Local Transportation Agency References

APPENDIX B
CONGESTION COST ESTIMATE

APPENDIX B

CONGESTION COST ESTIMATE

Delay in travel time represents a significant cost to the motoring public. This Appendix attempts to quantify these costs to the drivers in terms of time, fuel, and increased insurance rates. The delay calculations are affected by a number of constants and urban area/state specific variables that will be discussed in the following sections.

Cost Estimate Constants

The congestion cost estimate calculations utilized the following derived constant values.

1. Occupancy -- 1.25 persons per vehicle.
2. 250 working days per year.
3. Average cost of time (16) -- $8.20 per person hour[1].
4. Commercial vehicle operating cost (17) -- $1.65 per mile.
5. Vehicle mix -- 95 percent passenger and 5 percent commercial.
6. Vehicular speeds (7):
   Freeway/Expressway peak: 35 mph, off-peak: 55 mph.
   Principal Arterial peak: 20 mph, off-peak: 35 mph.

These constants were applied to all study areas consistently for the cost estimate calculations.

Cost Estimate Variables

In addition to the derived constants, five urban area/state specific variables were identified and used in the congestion cost estimate calculations. These variables are illustrated in Table B-1.

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[1]Reference value of $8.00/hr in 1985 adjusted with the Consumer Price Index to value used for the 1986 wage rate.

Table B-1. 1986 Congestion Cost Estimate Variables

Urban Area	Daily Vehicle-Miles of Travel			Auto Insurance Rates (Dollars)	Annual Insurance Difference (Dollars)	1986 State Avg Fuel Cost (Dollars)	1986 REGISTER AUTO'S	Popn. (1000's)
	FRWY (1000'S)	PRIN. ART. (1000'S)	TOTAL (1000'S)					
Phoenix AZ	4,620	15,840	20,460	560	80	1.06	1,107,502	1,675
Los Angeles CA	92,110	70,410	162,520	790	460	1.04	7,664,286	10,730
Sacramento CA	7,400	5,885	13,285	500	170		1,095,641	960
San Diego CA	21,020	7,850	28,870	510	180		1,095,641	2,000
San Fran-Oakland CA	36,925	12,000	48,925	660	330		2,684,433	3,470
Denver CO	9,290	10,680	19,970	450	30	1.03	1,249,335	1,485
Miami FL	6,970	12,300	19,270	830	320	1.02	1,431,385	1,795
Tampa FL	2,940	3,650	6,590	530	20		683,618	600
Atlanta GA	21,530	9,055	30,585	510	100	.94	1,411,339	1,855
Indianapolis IN	5,800	3,790	9,590	370	40	.98	485,471	910
Louisville KY	4,785	2,735	7,520	350	20	.98	443,940	785
Minn-St Paul MN	14,560	4,100	18,660	460	60	1.00	1,142,655	1,950
Kansas City MO	10,905	4,385	15,290	420	90	.87	621,987	1,130
St Louis MO	15,620	10,765	26,385	470	140		1,375,682	1,925
Albuquerque NM	1,930	3,250	5,180	390	30	.97	380,360	455
Oklahoma City OK	5,780	3,310	9,090	430	70	.93	447,705	730
Portland OR	6,325	3,140	9,465	430	80	.91	595,240	1,040
Memphis TN	3,110	3,760	6,870	450	80	.98	470,784	850
Nashville TN	4,250	4,805	9,055	400	30		353,718	550
Salt Lake City UT	3,450	1,825	5,275	340	30	.97	620,550	760
Seattle-Everett WA	15,500	8,325	23,825	400	20	1.01	1,047,852	1,565
Milwaukee WI	6,315	4,700	11,015	380	80	.97	806,687	1,210
Austin TX	5,300	2,190	7,490	460	50	.94	453,970	470
Corpus Christi TX	1,420	1,400	2,820	420	10		273,810	270
Dallas TX	22,575	8,230	30,805	540	130		1,621,007	1,895
El Paso TX	3,420	2,915	6,335	420	10		346,984	490
Fort Worth TX	10,725	4,250	14,975	480	70		902,139	1,120
Houston TX	24,115	10,810	34,925	600	190		1,901,164	2,800
San Antonio TX	9,560	4,585	14,145	450	40		800,255	1,050
Outside Texas Avg.	13,688	9,389	23,077	483	112	.98	1,237,082	1,747
Texas Avg.	11,016	4,911	15,928	481	71	.94	899,904	1,156
Congested Texas Avg.	14,455	6,013	20,468	506	96	.19	1,135,707	1,467
Total Avg.	13,043	8,308	21,351	483	102	.98	1,155,694	1,604
Maximum Value	92,110	70,410	162,520	830	460	1.06	7,664,286	10,730
Minimum Value	1,420	1,400	2,820	340	10	.87	273,810	270

Source: TTI Analysis and Local Transportation Agency References.

Daily Vehicle Miles Of Travel

The daily vehicle-miles of travel (DVMT) is the average daily traffic (ADT) of a section of roadway multiplied by the length, in miles, of that section of roadway. This allows the daily volume of a facility to be represented in terms that can be quantified and utilized in cost calculations. DVMT was estimated for the freeways and principal arterials located in each study urban area. These estimates originate from the HPMS data base and are presented in Chapter 3 of this report.

Insurance Rates

Auto insurance rates reported in Table B-1 represent the state and urban area averages. These rates were compiled by averaging the rates for minimum required automobile coverage in the various areas and states as quoted by three major insurance carriers. The statewide rate is the average state rate excluding the study areas and other large urban areas. This allowed the calculation of the additional insurance premiums paid by motorists operating vehicles in large urban areas.

Fuel Costs

Statewide average fuel cost estimates were obtained from 1986 data published by the American Automobile Association (AAA) (18). These data represent the reported fuel cost for 1986. Values for different fuel types used in motor vehicles, i.e., diesel and gasoline, did not vary enough to be reported separately. Therefore, an average rate for fuel was used in cost estimate calculations.

Registered Vehicles

The registered vehicle data was obtained from the county Tax Assessor's office in each study area. These data represent the passenger automobiles and light trucks (pick-ups) registered within the study area in 1986.

Population

Population data were obtained from the combination of 1985 U.S. Census Bureau estimates and 1986 population estimates reported in the Federal Highway Administration's Highway Performance Monitoring System (HPMS).

Cost Estimate Calculations

The first step in the cost estimate procedure was to convert DVMT into vehicle-hours of delay. Vehicle-hours of delay is the basis for the delay and fuel cost calculations. To obtain vehicle-hours of delay, the DVMT had to first be represented in terms of peak-period congested DVMT. This was accomplished by the use of two congestion factors.

The first factor, DVMT congestion factor, was calculated utilizing Highway Performance Monitoring System (HPMS) data to determine the percentage of urban area DVMT occurring on congested facilities. Two functional classes, freeways/expressways and principal arterial streets, were considered in the calculation of this factor. Congested conditions for these facilities were defined by the following ADT per lane values:

- Freeways/Expressways-------ADT/lane greater than 15,000
- Principal Arterials Streets--------ADT/lane greater than 5,750

The DVMT congestion factor was calculated by summing the DVMT occurring on facilities with ADT meeting the criteria for congested operation for each functional class, and dividing by the total DVMT of those facilities within each study area. Each study area has DVMT congestion factors for both freeway and principal arterial roadways. The DVMT congestion factor was applied to the functional class DVMT to obtain an estimate of the functional class DVMT operating in congested conditions.

The second value, peak-period traffic volume factor, adjusts the congested DVMT values to represent the percentage of congested DVMT occurring in the peak-periods. This factor was calculated using Texas Department of Highways and Public Transportation (TDHPT) 1986 Automatic Traffic Recorder Data (8) for the study areas in Texas. Using these data, the percentage of ADT occurring during the morning and evening peak periods could be determined. These data indicated that 45 percent of total ADT occurred during the peak periods. This factor was applied to all the study areas.

Once the DVMT was converted to peak-period congested DVMT (Table B-2), the recurring vehicle-hours of delay were computed (Equation B-1).

Table B-2. 1986 Congested Daily Vehicle-Miles of Travel and Vehicle-Hours of Delay

Urban Area	Daily Vehicle-Miles of Travel			Percent of Congested DVMT[1,2]		Peak-Period Congested[1,3]		DVMT Total
	Freeway/ Expressway (1000)	Principal Arterial (1000)	Total (1000)	Freeway	Principal	Freeway/ Expressway	Principal Arterial	
Phoenix AZ	4,620	15,840	20,460	.70	.70	1,455	4,990	6,445
Los Angeles CA	92,110	70,410	162,520	.85	.50	35,230	15,840	51,070
Sacramento CA	7,400	5,885	13,285	.30	.40	1,000	1,060	2,060
San Diego CA	21,020	7,850	28,870	.40	.30	3,785	1,060	4,845
San Fran-Oak CA	36,925	12,000	48,925	.75	.60	12,460	3,240	15,700
Denver CO	9,290	10,680	19,970	.50	.50	2,090	2,405	4,495
Miami FL	6,970	12,300	19,270	.50	.70	1,570	3,875	5,445
Tampa FL	2,940	3,650	6,590	.20	.65	265	1,070	1,335
Atlanta GA	21,530	9,055	30,585	.50	.65	4,845	2,650	7,495
Indianapolis IN	5,800	3,790	9,590	.00	.15	0	255	255
Louisville KY	4,785	2,735	7,520	.05	.50	110	615	725
Minn-St Paul MN	14,560	4,100	18,660	.25	.50	1,640	925	2,565
Kansas City MO	10,905	4,385	15,290	.05	.20	245	395	640
St Louis MO	15,620	10,765	26,385	.20	.65	1,405	3,150	4,555
Albuquerque NM	1,930	3,250	5,180	.10	.40	85	585	670
Oklahoma City OK	5,780	3,310	9,090	.05	.35	130	520	650
Portland OR	6,325	3,140	9,465	.30	.60	855	850	1,705
Memphis TN	3,110	3,760	6,870	.10	.35	140	590	730
Nashville TN	4,250	4,805	9,055	.15	.40	285	865	1,150
Salt Lake City UT	3,450	1,825	5,275	.10	.45	155	370	525
Seattle-Everett WA	15,500	8,325	23,825	.55	.55	3,835	2,060	5,895
Milwaukee WI	6,315	4,700	11,015	.25	.35	710	740	1,450
Austin TX	5,300	2,190	7,490	.55	.45	1,310	445	1,755
Corpus Christi TX	1,420	1,400	2,820	.10	.10	65	65	130
Dallas TX	22,575	8,230	30,805	.55	.30	5,585	1,110	6,695
El Paso TX	3,420	2,915	6,335	.20	.05	310	65	375
Fort Worth TX	10,725	4,250	14,975	.40	.30	1,930	575	2,505
Houston TX	24,115	10,810	34,925	.75	.55	8,140	2,675	10,815
San Antonio TX	9,560	4,585	14,145	.40	.15	1,720	310	2,030
Outside Texas Avg.	13,685	9,390	23,075	.31	.48	3,285	2,185	5,475
Texas Avg.	11,015	4,910	15,925	.42	.27	2,725	750	3,470
Congested Texas Avg.	14,455	6,015	20,465	.53	.35	3,740	1,025	4,760
Total Avg.	13,045	8,305	21,350	.34	.43	3,150	1,840	4,990
Maximum Value	92,110	70,410	162,520	.85	.70	35,230	15,840	51,075
Minimum Value	1,420	1,400	2,820	.00	.05	0	65	125

[1]Daily vehicle-miles of travel
[2]Represents the percentage of daily vehicle-miles of travel on each roadway system during the peak period operating in congested conditions
[3]Daily vehicle-miles of travel multiplied by peak-period vehicle travel and percent of congested DVMT

Source: TTI Analysis and Local Transportation Agency References

$$\frac{\text{Recurring Vehicle-Hour Delay}}{\text{Day}} = \frac{\text{Peak-Period Congested DVMT}}{\text{Avg. Peak-Period Speed}} - \frac{\text{Peak-Period Congested DVMT}}{\text{Avg. Off-Peak Speed}} \quad \text{Eq. B-1}$$

This calculation was done for both freeways and principal arterials in a study area; the total recurring vehicle-hours of delay is the sum of the two. The result of these calculations is shown in Table B-3.

Another type of delay encountered by the vehicles is incident delay. This is the vehicle-hours of delay as a result of an and construction or maintenance operations. Incident vehicle-hours of delay varies from area by area and facility type, i.e., freeway/expressway or arterial street. For the freeway system in individual study areas the recurring to incident ratios reported by Lindley [6] were used. The resulting incident delay was calculated by using Equation B-2.

$$\frac{\text{Frwy Incident Vehicle Hour Delay}}{\text{Day}} = \frac{\text{Recurring Frwy Vehicle-Hour Delay}}{\text{Per Day}} \times \text{Frwy Incident/Recurring Ratio} \qquad \text{Eq. B-2}$$

An incident will have varying effects on different types of facilities, for the purpose of this study incident delay for arterial streets is defined as 110 percent of arterial street recurring delay. This incident delay factor was calculated using Equation B-3.

$$\frac{\text{Principal Arterial Incident Vehicle-Hour Delay}}{\text{Day}} = \frac{\text{Principal Arterial Peak Period Vehicle-Hour Delay}}{\text{Day}} \times 1.1 \qquad \text{Eq. B-3}$$

The factor of 1.1 is based on the following assumptions as they relate to delay:

1. Arterial street systems are more consistent from city to city than freeway systems.

2. The side streets, drives, median openings, and other appurtenances associated with arterial streets allow numerous opportunities to remove incidents from the travel-way.

3. Historical data shows the accident rate on arterial streets to be approximately twice that of freeways but, as stated in our second assumption, there is a greater opportunity to remove the incident from the roadway.

Table B-3 shows the results of the freeway and principal arterial recurring and incident delay calculations.

Table B-3. Recurring and Incident Delay Relationships

State and City	1986 Pk Period Congested DVMT[1,2]			Incident/Recurring[3] Ratio		Recurring Vehicle-Hours[4] of Delay			Incident Vehicle-Hours[4] of Delay		
	Frwy (1000's)	Prin. Art. (1000's)	Totals (1000's)	Frwy	Prin. Arterial	Total (Daily)	Frwy	Prin. Arterial	Total (Daily)	Frwy	Prin. Arterial
Phoenix AZ	1,455	4,990	6,445	.40	1.1	124,245	17,325	106,920	124,540	6,930	117,610
Los Angeles CA	35,230	15,840	51,075	1.20	1.1	758,905	419,430	339,475	910,685	503,315	373,425
Sacramento CA	1,000	1,060	2,055	.60	1.1	34,590	11,895	22,700	20,755	7,135	24,970
San Diego CA	3,785	1,060	4,845	.60	1.1	67,750	45,045	22,710	40,650	27,025	24,980
San Fran-Oakland CA	12,460	3,240	15,700	1.30	1.1	217,785	148,360	69,430	283,125	192,865	76,370
Denver CO	2,090	2,405	4,495	1.00	1.1	76,375	24,885	51,495	76,375	24,885	56,640
Miami FL	1,570	3,875	5,445	1.50	1.1	101,695	18,670	83,025	152,540	28,005	91,325
Tampa FL	265	1,065	1,330	1.50	1.1	26,025	3,150	22,875	39,040	4,725	25,165
Atlanta GA	4,845	2,650	7,495	1.10	1.1	114,425	57,670	56,755	125,865	63,435	62,430
Indianapolis IN	0	255	255	1.50	1.1	5,480	0	5,480	8,225	0	6,030
Louisville KY	105	615	725	1.10	1.1	14,465	1,280	13,185	15,915	1,410	14,505
Minn-St Paul MN	1,635	925	2,560	.90	1.1	39,265	19,500	19,765	35,340	17,550	21,745
Kansas City MO	245	395	640	3.10	1.1	11,375	2,920	8,455	35,270	9,055	9,300
St Louis MO	1,405	3,150	4,555	1.20	1.1	84,210	16,735	67,475	101,050	20,085	74,220
Albuquerque NM	85	585	670	1.10	1.1	13,570	1,035	12,535	14,925	1,135	13,790
Oklahoma City OK	130	520	650	1.10	1.1	12,720	1,545	11,170	13,990	1,705	12,285
Portland OR	855	845	1,700	2.00	1.1	28,330	10,165	18,165	56,665	20,330	19,985
Memphis TN	140	590	730	1.10	1.1	14,355	1,665	12,690	15,790	1,835	13,960
Nashville TN	285	865	1,150	1.10	1.1	21,950	3,415	18,535	24,145	3,755	20,385
Salt Lake City UT	155	370	525	.60	1.1	9,765	1,845	7,920	5,860	1,110	8,710
Seattle-Everett WA	3,835	2,060	5,895	1.40	1.1	89,820	45,670	44,150	125,750	63,935	48,565
Milwaukee WI	710	740	1,450	1.00	1.1	24,320	8,455	15,865	24,320	8,455	17,450
Austin, TX	1,310	445	1,755	1.10	1.1	25,120	15,615	9,505	27,630	17,175	10,455
Corpus Christi TX	65	65	125	1.10	1.1	2,110	760	1,350	2,320	835	1,485
Dallas TX	5,585	1,110	6,695	1.80	1.1	90,325	66,515	23,805	162,585	119,725	26,190
El Paso TX	305	65	375	1.10	1.1	5,070	3,665	1,405	5,575	4,030	1,545
Fort Worth TX	1,930	575	2,505	1.80	1.1	35,275	22,980	12,295	63,495	41,365	13,525
Houston TX	8,140	2,675	10,815	1.40	1.1	154,220	96,890	57,330	215,910	135,645	63,065
San Antonio TX	1,720	310	2,030	1.10	1.1	27,115	20,485	6,630	29,830	22,535	7,295
Outside Texas Avg.	3,285	2,185	5,475	1.20		85,975	39,120	46,855	102,310	45,850	51,540
Texas Avg.	2,725	750	3,470	1.34		48,465	32,415	16,045	72,480	48,760	17,650
Congested Texas Avg.	3,735	1,025	4,760	1.44		66,410	44,495	21,915	99,890	67,290	24,105
Total Avg.	3,150	1,840	4,990	1.23		76,920	37,505	39,415	95,110	46,550	43,360
Maximum Value	35,230	15,840	51,075	3.10		758,905	419,425	339,475	910,685	503,315	373,425
Minimum Value	0	65	125	.40		2,110	0	1,350	2,320	0	1,485

[1] Daily vehicle-miles of travel
[2] Represents the percentage of daily vehicle-miles of travel on each roadway system during the peak period operating in congested conditions
[3] Percentage of Incident delay related to recurring delay
[4] Facility Delays as calculated by type and urban area.

Note: Congested Texas Cities average includes Austin, Dallas, Fort Worth, Houston, and San Antonio

Source: TTI Analysis and Local Transportation Agency References

Congestion Cost

Three types of cost can be associated with congestion: 1) delay cost, 2) fuel cost, and 3) insurance cost. These costs can be directly related to the vehicle-hours of delay, with the exception of the insurance cost. Table B-4 is a summary of the cost calculations for the component congestion cost per each urban area.

Table B-4. Component and Total Congestion Costs By Urban Area

Urban Area	Annual Cost Due to Congestion					Total	Total Delay/Fuel Cost (Millions)
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Insurance		
Phoenix AZ	360	365	55	55	90	920	830
Los Angeles CA	2,320	2,785	365	440	3,525	9,440	5,915
Sacramento CA	105	60	15	9	185	375	190
San Diego CA	210	125	35	20	195	585	390
San Fran-Oakland CA	675	875	110	140	885	2,685	1,795
Denver CO	230	230	35	35	35	565	525
Miami FL	300	450	40	64	460	1,310	850
Tampa FL	75	115	10	16	15	230	215
Atlanta GA	350	385	49	50	140	975	835
Indianapolis IN	15	25	0	5	20	65	45
Louisville KY	40	45	5	5	10	110	100
Minn-St Paul MN	120	110	20	15	70	330	260
Kansas City MO	35	105	5	15	55	210	155
St Louis MO	250	295	30	35	195	805	610
Albuquerque NM	40	45	5	5	10	105	95
Oklahoma City OK	35	40	5	5	30	120	90
Portland OR	85	170	10	25	50	335	290
Memphis TN	40	45	5	5	40	135	100
Nashville TN	65	70	10	10	10	165	155
Salt Lake City UT	30	15	5	0	20	70	50
Seattle-Everett WA	275	385	40	60	20	780	755
Milwaukee WI	75	75	10	10	65	230	165
Austin TX	75	85	10	10	25	210	185
Corpus Christi TX	5	5	0	0	5	20	15
Dallas TX	280	505	40	75	210	1,110	900
El Paso TX	15	15	0	5	5	40	40
Fort Worth TX	110	195	15	30	65	410	350
Houston TX	475	665	68	95	360	1,665	1,305
San Antonio TX	85	95	10	15	30	235	205
Outside Texas Avg.	260	310	40	45	280	935	655
Texas Avg.	150	225	20	30	100	525	430
Congested Texas Avg.	205	310	30	45	140	725	590
Total Avg.	235	290	35	45	235	835	600
Maximum Value	2,320	2,785	365	440	3,525	9,440	5,915
Minimum Value	5	5	0	0	5	20	15

Note: Congested Texas cities average includes Austin, Dallas, Fort Worth, Houston, and San Antonio

Source: TTI Analysis Tools and Local Transportation Agency References

Prior to calculating the congestion costs, two other variables were calculated to simplify the cost equations. These variables are the Average Vehicular Speed and the average fuel mileage for the vehicles operating in congested conditions. The Average vehicular Speed is a weighted average of the operating speeds on the facility under consideration and is defined by Equation B-4.

$$\text{Avg. Speed (mph)} = \frac{(35 \text{ mph X Peak-Period Frwy DVMT}) + (20 \text{ mph X Peak-Period Prin. Art. DVMT})}{\text{Total Peak-Period DVMT}} \qquad \text{Eq.B-4}$$

The Average Fuel Mileage represents the fuel consumption of the vehicles operating in congested conditions. The equation (Equation B-5) is a linear regression applied to a modified version of fuel consumption reported by Raus (7).

$$\text{Average Fuel Mileage (mpg)} = 8.8 + 0.25 \text{ (Average Vehicular Speed)} \qquad \text{Eq. B-5}$$

Delay Cost - The delay cost is the cost of lost time due to congested roadways. This cost was calculated by Equation B-5.

$$\text{Annual Delay Cost} = \frac{\text{Veh-Hours of Delay}}{\text{Day}} \times \frac{1.25 \text{ Persons}}{\text{Vehicle}} \times \frac{\$ 8.00}{\text{Hr.}} \times \frac{250 \text{ Workdays}}{\text{Year}} \qquad \text{Eq. B-6}$$

where: vehicle-hrs. of delay/day is the combined total freeway and principal arterial representing cities recurring or incident type delay.

This equation is used to separately calculate delay costs resulting from both incident and recurring delays.

Fuel Cost - Fuel cost was also related to vehicle-hours of delay per day and speed by Equation B-6 for passenger vehicles and Equation B-7 for commercial vehicles. The difference in congested and uncongested freeway and arterial street speeds was applied to the estimate of peak-period congested daily vehicle-miles of travel.

$$\text{Passenger} = \frac{\frac{\text{Vehicle - Hrs. of Delay}}{\text{Day}} \times \text{Avg. Speed}}{\text{Avg. Fuel Mileage}} \qquad \text{Eq. B-7}$$

$$\text{Commercial Fuel Cost} = \frac{\frac{\text{Vehicle-Hrs. of Delay}}{\text{Day}} \times 5\% \times \text{Avg. Speed}}{\text{Avg. Fuel Mileage}} \qquad \text{Eq. B-8}$$

where: Vehicle-hrs. of delay is the combined total freeway and principal arterial representing either recurring or incident type delay.

These calculations were completed for both incident and recurring delay. The respective portions i.e., incident and recurring, were combined in Equation B-9 to determine the yearly fuel cost due to congestion resulting from incident and recurring delay.

$$\text{Avg. Urban Area Fuel Cost} = (\text{Passenger Fuel Cost} + \text{Commercial Fuel Cost}) \times \frac{\text{250 Days}}{\text{Year}} \qquad \text{Eq. B-9}$$

This calculation was done for each study area using the specific area/state fuel cost, peak-period congested DVMT, and vehicle-hours of recurring and incident delay per day.

Insurance Cost - Insurance cost was calculated by multiplying the insurance rate differential by the number of registered vehicles within the area (Equation B-10).

$$\text{Excess Insurance Cost per year} = (\text{Study Area Rate} - \text{Average State Rate}) \times \text{Number Registered Vehicles} \qquad \text{Eq. B-10}$$

The study area and average state rates are based on a married made over 25 years old with the minimum insurance coverage required by state law.

The insurance costs do not include commercial vehicles because of the wide variance in rates and the difficulty in identifying the registered commercial vehicles actually operating within that particular area.

Results of Cost Estimate Calculations

Using the methods and equations discussed in the previous sections, the annual cost for each urban area was calculated (Table 4-B). The impacts of the component and total congestion cost in terms of per capita, per registered vehicle and per vehicle-mile of travel are shown in Table 5-B. The results are summarized in Figure B-1, with the vertical axis denoting the urban area and the horizontal illustrates the annual congestion costs per capita in dollars. Figure B-1 indicates the total annual congestion cost per capita including insurance costs. Insurance costs, account for a minimum of three percent (Seattle-Everett) to a maximum of 39 percent (Sacramento) of the annual congestion cost. The average insurance percentage of total cost is 20 percent inclusive of all study areas. Texas has a statewide average of 15 percent, five percent lower than the congested Texas cities averaged (16) one percent over the statewide average.

Table B-6 illustrates the ranking of the urban study areas by annual congestion cost and congestion cost per capita. It is shown that the elimination of the insurance cost from the annual congestion cost did not significantly affect the urban area ranking. While auto insurance premiums are not solely affected by congested roadways, their inclusion does not appear to alter the relative rankings developed in this report.

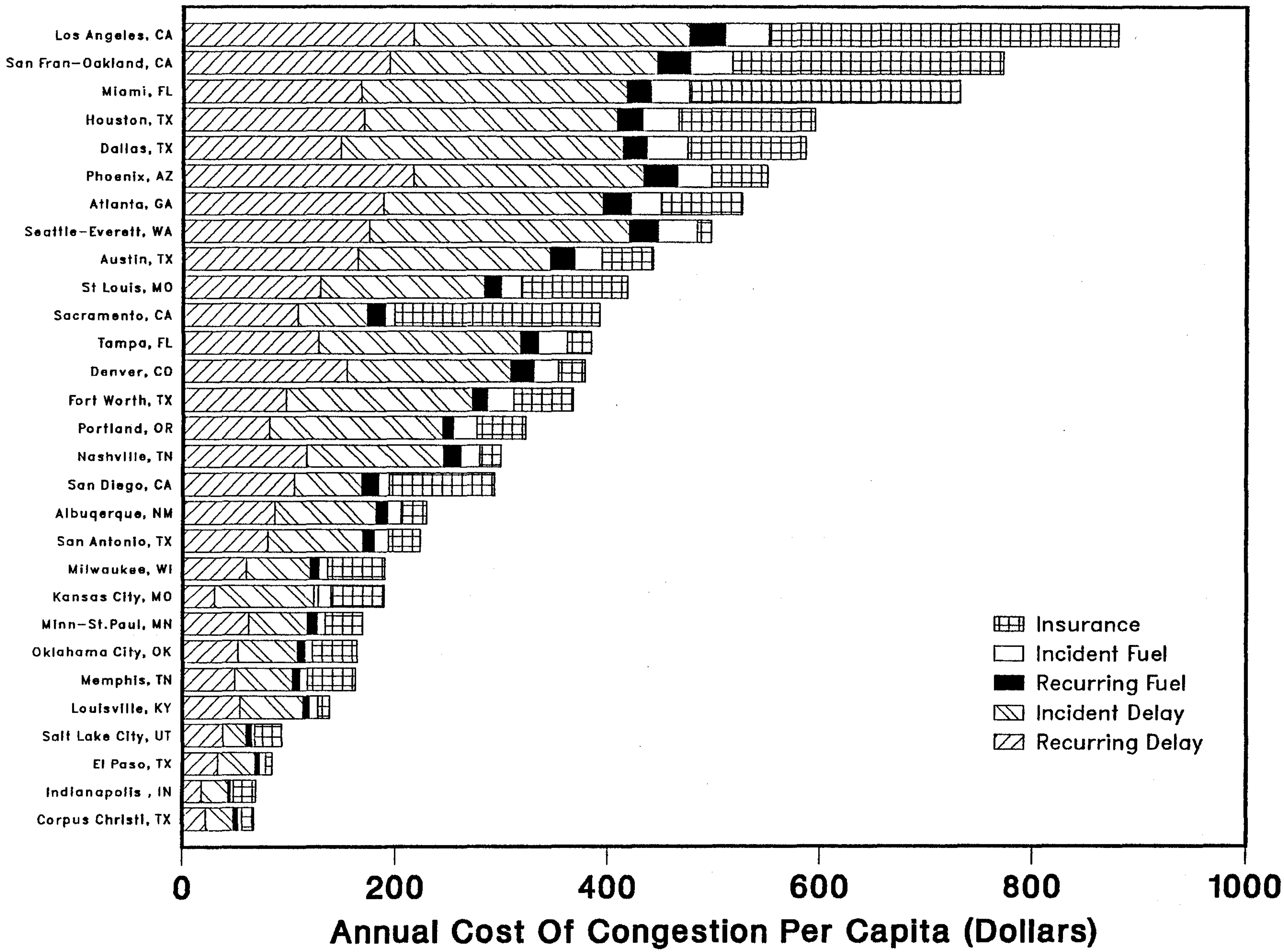

Figure B-1. Urban Area Annual Congestion Cost per Capita

Table B-5. Estimated Economic Impact of Congestion in 1986

Urban Area	Congestion Cost Per Capita (Dollars)	Delay/Fuel Cost Per Capita (Dollars)	Congestion Cost Per Reg. Veh. (Dollars)	Delay/Fuel Cost Per Reg. Veh. (Dollars)
Phoenix AZ	550	495	830	750
Los Angeles CA	880	550	1,230	770
Sacramento CA	395	200	345	175
San Diego CA	295	195	535	355
San Fran-Oakland CA	775	520	1,000	670
Denver CO	380	355	450	420
Miami FL	730	475	915	595
Tampa FL	380	360	335	315
Atlanta GA	525	450	690	590
Indianapolis IN	70	50	130	90
Louisville KY	140	125	245	225
Minn-St Paul MN	170	135	290	230
Kansas City MO	185	140	340	250
St Louis MO	420	320	585	445
Albuquerque NM	230	205	275	245
Oklahoma City OK	165	120	265	195
Portland OR	325	280	565	485
Memphis TN	160	115	290	210
Nashville TN	295	280	460	430
Salt Lake City UT	95	70	115	85
Seattle-Everett WA	495	485	740	720
Milwaukee WI	190	140	285	205
Austin TX	445	395	460	410
Corpus Christi TX	65	55	66	55
Dallas TX	585	475	685	555
El Paso TX	85	75	120	110
Fort Worth TX	370	310	455	385
Houston TX	595	465	875	685
San Antonio TX	225	195	295	255

Source: TTI Analysis Tools and Local Transportation Agency References

The congestion cost per capita (Table B-3) compares favorably with the Congestion Index rankings in Chapter 3. There are some changes in ranking, but as a group, the values seem to be relatively consistent.

Table B-6. 1986 Rankings of Urban Area by Estimated Economic Impact of Congestion

Urban Area	Total Congestion Cost	Total Delay/Fuel Cost	Congestion Cost Per Capita	Delay/Fuel Cost Per Capita	Congestion Cost Per Reg. Veh.	Total Delay/Fuel Cost Per Reg. Veh.
Phoenix AZ	7	7	6	3	5	2
Los Angeles CA	1	1	1	1	1	1
Sacramento CA	13	17	11	17	16	25
San Diego CA	10	11	17	18	11	15
San Fran-Oakland CA	2	2	2	2	2	5
Denver CO	11	10	13	11	15	12
Miami FL	4	5	3	5	3	6
Tampa FL	18	15	12	10	18	16
Atlanta GA	6	6	7	8	7	7
Indianapolis IN	27	27	28	29	26	27
Louisville KY	24	22	25	23	25	21
Minn-St Paul MN	15	14	22	22	21	20
Kansas City MO	19	20	21	20	17	18
St Louis MO	8	9	10	12	9	10
Albuquerque NM	25	24	18	16	23	19
Oklahoma City OK	23	25	23	24	24	24
Portland OR	14	13	15	15	10	9
Memphis TN	22	23	24	25	20	22
Nashville TN	21	21	16	14	12	11
Salt Lake City UT	26	26	26	27	28	28
Seattle-Everett WA	9	8	8	4	6	3
Milwaukee WI	17	19	20	21	22	23
Austin TX	20	18	9	9	13	13
Corpus Christi TX	29	29	29	28	29	29
Dallas TX	5	4	5	6	8	8
El Paso TX	28	28	27	26	27	26
Fort Worth TX	12	12	14	13	14	14
Houston TX	3	3	4	7	4	4
San Antonio TX	16	16	19	19	19	17

Source: TTI Analysis

Sensitivity Analysis of Data

A concern of this economic analysis was the sensitivity of cost to the data and methods used to calculate economic impact. To accomplish this sensitivity analysis the DVMT, incident delay, percent congested and population were varied by 10 percent of the original estimated values. Fuel and Insurance costs were also varied and plus minus 10 percent of their respective values. The results of the sensitivity analysis were analyzed in terms of congestion cost per capita and registered vehicles including and excluding insurance cost.

This analysis varied the, above mentioned, factors plus and minus 10 percent for each individual urban area. By analyzing the data in this manner, relative changes in rank due to variance of a single factors could be identified on an individual urban area basis. Once

Once calculations varing factor had been completed, the change in rank compared to initial ranking was determined.

This analysis concluded that a 10 percent variance in any single factor would not affect the overall urban area rank. Extreme changes were were on the order of three positions. None of the rank changes altered the top ten ranked urban areas, i.e. caused an urban area to be included or excluded if presently ranked in the top ten. The most prominate changes, as expected, occured with varience in population for per capita costs and registered vehicle for per registered vehicle costs.

APPENDIX C

BUSINESS LEADER SURVEY

AND

LETTER OF INTRODUCTION

25TH FLOOR
1100 MILAM BUILDING
HOUSTON, TEXAS 77002
(713) 651-1313

Houston CHAMBER OF COMMERCE

Gerry Griffin
President and
Chief Executive Officer

Dear Business Leader:

We need your help in a special study of urban mobility in major U.S. cities being conducted by the Texas Transportation Institute, a research organization of The Texas A&M University System. As you are aware, good mobility is vital to maintaining a healthy urban economy and a high "quality of life" for area residents.

Since you are a recognized leader in the City of Houston, we need your help to determine what effect (if any) traffic conditions have had on the business activities of your firm. Because of the small number of business leaders contacted, your specific reply is essential to insure the success of the project. All information you provide will remain strictly confidential.

Your cooperation and timely return of the completed questionnaire in the enclosed postage-paid envelope will be greatly appreciated. Thank you for your time and assistance in this important undertaking.

Sincerely,

Gerry Griffin
President and Chief Executive Officer

HOUSTON PROUD

HOUSTON AREA

BUSINESS LEADER SURVEY

Undertaken by the Texas Transportation Institute, Texas A&M University System
in cooperation with the Texas State Department of Highways and Public Transportation,
and the U.S. Department of Transportation

This questionnaire is designed to be easy to complete and should take no more than a few minutes of your time. All answers to the questions will remain confidential. Please return the completed form in the stamped envelope at your earliest convenience.

Company Name ____

Street Address ____

City _______________ State ______ Zip Code _________ Telephone _______________

Name and title of person providing information ______________________________

____

1. How would you classify the business activities of your company?

___Government Agency (State)
___Government Agency (Federal)
___Government Agency (Local)
___Public Utilities, Communications
___Service (Finance, Insurance, Real Estate)
___Service (Health)
___Other Services (Education, Business, Law)
___Manufacturing
___Retail Trade
___Wholesale Trade
___Construction, Transportation & Related Industries
___Other (specify) ____________________

2. Approximately how many people, including yourself and part-time workers, are employed at this facility?_________

3. What is the gross annual income of this facility?

___ Less than $500,000
___ $500,000 to $1 million
___ $1 million to 5 million
___ $5 million to $10 million
___ $10 million or greater

4. How long has your company been at its present location? _________ years

Before selecting its present site in the Houston area, did your company consider locating in a different city? ___ Yes ___ No

5. **What was the relative importance of each of the following in your company's decision to locate at its present site?**

	Not Important		Neutral		Very Important
Proximity to markets	1	2	3	4	5
Existing residential locations of professional and managerial staff	1	2	3	4	5
Existing residential locations of support and/or production staff	1	2	3	4	5
Availability of good housing nearby	1	2	3	4	5
Land ownership or leasing costs	1	2	3	4	5
Availability of parking	1	2	3	4	5
Physical environment	1	2	3	4	5
Cost of living in Houston	1	2	3	4	5
Convenient access to highway facilities	1	2	3	4	5
Uncongested highway facilities	1	2	3	4	5
Convenient access to the airport	1	2	3	4	5
Proximity to public transportation	1	2	3	4	5
Availability of trained labor force	1	2	3	4	5
Local taxes	1	2	3	4	5
Local government attitude or incentives	1	2	3	4	5
Other (specify)______________________________	1	2	3	4	5

6. **What is the relative importance of each of the following to the current business activities of your firm?**

	Not Important		Neutral		Very Important
Transport of materials and products to and from markets and suppliers	1	2	3	4	5
Access for your personnel to others in your industry (such as clients, firms in similar lines, educators, researchers and trade representatives)	1	2	3	4	5
The quality of transportation facilities and services in making your city a pleasant place to live and work	1	2	3	4	5

7. **How would you rate traffic conditions of the roadway network that serves your firm?**

Weekday peak travel hours: ___Not congested ___Slightly congested ___Severely congested

Weekday off-peak travel hours: ___Not congested ___Slightly congested ___Severely congested

8. Do you think that the traffic conditions in your area have had an impact on your business (hours of business, employee morale/punctuality, business productivity/efficiency, etc.)?

___ Yes ___No ___Not sure

If "yes," is that impact positive or negative and what is the magnitude?

___Positive ___Negative Please explain: ______________________________

____

____

9. Have the traffic conditions in your area had any influence on your firm's current or future plans for development or expansion in terms of:

Where to develop or expand? ___Yes ___No

When to develop or expand? ___Yes ___No

How much to develop or expand? ___Yes ___No

What to develop or expand? ___Yes ___No

If you answered "yes" to any of the above, please explain how. ______________________

____

____

____

10. What specific transportation improvements are needed to enhance business in your area?

___Widening and upgrading major surface streets

___Resurfacing of urban freeway system

___Construction of additional freeway lanes

___Grade separations for surface roads, railroads and freeway interchanges

___Construction of special freeway lanes for use by buses, carpools and vanpools

___Upgrade existing public transportation system

___Construction of a rail transit system

___Increased promotion of flextime and ridesharing programs

___Other (please specify) ____

11. Do you think that the roadway/freeway reconstruction activities currently underway in Houston have had an adverse effect on the business activities of your firm? ___Yes ___No ___Not sure

If "yes", please explain how. ____

____

____