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16. Abstract

This research report represents the sixth 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 1991. 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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TRENDS IN URBAN ROADWAY CONGESTION - 1982 TO 1991
VOLUME 1: ANNUAL REPORT

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IMPLEMENTATION STATEMENT

To determine future highway needs and assist the Texas Department of Transportation in planning, it is desirable to measure and monitor the severity of congestion in the large Texas metropolitan areas. This report quantifies those congestion levels and the economic impact of congestion on urban motorists. The report also presents data on other large metropolitan areas throughout the country to assist in determining nationwide mobility trends and the performance of Texas' roadway networks relative to those of other areas. Information in this report should be of value in identifying transportation trends and prioritizing needs for the future.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. In addition, this report is not intended for construction, bidding, or permit purposes. David L. Schrank, Shawn M. Turner, and Timothy J. Lomax (Texas Professional Engineer certification number 54597) prepared this research report.

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SUMMARY

This report represents the sixth 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 (1-7). The Roadway Congestion Index (RCI) combines the daily vehicle-kilometers of travel (DVKT) 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.

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

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 DVKT and DVKT per lane-kilometer into the 1991 estimated Roadway Congestion Index (RCI). The ten most congested urban areas in the study are displayed. The RCI values range from 1.56 (Los Angeles) to 1.14 (Atlanta and New York). All of these urban areas have surpassed the RCI value at which undesirable levels of congestion occur (1.0).

Table S-1. 1991 Roadway Congestion Levels

Urban Area	Freeway / Expressway		Principal Arterial Street		Roadway[3] Congestion Index	Rank
	DVKT[1] (1000)	DVKT/[2] Ln-Kilometer	DVKT[1] (1000)	DVKT/[2] Ln-Kilometer		
Los Angeles CA	177,550	21,110	131550	6,590	1.56	1
Washington DC	41,470	16,830	31,640	8,470	1.39	2
San Fran-Oak CA	67,620	17,570	22,590	6,100	1.34	3
Chicago IL	62,760	16,010	49,160	7,180	1.28	4
Miami FL	14,140	14,280	25,760	7,690	1.28	4
San Diego CA	44,600	16,060	15,300	5,490	1.22	6
San Bernardino-Riv CA	24,100	16,540	17,150	4,660	1.20	7
Seattle-Everett WA	30,590	15,570	15,810	6,140	1.20	7
Atlanta GA	40,200	14,520	15,920	6,280	1.14	9
New York NY	133,650	14,020	85,360	6,960	1.14	9

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

See Table 3 for complete listing of urban areas.
Source: TTI Analysis

The eleven urban areas which have experienced the greatest growth in congestion between 1982 and 1991 are displayed in Table S-2. The RCI values reflect the level of congestion occurring in the urban areas. San Diego experienced a 56 percent increase in congestion during the ten year period. The congestion increase rate in all cities in the top eleven exceeded two percent per year.

Table S-2. Fastest Congestion Growth Areas

Urban Area	Year										Percent Change 1982 to 1991
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
San Jose CA	0.85	0.87	0.90	0.94	0.96	0.98	0.99	1.02	1.04	1.07	26
Dallas TX	0.84	0.89	0.94	0.98	1.04	1.02	1.02	1.02	1.05	1.06	26
Seattle-Everett WA	0.95	0.99	1.02	1.05	1.09	1.14	1.17	1.21	1.20	1.20	26
Minn-St. Paul MN	0.74	0.79	0.81	0.83	0.87	0.87	0.88	0.90	0.93	0.94	27
Los Angeles CA	1.22	1.27	1.32	1.36	1.42	1.47	1.52	1.54	1.55	1.56	28
Atlanta GA	0.89	0.94	0.97	1.02	1.09	1.11	1.14	1.14	1.11	1.14	28
Washington DC	1.07	1.09	1.12	1.20	1.28	1.30	1.32	1.36	1.37	1.39	30
Sacramento CA	0.80	0.84	0.88	0.92	0.95	1.00	1.03	1.01	1.02	1.04	30
San Fran-Oak CA	1.01	1.05	1.12	1.17	1.24	1.31	1.33	1.36	1.35	1.34	33
Salt Lake City UT	0.63	0.63	0.65	0.68	0.68	0.70	0.72	0.81	0.85	0.86	37
San Diego CA	0.78	0.83	0.91	0.95	1.00	1.08	1.13	1.18	1.22	1.22	56

See Table 4 for complete listing of urban areas.

Source: TTI Analysis

The ten urban areas with the smallest growth in congestion between 1982 and 1991 are shown in Table S-3. Phoenix, Houston, and Detroit all experienced decreases in congestion with Phoenix showing the greatest decrease (10 percent). Congestion increases in these areas were less than one percent per year.

Table S-3. Slowest Congestion Growth Areas

Urban Area	Year										Percent Change 1982 to 1991
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Phoenix AZ	1.15	1.16	1.10	1.13	1.20	1.18	1.00	1.03	1.03	1.04	-10
Houston TX	1.17	1.21	1.25	1.23	1.21	1.19	1.15	1.13	1.12	1.11	-5
Detroit MI	1.13	1.10	1.13	1.12	1.11	1.10	1.09	1.08	1.09	1.10	-3
Louisville KY	0.84	0.82	0.81	0.79	0.80	0.88	0.87	0.86	0.86	0.88	5
Pittsburgh PA	0.78	0.76	0.76	0.78	0.79	0.79	0.81	0.82	0.82	0.82	5
Philadelphia PA	1.00	1.03	1.04	0.90	1.06	1.06	1.07	1.05	1.05	1.06	6
Memphis TN	0.86	0.80	0.76	0.75	0.77	0.84	0.86	0.91	0.91	0.92	7
Corpus Christi TX	0.67	0.69	0.69	0.71	0.71	0.72	0.70	0.71	0.72	0.72	7
Orlando FL	0.66	0.68	0.67	0.71	0.71	0.72	0.74	0.72	0.72	0.72	9
Jacksonville FL	0.87	0.98	0.98	0.98	0.95	0.94	0.95	0.93	0.94	0.95	9

See Table 4 for complete listing of urban areas

Source: TTI Analysis

Table S-4 combines existing freeway and principal arterial street distances with (1987 to 1991) recent annual traffic volume growth rates to produce the number of additional lane-kilometers 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. Los Angeles would require 851 lane-kilometers (252 freeway, 599 principal arterial street) to maintain current levels of mobility. The urban area with the smallest additional lane-kilometers in this summary group, Cleveland, would require 201 lane-kilometers (101 freeway, 100 principal arterial street). Additional roadway facilities have not been constructed at these rates in most cities in the recent past, indicating a need to pursue other methods to improve mobility.

Table S-4. **Roadway Necessary to Maintain Constant Congestion Levels**

Urban Area	Existing (1991) Lane-km		Average Annual VKT Growth (%)[1]	Annual Additional Lane-km Needed		Rank[2]
	Freeway	Prin. Art.		Freeway	Prin. Art.	
Los Angeles CA	8,412	19,964	3.00	252	599	1
Chicago IL	3,920	6,843	5.61	220	384	2
New York NY	9,531	12,268	2.75	262	337	3
Phoenix AZ	1,030	5,184	5.60	58	290	4
San Diego CA	2,777	2,785	4.42	123	123	5
Detroit MI	2,866	5,997	2.53	73	152	6
Miami FL	990	3,349	4.98	49	167	7
San Bernardino-Riv CA	1,457	3,679	4.20	61	155	7
St. Louis MO	2,729	2,914	3.74	102	109	9
Cleveland OH	1,835	1,811	5.50	101	100	10

[1] Average Annual Growth rate of Freeway and Principal Arterial Streets DVKT between 1987-1991
[2] Ranked by total of freeway and principal arterial street lane-kilometers.

See Table 6 for complete listing of urban areas.
Source: TTI Analysis

The urban areas with the highest congestion costs are shown in Table S-5. The total congestion costs are comprised of delay and fuel costs. The delay and fuel costs have components related to the type of delay (recurring or incident) that occurs in the urban area. Los Angeles and New York had the highest total congestion costs with values of $7.79 billion and $6.62 billion, respectively. The tenth urban area in the table, Dallas, had a total congestion cost of $1.18 billion.

Table S-5. **Component and Total Congestion Costs By Urban Area for 1991**

Urban Area	Annual Cost Due to Congestion ($Millions)					Rank
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost	
Los Angeles CA	3,180	3,740	400	470	7,790	1
New York NY	2,030	3,840	260	490	6,620	2
San Fran-Oak CA	1,110	1,400	140	180	2,830	3
Washington DC	800	1,360	100	170	2,430	4
Chicago IL	970	1,120	130	150	2,360	5
Houston TX	660	900	80	110	1,750	6
Detroit MI	550	880	70	100	1,610	7
Boston MA	350	1,000	40	120	1,520	8
Seattle-Everett WA	450	600	60	80	1,190	9
Dallas TX	390	670	50	80	1,180	10

See Table 14 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-6 lists the top ten congestion costs per registered vehicle for 1991. Washington D.C. ranks first with a cost of $1,440 per vehicle. Dallas and Houston each have costs of $780 per vehicle, or approximately $3 per workday.

Table S-6. 1991 Congestion Cost per Registered Vehicle

Urban Area	Congestion Cost Per Registered Vehicle	Rank
Washington DC	$1,440	1
San Bernardino-Riv. CA	$1,340	2
New York NY	$1,090	3
Los Angeles CA	$1,000	4
San Jose CA	$ 990	5
San Fran-Oak CA	$ 930	6
Boston MA	$ 920	7
Seattle-Everett WA	$ 890	8
Dallas TX	$ 780	10
Houston TX	$ 780	10

See Table 15 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-7). The highest 1991 cost per capita occurred in San Bernardino-Riverside with a cost per capita of $870. Boston had the smallest cost per capita of the top ten urban areas with a cost of approximately $2 per capita for each workday.

Table S-7. 1991 Congestion Cost per Capita

Urban Area	Congestion Cost Per Capita	Rank
San Bernardino-Riv CA	$ 870	1
Washington DC	$ 760	2
San Fran-Oak CA	$ 740	3
San Jose CA	$ 670	4
Los Angeles CA	$ 660	6
Seattle-Everett WA	$ 660	6
Dallas TX	$ 600	7
Houston TX	$ 570	8
Atlanta GA	$ 530	9
Miami FL	$ 510	10

See Table 15 for complete listing of urban areas
Source: TTI Analysis

By arranging the urban areas into groups based on characteristics such as population size, it is possible to view the effects of congestion on the different groups of areas in the study. Table S-8 shows the vehicle hours of delay present in the study areas. The largest group (Chicago, Los Angeles, New York) has vehicle delay of at least 110 hours per person annually. The smallest group, comprised of areas with populations of 810,000 or less, has vehicle delay of 55 hours per person annually. This seems to indicate that the average congestion impact is twice as large on the average resident of a city with a population greater than 7 million than in the group of the smallest cities in our study.

Table S-8. Annual Vehicle Hours of Delay for 1991 Grouped by Population

Population Group	Average Delay (Vehicle-hours)	Total Delay per 1000 Persons (Veh-Hours)
Fifth Group	1,311,390	110
Fourth Group	314,430	105
Third Group	157,090	100
Second Group	57,220	55
First Group	32,840	55

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.

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. Measuring congestion provides an understanding of the phenomenon which assists transportation professionals, policy makers, and the general public in effectively communicating problems and developing necessary transportation system improvements.

PURPOSE OF CONGESTION RESEARCH

Why should we research and investigate effects of urban congestion? Quite simply, old solutions are not working anymore. In the past, the mobility situation in most metropolitan areas has had the limited choices of controlling area growth, large expenditures 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 generally 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.

CONGESTION RESEARCH BACKGROUND

This research study uses existing data from federal, state, and local agencies to develop planning estimates of the level of mobility within an urban area. The analyses presented in this report are the result of previous research (1-7) 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. Currently, the database developed for this research contains vehicle travel, population, urban area size, and system length from 1982 to 1991. Primarily, vehicle travel and vehicle travel per lane-kilometer are used as the basis of measuring urban mobility and comparing areawide roadway systems.

REPORT ORGANIZATION/CONTENT

There have been some changes incorporated in this report that differentiate it from others in this series (3,4,5,6,7). This report will be similar to a recent congestion report (5) which contained detailed discussions of development for both the roadway congestion index (RCI) and cost methodology, including extensive appendices containing data compiled during the study. This report is also the first in the series to utilize the metric system in the analyses. Tables 1 through 43 are reprinted in English units in Appendix A. 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 will focus on the results of analyses estimating 1991 congestion levels and trends displayed by the data from 1982 to 1991. In addition, the metropolitan areas in the study have been grouped by such factors as population, land area, and population density to display trends that exist between these various groups. Information on the methodology and detailed yearly summaries of the data are available in the Appendix to this report.

This report summarizes and discusses urban mobility levels in 50 metropolitan areas throughout the United States. Seven of the areas studied represent the largest metropolitan 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. Figure 1 illustrates the geographic regions used in the analyses to combine urban areas studied. There are three major topics addressed in this report: areawide mobility, the impacts of congestion, and the cost of congestion. The following are brief descriptions of the information included within each of these topics.

Areawide Mobility

Understanding the reasons for the type and scope of the urban congestion problems has become important to transportation planners and policy makers. Obtaining quantitative estimates of mobility levels that allow the comparisons of transportation systems provides 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 1991 Roadway Congestion Index (RCI) values for 50 urban areas included within the study.

Impacts of Congestion

The most quantifiable impacts of congestion are additional capacity required to eliminate congested conditions and the amount of time spent by motorists in congestion. This section discusses the relationship between the freeway and principal arterial street systems and annual traffic growth. Travel delays are also addressed in this section. Delay, the most apparent impact of congestion to the motoring public, may be categorized into two general

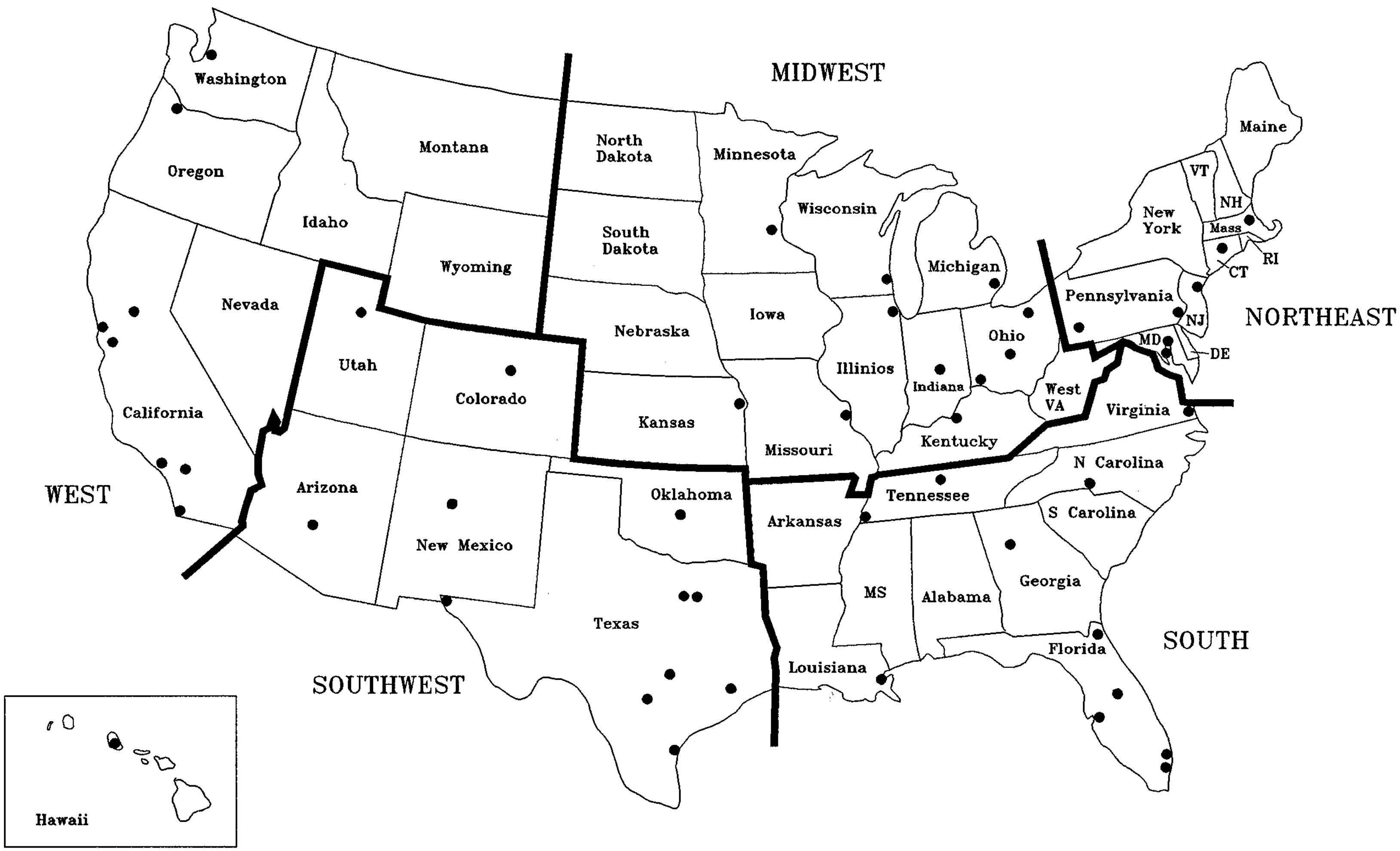

Figure 1. Regional Designations Used in Congestion Summaries

components—recurring and incident. The impacts of travel delay and the relationship with an urban area's RCI are analyzed.

Cost of Congestion

Within this section 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.

AREAWIDE MOBILITY

A 1989 report (8) 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" (8).

TRENDS IN URBAN DEVELOPMENT

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

TRAVEL AND SYSTEM LENGTH STATISTICS

Previous TTI research (3,4,5,6,7) used daily vehicle-kilometers of travel (DVKT) per lane-kilometer of freeway and principal arterial street as indicators of urban congestion levels. The previous studies established the values of 13,000 DVKT per freeway lane-kilometer and 5,000 DVKT 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 DVKT 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 DVKT per lane-kilometer.

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

Freeway Travel and Distance Statistics

Areawide freeway operating statistics are summarized in Table 1. The urban areas are ranked according to the primary congestion indicator, DVKT per lane-kilometer. Summary statistics for each geographical region are located at the bottom of Table 1.

Nineteen urbanized areas exceeded the 13,000 DVKT per lane-kilometer level indicating areawide congested conditions on the freeway systems. Of the ten urban areas with the highest DVKT per lane-kilometer values, five have experienced congested freeway systems since 1982. An additional fourteen urban areas studied have DVKT per lane-kilometer values within ten percent of the 13,000 level. Urban areas with travel demands in this range would only have to

Table 1. 1991 Freeway System Length and Travel Volume

Urban Area	DVKT[1] (1000)	Lane-Kilometers	Avg. No. Lanes[2]	DVKT/ Ln-Kilometer[3]	Rank[4]
Los Angeles CA	177,550	8,410	8.2	21,110	1
San Fran-Oak CA	67,620	3,850	6.8	17,570	2
Washington DC	41,470	2,460	5.3	16,830	3
San Bernardino-Riv CA	24,100	1,460	7.2	16,540	4
San Diego CA	44,600	2,780	7.5	16,060	5
Chicago IL	62,760	3,920	5.7	16,010	6
Seattle-Everett WA	30,590	1,960	5.9	15,570	7
Houston TX	47,500	3,240	6.3	14,640	8
Atlanta GA	40,200	2,770	6.2	14,520	9
Miami FL	14,140	990	5.4	14,280	10
Boston MA	34,900	2,450	5.9	14,260	11
San Jose CA	26,600	1,890	6.6	14,060	12
New York NY	133,650	9,530	5.6	14,020	13
Dallas TX	38,480	2,760	5.9	13,940	14
Honolulu HI	7,570	550	5.2	13,820	15
New Orleans LA	8,110	590	5.8	13,810	16
Portland OR	12,110	900	5.1	13,430	17
Detroit MI	38,160	2,870	5.9	13,310	18
Milwaukee WI	12,570	970	5.6	13,020	19
Baltimore MD	25,820	2,010	5.4	12,830	20
Denver CO	18,390	1,440	5.2	12,770	21
Cincinnati OH	18,680	1,470	5.7	12,750	22
Phoenix AZ	13,140	1,030	5.6	12,750	22
Sacramento CA	15,520	1,220	6.9	12,680	24
Cleveland OH	22,490	1,840	4.8	12,250	25
Minn-St. Paul MN	29,320	2,410	4.9	12,180	26
Jacksonville FL	8,810	720	4.6	12,160	27
Philadelphia PA	29,620	2,440	5.1	12,150	28
Austin TX	8,860	730	5.6	12,090	29
Tampa FL	5,880	490	4.9	11,970	30
Fort Worth TX	19,800	1,660	5.9	11,940	31
Ft. Lauderdale FL	11,480	970	5.4	11,880	32
Norfolk VA	8,960	760	4.6	11,840	33
Albuquerque NM	3,990	350	5.0	11,530	34
San Antonio TX	15,090	1,340	5.3	11,300	35
Memphis TN	7,080	630	5.4	11,280	36
St. Louis MO	30,670	2,730	5.6	11,240	37
Hartford CT	10,050	930	5.5	10,760	38
Indianapolis IN	13,120	1,230	5.3	10,650	39
Salt Lake City UT	8,830	830	5.6	10,650	39
Louisville KY	10,060	950	4.6	10,590	41
Columbus OH	13,690	1,300	5.8	10,550	42
Nashville TN	8,390	810	4.6	10,320	43
Orlando FL	9,730	970	4.9	10,080	44
Oklahoma City OK	11,310	1,170	5.2	9,690	45
El Paso TX	5,460	570	5.3	9,550	46
Kansas City MO	20,150	2,190	4.4	9,200	47
Corpus Christi TX	2,580	300	5.5	8,630	48
Charlotte NC	4,010	480	4.2	8,300	49
Pittsburgh PA	13,280	1,630	4.3	8,130	50
Northeastern Avg	41,260	3,070	5.3	12,710	
Midwestern Avg	23,580	1,920	5.3	11,790	
Southern Avg	11,530	930	5.1	11,860	
Southwestern Avg	16,560	1,300	5.6	11,800	
Western Avg	45,140	2,560	6.6	15,650	
Texas Avg	19,680	1,510	5.7	11,730	
Total Avg	25,740	1,840	5.5	12,630	
Maximum Value	177,550	9,530	8.2	21,110	
Minimum Value	2,580	300	4.2	8,130	

Note: [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 DVKT/Lane-kilometer

Source: TTI Analysis and Local Transportation Agency References

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 1 show average DVKT per lane-kilometer values by geographic region. Every region, except the Western region, has DVKT per lane-kilometer values below the 13,000 level. Comparing these statistics with the similar 1990 analysis (7) shows that the average DVKT per lane-kilometer value for every geographic region has increased by approximately one percent.

Principal Arterial Street Travel and System Length Statistics

Table 2 shows the operating characteristics of the principal arterial street system for each urban area included in this study. As in Table 1, Table 2 ranks urban areas by travel per lane-kilometer and contains regional summary statistics. In 1991, 34 of the urban areas studied experienced DVKT per lane-kilometer levels exceeding 5,000. Of these 34 urban areas, 27 have had travel demands exceeding 5,000 DVKT per lane-kilometer since 1982.

The summary statistics show that all the regional averages, except the Texas average, exceed the 5,000 DVKT 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 1990 levels in the Midwestern, Southern, and Western regions. The regional average travel demands showed small decreases in the Northeastern and Southwestern regions (less than 1 percent). The Texas regional average did not change from 1990.

Table 2. 1991 Principal Arterial Street System Length and Travel Volume

Urban Area	DVKT[1] (1000)	Lane-Kilometers	Avg. No. Lanes[2]	DVKT/[3] Ln-Kilometer	Rank[4]
Washington DC	31,640	3,740	4.0	8,470	1
Honolulu HI	2,610	320	3.8	8,100	2
Miami FL	25,760	3,350	4.3	7,690	3
Chicago IL	49,160	6,840	3.7	7,180	4
St. Louis MO	20,530	2,910	3.4	7,040	5
New York NY	85,360	12,270	3.4	6,960	6
Philadelphia PA	34,810	5,250	3.1	6,630	7
New Orleans LA	6,660	1,010	4.2	6,620	8
Portland OR	6,170	930	3.3	6,600	9
Los Angeles CA	131550	19,960	4.0	6,590	10
Tampa FL	7,080	1,080	3.8	6,570	11
Detroit MI	38,930	6,000	4.4	6,490	12
Atlanta GA	15,920	2,540	3.7	6,280	13
Sacramento CA	11,270	1,800	4.1	6,280	13
Seattle-Everett WA	15,810	2,580	3.4	6,140	15
San Fran-Oak CA	22,590	3,700	4.0	6,100	16
Louisville KY	5,020	840	3.6	6,000	17
Pittsburgh PA	17,830	2,990	3.2	5,970	18
Baltimore MD	15,900	2,690	4.1	5,910	19
Charlotte NC	5,140	870	3.0	5,910	19
Norfolk VA	7,130	1,210	3.5	5,910	19
Salt Lake City UT	3,350	570	3.6	5,860	22
Hartford CT	6,120	1,050	3.8	5,850	23
Denver CO	17,390	2,980	3.9	5,840	24
Nashville TN	8,790	1,530	3.4	5,750	25
Phoenix AZ	29,000	5,180	4.1	5,590	26
San Diego CA	15,300	2,790	3.5	5,490	27
Oklahoma City OK	6,070	1,110	3.2	5,460	28
Ft. Lauderdale FL	9,660	1,810	4.3	5,330	29
Columbus OH	5,310	1,000	3.4	5,320	30
Memphis TN	6,760	1,300	4.3	5,220	31
Cleveland OH	9,420	1,810	3.0	5,200	32
Albuquerque NM	6,200	1,210	3.8	5,130	33
Houston TX	17,550	3,500	4.3	5,010	34
Austin TX	3,460	700	4.2	4,940	35
San Antonio TX	8,770	1,800	3.6	4,890	36
Dallas TX	13,520	2,770	4.8	4,880	37
Jacksonville FL	9,500	1,950	3.7	4,880	37
Milwaukee WI	7,940	1,630	3.4	4,880	37
Fort Worth TX	6,840	1,420	4.1	4,830	40
San Jose CA	10,830	2,250	4.2	4,800	41
Minn-St. Paul MN	9,210	1,950	3.4	4,730	42
San Bernardino-Riv CA	17,150	3,680	4.2	4,660	43
Cincinnati OH	6,120	1,330	3.3	4,610	44
Kansas City MO	7,790	1,690	3.5	4,610	44
Boston MA	20,130	4,440	2.3	4,530	46
Indianapolis IN	6,380	1,420	3.7	4,500	47
Corpus Christi TX	2,490	560	4.0	4,410	48
El Paso TX	5,270	1,350	4.2	3,900	49
Orlando FL	6,400	2,540	3.7	2,520	50
Northeastern Avg	30,250	4,630	3.4	6,330	
Midwestern Avg	14,320	2,380	3.5	5,500	
Southern Avg	9,890	1,740	3.8	5,700	
Southwestern Avg	10,350	2,000	4.1	5,030	
Western Avg	25,920	4,220	3.8	6,080	
Texas Avg	8,270	1,730	4.2	4,700	
Total Avg	16,790	2,800	3.7	5,660	
Maximum Value	131550	19,960	4.8	8,470	
Minimum Value	2,490	320	2.3	2,520	

Notes: [1] Daily vehicle-kilometers of travel
[2] Average number of lanes
[3] Daily vehicle-kilometers of travel per lane-kilometer of principal arterial
[4] Rank value of 1 associated with most congested condition ranked by DVKT/Lane-kilometer

Source: TTI Analysis and Local Transportation Agency References

ROADWAY CONGESTION INDEX VALUES, 1991

Table 3 combines the freeway and principal arterial street system DVKT and DVKT per lane-kilometer values into the estimated 1991 Roadway Congestion Index (RCI). Equation 1 illustrates how those values are used to calculate the RCI value for individual urban areas. The RCI value is a relative measure of the level of congestion for a given urban area. An RCI value of 1.0 or greater indicates an undesirable areawide congestion level. The RCI value 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.

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

1991 Roadway Congestion Index Estimates

Of the 50 urban areas studied, 25 have RCI values exceeding 1.0. RCI values for the ten most congested urban areas range from 1.56 (Los Angeles) to 1.14 (Atlanta and New York). Twelve urban areas have estimated RCI values ranging between 0.99 and 0.90 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 of 1.20. The only other regional average exceeding 1.0 was the Northeastern (1.05). The Southwestern, Southern, and Midwestern regions have average RCI values below 1.0.

Table 3. 1991 Roadway Congestion Index Value

Urban Area	Freeway / Expressway		Principal Arterial Street		Roadway[3] Congestion Index	Rank
	DVKT[1] (1000)	DVKT/[2] Ln-Km	DVKT[1] (1000)	DVKT/[2] Ln-Km		
Los Angeles CA	177,550	21,110	131,550	6,590	1.56	1
Washington DC	41,470	16,830	31,640	8,470	1.39	2
San Fran-Oak CA	67,620	17,570	22,590	6,100	1.34	3
Chicago IL	62,760	16,010	49,160	7,180	1.28	4
Miami FL	14,140	14,280	25,760	7,690	1.28	4
San Diego CA	44,600	16,060	15,300	5,490	1.22	6
San Bernardino-Riv CA	24,100	16,540	17,150	4,660	1.20	7
Seattle-Everett WA	30,590	15,570	15,810	6,140	1.20	7
Atlanta GA	40,200	14,520	15,920	6,280	1.14	9
New York NY	133,650	14,020	85,360	6,960	1.14	9
Honolulu HI	7,570	13,820	2,610	8,100	1.13	11
New Orleans LA	8,110	13,810	6,660	6,620	1.12	12
Houston TX	47,500	14,640	17,550	5,010	1.11	13
Detroit MI	38,160	13,310	38,930	6,490	1.10	14
Portland OR	12,110	13,430	6,170	6,600	1.08	15
San Jose CA	26,600	14,060	10,830	4,800	1.07	16
Boston MA	34,900	14,260	20,130	4,530	1.06	17
Dallas TX	38,480	13,940	13,520	4,880	1.06	17
Philadelphia PA	29,620	12,150	34,810	6,630	1.06	17
Tampa FL	5,880	11,970	7,080	6,570	1.05	20
Phoenix AZ	13,140	12,750	29,000	5,590	1.04	21
Sacramento CA	15,520	12,680	11,270	6,280	1.04	21
Denver CO	18,390	12,770	17,390	5,840	1.03	23
Baltimore MD	25,820	12,830	15,900	5,910	1.02	24
Milwaukee WI	12,570	13,020	7,940	4,880	1.00	25
St. Louis MO	30,670	11,240	20,530	7,040	0.98	26
Cincinnati OH	18,680	12,750	6,120	4,610	0.97	27
Norfolk VA	8,960	11,840	7,130	5,910	0.97	27
Cleveland OH	22,490	12,250	9,420	5,200	0.96	29
Ft. Lauderdale FL	11,480	11,880	9,660	5,330	0.95	30
Jacksonville FL	8,810	12,160	9,500	4,880	0.95	30
Albuquerque NM	3,990	11,530	6,200	5,130	0.94	32
Austin TX	8,860	12,090	3,460	4,940	0.94	32
Minn-St. Paul MN	29,320	12,180	9,210	4,730	0.94	32
Fort Worth TX	19,800	11,940	6,840	4,830	0.92	35
Memphis TN	7,080	11,280	6,760	5,220	0.92	35
Nashville TN	8,390	10,320	8,790	5,750	0.90	37
Hartford CT	10,050	10,760	6,120	5,850	0.89	38
San Antonio TX	15,090	11,300	8,770	4,890	0.89	38
Louisville KY	10,060	10,590	5,020	6,000	0.88	40
Salt Lake City UT	8,830	10,650	3,350	5,860	0.86	41
Columbus OH	13,690	10,550	5,310	5,320	0.84	42
Indianapolis IN	13,120	10,650	6,380	4,500	0.83	43
Charlotte NC	4,010	8,300	5,140	5,910	0.82	44
Pittsburgh PA	13,280	8,130	17,830	5,970	0.82	44
Oklahoma City OK	11,310	9,690	6,070	5,460	0.80	46
El Paso TX	5,460	9,550	5,270	3,900	0.75	47
Kansas City MO	20,150	9,200	7,790	4,610	0.74	48
Corpus Christi TX	2,580	8,630	2,490	4,410	0.72	49
Orlando FL	9,730	10,080	6,400	2,520	0.72	49
Northeastern Avg	41,260	12,710	30,250	6,330	1.05	
Midwestern Avg	23,580	11,790	14,320	5,500	0.94	
Southern Avg	11,530	11,860	9,890	5,700	0.98	
Southwestern Avg	16,560	11,800	10,350	5,030	0.93	
Western Avg	45,140	15,650	25,920	6,080	1.20	
Texas Avg	19,680	11,730	8,270	4,700	0.91	
Total Avg	25,740	12,630	16,790	5,660	1.01	
Maximum Value	177,550	21,110	131550	8,470	1.56	
Minimum Value	2,580	8,130	2,490	2,520	0.72	

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

Source: TTI Analysis

None of the urban areas studied in Texas were included in the ten most congested areas. Houston (13th) 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 (32nd).

Roadway Congestion Index Growth, 1982 to 1991

Roadway congestion index values for all 50 urban areas from 1982 to 1991 are summarized in Table 4. During the study period, San Diego, San Francisco-Oakland, and Salt Lake City were estimated to have experienced the fastest increase in congestion, while Phoenix, Detroit, and Houston have experienced the smallest. Of the urban areas in Texas, Dallas has the largest increase in RCI from 1982 levels (26 percent). Over 50 percent of the urban areas have experienced at least 20 percent growth between 1982 and 1991. The summary statistics show that no geographic region experienced a decrease in average 1991 RCI values from 1990 levels.

Figure 2 illustrates trend data for the Texas urban areas studied. This figure graphically shows the improving trend of congestion in Houston which is currently below 1982 levels. Austin has also shown a slight decrease in congestion since 1986. Dallas, Fort Worth, El Paso, and San Antonio have shown similar characteristics with steady growth in their congestion levels since 1986. Corpus Christi is near its 1986 congestion level.

Table 4. Roadway Congestion Index Values, 1982 to 1991

Urban Area	Year										Percent Change 1982 to 1991
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Phoenix AZ	1.15	1.16	1.10	1.13	1.20	1.18	1.00	1.03	1.03	1.04	-10
Houston TX	1.17	1.21	1.25	1.23	1.21	1.19	1.15	1.13	1.12	1.11	-5
Detroit MI	1.13	1.10	1.13	1.12	1.11	1.10	1.09	1.08	1.09	1.10	-3
Louisville KY	0.84	0.82	0.81	0.79	0.80	0.88	0.87	0.86	0.86	0.88	5
Pittsburgh PA	0.78	0.76	0.76	0.78	0.79	0.79	0.81	0.82	0.82	0.82	5
Philadelphia PA	1.00	1.03	1.04	0.90	1.06	1.06	1.07	1.05	1.05	1.06	6
Memphis TN	0.86	0.80	0.76	0.75	0.77	0.84	0.86	0.91	0.91	0.92	7
Corpus Christi TX	0.67	0.69	0.69	0.71	0.71	0.72	0.70	0.71	0.72	0.72	7
Orlando FL	0.66	0.68	0.67	0.71	0.71	0.72	0.74	0.72	0.72	0.72	9
Jacksonville FL	0.87	0.98	0.98	0.98	0.95	0.94	0.95	0.93	0.94	0.95	9
San Bernardino-Riv CA	1.09	1.11	1.12	1.11	1.14	1.13	1.16	1.16	1.19	1.20	10
Ft. Lauderdale FL	0.86	0.85	0.84	0.84	0.84	0.90	0.90	0.92	0.94	0.95	10
Oklahoma City OK	0.72	0.72	0.75	0.74	0.71	0.76	0.78	0.78	0.79	0.80	11
Tampa FL	0.94	0.91	1.03	1.00	0.96	1.02	1.03	1.03	1.05	1.05	12
Cincinnati OH	0.86	0.83	0.82	0.83	0.84	0.87	0.88	0.94	0.96	0.97	13
New York NY	1.01	1.02	0.99	1.00	1.06	1.06	1.10	1.12	1.14	1.14	13
New Orleans LA	0.98	1.00	1.05	1.10	1.11	1.14	1.13	1.13	1.12	1.12	14
San Antonio TX	0.77	0.79	0.82	0.87	0.90	0.85	0.86	0.87	0.88	0.89	16
Indianapolis IN	0.71	0.66	0.75	0.76	0.80	0.85	0.84	0.85	0.83	0.83	17
Hartford CT	0.76	0.79	0.86	0.85	0.85	0.87	0.91	0.89	0.89	0.89	17
Boston MA	0.90	0.93	0.95	0.98	1.04	1.04	1.12	1.09	1.06	1.06	18
St. Louis MO	0.83	0.87	0.88	0.89	0.93	0.96	0.98	0.96	0.99	0.98	18
El Paso TX	0.63	0.64	0.65	0.70	0.75	0.71	0.74	0.74	0.74	0.75	19
Kansas City MO	0.62	0.62	0.60	0.65	0.69	0.71	0.72	0.72	0.74	0.74	19
Cleveland OH	0.80	0.82	0.83	0.81	0.86	0.89	0.97	0.95	0.97	0.96	20
Milwaukee WI	0.83	0.84	0.87	0.88	0.90	0.95	0.94	0.97	0.99	1.00	20
Albuquerque NM	0.78	0.83	0.89	0.93	0.88	0.91	0.90	0.91	0.93	0.94	21
Fort Worth TX	0.76	0.79	0.80	0.82	0.87	0.87	0.87	0.87	0.90	0.92	21
Denver CO	0.85	0.88	0.93	0.96	0.97	0.95	0.99	1.01	1.03	1.03	21
Baltimore MD	0.84	0.84	0.85	0.84	0.88	0.90	0.92	0.99	1.01	1.02	21
Honolulu HI	0.93	0.95	0.97	0.97	1.05	1.07	1.10	1.09	1.11	1.13	22
Nashville TN	0.74	0.76	0.83	0.81	0.86	0.88	0.94	0.90	0.89	0.90	22
Miami FL	1.05	1.09	1.07	1.13	1.10	1.14	1.18	1.25	1.26	1.28	22
Austin TX	0.77	0.84	0.89	0.91	0.98	0.96	0.96	0.96	0.94	0.94	22
Charlotte NC	0.67	0.72	0.72	0.73	0.73	0.74	0.73	0.74	0.78	0.82	22
Norfolk VA	0.79	0.77	0.79	0.84	0.90	0.93	0.94	0.95	0.96	0.97	23
Columbus OH	0.68	0.71	0.71	0.71	0.75	0.78	0.79	0.82	0.83	0.84	24
Portland OR	0.87	0.86	0.88	0.93	0.97	1.00	1.05	1.07	1.07	1.08	24
Chicago IL	1.02	1.02	1.05	1.08	1.15	1.15	1.18	1.21	1.25	1.28	25
San Jose CA	0.85	0.87	0.90	0.94	0.96	0.98	0.99	1.02	1.04	1.07	26
Dallas TX	0.84	0.89	0.94	0.98	1.04	1.02	1.02	1.02	1.05	1.06	26
Seattle-Everett WA	0.95	0.99	1.02	1.05	1.09	1.14	1.17	1.21	1.20	1.20	26
Minn-St. Paul MN	0.74	0.79	0.81	0.83	0.87	0.87	0.88	0.90	0.93	0.94	27
Los Angeles CA	1.22	1.27	1.32	1.36	1.42	1.47	1.52	1.54	1.55	1.56	28
Atlanta GA	0.89	0.94	0.97	1.02	1.09	1.11	1.14	1.14	1.11	1.14	28
Washington DC	1.07	1.09	1.12	1.20	1.28	1.30	1.32	1.36	1.37	1.39	30
Sacramento CA	0.80	0.84	0.88	0.92	0.95	1.00	1.03	1.01	1.02	1.04	30
San Fran-Oak CA	1.01	1.05	1.12	1.17	1.24	1.31	1.33	1.36	1.35	1.34	33
Salt Lake City UT	0.63	0.63	0.65	0.68	0.68	0.70	0.72	0.81	0.85	0.86	37
San Diego CA	0.78	0.83	0.91	0.95	1.00	1.08	1.13	1.18	1.22	1.22	56
Northeastern Avg	0.91	0.92	0.94	0.94	0.99	1.00	1.04	1.05	1.05	1.05	
Midwestern Avg	0.82	0.82	0.83	0.84	0.87	0.90	0.91	0.92	0.94	0.94	
Southern Avg	0.85	0.86	0.88	0.90	0.91	0.94	0.96	0.97	0.97	0.98	
Southwestern Avg	0.82	0.85	0.87	0.90	0.93	0.91	0.90	0.91	0.93	0.93	
Western Avg	0.94	0.97	1.01	1.04	1.09	1.13	1.16	1.18	1.19	1.20	
Texas Avg	0.80	0.84	0.86	0.89	0.92	0.90	0.90	0.90	0.91	0.91	
Total Avg	0.86	0.88	0.90	0.92	0.95	0.97	0.98	0.99	1.00	1.01	
Maximum Value	1.22	1.27	1.32	1.36	1.42	1.47	1.52	1.54	1.55	1.56	
Minimum Value	0.62	0.62	0.60	0.65	0.68	0.70	0.70	0.71	0.72	0.72	

Source: TTI Analysis

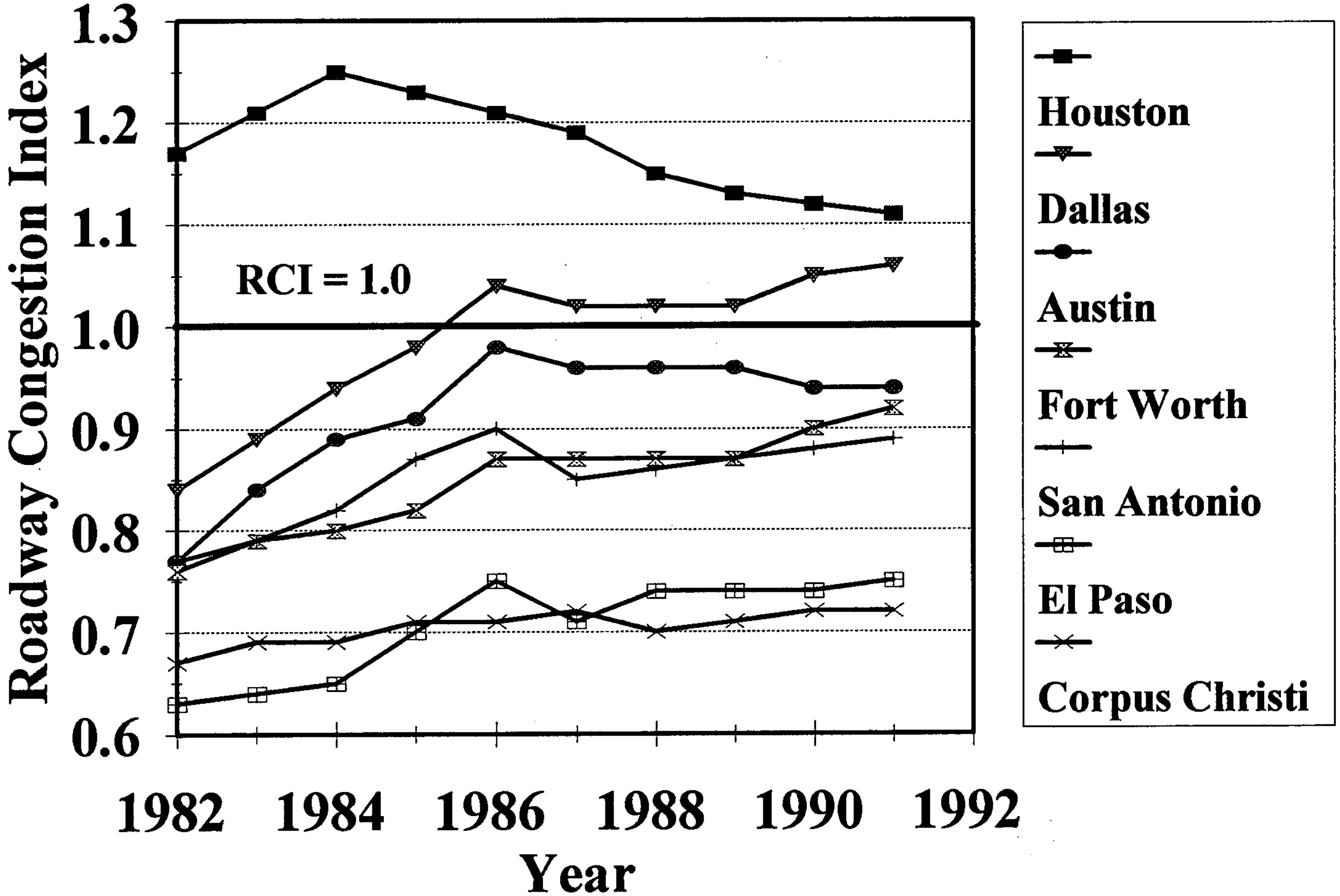

Figure 2. Texas Urban Area RCIs 1982 - 1991

IMPACTS OF CONGESTION

The most quantifiable impacts of congestion are additional capacity that would be required to eliminate the congested conditions, and the time spent in congested traffic conditions. Additional capacity required annually to maintain existing traffic density levels indicates the burden of congestion on the transportation infrastructure and available roadway funds. Travel delay is the measure of inconvenience congestion imposes on the motoring public.

TRAVEL VOLUMES

Freeway and principal arterial street systems are the primary facilities selected for expansion because the majority (60 to 70 percent) of an urban area's DVKT is served by these facilities. Table 5 illustrates the percentage of daily VKT served by the freeway and principal arterial street systems. While the average amount of daily VKT served by these facilities is significant in all areas, comparing the percentage for each urban and geographic area (Table 5) does give some indication of the facility carrying the majority of the demand.

Figure 3 illustrates the regional daily VKT served by the freeway system for each geographical region studied. During the study period, the percentages have remained relatively constant for each region. Motorists in the Western region place the highest demand on the freeway system, while the Southern region places the lowest. Motorists in the Texas and Midwestern regions place the second highest average demand on the freeway system of all geographic regions.

Figure 4 shows the corresponding demands placed on the principal arterial street systems. This figure shows that the highest demand on the principal arterial street system is placed by the Northeastern and Southern regions. The Texas and Midwestern regions depend the least on this system for urban travel. Each of the regions have shown a decrease in the percentage of DVKT serviced by principal arterial streets from 1982 to 1991. The greatest overall percentage of demand served by the combination of freeways and principal arterial streets (Table 5) occurred in the Southwestern region followed by the Northeastern region.

Table 5. 1991 Urban Area Travel by Facility Type

Urban Area	Daily Vehicle-Kilometers of Travel			Fwy/Expwy[1]	Prin.Art.Str.[1]	Fwy/Prin.Art.Str.
	Fwy/Expwy	Prin.Art.Str.	Area Total	% of Total	% of Total	% of Total
Northeastern Cities						
Baltimore MD	25,820	15,900	59,450	43	27	70
Boston MA	34,900	20,130	83,140	42	24	66
Hartford CT	10,050	6,120	22,570	45	27	72
New York NY	133,650	85,360	362,610	37	24	61
Philadelphia PA	29,620	34,810	107,510	28	32	60
Pittsburgh PA	13,280	17,830	53,400	25	33	58
Washington DC	41,470	31,640	104,770	40	30	70
Midwestern Cities						
Chicago IL	62,760	49,160	203,570	31	24	55
Cincinnati OH	18,680	6,120	42,690	44	14	58
Cleveland OH	22,490	9,420	55,440	41	17	58
Columbus OH	13,690	5,310	33,270	41	16	57
Detroit MI	38,160	38,930	127,800	30	30	60
Indianapolis IN	13,120	6,380	33,530	39	19	58
Kansas City MO	20,150	7,790	45,030	45	17	62
Louisville KY	10,060	5,020	29,970	34	17	51
Milwaukee WI	12,570	7,940	47,410	27	17	44
Minn-St. Paul MN	29,320	9,210	70,730	41	13	54
Oklahoma City OK	11,310	6,070	31,400	36	19	55
St. Louis MO	30,670	20,530	72,900	42	28	70
Southern Cities						
Atlanta GA	40,200	15,920	100,880	40	16	56
Charlotte NC	4,010	5,140	17,030	24	30	54
Ft. Lauderdale FL	11,480	9,660	40,900	28	24	52
Jacksonville FL	8,810	9,500	29,220	30	33	63
Memphis TN	7,080	6,760	26,130	27	26	53
Miami FL	14,140	25,760	54,420	26	47	73
Nashville TN	8,390	8,790	24,800	34	35	69
New Orleans LA	8,110	6,660	24,750	33	27	60
Norfolk VA	8,960	7,130	33,120	27	22	49
Orlando FL	9,730	6,400	30,210	32	21	53
Tampa FL	5,880	7,080	26,160	22	27	49
Southwestern Cities						
Albuquerque NM	3,990	6,200	16,340	24	38	62
Austin TX	8,860	3,460	19,240	46	18	64
Corpus Christi TX	2,580	2,490	9,900	26	25	51
Dallas TX	38,480	13,520	80,220	48	17	65
Denver CO	18,390	17,390	46,620	39	37	76
El Paso TX	5,460	5,270	15,120	36	35	71
Fort Worth TX	19,800	6,840	43,190	46	16	62
Houston TX	47,500	17,550	117,670	40	15	55
Phoenix AZ	13,140	29,000	66,690	20	43	63
Salt Lake City UT	8,830	3,350	25,640	34	13	47
San Antonio TX	15,090	8,770	41,460	36	21	57
Western Cities						
Honolulu HI	7,570	2,610	17,630	43	15	58
Los Angeles CA	177,550	131,550	397,910	45	33	78
Portland OR	12,110	6,170	32,180	38	19	57
Sacramento CA	15,520	11,270	38,550	40	29	69
San Bernardino-Riv CA	24,100	17,150	43,490	55	39	94
San Diego CA	44,600	15,300	83,290	54	18	72
San Fran-Oak CA	67,620	22,590	123,140	55	18	73
San Jose CA	26,600	10,830	52,930	50	20	70
Seattle-Everett WA	30,590	15,810	69,390	44	23	67
Northeastern Avg	41,260	30,250	113,350	37	28	65
Midwestern Avg	23,580	14,320	66,150	38	19	57
Southern Avg	11,530	9,890	37,060	29	28	57
Southwestern Avg	16,560	10,350	43,830	36	25	61
Western Avg	45,140	25,920	95,390	47	24	71
Texas Avg	19,680	8,270	46,690	40	21	61
Total Avg	25,740	16,790	66,710	37	25	62
Maximum Value	177,550	131,550	397,910	55	47	94
Minimum Value	2,580	2,490	9,900	20	13	44

Notes: [1] Percentage of Total Daily Vehicle-Kilometers of Travel serviced by specified facility

Source: TTI Analysis and Local Transportation Agency References

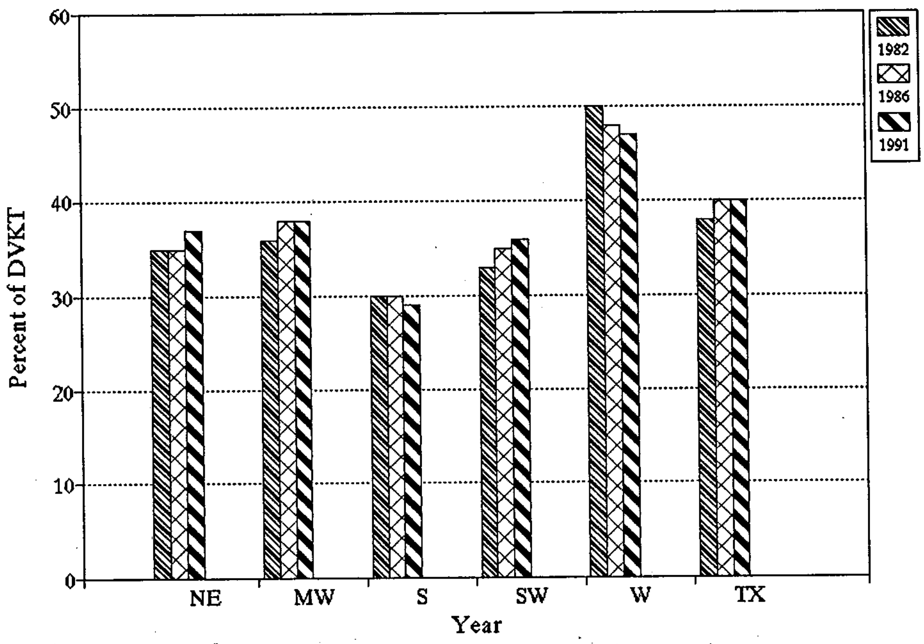

Figure 3. Freeway Percentage of DVKT

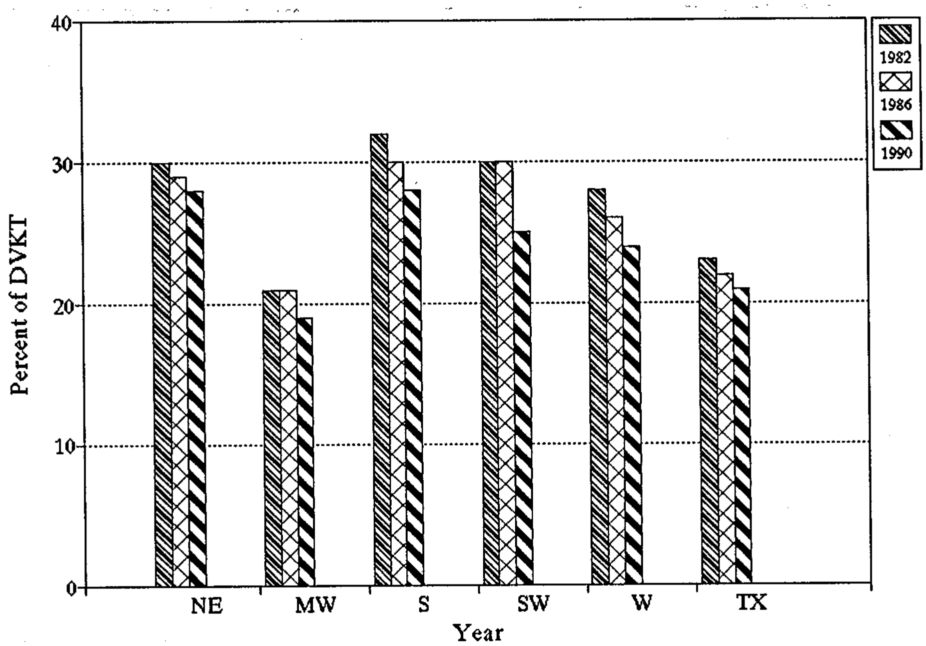

Figure 4. Principal Arterial Street Percentage of DVKT

ADDITIONAL CAPACITY

The addition of capacity to alleviate congestion is becoming more difficult in many urban areas, but it can be an effective tool in addressing congestion problems. As Table 6 illustrates, this practice is difficult to maintain over many years.

An 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, Phoenix would require 58 additional lane-kilometers of freeway and 290 lane-kilometers of principal arterial streets per year to maintain the 1991 congestion level with the 5.6 percent annual growth in DVKT it experienced between 1987 and 1991.

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.

TRAVEL DELAYS

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. The most common example of recurring delay is the increased travel time during peak periods of operation.

Table 6. Illustration of Annual Capacity Increase Required to Prevent Congestion Growth

Urban Area	Existing (1991) Lane-km		Average Annual VKT Growth (%)[1]	Annual Additional Lane-km Needed		Freeway Lane-km:		Prin. Art. Lane-km:	
	Freeway	Prin. Art.		Freeway	Prin. Art.	Needed	Added 87-91[2]	Needed	Added 87-91[2]
Albuquerque NM	346	1,208	3.24	11	39	44	24	156	161
Atlanta GA	2,769	2,536	1.93	53	49	212	129	196	290
Austin TX	733	700	1.18	9	8	36	56	32	32
Baltimore MD	2,013	2,689	3.33	67	89	268	16	356	-16
Boston MA	2,447	4,444	0.24	6	11	24	48	44	129
Charlotte NC	483	869	4.63	22	40	88	32	160	48
Chicago IL	3,920	6,843	5.61	220	384	880	403	1,536	821
Cincinnati OH	1,465	1,328	4.63	68	61	272	105	244	56
Cleveland OH	1,835	1,811	5.50	101	100	404	290	400	40
Columbus OH	1,298	998	3.33	43	33	172	50	132	40
Corpus Christi TX	299	564	1.33	4	7	16	10	28	48
Dallas TX	2,761	2,769	1.62	45	45	180	89	180	48
Denver CO	1,441	2,979	2.49	36	74	144	64	296	32
Detroit MI	2,866	5,997	2.53	73	152	292	274	608	443
El Paso TX	572	1,352	1.83	10	25	40	8	100	56
Fort Worth TX	1,658	1,417	2.07	34	29	136	64	116	32
Ft. Lauderdale FL	966	1,811	2.93	28	53	112	64	212	89
Hartford CT	934	1,047	2.59	24	27	96	48	108	105
Honolulu HI	547	322	2.21	12	7	48	16	28	16
Houston TX	3,244	3,502	2.71	88	95	352	604	380	330
Indianapolis IN	1,232	1,417	0.78	10	11	40	89	44	56
Jacksonville FL	725	1,948	2.41	17	47	68	81	188	113
Kansas City MO	2,190	1,691	1.64	36	28	144	48	112	16
Los Angeles CA	8,412	19,964	3.00	252	599	1,008	555	2,396	998
Louisville KY	950	837	2.93	28	25	112	129	100	24
Memphis TN	628	1,296	2.95	19	38	76	16	152	81
Miami FL	990	3,349	4.98	49	167	196	97	668	129
Milwaukee WI	966	1,626	2.68	26	44	104	81	176	48
Minn-St. Paul MN	2,407	1,948	3.55	85	69	340	169	276	81
Nashville TN	813	1,530	3.22	26	49	104	121	196	72
New Orleans LA	588	1,006	1.32	8	13	32	56	52	8
New York NY	9,531	12,268	2.75	262	337	1,048	209	1,348	1,159
Norfolk VA	757	1,208	2.60	20	31	80	32	124	81
Oklahoma City OK	1,167	1,111	2.46	29	27	116	40	108	56
Orlando FL	966	2,544	2.34	23	60	92	89	240	81
Philadelphia PA	2,439	5,249	1.52	37	80	148	290	320	64
Phoenix AZ	1,030	5,184	5.60	58	290	232	483	1,160	1,055
Pittsburgh PA	1,634	2,987	3.12	51	93	204	129	372	250
Portland OR	902	934	3.48	31	33	124	32	132	89
Sacramento CA	1,224	1,795	4.07	50	73	200	161	292	185
Salt Lake City UT	829	572	7.59	63	43	252	72	172	16
San Antonio TX	1,336	1,795	2.18	29	39	116	24	156	105
San Bernardino-Ri	1,457	3,679	4.20	61	155	244	81	620	910
San Diego CA	2,777	2,785	4.42	123	123	492	137	492	274
San Fran-Oak CA	3,848	3,703	1.78	68	66	272	137	264	475
San Jose CA	1,892	2,254	2.66	50	60	200	56	240	64
Seattle-Everett W	1,964	2,576	3.06	60	79	240	129	316	201
St. Louis MO	2,729	2,914	3.74	102	109	408	427	436	105
Tampa FL	491	1,079	2.92	14	31	56	40	124	97
Washington DC	2,463	3,735	2.40	59	90	236	97	360	129

[1] Average annual growth rate of freeway and principal arterial streets between 1987 and 1991.
[2] Lane-kilometers added from 1987 to 1991.

The other type of delay related to congestion is incident delay. Incident delay is caused by accidents, breakdowns, or other occurrences which decrease roadway capacity. When congestion levels increase (creating higher RCI values), it is the recurring delay that is directly affected. While incident delay is not directly related to or caused by congestion, 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 (DVKT) 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 0.45 to estimate the amount of total travel during the peak periods.

The resulting quantities, peak period travel volume (DVKT) in each of four levels of congestion, were combined with average peak period travel speeds derived from an extensive travel speed and traffic volume survey in Houston (Appendix B).

The speeds shown in Table 7 for each of the four congested categories were combined with the travel volume for the category 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 (Tables 8 and 9).

Table 7. 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] Value represents a weighted average.

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

The estimate of recurring delay is accompanied by an estimate of delay due to incidents. The incident delay calculation is based on research by Lindley (13) which is quantified in this report as ratios of incident to recurring delay (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 in Table 9 is estimated as 1.1. Table 10 summarizes the vehicle-hours of delay by type and urban area. These values were also used to estimate the economic impacts of congestion.

The delay rankings in Table 10 are similar to the rankings by RCI (Table 3). Vehicle-hours of delay are also ranked after being normalized by population. The total delay per 1000 persons 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. Summary statistics show that the Western and Northeastern regions have the largest average per capita delay, while the Midwestern region has the least.

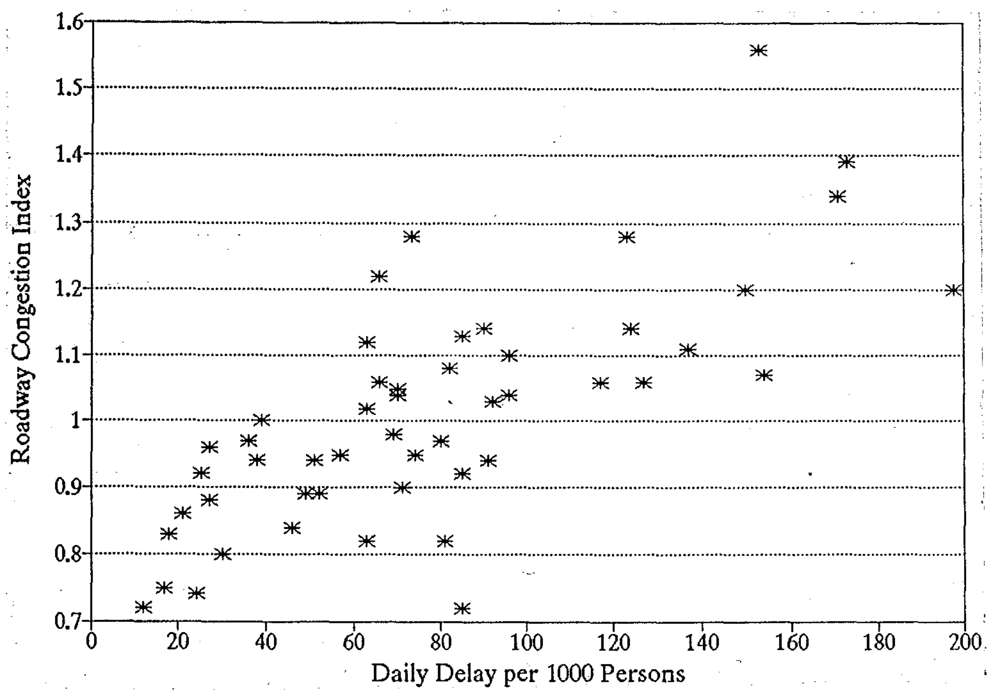

Figure 5. Roadway Congestion Index and Delay per 1000 Persons

The excess fuel consumed in congestion is estimated from the speeds used in the travel delay estimates. Raus (21) developed an equation for fuel economy that is appropriate for areawide speed and travel estimates. Equation 2 is a simple linear relationship between average speed and vehicle fuel efficiency. The speeds for the three congestion 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. Table 11 presents the estimates for recurring and incident delay conditions.

$$\underset{(kpl)}{\text{Fuel Economy}} = 3.74 + 0.11 \; \underset{(kpg)}{(\text{average vehicular speed})} \qquad \text{Eq. 2}$$

Table 8. Freeway and Expressway Recurring and Incident Hours of Daily Delay for 1991[1]

Urban Area	Recurring Hours of Delay				Incident Hours of Delay			
	Moderate	Heavy	Severe	Total	Moderate	Heavy	Severe	Total
Northeastern Cities								
Baltimore MD	4,370	7,120	15,370	26,860	10,050	16,380	35,340	61,770
Boston MA	6,850	21,840	38,290	66,980	23,960	76,450	134,000	234,410
Hartford CT	3,420	920	430	4,770	9,230	2,480	1,170	12,880
New York NY	105,920	69,820	126,150	301,890	264,790	174,560	315,370	754,720
Philadelphia PA	10,180	6,080	11,430	27,690	21,380	12,760	24,010	58,150
Pittsburgh PA	1,530	2,950	6,760	11,240	4,430	8,560	19,590	32,580
Washington DC	9,430	36,330	71,020	116,780	20,740	79,930	156,240	256,910
Midwestern Cities								
Chicago IL	13,240	22,040	118,920	154,200	15,890	26,450	142,700	185,040
Cincinnati OH	9,270	7,170	2,850	19,290	7,410	5,740	2,280	15,430
Cleveland OH	9,710	6,730	2,740	19,180	6,790	4,710	1,920	13,420
Columbus OH	950	5,420	8,450	14,820	670	3,790	5,910	10,370
Detroit MI	9,280	7,860	49,090	66,230	20,410	17,290	107,990	145,690
Indianapolis IN	3,090	0	1,160	4,250	4,630	0	1,740	6,370
Kansas City MO	1,620	1,290	590	3,500	5,030	3,990	1,830	10,850
Louisville KY	820	30	990	1,840	900	40	1,090	2,030
Milwaukee WI	3,100	5,380	6,570	15,050	3,100	5,380	6,570	15,050
Minn-St. Paul MN	6,870	7,520	22,050	36,440	6,180	6,770	19,850	32,800
Oklahoma City OK	2,210	1,440	0	3,650	2,430	1,590	0	4,020
St. Louis MO	8,820	2,600	11,780	23,200	10,590	3,120	14,130	27,840
Southern Cities								
Atlanta GA	4,870	27,480	46,370	78,720	5,350	30,220	51,010	86,580
Charlotte NC	4,900	1,200	0	6,100	3,920	960	0	4,880
Ft. Lauderdale FL	4,680	3,820	1,400	9,900	7,020	5,730	2,100	14,850
Jacksonville FL	6,330	3,240	350	9,920	9,490	4,860	520	14,870
Memphis TN	2,720	470	0	3,190	2,990	520	0	3,510
Miami FL	8,190	5,590	20,650	34,430	12,280	8,380	30,970	51,630
Nashville TN	4,250	1,860	760	6,870	4,670	2,050	830	7,550
New Orleans LA	800	9,290	6,480	16,570	1,440	16,730	11,660	29,830
Norfolk VA	930	6,300	10,390	17,620	2,320	15,740	25,970	44,030
Orlando FL	6,970	2,360	4,280	13,610	10,460	3,540	6,420	20,420
Tampa FL	690	2,010	3,540	6,240	1,030	3,020	5,310	9,360
Southwestern Cities								
Albuquerque NM	850	1,250	930	3,030	930	1,370	1,020	3,320
Austin TX	4,800	7,320	6,670	18,790	5,280	8,050	7,340	20,670
Corpus Christi TX	670	100	0	770	740	110	0	850
Dallas TX	13,050	21,110	55,270	89,430	23,490	38,000	99,480	160,970
Denver CO	6,420	13,060	22,480	41,960	6,420	13,060	22,480	41,960
El Paso TX	1,660	1,830	270	3,760	1,830	2,020	290	4,140
Fort Worth TX	4,880	7,900	20,690	33,470	8,790	14,220	37,240	60,250
Houston TX	10,570	36,660	99,390	146,620	14,800	51,320	139,140	205,260
Phoenix AZ	3,610	15,710	13,130	32,450	1,440	6,280	5,250	12,970
Salt Lake City UT	1,920	3,010	1,670	6,600	1,150	1,810	1,000	3,960
San Antonio TX	2,170	9,640	13,980	25,790	2,390	10,600	15,380	28,370
Western Cities								
Honolulu HI	2,080	3,980	10,060	16,120	3,740	7,160	18,110	29,010
Los Angeles CA	24,710	22,850	579,380	626,940	29,650	27,420	695,260	752,330
Portland OR	7,330	5,000	8,040	20,370	14,660	10,000	16,070	40,730
Sacramento CA	10,050	11,150	3,400	24,600	6,030	6,690	2,040	14,760
San Bernardino-Riv CA	9,060	13,630	61,990	84,680	10,870	16,360	74,390	101,620
San Diego CA	15,250	21,150	46,160	82,560	9,150	12,690	27,700	49,540
San Fran-Oak CA	21,460	34,730	184,890	241,080	27,900	45,150	240,360	313,410
San Jose CA	10,710	13,800	55,760	80,270	12,860	16,560	66,910	96,330
Seattle-Everett WA	7,240	44,230	38,070	89,540	10,140	61,920	53,300	125,360
Northeastern Avg	20,240	20,720	38,490	79,450	50,660	53,020	97,960	201,640
Midwestern Avg	5,750	5,620	18,760	30,130	7,000	6,570	25,500	39,070
Southern Avg	4,120	5,780	8,560	18,460	5,540	8,340	12,250	26,130
Southwestern Avg	4,600	10,690	21,320	36,610	6,110	13,350	29,880	49,340
Western Avg	11,990	18,950	109,750	140,690	13,890	22,660	132,680	169,230
Texas Avg	5,400	12,080	28,040	45,520	8,190	17,760	42,700	68,650
Total Avg	8,290	11,290	36,220	55,800	13,840	17,850	52,990	84,680
Maximum Value	105,920	69,820	579,380	755,120	264,790	174,560	695,260	1134610
Minimum Value	670	0	0	670	670	0	0	670

Note: [1] Delay calculated based on vehicular speed in Table 7.

Source: TTI Analysis

Table 9. Principal Arterial Street Recurring and Incident Hours of Daily Delay for 1991[1]

Urban Area	Recurring Hours of Delay				Incident Hours of Delay			
	Moderate	Heavy	Severe	Total	Moderate	Heavy	Severe	Total
Northeastern Cities								
Baltimore MD	870	4,010	15,040	19,920	960	4,410	16,540	21,910
Boston MA	4,120	3,480	18,500	26,100	4,540	3,830	20,350	28,720
Hartford CT	1,590	2,090	2,320	6,000	1,750	2,300	2,560	6,610
New York NY	23,450	39,580	169,120	232,150	25,800	43,540	186,040	255,380
Philadelphia PA	7,210	21,290	60,510	89,010	7,930	23,420	66,560	97,910
Pittsburgh PA	5,300	7,460	21,290	34,050	5,830	8,210	23,420	37,460
Washington DC	4,310	19,900	71,780	95,990	4,740	21,890	78,960	105,590
Midwestern Cities								
Chicago IL	13,260	27,900	61,970	103,130	14,580	30,690	68,160	113,430
Cincinnati OH	1,060	670	2,910	4,640	1,160	740	3,200	5,100
Cleveland OH	1,850	2,920	3,410	8,180	2,030	3,220	3,750	9,000
Columbus OH	850	2,360	4,590	7,800	940	2,590	5,050	8,580
Detroit MI	5,470	15,750	60,590	81,810	6,010	17,320	66,650	89,980
Indianapolis IN	1,590	290	1,210	3,090	1,750	320	1,330	3,400
Kansas City MO	610	1,150	4,930	6,690	670	1,260	5,430	7,360
Louisville KY	1,030	4,690	2,650	8,370	1,140	5,160	2,920	9,220
Milwaukee WI	1,590	2,210	4,710	8,510	1,750	2,430	5,180	9,360
Minn-St. Paul MN	1,840	1,750	13,860	17,450	2,030	1,920	15,250	19,200
Oklahoma City OK	880	1,860	4,110	6,850	970	2,050	4,520	7,540
St. Louis MO	4,460	17,120	17,050	38,630	4,910	18,830	18,760	42,500
Southern Cities								
Atlanta GA	2,890	8,140	24,290	35,320	3,180	8,960	26,720	38,860
Charlotte NC	380	2,200	9,590	12,170	420	2,420	10,550	13,390
Ft. Lauderdale FL	2,310	7,120	12,620	22,050	2,540	7,830	13,880	24,250
Jacksonville FL	2,790	3,860	7,780	14,430	3,070	4,240	8,560	15,870
Memphis TN	1,250	2,810	3,040	7,100	1,370	3,090	3,340	7,800
Miami FL	1,250	7,700	59,060	68,010	1,370	8,470	64,960	74,800
Nashville TN	840	2,600	8,790	12,230	920	2,860	9,670	13,450
New Orleans LA	1,200	2,390	7,520	11,110	1,320	2,630	8,270	12,220
Norfolk VA	1,270	1,910	4,670	7,850	1,400	2,110	5,140	8,650
Orlando FL	560	1,750	16,880	19,190	620	1,920	18,570	21,110
Tampa FL	3,050	2,360	10,420	15,830	3,350	2,600	11,460	17,410
Southwestern Cities								
Albuquerque NM	2,060	3,350	1,000	6,410	2,270	3,690	1,100	7,060
Austin TX	950	1,750	1,850	4,550	1,040	1,930	2,040	5,010
Corpus Christi TX	450	240	190	880	490	260	210	960
Dallas TX	3,160	3,840	4,250	11,250	3,480	4,220	4,680	12,380
Denver CO	2,220	7,920	19,470	29,610	2,440	8,710	21,410	32,560
El Paso TX	140	140	560	840	150	160	620	930
Fort Worth TX	1,600	1,940	2,150	5,690	1,760	2,140	2,370	6,270
Houston TX	3,310	11,180	13,180	27,670	3,640	12,290	14,500	30,430
Phoenix AZ	15,070	16,950	31,610	63,630	16,580	18,650	34,770	70,000
Salt Lake City UT	1,320	1,010	1,140	3,470	1,450	1,110	1,250	3,810
San Antonio TX	680	890	2,600	4,170	740	980	2,860	4,580
Western Cities								
Honolulu HI	1,320	870	3,760	5,950	1,450	960	4,140	6,550
Los Angeles CA	23,620	57,440	135,590	216,650	25,980	63,180	149,150	238,310
Portland OR	690	4,820	6,970	12,480	760	5,300	7,660	13,720
Sacramento CA	890	3,570	15,850	20,310	980	3,930	17,440	22,350
San Bernardino-Riv CA	9,260	10,580	10,350	30,190	10,190	11,640	11,380	33,210
San Diego CA	2,060	8,950	2,140	13,150	2,270	9,850	2,350	14,470
San Fran-Oak CA	2,520	4,720	42,300	49,540	2,770	5,200	46,530	54,500
San Jose CA	2,950	1,250	24,240	28,440	3,250	1,370	26,670	31,290
Seattle-Everett WA	2,940	5,340	21,260	29,540	3,230	5,870	23,390	32,490
Northeastern Avg	6,700	13,970	51,220	71,890	7,370	15,370	56,350	79,090
Midwestern Avg	2,870	6,560	15,170	24,600	3,160	7,210	16,680	27,050
Southern Avg	1,620	3,900	14,970	20,490	1,780	4,280	16,470	22,530
Southwestern Avg	2,810	4,470	7,090	14,370	3,100	4,920	7,800	15,820
Western Avg	5,140	10,840	29,160	45,140	5,650	11,920	32,080	49,650
Texas Avg	1,470	2,850	3,540	7,860	1,620	3,140	3,900	8,660
Total Avg	3,530	7,320	20,910	31,760	3,880	8,050	23,000	34,930
Maximum Value	23,620	57,440	169,120	250,180	25,980	63,180	186,040	275,200
Minimum Value	140	140	190	470	150	160	210	520

Note: [1] Delay calculation based on vehicular speed in Table 7.

Source: TTI Analysis

Table 10. Daily Vehicle Hours of Delay for 1991

Urban Area	Vehicle Hours of Delay Recurring	Incident	Total	Rank[1]	Daily Delay per 1000 Persons	Rank[1]
Northeastern Cities						
Baltimore MD	46,780	83,690	130,470	20	60	30
Boston MA	93,080	263,130	356,220	8	120	10
Hartford CT	10,780	19,480	30,260	41	50	35
New York NY	534,050	1010090	1,544,140	2	90	13
Philadelphia PA	116,700	156,060	272,760	11	60	30
Pittsburgh PA	45,290	70,040	115,340	21	60	30
Washington DC	212,770	362,510	575,280	4	180	2
Midwestern Cities						
Chicago IL	257,320	298,470	555,790	5	70	23
Cincinnati OH	23,920	20,530	44,440	37	40	39
Cleveland OH	27,360	22,420	49,780	33	30	42
Columbus OH	22,620	18,950	41,570	38	50	35
Detroit MI	148,020	235,670	383,690	7	100	12
Indianapolis IN	7,350	9,780	17,130	48	20	45
Kansas City MO	10,190	18,200	28,390	42	20	45
Louisville KY	10,220	11,240	21,470	45	30	42
Milwaukee WI	23,550	24,400	47,960	36	40	39
Minn-St. Paul MN	53,890	51,990	105,880	22	50	35
Oklahoma City OK	10,510	11,560	22,070	43	30	42
St. Louis MO	61,830	70,340	132,170	19	70	23
Southern Cities						
Atlanta GA	114,040	125,450	239,490	13	130	8
Charlotte NC	18,280	18,270	36,550	40	80	19
Ft. Lauderdale FL	31,950	39,100	71,040	28	60	30
Jacksonville FL	24,350	30,750	55,100	32	70	23
Memphis TN	10,290	11,320	21,600	44	20	45
Miami FL	102,430	126,440	228,860	15	120	10
Nashville TN	19,090	21,000	40,090	39	70	23
New Orleans LA	27,680	42,050	69,730	29	60	30
Norfolk VA	25,470	52,680	78,150	26	80	19
Orlando FL	32,800	41,530	74,330	27	80	19
Tampa FL	22,070	26,770	48,840	35	70	23
Southwestern Cities						
Albuquerque NM	9,450	10,390	19,840	46	40	39
Austin TX	23,340	25,680	49,020	34	90	13
Corpus Christi TX	1,650	1,820	3,470	50	10	50
Dallas TX	100,680	173,350	274,030	10	130	8
Denver CO	71,570	74,530	146,110	18	90	13
El Paso TX	4,600	5,070	9,670	49	20	45
Fort Worth TX	39,160	66,510	105,680	23	90	13
Houston TX	174,280	235,690	409,970	6	140	7
Phoenix AZ	96,080	82,980	179,060	16	90	13
Salt Lake City UT	10,070	7,770	17,850	47	20	45
San Antonio TX	29,960	32,950	62,910	30	50	35
Western Cities						
Honolulu HI	22,070	35,570	57,640	31	90	13
Los Angeles CA	843,590	990,650	1,834,240	1	160	4
Portland OR	32,840	54,450	87,280	24	80	19
Sacramento CA	44,910	37,100	82,020	25	70	23
San Bernardino-Riv CA	114,880	134,840	249,720	12	200	1
San Diego CA	95,710	64,000	159,710	17	70	23
San Fran-Oak CA	290,630	367,910	658,550	3	180	2
San Jose CA	108,710	127,600	236,310	14	160	4
Seattle-Everett WA	119,080	157,850	276,930	9	150	6
Northeastern Avg	151,350	280,720	432,060		90	
Midwestern Avg	54,730	66,130	120,860		40	
Southern Avg	38,950	48,670	87,620		80	
Southwestern Avg	50,990	65,160	116,140		70	
Western Avg	185,820	218,890	404,710		130	
Texas Avg	53,380	77,300	130,680		80	
Total Avg	87,560	119,610	207,170		80	
Maximum Value	843,590	1010090	1,834,240		200	
Minimum Value	1,650	1,820	3,470		10	

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

Source: TTI Analysis

Table 11. Annual Excess Fuel Consumed due to Traffic Congestion in 1991

Urban Area	Liters of Fuel Wasted (million)				Excess Fuel Consumed per 1000 Persons (Liters)	Rank[1]
	Recurring	Incident	Total	Rank[1]		
Northeastern Cities						
Baltimore MD	61	109	170	20	83,081	30
Boston MA	123	349	472	8	159,593	10
Hartford CT	14	26	40	41	66,319	37
New York NY	709	1,340	2,049	2	121,753	14
Philadelphia PA	148	197	345	11	81,598	32
Pittsburgh PA	57	88	145	21	77,901	33
Washington DC	275	469	744	4	226,741	3
Midwestern Cities						
Chicago IL	334	388	722	5	96,033	24
Cincinnati OH	33	29	62	37	51,474	40
Cleveland OH	38	31	68	33	38,164	43
Columbus OH	30	25	55	38	60,596	38
Detroit MI	189	301	490	7	123,086	13
Indianapolis IN	10	13	23	48	24,548	48
Kansas City MO	13	24	37	42	31,704	46
Louisville KY	13	14	27	45	33,482	44
Milwaukee WI	31	32	64	36	52,036	39
Minn-St. Paul MN	71	69	140	23	68,149	36
Oklahoma City OK	14	15	29	43	39,046	42
St. Louis MO	80	91	171	19	87,723	29
Southern Cities						
Atlanta GA	150	165	315	13	165,785	9
Charlotte NC	24	24	48	40	104,102	22
Ft. Lauderdale FL	41	50	92	28	71,962	34
Jacksonville FL	32	41	73	32	97,360	23
Memphis TN	14	15	28	44	32,808	45
Miami FL	130	160	289	15	153,978	11
Nashville TN	25	27	52	39	91,162	27
New Orleans LA	36	55	91	29	82,713	31
Norfolk VA	34	69	103	26	108,278	21
Orlando FL	43	54	97	27	110,420	20
Tampa FL	29	35	64	35	89,886	28
Southwestern Cities						
Albuquerque NM	12	13	26	46	47,599	41
Austin TX	32	35	67	34	127,371	12
Corpus Christi TX	2	2	5	50	16,474	50
Dallas TX	137	235	372	9	179,549	8
Denver CO	94	98	191	18	121,135	15
El Paso TX	6	7	13	49	24,022	49
Fort Worth TX	53	90	143	22	118,978	16
Houston TX	233	315	548	6	188,944	7
Phoenix AZ	123	106	229	16	118,872	17
Salt Lake City UT	14	10	24	47	28,611	47
San Antonio TX	40	44	85	30	71,849	35
Western Cities						
Honolulu HI	29	47	77	31	115,230	18
Los Angeles CA	1,101	1,293	2,394	1	203,589	6
Portland OR	44	73	117	24	112,326	19
Sacramento CA	60	50	109	25	93,966	25
San Bernardino-Riv CA	152	179	331	12	267,963	1
San Diego CA	130	87	217	17	92,343	26
San Fran-Oak CA	387	490	877	3	235,404	2
San Jose CA	144	169	313	14	208,946	4
Seattle-Everett WA	159	211	370	10	205,064	5
Northeastern Avg	197	366	567		124,638	
Midwestern Avg	72	87	157		77,748	
Southern Avg	51	64	114		110,436	
Southwestern Avg	68	87	155		125,109	
Western Avg	247	291	534		190,353	
Texas Avg	72	105	176		141,305	
Total Avg	116	158	272		128,075	
Maximum Value	1,173	1,405	2,394		142,258	
Minimum Value	2	2	5		16,474	

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

Source: TTI Analysis

COST OF CONGESTION

Another method of assessing impact is to look at economic factors. Two quantities closely related to congestion are delay and wasted fuel. This chapter presents estimates of the value of traffic delay and fuel wasted due to congested traffic for the 50 study areas.

ECONOMIC IMPACT ESTIMATES

The two primary components of the congestion cost estimates were 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 10) and fuel wasted in congested travel conditions (Table 11).

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 (9)—$10.25 per person-hour (1991 value),
4. Commercial vehicle operating cost (10)—$1.27 per kilometer (1991 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 (DVKT)—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 1991,

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

4. Population—estimated using the 1991 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. Previous reports have included additional insurance costs resulting from operating a vehicle in larger metropolitan areas. Due to the difficulty in obtaining data from the insurance industry, these costs have been omitted from this cost analysis since the report was based on 1988 data.

ECONOMIC ANALYSIS

While the above variables are used to analyze congestion cost in this study, some of these cost variables fluctuate with economic 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.

Table 12 gives the daily delay in each urban area from 1986 to 1991. Thirty-five of the 50 urban areas had at least a 15 percent growth in delay over the six-year period. Eleven of the areas had at least a 50 percent delay growth in the same period. Sacramento and Salt Lake City showed a 100 percent increase in delay during this same time. None of the urban areas showed a decrease in delay during this six-year period.

The summary statistics show that only the Southwestern and Texas regions did not have at least a 15 percent growth in delay from 1986 to 1991. The Texas region displayed a small change in delay (four percent) over this period. The Northeastern and Southern regions showed the largest percent increase in daily delay over the six-year period.

Table 12. Daily Vehicle Hours of Delay, 1986 to 1991

Urban Area	Daily Delay (1000 Veh-Hours) 1986	1987	1988	1989	1990	1991	% change 1986-1991
Northeastern Cities							
Baltimore MD	95	100	105	120	130	130	37
Boston MA	290	280	380	360	350	355	22
Hartford CT	20	20	30	35	30	30	50
New York NY	1,210	1,290	1,395	1,540	1,540	1,545	28
Philadelphia PA	245	260	270	265	270	275	12
Pittsburgh PA	95	100	110	115	115	115	21
Washington DC	445	480	500	545	560	575	29
Midwestern Cities							
Chicago IL	485	475	470	500	535	555	14
Cincinnati OH	25	30	40	40	45	45	80
Cleveland OH	35	40	45	45	50	50	43
Columbus OH	30	35	35	40	40	40	33
Detroit MI	340	345	350	365	360	385	13
Indianapolis IN	10	10	15	15	20	15	50
Kansas City MO	20	20	30	25	30	30	50
Louisville KY	20	20	20	20	20	20	0
Milwaukee WI	35	40	45	45	45	50	43
Minn-St. Paul MN	70	95	95	95	105	105	50
Oklahoma City OK	20	20	20	20	20	20	0
St. Louis MO	110	120	105	135	130	130	18
Southern Cities							
Atlanta GA	230	245	230	235	240	240	4
Charlotte NC	25	25	30	30	35	35	40
Ft. Lauderdale FL	60	65	65	65	70	70	17
Jacksonville FL	40	45	45	55	55	55	38
Memphis TN	15	15	20	20	20	20	33
Miami FL	150	165	200	220	230	230	53
Nashville TN	30	35	40	40	40	40	33
New Orleans LA	65	65	70	70	70	70	8
Norfolk VA	65	70	75	75	75	80	23
Orlando FL	60	60	60	70	70	75	25
Tampa FL	35	40	45	45	45	50	43
Southwestern Cities							
Albuquerque NM	15	15	15	20	20	20	33
Austin TX	50	50	50	45	50	50	0
Corpus Christi TX	5	5	5	5	5	5	0
Dallas TX	270	245	250	250	270	275	2
Denver CO	110	110	115	120	135	145	32
El Paso TX	10	10	10	10	10	10	0
Fort Worth TX	95	90	95	95	100	105	11
Houston TX	380	365	380	385	395	410	8
Phoenix AZ	140	140	180	175	170	180	29
Salt Lake City UT	10	15	10	15	15	20	100
San Antonio TX	65	65	60	60	60	65	0
Western Cities							
Honolulu HI	45	45	55	55	55	60	33
Los Angeles CA	1,685	1,755	1,720	1,790	1,820	1,835	9
Portland OR	50	60	70	75	80	85	70
Sacramento CA	40	55	70	80	80	80	100
San Bernardino-Riv CA	185	190	220	235	240	250	35
San Diego CA	100	130	150	160	160	160	60
San Fran-Oak CA	555	635	645	670	665	660	19
San Jose CA	200	215	220	230	230	235	18
Seattle-Everett WA	180	215	240	260	265	275	53
Northeastern Avg	345	360	400	425	430	430	25
Midwestern Avg	100	105	105	110	115	120	20
Southern Avg	70	75	80	85	85	90	29
Southwestern Avg	105	100	105	105	110	115	10
Western Avg	340	365	375	395	400	405	19
Texas Avg	125	120	120	120	125	130	4
Total Avg	170	180	190	200	205	205	21
Maximum Value	1,685	1,755	1,720	1,790	1,820	1,835	9
Minimum Value	5	5	5	5	5	5	0

Source: TTI Analysis

The annual amount of fuel wasted due to congestion from 1986 to 1991 is shown in Table 13. The summary statistics show that the Northeastern and Southern regions had the highest average growth over the period. The Southwestern and Texas regions were the only two which did not surpass a 15 percent growth in wasted fuel over the six year period.

The component and total congestion costs for each urban area are shown in Table 14. In 1991, the total cost of congestion for the urban areas studied was approximately \$44.1 billion. This represents a four percent increase in the economic impact of congestion since 1990 (\$42.3 billion). The increase in the value of time rate was 2.5 percent and fuel costs averaged a 3 percent decrease. Studywide averages indicate that recurring and incident delay accounted for approximately 89 percent of an urban area's congestion cost. The average economic burden placed on urban areas in 1991 due to congestion was \$785 million, compared to \$750 million in 1990.

Fourteen urban areas had total congestion costs exceeding \$1 billion. Of the seven urban areas studied in Texas, only two, Houston—6th and Dallas—10th, ranked in the top ten. Congestion in the Texas urbanized areas resulted in a cost of approximately \$3.9 billion, a six percent increase from 1990 congestion costs.

Table 15 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. The urban area with the highest per vehicle cost was Washington, D.C. (\$1,440 per registered vehicle), while San Bernardino-Riverside had the highest per capita cost (\$870 per person).

The individual relationships of the "congestion tax" estimates to total congestion cost can be seen in Table 16, which illustrates the rankings of urban areas by the annual, per capita, and per registered vehicle costs. The rankings of the cost estimates are fairly consistent among the urban areas occupying the top ten positions in all three categories. The individual cost components, however, should be more closely related to the roadway congestion index values, which is also

Table 13. Annual Wasted Fuel Due to Congestion

Urban Area	Annual Wasted Liters (millions) 1986	1987	1988	1989	1990	1991	Pct Change 1986-1991
Northeastern Cities							
Baltimore MD	128	135	141	157	169	170	33
Boston MA	388	373	504	479	463	472	22
Hartford CT	27	29	41	46	41	40	48
New York NY	1,611	1,703	1,837	2,038	2,042	2,049	27
Philadelphia PA	308	330	340	338	342	345	12
Pittsburgh PA	120	126	140	142	147	145	21
Washington DC	586	630	652	708	727	744	27
Midwestern Cities							
Chicago IL	622	611	614	648	694	722	16
Cincinnati OH	36	43	54	57	60	62	72
Cleveland OH	48	53	60	64	67	68	42
Columbus OH	41	46	49	51	53	55	34
Detroit MI	439	445	448	463	464	490	12
Indianapolis IN	13	14	22	21	24	23	77
Kansas City MO	29	29	36	35	37	37	28
Louisville KY	22	26	24	25	25	27	23
Milwaukee WI	49	56	59	59	62	64	31
Minn-St. Paul MN	95	124	127	129	138	140	47
Oklahoma City OK	24	23	29	28	28	29	21
St. Louis MO	146	153	135	176	171	171	17
Southern Cities							
Atlanta GA	302	322	302	307	312	315	4
Charlotte NC	32	33	38	40	44	48	50
Ft. Lauderdale FL	79	85	86	86	90	92	16
Jacksonville FL	51	60	59	70	73	73	43
Memphis TN	18	21	23	24	26	28	56
Miami FL	192	212	254	277	288	289	51
Nashville TN	39	42	53	52	52	52	33
New Orleans LA	85	86	90	92	92	91	7
Norfolk VA	85	94	96	98	101	103	21
Orlando FL	78	81	81	90	94	97	24
Tampa FL	46	50	55	54	59	64	39
Southwestern Cities							
Albuquerque NM	17	19	20	25	26	26	53
Austin TX	69	65	65	64	66	67	-3
Corpus Christi TX	4	4	4	4	4	5	25
Dallas TX	361	333	343	343	364	372	3
Denver CO	143	142	151	160	178	191	34
El Paso TX	13	12	13	13	13	13	0
Fort Worth TX	129	125	128	129	136	143	11
Houston TX	505	489	506	517	528	548	9
Phoenix AZ	179	178	224	221	220	229	28
Salt Lake City UT	13	17	17	20	20	24	85
San Antonio TX	87	86	82	82	82	85	-2
Western Cities							
Honolulu HI	62	62	70	73	73	77	24
Los Angeles CA	2,207	2,301	2,240	2,333	2,377	2,394	8
Portland OR	67	83	96	103	106	117	75
Sacramento CA	57	73	92	103	108	109	91
San Bernardino-Riv CA	250	257	290	307	321	331	32
San Diego CA	137	177	201	214	215	217	58
San Fran-Oak CA	737	838	858	887	887	877	19
San Jose CA	263	284	293	303	302	313	19
Seattle-Everett WA	240	291	322	350	359	370	54
Northeastern Avg	453	475	522	558	562	567	25
Midwestern Avg	130	135	138	146	152	157	21
Southern Avg	92	99	103	108	112	114	24
Southwestern Avg	138	134	141	143	149	155	12
Western Avg	447	485	496	519	527	534	19
Texas Avg	167	159	163	164	171	176	5
Total Avg	226	237	249	262	267	272	20
Maximum Value	2,207	2,301	2,240	2,333	2,377	2,394	8
Minimum Value	4	4	4	4	4	5	25

Source: TTI Analysis and Local Transportation Agency References

Table 14. Component and Total Congestion Costs By Urban Area for 1991

Urban Area	Annual Cost Due to Congestion ($Millions)					Rank
	Recurring Delay	Incident Delay	Recurring Fuel	Incident Fuel	Delay&Fuel Cost	
Los Angeles CA	3,180	3,740	400	470	7,790	1
New York NY	2,030	3,840	260	490	6,620	2
San Fran-Oak CA	1,110	1,400	140	180	2,830	3
Washington DC	800	1,360	100	170	2,430	4
Chicago IL	970	1,120	130	150	2,360	5
Houston TX	660	900	80	110	1,750	6
Detroit MI	550	880	70	100	1,610	7
Boston MA	350	1,000	40	120	1,520	8
Seattle-Everett WA	450	600	60	80	1,190	9
Dallas TX	390	670	50	80	1,180	10
Philadelphia PA	430	580	50	70	1,140	11
San Bernardino-Riv CA	440	510	60	70	1,070	12
Atlanta GA	430	470	50	50	1,010	14
San Jose CA	410	490	50	60	1,010	14
Miami FL	380	470	50	60	950	15
Phoenix AZ	360	310	40	40	750	16
San Diego CA	370	250	50	30	690	17
Denver CO	270	280	30	40	620	18
Baltimore MD	180	320	20	40	550	20
St. Louis MO	230	260	30	30	550	20
Pittsburgh PA	170	260	20	30	480	21
Fort Worth TX	150	260	20	30	450	23
Minn-St. Paul MN	200	200	20	20	450	23
Portland OR	130	210	20	30	380	24
Sacramento CA	170	140	20	20	350	25
Norfolk VA	100	200	10	20	330	26
Orlando FL	120	160	10	20	310	27
Ft. Lauderdale FL	120	150	10	20	300	28
New Orleans LA	100	160	10	20	290	29
San Antonio TX	110	130	10	20	270	30
Honolulu HI	80	140	10	20	250	31
Jacksonville FL	90	120	10	10	230	32
Cleveland OH	110	90	10	10	220	33
Austin TX	90	100	10	10	210	35
Tampa FL	80	100	10	10	210	35
Milwaukee WI	90	90	10	10	200	36
Cincinnati OH	90	80	10	10	190	37
Columbus OH	90	70	10	10	180	38
Nashville TN	70	80	10	10	170	39
Charlotte NC	70	70	10	10	150	40
Hartford CT	40	70	10	10	130	41
Kansas City MO	40	70	0	10	120	42
Louisville KY	40	40	0	0	90	44
Memphis TN	40	40	0	10	90	44
Oklahoma City OK	40	40	0	10	90	44
Albuquerque NM	40	40	0	0	80	47
Salt Lake City UT	40	30	0	0	80	47
Indianapolis IN	30	40	0	0	70	48
El Paso TX	20	20	0	0	40	49
Corpus Christi TX	10	10	0	0	10	50
Northeastern Avg	570	1,060	70	130	1,840	
Midwestern Avg	210	250	30	30	510	
Southern Avg	150	180	20	20	370	
Southwestern Avg	190	250	20	30	500	
Western Avg	700	830	90	110	1,730	
Texas Avg	200	300	20	40	560	
Total Avg	330	450	40	60	880	
Maximum Value	3,180	3,840	400	490	7,790	
Minimum Value	10	10	0	0	10	

Source: TTI Analysis and Local Transportation Agency References

Table 15. Estimated Unit Costs of Congestion in 1991

	Total Congestion Cost	
	Per Registered Vehicle (Dollars)	Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	530	270
Boston MA	920	510
Hartford CT	250	210
New York NY	1,090	390
Philadelphia PA	410	270
Pittsburgh PA	390	260
Washington DC	1,440	740
Midwestern Cities		
Chicago IL	580	310
Cincinnati OH	210	160
Cleveland OH	140	120
Columbus OH	240	200
Detroit MI	560	400
Indianapolis IN	130	80
Kansas City MO	160	100
Louisville KY	190	110
Milwaukee WI	380	170
Minn-St. Paul MN	270	220
Oklahoma City OK	190	130
St. Louis MO	540	280
Southern Cities		
Atlanta GA	640	530
Charlotte NC	410	340
Ft. Lauderdale FL	290	230
Jacksonville FL	390	310
Memphis TN	150	110
Miami FL	670	510
Nashville TN	330	290
New Orleans LA	330	270
Norfolk VA	400	350
Orlando FL	420	360
Tampa FL	320	290
Southwestern Cities		
Albuquerque NM	200	150
Austin TX	410	400
Corpus Christi TX	70	50
Dallas TX	780	570
Denver CO	450	390
El Paso TX	120	80
Fort Worth TX	450	380
Houston TX	780	600
Phoenix AZ	600	390
Salt Lake City UT	110	90
San Antonio TX	310	230
Western Cities		
Honolulu HI	500	380
Los Angeles CA	1,000	660
Portland OR	550	360
Sacramento CA	280	300
San Bernardino-Riv CA	1,340	870
San Diego CA	490	300
San Fran-Oak CA	930	760
San Jose CA	990	670
Seattle-Everett WA	890	660
Northeastern Avg	720	380
Midwestern Avg	300	190
Southern Avg	400	330
Southwestern Avg	390	300
Western Avg	770	550
Texas Avg	420	330
Total Avg	480	340
Maximum Value	1,440	870
Minimum Value	70	50

Source: TTI Analysis and Local Transportation Agency References

Table 16. 1991 Rankings of Urban Area by Estimated Impact of Congestion

Urban Area	Total Congestion Cost	Congestion Cost Per Capita	Congestion Cost Per Reg. Vehicle	Roadway Congestion Index
Northeastern Cities				
Baltimore MD	19	30	18	24
Boston MA	8	10	7	17
Hartford CT	41	37	38	38
New York NY	2	15	3	9
Philadelphia PA	11	32	26	17
Pittsburgh PA	21	33	29	44
Washington DC	4	3	1	2
Midwestern Cities				
Chicago IL	5	23	14	4
Cincinnati OH	37	40	40	27
Cleveland OH	33	43	46	29
Columbus OH	38	38	39	42
Detroit MI	7	13	15	14
Indianapolis IN	48	48	47	43
Kansas City MO	42	46	44	48
Louisville KY	45	44	42	40
Milwaukee WI	36	39	30	25
Minn-St. Paul MN	23	36	37	32
Oklahoma City OK	43	42	43	46
St. Louis MO	20	29	17	26
Southern Cities				
Atlanta GA	14	9	12	9
Charlotte NC	40	22	25	44
Ft. Lauderdale FL	28	34	35	30
Jacksonville FL	32	24	28	30
Memphis TN	44	45	45	35
Miami FL	15	11	11	4
Nashville TN	39	27	32	37
New Orleans LA	29	31	31	12
Norfolk VA	26	21	27	27
Orlando FL	27	20	23	49
Tampa FL	35	28	33	20
Southwestern Cities				
Albuquerque NM	46	41	41	32
Austin TX	34	12	24	32
Corpus Christi TX	50	50	50	49
Dallas TX	10	8	9	17
Denver CO	18	14	22	23
El Paso TX	49	49	48	47
Fort Worth TX	22	18	21	35
Houston TX	6	7	10	13
Phoenix AZ	16	16	13	21
Salt Lake City UT	47	47	49	41
San Antonio TX	30	35	34	38
Western Cities				
Honolulu HI	31	17	19	11
Los Angeles CA	1	5	4	1
Portland OR	24	19	16	15
Sacramento CA	25	25	36	21
San Bernardino-Riv CA	12	1	2	7
San Diego CA	17	26	20	6
San Fran-Oak CA	3	2	6	3
San Jose CA	13	4	5	16
Seattle-Everett WA	9	6	8	7

Source: TTI Analysis

a measure of impact on individuals. Fifteen areas occupy the top ten positions in the three "individual impact" categories.

The 1990 and 1991 rankings of the RCI values and the congestion costs per capita are displayed in Table 17. The change during the past year can be seen in the cost and RCI rankings.

Tables 18 through 29 present estimates of congestion cost from 1986 to 1991. Previously published estimates presented in this series of reports have been revised for some areas to reflect new information. The data in Tables 18 through 29 are the best current information on the delay, fuel and cost values for the years 1986 through 1991. Some of the data missing in 1986 and 1987 was unobtainable because of the various methods of reporting information in the HPMS database.

Table 17. Congestion Index and Cost Values, 1990 and 1991

Urban Area	1991 DVKT/Ln-Km		Roadway Congestion Index			Congestion Cost Per Capita	
	Frwy	Prin. Art. Street	1991 Value	Rank 1990	Rank 1991	1990	1991
Northeastern Cities							
Baltimore MD	12,830	5,910	1.02	24	24	270	270
Boston MA	14,260	4,530	1.06	16	17	490	510
Hartford CT	10,760	5,850	0.89	37	38	210	210
New York NY	14,020	6,960	1.14	9	9	380	390
Philadelphia PA	12,150	6,630	1.06	17	17	260	270
Pittsburgh PA	8,130	5,970	0.82	44	44	250	260
Washington DC	16,830	8,470	1.39	2	2	750	740
Midwestern Cities							
Chicago IL	16,010	7,180	1.28	5	4	300	310
Cincinnati OH	12,750	4,610	0.97	28	27	160	160
Cleveland OH	12,250	5,200	0.96	27	29	120	120
Columbus OH	10,550	5,320	0.84	42	42	200	200
Detroit MI	13,310	6,490	1.10	14	14	370	400
Indianapolis IN	10,650	4,500	0.83	42	43	80	80
Kansas City MO	9,200	4,610	0.74	47	48	100	100
Louisville KY	10,590	6,000	0.88	40	40	100	110
Milwaukee WI	13,020	4,880	1.00	25	25	160	170
Minn-St. Paul MN	12,180	4,730	0.94	33	32	220	220
Oklahoma City OK	9,690	5,460	0.80	45	46	120	130
St. Louis MO	11,240	7,040	0.98	25	26	270	280
Southern Cities							
Atlanta GA	14,520	6,280	1.14	12	9	520	530
Charlotte NC	8,300	5,910	0.82	46	44	310	340
Ft. Lauderdale FL	11,880	5,330	0.95	30	30	230	230
Jacksonville FL	12,160	4,880	0.95	30	30	320	310
Memphis TN	11,280	5,220	0.92	35	35	100	110
Miami FL	14,280	7,690	1.28	4	4	500	510
Nashville TN	10,320	5,750	0.90	37	37	290	290
New Orleans LA	13,810	6,620	1.12	10	12	270	270
Norfolk VA	11,840	5,910	0.97	28	27	340	350
Orlando FL	10,080	2,520	0.72	49	49	350	360
Tampa FL	11,970	6,570	1.05	17	20	270	290
Southwestern Cities							
Albuquerque NM	11,530	5,130	0.94	33	32	160	150
Austin TX	12,090	4,940	0.94	30	32	400	400
Corpus Christi TX	8,630	4,410	0.72	49	49	40	50
Dallas TX	13,940	4,880	1.06	17	17	570	570
Denver CO	12,770	5,840	1.03	21	23	360	390
El Paso TX	9,550	3,900	0.75	47	47	80	80
Fort Worth TX	11,940	4,830	0.92	36	35	350	380
Houston TX	14,640	5,010	1.11	10	13	570	600
Phoenix AZ	12,750	5,590	1.04	21	21	370	390
Salt Lake City UT	10,650	5,860	0.86	41	41	80	90
San Antonio TX	11,300	4,890	0.89	39	38	220	230
Western Cities							
Honolulu HI	13,820	8,100	1.13	12	11	360	380
Los Angeles CA	21,110	6,590	1.56	1	1	660	660
Portland OR	13,430	6,600	1.08	15	15	320	360
Sacramento CA	12,680	6,280	1.04	23	21	310	300
San Bernardino-Riv CA	16,540	4,660	1.20	8	7	870	870
San Diego CA	16,060	5,490	1.22	6	6	290	300
San Fran-Oak CA	17,570	6,100	1.34	3	3	760	760
San Jose CA	14,060	4,800	1.07	20	16	680	670
Seattle-Everett WA	15,570	6,140	1.20	7	7	650	660

Source: TTI Analysis and Local Transportation Agency References

Table 18. 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	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	-	-	-	-	-
Boston MA	-	-	-	-	-
Hartford CT	20	40	-	-	-
New York NY	-	-	-	-	-
Philadelphia PA	-	-	-	-	-
Pittsburgh PA	-	-	-	-	-
Washington DC	-	-	-	-	-
Midwestern Cities					
Chicago IL	-	-	-	-	-
Cincinnati OH	-	-	-	-	-
Cleveland OH	-	-	-	-	-
Columbus OH	50	40	-	-	-
Detroit MI	-	-	-	-	-
Indianapolis IN	-	-	-	-	-
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	-	-	-	-	-
St. Louis MO	160	180	70	80	490
Southern Cities					
Atlanta GA	330	370	40	40	770
Charlotte NC	40	40	-	-	-
Ft. Lauderdale FL	80	100	10	10	210
Jacksonville FL	50	70	10	10	130
Memphis TN	20	20	0	0	50
Miami FL	200	250	20	30	500
Nashville TN	40	50	0	10	100
New Orleans LA	80	120	10	10	220
Norfolk VA	60	130	-	-	-
Orlando FL	80	100	10	10	200
Tampa FL	50	60	10	10	120
Southwestern Cities					
Albuquerque NM	20	20	0	0	40
Austin TX	70	80	10	10	170
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	20	0	0	30
Fort Worth TX	110	190	10	20	330
Houston TX	500	660	50	70	1,280
Phoenix AZ	230	200	30	20	470
Salt Lake City UT	20	10	0	0	30
San Antonio TX	100	100	10	10	220
Western Cities					
Honolulu HI	50	90	10	10	160
Los Angeles CA	2,340	2,750	280	330	5,700
Portland OR	60	90	10	10	170
Sacramento CA	70	60	10	10	140
San Bernardino-Riv CA	260	310	30	40	640
San Diego CA	180	120	20	20	350
San Fran-Oak CA	750	950	90	110	1,900
San Jose CA	280	330	30	40	680
Seattle-Everett WA	240	310	30	40	610
Northeastern Avg	20	40	-	-	-
Midwestern Avg	70	80	20	20	200
Southern Avg	90	120	10	10	260
Southwestern Avg	140	180	20	20	350
Western Avg	470	560	60	70	1,150
Texas Avg	160	230	20	20	420
Total Avg	190	230	30	30	520
Maximum Value	2,340	2,750	280	330	5,700
Minimum Value	0	0	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 19. Estimated Impact of Congestion in 1986

	Annual Congestion Cost	
	Per Registered Vehicle (Dollars)	Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	-	-
Boston MA	-	-
Hartford CT	-	-
New York NY	-	-
Philadelphia PA	-	-
Pittsburgh PA	-	-
Washington DC	-	-
Midwestern Cities		
Chicago IL	-	-
Cincinnati OH	-	-
Cleveland OH	-	-
Columbus OH	-	-
Detroit MI	-	-
Indianapolis IN	-	-
Kansas City MO	120	60
Louisville KY	130	70
Milwaukee WI	160	100
Minn-St. Paul MN	210	130
Oklahoma City OK	-	-
St. Louis MO	350	250
Southern Cities		
Atlanta GA	550	460
Charlotte NC	-	-
Ft. Lauderdale FL	220	180
Jacksonville FL	240	200
Memphis TN	100	60
Miami FL	350	280
Nashville TN	280	200
New Orleans LA	270	200
Norfolk VA	-	-
Orlando FL	360	290
Tampa FL	180	200
Southwestern Cities		
Albuquerque NM	120	100
Austin TX	380	380
Corpus Christi TX	40	40
Dallas TX	560	480
Denver CO	290	250
El Paso TX	100	70
Fort Worth TX	360	290
Houston TX	680	460
Phoenix AZ	430	270
Salt Lake City UT	50	40
San Antonio TX	280	230
Western Cities		
Honolulu HI	330	270
Los Angeles CA	740	530
Portland OR	280	160
Sacramento CA	130	150
San Bernardino-Riv CA	940	650
San Diego CA	320	170
San Fran-Oak CA	710	550
San Jose CA	700	510
Seattle-Everett WA	580	390
Northeastern Avg	-	-
Midwestern Avg	190	130
Southern Avg	280	230
Southwestern Avg	300	240
Western Avg	530	380
Texas Avg	340	280
Total Avg	340	260
Maximum Value	940	650
Minimum Value	40	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 20. 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	Delay&Fuel Cost
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	560	940	70	110	1,670
Midwestern Cities					
Chicago IL	680	790	80	90	1,640
Cincinnati OH	50	50	10	10	110
Cleveland OH	70	50	10	10	140
Columbus OH	60	50	10	10	120
Detroit MI	420	650	50	80	1,190
Indianapolis IN	-	-	-	-	-
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	-	-	-	-	-
St. Louis MO	170	200	20	20	410
Southern Cities					
Atlanta GA	370	400	40	50	850
Charlotte NC	40	40	0	0	90
Ft. Lauderdale FL	90	110	10	10	230
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	120	10	10	230
Norfolk VA	70	150	10	20	250
Orlando FL	90	110	10	10	220
Tampa FL	60	70	10	10	140
Southwestern Cities					
Albuquerque NM	-	-	-	-	-
Austin TX	70	80	10	10	170
Corpus Christi TX	0	10	0	0	10
Dallas TX	290	490	30	60	870
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	100	110	10	10	230
Western Cities					
Honolulu HI	60	90	10	10	160
Los Angeles CA	2,510	2,960	300	360	6,130
Portland OR	70	120	10	10	220
Sacramento CA	90	80	10	10	190
San Bernardino-Riv CA	280	330	30	40	680
San Diego CA	250	170	30	20	460
San Fran-Oak CA	870	1,110	110	130	2,220
San Jose CA	310	360	40	40	760
Seattle-Everett WA	290	390	40	50	760
Northeastern Avg	400	730	50	80	1,260
Midwestern Avg	170	210	20	20	420
Southern Avg	110	130	10	20	260
Southwestern Avg	150	190	20	20	380
Western Avg	530	620	60	80	1,290
Texas Avg	150	220	20	30	420
Total Avg	250	340	30	40	670
Maximum Value	2,510	2,960	300	360	6,130
Minimum Value	0	10	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 21. Estimated Impact of Congestion in 1987

	Total Congestion Cost	
	Per Registered Vehicle (Dollars)	Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	360	190
Boston MA	640	340
Hartford CT	150	130
New York NY	780	280
Philadelphia PA	330	220
Pittsburgh PA	280	190
Washington DC	1,040	560
Midwestern Cities		
Chicago IL	410	230
Cincinnati OH	120	120
Cleveland OH	100	80
Columbus OH	160	140
Detroit MI	420	310
Indianapolis IN	-	-
Kansas City MO	120	70
Louisville KY	160	90
Milwaukee WI	280	120
Minn-St. Paul MN	210	170
Oklahoma City OK	-	-
St. Louis MO	430	210
Southern Cities		
Atlanta GA	560	480
Charlotte NC	250	210
Ft. Lauderdale FL	240	200
Jacksonville FL	280	240
Memphis TN	90	70
Miami FL	430	320
Nashville TN	240	220
New Orleans LA	270	210
Norfolk VA	320	290
Orlando FL	350	280
Tampa FL	230	210
Southwestern Cities		
Albuquerque NM	-	-
Austin TX	370	360
Corpus Christi TX	50	40
Dallas TX	550	450
Denver CO	290	250
El Paso TX	90	60
Fort Worth TX	330	290
Houston TX	580	460
Phoenix AZ	420	270
Salt Lake City UT	70	60
San Antonio TX	280	220
Western Cities		
Honolulu HI	330	270
Los Angeles CA	800	560
Portland OR	350	210
Sacramento CA	160	190
San Bernardino-Riv CA	950	670
San Diego CA	350	220
San Fran-Oak CA	760	630
San Jose CA	770	560
Seattle-Everett WA	670	480
Northeastern Avg	510	270
Midwestern Avg	240	150
Southern Avg	300	250
Southwestern Avg	300	240
Western Avg	570	420
Texas Avg	320	270
Total Avg	370	260
Maximum Value	1,040	670
Minimum Value	50	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 22. 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	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	130	220	20	30	390
Boston MA	320	920	40	110	1,380
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	610	1,010	70	120	1,810
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	70	50	10	10	130
Detroit MI	430	690	50	80	1,260
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	160	180	20	20	370
Southern Cities					
Atlanta GA	360	390	40	50	830
Charlotte NC	50	50	10	10	110
Ft. Lauderdale FL	100	120	10	10	240
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	90	110	10	10	230
Tampa FL	60	80	10	10	160
Southwestern Cities					
Albuquerque NM	20	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	940
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	1,390
Phoenix AZ	290	270	40	40	640
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	2,560	3,000	320	380	6,260
Portland OR	90	150	10	20	260
Sacramento CA	120	100	20	10	250
San Bernardino-Riv CA	330	390	40	50	810
San Diego CA	290	200	40	30	550
San Fran-Oak CA	930	1,180	120	150	2,380
San Jose CA	330	390	40	50	810
Seattle-Everett WA	340	450	40	60	880
Northeastern Avg	460	840	50	100	1,440
Midwestern Avg	160	190	20	20	380
Southern Avg	110	140	10	20	290
Southwestern Avg	150	200	20	20	390
Western Avg	560	660	70	80	1,380
Texas Avg	160	230	20	30	450
Total Avg	260	360	30	40	690
Maximum Value	2,560	3,000	320	380	6,260
Minimum Value	0	0	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 23. Estimated Impact of Congestion in 1988

	Total Congestion Cost	
	Per Registered Vehicle (Dollars)	Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	390	200
Boston MA	900	480
Hartford CT	220	190
New York NY	860	310
Philadelphia PA	350	230
Pittsburgh PA	330	210
Washington DC	1,100	600
Midwestern Cities		
Chicago IL	430	230
Cincinnati OH	160	150
Cleveland OH	110	90
Columbus OH	180	160
Detroit MI	440	320
Indianapolis IN	100	60
Kansas City MO	150	90
Louisville KY	150	80
Milwaukee WI	310	130
Minn-St. Paul MN	220	180
Oklahoma City OK	170	110
St. Louis MO	400	190
Southern Cities		
Atlanta GA	540	470
Charlotte NC	280	250
Ft. Lauderdale FL	250	200
Jacksonville FL	280	240
Memphis TN	110	80
Miami FL	530	400
Nashville TN	300	280
New Orleans LA	300	240
Norfolk VA	330	300
Orlando FL	350	290
Tampa FL	260	240
Southwestern Cities		
Albuquerque NM	150	120
Austin TX	360	360
Corpus Christi TX	50	40
Dallas TX	590	480
Denver CO	310	270
El Paso TX	100	70
Fort Worth TX	340	300
Houston TX	620	490
Phoenix AZ	550	350
Salt Lake City UT	70	60
San Antonio TX	250	190
Western Cities		
Honolulu HI	390	300
Los Angeles CA	800	560
Portland OR	420	280
Sacramento CA	200	240
San Bernardino-Riv CA	1,110	780
San Diego CA	400	250
San Fran-Oak CA	790	660
San Jose CA	820	590
Seattle-Everett WA	760	540
Northeastern Avg	590	320
Midwestern Avg	230	150
Southern Avg	320	270
Southwestern Avg	310	250
Western Avg	630	470
Texas Avg	330	280
Total Avg	390	280
Maximum Value	1,110	780
Minimum Value	50	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 24. 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	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	150	260	20	30	460
Boston MA	330	910	40	110	1,390
Hartford CT	40	80	10	10	140
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	690	1,160	90	150	2,090
Midwestern Cities					
Chicago IL	790	910	100	120	1,910
Cincinnati OH	80	70	10	10	160
Cleveland OH	90	70	10	10	190
Columbus OH	70	60	10	10	150
Detroit MI	470	750	60	90	1,380
Indianapolis IN	20	30	0	0	60
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	120
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	270
Norfolk VA	80	170	10	20	290
Orlando FL	100	130	10	20	260
Tampa FL	60	80	10	10	160
Southwestern Cities					
Albuquerque NM	30	30	0	0	70
Austin TX	80	90	10	10	180
Corpus Christi TX	0	0	0	0	10
Dallas TX	320	550	40	70	980
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	310	280	40	30	660
Salt Lake City UT	30	20	0	0	60
San Antonio TX	100	110	10	10	240
Western Cities					
Honolulu HI	70	120	10	20	210
Los Angeles CA	2,800	3,290	370	440	6,900
Portland OR	100	170	10	20	300
Sacramento CA	150	120	20	20	300
San Bernardino-Riv CA	370	430	50	60	900
San Diego CA	330	220	40	30	620
San Fran-Oak CA	1,010	1,280	140	170	2,600
San Jose CA	360	420	50	60	890
Seattle-Everett WA	390	520	50	60	1,020
Northeastern Avg	510	950	60	120	1,640
Midwestern Avg	170	210	20	30	430
Southern Avg	130	160	20	20	320
Southwestern Avg	160	210	20	30	420
Western Avg	620	730	80	100	1,530
Texas Avg	170	250	20	30	470
Total Avg	290	390	40	50	770
Maximum Value	2,800	3,460	370	440	6,900
Minimum Value	0	0	0	0	10

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 25. Estimated Impact of Congestion in 1989

	Total Congestion Cost	
	Per Registered Vehicle (Dollars)	Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	460	240
Boston MA	840	470
Hartford CT	260	220
New York NY	1,000	360
Philadelphia PA	360	240
Pittsburgh PA	350	230
Washington DC	1,250	680
Midwestern Cities		
Chicago IL	470	260
Cincinnati OH	170	140
Cleveland OH	120	100
Columbus OH	200	180
Detroit MI	480	350
Indianapolis IN	110	70
Kansas City MO	150	90
Louisville KY	160	90
Milwaukee WI	320	140
Minn-St. Paul MN	230	190
Oklahoma City OK	170	110
St. Louis MO	540	270
Southern Cities		
Atlanta GA	580	480
Charlotte NC	310	270
Ft. Lauderdale FL	250	200
Jacksonville FL	340	280
Memphis TN	120	80
Miami FL	590	450
Nashville TN	310	280
New Orleans LA	320	260
Norfolk VA	350	310
Orlando FL	360	330
Tampa FL	250	240
Southwestern Cities		
Albuquerque NM	180	150
Austin TX	370	360
Corpus Christi TX	50	40
Dallas TX	660	500
Denver CO	340	300
El Paso TX	110	70
Fort Worth TX	380	320
Houston TX	690	520
Phoenix AZ	560	350
Salt Lake City UT	80	70
San Antonio TX	270	200
Western Cities		
Honolulu HI	430	320
Los Angeles CA	880	610
Portland OR	460	300
Sacramento CA	240	290
San Bernardino-Riv CA	1,180	820
San Diego CA	440	280
San Fran-Oak CA	850	720
San Jose CA	890	640
Seattle-Everett WA	800	600
Northeastern Avg	650	350
Midwestern Avg	260	170
Southern Avg	340	290
Southwestern Avg	330	260
Western Avg	690	510
Texas Avg	360	290
Total Avg	430	300
Maximum Value	1,250	820
Minimum Value	50	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 26. 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	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	170	300	20	40	540
Boston MA	340	950	40	120	1,450
Hartford CT	40	70	10	10	130
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	760	1,290	100	170	2,320
Midwestern Cities					
Chicago IL	900	1,050	120	140	2,220
Cincinnati OH	90	80	10	10	190
Cleveland OH	100	80	10	10	210
Columbus OH	80	70	10	10	170
Detroit MI	510	810	60	100	1,480
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	0	90
St. Louis MO	230	260	30	30	540
Southern Cities					
Atlanta GA	420	460	50	60	980
Charlotte NC	60	60	10	10	140
Ft. Lauderdale FL	110	140	10	20	290
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	120	150	10	20	300
Tampa FL	80	90	10	10	190
Southwestern Cities					
Albuquerque NM	40	40	0	0	80
Austin TX	90	100	10	10	210
Corpus Christi TX	0	10	0	0	10
Dallas TX	370	630	50	80	1,130
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	340	290	40	40	700
Salt Lake City UT	30	30	0	0	60
San Antonio TX	110	120	10	20	260
Western Cities					
Honolulu HI	80	130	10	20	230
Los Angeles CA	3,070	3,600	410	480	7,570
Portland OR	110	180	20	20	330
Sacramento CA	160	140	20	20	340
San Bernardino-Riv CA	410	480	60	70	1,010
San Diego CA	350	240	50	30	670
San Fran-Oak CA	1,090	1,380	150	190	2,800
San Jose CA	390	450	50	60	960
Seattle-Everett WA	430	570	60	80	1,130
Northeastern Avg	550	1,020	70	140	1,780
Midwestern Avg	190	230	30	30	480
Southern Avg	140	180	20	20	350
Southwestern Avg	180	230	20	30	470
Western Avg	680	800	90	110	1,670
Texas Avg	190	280	20	40	530
Total Avg	320	430	40	60	850
Maximum Value	3,070	3,720	410	510	7,570
Minimum Value	0	10	0	0	10

Source: TTI Analysis and Local Transportation Agency References

Table 27. Estimated Impact of Congestion in 1990

	Total Congestion Cost	
	Per Registered Vehicle (Dollars)	Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	520	270
Boston MA	880	490
Hartford CT	250	210
New York NY	1,070	380
Philadelphia PA	400	260
Pittsburgh PA	390	250
Washington DC	1,390	750
Midwestern Cities		
Chicago IL	550	300
Cincinnati OH	200	160
Cleveland OH	140	120
Columbus OH	230	200
Detroit MI	520	370
Indianapolis IN	130	80
Kansas City MO	150	100
Louisville KY	180	100
Milwaukee WI	360	160
Minn-St. Paul MN	260	220
Oklahoma City OK	180	120
St. Louis MO	520	270
Southern Cities		
Atlanta GA	630	520
Charlotte NC	370	310
Ft. Lauderdale FL	280	230
Jacksonville FL	390	320
Memphis TN	130	100
Miami FL	650	500
Nashville TN	320	290
New Orleans LA	330	270
Norfolk VA	390	340
Orlando FL	400	350
Tampa FL	300	270
Southwestern Cities		
Albuquerque NM	200	160
Austin TX	410	400
Corpus Christi TX	50	40
Dallas TX	750	570
Denver CO	410	360
El Paso TX	120	80
Fort Worth TX	420	350
Houston TX	740	570
Phoenix AZ	590	370
Salt Lake City UT	90	80
San Antonio TX	290	220
Western Cities		
Honolulu HI	460	360
Los Angeles CA	970	660
Portland OR	490	320
Sacramento CA	270	310
San Bernardino-Riv CA	1,300	870
San Diego CA	480	290
San Fran-Oak CA	930	760
San Jose CA	940	680
Seattle-Everett WA	870	650
Northeastern Avg	700	370
Midwestern Avg	280	180
Southern Avg	380	320
Southwestern Avg	370	290
Western Avg	750	540
Texas Avg	400	320
Total Avg	470	330
Maximum Value	1,390	870
Minimum Value	50	40

Note: - Denotes Data Not Available

Source: TTI Analysis and Local Transportation Agency References

Table 28. 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	Delay&Fuel Cost
Northeastern Cities					
Baltimore MD	180	320	20	40	550
Boston MA	350	1,000	40	120	1,520
Hartford CT	40	70	10	10	130
New York NY	2,030	3,840	260	490	6,620
Philadelphia PA	430	580	50	70	1,140
Pittsburgh PA	170	260	20	30	480
Washington DC	800	1,360	100	170	2,430
Midwestern Cities					
Chicago IL	970	1,120	130	150	2,360
Cincinnati OH	90	80	10	10	190
Cleveland OH	110	90	10	10	220
Columbus OH	90	70	10	10	180
Detroit MI	550	880	70	100	1,610
Indianapolis IN	30	40	0	0	70
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	200	200	20	20	450
Oklahoma City OK	40	40	0	10	90
St. Louis MO	230	260	30	30	550
Southern Cities					
Atlanta GA	430	470	50	50	1,010
Charlotte NC	70	70	10	10	150
Ft. Lauderdale FL	120	150	10	20	300
Jacksonville FL	90	120	10	10	230
Memphis TN	40	40	0	10	90
Miami FL	380	470	50	60	950
Nashville TN	70	80	10	10	170
New Orleans LA	100	160	10	20	290
Norfolk VA	100	200	10	20	330
Orlando FL	120	160	10	20	310
Tampa FL	80	100	10	10	210
Southwestern Cities					
Albuquerque NM	40	40	0	0	80
Austin TX	90	100	10	10	210
Corpus Christi TX	10	10	0	0	10
Dallas TX	390	670	50	80	1,180
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	310	40	40	750
Salt Lake City UT	40	30	0	0	80
San Antonio TX	110	130	10	20	270
Western Cities					
Honolulu HI	80	140	10	20	250
Los Angeles CA	3,180	3,740	400	470	7,790
Portland OR	130	210	20	30	380
Sacramento CA	170	140	20	20	350
San Bernardino-Riv CA	440	510	60	70	1,070
San Diego CA	370	250	50	30	690
San Fran-Oak CA	1,110	1,400	140	180	2,830
San Jose CA	410	490	50	60	1,010
Seattle-Everett WA	450	600	60	80	1,190
Northeastern Avg	570	1,060	70	130	1,840
Midwestern Avg	210	250	30	30	510
Southern Avg	150	180	20	20	370
Southwestern Avg	190	250	20	30	500
Western Avg	700	830	90	110	1,730
Texas Avg	200	300	20	40	560
Total Avg	330	450	40	60	880
Maximum Value	3,180	3,840	400	490	7,790
Minimum Value	10	10	0	0	10

Note: - Denotes Data Not Available
Source: TTI Analysis and Local Transportation Agency References

Table 29. Estimated Impact of Congestion in 1991

	Total Congestion Cost Per Registered Vehicle (Dollars)	Total Congestion Cost Per Capita (Dollars)
Northeastern Cities		
Baltimore MD	530	270
Boston MA	920	510
Hartford CT	250	210
New York NY	1,090	390
Philadelphia PA	410	270
Pittsburgh PA	390	260
Washington DC	1,440	740
Midwestern Cities		
Chicago IL	580	310
Cincinnati OH	210	160
Cleveland OH	140	120
Columbus OH	240	200
Detroit MI	560	400
Indianapolis IN	130	80
Kansas City MO	160	100
Louisville KY	190	110
Milwaukee WI	380	170
Minn-St. Paul MN	270	220
Oklahoma City OK	190	130
St. Louis MO	540	280
Southern Cities		
Atlanta GA	640	530
Charlotte NC	410	340
Ft. Lauderdale FL	290	230
Jacksonville FL	390	310
Memphis TN	150	110
Miami FL	670	510
Nashville TN	330	290
New Orleans LA	330	270
Norfolk VA	400	350
Orlando FL	420	360
Tampa FL	320	290
Southwestern Cities		
Albuquerque NM	200	150
Austin TX	410	400
Corpus Christi TX	70	50
Dallas TX	780	570
Denver CO	450	390
El Paso TX	120	80
Fort Worth TX	450	380
Houston TX	780	600
Phoenix AZ	600	390
Salt Lake City UT	110	90
San Antonio TX	310	230
Western Cities		
Honolulu HI	500	380
Los Angeles CA	1,000	660
Portland OR	550	360
Sacramento CA	280	300
San Bernardino-Riv CA	1,340	870
San Diego CA	490	300
San Fran-Oak CA	930	760
San Jose CA	990	670
Seattle-Everett WA	890	660
Northeastern Avg	720	380
Midwestern Avg	300	190
Southern Avg	400	330
Southwestern Avg	390	300
Western Avg	770	550
Texas Avg	420	330
Total Avg	480	340
Maximum Value	1,440	870
Minimum Value	70	50

Source: TTI Analysis and Local Transportation Agency References

CONGESTION TRENDS FOR URBAN AREA GROUPS

Previous sections in this report have presented travel, roadway supply, and congestion statistics for individual urban areas and geographic regions across the United States. Other urban area groupings based on population size and population density were used to further examine the various congestion trends that occur between the urban areas and over the past decade. Grouping areas by population size or population density can reveal how the size of a city or its development characteristics are related to congestion. This section presents and examines the various congestion trends for the 50 urban areas grouped by population size and population density.

POPULATION SIZE

The amount of congestion in an urban area is intuitively related to its population. Larger urban centers tend to be more congested and typically have a range of solutions to address transportation problems, indicating a recognition of the problems of relying on roadway solutions. This section presents an analysis of the relationship between population and congestion level.

For the purposes of this analysis, Chicago, New York, and Los Angeles were separated because of their comparatively large populations; the remaining areas were divided into four approximately even groups based on the 1991 population estimates (Table 30). Chicago, New York, and Los Angeles have populations much greater than the areas in the adjacent group, and the statistics for these three areas would have distorted the average statistics for the next lower population group. The major Texas urban areas are located in three of the groups: Corpus Christi, Austin, and El Paso are in the first group; San Antonio and Forth Worth are in the second group; and, Dallas and Houston fall into the fourth group. Table 30 also shows the 1991 RCI value and percentage change in the RCI from 1982 to 1991 for each urban area in the five groups.

Table 30. Urban Area Grouping by Population Size

Urban Area	Population 1991 (000)	Population Pct Change 1982 to 1991	Roadway Congestion Index 1991 Value	Roadway Congestion Index Pct Change 1982 to 1991
First Group				
Corpus Christi TX	285	14.00	0.72	7.46
Charlotte NC	460	31.43	0.82	22.39
Austin TX	525	38.16	0.94	22.08
Albuquerque NM	540	20.00	0.94	20.51
El Paso TX	560	24.44	0.75	19.05
Nashville TN	575	2.68	0.90	21.62
Hartford CT	610	7.96	0.89	17.11
Honolulu HI	665	16.67	1.13	21.51
Tampa FL	710	31.48	1.05	11.70
Oklahoma City OK	740	15.63	0.80	11.11
Jacksonville FL	750	21.95	0.95	11.76
Louisville KY	810	5.19	0.88	4.76
Second Group				
Salt Lake City UT	840	23.53	0.86	36.51
Memphis TN	865	6.79	0.92	6.98
Orlando FL	880	44.26	0.72	9.09
Columbus OH	900	7.78	0.84	23.53
Indianapolis IN	950	10.47	0.83	16.90
Norfolk VA	950	23.38	0.97	22.78
Portland OR	1,040	2.97	1.08	24.14
New Orleans LA	1,095	1.39	1.12	14.29
Kansas City MO	1,160	5.45	0.74	19.35
Sacramento CA	1,165	40.36	1.04	30.00
San Antonio TX	1,180	24.21	0.89	15.58
Fort Worth TX	1,200	10.60	0.92	21.05
Third Group				
Cincinnati OH	1,200	-2.44	0.97	12.79
Milwaukee WI	1,225	1.24	1.00	20.48
San Bernardino-Riv CA	1,235	30.69	1.20	10.09
Ft. Lauderdale FL	1,275	19.72	0.95	10.47
San Jose CA	1,500	25.00	1.07	25.88
Denver CO	1,580	17.04	1.03	21.18
Cleveland OH	1,790	-9.60	0.96	20.00
Seattle-Everett WA	1,802	25.14	1.20	26.32
Pittsburgh PA	1,865	3.04	0.82	5.13
Miami FL	1,880	8.67	1.28	21.90
Atlanta GA	1,900	18.01	1.14	28.09
Phoenix AZ	1,930	36.88	1.04	-9.57
Fourth Group				
St. Louis MO	1,950	5.41	0.98	18.07
Baltimore MD	2,051	66.75	1.02	21.43
Minn-St. Paul MN	2,060	17.71	0.94	27.03
Dallas TX	2,070	14.36	1.06	26.19
San Diego CA	2,350	32.02	1.22	56.41
Houston TX	2,900	20.33	1.11	-5.13
Boston MA	2,960	3.86	1.06	17.78
Washington DC	3,280	-4.65	1.39	29.91
San Fran-Oak CA	3,725	11.86	1.34	32.67
Detroit MI	3,985	4.59	1.10	-2.65
Philadelphia PA	4,225	3.81	1.06	6.00
Fifth Group				
Chicago IL	7,515	6.14	1.28	25.49
Los Angeles CA	11,760	18.79	1.56	27.87
New York NY	16,830	1.02	1.14	12.87

Source: TTI Analysis and Local Transportation Agency References

Travel Volume and Roadway Supply Statistics

The average freeway and principal arterial street travel volumes (DVKT) and roadway supply for the five population groups are shown in Tables 31 and 32. The general trend is increasing average roadway supply and travel volumes for an increasing population size. Chicago, New York, and Los Angeles (fifth group) have disproportionately higher travel volumes and roadway supply than the first four groups. The average DVKT per lane-kilometer, a measure of the severity of congestion, shows that freeway and principal arterial street congestion is more extensive in the larger population groups.

The magnitude of the freeway DVKT per lane-kilometer values also indicate that, on the average, urban areas in the third, fourth, and fifth groups experience undesirable areawide levels of congestion on the freeway system. The magnitude of the principal arterial street DVKT per lane-kilometer values suggest that, on the average, all population groups experience undesirable levels of congestion on principal arterial streets.

Table 31. 1991 Freeway Travel Volume and Roadway Supply Grouped by Population

Population Group	DVKT[1] (1000)	Lane-Kms	Avg. No. Lanes	DVKT/ Ln-Km[2,3]
Fifth Group	124,650	7,290	6.5	17,050
Fourth Group	38,920	2,730	5.9	14,090
Third Group	20,470	1,530	5.7	13,210
Second Group	12,680	1,130	5.4	11,450
First Group	7,250	670	5.0	10,780

Note: [1] Daily vehicle-kilometers of travel
[2] Daily vehicle-kilometers of travel per lane-kilometer of freeway
[3] Value in excess of 13,000 indicates undesirable level of congestion on area freeway system

Source: TTI Analysis and Local Transportation Agency References

Table 32. 1991 Principal Arterial Street Travel Volume and Roadway Supply Grouped by Population

Population Group	DVKT[1] (1000)	Lane-Kms	Avg. No. Lanes	DVKT/ Ln-Km[2,3]
Fifth Group	88,690	13,020	3.7	6,910
Fourth Group	21,830	3,610	3.8	5,940
Third Group	15,240	2,680	3.7	5,580
Second Group	6,900	1,390	3.8	5,260
First Group	5,650	1,050	3.7	5,570

Note: [1] Daily vehicle-kilometers of travel
[2] Daily vehicle-kilometers of travel per lane-kilometer of principal arterial street
[3] Value in excess of 5,000 indicates undesirable level of congestion on area principal arterial street system

Source: TTI Analysis and Local Transportation Agency References

1991 Roadway Congestion Index Estimates

The components of the RCI equation and the average 1991 RCI values for the five population groups are shown in Table 33. The average RCI values exhibit the general trend of increasing average levels of congestion for increasing urban area population size. The urban areas with large populations (fourth and fifth group) have significant undesirable levels of congestion (RCI values of 1.12 and 1.33, respectively); and, the average for the medium-size areas (third group) also indicates undesirable areawide congestion (RCI value of 1.05). Smaller urban areas in the first and second groups have average RCI values of 0.90 and 0.91, below what is considered areawide congestion.

Table 33. 1991 Roadway Congestion Index Values Grouped by Population

	Freeway / Expressway		Principal Arterial Street		
Population Group	DVKT[1] (1000)	DVKT/[2] Ln-Km	DVKT[1] (1000)	DVKT/[2] Ln-Km	Roadway[3] Congestion Index
Fifth Group	124,650	17,050	88,690	6,910	1.33
Fourth Group	38,920	14,090	21,830	5,940	1.12
Third Group	20,470	13,210	15,240	5,580	1.05
Second Group	12,680	11,450	6,900	5,260	0.91
First Group	7,250	10,780	5,650	5,570	0.90

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

Source: TTI Analysis

Roadway Congestion Trends, 1982 to 1991

The average growth in congestion between 1982 and 1991 for the five population groups ranges between 16 and 22 percent (Table 34, Figure 6). Congestion has increased faster in the larger population groups than in the smaller population groups. Interestingly, the average growth in congestion for the small to medium areas in the second group is comparable to average growth in the largest urban areas.

Table 34. Roadway Congestion Index Values Grouped by Population, 1982 to 1991

Population Group	Year										% Change 1982 to 1991
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Fifth Group	1.08	1.10	1.12	1.15	1.21	1.23	1.27	1.29	1.31	1.33	22
Fourth Group	0.94	0.97	1.00	1.01	1.06	1.08	1.09	1.10	1.11	1.12	19
Third Group	0.91	0.93	0.94	0.96	0.98	1.00	1.01	1.03	1.04	1.05	16
Second Group	0.76	0.76	0.78	0.81	0.84	0.87	0.88	0.89	0.90	0.91	20
First Group	0.78	0.80	0.84	0.84	0.85	0.87	0.88	0.88	0.89	0.90	16

Source: TTI Analysis

Travel Delays

Table 35 illustrates travel delay information for the five population groups. Inspection of the table reveals that the average total delay for Chicago, New York, and Los Angeles (fifth group) exceeds 1.3 million vehicle-hours of delay. This means the average total delay is over four times that of the other large urban areas in the fourth group. The general trend for the other groups is one of higher delay for larger population size. The total delay per 1000 persons for the five population groups ranges from 110 to 50 vehicle-hours, with lower delay values in smaller population areas.

Table 35. Daily Vehicle Hours of Delay for 1991 Grouped by Population

Population Group	Total Delay (vehicle hours)	Total Delay per 1000 Persons
Fifth Group	1,311,390	110
Fourth Group	314,430	105
Third Group	157,090	100
Second Group	57,220	55
First Group	32,840	55

Source: TTI Analysis

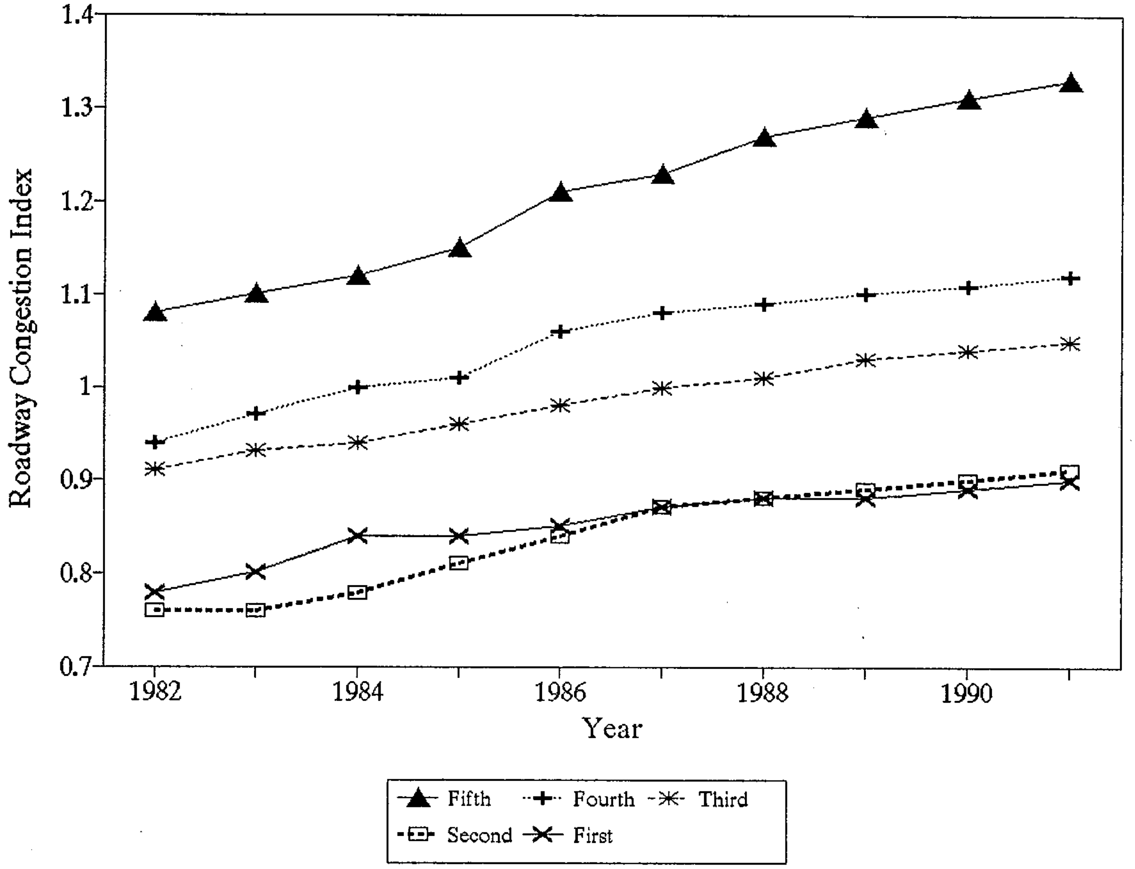

Figure 6. Roadway Congestion Index Values Grouped by Population, 1982 to 1991

Costs of Congestion

The congestion cost data presented in Tables 14 and 15 were summarized to determine the average costs of congestion for the five population groups (Table 36). The larger urban areas in the fourth group had average annual congestion costs exceeding $1.3 billion, while the average congestion cost in the fifth group was almost $5.6 billion. The congestion cost per registered vehicle and per capita are also shown in Table 36. These "congestion tax" estimates are the additional cost that congestion imposes upon residents of the urban area. The cost per registered vehicle ranged from $890 to $280 for the five population groups, and the annual cost per capita ranged from $460 to $230 per person. The costs per capita in the fourth and fifth group are much lower than the cost per vehicle, which reflects the lower vehicle ownership rates in urban areas in the Northeast and Midwest that comprise most of the cities in those two groups.

Table 36. 1991 Annual Congestion Costs Grouped by Population

Population Group	Annual Cost Due to Congestion ($Millions)			Cost per Registered Vehicle ($)	Cost per Capita ($)
	Delay	Fuel	Total		
Fifth Group	4,960	630	5,590	890	460
Fourth Group	1,190	150	1,340	690	450
Third Group	600	70	670	580	410
Second Group	210	30	240	290	240
First Group	130	20	140	280	230

Source: TTI Analysis and Local Transportation Agency References

POPULATION DENSITY

The population density of an urban area provides some indication of the compactness of development. In the United States, a general trend is that older cities in the Northeast, Midwest, and California exhibit more dense development than those cities in the Southern and Southwestern regions. The 50 urban areas in this study were divided into four approximately even groups based on the population density (Table 37). Examination of the table reveals that those urban areas with the greatest population density (fourth group) are primarily located in the Northeast or in California.

Table 37. Urban Area Grouping by Population Density

Urban Area	Population Density		Roadway Congestion Index	
	1991 (Persons/SqKm)	Pct Change 1982 to 1991	1991 Value	Pct Change 1982 to 1991
First Group				
Nashville TN	444	-32.23	0.90	21.62
Norfolk VA	450	20.35	0.97	22.78
Atlanta GA	473	11.16	1.14	28.09
Jacksonville FL	536	17.43	0.95	11.76
Fort Worth TX	545	5.39	0.92	21.05
Dallas TX	551	8.05	1.06	26.19
Austin TX	563	-23.25	0.94	22.08
Oklahoma City OK	571	-7.50	0.80	11.11
Tampa FL	609	2.26	1.05	11.70
Corpus Christi TX	611	7.67	0.72	7.46
Hartford CT	654	4.97	0.89	17.11
Houston TX	683	-3.88	1.11	-5.13
Denver CO	685	9.15	1.03	21.18
Second Group				
Salt Lake City UT	690	-5.38	0.86	36.51
Kansas City MO	734	5.45	0.74	19.35
Charlotte NC	740	9.52	0.82	22.39
Phoenix AZ	757	-23.57	1.04	-9.57
Minn-St. Paul MN	780	-7.67	0.94	27.03
Memphis TN	795	-11.01	0.92	6.98
Albuquerque NM	802	-3.08	0.94	20.51
Cincinnati OH	806	3.50	0.97	12.79
Louisville KY	823	-0.34	0.88	4.76
Orlando FL	829	33.71	0.72	9.09
Indianapolis IN	834	5.44	0.83	16.90
Milwaukee WI	860	1.24	1.00	20.48
San Antonio TX	939	-10.36	0.89	15.58
Third Group				
Portland OR	945	-15.20	1.08	24.14
Seattle-Everett WA	960	12.19	1.20	26.32
Pittsburgh PA	967	35.54	0.82	5.13
San Bernardino-Riv CA	973	6.68	1.20	10.09
El Paso TX	1,030	-11.11	0.75	19.05
Boston MA	1,068	-11.67	1.06	17.78
Cleveland OH	1,072	9.33	0.96	20.00
St. Louis MO	1,085	-1.28	0.98	18.07
Columbus OH	1,103	4.36	0.84	23.53
Ft. Lauderdale FL	1,145	-5.34	0.95	10.47
New Orleans LA	1,174	-4.24	1.12	14.29
Detroit MI	1,221	-9.52	1.10	-2.65
Fourth Group				
Sacramento CA	1,232	7.67	1.04	30.00
San Diego CA	1,278	13.43	1.22	56.41
San Jose CA	1,287	12.50	1.07	25.88
Washington DC	1,377	-15.02	1.39	29.91
Baltimore MD	1,414	22.08	1.02	21.43
Philadelphia PA	1,437	-11.28	1.06	6.00
Chicago IL	1,458	1.34	1.28	25.49
Miami FL	1,497	-8.13	1.28	21.90
San Fran-Oak CA	1,644	2.27	1.34	32.67
Honolulu HI	1,902	-0.62	1.13	21.51
New York NY	2,040	0.83	1.14	12.87
Los Angeles CA	2,078	-0.51	1.56	27.87

Source: TTI Analysis and Local Transportation Agency References

With respect to population density, the urban areas of Chicago, New York, and Los Angeles are comparable to those urban areas in the fourth group and were so included. All of the major Texas urban areas are within the first group of population density (440 to 685 persons per square kilometer) with the exception of San Antonio and El Paso, which fall into the second and third group, respectively. The presence of large urban areas such as Dallas, Houston, Denver, and Atlanta in the first group alters the trend of increasing congestion and congestion impact statistics as population density increases. This trend is present in almost all of the relationships analyzed in this section.

Distance and Travel Volume Statistics

Tables 38 and 39 present the average freeway and principal arterial street DVKT and roadway supply for the four population density groups. The first three groups have relatively comparable travel and roadway characteristics, while the fourth group has much greater travel volumes and roadway supply for both freeways and principal arterial streets. The average freeway DVKT per lane-kilometer for the fourth group is greater than 15,000, but the average for the other three is below what could be considered areawide congestion. The average principal arterial street congestion for urban areas in the first, third, and fourth groups could be considered above undesirable levels, whereas urban areas in the second group are just approaching undesirable levels of arterial street congestion.

Table 38. 1991 Freeway Travel Volume and Roadway Supply Grouped by Population Density

Population Density Group	DVKT[1] (1000)	Lane-Kms	Avg. No. Lanes	DVKT/ Ln-Km[2,3]
Fourth Group	53,910	3,340	6.1	15,120
Third Group	20,420	1,600	5.6	12,540
Second Group	12,750	1,140	5.1	11,100
First Group	17,630	1,370	5.4	11,940

Note: [1] Daily vehicle-kilometers of travel
[2] Daily vehicle-kilometers of travel per lane-kilometer of freeway
[3] Value in excess of 13,000 indicates undesirable level of congestion on area freeway system

Source: TTI Analysis and Local Transportation Agency References

Table 39. 1991 Principal Arterial Street Travel Volume and Roadway Supply Grouped by Population Density

Population Density Group	DVKT[1] (1000)	Lane-Kms	Avg. No. Lanes	DVKT/ Ln-Km[2,3]
Fourth Group	36,400	5,410	3.8	6,680
Third Group	14,400	2,540	3.6	5,650
Second Group	8,310	1,720	3.6	4,960
First Group	9,370	1,720	3.9	5,430

Note: [1] Daily vehicle-kilometers of travel
[2] Daily vehicle-kilometers of travel per lane-kilometer of principal arterial street
[3] Value in excess of 5,000 indicates undesirable level of congestion on area principal arterial street system

Source: TTI Analysis and Local Transportation Agency References

1991 Roadway Congestion Index Estimates

The average congestion levels (as represented by the RCI values) for the four population density groups are shown in Table 40. Urban areas in the fourth group have an average level of congestion 21 percent greater than what might be considered the beginning of areawide congestion (RCI value of 1.21). The other three groups have average congestion levels at, or slightly less than the threshold for average areawide congestion. The large difference between the fourth group and the other three indicates that population density appears to be a greater determining factor on congestion level than population.

Table 40. 1991 Roadway Congestion Index Values Grouped by Population Density

Population Density Group	Freeway / Expressway		Principal Arterial Street		Roadway[3] Congestion Index
	DVKT[1] (1000)	DVKT/[2] Ln-Km	DVKT[1] (1000)	DVKT/[2] Ln-Km	
Fourth Group	53,910	15,120	36,400	6,680	1.21
Third Group	20,420	12,540	14,400	5,650	1.00
Second Group	12,750	11,100	8,310	4,960	0.89
First Group	17,630	11,940	9,370	5,430	0.96

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

Source: TTI Analysis

Roadway Congestion Trends, 1982 to 1991

The average congestion levels from 1982 through 1991 for the four population density groups are presented in Table 41. The urban areas with the highest population density (fourth group) have exhibited the largest increase in congestion at 25 percent. The other three groups have experienced a slower growth in congestion, increasing between 14 and 16 percent between 1982 and 1991. As with the 1991 RCI values, the population density groups seem to segregate the areas with the greatest congestion problem better than population groups. Figure 7 provides a graphical picture of congestion trends for the four groups over the past nine years.

Table 41. Roadway Congestion Index Values Grouped by Population Density, 1982 to 1991

Population Density Group	Year										% Change 1982 to 1991
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	
Fourth Group	0.96	0.99	1.02	1.04	1.10	1.13	1.16	1.18	1.20	1.21	25
Third Group	0.88	0.89	0.90	0.92	0.95	0.97	0.99	1.00	1.00	1.00	15
Second Group	0.78	0.78	0.79	0.81	0.83	0.85	0.84	0.86	0.86	0.89	14
First Group	0.83	0.86	0.90	0.91	0.93	0.94	0.95	0.95	0.95	0.96	16

Source: TTI Analysis

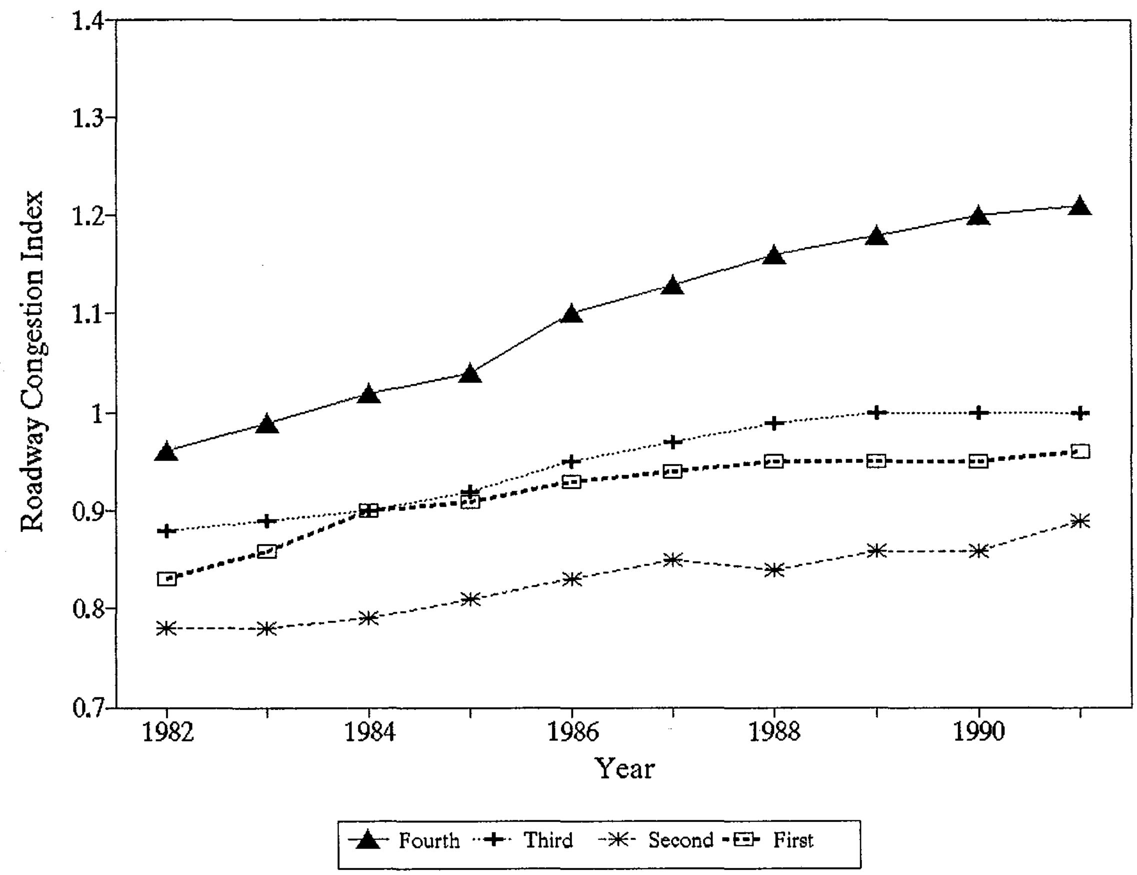

Figure 7. Roadway Congestion Index Values Grouped by Population Density, 1982 to 1991

Travel Delays

Table 42 presents the average delay for the four groups. Again, urban areas in the fourth group of population density experience greater than three times the average amount of daily delay as areas in any of the other groups. The daily delay per 1000 persons ranges from 110 vehicle-hours for the fourth group to 50 vehicle-hours for the second group.

Table 42. Daily Vehicle-Hours of Delay for 1991 Grouped by Population Density

Pop. Density Group	Daily Delay (vehicle-hours)	Daily Delay per 1000 Persons
Fourth Group	527,980	110
Third Group	153,590	85
Second Group	52,110	45
First Group	115,560	80

Source: TTI Analysis

Costs of Congestion

The annual congestion costs for delay and wasted fuel are shown in Table 43. The average total delay and fuel cost for urban areas in the fourth group is $2.25 billion per year, almost four times the cost incurred by congestion in the next largest group. The congestion costs per vehicle range from $740 for the fourth group to $270 for the second group. The cost per capita is slightly lower, ranging from $460 in the fourth group to $190 in the second group. As illustrated earlier, the larger difference in costs per capita and per vehicle in the cities in the fourth group reflects the lower vehicle ownership rates of urban areas with high population density.

Table 43. 1991 Component and Total Congestion Costs Grouped by Population Density

Pop. Density Group	Annual Cost Due to Congestion ($Millions)			Cost per Registered Vehicle ($)	Cost per Capita ($)
	Delay	Fuel	Total		
Fourth Group	1,990	260	2,250	740	460
Third Group	580	70	650	530	350
Second Group	200	20	220	270	190
First Group	440	50	490	420	350

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 1991. 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 other areas have come close to maintaining a constant congestion level over the period from 1982 to 1991.

The estimate of the amount of roadway construction required to maintain a congestion level, or to reduce congestion to acceptable levels (Table 6) 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 combination of construction, operation, and demand management improvements will be required to improve mobility.

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