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16. Abstract

This research report represents the seventh year of a ten-year research effort focused on quantifying urban mobility. This study contains the facility information for 50 urban areas throughout the country. The database used for this research contains information on vehicle travel, system length, and urban area characteristics from 1982 to 1992. Various federal, state, and local agencies provided the information used to update and verify the primary database. The primary database and original source of most of the information is the Federal Highway Administration's Highway Performance Monitoring System (HPMS).

Vehicle travel and system length data were combined to develop Roadway Congestion Index (RCI) values for 50 urban areas including the seven largest in Texas. The RCI values provide an indicator of the relative mobility level within an urban area.

An analysis of the cost of congestion was also performed using travel delay and increased fuel consumption as estimated quantities. The impact of congestion was also estimated by the amount of additional facility capacity required to provide urban mobility. Congestion costs were estimated on an areawide, per registered vehicle, and per capita basis.

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URBAN ROADWAY CONGESTION - 1982 TO 1992
VOLUME 1: ANNUAL REPORT

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IMPLEMENTATION STATEMENT

This report provides information that will assist the Texas Department of Transportation in planning future transportation needs for urban areas in Texas. This report quantifies congestion levels and the economic impact of congestion on urban motorists in seven large cities in Texas. The report also presents data for other large U.S. metropolitan areas to assist in determining mobility trends and the performance of Texas' roadway networks relative to others. This report is valuable for identifying transportation trends and prioritizing future needs.

DISCLAIMER

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SUMMARY

This report represents the seventh year of a planned ten-year study to measure and monitor urban mobility in 50 urbanized areas throughout the United States. This research study estimates the level of congestion in the seven largest Texas urban areas and 43 other areas representing a cross-section of urban areas throughout the country. Quantitative estimates of mobility levels allow comparisons of transportation systems in the various urbanized areas and assist the transportation community in analyzing urban mobility.

The level of congestion in an urban area was estimated using procedures developed in previous research (1-8). The Roadway Congestion Index (RCI) combines the daily vehicle-kilometers of travel (VKT) per lane-kilometer for freeways and principal arterial street systems in a ratio comparing the existing value to values identified with congested conditions. Equation S-1 illustrates how the areawide and congested level travel per lane values are combined into the RCI values for each urban area.

$$\begin{matrix}\textit{Roadway}\\ \textit{Congestion}\\ \textit{Index}\end{matrix} = \frac{\begin{matrix}\textit{Freeway}\\ \textit{VKT/Ln.-Km.}\end{matrix} \times \begin{matrix}\textit{Freeway}\\ \textit{VKT}\end{matrix} + \begin{matrix}\textit{Prin Art Str}\\ \textit{VKT/Ln.-Km.}\end{matrix} \times \begin{matrix}\textit{PrinArtStr}\\ \textit{VKT}\end{matrix}}{13{,}000 \times \begin{matrix}\textit{Freeway}\\ \textit{VKT}\end{matrix} + 5{,}000 \times \begin{matrix}\textit{PrinArtStr}\\ \textit{VKT}\end{matrix}} \qquad \text{Eq. S-1}$$

An RCI value of 1.0 or greater indicates that congested conditions exist areawide. It should be noted that urban areas with areawide values less than 1.0 may have sections of roadway that experience periods of heavy congestion, but the average mobility level within the urban area could be defined as uncongested. The RCI analyses presented in this report are intended to evaluate entire urban areas and not specific locations. The nature of the RCI equation (Eq. S-1) is to underestimate point or specific facility congestion if the overall system has "good" operational characteristics.

AREAWIDE MOBILITY

Table S-1 combines the freeway and principal arterial street system daily VKT and daily VKT per lane-kilometer into the 1992 estimated Roadway Congestion Index (RCI). The ten most congested urban areas in the study are displayed. The RCI values range from 1.54 (Los Angeles) to 1.17 (Atlanta). All of these urban areas have surpassed the RCI value at which undesirable levels of congestion occur (1.0).

Table S-1. 1992 Roadway Congestion Index Value

Urban Area	Freeway/Expressway		Principal Arterial Street		Roadway/[3] Congestion Index	Rank
	Daily VKT[1] (1000)	Daily VKT/[2] Ln-Km	Daily VKT[1] (1000)	Daily VKT/[2] Ln-Km		
Los Angeles CA	180,240	20,750	132,830	6,600	1.54	1
Washington DC	44,190	16,940	29,790	7,970	1.36	2
San Fran-Oak CA	68,100	17,410	22,830	6,110	1.33	3
Miami FL	15,090	14,990	27,050	7,530	1.30	4
Chicago IL	63,110	16,070	52,810	7,050	1.28	5
San Bernardino-Riv CA	24,330	16,600	17,310	5,120	1.22	6
San Diego CA	44,760	15,980	15,620	5,590	1.22	6
Seattle-Everett WA	32,640	15,960	15,780	6,030	1.22	6
Detroit MI	46,050	15,710	39,450	5,740	1.19	9
Atlanta GA	42,670	15,140	16,100	6,170	1.17	10

Notes: [1] Daily vehicle-kilometers of travel.
[2] Daily vehicle-kilometers of travel per lane-kilometer.
[3] See Equation S-1.

See Table 1 for complete listing of urban areas.
Source: TTI Analysis

Table S-2 displays the ten urban areas which have experienced the greatest growth in congestion between 1982 and 1992. The RCI values reflect the level of congestion occurring in the urban areas. San Diego experienced a 56 percent increase in congestion during the eleven year period. The congestion increase rate in all cities in the top ten exceeded two percent per year.

Table S-2. Fastest Congestion Growth Areas

Rank of % Change		Urban Area	Percent Change		Year				
1982-92	1987-92		1982-92	1987-92	1982	1987	1990	1991	1992
1	7	San Diego CA	56	13	0.78	1.08	1.22	1.22	1.22
2	1	Salt Lake City UT	43	29	0.63	0.70	0.85	0.88	0.90
3	2	Columbus OH	37	19	0.68	0.78	0.89	0.91	0.93
4	41	San Fran-Oak CA	32	2	1.01	1.31	1.36	1.34	1.33
5	10	Minn-St. Paul MN	30	11	0.76	0.89	0.96	0.96	0.99
6	34	Sacramento CA	30	4	0.80	1.00	1.02	1.04	1.04
7	25	Atlanta GA	29	5	0.91	1.11	1.14	1.16	1.17
8	21	Seattle-Everett WA	28	7	0.95	1.14	1.20	1.20	1.22
9	28	Dallas TX	27	5	0.84	1.02	1.05	1.06	1.07
10	42	Indianapolis IN	27	0	0.67	0.85	0.84	0.84	0.85

See Table 2 for complete listing of urban areas.

Source: TTI Analysis

The ten urban areas with the smallest growth in congestion between 1982 and 1992 are shown in Table S-3. Phoenix and Houston experienced decreases in congestion with Phoenix showing the greatest decrease (6 percent). Congestion increases in these ten urban areas were less than one percent per year.

Table S-3. Slowest Congestion Growth Areas

Rank of % Change		Urban Area	Percent Change		Year				
1982-92	1987-92		1982-92	1987-92	1982	1987	1990	1991	1992
1	1	Phoenix AZ	-6	-8	1.15	1.18	1.05	1.08	1.08
2	2	Houston TX	-4	-6	1.17	1.19	1.12	1.11	1.12
3	11	Pittsburgh PA	4	3	0.78	0.79	0.82	0.82	0.81
4	8	Philadelphia PA	5	-1	1.00	1.06	1.05	1.05	1.05
5	14	Jacksonville FL	7	3	0.91	0.94	0.93	0.95	0.97
6	30	San Bernardino-Riv CA	10	7	1.11	1.14	1.21	1.22	1.22
7	28	Ft. Lauderdale FL	10	7	0.87	0.90	0.94	0.95	0.96
8	12	Corpus Christi TX	10	3	0.67	0.72	0.72	0.72	0.74
9	38	Memphis TN	11	10	0.83	0.84	0.89	0.91	0.92
10	16	Orlando FL	11	4	0.72	0.77	0.77	0.78	0.80

See Table 2 for complete listing of urban areas

Source: TTI Analysis

Table S-4 lists the top ten urban areas based on the amount of fuel wasted annually due to congested travel. Los Angeles tops the list with almost 2.5 billion liters of wasted fuel annually. New York is second with about 2.2 billion liters. Dallas is tenth in this group with 380 million liters of fuel wasted annually. These ten areas consume 10 billion liters annually due to congestion in their urban areas.

Table S-4. Annual Excess Fuel Consumed Due to Traffic Congestion in 1992

Urban Area	Annual Liters of Fuel Wasted (million)				Annual Excess Fuel Consumed per Capita (liters)	Rank[1]
	Recurring	Incident	Total	Rank[1]		
Los Angeles CA	1,147	1,344	2,491	1	210	5
New York NY	761	1,414	2,175	2	128	13
San Fran-Oak CA	387	489	876	3	230	3
Chicago IL	375	434	809	4	108	20
Washington DC	292	516	808	5	246	1
Detroit MI	235	387	622	6	155	11
Houston TX	237	321	558	7	192	6
Boston MA	126	356	482	8	163	9
Seattle-Everett WA	171	228	399	9	217	4
Dallas TX	140	240	380	10	182	7

Notes: [1] Rank value of 1 associated with greatest fuel consumption.

See Table 6 for complete listing of urban areas.

Source: TTI Analysis

Table S-5 combines existing freeway and principal arterial street distances with (1988 to 1992) recent annual traffic volume growth rates to produce the number of additional lane-kilometers for both freeway and principal arterial streets which would be necessary to avoid increases in areawide congestion. This value illustrates the amount of roadway that would have to be added *every year* to maintain a constant congestion level. The average amount of roadway which was added annually during this time period was also calculated. The annual deficiency in construction of lane-kilometers of freeway and principal arterial streets is shown. Detroit leads this list of cities with a deficiency of 297 lane-kilometers annually between 1988 and 1992 (92 lane-kilometers of freeway and 205 lane-kilometers of principal arterial streets).

Table S-5. Illustration of Annual Capacity Increase Required to Prevent Congestion Growth

Urban Area	Existing (1992) Lane-km		Average Annual VKT Growth (%)[1]	Annual Freeway Lane-km		Annual Prin.Art. Lane-km		Lane-km Deficiency	
	Fwy	Prin. Art.		Needed	Added	Needed	Added	Fwy	Prin. Art.
Detroit MI	2,930	6,875	5.61	164	72	386	181	92	205
Chicago IL	3,928	7,487	5.57	219	95	417	360	124	57
Baltimore MD	2,174	2,689	4.49	98	52	121	-12	46	133
Los Angeles CA	8,686	20,125	1.90	165	175	383	201	-10	182
New York NY	9,741	12,276	2.11	206	97	259	207	109	52
Miami FL	1,006	3,590	4.90	49	20	176	85	29	91
Cincinnati OH	1,473	1,328	5.66	83	28	75	12	55	63
Columbus OH	1,304	1,022	5.31	69	10	54	14	59	40
Minn-St. Paul MN	2,431	1,852	4.41	107	30	82	72	77	10
Salt Lake City UT	845	684	8.80	74	18	60	30	56	30

[1] Average Annual Growth rate of Freeway and Principal Arterial Streets Daily VKT between 1987-1991.

See Table 8 for complete listing of urban areas.

Source: TTI Analysis

The urban areas with the highest annual congestion costs are shown in Table S-6. Delay and fuel costs comprise the total congestion costs. These eleven urban areas have an annual combined congestion cost of over $33 billion. Los Angeles and New York had the highest total congestion costs with values of $8.33 billion and $7.25 billion, respectively. The final two urban areas in the table, Dallas and Philadelphia, each had a total congestion cost of $1.24 billion annually.

Table S-6. Component and Total Congestion Costs by Urban Area for 1992

Urban Area	Annual Cost Due to Congestion ($ millions)			Rank
	Delay	Fuel	Total	
Los Angeles CA	7,420	910	8,330	1
New York NY	6,450	800	7,250	2
San Fran-Oak CA	2,570	320	2,890	3
Chicago IL	2,420	310	2,730	4
Washington DC	2,410	300	2,710	5
Detroit MI	1,870	220	2,090	6
Houston TX	1,640	190	1,830	7
Boston MA	1,420	170	1,590	8
Seattle-Everett WA	1,180	150	1,330	9
Dallas TX	1,110	130	1,240	10
Philadelphia PA	1,110	130	1,240	10

See Table 9 for complete listing of urban areas.

Source: TTI Analysis and Local Transportation Agency Reference

Congestion costs can be used in relation to registered vehicles to show the economic impact on each automobile in the urban area. Table S-7 lists the top ten congestion costs per registered vehicle for 1992. Washington D.C. ranks first with a cost of $1,580 per vehicle. Dallas and Houston have costs of $750 and $810 per vehicle, respectively, or approximately $3 per workday.

Table S-7. 1992 Congestion Cost per Vehicle

Urban Area	Total Congestion Cost	
	Per Registered Vehicle (dollars)	Rank
Washington DC	1,580	1
San Bernardino-Riv. CA	1,260	2
New York NY	1,190	3
Los Angeles CA	1,060	4
Seattle-Everett WA	990	5
Boston MA	950	6
San Fran-Oak CA	930	7
San Jose CA	860	8
Houston TX	810	9
Dallas TX	750	10

See Table 10 for complete listing of urban areas.

Source: TTI Analysis

Expressing congestion costs on a per capita basis illustrates the congestion "tax" paid by residents (Table S-8). The highest 1992 cost per capita occurred in Washington, D.C. with a cost per capita of $820. Atlanta and Detroit had the smallest cost per capita ($520) of the top eleven urban areas with a cost of approximately $2 per capita for each workday.

Table S-8. 1992 Congestion Cost per Capita

Urban Area	Total Congestion Cost	
	Per Registered Vehicle (dollars)	Rank
Washington DC	820	1
San Bernardino-Riv. CA	770	2
San Fran-Oak CA	760	3
Seattle-Everett WA	720	4
Los Angeles CA	700	5
Houston, TX	630	6
Dallas, TX	590	7
San Jose CA	590	7
Boston MA	540	9
Atlanta GA	520	10
Detroit MI	520	10

See Table 10 for complete listing of urban areas.

Source: TTI Analysis

INTRODUCTION

Congestion within the inner city has long been recognized as a severe problem. Congested streets and freeways have forced residents and businesses to relocate in the surrounding suburbs. Relocating to the suburbs, however, proved to be only a temporary solution to metropolitan area congestion problems. Congestion has expanded into the suburbs, with street systems designed for service to residential areas overburdened with traffic headed to large shopping malls and business parks. Urban transportation systems have been required to serve more travel needs between suburbs and fewer trips to or from downtown business districts.

A recent study (9) showed this move to the suburbs has been occurring with the length of work trips increasing in all urban sizes. Between 1983 and 1990, work trip length in urban areas under 1 million increased by 20 percent to 13 kilometers, and by 13 percent to 17 kilometers in urban areas with populations over 1 million. The percentage of the population with a work trip length of greater than 16 kilometers increased from 19 percent of the population in 1983 to 23 percent in 1990 for urban areas under 1 million in population. This increase was also true in urban areas with over 1 million in population, with an increase from 31 percent of the population to 36 percent in 1990.

The decline in urban mobility resulting from congestion has become a major concern not only to the transportation community, but also to the motoring public and business community. The understanding that comes from measuring congestion assists transportation professionals, policy makers, the general public in communicating problems, developing necessary transportation system improvements, and in formulating new policies and programs.

PURPOSE OF CONGESTION RESEARCH

Mobility improvement in most metropolitan areas has meant choosing from a limited set of alternatives including controlling area development, spending large sums of money for general use and transit facility improvements, or accepting decline in the quality of transportation in the cities and suburbs. Transportation professionals, policy makers, the media, and the general public typically view these options as undesirable. In recent years, cities have encouraged the use of various aspects of travel demand management (TDM). Some of these techniques reduce vehicle travel, thus reducing congestion, while others only modify demand by shifting the time of travel.

Whether cities use more traditional techniques of congestion management or the more recent techniques such as TDM, measuring congestion is still a vital step in understanding the problems of congestion and aiding in the development of effective solutions to the urban mobility problem.

Previous research efforts of this series developed a quantitative procedure to compare traffic volumes and roadway systems. The procedure estimates the mobility levels within an urban area and permits the comparison of roadway networks from year to year and area to area. It is important to note that this research is areawide and does not show direct effects from particular corridors or projects within an urban area. From previous research, it was determined that approximately 95 percent of trips are contained in private auto and truck trips in an urban area. Thus, this report shows the effects of the vast majority of travel within the urban area. This research does not, however, show the effects of operational improvements, transit, or ridesharing.

CONGESTION RESEARCH BACKGROUND

This research study uses existing data from federal, state, and local agencies to develop planning estimates of the level of congestion within an urban area. The analyses presented in this report are the result of previous research (1-8) conducted at the Texas Transportation Institute. The methodology developed by the previous research provides a procedure which yields a quantitative estimate of urbanized area mobility levels, utilizing generally available data, while minimizing the need for extensive data collection.

The methodology primarily uses the Federal Highway Administration's Highway Performance Monitoring System (HPMS) database with supporting information from various state and local agencies. The HPMS database is used as a base because of the relative consistency and comprehensive nature. State departments of transportation collect, review, and report the data. Since each state classifies roadways in a slightly different manner, the data are reviewed and adjusted by TTI and then reviewed by state and local agencies familiar with each urban area.

This process was of particular importance with the 1992 HPMS data because many of the urban areas were affected by a U.S. Census realignment. This realignment may have significantly changed the size of the urban area which, in turn, would also cause a change in system length and vehicle travel with resulting changes in the areawide congestion levels. To avoid a stair-step appearance in the data, some historical data may have been changed also to make the realignment a smoother transition. Thus, some figures which have been reported in past reports may have changed in this report.

Currently, the database developed for this research contains vehicle travel, population, urban area size, and system length from 1982 to 1992. Vehicle travel and vehicle travel per lane-kilometer are used as the basis of measuring urban congestion levels and comparing areawide roadway systems.

REPORT ORGANIZATION/CONTENT

This report is the seventh of a series (3-8) of reports and is the second in the series to utilize the metric system in the analyses. Tables 1 through 26 and the tables in the Appendix of Volume 1 are reprinted in English units in Appendix A of Volume 2. It is important to note that the calculations performed in this report may produce slightly different results between the two systems due to conversions. This research report focuses on 1992 congestion levels and trends displayed by the data from 1982 to 1992. Information on the methodology and the equations utilized to produce the tables, along with detailed yearly summaries of the data are available in Volume 2 of this report.

This report summarizes and discusses urban mobility levels in 50 urban areas throughout the United States. Seven of the areas studied represent the largest urban areas in Texas; the remaining 43 areas are located in 27 states (Figure 1). These 50 areas include nearly all of the urban areas in the United States with populations of 800,000 or more that have a significant amount of congestion.

There are three major topics addressed in this report: areawide congestion, the impacts of congestion, and the cost of congestion. The following are brief descriptions of the information included within each of these topics.

Areawide Congestion

Understanding the reasons for the type and scope of the urban congestion problems has become important to transportation planners and policy makers. Quantitative estimates of congestion levels on major roadways allow comparisons of transportation systems and provide a tool to analyze the differences between different transportation systems and urban areas. This section discusses the trends in urban development, travel and system length statistics, and the 1992 Roadway Congestion Index (RCI) values for 50 urban areas included within the study.

Impacts of Congestion

This section addresses travel delay, the most apparent impact of congestion to the motoring public. Delay may be categorized into two general components—recurring and incident. The impacts of travel delay and the relationship with an urban area's roadway congestion index are analyzed. The amount of excess fuel consumed by vehicles moving slowly in traffic congestion is also estimated. The variation in delay and fuel consumption is explored using vehicle and population ratios.

Cost of Congestion

The economic impact of congestion was estimated for the 50 urban areas studied. Congestion costs have two components—travel delay and wasted fuel. Estimating the costs associated with congestion provides another tool for comparing urban mobility from one area to another. More importantly, estimating congestion costs allows a method of tracking changes in congestion levels and their impact on an urbanized area over an extended period of time. Another quantifiable impact of congestion is the additional capacity required to eliminate congestion conditions with only roadway improvements.

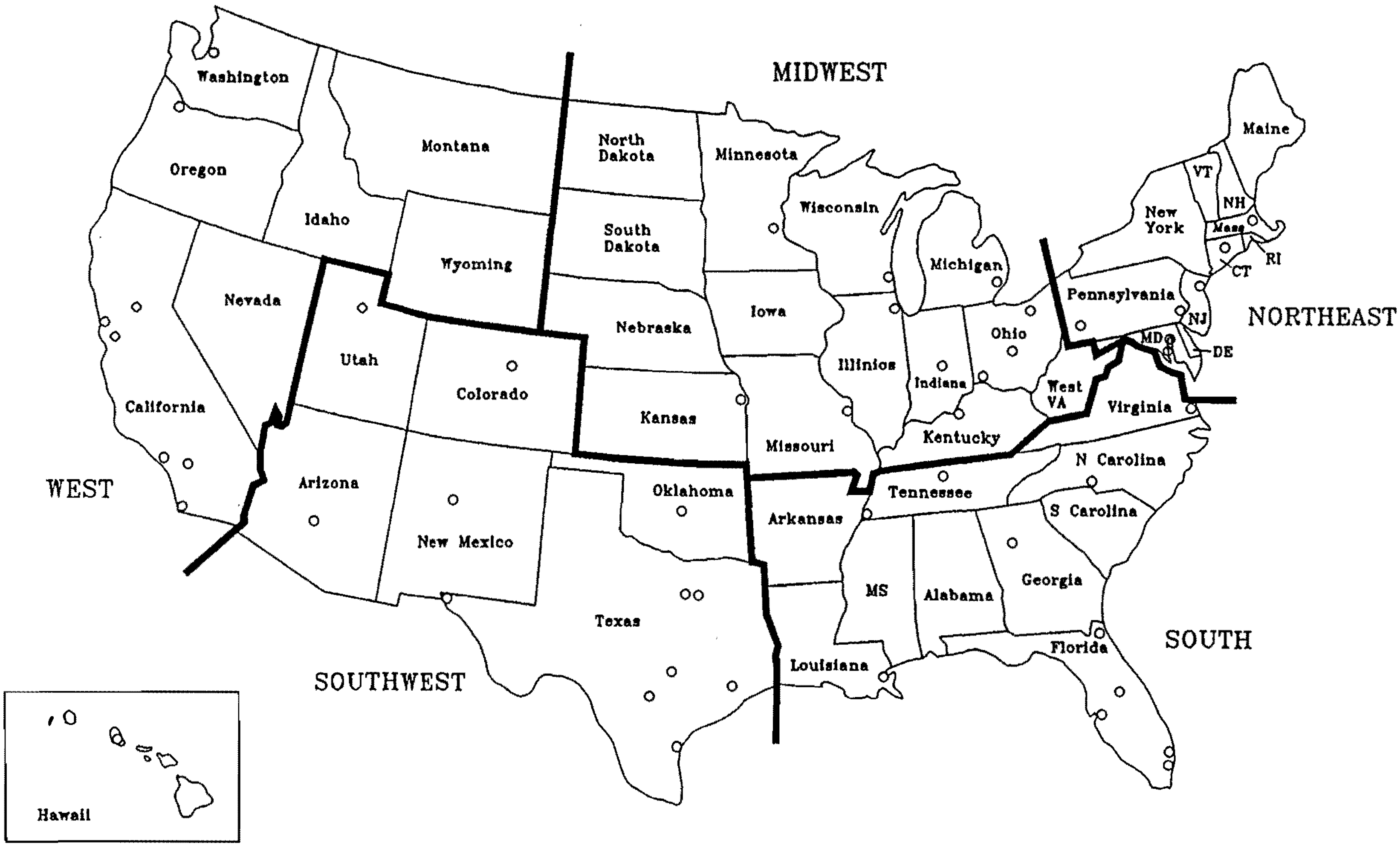

Figure 1. Regional Designations Used in Congestion Summaries

AREAWIDE MOBILITY

A 1989 report (10) identified several trends shaping traffic congestion. The interrelated forces impacting the nature and severity of congestion identified in that report include: (1) suburban development, (2) the economy, (3) the labor force, (4) automobile usage, (5) percent of truck traffic, and (6) the highway infrastructure. The following is an example of how these forces interact:

> "Trends in suburban and economic development have supported and generated increased automobile usage and truck traffic. This has resulted in increasing traffic congestion in many metropolitan areas throughout the country" (10).

TRENDS IN URBAN DEVELOPMENT

Most metropolitan areas have experienced dynamic suburban growth since the 1960s. The prevailing desire to live away from the inner city and yet be in close enough proximity to enjoy urban amenities encouraged suburban development. This evolutionary process begins with families and then expands to commercial services and jobs. The process shapes traffic congestion in most metropolitan areas by altering the commuting patterns.

The demands placed on the existing highway infrastructure in general, and by the migration of the population and employment opportunities, have not been met by new facility construction. Demands for suburban traffic movement, increasing vehicle-kilometers of travel, and more freeway access points have greatly altered the function of the freeway/expressway system in most metropolitan areas. Increases in delay are the result of the roadway system capacity not increasing to meet new demands.

The decline in new facility construction during the past 20 years may be attributed to reduced funding, increased construction costs, and public resistance to building and widening transportation facilities. These factors have promoted lower levels of mobility and greater dispersion of the metropolitan area's population. In recent years, an increasingly negative perception of the mobility level has renewed interest in the condition of transportation systems. This perception has also increased the desire of the transportation community, general public, policy makers, and numerous others to understand the causes, effects, and solutions to urban congestion.

ROADWAY CONGESTION INDEX VALUES, 1992

Urban roadway congestion levels are estimated using a formula that measures the density of traffic. Average travel volume per lane on freeways and principal arterial streets are estimated using areawide estimates of vehicle-kilometers of travel (VKT) and lane-kilometers of roadway (Ln-Km). The resulting ratios are combined into one value using the amount of travel on each portion of the system. This variable weighting factor allows comparisons between areas such as Phoenix, where principal arterial streets carry twice the amount of travel of freeways, and cities such as Portland where the ratio is reversed.

The traffic density ratio is divided by a similar ratio that represents congestion for a system with the same mix of freeway and street volume. While it may appear that the travel volume factors on the top and bottom of the equation cancel each other, a sample calculation should satisfy the reader that this is not the case.

Equation 1 illustrates the factors used in the estimate and their combination. The resulting ratio indicates an undesirable level of <u>areawide</u> congestion if a value greater than or equal to 1.0 is obtained.

$$\text{Roadway Congestion Index (RCI)} = \frac{\dfrac{\text{Freeway}}{\text{VKT/Ln.-Km.}} \times \dfrac{\text{Freeway}}{\text{VKT}} + \dfrac{\text{Prin Art Str}}{\text{VKT/Ln.-Km.}} \times \dfrac{\text{Prin Art Str}}{\text{VKT}}}{13{,}000 \times \dfrac{\text{Freeway}}{\text{VKT}} + 5{,}000 \times \dfrac{\text{Prin Art Str}}{\text{VKT}}} \qquad \text{Eq. 1}$$

The congestion index is a macroscopic measure which does not account for local bottlenecks or variations in travel patterns that affect time of travel or origin-destination combinations. It also does not indicate the improvements such as ramp metering, or of treatments designed to give a travel speed advantage to transit and carpool riders.

1992 Roadway Congestion Index Estimates

Table 1 lists the roadway congestion index values for 1992. Of the 50 urban areas studied, 26 have 1992 RCI values of or exceeding 1.0. RCI values for the ten most congested urban areas range from 1.56 (Los Angeles) to 1.17 (Atlanta). Sixteen urban areas have estimated RCI values ranging between 0.90 and 0.99 indicating the potential approach of undesirable congestion levels. These areas may not currently experience undesirable levels of congestion; however, traffic growth rates indicate congestion levels could become undesirable within the next few years in many of these cities.

The Western region has the highest average RCI value (1.20), and the Northeastern (1.05) and Southern (1.0) regional averages also exceeded 1.0. The Southwestern and Midwestern regions have average RCI values below 1.0.

Four areas in California ranked in the top ten including two from the Los Angeles Metropolitan area (also San Bernardino-Riverside). None of the urban areas studied in Texas were included in the ten most congested areas. Houston (12th) and Dallas (17th) were the only urban areas studied in Texas which were in the twenty most congested urban areas. Austin had the next highest rank of the Texas urban areas (30th). Florida was the only other state with more than one area in the twenty most congested systems.

The limitation of any roadway congestion estimate based on traffic volumes, however, is that only part of the land use-transportation system is addressed. As Richardson et al. point out, travel times for work trips have not substantially increased between 1983 to 1990 (11). This reflects the impact of "urban sprawl" as a congestion relief mechanism. As congestion has

Table 1. 1992 Roadway Congestion Index Value

Urban Area	Freeway/Expressway		Principal Arterial Street		Roadway/[3] Congestion Index	Rank
	Daily VKT[1] (1000)	Daily VKT/[2] Ln-Km	Daily VKT[1] (1000)	Daily VKT/[2] Ln-Km		
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Washington DC	44,190	16,940	29,790	7,970	1.36	2
San Fran-Oak CA	68,100	17,410	22,830	6,110	1.33	3
Miami FL	15,090	14,990	27,050	7,530	1.30	4
Chicago IL	63,110	16,070	52,810	7,050	1.28	5
San Bernardino-Riv CA	24,330	16,600	17,310	5,120	1.22	6
San Diego CA	44,760	15,980	15,620	5,590	1.22	6
Seattle-Everett WA	32,640	15,960	15,780	6,030	1.22	6
Detroit MI	46,050	15,710	39,450	5,740	1.19	9
Atlanta GA	42,670	15,140	16,100	6,170	1.17	10
New York NY	134,440	13,800	89,070	7,260	1.14	11
Houston TX	49,110	14,700	17,940	5,110	1.12	12
Honolulu HI	8,190	13,570	2,810	7,430	1.10	13
New Orleans LA	8,130	13,470	6,760	6,410	1.10	13
Portland OR	12,830	13,860	6,300	6,460	1.10	13
Phoenix AZ	15,700	13,930	29,150	5,470	1.08	16
Boston MA	35,250	14,450	20,920	4,560	1.07	17
Dallas TX	39,450	14,000	13,770	4,890	1.07	17
San Jose CA	26,730	13,840	11,910	5,360	1.07	17
Tampa FL	6,120	12,260	7,490	6,640	1.07	17
Denver CO	20,130	13,020	17,710	5,910	1.05	21
Philadelphia PA	31,220	12,010	34,860	6,640	1.05	21
Baltimore MD	28,340	13,040	15,940	5,930	1.04	23
Sacramento CA	16,290	12,640	12,450	6,240	1.04	23
Cincinnati OH	19,180	13,020	7,250	5,450	1.01	25
Milwaukee WI	12,610	13,060	8,370	4,910	1.00	26
Minn-St. Paul MN	30,590	12,580	10,950	5,910	0.99	27
Jacksonville FL	9,270	12,650	9,890	4,800	0.97	28
Ft. Lauderdale FL	12,480	11,920	10,220	5,520	0.96	29
Albuquerque NM	4,030	10,870	6,920	5,580	0.95	30
Austin TX	9,100	12,280	3,540	4,940	0.95	30
Cleveland OH	22,800	12,000	10,140	5,530	0.95	30
St. Louis MO	30,480	11,140	20,090	6,590	0.95	30
Fort Worth TX	20,610	12,190	6,990	4,820	0.94	34
Columbus OH	15,230	11,680	5,760	5,630	0.93	35
Memphis TN	8,100	11,430	8,070	5,110	0.92	36
Nashville TN	9,660	10,910	8,860	5,730	0.92	36
Norfolk VA	9,450	10,480	7,690	6,370	0.92	36
Hartford CT	10,870	11,160	6,180	5,860	0.91	39
Louisville KY	10,510	10,790	5,350	6,330	0.90	40
Salt Lake City UT	9,300	11,000	4,150	6,060	0.90	40
San Antonio TX	16,000	11,290	9,560	5,280	0.90	40
Charlotte NC	5,150	10,490	5,150	5,520	0.89	43
Indianapolis IN	13,390	10,800	6,840	4,800	0.85	44
Oklahoma City OK	11,750	10,070	6,390	5,510	0.83	45
Pittsburgh PA	14,710	8,160	17,870	5,980	0.81	46
Orlando FL	9,740	10,080	7,810	4,450	0.80	47
Kansas City MO	22,060	9,720	7,870	4,490	0.77	48
El Paso TX	5,640	9,860	5,350	3,890	0.76	49
Corpus Christi TX	2,700	8,910	2,630	4,370	0.74	50
Northeastern Avg	42,710	12,790	30,660	6,310	1.05	
Midwestern Avg	24,810	12,220	15,110	5,660	0.97	
Southern Avg	12,350	12,170	10,460	5,840	1.00	
Southwestern Avg	17,430	12,000	10,700	5,120	0.95	
Western Avg	46,010	15,620	26,430	6,100	1.20	
Texas Avg	20,370	11,890	8,540	4,760	0.93	
Total Avg	26,770	12,850	17,330	5,750	1.03	
Maximum Value	180,240	20,750	132,830	7,970	1.54	
Minimum Value	2,700	8,160	2,630	3,890	0.74	

Notes: [1] Daily vehicle-kilometers of travel.
[2] Daily vehicle-kilometers of travel per lane-kilometer.
[3] See Equation 1.

Source: TTI Analysis

grown in certain corridors, jobs, residences or both have relocated to take advantage of less congested roads. Trip lengths and travel speeds can thus both increase as traffic volumes rise due to growth in development. As more development occurs outside the defined urban area, urban area residents make more trips on the roadway system. The long term sustainability of this growth pattern is being debated, but there is no doubt as to its impact on transportation systems.

Travel time is a very useful congestion measure. It can be used in multimodal analyses and can illustrate the effect of operational improvements and policy changes designed to make the land use/transportation system function better. Unfortunately, if an analysis focuses only on the work trip, it ignores approximately 50 percent of weekday peak period vehicle trips and 66 percent of weekday vehicle trips. In addition, since 1969, work trips have declined from 36 to 28 percent of total vehicle-trips while family and personal business trips have increased from 31 to 45 percent of total vehicle trips. To suggest that congestion is not increasing because work trip travel times have not substantially changed, is to ignore traffic volumes that are significantly larger than roadway designs envisioned and to discount the effect of three hour peak periods on economic activity in congested travel corridors.

Roadway Congestion Index Growth, 1982 to 1992

Table 2 summarizes roadway congestion index values for all 50 urban for certain years between 1982 to 1992. During the study period, San Diego, Salt Lake City, and Columbus were estimated to have experienced the fastest increase in congestion, while Phoenix, Houston, and Pittsburgh have experienced the smallest. Growth over the last half of the study period was also identified. Significant changes were noted which seem to reflect a combination of infrastructure investment and economic activity. Slower economic growth and freeway and street expansions funded by increases in fuel tax in the early 1980s have slowed the growth of roadway congestion in Texas relative to most other states. Salt Lake City, Columbus, and Cincinnati showed the greatest growth over this shorter period while Phoenix, Houston, and Austin fared the best.

Table 2. Roadway Congestion Index Values, 1982 to 1992

Rank of % Change 1982-92	Rank of % Change 1987-92	Urban Area	Percent Change 1982-92	Percent Change 1987-92	1982	1984	1986	1987	1988	1990	1991	1992
1	1	Phoenix AZ	(6)	(8)	1.15	1.10	1.20	1.18	1.04	1.05	1.08	1.08
2	2	Houston TX	(4)	(6)	1.17	1.25	1.21	1.19	1.15	1.12	1.11	1.12
3	11	Pittsburgh PA	4	3	0.78	0.76	0.79	0.79	0.81	0.82	0.82	0.81
4	8	Philadelphia PA	5	(1)	1.00	1.04	1.06	1.06	1.07	1.05	1.05	1.05
5	14	Jacksonville FL	7	3	0.91	0.96	0.95	0.94	0.95	0.93	0.95	0.97
6	30	San Bernardino-Riv CA	10	7	1.11	1.13	1.15	1.14	1.18	1.21	1.22	1.22
7	28	Ft. Lauderdale FL	10	7	0.87	0.86	0.85	0.90	0.90	0.94	0.95	0.96
8	12	Corpus Christi TX	10	3	0.67	0.69	0.71	0.72	0.70	0.72	0.72	0.74
9	38	Memphis TN	11	10	0.83	0.79	0.80	0.84	0.86	0.89	0.91	0.92
10	16	Orlando FL	11	4	0.72	0.73	0.76	0.77	0.78	0.77	0.78	0.80
11	4	New Orleans LA	12	(4)	0.98	1.05	1.09	1.14	1.13	1.12	1.12	1.10
12	47	Detroit MI	12	14	1.06	1.07	1.05	1.04	1.07	1.13	1.16	1.19
13	33	New York NY	13	8	1.01	0.99	1.06	1.06	1.10	1.14	1.14	1.14
14	3	Austin TX	13	(5)	0.84	0.86	0.94	1.00	0.96	0.94	0.94	0.95
15	23	Tampa FL	14	5	0.94	1.03	0.96	1.02	1.03	1.05	1.05	1.07
16	6	St. Louis MO	14	(1)	0.83	0.88	0.93	0.96	0.98	0.95	0.95	0.95
17	37	Oklahoma City OK	15	9	0.72	0.75	0.76	0.76	0.78	0.79	0.81	0.83
18	19	Louisville KY	15	5	0.78	0.82	0.80	0.86	0.87	0.86	0.88	0.90
19	5	Norfolk VA	16	(1)	0.79	0.81	0.90	0.93	0.94	0.96	0.93	0.92
20	19	San Antonio TX	17	5	0.77	0.82	0.88	0.86	0.86	0.88	0.89	0.90
21	48	Cincinnati OH	17	16	0.86	0.82	0.84	0.87	0.88	0.96	0.99	1.01
22	29	Cleveland OH	19	7	0.80	0.83	0.86	0.89	0.97	0.94	0.95	0.95
23	13	Boston MA	19	3	0.90	0.95	1.04	1.04	1.12	1.06	1.06	1.07
24	39	Denver CO	19	11	0.88	0.93	0.97	0.95	0.99	1.03	1.03	1.05
25	15	Nashville TN	19	3	0.77	0.83	0.86	0.89	0.94	0.89	0.90	0.92
26	21	Honolulu HI	20	5	0.92	0.95	1.03	1.05	1.07	1.09	1.10	1.10
27	18	Hartford CT	20	5	0.76	0.86	0.85	0.87	0.90	0.89	0.89	0.91
28	25	Milwaukee WI	20	5	0.83	0.87	0.90	0.95	0.94	0.99	1.00	1.00
29	32	El Paso TX	21	7	0.63	0.65	0.75	0.71	0.74	0.74	0.75	0.76
30	27	Washington DC	21	5	1.12	1.11	1.27	1.29	1.30	1.34	1.33	1.36
31	6	Albuquerque NM	22	(1)	0.78	0.89	0.96	0.96	0.96	0.98	0.96	0.95
32	34	Fort Worth TX	24	8	0.76	0.80	0.87	0.87	0.87	0.90	0.92	0.94
33	45	Miami FL	24	14	1.05	1.10	1.14	1.14	1.18	1.27	1.28	1.30
34	46	Baltimore MD	24	14	0.84	0.85	0.88	0.91	0.92	1.01	1.02	1.04
35	36	Kansas City MO	24	8	0.62	0.60	0.68	0.71	0.72	0.74	0.75	0.77
36	35	San Jose CA	24	8	0.86	0.91	0.97	0.99	1.00	1.05	1.08	1.07
37	43	Charlotte NC	25	13	0.71	0.76	0.78	0.79	0.80	0.86	0.89	0.89
38	42	Chicago IL	25	11	1.02	1.05	1.15	1.15	1.18	1.25	1.27	1.28
39	22	Los Angeles CA	26	5	1.22	1.32	1.42	1.47	1.52	1.55	1.56	1.54
40	40	Portland OR	26	11	0.87	0.88	0.97	0.99	1.04	1.08	1.08	1.10
41	9	Indianapolis IN	27	0	0.67	0.75	0.81	0.85	0.85	0.84	0.84	0.85
42	23	Dallas TX	27	5	0.84	0.94	1.04	1.02	1.02	1.05	1.06	1.07
43	30	Seattle-Everett WA	28	7	0.95	1.02	1.09	1.14	1.17	1.20	1.20	1.22
44	26	Atlanta GA	29	5	0.91	0.97	1.09	1.11	1.14	1.14	1.16	1.17
45	17	Sacramento CA	30	4	0.80	0.88	0.95	1.00	1.03	1.02	1.04	1.04
46	41	Minn-St. Paul MN	30	11	0.76	0.84	0.89	0.89	0.90	0.95	0.96	0.99
47	10	San Fran-Oak CA	32	2	1.01	1.12	1.24	1.31	1.33	1.36	1.34	1.33
48	49	Columbus OH	37	19	0.68	0.71	0.75	0.78	0.79	0.89	0.91	0.93
49	50	Salt Lake City UT	43	29	0.63	0.65	0.68	0.70	0.72	0.85	0.88	0.90
50	44	San Diego CA	56	13	0.78	0.91	1.00	1.08	1.13	1.22	1.22	1.22
		Northeastern Avg	14	5	0.92	0.94	0.99	1.00	1.03	1.04	1.04	1.05
		Midwestern Avg	21	9	0.80	0.83	0.87	0.89	0.91	0.94	0.96	0.97
		Southern Avg	16	5	0.86	0.90	0.93	0.95	0.97	0.98	0.99	1.00
		Southwestern Avg	14	3	0.83	0.87	0.93	0.92	0.91	0.93	0.94	0.95
		Western Avg	26	6	0.95	1.01	1.09	1.13	1.16	1.20	1.20	1.20
		Texas Avg	14	2	0.81	0.86	0.91	0.91	0.90	0.91	0.91	0.93
		Total Avg	20	6	0.86	0.90	0.95	0.97	0.99	1.01	1.02	1.03
		Maximum Value	56	29	1.22	1.32	1.42	1.47	1.52	1.55	1.56	1.54
		Minimum Value	(6)	(8)	0.62	0.60	0.68	0.70	0.70	0.72	0.72	0.74

Source: TTI Analysis

Half of the urban areas have experienced at least 20 percent growth between 1982 and 1992. Of the urban areas in Texas, Dallas has the largest increase in RCI from 1982 levels (27 percent). The summary statistics show that no geographic region experienced a decrease in average 1992 RCI values from 1992 levels. The Western average has shown no change in RCI value since 1990.

Figure 2 illustrates trend data for the Texas urban areas studied. This figure graphically shows that 1992 was the first year since 1983 in which all seven Texas urban areas experienced an increase in congestion levels. Austin, Fort Worth, and San Antonio are all above the 0.90 level which means they could reach the 1.00 level in the next few years.

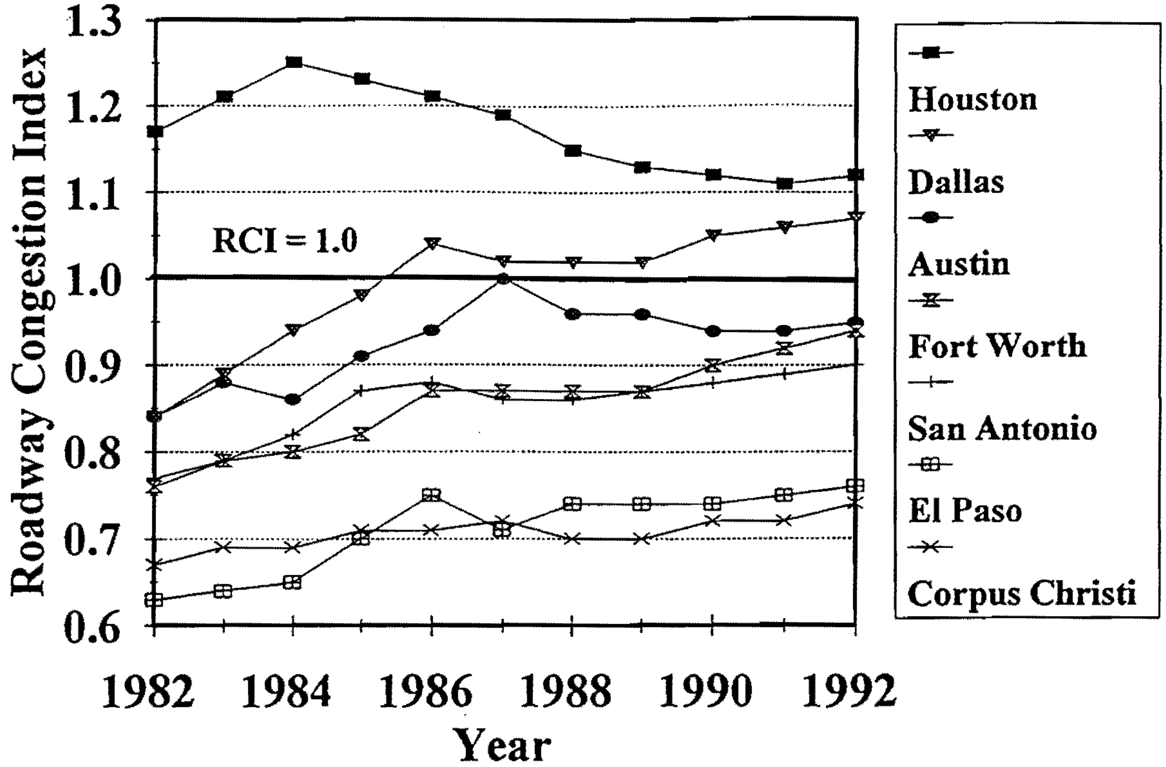

Figure 2. Texas Urban Area Congestion Levels 1982 - 1992

TRAVEL DELAY

Travel delay is the most apparent impact of congestion to the motoring public. Analyses of delay have generally been divided into two estimates—recurring and incident. Recurring delay occurs due to normal daily operations. This type of delay occurs when demand for roadway facilities is near or exceeds capacity. The most common example of recurring delay is the increased travel time during peak periods.

Accidents, breakdowns, or other occurrences which temporarily decrease roadway capacity cause incident delay. When congestion levels increase (creating higher RCI values), it is the recurring delay that is being measured. Incident delay is not directly related to or caused by high traffic volume congestion, but the delay resulting from incidents significantly increases under congested conditions.

Estimates of travel delay are based on categorizing roadway traffic into four levels of severity—uncongested, moderate, heavy, and severe. These categories are based on the average daily traffic volume per lane values in the HPMS sample sections for each urbanized area. The percentage of travel (Daily VKT) in each congestion category from the sample section data was applied to the areawide travel estimates for freeways and principal arterial streets. The values were multiplied by 45 percent to estimate the amount of total travel during the peak periods. It is important to note that all of these calculations are performed on morning and evening peak period congestion. These estimates do not include midday, weekend, and special event congestion.

The speeds shown in Table 3 for each of the four congested categories were derived from extensive observations combined with the travel volume for each of the four categories to estimate total travel time. This time was compared to travel time at free-flow speed (uncongested); the difference is the amount of travel delay for that congestion category.

Table 3. Speed Relationships with Average Daily Traffic (ADT) per Lane Volumes

Functional Class	Parameters	Severity of Congestion[1,2]			
		Uncongested	Moderate	Heavy	Severe
Freeway/Expressway	ADT/Lane	Under 15,000	15,000 - 17,500	17,501 - 20,000	Over 20,000
	Speed (kph)[3]	100	61	53	48
Principal Arterial Streets	ADT/Lane	Under 5,750	5,750 - 7,000	7,001 - 8,500	Over 8,500
	Speed (kph)[3]	60	45	40	37

Note: [1] Assumes congested freeway operation when ADT/Lane exceeds 15,000.
[2] Assumes congested principal arterial street operations when ADT/lane exceeds 5,750.
[3] Moderate, Heavy, and Severe values represent a "soft" conversion from miles per hour.

Source: TTI Analysis and Houston-Galveston Regional Transportation Study (Volume 2, Appendix B)

The estimate of recurring delay is used as a basis for the estimate of incidents. The incident delay calculation is based on research by Lindley (16); that research is quantified in this report as ratios of incident to recurring delay (Volume 2—Appendix C). Incident delay on principal arterial streets was not studied by Lindley, but based on street characteristics and freeway delay ratios; the principal arterial street ratio is estimated as 1.1 for all study areas. Table 4 summarizes the vehicle-hours of delay by delay type.

Table 4 illustrates the daily delay estimates and rankings. Vehicle-hours of delay are translated into person-hours of delay and area annualized after being normalized by population. A ranking of these values are also shown. Summary statistics show that the Western and Northeastern regions have the largest average per capita delay, while the Midwestern region has the least.

The annual delay per person quantifies the congestion levels independent of urban area size and population. Ranking delay in this manner allows an evaluation similar to the RCI in that it analyzes the effects on individual motorists. Figure 3 illustrates this comparison.

Table 4. Daily Vehicle Hours of Delay for 1992

Urban Area	Daily Vehicle Hours of Delay (000)				Annual Hours of Delay per Capita	Rank[1]
	Recurring	Incident	Total	Rank[1]		
Northeastern Cities						
Baltimore MD	55	102	157	18	24	22
Boston MA	95	269	364	8	38	9
Hartford CT	13	24	37	41	19	30
New York NY	579	1,076	1,655	2	31	13
Philadelphia PA	123	168	291	10	18	35
Pittsburgh PA	47	74	121	21	20	28
Washington DC	224	397	621	5	59	1
Midwestern Cities						
Chicago IL	289	335	624	4	26	19
Cincinnati OH	31	27	58	33	15	38
Cleveland OH	36	30	66	30	11	42
Columbus OH	30	25	55	34	18	35
Detroit MI	183	302	484	6	38	9
Indianapolis IN	9	11	20	48	7	49
Kansas City MO	14	30	44	38	11	42
Louisville KY	13	14	27	43	10	45
Milwaukee WI	24	25	50	35	13	41
Minn-St. Paul MN	60	58	118	22	17	37
Oklahoma City OK	12	13	26	44	11	42
St. Louis MO	59	67	126	20	20	28
Southern Cities						
Atlanta GA	129	141	270	12	37	11
Charlotte NC	18	17	35	42	22	24
Ft. Lauderdale FL	34	45	79	25	19	30
Jacksonville FL	26	34	60	32	25	21
Memphis TN	12	13	26	44	9	46
Miami FL	102	127	228	14	37	11
Nashville TN	19	20	39	40	21	27
New Orleans LA	26	40	66	29	19	30
Norfolk VA	26	50	76	26	24	22
Orlando FL	18	25	43	39	15	38
Tampa FL	23	28	51	35	22	24
Southwestern Cities						
Albuquerque NM	11	12	23	46	14	40
Austin TX	24	26	50	35	28	17
Corpus Christi TX	2	2	4	50	5	50
Dallas TX	103	176	279	11	42	7
Denver CO	75	78	153	19	30	14
El Paso TX	7	7	14	49	8	47
Fort Worth TX	40	68	108	23	28	17
Houston TX	177	239	416	7	45	6
Phoenix AZ	103	84	187	16	29	15
Salt Lake City UT	12	9	21	47	8	47
San Antonio TX	34	38	72	28	19	30
Western Cities						
Honolulu HI	25	40	65	31	29	15
Los Angeles CA	881	1,032	1,913	1	50	5
Portland OR	33	55	88	24	26	19
Sacramento CA	39	34	73	27	19	30
San Bernardino-Riv CA	106	124	230	13	55	2
San Diego CA	106	72	178	17	22	24
San Fran-Oak CA	290	366	656	3	54	3
San Jose CA	93	109	202	15	42	7
Seattle-Everett WA	129	171	300	9	51	4
Northeastern Avg	162	301	463		24	
Midwestern Avg	63	78	141		13	
Southern Avg	39	49	88		18	
Southwestern Avg	53	67	120		19	
Western Avg	189	223	412		31	
Texas Avg	55	80	135		20	
Total Avg	92	127	219		20	
Maximum Value	881	1,076	1,913		59	
Minimum Value	2	2	4		5	

Notes: [1] Rank value of 1 associated with most congested conditions.

Source: TTI Analysis

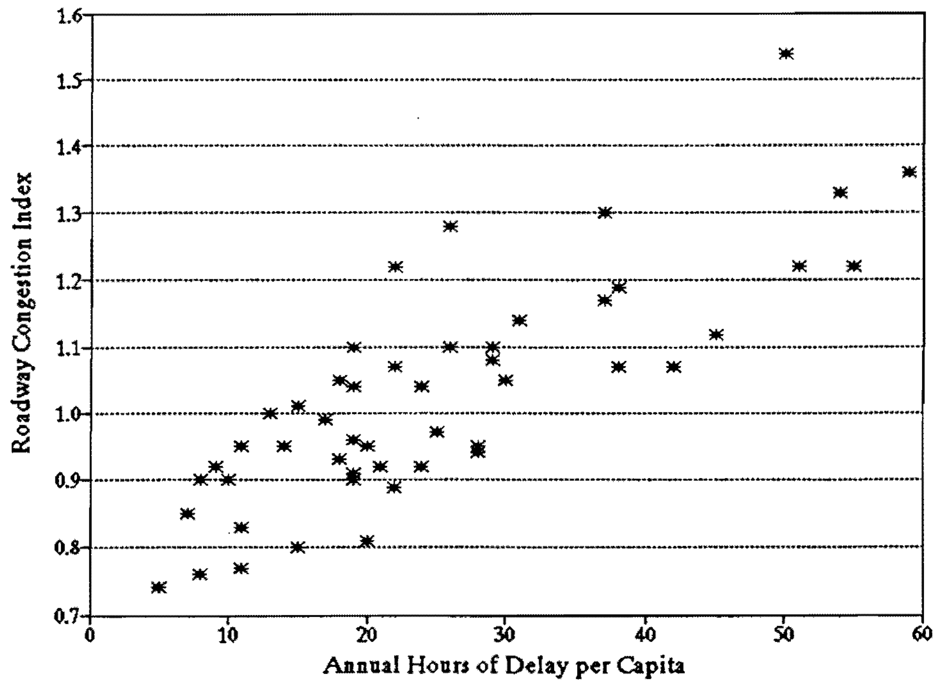

Figure 3. Roadway Congestion Index and Annual Delay per Capita

Table 5 gives the annual delay per capita in each urban area for certain years from 1986 to 1992. Thirty-two of the 50 urban areas had at least a 20 percent growth in delay per capita over the seven-year period. Twelve of the areas had at least a 50 percent delay per capita growth in the same period. Cincinnati and Salt Lake City showed at least a 100 percent increase in delay per capita during this same time. Philadelphia, Austin, and Dallas showed small decreases during this seven-year period. Six urban areas—Atlanta, New Orleans, Norfolk, Orlando, and San Antonio—showed no change in delay per capita during this period.

The summary statistics show that all regions except Texas had at least a 20 percent growth in delay per capita between 1986 and 1992. The Texas cities displayed an 18 percent increase in delay per capita over this period. The Midwestern region showed the largest percent increase in annual delay per capita over the seven-year period.

Table 5. Annual Hours of Delay per Capita, 1986 to 1992

Urban Area	Annual Delay per Capita					% Change 1986 - 1992
	1986	1988	1990	1991	1992	
Northeastern Cities						
Baltimore MD	16	17	20	20	24	50
Boston MA	33	39	37	38	38	15
Hartford CT	11	16	18	17	19	73
New York NY	25	27	29	29	31	24
Philadelphia PA	19	20	19	18	18	(5)
Pittsburgh PA	16	19	20	19	20	25
Washington DC	46	50	55	53	59	28
Midwestern Cities						
Chicago IL	21	20	22	23	26	24
Cincinnati OH	7	11	12	12	15	114
Cleveland OH	6	7	10	10	11	83
Columbus OH	11	13	18	17	18	64
Detroit MI	26	30	33	35	38	46
Indianapolis IN	4	5	6	6	7	75
Kansas City MO	6	7	8	8	11	83
Louisville KY	7	7	8	8	10	43
Milwaukee WI	10	11	12	12	13	30
Minn-St. Paul MN	12	16	16	16	17	42
Oklahoma City OK	8	10	9	9	11	38
St. Louis MO	18	19	20	20	20	11
Southern Cities						
Atlanta GA	37	36	36	36	37	0
Charlotte NC	17	18	21	22	22	29
Ft. Lauderdale FL	14	15	18	18	19	36
Jacksonville FL	18	20	24	23	25	39
Memphis TN	6	7	7	8	9	50
Miami FL	27	35	39	38	37	37
Nashville TN	17	24	22	22	21	24
New Orleans LA	19	20	20	20	19	0
Norfolk VA	24	25	26	25	24	0
Orlando FL	15	14	14	14	15	0
Tampa FL	19	21	21	21	22	16
Southwestern Cities						
Albuquerque NM	10	11	14	13	14	40
Austin TX	30	29	28	27	28	(7)
Corpus Christi TX	3	3	3	4	5	67
Dallas TX	44	41	43	42	42	(5)
Denver CO	23	23	27	29	30	30
El Paso TX	5	6	5	5	8	60
Fort Worth TX	27	26	26	28	28	4
Houston TX	43	42	43	44	45	5
Phoenix AZ	25	27	27	28	29	16
Salt Lake City UT	4	5	6	7	8	100
San Antonio TX	19	17	17	17	19	0
Western Cities						
Honolulu HI	25	25	26	26	29	16
Los Angeles CA	47	49	51	50	50	6
Portland OR	15	20	22	22	26	73
Sacramento CA	15	17	20	18	19	27
San Bernardino-Riv CA	51	53	54	53	55	8
San Diego CA	16	23	23	23	22	38
San Fran-Oak CA	51	56	57	55	54	6
San Jose CA	38	43	43	42	42	11
Seattle-Everett WA	36	46	48	48	51	42
Northeastern Avg	24	26	27	27	29	30
Midwestern Avg	11	12	15	15	17	54
Southern Avg	19	21	22	22	22	21
Southwestern Avg	21	21	21	22	23	28
Western Avg	33	37	39	37	39	25
Texas Avg	24	24	23	24	25	18
Total Avg	21	23	23	24	25	33
Maximum Value	51	56	57	55	59	114
Minimum Value	3	3	3	3	5	(7)

Source: TTI Analysis

One direct effect of congestion is that excess fuel is consumed while vehicles drive in congested traffic conditions. The excess fuel consumed in congestion is estimated from the speeds used in the travel delay estimates. Raus (24) developed an equation for fuel economy that is appropriate for use with areawide speed and travel estimates. Equation 2 is a simple linear relationship between average speed and vehicle fuel efficiency. The speeds for the three congested categories of travel and the uncongested range were used in Equation 2 to estimate fuel economy values for each range. The amount of peak period travel was combined with the fuel consumption rate for each congested category to estimate the amount of fuel consumed in excess of that which would have been consumed during uncongested travel.

$$\frac{\textit{Fuel Economy}}{\textit{(kilometers per liter)}} = 3.74 + 0.11 \frac{\textit{(average vehicular speed)}}{\textit{(kilometers per hour)}} \qquad \text{Eq. 2}$$

Table 6 shows the annual excess fuel consumed in congested travel within the study areas. Los Angeles and New York had the highest fuel consumption with more than 2 billion liters wasted annually. Houston ranked seventh with 560 million liters consumed annually due to congestion. Dallas was the only other Texas urban area in the top ten (380 million liters). To see the effect of this on the individual motorist, the wasted fuel was normalized by population. Washington D.C. had the most fuel consumed per person with about 246 liters. This value shows that each person wastes almost 1 liter per workday, in congested travel. Houston and Dallas rank in the top ten urban areas with about 190 and 180 liters per person.

The annual amount of fuel wasted due to congestion for certain years from 1986 to 1992 is shown in Table 7. Five urban areas, Cincinnati, Cleveland, Indianapolis, Kansas City, and Salt Lake City, experienced at least a 100 percent increase in the amount of wasted fuel. The summary statistics show that the Midwestern, Northeastern, and Southern regions had the highest average growth over the period. The Southwestern region and Texas were the only two which did not surpass a 25 percent growth in wasted fuel over the seven-year period.

Table 6. Annual Excess Fuel Consumed Due to Traffic Congestion in 1992

Urban Area	Annual Liters of Fuel Wasted (million)				Annual Excess Fuel Consumed per Capita (liters)	Rank[2]
	Recurring	Incident	Total	Rank[1]		
Northeastern Cities						
Baltimore MD	72	135	207	18	102	23
Boston MA	126	356	482	8	163	9
Hartford CT	17	32	49	41	79	34
New York NY	761	1,414	2,175	2	128	13
Philadelphia PA	154	211	365	11	73	37
Pittsburgh PA	59	93	152	22	81	31
Washington DC	292	516	808	5	246	1
Midwestern Cities						
Chicago IL	375	434	809	4	108	20
Cincinnati OH	42	37	79	32	65	38
Cleveland OH	49	40	89	29	50	42
Columbus OH	39	32	71	34	75	35
Detroit MI	235	387	622	6	155	11
Indianapolis IN	12	15	27	48	28	49
Kansas City MO	18	41	59	38	49	43
Louisville KY	16	18	34	43	41	45
Milwaukee WI	32	33	65	36	53	41
Minn-St. Paul MN	79	77	156	21	74	36
Oklahoma City OK	16	17	33	45	45	44
St. Louis MO	77	87	164	20	83	28
Southern Cities						
Atlanta GA	170	187	357	12	157	10
Charlotte NC	23	23	46	42	91	25
Ft. Lauderdale FL	45	60	105	25	82	29
Jacksonville FL	35	44	79	32	104	21
Memphis TN	16	18	34	43	38	46
Miami FL	129	161	290	14	151	12
Nashville TN	25	27	52	40	87	27
New Orleans LA	35	53	88	30	80	32
Norfolk VA	34	65	99	26	103	22
Orlando FL	24	33	57	39	65	38
Tampa FL	29	35	64	37	89	26
Southwestern Cities						
Albuquerque NM	14	15	29	46	56	40
Austin TX	33	36	69	35	122	16
Corpus Christi TX	3	3	6	50	22	50
Dallas TX	140	240	380	10	182	7
Denver CO	99	103	202	19	126	14
El Paso TX	9	10	19	49	34	47
Fort Worth TX	54	92	146	23	122	16
Houston TX	237	321	558	7	192	6
Phoenix AZ	132	108	240	17	119	18
Salt Lake City UT	16	13	29	46	33	48
San Antonio TX	46	51	97	27	82	29
Western Cities						
Honolulu HI	33	52	85	31	124	15
Los Angeles CA	1,147	1,344	2,491	1	210	5
Portland OR	44	73	117	24	111	19
Sacramento CA	51	45	96	28	80	32
San Bernardino-Riv CA	139	163	302	13	232	2
San Diego CA	145	98	243	16	98	24
San Fran-Oak CA	387	489	876	3	230	3
San Jose CA	123	145	268	15	178	8
Seattle-Everett WA	171	228	399	9	217	4
Northeastern Avg	211	391	602		130	
Midwestern Avg	83	103	186		90	
Southern Avg	51	64	115		107	
Southwestern Avg	71	90	161		129	
Western Avg	250	295	545		190	
Texas Avg	75	108	183		145	
Total Avg	122	167	289		132	
Maximum Value	1,213	1,481	2,694		246	
Minimum Value	3	3	6		22	

Notes: [1] Rank value of 1 associated with greatest fuel consumption.
[2] Rank value of 1 associated with greatest fuel consumption per capita.

Source: TTI Analysis

Table 7. Annual Wasted Fuel Due to Congestion

Urban Area	Annual Wasted Liters (millions)					% Change 1986 - 1992	Rank
	1986	1988	1990	1991	1992		
Cincinnati OH	36	54	60	66	79	119	1
Salt Lake City UT	13	17	20	25	28	115	2
Kansas City MO	28	35	37	37	59	111	3
Indianapolis IN	13	22	24	24	27	108	4
Cleveland OH	44	59	77	78	89	102	5
Hartford CT	27	41	45	44	49	81	6
Columbus OH	40	47	63	66	72	80	7
Memphis TN	19	23	26	30	34	79	8
San Diego CA	137	219	235	237	243	77	9
Portland OR	67	87	96	98	117	75	10
Seattle-Everett WA	240	322	359	370	399	66	11
Minn-St. Paul MN	95	127	138	143	155	63	12
Baltimore MD	128	141	169	172	207	62	13
Charlotte NC	28	33	39	43	45	61	14
Sacramento CA	60	76	90	90	96	60	15
El Paso TX	12	13	13	13	19	58	16
Ft. Lauderdale FL	67	77	95	97	105	57	17
Jacksonville FL	51	59	73	73	79	55	18
Louisville KY	22	24	25	27	34	55	18
Albuquerque NM	19	23	28	27	29	53	20
Corpus Christi TX	4	4	4	5	6	50	21
Detroit MI	421	477	541	575	621	48	22
Miami FL	200	254	288	289	290	45	23
Washington DC	570	633	706	727	807	42	24
Denver CO	143	151	178	191	201	41	25
San Bernardino-Riv CA	215	235	271	287	301	40	26
Tampa FL	46	57	59	64	64	39	27
Nashville TN	37	53	52	52	51	38	28
Honolulu HI	62	70	73	76	85	37	29
Phoenix AZ	175	204	212	225	240	37	29
Milwaukee WI	49	59	62	64	66	35	31
New York NY	1,611	1,837	2,042	2,044	2,175	35	31
Atlanta GA	271	294	316	322	357	32	33
Oklahoma City OK	25	29	28	29	33	32	33
Chicago IL	622	614	697	730	809	30	35
Orlando FL	44	47	51	53	57	30	35
Pittsburgh PA	120	140	147	145	152	27	37
San Jose CA	215	247	255	265	268	25	38
Boston MA	388	481	463	472	482	24	39
Philadelphia PA	308	340	342	349	365	19	40
San Fran-Oak CA	737	858	887	877	876	19	40
Los Angeles CA	2,106	2,293	2,430	2,449	2,491	18	42
Norfolk VA	85	96	101	100	99	16	43
Austin TX	60	65	66	67	69	15	44
San Antonio TX	84	85	86	88	97	15	44
Fort Worth TX	129	128	136	143	146	13	46
St. Louis MO	146	150	163	167	164	12	47
Houston TX	505	506	528	548	558	10	48
Dallas TX	361	348	369	376	380	5	49
New Orleans LA	84	90	90	89	88	5	49
Northeastern Avg	450	516	559	565	605	34	
Midwestern Avg	128	141	160	167	184	44	
Southern Avg	85	99	108	110	115	35	
Southwestern Avg	137	140	149	155	161	18	
Western Avg	427	490	522	528	542	27	
Texas Avg	165	164	172	177	182	10	
Total Avg	219	247	267	273	287	31	
Maximum Value	2,106	2,293	2,430	2,449	2,491	119	
Minimum Value	4	4	4	5	6	5	

Source: TTI Analysis and Local Transportation Agency References

COST OF CONGESTION

Another method of assessing impact is to look at economic factors. Travel delay and wasted fuel can be expressed as costs of congestion. This section presents estimates of this cost in each of the study areas and relates these costs to the persons and vehicles in the area. This chapter also reviews the effort required by urban areas to maintain a constant congestion level using additional roadway construction as the only enhancement.

ADDITIONAL CAPACITY

The addition of capacity to alleviate congestion is becoming more difficult and less acceptable in many urban areas, but it is among the effective tools that can be used to address congestion problems. As Table 2 indicates, very few urban areas have been able to sustain the level of roadway construction necessary to maintain a slow congestion growth rate on their major roadway system. Table 8 compares the amount of roadway needed each year to maintain the 1992 congestion level based on the recent traffic growth rate and the amount of roadway constructed over the most recent five years.

The estimate of the annual roadway construction needed to address increasing traffic levels is developed by applying the annual traffic growth rate to the amount of freeway and principal arterial streets. The congestion index is a ratio of traffic volume (demand) to facility length (supply). If the RCI is to remain constant (indicating the same congestion level), system supply has to increase by the same percentage as demand.

For example, Jacksonville would require an additional 18 lane-kilometers of freeway and 50 lane-kilometers of principal arterial streets to maintain the 1992 congestion level with 2.43 percent annual growth in daily VKT between 1988 and 1992. During this 5 year period, only an average of 14 lane-kilometers of freeway and 48 lane-kilometers of principal arterial street were added annually. This gave Jacksonville an annual deficit of 4 lane-kilometers of freeway and 2 lane-kilometers of principal arterial streets.

Table 8. Illustration of Annual Capacity Increase Required to Prevent Congestion Growth

Urban Area	Existing (1992) Lane-km		Average Annual VKT Growth (%)[1]	Annual Freeway Lane-km		Annual Prin.Art Lane-km		Lane-km Deficiency	
	Fwy	Prin. Art.		Needed	Added[2]	Needed	Added[2]	Fwy	Prin. Art.
Detroit MI	2,930	6,875	5.61	164	72	386	181	92	205
Chicago IL	3,928	7,487	5.57	219	95	417	360	124	57
Baltimore MD	2,174	2,689	4.49	98	52	121	(12)	46	133
Los Angeles CA	8,686	20,125	1.90	165	175	383	201	(10)	182
New York NY	9,741	12,276	2.11	206	97	259	207	109	52
Miami FL	1,006	3,590	4.90	49	20	176	85	29	91
Cincinnati OH	1,473	1,328	5.66	83	28	75	12	55	63
Columbus OH	1,304	1,022	5.31	69	10	54	14	59	40
Minn-St. Paul MN	2,431	1,852	4.41	107	30	82	72	77	10
Salt Lake City UT	845	684	8.80	74	18	60	30	56	30
Denver CO	1,546	2,995	2.95	46	40	88	10	6	78
San Diego CA	2,801	2,793	2.59	73	18	72	46	55	26
Kansas City MO	2,270	1,755	2.87	65	26	50	18	39	32
Washington DC	2,608	3,735	3.03	79	53	113	68	26	45
Ft. Lauderdale FL	1,047	1,852	4.16	43	28	77	24	15	53
Phoenix AZ	1,127	5,329	5.46	62	72	291	213	(10)	78
Dallas TX	2,818	2,818	2.01	57	30	57	22	27	35
Orlando FL	966	1,755	3.54	34	18	62	16	16	46
Seattle-Everett WA	2,045	2,616	3.71	76	52	97	60	24	37
San Antonio TX	1,417	1,811	3.14	45	24	57	22	21	35
Fort Worth TX	1,691	1,449	2.80	47	20	41	14	27	27
San Jose CA	1,932	2,222	2.85	55	20	63	44	35	19
Cleveland OH	1,900	1,835	3.74	71	76	69	12	(5)	57
Memphis TN	708	1,578	5.87	42	24	93	70	18	23
Charlotte NC	491	934	5.04	25	10	47	24	15	23
Pittsburgh PA	1,803	2,987	2.96	53	68	88	36	(15)	52
Oklahoma City OK	1,167	1,159	2.87	34	8	33	26	26	7
Milwaukee WI	966	1,707	2.39	23	6	41	28	17	13
Portland OR	926	974	3.44	32	14	34	26	18	8
Louisville KY	974	845	2.59	25	16	22	6	9	16
Norfolk VA	902	1,208	3.75	34	42	45	16	(8)	29
Atlanta GA	2,818	2,608	2.00	56	40	52	52	16	0
Sacramento CA	1,288	1,996	4.33	56	50	86	76	6	10
Nashville TN	886	1,546	3.14	28	44	49	18	(16)	31
Philadelphia PA	2,600	5,249	1.42	37	87	75	12	(50)	63
Tampa FL	499	1,127	3.03	15	8	34	30	7	4
Honolulu HI	604	378	3.63	22	18	14	8	4	6
El Paso TX	572	1,377	1.50	9	2	21	20	7	1
Hartford CT	974	1,055	2.82	28	22	30	28	6	2
Corpus Christi TX	303	602	2.93	9	1	18	20	8	(2)
Jacksonville FL	733	2,061	2.43	18	14	50	48	4	2
Indianapolis IN	1,240	1,425	1.47	18	20	21	14	(2)	7
Austin TX	741	716	1.89	14	16	14	10	(2)	4
Albuquerque NM	370	1,240	2.25	8	10	28	28	(2)	0
Houston TX	3,341	3,510	2.80	93	115	98	81	(22)	17
New Orleans LA	604	1,055	1.20	7	14	13	14	(7)	(1)
St. Louis MO	2,737	3,051	2.19	60	87	67	60	(27)	7
San Bernardino-Riv CA	1,465	3,381	3.35	49	16	113	169	33	(56)
San Fran-Oak CA	3,912	3,735	1.19	46	42	44	103	4	(59)
Boston MA	2,439	4,589	(0.47)	(11)	2	(22)	64	(13)	(86)

Notes: [1] Average annual growth rate of freeway and principal arterial streets between 1988 and 1992.
[2] Average lane-kilometers added annually from 1988 to 1992.

The amount of additional capacity required for freeway and principal arterial street systems make it apparent that the construction of additional lane-kilometers as the sole alternative to alleviate congestion is not feasible for many urban areas. Regardless of whether the majority of an area's travel is served by the freeway or principal arterial street system, roadway construction must be combined with a range of other improvements and programs to address the needs of severely congested corridors.

ECONOMIC IMPACT ESTIMATES

The two primary components of the congestion cost estimates in this study are traffic delay and excess fuel consumption. Congestion severity affects both the travel time and fuel consumption by decreasing the speed and vehicle fuel efficiency as congestion becomes worse. The congestion information was used to estimate vehicle-hours of delay (Table 4) and fuel wasted in congested travel conditions (Table 6).

Congestion cost estimates also used several study constants and urban area variables in the calculations. The five values held constant for all urban areas in the congestion cost analyses and calculations included:

1. Average vehicle occupancy—1.25 persons per vehicle,
2. Working days per year—250 days,
3. Average cost of time (10)—$10.50 per person-hour (1992 value),
4. Commercial vehicle operating cost (11)—$1.34 per kilometer (1992 value), and
5. Vehicle mix—95 percent passenger and 5 percent commercial.

Four area specific variables were also used in the congestion cost estimates. These variables are briefly described below:

1. Daily vehicle-kilometers of travel (VKT)—the average daily traffic (ADT) of a section of roadway multiplied by the length (in kilometers) of that roadway section,

2. Fuel cost—the state average fuel cost per liter for 1992,

3. Registered vehicles—the number of registered vehicles as reported by local agencies, and

4. Population—estimated using the 1992 Census Bureau estimates and HPMS data.

These variables were used to estimate and analyze the effects of congestion in each urban area. The economic impact of congestion was stated in terms of annual congestion cost, cost per registered vehicle, and cost per capita.

ECONOMIC ANALYSIS

While the above variables are used to analyze congestion cost in this study, some of these cost variables fluctuate with price trends. The variables—fuel cost, commercial vehicle operating cost, and the average cost of time—are updated annually to reflect the change in these costs. Estimates of vehicle-hours of delay and liters of wasted fuel should be used to analyze congestion trends since congestion costs reflect changes in the price, as well as changes in the transportation situation in an urban area.

The component and total congestion costs for each urban area are shown in Table 9. In 1992, the total cost of congestion for the urban areas studied was approximately $48 billion. This represents a nine percent increase in the economic impact of congestion since 1991 ($44 billion). The increase in the value of time rate was 2.4 percent, and fuel costs averaged less than a one percent increase. Most of the increase, therefore, was due to the increase in travel delay, which averaged 18 percent for the period spanning 1986 to 1992 (Table 5). Studywide averages indicate that delay accounted for approximately 89 percent of an urban area's congestion cost. The average economic burden placed on urban areas in 1992 due to congestion was $850 million, compared to $780 million in 1991.

Thirteen urban areas had total congestion costs of or exceeding $1 billion. Of the seven urban areas studied in Texas, only two, Houston—7th and Dallas—tied at 11th, ranked in this highest group. Congestion in the Texas urbanized areas resulted in a cost of approximately $4.2 billion, an eight percent increase from 1991 congestion costs.

Table 9. Total Congestion Costs by Urban Area for 1992

Urban Area	Annual Cost Due to Congestion ($ millions)			Rank
	Delay	Fuel	Total	
Los Angeles CA	7,420	910	8,330	1
New York NY	6,450	800	7,250	2
San Fran-Oak CA	2,570	320	2,890	3
Chicago IL	2,420	310	2,730	4
Washington DC	2,410	300	2,710	5
Detroit MI	1,870	220	2,090	6
Houston TX	1,640	190	1,830	7
Boston MA	1,420	170	1,590	8
Seattle-Everett WA	1,180	150	1,330	9
Dallas TX	1,110	130	1,240	11
Philadelphia PA	1,110	130	1,240	11
Atlanta GA	1,050	120	1,170	12
San Bernardino-Riv CA	890	110	1,000	13
Miami FL	880	100	980	14
San Jose CA	790	100	890	15
Phoenix AZ	720	80	800	17
San Diego CA	710	90	800	17
Baltimore MD	610	80	690	18
Denver CO	600	70	670	19
St. Louis MO	490	50	540	20
Minn-St. Paul MN	460	50	510	22
Pittsburgh PA	460	50	510	22
Fort Worth TX	430	50	480	23
Portland OR	350	40	390	24
Ft. Lauderdale FL	310	40	350	25
Norfolk VA	290	40	330	26
Sacramento CA	280	40	320	27
San Antonio TX	280	30	310	28
Cleveland OH	260	30	290	30
Honolulu HI	250	40	290	30
New Orleans LA	260	30	290	30
Cincinnati OH	230	30	260	33
Jacksonville FL	230	30	260	33
Columbus OH	210	30	240	34
Austin TX	200	20	220	35
Milwaukee WI	190	20	210	37
Tampa FL	190	20	210	37
Kansas City MO	170	20	190	39
Orlando FL	170	20	190	39
Hartford CT	150	20	170	41
Nashville TN	150	20	170	41
Charlotte NC	140	20	160	42
Louisville KY	100	10	110	44
Memphis TN	100	10	110	44
Oklahoma City OK	100	10	110	44
Albuquerque NM	90	10	100	46
Indianapolis IN	80	10	90	48
Salt Lake City UT	80	10	90	48
El Paso TX	60	10	70	49
Corpus Christi TX	20	0	20	50
Northeastern Avg	1,800	220	2,020	
Midwestern Avg	550	70	620	
Southern Avg	340	40	380	
Southwestern Avg	470	60	530	
Western Avg	1,600	200	1,800	
Texas Avg	530	60	590	
Total Avg	850	100	950	
Maximum Value	7,420	910	8,330	
Minimum Value	20	0	20	

Source: TTI Analysis and Local Transportation Agency References

Table 10 illustrates the estimated economic impact of congestion per capita and per registered vehicle. Viewing congestion costs in relation to population and vehicles provides an estimate of the effects of congestion on the individual, which might be thought of as the "congestion tax" on residents of urban areas. Washington D.C. had the highest per vehicle cost ($1,580 per registered vehicle) as well as the highest per capita cost ($820 per person). Houston had the highest values of any of the urban areas in Texas in both categories with a per vehicle cost of $810 and a per capita cost of $630.

The individual relationships of the "congestion tax" estimates to roadway congestion index can be seen in Table 11, which illustrates the rankings of urban areas by the roadway congestion index, annual per capita, and per registered vehicle costs. The rankings of the cost estimates are fairly consistent with just fifteen urban areas occupying the top ten positions in the three categories. The individual cost components should be more closely related to the roadway congestion index values, which is also a measure of the impact of congestion on individuals. When compared with the roadway congestion index rankings, only three urban areas, Chicago, Miami, and San Diego, are ranked in the top ten in the RCI but not in either of the cost categories.

Table 12 displays the 1991 and 1992 rankings of the RCI values and the congestion costs per capita. The change during the past year can be seen in the cost and RCI rankings. Twelve urban areas had their RCI ranking change by more than one position. Of these twelve, only four had their rank decrease between 1991 and 1992 (Charlotte, Norfolk, Albuquerque, and San Jose).

Tables 13 through 26 present estimates of congestion cost from 1986 to 1992. Previously published estimates presented in this series of reports have been revised for some areas to reflect new information. The data in Tables 13 through 26 are the best current information on the delay, fuel, and cost values for the years 1986 through 1992. Some of the data missing in 1986 and 1987 was unobtainable because of the various methods of reporting information in the HPMS database.

Table 10. Estimated Unit Costs of Congestion in 1992

Urban Area	Congestion Cost	
	Per Registered Vehicle (dollars)	Per Capita (dollars)
Northeastern Cities		
Baltimore MD	640	340
Boston MA	950	540
Hartford CT	310	270
New York NY	1,190	430
Philadelphia PA	440	250
Pittsburgh PA	410	270
Washington DC	1,580	820
Midwestern Cities		
Chicago IL	670	360
Cincinnati OH	260	210
Cleveland OH	190	160
Columbus OH	300	250
Detroit MI	720	520
Indianapolis IN	150	90
Kansas City MO	250	160
Louisville KY	250	140
Milwaukee WI	400	180
Minn-St. Paul MN	300	240
Oklahoma City OK	220	150
St. Louis MO	520	270
Southern Cities		
Atlanta GA	660	520
Charlotte NC	370	300
Ft. Lauderdale FL	330	270
Jacksonville FL	420	340
Memphis TN	170	130
Miami FL	670	510
Nashville TN	320	290
New Orleans LA	330	270
Norfolk VA	390	340
Orlando FL	250	210
Tampa FL	330	300
Southwestern Cities		
Albuquerque NM	230	190
Austin TX	430	400
Corpus Christi TX	90	70
Dallas TX	750	590
Denver CO	480	420
El Paso TX	180	110
Fort Worth TX	480	400
Houston TX	810	630
Phoenix AZ	620	400
Salt Lake City UT	130	110
San Antonio TX	360	270
Western Cities		
Honolulu HI	550	420
Los Angeles CA	1,060	700
Portland OR	560	370
Sacramento CA	250	270
San Bernardino-Riv CA	1,260	770
San Diego CA	540	320
San Fran-Oak CA	930	760
San Jose CA	860	590
Seattle-Everett WA	990	720
Northeastern Avg	790	420
Midwestern Avg	350	230
Southern Avg	390	320
Southwestern Avg	410	330
Western Avg	780	550
Texas Avg	440	350
Total Avg	510	350
Maximum Value	1,580	820
Minimum Value	90	70

Notes: TTI Analysis and Local Transportation Agency References

Table 11. 1992 Rankings of Urban Area by Estimated Impact of Congestion

Urban Area	Roadway Congestion Index	Congestion Cost per Capita	Congestion Cost per Registered Vehicle
Northeastern Cities			
Baltimore MD	23	21	15
Boston MA	17	9	6
Hartford CT	39	28	35
New York NY	11	13	3
Philadelphia PA	21	35	23
Pittsburgh PA	46	28	26
Washington DC	2	1	1
Midwestern Cities			
Chicago IL	5	20	12
Cincinnati OH	25	38	38
Cleveland OH	30	42	45
Columbus OH	35	35	36
Detroit MI	9	10	11
Indianapolis IN	44	49	48
Kansas City MO	48	42	39
Louisville KY	40	45	39
Milwaukee WI	26	41	27
Minn-St. Paul MN	27	37	36
Oklahoma City OK	45	44	44
St. Louis MO	30	28	20
Southern Cities			
Atlanta GA	10	10	14
Charlotte NC	43	25	29
Ft. Lauderdale FL	29	28	31
Jacksonville FL	28	21	25
Memphis TN	36	46	47
Miami FL	4	12	12
Nashville TN	36	27	34
New Orleans LA	13	28	31
Norfolk VA	36	21	28
Orlando FL	47	38	39
Tampa FL	17	25	31
Southwestern Cities			
Albuquerque NM	30	40	43
Austin TX	30	16	24
Corpus Christi TX	50	50	50
Dallas TX	17	7	10
Denver CO	21	14	21
El Paso TX	49	47	46
Fort Worth TX	34	16	21
Houston TX	12	6	9
Phoenix AZ	16	16	16
Salt Lake City UT	40	47	49
San Antonio TX	40	28	30
Western Cities			
Honolulu HI	13	14	18
Los Angeles CA	1	5	4
Portland OR	13	19	17
Sacramento CA	23	28	39
San Bernardino-Riv CA	6	2	2
San Diego CA	6	24	19
San Fran-Oak CA	3	3	7
San Jose CA	17	7	8
Seattle-Everett WA	6	4	5

Source: TTI Analysis

Table 12. Congestion Index and Cost Values, 1991 and 1992

Urban Area	Roadway Congestion Index				Congestion Cost per Capita		Annual Congestion Cost ($ millions)	
	1991 Value	1992 Value	1991 Rank	Rank 1992	1991	1992	1991	1992
Northeastern Cities								
Baltimore MD	1.02	1.04	24	23	280	340	560	690
Boston MA	1.06	1.07	18	17	510	540	1,520	1,590
Hartford CT	0.89	0.91	39	39	240	270	140	170
New York NY	1.14	1.14	11	11	390	430	6,600	7,250
Philadelphia PA	1.05	1.05	20	21	240	250	1,150	1,240
Pittsburgh PA	0.82	0.81	45	46	260	270	480	510
Washington DC	1.33	1.36	3	2	720	820	2,370	2,710
Midwestern Cities								
Chicago IL	1.27	1.28	5	5	320	360	2,390	2,730
Cincinnati OH	0.99	1.01	26	25	170	210	210	260
Cleveland OH	0.95	0.95	29	30	140	160	250	290
Columbus OH	0.91	0.93	36	35	240	250	210	240
Detroit MI	1.16	1.19	9	9	470	520	1,870	2,090
Indianapolis IN	0.84	0.85	44	44	80	90	80	90
Kansas City MO	0.75	0.77	48	48	100	160	120	190
Louisville KY	0.88	0.90	42	40	110	140	90	110
Milwaukee WI	1.00	1.00	25	26	170	180	200	210
Minn-St. Paul MN	0.96	0.99	27	27	220	240	460	510
Oklahoma City OK	0.81	0.83	46	45	130	150	90	110
St. Louis MO	0.95	0.95	29	30	270	270	540	540
Southern Cities								
Atlanta GA	1.16	1.17	9	10	480	520	1,030	1,170
Charlotte NC	0.89	0.89	39	43	300	300	140	160
Ft. Lauderdale FL	0.95	0.96	29	29	240	270	310	350
Jacksonville FL	0.95	0.97	29	28	310	340	230	260
Memphis TN	0.91	0.92	36	36	110	130	100	110
Miami FL	1.28	1.30	4	4	510	510	950	980
Nashville TN	0.90	0.92	38	36	290	290	170	170
New Orleans LA	1.12	1.10	12	13	260	270	290	290
Norfolk VA	0.93	0.92	34	36	340	340	320	330
Orlando FL	0.78	0.80	47	47	190	210	170	190
Tampa FL	1.05	1.07	20	17	290	300	210	210
Southwestern Cities								
Albuquerque NM	0.96	0.95	27	30	170	190	90	100
Austin TX	0.94	0.95	33	30	380	400	210	220
Corpus Christi TX	0.72	0.74	50	50	50	70	10	20
Dallas TX	1.06	1.07	18	17	580	590	1,200	1,240
Denver CO	1.03	1.05	23	21	390	420	620	670
El Paso TX	0.75	0.76	48	49	80	110	40	70
Fort Worth TX	0.92	0.94	35	34	380	400	450	480
Houston TX	1.11	1.12	13	12	600	630	1,750	1,830
Phoenix AZ	1.08	1.08	15	16	380	400	730	800
Salt Lake City UT	0.88	0.90	42	40	100	110	80	90
San Antonio TX	0.89	0.90	39	40	240	270	280	310
Western Cities								
Honolulu HI	1.10	1.10	14	13	370	420	250	290
Los Angeles CA	1.56	1.54	1	1	680	700	7,980	8,330
Portland OR	1.08	1.10	15	13	300	370	320	390
Sacramento CA	1.04	1.04	22	23	250	270	290	320
San Bernardino-Riv CA	1.22	1.22	6	6	730	770	930	1,000
San Diego CA	1.22	1.22	6	6	320	320	760	800
San Fran-Oak CA	1.34	1.33	2	3	760	760	2,830	2,890
San Jose CA	1.08	1.07	15	17	570	590	860	890
Seattle-Everett WA	1.20	1.22	8	6	650	720	1,190	1,330

Source: TTI Analysis and Local Transportation Agency References

Table 13. Component and Total Congestion Costs by Urban Area for 1986

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	110	190	-	-	-
Boston MA	240	650	-	-	-
Hartford CT	20	40	-	-	-
New York NY	1,280	2,410	-	-	-
Philadelphia PA	320	410	-	-	-
Pittsburgh PA	110	170	-	-	-
Washington DC	480	830	-	-	-
Midwestern Cities					
Chicago IL	670	780	-	-	-
Cincinnati OH	40	40	-	-	-
Cleveland OH	60	40	-	-	-
Columbus OH	50	40	-	-	-
Detroit MI	380	600	-	-	-
Indianapolis IN	10	20	0	0	30
Kansas City MO	20	40	0	0	70
Louisville KY	30	30	0	0	60
Milwaukee WI	60	60	10	10	130
Minn-St. Paul MN	110	110	10	10	240
Oklahoma City OK	30	30	0	0	60
St. Louis MO	160	180	70	80	490
Southern Cities					
Atlanta GA	290	320	30	40	690
Charlotte NC	30	30	-	-	-
Ft. Lauderdale FL	70	90	10	10	170
Jacksonville FL	50	60	10	10	130
Memphis TN	20	20	0	0	50
Miami FL	210	260	20	30	520
Nashville TN	40	50	0	10	100
New Orleans LA	80	120	10	10	210
Norfolk VA	60	130	-	-	-
Orlando FL	40	60	10	10	110
Tampa FL	50	60	10	10	120
Southwestern Cities					
Albuquerque NM	20	20	0	0	50
Austin TX	60	70	10	10	150
Corpus Christi TX	0	0	0	0	10
Dallas TX	300	520	30	60	910
Denver CO	160	170	20	20	370
El Paso TX	10	10	0	0	30
Fort Worth TX	110	190	10	20	330
Houston TX	500	660	50	70	1,280
Phoenix AZ	220	190	30	20	460
Salt Lake City UT	20	10	0	0	30
San Antonio TX	90	100	10	10	210
Western Cities					
Honolulu HI	50	90	10	10	160
Los Angeles CA	2,240	2,630	270	310	5,450
Portland OR	60	90	10	10	170
Sacramento CA	70	60	10	10	150
San Bernardino-Riv CA	230	260	30	30	550
San Diego CA	180	120	20	20	350
San Fran-Oak CA	750	950	90	110	1,900
San Jose CA	230	270	30	30	550
Seattle-Everett WA	240	310	30	40	610
Northeastern Avg	370	670	-	-	-
Midwestern Avg	130	160	10	20	150
Southern Avg	90	110	10	10	230
Southwestern Avg	140	180	20	20	350
Western Avg	450	530	50	60	1,100
Texas Avg	150	220	20	20	420
Total Avg	210	290	20	30	470
Maximum Value	2,240	2,630	270	310	5,450
Minimum Value	0	0	0	0	10

Notes: - Denotes data not available.

Source: TTI Analysis and Local Transportation Agency References

Table 14. Estimated Impact of Congestion in 1986

Urban Area	Congestion Cost		Roadway Congestion Index
	Per Registered Vehicle (dollars)	Per Capita (dollars)	
Northeastern Cities			
Baltimore MD	-	-	0.88
Boston MA	-	-	1.04
Hartford CT	-	-	0.85
New York NY	-	-	1.06
Philadelphia PA	-	-	1.06
Pittsburgh PA	-	-	0.79
Washington DC	-	-	1.27
Midwestern Cities			
Chicago IL	-	-	1.15
Cincinnati OH	-	-	0.84
Cleveland OH	-	-	0.86
Columbus OH	-	-	0.75
Detroit MI	-	-	1.05
Indianapolis IN	70	40	0.81
Kansas City MO	120	60	0.68
Louisville KY	130	70	0.80
Milwaukee WI	250	100	0.90
Minn-St. Paul MN	160	130	0.89
Oklahoma City OK	140	90	0.76
St. Louis MO	520	250	0.93
Southern Cities			
Atlanta GA	490	400	1.09
Charlotte NC	-	-	0.78
Ft. Lauderdale FL	180	150	0.85
Jacksonville FL	230	200	0.95
Memphis TN	80	60	0.80
Miami FL	390	290	1.14
Nashville TN	210	180	0.86
New Orleans LA	260	200	1.09
Norfolk VA	-	-	0.90
Orlando FL	200	160	0.76
Tampa FL	220	200	0.96
Southwestern Cities			
Albuquerque NM	130	100	0.96
Austin TX	330	320	0.94
Corpus Christi TX	40	40	0.71
Dallas TX	600	480	1.04
Denver CO	290	250	0.97
El Paso TX	90	60	0.75
Fort Worth TX	360	290	0.87
Houston TX	680	460	1.21
Phoenix AZ	410	260	1.20
Salt Lake City UT	50	40	0.68
San Antonio TX	270	210	0.88
Western Cities			
Honolulu HI	330	270	1.03
Los Angeles CA	710	510	1.42
Portland OR	280	160	0.97
Sacramento CA	140	160	0.95
San Bernardino-Riv CA	810	560	1.15
San Diego CA	320	170	1.00
San Fran-Oak CA	710	550	1.24
San Jose CA	570	410	0.97
Seattle-Everett WA	580	390	1.09
Northeastern Avg	-	-	0.99
Midwestern Avg	200	110	0.87
Southern Avg	250	210	0.93
Southwestern Avg	300	230	0.93
Western Avg	490	350	1.09
Texas Avg	340	270	0.91
Total Avg	320	230	0.95
Maximum Value	810	560	1.42
Minimum Value	40	40	0.68

Notes: - Denotes data not available.

Source: TTI Analysis and Local Transportation Agency References

Table 15. Component and Total Congestion Costs by Urban Area for 1987

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	120	200	10	20	360
Boston MA	240	640	30	70	970
Hartford CT	20	40	0	10	80
New York NY	1,400	2,630	160	290	4,480
Philadelphia PA	350	450	40	50	890
Pittsburgh PA	120	190	10	20	340
Washington DC	540	920	60	110	1,630
Midwestern Cities					
Chicago IL	680	790	80	90	1,640
Cincinnati OH	50	50	10	10	110
Cleveland OH	60	50	10	10	130
Columbus OH	60	50	10	10	120
Detroit MI	400	630	50	70	1,140
Indianapolis IN	10	20	0	0	40
Kansas City MO	20	50	0	10	80
Louisville KY	30	30	0	0	70
Milwaukee WI	70	70	10	10	150
Minn-St. Paul MN	150	140	20	20	330
Oklahoma City OK	30	30	0	0	60
St. Louis MO	170	200	20	20	410
Southern Cities					
Atlanta GA	340	370	40	40	780
Charlotte NC	30	40	0	0	80
Ft. Lauderdale FL	80	100	10	10	200
Jacksonville FL	60	80	10	10	160
Memphis TN	20	30	0	0	60
Miami FL	230	280	30	30	570
Nashville TN	50	50	10	10	110
New Orleans LA	80	130	10	10	230
Norfolk VA	70	150	10	20	250
Orlando FL	50	60	10	10	120
Tampa FL	60	70	10	10	140
Southwestern Cities					
Albuquerque NM	20	30	0	0	50
Austin TX	70	80	10	10	170
Corpus Christi TX	0	10	0	0	10
Dallas TX	280	490	30	60	860
Denver CO	160	170	20	20	380
El Paso TX	10	20	0	0	30
Fort Worth TX	110	180	10	20	330
Houston TX	490	660	60	80	1,290
Phoenix AZ	230	200	30	30	480
Salt Lake City UT	20	20	0	0	40
San Antonio TX	90	100	10	10	220
Western Cities					
Honolulu HI	60	80	10	10	170
Los Angeles CA	2,400	2,820	290	340	5,850
Portland OR	70	120	10	10	220
Sacramento CA	90	70	10	10	180
San Bernardino-Riv CA	240	280	30	30	580
San Diego CA	250	170	30	20	460
San Fran-Oak CA	870	1,110	110	130	2,220
San Jose CA	260	310	30	40	640
Seattle-Everett WA	290	390	40	50	760
Northeastern Avg	400	720	40	80	1,250
Midwestern Avg	140	170	20	20	360
Southern Avg	100	120	10	10	250
Southwestern Avg	140	180	20	20	350
Western Avg	500	590	60	70	1,230
Texas Avg	150	220	20	30	420
Total Avg	230	320	30	40	610
Maximum Value	2,400	2,820	290	340	5,850
Minimum Value	0	10	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 16. Estimated Impact of Congestion in 1987

Urban Area	Congestion Cost		Roadway Congestion Index
	Per Registered Vehicle (dollars)	Per Capita (dollars)	
Northeastern Cities			
Baltimore MD	360	190	0.91
Boston MA	640	340	1.04
Hartford CT	150	130	0.87
New York NY	780	280	1.06
Philadelphia PA	330	220	1.06
Pittsburgh PA	280	190	0.79
Washington DC	1,010	550	1.29
Midwestern Cities			
Chicago IL	410	230	1.15
Cincinnati OH	120	100	0.87
Cleveland OH	90	70	0.89
Columbus OH	160	140	0.78
Detroit MI	400	290	1.04
Indianapolis IN	70	40	0.85
Kansas City MO	120	70	0.71
Louisville KY	160	90	0.86
Milwaukee WI	280	120	0.95
Minn-St. Paul MN	210	170	0.89
Oklahoma City OK	130	90	0.76
St. Louis MO	430	210	0.96
Southern Cities	510	440	1.11
Atlanta GA	220	190	0.79
Charlotte NC	210	170	0.90
Ft. Lauderdale FL	280	240	0.94
Jacksonville FL	90	70	0.84
Memphis TN			
Miami FL	430	320	1.14
Nashville TN	240	210	0.89
New Orleans LA	280	220	1.14
Norfolk VA	320	290	0.93
Orlando FL	200	160	0.77
Tampa FL	230	210	1.02
Southwestern Cities			
Albuquerque NM	140	110	0.96
Austin TX	370	360	1.00
Corpus Christi TX	50	40	0.72
Dallas TX	550	450	1.02
Denver CO	290	250	0.95
El Paso TX	90	60	0.71
Fort Worth TX	350	290	0.87
Houston TX	610	460	1.19
Phoenix AZ	420	270	1.18
Salt Lake City UT	70	60	0.70
San Antonio TX	270	210	0.86
Western Cities			
Honolulu HI	340	270	1.05
Los Angeles CA	760	540	1.47
Portland OR	350	210	0.99
Sacramento CA	150	180	1.00
San Bernardino-Riv CA	820	570	1.14
San Diego CA	350	220	1.08
San Fran-Oak CA	760	630	1.31
San Jose CA	650	470	0.99
Seattle-Everett WA	670	480	1.14
Northeastern Avg	510	270	1.00
Midwestern Avg	220	140	0.89
Southern Avg	270	230	0.95
Southwestern Avg	290	230	0.92
Western Avg	540	400	1.13
Texas Avg	330	270	0.91
Total Avg	340	240	0.97
Maximum Value	1,010	630	1.47
Minimum Value	50	40	0.70

Source: TTI Analysis and Local Transportation Agency References

Table 17. Component and Total Congestion Costs by Urban Area for 1988

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	130	220	20	30	390
Boston MA	310	870	40	100	1,310
Hartford CT	30	70	0	10	110
New York NY	1,580	2,950	180	340	5,060
Philadelphia PA	370	480	40	50	960
Pittsburgh PA	140	210	20	20	400
Washington DC	580	980	70	120	1,760
Midwestern Cities					
Chicago IL	710	820	90	100	1,710
Cincinnati OH	70	60	10	10	150
Cleveland OH	80	60	10	10	160
Columbus OH	60	50	10	10	130
Detroit MI	450	740	50	90	1,330
Indianapolis IN	20	30	0	0	60
Kansas City MO	30	60	0	10	100
Louisville KY	30	30	0	0	70
Milwaukee WI	70	70	10	10	160
Minn-St. Paul MN	160	150	20	20	350
Oklahoma City OK	30	40	0	0	80
St. Louis MO	170	200	20	20	410
Southern Cities					
Atlanta GA	340	380	40	40	810
Charlotte NC	40	40	0	0	90
Ft. Lauderdale FL	80	110	10	10	220
Jacksonville FL	60	80	10	10	160
Memphis TN	30	30	0	0	60
Miami FL	290	350	30	40	720
Nashville TN	60	70	10	10	150
New Orleans LA	90	130	10	20	250
Norfolk VA	80	160	10	20	260
Orlando FL	50	70	10	10	130
Tampa FL	70	80	10	10	160
Southwestern Cities					
Albuquerque NM	30	30	0	0	60
Austin TX	70	80	10	10	180
Corpus Christi TX	0	0	0	0	10
Dallas TX	310	530	40	70	950
Denver CO	180	190	20	20	420
El Paso TX	10	20	0	0	30
Fort Worth TX	120	200	10	20	350
Houston TX	530	710	60	90	1390
Phoenix AZ	270	250	30	30	580
Salt Lake City UT	20	20	0	0	50
San Antonio TX	100	110	10	10	230
Western Cities					
Honolulu HI	70	110	10	10	200
Los Angeles CA	2,620	3,070	330	390	6,410
Portland OR	80	130	10	10	240
Sacramento CA	100	90	10	10	210
San Bernardino-Riv CA	270	310	30	40	650
San Diego CA	320	210	40	30	600
San Fran-Oak CA	930	1,180	120	150	2,380
San Jose CA	280	330	40	40	680
Seattle-Everett WA	340	450	40	60	880
Northeastern Avg	450	830	50	100	1,430
Midwestern Avg	160	190	20	20	390
Southern Avg	110	140	10	20	270
Southwestern Avg	150	190	20	20	390
Western Avg	560	650	70	80	1,360
Texas Avg	160	240	20	30	450
Total Avg	260	350	30	40	680
Maximum Value	2,620	3,070	330	390	6,410
Minimum Value	0	0	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 18. Estimated Impact of Congestion in 1988

Urban Area	Congestion Cost Per Registered Vehicle (dollars)	Congestion Cost Per Capita (dollars)	Roadway Congestion Index
Northeastern Cities			
Baltimore MD	390	200	0.92
Boston MA	860	450	1.12
Hartford CT	220	190	0.90
New York NY	860	310	1.10
Philadelphia PA	350	230	1.07
Pittsburgh PA	330	210	0.81
Washington DC	1,070	580	1.30
Midwestern Cities			
Chicago IL	430	230	1.18
Cincinnati OH	160	130	0.88
Cleveland OH	110	90	0.97
Columbus OH	170	150	0.79
Detroit MI	460	340	1.07
Indianapolis IN	110	70	0.85
Kansas City MO	150	90	0.72
Louisville KY	150	80	0.87
Milwaukee WI	310	130	0.94
Minn-St. Paul MN	220	180	0.90
Oklahoma City OK	170	110	0.78
St. Louis MO	440	210	0.98
Southern Cities			
Atlanta GA	530	430	1.14
Charlotte NC	240	210	0.80
Ft. Lauderdale FL	220	180	0.90
Jacksonville FL	280	240	0.95
Memphis TN	110	80	0.86
Miami FL	530	400	1.18
Nashville TN	300	280	0.94
New Orleans LA	300	240	1.13
Norfolk VA	330	300	0.94
Orlando FL	200	160	0.78
Tampa FL	270	240	1.03
Southwestern Cities			
Albuquerque NM	160	130	0.96
Austin TX	360	350	0.96
Corpus Christi TX	50	40	0.70
Dallas TX	590	490	1.02
Denver CO	310	270	0.99
El Paso TX	100	70	0.74
Fort Worth TX	360	300	0.87
Houston TX	650	490	1.15
Phoenix AZ	490	320	1.04
Salt Lake City UT	70	60	0.72
San Antonio TX	280	200	0.86
Western Cities			
Honolulu HI	390	300	1.07
Los Angeles CA	820	580	1.52
Portland OR	380	230	1.04
Sacramento CA	170	200	1.03
San Bernardino-Riv CA	890	620	1.18
San Diego CA	430	280	1.13
San Fran-Oak CA	790	660	1.33
San Jose CA	690	500	1.00
Seattle-Everett WA	760	540	1.17
Northeastern Avg	580	310	1.03
Midwestern Avg	240	150	0.91
Southern Avg	300	250	0.97
Southwestern Avg	310	250	0.91
Western Avg	590	430	1.16
Texas Avg	340	280	0.90
Total Avg	380	270	0.99
Maximum Value	1,070	660	1.52
Minimum Value	50	40	0.70

Source: TTI Analysis and Local Transportation Agency References

Table 19. Component and Total Congestion Costs by Urban Area for 1989

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	150	260	20	30	460
Boston MA	330	910	40	110	1,390
Hartford CT	40	80	10	10	130
New York NY	1,820	3,460	230	440	5,950
Philadelphia PA	390	510	50	60	1,000
Pittsburgh PA	150	220	20	30	420
Washington DC	660	1,130	80	140	2,020
Midwestern Cities					
Chicago IL	790	910	100	120	1,910
Cincinnati OH	80	70	10	10	160
Cleveland OH	100	80	10	10	210
Columbus OH	70	60	10	10	150
Detroit MI	500	830	60	100	1,500
Indianapolis IN	20	30	0	0	70
Kansas City MO	30	60	0	10	100
Louisville KY	30	30	0	0	70
Milwaukee WI	80	80	10	10	170
Minn-St. Paul MN	170	160	20	20	380
Oklahoma City OK	30	40	0	0	80
St. Louis MO	220	250	30	30	520
Southern Cities					
Atlanta GA	380	420	50	50	900
Charlotte NC	50	50	10	10	110
Ft. Lauderdale FL	100	120	10	20	250
Jacksonville FL	80	100	10	10	200
Memphis TN	30	30	0	0	70
Miami FL	330	410	40	50	830
Nashville TN	70	70	10	10	150
New Orleans LA	90	140	10	20	260
Norfolk VA	80	170	10	20	290
Orlando FL	50	70	10	10	140
Tampa FL	70	80	10	10	160
Southwestern Cities					
Albuquerque NM	40	40	0	0	80
Austin TX	80	90	10	10	180
Corpus Christi TX	0	0	0	0	10
Dallas TX	330	560	40	70	990
Denver CO	200	210	30	30	470
El Paso TX	20	20	0	0	40
Fort Worth TX	120	210	20	30	370
Houston TX	570	770	70	90	1,500
Phoenix AZ	300	260	40	30	630
Salt Lake City UT	30	20	0	0	60
San Antonio TX	100	110	10	10	250
Western Cities					
Honolulu HI	70	120	10	20	210
Los Angeles CA	2,870	3,370	380	450	7,070
Portland OR	90	150	10	20	270
Sacramento CA	120	100	20	10	250
San Bernardino-Riv CA	290	330	40	50	700
San Diego CA	360	240	50	30	680
San Fran-Oak CA	1,010	1,280	140	170	2,600
San Jose CA	310	360	40	50	750
Seattle-Everett WA	390	520	50	60	1,020
Northeastern Avg	500	940	60	120	1,630
Midwestern Avg	180	220	20	30	440
Southern Avg	120	150	20	20	310
Southwestern Avg	160	210	20	30	420
Western Avg	610	720	80	100	1,510
Texas Avg	170	250	20	30	480
Total Avg	280	390	40	50	760
Maximum Value	2,870	3,460	380	450	7,070
Minimum Value	0	0	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 20. Estimated Impact of Congestion in 1989

Urban Area	Congestion Cost		Roadway Congestion Index
	Per Registered Vehicle (dollars)	Per Capita (dollars)	
Northeastern Cities			
Baltimore MD	460	240	0.98
Boston MA	840	470	1.09
Hartford CT	250	220	0.89
New York NY	1,000	360	1.12
Philadelphia PA	360	240	1.05
Pittsburgh PA	350	230	0.82
Washington DC	1,210	650	1.33
Midwestern Cities			
Chicago IL	470	260	1.21
Cincinnati OH	170	140	0.94
Cleveland OH	140	120	0.96
Columbus OH	200	180	0.82
Detroit MI	520	380	1.09
Indianapolis IN	110	70	0.86
Kansas City MO	150	90	0.72
Louisville KY	160	90	0.86
Milwaukee WI	320	140	0.97
Minn-St. Paul MN	230	190	0.92
Oklahoma City OK	170	110	0.78
St. Louis MO	540	270	0.96
Southern Cities			
Atlanta GA	580	450	1.14
Charlotte NC	280	240	0.82
Ft. Lauderdale FL	240	200	0.92
Jacksonville FL	340	280	0.93
Memphis TN	120	80	0.90
Miami FL	590	450	1.25
Nashville TN	310	280	0.90
New Orleans LA	310	250	1.13
Norfolk VA	350	310	0.95
Orlando FL	190	170	0.77
Tampa FL	260	240	1.03
Southwestern Cities			
Albuquerque NM	200	170	0.98
Austin TX	370	350	0.96
Corpus Christi TX	50	40	0.70
Dallas TX	620	500	1.02
Denver CO	340	300	1.01
El Paso TX	100	70	0.74
Fort Worth TX	380	320	0.87
Houston TX	690	520	1.13
Phoenix AZ	530	330	1.03
Salt Lake City UT	80	70	0.81
San Antonio TX	290	210	0.87
Western Cities			
Honolulu HI	430	320	1.07
Los Angeles CA	900	630	1.54
Portland OR	410	270	1.07
Sacramento CA	200	240	1.01
San Bernardino-Riv CA	920	640	1.17
San Diego CA	480	310	1.18
San Fran-Oak CA	860	720	1.36
San Jose CA	750	540	1.03
Seattle-Everett WA	800	600	1.20
Northeastern Avg	640	340	1.04
Midwestern Avg	270	170	0.92
Southern Avg	320	270	0.98
Southwestern Avg	330	260	0.92
Western Avg	640	470	1.18
Texas Avg	360	290	0.90
Total Avg	410	290	1.00
Maximum Value	1,210	720	1.54
Minimum Value	50	40	0.70

Source: TTI Analysis and Local Transportation Agency References

Table 21. Component and Total Congestion Costs by Urban Area for 1990

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	170	300	20	40	540
Boston MA	340	950	40	120	1,450
Hartford CT	40	80	10	10	140
New York NY	1,960	3,720	270	510	6,450
Philadelphia PA	420	560	50	70	1,100
Pittsburgh PA	170	260	20	30	480
Washington DC	730	1,260	100	170	2,250
Midwestern Cities					
Chicago IL	910	1,050	130	150	2,230
Cincinnati OH	90	80	10	10	190
Cleveland OH	120	90	20	10	240
Columbus OH	100	80	10	10	200
Detroit MI	570	950	70	120	1,720
Indianapolis IN	30	40	0	0	70
Kansas City MO	40	70	0	10	110
Louisville KY	30	40	0	0	80
Milwaukee WI	90	90	10	10	200
Minn-St. Paul MN	200	190	30	20	430
Oklahoma City OK	40	40	0	10	90
St. Louis MO	210	240	20	30	510
Southern Cities					
Atlanta GA	420	460	50	60	990
Charlotte NC	50	60	10	10	120
Ft. Lauderdale FL	110	150	10	20	300
Jacksonville FL	90	110	10	10	230
Memphis TN	30	40	0	0	80
Miami FL	370	450	50	60	930
Nashville TN	70	80	10	10	170
New Orleans LA	100	150	10	20	290
Norfolk VA	90	190	10	20	320
Orlando FL	60	80	10	10	160
Tampa FL	80	90	10	10	190
Southwestern Cities					
Albuquerque NM	40	40	0	10	90
Austin TX	90	100	10	10	210
Corpus Christi TX	0	10	0	0	10
Dallas TX	370	640	50	80	1,140
Denver CO	240	250	30	30	560
El Paso TX	20	20	0	0	40
Fort Worth TX	140	240	20	30	420
Houston TX	620	840	80	110	1,650
Phoenix AZ	330	280	40	30	680
Salt Lake City UT	30	30	0	0	60
San Antonio TX	110	120	10	20	270
Western Cities					
Honolulu HI	80	130	10	20	230
Los Angeles CA	3,140	3,680	420	500	7740
Portland OR	100	170	10	20	300
Sacramento CA	130	120	20	20	290
San Bernardino-Riv CA	350	410	50	60	860
San Diego CA	390	260	50	40	730
San Fran-Oak CA	1,090	1,380	150	190	2,800
San Jose CA	330	380	40	50	810
Seattle-Everett WA	430	570	60	80	1,130
Northeastern Avg	550	1,020	70	140	1,770
Midwestern Avg	200	250	30	30	510
Southern Avg	130	170	20	20	340
Southwestern Avg	180	230	20	30	470
Western Avg	670	790	90	110	1,650
Texas Avg	190	280	20	40	530
Total Avg	310	430	40	60	850
Maximum Value	3,140	3,720	420	510	7,740
Minimum Value	0	10	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 22. Estimated Impact of Congestion in 1990

Urban Area	Congestion Cost		Roadway Congestion Index
	Per Registered Vehicle (dollars)	Per Capita (dollars)	
Northeastern Cities			
Baltimore MD	520	270	1.01
Boston MA	880	490	1.06
Hartford CT	270	230	0.89
New York NY	1,070	380	1.14
Philadelphia PA	400	250	1.05
Pittsburgh PA	390	250	0.82
Washington DC	1,350	730	1.34
Midwestern Cities			
Chicago IL	550	300	1.25
Cincinnati OH	200	160	0.96
Cleveland OH	160	130	0.94
Columbus OH	270	240	0.89
Detroit MI	600	430	1.13
Indianapolis IN	130	80	0.84
Kansas City MO	160	100	0.74
Louisville KY	180	100	0.86
Milwaukee WI	360	160	0.99
Minn-St. Paul MN	260	220	0.95
Oklahoma City OK	180	120	0.79
St. Louis MO	510	260	0.95
Southern Cities			
Atlanta GA	620	470	1.14
Charlotte NC	330	280	0.86
Ft. Lauderdale FL	290	230	0.94
Jacksonville FL	390	320	0.93
Memphis TN	130	100	0.89
Miami FL	650	500	1.27
Nashville TN	320	290	0.89
New Orleans LA	330	260	1.12
Norfolk VA	390	340	0.96
Orlando FL	220	190	0.77
Tampa FL	300	270	1.05
Southwestern Cities			
Albuquerque NM	210	180	0.98
Austin TX	410	380	0.94
Corpus Christi TX	50	40	0.72
Dallas TX	710	570	1.05
Denver CO	410	360	1.03
El Paso TX	120	70	0.74
Fort Worth TX	420	350	0.90
Houston TX	740	570	1.12
Phoenix AZ	560	360	1.05
Salt Lake City UT	90	80	0.85
San Antonio TX	310	230	0.88
Western Cities			
Honolulu HI	460	360	1.09
Los Angeles CA	990	680	1.55
Portland OR	450	290	1.08
Sacramento CA	230	260	1.02
San Bernardino-Riv CA	1,100	730	1.21
San Diego CA	510	320	1.22
San Fran-Oak CA	930	760	1.36
San Jose CA	790	570	1.05
Seattle-Everett WA	870	650	1.20
Northeastern Avg	700	370	1.04
Midwestern Avg	300	190	0.94
Southern Avg	360	300	0.98
Southwestern Avg	370	290	0.93
Western Avg	700	510	1.20
Texas Avg	390	320	0.91
Total Avg	450	320	1.01
Maximum Value	1,350	760	1.55
Minimum Value	50	40	0.72

Source: TTI Analysis and Local Transportation Agency References

Table 23. Component and Total Congestion Costs by Urban Area for 1991

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	180	320	20	40	560
Boston MA	350	1,000	40	120	1,520
Hartford CT	40	80	10	10	140
New York NY	2,030	3,830	260	490	6,600
Philadelphia PA	440	590	50	70	1,150
Pittsburgh PA	170	260	20	30	480
Washington DC	770	1,330	100	170	2,370
Midwestern Cities					
Chicago IL	980	1,140	130	150	2,390
Cincinnati OH	100	90	10	10	210
Cleveland OH	120	100	20	10	250
Columbus OH	100	80	10	10	210
Detroit MI	630	1,050	80	130	1,870
Indianapolis IN	30	40	0	0	80
Kansas City MO	40	70	0	10	120
Louisville KY	40	40	0	0	90
Milwaukee WI	90	90	10	10	200
Minn-St. Paul MN	210	200	30	20	460
Oklahoma City OK	40	40	0	10	90
St. Louis MO	230	260	20	30	540
Southern Cities					
Atlanta GA	440	490	50	60	1,030
Charlotte NC	60	60	10	10	140
Ft. Lauderdale FL	120	160	10	20	310
Jacksonville FL	90	120	10	10	230
Memphis TN	40	50	10	10	100
Miami FL	380	470	50	60	950
Nashville TN	70	80	10	10	170
New Orleans LA	100	160	10	20	290
Norfolk VA	90	190	10	20	320
Orlando FL	60	90	10	10	170
Tampa FL	80	100	10	10	210
Southwestern Cities					
Albuquerque NM	40	40	0	10	90
Austin TX	90	100	10	10	210
Corpus Christi TX	10	10	0	0	10
Dallas TX	390	670	50	80	1,200
Denver CO	270	280	30	40	620
El Paso TX	20	20	0	0	40
Fort Worth TX	150	260	20	30	450
Houston TX	660	900	80	110	1,750
Phoenix AZ	360	300	40	40	730
Salt Lake City UT	40	30	10	0	80
San Antonio TX	120	130	10	20	280
Western Cities					
Honolulu HI	80	130	10	20	250
Los Angeles CA	3,260	3,820	410	480	7,980
Portland OR	110	170	10	20	320
Sacramento CA	140	120	20	20	290
San Bernardino-Riv CA	380	440	50	60	930
San Diego CA	400	270	50	30	760
San Fran-Oak CA	1,110	1,400	140	180	2,830
San Jose CA	350	410	40	50	860
Seattle-Everett WA	450	600	60	80	1,190
Northeastern Avg	570	1,060	70	130	1,830
Midwestern Avg	220	270	30	30	540
Southern Avg	140	180	20	20	360
Southwestern Avg	200	250	20	30	500
Western Avg	700	820	90	100	1,710
Texas Avg	210	300	20	40	560
Total Avg	330	450	40	60	880
Maximum Value	3,260	3,830	410	490	7,980
Minimum Value	10	10	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 24. Estimated Impact of Congestion in 1991

Urban Area	Congestion Cost		Roadway Congestion Index
	Per Registered Vehicle (dollars)	Per Capita (dollars)	
Northeastern Cities			
Baltimore MD	530	280	1.02
Boston MA	920	510	1.06
Hartford CT	270	240	0.89
New York NY	1,090	390	1.14
Philadelphia PA	410	240	1.05
Pittsburgh PA	390	260	0.82
Washington DC	1,410	720	1.33
Midwestern Cities			
Chicago IL	590	320	1.27
Cincinnati OH	220	170	0.99
Cleveland OH	170	140	0.95
Columbus OH	280	240	0.91
Detroit MI	650	470	1.16
Indianapolis IN	130	80	0.84
Kansas City MO	160	100	0.75
Louisville KY	190	110	0.88
Milwaukee WI	380	170	1.00
Minn-St. Paul MN	270	220	0.96
Oklahoma City OK	190	130	0.81
St. Louis MO	530	270	0.95
Southern Cities			
Atlanta GA	630	480	1.16
Charlotte NC	370	300	0.89
Ft. Lauderdale FL	300	240	0.95
Jacksonville FL	390	310	0.95
Memphis TN	160	110	0.91
Miami FL	670	510	1.28
Nashville TN	330	290	0.90
New Orleans LA	330	260	1.12
Norfolk VA	390	340	0.93
Orlando FL	230	190	0.78
Tampa FL	320	290	1.05
Southwestern Cities			
Albuquerque NM	210	170	0.96
Austin TX	410	380	0.94
Corpus Christi TX	70	50	0.72
Dallas TX	740	580	1.06
Denver CO	450	390	1.03
El Paso TX	120	80	0.75
Fort Worth TX	450	380	0.92
Houston TX	780	600	1.11
Phoenix AZ	590	380	1.08
Salt Lake City UT	120	100	0.88
San Antonio TX	320	240	0.89
Western Cities			
Honolulu HI	490	370	1.10
Los Angeles CA	1,020	680	1.56
Portland OR	460	300	1.08
Sacramento CA	230	250	1.04
San Bernardino-Riv CA	1,170	730	1.22
San Diego CA	520	320	1.22
San Fran-Oak CA	930	760	1.34
San Jose CA	840	570	1.08
Seattle-Everett WA	890	650	1.20
Northeastern Avg	720	380	1.04
Midwestern Avg	310	200	0.96
Southern Avg	370	300	0.99
Southwestern Avg	390	300	0.94
Western Avg	730	520	1.20
Texas Avg	410	330	0.91
Total Avg	470	330	1.02
Maximum Value	1,410	760	1.56
Minimum Value	70	50	0.72

Source: TTI Analysis and Local Transportation Agency References

Table 25. Component and Total Congestion Costs by Urban Area for 1992

Urban Area	Annual Cost Due to Congestion ($ millions)				
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total
Northeastern Cities					
Baltimore MD	210	400	30	50	690
Boston MA	370	1,050	40	130	1,590
Hartford CT	50	100	10	10	170
New York NY	2,260	4,190	280	520	7,250
Philadelphia PA	470	640	60	70	1,240
Pittsburgh PA	180	280	20	30	510
Washington DC	870	1,540	110	190	2,710
Midwestern Cities					
Chicago IL	1,120	1,300	140	170	2,730
Cincinnati OH	120	110	10	20	260
Cleveland OH	140	120	10	20	290
Columbus OH	110	100	10	20	240
Detroit MI	710	1,160	80	140	2,090
Indianapolis IN	30	50	0	10	90
Kansas City MO	50	120	10	10	190
Louisville KY	50	50	0	10	110
Milwaukee WI	90	100	10	10	210
Minn-St. Paul MN	230	230	20	30	510
Oklahoma City OK	50	50	0	10	110
St. Louis MO	230	260	20	30	540
Southern Cities					
Atlanta GA	500	550	60	60	1,170
Charlotte NC	70	70	10	10	160
Ft. Lauderdale FL	130	180	20	20	350
Jacksonville FL	100	130	10	20	260
Memphis TN	50	50	0	10	110
Miami FL	390	490	50	50	980
Nashville TN	70	80	10	10	170
New Orleans LA	100	160	10	20	290
Norfolk VA	100	190	20	20	330
Orlando FL	70	100	10	10	190
Tampa FL	90	100	10	10	210
Southwestern Cities					
Albuquerque NM	40	50	0	10	100
Austin TX	100	100	10	10	220
Corpus Christi TX	10	10	0	0	20
Dallas TX	410	700	50	80	1,240
Denver CO	300	300	30	40	670
El Paso TX	30	30	0	10	70
Fort Worth TX	160	270	20	30	480
Houston TX	700	940	80	110	1,830
Phoenix AZ	400	320	40	40	800
Salt Lake City UT	40	40	0	10	90
San Antonio TX	140	140	10	20	310
Western Cities					
Honolulu HI	100	150	20	20	290
Los Angeles CA	3,420	4,000	420	490	8,330
Portland OR	130	220	20	20	390
Sacramento CA	150	130	20	20	320
San Bernardino-Riv CA	410	480	50	60	1,000
San Diego CA	420	290	40	50	800
San Fran-Oak CA	1,140	1,430	140	180	2,890
San Jose CA	360	430	50	50	890
Seattle-Everett WA	500	680	70	80	1,330
Northeastern Avg	630	1,170	80	140	2,020
Midwestern Avg	250	300	30	40	610
Southern Avg	150	190	20	20	380
Southwestern Avg	210	260	20	30	530
Western Avg	740	870	90	110	1,800
Texas Avg	220	310	30	40	600
Total Avg	360	490	40	60	960
Maximum Value	3,420	4,190	420	520	8,330
Minimum Value	10	10	0	0	20

Source: TTI Analysis and Local Transportation Agency References

Table 26. Estimated Impact of Congestion 1992

Urban Area	Congestion Cost		Roadway Congestion Index
	Per Registered Vehicle (dollars)	Per Capita (dollars)	
Northeastern Cities			
Baltimore MD	640	340	1.04
Boston MA	950	540	1.07
Hartford CT	310	270	0.91
New York NY	1,190	430	1.14
Philadelphia PA	440	250	1.05
Pittsburgh PA	410	270	0.81
Washington DC	1,580	820	1.36
Midwestern Cities			
Chicago IL	670	360	1.28
Cincinnati OH	260	210	1.01
Cleveland OH	190	160	0.95
Columbus OH	300	250	0.93
Detroit MI	720	520	1.19
Indianapolis IN	150	90	0.85
Kansas City MO	250	160	0.77
Louisville KY	250	140	0.90
Milwaukee WI	400	180	1.00
Minn-St. Paul MN	300	240	0.99
Oklahoma City OK	220	150	0.83
St. Louis MO	520	270	0.95
Southern Cities			
Atlanta GA	660	520	1.17
Charlotte NC	370	300	0.89
Ft. Lauderdale FL	330	270	0.96
Jacksonville FL	420	340	0.97
Memphis TN	170	130	0.92
Miami FL	670	510	1.30
Southwestern Cities			
Nashville TN	320	290	0.92
New Orleans LA	330	270	1.10
Norfolk VA	390	340	0.92
Orlando FL	250	210	0.80
Tampa FL	330	300	1.07
Albuquerque NM	230	190	0.95
Austin TX	430	400	0.95
Corpus Christi TX	90	70	0.74
Dallas TX	750	590	1.07
Denver CO	480	420	1.05
El Paso TX	180	110	0.76
Fort Worth TX	480	400	0.94
Houston TX	810	630	1.12
Phoenix AZ	620	400	1.08
Salt Lake City UT	130	110	0.90
San Antonio TX	360	270	0.90
Western Cities			
Honolulu HI	550	420	1.10
Los Angeles CA	1,060	700	1.54
Portland OR	560	370	1.10
Sacramento CA	250	270	1.04
San Bernardino-Riv CA	1,260	770	1.22
San Diego CA	540	320	1.22
San Fran-Oak CA	930	760	1.33
San Jose CA	860	590	1.07
Seattle-Everett WA	990	720	1.22
Northeastern Avg	790	420	1.05
Midwestern Avg	350	230	0.97
Southern Avg	390	320	1.00
Southwestern Avg	410	330	0.95
Western Avg	780	550	1.20
Texas Avg	440	350	0.93
Total Avg	510	350	1.03
Maximum Value	1,580	820	1.54
Minimum Value	90	70	0.74

Source: TTI Analysis and Local Transportation Agency References

CONCLUSIONS

This report presents estimates of congestion and the importance of congestion for 50 large and medium cities from 1982 to 1992. The congestion estimates are based on travel volume and roadway capacity in urbanized areas. Given that traffic volume continues to increase and transportation funding has not kept pace with the rising cost of transportation projects, it should be no surprise that congestion, when measured by vehicle travel per kilometer of roadway, has increased significantly in most major urban areas since 1982. Only a few areas have come close to maintaining a constant congestion level over the period from 1982 to 1992.

The estimate of the amount of roadway construction required to maintain a congestion level, or to reduce congestion to acceptable levels (Table 8) also gives little hope for those who think that congestion problems can be solved by the construction of additional freeway and arterial street lanes. The commitment to sustain such a construction program has not been in place in many areas, and the magnitude of the problem suggests that such an approach will not be effective in most of the areas studied.

When funding problems are combined with air quality and other environmental concerns, it becomes apparent that for most medium and large urban areas, a multimodal and multiprogram combination of construction, operation, and demand management improvements will be required to improve mobility.

APPENDIX A

SYSTEM LENGTH AND TRAVEL CHARACTERISTICS

TRAVEL AND SYSTEM LENGTH STATISTICS

Previous TTI research (3-8) used daily vehicle-kilometers of travel (daily VKT) per lane-kilometer of freeway and principal arterial street as indicators of urban congestion levels. The previous studies established the values of 13,000 daily VKT per freeway lane-kilometer and 5,000 daily VKT per principal arterial street lane-kilometer as the thresholds for undesirable congestion levels. Briefly, when areawide freeway travel volumes exceed an average of 13,000 daily VKT per lane-kilometer, undesirable levels of congestion occur. The corresponding level of service is reached on principal arterial streets when travel volumes average 5,000 daily VKT per lane-kilometer. More information is available on the development of the methodology in Volume 2.

This section presents comparisons of mobility within geographic regions and between individual urban areas using daily VKT per lane-kilometer statistics.

Freeway Travel and Distance Statistics

Table A-1 summarizes areawide freeway operating statistics. The urban areas are ranked according to the primary congestion indicator, daily VKT per lane-kilometer. Twenty-three urbanized areas exceeded the 13,000 daily VKT per lane-kilometer level indicating areawide congested conditions on the freeway systems. Six of these areas have experienced congested freeway systems since 1982. An additional nine urban areas studied have daily VKT per lane-kilometer values within ten percent of the 13,000 level. Urban areas with travel demands in this range would only have to experience moderate to slight increases in travel demands over a few years to cause their freeway systems to operate under congested conditions. The summary statistics at the bottom of Table A-1 show average daily VKT per lane-kilometer values by geographic region. Every region, except the Western region (affected by the California cities), has daily VKT per lane-kilometer values below the 13,000 level.

Table A-1. 1992 Freeway System Length and Travel Volume

Urban Area	Daily VKT[1] (1000)	Lane-Kilometers	Avg. No. Lanes[2]	Daily VKT/ Lane-Kilometer[3]	Rank[4]
Los Angeles CA	180,240	8,690	8.20	20,750	1
San Fran-Oak CA	68,100	3,910	6.80	17,410	2
Washington DC	44,190	2,610	5.40	16,940	3
San Bernardino-Riv CA	24,330	1,470	7.20	16,600	4
Chicago IL	63,110	3,930	5.70	16,070	5
San Diego CA	44,760	2,800	7.60	15,980	6
Seattle-Everett WA	32,640	2,040	6.00	15,960	7
Detroit MI	46,050	2,930	5.90	15,710	8
Atlanta GA	42,670	2,820	6.30	15,140	9
Miami FL	15,090	1,010	5.40	14,990	10
Houston TX	49,110	3,340	6.30	14,700	11
Boston MA	35,250	2,440	5.90	14,450	12
Dallas TX	39,450	2,820	5.90	14,000	13
Phoenix AZ	15,700	1,130	5.70	13,930	14
Portland OR	12,830	930	5.20	13,860	15
San Jose CA	26,730	1,930	6.70	13,840	16
New York NY	134,440	9,740	5.70	13,800	17
Honolulu HI	8,190	600	5.30	13,570	18
New Orleans LA	8,130	600	5.80	13,470	19
Milwaukee WI	12,610	970	5.60	13,060	20
Baltimore MD	28,340	2,170	5.50	13,040	21
Cincinnati OH	19,180	1,470	5.70	13,020	22
Denver CO	20,130	1,550	5.20	13,020	22
Jacksonville FL	9,270	730	4.60	12,650	24
Sacramento CA	16,290	1,290	7.00	12,640	25
Minn-St. Paul MN	30,590	2,430	4.90	12,580	26
Austin TX	9,100	740	5.60	12,280	27
Tampa FL	6,120	500	5.00	12,260	28
Fort Worth TX	20,610	1,690	5.90	12,190	29
Philadelphia PA	31,220	2,600	5.10	12,010	30
Cleveland OH	22,800	1,900	4.80	12,000	31
Ft. Lauderdale FL	12,480	1,050	5.40	11,920	32
Columbus OH	15,230	1,300	5.80	11,680	33
Memphis TN	8,100	710	5.40	11,430	34
San Antonio TX	16,000	1,420	5.40	11,290	35
Hartford CT	10,870	970	5.60	11,160	36
St. Louis MO	30,480	2,740	5.70	11,140	37
Salt Lake City UT	9,300	850	5.70	11,000	38
Nashville TN	9,660	890	4.70	10,910	39
Albuquerque NM	4,030	370	5.00	10,870	40
Indianapolis IN	13,390	1,240	5.30	10,800	41
Louisville KY	10,510	970	4.60	10,790	42
Charlotte NC	5,150	490	4.20	10,490	43
Norfolk VA	9,450	900	4.70	10,480	44
Orlando FL	9,740	970	4.90	10,080	45
Oklahoma City OK	11,750	1,170	5.20	10,070	46
El Paso TX	5,640	570	5.30	9,860	47
Kansas City MO	22,060	2,270	4.40	9,720	48
Corpus Christi TX	2,700	300	5.50	8,910	49
Pittsburgh PA	14,710	1,800	4.30	8,160	50
Northeastern Avg	42,710	3,190	5.36	12,790	
Midwestern Avg	24,810	1,940	5.30	12,220	
Southern Avg	12,350	970	5.13	12,170	
Southwestern Avg	17,430	1,340	5.59	12,000	
Western Avg	46,010	2,630	6.67	15,620	
Texas Avg	20,370	1,550	5.70	11,890	
Total Avg	26,770	1,890	5.58	12,850	
Maximum Value	180,240	9,740	8.20	20,750	
Minimum Value	2,700	300	4.20	8,160	

Notes: [1] Daily vehicle-kilometers of travel.
[2] Average number of lanes.
[3] Daily vehicle-kilometers of travel per lane-kilometer of freeway.
[4] Rank value of 1 associated with most congested condition.
Ranked by daily VKT/lane-kilometer.

Source: TTI Analysis and Local Transportation Agency References

Principal Arterial Street Travel and System Length Statistics

Table A-2 shows the operating characteristics of the principal arterial street system for each urban area included in this study. As in Table A-1, Table A-2 ranks urban areas by travel per lane-kilometer and contains regional summary statistics. In 1992, 39 of the urban areas studied experienced daily VKT per lane-kilometer levels exceeding 5,000. Of the 50 study areas, 27 have had travel demands exceeding 5,000 daily VKT per lane-kilometer since 1982.

The summary statistics show that all the regional averages, except the Texas average, exceed the 5,000 daily VKT per lane-kilometer level. In contrast to the freeway values, the arterial street statistics indicate more congested operation on the arterial street systems in this study. The regional average travel demand on principal arterial street systems increased between one and two percent from 1991 levels in the Midwestern and Texas regions. The regional average travel demands showed smaller increases in the Northeastern, Southern, and Southwestern regions (less than 1 percent).

Travel Delay

The recurring and incident hours of delay are shown by congestion level in Tables A-3 and A-4. These two tables give a more detailed look at the delay previously shown in Table 4. The types and severity of delay and facility on which it occurs are shown in these two tables. Table A-3 shows these values for the freeway facilities in the 50 urban areas. This table shows which levels of congestion contain the greatest amount of delay within recurring and incident delay types. Table A-4 shows this same information for the principal arterial street systems in the 50 urban areas.

Table A-2. 1992 Principal Arterial Street System Length and Travel Volume

Urban Area	Daily VKT[1] (1000)	Lane-Kilometers	Avg. No. Lanes[2]	Daily VKT/ Lane-Kilometer[3]	Rank[4]
Washington DC	29,790	3,740	4.00	7,970	1
Miami FL	27,050	3,590	4.40	7,530	2
Honolulu HI	2,810	380	3.80	7,430	3
New York NY	89,070	12,280	3.40	7,260	4
Chicago IL	52,810	7,490	3.80	7,050	5
Philadelphia PA	34,860	5,250	3.30	6,640	6
Tampa FL	7,490	1,130	3.80	6,640	6
Los Angeles CA	132,830	20,130	4.10	6,600	8
St. Louis MO	20,090	3,050	3.60	6,590	9
Portland OR	6,300	970	3.40	6,460	10
New Orleans LA	6,760	1,050	4.20	6,410	11
Norfolk VA	7,690	1,210	3.50	6,370	12
Louisville KY	5,350	850	3.60	6,330	13
Sacramento CA	12,450	2,000	4.20	6,240	14
Atlanta GA	16,100	2,610	3.80	6,170	15
San Fran-Oak CA	22,830	3,740	4.00	6,110	16
Salt Lake City UT	4,150	680	3.80	6,060	17
Seattle-Everett WA	15,780	2,620	3.50	6,030	18
Pittsburgh PA	17,870	2,990	3.20	5,980	19
Baltimore MD	15,940	2,690	4.10	5,930	20
Denver CO	17,710	2,990	3.90	5,910	21
Minn-St. Paul MN	10,950	1,850	3.40	5,910	21
Hartford CT	6,180	1,050	3.80	5,860	23
Detroit MI	39,450	6,870	4.40	5,740	24
Nashville TN	8,860	1,550	3.50	5,730	25
Columbus OH	5,760	1,020	3.50	5,630	26
San Diego CA	15,620	2,790	3.50	5,590	27
Albuquerque NM	6,920	1,240	3.90	5,580	28
Cleveland OH	10,140	1,840	3.00	5,530	29
Charlotte NC	5,150	930	3.20	5,520	30
Ft. Lauderdale FL	10,220	1,850	4.40	5,520	30
Oklahoma City OK	6,390	1,160	3.30	5,510	32
Phoenix AZ	29,150	5,330	4.20	5,470	33
Cincinnati OH	7,250	1,330	3.30	5,450	34
San Jose CA	11,910	2,220	4.20	5,360	35
San Antonio TX	9,560	1,810	3.60	5,280	36
San Bernardino-Riv CA	17,310	3,380	4.20	5,120	37
Houston TX	17,940	3,510	4.50	5,110	38
Memphis TN	8,070	1,580	4.50	5,110	38
Austin TX	3,540	720	4.20	4,940	40
Milwaukee WI	8,370	1,710	3.40	4,910	41
Dallas TX	13,770	2,820	4.80	4,890	42
Fort Worth TX	6,990	1,450	4.20	4,820	43
Indianapolis IN	6,840	1,420	3.70	4,800	44
Jacksonville FL	9,890	2,060	3.80	4,800	44
Boston MA	20,920	4,590	2.40	4,560	46
Kansas City MO	7,870	1,750	3.60	4,490	47
Orlando FL	7,810	1,750	3.70	4,450	48
Corpus Christi TX	2,630	600	4.10	4,370	49
El Paso TX	5,350	1,380	4.20	3,890	50
Northeastern Avg	30,660	4,650	3.46	6,310	
Midwestern Avg	15,110	2,530	3.55	5,660	
Southern Avg	10,460	1,760	3.89	5,840	
Southwestern Avg	10,700	2,050	4.13	5,120	
Western Avg	26,430	4,250	3.88	6,100	
Texas Avg	8,540	1,750	4.23	4,760	
Total Avg	17,330	2,860	3.80	5,750	
Maximum Value	132,830	20,130	4.80	7,970	
Minimum Value	2,630	380	2.40	3,890	

Notes:
[1] Daily vehicle-kilometers of travel.
[2] Average number of lanes.
[3] Daily vehicle-kilometers of travel per lane-kilometer of freeway.
[4] Rank value of 1 associated with most congested condition.
Ranked by daily VKT/lane-kilometer.

Source: TTI Analysis and Local Transportation Agency References

Table A-3. Freeway and Expressway Recurring and Incident Hours of Daily Delay for 1992[1]

Urban Area	Recurring Hours of Delay				Incident Hours of Delay			
	Moderate	Heavy	Severe	Total	Moderate	Heavy	Severe	Total
Northeastern Cities								
Baltimore MD	6,850	7,460	20,720	35,030	15,750	17,170	47,660	80,580
Boston MA	6,130	19,840	42,700	68,670	21,450	69,440	149,460	240,350
Hartford CT	1,250	2,670	2,560	6,480	3,380	7,220	6,910	17,510
New York NY	82,870	99,620	131,060	313,550	207,180	249,060	327,650	783,890
Philadelphia PA	6,120	5,660	20,750	32,530	12,860	11,890	43,580	68,330
Pittsburgh PA	1,920	3,740	6,520	12,180	5,580	10,830	18,900	35,310
Washington DC	9,370	35,730	91,270	136,370	20,620	78,610	200,080	300,030
Midwestern Cities								
Chicago IL	18,880	18,130	130,460	167,470	22,660	21,760	156,550	200,970
Cincinnati OH	9,250	10,340	4,410	24,000	7,400	8,270	3,530	19,200
Cleveland OH	10,160	6,160	8,610	24,930	7,110	4,310	6,020	17,440
Columbus OH	1,270	5,410	13,510	20,190	890	3,790	9,460	14,140
Detroit MI	11,740	7,520	71,930	91,190	25,840	16,540	158,250	200,630
Indianapolis IN	2,930	640	780	4,350	4,390	960	1,170	6,520
Kansas City MO	4,000	980	2,790	7,770	12,390	3,030	8,640	24,060
Louisville KY	,630	350	1,060	2,040	700	390	1,160	2,250
Milwaukee WI	2,870	4,770	7,770	15,410	2,870	4,770	7,770	15,410
Minn-St. Paul MN	8,490	2,610	27,160	38,260	7,640	2,350	24,440	34,430
Oklahoma City OK	1,830	2,150	0	3,980	2,010	2,360	0	4,370
St. Louis MO	9,940	7,300	3,960	21,200	11,930	8,760	4,750	25,440
Southern Cities								
Atlanta GA	6,140	34,050	52,000	92,190	6,750	37,460	57,200	101,410
Charlotte NC	2,830	1,390	2,300	6,520	2,260	1,110	1,840	5,210
Ft. Lauderdale FL	5,810	9,080	3,410	18,300	8,710	13,610	5,110	27,430
Jacksonville FL	3,410	7,260	1,160	11,830	5,120	10,890	1,740	17,750
Memphis TN	2,300	1,140	630	4,070	2,530	1,260	700	4,490
Miami FL	9,000	4,910	22,880	36,790	13,500	7,360	34,320	55,180
Nashville TN	4,420	1,750	2,140	8,310	4,860	1,930	2,350	9,140
New Orleans LA	2,340	9,730	3,960	16,030	4,210	17,520	7,130	28,860
Norfolk VA	2,420	6,540	6,350	15,310	6,040	16,340	15,870	38,250
Orlando FL	4,020	2,190	4,750	10,960	6,030	3,290	7,120	16,440
Tampa FL	750	1,380	4,500	6,630	1,120	2,070	6,750	9,940
Southwestern Cities								
Albuquerque NM	730	1,200	1,220	3,150	800	1,320	1,340	3,460
Austin TX	5,040	6,990	7,32	19,350	5,540	7,690	8,050	21,280
Corpus Christi TX	910	350	0	1,260	1,000	390	0	1,390
Dallas TX	14,320	26,970	48,540	89,830	25,780	48,540	87,380	161,700
Denver CO	7,700	12,110	26,110	45,920	7,700	12,110	26,110	45,920
El Paso TX	1,780	2,470	830	5,080	1,960	2,720	910	5,590
Fort Worth TX	5,440	10,250	18,450	34,140	9,800	18,440	33,200	61,440
Houston TX	14,700	35,230	99,640	149,570	20,570	49,320	139,490	209,380
Phoenix AZ	4,960	5,870	30,330	41,160	1,980	2,350	12,130	16,460
Salt Lake City UT	1,630	3,000	2,650	7,280	980	1,800	1,590	4,370
San Antonio TX	2,990	8,280	16,020	27,290	3,280	9,110	17,620	30,010
Western Cities								
Honolulu HI	1,770	4,910	10,990	17,670	3,180	8,830	19,780	31,790
Los Angeles CA	25,940	23,950	585,790	635,680	31,130	28,740	702,940	762,810
Portland OR	4,660	4,040	12,180	20,880	9,330	8,090	24,360	41,780
Sacramento CA	5,930	9,750	1,860	17,540	3,560	5,850	1,120	10,530
San Bernardino-Riv CA	3,180	11,470	63,610	78,260	3,820	13,770	76,330	93,920
San Diego CA	21,790	20,380	47,270	89,440	13,080	12,230	28,360	53,670
San Fran-Oak CA	27,020	32,480	180,130	239,630	35,130	42,230	234,170	311,530
San Jose CA	9,230	12,720	47,020	68,970	11,080	15,260	56,420	82,760
Seattle-Everett WA	7,220	35,810	55,430	98,460	10,110	50,130	77,600	137,840
Northeastern Avg	16,360	24,960	45,080	86,400	40,970	63,460	113,570	218,000
Midwestern Avg	6,830	5,530	22,700	35,060	8,820	6,440	31,810	47,070
Southern Avg	3,950	7,220	9,460	20,630	5,560	10,260	12,740	28,560
Southwestern Avg	5,470	10,250	22,830	38,550	7,220	13,980	29,800	51,000
Western Avg	11,860	17,280	111,590	140,730	13,380	20,570	135,680	169,630
Texas Avg	6,450	12,930	27,260	46,640	9,710	19,460	40,950	70,120
Total Avg	8,140	11,770	38,950	58,860	13,070	19,470	57,320	89,860
Maximum Value	82,870	99,620	585,790	635,680	207,180	249,060	702,940	783,890
Minimum Value	630	350	0	1,260	800	390	0	1,390

Notes: [1] Delay calculated based on vehicular speed in Table 3.

Source: TTI Analysis

Table A-4. Principal Arterial Street Recurring and Incident Hours of Daily Delay for 1992[1]

Urban Area	Recurring Hours of Delay				Incident Hours of Delay			
	Moderate	Heavy	Severe	Total	Moderate	Heavy	Severe	Total
Northeastern Cities								
Baltimore MD	1,400	2,750	15,570	19,720	1,540	3,030	17,120	21,690
Boston MA	4,630	5,210	16,420	26,260	5,090	5,730	18,060	28,880
Hartford CT	1,310	2,400	2,630	6,340	1,440	2,640	2,900	6,980
New York NY	16,460	55,540	193,250	265,250	18,110	61,090	212,570	291,770
Philadelphia PA	6,870	18,360	65,190	90,420	7,560	20,200	71,710	99,470
Pittsburgh PA	5,050	6,290	23,470	34,810	5,550	6,920	25,820	38,290
Washington DC	7,240	13,970	66,800	88,010	7,960	15,360	73,480	96,800
Midwestern Cities								
Chicago IL	12,600	35,440	73,570	121,610	13,860	38,990	80,920	133,770
Cincinnati OH	1,300	1,500	3,870	6,670	1,420	1,650	4,250	7,320
Cleveland OH	1,360	4,960	4,710	11,030	1,500	5,460	5,180	12,140
Columbus OH	1,120	1,540	7,000	9,660	1,240	1,690	7,700	10,630
Detroit MI	3,840	19,440	68,440	91,720	4,230	21,380	75,280	100,890
Indianapolis IN	1,800	1,050	1,500	4,350	1,980	1,150	1,650	4,780
Kansas City MO	1,310	1,730	2,740	5,780	1,440	1,900	3,010	6,350
Louisville KY	790	3,460	6,560	10,810	870	3,810	7,220	11,900
Milwaukee WI	1,600	2,660	4,710	8,970	1,760	2,930	5,180	9,870
Minn-St. Paul MN	1,090	3,930	16,480	21,500	1,200	4,320	18,130	23,650
Oklahoma City OK	1,060	2,470	4,650	8,180	1,170	2,710	5,120	9,000
St. Louis MO	5,570	11,740	20,570	37,880	6,120	12,920	22,620	41,660
Southern Cities								
Atlanta GA	2,890	6,100	27,420	36,410	3,180	6,710	30,160	40,050
Charlotte NC	450	2,160	8,530	11,140	490	2,370	9,380	12,240
Ft. Lauderdale FL	2,370	5,420	8,140	15,930	2,600	5,960	8,950	17,510
Jacksonville FL	3,880	1,720	8,950	14,550	4,270	1,900	9,840	16,010
Memphis TN	1,740	3,400	3,030	8,170	1,910	3,740	3,330	8,980
Miami FL	1,640	10,370	52,930	64,940	1,800	11,410	58,230	71,440
Nashville TN	2,230	4,210	3,740	10,180	2,460	4,640	4,110	11,210
New Orleans LA	2,020	2,420	5,900	10,340	2,220	2,660	6,490	11,370
Norfolk VA	1,010	1,970	7,480	10,460	1,110	2,160	8,230	11,500
Orlando FL	150	690	6,560	7,400	160	760	7,210	8,130
Tampa FL	2,070	3,280	10,770	16,120	2,280	3,610	11,850	17,740
Southwestern Cities								
Albuquerque NM	2,150	2,510	3,070	7,730	2,360	2,760	3,380	8,500
Austin TX	1,010	1,710	1,900	4,620	1,120	1,880	2,090	5,090
Corpus Christi TX	410	400	140	950	450	440	160	1,050
Dallas TX	4,000	3,860	5,420	13,280	4,400	4,240	5,960	14,600
Denver CO	3,830	5,180	20,140	29,150	4,220	5,690	22,150	32,060
El Paso TX	320	270	1,070	1,660	360	300	1,170	1,830
Fort Worth TX	1,740	1,680	2,360	5,780	1,910	1,850	2,590	6,350
Houston TX	3,940	12,810	10,460	27,210	4,330	14,090	11,510	29,930
Phoenix AZ	11,320	20,160	30,290	61,770	12,450	22,170	33,310	67,930
Salt Lake City UT	1,960	1,690	940	4,590	2,150	1,860	1,040	5,050
San Antonio TX	1,500	1,770	3,940	7,210	1,650	1,950	4,330	7,930
Western Cities								
Honolulu HI	850	750	5,560	7,160	930	830	6,110	7,870
Los Angeles CA	18,260	81,250	145,390	244,900	20,090	89,380	159,930	269,400
Portland OR	1,030	4,920	6,380	12,330	1,140	5,410	7,020	13,570
Sacramento CA	1,730	4,590	15,030	21,350	1,910	5,050	16,530	23,490
San Bernardino-Riv CA	7,110	7,200	12,980	27,290	7,820	7,920	14,270	30,010
San Diego CA	1,640	9,860	5,380	16,880	1,800	10,850	5,920	18,570
San Fran-Oak CA	2,320	6,350	41,210	49,880	2,550	6,990	45,330	54,870
San Jose CA	2,870	3,660	17,440	23,970	3,150	4,020	19,180	26,350
Seattle-Everett WA	2,210	5,140	23,030	30,380	2,440	5,650	25,330	33,420
Northeastern Avg	6,140	14,930	54,760	75,830	6,750	16,420	60,240	83,410
Midwestern Avg	2,790	7,490	17,900	28,180	3,070	8,240	19,690	31,000
Southern Avg	1,860	3,790	13,040	18,690	2,040	4,170	14,340	20,550
Southwestern Avg	2,930	4,730	7,250	14,910	3,220	5,200	7,970	16,390
Western Avg	4,230	13,750	30,270	48,250	4,650	15,120	33,290	53,060
Texas Avg	1,850	3,210	3,610	8,670	2,030	3,540	3,970	9,540
Total Avg	3,340	8,240	21,870	33,450	3,680	9,060	24,060	36,800
Maximum Value	18,260	81,250	193,250	265,250	20,090	89,380	212,570	291,770
Minimum Value	150	270	140	950	160	300	160	1,050

Notes: [1] Delay calculated based on vehicular speed in Table 3.

Source: TTI Analysis

APPENDIX B

ESTIMATION OF CONGESTION COST

ESTIMATION OF CONGESTION COST

The cost of congestion in each area is estimated using the Highway Performance Monitoring System database and several factors developed from studies of urban travel speeds and traffic volume. This Appendix summarizes the constant values and the variables used to estimate travel delay and fuel consumption costs resulting from traffic congestion.

Cost Estimate Constants

Congestion cost estimates are prepared with the following values held constant for all 50 areas.

- Occupancy—1.25 persons per vehicle. This value is representative of most urban travel during peak travel periods. Occupancy levels are slightly higher near major activity centers and lower in the suburbs.
- Working days per year—250. Weekends and holidays when congestion levels drop dramatically are not considered in the conversion from average daily to annual estimates.
- Average cost of time—$10.50 per person hour (14).[1]

The concept of time valuation used in this study is that people demonstrate a value that they place on time by their actions. Use of a toll facility, frequent lane changing maneuvers, close headway driving or using residential streets to bypass a congested arterial are behaviors that could lead to accidents or traffic citations, but also may be perceived as time-saving actions. These are the types of characteristics that are included in the value of time used in this study, rather than a wage-based value that might estimate the value to society from time spent in congestion.

- Commercial vehicle operating cost—$1.34 per kilometer (13). The congestion impact on cargo is not measured in this cost component, only the value of the vehicle and driver.

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[1]Referenced value of $8.00/hr in 1985 adjusted with the Consumer Price Index to value used for 1992 wage rate.

- Vehicle types—95 percent passenger and 5 percent commercial. While the truck percentage is significantly higher in some corridors, this is a good estimate for most urban areas during the peak periods.
- Vehicle Speeds—illustrated in Table B-1. An analysis of traffic volume per lane and peak period travel speed resulted in the speed estimates used in the delay estimates.

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

Table B-1. Congested Daily Vehicle-Kilometers of Travel by Average Annual Daily Traffic per Lane Volumes

Functional Class	Parameters	Uncongested	Congested Daily VKT[1,2]		
			Moderate	Heavy	Severe
Freeway/Expressway	ADT/Lane	Under 15,000	15,000 - 17,500	17,501 - 20,000	Over 20,000
	Speed (kph)[3]	100	61	53	48
Principal Arterial Streets	ADT/Lane	Under 5,750	5,750 - 7,000	7,001 - 8,500	Over 8,500
	Speed (kph)[3]	60	45	40	37

Note: [1] Assumes congested freeway operation when ADT/Lane exceeds 15,000.
[2] Assumes congested principal arterial street operations when ADT/lane exceeds 5,750.
[3] Moderate, heavy, and severe values represent a "soft" conversion from miles per hour

Source: TTI Analysis and Houston-Galveston Regional Transportation Study (Volume 2, Appendix B)

Cost Estimate Variables

In addition to the derived constants, five urbanized area/state specific variables were identified and used in the congestion cost estimate calculations. These variables are illustrated in Table B-2.

Table B-2. 1992 Congestion Cost Estimate Variables

Urban Area	Daily VKT Freeway (1000)	Daily VKT Prin. Art. St. (1000)	State Average Fuel Cost, ($/liter)	Registered Autos (1000)	Population (1000)	Population per Registered Vehicle
Northeastern Cities						
Baltimore MD	28,340	15,940	0.37	1,080	2,040	1.90
Boston MA	35,250	20,920	0.36	1,670	2,960	1.77
Hartford CT	10,870	6,180	0.37	530	620	1.16
New York NY	134,440	89,070	0.37	6,100	16,950	2.78
Philadelphia PA	31,220	34,860	0.35	2,820	5,000	1.77
Pittsburgh PA	14,710	17,870	0.35	1,250	1,880	1.50
Washington DC	44,190	29,790	0.37	1,710	3,290	1.92
Midwestern Cities						
Chicago IL	63,110	52,810	0.38	4,050	7,520	1.86
Cincinnati OH	19,180	7,250	0.35	970	1,220	1.26
Cleveland OH	22,800	10,140	0.35	1,500	1,790	1.19
Columbus OH	15,230	5,760	0.35	800	950	1.19
Detroit MI	46,050	39,450	0.35	2,880	4,000	1.39
Indianapolis IN	13,390	6,840	0.34	590	960	1.61
Kansas City MO	22,060	7,870	0.32	770	1,200	1.56
Louisville KY	10,510	5,350	0.34	460	820	1.75
Milwaukee WI	12,610	8,370	0.35	540	1,230	2.27
Minn-St. Paul MN	30,590	10,950	0.35	1,730	2,110	1.22
Oklahoma City OK	11,750	6,390	0.34	490	750	1.51
St. Louis MO	30,480	20,090	0.32	1,030	1,990	1.92
Southern Cities						
Atlanta GA	42,670	16,100	0.33	1,770	2,280	1.28
Charlotte NC	5,150	5,150	0.35	410	500	1.22
Ft. Lauderdale FL	12,480	10,220	0.35	1,040	1,290	1.23
Jacksonville FL	9,270	9,890	0.35	620	760	1.23
Memphis TN	8,100	8,070	0.35	640	880	1.37
Miami FL	15,090	27,050	0.35	1,460	1,920	1.32
Nashville TN	9,660	8,860	0.35	530	590	1.11
New Orleans LA	8,130	6,760	0.36	890	1,100	1.24
Norfolk VA	9,450	7,690	0.36	840	970	1.15
Orlando FL	9,740	7,810	0.35	750	880	1.18
Tampa FL	6,120	7,490	0.35	640	720	1.11
Southwestern Cities						
Albuquerque NM	4,030	6,920	0.35	430	530	1.22
Austin TX	9,100	3,540	0.34	510	570	1.10
Corpus Christi TX	2,700	2,630	0.34	230	290	1.24
Dallas TX	39,450	13,770	0.34	1,640	2,080	1.27
Denver CO	20,130	17,710	0.37	1,400	1,600	1.14
El Paso TX	5,640	5,350	0.34	350	570	1.60
Fort Worth TX	20,610	6,990	0.34	1,000	1,200	1.20
Houston TX	49,110	17,940	0.34	2,260	2,910	1.29
Phoenix AZ	15,700	29,150	0.35	1,290	2,020	1.56
Salt Lake City UT	9,300	4,150	0.37	730	860	1.18
San Antonio TX	16,000	9,560	0.34	880	1,190	1.35
Western Cities						
Honolulu HI	8,190	2,810	0.43	530	690	1.30
Los Angeles CA	180,240	132,830	0.37	7,880	11,850	1.50
Portland OR	12,830	6,300	0.36	700	1,060	1.51
Sacramento CA	16,290	12,450	0.37	1290	1,190	0.93
San Bernardino-Riv CA	24,330	17,310	0.37	800	1,300	1.63
San Diego CA	44,760	15,620	0.37	1,490	2,480	1.67
San Fran-Oak CA	68,100	22,830	0.37	3,120	3,810	1.22
San Jose CA	26,730	11,910	0.37	1,040	1,510	1.45
Seattle-Everett WA	32,640	15,780	0.36	1,330	1,840	1.38
Northeastern Avg	42,710	30,660	0.36	2,160	4,670	1.83
Midwestern Avg	24,810	15,110	0.35	1,320	2,040	1.56
Southern Avg	12,350	10,460	0.35	870	1,080	1.22
Southwestern Avg	17,430	10,700	0.35	980	1,250	1.29
Western Avg	46,010	26,430	0.37	2,020	2,860	1.40
Texas Avg	20,370	8,540	0.34	980	1,260	1.29
Total Avg	26,770	17,330	0.35	1,390	2,170	1.43
Maximum Value	180,240	132,830	0.43	7,880	16,950	2.78
Minimum Value	2,700	2,630	0.32	230	290	0.93

Source: TTI Analysis and Local Transportation Agency References

Daily Vehicle-Kilometers of Travel

The daily vehicle-kilometers of travel (VKT) is the average daily traffic (ADT) of a section of roadway multiplied by the length (in kilometers) of that section of roadway. This allows the daily volume of all urban facilities to be represented in terms that can be quantified and utilized in cost calculations. Daily VKT was estimated for the freeways and principal arterial streets located in each study urbanized area. These estimates originate from the HPMS data base and other local transportation data sources and are presented in a previous section of this report.

Fuel Costs

Statewide average fuel cost estimates were obtained from 1992 data published by the American Automobile Association (AAA). These data represent the average reported fuel cost for 1992. 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 were 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 1992.

Population

Population data were obtained from the combination of 1990 U.S. Census Bureau estimates and 1992 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 daily VKT 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, vehicle-kilometers of travel on congested roadways during each peak period was estimated. This was accomplished by the use of two factors.

Highway Performance Monitoring System (HPMS) data were used to determine the percentage of urbanized area daily VKT 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 ADT per lane values shown in Table B-1.

Using Table B-1 values, the percentage of daily VKT operating in each of the three congested conditions could be calculated for each functional class. These percentages adjust daily VKT to congested daily VKT, the first step in the process to obtain travel volume that occurs during congested conditions.

The congested daily travel values were adjusted by a factor to represent the percentage of travel occurring in the peak period. This factor was calculated using the Texas Department of Transportation's (TxDOT) 1986 Automatic Traffic Recorder Data (23) for the study areas in Texas. Using these data, the percentage of ADT occurring during the morning and evening peak periods was estimated using these data. These data indicated that a relatively consistent value of 45 percent of total daily traffic occurred during the peak periods. This factor was applied to all the study areas.

Once the daily VKT was converted to peak-period congested vehicle-kilometers of travel (Table B-3), the recurring vehicle-hours of delay were computed (Equation B-1). Recurring delay is caused by the peak facility conditions during normal operations. This value does not include delay resulting from accidents, construction, or maintenance operations.

$$\begin{array}{c}\textit{Recurring}\\ \textit{Vehicle-Hours of}\\ \textit{Delay per Day}\end{array} = \frac{\textit{Peak-Period Congested DVKT}}{\textit{Avg. Peak-Period Speed}} - \frac{\textit{Peak-Period Congested DVKT}}{\textit{Avg. Off-Peak Speed}} \qquad \text{Eq. B-1}$$

This calculation was performed for both freeways and principal arterial streets 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-4.

Another type of delay encountered by vehicles is incident delay. This is the delay that results from an accident or disabled vehicle. Incident vehicle-hours of delay vary for each area by facility type, i.e., freeway/expressway or arterial street. For the freeway system in individual study areas, the ratio of recurring to incident delay reported by Lindley (16) were used. The resulting incident delay was calculated using Equation B-2.

$$\begin{array}{c}\textit{Frwy Incident}\\ \textit{Vehicle-Hours of Delay}\\ \textit{per Day}\end{array} = \begin{array}{c}\textit{Peak-Period}\\ \textit{Frwy Vehicle-Hours of Delay}\\ \textit{per Day}\end{array} \times \begin{array}{c}\textit{Frwy}\\ \textit{Incident/Recurring}\\ \textit{Ratio}\end{array} \qquad \text{Eq. B-2}$$

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.

$$\begin{array}{c}\textit{Principal Arterial Street Incident}\\ \textit{Vehicle-Hour Delay}\\ \textit{per Day}\end{array} = \begin{array}{c}\textit{Principal Artrial Street Recurring}\\ \textit{Vehicle-Hour Delay}\\ \textit{per Day}\end{array} \times 1.1 \qquad \text{Eq. B-3}$$

Table B-3. 1992 Congested Daily Vehicle-Kilometers of Travel

Urban Area	Daily Vehicle-Kilometers of Travel		Percent of Peak-Period[1,2] VKT on Congested Roads		Peak Period Congested Daily VKT[1,3]		
	Freeway (1000)	Prin.Art.St. (1000)	Freeway (%)	Prin.Art.St. (%)	Freeway (1000)	Prin.Art.St. (1000)	Freeway & Prin.Art.St. (1000)
Northeastern Cities							
Baltimore MD	28,340	15,940	30	35	3,830	2,510	6,340
Boston MA	35,250	20,920	45	40	7,140	3,770	10,900
Hartford CT	10,870	6,180	15	35	730	970	1,710
New York NY	134,440	89,070	60	85	36,300	34,070	70,360
Philadelphia PA	31,220	34,860	25	75	3,510	11,760	15,280
Pittsburgh PA	14,710	17,870	20	60	1,320	4,830	6,150
Washington DC	44,190	29,790	70	85	13,920	11,390	25,310
Midwestern Cities							
Chicago IL	63,110	52,810	60	70	17,040	16,630	33,670
Cincinnati OH	19,180	7,250	35	30	3,020	980	4,000
Cleveland OH	22,800	10,140	30	35	3,080	1,600	4,680
Columbus OH	15,230	5,760	30	50	2,060	1,300	3,350
Detroit MI	46,050	39,450	45	65	9,320	11,540	20,860
Indianapolis IN	13,390	6,840	10	25	600	770	1,370
Kansas City MO	22,060	7,870	10	25	990	890	1,880
Louisville KY	10,510	5,350	5	60	240	1,450	1,680
Milwaukee WI	12,610	8,370	30	35	1,700	1,320	3,020
Minn-St. Paul MN	30,590	10,950	30	55	4,130	2,710	6,840
Oklahoma City OK	11,750	6,390	10	40	530	1,150	1,680
St. Louis MO	30,480	20,090	20	60	2,740	5,430	8,170
Southern Cities							
Atlanta GA	42,670	16,100	50	65	9,600	4,710	14,310
Charlotte NC	5,150	5,150	35	60	810	1,390	2,200
Ft. Lauderdale FL	12,480	10,220	40	50	2,250	2,300	4,550
Jacksonville FL	9,270	9,890	35	50	1,460	2,230	3,690
Memphis TN	8,100	8,070	15	35	550	1,270	1,820
Miami FL	15,090	27,050	60	65	4,070	7,910	11,980
Nashville TN	9,660	8,860	25	40	1,090	1,590	2,680
New Orleans LA	8,130	6,760	50	50	1,830	1,520	3,350
Norfolk VA	9,450	7,690	40	40	1,700	1,380	3,080
Orlando FL	9,740	7,810	30	25	1,310	880	2,190
Tampa FL	6,120	7,490	25	65	690	2,190	2,880
Southwestern Cities							
Albuquerque NM	4,030	6,920	20	40	360	1,250	1,610
Austin TX	9,100	3,540	55	45	2,250	720	2,970
Corpus Christi TX	2,700	2,630	15	15	180	180	360
Dallas TX	39,450	13,770	55	35	9,760	2,170	11,930
Denver CO	20,130	17,710	55	50	4,980	3,980	8,970
El Paso TX	5,640	5,350	25	10	630	240	870
Fort Worth TX	20,610	6,990	40	30	3,710	940	4,650
Houston TX	49,110	17,940	70	50	15,470	4,040	19,500
Phoenix AZ	15,700	29,150	60	70	4,240	9,180	13,420
Salt Lake City UT	9,300	4,150	20	45	840	840	1,680
San Antonio TX	16,000	9,560	40	25	2,880	1,080	3,960
Western Cities							
Honolulu HI	8,190	2,810	50	75	1,840	950	2,790
Los Angeles CA	180,240	132,830	75	55	60,830	32,870	93,710
Portland OR	12,830	6,300	40	60	2,310	1,700	4,010
Sacramento CA	16,290	12,450	30	50	2,200	2,800	5,000
San Bernardino-Riv CA	24,330	17,310	70	55	7,660	4,280	11,950
San Diego CA	44,760	15,620	50	35	10,070	2,460	12,530
San Fran-Oak CA	68,100	22,830	80	60	24,520	6,160	30,680
San Jose CA	26,730	11,910	60	60	7,220	3,220	10,430
Seattle-Everett WA	32,640	15,780	70	55	10,280	3,910	14,190
Northeastern Avg	42,710	30,660	38	59	9,540	9,900	19,440
Midwestern Avg	24,810	15,110	26	46	3,790	3,810	7,600
Southern Avg	12,350	10,460	37	50	2,310	2,490	4,790
Southwestern Avg	17,430	10,700	41	38	4,120	2,240	6,360
Western Avg	46,010	26,430	58	56	14,100	6,480	20,590
Texas Avg	20,370	8,540	43	30	4,980	1,340	6,320
Total Avg	26,770	17,330	39	49	6,200	4,510	10,700
Maximum Value	180,240	132,830	80	85	60,830	34,070	93,710
Minimum Value	2,700	2,630	5	10	180	180	360

Notes: [1] Daily vehicle-kilometers of travel.

[2] Represents the percentage of daily vehicle-kilometers of travel on each roadway system during the peak period operating on congested conditions.

[3] Daily vehicle-kilometers of travel multiplied by peak-period vehicle travel and percent of congested daily VKT.

Source: TTI Analysis and Local Transportation Agency References

Table B-4. Recurring and Incident Delay Relationships for 1992

Urban Area	Peak Period Congested Daily VKT[1]			Ratio of Incident[2] Delay to Recurring Delay		Daily Recurring Vehicle[3] Hours of Delay			Daily Incident Vehicle[3] Hours of Delay		
	Freeway (1000)	Prin.Art.St. (1000)	Freeway and Prin. Art. St. (1000)	Freeway	Prin.Art.St.	Freeway	Hours of Delay Prin.Art.St.	Total	Freeway	Prin.Art.St.	Total
Northeastern Cities											
Baltimore MD	3,830	2,510	6,340	2.3	1.1	35,030	19,720	54,750	80,570	21,690	102,270
Boston MA	7,140	3,770	10,900	3.5	1.1	68,670	26,260	94,930	240,350	28,880	269,230
Hartford CT	730	970	1,710	2.7	1.1	6,490	6,340	12,830	17,510	6,970	24,490
New York NY	36,300	34,070	70,360	2.5	1.1	313,550	265,250	578,800	783,890	291,770	1,075,660
Philadelphia PA	3,510	11,760	15,280	2.1	1.1	32,540	90,420	122,960	68,330	99,470	167,800
Pittsburgh PA	1,320	4,830	6,150	2.9	1.1	12,180	34,810	46,990	35,310	38,290	73,600
Washington DC	13,920	11,390	25,310	2.2	1.1	136,370	88,010	224,380	300,020	96,810	396,830
Midwestern Cities											
Chicago IL	17,040	16,630	33,670	1.2	1.1	167,470	121,610	289,090	200,970	133,770	334,740
Cincinnati OH	3,020	980	4,000	0.8	1.1	24,000	6,660	30,670	19,200	7,330	26,530
Cleveland OH	3,080	1,600	4,680	0.7	1.1	24,920	11,030	35,960	17,450	12,140	29,580
Columbus OH	2,060	1,300	3,350	0.7	1.1	20,190	9,660	29,860	14,140	10,630	24,760
Detroit MI	9,320	11,540	20,860	2.2	1.1	91,190	91,720	182,910	200,620	100,890	301,510
Indianapolis IN	600	770	1,370	1.5	1.1	4,350	4,350	8,700	6,530	4,790	11,310
Kansas City MO	990	890	1,880	3.1	1.1	7,760	5,770	13,530	24,060	6,340	30,400
Louisville KY	240	1,450	1,680	1.1	1.1	2,040	10,820	12,860	2,250	11,900	14,150
Milwaukee WI	1,700	1,320	3,020	1.0	1.1	15,400	8,970	24,370	15,400	9,870	25,270
Minn-St. Paul MN	4,130	2,710	6,840	0.9	1.1	38,260	21,500	59,760	34,430	23,650	58,080
Oklahoma City OK	530	1,150	1,680	1.1	1.1	3,980	8,180	12,160	4,380	9,000	13,380
St. Louis MO	2,740	5,430	8,170	1.2	1.1	21,200	37,880	59,070	25,440	41,670	67,100
Southern Cities											
Atlanta GA	9,600	4,710	14,310	1.1	1.1	92,190	36,400	128,590	101,410	40,040	141,450
Charlotte NC	810	1,390	2,200	0.8	1.1	6,520	11,130	17,650	5,210	12,240	17,460
Ft. Lauderdale FL	2,250	2,300	4,550	1.5	1.1	18,290	15,920	34,210	27,430	17,510	44,950
Jacksonville FL	1,460	2,230	3,690	1.5	1.1	11,830	14,560	26,390	17,750	16,010	33,760
Memphis TN	550	1,270	1,820	1.1	1.1	4,070	8,160	12,230	4,480	8,980	13,460
Miami FL	4,070	7,910	11,980	1.5	1.1	36,790	64,950	101,730	55,180	71,440	126,620
Nashville TN	1,090	1,590	2,680	1.1	1.1	8,310	10,190	18,500	9,150	11,210	20,350
New Orleans LA	1,830	1,520	3,350	1.8	1.1	16,040	10,340	26,370	28,870	11,370	40,240
Norfolk VA	1,700	1,380	3,080	2.5	1.1	15,300	10,450	25,750	38,250	11,500	49,750
Orlando FL	1,310	880	2,190	1.5	1.1	10,960	7,390	18,360	16,450	8,130	24,580
Tampa FL	690	2,190	2,880	1.5	1.1	6,630	16,120	22,760	9,950	17,740	27,680

Table B-4. Recurring and Incident Delay Relationships for 1992 (continued)

Urban Area	Peak Period Congested Daily VKT[1]			Ratio of Incident[2] Delay to Recurring Delay		Daily Recurring Vehicle[3] Hours of Delay			Daily Incident Vehicle[3] Hours of Delay		
	Freeway (1000)	Prin.Art.St. (1000)	Freeway and Prin. Art. St. (1000)	Freeway	Prin.Art.St.	Freeway	Hours of Delay Prin.Art.St.	Total	Freeway	Prin.Art.St.	Total
Southwestern Cities											
Albuquerque NM	360	1,250	1,610	1.1	1.1	3,150	7,730	10,880	3,460	8,500	11,960
Austin TX	2,250	720	2,970	1.1	1.1	19,340	4,630	23,970	21,280	5,090	26,370
Corpus Christi TX	180	180	360]	1.1	1.1	1,260	960	2,220	1,390	1,060	2,440
Dallas TX	9,760	2,170	11,930	1.8	1.1	89,840	13,270	103,110	161,710	14,600	176,310
Denver CO	4,980	3,980	8,970	1.0	1.1	45,930	29,150	75,070	45,930	32,060	77,990
El Paso TX	630	240	870	1.1	1.1	5,080	1,660	6,750	5,590	1,830	7,420
Fort Worth TX	3,710	940	4,650	1.8	1.1	34,130	5,780	39,910	61,440	6,350	67,800
Houston TX	15,470	4,040	19,500	1.4	1.1	149,560	27,210	176,760	209,380	29,930	239,310
Phoenix AZ	4,240	9,180	13,420	0.4	1.1	41,170	61,760	102,930	16,470	67,940	84,410
Salt Lake City UT	840	840	1,680	0.6	1.1	7,270	4,590	11,860	4,360	5,050	9,420
San Antonio TX	2,880	1,080	3,960	1.1	1.1	27,280	72,10	34,490	30,010	7,930	37,940
Western Cities											
Honolulu HI	1,840	950	2,790	1.8	1.1	17,660	7,160	24,820	31,790	7,870	39,660
Los Angeles CA	60,830	32,870	93,710	1.2	1.1	635,680	244,900	880,580	762,810	269,390	1,032,210
Portland OR	2,310	1,700	4,010	2.0	1.1	20,890	12,340	33,230	41,770	13,580	55,350
Sacramento CA	2,200	2,800	5,000	0.6	1.1	17,540	21,360	38,890	10,520	23,490	34,010
San Bernardino-Riv CA	7,660	4,280	11,950	1.2	1.1	78,260	27,290	105,550	93,910	30,020	123,930
San Diego CA	10,070	2,460	12,530	0.6	1.1	89,450	16,880	106,320	53,670	18,570	72,230
San Fran-Oak CA	24,520	6,160	30,680	1.3	1.1	239,640	49,880	289,520	311,530	54,870	366,390
San Jose CA	7,220	3,220	10,430	1.2	1.1	68,970	23,960	92,930	82,760	26,350	109,120
Seattle-Everett WA	10,280	3,910	14,190	1.4	1.1	98,460	30,380	128,840	137,840	33,420	171,260
Northeastern Avg	9,540	9,900	19,440	2.6	1.1	86,400	75,830	162,230	218,000	83,410	301,410
Midwestern Avg	3,790	3,810	7,600	1.3	1.1	35,070	28,180	63,240	47,070	31,000	78,070
Southern Avg	2,310	2,490	4,790	1.4	1.1	20,630	18,690	39,320	28,560	20,560	49,120
Southwestern Avg	4,120	2,240	6,360	1.1	1.1	38,550	14,900	53,450	51,000	16,390	67,400
Western Avg	14,100	6,480	20,590	1.3	1.1	140,730	48,240	188,960	169,620	53,060	222,680
Texas Avg	4,980	1,340	6,320	1.3	1.1	46,640	8,670	55,320	70,110	9,540	79,660
Total Avg	6,200	4,510	10,700	1.5	1.1	58,860	33,450	92,320	89,850	36,800	126,650
Maximum Value	60,830	34,070	93,710	3.5	1.1	635,680	265,250	880,580	783,890	291,770	1,075,660
Minimum Value	180	180	360	0.4	1.1	1,260	960	2,220	1,390	1,060	2,440

Notes:
[1] Daily vehicle-kilometers of travel. Represents the percentage of Daily Vehicle-Kilometers of travel on each roadway system during the peak period operating in congested conditions.
[2] Percentage of Incident Delay related to Recurring Delay.
[3] Facility delays as calculated by type and urban area.

Source: TTI Analysis and Local Transportation Agency References

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

1. Arterial street system designs are more consistent from city to city than freeway design;

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

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

Table B-4 shows the results of the freeway and principal arterial street recurring and incident delay calculations.

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 economy 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.

$$\underset{(kph)}{\textit{Avg. Speed}} = \frac{(\textit{Frwy speed}^{1} \times \textit{Peak-Period Frwy VKT}) + (\textit{Prin.Art. Speed}^{1} \times \textit{Peak-Period Prin.Art. Str. VKT})}{\textit{Total Peak-Period VKT}} \quad \text{Eq. B-4}$$

[1] Speeds determined by congestion severity (Table B-1).

Congestion Cost

Two cost components can be associated with congestion: delay cost and fuel cost. These costs can be directly related to the vehicle-hours of delay. Table B-5 is a summary of the cost calculations for the component congestion cost per each urbanized area.

The average fuel economy 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 (24).

$$\underset{(kph)}{\textit{Average Fuel Economy}} = 3.74 + 0.11\ \underset{(kph)}{(\textit{Average Vehicular Speed})} \qquad \text{Eq. B-5}$$

Delay Cost - The delay cost is the cost of lost time due to congested roadways. This cost was calculated by Equation B-6.

$$\begin{matrix}\textit{Annual}\\ \textit{Delay Cost}\end{matrix} = \frac{\textit{Vehicle-Hrs. of Delay}}{\textit{Day}} \times \frac{1.25\,\textit{person}}{\textit{Vehicle}} \times \frac{\$10.50}{\textit{Hour}} \times \frac{250\,\textit{Workdays}}{\textit{Year}} \qquad \text{Eq. B-6}$$

where: vehicle-hours of delay/day is the combined freeway and principal arterial street representing the city's recurring or incident delay.

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

Table B-5. Component and Total Congestion Costs by Urban Area for 1992

Urban Area	Annual Cost Due to Congestion ($ millions)					Rank
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Total	
Los Angeles CA	3,420	4,000	420	490	8,330	1
New York NY	2,260	4,190	280	520	7,250	2
San Fran-Oak CA	1,140	1,430	140	180	2,890	3
Chicago IL	1,120	1,300	140	170	2,730	4
Washington DC	870	1,540	110	190	2,710	5
Detroit MI	710	1,160	80	140	2,090	6
Houston TX	700	940	80	110	1,830	7
Boston MA	370	1,050	40	130	1,590	8
Seattle-Everett WA	500	680	70	80	1,330	9
Dallas TX	410	700	50	80	1,240	11
Philadelphia PA	470	640	60	70	1,240	11
Atlanta GA	500	550	60	60	1,170	12
San Bernardino-Riv CA	410	480	50	60	1,000	13
Miami FL	390	490	50	50	980	14
San Jose CA	360	430	50	50	890	15
Phoenix AZ	400	320	40	40	800	17
San Diego CA	420	290	40	50	800	17
Baltimore MD	210	400	30	50	690	18
Denver CO	300	300	30	40	670	19
St. Louis MO	230	260	20	30	540	20
Pittsburgh PA	180	280	20	30	510	22
Minn-St. Paul MN	230	230	20	30	510	22
Fort Worth TX	160	270	20	30	480	23
Portland OR	130	220	20	20	390	24
Ft. Lauderdale FL	130	180	20	20	350	25
Norfolk VA	100	190	20	20	330	26
Sacramento CA	150	130	20	20	320	27
San Antonio TX	140	140	10	20	310	28
Cleveland OH	140	120	10	20	290	30
Honolulu HI	100	150	20	20	290	30
New Orleans LA	100	160	10	20	290	30
Cincinnati OH	120	110	10	20	260	33
Jacksonville FL	100	130	10	20	260	33
Columbus OH	110	100	10	20	240	34
Austin TX	100	100	10	10	220	35
Milwaukee WI	90	100	10	10	210	37
Tampa FL	90	100	10	10	210	37
Kansas City MO	50	120	10	10	190	39
Orlando FL	70	100	10	10	190	39
Nashville TN	70	80	10	10	170	41
Hartford CT	50	100	10	10	170	41
Charlotte NC	70	70	0	10	160	42
Louisville KY	50	50	0	10	110	44
Memphis TN	50	50	0	10	110	44
Oklahoma City OK	50	50	0	10	110	44
Albuquerque NM	40	50	0	10	100	46
Indianapolis IN	30	50	0	10	90	48
Salt Lake City UT	40	40	0	10	90	48
El Paso TX	30	30	0	10	70	49
Corpus Christi TX	10	10	0	0	20	50
Northeastern Avg	630	1,170	80	140	2,020	
Midwestern Avg	240	300	30	40	610	
Southern Avg	150	190	20	20	380	
Southwestern Avg	210	260	20	30	530	
Western Avg	740	870	90	110	1,800	
Texas Avg	220	310	30	40	600	
Total Avg	360	490	40	60	960	
Maximum Value	3,420	4,190	420	520	8,330	
Minimum Value	10	10	0	0	20	

Source: TTI Analysis and Local Transportation Agency References

Fuel Cost - Fuel cost was also related to vehicle-hours of delay per day and speed by Equation B-7 for passenger vehicles and Equation B-8 for commercial vehicles.

$$\begin{matrix} Passenger \\ Fuel\,Cost \end{matrix} = \frac{\frac{Vehicle\text{-}Hrs\,of\,Delay}{Day} \ x\ 95\% \ x\ Avg.Speed\ x\ Avg.Fuel\,Cost}{Avg.Fuel\,Economy} \qquad \text{Eq. B-7}$$

$$\begin{matrix} Commercial \\ Fuel\,Cost \end{matrix} = \frac{\frac{Vehicle\text{-}Hrs\,of\,Delay}{Day} \ x\ 5\% \ x\ Avg.Speed\ x\ Avg.Fuel\,Cost}{Avg.Fuel\,Economy} \qquad \text{Eq. B-8}$$

where: vehicle-hours of delay is the combined value for freeways and principal arterial streets representing either recurring or incident 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.

$$\begin{matrix} Average\,Urbanized\,Area \\ Fuel\,Cost \end{matrix} = (Passenger\,Fuel\,Cost + Commercial\,Fuel\,Cost)\ x\ \frac{250\,Days}{Year} \qquad \text{Eq. B-9}$$

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

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