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URBAN ROADWAY CONGESTION

Annual Report
1998

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SUMMARY

The annual traffic congestion study is an effort to monitor roadway congestion in major urban areas in the United States. The comparisons to other areas and to previous experiences in each area are facilitated by a database that begins in 1982 and includes 70 urbanized areas.

The effects of congestion are widespread and affect the movement of people and goods. The effects show up in increased travel time, increased fuel consumption in stop-and-go traffic and lost productivity of people and freight moving vehicles. Congestion also affects the efficiency of just-in-time manufacturing processes—a crash or vehicle breakdown that increases travel time can mean that components do not arrive in time to be installed on schedule, or the business must keep more inventory to accommodate unreliable delivery schedules.

MORE CITIES, MORE SPONSORS, MORE MEASURES

The 1998 report evaluates travel conditions and operations of the freeway and principal arterial street networks in 70 urbanized areas from 1982 to 1996. The statistics are updated for the 50 areas included in previous studies and estimates are presented for 20 newly included urban areas.

The report provides information at the urban area level due to the consistent treatment that can be provided—only developed land with a density of greater than 1,000 persons per square mile is included in the boundary. The information is targeted for communication to general audiences and consistency is important if the comparisons and trend analyses are to be relevant.

In addition to the expanded list of cities and years, a new measure was added to the report. The travel rate index combines information that had been used in previous reports in

a different way. The measure expresses the speed data in a way that may be more relevant to travelers, essentially answering part of the “how long will it take me to get there?” question.

One other important change in the study was the addition of sponsorship from state departments of transportation outside Texas. DOTs from the states listed below participated in designing and funding this report. In addition, Maryland has agreed to join the study this year. These states will also assist in developing more relevant measures to be used in expanded analyses in the coming years.

- gCalifornia
- gNew York
- gTexas
- gColorado
- gOregon
- gWashington
- gMinnesota
- gPennsylvania
- gKentucky (partial sponsor)

The existing information is, for the most part, focused on developing road congestion measures. Given the range of transportation improvement options that cities and regions are pursuing, a more broad-based set of measures that analyze mobility from a multimodal perspective will be required at the system level.

The improvements that local and state agencies are selecting have a variety of effects; only some of these listed below are currently captured in the road congestion statistics.

Add road space—This might be new roads or widened existing roads.

Lower the number of vehicles—Some of the techniques attempt to reduce the number of vehicles or increase the number of people in each vehicle.

Change the time that vehicles use the road—This reduces the load on the system at peak travel times.

Getting more vehicles past a spot on the road—More efficient operation of the roadway has the effect of adding capacity, although not usually of the same magnitude as adding a full lane.

Provide more land use pattern options—To the extent that existing land use development encourages or requires vehicle use, it contributes to congestion. Certainly there are many people who like this lifestyle, but some urban areas are pursuing a more varied approach to land development to provide choices, some of which seek to put jobs, shops and houses closer together.

THE REPORT AT A GLANCE

The report includes information on 3 general categories of congestion measures—measures of congestion related to an individual’s experience, measures of total congestion effects on an area and trend comparisons of measures over several years. These 3 categories each tell a different part of the congestion “story” for an area. A brief summary of the findings and measures in each category is included below. More extensive statistics are available for each city on the study web site (<http://mobility.tamu.edu>).

Individual Measures

Measures related to a traveler’s experience with congestion include those that illustrate the amount of extra time each traveler spends on the road or the effects of that time. This may be measured with volume count data that shows the intensity of vehicle use of the road space, with speed information that estimates the extra time on the road or with computer models that illustrate the effect of inefficient operation in terms of extra fuel used.

- , **Roadway Congestion Index**—cars per road space
- , **Travel Rate Index**—amount of extra travel time
- , **Delay per eligible driver**—annual time per driver
- , **Delay per capita**—annual time per person
- , **Wasted fuel per eligible driver**—extra fuel due to congestion
- , **Wasted fuel per capita**—extra fuel due to congestion
- , **Congestion cost per eligible driver**—annual “tax” per driver
- , **Congestion cost per capita**—annual “tax” per capita

These individual measures indicate congestion is at undesirable levels in more than half of the 70 urban areas studied.

Table S-1. 10 Most Congested Areas - 1996

Urban Area	Roadway ¹ Congestion Index	Rank
Los Angeles, CA	1.57	1
Washington, DC-MD-VA	1.43	2
Miami-Hialeah, FL	1.34	3
Chicago, IL-Northwestern, IN	1.34	4
San Francisco-Oakland, CA	1.33	5
Seattle-Everett, WA	1.27	6
Detroit, MI	1.24	7
Atlanta, GA	1.24	8
San Diego, CA	1.23	9
San Bernardino-Riverside, CA	1.22	10

If delay were averaged across all eligible drivers in an urban area, more than one-third of those areas (28) would see delays exceed the equivalent of one work week in extra travel time. Another 22 areas had annual delays between 30 and 40 hours per driver.

The congested driving conditions mean less efficient vehicle operation which wastes fuel. Drivers in 42 urban areas purchased the equivalent of 1 extra tank of fuel per season of the year due to congestion.

Areas of all population sizes have congestion problems. Exhibit S-1 shows that medium, large and very large population urbanized areas exceed the desirable congestion level (RCI = 1.0). A few years of rapid growth without the accompanying planning regulations or roadway construction could see some of the areas with less than 500,000 population exceed 1.0 on the RCI scale.

The value of delay and fuel was estimated as a “congestion tax.” This value was \$500 per eligible driver or larger in 48 of the 70 areas studied including areas in all 4 population groups. It exceeded \$1,000 per driver in 10 areas with the most intense congestion problems, the equivalent of \$4 per work day.

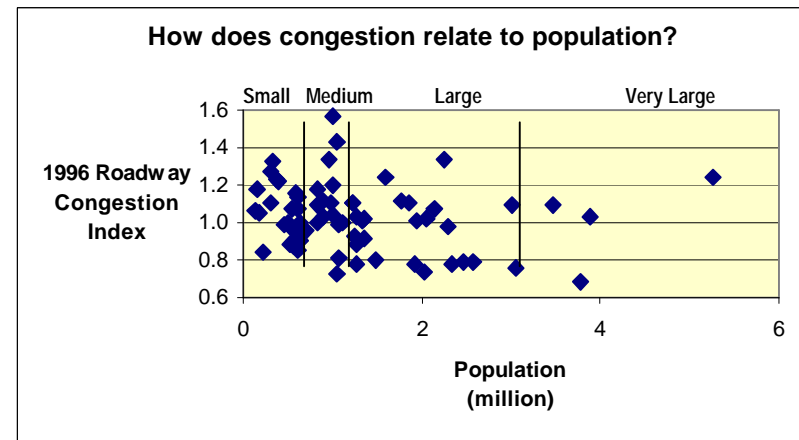
Roadway Congestion Index

Chapter II, Tables 2, 3

Chapter VII, Table 17

The RCI is a measure of vehicle travel density on major roadways in an urban area. An RCI exceeding 1.0 indicates an undesirable congestion level, **on average** on the freeways and principal arterial street system during the peak period. Even in areas with an RCI less than 1.0, however, there will be segments of road and intersections where congestion is a significant problem.

Exhibit S-1



Travel Rate Index

Chapter V, Tables 8, 9

The TRI is a measure of the amount of extra time it takes to travel during the peak period. The travel rate (in minutes per mile) in the peak is compared to the off-peak, uncongested speeds. A TRI of 1.20, for example, indicates that it will take 20 percent longer to travel to a destination during the peak, than during the off-peak.

, Delay Per Eligible Driver

, Delay per Capita

Chapter IV, Tables 6, 7

These measures express the extra travel time in a ratio with the number of eligible drivers and the population of an urban area. This measure estimates the amount of time each driver or person spends in congested traffic each year.

, Wasted Fuel Per Eligible Driver

, Wasted Fuel per Capita

Chapter VI, Tables 10, 12

These measures express the extra fuel consumed due to congestion in a ratio with the number of eligible drivers and persons in the urban area. This is a measure of the effect of slow speeds on the extra fuel needed each year to travel in congested conditions.

, Congestion Cost Per Eligible Driver

, Congestion Cost per Capita

Chapter VII, Tables 14, 17

The cost of congestion is estimated with a value for each hour of travel time and each gallon of fuel. The value of travel time used in this report is not based on the wage rate; it is based on the value that people demonstrate by their behavior. Paying tolls, erratic lane changing and traffic violations that risk accidents and traffic citations are some ways motorists illustrate they value their travel time. Fuel cost is estimated from state averages.

Areawide Measures

The magnitude of congestion in an area is closely related to the size and population of the urban area. It can be measured by the impacts -- the total hours and fuel wasted in traffic -- or the cost associated with those factors. It can also be measured by the magnitude of the remedies needed to alleviate congestion.

- , **Travel delay**
- , **Wasted Fuel**
- , **Congestion cost**
- , **Amount of capacity needed each year**

These measures estimate the impact congestion has on the entire urban area. Areas with large populations are ranked higher in these measures mostly by virtue of their size. The very large population group areas have a significant share of the congestion-related impacts in all categories—more than half of the delay in all 70 cities is in the 9 areas with an urban area population over 3 million people. Where the intensity (individual) measures have a mixture of population sizes through the rankings, the delay, fuel and cost magnitude measures follow population closely.

Table S-2. Annual Person-Hours of Delay for 1996

Population Group	Urban Area	Annual Person-Hours of Delay (million)	
		Total	Rank
Vlg	Los Angeles, CA	684	1
Vlg	New York, NY-Northeastern, NJ	611	2
Vlg	Chicago, IL-Northwestern, IN	251	3
Vlg	Washington, CD-MD-VA	231	4
Vlg	San Francisco-Oakland, CA	203	5
Vlg	Detroit, MI	200	6
Vlg	Houston, TX	150	7
Vlg	Boston, MA	136	8
Lrg	Atlanta, GA	133	9
Vlg	Philadelphia, PA-NJ	117	10

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

One solution to the congestion problem is additional roadway construction. Remedying the undesirable levels of congestion with additional roadway is not an option in some locations, particularly in large areas. In many areas, however, providing enough roadway to keep the congestion level constant or to keep delay from growing, may be an achievable alternative. On average, 60 percent of the roadway needed to keep pace with this “road-only” solution were added between 1993 and 1996. While the number of lane-miles needed is smaller in the medium and small population urban areas, the “success” rate did not vary.

Table S-3. If Road Expansion were the Only Congestion Reduction Technique

Population Group	1993-1996	
	Annual Percent Growth in Road Needed	Percent Added ¹
70 Area Average	2.9	60
Very Large	1.9	58
Large	3.4	56
Medium	4.9	62
Small	3.4	52

¹ Lane-miles added divided by lane-miles needed.

Note: Assumes that all added lane-miles would be roadway expansion since no reliable data exists concerning the addition of lane-miles through changing urban boundaries.

, Travel delay

Chapter IV, Table 6

The total hours lost due to delay during the peak travel periods is estimated from travel speed estimates on the freeways and principal arterial streets. Total delay is related to the speed and the population; the rankings in Table 6 closely track the population estimates with very few areas from one population group rising or falling into another.

, Wasted fuel

Chapter VI, Tables 10, 11

The fuel lost due to inefficient operation can be totaled just as the travel delay is, and the relationship is very similar. Most of the areas have excess fuel consumption rankings very near to their population rankings. Large areas are not necessarily more difficult places to travel, but the size is a particularly important determining factor for any of the magnitude measures.

, Congestion cost

Chapter VII, Tables 13, 17

The cost of congestion is estimated by applying hourly values to the amount of travel time delay and per-gallon estimates of the amount of fuel wasted in congested travel. The areawide “congestion tax” may be thought of as one expression of the cost of congestion to residents of an urban area.

, Amount of capacity needed each year

Chapter VII, Tables 15, 16

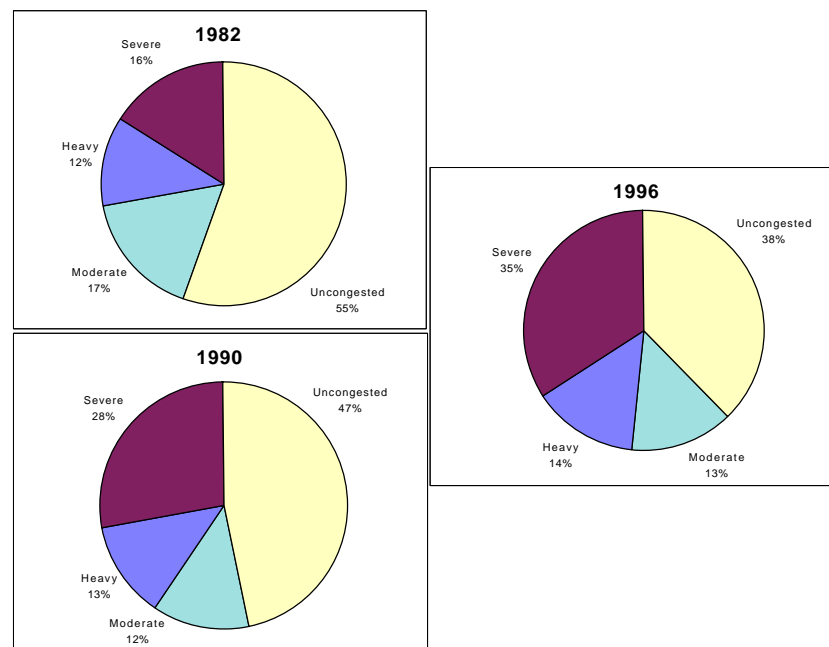
Another expression of the costs associated with congestion is the amount of roadway that would be needed every year to maintain a constant level of congestion. This measure is not meant to imply that road-only solutions are the answer in all cases. In fact, it demonstrates that in large, fast growing areas it may be impossible to afford the road construction budget required, even if public or environmental concerns could be addressed. As a very simple measure, the rate of traffic growth (in percent of additional traffic volume per year) has to equal the rate of freeway and street expansion (in percent of the system added per year). Comparing the two growth rates, yields an estimate of the amount of additional road system expansion needed every year to keep a constant congestion level if traffic continues to grow at the present rate.

Trend Measures

Most of the measures quantified in this report relate to the growth of congestion—the database extends from 1982 to 1996.

The growth of both the individual and areawide congestion measures provides comparisons of the growth in population, vehicle travel and congestion or mobility levels.

Exhibit S-2. Growth of Congested Travel, 1982 to 1996



What these trends show is that there are not many areas that are successful at maintaining travel time or congestion level. Over the period from 1982 to 1996, only 2 areas—Phoenix and

Houston—reduced their roadway congestion index. And the average delay that drivers in each of those areas experienced actually went up. So the trends say drivers are sitting in more congestion, for longer periods of time and using more fuel.

The amount of uncongested peak period travel continues to decline (Exhibit S-2). In 1982, over half of the peak-period travel in the 70 urban areas was uncongested. By 1996, this had dropped to about 1/3 of travel. The greatest growth in congested travel came in the most severe category, where the greatest delay occurs. The percentage of travel in the most severely congested conditions more than doubled from about 15 percent in 1982 to about 35 percent in 1996.

This trend points out that many areas, especially the large and very large areas, may pursue a strategy of reducing the amount of travel in the severely congested category. While this may not substantially reduce the amount of congested facility miles, it may improve the travel time and reliability that the transportation network can provide. More information can be found in Chapters 3 and 7.

What is happening and what are the solutions?

This report presents several congestion measures that are relevant to transportation planners and designers, the general public and policy decision-makers. It does not presume to decide for each area what projects should be selected, but the data are fairly clear—not enough roadway is being added to stop the growth in road congestion. Mobility—as measured by individual’s travel speed—might be increased by projects such as bus/carpool lanes, transit improvements, and coordinating traffic signals to speed traffic. The effect of these projects is, however, not included in this year’s road congestion measures.

If an area wishes to pursue only road additions as the way to stop the growth in congestion and improve travel speed, the recent record is not encouraging. From 1993 to 1996, only 60 percent of the lane-miles needed to maintain congestion at the existing level were added in the 70 urban areas. New lane-miles constructed is even less than this, however, because the 60 percent figure includes roads brought into the urbanized area boundary by growth and land development.

Congestion, as measured by the roadway congestion index, declined in only Phoenix and Houston from 1982 to 1996. The significant road construction programs implemented by these areas have not been replicated elsewhere. While road construction may be the only solution pursued, needed or supported by the public in some areas—particularly the small areas, or slowly growing or declining areas—a broader range of solutions may be needed to make progress on mobility in the future. Indeed, this is the path being pursued by many cities, Phoenix and Houston included.

In summary, congestion cost U.S. travelers 4.6 billion hours of delay, 6.7 billion gallons of wasted fuel consumed and \$74 billion of time and fuel cost in 1996. Addressing this problem will not require only one solution, but a range of strategies. These include projects such as bus/carpool lanes, transit operating and capital improvements, coordinating traffic signals to speed traffic and removing crashes and vehicle breakdowns from the traffic stream. The possible solutions also include managing demand through variable work hours or telecommuting, and rearranging the land use patterns to decrease the reliance on motor vehicle travel. These solutions

cannot rely on one agency or level of government, and cannot proceed without public support for funding the projects or programs, and for any lifestyle changes that the alternative land use or transportation strategies may require.

CHAPTER 1—INTRODUCTION – WHY STUDY CONGESTION AND MOBILITY?

Congestion and mobility issues have been discussed and debated for a long time; probably for as long as there have been urbanized areas. The Urban Mobility Study attempts to provide some information about one part of those issues in ways that both the public and professional groups can understand. Ultimately the quality of public information is measured by its usefulness; in the transportation issues context there are several “information markets” that must be addressed. These are being examined in a variety of studies; this one is only a part of the literature.

A BRIEF REVIEW OF THE STUDY HISTORY

The Urban Mobility Study attempts to develop useful statistics from generally available sources and provide information on trends in congestion levels. To this end, the study began several years ago by identifying the road congestion levels in relatively large urbanized areas. The Texas Department of

Transportation identified the need for a technique that allowed them to communicate with the public about the effect of increased transportation funding. The Texas Transportation Institute developed and applied a method to assess road congestion levels at a relatively broad scale—the urbanized area. Over the years, the study has expanded the list of measures and the list of urban areas.

WHY IS THIS YEAR DIFFERENT?

With an expanded list of sponsoring state Departments of Transportation this year (see below), the list of studied areas is longer and includes a significant number of relatively small urbanized areas. The effect of this change will be that congestion in urban areas can be compared to cities of similar sizes and at the same time congestion trends can be tracked at the local and national level on a more comprehensive basis. The list of the 70 urbanized areas included in this year’s report and their populations are in Table 1. The new cities were

Table 1. Study Population Groups

Population Group	Urban Area	1996 Population	Population Growth				Urban Area	
			1982 to 1996		1992 to 1996		Site (sq. Mi.)	Population Density (pers/sq. mi.)
			Change	Rank	Change	Rank		
Vlg	Boston, MA	3,010	6	62	2	60	1,155	2,605
Vlg	Houston, TX	3,060	28	31	5	37	1,680	1,820
Vlg	Washington, DC-MD-VA	3,460	28	31	5	37	1,000	3,460
Vlg	Detroit, MI	3,768	(1)	68	(6)	70	1,304	2,890
Vlg	San Francisco-Oakland, CA	3,890	18	45	2	60	1,050	3,705
Vlg	Philadelphia, PA-NJ	5,265	29	28	5	37	1,505	3,500
Vlg	Chicago, IL-Northwestern, IN	7,850	11	55	4	44	2,740	2,865
Vlg	Los Angeles, CA	12,220	23	41	3	50	2,245	5,445
Vlg	New York, NY-Northeastern, NJ	17,150	3	64	1	65	3,500	4,900
Lrg	Columbus, OH	1,010	21	44	6	31	475	2,125
Lrg	Norfolk, VA	1,010	31	25	5	37	835	1,210
Lrg	Orlando, FL	1,055	73	2	20	3	515	2,050
Lrg	Las Vegas, NV	1,075	139	1	30	1	275	3,910
Lrg	Buffalo-Niagara Falls, NY	1,075	0	67	0	68	570	1,885
Lrg	New Orleans, LA	1,115	3	64	1	65	370	3,015
Lrg	San Antonio, TX	1,225	29	28	3	50	510	2,400
Lrg	Sacramento, CA	1,230	48	13	3	50	395	3,115
Lrg	Milwaukee, WI	1,250	3	64	2	60	560	2,230
Lrg	Cincinnati, OH-KY	1,265	12	53	4	44	650	1,945
Lrg	Portland-Vancouver, OR-WA	1,275	26	35	14	9	470	2,715
Lrg	Fort Worth, TX	1,275	18	45	6	31	960	1,330
Lrg	Kansas City, MO-KS	1,340	23	41	12	12	770	1,740
Lrg	San Bernardino-Riverside, CA	1,350	43	15	4	44	520	2,595
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	1,485	39	19	16	6	490	3,030
Lrg	San Jose, CA	1,595	33	22	6	31	475	3,360
Lrg	Denver, CO	1,770	31	25	11	16	955	1,855
Lrg	Cleveland, OH	1,860	6	62	4	44	780	2,385
Lrg	Pittsburgh, PA	1,930	7	61	3	50	945	2,040
Lrg	Seattle-Everett, WA	1,950	35	20	6	31	810	2,405
Lrg	St Louis, MO-IL	2,020	9	58	2	60	850	2,375
Lrg	Miami-Hialeah, FL	2,050	18	45	7	27	540	3,795
Lrg	Baltimore, MD	2,145	26	35	5	37	740	2,900
Lrg	Minneapolis-St Paul, MN	2,250	29	28	7	27	1210	1,860
Lrg	Dallas, TX	2,290	27	33	10	17	1595	1,435
Lrg	Phoenix, AZ	2,340	64	3	16	6	1080	2,165
Lrg	Atlanta, GA	2,470	53	9	9	19	1785	1,385
Lrg	San Diego, CA	2,565	44	14	3	50	750	3,420

Table 1. Study Population Groups, continued

Population Group	Urban Area	1996 Population	Population Growth				Urban Area	
			1982 to 1996		1992 to 1996		Site (sq. Mi.)	Population Density (pers/sq. mi.)
			Change	Rank	Change	Rank		
Med	Fresno,, CA	530	54	8	8	23	175	3,030
Med	Omaha, NE-IA	555	11	55	4	44	225	2,465
Med	Albuquerque, NM	560	27	33	7	27	275	2,035
Med	Charlotte, NC	570	63	4	14	9	320	1,780
Med	Tacoma, WA	590	40	18	8	23	340	1,735
Med	El Paso, TX-NM	605	34	21	7	27	235	2,575
Med	Austin, TX	620	63	4	10	17	395	1,570
Med	Rochester, NY	620	(3)	70	0	68	335	1,850
Med	Nashville, TN	625	25	38	6	31	585	1,070
Med	Hartford-Middletown, CT	635	12	53	3	50	375	1,695
Med	Tucson, AZ	640	42	17	12	12	280	2,285
Med	Honolulu, HI	705	24	39	3	50	185	3,810
Med	Tampa, FL	820	52	11	15	8	515	1,590
Med	Jacksonville, FL	820	33	22	8	23	650	1,260
Med	Louisville, KY-IN	835	8	60	2	60	395	2,115
Med	Salt Lake City, UT	895	32	24	4	44	495	1,810
Med	Providence-Pawtucket, RI-MA	900	9	58	3	50	520	1,730
Med	Memphis, TN-AR-MS	960	26	35	9	19	455	2,110
Med	Oklahoma City, OK	980	53	9	26	2	650	1,510
Med	Indianapolis, IN	1,000	16	49	5	37	490	2,040
Sml	Boulder, CO	105	31	25	5	37	40	2,625
Sml	Brownsville, TX	135	50	12	13	11	45	3,000
Sml	Beaumont, TX	140	22	43	12	12	105	1,335
Sml	Laredo, TX	150	58	7	20	3	45	3,335
Sml	Salem, OR	180	13	52	6	31	75	2,400
Sml	Eugene-Springfield, OR	210	11	55	8	23	105	2,000
Sml	Corpus Christi, TX	310	24	39	9	19	195	1,590
Sml	Harrisburg, PA	315	15	51	9	19	215	1,465
Sml	Spokane, WA	325	18	45	3	50	165	1,970
Sml	Bakersfield, CA	365	59	6	12	12	180	2,030
Sml	Colorado Springs, CO	400	43	15	18	5	275	1,455
Sml	Allentown-Bethlehem-Easton, PA-NJ	465	16	49	3	50	195	2,385
Sml	Albany-Schenectady-Troy, NY	495	(1)	68	1	65	370	1,340
	70 area average	1,757	29	35	7	34	671	2,355
	Very large area average	6,630	16	47	2	51	1,798	3,466
	Large area average	1,617	32	33	8	33	746	2,381
	Medium area average	723	31	31	8	31	395	2,003
	Small area average	277	28	36	9	26	155	2,072

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

selected from the sponsoring states or other large population centers that had not previously been included in the study.

Study Sponsors

- California
- Colorado
- Minnesota
- New York
- Oregon
- Pennsylvania
- Texas
- Washington
- Kentucky (partial)

SO WHAT IS THE FOCUS OF THIS STUDY?

This report broadens the coverage of previous reports by including more urban areas and more information on mobility measures. As a more diverse set of solutions are pursued in urban areas, the measurement techniques must also evolve.

The study will continue to include a few basic elements:

- , Urban area information—to be used as a benchmark of the mobility changes that have been experienced, not as a guide to which project, corridor or mode should be selected for funding.

- , Public information—another source of data that citizens and transportation professionals can use to discuss which projects, programs and policies should be pursued.
- , Trend information—which inevitably means that as new information becomes available, it has to be meshed with the existing database to form consistent measures and a comparable database.
- , Free-flow speed comparisons—used for consistency between urban areas. Individual areas may wish to use some other standard, but for the speed and delay measures in this study, free-flow or “speed limit” speeds appear appropriate.

WHERE ARE OTHER SOURCES OF MOBILITY AND CONGESTION INFORMATION?

The measures included in this report indicate the effect of techniques or treatments that add lane-miles or reduce vehicle travel. This includes roadway construction or widening, and demand reduction measures. To the extent that road capacity

is increased or traffic volumes lowered, the estimation procedures in this report will illustrate their effectiveness.

Operational improvements such as ramp metering, incident management, traffic signal coordination are not included in the measures of mobility. Transit operations are also not included. Other mobility enhancing treatments, such as bus and carpool lanes or bicycle and pedestrian improvements are also not included.

Additional information on personal trip making or travel characteristics can be found in the 1995 Nationwide Personal Transportation Survey (1) (<http://www-cta.ornl.gov/npts>). The NPTS shows that since 1983, average work trip length has increased from 8.5 miles to 11.6 miles, and the speed of that average trip has increased from 28 mph to 33.6 mph. The NPTS analysis also shows some ways to interpret this increase in mobility. The Urban Mobility Study, in contrast, points to a decline in mobility. Among the factors (1) that might be included in a comparison of this report and the NPTS information are:

- , Work trips are less than one-third of trips made in the peak period; an important component, but not as much as many people think.
- , Jobs and houses have moved to the suburbs where trips are made on relatively higher speed facilities. At least for now, the freeways and major arterials are faster than the streets closer to the urban core.
- , Trips have shifted from carpools and transit to personal vehicles with no passengers, which take less time to reach a destination.
- , The peak period has expanded, as work hours have become more flexible; trips are not as time-constrained as they used to be.

There are also some good sources of information about the effectiveness of certain types of improvements, or about the success that some areas have had in addressing mobility issues.

- , Urban Land Institute - www.uli.org
- , Surface Transportation Policy Project - www.transact.org

- , ITS America - <http://www.itsa.org>
- , American Road and Transportation Builders Association - <http://www.artba-hq.org/index.htm>

There are a number of national level publications with information about congestion and mobility statistics. Most of these illustrate information at the system, state or national level. Many of these can be accessed at web sites or from the organization.

- , Highway Statistics
<http://www.fhwa.dot.gov/ohim/ohimstat.htm>
- , Transit Statistics
<http://www.fta.dot.gov/ntl/database.html>
- , Bureau of Transportation Statistics
<http://www.bts.gov>
- , Eno Transportation Foundation, Inc., Washington, D.C.
<http://www.enotrans.com>

Real-time transportation information is also becoming more useful to planning and project selection processes, in addition to daily trip and route planning. There are several web sites that give a good overview of system operating characteristics and some of the trip planner activities that are available to interested persons. Many of these can be accessed at <http://translink.tamu.edu/links/links.html>

HOW DO URBAN SYSTEM USERS MAKE TRAVEL DECISIONS?

Travelers and businesses use a number of factors to evaluate their trip and the transport system. This report evaluates some but not all of these. Here are some questions that people ask about travel to give the reader an idea of how broad the topic is and to place the report in the proper context.

- , Can I get there?—This is often the first question asked by those without ready access to a personal vehicle. It may also include questions about parking near the destination.

- , How long is the trip?—Sometimes this is related to distance, but usually it is a time measure.
- , What are my travel mode options?—How many ways are there to make the trip that satisfy my needs?
- , What route do I take? What roads, paths or transit routes do I use? And do these change depending on when I'm traveling?
- , When do I leave?—This relates to trip time and to the variability in trip time for the mode and route chosen. Travel time variability in trip time for the mode and route chosen. Travel time variability is particularly important to freight shippers involved in just-in-time manufacturing.
- , Will I be comfortable and safe? Many times the uncertainty in these two factors will be an incentive to take a known mode/route rather than experiment.
- , How much will it cost? Frequently users seem to view their time, vehicle operating costs and out-of-pocket expenses (e.g., tolls, fares) differently even though all can be expressed in monetary terms.

- , Do I need to make this trip? In the context of urban areas, this is often thought of as a question that leads to an “electronic trip” to telecommute or “teleshop.” It is also a significant question for those without easily available travel options and in areas with climatic extremes.

The information in this report may assist in identifying whether the existing system performance and the improvements that might be made are adequate to meet the needs of the traveling public. At best this report can provide some statistics that compare the mobility trends in urban areas and allow the public, the decisions-makers and the transportation professionals to discuss where transport issues fall in the range of other societal concerns. No matter the transport improvement solutions that are pursued, measuring congestion and mobility is one part of the participation and decision-making process.

WHAT IS THE SOURCE OF DATA FOR THIS REPORT?

This research study uses data from federal, state, and local agencies to develop planning estimates of the level of congestion within an urban area. The analyses presented in this report are the results of previous research (1-4) conducted at the Texas Transportation Institute (TTI). The methodology developed by the previous research provides a procedure that 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 (5). The HPMS database is used because of the relative consistency and comprehensive nature. State departments of transportation collect, review, and report the data. Since each state classifies roadways in a slightly different manner, TTI reviews and adjusts the data, and then

state and local agencies familiar with each urban area review the data.

This process is of particular importance when urban boundaries are redrawn due to realignments or when local agencies update the boundary to account for urban growth. These changes may significantly change the size of the urban area, which also causes a change in system length and vehicle travel with resulting changes in areawide congestion levels. To avoid a stair-step appearance in the data, some previous year statistics may also change to make the boundary realignment a smoother transition that more closely resembles the actual experience for each year. Thus, *some statistics that have been reported in past reports may be different in this report.*

The database developed for this research contains vehicle travel, population, urban area size, and system length from 1982 to 1996. Vehicle travel and vehicle travel per lane-mile are used as the basis of measuring urban congestion levels and comparing areawide roadway systems.

WHAT IS IN THIS REPORT?

This report includes many of the statistics reported in previous renditions of this report series. Some new measures are presented and the formats of some statistics have been altered. Almost all of the measures for the 20 new urban areas are presented for the full study period from 1982 to 1996. While most of the large urban areas are included in the study, it would be incorrect to assume that the totals represent an estimate of national congestion impacts.

The report presents data in either a ranking format or in population groups. The population group comparisons are not without inconsistencies, given the diversity of land use patterns, community goals, fiscal capacity, etc. between cities. Analyzing trends for areas of different size does, however, provide some information regarding the extent and growth of congestion.

The measures are organized in report chapters that include both 1996 data and trend information from 1982 to 1996:

- , Roadway Congestion Index (Chapter II)—This is an areawide measure of traffic density on the freeways and principal arterials; it is used as a technique to illustrate congestion levels from an individual traveler’s perspective.
- , Congested Travel and Facilities (Chapter III)-- The impact on travelers and the major roadway system can be discussed with data on the percentage of travel and percentage of lane-miles that operate in congested conditions.
- , Travel Delay (Chapter IV)—The most apparent impact of congestion for individuals is time delay. This section relates delay to free-flow speeds and includes sub-categories of incident and recurring delay.
- , Travel Time (Chapter V)—The Travel Rate Index is a measure that can be used to discuss travel conditions in relation to desired levels. The TRI quantifies the longer trip times experienced during peak-travel periods.
- , Wasted Fuel (Chapter VI)—The estimate of fuel consumption rates in congested and free-flow travel provides an estimate of the amount of extra fuel

consumed due to slow speeds. This is presented as a total value and as a value per person and per eligible driver.

, Congestion Cost (Chapter VII)—The economic value of delay and fuel consumption is presented in this section. This is presented in total cost, cost per capita and cost per eligible driver formats. The annual roadway additions needed to maintain a constant congestion level are provided as another measure of the cost of congestion. The data contrast the rate that urban areas have constructed additional roads with the growth in traffic volume.

CHAPTER II—ROADWAY CONGESTION INDEX

SUMMARY

The roadway congestion index estimates congestion levels as perceived by individuals. In general, congestion levels are higher in the larger areas, and decline as population decreases. Travelers in 43 of the 70 areas in the study are estimated to endure undesirable areawide congestion (Table 2).

The urban areas with the highest congestion index values for each of the population groups in the study are:

<i>over 3 million population—Very Large</i>	<i>Los Angeles</i>	<i>RCI: 1.57</i>
<i>1 million to 3 million population—Large</i>	<i>Miami-Hialeah</i>	<i>RCI: 1.34</i>
<i>500,000 to 1 million population—Medium</i>	<i>Tacoma</i>	<i>RCI: 1.18</i>
<i>below 500,000—Small</i>	<i>Eugene-Springfield</i>	<i>RCI: 0.92</i>

Only 4 urban areas showed short-term decreases in congestion levels in the period between 1992 and 1996 (Table 3). These areas are:

, Tacoma
, Tampa
, New Orleans
, Houston

Only 2 urban areas had a decrease in their congestion levels for the period between 1982 and 1996. In both Houston and Phoenix, the major reason for the decline in congestion levels is the massive construction efforts over the past decade. The increase amounts to between a 50 percent and 60 percent increase in freeway and street lane-miles between 1982 and 1996. This level of investment is not approached in any of the larger cities in the study. In fact, it remains to be seen if it can be sustained in these areas. The public support and financial burdens are significant obstacles; both of these areas recognize that and are pursuing a range of improvements, including road construction.

BACKGROUND

Urban roadway congestion levels are estimated using a formula that measures the density of traffic on an areawide scale.

Average travel volume per lane on freeways and principal arterial streets are estimated using areawide estimates of vehicle-miles of travel (VMT) and lane-miles of roadway (ln-mi). The resulting ratios are combined into one value using the amount of travel on each portion of the system. This variable weighting factor allows comparisons between areas such as Phoenix, where principal arterial streets carry about 50 percent more traffic than freeways, and cities such as Portland, where the ratio is reversed.

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

estimate and their combination. The resulting ratio indicates an undesirable level of areawide congestion if a value greater than or equal to 1.0 is obtained.

$$\text{Roadway Congestion Index (RCI)} = \frac{\text{Freeway VMT/Ln.\&Mi.} \times \text{Freeway \% VMT}}{13,000 \times \text{Freeway \% VMT}} \times \frac{\text{Prin Art Str VMT/Ln.\&Mi.} \times \text{Prin Art Str VMT}}{5,000 \times \text{Prin Art Str VMT}}$$

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

There are many reasons that can cause the RCI to decrease in an urban area. New roadway facilities can open. In the short-term, this causes the congestion index to dip slightly since the index measures vehicle travel and roadway mileage. Often, however, the new roadway facilities are not sufficiently increased to accommodate that year's growth. The fact that

only 4 areas decreased the congestion index between 1992 and 1996 says it does not take long for roadways to fill traffic and the congestion level begin to increase.

The other explanation for congestion decreases seen in this study is economic slowdowns or recessions. If a major employer or industry suffers a job loss, there may be less travel, or the rate of growth in traffic volume will slow down. Although this is not a method many areas choose, nor is it one that transportation planners have much control over, it is apparent from the data that it is very successful. California in the early and mid-1990s is only the most recent example of this event.

TABLES AND EXHIBITS

Table 2 shows the RCI values for each of the 70 urban areas in 1996. The urban areas are ranked in order by their RCI value. Also shown are the daily vehicle-miles of travel that were used to calculate the Roadway Congestion Index values.

Following Table 2 are graphics that display information such as:

- , congestion levels and population size groups
- , congestion and population
- , congestion and road travel

Table 3 shows the RCI values for selected years between 1982 and 1996. Also shown are the percent changes for 1982 to 1996 and 1992 to 1996.

Following Table 3 are exhibits that display information such as:

- , congestion levels in 1982, 1992 and 1996 by population size
- , congestion levels from 1982 to 1996 by population size group
- , congestion growth, 1982 to 1996
- , congestion growth, 1992 to 1996
- , congestion and population growth, 1982 to 1996

Table 2. 1996 Roadway Congestion Index Value

Population Group	Urban Area	Roadway ^f Congestion Index	Rank	Freeway/Expressway		Principal Arterial Street	
				Daily VMT ² (000)	Daily VMT ^β Ln-Mile	Daily VMT ² (000)	Daily VMT ^β Ln-Mile
Vlg	Los Angeles, CA	1.57	1	117,700	21,205	85,000	6,695
Vlg	Washington, DC-MD-VA	1.43	2	33,370	18,185	18,900	7,840
Lrg	Miami-Hialeah, FL	1.34	3	11,500	16,665	17,260	7,190
Vlg	Chicago, IL-Northwestern, IN	1.34	3	45,200	17,155	38,010	6,995
Vlg	San Francisco-Oakland, CA	1.33	5	43,300	17,390	14,860	6,255
Lrg	Seattle-Everett, WA	1.27	6	22,100	16,870	8,350	5,405
Vlg	Detroit, MI	1.24	7	29,690	15,960	28,300	6,315
Lrg	Atlanta, GA	1.24	7	35,010	16,060	13,750	6,250
Lrg	San Diego, CA	1.23	9	28,980	16,235	10,000	5,525
Lrg	San Bernardino-Riverside, CA	1.22	10	16,280	16,530	11,200	5,210
Lrg	Las Vegas, NV	1.20	11	5,570	15,260	3,500	6,540
Vlg	New York, NY-Northeastern, NJ	1.18	12	93,500	14,475	56,850	7,280
Med	Tacoma, WA	1.18	12	4,805	16,015	2,750	4,700
Lrg	Portland-Vancouver, OR-WA	1.16	14	9,610	14,670	5,300	6,625
Lrg	Phoenix, AZ	1.14	15	13,200	15,085	18,700	5,575
Lrg	Denver, CO	1.12	16	14,900	14,325	11,650	5,990
Lrg	Minneapolis-St Paul, MN	1.12	16	22,900	14,495	7,220	5,685
Lrg	San Jose, CA	1.11	18	17,320	13,910	10,000	6,580
Vlg	Houston, TX	1.11	18	35,150	14,555	12,400	5,290
Lrg	Dallas, TX	1.11	18	27,030	14,495	10,705	5,325
Med	Memphis, TN-AR-MS	1.11	18	5,725	14,315	6,100	5,650
Med	Honolulu, HI	1.10	22	5,685	13,375	2,030	7,960
Vlg	Boston, MA	1.09	23	22,170	14,305	15,500	5,160
Lrg	Baltimore, MD	1.09	23	20,300	14,000	10,100	5,690
Lrg	New Orleans, LA	1.09	23	5,450	12,825	5,225	6,785
Lrg	Sacramento, CA	1.07	26	10,750	13,030	8,400	6,460
Lrg	Cincinnati, OH-KY	1.07	26	13,865	13,935	4,655	5,475
Vlg	Philadelphia, PA-NJ	1.07	26	21,385	12,255	23,000	6,865
Med	Tampa, FL	1.06	29	5,010	12,845	5,485	6,200
Lrg	St Louis, MO-IL	1.05	30	23,700	13,165	12,740	6,140
Med	Louisville, KY-IN	1.04	31	9,200	13,235	3,850	5,835
Med	Austin, TX	1.03	32	7,270	13,220	3,900	5,570
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	1.03	32	10,250	13,310	6,850	5,230
Lrg	Milwaukee, WI	1.03	32	8,300	13,280	6,500	5,200
Med	Tucson, AZ	1.02	35	1,650	10,315	4,600	6,135
Lrg	Cleveland, OH	1.02	35	16,020	13,080	6,520	5,435
Lrg	Fort Worth, TX	1.01	37	14,875	12,825	6,115	5,635
Med	Albuquerque, NM	1.01	37	3,600	12,415	5,020	5,580
Lrg	Columbus, OH	1.01	37	10,980	12,765	3,945	5,890
Med	Nashville, TN	1.00	40	8,880	12,420	6,100	5,920

Table 2. 1996 Roadway Congestion Index Value, continued

Population Group	Urban Area	Roadway/ ^f Congestion Index	Rank	Freeway/Expressway		Principal Arterial Street	
				Daily VMT ² (000)	Daily VMT ² Ln-Mile	Daily VMT ² (000)	Daily VMT ² Ln-Mile
Med	Omaha, NE-IA	1.00	40	2,870	9,895	4,070	7,140
Med	Indianapolis, IN	1.00	40	10,800	12,345	6,700	6,175
Med	Salt Lake City, UT	1.00	40	6,950	12,635	2,950	5,730
Med	Jacksonville, FL	0.99	44	8,000	12,905	6,800	4,890
Lrg	San Antonio, TX	0.99	44	13,275	12,705	6,375	5,290
Med	Charlotte, NC	0.98	46	4,980	12,295	3,450	5,565
Lrg	Norfolk, VA	0.96	47	6,700	10,985	5,470	6,590
Med	Providence-Pawtucket, RI-MA	0.96	47	7,330	11,825	4,720	5,755
Med	Hartford-Middletown, CT	0.93	49	7,300	11,495	3,940	5,710
Sml	Eugene-Springfield, OR	0.92	50	1,165	10,590	850	6,540
Lrg	Orlando, FL	0.91	51	7,640	10,685	7,660	5,715
Med	Oklahoma City, OK	0.91	51	8,500	11,335	4,830	5,365
Sml	Harrisburg, PA	0.88	53	4,045	10,505	1,980	6,285
Sml	Salem, OR	0.88	53	1,025	10,790	1,290	4,870
Sml	Allentown-Bethlehem-Easton, PA-NJ	0.87	55	2,820	9,725	2,575	6,060
Med	Rochester, NY	0.87	55	5,300	10,930	1,120	6,220
Lrg	Pittsburgh, PA	0.85	57	10,310	8,700	11,770	6,230
Sml	Spokane, WA	0.84	58	1,295	10,360	2,460	4,475
Lrg	Kansas City, MO-KS	0.81	59	16,930	10,105	5,840	5,125
Sml	Albany-Schenectady-Troy, NY	0.81	59	4,850	9,150	3,240	6,000
Med	El Paso, TX-NM	0.80	61	3,970	10,445	3,630	3,945
Sml	Brownsville, TX	0.79	62	280	9,335	550	4,400
Sml	Boulder, CO	0.79	62	440	8,800	515	5,150
Med	Fresno, CA	0.78	64	2,000	8,335	2,470	5,430
Lrg	Buffalo-Niagara Falls, NY	0.78	64	5,750	9,350	5,095	4,850
Sml	Corpus Christi, TX	0.78	64	2,550	9,625	1,815	4,655
Sml	Beaumont, TX	0.76	67	1,200	10,435	700	2,915
Sml	Colorado Springs, CO	0.74	68	2,265	8,710	1,880	4,700
Sml	Laredo, TX	0.73	69	415	7,545	660	4,890
Sml	Bakersfield, CA	0.68	70	1,600	8,000	2,310	3,950
	70 area average	1.14		14,353	12,729	9,129	5,753
	Very large area average	1.29		49,052	16,165	32,536	6,522
	Large area average	1.08		14,982	13,548	8,603	5,844
	Medium area average	0.98		5,991	12,130	4,226	5,774
	Small area average	0.80		1,842	9,505	1,602	4,992

Notes: ¹ See Roadway Congestion Index equation.

² Daily vehicle-miles of travel.

³ Daily vehicle-miles of travel per lane-mile.

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

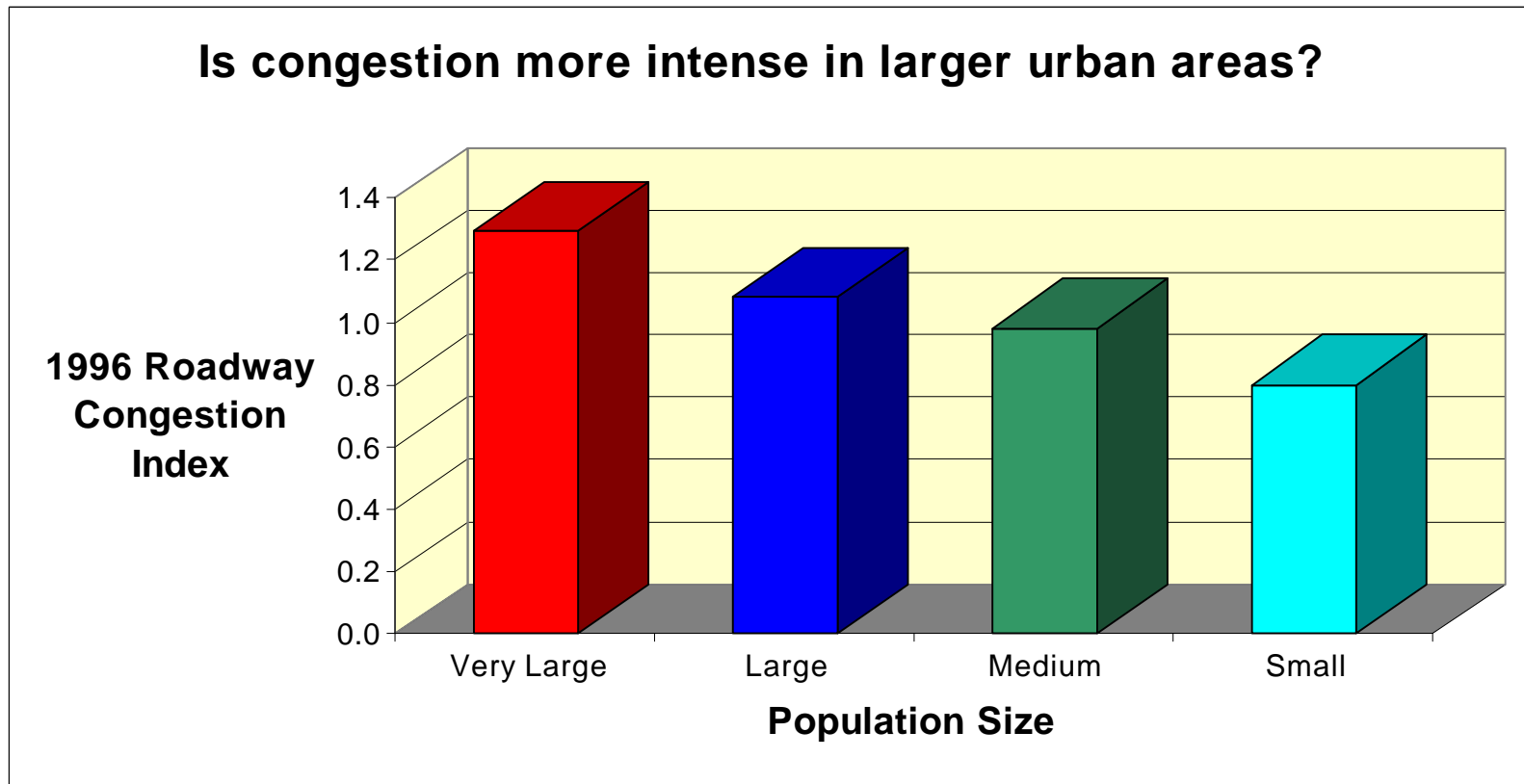
Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

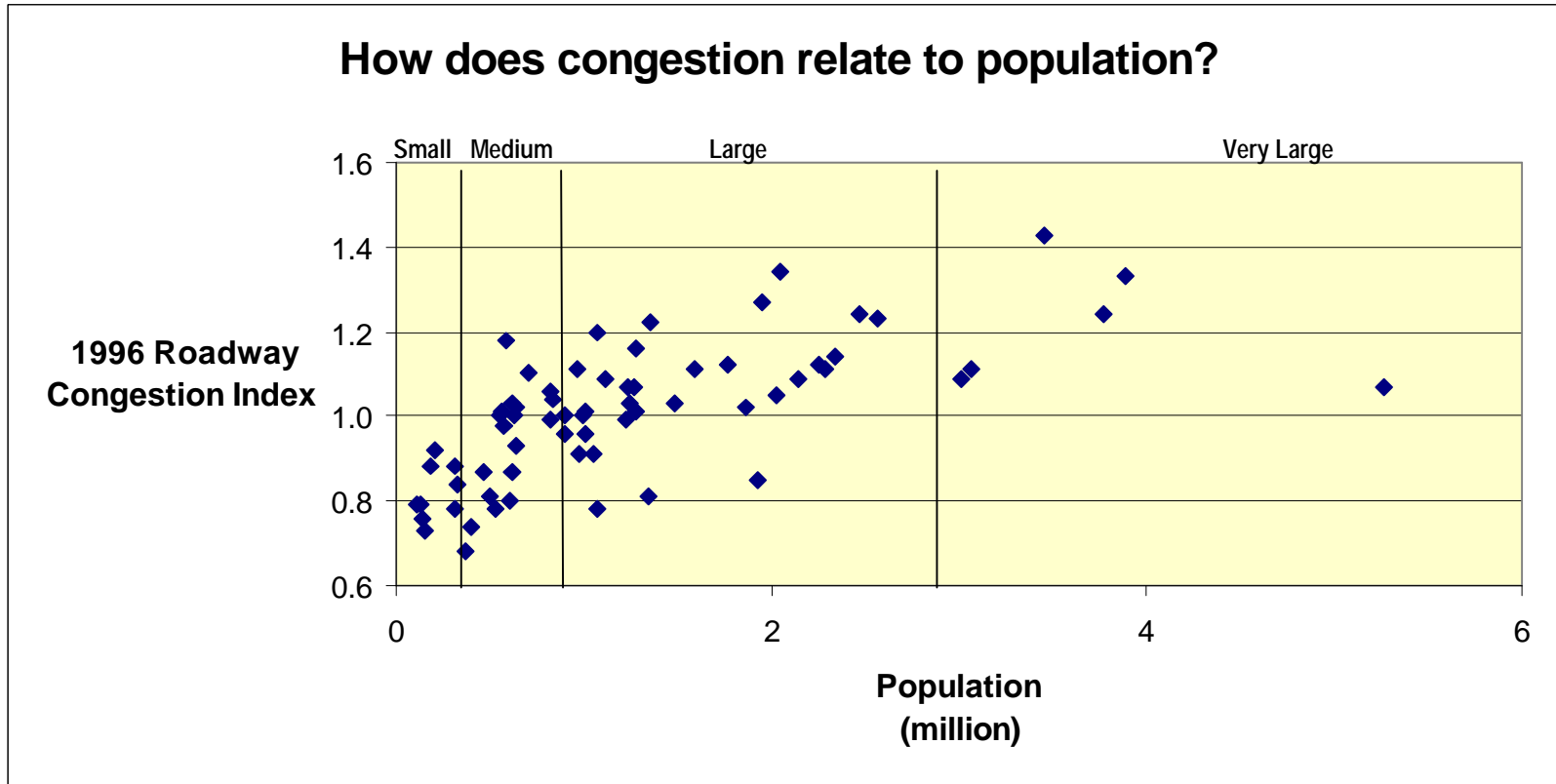
- , 43 urban areas have RCI values of 1.0 or greater
- , 5 urban areas are within 0.05 of reaching the 1.0 RCI level—2 or 3 years of moderate growth.
- , 32 urban areas have more than 13,000 vehicle-miles per lane-mile on the freeways—the beginning of a congested areawide freeway system.
- , 58 urban areas have more than 5,000 vehicle-miles per lane-mile on the principal arterial streets
- , 1 urban area from medium population group is included in the top 20 congested areas (Tacoma)
- , Highest ranking: Small urban area—Eugene-Springfield (5th)
 - Medium urban area—Tacoma (T 1st)
 - Large urban area—Miami-Hialeah (T 3rd)
 - Very large urban area—Los Angeles (4th)
- , Lowest ranking: Small urban area—Bakersfield (7th)
 - Medium urban area—Fresno (T 6th)
 - Large urban area—Buffalo-Niagara Falls (T 6th)
 - Very large urban area—Philadelphia (T 2nd)
- , On average, the medium and small urban areas are below the 13,000 vehicle-miles per lane-mile level on the freeways
- , On average, the small urban areas are slightly below the 5,000 vehicle-miles per lane-mile level on principal arterial streets

Exhibit 1



- , Congestion is approximately 20 percent greater in the Very Large urban areas than in the Large urban areas
- , Congestion is approximately 30 percent greater in the Very Large urban areas than in the Medium urban areas
- , Congestion is approximately 60 percent greater in the Very Large urban areas than in the Small urban areas
- , The Medium urban area congestion level is approaching the 'congested' (RCI = 1.00) status and could reach it in the next year or 2.
- , There is a greater difference between the congestion levels in the Very Large urban areas and Large urban areas (0.21) than between congestion levels in any other 2 adjacent population groups.
- , The smallest difference between congestion levels between population groups occurs between the Medium and Large population groups with a difference of 0.10.

Exhibit 2



(Data from Los Angeles, New York, and Chicago have been omitted from the graph because their populations are much larger). Their values are:

New York: population 17,150,000 RCI 1.18

Los Angeles: population 12,220,000 RCI 1.57

Chicago: population 7,850,000 RCI 1.34

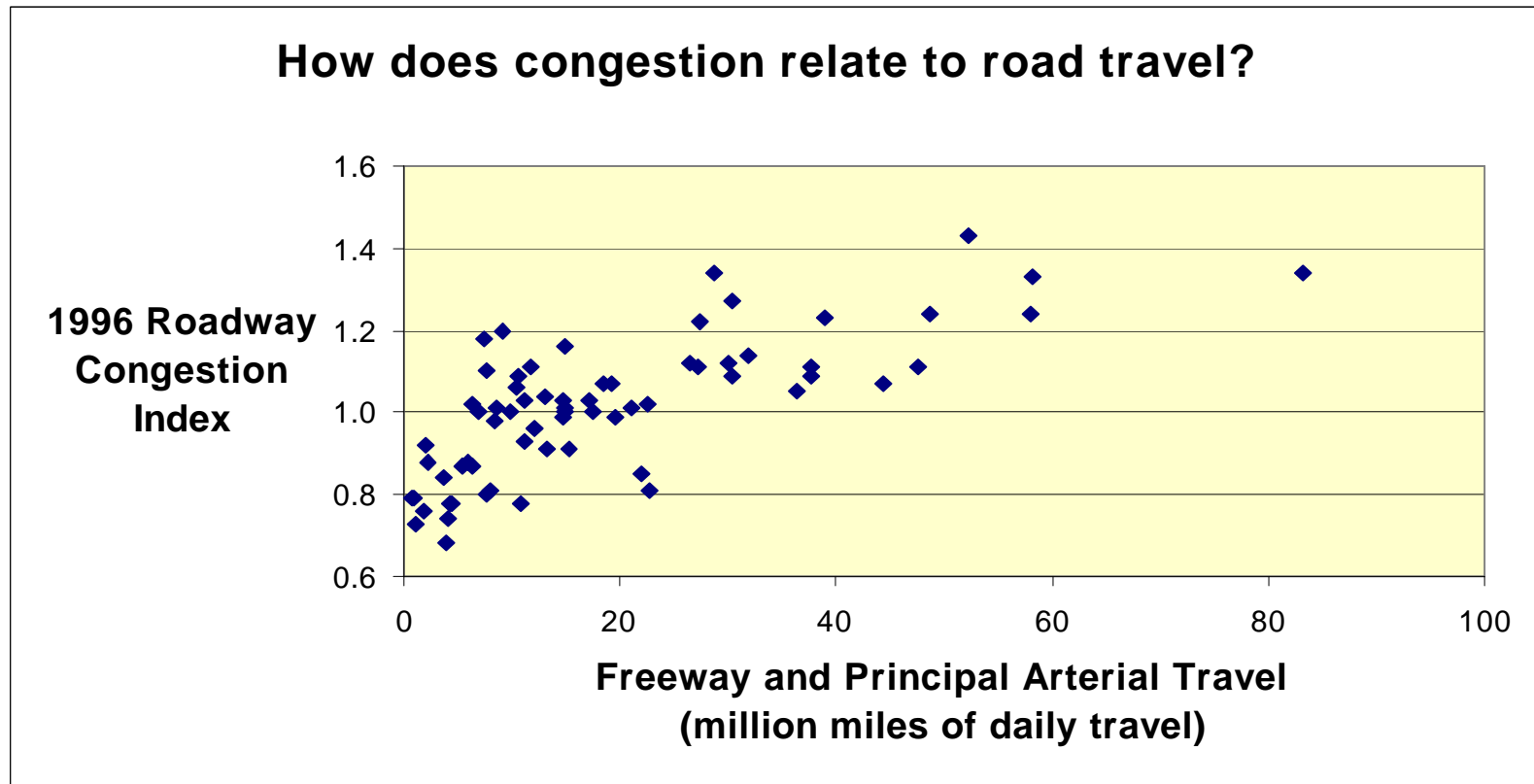
, Generally, the Small urban areas have congestion index values between 0.7 and 0.9.

, Generally, the Medium urban areas have congestion index values between 0.8 and 1.2.

, Generally, the Large urban areas have congestion index values between 0.9 and 1.3.

, Generally, the Very Large urban areas have congestion index values between 1.1 and 1.4.

Exhibit 3



(Data from Los Angeles and New York have been omitted from the graph because they have very large daily miles of travel). Their values are:

Los Angeles: daily VMT 202,700,000 RCI 1.57

New York: daily VMT 150,350,000 RCI 1.18

- , Generally, urban areas with less than 25 million daily vehicle-miles of travel on the freeways and principal arterial streets have congestion index values between 0.7 and 1.2.
- , Generally, urban areas with more than 25 million daily vehicle-miles of travel on the freeways and principal arterial streets have congestion index values between 1.0 and 1.4.

Table 3. Roadway Congestion Index Values, 1982 to 1996

Population Group	Urban Area	Percent Change				Year						
		Short-Term 1992 to 1996		Long-Term 1982 to 1996		1982	1986	1990	1992	1994	1995	1996
		Percent	Rank	Percent	Rank							
Med	Tacoma, WA	(3)	1	48	62	0.80	1.00	1.18	1.22	1.20	1.19	1.18
Med	Tampa, FL	(1)	2	13	9	0.94	0.96	1.05	1.07	1.07	1.08	1.06
Lrg	New Orleans, LA	(1)	3	11	8	0.98	1.09	1.12	1.10	1.11	1.10	1.09
Vlg	Houston, TX	(1)	4	(5)	1	1.17	1.21	1.12	1.12	1.12	1.13	1.11
Med	Honolulu, HI	0	5	21	22	0.91	1.03	1.09	1.10	1.13	1.11	1.10
Lrg	San Bernardino-Riverside, CA	0	5	10	7	1.11	1.15	1.21	1.22	1.20	1.22	1.22
Vlg	San Francisco-Oakland, CA	0	5	32	47	1.01	1.24	1.36	1.33	1.33	1.33	1.33
Lrg	San Diego, CA	1	8	58	67	0.78	1.00	1.22	1.22	1.21	1.22	1.23
Sml	Salem, OR	1	9	42	60	0.62	0.72	0.81	0.87	0.85	0.87	0.88
Vlg	Boston, MA	2	10	21	23	0.90	1.04	1.06	1.07	1.08	1.08	1.09
Vlg	Philadelphia, PA-NJ	2	11	7	4	1.00	1.06	1.05	1.05	1.05	1.06	1.07
Vlg	Los Angeles, CA	2	12	29	39	1.22	1.42	1.55	1.54	1.52	1.54	1.57
Med	Jacksonville, FL	2	13	9	5	0.91	0.95	0.93	0.97	0.97	0.98	0.99
Med	Providence-Pawtucket, RI-MA	2	14	14	11	0.84	0.94	0.88	0.94	0.95	0.94	0.96
Med	Hartford-Middletown, CT	2	15	22	25	0.76	0.85	0.89	0.91	0.93	0.93	0.93
Sml	Allentown-Bethlehem-Easton, PA-NJ	2	16	5	3	0.83	0.84	0.87	0.85	0.87	0.87	0.87
Med	Fresno, CA	3	17	18	18	0.66	0.70	0.74	0.76	0.75	0.76	0.78
Sml	Colorado Springs, CO	3	18	30	43	0.57	0.69	0.71	0.72	0.74	0.74	0.74
Lrg	Sacramento, CA	3	19	34	55	0.80	0.95	1.02	1.04	1.06	1.06	1.07
Lrg	Milwaukee, WI	3	20	24	27	0.83	0.90	0.99	1.00	1.00	1.01	1.03
Lrg	Miami-Hialeah, FL	3	21	28	36	1.05	1.14	1.27	1.30	1.32	1.33	1.34
Vlg	New York, NY-Northeastern, NJ	4	22	17	14	1.01	1.06	1.14	1.14	1.15	1.16	1.18
Sml	Spokane, WA	4	23	20	21	0.70	0.80	0.79	0.81	0.84	0.83	0.84
Lrg	Dallas, TX	4	24	32	48	0.84	1.04	1.05	1.07	1.09	1.10	1.11
Lrg	San Jose, CA	4	24	29	40	0.86	0.97	1.05	1.07	1.06	1.09	1.11
Sml	Boulder, CO	4	26	14	12	0.69	0.77	0.77	0.76	0.77	0.77	0.79
Med	Tucson, AZ	4	27	17	17	0.87	0.83	0.92	0.98	0.99	1.00	1.02
Lrg	Seattle-Everett, WA	4	28	34	53	0.95	1.09	1.20	1.22	1.24	1.24	1.27
Vlg	Detroit, MI	4	29	17	16	1.06	1.05	1.13	1.19	1.24	1.24	1.24
Lrg	Norfolk, VA	4	30	22	24	0.79	0.89	0.96	0.92	0.93	0.94	0.96
Vlg	Chicago, IL-Northwestern, IN	5	31	31	46	1.02	1.15	1.25	1.28	1.28	1.31	1.34
Sml	Harrisburg, PA	5	32	14	10	0.77	0.79	0.81	0.84	0.86	0.87	0.88
Lrg	Baltimore, MD	5	33	30	42	0.84	0.88	1.01	1.04	1.06	1.08	1.09
Lrg	Pittsburgh, PA	5	34	9	6	0.78	0.79	0.82	0.81	0.83	0.84	0.85
Vlg	Washington, DC-MD-VA	5	35	28	37	1.12	1.27	1.34	1.36	1.43	1.40	1.43
Lrg	Kansas City, MO-KS	5	36	31	45	0.62	0.68	0.74	0.77	0.80	0.81	0.81
Med	El Paso, TX-NM	5	37	27	33	0.63	0.75	0.74	0.76	0.78	0.79	0.80
Med	Omaha, NE-IA	5	37	37	57	0.73	0.81	0.89	0.95	0.98	0.98	1.00
Lrg	Buffalo-Niagara Falls, NY	5	39	20	20	0.65	0.62	0.69	0.74	0.79	0.78	0.78
Sml	Corpus Christi, TX	5	39	16	13	0.67	0.71	0.72	0.74	0.76	0.77	0.78

Table 3. Roadway Congestion Index Values, 1982 to 1996, continued

Population Group	Urban Area	Percent Change				Year						
		Short-Term 1992 to 1996		Long-Term 1982 to 1996		1982	1986	1990	1992	1994	1995	1996
		Percent	Rank	Percent	Rank							
Lrg	Portland-Vancouver, OR-WA	5	41	33	50	0.87	0.97	1.08	1.10	1.11	1.14	1.16
Lrg	Phoenix, AZ	6	42	(1)	2	1.15	1.20	1.05	1.08	1.09	1.11	1.14
Lrg	Cincinnati, OH-KY	6	43	24	28	0.86	0.84	0.96	1.01	1.05	1.06	1.07
Lrg	Atlanta, GA	6	44	36	56	0.91	1.09	1.14	1.17	1.18	1.22	1.24
Med	Rochester, NY	6	45	53	65	0.57	0.60	0.75	0.82	0.82	0.87	0.87
Sml	Bakersfield, CA	6	46	33	52	0.51	0.58	0.63	0.64	0.66	0.67	0.68
Med	Albuquerque, NM	6	47	29	41	0.78	0.96	0.98	0.95	0.99	1.00	1.01
Lrg	Denver, CO	7	48	27	34	0.88	0.97	1.03	1.05	1.07	1.09	1.12
Sml	Beaumont, TX	7	49	17	15	0.65	0.69	0.70	0.71	0.73	0.74	0.76
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	7	50	18	19	0.87	0.85	0.94	0.96	0.99	1.01	1.03
Lrg	Cleveland, OH	7	51	28	35	0.80	0.86	0.94	0.95	1.00	1.02	1.02
Lrg	Fort Worth, TX	7	52	33	49	0.76	0.87	0.90	0.94	0.97	1.00	1.01
Sml	Albany-Schenectady-Troy, NY	8	53	56	66	0.52	0.60	0.73	0.75	0.77	0.79	0.81
Med	Austin, TX	8	54	23	26	0.84	0.94	0.94	0.95	0.97	1.00	1.03
Lrg	Columbus, OH	9	55	49	63	0.68	0.75	0.89	0.93	0.95	0.97	1.01
Med	Nashville, TN	9	56	30	44	0.77	0.86	0.89	0.92	0.96	0.98	1.00
Med	Oklahoma City, OK	10	57	26	30	0.72	0.76	0.79	0.83	0.85	0.88	0.91
Lrg	San Antonio, TX	10	58	29	38	0.77	0.88	0.88	0.90	0.92	0.95	0.99
Med	Charlotte, NC	10	59	38	58	0.71	0.78	0.86	0.89	0.94	0.95	0.98
Lrg	St. Louis, MO-IL	11	60	27	32	0.83	0.93	0.95	0.95	0.98	1.01	1.05
Sml	Laredo, TX	11	61	26	29	0.58	0.61	0.63	0.66	0.69	0.71	0.73
Sml	Eugene-Springfield, OR	11	62	59	68	0.58	0.58	0.75	0.83	0.89	0.90	0.92
Lrg	Las Vegas, NV	11	63	64	70	0.73	0.85	1.01	1.08	1.18	1.21	1.20
Med	Salt Lake City, UT	11	64	59	69	0.63	0.68	0.85	0.90	0.94	0.97	1.00
Lrg	Minneapolis-St. Paul, MN	13	65	47	61	0.76	0.89	0.95	0.99	1.04	1.07	1.12
Lrg	Orlando, FL	14	66	26	30	0.72	0.76	0.77	0.80	0.86	0.89	0.91
Sml	Brownsville, TX	14	67	41	59	0.56	0.57	0.65	0.69	0.75	0.77	0.79
Med	Louisville, KY-IN	16	68	33	51	0.78	0.80	0.86	0.90	0.95	0.98	1.04
Med	Indianapolis, IN	18	69	49	64	0.67	0.81	0.84	0.85	0.92	0.96	1.00
Med	Memphis, TN-AR-MS	21	70	34	54	0.83	0.80	0.89	0.92	0.94	0.96	1.11
	70 area average	5		25		0.91	1.01	1.07	1.09	1.11	1.12	1.14
	Very large area average	2		22		1.06	1.18	1.26	1.26	1.27	1.28	1.29
	Large area average	6		30		0.83	0.93	1.00	1.02	1.04	1.06	1.08
	Medium area average	8		31		0.75	0.83	0.88	0.91	0.94	0.96	0.98
	Small area average	5		29		0.62	0.68	0.74	0.76	0.78	0.79	0.80

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

- , 54 urban areas showed an increase in congestion since 1995.
- , 6 urban areas showed decreases in congestion since 1995 (Tacoma, Tampa, New Orleans, Houston, Honolulu, and Las Vegas).
- , 4 urban areas had decreases in their congestion levels between 1992 and 1996 (Tacoma, Tampa, New Orleans, and Houston).
- , 2 urban areas had decreases in their congestion levels between 1982 and 1996 (Houston and Phoenix).
- , Several urban areas have shown dramatic increases in congestion levels. These urban areas represent all population size groups.

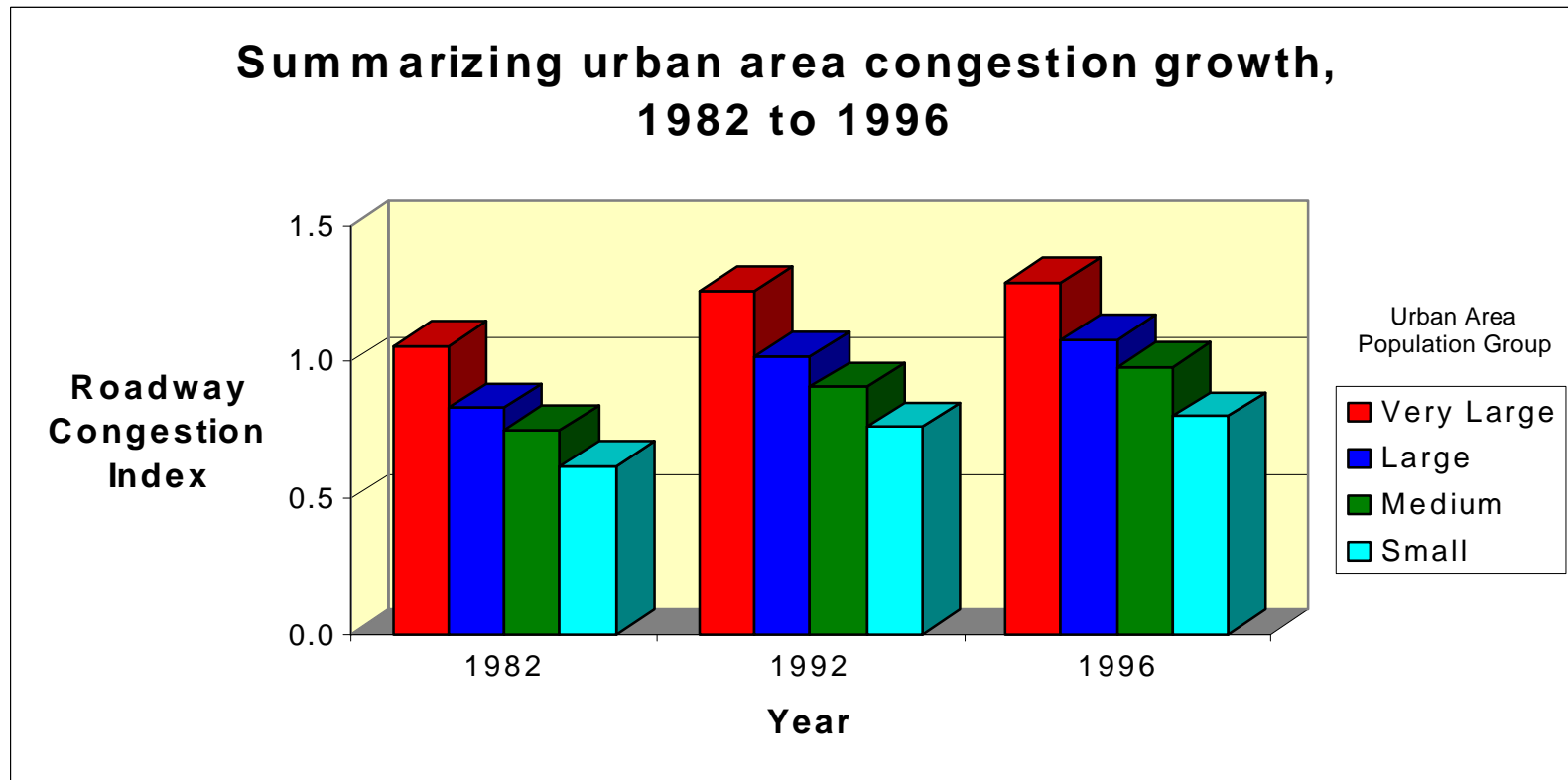
Tacoma	Medium	1982 RCI: 0.80	1990 RCI: 1.18
San Fran-Oakland	Very Large	1982 RCI: 1.01	1990 RCI: 1.36
San Diego	Large	1982 RCI: 0.78	1990 RCI: 1.22
Los Angeles	Very Large	1982 RCI: 1.22	1990 RCI: 1.55
Colorado Springs	Small	1982 RCI: 0.57	1990 RCI: 0.71
Rochester	Medium	1982 RCI: 0.57	1990 RCI: 0.75
Albany-Schenectady-Troy	Small	1982 RCI: 0.52	1990 RCI: 0.73
Las Vegas	Large	1982 RCI: 0.73	1990 RCI: 1.01

- , Some urban areas have shown very little or no growth in congestion.
- Philadelphia Very Large 92-96% growth: 2% 82-96% growth: 7%
- Houston Very Large 92-96% growth: -1% 82-96% growth: -5%
- Allentown-Bethl-Easton Small 92-96% growth: 2% 82-96% growth: 5%
- Phoenix Large 92-96% growth: 6% 82-96% growth: -1%
- , Some urban areas have shown high growth in congestion over the long-term but growth has slowed down in the past few years.

Tacoma	Medium	92-96% growth: -3%	82-96 % growth: 48%
San Diego	Large	92-96% growth: 1%	82-96 % growth: 58%
San Francisco-Oakland	Very Large	92-96% growth: 0%	82-96 % growth: 32%
Salem	Small	92-96% growth: 1%	82-96 % growth: 42%

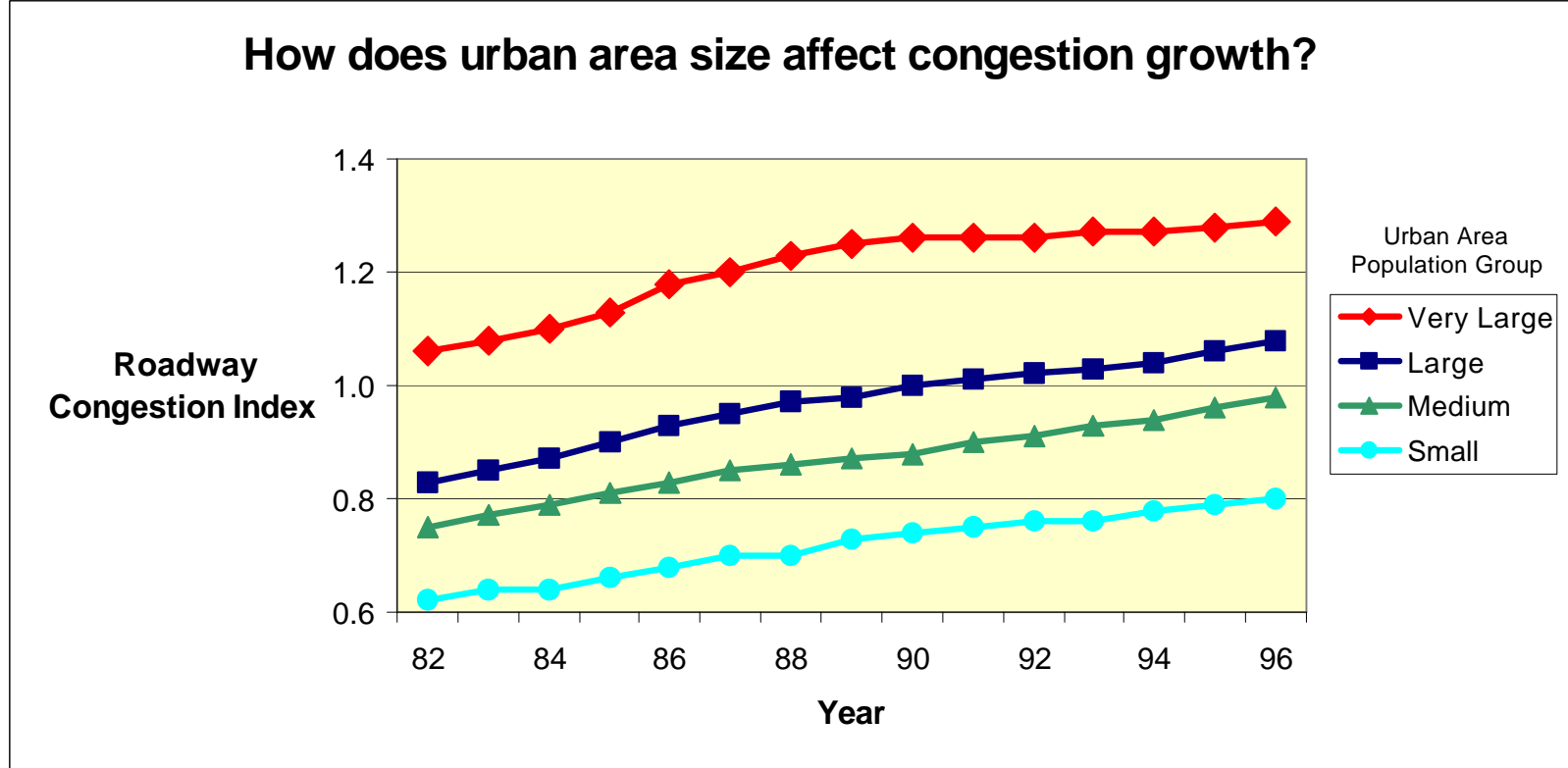
- , The largest increase in congestion between 1982 and 1996 occurred in Las Vegas (64% increase).
- , The largest decrease in congestion between 1982 and 1996 occurred in Houston (5% decrease).
- , The largest increase in congestion between 1992 and 1996 occurred in Memphis (21% increase).
- , The largest decrease in congestion between 1992 and 1996 occurred in Tacoma (3% decrease).
- , The change in congestion levels from 1992 to 1996 is fairly consistent among the Small, Medium, and Large population groups. Each population group has an annual percent increase in congestion of between 1 and 2 percent.
- , The Very Large population group has a much smaller percent increase in congestion for both the short and long-terms than the other 3 population groups.

Exhibit 4



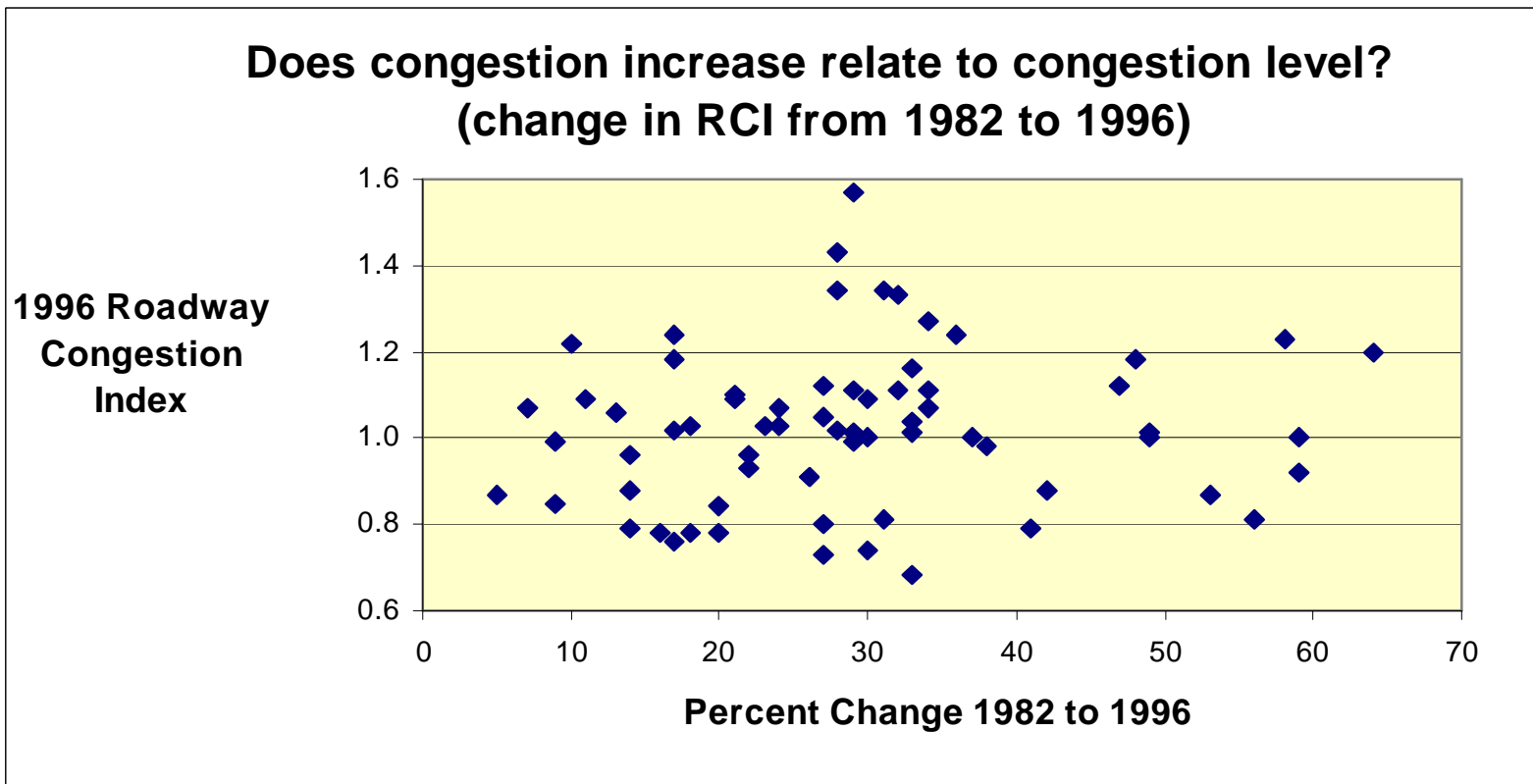
- , Congestion growth in Very Large urban areas has leveled off in the past few years while other areas have increased at about 1.5% per year.
- , Over the long term, the Very Large urban areas have shown about 2/3 of the growth in congestion as the remaining areas.
- , In 1982, congestion levels ranged from an average of 0.62 for the Small urban areas to 1.06 on average for the Very Large urban areas.
- , In 1996 the range had not increased very much from 1982, but the values had increased to 0.80 (Small) and 1.29 (Very Large).
- , Congestion has grown at about the same pace in the Small, Medium, and Large urban areas between 1992 and 1996.
- , The congestion growth in the Very Large urban areas has been at a smaller rate between 1992 and 1996 than in the other 3 population sizes.

Exhibit 5



- , The congestion level of the Small urban areas in 1996 is slightly above the congestion level of the Medium urban areas in 1982.
- , The congestion level of the Large urban areas in 1996 is at about the same level that the Very Large urban areas were in 1982.
- , The congestion growth for the Medium and Large urban areas has been at about the same rate between 1982 and 1996.

Exhibit 6



(Data from Houston and Phoenix have been omitted from the graph because their congestion “growth” rates were negative between 1982 and 1996). Their values are:

Houston Very Large 82-96% growth: -5% 1996 RCI: 1.11

Phoenix Large 82-96% growth: -1% 1996 RCI: 1.14

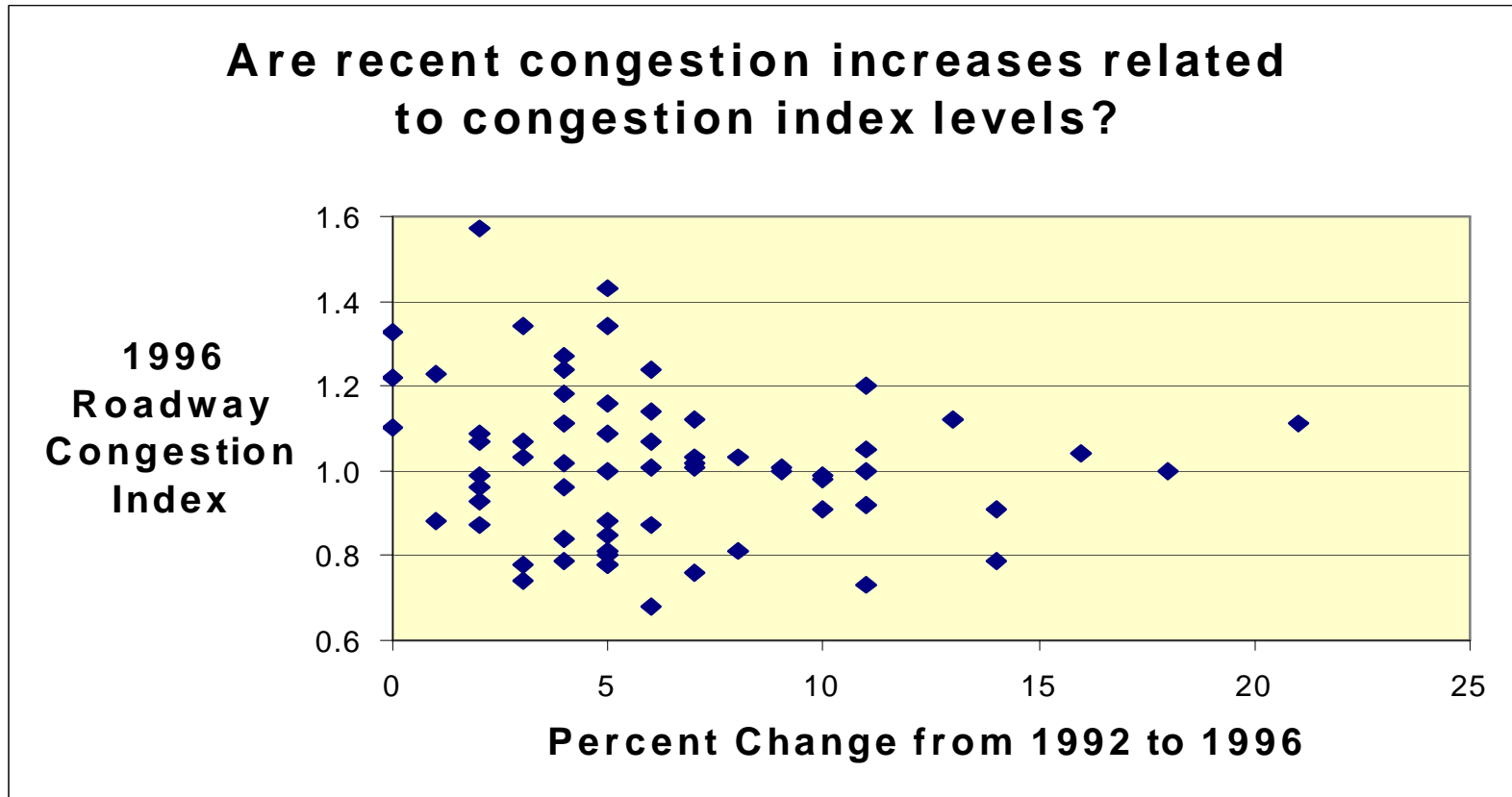
, The range in growth is -5% in Houston to 64% in Las Vegas

, The majority of urban areas in the study have seen increases in their congestion levels of between 10 and 40 percent between 1982 and 1996.

, Most of the very high percent changes occurred in urban areas with congestion index values between 0.8 and 1.2.

, Many of the urban areas with very high congestion index values had percent increases of approximately 30 percent between 1982 and 1996.

Exhibit 7

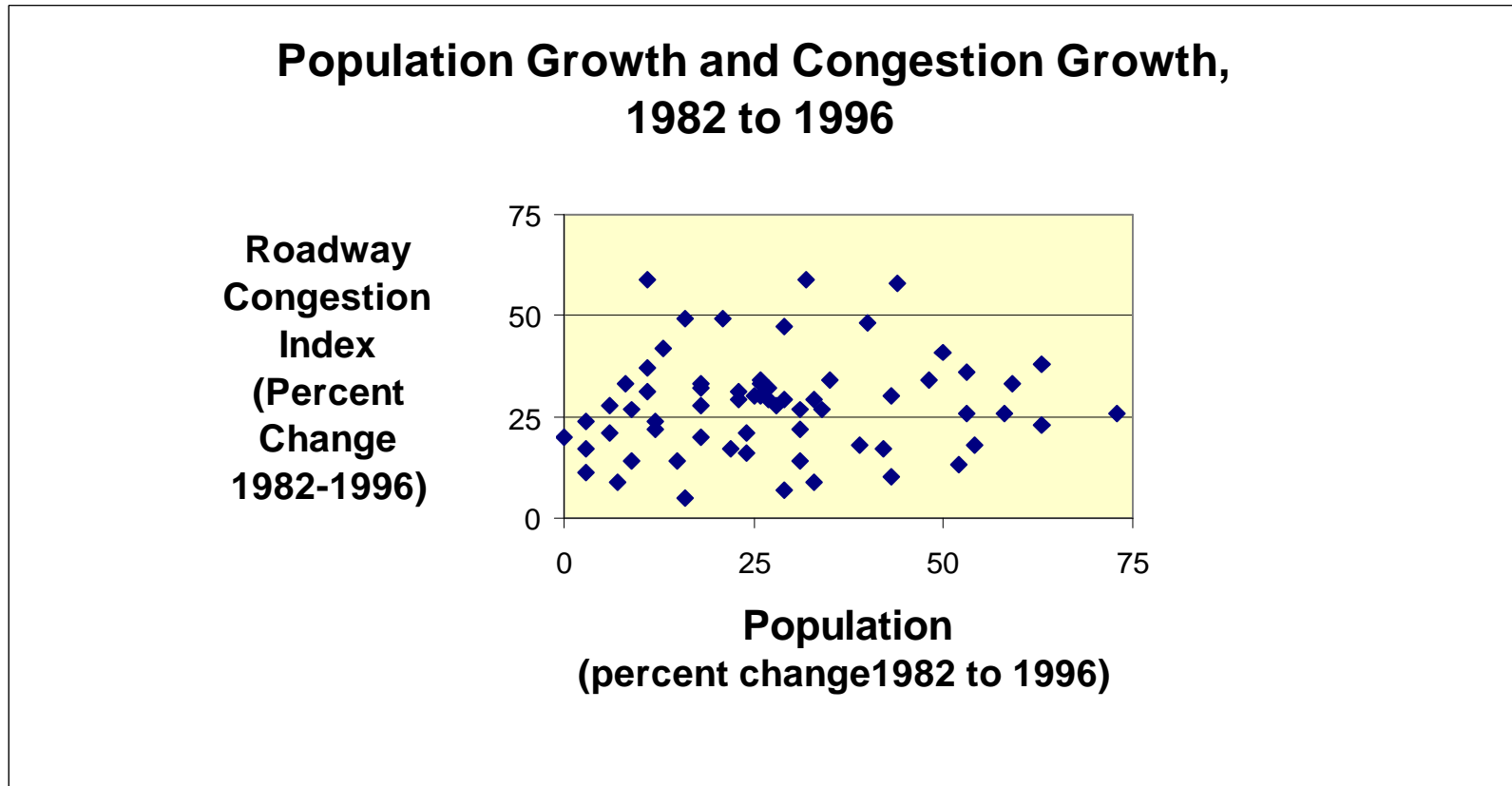


(Data from Tacoma, Tampa, New Orleans, and Houston have been omitted from the graph because their congestion growth rates were negative between 1992 and 1996). Their values are:

Tacoma	Medium	92-96 % growth: -3%	1996 RCI: 1.18
Tampa	Medium	92-96 % growth: -1%	1996 RCI: 1.06
New Orleans	Large	92-96 % growth: -1%	1996 RCI: 1.09
Houston	Very Large	92-96 % growth: -1%	1996 RCI: 1.11

- , Three urban areas had increases in congestion of over 15% between 1992 and 1996 (Louisville, Indianapolis, and Memphis)
- , Three urban areas had no increase in congestion between 1992 and 1996 (Honolulu, San Bernardino-Riverside, and San Francisco-Oakland)
- , Most urban areas experienced between 2 and 11 percent increases between 1992 and 1996.
- , The urban areas with the larger congestion index values (above 1.2), typically experienced between a 0 and 6 percent increase in congestion.

Exhibit 8



(Data from Albany-Schenectady-Troy, Detroit, Las Vegas, Houston, and Phoenix have been omitted from the graph because they either have negative population growth, very high population growth, or have a congestion decrease).

Their values are:

Albany-Schenectady-Troy	population growth: -1%	RCI increase 82-96: 56%
Detroit	population growth: -1%	RCI increase 82-96: 17%
Las Vegas	population growth: 139%	RCI increase 82-96: 64%
Houston	population growth: 28%	RCI increase 82-96: -5%
Phoenix	population growth: 64%	RCI increase 82-96: -1%

, This graph demonstrates that there must be more factors involved with congestion growth than just population since no definite pattern is evident.

CHAPTER III—CONGESTED TRAVEL AND FACILITIES

SUMMARY

The percent of congested peak period travel on the freeways at least tripled between 1982 and 1996 in 20 urban areas. The percent of congested peak period freeway travel at least doubled in 23 other urban areas between 1982 and 1996. In total, 53 urban areas showed increases of at least 50 percent in congested peak period freeway travel between 1982 and 1996.

Comprehensive data are not yet available on congested roadway percentage before 1994. In 1996, 16 urban areas had at least 50 percent of the freeway facilities with congestion during the peak travel periods. Twenty-nine urban areas have at least 50 percent of the principal arterial streets with congestion during the peak periods in 1996.

BACKGROUND

One way of looking at roadway congestion is to estimate the amount of travel that occurs in congested conditions. The percentage of the freeway travel occurring on sections of roadway with congested travel conditions (15,000 vehicles per lane per day) is a way of determining the amount of freeway system congestion. The same estimate can be made for travel on the principal arterial system with the threshold set at 5,750 vehicles per lane per day. The level of congestion (moderate, heavy, or severe) depends on the intensity of roadway traffic volume per lane.

Another way of looking at the amount of roadway congestion is to look at the supply side of the equation. The percentage of the freeway system operating with congested conditions (15,000 vehicle per lane per day) and the percentage of the principal arterial street system operating with congested conditions (5,750 vehicles per lane per day) is another description of congestion and mobility levels. A lane-mile of

freeway that has 15,000 vehicles per day would be considered to be congested during the peak periods. The level of congestion, again, depends on just how far above the lower threshold the traffic volume is.

Arithmetically, the percent of congested travel will always be greater than the percent of congested roadway—the travel is weighted more at the high volume locations (because there is more traffic at high volume locations), while the high volume roadway receives no such additional weight (there are not necessarily more lanes at congested locations than at uncongested locations). Locations that act as “bottlenecks” on a roadway, possibly just a few miles of facility, may be responsible for a significant amount of the congestion in an area.

The delay estimates calculated in this report are based on the amount of vehicle travel that occurs in each of four levels of congestion: uncongested, moderate, heavy, and severe. These four levels are estimated using the daily traffic per lane values on freeways and streets. This calculation is detailed in Appendix C.

TABLES AND EXHIBITS

Table 4 shows the percentage of the peak period travel that falls in the congested categories for both freeways and principal arterial streets for 1982, 1990, and 1996.

Following Table 4 are charts that display information such as:

- , congested travel trends for all 70 urban areas
- , congested travel trends for Very Large urban areas
- , congested travel trends for Large urban areas
- , congested travel trends for Medium urban areas
- , congested travel trends for Small urban areas
- , the trend in percent of freeway travel that is congested for urban area groups; 1982 to 1996
- , the relationship between the percent of congested freeway travel and population size

Table 5 shows the percentage of roadways that have congested travel during the peak periods for 1994, 1995, and 1996. More complete statistics on roadway congestion will be available in next year's study.

Following Table 5 are bar charts displaying the relationships between:

- , average percent of congested lane-miles of freeway and population size group
- , average percent of congested lane-miles of principal arterial streets and population size group

Table 4. Congested Travel

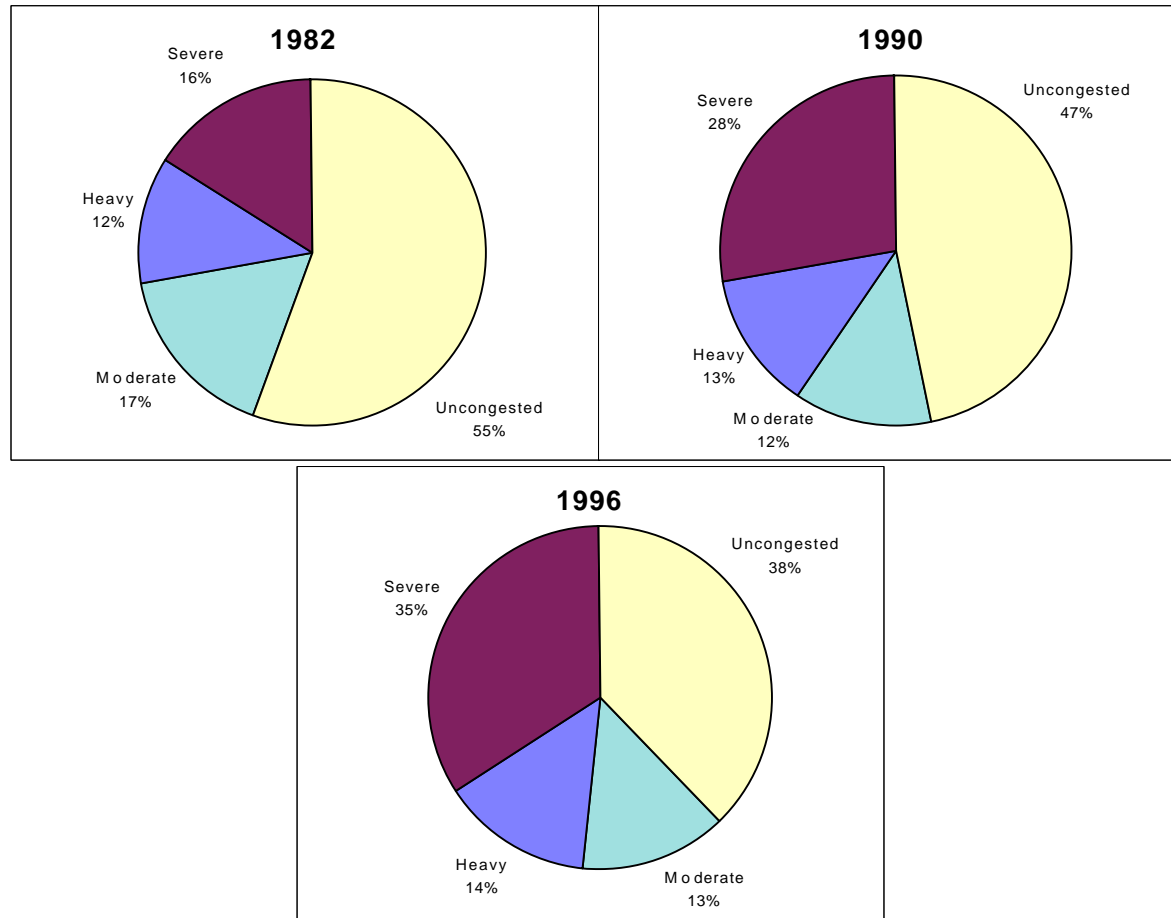
Urban Area	Congested Percent of Person-Miles of Travel (%)					
	Freeway			Principal Arterial Street		
	1982	1990	1996	1982	1990	1996
Very Large Areas (over 3 million population)						
Boston, MA	30	45	50	35	45	55
Chicago, IL-Northwestern, IN	50	55	70	60	65	75
Detroit, MI	40	50	65	60	65	70
Houston, TX	65	70	70	50	50	60
Los Angeles, CA	75	75	85	35	55	65
New York, NY-Northeastern, NJ	55	60	65	75	80	85
Philadelphia, PA-NJ	20	25	40	70	75	75
San Francisco-Oakland, CA	65	80	80	60	60	70
Washington, DC-MD-VA	60	65	75	80	85	85
Large Urban Areas (over 1 million and less than 3 million population)						
Atlanta, GA	40	45	65	60	65	75
Baltimore, MD	20	35	45	25	35	40
Buffalo-Niagara Falls, NY	10	15	25	25	35	40
Cincinnati, OH-KY	20	35	55	20	30	50
Cleveland, OH	20	30	45	20	40	60
Columbus, OH	25	30	45	30	45	65
Dallas, TX	45	55	60	25	35	50
Denver, CO	45	50	65	50	55	70
Fort Worth, TX	30	40	50	25	30	40
Ft Lauderdale-Hollywood-Pompano Beach, FL	20	40	60	45	50	60
Kansas City, MO-KS	5	10	25	20	30	40
Las Vegas, NV	40	55	75	50	65	75
Miami-Hialeah, FL	45	60	75	60	70	70
Milwaukee, WI	20	45	60	30	35	50
Minneapolis-St Paul, MN	20	40	55	40	55	60
New Orleans, LA	40	50	50	45	50	65
Norfolk, VA	35	45	50	30	35	50
Orlando, FL	25	40	55	20	30	50
Phoenix, AZ	50	60	65	65	70	70
Pittsburgh, PA	15	20	25	50	60	70
Portland-Vancouver, OR-WA	30	35	55	60	60	70
Sacramento, CA	25	45	65	40	50	70
San Antonio, TX	35	40	45	5	25	45
San Bernardino-Riverside, CA	60	70	75	50	55	60
San Diego, CA	35	55	70	25	30	45
San Jose, CA	45	60	70	40	60	70
Seattle-Everett WA	40	70	80	50	55	60
St Louis, MO-IL	20	25	45	65	60	70

Table 4. Congested Travel, continued

Urban Area	Congested Percent of Person-Miles of Travel (%)					
	Freeway			Principal Arterial Street		
	1982	1990	1996	1982	1990	1996
Medium Urban Areas (over 500,000 and less than 1 million population)						
Albuquerque, NM	5	30	45	35	45	60
Austin, TX	50	55	55	40	45	65
Charlotte, NC	20	30	45	45	60	70
El Paso, TX-NM	15	25	35	5	10	20
Fresno, CA	10	20	30	35	50	60
Hartford-Middletown, CT	10	15	30	20	35	40
Honolulu, HI	40	50	50	65	70	80
Indianapolis, IN	5	15	30	15	25	35
Jacksonville, FL	25	35	50	35	50	60
Louisville, KY-IN	5	20	30	50	55	70
Memphis, TN-AR-MS	10	30	40	30	35	55
Nashville, TN	20	25	40	35	40	50
Oklahoma City, OK	5	10	30	30	35	40
Omaha, NE-IA	15	30	35	40	65	70
Providence-Pawtucket, RI-MA	20	30	45	35	45	50
Rochester, NY	10	20	30	25	35	45
Salt Lake City, UT	10	25	50	35	40	60
Tacoma, WA	30	60	70	35	40	45
Tampa, FL	20	25	40	60	65	70
Tucson, AZ	25	35	40	65	70	75
Small Urban Areas (less than 500,000 population)						
Albany-Schenectady-Troy, NY	5	5	5	25	40	55
Allentown-Bethlehem-Easton, PA-NJ	10	20	30	50	65	75
Bakersfield, CA	5	10	15	10	25	40
Beaumont, TX	5	10	10	5	15	30
Boulder, CO	5	5	5	30	45	55
Brownsville, TX	5	10	15	15	30	45
Colorado Springs, CO	10	25	35	10	35	55
Corpus Christi, TX	5	10	15	10	10	15
Eugene-Springfield, OR	0	5	10	50	55	60
Harrisburg, PA	10	20	25	60	70	75
Laredo, TX	5	5	15	35	35	50
Salem, OR	15	25	35	20	35	45
Spokane, WA	10	15	30	25	35	40
70 area average	42	51	61	48	56	65
Very large area average	58	64	72	56	65	72
Large area average	32	45	57	43	51	60
Medium area average	17	28	40	35	45	55
Small area average	7	14	19	29	40	51

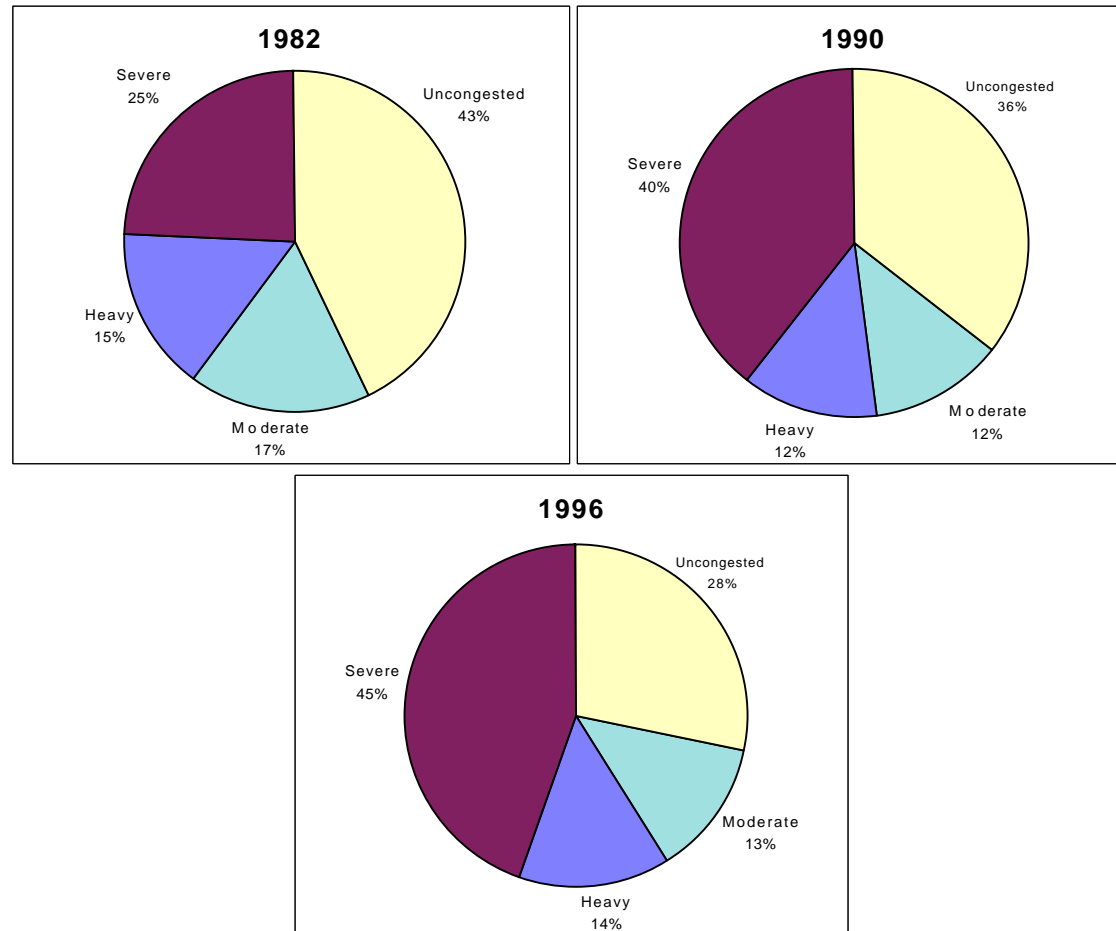
- , Several urban areas showed very large increases in their percent of congested freeway travel between 1982 and 1996: Kansas City (5 to 25%), Albuquerque (5 to 45%), Indianapolis (5 to 30%), Memphis (10 to 40%), Oklahoma City (5 to 30%), Salt Lake City (10 to 50%).
- , Several urban areas showed very large increases in their percent of congested principal arterial travel between 1982 and 1996: San Antonio (5 to 45%), El Paso (5 to 20%), Bakersfield (10 to 40%), Beaumont (5 to 30%).
- , The percent of congested peak period travel on the freeways at least tripled between 1982 and 1996 in 20 urban areas.
- , The percent of congested peak period travel on the freeways at least doubled between 1982 and 1996 in 23 urban areas.
- , The percent of congested peak period travel on the freeways showed at least a 50 percent increases between 1982 and 1996 in 10 urban areas.
- , The percent of congested peak period travel on the principal arterial streets at least tripled between 1982 and 1996 in 6 urban areas.
- , The percent of congested peak period travel on the principal arterial streets at least doubled between 1982 and 1996 in 8 urban areas.
- , The percent of congested peak period travel on the principal arterial streets showed at least a 50 percent increase between 1982 and 1996 in 25 urban areas.
- , The average percent of congested freeway travel in the Small urban areas doubled between 1982 and 1990 (7 to 14 percent), and climbed to 19 percent by 1996.
- , The average percent of congested freeway travel in the Medium urban areas more than doubled between 1982 and 1996 (17 to 40 percent).
- , The average percent of congested freeway travel in the Large urban areas nearly doubled between 1982 and 1996 (32 to 57 percent).
- , The average percent of congested freeway travel in the Very Large urban areas increased by almost 50 percent between 1982 and 1996 (58 to 72 percent).
- , The average percent of congested principal arterial travel increased between 25 percent and 60 percent in the 4 population groups from 1982 to 1996.

Exhibit 9 Congested Travel Trend for All Urban Areas



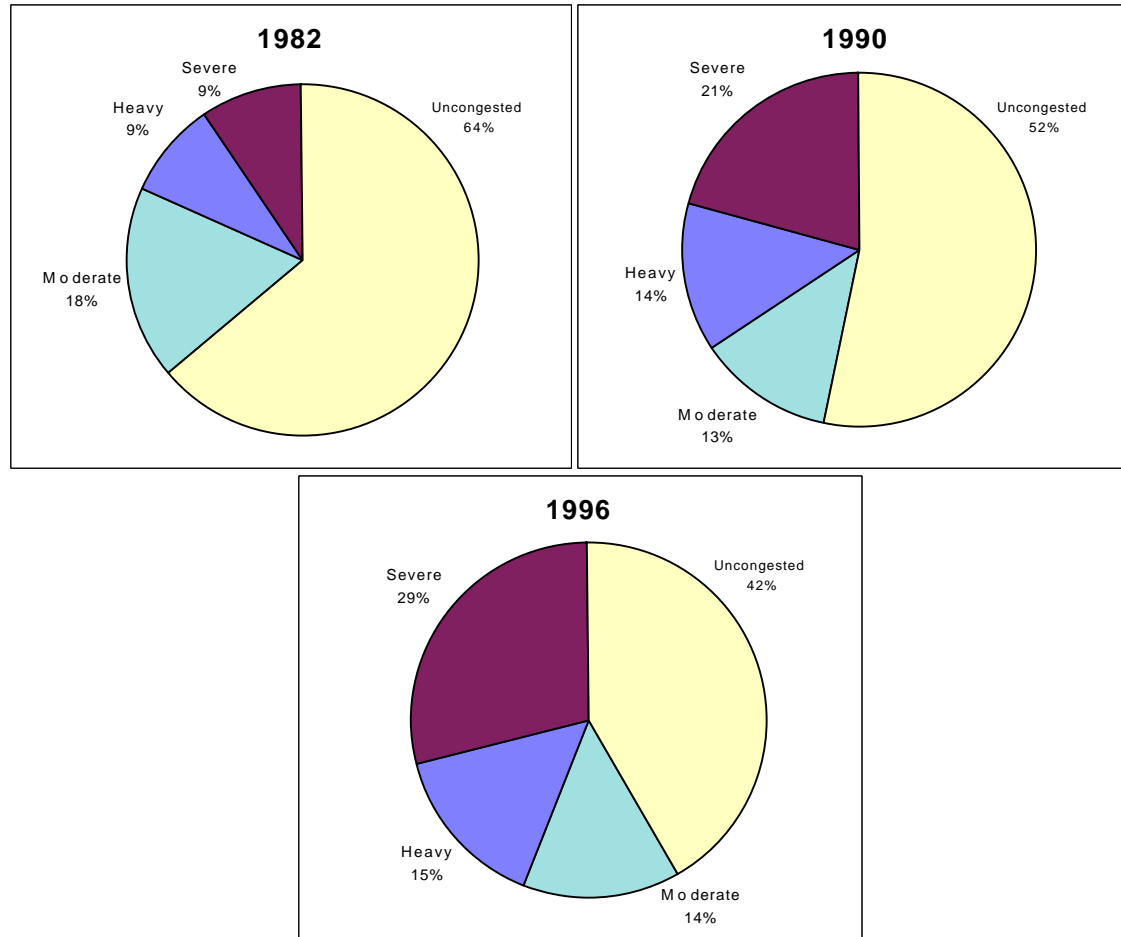
- , Uncongested travel in all 70 urban areas has fallen from over half of the travel in 1982 (55%) to about 1/3 of the travel in 1996 (38%).
- , The amount of severe congestion in all 70 urban areas has more than doubled between 1982 and 1996 (16% to 35%).
- , The amount of moderate congestion in all 70 urban areas has remained about the same between 1982 and 1996 (17% to 13%).
- , The amount of heavy congestion in all 70 urban areas has remained about the same between 1982 and 1996 (12% to 14%).

Exhibit 10 Congested Travel Trend for Very Large Urban Areas



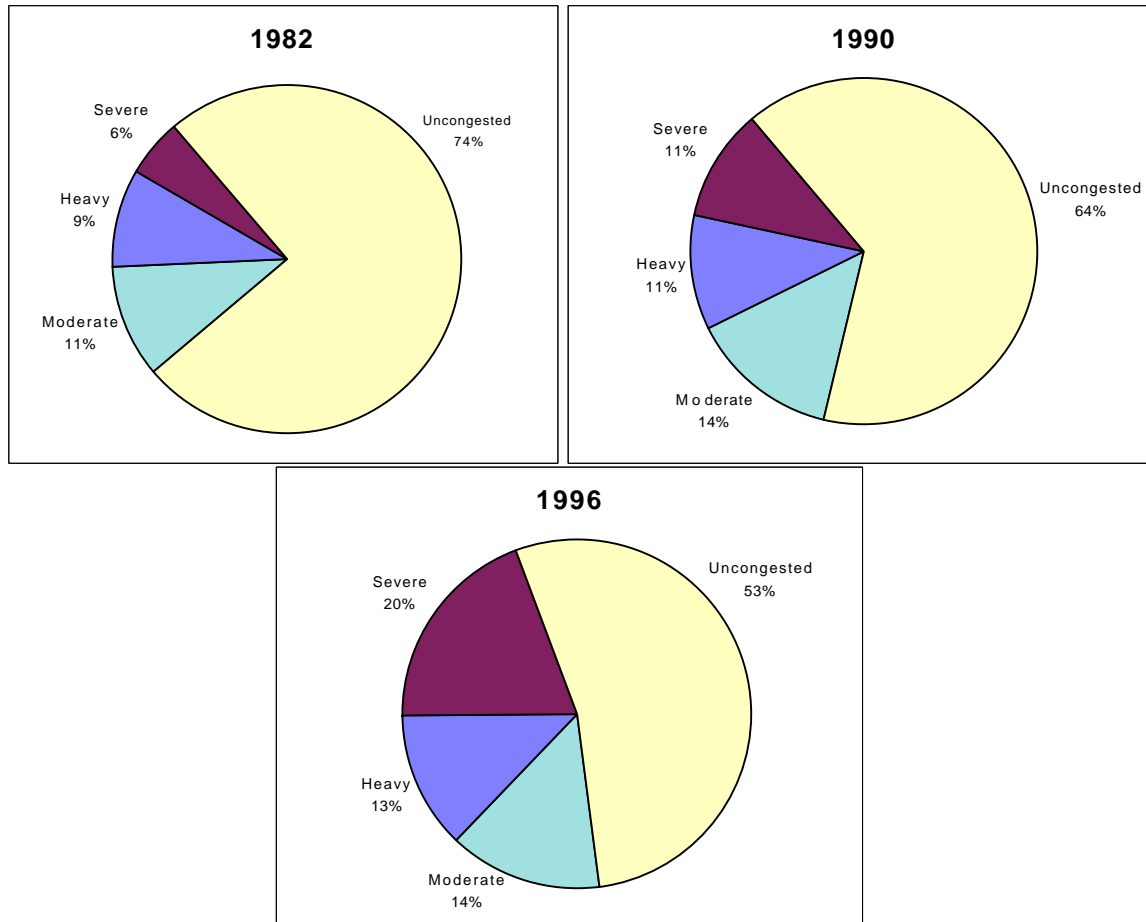
- , The amount of uncongested travel in the Very Large urban areas has decreased from 43% in 1982 to 28% in 1996.
- , The amount of severe congestion has increased in the Very Large urban areas from 25% in 1982 to 45% in 1996.
- , The percent of heavy congestion has remained about the same between 1982 and 1996 in the Very Large urban areas (15% to 14%).
- , The percent of moderate congestion has remained about the same between 1982 and 1996 in the Very Large urban areas (17% to 13%).

Exhibit 11 Congested Travel Trends for Large Urban Areas



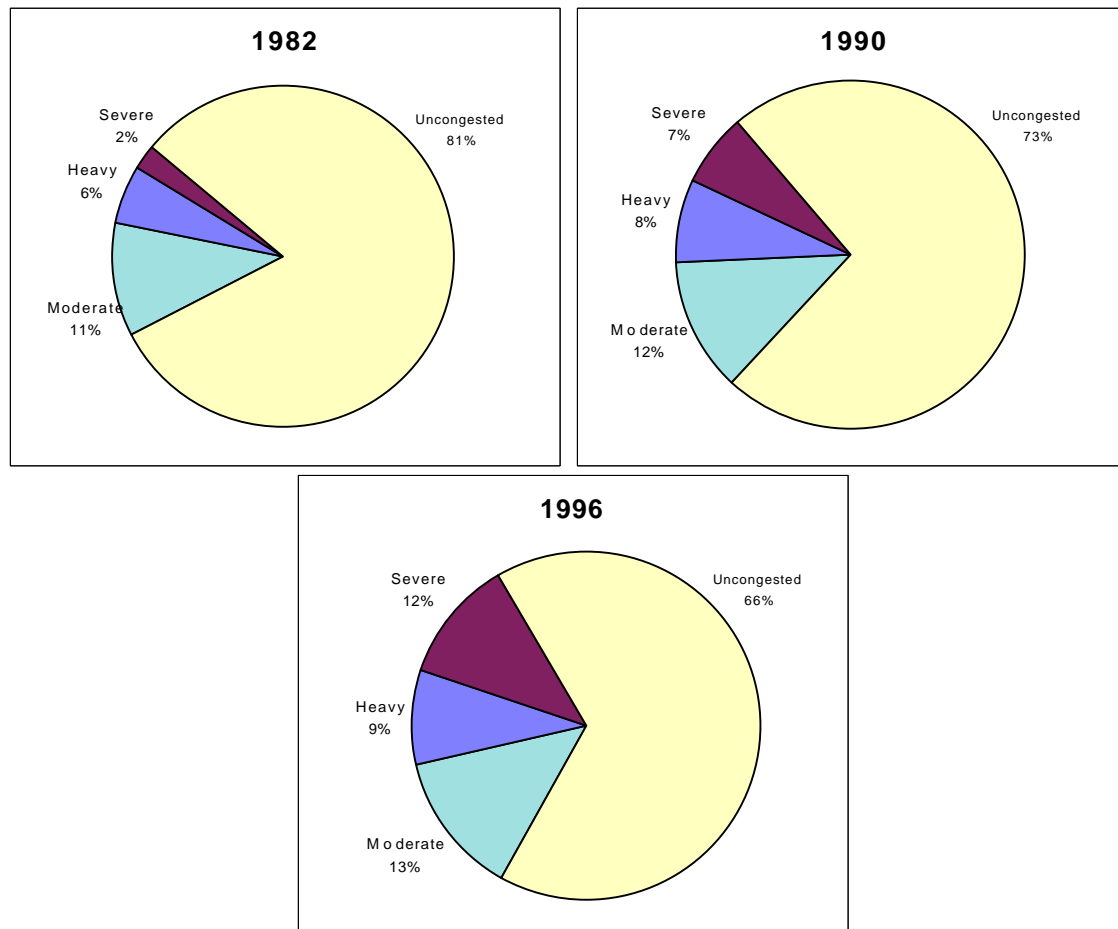
- , Uncongested travel has decreased in the Large urban areas from 64% in 1982 to 42% in 1996.
- , The amount of severe congestion has more than tripled in the Large urban areas from 9% in 1982 to 29% in 1996.
- , The percent of heavy congestion has increased from 9% in 1982 to 15% in 1996 in the Large urban areas.
- , The percent of moderate congestion has remained about the same between 1982 and 1996 (18% to 14%).

Exhibit 12 Congested Travel Trend for Medium Urban Areas



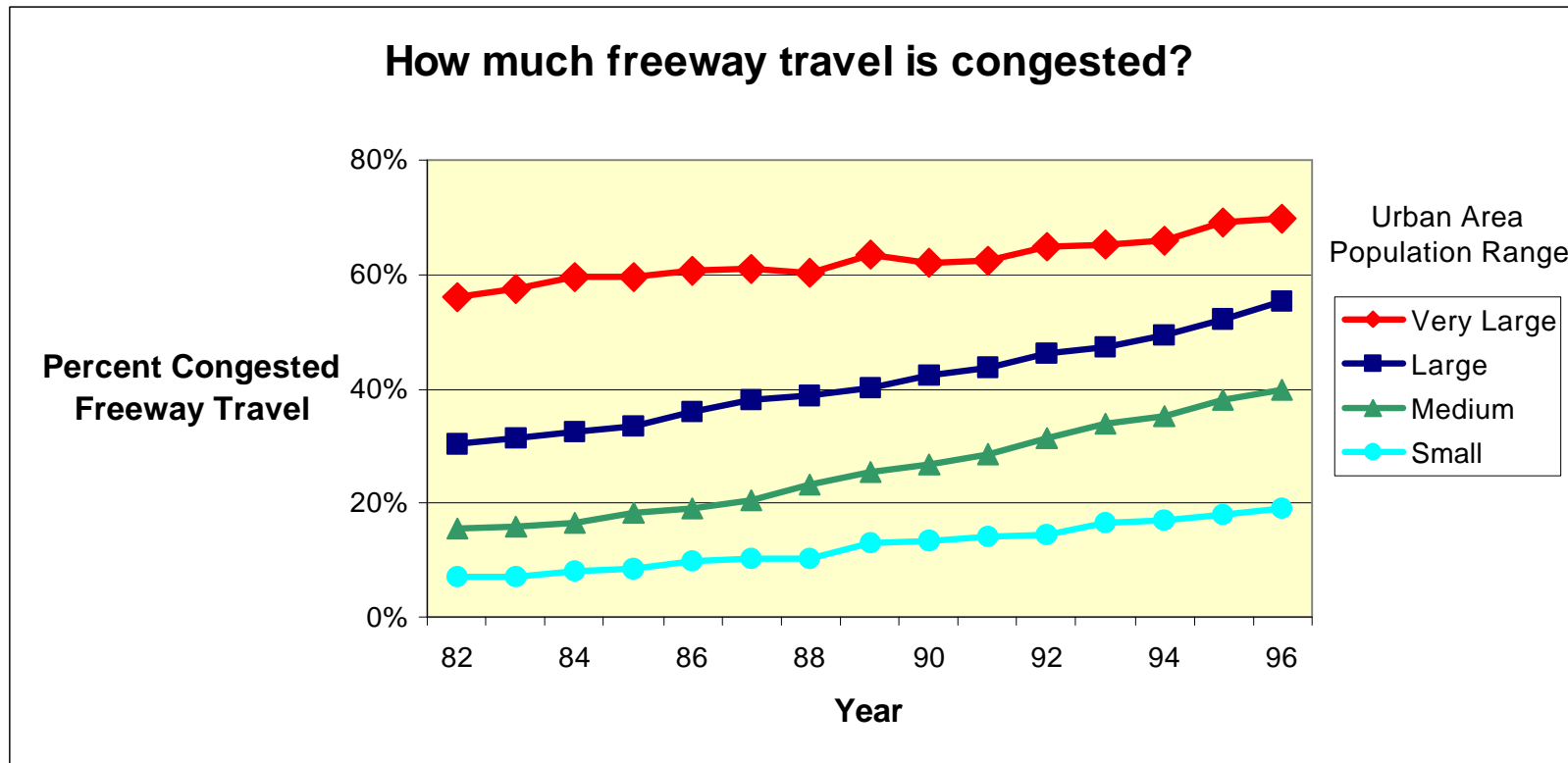
- , The amount of uncongested travel has decreased from 74% in 1982 to 53% in 1996 for the Medium urban areas.
- , The percent of severe congestion has more than tripled from 6% in 1982 to 20% in 1996 for the Medium urban areas.
- , The amount of heavy congestion has increased from 9% in 1982 to 13% in 1996 for the Medium urban areas.
- , The amount of moderate congestion has remained about the same between 1982 and 1996 in the Medium areas (11% to 14%).

Exhibit 13 Congested Travel Trend for Small Urban Areas



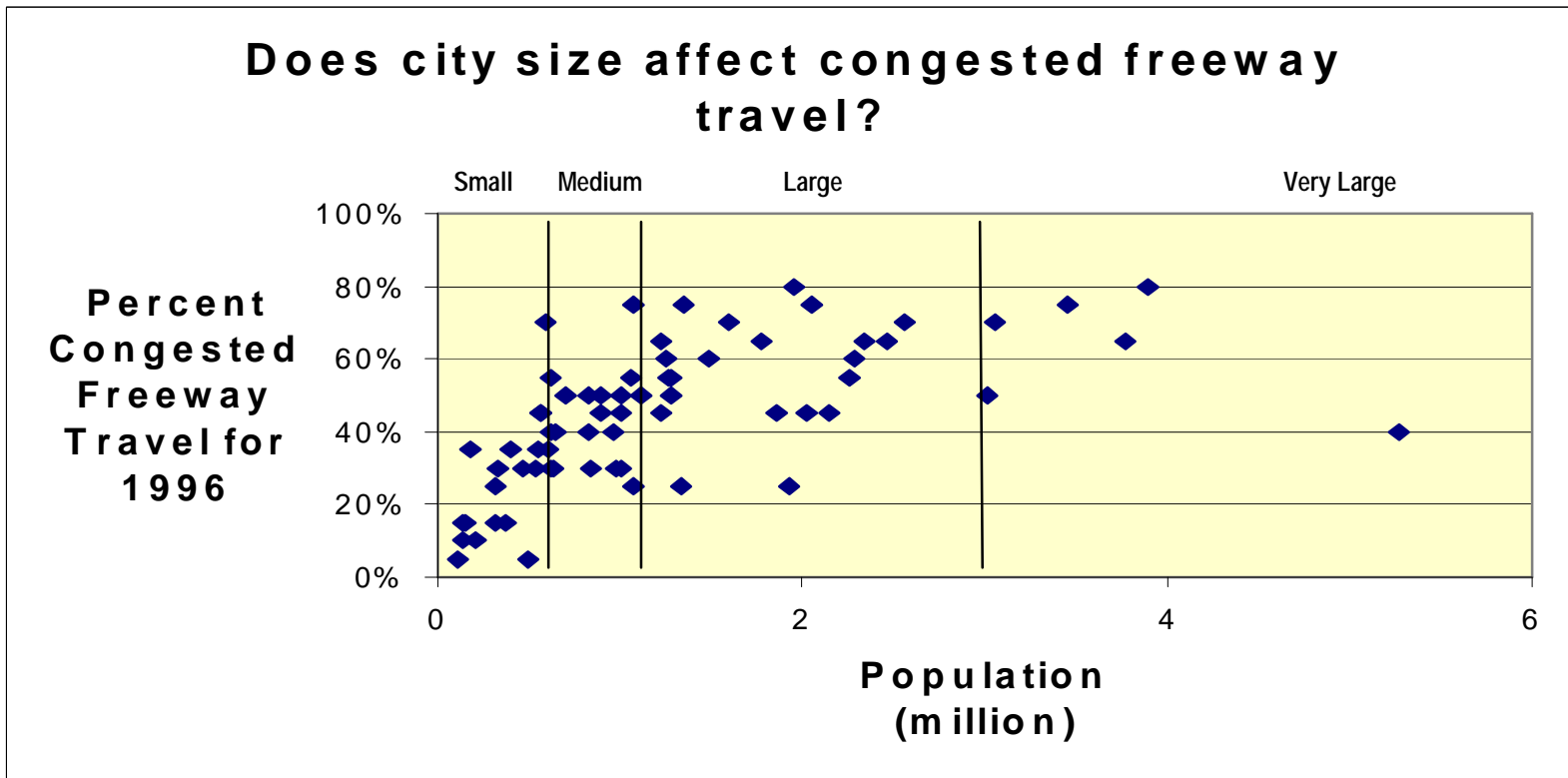
- , Uncongested travel has decreased from 81% in 1982 in the Small urban areas to 66% in 1996.
- , The amount of severe congestion has increased by about 6 times between 1982 and 1996 in the Small urban areas (2% to 12%).
- , The percent of heavy congestion has increased from 6% to 9% between 1982 and 1996 in the Small urban areas.
- , The percent of moderate congestion has remained about the same in the Small urban areas between 1982 and 1996 (11% to 13%).

Exhibit 14



- , The percent of congested freeway travel in the Small and Very Large urban areas appears to be increasing slower than in the Medium and Large urban areas.
- , The percent of congested freeway travel in the Small urban areas and Very Large urban areas appear to be increasing at about the same rate over the period 1982 to 1996.
- , The percent of congested freeway travel in the Medium urban areas and Large urban areas appear to be increasing at about the same rate between 1982 and 1996.
- , The average percent of congested freeway travel in the Small urban areas in 1996 is at about the same level that the Medium urban areas were in 1982.
- , The average percent of congested freeway travel in the Large urban areas in 1996 is at about the same level that the Very Large urban areas were in 1982.

Exhibit 15



(Data from Los Angeles, New York, and Chicago have been omitted from the graph because they have very large populations).
Their values are:

New York:	population 17,150,000	Percent of Congested Freeway Travel: 65%
Los Angeles:	population 12,220,000	Percent of Congested Freeway Travel: 85%
Chicago:	population 7,850,000	Percent of Congested Freeway Travel: 70%

- , The Small urban areas have congested travel percentages between 5% and 40%.
- , The Medium urban areas have congested travel percentages between 30% and 70%.
- , The Large urban areas have congested travel percentages between 25% and 80%.
- , The Very Large urban areas have congested travel percentages between 40% and 85%.
- , In general, the higher population areas have more congested travel on the freeways.

Table 5. Congested Roadway

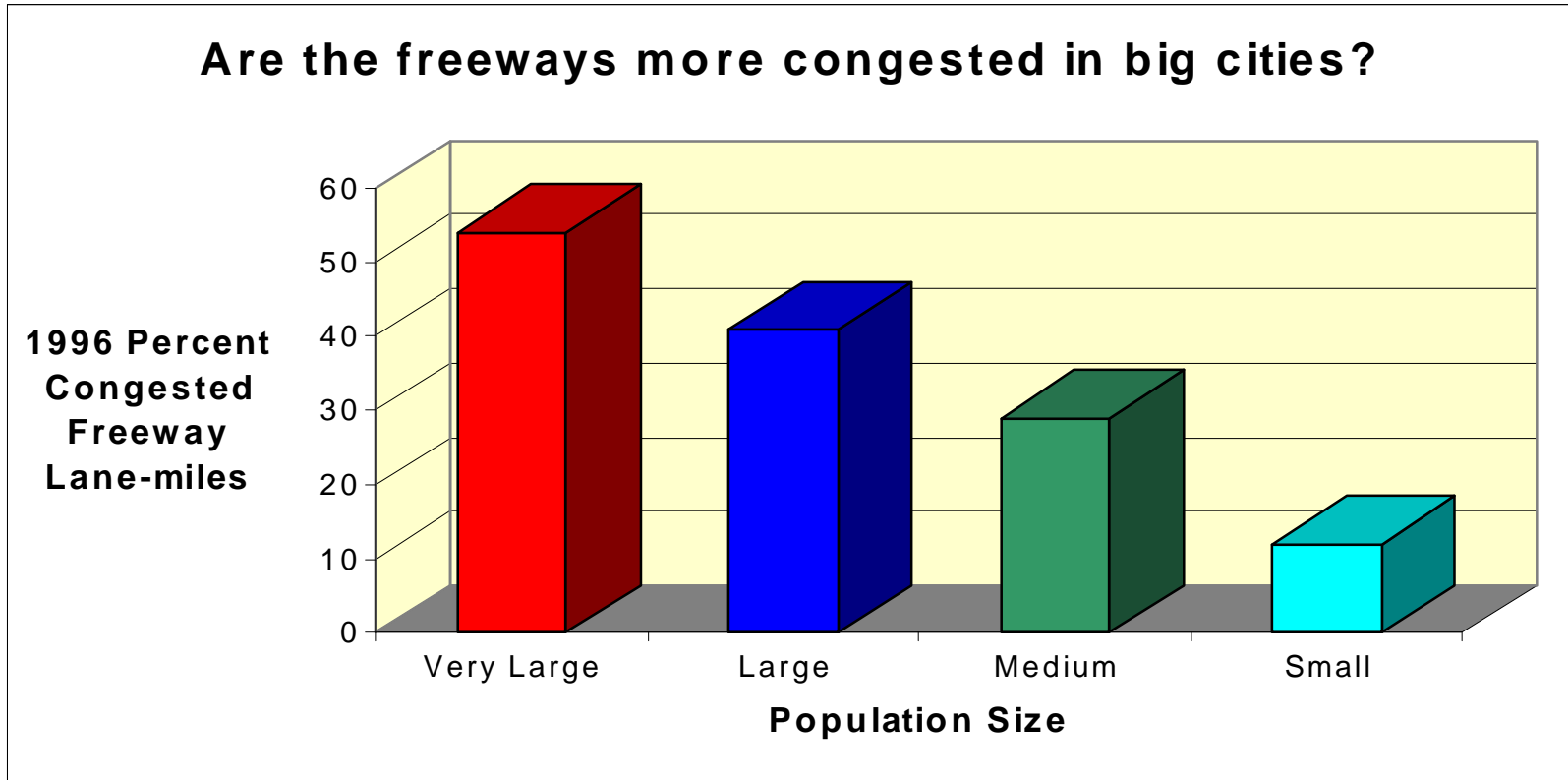
Urban Area	Congested Lane Miles (%)					
	Freeway			Principal Arterial Street		
	1994	1995	1996	1994	1995	1996
Very Large Areas (over 3 million population)						
Boston, MA	35	40	40	40	45	45
Chicago, IL-Northwestern, IN	50	55	55	65	65	65
Detroit, MI	50	50	55	50	50	50
Houston, TX	40	40	45	35	35	40
Los Angeles, CA	70	70	75	55	55	55
New York, NY-Northeastern, NJ	35	35	40	50	50	50
Philadelphia, PA-NJ	25	25	25	55	55	55
San Francisco-Oakland, CA	70	70	70	50	50	55
Washington, DC-MD-VA	60	60	60	70	70	70
Large Urban Areas (over 1 million and less than 3 million population)						
Atlanta, GA	50	50	55	60	55	55
Baltimore, MD	25	30	30	35	40	40
Buffalo-Niagara Falls, NY	10	10	10	20	20	20
Cincinnati, OH-KY	40	40	40	30	30	30
Cleveland, OH	35	35	35	35	35	40
Columbus, OH	30	35	35	40	45	50
Dallas, TX	30	30	35	30	30	30
Denver, CO	40	45	45	60	60	60
Fort Worth, TX	30	30	35	30	30	30
Ft Lauderdale-Hollywood-Pompano Beach, FL	40	40	45	45	45	45
Kansas City, MO-KS	15	15	15	30	30	30
Las Vegas, NV	50	50	50	60	65	65
Miami-Hialeah, FL	60	60	60	55	60	60
Milwaukee, WI	45	45	50	40	40	40
Minneapolis-St Paul, MN	40	45	45	50	50	50
New Orleans, LA	35	30	30	45	50	50
Norfolk, VA	25	30	35	40	45	45
Orlando, FL	30	35	35	35	40	40
Phoenix, AZ	45	40	40	50	50	55
Pittsburgh, PA	10	10	10	50	50	50
Portland-Vancouver, OR-WA	40	40	40	50	50	50
Sacramento, CA	50	50	55	60	60	65
San Antonio, TX	25	30	30	30	35	35
San Bernardino-Riverside, CA	60	60	60	45	45	45
San Diego, CA	55	55	60	30	35	35
San Jose, CA	55	55	60	60	60	60
Seattle-Everett, WA	60	60	60	45	45	45
St Louis, MO-IL	30	30	35	60	60	60

Table 5. Congested Roadway, continued

Urban Area	Congested Lane Miles (%)					
	Freeway			Principal Arterial Street		
	1994	1995	1996	1994	1990	1996
Medium Urban Areas (over 500,000 and less than 1 million population)						
Albuquerque, NM	25	25	30	45	45	45
Austin, TX	30	35	35	50	50	45
Charlotte, NC	30	30	30	55	55	55
El Paso, TX-NM	25	25	25	10	15	15
Fresno, CA	10	10	10	40	40	40
Hartford-Middletown, CT	15	20	20	30	30	30
Honolulu, HI	45	45	50	50	50	55
Indianapolis, IN	30	30	30	30	30	30
Jacksonville, FL	35	35	35	40	40	40
Louisville, KY-IN	15	15	20	55	55	55
Memphis, TN-AR-MS	25	30	30	40	45	45
Nashville, TN	25	25	30	40	40	40
Oklahoma City, OK	15	20	20	25	25	25
Omaha, NE-IA	20	20	20	50	50	50
Providence-Pawtucket, RI-MA	25	25	25	45	45	45
Rochester, NY	15	20	20	30	30	30
Salt Lake City, UT	35	40	40	45	45	45
Tacoma, WA	60	60	60	30	30	30
Tampa, FL	30	30	30	60	60	60
Tucson, AZ	25	25	25	60	60	60
Small Urban Areas (less than 500,000 population)						
Albany-Schenectady-Troy, NY	5	5	5	35	35	35
Allentown-Bethlehem-Easton, PA-NJ	10	15	15	60	60	60
Bakersfield, CA	10	10	10	20	20	25
Beaumont, TX	5	5	10	10	10	30
Boulder, CO	5	5	5	40	45	45
Brownsville, TX	5	5	10	30	30	30
Colorado Springs, CO	15	15	20	40	45	45
Corpus Christi, TX	5	5	5	5	10	10
Eugene-Springfield, OR	0	0	5	45	50	50
Harrisburg, PA	10	15	15	60	60	65
Laredo, TX	5	5	5	20	25	25
Salem, OR	25	25	25	35	35	35
Spokane, WA	10	15	20	25	25	25
70 area average	40	41	43	47	48	49
Very large area average	50	50	54	53	54	54
Large area average	38	39	41	45	46	46
Medium area average	26	28	29	41	41	41
Small area average	9	10	12	32	34	37

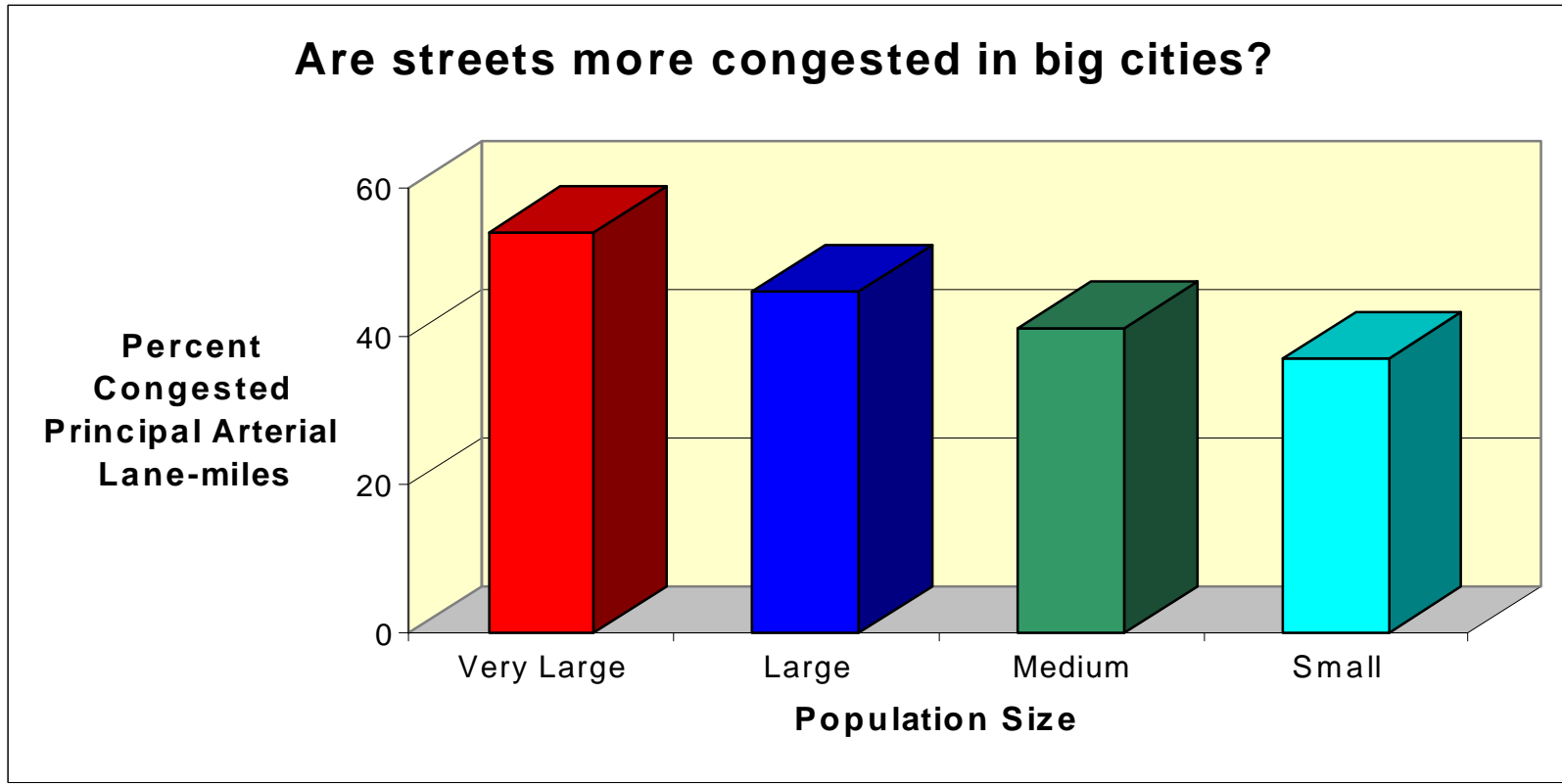
- , New Orleans and Phoenix were the only 2 urban areas that showed a decline in the percent of congested freeway lane-miles between 1994 and 1996: New Orleans (35% to 30%) and Phoenix (45% to 40%).
- , Atlanta was the only urban area that showed a decline (60% to 55%) in the percent of congested principal arterial lane-miles between 1994 and 1996.
- , Spokane was the only urban area that showed a gain of 10 percentage points (10% to 20%) or more in the percent of congested freeway lane-miles between 1994 and 1996.
- , Columbus and Beaumont were the only 2 urban areas that showed a gain of 10 percentage points or more in the percent of congested principal arterial lane-miles between 1994 and 1996: Columbus (40% to 50%) and Beaumont (10% to 30%).
- , The average change in percentage points for all 70 urban areas was 3 percent (40% to 43%) for freeways and 2 percent (47% to 49%) for principal arterial streets.
- , The change in percentage points between 1994 and 1996 for the freeways was higher in the Very Large urban areas (4 percentage points) than the 70 urban area average (3 percentage points).
- , The change in percentage points between 1994 and 1996 for the principal arterial streets was higher in the Small urban areas (5 percentage points) than the 70 urban area average (2 percentage points).
- , The change in percentage points between 1994 and 1996 for the principal arterial streets was lower in the Very Large (1 percentage point), Large (1 percentage point), and Medium (no change) urban areas than the 70 urban area average (2 percentage points).

Exhibit 16



- , The percentage of congested lane-miles of freeway range from about 10% in the Small urban areas to over 50% in the Very Large urban areas.
- , The percentage of congested freeway lane-miles is over twice as much in the Medium urban areas as the Small urban areas.
- , The percentage of congested freeway lane-miles is over 3 times as much in the Large urban areas as the Small urban areas.
- , The percentage of congested freeway lane-miles is over 4 times as much in the Very Large urban areas as the Small urban areas.
- , The percentage of congested freeway lane-miles is about twice as much in the Very Large urban areas as the Medium urban areas.

Exhibit 17



- , The percentage of congested principal arterial street lane-miles ranges from about 35% in the Small urban areas to over 50% in the Very Large urban areas.
- , The percentage of congested principal arterial street lane-miles is about the same in the Small (about 35%) and Medium (about 40%) urban areas and not much higher in the Large urban areas (about 45%).
- , The percentage of congested principal arterial street lane-miles in the Very Large urban areas is about 10 percentage points higher than the next highest population group which is the Large urban areas (about 45%).
- , The percentage of congested streets is larger than the percentage of congested freeway lane-miles in all groups except Very Large.

CHAPTER IV—TRAVEL DELAY

SUMMARY

The annual hours of delay experienced by urban areas in 1996 in the study varied from a low of about 955,000 hours in Boulder to a high of about 684 million hours in Los Angeles (Table 6). Twelve urban areas had at least 100 million hours of delay on its roadways. Thirteen urban areas, on the other hand, had less than 10 million hours of delay. The average annual delay for the 70 urban areas in the study was about 65 million hours.

Drivers in 11 urban areas spent the equivalent of more than 1.5 work weeks (60 hours) stuck in traffic in 1996 (Table 6). Drivers in 28 urban areas spent the equivalent of at least 1 work week stuck in traffic, while drivers in 60 of the 70 urban areas studied spent at least one-half of a work week (20 hours) stuck in traffic.

Washington, DC had the greatest amount of delay per driver with about 82 hours per year while Brownsville had the least

amount of delay per driver in the study with about 11 hours per year (Table 6).

The highest ranked areas for delay per driver in each of the population categories is:

<i>Very Large</i>	<i>Washington, DC</i>	<i>82 hours per driver</i>
<i>Large</i>	<i>Seattle-Everett, WA</i>	<i>71 hours per driver</i>
<i>Medium</i>	<i>Austin, TX</i>	<i>61 hours per driver</i>
<i>Small</i>	<i>Harrisburg, PA</i>	<i>52 hours per driver</i>

In general, the amount of delay experienced by drivers in urban areas is on the increase. The average increase for all 70 urban areas in delay per driver was 208 percent between 1982 and 1996 and 33 percent between 1992 and 1996 (Table 7).

Only 2 urban areas (Tacoma and Phoenix) in the study showed no increase in delay per driver between 1992 and 1996, but these areas did have increases in delay per driver over the long-term (between 1982 and 1996). Additionally, only 11 urban areas have increases in delay per driver of less than 100 percent between 1982 and 1996.

BACKGROUND

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 when travel times are longer during normal daily operations because demand for roadway facilities is near or exceeds capacity. The most common example of recurring delay is the increased travel time during peak periods. This increased travel time results from the slower speeds associated with congestion conditions on the freeways and principal arterial streets.

Crashes, breakdowns, or other occurrences that temporarily decrease roadway capacity cause incident delay. When congestion levels increase (creating higher RCI values), it is the recurring delay that is being measured. Incident delay is not only caused by high traffic volume, and incident congestion may be a much greater percentage of total delay in less congested areas. A severe incident will cause an increase in travel delay for an already congested area, but it may cause a very significant increase in a moderately congested facility.

The delay estimates provide additional insight into the congestion level in an urban area, which is not always evident in the Roadway Congestion Index (RCI). The RCI is a macroscopic view of roadway traffic for an urban area. It analyzes total travel and roadway capacity for an area. The RCI does not account for point-specific congestion problems such as capacity bottlenecks or points where demand is funneled into a few corridors. Examples of these locations include points where the number of lanes decrease or tunnels and bridges that cross major geographic features. Toll freeways also carry lower than typical traffic volume per lane and can therefore contribute significant reductions in traffic density as measured by the roadway congestion index, but not contribute as much to reducing travel delay. Thus, it is possible for the RCI and delay rankings to be quite different for the urban areas in the study. The delay per capita and delay per driver estimates show the penalties in wasted time that all citizens and motorists pay because of these congested roadways.

TABLES AND FIGURES

Table 6 shows the annual recurring and incident delay associated with each of the urban areas. Also shown are the annual delay per capita and per eligible driver. The urban areas in the Table are ranked by the annual delay per eligible driver.

Following Table 6 is an exhibit showing:

- , average delay per driver and urban area group size

Table 7 presents the annual delay per eligible driver data for selected years between 1982 and 1996. The percent change in delay per eligible driver is shown for the periods 1982 to 1996 and 1992 to 1996.

Following Table 7 are exhibits showing:

- , the growth in delay per driver for each urban area
- , delay per driver growth for urban area population groups
- , the range in hours of delay per driver and urban area size
- , growth in delay per driver and population

Table 6. Annual Person-Hours of Delay for 1996

Population Group	Urban Area	Annual Person-Hours of Delay per Capita	Rank ¹	Annual Person-Hours of Delay per Eligible Driver	Rank ¹	Annual Person-Hours of Delay (000)			
						Recurring	Incident	Total	Rank ¹
Vlg	Washington, DC-MD-VA	67	1	82	1	82,135	148,945	231,080	4
Vlg	Los Angeles, CA	56	2	76	2	315,265	369,145	684,410	1
Lrg	Seattle-Everett, WA	56	2	71	3	46,935	63,155	110,090	11
Lrg	Atlanta, GA	54	4	69	4	63,315	69,645	132,960	9
Vlg	Detroit, MI	53	5	69	4	74,520	125,480	200,000	6
Lrg	San Jose, CA	52	6	68	6	38,360	44,785	83,145	14
Vlg	San Francisco-Oakland, CA	52	6	66	7	89,775	113,210	202,985	5
Vlg	Houston, TX	49	8	66	7	64,120	86,120	150,240	7
Lrg	San Bernardino-Riverside, CA	46	11	65	9	35,595	26,355	61,950	21
Lrg	Dallas, TX	48	9	63	10	41,515	68,390	109,905	12
Med	Austin, TX	47	10	61	11	12,300	16,820	29,120	36
Lrg	Miami-Hialeah, FL	45	12	58	12	40,565	52,020	92,585	13
Med	Nashville, TN	45	12	58	12	11,375	17,000	28,375	37
Vlg	Boston, MA	45	12	57	14	38,435	97,980	136,415	8
Lrg	Denver, CO	39	18	52	15	34,205	35,580	69,785	18
Lrg	St. Louis, MO-IL	40	16	52	15	37,705	43,540	81,245	15
Lrg	Fort Worth, TX	40	16	52	15	19,025	31,350	50,375	22
Med	Jacksonville, FL	39	18	52	15	14,710	16,915	31,625	33
Sml	Harrisburg, PA	41	15	52	15	4,495	8,560	13,055	56
Lrg	Portland-Vancouver, OR-WA	37	20	48	20	17,790	29,765	47,555	24
Lrg	Sacramento, CA	34	24	46	21	23,075	19,075	42,150	26
Med	Louisville, KY-IN	36	21	45	22	9,890	19,970	29,860	34
Lrg	Baltimore, MD	35	23	44	23	25,080	49,490	74,570	16
Med	Albuquerque, NM	34	24	44	23	7,960	11,095	19,055	46
Vlg	New York NY-Northeastern, NJ	36	21	44	23	211,280	400,140	611,420	2
Lrg	Orlando, FL	32	26	42	26	16,060	17,670	33,730	31
Vlg	Chicago, IL-Northwestern, IN	32	26	42	26	116,210	134,630	250,840	3
Lrg	Norfolk, VA	32	26	41	28	11,085	20,840	31,925	32
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	31	29	39	29	19,345	26,215	45,560	25
Med	Tampa, FL	31	29	39	29	11,200	14,020	25,220	41
Med	Providence-Pawtucket, RI-MA	30	31	39	29	10,735	16,690	27,425	38
Lrg	San Diego, CA	29	33	38	32	43,630	30,010	73,640	17
Lrg	San Antonio, TX	28	39	38	32	16,415	18,055	34,470	30
Lrg	Kansas City, MO-KS	29	33	38	32	11,580	27,595	39,175	27
Med	Omaha, NE-IA	29	33	38	32	7,025	8,970	15,995	51
Med	Hartford-Middletown, CT	30	31	38	32	6,170	12,875	19,045	47
Lrg	Phoenix, AZ	29	33	37	37	37,880	29,760	67,640	19
Med	Charlotte, NC	29	33	37	37	8,390	7,985	16,375	50
Lrg	Cincinnati, OH-KY	28	39	36	39	18,940	16,295	35,235	29
Sml	Allentown-Bethlehem-Easton, PA-NJ	29	33	36	39	5,010	8,440	13,450	55

Table 6. Annual Person-Hours of Delay for 1996, continued

Population Group	Urban Area	Annual Person-Hours of Delay per Capita	Rank ¹	Annual Person-Hours of Delay per Eligible Driver	Rank ¹	Annual Person-Hours of Delay (000)			
						Recurring	Incident	Total	Rank ¹
Lrg	Minneapolis-St. Paul, MN	28	39	35	41	32,240	30,480	62,720	20
Med	Tacoma, WA	25	42	33	42	8,225	6,445	14,670	53
Lrg	Las Vegas, NV	25	42	32	43	13,425	12,960	26,385	40
Lrg	New Orleans, LA	25	42	32	43	11,130	16,190	27,320	39
Lrg	Columbus, OH	25	42	32	43	13,715	11,280	24,995	43
Med	Memphis, TN-AR-MS	24	48	32	43	9,745	13,635	23,380	44
Med	Indianapolis, IN	25	42	32	43	10,760	14,400	25,160	42
Lrg	Pittsburgh, PA	25	42	31	48	18,820	29,620	48,440	23
Med	Honolulu, HI	24	48	31	48	8,760	8,465	17,225	48
Lrg	Milwaukee, WI	23	50	30	50	14,330	14,810	29,140	35
Sml	Colorado Springs, CO	22	51	29	51	3,325	5,450	8,775	58
Med	Oklahoma City, OK	22	51	28	52	7,240	13,870	21,110	45
Vlg	Philadelphia, PA-NJ	22	51	28	52	47,540	69,040	116,580	10
Med	Tucson, AZ	21	54	27	54	6,290	7,240	13,530	54
Med	Salt Lake City, UT	19	55	27	54	9,650	7,180	16,830	49
Med	Rochester, NY	19	55	25	56	3,615	7,975	11,590	57
Lrg	Cleveland, OH	19	55	24	57	19,375	16,125	35,500	28
Med	Fresno, CA	16	59	22	58	3,305	5,015	8,320	59
Sml	Salem, OR	17	58	22	58	1,370	1,720	3,090	65
Sml	Spokane, WA	16	59	21	60	2,020	3,280	5,300	62
Sml	Albany-Schenectady-Troy, NY	15	61	19	61	3,030	4,310	7,340	61
Sml	Corpus Christi, TX	14	62	19	61	1,135	3,335	4,470	63
Lrg	Buffalo-Niagara Falls, NY	14	62	18	63	5,105	9,740	14,845	52
Med	El Paso, TX-NM	13	64	18	63	3,280	4,535	7,815	60
Sml	Bakersfield, CA	12	65	16	65	1,735	2,525	4,260	64
Sml	Eugene-Springfield, OR	11	66	15	66	860	1,480	2,340	66
Sml	Laredo, TX	10	67	15	66	625	900	1,525	67
Sml	Beaumont, TX	10	67	13	68	455	1,010	1,465	68
Sml	Boulder, CO	9	69	12	69	420	535	955	70
Sml	Brownsville, TX	7	70	11	70	400	595	995	69
	70 area average	30		40		28,015	38,268	66,282	
	Very large area average	46		59		115,476	171,632	287,108	
	Large area average	34		44		25,937	30,743	56,680	
	Medium area average	28		36		8,531	11,555	20,086	
	Small area average	16		22		1,914	3,242	5,155	

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

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

- , Drivers in Washington DC experience the most delay annually with 82 hours wasted per year.
- , Drivers in Brownsville experience the smallest amount of time wasted in traffic with 11 hours per year.
- , The Los Angeles urban area experienced the most delay in 1996 with about 684 million hours.
- , The Boulder urban area experienced the least delay in 1996 with about 955,000 hours.
- , Drivers spent the equivalent of more than 1.5 work weeks stuck in traffic in 11 urban areas in 1996.
- , Drivers spent the equivalent of at least 1 work week stuck in traffic in 28 urban areas in 1996.
- , Drivers spent at least one-half of a work week in 1996 stuck in traffic in 60 of the 70 urban areas in the study.
- , Several urban areas had much higher rankings in delay per driver than in total delay. This situation is usually seen in smaller urban areas that have a significant number of problem areas in the highway system. Total delay is usually correlated with size of area, while delay per driver is a congestion intensity measure.

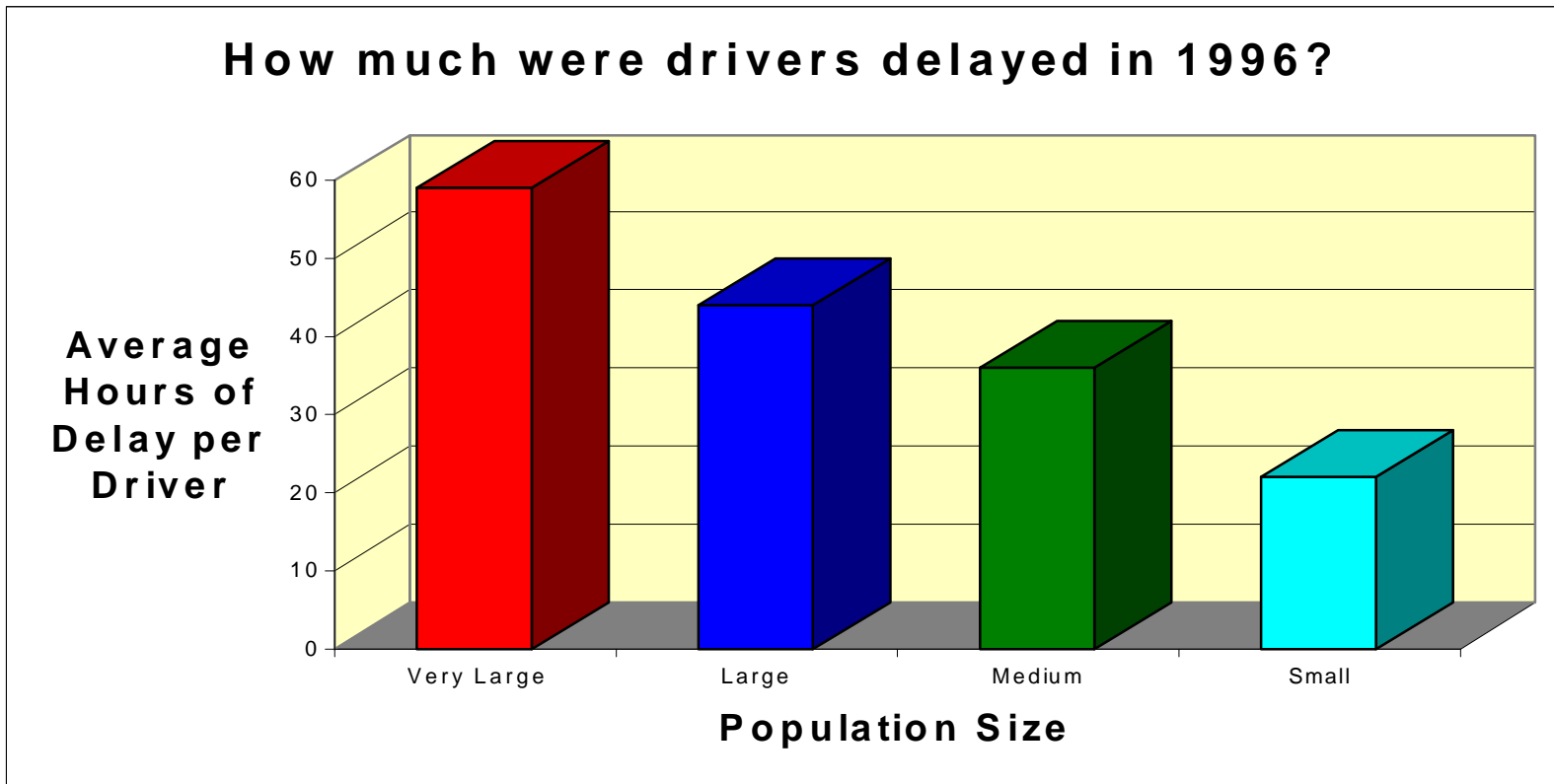
Austin		Medium	Total delay rank: 36, Delay/driver rank: 11
Nashville		Medium	Total delay rank: 37, Delay/driver rank: T12
Harrisburg		Small	Total delay rank: 56, Delay/driver rank: T15

- , Several urban areas had much higher rankings in total delay than in delay per driver. These were all in the large and very large size categories.

New York		Very Large	Total delay rank: 2, Delay/driver rank: T23
Chicago		Very Large	Total delay rank: 3, Delay/driver rank: T26
Philadelphia		Very Large	Total delay rank: 10, Delay/driver rank: T52
Cleveland		Large	Total delay rank: 28, Delay/driver rank: 57

- , Washington DC was the highest ranked Very Large urban area for delay per driver (1).
- , Seattle-Everett was the highest ranked Large urban area for delay per driver (3).
- , Austin was the highest ranked Medium urban area for delay per driver (1).
- , Harrisburg was the highest ranked Small urban area for delay per driver (T 15th).
- , The Large urban areas experienced twice as much delay per driver (44 hours) as the Small urban areas (22 hours).
- , The Medium urban areas experienced over 50% more delay per driver (36 hours) than the Small urban areas (22 hours).
- , The Very Large urban areas experienced about 1/3 more delay per driver (59 hours) as the Large urban areas (44 hours).
- , Very Large urban areas had, on average, over 50 times more delay per urban area (287 million hours) than the Small urban areas (5 million hours).
- , Very Large urban areas had, on average, about 14 times more delay per urban area (287 million hours) than the Medium urban areas (20 million hours).
- , Very Large urban areas had, on average, about 5 times more delay per urban area (287 million hours) than the Large urban areas (55 million hours).
- , On average, delay from incidents (accidents, breakdowns, etc.) Account for 58 percent of delay.

Exhibit 18



- , Annual delay per driver ranges from 22 hours per year in the Small urban areas to about 59 hours per year in the Very Large urban areas.
- , While total delay in the Very Large urban areas is 5 times that of the Large urban areas, delay per driver is only about 34 percent greater in the Very Large urban areas than the Large urban areas.
- , Delay per driver equates to about ½ work week in the Small urban areas.
- , Delay per driver equates to about 1 work week in the Medium urban areas.
- , Delay per driver equates to about 1 work week in the Large urban areas.
- , Delay per driver equates to about 1 ½ work weeks in the Very Large urban areas.
- , The average delay per driver for all 70 urban areas is equal to about 1 work week per year.

Table 7. Annual Person-Hours of Delay per Eligible Driver, 1982 to 1996

Population Group	Urban Area	Annual Delay per Eligible Driver							Percent Change 1982 - 1996	Percent Change 1992 - 1996
		1982	1986	1990	1992	1994	1995	1996		
Lrg	Kansas City, MO-KS	6	8	16	21	29	36	38	533	81
Med	Nashville, TN	19	24	30	33	49	52	58	205	76
Med	Indianapolis, IN	4	5	11	19	24	30	32	700	68
Lrg	Orlando FL	12	16	19	26	34	37	42	250	62
Med	Louisville, KY-IN	9	13	21	28	37	38	45	400	61
Med	Salt Lake City UT	5	6	10	17	21	24	27	440	59
Sml	Corpus Christi, TX	5	7	7	12	16	19	19	280	58
Lrg	Cincinnati OH-KY	7	9	18	23	31	33	36	414	57
Med	Jacksonville, FL	20	24	31	34	41	45	52	160	53
Med	Albuquerque NM	10	14	24	29	40	44	44	340	52
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	13	17	21	26	33	37	39	200	50
Med	Providence-Pawtucket RI-MA	11	17	22	26	32	35	39	255	50
Lrg	St Louis, MO-IL	20	24	29	35	45	48	52	160	49
Med	Oklahoma City OK	8	10	14	19	22	25	28	250	47
Med	Rochester, NY	4	7	13	17	18	24	25	525	47
Med	Hartford-Middletown CT	9	14	22	26	32	37	38	322	46
Sml	Bakersfield, CA	3	5	10	11	15	16	16	433	45
Lrg	Fort Worth TX	21	34	33	36	44	49	52	148	44
Lrg	Atlanta, GA	29	47	43	48	58	62	69	138	44
Med	Austin TX	29	42	42	43	55	58	61	110	42
Lrg	Cleveland, OH	5	8	14	17	21	22	24	380	41
Lrg	Portland-Vancouver OR-WA	16	18	26	34	39	44	48	200	41
Sml	Spokane, WA	8	12	14	15	20	19	21	163	40
Lrg	Sacramento CA	14	20	28	33	40	42	46	229	39
Med	Tampa, FL	21	24	27	28	34	38	39	86	39
Lrg	Las Vegas NV	15	20	24	23	28	30	32	113	39
Sml	Allentown-Bethlehem-Easton, PA-NJ	12	17	25	26	34	34	36	200	38
Sml	Brownsville TX	3	4	6	8	8	10	11	267	38
Med	Charlotte, NC	17	22	26	27	31	35	37	118	37
Lrg	Norfolk VA	18	25	28	30	32	36	41	128	37
Sml	Eugene-Springfield, OR	4	6	11	11	10	11	15	275	36
Sml	Laredo TX	6	6	8	11	11	14	15	150	36
Med	Omaha, NE-IA	12	18	25	28	34	35	38	217	36
Lrg	San Antonio TX	14	25	23	28	30	36	38	171	36
Sml	Boulder, CO	5	6	8	9	11	12	12	140	33
Lrg	Columbus OH	11	14	21	24	27	28	32	191	33
Med	Memphis, TN-AR-MS	7	10	17	24	29	32	32	357	33
Med	Fresno CA	10	15	17	17	19	21	22	120	29
Lrg	Buffalo-Niagara Falls, NY	6	9	12	14	14	15	18	200	29
Med	Tucson AZ	12	14	19	21	24	26	27	125	29

Table 7. Annual Person-Hours of Delay per Eligible Driver, 1982 to 1996, continued

Population Group	Urban Area	Annual Delay per Eligible Driver							Percent Change 1982 - 1996	Percent Change 1992 - 1996
		1982	1986	1990	1992	1994	1995	1996		
Lrg	San Jose, CA	34	50	55	53	54	62	68	100	28
Vlg	Detroit, MI	30	36	47	54	59	64	69	130	28
Vlg	Chicago, IL-Northwestern, IN	19	28	29	33	37	38	42	121	27
Sml	Harrisburg, PA	22	33	44	41	48	49	52	136	27
Lrg	Milwaukee, WI	9	13	20	24	27	29	30	233	25
Lrg	Minneapolis-St Paul, MN	9	15	24	28	31	34	35	289	25
Lrg	Pittsburgh, PA	13	20	24	25	27	31	31	138	24
Lrg	Denver, CO	24	28	35	42	43	44	52	117	24
Lrg	New Orleans, LA	15	25	26	26	30	31	32	113	23
Vlg	Boston, MA	26	39	44	47	49	55	57	119	21
Sml	Colorado Springs, CO	5	13	20	24	26	28	29	480	21
Lrg	Miami-Hialeah, FL	28	35	47	48	54	56	58	107	21
Med	El Paso, TX-NM	5	9	11	15	19	20	18	260	20
Lrg	Baltimore, MD	13	21	32	37	38	43	44	238	19
Vlg	New York NY-Northeastern, NJ	25	31	35	37	40	43	44	76	19
Sml	Albany-Schenectady-Troy, NY	6	10	13	16	18	19	19	217	19
Vlg	Washington, DC-MD-VA	42	55	65	70	70	79	82	95	17
Lrg	Dallas, TX	36	55	53	54	57	61	63	75	17
Sml	Salem, OR	6	11	16	19	22	23	22	267	16
Lrg	San Diego, CA	12	19	31	33	34	36	38	217	15
Lrg	Seattle-Everett, WA	26	41	55	62	67	67	71	173	15
Vlg	Houston, TX	50	53	55	58	63	64	66	32	14
Lrg	San Bernardino-Riverside, CA	33	55	59	58	60	60	65	97	12
Med	Honolulu, HI	19	22	23	28	30	32	31	63	11
Vlg	Los Angeles, CA	41	59	64	70	70	75	76	85	9
Sml	Beaumont, TX	4	9	9	12	12	13	13	225	8
Vlg	Philadelphia, PA-NJ	20	25	24	27	27	27	28	40	4
Vlg	San Francisco-Oakland, CA	39	60	66	65	65	66	66	69	2
Med	Tacoma, WA	13	20	30	33	34	34	33	154	0
Lrg	Phoenix, AZ	31	34	37	38	39	36	37	19	(3)
	70 area, average	16	22	27	30	35	37	40	208	33
	Very large area average	32	43	48	51	53	57	59	85	16
	Large area average	18	25	30	34	38	41	44	192	33
	Medium area average	12	17	22	26	31	34	36	260	42
	Small area average	7	11	15	17	19	21	22	249	32

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

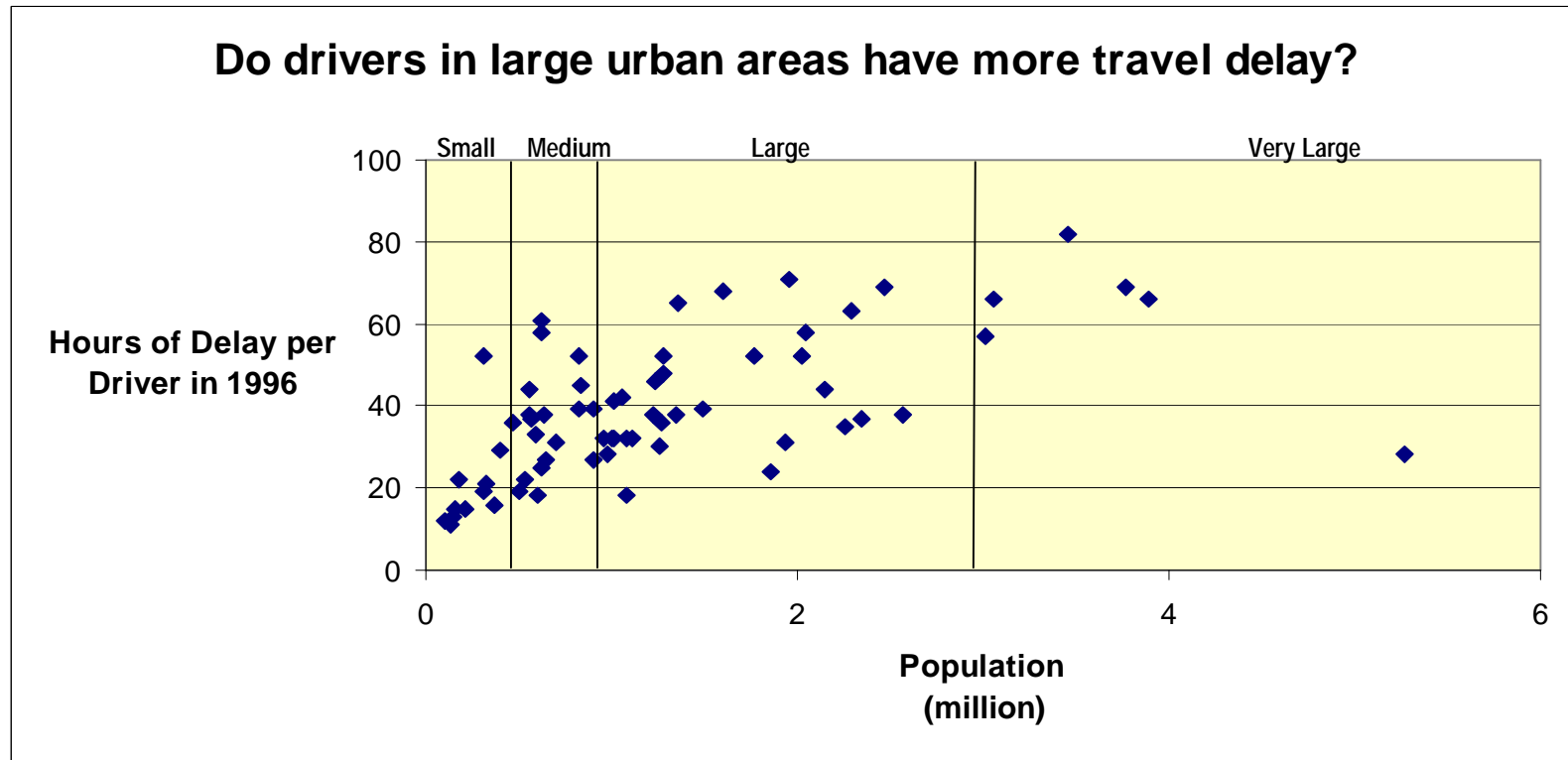
Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

- , The largest percent growth in delay per driver between 1982 and 1996 occurred in Indianapolis (700 percent).
- , The largest percent growth in delay per driver between 1992 and 1996 occurred in Kansas City (81 percent).
- , Phoenix experienced a decrease in delay per driver between 1992 and 1996.
- , Tacoma showed no increase in delay per driver between 1992 and 1996.
- , 11 urban areas have shown an increase in delay per driver of under 100 percent between 1982 and 1996.
- , 3 urban areas have shown an increase of over 500 percent in delay per driver between 1982 and 1996 (Kansas City, Indianapolis, and Rochester).
- , 8 urban areas have shown an increase of over 400 percent in delay per driver between 1982 and 1996.
- , 15 urban areas experienced a growth rate of greater than 10 percent per year in delay per driver between 1992 and 1996.
- , 49 urban areas experienced a growth rate of greater than 5 percent per year in delay per driver between 1992 and 1996.
- , The average increase for all 70 urban areas in delay per driver was 208 percent between 1982 and 1996 and 33 percent between 1992 and 1996.
- , The percent increase in delay per driver was more than double that of the Very Large urban areas in each of the other population groups for both 1982 to 1996 and 1992 to 1996.

Exhibit 19

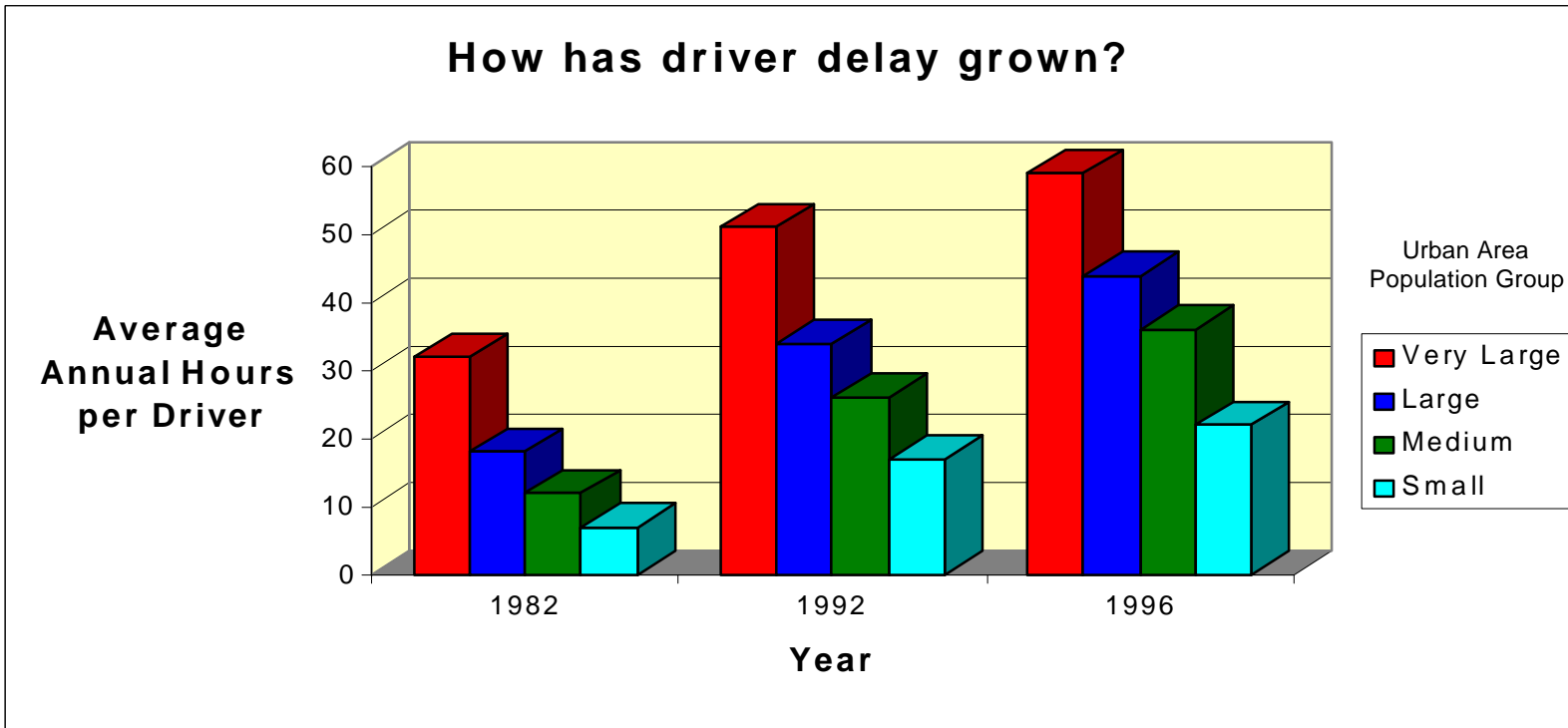


(Data from Los Angeles, New York, and Chicago have been omitted from the graph because they have very large populations). Their values are:

New York:	population 17,150,000	Delay per driver: 44
Los Angeles:	population 12,220,000	Delay per driver: 76
Chicago:	population 7,850,000	Delay per driver: 42

- , Generally, as the population of an area increases, the amount of delay each driver experiences.
- , In Small urban areas, the delay per driver ranges from about 15 to about 50 hours.
- , In Medium urban areas, the delay per driver ranges from about 20 to 60 hours.
- , In Large urban areas, the delay per driver ranges from about 20 to 70 hours.
- , In Very Large urban areas, the delay per driver ranges from about 30 to 80 hours.

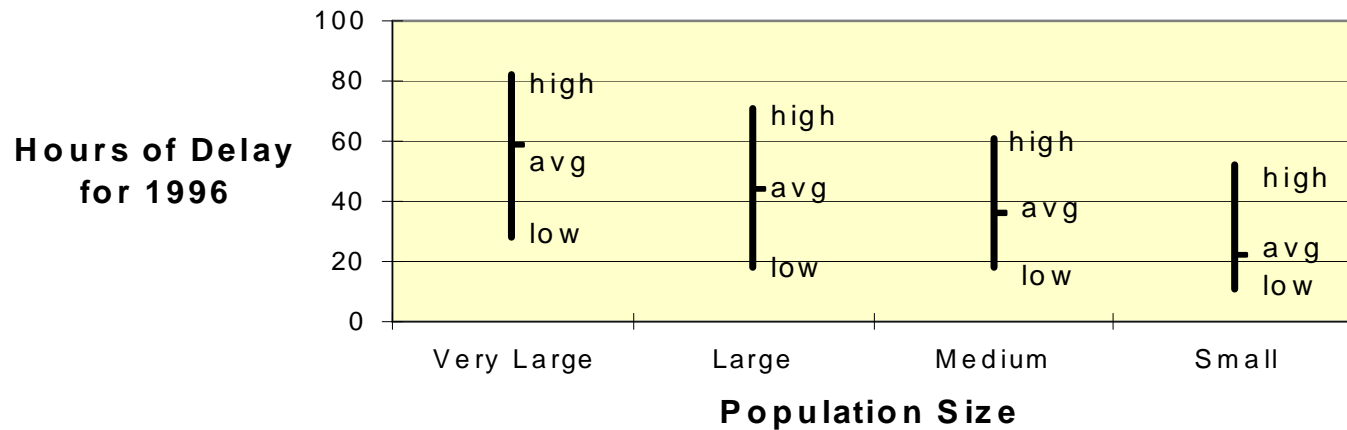
Exhibit 20



- , The delay per driver ranges from 7 hours in 1982 to 22 hours in 1996 for the Small urban areas.
- , The delay per driver ranges from 12 hours in 1982 to 36 hours in 1996 for the Medium urban areas.
- , The delay per driver ranges from 18 hours in 1982 to 44 hours in 1996 for the Large urban areas.
- , The delay per driver ranges from 32 hours in 1982 to 59 hours in 1996 for the Very Large urban areas.
- , The 1996 delay per driver in the Small urban areas is greater than the 1982 delay per driver in the Large urban areas.
- , The 1996 delay per driver in the Small urban areas is about equal to the 1992 delay per driver in the Medium urban areas.
- , The 1996 delay per driver in the Medium urban areas is larger than then 1992 delay per driver in the Large urban areas.
- , The hours of delay per driver since 1982 has more than doubled in the Small urban areas, tripled in the Medium urban areas, doubled in the Large urban areas, and almost doubled in the Very Large urban areas.

Exhibit 21

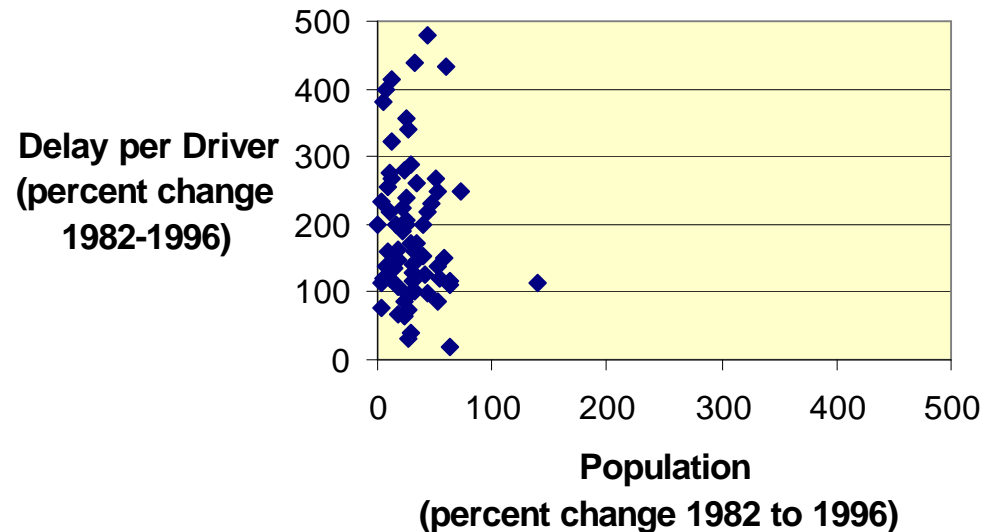
How much does delay vary by city size? (annual delay per driver)



- , Delay per driver ranges from 11 (Brownsville) to 52 (Harrisburg) hours per driver in the Small urban areas
- , The average delay per driver value in the Small urban areas is 22 hours per driver
- , Delay per driver ranges from 18 (El Paso) to 61 (Austin) hours per driver in the Medium urban areas
- , The average delay per driver value in the Medium urban areas is 36 hours per driver
- , Delay per driver ranges from 18 (Buffalo-Niagara Falls) to 71 (Seattle-Everett) hours per driver in the Large urban areas
- , The average delay per driver value in the Large urban areas is 44 hours per driver
- , Delay per driver ranges from 28 (Philadelphia) to 82 (Washington DC) hours per driver in the Very Large urban areas
- , The average delay per driver value in the Very Large urban areas is 59 hours per driver
- , The average delay per driver value is somewhat below the middle of the range of values for the Small urban areas
- , The average delay per driver values in the Medium and Large urban areas are very near to the middle of the range of values for delay per driver

Exhibit 22

Population Growth and Delay per Driver Growth, 1982 to 1996



(Data from Albany-Schenectady-Troy, Detroit, and Las Vegas have been omitted from the graph because they either have negative population growth or very high population growth).

Their values are:

Albany-Schenectady-Troy	population growth: -1%	delay/driver increase 82-96: 217%
Detroit	population growth: -1%	delay/driver increase 82-96: 130%
Las Vegas	population growth: 139%	delay/driver increase 82-96: 113%

, This graph shows that delay per driver is growing at a much quicker rate than population.

CHAPTER V—TRAVEL TIME

SUMMARY

The travel rate index is an indicator of the additional travel time that is necessary for an individual to make a trip during the peak period because of congestion. The index is defined as the travel rate (in minutes per mile) during the peak period divided by the rate in the off-peak. A travel rate index (TRI) of 1.30 indicates the average peak trip takes 30% longer than in the midday—a 20 minute trip becomes a 26 minute trip.

Twenty-four urban areas have travel rate indices of 1.30 or higher (Table 8). Forty-seven urban areas have travel rate indices of 1.20 or higher. This means that in about two-thirds of the urban areas studied, it takes an average of at least 20 percent longer to make a trip during peak travel times some corridors may be much worse. The urban areas with the highest travel rate index in 1996 for each population size are:

<i>Very Large</i>	<i>Los Angeles, CA</i>	<i>TRI: 1.51</i>
	<i>San Francisco-Oakland, CA</i>	
<i>Large</i>	<i>Seattle-Everett, WA</i>	<i>TRI: 1.51</i>
<i>Medium</i>	<i>Tacoma, WA</i>	<i>TRI: 1.34</i>
<i>Small</i>	<i>Allentown-Bethl-Easton, PA</i>	<i>TRI: 1.22</i>

Over half (39) of the urban areas had increases in their TRI values of more than 10 percent between 1982 and 1996 (Table 9). The average increase in the TRI values for all 70 urban areas between 1982 and 1996 was 11 percent. On average, the largest increase in travel times occurred in the Large urban areas, with 14 percent growth between 1982 and 1996. The smallest average increase occurred in the Small urban areas with a growth of about 6 percent in travel times between 1982 and 1996.

Examining the range of TRI values gives the reader the conclusion that traveling the same distance in large areas takes more time than in smaller areas. While not an earth-shattering conclusion, it does speak to the difficulty that growing areas face in developing transportation facilities and programs.

BACKGROUND

The Travel Rate Index (TRI) is another way of looking at how fast a peak period trip occurs; it focuses on time rather than the more traditional measure—speed. The TRI indicates how much longer it takes to make a trip than would be the case if the trip occurred in uncongested conditions. A TRI value of 1.30 indicates that it takes 30 percent longer to make a trip than it would take if the travel occurred at off-peak (freeflow) speeds. The TRI equation is shown below. The TRI is a weighted average of the peak period travel rates on the freeway and principal arterial streets.

TABLES AND EXHIBITS

Table 8 displays the Travel Rate Index and associated rank for each urban area for 1996. Also shown are the peak period speeds on the freeways and principal arterial streets.

Following Table 8 are several graphs displaying information from the table including:

- , the range of TRI values for urban area sizes
- , the average freeway and principal arterial street speeds for each urban area size group
- , the average TRI values for urban area size groups

The travel rate index values for each urban area are shown in Table 9 for selected years between 1982 and 1996. Also shown are the percent changes for the periods 1982 to 1996 and 1992 to 1996.

Following Table 9 are charts showing the relationship between:

- , percent change in TRI from 1982 to 1996, and 1996 population
- , the range of percent change in TRI from 1982 to 1996 by population size
- , the average TRI values for 1982, 1992, 1996 by population size
- , the percent change in TRI and the percent change in population from 1982 to 1996

$$\text{Travel Rate Index} = \frac{\left(\frac{\text{Freeway Peak Period Travel Rate}}{\text{Freeway Freeflow Travel Rate}} \times \frac{\text{Freeway Peak Period VMT}}{\text{Freeway Peak Period VMT}} \right) \% \left(\frac{\text{Principal Arterial Street Peak Period Travel Rate}}{\text{Principal Arterial Street Freeflow Travel Rate}} \times \frac{\text{Principal Arterial Street Peak Period VMT}}{\text{Principal Arterial Street Peak Period VMT}} \right)}{\left(\frac{\text{Freeway Peak Period VMT}}{\text{Freeway Peak Period VMT}} \% \frac{\text{Principal Arterial Street Peak Period VMT}}{\text{Principal Arterial Street Peak Period VMT}} \right)}$$

Table 8. Travel Rate Index for 1996

Population Group	Urban Area	Travel Rate Index		Peak Period Speeds	
		1996	Rank	Freeway	Principal Arterial Street
Vlg	Los Angeles, CA	1.51	1	35	28
Vlg	San Francisco-Oakland, CA	1.51	1	38	28
Lrg	Seattle-Everett, WA	1.51	1	37	29
Vlg	Washington, DC-MD-VA	1.48	4	39	26
Lrg	Las Vegas, NV	1.45	5	39	27
Vlg	Houston, TX	1.42	6	40	29
Lrg	San Jose, CA	1.41	7	40	28
Vlg	Chicago, IL-Northwestern, IN	1.40	8	40	27
Vlg	New York, NY-Northeastern, NJ	1.40	8	42	26
Lrg	San Bernardino-Riverside, CA	1.40	8	39	29
Lrg	Miami-Hialeah, FL	1.39	11	39	27
Lrg	Atlanta, GA	1.38	12	42	27
Lrg	Denver, CO	1.36	13	42	28
Vlg	Detroit, MI	1.35	14	42	28
Lrg	San Diego, CA	1.35	14	42	30
Lrg	Sacramento, CA	1.34	16	43	28
Med	Tacoma, WA	1.34	16	41	31
Lrg	Dallas, TX	1.32	18	44	30
Lrg	Phoenix, AZ	1.32	18	42	28
Lrg	Portland-Vancouver, OR-WA	1.32	18	44	28
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	1.31	21	44	29
Med	Honolulu, HI	1.31	21	46	27
Med	Austin, TX	1.30	23	45	29
Lrg	Minneapolis-St. Paul, MN	1.30	23	45	29
Lrg	Cincinnati, OH-KY	1.29	25	45	30
Lrg	Milwaukee, WI	1.27	26	44	30
Lrg	New Orleans, LA	1.27	26	46	29
Lrg	Orlando, FL	1.27	26	45	29
Vlg	Boston, MA	1.26	29	46	29
Vlg	Philadelphia, PA-NJ	1.26	29	49	27
Med	Salt Lake City, UT	1.26	29	46	29
Lrg	St. Louis, MO-IL	1.26	29	48	27
Med	Charlotte, NC	1.25	33	48	28
Lrg	Fort Worth, TX	1.25	33	46	31
Med	Jacksonville, FL	1.25	33	47	29
Med	Tampa, FL	1.25	33	49	27
Lrg	Columbus, OH	1.24	37	48	29
Med	Omaha, NE-IA	1.24	37	51	27
Med	Tucson, AZ	1.24	37	50	28
Lrg	Cleveland, OH	1.23	40	48	29

Table 8. Travel Rate Index for 1996, continued

Population Group	Urban Area	Travel Rate Index		Peak Period Speeds	
		1996	Rank	Freeway	Principal Arterial Street
Lrg	Norfolk, VA	1.23	40	47	30
Med	Providence-Pawtucket, RI-MA	1.23	40	47	30
Med	Albuquerque, NM	1.22	43	47	29
Sml	Allentown-Bethlehem-Easton, PA-NJ	1.22	43	52	27
Lrg	Baltimore, MD	1.22	43	48	31
Lrg	San Antonio, TX	1.22	43	48	31
Med	Memphis, TN-AR-MS	1.20	47	50	29
Sml	Colorado Springs, CO	1.19	48	50	29
Med	Nashville, TN	1.19	48	50	30
Lrg	Pittsburgh, PA	1.19	48	53	28
Sml	Harrisburg, PA	1.18	51	54	27
Med	Louisville, KY-IN	1.18	51	52	28
Med	Fresno, CA	1.17	53	53	29
Med	Rochester, NY	1.15	54	52	31
Med	Hartford-Middletown, CT	1.14	55	52	31
Med	Indianapolis, IN	1.14	55	52	31
Sml	Salem, OR	1.14	55	52	31
Med	Oklahoma City, OK	1.13	58	53	31
Lrg	Kansas City, MO-KS	1.12	59	54	31
Sml	Laredo, TX	1.12	59	57	30
Sml	Spokane, WA	1.12	59	53	31
Lrg	Buffalo-Niagara Falls, NY	1.11	62	54	31
Med	El Paso, TX-NM	1.11	62	51	33
Sml	Bakersfield, CA	1.10	64	56	31
Sml	Brownsville, TX	1.10	64	57	31
Sml	Eugene-Springfield, OR	1.10	64	58	30
Sml	Boulder, CO	1.09	67	59	30
Sml	Albany-Schenectady-Troy, NY	1.08	68	59	30
Sml	Corpus Christi, TX	1.06	69	56	34
Sml	Beaumont, TX	1.05	70	58	32
	70 area average	1.25		48	29
	Very large area average	1.40		41	28
	Large area average	1.30		45	29
	Medium area average	1.22		49	29
	Small area average	1.12		55	30

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

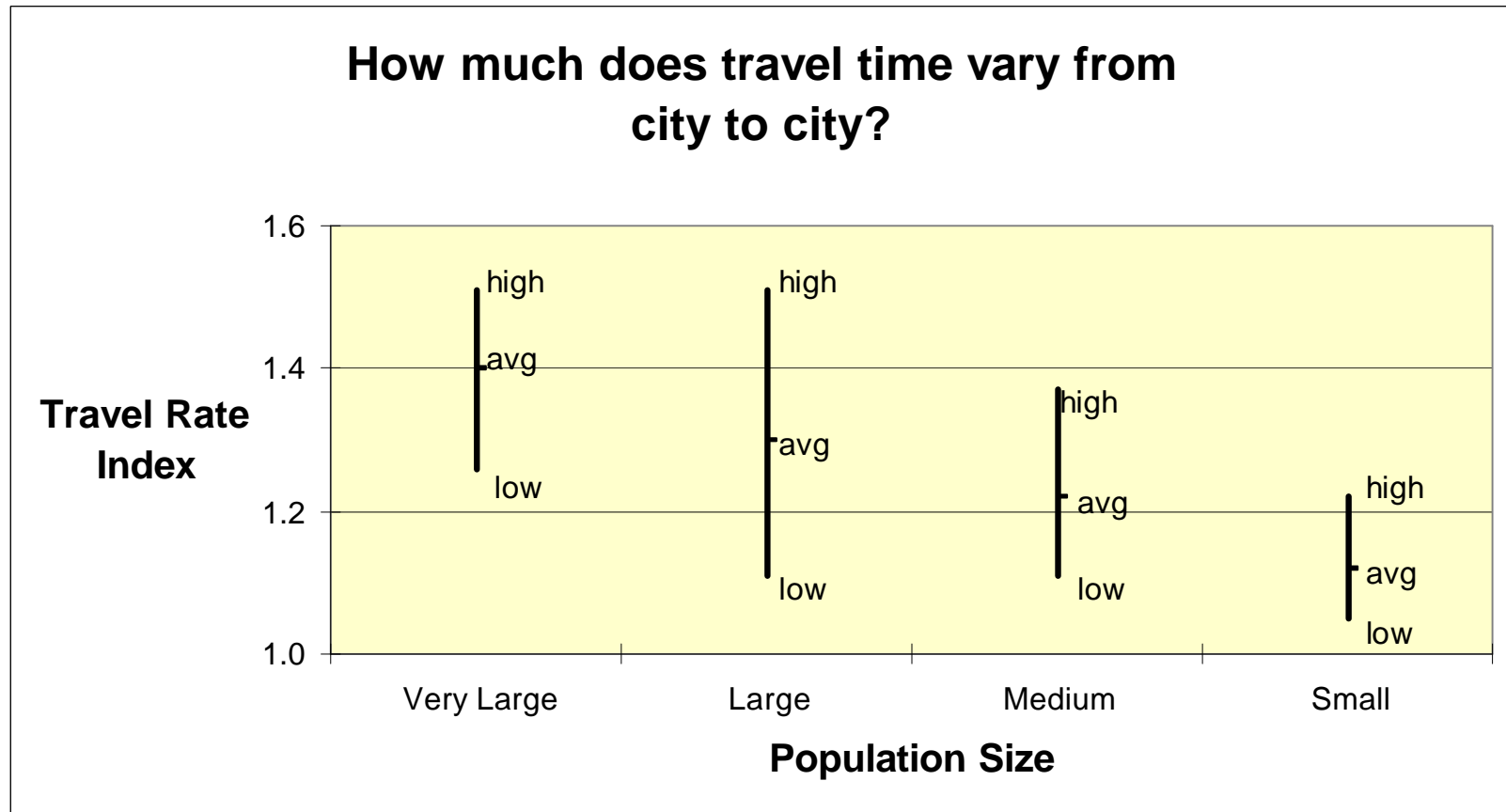
Sml — Small urban areas - less than 500,000 population

- , The urban area with highest travel rate index in 1996 for each population size:
 - Very Large Los Angeles TRI: 1.51 (T 1st)
San Francisco-Oakland
 - Large Seattle-Everett TRI: 1.51 (T 1st)
 - Medium Tacoma TRI: 1.34 (T 16th)
 - Small Allentown-Bethl-Easton TRI: 1.22 (T 43rd)
- , The urban area with the lowest travel rate index in 1996 for each population size:
 - Very Large Philadelphia TRI: 1.26 (T 29th)
Boston
 - Large Buffalo-Niagara Falls TRI: 1.11 (T 62nd)
 - Medium El Paso TRI: 1.11 (T 62nd)
 - Small Beaumont TRI: 1.05 (70th)
- , Honolulu (1.31) and Austin (1.30) are two Medium urban areas that rank relatively high.
- , Kansas City (1.12) is a Large urban area that ranks relatively low.
- , 10 urban areas have TRI values of at least 1.40, meaning it takes 40% longer to drive somewhere in the peak than in the off-peak.
- , 24 urban areas have TRI values of at least 1.30.
- , 47 urban areas have TRI values of at least 1.20.
- , 23 urban areas have TRI values less than 1.20, meaning it will take less than 20% longer to drive somewhere in the peak than in the off-peak.
- , 44 urban areas have peak period freeway speeds of greater than 45 miles per hour. There are undoubtedly, however, locations of stop-and-go traffic in most of these areas. Average speeds are relatively high.

Converting Speed to Travel Rate

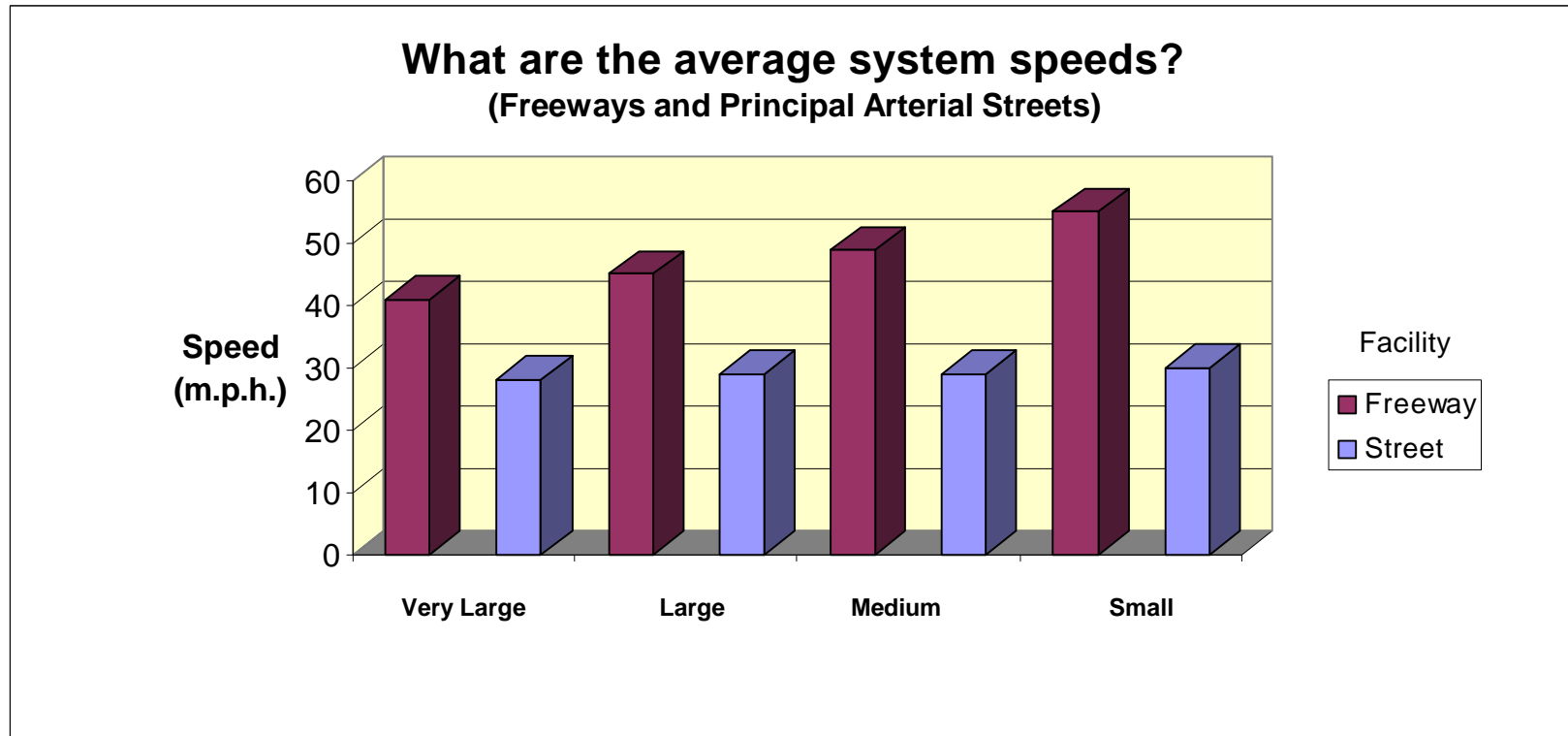
Freeway Speed	Travel Rate	It will take you this much longer than during free-flow conditions.	A 20-minute trip becomes:
60	1.00	No extra time	20 minutes
45	1.33	33%	27 minutes
35	1.71	71%	34 minutes
30	2.00	100%	40 minutes
20	3.00	200%	60 minutes

Exhibit 23



- , The range of TRI values for the Very Large urban areas is 1.26 (Low) to 1.51 (High) with an average TRI value of 1.40.
- , The range of TRI values for the Large urban areas is 1.11 (Low) to 1.51 (High) with an average TRI value of 1.30.
- , The range of TRI values for the Medium urban areas is 1.11 (Low) to 1.34 (High) with an average TRI value of 1.22.
- , The range of TRI values for the Small urban areas is 1.05 (Low) to 1.22 (High) with an average TRI value of 1.12.
- , The Large urban area group has the widest range of TRI values with 0.40 separating the High and Low values.
- , The Small urban area group has the narrowest range of TRI values with 0.17 separating the High and Low values.
- , The average TRI value for each population size tends to grow by about 0.10 as the population size group increases: Small (1.12), Medium (1.22), Large (1.30), and Very Large (1.40).

Exhibit 24



, The average peak period freeway speeds for each of the population sizes in 1996 are:

Very Large	41 mph
Large	45 mph
Medium	49 mph
Small	55 mph

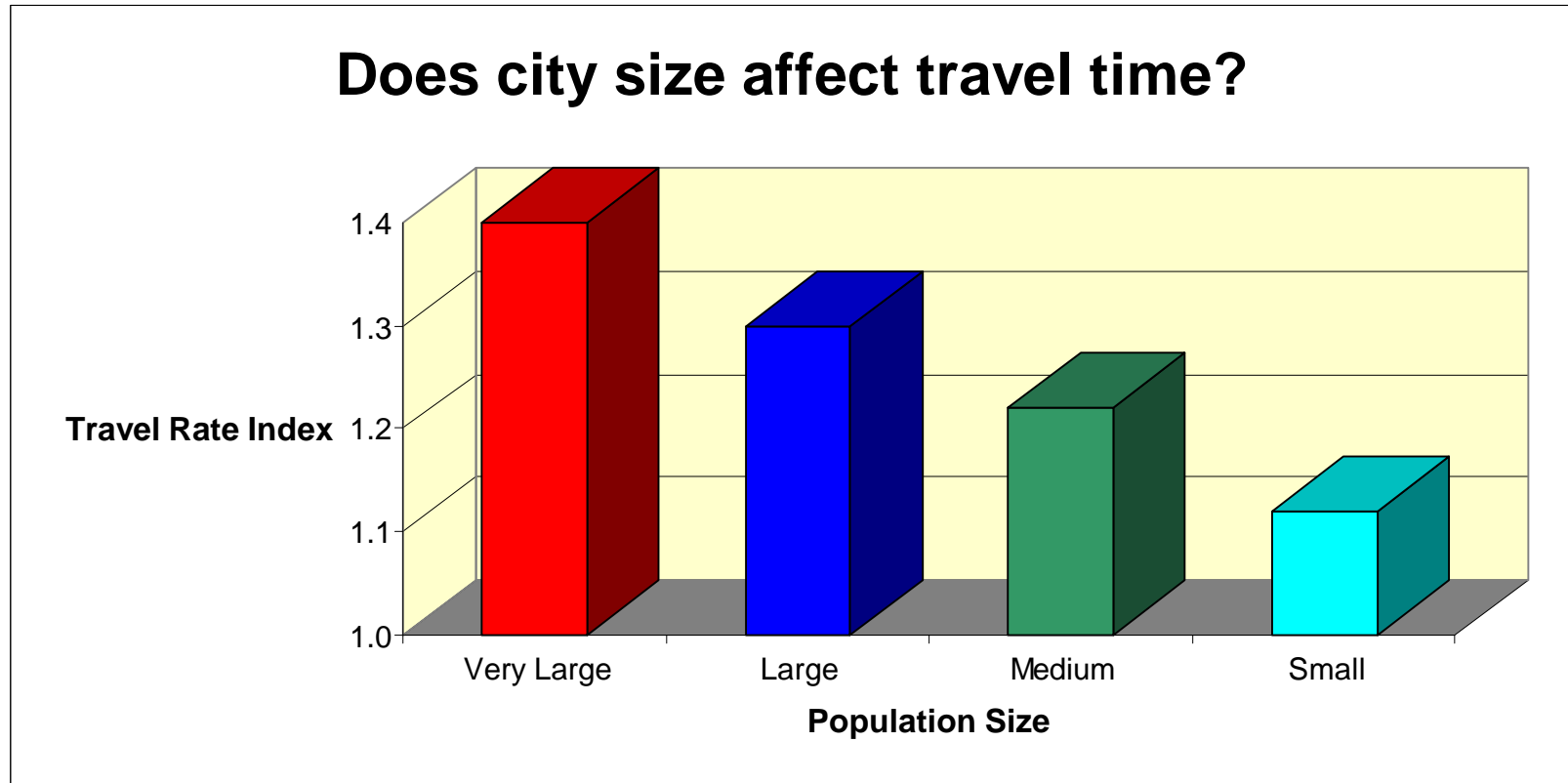
, The average peak period principal arterial street speeds for each of the population sizes in 1996 are:

Very Large	28 mph
Large	29 mph
Medium	29 mph
Small	30 mph

, There is a much wider gap between peak period freeway and principal arterial speeds as the population size gets smaller.

, There is not much difference between the principal peak period arterial speeds across the 4 population sizes.

Exhibit 25



- , The TRI values range from 1.12 in the Small urban area groups up to 1.40 in the Very Large urban area group.
- , The TRI values increase by about 0.1 for each increase in population size.
- , The TRI value in Very Large urban areas shows that it takes about 40 percent longer to make a trip because of congestion while in the Small urban areas it only takes about 10 percent longer to make the trip due to congestion

Table 9. Travel Rate Index, 1982 to 1996

Population Group	Urban Area	1982	1986	1990	1992	1994	1995	1996	Percent Change			
									Long-term 1982 to 1996		Short-term 1992 to 1996	
									Percent	Rank	Percent	Rank
Lrg	Las Vegas, NV	1.17	1.22	1.28	1.29	1.36	1.40	1.45	24	2	12	1
Lrg	Cincinnati, OH-KY	1.07	1.09	1.15	1.19	1.25	1.26	1.29	20	3	9	2
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	1.11	1.15	1.19	1.21	1.24	1.28	1.31	18	9	9	2
Lrg	Sacramento, CA	1.11	1.14	1.20	1.24	1.29	1.30	1.34	20	3	8	4
Med	Salt Lake City, UT	1.06	1.07	1.12	1.17	1.21	1.24	1.26	19	7	8	4
Lrg	Seattle-Everett, WA	1.19	1.27	1.38	1.40	1.45	1.46	1.51	27	1	8	4
Lrg	Portland-Vancouver, OR-WA	1.16	1.16	1.19	1.24	1.27	1.30	1.32	14	18	7	7
Lrg	Atlanta, GA	1.20	1.26	1.26	1.31	1.31	1.34	1.38	15	13	6	8
Lrg	Cleveland, OH	1.07	1.10	1.13	1.16	1.20	1.21	1.23	15	13	6	8
Lrg	Denver, CO	1.18	1.21	1.25	1.28	1.29	1.29	1.36	15	13	6	8
Med	Jacksonville, FL	1.11	1.12	1.17	1.18	1.21	1.23	1.25	13	20	6	8
Lrg	Miami-Hialeah, FL	1.23	1.27	1.31	1.31	1.34	1.36	1.39	13	20	6	8
Lrg	Orlando, FL	1.09	1.12	1.16	1.20	1.23	1.24	1.27	17	10	6	8
Lrg	San Jose, CA	1.21	1.31	1.34	1.33	1.35	1.39	1.41	16	12	6	8
Lrg	St. Louis, MO-IL	1.15	1.15	1.16	1.19	1.24	1.24	1.26	10	36	6	8
Med	Albuquerque, NM	1.07	1.09	1.14	1.17	1.21	1.23	1.22	14	18	5	16
Med	Charlotte, NC	1.12	1.15	1.18	1.20	1.22	1.25	1.25	12	24	5	16
Vlg	Chicago, IL-Northwestern, IN	1.26	1.32	1.30	1.33	1.36	1.36	1.40	11	30	5	16
Lrg	Columbus, OH	1.12	1.12	1.15	1.19	1.22	1.22	1.24	12	24	5	16
Lrg	Fort Worth, TX	1.13	1.19	1.19	1.19	1.21	1.24	1.25	10	36	5	16
Lrg	Kansas City, MO-KS	1.03	1.03	1.06	1.07	1.10	1.12	1.12	9	40	5	16
Lrg	Minneapolis-St. Paul, MN	1.10	1.14	1.22	1.24	1.27	1.30	1.30	19	7	5	16
Med	Nashville, TN	1.10	1.10	1.12	1.13	1.17	1.17	1.19	8	50	5	16
Lrg	Norfolk, VA	1.13	1.17	1.18	1.18	1.19	1.21	1.23	9	40	5	16
Med	Oklahoma City, OK	1.04	1.05	1.06	1.08	1.10	1.12	1.13	9	40	5	16
Med	Providence-Pawtucket, RI-MA	1.09	1.12	1.14	1.16	1.19	1.22	1.23	13	20	5	16
Med	Tampa, FL	1.17	1.18	1.19	1.19	1.23	1.26	1.25	7	52	5	16
Sml	Allentown-Bethlehem-Easton, PA-NJ	1.10	1.12	1.17	1.18	1.21	1.21	1.22	11	30	4	28
Sml	Colorado Springs, CO	1.03	1.08	1.11	1.15	1.16	1.18	1.19	15	13	4	28
Lrg	Dallas, TX	1.21	1.28	1.27	1.27	1.28	1.31	1.32	9	40	4	28
Vlg	Detroit, MI	1.20	1.23	1.28	1.30	1.32	1.35	1.35	12	24	4	28
Med	Hartford-Middletown, CT	1.04	1.06	1.08	1.10	1.12	1.13	1.14	9	40	4	28
Vlg	Los Angeles, CA	1.34	1.44	1.42	1.45	1.45	1.50	1.51	12	24	4	28
Med	Louisville, KY-IN	1.07	1.09	1.12	1.14	1.17	1.16	1.18	10	36	4	28
Lrg	Milwaukee, WI	1.09	1.12	1.20	1.23	1.25	1.26	1.27	17	10	4	28
Lrg	San Diego, CA	1.13	1.17	1.27	1.30	1.32	1.33	1.35	20	3	4	28

Table 9. Travel Rate Index, 1982 to 1996, continued

Population Group	Urban Area	1982	1986	1990	1992	1994	1995	1996	Percent Change			
									Long-term 1982 to 1996		Short-term 1992 to 1996	
									Percent	Rank	Percent	Rank
Sml	Bakersfield, CA	1.02	1.03	1.05	1.07	1.09	1.09	1.10	7	52	3	37
Lrg	Baltimore, MD	1.08	1.12	1.16	1.19	1.19	1.22	1.22	12	24	3	37
Vlg	Boston, MA	1.14	1.18	1.22	1.22	1.23	1.26	1.26	11	30	3	37
Sml	Brownsville, TX	1.03	1.04	1.06	1.07	1.08	1.09	1.10	7	52	3	37
Med	Fresno, CA	1.08	1.11	1.13	1.14	1.16	1.17	1.17	9	40	3	37
Med	Indianapolis, IN	1.03	1.03	1.07	1.11	1.12	1.15	1.14	11	30	3	37
Sml	Laredo, TX	1.08	1.08	1.08	1.09	1.10	1.11	1.12	4	64	3	37
Med	Memphis, TN-AR-MS	1.06	1.08	1.13	1.16	1.17	1.19	1.20	13	20	3	37
Vlg	New York, NY-Northeastern, NJ	1.29	1.30	1.34	1.36	1.37	1.40	1.40	9	40	3	37
Med	Omaha, NE-IA	1.11	1.15	1.19	1.20	1.22	1.22	1.24	12	24	3	37
Lrg	Pittsburgh, PA	1.12	1.16	1.17	1.16	1.18	1.20	1.19	7	52	3	37
Med	Rochester, NY	1.04	1.07	1.09	1.11	1.12	1.14	1.15	10	36	3	37
Lrg	San Antonio, TX	1.12	1.17	1.17	1.18	1.19	1.22	1.22	9	40	3	37
Lrg	San Bernardino-Riverside, CA	1.21	1.31	1.35	1.35	1.36	1.36	1.40	15	13	3	37
Sml	Spokane, WA	1.06	1.07	1.09	1.09	1.11	1.11	1.12	6	57	3	37
Vlg	Washington, DC-MD-VA	1.33	1.36	1.40	1.44	1.43	1.47	1.48	11	30	3	37
Sml	Boulder, CO	1.06	1.07	1.08	1.08	1.09	1.09	1.09	4	64	2	53
Lrg	Buffalo-Niagara Falls, NY	1.05	1.07	1.08	1.09	1.09	1.10	1.11	6	57	2	53
Med	El Paso, TX-NM	1.04	1.05	1.07	1.09	1.11	1.12	1.11	7	52	2	53
Sml	Harrisburg, PA	1.12	1.14	1.16	1.15	1.17	1.17	1.18	5	62	2	53
Lrg	New Orleans, LA	1.17	1.25	1.24	1.24	1.25	1.25	1.27	8	50	2	53
Lrg	Phoenix, AZ	1.21	1.28	1.28	1.29	1.33	1.30	1.32	9	40	2	53
Sml	Salem, OR	1.05	1.08	1.10	1.12	1.14	1.14	1.14	9	40	2	53
Med	Tacoma, WA	1.12	1.18	1.25	1.31	1.34	1.34	1.34	20	3	2	53
Med	Tucson, AZ	1.17	1.17	1.20	1.21	1.23	1.23	1.24	6	57	2	53
Sml	Albany-Schenectady-Troy, NY	1.04	1.05	1.06	1.07	1.08	1.08	1.08	4	64	1	62
Med	Austin, TX	1.22	1.27	1.28	1.28	1.30	1.30	1.30	6	57	1	62
Sml	Beaumont, TX	1.02	1.03	1.04	1.04	1.05	1.05	1.05	4	64	1	62
Sml	Corpus Christi, TX	1.02	1.03	1.03	1.05	1.05	1.06	1.06	3	70	1	62
Sml	Eugene-Springfield, OR	1.05	1.06	1.08	1.08	1.08	1.09	1.10	4	64	1	62
Med	Honolulu, HI	1.23	1.26	1.28	1.30	1.29	1.31	1.31	6	57	1	62
Vlg	Houston, TX	1.37	1.44	1.40	1.40	1.41	1.41	1.42	4	64	1	62
Vlg	Philadelphia, PA-NJ	1.20	1.22	1.22	1.25	1.25	1.25	1.26	5	62	1	62
Vlg	San Francisco-Oakland, CA	1.36	1.48	1.51	1.51	1.51	1.51	1.51	11	30	0	70
	70 area average	1.13	1.16	1.19	1.21	1.23	1.24	1.25	11		4	
	Very large area average	1.28	1.33	1.34	1.36	1.37	1.39	1.40	10		3	
	Large area average	1.14	1.18	1.21	1.23	1.26	1.28	1.30	14		5	
	Medium area average	1.10	1.12	1.15	1.17	1.20	1.21	1.22	11		4	
	Small area average	1.05	1.07	1.09	1.10	1.11	1.11	1.12	6		2	

Vlg — Very Large urban areas - over 3 million population
Lrg — Large urban areas - over 1 million and less than 3 million population

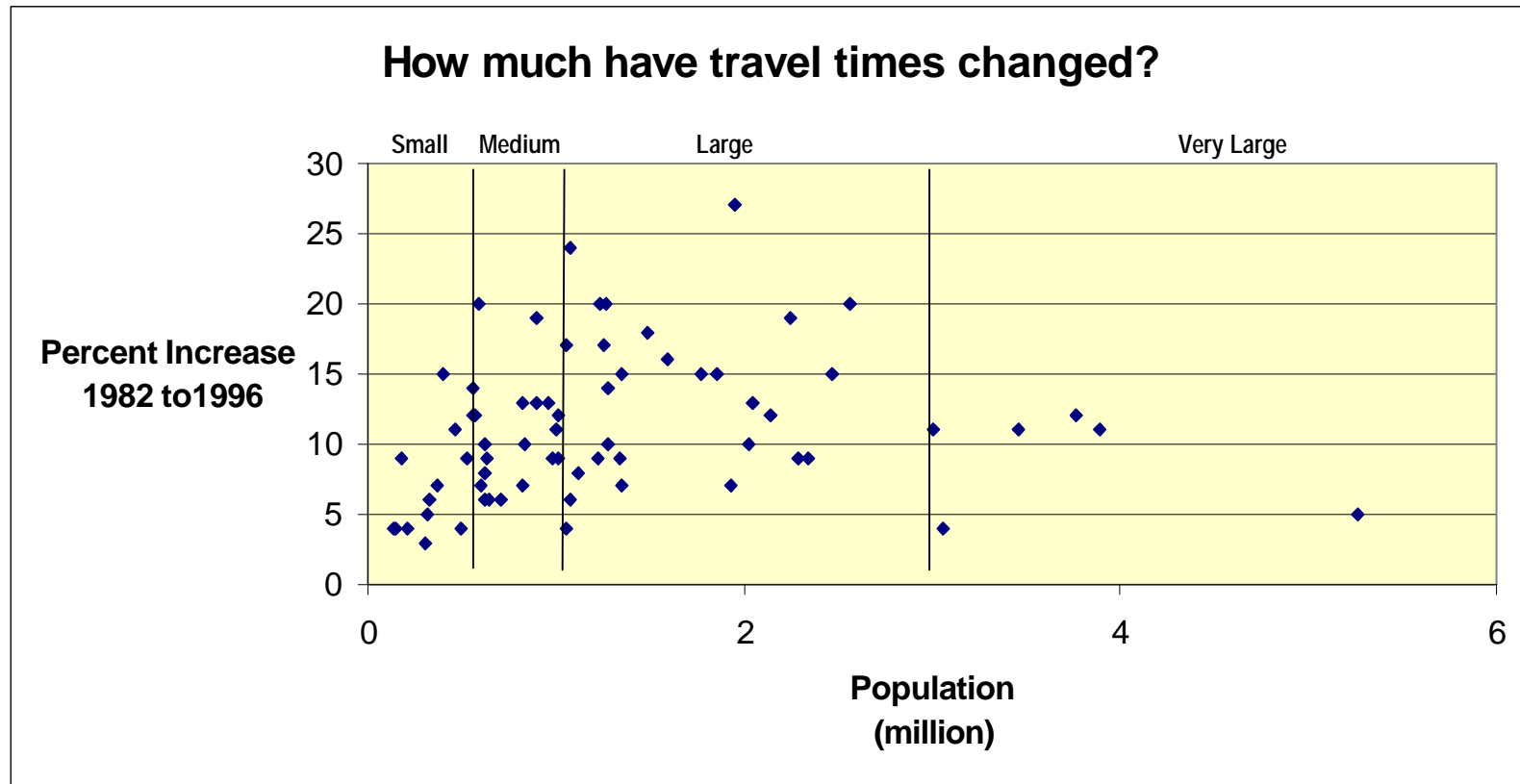
Med — Medium urban areas - over 500,000 and less than 1 million population
Sml — Small urban areas - less than 500,000 population

- , The urban area with the greatest percentage increase in TRI values between 1982 and 1996 for each population size:

Very Large	Detroit	% change 82-96: 12%
	Los Angeles	
Large	Seattle-Everett	% change 82-96: 27%
Medium	Tacoma	% change 82-96: 20%
Small	Colorado Springs	% change 82-96: 15%
- , The urban area with the greatest percentage increase in TRI values between 1992 and 1996 for each population size:

Very Large	Chicago	% change 92-96: 5%
Large	Las Vegas	% change 92-96: 12%
Medium	Salt Lake City	% change 92-96: 8%
Small	Allentown-Bethl-Easton	% change 92-96: 4%
	Colorado Springs	
- , 39 urban areas had increases in their TRI values of more than 10 percent between 1982 and 1996.
- , 12 urban areas experienced at least half of their 1982 to 1996 increase in TRI values between 1992 and 1996.
- , On average, the largest increase in TRI values occurred in the Large urban areas with 14% between 1982 and 1996 and 5% between 1992 and 1996.
- , On average, the smallest increase in TRI values occurred in the Small urban areas with 6% between 1982 and 1996 and 2% between 1992 and 1996.
- , The average increase in the TRI values for all 70 urban areas between 1982 and 1996 was 11%; between 1992 and 1996 it was 4%.
- , The Very Large and Small urban areas had percent increases for 1982 to 1996 and 1992 to 1996 that were smaller than the 70 urban area average.

Exhibit 26



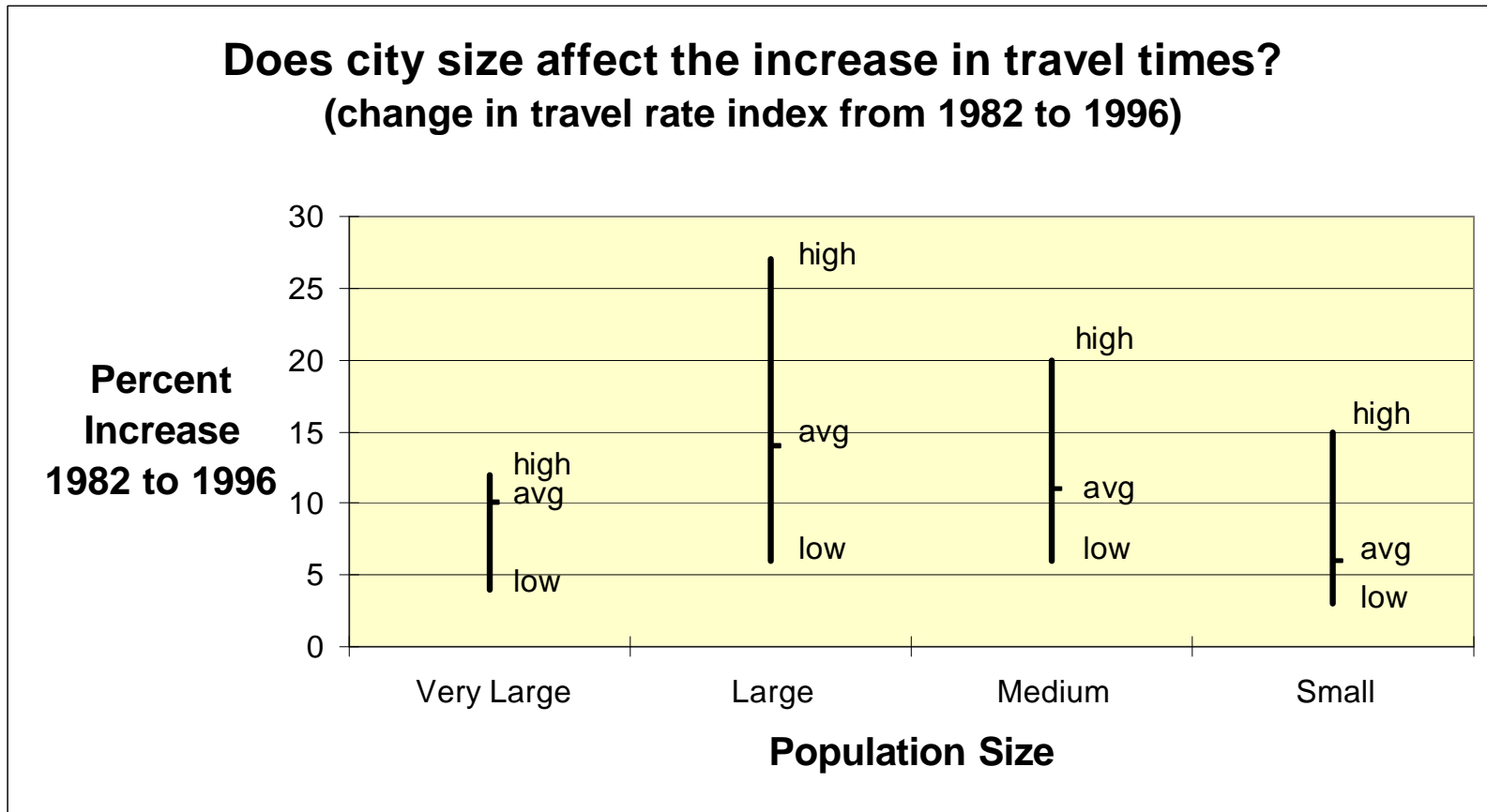
(Data from Los Angeles, New York, and Chicago have been omitted from the graph because they have large populations).

Their values are:

New York	population 17,150,000	% increase 82-96: 9%
Los Angeles	population 12,220,000	% increase 82-96: 12%
Chicago	population 7,850,000	% increase 82-96: 11%

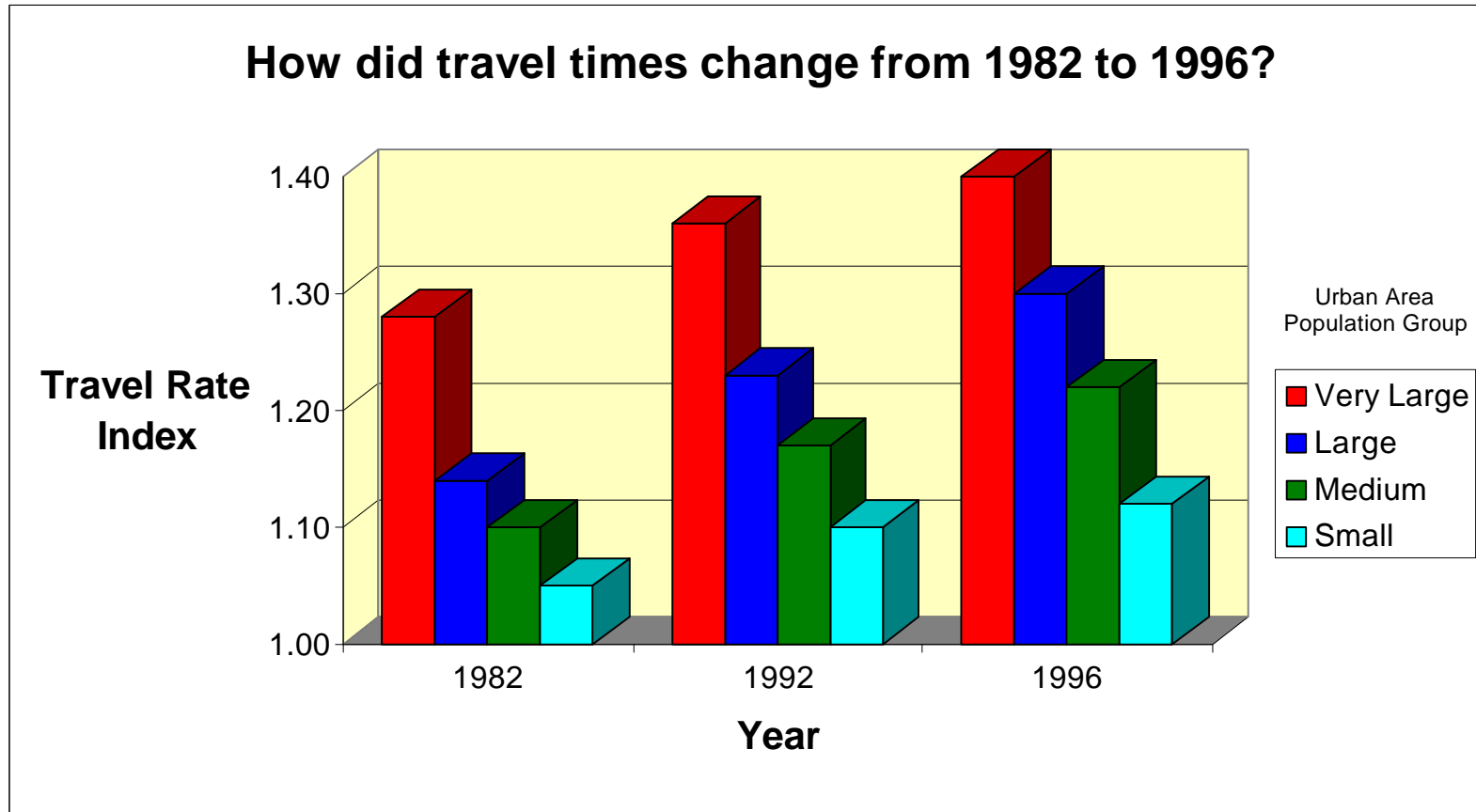
- , The Small urban areas experienced percent increases in the TRI of between 3% and 15% between 1982 and 1996.
- , The Medium urban areas experienced percent increases in the TRI of between 6% and 20% between 1982 and 1996.
- , The Large urban areas experienced percent increases in the TRI of between 6% and 27% between 1982 and 1996.
- , The Very Large urban areas experienced percent increases in the TRI of between 4% and 12% between 1982 and 1996.
- , In general, the Medium and Large population sizes experienced greater increases in the TRI between 1982 and 1996 than the Small and Very Large urban areas.

Exhibit 27



- , The Very Large urban areas experienced a range of percent increases in TRI of 4% to 12% between 1982 and 1996.
- , The Large urban areas experienced a range of percent increases in TRI of 6% to 27% between 1982 and 1996.
- , The Medium urban areas experienced a range of percent increases in TRI of 6% to 20% between 1982 and 1996.
- , The Small urban areas experienced a range of percent increases in TRI of 3% to 15% between 1982 and 1996.
- , The average percent increases between 1982 and 1996 for Very Large urban areas was 10%, for Large urban areas was 14%, for Medium urban areas was 11%, and for Small urban areas was 6%.
- , The range of percent increases in TRI was greatest for the Large population size with over 21 percentage points separating the high and low.
- , The range of percent increases in TRI was smallest for the Very Large population size with only 8 percentage points separating the high and low.

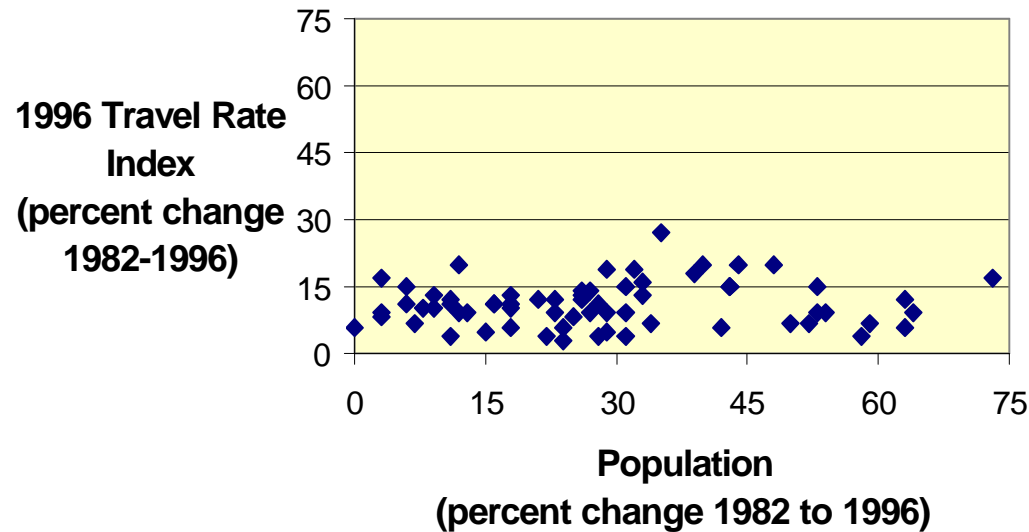
Exhibit 28



- , The TRI values in 1982 range from 1.05 in the Small urban areas to 1.28 in the Very Large urban areas.
- , The TRI values in 1996 range from 1.12 in the Small urban areas to 1.40 in the Very Large urban areas.
- , The largest increase in the TRI came in the Large urban areas with a 14% increase between 1982 and 1996.
- , The Medium urban areas experienced the second largest increase in TRI between 1982 and 1996 with a 11% increase.
- , The range from Small to Medium and Very Large group average TRI widened only slightly between 1982 and 1996.
- , The range from Small to Large group average TRI widened significantly from 1982 to 1996.

Exhibit 29

Population Growth and Travel Time Growth, 1982 to 1996



(Data from Albany-Schenectady-Troy, Detroit, and Las Vegas have been omitted from the graph because they either have negative population growth or very high population growth).

Their values are:

Albany-Schenectady-Troy

population growth: -1%

delay/driver increase 82-96: 217%

Detroit

population growth: -1%

delay/driver increase 82-96: 130%

Las Vegas

population growth: 139%

delay/driver increase 82-96: 113%

, This graph shows that the population is growing at a much quicker rate than the travel times.

CHAPTER VI—WASTED FUEL

SUMMARY

On average, travelers in each studied urban area waste just under 100 million gallons of fuel each year because of congested travel (Table 10). Los Angeles had the greatest amount of wasted fuel in 1996 with about 984 million gallons. In all 70 urban areas, over 6.7 billion gallons of fuel was wasted because of traffic congestion. This is the equivalent of 134 fully-loaded super tankers or 670,000 gasoline tank trucks loaded with gasoline.

Four urban areas had more than 100 gallons of wasted fuel per driver in 1996: Washington, DC, Los Angeles, Seattle-Everett, and Atlanta (Table 10). Eight urban areas have more than 96 gallons of wasted fuel per driver which equates to about 2 tanks of fuel for each season of the year. Forty-two urban areas had more than 48 gallons of wasted fuel per driver, equating to about 1 tank of fuel per season. The urban

areas with the most wasted fuel per driver in 1996 for each population size were:

<i>Very Large</i>	<i>Washington, DC</i>	<i>118 gallons/driver</i>
<i>Large</i>	<i>Seattle-Everett, WA</i>	<i>105 gallons/driver</i>
<i>Medium</i>	<i>Austin, TX</i>	<i>90 gallons/driver</i>
<i>Small</i>	<i>Harrisburg, PA</i>	<i>72 gallons/driver</i>

In 1982, approximately 2.7 billion gallons of fuel were wasted due to congestion. This equates to about 54 fully-loaded super tankers or 270,000 tank trucks loaded with gasoline. In 1982, only 16 urban areas had more than 36 gallons of wasted fuel per year, or the equivalent of about 3 tanks per year. Only one of the small or medium-sized urban areas (Austin) was included in this 1982 group. By 1996, 58 urban areas had more than 36 gallons of wasted fuel per year per driver. Eighteen medium-sized urban areas and 4 Small urban areas were included in this group.

BACKGROUND

The speed estimates developed in previous chapters of this report are used in the fuel consumption estimation procedures. The approach uses the peak period speed estimates in an equation suitable for areawide fuel economy approximation. The equation below yields a fuel economy value (i.e., miles per gallon) that is higher at higher speeds. While this does not reflect individual vehicle fuel economy rates (which peak around 40 mph and are lower at lower and higher speeds), it does provide reasonable estimates for areawide analyses.

$$\text{Average Fuel Economy} = 8.8 \% \cdot 0.25 \left(\frac{\text{Average Peak Period Congested System Speed}}{\text{System Speed}} \right)$$

The calculations are made for peak period speeds and for free-flow speeds on both the freeway and principal arterial street system. “Wasted” fuel is the difference between the fuel consumed in estimated existing conditions and the fuel consumption if all traffic was at free-flow conditions.

The less efficient operation of cars and trucks in stop-and-go conditions are also related to mobile source emissions. Air pollution levels are not estimated in this report, however.

TABLES AND EXHIBITS

Table 10 displays the annual excess fuel consumed in each urban area due to both recurring and incident delay. The wasted fuel, fuel per capita and wasted fuel per driver are shown in the table along with the ranks of each of these two data items.

Following Table 10 is a graph displaying the 1996 data points for:

, annual wasted fuel for each urban area arranged by population

Table 11 displays the annual wasted fuel for each urban area for selected years between 1982 and 1996. Also shown is the percent change in wasted fuel totals between 1982 and 1996 and between 1992 and 1996.

Following Table 11 is a graph showing the:

- , average annual fuel wasted per driver for 1996 in each urban area

Table 12 contains information on wasted fuel per driver for selected years between 1982 and 1996. Also shown is the percent change in wasted fuel per driver between 1982 and 1996 and between 1992 and 1996.

Following Table 12 are graphs showing relationships between:

- , annual fuel wasted in population groups in 1982, 1992 and 1996
- , wasted fuel per driver and population size group for 1982, 1992, and 1996

Table 10. Annual Excess Fuel Consumed Due to Traffic Congestion in 1996

Population Group	Urban Area	Annual Excess Fuel Consumed per Capita (gallons)	Rank ¹	Annual Excess Fuel Consumed per Eligible Driver (gallons)	Rank ¹	Annual Gallons of Fuel Wasted (million)			
						Recurring	Incident	Total	Rank ²
Vlg	Washington, DC-MD-VA	96	1	118	1	118	215	333	4
Vlg	Los Angeles, CA	81	3	110	2	453	531	984	1
Lrg	Seattle-Everett, WA	83	2	105	3	69	93	162	11
Lrg	Atlanta, GA	79	4	102	4	93	103	196	8
Vlg	Detroit, MI	76	6	99	5	106	179	285	6
Vlg	San Francisco-Oakland, CA	77	5	98	6	133	168	301	5
Lrg	San Jose, CA	75	7	98	6	55	65	120	14
Vlg	Houston, TX	73	8	97	8	95	127	222	7
Lrg	San Bernardino-Riverside, CA	67	11	95	9	52	39	91	21
Lrg	Dallas, TX	72	9	94	10	62	102	164	10
Med	Austin, TX	69	10	90	11	18	25	43	34
Med	Nashville, TN	67	11	86	12	17	25	42	37
Vlg	Boston, MA	65	13	81	13	55	141	196	8
Lrg	Miami-Hialeah, FL	63	14	81	13	57	73	130	13
Lrg	Fort Worth, TX	59	15	78	15	28	47	75	22
Lrg	St. Louis, MO-IL	58	16	75	16	54	63	117	15
Lrg	Denver, CO	56	18	74	17	49	51	100	18
Med	Jacksonville, FL	55	19	74	17	21	24	45	33
Sml	Harrisburg, PA	57	17	72	19	6	12	18	56
Lrg	Portland-Vancouver, OR-WA	54	20	69	20	26	43	69	23
Lrg	Sacramento, CA	50	24	67	21	34	28	62	26
Med	Louisville, KY-IN	51	21	65	22	14	29	43	34
Lrg	Baltimore, MD	51	21	65	22	37	73	110	17
Vlg	New York NY-Northeastern, NJ	51	21	63	24	305	578	883	2
Med	Albuquerque, NM	48	25	63	24	11	16	27	47
Vlg	Chicago, IL-Northwestern, IN	46	26	60	26	166	192	358	3
Lrg	Norfolk, VA	46	26	59	27	16	30	46	32
Lrg	Orlando, FL	45	28	59	27	23	25	48	31
Lrg	San Diego, CA	44	29	58	29	67	46	113	16
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	44	29	56	30	28	38	66	25
Med	Providence-Pawtucket, RI-MA	44	29	56	30	16	24	40	38
Med	Hartford-Middletown, CT	44	29	56	30	9	19	28	46
Lrg	Kansas City, MO-KS	43	33	56	30	17	41	58	27
Lrg	San Antonio, TX	42	35	56	30	24	27	51	30
Med	Charlotte, NC	42	35	55	35	12	12	24	50
Med	Tampa, FL	43	33	54	36	16	19	35	43
Lrg	Cincinnati, OH-KY	41	38	54	36	28	24	52	29
Lrg	Minneapolis-St. Paul, MN	42	35	53	38	48	46	94	20
Lrg	Phoenix, AZ	41	38	53	38	54	42	96	19
Med	Omaha, NE-IA	40	41	52	40	10	12	22	51

Table 10. Annual Excess Fuel Consumed Due to Traffic Congestion in 1996, continued

Population Group	Urban Area	Annual Excess Fuel Consumed per Capita (gallons)	Rank ¹	Annual Excess Fuel Consumed per Eligible Driver (gallons)	Rank ¹	Annual Gallons of Fuel Wasted (million)			
						Recurring	Incident	Total	Rank ²
Sml	Allentown-Bethlehem-Easton, PA-NJ	41	38	51	41	7	12	19	54
Med	Tacoma, WA	37	42	49	42	12	10	22	51
Lrg	Columbus, OH	37	42	47	43	20	17	37	41
Med	Indianapolis, IN	37	42	47	43	16	21	37	41
Med	Memphis, TN-AR-MS	35	45	47	43	14	20	34	44
Lrg	Las Vegas, NV	35	45	46	46	19	19	38	40
Lrg	New Orleans, LA	35	45	45	47	16	23	39	39
Med	Honolulu, HI	35	45	45	47	13	12	25	48
Lrg	Milwaukee, WI	34	50	45	47	21	22	43	34
Lrg	Pittsburgh, PA	35	45	43	50	26	41	67	24
Sml	Colorado Springs, CO	33	51	43	50	5	8	13	58
Med	Oklahoma City, OK	33	51	43	50	11	21	32	45
Med	Salt Lake City, UT	28	56	40	53	14	11	25	48
Vlg	Philadelphia, PA-NJ	31	53	39	54	66	96	162	11
Med	Tucson, AZ	30	54	38	55	9	10	19	54
Med	Rochester, NY	29	55	38	55	6	12	18	56
Lrg	Cleveland, OH	28	56	36	57	29	24	53	28
Sml	Salem, OR	28	56	36	57	2	3	5	65
Sml	Spokane, WA	25	59	32	59	3	5	8	62
Med	Fresno, CA	23	60	32	59	5	7	12	59
Sml	Corpus Christi, TX	23	60	30	61	2	5	7	63
Med	El Paso, TX-NM	20	62	28	62	5	7	12	59
Sml	Albany-Schenectady-Troy, NY	20	62	26	63	4	6	10	61
Lrg	Buffalo-Niagara Falls, NY	20	62	26	63	8	14	22	51
Sml	Boulder, CO	19	65	25	65	1	1	2	67
Sml	Bakersfield, CA	16	66	23	66	2	4	6	64
Sml	Brownsville, TX	15	67	22	67	1	1	2	67
Sml	Laredo, TX	13	70	20	68	1	1	2	67
Sml	Eugene-Springfield, OR	14	68	19	69	1	2	3	66
Sml	Beaumont, TX	14	68	18	70	1	1	2	67
	70 area average	44		58		41	55	96	
	Very large area average	66		85		166	247	414	
	Large area average	49		64		38	45	83	
	Medium area average	41		53		12	17	29	
	Small area average	24		32		3	5	7	

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

² Rank value of 1 associated with greatest fuel consumption.

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

, The urban areas with the greatest amount of wasted fuel annually per area by population size are:

Very Large	Los Angeles	984 million gallons
Large	Atlanta	196 million gallons
Medium	Jacksonville	45 million gallons
Small	Allentown-Bethl-Easton	19 million gallons

, The urban areas with the most wasted fuel per driver in 1996 for each population size are:

Very Large	Washington DC	118 gallons/driver
Large	Seattle-Everett	105 gallons/driver
Medium	Austin	90 gallons/driver
Small	Harrisburg	72 gallons/driver

, The urban areas with the least wasted fuel per driver in 1996 for each population size are:

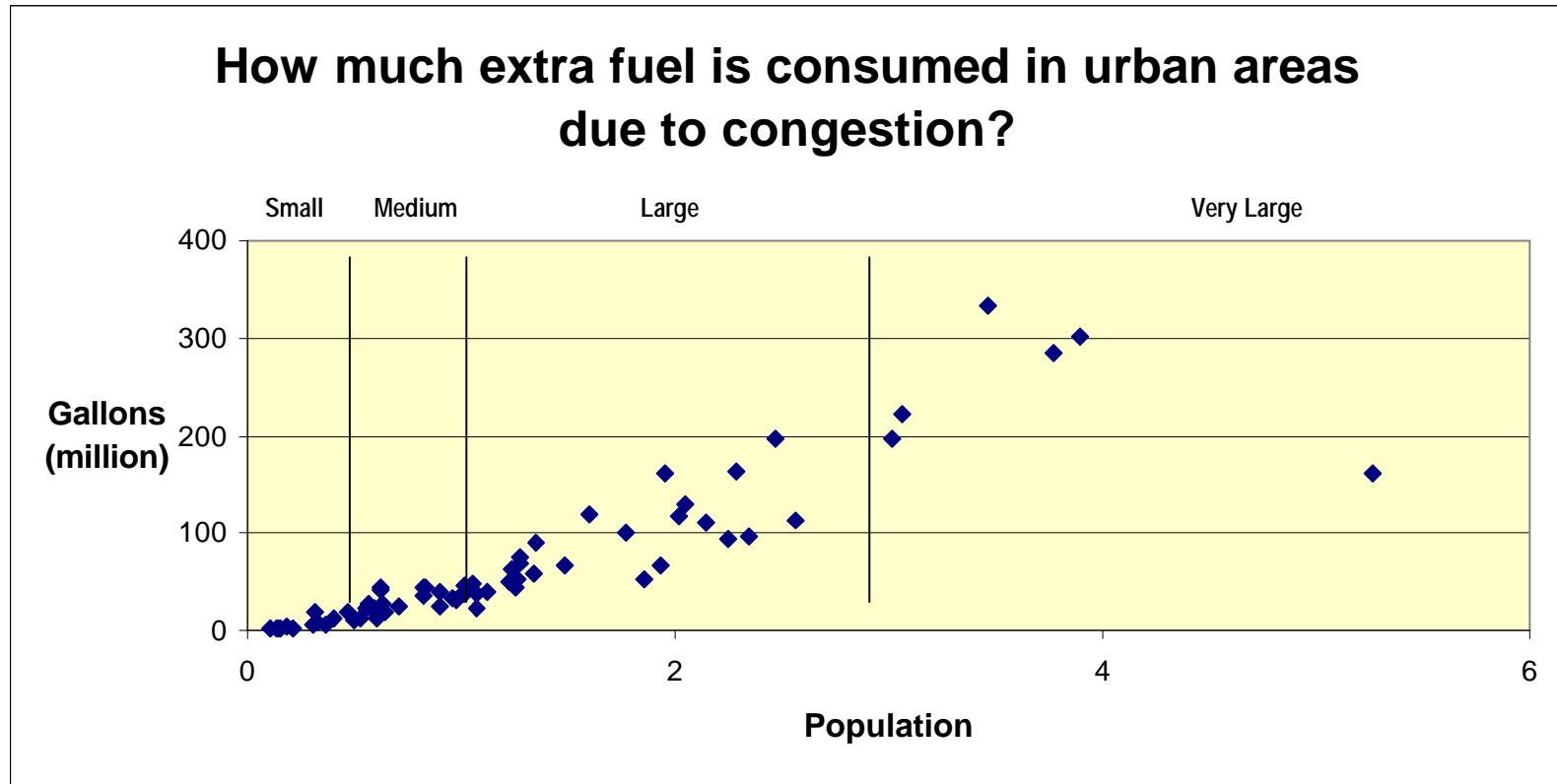
Very Large	Philadelphia	39 gallons/driver
Large	Buffalo-Niagara Falls	26 gallons/driver
Medium	El Paso	28 gallons/driver
Small	Beaumont	18 gallons/driver

, 4 urban areas have more than 100 gallons of wasted fuel per driver each year due to congestion: Washington DC, Los Angeles, Seattle-Everett, and Atlanta.

, 8 urban areas have more than 96 gallons of wasted fuel per driver each year. This equates to more than 2 tanks of fuel for each season.

, 42 urban areas have more than 48 gallons of wasted fuel per driver each year. This equates to about 1 tank of fuel for each season.

Exhibit 30



(Data from Los Angeles, New York, and Chicago have been omitted from the graph because their very large populations make them outliers on the graph). Their values are:

New York:	population 17,150,000	Million gallons: 883
Los Angeles:	population 12,220,000	Million gallons: 984
Chicago:	population 7,850,000	Million gallons: 358

- , In general, the Small urban areas waste between about 2 and 18 million gallons of fuel per year.
- , In general, the Medium urban areas waste between about 12 and 45 million gallons of fuel per year.
- , In general, the Large urban areas waste between about 22 and 196 million gallons of fuel per year.
- , In general, the Very Large urban areas waste between about 196 and 984 million gallons of fuel per year.
- , In general, as an urban area becomes larger, more fuel is wasted per year.

Table 11. Annual Wasted Fuel Due to Congestion, 1982 to 1996

Population Group	Urban Area	Annual Wasted Gallons (millions)							Percent Change 1982-1996	Percent Change 1992-1996
		1982	1986	1990	1992	1994	1995	1996		
Sml	Beaumont, TX	0	1	1	1	2	2	2	-	100
Sml	Boulder, CO	0	0	1	1	2	2	2	-	100
Sml	Brownsville, TX	0	0	0	1	1	1	2	-	100
Sml	Laredo, TX	0	0	0	1	2	2	2	-	100
Med	Oklahoma City, OK	6	7	11	16	22	26	32	433	100
Lrg	Kansas City, MO-KS	8	10	21	30	44	55	58	625	93
Med	Nashville, TN	10	14	19	22	35	37	42	320	91
Lrg	Las Vegas, NV	7	11	18	20	29	33	38	443	90
Med	Louisville, KY-IN	7	11	20	23	33	35	43	514	87
Lrg	Orlando, FL	9	13	19	27	36	42	48	433	78
Med	Indianapolis, IN	4	5	12	21	27	35	37	825	76
Sml	Corpus Christi, TX	1	2	3	4	5	6	7	600	75
Med	Albuquerque, NM	4	7	14	16	23	26	27	575	69
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	16	23	32	39	50	59	66	313	69
Med	Salt Lake City, UT	4	4	9	15	19	23	25	525	67
Lrg	Cincinnati, OH-KY	10	12	24	32	45	49	52	420	63
Sml	Colorado Springs, CO	2	5	6	8	10	11	13	550	63
Med	Jacksonville, FL	13	17	25	28	35	39	45	246	61
Lrg	Portland-Vancouver, OR-WA	18	23	33	43	53	60	69	283	60
Sml	Spokane, WA	2	4	5	5	7	7	8	300	60
Med	Tampa, FL	13	16	20	22	29	34	35	169	59
Lrg	Atlanta, GA	54	92	105	126	160	178	196	263	56
Lrg	Fort Worth, TX	26	43	46	49	61	70	75	188	53
Sml	Bakersfield, CA	0	2	3	4	5	5	6	-	50
Med	Charlotte, NC	6	10	13	16	18	22	24	300	50
Sml	Eugene-Springfield, OR	0	2	2	2	2	2	3	-	50
Med	Fresno, CA	4	5	7	8	10	11	12	200	50
Med	Rochester, NY	3	6	9	12	13	17	18	500	50
Lrg	St Louis, MO-IL	41	51	64	78	99	106	117	185	50
Med	Austin, TX	13	23	27	29	38	40	43	231	48
Med	Providence-Pawtucket, RI-MA	10	17	22	27	33	36	40	300	48
Med	Hartford-Middletown, CT	6	9	14	19	24	27	28	367	47
Sml	Allentown-Bethlehem-Easton, PA-NJ	5	8	12	13	16	18	19	280	46
Med	Tucson, AZ	6	7	11	13	16	17	19	217	46
Lrg	Norfolk, VA	17	25	31	32	35	40	46	171	44
Lrg	Cleveland, OH	11	16	29	37	44	48	53	382	43
Lrg	Columbus, OH	11	13	20	26	31	33	37	236	42
Med	Memphis, TN-AR-MS	6	9	17	24	29	32	34	467	42
Lrg	San Antonio, TX	15	28	30	36	40	48	51	240	42
Lrg	Sacramento, CA	14	21	35	44	53	56	62	343	41

Table 11. Annual Wasted Fuel Due to Congestion, 1982 to 1996, continued

Population Group	Urban Area	Annual Wasted Gallons (millions)							Percent Change 1982-1996	Percent Change 1992-1996
		1982	1986	1990	1992	1994	1995	1996		
Lrg	Minneapolis-St Paul, MN	19	32	57	68	78	88	94	395	38
Med	Omaha, NE-IA	6	9	14	16	20	20	22	267	38
Lrg	Denver, CO	39	49	63	73	79	84	100	156	37
Med	El Paso, TX-NM	3	5	7	9	12	12	12	300	33
Lrg	San Jose, CA	44	72	86	91	93	108	120	173	32
Vlg	Chicago, IL-Northwestern, IN	145	211	237	276	315	322	358	147	30
Lrg	Milwaukee, WI	12	17	28	33	39	41	43	258	30
Lrg	Buffalo-Niagara Falls, NY	8	11	14	17	18	19	22	175	29
Lrg	Dallas, TX	74	120	124	127	141	157	164	122	29
Sml	Harrisburg, PA	7	10	13	14	17	18	18	157	29
Lrg	Miami-Hialeah, FL	55	69	94	101	115	121	130	136	29
Lrg	Pittsburgh, PA	26	41	50	53	57	67	67	158	26
Lrg	Baltimore, MD	26	43	73	88	94	107	110	323	25
Sml	Salem, OR	1	2	3	4	4	5	5	400	25
Lrg	New Orleans, LA	18	28	30	32	37	38	39	117	22
Lrg	Seattle-Everett, WA	48	81	121	133	147	149	162	238	22
Vlg	Washington, DC-MD-VA	133	193	238	272	288	323	333	150	22
Vlg	Detroit, MI	122	143	197	235	261	282	285	134	21
Vlg	Boston, MA	87	131	158	164	169	190	196	125	20
Vlg	New York NY-Northeastern, NJ	478	546	692	737	798	867	883	85	20
Lrg	San Diego, CA	25	46	86	95	101	106	113	352	19
Vlg	Houston, TX	129	166	176	188	204	211	222	72	18
Lrg	Phoenix, AZ	46	61	75	83	90	90	96	109	16
Lrg	San Bernardino-Riverside, CA	37	60	73	79	84	84	91	146	15
Med	Honolulu, HI	12	16	18	22	24	25	25	108	14
Vlg	Philadelphia, PA-NJ	86	107	118	144	154	157	162	88	13
Vlg	Los Angeles, CA	469	710	818	880	892	964	984	110	12
Sml	Albany-Schenectady-Troy, NY	3	5	7	9	10	10	10	233	11
Med	Tacoma, WA	6	11	17	20	22	22	22	267	10
Vlg	San Francisco-Oakland, CA	156	247	295	290	296	298	301	93	4
	70 area average	39	54	68	76	84	91	96	282	46
	Very large area average	201	273	325	354	375	402	414	112	18
	Large area average	26	40	53	60	70	76	83	264	43
	Medium area average	7	10	15	19	24	27	29	357	54
	Small area average	2	3	4	5	6	7	7	360	62

Source: TTI Analysis and Local Transportation Agency References.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

, The urban areas with the greatest growth in wasted fuel per driver between 1982 and 1996 by population size are:

Very Large	Washington DC	% growth 82-96: 150%
Large	Kansas City	% growth 82-96: 625%
Medium	Indianapolis	% growth 82-96: 825%
Small	Corpus Christi	% growth 82-96: 600%

, The urban areas with the least growth in wasted fuel per driver between 1982 and 1996 by population size are:

Very Large	Houston	% growth 82-96: 72%
Large	Phoenix	% growth 82-96: 109%
Medium	Honolulu	% growth 82-96: 108%
Small	Harrisburg	% growth 82-96: 157%

, The urban areas with the greatest growth in wasted fuel per driver between 1992 and 1996 by population size are:

Very Large	Chicago	% growth 92-96: 30%
Large	Kansas City	% growth 92-96: 93%
Medium	Oklahoma City	% growth 92-96: 100%
Small	Beaumont	% growth 92-96: 100%
	Brownsville	
	Boulder	
	Laredo	

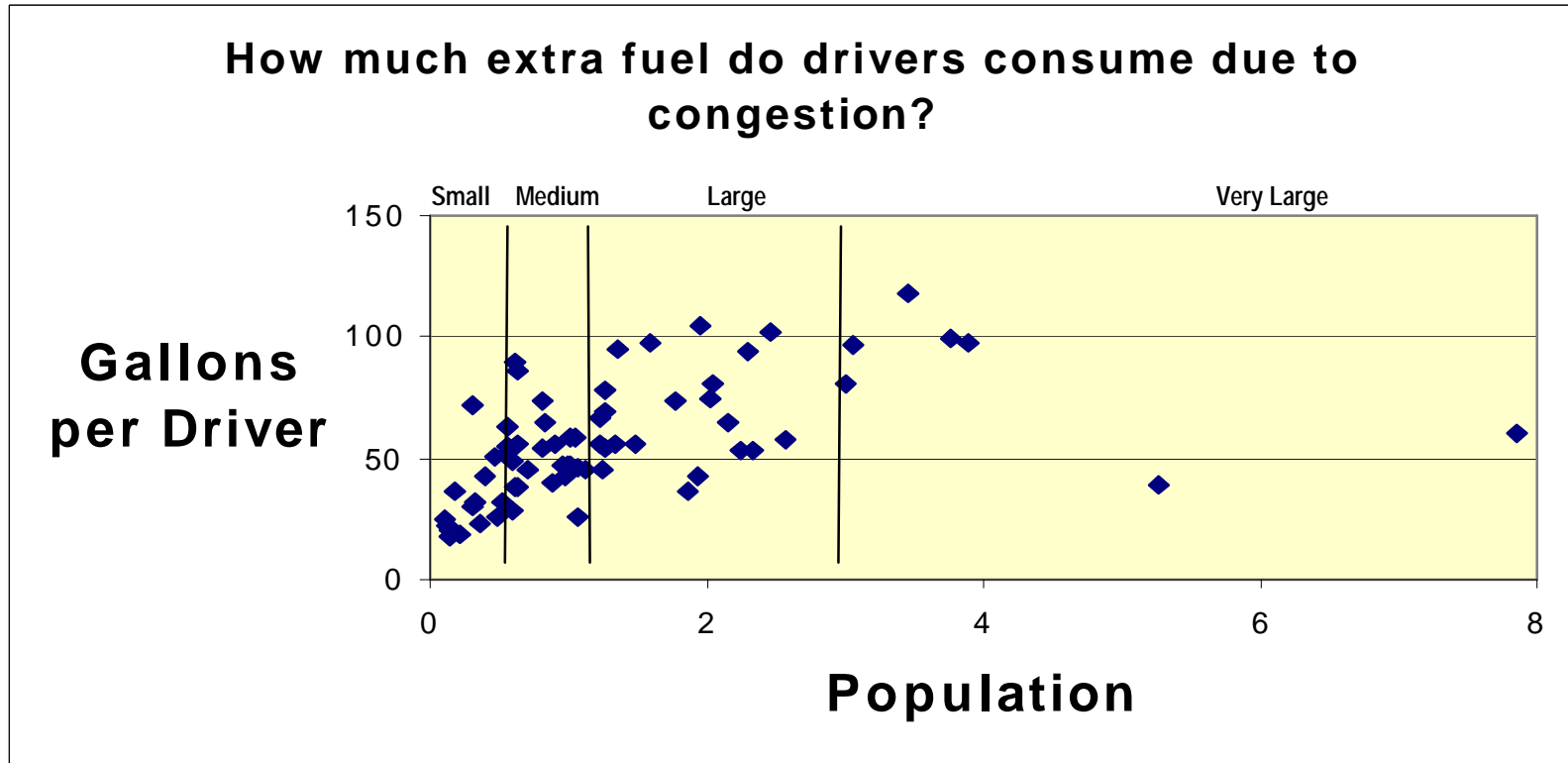
, On average, the Very Large urban areas showed the smallest change in wasted fuel with 81% growth between 1982 and 1996 and 15% growth between 1992 and 1996.

, On average, the Small urban areas showed the largest change in wasted fuel with 357% growth between 1982 and 1996 and 39% growth between 1992 and 1996.

, Between 1982 and 1996 the Medium urban areas experienced 194% growth in wasted fuel while the Large urban areas had an increase of 146%.

, Between 1992 and 1996 the Medium urban areas experienced 43% growth in wasted fuel while the Large urban areas had an increase of 28%.

Exhibit 31



(Data from Los Angeles, New York, and Chicago have been omitted from the graph because they have very large populations). Their values are:

New York:	population 17,150,000	Gallons per driver: 63
Los Angeles:	population 12,220,000	Gallons per driver: 110
Chicago:	population 7,850,000	Gallons per driver: 60

- , The amount of fuel wasted per driver in Very Large urban areas is between 39 and 118 gallons per driver.
- , The amount of fuel wasted per driver in the Large urban areas is between 26 and 105 gallons per driver.
- , The amount of fuel wasted per driver in the Medium urban areas is between 28 and 90 gallons per driver.
- , The amount of fuel wasted per driver in the Small urban areas is between 18 and 72 gallons per driver.
- , In general, as the population of an area increases, the amount of wasted fuel per driver increases as well.

Table 12. Wasted Fuel per Eligible Driver, 1982 to 1996

Population Group	Urban Area	Wasted Fuel per Eligible Driver							% Change 1982-1996	% Change 1992-1996
		1982	1986	1990	1992	1994	1995	1996		
Sml	Boulder, CO	0	0	13	13	25	25	25	-	92
Med	Nashville, TN	26	34	42	48	73	76	86	231	79
Lrg	Kansas City, MO-KS	10	11	23	32	43	54	56	460	75
Med	Louisville, KY-IN	12	18	31	38	52	54	65	442	71
Sml	Brownsville, TX	0	0	0	13	11	11	22	-	69
Med	Indianapolis, IN	6	7	16	28	36	45	47	683	68
Sml	Beaumont, TX	0	11	10	11	20	20	18	-	64
Med	Salt Lake City, UT	8	7	15	25	31	37	40	400	60
Lrg	Cincinnati, OH-KY	11	14	27	34	46	51	54	391	59
Med	Oklahoma City, OK	12	13	20	27	34	37	43	258	59
Med	Albuquerque, NM	12	19	36	40	56	62	63	425	58
Sml	Corpus Christi, TX	6	10	15	19	24	27	30	400	58
Sml	Laredo, TX	0	0	0	13	20	20	20	-	54
Med	Rochester, NY	6	14	20	25	27	36	38	533	52
Sml	Spokane, WA	10	18	22	21	29	28	32	220	52
Med	Jacksonville, FL	28	35	45	49	59	65	74	164	51
Lrg	Orlando, FL	19	24	28	39	49	53	59	211	51
Lrg	St. Louis, MO-IL	29	34	42	51	65	69	75	159	47
Sml	Eugene-Springfield, OR	0	14	13	13	13	13	19	-	46
Lrg	Atlanta, GA	44	70	64	71	85	92	102	132	44
Lrg	Fort Worth, TX	32	51	51	54	66	74	78	144	44
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	18	24	30	39	48	54	56	211	44
Med	Hartford-Middletown, CT	14	20	30	39	49	55	56	300	44
Lrg	Las Vegas, NV	21	28	34	32	41	43	46	119	44
Med	Providence-Pawtucket, RI-MA	16	26	33	39	47	51	56	250	44
Sml	Allentown-Bethlehem-Easton, PA-NJ	16	25	35	36	44	50	51	219	42
Lrg	Portland-Vancouver, OR-WA	22	27	38	49	57	63	69	214	41
Med	Fresno, CA	16	18	23	23	28	30	32	100	39
Lrg	Cleveland, OH	8	12	21	26	31	33	36	350	38
Med	Tampa, FL	31	33	36	39	48	52	54	74	38
Lrg	Norfolk, VA	28	38	42	43	46	52	59	111	37
Lrg	Sacramento, CA	22	28	42	49	58	62	67	205	37
Lrg	San Antonio, TX	22	38	34	41	44	53	56	155	37
Med	Austin, TX	43	62	63	66	83	85	90	109	36
Sml	Bakersfield, CA	0	11	14	17	20	20	23	-	35
Med	Charlotte, NC	22	32	37	41	43	51	55	150	34
Sml	Colorado Springs, CO	10	23	26	32	36	38	43	330	34
Lrg	Columbus, OH	17	20	30	35	40	42	47	176	34
Med	Memphis, TN-AR-MS	11	15	26	36	43	46	47	327	31
Lrg	Buffalo-Niagara Falls, NY	10	14	17	20	21	23	26	160	30
Med	Omaha, NE-IA	17	24	36	40	49	48	52	206	30

Table 12. Wasted Fuel per Eligible Driver, 1982 to 1996, continued

Population Group	Urban Area	Wasted Fuel per Eligible Driver							% Change 1982-1996	% Change 1992-1996
		1982	1986	1990	1992	1994	1995	1996		
Vlg	Detroit, MI	44	50	67	77	85	92	99	125	29
Lrg	Milwaukee, WI	13	18	30	35	41	43	45	246	29
Lrg	Minneapolis-St. Paul, MN	14	22	36	41	46	50	53	279	29
Med	Tucson, AZ	18	19	28	30	34	35	38	111	27
Lrg	San Jose, CA	50	72	80	78	78	90	98	96	26
Vlg	Chicago, IL-Northwestern, IN	27	39	41	48	53	54	60	122	25
Lrg	Denver, CO	36	41	50	60	62	64	74	106	23
Lrg	Pittsburgh, PA	18	28	33	35	37	43	43	139	23
Med	El Paso, TX-MN	10	15	18	23	29	29	28	180	22
Lrg	Miami-Hialeah, FL	39	48	64	67	75	77	81	108	21
Vlg	New York, NY-Northeastern, NJ	37	45	52	53	57	62	63	70	19
Lrg	Baltimore, MD	20	30	47	55	56	64	65	225	18
Sml	Harrisburg, PA	35	50	62	61	71	72	72	106	18
Lrg	New Orleans, LA	22	35	37	38	44	45	45	105	18
Vlg	Washington, DC-MD-VA	61	81	93	100	101	114	118	93	18
Vlg	Boston, MA	38	58	64	69	70	79	81	113	17
Lrg	Dallas, TX	54	82	81	81	84	92	94	74	16
Sml	Salem, OR	8	17	25	31	31	38	36	350	16
Lrg	San Diego, CA	18	29	47	50	52	54	58	222	16
Lrg	Seattle-Everett, WA	39	61	82	92	98	98	105	169	14
Sml	Albany-Schenectady-Troy, NY	8	13	18	23	26	26	26	225	13
Lrg	San Bernardino-Riverside, CA	53	82	86	85	88	88	95	79	12
Vlg	Houston, TX	72	79	80	87	94	95	97	35	11
Vlg	Los Angeles, CA	61	85	92	100	100	108	110	80	10
Med	Honolulu, HI	26	33	33	42	44	46	45	73	7
Vlg	Philadelphia, PA-NJ	27	34	33	37	37	38	39	44	5
Vlg	San Francisco-Oakland, CA	58	88	98	96	96	97	98	69	2
Med	Tacoma, WA	19	31	45	49	51	50	49	158	0
Lrg	Phoenix, AZ	43	47	52	54	55	52	53	23	(2)
	70 area average	23	32	39	44	51	54	58	201	35
	Very large area average	47	62	45	74	77	82	85	83	15
	Large area average	26	37	32	50	56	60	64	181	32
	Medium area average	18	24	19	37	46	50	53	259	46
	Small area average	7	15	45	23	28	30	32	264	32

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

, The urban areas with the greatest percent increase in wasted fuel between 1982 and 1996 by population size are:

Very Large	Chicago	% increase 82-96: 122%
Large	Kansas City	% increase 82-96: 460%
Medium	Indianapolis	% increase 82-96: 683%
Small	Corpus Christi	% increase 82-96: 400%

, The urban areas with the greatest percent increase in wasted fuel between 1992 and 1996 by population size are:

Very Large	Detroit	% increase 92-96: 29%
Large	Kansas City	% increase 92-96: 75%
Medium	Nashville	% increase 92-96: 79%
Small	Boulder	% increase 92-96: 92%

, The urban areas with the smallest percent increase in wasted fuel between 1992 and 1996 by population size are:

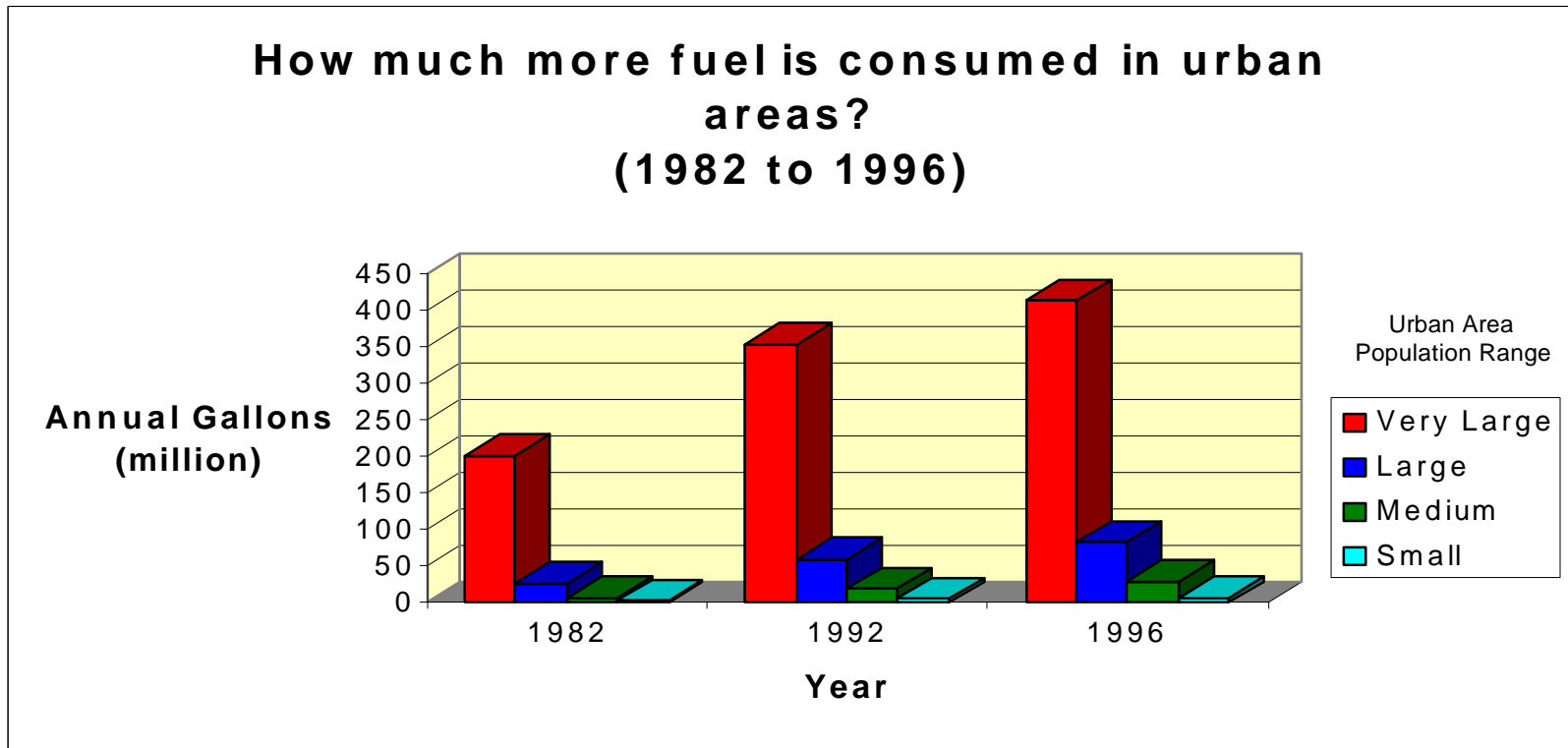
Very Large	San Francisco-Oakland	% increase 92-96: 2%
Large	Phoenix	% increase 92-96: -2%
Medium	Tacoma	% increase 92-96: 0%
Small	Albany-Schenectady-Troy	% increase 92-96: 13%

, The average percent growth in wasted fuel per driver for all 70 urban areas between 1982 and 1996 was 201% and between 1992 and 1996 was 46%.

, The Small urban areas had the highest average growth in wasted fuel per driver for both periods: 1982 to 1996 was 264%, 1992 to 1996 was 62%. The small value in 1982 contributed to the appearance of a significant increase.

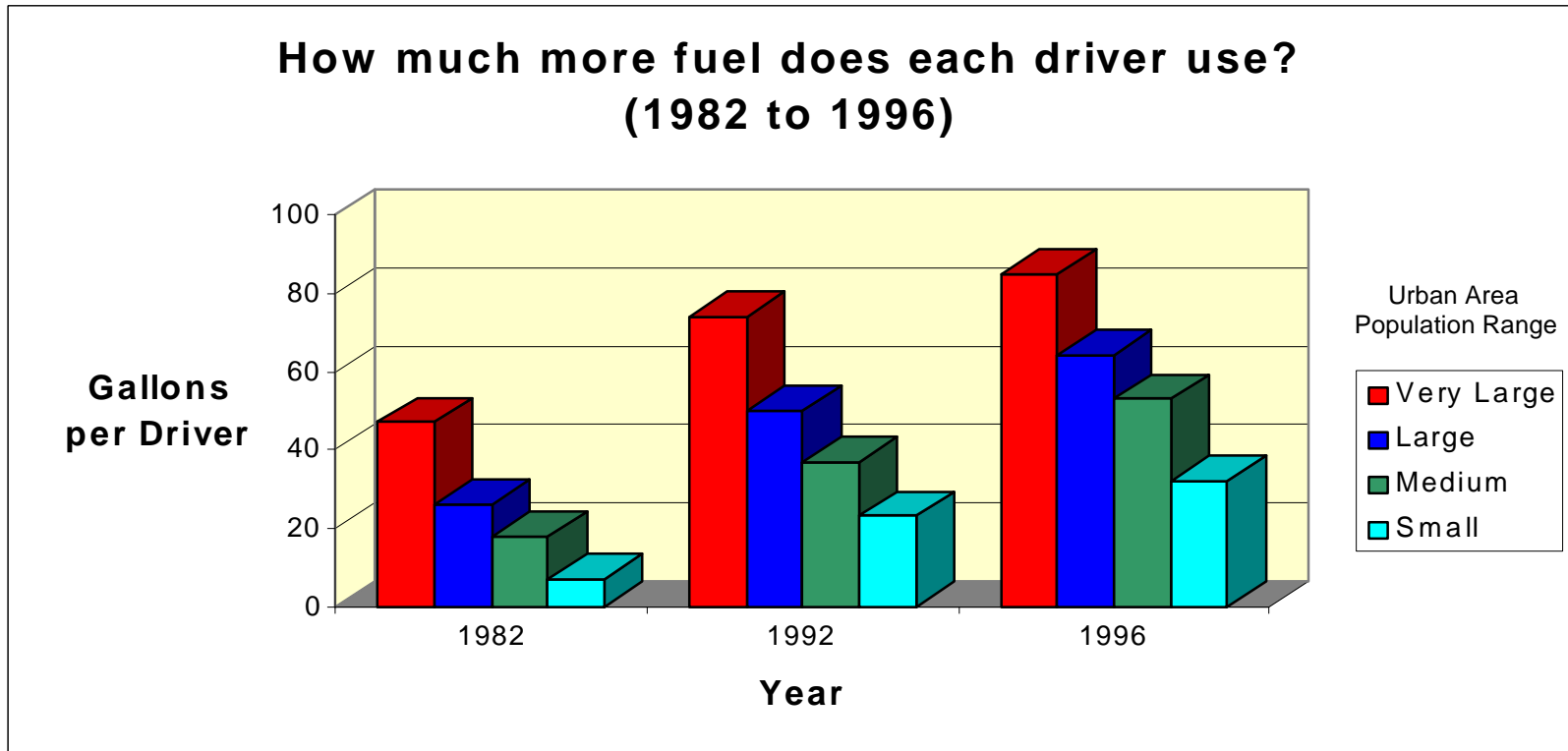
, The Very Large urban areas had the smallest average growth in wasted fuel per driver for both periods: 1982 to 1996 was 83%, 1992 to 1996 was 18%.

Exhibit 32



- , In 1982, the average wasted fuel per urban area ranged from 2 million gallons in the Small urban areas to 201 million gallons in the Very Large urban areas.
- , In 1992, the average wasted fuel per urban area ranged from 5 million gallons in the Small urban areas to 354 million gallons in the Very Large urban areas.
- , In 1996, the average wasted fuel per urban area ranged from 7 million gallons in the Small urban areas to 414 million gallons in the Very Large urban areas.
- , The average wasted fuel in the Small urban areas showed the largest percentage increase between 1982 and 1996 (360%) and between 1992 and 1996 (62%).
- , The average wasted fuel in the Very Large urban areas showed the smallest increase between 1982 and 1996 (112%) and between 1992 and 1996 (18%).
- , Total fuel “wasted” due to congestion was 2.7 billion gallons in 1982, 5.3 billion gallons in 1992 and 6.7 billion gallons in 1996.

Exhibit 33



- , The average amount of wasted fuel per driver in Very Large urban areas grew from 47 gallons in 1982 to 85 gallons in 1996, an increase of 81%.
- , The average amount of wasted fuel per driver in Large urban areas grew from 26 gallons in 1982 to 64 gallons in 1996, an increase of 146%.
- , The average amount of wasted fuel per driver in Medium urban areas grew from 18 gallons in 1982 to 53 gallons in 1996, an increase of 194%.
- , The average amount of wasted fuel per driver in Small urban areas grew from 7 gallons in 1982 to 32 gallons in 1996, an increase of 357%

CHAPTER VII—CONGESTION COST

SUMMARY

The total congestion cost for all 70 urban areas was about \$74 billion in 1996, a little more than \$1 billion per urban area.

Fifty-six percent of this \$74 billion was attributed to the delay in the nine urban areas comprising the Very Large urban areas group while an additional 34 percent was attributed to the 28 urban areas comprising the Large urban areas group. The Small (13 urban areas) and Medium (20 urban areas) groups totaled less than 10 percent of the \$74 billion price tag on congestion in the 70 study areas.

The urban areas with the highest annual congestion cost (Table 13) by population size are:

Very Large	Los Angeles, CA	Cost: \$10.8 billion
Large	Atlanta, GA	Cost: \$2.1 billion
Medium	Jacksonville, FL	Cost: \$505 million
Small	Harrisburg, PA	Cost: \$210 million

The average congestion cost per driver ranges from about \$333 per year in the Small urban areas to \$936 per year in the Very Large urban areas. On average, the annual congestion cost per driver equates to about \$4 per workday in the Very Large areas, \$3 per workday in the Large areas, \$2 per workday in the Medium areas, and \$1 per workday in the Small areas.

The urban areas with the highest annual congestion cost by population size are:

Very Large	Washington, DC	Cost per driver: \$1,290
Large	Seattle-Everett, WA	Cost per driver: \$1,155
Medium	Austin, TX	Cost per driver: \$970
Small	Harrisburg, PA	Cost per driver: \$840

BACKGROUND

Cost

Another method of assessing impact is to look at the dollar value of travel delay and wasted fuel. Many variables are used to estimate congestion cost in this study. Some of these cost variables fluctuate with price trends. The variables—fuel cost, commercial vehicle operating cost, and the average cost of time—are updated annually to reflect the change in these costs.

A more detailed discussion of the calculation of cost can be found in Appendix C of this report. Estimates of vehicle-hours of delay and gallons of wasted fuel should be used to analyze congestion trends since congestion costs reflect changes in the price per hour due to inflation, as well as in congestion.

Additional Capacity

Another way of looking at cost is the additional capacity required to alleviate congestion. Very few urban areas have been able to sustain the level of roadway construction necessary to maintain a slow congestion growth rate on their

major roadway system. The estimate of 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 roadway congestion index (RCI) is a ratio of traffic volume (demand) to facility length (supply). If an area wants to keep the RCI constant (indicating no increase in congestion), system supply has to increase by the same percentage as demand. **The figures showing the amount of additional capacity needed versus that supplied make it apparent that the construction of additional roadway cannot be the sole alternative used to alleviate congestion in every city.**

TABLES AND EXHIBITS

Table 13 shows information on congestion costs for the 70 urban areas for 1996. The congestion costs attributed to travel delay and wasted fuel are shown in addition to the total congestion cost for each urban area. A rank is included for each urban area based on its total congestion cost.

Following Table 13 is a bar graph showing the:

, average congestion cost for each urban area size group

Table 14 displays data on the annual congestion cost per capita and annual congestion cost per eligible driver for the 70 urban areas in the study. Also included are ranks for each of these two costs.

Following Table 14 are graphs showing data for population size groups and:

- , average cost per driver
- , range of cost per driver
- , average cost per capita

Table 15 illustrates the annual capacity increase that is required to offset the growth of congestion. The existing lane-miles of freeway and principal arterial streets in 1996 and the recent traffic growth rate are shown for each urban area. The annual freeway and principal arterial street lane-miles that were added between 1992 and 1996 and the amount that were needed to offset the travel growth are also shown. The “deficiency” in lane-mile construction for both freeway and principal arterial streets is displayed. This “deficiency” is typically larger in the Large and Very Large population groups.

Following Table 15 is a bar graph displaying:

- , the average additional lane-miles needed for each urban area size group

Table 16 shows the construction experienced during several time frames within the study period and the amount of lane-miles that were needed to offset growth in travel. This information is displayed in the form of the percent of lane-miles constructed. This methodology does not suggest that road construction is the only solution; it compares the construction activity to the amount needed if construction were the only solution chosen. The time periods shown are from 1982 to 1985, 1988 to 1991, and 1993 to 1996.

Following Table 16 is a bar graph illustrating:

- , the percent of capacity constructed for each urban area size group

Table 17 shows the annual congestion cost, the annual congestion cost per driver, and the Roadway Congestion Index values for each urban area for 1994 and 1996. Also shown are ranks for each of these variables. This table provides a summary of three of the key congestion measures.

Table 13. Total Congestion Costs by Urban Area for 1996

Population Group	Urban Area	Annual Cost Due to Congestion (\$ millions)			Rank
		Delay	Fuel	Total	
Vlg	Los Angeles, CA	\$ 9,615	\$ 1,190	\$ 10,805	1
Vlg	New York NY-Northeastern, NJ	8,600	1,210	9,810	2
Vlg	Chicago, IL-Northwestern, IN	3,510	495	4,005	3
Vlg	Washington, DC-MD-VA	3,250	405	3,655	4
Vlg	San Francisco-Oakland, CA	2,885	365	3,250	5
Vlg	Detroit, MI	2,800	365	3,165	6
Vlg	Houston, TX	2,135	270	2,405	7
Vlg	Boston, MA	1,915	255	2,170	8
Lrg	Atlanta, GA	1,890	220	2,110	9
Vlg	Philadelphia, PA-NJ	1,620	205	1,825	10
Lrg	Seattle-Everett, WA	1,560	220	1,780	11
Lrg	Dallas, TX	1,565	200	1,765	12
Lrg	Miami-Hialeah, FL	1,290	170	1,460	13
Lrg	San Jose, CA	1,170	145	1,315	14
Lrg	St. Louis, MO-IL	1,140	140	1,280	15
Lrg	Baltimore, MD	1,060	145	1,205	16
Lrg	San Diego, CA	1,065	135	1,200	17
Lrg	Denver, CO	980	135	1,115	18
Lrg	Phoenix, AZ	945	125	1,070	19
Lrg	Minneapolis-St. Paul, MN	895	125	1,020	20
Lrg	San Bernardino-Riverside, CA	880	110	990	21
Lrg	Fort Worth, TX	715	90	805	22
Lrg	Portland-Vancouver, OR-WA	670	95	765	23
Lrg	Pittsburgh, PA	670	85	755	24
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	645	85	730	25
Lrg	Sacramento, CA	595	75	670	26
Lrg	Kansas City, MO-KS	560	70	630	27
Lrg	Cincinnati, OH-KY	505	65	570	28
Lrg	Cleveland, OH	505	65	570	28
Lrg	San Antonio, TX	490	60	550	30
Lrg	Orlando, FL	470	65	535	31
Med	Jacksonville, FL	445	60	505	32
Lrg	Norfolk, VA	450	55	505	32
Med	Louisville, KY-IN	420	55	475	34
Lrg	Milwaukee, WI	415	60	475	34
Med	Austin, TX	415	50	465	36
Med	Nashville, TN	400	50	450	37
Med	Providence-Pawtucket, RI-MA	385	50	435	38
Lrg	New Orleans, LA	380	50	430	39
Lrg	Las Vegas, NV	370	50	420	40

Table 13. Total Congestion Costs by Urban Area for 1996, continued

Population Group	Urban Area	Annual Cost Due to Congestion (\$ millions)			Rank
		Delay	Fuel	Total	
Lrg	Columbus, OH	\$ 355	\$ 45	\$ 400	41
Med	Indianapolis, IN	355	45	400	41
Med	Tampa, FL	350	45	395	43
Med	Memphis, TN-AR-MS	325	40	365	44
Med	Oklahoma City, OK	305	40	345	45
Med	Hartford-Middletown, CT	275	45	320	46
Med	Albuquerque, NM	265	35	300	47
Med	Honolulu, HI	245	40	285	48
Med	Salt Lake City, UT	235	35	270	49
Med	Charlotte, NC	230	30	260	50
Med	Omaha, NE-IA	220	30	250	51
Med	Tacoma, WA	210	30	240	52
Lrg	Buffalo-Niagara Falls, NY	210	30	240	52
Sml	Harrisburg, PA	185	25	210	54
Sml	Allentown-Bethlehem-Easton, PA-NJ	185	25	210	54
Med	Tucson, AZ	185	25	210	54
Med	Rochester, NY	165	25	190	57
Sml	Colorado Springs, CO	120	15	135	58
Med	Fresno, CA	115	15	130	59
Med	El Paso, TX-NM	110	15	125	60
Sml	Albany-Schenectady-Troy, NY	100	15	115	61
Sml	Spokane, WA	75	10	85	62
Sml	Bakersfield, CA	60	10	70	63
Sml	Corpus Christi, TX	60	5	65	64
Sml	Salem, OR	45	10	55	65
Sml	Eugene-Springfield, OR	30	5	35	66
Sml	Laredo, TX	20	0	20	67
Sml	Beaumont, TX	20	0	20	67
Sml	Brownsville, TX	15	0	15	69
Sml	Boulder, CO	10	0	10	70
	70 Area Total	65,380	8,540	73,920	
	70 City Average	934	122	1,056	
	Very large	4,037	529	4,566	
	Large	802	104	906	
	Medium	283	38	321	
	Small	71	9	80	

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

, The urban areas with the highest annual congestion cost by population size are:

Very Large	Los Angeles	Cost: \$10,805 million
Large	Atlanta	Cost: \$2,110 million
Medium	Jacksonville	Cost: \$505 million
Small	Harrisburg	Cost: \$210 million

, The urban areas with the lowest annual congestion cost by population size are:

Very Large	Philadelphia	Cost: \$1,825 million
Large	Buffalo-Niagara Falls	Cost: \$240 million
Medium	El Paso	Cost: \$125 million
Small	Boulder	Cost: \$10 million

, 17 urban areas had annual delay costs of more than \$1 billion

, 20 urban areas had total congestion costs of more than \$1 billion

, 33 urban areas had total congestion costs of at least \$500 million

, 51 urban areas had total congestion costs of at least \$250 million

, The annual congestion costs in Los Angeles and New York are larger than the annual congestion cost in the Small and Medium urban areas combined

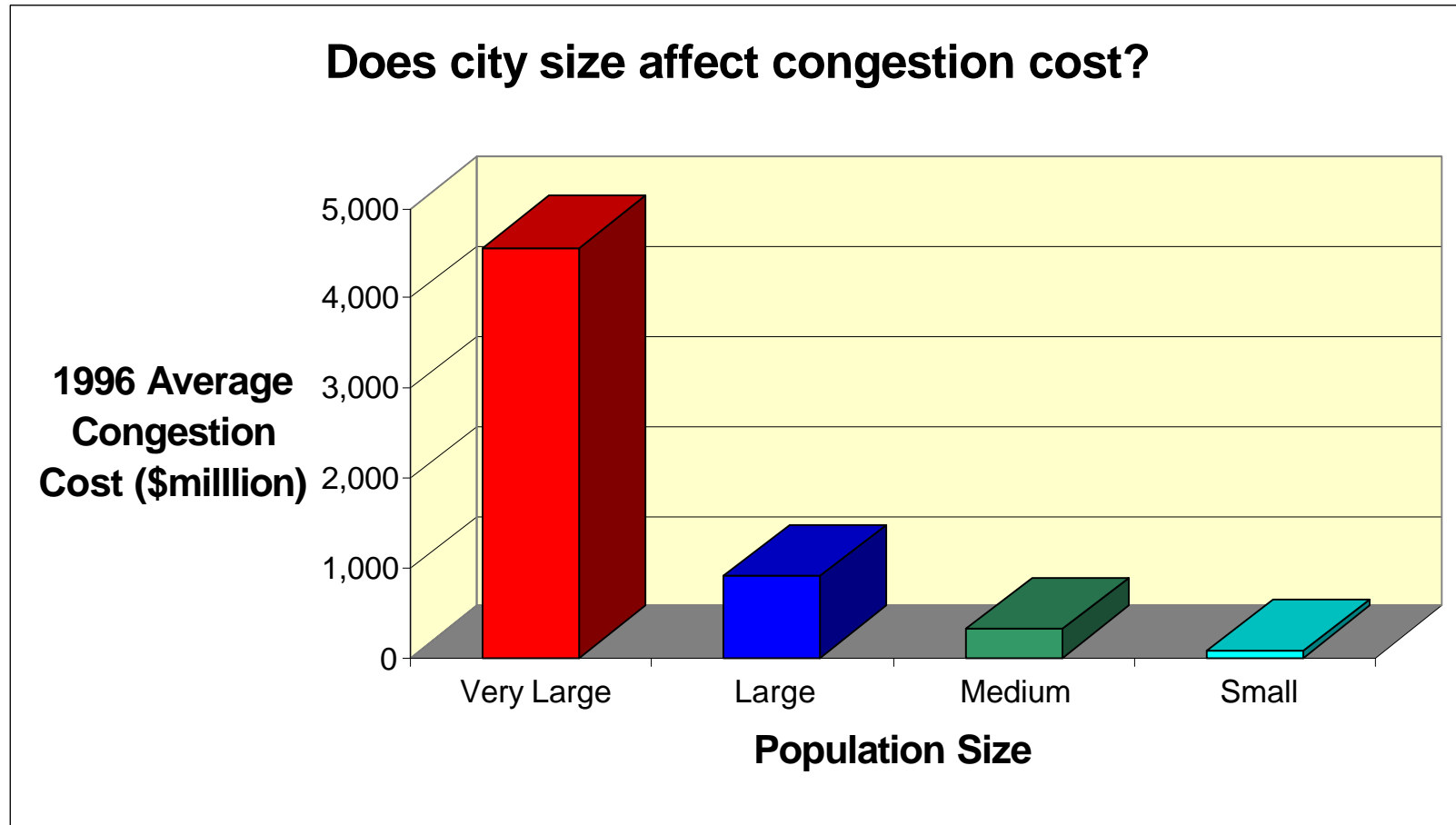
, The annual congestion cost in the top 4 urban areas (Los Angeles, New York, Chicago, and Washington DC), when combined, is greater than the congestion cost in all of the Large urban areas combined

, The top 7 urban areas by congestion cost account for over half of the congestion cost associated with all 70 urban areas

, The delay costs comprise about 88% of the total annual costs with the remainder of the annual costs coming from wasted fuel (12%)

, The congestion cost for all 70 urban areas totaled almost \$74 billion in 1996

Exhibit 34



- , 1996 congestion cost for all 70 urban areas is about \$74 billion
- , The average congestion cost for a Very Large urban area is about 5 times that of a Large urban area
- , The average congestion cost for a Large urban area is about 3 times that of a Medium urban area
- , The average congestion cost of a Medium urban area is about 4 times that of a Small urban area

Table 14. Congestion Tax in 1996

Population Group	Urban Area	Annual Congestion Cost			
		Per Eligible Driver (dollars)	Rank	Per Capita (dollars)	Rank
Vlg	Washington, DC-MD-VA	\$ 1,290	1	\$ 1,055	1
Vlg	Los Angeles, CA	1,205	2	885	3
Lrg	Seattle-Everett, WA	1,155	3	915	2
Vlg	Detroit, MI	1,095	4	840	5
Lrg	Atlanta, GA	1,095	4	855	4
Lrg	San Jose, CA	1,070	6	825	7
Vlg	San Francisco-Oakland, CA	1,055	7	835	6
Vlg	Houston, TX	1,055	7	785	8
Lrg	San Bernardino-Riverside, CA	1,030	9	735	11
Lrg	Dallas, TX	1,015	10	770	9
Med	Austin, TX	970	11	750	10
Med	Nashville, TN	920	12	720	12
Lrg	Miami-Hialeah, FL	905	13	710	14
Vlg	Boston, MA	900	14	720	12
Lrg	Fort Worth, TX	840	15	630	17
Sml	Harrisburg, PA	840	15	665	15
Med	Jacksonville, FL	830	17	615	19
Lrg	St. Louis, MO-IL	825	18	635	16
Lrg	Denver, CO	825	18	630	17
Lrg	Portland-Vancouver, OR-WA	765	20	600	20
Lrg	Sacramento, CA	730	21	545	24
Med	Louisville, KY-IN	720	22	570	21
Lrg	Baltimore, MD	715	23	560	23
Vlg	New York NY-Northeastern, NJ	705	24	570	21
Med	Albuquerque, NM	700	25	535	25
Vlg	Chicago, IL-Northwestern, IN	670	26	510	26
Lrg	Orlando, FL	660	27	505	27
Lrg	Norfolk, VA	645	28	500	29
Med	Hartford-Middletown, CT	640	29	505	27
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	625	30	490	30
Lrg	San Diego, CA	620	31	470	33
Med	Providence-Pawtucket, RI-MA	615	32	485	31
Lrg	Kansas City, MO-KS	610	33	470	33
Med	Tampa, FL	610	33	480	32
Lrg	San Antonio, TX	605	35	450	38
Med	Omaha, NE-IA	595	36	450	38
Lrg	Phoenix, AZ	590	37	455	35
Lrg	Cincinnati, OH-KY	590	37	450	38
Med	Charlotte, NC	590	37	455	35
Lrg	Minneapolis-St. Paul, MN	575	40	455	35

Table 14. Congestion Tax in 1996, continued

Population Group	Urban Area	Annual Congestion Cost			
		Per Eligible Driver (dollars)	Rank	Per Capita (dollars)	Rank
Sml	Allentown-Bethlehem-Easton, PA-NJ	\$ 570	41	\$ 450	38
Med	Tacoma, WA	535	42	405	42
Med	Honolulu, HI	520	43	405	42
Lrg	Las Vegas, NV	510	44	390	46
Lrg	Columbus, OH	505	45	395	45
Med	Indianapolis, IN	505	45	400	44
Med	Memphis, TN-AR-MS	505	45	380	49
Lrg	New Orleans, LA	500	48	385	48
Lrg	Milwaukee, WI	495	49	380	49
Lrg	Pittsburgh, PA	485	50	390	46
Med	Oklahoma City, OK	460	51	350	51
Sml	Colorado Springs, CO	450	52	340	53
Vlg	Philadelphia, PA-NJ	445	53	345	52
Med	Salt Lake City, UT	430	54	300	58
Med	Tucson, AZ	420	55	330	54
Med	Rochester, NY	405	56	305	55
Sml	Salem, OR	395	57	305	55
Lrg	Cleveland, OH	390	58	305	55
Med	Fresno, CA	350	59	245	60
Sml	Spokane, WA	340	60	260	59
Sml	Albany-Schenectady-Troy, NY	295	61	230	61
Med	El Paso, TX-NM	290	62	205	64
Lrg	Buffalo-Niagara Falls, NY	285	63	225	62
Sml	Corpus Christi, TX	285	63	210	63
Sml	Bakersfield, CA	270	65	190	65
Sml	Eugene-Springfield, OR	220	66	165	66
Sml	Laredo, TX	200	67	135	68
Sml	Beaumont, TX	180	68	145	67
Sml	Brownsville, TX	165	69	110	69
Sml	Boulder, CO	125	70	95	70
	70 City Average	629		484	
	Very large	936		727	
	Large	702		540	
	Medium	581		445	
	Small	333		254	

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population
 Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population
 Sml — Small urban areas - less than 500,000 population

, The urban areas with the highest annual congestion cost per driver by population size are:

Very Large	Washington DC	Cost per driver: \$1,290
Large	Seattle-Everett	Cost per driver: \$1,155
Medium	Austin	Cost per driver: \$970
Small	Harrisburg	Cost per driver: \$840

, The urban areas with the lowest annual congestion cost per driver by population size are:

Very Large	Philadelphia	Cost per driver: \$445
Large	Buffalo-Niagara Falls	Cost per driver: \$285
Medium	El Paso	Cost per driver: \$290
Small	Boulder	Cost per driver: \$125

, 10 urban areas have congestion costs per driver of more than \$1000 per year which equates to more than \$4 per work day

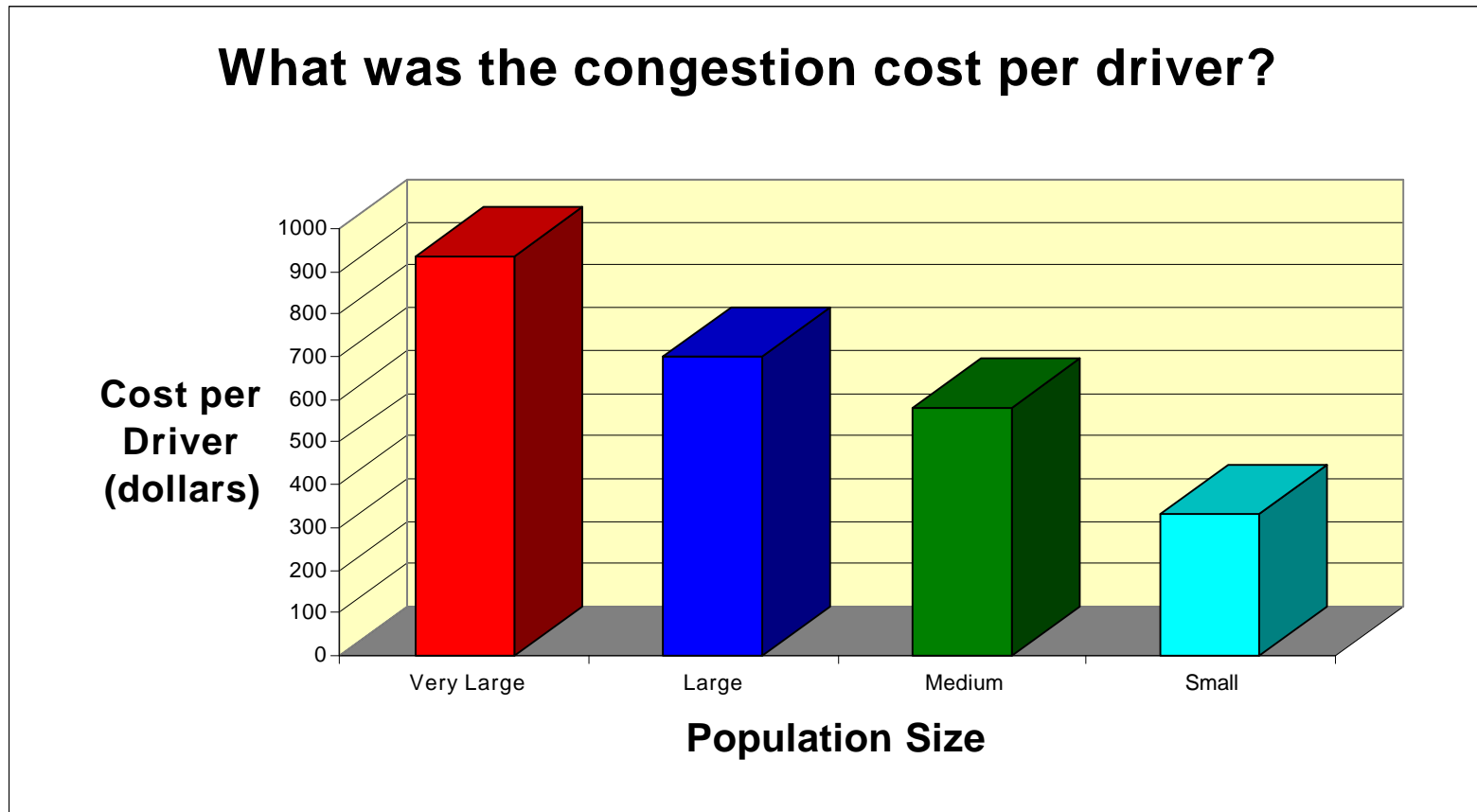
, 10 urban areas have congestion costs per driver of between \$750 and \$1000 which equates to more than \$3 per work day

, 28 urban areas have congestion costs per driver of between \$500 and \$750 which equates to between \$2 and \$3 per work day

, 17 urban areas have congestion costs per driver of between \$250 and \$500 which equates to between \$1 and \$2 per work day

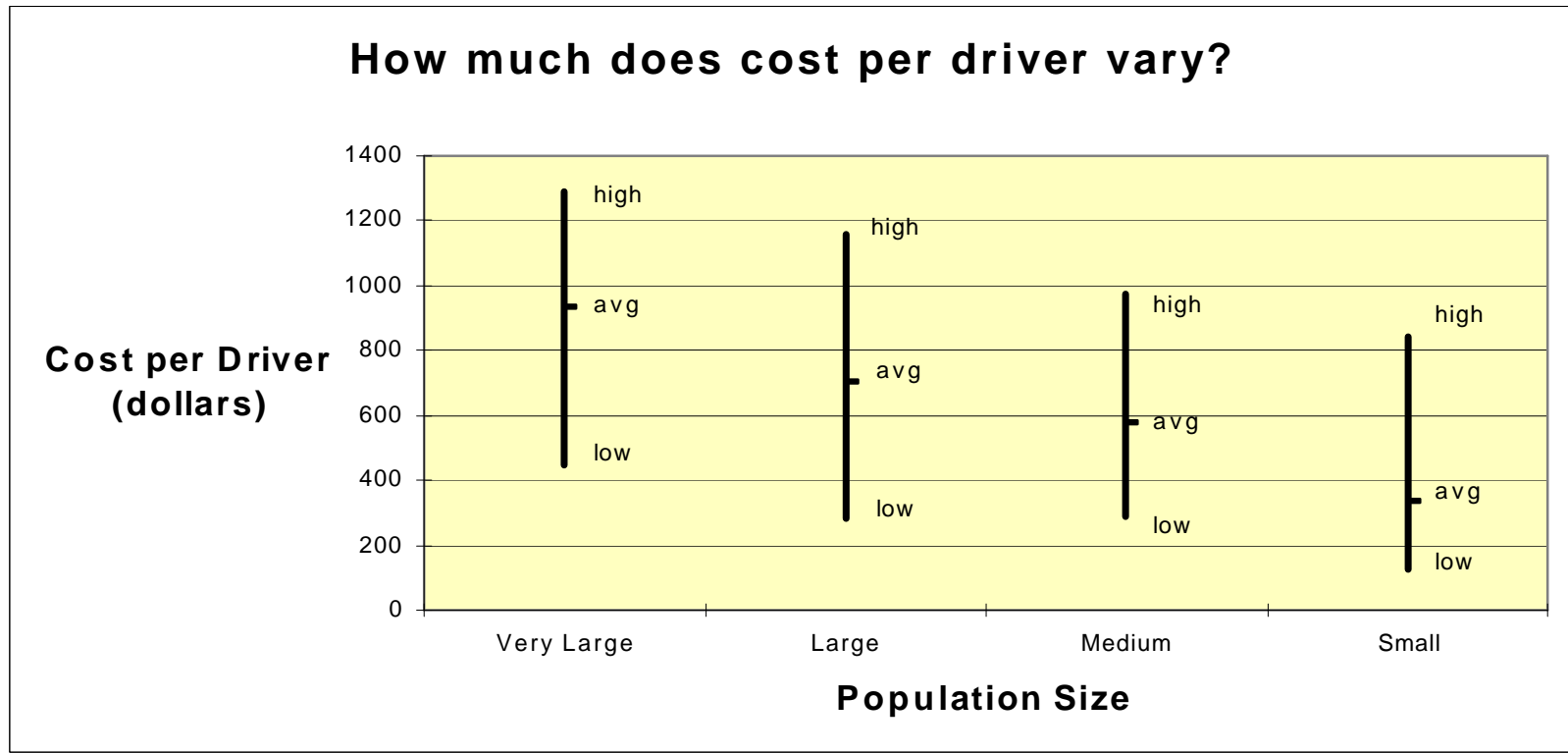
, 5 urban areas have congestion cost per driver of less than \$250 which equate to less than \$1 per work day

Exhibit 35



- , The average congestion cost per driver ranges from \$333 in the Small urban areas to \$936 in the Very Large urban areas
- , The annual congestion cost per driver in the Very Large urban areas equate to about \$4 per workday
- , The annual congestion cost per driver in the Small urban areas equate to just over \$1 per workday
- , In the Medium and Large urban areas, drivers spend about \$2 and \$3, respectively, per workday due to congestion

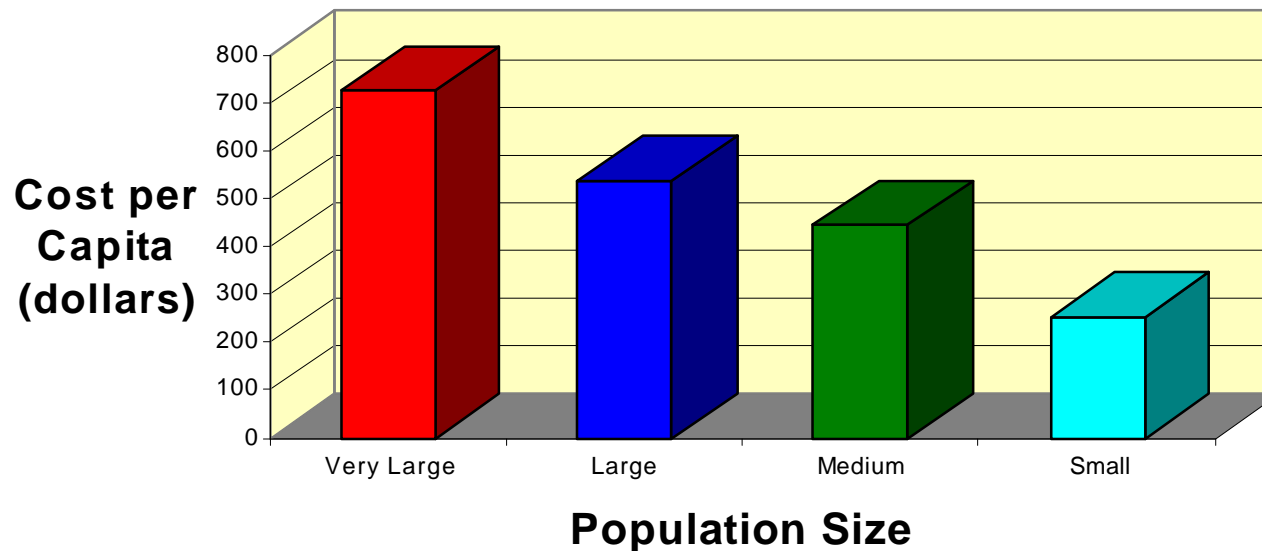
Exhibit 36



- , The congestion cost per driver in the Very Large urban areas range from \$445 (Low) to \$1,290 (High) with the average at \$936
- , The congestion cost per driver in the Large urban areas range from \$285 (Low) to \$1,155 (High) with the average at \$702
- , The congestion cost per driver in the Medium urban areas range from \$290 (Low) to \$970 (High) with an average at \$581
- , The congestion cost per driver in the Small urban areas range from \$125 (Low) to \$840 (High) with an average at \$333

Exhibit 37

What was the congestion cost per capita?



- , The average congestion cost per capita ranges from \$254 in the Small urban areas to \$727 in the Very Large urban areas
- , The annual congestion cost per capita in the Very Large urban areas equate to about \$3 per workday
- , The annual congestion cost per capita in the Small urban areas equate to just over \$1 per workday
- , In the Medium and Large urban areas, persons spend about \$2 per workday due to congestion

Table 15. Illustration of Annual Capacity Increase Required to Prevent Congestion Growth

Population Group	Urban Area	Existing (1996) Lane-mile		Average Annual VMT Growth (%) ¹	Annual Freeway Lane-mile		Annual Prin. Arterial Lane-mile		Lane-mile Deficiency	
		Fwy	Prin. Art.		Needed	Added ²	Needed	Added ²	Fwy	Prin. Art.
Vlg	New York NY-Northeastern, NJ	6,460	7,810	2.0	130	103	157	46	27	111
Vlg	Los Angeles, CA	5,550	12,700	1.0	58	39	133	50	19	83
Med	Indianapolis, IN	875	1,085	8.6	76	26	94	50	50	44
Lrg	Orlando, FL	715	1,340	8.9	64	29	119	63	35	56
Lrg	Phoenix, AZ	875	3,355	3.5	30	44	116	11	(14)	105
Lrg	Atlanta, GA	2,180	2,200	7.6	166	108	168	145	58	23
Vlg	Detroit, MI	1,860	4,480	2.2	42	10	100	53	32	47
Lrg	St. Louis, MO-IL	1,800	2,075	3.8	68	25	79	45	43	34
Lrg	Kansas City, MO-KS	1,675	1,140	5.2	88	66	60	13	22	47
Lrg	Minneapolis-St. Paul, MN	1,580	1,270	3.9	62	18	50	30	44	20
Lrg	San Antonio, TX	1,045	1,205	5.5	57	41	66	20	16	46
Vlg	Washington, DC-MD-VA	1,835	2,410	3.3	60	54	79	23	6	56
Med	Nashville, TN	715	1,030	6.9	49	41	71	18	8	53
Vlg	Chicago, IL-Northwestern, IN	2,635	5,435	3.7	97	49	201	196	48	5
Lrg	Denver, CO	1,040	1,945	3.1	32	20	60	21	12	39
Med	Memphis, TN-AR-MS	400	1,080	4.2	17	(10)	45	25	27	20
Vlg	Philadelphia, PA-NJ	1,745	3,350	2.0	35	33	66	23	2	43
Lrg	Fort Worth, TX	1,160	1,085	5.2	61	28	57	46	33	11
Med	Jacksonville, FL	620	1,390	5.6	35	41	78	28	(6)	50
Lrg	Las Vegas, NV	365	535	8.3	30	28	45	4	2	41
Lrg	Pittsburgh, PA	1,185	1,890	2.2	26	16	42	9	10	33
Med	Louisville, KY-IN	695	660	7.3	51	23	48	34	28	14
Lrg	San Jose, CA	1,245	1,520	3.3	41	11	51	40	30	11
Vlg	Boston, MA	1,550	3,005	1.9	30	9	58	39	21	19
Med	Charlotte, NC	405	620	7.1	29	25	44	10	4	34
Lrg	Dallas, TX	1,865	2,010	3.4	63	29	68	65	34	3
Vlg	Houston, TX	2,415	2,345	3.4	82	85	79	41	(3)	38
Lrg	Cleveland, OH	1,225	1,200	2.5	30	11	29	15	19	14
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	770	1,310	4.9	38	30	65	40	8	25
Lrg	Baltimore, MD	1,450	1,775	2.5	37	25	45	26	12	19
Lrg	Cincinnati, OH-KY	995	850	3.1	31	20	26	6	11	20
Lrg	Columbus, OH	860	670	3.4	30	13	23	9	17	14
Med	Austin, TX	550	700	9.3	51	23	65	64	28	1
Med	Albuquerque, NM	290	900	6.1	18	15	55	33	3	22
Sml	Corpus Christi, TX	265	390	7.2	19	19	28	4	0	24
Lrg	Seattle-Everett, WA	1,310	1,545	0.9	12	10	14	(8)	2	22
Lrg	Buffalo-Niagara Falls, NY	615	1,050	1.0	6	(5)	11	1	11	10
Med	Oklahoma City, OK	750	900	4.3	32	6	39	45	26	(6)
Sml	Albany-Schenectady-Troy, NY	530	540	2.1	11	3	11	1	8	10
Lrg	Sacramento, CA	825	1,300	1.8	15	6	23	15	9	8

Table 15. Illustration of Annual Capacity Increase Required to Prevent Congestion Growth, continued

Population Group	Urban Area	Existing (1996) Lane-mile		Average Annual VMT Growth (%) ¹	Annual Freeway Lane-mile		Annual Prin. Arterial Lane-mile		Lane-mile Deficiency	
		Fwy	Prin. Art.		Needed	Added ²	Needed	Added ²	Fwy	Prin. Art.
Med	Salt Lake City, UT	550	515	4.4	24	6	22	23	18	(1)
Lrg	Norfolk, VA	610	830	3.4	21	13	28	20	8	8
Lrg	Portland-Vancouver, OR-WA	655	800	5.9	38	20	47	49	18	(2)
Lrg	San Bernardino-Riverside, CA	985	2,150	1.5	15	19	33	13	(4)	20
Med	Omaha, NE-IA	290	570	4.2	12	10	24	11	2	13
Lrg	Miami-Hialeah, FL	690	2,400	2.4	16	16	57	43	0	14
Med	El Paso, TX-NM	380	920	2.7	10	6	25	16	4	9
Sml	Harrisburg, PA	385	315	3.5	13	11	11	0	2	11
Med	Tucson, AZ	160	750	6.5	10	8	49	38	2	11
Sml	Bakersfield, CA	200	585	3.9	8	4	23	16	4	7
Sml	Colorado Springs, CO	260	400	3.7	10	10	15	4	0	11
Med	Fresno, CA	240	455	2.9	7	6	13	4	1	9
Sml	Eugene-Springfield, OR	110	130	3.2	4	0	4	1	4	3
Sml	Allentown-Bethlehem-Easton, PA-NJ	290	425	3.0	9	8	13	8	1	5
Sml	Laredo, TX	55	135	6.9	4	1	9	6	3	3
Lrg	Milwaukee, WI	625	1,250	3.2	20	6	40	48	14	(8)
Vlg	San Francisco-Oakland, CA	2,490	2,375	0.7	18	15	17	14	3	3
Med	Tampa, FL	390	885	5.6	22	20	50	46	2	4
Sml	Brownsville, TX	30	125	3.8	1	0	5	1	1	4
Med	Rochester, NY	485	180	2.9	14	1	5	13	13	(8)
Lrg	San Diego, CA	1,785	1,810	1.0	17	11	18	19	6	(1)
Sml	Beaumont, TX	115	240	3.1	4	0	8	9	4	(1)
Med	Hartford-Middletown, CT	635	690	1.5	10	8	10	9	2	1
Med	Honolulu, HI	425	255	3.1	13	13	8	5	0	3
Lrg	New Orleans, LA	425	770	3.7	16	13	29	29	3	0
Sml	Boulder, CO	50	100	3.5	2	1	4	3	1	1
Med	Providence-Pawtucket, RI-MA	620	820	2.4	15	13	20	20	2	0
Sml	Salem, OR	95	265	1.5	1	1	4	4	0	0
Sml	Spokane, WA	125	550	1.5	2	0	8	10	2	(2)
Med	Tacoma, WA	300	585	1.0	3	5	6	5	(2)	1
	70 Area total	69,370	104,370		2,240	1,400	3,290	1,890	840	1,400
	70 area average	991	1,491	3.8	32	20	47	27	12	20
	Very large area average	2,949	4,879	2.3	61	44	99	54	17	45
	Large area average	1,091	1,474	3.8	40	24	52	30	16	23
	Medium area average	489	750	4.8	25	14	39	25	11	14
	Small area average	193	323	3.6	7	4	11	5	2	6

Notes: ¹ Average annual growth rate of freeway and principal arterial streets travel between 1992 and 1996.

² Average lane-miles added annually from 1992 to 1996.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

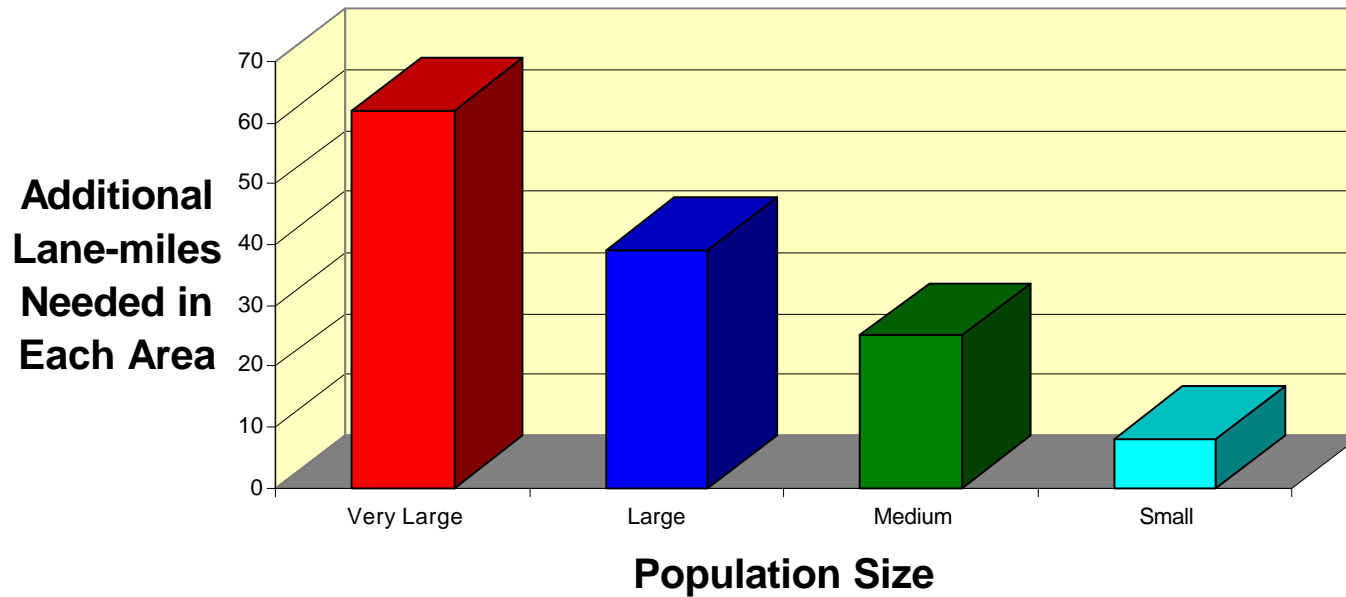
Sml — Small urban areas - less than 500,000 population

- , The urban area from the Very Large population group with the largest annual lane-mile deficiency is New York with about a 138 lane-mile deficiency per year
- , The urban areas from the Large population group with the largest annual lane-mile deficiency are Orlando and Phoenix with about a 91 lane-mile deficiency per year
- , The urban area from the Medium population group with the largest annual lane-mile deficiency is Indianapolis with about a 94 lane-mile deficiency per year
- , The urban area from the Small population group with the largest annual lane-mile deficiency is Corpus Christi with about a 24 lane-mile deficiency per year
- , Some urban areas that have fairly high lane-mile deficiency for their population size are: Nashville (Medium) with 61 lane-miles
 Memphis (Medium) with 47 lane-miles
 Jacksonville (Medium) 44 lane-miles
 Albany-Schenectady-Troy (Small) 18 lane-miles
- , Some urban areas that have fairly low lane-mile deficiency for their population size are: San Francisco-Oakland (Very Large) with 6 lane-miles
 San Diego (Large) with 5 lane-miles
 New Orleans (Large) with 3 lane-miles
- , The number of freeway lane-miles deficient in all 70 urban areas is 840, which is equal to about 105 miles of an 8-lane freeway
- , The number of principal arterial lane-miles deficient in all 70 urban areas is 1,400, which is equal to about 350 miles of a 4-lane street

Exhibit 38

How much more roadway is needed every year?

(If road construction were the only solution).



- , Very Large urban areas have about 8 times the lane-deficiency as the Small urban areas
- , The Small urban area lane-deficiency is 1/3 of the Medium urban area deficiency
- , The annual lane-mile deficiency in all 70 urban areas combined is over 2,200 lane-miles

Table 16. If Road Expansion Were the Only Congestion Reduction Technique

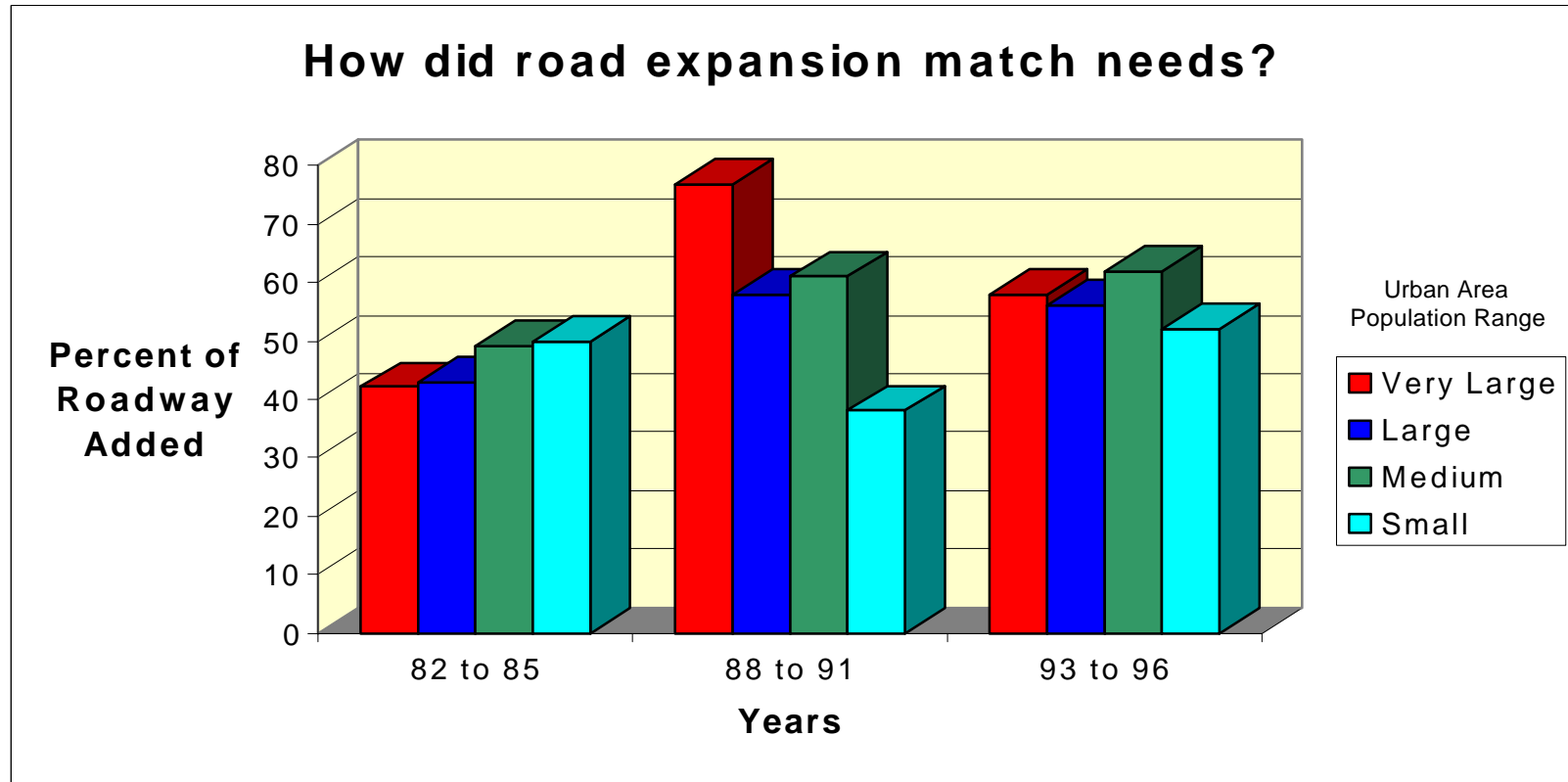
Population Group	1982-1985		1988-1991		1993-1996	
	Percent Growth in VMT	Percent Added ^d	Percent Growth in VMT	Percent Added ^d	Percent Growth in VMT	Percent Added ^d
70 Area Average	4.4	45	2.9	65	2.9	60
Very Large	3.7	42	2.5	77	1.9	58
Large	4.8	43	3.3	58	3.4	56
Medium	5.5	49	3.1	61	4.9	62
Small	4.9	50	3.3	38	3.4	52

¹ Lane-miles added divided by lane-miles needed.

Note: Assumes that all added lane-miles would be roadway expansion since no reliable data exists concerning the addition of lane-miles through changing urban boundaries.

- , The amount of roadway constructed in 1988 to 1991 and 1993 to 1996 is generally higher than the percent constructed in 1982 to 1985. This may be due to a higher growth rate in VMT in the early 1980s
- , The Very Large urban areas experienced a peak in percent constructed in 1988 to 1991 of 77%
- , The Medium and Large urban areas experienced increased in percent constructed between in between 1982 and 1991, but leveled off after that point
- , The Small urban areas experienced a dip in the 1988 to 1991 period in percent constructed

Exhibit 39



- , The Very Large urban areas experienced a peak in percent constructed in 1988 to 1991 of 77%
- , The Medium and Large urban areas experienced increases in percent constructed between 1982 and 1991, up to 61% and 58% respectively, but leveled off after that point
- , The Small urban areas experienced a dip in the 1988 to 1991 period (down to 38%) in percent constructed

Table 17. Congestion Index and Cost Values, 1994 and 1996

Population Group	Urban Area	Roadway Congestion Index				Annual Congestion Cost per Driver (\$)				Annual Congestion Cost (\$ millions)			
		1994 Value	1996 Value	1994 Rank	1996 Rank	1994	1996	1994 Rank	1996 Rank	1994	1996	1994 Rank	1996 Rank
Vlg	Los Angeles, CA	1.52	1.57	1	1	\$1,035	\$1,205	1	2	\$9,185	\$10,805	1	1
Vlg	Washington, DC-MD-VA	1.43	1.43	2	2	1,030	1,290	2	1	2,930	3,655	5	4
Vlg	Chicago, IL-Northwestern, IN	1.28	1.34	5	3	545	670	26	26	3,225	4,005	3	3
Lrg	Miami-Hialeah, FL	1.32	1.34	4	3	780	905	12	13	1,195	1,460	13	13
Vlg	San Francisco-Oakland, CA	1.33	1.33	3	5	975	1055	4	7	3,000	3,250	4	5
Lrg	Seattle-Everett, WA	1.24	1.27	6	6	995	1155	3	3	1,495	1,780	11	11
Lrg	Atlanta, GA	1.18	1.24	11	7	850	1095	8	4	1,595	2,110	9	9
Vlg	Detroit, MI	1.24	1.24	6	7	860	1095	7	4	2,655	3,165	6	6
Lrg	San Diego, CA	1.21	1.23	8	9	520	620	28	31	1,015	1,200	14	17
Lrg	San Bernardino-Riverside, CA	1.20	1.22	9	10	890	1030	6	9	855	990	19	21
Lrg	Las Vegas, NV	1.18	1.20	11	11	425	510	44	44	300	420	41	40
Vlg	New York NY-Northeastern, NJ	1.15	1.18	13	12	590	705	21	24	8,235	9,810	2	2
Med	Tacoma, WA	1.20	1.18	9	12	510	535	29	42	220	240	48	52
Lrg	Portland-Vancouver, OR-WA	1.11	1.16	16	14	585	765	22	20	545	765	24	23
Lrg	Phoenix, AZ	1.09	1.14	18	15	580	590	24	37	950	1,070	17	19
Lrg	Denver, CO	1.07	1.12	21	16	635	825	18	18	815	1,115	20	18
Lrg	Minneapolis-St. Paul, MN	1.04	1.12	28	16	465	575	37	40	795	1,020	21	20
Lrg	Dallas, TX	1.09	1.11	18	18	845	1015	9	10	1,410	1,765	12	12
Vlg	Houston, TX	1.12	1.11	15	18	935	1055	5	7	2,040	2,405	7	7
Med	Memphis, TN-AR-MS	0.94	1.11	43	18	425	505	44	45	290	365	43	44
Lrg	San Jose, CA	1.06	1.11	23	18	805	1070	10	6	955	1,315	16	14
Med	Honolulu, HI	1.13	1.10	14	22	465	520	37	43	250	285	45	48
Lrg	Baltimore, MD	1.06	1.09	23	23	565	715	25	23	950	1,205	17	16
Vlg	Boston, MA	1.08	1.09	20	23	720	900	14	14	1,725	2,170	8	8
Lrg	New Orleans, LA	1.11	1.09	16	23	440	500	43	48	375	430	32	39
Lrg	Cincinnati, OH-KY	1.05	1.07	26	26	460	590	39	37	445	570	27	28
Vlg	Philadelphia, PA-NJ	1.05	1.07	26	26	385	445	49	53	1,585	1,825	10	10
Lrg	Sacramento, CA	1.06	1.07	23	26	595	730	20	21	540	670	25	26
Med	Tampa, FL	1.07	1.06	21	29	490	610	33	33	300	395	41	43
Lrg	St. Louis, MO-IL	0.98	1.05	34	30	650	825	17	18	995	1,280	15	15
Med	Louisville, KY-IN	0.95	1.04	40	31	540	720	27	22	340	475	38	34
Med	Austin, TX	0.97	1.03	36	32	805	970	10	11	370	465	34	36
Lrg	Ft. Lauderdale-Hollywd-Pompano Beach, FL	0.99	1.03	31	32	495	625	32	30	515	730	26	25
Lrg	Milwaukee, WI	1.00	1.03	29	32	405	495	48	49	385	475	31	34
Lrg	Cleveland, OH	1.00	1.02	29	35	305	390	57	58	435	570	28	28
Med	Tucson, AZ	0.99	1.02	31	35	360	420	52	55	170	210	55	54
Med	Albuquerque, NM	0.99	1.01	31	37	585	700	22	25	240	300	46	47
Lrg	Columbus, OH	0.95	1.01	40	37	410	505	47	45	320	400	40	41
Lrg	Fort Worth, TX	0.97	1.01	36	37	655	840	16	15	610	805	22	22
Med	Indianapolis, IN	0.92	1.00	48	40	360	505	52	45	275	400	44	41

Table 17. Congestion Index and Cost Values, 1994 and 1996, continued

Population Group	Urban Area	Roadway Congestion Index				Annual Congestion Cost per Driver (\$)				Annual Congestion Cost (\$ millions)			
		1994 Value	1996 Value	1994 Rank	1996 Rank	1994	1996	1994 Rank	1996 Rank	1994	1996	1994 Rank	1996 Rank
Med	Nashville, TN	0.96	1.00	39	40	\$ 730	\$ 920	13	12	\$ 350	\$ 450	36	37
Med	Omaha, NE-IA	0.98	1.00	34	40	500	595	31	36	205	250	50	51
Med	Salt Lake City, UT	0.94	1.00	43	40	315	430	55	54	195	270	51	49
Med	Jacksonville, FL	0.97	0.99	36	44	600	830	19	17	355	505	35	32
Lrg	San Antonio, TX	0.92	0.99	48	44	450	605	41	35	405	550	30	30
Med	Charlotte, NC	0.94	0.98	43	46	450	590	41	37	190	260	52	50
Lrg	Norfolk, VA	0.93	0.96	46	47	460	645	39	28	350	505	36	32
Med	Providence-Pawtucket, RI-MA	0.95	0.96	40	47	480	615	36	32	335	435	39	38
Med	Hartford-Middletown, CT	0.93	0.93	46	49	490	640	33	29	240	320	46	46
Sml	Eugene-Springfield, OR	0.89	0.92	50	50	125	220	68	66	20	35	66	66
Med	Oklahoma City, OK	0.85	0.91	54	51	325	460	54	51	210	345	49	45
Lrg	Orlando, FL	0.86	0.91	52	51	505	660	30	27	375	535	32	31
Sml	Harrisburg, PA	0.86	0.88	52	53	690	840	15	15	165	210	56	54
Sml	Salem, OR	0.85	0.88	54	53	310	395	56	57	40	55	65	65
Sml	Allentown-Bethlehem-Easton, PA-NJ	0.87	0.87	51	55	485	570	35	41	175	210	54	54
Med	Rochester, NY	0.82	0.87	58	55	280	405	59	56	135	190	57	57
Lrg	Pittsburgh, PA	0.83	0.85	57	57	385	485	49	50	595	755	23	24
Sml	Spokane, WA	0.84	0.84	56	58	290	340	58	60	70	85	62	62
Sml	Albany-Schenectady-Troy, NY	0.77	0.81	62	59	270	295	62	61	105	115	59	61
Lrg	Kansas City, MO-KS	0.80	0.81	59	59	425	610	44	33	435	630	28	27
Med	El Paso, TX-NM	0.78	0.80	61	61	280	290	59	62	115	125	58	60
Sml	Boulder, CO	0.77	0.79	62	62	125	125	68	70	10	10	69	70
Sml	Brownsville, TX	0.75	0.79	65	62	110	165	70	69	10	15	69	69
Lrg	Buffalo-Niagara Falls, NY	0.79	0.78	60	64	215	285	65	63	180	240	53	52
Sml	Corpus Christi, TX	0.76	0.78	64	64	240	285	63	63	50	65	64	64
Med	Fresno, CA	0.75	0.78	65	64	280	350	59	59	100	130	61	59
Sml	Beaumont, TX	0.73	0.76	68	67	150	180	66	68	15	20	67	67
Sml	Colorado Springs, CO	0.74	0.74	67	68	375	450	51	52	105	135	59	58
Sml	Laredo, TX	0.69	0.73	69	69	150	200	66	67	15	20	67	67
Sml	Bakersfield, CA	0.66	0.68	70	70	220	270	64	65	55	70	63	63
	70 City Average	1.11	1.14			510	629			859	1,056		
	Very large	1.27	1.29			786	936			3,842	4,566		
	Large	1.04	1.08			564	702			708	906		
	Medium	0.94	0.98			464	581			244	321		
	Small	0.78	0.80			272	333			64	80		

Source: TTI Analysis and Local Transportation Agency References.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

CHAPTER VIII—CONCLUSIONS

The problem with describing traffic congestion is that there is not a single measure that everyone agrees with, and the experiences of the travelers and residents varies by what routes are used and what time of day/week/year the travel occurs. Each traveler also has different expectations about their desired speed, cost and comfort of the trip, and they use these expectations to “grade” their trip. And these disagreements are vastly overshadowed by the discussion of what to do about the problem, if there is a problem.

USING CONGESTION MEASURE INFORMATION

Against this backdrop, the annual urban congestion statistics can be a part of the discussion. The report provides a source of data that can be used and interpreted for many purposes. It provides a method of gauging congestion from a system element perspective—looking at road segments, and the freeway and major street system as a whole. It also develops

information to estimate the conditions that a road traveler would experience—at the individual level.

The information can be used in conjunction with other analyses as a component in a future condition forecast. These have been used in cities when long-term planning and financing decisions are being made.

The lack of a single agreed-upon measure means that there are several techniques and measures presented in the study. No single measure is “more correct” than any other. The application depends on the type of concern, the type of analysis and the problem or solution being tested.

Some address the intensity or severity issue—“How bad is congestion for me?” The study offers a number of measures that relate to individual concerns.

The report shows congestion intensity is frequently related to size—larger urban areas have more congestion. Rapid congestion growth, however, is more often related to a growing economy rather than the size of the area—significant increases in residents and jobs almost always occur before the transportation system is expanded. So the trend information may be more relevant in some cities.

Some measures address the magnitude issue—“How much congestion is in our area?” This measure is very often related to population size; larger areas have greater delay and fuel consumed in congestion and higher costs as a result. These are useful in a benefit/cost sense and to identify the possible transportation needs.

The magnitude statistics are also useful in describing where in the United States the congestion problem is most significant—from a population size perspective. Certainly every major urban area has locations that cause travelers to believe there is a significant congestion problem. This local perception of

congestion may be more related to the recent traffic growth rate rather than to any research study measure.

HOW DO WE SOLVE THE CONGESTION PROBLEM?

The measurement of road congestion does not automatically mean that all the solutions should be in the form of road construction. One inescapable conclusion of this report is that it is very difficult to maintain the financial and public support to add roads and lanes as fast as travel volume grows. There are only 2 of the 70 areas studied—Houston and Phoenix—with congestion levels lower (by any of the measures) in 1996 than in 1982.

These areas addressed the congestion problems they faced in the early 1980s primarily by widening existing roads and constructing new roads. Phoenix and Houston have also implemented a number of other types of projects to address mobility concerns.

Almost all the urban areas in this study are pursuing more than one technique to improve mobility. At a relatively basic level, congestion levels can be improved by one or more of the following approaches. **The combination of techniques that are implemented in an urban area is a product of financial, environmental, public support and other concerns; the program may be different in every urban area.**

Add road space—This might be new roads or widened existing roads.

Lower the number of vehicles—Techniques attempt to reduce the number of vehicles or increase the number of people in each vehicle.

Change the time that vehicles use the road—This reduces the load on the system at peak travel times.

Getting more vehicles past a spot on the road—More efficient operation of the roadway has the effect of adding capacity, although not usually of the same magnitude as adding a full lane.

Provide more land use pattern options—To the extent that existing land use development encourages or requires

vehicle use, it contributes to congestion. Certainly there are many people who like this lifestyle, but some urban areas are pursuing a more varied approach to land development to provide choices, some of which seek to put jobs, shops and houses closer together.

Add Road Space

The expenditures and/or public support to build more capacity have not maintained pace with the growth in demand, but there have been significant additions. Most of these have been traditional (e.g., non-toll) street or freeway lanes. There are, however, several toll highway projects under development and several tests of variable pricing ideas. These projects attempt to provide more capacity to a targeted market that is willing to pay for better service from the transport system than they get from a congested road.

Lower the number of vehicles

Increasing the number of carpoolers and transit riders decreases the number of vehicles on the transport network.

The typical situation may have a priority lane for high-occupancy vehicles installed on a freeway. If it is successful at increasing carpooling and transit and reduces vehicle use, it is usually because there is congestion on the freeway.

Unfortunately in most cases the gains in cars reduced are overwhelmed by more vehicles coming to the freeway from adjacent streets or changing the time they travel. This does not necessarily mean the treatment was a failure (although some carpool lanes do not increase carpooling), but rather the effects are not always obvious in a specific corridor or follow the expectations of congestion reduction.

Another very effective way areas have “addressed” congestion is to have an economic slowdown or recession. If a major industry has a slow period or a decline, congestion levels do not increase as sharply, or may decrease. The effect of the California economic slowdown of the early 1990s is evident in

the trend data in this report. Needless to say, congestion reduction was not the intended result of this slowdown, and recession is not the preferred option in most cities.

Change the time that vehicles use the road

Flexible work hours and telecommunication technology can provide ways for travelers to change the time they need to use the road system. Telecommunication technology can eliminate the need for physical travel altogether. The daily system travel amount may not change but if trips are moved away from the peak period, vehicle congestion can be reduced.

Getting more vehicles past a spot on the road

A more efficiently operating transport system can improve the vehicle moving capability of the roadway and the person moving capability of the transit system. The intelligent transportation system (ITS) is a group of technologies and processes that focus on making better use of the road space that already exists and the computer applications that improve

communications. Included in this range of road improvements are ideas such as ramp metering to smooth freeway traffic flow, traffic signal coordination, and systems for detecting and removing incidents quickly. Transit systems can also benefit from better methods for communicating between buses, control centers, the traffic signal system and customers.

Provide more land use pattern options

Changing the land use pattern is not a quick solution, and not everyone wishes to live near his or her office in a townhouse/apartment type of development. There are many reasons why city residents choose a place to live, many of which have nothing to do with transportation. However, there are a variety of ways to mix jobs, shops and homes that may result in lower vehicle trip-making. These developments can also be more conducive to transit use. The challenge is to make these economically viable for developers and desirable for consumers. With the shift of the “baby boom” families to more homes without children, there may be a more diversified

home ownership market in the future that may include less vehicle use as one aspect.

SO HOW DO WE MEASURE ALL OF THIS?

The focus of this report is on measuring congestion and mobility at the urban area level. But the effect of many of the solutions noted above is not illustrated in the measures in this report. Most of the urban areas in the report still rely on the basic freeway and street network to provide at least 95% of their mobility needs. The existing measures work reasonably well for describing this type of system.

As operational improvements and demand management activities are implemented, however, the measures will do a less effective job of describing travel conditions. The research team is pursuing a number of new measures and improvements to existing measures that will illustrate improvements in urban mobility well into the next century. These changes should be apparent over the next two reports as new information is produced.

APPENDIX A

INTENSITY MEASURE COMPARISONS

Tables A-1 through A-4 provide comparisons of several of the intensity measures of congestion. The measures all approach congestion from some aspect of an individual's experience.

These tables assist the reader in comparing the usefulness of each measure, and where individual urban areas rank on several measures. Population is also included to give the reader an idea of how urban area size compares to the intensity measure rankings. The list of measures include:

- ◆ Roadway Congestion Index
- ◆ Travel Rate Index
- ◆ Travel Delay per Driver
- ◆ Travel Delay per Capita
- ◆ Wasted Fuel per Driver
- ◆ Wasted Fuel per Capita
- ◆ Congestion Cost per Eligible Driver
- ◆ Congestion Cost per Capita

MAGNITUDE MEASURE COMPARISONS

Tables A-5, A-6 and A-7 provide a comparison of the size-related rankings and a summary of the growth in population and travel. More comprehensive statistics are available on the Urban Mobility Study web site(<http://mobility.tamu.edu>) for each area studied.

Table A-1. Travel Time and Traffic Density Measures for 1996

Population Group	Urban Area	Travel Rate Index	Rank	Roadway Congestion Index	Rank	Peak Period Speeds (mph)	
						Freeway	Prin. Arterial
Vlg	San Francisco-Oakland, CA	1.51	1	1.33	5	38	28
Lrg	Seattle-Everett, WA	1.51	2	1.27	6	37	29
Vlg	Los Angeles, CA	1.51	3	1.57	1	35	28
Vlg	Washington, DC-MD-VA	1.48	4	1.43	2	39	26
Lrg	Las Vegas, NV	1.45	5	1.20	11	39	27
Vlg	Houston, TX	1.42	6	1.11	18	40	29
Lrg	San Jose, CA	1.41	7	1.11	18	40	28
Vlg	Chicago, IL-Northwestern, IN	1.40	8	1.34	3	40	27
Vlg	New York, NY-Northeastern, NJ	1.40	9	1.18	12	42	26
Lrg	San Bernardino-Riverside, CA	1.40	10	1.22	10	39	29
Lrg	Miami-Hialeah, FL	1.39	11	1.34	3	39	27
Lrg	Atlanta, GA	1.38	12	1.24	7	42	27
Lrg	Denver, CO	1.36	13	1.12	16	42	28
Lrg	San Diego, CA	1.35	14	1.23	9	42	30
Vlg	Detroit, MI	1.35	15	1.24	7	42	28
Med	Tacoma, WA	1.34	16	1.18	12	41	31
Lrg	Sacramento, CA	1.34	17	1.07	26	43	28
Lrg	Portland-Vancouver, OR-WA	1.32	18	1.16	14	44	28
Lrg	Dallas, TX	1.32	19	1.11	18	44	30
Lrg	Phoenix, AZ	1.32	20	1.14	15	42	28
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	1.31	21	1.03	32	44	29
Med	Honolulu, HI	1.31	22	1.10	22	46	27
Lrg	Minneapolis-St. Paul, MN	1.30	23	1.12	16	45	29
Med	Austin, TX	1.30	24	1.03	32	45	29
Lrg	Cincinnati, OH-KY	1.29	25	1.07	26	45	30
Lrg	Milwaukee, WI	1.27	26	1.03	32	44	30
Lrg	Orlando, FL	1.27	27	0.91	51	45	29
Lrg	New Orleans, LA	1.27	28	1.09	23	46	29
Lrg	St. Louis, MO-IL	1.26	29	1.05	30	48	27
Med	Salt Lake City, UT	1.26	30	1.00	40	46	29
Vlg	Boston, MA	1.26	31	1.09	23	46	29
Vlg	Philadelphia, PA-NJ	1.26	32	1.07	26	49	27
Med	Tampa, FL	1.25	33	1.06	29	49	27
Med	Jacksonville, FL	1.25	34	0.99	44	47	29
Med	Charlotte, NC	1.25	35	0.98	46	48	28
Lrg	Fort Worth, TX	1.25	36	1.01	37	46	31
Lrg	Columbus, OH	1.24	37	1.01	37	48	29
Med	Tucson, AZ	1.24	38	1.02	35	50	28
Med	Omaha, NE-IA	1.24	39	1.00	40	51	27
Lrg	Norfolk, VA	1.23	40	0.96	47	47	30

Table A-1. Travel Time and Traffic Density Measures for 1996, continued

Population Group	Urban Area	Travel Rate Index	Rank	Roadway Congestion Index	Rank	Peak Period Speeds (mph)	
						Freeway	Prin. Arterial
Lrg	Cleveland, OH	1.23	41	1.02	35	48	29
Med	Providence-Pawtucket, RI-MA	1.23	42	0.96	47	47	30
Med	Albuquerque, NM	1.22	43	1.01	37	47	29
Lrg	San Antonio, TX	1.22	44	0.99	44	48	31
Sml	Allentown-Bethlehem-Easton, PA-NJ	1.22	45	0.87	55	52	27
Lrg	Baltimore, MD	1.22	46	1.09	23	48	31
Med	Memphis, TN-AR-MS	1.20	47	1.11	18	50	29
Lrg	Pittsburgh, PA	1.19	48	0.85	57	53	28
Sml	Colorado Springs, CO	1.19	49	0.74	68	50	29
Med	Nashville, TN	1.19	50	1.00	40	50	30
Med	Louisville, KY-IN	1.18	51	1.04	31	52	28
Sml	Harrisburg, PA	1.18	52	0.88	53	54	27
Med	Fresno, CA	1.17	53	0.78	64	53	29
Med	Rochester, NY	1.15	54	0.87	55	52	31
Med	Indianapolis, IN	1.14	55	1.00	40	52	31
Sml	Salem, OR	1.14	56	0.88	53	52	31
Med	Hartford-Middletown, CT	1.14	57	0.93	49	52	31
Med	Oklahoma City, OK	1.13	58	0.91	51	53	31
Sml	Laredo, TX	1.12	59	0.73	69	57	30
Lrg	Kansas City, MO-KS	1.12	60	0.81	59	54	31
Sml	Spokane, WA	1.12	61	0.84	58	53	31
Med	El Paso, TX-NM	1.11	62	0.80	61	51	33
Lrg	Buffalo-Niagara Falls, NY	1.11	63	0.78	64	54	31
Sml	Brownsville, TX	1.10	64	0.79	62	57	31
Sml	Eugene-Springfield, OR	1.10	65	0.92	50	58	30
Sml	Bakersfield, CA	1.10	66	0.68	70	56	31
Sml	Boulder, CO	1.09	67	0.79	62	59	30
Sml	Albany-Schenectady-Troy, NY	1.08	68	0.81	59	59	30
Sml	Corpus Christi, TX	1.06	69	0.78	64	56	34
Sml	Beaumont, TX	1.05	70	0.76	67	58	32
	70 City Average	1.44		1.25		48	29
	Very Large	1.29		1.40		41	28
	Large	1.08		1.30		45	29
	Medium	0.98		1.22		49	29
	Small	0.80		1.12		55	30

Source: TTI Analysis.

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

Table A-2. Travel Time and Delay Measures for 1996

Population Group	Urban Area	Annual Hours of Delay per Capita	Rank	Travel Rate Index	Rank
Vlg	Washington, DC-MD-VA	67	1	1.48	4
Lrg	Seattle-Everett, WA	56	2	1.51	2
Vlg	Los Angeles, CA	56	2	1.51	3
Lrg	Atlanta, GA	54	4	1.38	12
Vlg	Detroit, MI	53	5	1.35	15
Vlg	San Francisco-Oakland, CA	52	6	1.51	1
Lrg	San Jose, CA	52	6	1.41	7
Vlg	Houston, TX	49	8	1.42	6
Lrg	Dallas, TX	48	9	1.32	19
Med	Austin, TX	47	10	1.30	24
Lrg	San Bernardino-Riverside, CA	46	11	1.40	10
Lrg	Miami-Hialeah, FL	45	12	1.39	11
Vlg	Boston, MA	45	12	1.26	31
Med	Nashville, TN	45	12	1.19	50
Sml	Harrisburg, PA	41	15	1.18	52
Lrg	St. Louis, MO-IL	40	16	1.26	29
Lrg	Fort Worth, TX	40	16	1.25	36
Lrg	Denver, CO	39	18	1.36	13
Med	Jacksonville, FL	39	18	1.25	34
Lrg	Portland-Vancouver, OR-WA	37	20	1.32	18
Vlg	New York, NY-Northeastern, NJ	36	21	1.40	9
Med	Louisville, KY-IN	36	21	1.18	51
Lrg	Baltimore, MD	35	23	1.22	46
Lrg	Sacramento, CA	34	24	1.34	17
Med	Albuquerque, NM	34	24	1.22	43
Vlg	Chicago, IL-Northwestern, IN	32	26	1.40	8
Lrg	Orlando, FL	32	26	1.27	27
Lrg	Norfolk, VA	32	26	1.23	40
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	31	29	1.31	21
Med	Tampa, FL	31	29	1.25	33
Med	Providence-Pawtucket, RI-MA	30	31	1.23	42
Med	Hartford-Middletown, CT	30	31	1.14	57
Lrg	San Diego, CA	29	33	1.35	14
Lrg	Phoenix, AZ	29	33	1.32	20
Med	Charlotte, NC	29	33	1.25	35
Med	Omaha, NE-IA	29	33	1.24	39
Sml	Allentown-Bethlehem-Easton, PA-NJ	29	33	1.22	45
Lrg	Kansas City, MO-KS	29	33	1.12	60
Lrg	Minneapolis-St. Paul, MN	28	39	1.30	23
Lrg	Cincinnati, OH-KY	28	39	1.29	25

Source: TTI Analysis.

Table A-2. Travel Time and Delay Measures for 1996, continued

Population Group	Urban Area	Annual Hours of Delay per Capita	Rank	Travel Rate Index	Rank
Lrg	San Antonio, TX	28	39	1.22	44
Lrg	Las Vegas, NV	25	42	1.45	5
Med	Tacoma, WA	25	42	1.34	16
Lrg	New Orleans, LA	25	42	1.27	28
Lrg	Columbus, OH	25	42	1.24	37
Lrg	Pittsburgh, PA	25	42	1.19	48
Med	Indianapolis, IN	25	42	1.14	55
Med	Honolulu, HI	24	48	1.31	22
Med	Memphis, TN-AR-MS	24	48	1.20	47
Lrg	Milwaukee, WI	23	50	1.27	26
Vlg	Philadelphia, PA-NJ	22	51	1.26	32
Sml	Colorado Springs, CO	22	51	1.19	49
Med	Oklahoma City, OK	22	51	1.13	58
Med	Tucson, AZ	21	54	1.24	38
Med	Salt Lake City, UT	19	55	1.26	30
Lrg	Cleveland, OH	19	55	1.23	41
Med	Rochester, NY	19	55	1.15	54
Sml	Salem,, OR	17	58	1.14	56
Med	Fresno, CA	16	59	1.17	53
Sml	Spokane, WA	16	59	1.12	61
Sml	Albany-Schenectady-Troy, NY	15	61	1.08	68
Lrg	Buffalo-Niagara Falls, NY	14	62	1.11	63
Sml	Corpus Christi, TX	14	62	1.06	69
Med	El Paso, TX-NM	13	64	1.11	62
Sml	Bakersfield, CA	12	65	1.10	66
Sml	Eugene-Springfield, OR	11	66	1.10	65
Sml	Laredo, TX	10	67	1.12	59
Sml	Beaumont, TX	10	67	1.05	70
Sml	Boulder, CO	9	69	1.09	67
Sml	Brownsville, TX	7	70	1.10	64
	70 area average	30		1.25	
	Very large area average	46		1.40	
	Large area average	34		1.30	
	Medium area average	28		1.22	
	Small area average	16		1.12	

Source: TTI Analysis.

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Table A-3. 1996 Rankings of Urban Area by Estimated Impact of Congestion

Population Group	Urban Area	Roadway Congestion Index	Congestion Cost per Capita	Congestion Cost per Eligible Driver
Vlg	Los Angeles, CA	1	3	2
Vlg	Washington, DC-MD-VA	2	1	1
Lrg	Miami-Hialeah, FL	3	14	13
Vlg	Chicago, IL-Northwestern, IN	3	26	26
Vlg	San Francisco-Oakland, CA	5	6	7
Lrg	Seattle-Everett, WA	6	2	3
Vlg	Detroit, MI	7	5	4
Lrg	Atlanta, GA	7	4	4
Lrg	San Diego, CA	9	33	31
Lrg	San Bernardino-Riverside, CA	10	11	9
Lrg	Las Vegas, NV	11	46	44
Vlg	New York NY-Northeastern, NJ	12	21	24
Med	Tacoma, WA	12	42	42
Lrg	Portland-Vancouver, OR-WA	14	20	20
Lrg	Phoenix, AZ	15	35	37
Lrg	Denver, CO	16	17	18
Lrg	Minneapolis-St. Paul, MN	16	35	40
Lrg	San Jose, CA	18	7	6
Vlg	Houston, TX	18	8	7
Lrg	Dallas, TX	18	9	10
Med	Memphis, TN-AR-MS	18	49	45
Med	Honolulu, HI	22	42	43
Vlg	Boston, MA	23	12	14
Lrg	Baltimore, MD	23	23	23
Lrg	New Orleans, LA	23	48	48
Lrg	Sacramento, CA	26	24	21
Lrg	Cincinnati, OH-KY	26	38	37
Vlg	Philadelphia, PA-NJ	26	52	53
Med	Tampa, FL	29	32	33
Lrg	St. Louis, MO-IL	30	16	18
Med	Louisville, KY-IN	31	21	22
Med	Austin, TX	32	10	11
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	32	30	30
Lrg	Milwaukee, WI	32	49	49
Med	Tucson, AZ	35	54	55
Lrg	Cleveland, OH	35	55	58
Lrg	Fort Worth, TX	37	17	15
Med	Albuquerque, NM	37	25	25
Lrg	Columbus, OH	37	45	45
Med	Nashville, TN	40	12	12

Table A-3. 1996 Rankings of Urban Area by Estimated Impact of Congestion, continued

Population Group	Urban Area	Roadway Congestion Index	Congestion Cost per Capita	Congestion Cost per Eligible Driver
Med	Omaha, NE-IA	40	38	36
Med	Indianapolis, IN	40	44	45
Med	Salt Lake City, UT	40	58	54
Med	Jacksonville, FL	44	19	17
Lrg	San Antonio, TX	44	38	35
Med	Charlotte, NC	46	35	37
Lrg	Norfolk, VA	47	29	28
Med	Providence-Pawtucket, RI-MA	47	31	32
Med	Hartford-Middletown, CT	49	27	29
Sml	Eugene-Springfield, OR	50	66	66
Lrg	Orlando, FL	51	27	27
Med	Oklahoma City, OK	51	51	51
Sml	Harrisburg, PA	53	15	15
Sml	Salem, OR	53	55	57
Sml	Allentown-Bethlehem-Easton, PA-NJ	55	38	41
Med	Rochester, NY	55	55	56
Lrg	Pittsburgh, PA	57	46	50
Sml	Spokane, WA	58	59	60
Lrg	Kansas City, MO-KS	59	33	33
Sml	Albany-Schenectady-Troy, NY	59	61	61
Med	El Paso, TX-NM	61	64	62
Sml	Brownsville, TX	62	69	69
Sml	Boulder, CO	62	70	70
Med	Fresno, CA	64	60	59
Lrg	Buffalo-Niagara Falls, NY	64	62	63
Sml	Corpus Christi, TX	64	63	63
Sml	Beaumont, TX	67	67	68
Sml	Colorado Springs, CO	68	53	52
Sml	Laredo, TX	69	68	67
Sml	Bakersfield, CA	70	65	65

Source: TTI Analysis.

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Table A-4. 1996 Rankings of Magnitude Indicators

Population Group	Urban Area	Population Rank	Annual Hours of Delay Rank	Annual Wasted Fuel Rank	Annual Congestion Cost Rank
Vlg	New York NY-Northeastern, NJ	1	2	2	2
Vlg	Los Angeles, CA	2	1	1	1
Vlg	Chicago, IL-Northwestern, IN	3	3	3	3
Vlg	Philadelphia, PA-NJ	4	10	11	10
Vlg	San Francisco-Oakland, CA	5	5	5	5
Vlg	Detroit, MI	6	6	6	6
Vlg	Washington, DC-MD-VA	7	4	4	4
Vlg	Houston, TX	8	7	7	7
Vlg	Boston, MA	9	8	8	8
Lrg	San Diego, CA	10	17	16	17
Lrg	Atlanta, GA	11	9	8	9
Lrg	Phoenix, AZ	12	19	19	19
Lrg	Dallas, TX	13	12	10	12
Lrg	Minneapolis-St Paul, MN	14	20	20	20
Lrg	Baltimore, MD	15	16	17	16
Lrg	Miami-Hialeah, FL	16	13	13	13
Lrg	St Louis, MO-IL	17	15	15	15
Lrg	Seattle-Everett, WA	18	11	11	11
Lrg	Pittsburgh, PA	19	23	24	24
Lrg	Cleveland, OH	20	28	28	28
Lrg	Denver, CO	21	18	18	18
Lrg	San Jose, CA	22	14	14	14
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	23	25	25	25
Lrg	San Bernardino-Riverside, CA	24	21	21	21
Lrg	Kansas City, MO-KS	25	27	27	27
Lrg	Fort Worth, TX	26	22	22	22
Lrg	Portland-Vancouver, OR-WA	26	24	23	23
Lrg	Cincinnati, OH-KY	28	29	29	28
Lrg	Milwaukee, WI	29	35	34	34
Lrg	Sacramento, CA	30	26	26	26
Lrg	San Antonio, TX	31	30	30	30
Lrg	New Orleans, LA	32	39	39	39
Lrg	Buffalo-Niagara Falls, NY	33	52	51	52
Lrg	Las Vegas, NV	33	40	40	40
Lrg	Orlando, FL	35	31	31	31
Lrg	Columbus, OH	36	43	41	41
Lrg	Norfolk, VA	36	32	32	32

Table A-4. 1996 Rankings of Magnitude Indicators, continued

Population Group	Urban Area	Population Rank	Annual Hours of Delay Rank	Annual Wasted Fuel Rank	Annual Congestion Cost Rank
Med	Indianapolis, IN	38	42	41	41
Med	Oklahoma City, OK	39	45	45	45
Med	Memphis, TN-AR-MS	40	44	44	44
Med	Providence-Pawtucket, RI-MA	41	38	38	38
Med	Salt Lake City, UT	42	49	48	49
Med	Louisville, KY-IN	43	34	34	34
Med	Jacksonville, FL	44	33	33	32
Med	Tampa, FL	44	41	43	43
Med	Honolulu, HI	46	48	48	48
Med	Tucson, AZ	47	54	54	54
Med	Hartford-Middletown, CT	48	47	46	46
Med	Nashville, TN	49	37	37	37
Med	Austin, TX	50	36	34	36
Med	Rochester, NY	50	57	56	57
Med	El Paso, TX-NM	52	60	59	60
Med	Tacoma, WA	53	53	51	52
Med	Charlotte, NC	54	50	50	50
Med	Albuquerque, NM	55	46	47	47
Med	Omaha, NE-IA	56	51	51	51
Med	Fresno, CA	57	59	59	59
Sml	Albany-Schenectady-Troy, NY	58	61	61	61
Sml	Allentown-Bethlehem-Easton, PA-NJ	59	55	54	54
Sml	Colorado Springs, CO	60	58	58	58
Sml	Bakersfield, CA	61	64	64	63
Sml	Spokane, WA	62	62	62	62
Sml	Harrisburg, PA	63	56	56	54
Sml	Corpus Christi, TX	64	63	63	64
Sml	Eugene-Springfield, OR	65	66	66	66
Sml	Salem, OR	66	65	65	65
Sml	Laredo, TX	67	67	67	67
Sml	Beaumont, TX	68	68	67	67
Sml	Brownsville, TX	69	69	67	69
Sml	Boulder, CO	70	70	67	70

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Table A-5. 1996 Rankings of Intensity Indicators

Population Group	Urban Area	Population Rank	Roadway Congestion Index Rank	Travel Rate Index Rank	Rank of Annual Hours of Delay		Rank of Annual Wasted Fuel		Rank of Annual Congestion Cost	
					per Driver	per Capita	per Driver	per Capita	per Driver	per Capita
Vlg	New York, NY-Northeastern, NJ	1	12	8	23	21	24	21	24	21
Vlg	Los Angeles, CA	2	1	1	2	2	2	3	2	3
Vlg	Chicago, IL-Northwestern, IN	3	3	8	26	26	26	26	26	26
Vlg	Philadelphia, PA-NJ	4	26	29	52	51	54	53	53	52
Vlg	San Francisco-Oakland, CA	5	5	1	7	6	6	5	7	6
Vlg	Detroit, MI	6	7	14	4	5	5	6	4	5
Vlg	Washington, DC-MD-VA	7	2	4	1	1	1	1	1	1
Vlg	Houston, TX	8	18	6	7	8	8	8	7	8
Vlg	Boston, MA	9	23	29	14	12	13	13	14	12
Lrg	San Diego, CA	10	9	14	32	33	29	29	31	33
Lrg	Atlanta, GA	11	7	12	4	4	4	4	4	4
Lrg	Phoenix, AZ	12	15	18	37	33	38	38	37	35
Lrg	Dallas, TX	13	18	18	10	9	10	9	10	9
Lrg	Minneapolis-St. Paul, MN	14	16	23	41	39	38	35	40	35
Lrg	Baltimore, MD	15	23	43	23	23	22	21	23	23
Lrg	Miami-Hialeah, FL	16	3	11	12	12	13	14	13	14
Lrg	St. Louis, MO-IL	17	30	29	15	16	16	16	18	16
Lrg	Seattle-Everett, WA	18	6	1	3	2	3	2	3	2
Lrg	Pittsburgh, PA	19	57	48	48	42	50	45	50	46
Lrg	Cleveland, OH	20	35	40	57	55	57	56	58	55
Lrg	Denver, CO	21	16	13	15	18	17	18	18	17
Lrg	San Jose, CA	22	18	7	6	6	6	7	6	7
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	23	32	21	29	29	30	29	30	30
Lrg	San Bernardino-Riverside, CA	24	10	8	9	11	9	11	9	11
Lrg	Kansas City, MO-KS	25	59	59	32	33	30	33	33	33
Lrg	Fort Worth, TX	26	37	33	15	16	15	15	15	17
Lrg	Portland-Vancouver, OR-WA	26	14	18	20	20	20	20	20	20
Lrg	Cincinnati, OH-KY	28	26	25	39	39	36	38	37	38
Lrg	Milwaukee, WI	29	32	26	50	50	47	50	49	49
Lrg	Sacramento, CA	30	26	16	21	24	21	24	21	24
Lrg	San Antonio, TX	31	44	43	32	39	30	35	35	38
Lrg	New Orleans, LA	32	23	26	43	42	47	45	48	48
Lrg	Buffalo-Niagara Falls, NY	33	64	62	63	62	63	62	63	62
Lrg	Las Vegas, NV	33	11	5	43	42	46	45	44	46
Lrg	Orlando, FL	35	51	26	26	26	27	28	27	27
Lrg	Columbus, OH	36	37	37	43	42	43	42	45	45
Lrg	Norfolk, VA	36	47	40	28	26	27	26	28	29

Table A-5. 1996 Rankings of Intensity Indicators, continued

Population Group	Urban Area	Population Rank	Roadway Congestion Index Rank	Travel Rate Index Rank	Rank of Annual Hours of Delay		Rank of Annual Wasted Fuel		Rank of Annual Congestion Cost	
					per Driver	per Capita	per Driver	per Capita	per Driver	per Capita
Med	Indianapolis, IN	38	40	55	43	42	43	42	45	44
Med	Oklahoma City, OK	39	51	58	52	51	50	51	51	51
Med	Memphis, TN-AR-MS	40	18	47	43	48	43	45	45	49
Med	Providence-Pawtucket, RI-MA	41	47	40	29	31	30	29	32	31
Med	Salt Lake City, UT	42	40	29	54	55	53	56	54	58
Med	Louisville, KY-IN	43	31	51	22	21	22	21	22	21
Med	Jacksonville, FL	44	44	33	15	18	17	19	17	19
Med	Tampa, FL	44	29	33	29	29	36	33	33	32
Med	Honolulu, HI	46	22	21	48	48	47	45	43	42
Med	Tucson, AZ	47	35	37	54	54	55	54	55	54
Med	Hartford-Middletown, CT	48	49	55	32	31	30	29	29	27
Med	Nashville, TN	49	40	48	12	12	12	11	12	12
Med	Austin, TX	50	32	23	11	10	11	10	11	10
Med	Rochester, NY	50	55	54	56	55	55	55	56	55
Med	El Paso, TX-NM	52	61	62	63	64	62	62	62	64
Med	Tacoma, WA	53	12	16	42	42	42	42	42	42
Med	Charlotte, NC	54	46	33	37	33	35	35	37	35
Med	Albuquerque, NM	55	37	43	23	24	24	25	25	25
Med	Omaha, NE-IA	56	40	37	32	33	40	41	36	38
Med	Fresno, CA	57	64	53	58	59	59	60	59	60
Sml	Albany-Schenectady-Troy, NY	58	59	68	61	61	63	62	61	61
Sml	Allentown-Bethlehem-Easton, PA-NJ	59	55	43	39	33	41	38	41	38
Sml	Colorado Springs, CO	60	68	48	51	51	50	51	52	53
Sml	Bakersfield, CA	61	70	64	65	65	66	66	65	65
Sml	Spokane, WA	62	58	59	60	59	59	59	60	59
Sml	Harrisburg, PA	63	53	51	15	15	19	17	15	15
Sml	Corpus Christi, TX	64	64	69	61	62	61	60	63	63
Sml	Eugene-Springfield, OR	65	50	64	66	66	69	68	66	66
Sml	Salem, OR	66	53	55	58	58	57	56	57	55
Sml	Laredo, TX	67	69	59	66	67	68	70	67	68
Sml	Beaumont, TX	68	67	70	68	67	70	68	68	67
Sml	Brownsville, TX	69	62	64	70	70	67	67	69	69
Sml	Boulder, CO	70	62	67	69	69	65	65	70	70

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Table A-6. Urban Area Population, 1982 to 1996

Population Group	Urban Area	Short-term 1992 to 1996		Long-term 1982 to 1996		Population						
		Percent	Rank	Percent	Rank	1982	1986	1990	1992	1994	1995	1996
Lrg	Las Vegas, NV	30	1	139	1	450	525	710	825	930	1,000	1,075
Med	Oklahoma City, OK	26	2	53	9	640	735	735	775	850	910	980
Sml	Laredo, TX	20	3	58	7	95	105	120	125	140	145	150
Lrg	Orlando, FL	20	3	73	2	610	690	850	880	950	1,025	1,055
Sml	Colorado Springs, CO	18	5	43	15	280	300	320	340	370	385	400
Lrg	Ft. Lauderdale-Hollywood-Pompano Beach, FL	16	6	39	19	1,065	1,165	1,270	1,285	1,320	1,400	1,485
Lrg	Phoenix, AZ	16	6	64	3	1,430	1,735	1,895	2,022	2,130	2,250	2,340
Med	Tampa, FL	15	8	52	11	540	615	700	715	760	810	820
Med	Charlotte, NC	14	9	63	4	350	400	450	500	540	550	570
Lrg	Portland-Vancouver, OR-WA	14	9	26	35	1,010	1,040	1,085	1,120	1,195	1,225	1,275
Sml	Brownsville, TX	13	11	50	12	90	100	115	120	125	130	135
Sml	Bakersfield, CA	12	12	59	6	230	265	300	325	350	360	365
Sml	Beaumont, TX	12	12	22	43	115	120	125	125	130	135	140
Lrg	Kansas City, MO-KS	12	12	23	41	1,090	1,135	1,160	1,200	1,320	1,330	1,340
Med	Tucson, AZ	12	12	42	17	450	480	530	570	605	620	640
Lrg	Denver, CO	11	16	31	25	1,350	1,500	1,580	1,600	1,675	1,730	1,770
Med	Austin, TX	10	17	63	4	380	465	540	565	590	605	620
Lrg	Dallas, TX	10	17	27	33	1,810	1,890	1,990	2,080	2,200	2,250	2,290
Lrg	Atlanta, GA	9	19	53	9	1,610	1,695	2,100	2,275	2,400	2,460	2,470
Sml	Corpus Christi, TX	9	19	24	39	250	270	280	285	295	305	310
Sml	Harrisburg, PA	9	19	15	51	275	280	290	290	305	310	315
Med	Memphis, TN-AR-MS	9	19	26	35	760	800	860	880	905	930	960
Sml	Eugene-Springfield, OR	8	23	11	55	190	185	185	195	200	200	210
Med	Fresno, CA	8	23	54	8	345	400	460	490	515	525	530
Med	Jacksonville, FL	8	23	33	22	615	650	720	760	785	800	820
Med	Tacoma, WA	8	23	40	18	420	485	520	545	570	580	590
Med	Albuquerque, NM	7	27	27	33	440	475	505	525	540	550	560
Med	El Paso, TX-NM	7	27	34	21	450	480	540	565	580	590	605
Lrg	Miami-Hialeah, FL	7	27	18	45	1,730	1,780	1,850	1,920	1,940	2,000	2,050
Lrg	Minneapolis-St. Paul, MN	7	27	29	28	1,750	1,845	2,010	2,110	2,175	2,220	2,250
Lrg	Columbus, OH	6	31	21	44	835	835	850	950	995	1,005	1,010
Lrg	Fort Worth, TX	6	31	18	45	1,085	1,120	1,200	1,200	1,240	1,265	1,275
Med	Nashville, TN	6	31	25	38	500	520	565	590	615	620	625
Sml	Salem, OR	6	31	13	52	160	165	170	170	175	175	180
Lrg	San Jose, CA	6	31	33	22	1,200	1,340	1,410	1,505	1,540	1,550	1,595
Lrg	Seattle-Everett, WA	6	31	35	20	1,440	1,565	1,730	1,840	1,910	1,930	1,950

Table A-6. Urban Area Population, 1982 to 1996, continued

Population Group	Urban Area	Short-term 1992 to 1996		Long-term 1982 to 1996		Population						
		Percent	Rank	Percent	Rank	1982	1986	1990	1992	1994	1995	1996
Lrg	Baltimore, MD	5	37	26	35	1,700	1,860	1,990	2,040	2,130	2,140	12,145
Sml	Boulder, CO	5	37	31	25	80	90	100	100	105	105	105
Vlg	Houston, TX	5	37	28	31	2,400	2,790	2,880	2,910	2,940	2,990	3,060
Med	Indianapolis, IN	5	37	16	49	860	895	945	955	970	990	1,000
Lrg	Norfolk, VA	5	37	31	25	770	840	925	965	985	1,000	1,010
Vlg	Philadelphia, PA-NJ	5	37	29	28	4,070	4,070	4,500	5,000	5,250	5,260	5,265
Vlg	Washington, DC-MD-VA	5	37	28	31	2,700	2,920	3,100	3,285	3,445	3,455	3,460
Vlg	Chicago, IL-Northwestern, IN	4	44	11	55	7,080	7,160	7,510	7,515	7,700	7,745	7,850
Lrg	Cincinnati, OH-KY	4	44	12	53	1,130	1,130	1,140	1,220	1,255	1,260	1,265
Lrg	Cleveland, OH	4	44	6	62	1,750	1,750	1,790	1,790	1,810	1,840	1,860
Med	Omaha, NE-IA	4	44	11	55	500	515	530	535	545	550	555
Med	Salt Lake City, UT	4	44	32	24	680	760	800	860	880	890	895
Lrg	San Bernardino-Riverside, CA	4	44	43	15	945	990	1,170	1,300	1,340	1,345	1,350
Sml	Allentown-Bethlehem-Easton, PA-NJ	3	50	16	49	400	410	440	450	455	460	465
Med	Hartford-Middletown, CT	3	50	12	53	565	585	610	615	625	630	635
Med	Honolulu, HI	3	50	24	39	570	595	660	685	695	700	705
Vlg	Los Angeles, CA	3	50	23	41	9,900	10,710	11,420	11,845	12,000	12,090	12,220
Lrg	Pittsburgh, PA	3	50	7	61	1,810	1,810	1,865	1,875	1,910	1,925	1,930
Med	Providence-Pawtucket, RI-MA	3	50	9	58	825	840	855	870	885	895	900
Lrg	Sacramento, CA	3	50	48	13	830	955	1,095	1,190	1,220	1,225	1,230
Lrg	San Antonio, TX	3	50	29	28	950	1,020	1,170	1,185	1,210	1,220	1,225
Lrg	San Diego, CA	3	50	44	14	1,780	1,980	2,295	2,480	2,550	2,560	2,565
Sml	Spokane, WA	3	50	18	45	275	290	310	315	320	320	325
Vlg	Boston, MA	2	60	6	62	2,850	2,760	2,955	2,960	2,985	3,000	3,010
Med	Louisville, KY-IN	2	60	8	60	770	785	810	815	825	830	835
Lrg	Milwaukee, WI	2	60	3	64	1,210	1,215	1,230	1,230	1,240	1,245	1,250
Vlg	San Francisco-Oakland, CA	2	60	18	45	3,290	3,435	3,675	3,805	3,870	3,880	3,890
Lrg	St Louis, MO-IL	2	60	9	58	1,850	1,930	1,960	1,985	2,000	2,015	2,020
Sml	Albany-Schenectady-Troy, NY	1	65	(1)	68	500	480	490	490	495	495	495
Lrg	New Orleans, LA	1	65	3	64	1,080	1,070	1,080	1,100	1,110	1,115	1,115
Vlg	New York, NY-Northeastern, NJ	1	65	3	64	16,660	15,340	16,780	16,945	17,010	17,125	17,150
Lrg	Buffalo-Niagara Falls, NY	0	68	0	67	1,075	1,040	1,065	1,070	1,070	1,070	1,075
Med	Rochester, NY	0	68	(3)	70	640	600	615	620	620	615	620
Vlg	Detroit, MI	(6)	70	(1)	68	3,810	3,885	4,000	4,000	4,005	4,010	3,768
	70 City Average	7		29		1,462	1,509	1,621	1,675	1,719	1,741	1,757
	Very Large	2		16		5,862	5,897	6,313	6,474	6,578	6,617	6,630
	Large	8		32		1,262	1,338	1,445	1,509	1,563	1,593	1,617
	Medium	8		31		565	604	648	672	695	710	723
	Small	9		28		226	235	250	256	267	271	277

Vlg — Very Large urban areas - over 3 million population

Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population

Sml — Small urban areas - less than 500,000 population

Table A-7. Freeway and Principal Arterial Street Travel, 1982 to 1996

Population Group	Urban Area	Short-term 1992 to 1996		Long-term 1982 to 1996		Freeway and Principal Arterial Street Vehicle-Miles						
		Percent	Rank	Percent	Rank	1982	1986	1990	1992	1994	1995	1996
Med	Austin, TX	42	1	152	4	4,425	6,690	7,530	7,850	9,800	10,590	11,170
Lrg	Orlando, FL	40	2	94	13	7,885	8,990	10,050	10,900	13,025	14,350	15,300
Med	Indianapolis, IN	39	3	94	13	9,030	11,010	12,230	12,565	14,750	16,290	17,500
Lrg	Las Vegas, NV	38	4	181	1	3,225	4,270	5,980	6,590	7,810	8,290	9,070
Lrg	Atlanta, GA	34	5	119	7	22,305	30,585	34,740	36,500	45,750	47,750	48,760
Med	Charlotte, NC	32	6	105	8	4,110	4,990	5,975	6,400	7,120	7,750	8,430
Sml	Corpus Christi, TX	32	6	71	37	2,550	2,820	3,080	3,310	3,865	4,090	4,365
Med	Louisville, KY-IN	32	6	100	10	6,540	7,520	9,140	9,855	11,250	12,200	13,050
Sml	Laredo, TX	30	9	153	3	425	525	710	825	925	1,020	1,075
Med	Nashville, TN	30	9	120	6	6,800	9,055	10,440	11,500	13,650	14,550	14,980
Med	Tucson, AZ	28	11	155	2	2,450	3,100	4,110	4,865	5,435	5,840	6,250
Med	Albuquerque, NM	27	12	96	12	4,395	5,680	6,700	6,800	7,900	8,275	8,620
Lrg	Portland-Vancouver, OR-WA	26	13	98	11	7,515	9,465	11,180	11,880	13,340	13,785	14,910
Med	Jacksonville, FL	24	14	65	43	8,970	10,290	11,185	11,900	13,070	13,670	14,800
Lrg	San Antonio, TX	24	14	77	29	11,125	13,835	14,520	15,875	17,590	18,800	19,650
Med	Tampa, FL	24	14	103	9	5,170	6,590	7,990	8,450	9,520	10,090	10,495
Lrg	Fort Worth, TX	22	17	71	37	12,285	15,000	16,080	17,140	19,460	20,550	20,990
Lrg	Kansas City, MO-KS	22	17	79	23	12,705	15,190	17,365	18,590	21,250	21,730	22,770
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	21	19	58	48	10,800	11,080	12,905	14,100	15,750	16,630	17,100
Med	Salt Lake City, UT	19	20	129	5	4,325	5,275	7,365	8,350	9,280	9,665	9,900
Med	Memphis, TN-AR-MS	18	21	89	18	6,250	7,070	8,575	10,040	11,170	11,530	11,825
Med	Oklahoma City, OK	18	21	55	53	8,575	9,660	10,520	11,270	12,400	12,970	13,330
Med	Omaha, NE-IA	18	21	79	23	3,870	4,510	5,225	5,900	6,500	6,680	6,940
Lrg	Minneapolis-St Paul, MN	17	24	94	13	15,500	19,660	23,430	25,800	27,840	28,915	30,120
Sml	Bakersfield, CA	16	25	93	17	2,025	2,595	3,155	3,360	3,685	3,795	3,910
Sml	Brownsville, TX	16	25	80	22	460	565	660	715	795	815	830
Vlg	Chicago, IL-Northwestern, IN	16	25	79	23	46,365	55,925	67,480	72,000	79,125	80,850	83,210
Lrg	St Louis, MO-IL	16	25	74	31	20,990	26,385	30,710	31,410	33,325	34,940	36,440
Sml	Colorado Springs, CO	15	29	76	30	2,350	3,105	3,515	3,590	3,965	4,050	4,145
Sml	Harrisburg, PA	15	29	81	21	3,330	4,170	4,940	5,260	5,655	5,865	6,025
Lrg	New Orleans, LA	15	29	48	60	7,200	8,165	9,070	9,250	10,535	10,690	10,675
Lrg	Phoenix, AZ	15	29	79	23	17,780	20,460	25,580	27,855	29,020	30,375	31,900
Sml	Boulder, CO	14	33	74	31	550	665	790	835	910	940	955
Lrg	Columbus, OH	14	33	79	23	8,315	9,910	12,180	13,035	13,775	14,285	14,925
Lrg	Dallas, TX	14	33	62	44	23,310	30,805	31,990	33,050	36,225	37,150	37,735

Table A-7. Freeway and Principal Arterial Street Travel, 1982 to 1996, continued

Population Group	Urban Area	Short-term 1992 to 1996		Long-term 1982 to 1996		Freeway and Principal Arterial Street Vehicle-Miles						
		Percent	Rank	Percent	Rank	1982	1986	1990	1992	1994	1995	1996
Vlg	Houston, TX	14	33	54	54	30,805	34,925	39,060	41,640	44,700	46,045	47,550
Lrg	Milwaukee, WI	14	33	50	59	9,890	11,015	12,470	13,035	13,900	14,350	14,800
Lrg	Norfolk, VA	14	33	70	39	7,140	8,480	9,705	10,645	11,150	11,415	12,170
Lrg	San Jose, CA	14	33	58	48	17,310	20,450	22,555	24,005	24,150	25,740	27,320
Vlg	Washington, DC-MD-VA	14	33	78	28	29,375	38,305	43,195	45,945	49,125	51,280	52,270
Sml	Beaumont, TX	13	41	37	67	1,385	1,510	1,620	1,680	1,780	1,840	1,900
Lrg	Cincinnati, OH-KY	13	41	61	45	11,505	12,150	15,050	16,410	17,900	18,105	18,520
Lrg	Denver, CO	13	41	52	57	17,460	19,970	22,170	23,500	24,725	25,570	26,550
Sml	Eugene-Springfield, OR	13	41	72	34	1,170	1,445	1,825	1,780	1,920	1,950	2,015
Med	Honolulu, HI	13	41	57	50	4,900	5,645	6,190	6,835	7,540	7,630	7,715
Sml	Allentown-Bethlehem-Easton, PA-NJ	12	46	56	51	3,450	3,965	4,610	4,800	5,200	5,310	5,395
Med	Fresno, CA	12	46	47	61	3,050	3,490	3,835	4,000	4,105	4,260	4,470
Med	Rochester, NY	12	46	94	13	3,310	4,050	5,055	5,735	5,995	6,335	6,420
Lrg	Baltimore, MD	11	49	72	34	17,720	21,945	25,650	27,500	28,850	29,675	30,400
Med	El Paso, TX-NM	11	49	47	61	5,160	6,335	6,530	6,825	7,220	7,500	7,600
Lrg	Cleveland, OH	10	51	56	51	14,495	15,435	19,690	20,460	21,685	22,300	22,540
Lrg	Miami-Hialeah, FL	10	51	61	45	17,820	20,075	24,375	26,170	27,725	28,280	28,760
Med	Providence-Pawtucket, RI-MA	10	51	66	42	7,280	9,030	9,865	10,940	11,495	11,625	12,050
Sml	Albany-Schenectady-Troy, NY	9	54	74	31	4,650	5,940	7,280	7,445	7,755	7,855	8,090
Vlg	Detroit, MI	9	54	47	61	39,530	41,115	46,920	53,100	56,620	57,400	57,990
Lrg	Pittsburgh, PA	9	54	54	54	14,375	16,705	19,105	20,235	21,180	21,915	22,080
Vlg	Boston, MA	8	57	31	70	28,660	33,470	34,150	34,890	36,000	37,000	37,670
Vlg	New York, NY-Northeastern, NJ	8	57	40	66	107,505	119,050	134,975	138,820	143,775	147,150	150,350
Vlg	Philadelphia, PA-NJ	8	57	41	65	31,375	35,550	39,715	41,040	42,920	43,580	44,385
Lrg	Sacramento, CA	7	60	86	19	10,295	13,285	16,255	17,850	18,580	18,645	19,150
Med	Hartford-Middletown, CT	6	61	69	41	6,670	8,755	9,975	10,590	10,885	11,115	11,240
Sml	Salem, OR	6	61	70	39	1,365	1,745	2,025	2,185	2,250	2,295	2,315
Lrg	San Bernardino-Riverside, CA	6	61	42	64	19,400	21,540	24,730	25,860	26,650	27,275	27,480
Sml	Spokane, WA	6	61	34	68	2,800	3,245	3,405	3,535	3,740	3,690	3,755
Lrg	Buffalo-Niagara Falls, NY	4	65	33	69	8,160	8,725	10,035	10,435	10,875	10,810	10,845
Vlg	Los Angeles, CA	4	65	53	56	132,635	162,520	190,715	194,450	196,400	199,500	202,700
Lrg	San Diego, CA	4	65	84	20	21,205	28,870	37,030	37,500	37,625	38,220	38,980
Lrg	Seattle-Everett, WA	4	65	59	47	19,105	23,825	28,050	29,375	29,800	29,910	30,450
Med	Tacoma, WA	4	65	72	34	4,400	5,900	7,300	7,260	7,420	7,490	7,555
Vlg	San Francisco-Oakland, CA	3	70	51	58	38,550	48,925	56,585	56,480	57,535	58,035	58,160
	70 City Average	16		76		14,397	17,186	19,840	20,865	22,209	22,869	23,483
	Very Large	9		53		53,867	63,309	72,533	75,374	78,467	80,093	81,587
	Large	16		73		13,815	16,653	19,380	20,534	22,125	22,873	23,585
	Medium	21		90		5,484	6,732	7,787	8,397	9,325	9,803	10,217
	Small	15		75		2,039	2,484	2,893	3,025	3,265	3,347	3,444

Vlg — Very Large urban areas - over 3 million population
Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population
Sml — Small urban areas - less than 500,000 population

Table A-8. Freeway and Principal Arterial Street Facilities, 1982 to 1996

Population Group	Urban Area	Short-term 1992 to 1996		Long-term 1982 to 1996		Freeway and Principal Arterial Street Lane-Miles						
		Percent	Rank	Percent	Rank	1982	1986	1990	1992	1994	1995	1996
Med	Austin, TX	38	1	107	2	605	790	880	905	1,090	1,175	1,250
Lrg	Atlanta, GA	30	2	69	5	2,585	2,945	3,280	3,370	4,270	4,355	4,380
Med	Tampa, FL	26	3	73	4	735	870	960	1,010	1,150	1,225	1,275
Med	Tucson, AZ	25	4	130	1	395	545	655	730	815	865	910
Lrg	Portland-Vancouver, OR-WA	23	5	52	13	955	1,050	1,120	1,180	1,325	1,365	1,455
Lrg	Orlando, FL	22	6	48	16	1,385	1,555	1,660	1,690	1,850	1,985	2,055
Med	Louisville, KY-IN	20	7	47	17	920	1,000	1,110	1,130	1,275	1,330	1,355
Med	Albuquerque, NM	19	8	57	6	760	810	940	1,000	1,115	1,155	1,190
Sml	Laredo, TX	19	8	90	3	100	115	145	160	175	185	190
Med	Indianapolis, IN	18	10	31	39	1,495	1,530	1,640	1,655	1,820	1,925	1,960
Med	Charlotte, NC	16	11	46	19	700	775	835	885	930	985	1,025
Sml	Corpus Christi, TX	16	11	39	24	470	490	520	565	610	635	655
Lrg	Ft Lauderdale-Hollywood-Pompano Beach, FL	16	11	35	29	1,540	1,620	1,715	1,800	1,985	2,045	2,080
Med	Jacksonville, FL	16	11	47	17	1,365	1,515	1,650	1,735	1,870	1,910	2,010
Lrg	Las Vegas, NV	16	11	50	15	600	660	755	775	830	845	900
Med	Nashville, TN	16	11	53	11	1,140	1,325	1,430	1,510	1,645	1,715	1,745
Lrg	New Orleans, LA	16	11	34	30	890	910	985	1,030	1,155	1,175	1,195
Lrg	Fort Worth, TX	15	18	33	35	1,690	1,825	1,890	1,950	2,160	2,215	2,245
Vlg	Chicago, IL-Northwestern, IN	14	19	46	19	5,515	5,910	6,685	7,090	7,960	8,000	8,070
Med	Oklahoma City, OK	14	19	33	35	1,240	1,335	1,400	1,445	1,615	1,640	1,650
Lrg	Kansas City, MO-KS	13	21	31	39	2,150	2,300	2,420	2,500	2,695	2,715	2,815
Lrg	Milwaukee, WI	13	21	28	47	1,470	1,520	1,600	1,660	1,785	1,825	1,875
Vlg	Houston, TX	12	23	51	14	3,160	3,465	4,050	4,255	4,500	4,580	4,760
Med	Salt Lake City, UT	12	23	57	6	680	780	865	950	1,040	1,060	1,065
Lrg	San Antonio, TX	12	23	32	37	1,700	1,840	1,915	2,005	2,125	2,220	2,250
Sml	Bakersfield, CA	11	26	55	9	505	580	660	705	750	770	785
Sml	Beaumont, TX	11	26	25	50	285	295	310	320	335	345	355
Sml	Boulder, CO	11	26	36	27	110	115	130	135	145	150	150
Lrg	Dallas, TX	11	26	25	50	3,105	3,330	3,420	3,500	3,740	3,800	3,875
Med	Honolulu, HI	11	26	30	41	525	540	565	610	655	670	680
Med	Omaha, NE-IA	11	26	26	48	680	705	745	775	820	840	860
Lrg	Norfolk, VA	10	32	34	30	1,075	1,135	1,200	1,310	1,350	1,375	1,440
Med	Providence-Pawtucket, RI-MA	10	32	54	10	935	1,055	1,255	1,310	1,385	1,410	1,440
Sml	Allentown-Bethlehem-Easton, PA-NJ	9	34	38	26	520	570	630	655	695	705	715
Sml	Colorado Springs, CO	9	34	29	43	510	555	590	605	640	650	660
Med	Rochester, NY	9	34	32	37	505	585	590	610	670	660	665
Lrg	Miami-Hialeah, FL	8	37	29	43	2,390	2,515	2,680	2,855	3,010	3,060	3,090
Lrg	San Jose, CA	8	37	22	52	2,260	2,385	2,455	2,560	2,610	2,670	2,765
Lrg	St Louis, MO-IL	8	37	34	30	2,890	3,150	3,490	3,595	3,735	3,800	3,875
Vlg	Washington, DC-MD-VA	8	37	42	22	2,990	3,495	3,775	3,940	4,060	4,230	4,245

Table A-8. Freeway and Principal Arterial Street Facilities, 1982 to 1996, continued

Population Group	Urban Area	Short-term 1992 to 1996		Long-term 1982 to 1996		Freeway and Principal Arterial Street Lane-Miles						
		Percent	Rank	Percent	Rank	1982	1986	1990	1992	1994	1995	1996
Lrg	Baltimore, MD	7	41	30	41	2,485	2,855	2,910	3,020	3,110	3,145	3,225
Med	El Paso, TX-NM	7	41	20	58	1,085	1,150	1,185	1,210	1,250	1,290	1,300
Sml	Harrisburg, PA	7	41	39	24	505	590	660	655	680	690	700
Lrg	Minneapolis-St Paul, MN	7	41	36	27	2,090	2,240	2,480	2,660	2,790	2,825	2,850
Lrg	Cincinnati, OH-KY	6	45	21	55	1,525	1,600	1,725	1,740	1,820	1,830	1,845
Lrg	Columbus, OH	6	45	21	55	1,265	1,355	1,410	1,445	1,490	1,515	1,530
Lrg	Denver, CO	6	45	18	61	2,540	2,610	2,735	2,820	2,890	2,930	2,985
Med	Fresno, CA	6	45	16	66	600	625	645	655	675	685	695
Sml	Salem, OR	6	45	20	58	300	320	330	340	355	360	360
Sml	Spokane, WA	6	45	18	61	570	580	615	635	655	665	675
Lrg	Cleveland, OH	5	51	18	61	2,060	2,060	2,270	2,320	2,365	2,405	2,425
Med	Hartford-Middletown, CT	5	51	34	30	990	1,120	1,215	1,260	1,285	1,315	1,325
Vlg	Philadelphia, PA-NJ	5	51	29	43	3,950	4,250	4,760	4,875	5,030	5,065	5,095
Lrg	Phoenix, AZ	5	51	57	6	2,690	2,850	3,745	4,010	4,100	4,165	4,230
Med	Tacoma, WA	5	51	17	65	755	790	825	845	865	875	885
Vlg	Boston, MA	4	56	14	67	3,990	4,105	4,280	4,365	4,430	4,515	4,555
Vlg	Detroit, MI	4	56	26	48	5,030	5,280	5,640	6,090	6,260	6,315	6,340
Med	Memphis, TN-AR-MS	4	56	53	11	970	1,100	1,245	1,420	1,540	1,550	1,480
Vlg	New York, NY-Northeastern, NJ	4	56	20	58	11,940	12,470	13,460	13,675	14,055	14,205	14,270
Lrg	Sacramento, CA	4	56	46	19	1,460	1,620	1,850	2,040	2,085	2,100	2,125
Lrg	San Bernardino-Riverside, CA	4	56	41	23	2,230	2,420	2,835	3,010	3,090	3,110	3,135
Sml	Brownsville, TX	3	62	29	43	120	140	145	150	155	155	155
Lrg	Pittsburgh, PA	3	62	34	30	2,300	2,590	2,820	2,975	3,045	3,070	3,075
Lrg	San Diego, CA	3	62	22	52	2,950	3,155	3,435	3,475	3,525	3,545	3,595
Sml	Eugene-Springfield, OR	2	65	14	67	210	290	285	235	235	235	240
Vlg	Los Angeles, CA	2	65	18	61	15,510	16,410	17,635	17,895	18,080	18,115	18,250
Vlg	San Francisco-Oakland, CA	2	65	21	55	4,035	4,260	4,640	4,750	4,810	4,860	4,865
Sml	Albany-Schenectady-Troy, NY	1	68	9	69	985	1,060	1,060	1,055	1,075	1,065	1,070
Lrg	Seattle-Everett, WA	0	69	22	52	2,345	2,560	2,785	2,845	2,840	2,845	2,855
Lrg	Buffalo-Niagara Falls, NY	(1)	70	9	69	1,530	1,680	1,730	1,680	1,635	1,670	1,665
	70 City Average	8		31		1,894	2,038	2,214	2,295	2,409	2,448	2,482
	Very Large	5		26		6,236	6,627	7,214	7,437	7,687	7,765	7,828
	Large	9		33		1,934	2,083	2,261	2,351	2,479	2,522	2,566
	Medium	14		45		854	947	1,032	1,083	1,176	1,214	1,238
	Small	8		29		399	438	468	478	500	508	516

Vlg — Very Large urban areas - over 3 million population
Lrg — Large urban areas - over 1 million and less than 3 million population

Med — Medium urban areas - over 500,000 and less than 1 million population
Sml — Small urban areas - less than 500,000 population

APPENDIX C

METHODOLOGY AND CALCULATIONS ASSOCIATED WITH URBAN CONGESTION STATISTICS

This appendix summarizes the methodology utilized to calculate many of the statistics shown in the Urban Roadway Congestion Report. The methodology is divided into seven sections:

- ◆ Constants
- ◆ Travel Delay
- ◆ Travel Speed
- ◆ Fuel Economy
- ◆ Wasted Fuel
- ◆ Congestion Cost
- ◆ Areawide Speed Ratio
- ◆ Travel Rate Index

Variables in some of these sections refer to variables that were calculated in other sections. A note is included at the start of each section of calculations referencing any other sections that are needed. Generally, the sections are listed in the order that they will be needed to complete all calculations. An example calculation is shown with each equation utilizing 1996 Houston data. Because of rounding, some answers in calculations may not match exactly the data in the report.



Entire Methodology

What is the source of data?

This analysis uses the Highway Performance Monitoring System (HPMS) database compiled by the Federal Highway Administration (FHWA) from data submitted by State Department of Transportation (DOTs). Local planning and transportation agencies and state departments of transportation (DOT) were also contacted to obtain other data and provide local review of the Texas Transportation Institute (TTI) statistics.

HPMS data include information on state and local agency maintained roadway systems. This should give a more accurate representation of the urbanized area roadway condition than information that could be developed from a single organization. Data items such as functional classification vary from state to state. The amount of data used to update the HPMS database in each year also varies in each state. Locally developed planning data were, therefore, used to provide another source of information concerning the urban roadway system.

What is an urban area?

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

In defining urbanized area, it is not always possible to use jurisdictional limits as the defining boundaries due to either lack of data on related travel measures or non-comparability of information. County or metropolitan area boundaries may appear to provide consistency, but variations in county size, as well as percentage of urbanization, significantly impair the utility of county-based data.

Because of these factors and others, this study and HPMS uses the U.S. census definition of an urbanized area as the basis for the delineation of an urban area. This definition requires that an urbanized area, the central city and its surrounding "fringe" areas have a population of at least 50,000. The fringe areas must be contiguous to the central city and have a population density of more than 1,000 persons per square mile. The formal definition of urbanized area can be found on the U.S. Census website at <http://www.census.gov/population/censusdata/urdef.txt>.

Roadway Congestion Index

Urban roadway congestion levels are estimated using a formula that measures the density of traffic. Average daily travel volume per lane on freeways and principal arterial streets are estimated using areawide estimates of vehicle-miles of travel (VMT) and lane-miles of roadway (Ln-Mi). The resulting ratios are combined using the amount of travel on each portion of the system so that the combined index measures conditions on the freeway and principal arterial street systems. This variable weighting factor allows comparisons between areas such as Phoenix, where principal arterial streets carry 50% the amount of travel of freeways, and cities such as Portland where the ratio is reversed.

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

Equation 1 illustrates the factors used in the congestion index. The resulting ratio indicates an undesirable level of areawide congestion if a value greater than or equal to 1.0 is obtained.

$$\text{Roadway Congestion Index} = \frac{\text{Freeway VMT/Ln.-Mi.} \times \text{Freeway VMT} + \text{Prin Art Str VMT/Ln.-Mi.} \times \text{Prin Art Str VMT}}{13,000 \times \text{Freeway VMT} + 5,000 \times \text{Prin Art Str VMT}}$$

An Illustration of Travel Conditions When an Urban Area RCI Equals 1.0

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

- Typical commute time not more than 25% longer than off-peak travel time.
- Slower moving traffic during the peak period on the freeways, but not sustained stop-and-go conditions.
- Moderate congestion for not more than 1½ to 2 hours during each peak-period.
- Wait through one or two red lights at heavily traveled intersections, but not 3 or 4.
- The RCI includes roadway expansion, demand management, and vehicle travel reduction programs.
- The RCI does not include the effect of operations improvements (e.g., clearing accidents quickly, regional traffic signal coordination), person movement efficiencies (e.g., bus and carpool lanes) or transit improvements (e.g., priority at traffic signals).
- The RCI does not address situations where a traffic bottleneck means much less capacity than demand (e.g., a narrow bridge or tunnel crossing a harbor or river), or missing capacity due to a gap in the system.
- The congestion study averages all the developments within an urban area; there will be locations where congestion is much worse or better than average.

Constants

The congestion cost estimate calculations utilize the derived constant values in Table C-1.

Table C-1. Cost Estimate Constants

Constant	Value
Vehicle Occupancy	1.25 persons per vehilce
Working Days	250 days per year
Average Cost of Time	\$11.70 per person hour ¹
Commercial Vehicle Operating Cost	\$2.55 per mile
Vehicle Mix	95 percent passenger & 5 percent commercial
Percent of Daily Travel in Peak Periods	45 percent
Vehicular Speeds	Table 2

¹Adjusted annually using the Consumer Price Index

In addition to the derived constants, five urbanized area or state specific variables were identified and used in the congestion cost estimate calculations.

Daily Vehicle-Miles of Travel

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

Population

Population data were obtained from the combination of U.S. Census Bureau estimates and 1996 population estimates reported in the Federal Highway Administration's Highway Performance Monitoring System (HPMS).

Fuel Costs

Statewide average fuel cost estimates were obtained from 1996 data published by the American Automobile Association (AAA) (14). These data represent the average reported fuel cost for 1996. Values for different fuel types used in motor vehicles, i.e., diesel and gasoline, did not vary enough to be reported separately. Therefore, an average rate for fuel was used in cost estimate calculations.

Eligible Drivers

The number of eligible drivers for each area was obtained using the population estimate derived above, along with estimates of the percentage of population 16 years of age and older taken from the Statistical Abstract of the United States (15).

Travel Speed

The travel speed is estimated for each roadway link using the daily traffic volume per lane values. Each link is categorized as uncongested or placed in one of three congested levels, according to the values in Table C-2. The speed for each range represents the average peak period speed; the mileage traveled in the peak period is estimated as 45% of the daily traffic volume. This speed is used in the delay, fuel economy, system average speed and travel rate index calculations.

Table C-2. Congested Daily Vehicle-Miles of Travel by Average Annual Daily Traffic per Lane Volumes

Functional Class	Parameters	Uncongested	Congested ^{1,2}		
			Moderate	Heavy	Severe
Freeway/Expressway	ADT/Lane	Under 15,000	15,000 - 17,500	17,501 - 20,000	Over 20,000
	Speed (mph)	60	38	33	30
Principal Arterial Streets	ADT/Lane	Under 5,750	5,750 - 7,000	7,001 - 8,500	Over 8,500
	Speed (mph)	35	28	25	23

Note: ¹Assumes congested freeway operation when ADT/lane exceeds 15,000.

²Assumes congested principal arterial street operations when ADT/lane exceeds 5,750.

Source: TTI Analysis and Houston-Galveston Regional Transportation Study (10)

Travel Delay

Travel delay calculations are performed in two steps—recurring (or usual) delay and incident (due to crashes, vehicle breakdowns, etc.) delay.

Recurring Travel Delay

The travel delay estimate is derived from estimates of vehicle traffic per lane and traffic speed. The calculation procedures begin with areawide estimates of daily travel, reduce the travel amount to peak period travel and then calculate speeds based on the values in Table C-2. The speeds are used to calculate several delay statistics and excess fuel consumption.

Reduce Daily Travel to Peak-Period Travel

Based on data from continuous traffic data collecting stations (16), approximately 45 percent of the daily travel in an urban area occurs in the six hours of the morning and evening peak periods. This calculation is performed for both freeways and principal arterial streets.

$$\text{Peak-Period VMT} = \frac{\text{Daily VMT}}{\text{VMT}} \times 0.45$$

(Ex. Freeway) 15,817,500 = 35,150,000 x 0.45

Equation C - 1

Estimate Peak Period Congested Travel

Each segment of the freeway and principal arterial street system is evaluated using the values in Table C-2. Each segment (taken from HPMS) is classified as "uncongested" or in one of the three congested categories. The peak period VMT on the road segment is combined with the associated speed (from Table C-2) to estimate delay (Equations C-2 and C-3).

$$\text{Recurring Vehicle - Hours of Freeway Delay (Moderate Category)} = \left(\frac{\text{Moderate Congested}}{\text{Travel Time}} \right) - \left(\frac{\text{Freeflow}}{\text{Travel Time}} \right)$$

$$\text{Recurring Vehicle - Hours of Freeway Delay (Moderate Category)} = \left(\frac{\text{Moderate Congested}}{\text{Freeway VMT}} + \frac{\text{Moderate Congested}}{\text{Freeway Speed}} \right) - \left(\frac{\text{Moderate Congested}}{\text{Freeway VMT}} + \frac{\text{Freeflow}}{\text{Freeway Speed}} \right)$$

(Ex.) 20,405 = (2,114,800 ÷ 38) - (2,114,800 ÷ 60)

Equation C - 2

NOTE: Repeat Eq. C-2 for heavy and severe congestion levels in freeways and all three congestion levels in principal arterial streets.

$$\text{Daily Freeway Recurring Vehicle - Hours of Delay} = \text{Daily Freeway Recurring Vehicle - Hours of Moderate Delay} + \text{Daily Freeway Recurring Vehicle - Hours of Heavy Delay} + \text{Daily Freeway Recurring Vehicle - Hours of Severe Delay}$$

(Ex.) 166,240 = 20,405 + 15,550 + 130,285

Equation C - 3

NOTE: Repeat Eq. C-3 for principal arterial streets.

Estimate Annual Person Delay

This calculation was performed for both freeways and principal arterial streets in a study area; the total recurring vehicle-hours of delay is the sum of the delay resulting from all 3 levels of congestion on both types of facilities. To calculate the annual person-hours of delay, multiply Equation C-3 by the average vehicle occupancy (1.25 person per vehicle) and by 250 working days per year (Equation C-4).

$$\frac{\text{Annual Person-Hours of delay}}{\text{Daily Vehicle Hours of Delay}} = 1.25 \frac{\text{Persons per Vehicle}}{\text{Vehicle}} \times 250 \frac{\text{Working Days per Year}}{\text{Year}}$$

(Ex. Freeway) $51,950,000 = 166,240 \times 1.25 \times 250$

Equation C - 4

Incident-Related Travel Delay

Another type of delay encountered by vehicles is incident delay. This is the delay that results from an accident or disabled vehicle. Incident vehicle-hours of delay vary for each area by facility type, i.e., freeway/expressway or arterial street and facility designs. For the freeway system in individual study areas, the ratio of recurring to incident delay reported in a relatively detailed study by Lindley was used (6). The resulting incident delay was calculated using Equation C-5.

$$\frac{\text{Daily Freeway Incident Vehicle-Hours of Delay}}{\text{Daily Freeway Recurring Vehicle-Hours of Delay}} = \frac{\text{Freeway Recurring Vehicle-Hours of Delay}}{\text{Freeway Recurring Vehicle-Hours of Delay}} \times \text{Freeway Recurring to Incident Delay Ratio}$$

(Ex.) $232,735 = 166,240 \times 1.4$

Equation C - 5

An incident will have varying effects on streets. While there are more driveways that can be used to remove incidents, the crash rate is higher and the recurring delay lower on streets. Arterial street designs are more consistent than freeway designs in each city. For the purpose of this study, incident delay for arterial streets is estimated as 110 percent of arterial street recurring delay. This incident delay factor was calculated using Equation C-6.

$$\frac{\text{Daily Principal Arterial Street Incident Vehicle-Hours of Delay}}{\text{Daily Principal Arterial Street Recurring Vehicle-Hours of Delay}} = 1.1$$

(Ex.) $42,840 = 38,945 \times 1.1$

Equation C - 6

Total incident vehicle-hours of delay is the sum of the freeway and principal arterial street incident vehicle-hours of delay. To calculate the annual person-hours of delay, multiply Equations C-5 and C-6

by the average vehicle occupancy (1.25 person per vehicle) and by 250 working days per year (Equation C-7).

$$\begin{aligned} \text{Annual Person-Hours of Delay} &= \text{Daily Vehicle-Hours of Incident Delay} \times \text{Working Days per Year} \times \text{Persons per Vehicle} \\ (\text{Ex. Freeway}) 72,729,700 &= 232,735 \times 250 \times 1.25 \end{aligned}$$

Equation C - 7

System Travel Speed

[In order to complete this section, the equations used in the Travel Speed and Travel Delay sections should be calculated].

Congested Travel Speed

Equations C-8, C-9, and C-10 show the calculations needed to compute the average travel speed for the street and freeway system. Equation C-8 results in an interim value—the product of speed and vehicle travel distances. Equation C-9 illustrates the summation of the interim calculation values to obtain a value for freeways and principal arterial streets. The output from these equations is used to calculate the average system speed (Equation C-10) for the combination of the freeway and principal arterial street system. This value is the weighted average of the operating speeds of vehicles on each facility type.

$$\begin{aligned} \text{Interim Calculation Value} &= \text{Peak Period VMT} \times \text{Peak Period Speed} \\ (\text{Ex. Freeway Moderate}) 80,362,400 &= 2,114,800 \times 38 \end{aligned}$$

Equation C - 8

NOTE: Speed values are from Table C-2.

$$\begin{aligned} \text{Facility Type Calculation Value} &= \text{Moderate Interim Calculation Value} + \text{Heavy Interim Calculation Value} + \text{Severe Interim Calculation Value} \\ (\text{Ex.}) 352,507,230 &= 80,362,400 + 37,634,580 + 234,510,250 \end{aligned}$$

Equation C - 9

NOTE: Perform this calculation for freeways and principal arterial streets.

$$\text{Average Systemwide Peak-Period Congested Speed} = \frac{\text{Freeway Calculation Value} + \text{Princ. Arterial Calculation Value}}{\text{Peak-Period Congested VMT}}$$

(Ex.) $30.27 = \frac{352,507,230 + 83,954,440}{14,420,250}$

Equation C - 10

Facility Type Travel Speed

The freeway and principal arterial street speed values represent the average peak period speeds on all urban area roadways of each type. These values include the uncongested and congested travel occurring on each facility type. Equations C-11 and C-12 show how to calculate the average peak-period speed for freeways and principal arterial streets.

The congested speeds and travel volumes used to develop interim calculation values in Equation C-8 represent the congested side of Equation C-12. Equation C-11 estimates the uncongested "interim calculation value." The amount of travel not included in one of the three congested categories (see Equation C-2) is combined with the free-flow speed to create the uncongested calculation value.

$$\text{Uncongested Interim Calculation Value} = \text{Peak-Period Uncongested VMT} \times \text{Free-flow Speed}$$

(Ex. Freeway) $284,715,000 = 4,745,250 \times 60$

Equation C - 11

NOTE: Perform calculation for freeways and principal arterial streets.

$$\text{Peak-Period Average Speed} = \frac{\text{Uncongested Calculation Value} + \text{Congested Calculation Value (from Eq. 9)}}{\text{Peak-Period VMT}}$$

(Ex.) $40.3 = \frac{284,715,000 + 352,507,225}{15,817,500}$

Equation C - 12

NOTE: Perform calculation for freeways and principal arterial streets.

Fuel Economy

[In order to complete the calculations on Average Fuel Economy, the calculations in the System Travel Speed section should be completed].

Average Fuel Economy

The average fuel economy calculation is used to estimate the fuel consumption of the vehicles operating in congested and uncongested conditions. Equation (Eq. C-13) is a linear regression applied to a modified version of fuel consumption reported by Raus (17).

$$\text{Average Fuel Economy} = 8.8 + 0.25 \left(\frac{\text{Average Peak Period Congested}}{\text{System Speed}} \right)$$

$$(Ex.) 16.37 = 8.8 + 0.25(30.27)$$

Equation C - 13

Wasted Fuel

[In order to complete the calculations on Wasted Fuel, the sections on Average Fuel Economy, Travel Speed, Travel Delay and System Travel Speed should be completed].

"Wasted" Fuel Calculations

Equation C-14 calculates the wasted fuel due to vehicles moving at speeds slower than free-flow during peak period travel. Equation C-14 calculates the amount of fuel wasted by vehicles using the recurring delay from Equation C-3, the average peak period congested speed (Equation C-10), and the average fuel economy associated with the peak speed (Equation C-13).

$$\text{Daily Recurring Fuel Wasted} = \frac{\text{Recurring Delay (vehicle-hours)}}{\text{(Eqn C-3)}} \times \frac{\text{Average Peak Period System Speed}}{\text{(Eqn C-10)}} \div \frac{\text{Average Fuel Economy}}{\text{(Eqn C-13)}}$$

$$(Ex.) 379,410 = 205,185 \times 30.27 \div 16.37$$

Equation C - 14

Equation C-14 is also used for the wasted fuel due to incident delay (Equation C-15). Equation C-16 presents the total wasted fuel calculation as the sum of incident and recurring congestion fuel consumption multiplied by 250 working days per year.

$$\text{Daily Incident Fuel Wasted} = \frac{\text{Incident Delay (vehicle-hours)}}{\text{(Eqns C-5 \& C-6)}} \times \frac{\text{Average Peak Period System Speed}}{\text{(Eqn C-10)}} \div \frac{\text{Average Fuel Economy}}{\text{(Eqn C-13)}}$$

$$(Ex.) 509,570 = 275,575 \times 30.27 \div 16.37$$

Equation C - 15

$$\text{Annual Wasted Fuel Due to Congestion} = \frac{\text{Wasted Fuel Due to Recurring Congestion}}{\text{Recurring Congestion}} + \frac{\text{Wasted Fuel Due to Incident Congestion}}{\text{Incident Congestion}} \times \frac{250 \text{ Working Days per Year}}{\text{Year}}$$

$$(Ex.) 222,245,000 = 379,410 + 509,570 \times 250$$

Equation C - 16

Congestion Cost

[In order to complete the calculations in this section, the equations in the sections on Travel Speed, Travel Delay, System Travel Speed, Average Fuel Economy, and Wasted Fuel should be completed].

Two cost components are associated with congestion: delay cost and fuel cost. These values are directly related to the travel speed calculations. The following sections describe how to calculate the costs associated with each component.

Delay Cost

The delay cost is composed of the cost of lost time due to travel on congested roadways in passenger vehicles and the cost of operating commercial vehicles in congestion. Equations C-17 through C-19 show how to calculate the cost of delay. Equation C-17 shows how to calculate the passenger vehicle delay costs that result from lost time. Equation C-18 shows how to calculate the truck (commercial vehicle) delay costs that are based on the peak period congested speed and the cost per mile of operating a commercial vehicle. Equation C-19 totals the recurring delay cost for the system by adding the recurring delay costs for passenger vehicles and trucks.

$$\text{Daily Passenger Vehicle Recurring Delay Cost} = \frac{\text{Passenger Vehicle Recurring Hours of Delay}}{\text{Hour of Delay}} \times \frac{\text{Value of Person Time (\$/hour)}}{\text{Person Time}} \times \frac{\text{Vehicle Occupancy (persons/vehicle)}}{\text{Vehicle Occupancy}}$$

$$(Ex.) 2,850,800 = (205,185 \times 0.95) \times \$11.70 \times 1.25$$

Equation C - 17

$$\text{Daily Truck Recurring Delay Cost} = \frac{\text{Truck Recurring Vehicle-Hours of Delay}}{\text{Vehicle-Hours of Delay}} \times \frac{\text{Average Peak Period System Speed (miles/hour)}}{\text{System Speed}} \times \frac{\text{Truck Operating Cost (\$/mile)}}{\text{Operating Cost}}$$

$$(Ex.) 791,900 = (205,185 \times 0.05) \times 30.27 \times 2.55$$

Equation C - 18

$$\text{Daily Recurring Delay Cost} = \text{Passenger Vehicle Recurring Cost} + \text{Truck Recurring Delay Cost}$$

$$(Ex.) 3,642,700 = 2,850,800 + 791,900$$

Equation C - 19

NOTE: Perform these equations for incident delay to calculate incident delay costs.

Fuel Cost

Fuel cost is calculated for passenger vehicles and trucks experiencing recurring delay in Equation C-20. This is done by associating the peak period congested speeds, the average fuel economy, and the fuel costs with the vehicle-hours of recurring delay. Equation C-20 calculates the fuel cost associated with recurring delay.

$$\text{Daily Recurring Fuel Cost} = \text{Vehicle - Hours of Delay} \times \frac{\text{Average Peak Period Congested System Speed}}{\text{Average Fuel Economy}} \times \text{Fuel Cost}$$

(Ex.) $459,090 = 205,185 \times 30.27 \div 16.37 \times \1.21

Equation C - 20

NOTE: Perform Equation C-20 for incident delay to calculate incident fuel costs.

These calculations of cost components were completed for both incident and recurring delay. Equations C-21 through C-23 combine the four different portions— incident delay, recurring delay, incident fuel, and recurring fuel— to determine the annual cost due to congestion resulting from incident and recurring delay.

$$\text{Annual Cost Due to Recurring Congestion} = \left(\text{Daily Recurring Delay Cost} + \text{Daily Recurring Fuel Cost} \right) \times \text{working days}$$

(Ex.) $1,025,447,500 = (3,642,700 + 459,090) \times 250$

Equation C - 21

$$\text{Annual Cost Due to Incident Congestion} = \left(\text{Incident Delay Cost} + \text{Incident Fuel Cost} \right) \times \text{working days}$$

(Ex.) $1,377,232,500 = (4,892,350 + 616,580) \times 250$

Equation C - 22

$$\text{Annual Cost Due to Congestion} = \text{Annual Cost Due to Recurring Congestion} + \text{Annual Cost Due to Incident Congestion}$$

(Ex.) $2,402,680,000 = 1,025,447,500 + 1,377,232,500$

Equation C - 23

Travel Rate Index

[In order to complete this section, the equations in the Travel Speed and System Travel Speed section should be completed].

The travel rate index (TRI) shows the amount of additional time that is required to make a trip because of congested conditions on the roadways. A number such as 1.30 would show that it takes 30 percent more time to make a trip in the peak period than if the motorist could travel at freeflow speeds. Equations C-24 and C-25 show how to calculate the TRI.

Equation C-24 shows how to convert the average speed (in miles per hour) to a travel rate (in minutes per mile). The TRI is calculated in Equation C-25. The TRI is calculated by taking a weighted average of the travel rates on the freeways and principal arterial streets.

$$\text{Travel Rate} = \frac{60}{\text{Average Speed}}$$

$$(\text{Ex., Congested Freeway}) 1.49 = \frac{60}{40.3}$$

Equation C - 24

$$\text{Travel Rate Index} = \frac{\left(\frac{\text{Freeway Travel Rate}}{\text{Freeway Freeflow Rate}} \times \frac{\text{Freeway Peak Period VMT}}{\text{Freeway Peak Period VMT}} \right) + \left(\frac{\text{Principal Arterial Street Travel Rate}}{\text{Principal Arterial Street Freeflow Rate}} \times \frac{\text{Principal Arterial Street Peak Period VMT}}{\text{Principal Arterial Street Peak Period VMT}} \right)}{\left(\frac{\text{Freeway Peak Period VMT}}{\text{Freeway Peak Period VMT}} + \frac{\text{Principal Arterial Street Peak Period VMT}}{\text{Principal Arterial Street Peak Period VMT}} \right)}$$

$$(\text{Ex.}) 1.42 = \frac{\left(\frac{1.49}{1.0} \times 15,817,500 \right) + \left(\frac{2.07}{1.71} \times 5,580,000 \right)}{(15,817,500 + 5,580,000)}$$

Equation C - 25



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