2009 URBAN MOBILITY REPORT

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CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

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2009 Urban Mobility Report

This summary report describes the scope of the problem and some of the improvement strategies. For the complete report and congestion data on your city, see: http://mobility.tamu.edu/ums.

Congestion is a problem in America's 439 urban areas, and it has gotten worse in regions of all sizes. In 2007, congestion caused urban Americans to travel 4.2 billion hours more and to purchase an extra 2.8 billion gallons of fuel for a congestion cost of $87.2 billion – an increase of more than 50% over the previous decade (Exhibit 1). This was a decrease of 40 million hours and a decrease of 40 million gallons, but an increase of over $100 million from 2006 due to an increase in the cost of fuel and truck delay. Small traffic volume declines brought on by increases in fuel prices over the last half of 2007 caused a small reduction in congestion from 2006 to 2007.

There are many congestion problems but there are also many solutions. **The most effective strategy is one where agency actions are complemented by efforts of businesses, manufacturers, commuters and travelers. The best approach to selecting strategies is to identify projects, programs and policies that solve problems or capitalize on opportunities.** The strategies must address the issue that the problems are not the same in every region or on every day – the variation in travel time is often as frustrating and costly as the regular "daily slog" through traffic jams. The *2009 Urban Mobility Report* clearly demonstrates that all the solutions are not being implemented fast enough.

Exhibit 1. Major Findings for 2009 –
The Important Numbers for the 439 U.S. Urban Areas
(Note: See page 2 for description of changes since 2007 Report)

Measures of…	1982	1997	2006	2007
… Individual Traveler Congestion				
Annual delay per peak traveler (hours)	14	32	37	36
Travel Time Index	1.09	1.20	1.25	1.25
"Wasted" fuel per peak traveler (gallons)	9	21	25	24
Congestion Cost (constant 2007 dollars)	$290	$621	$758	$757
Urban areas with 40+ hours of delay per peak traveler	1	10	27	23
… The Nation's Congestion Problem				
Travel delay (billion hours)	0.79	2.72	4.20	4.16
"Wasted" fuel (billion gallons)	0.50	1.82	2.85	2.81
Congestion cost (billions of 2007 dollars)	$16.7	$53.6	$87.1	$87.2
… Travel Needs Served				
Daily travel on major roads (billion vehicle-miles)	1.68	2.93	3.79	3.82
Annual public transportation travel (billion person-miles)	38.8	42.6	53.4	55.8
… Expansion Needed to Keep Today's Congestion Level				
Lane-miles of freeways and major streets added every year	15,500	16,532	15,032	12,676
Public transportation riders added every year (million)	3,456	3,876	3,779	3,129
… The Effect of Some Solutions				
Travel delay saved by				
Operational treatments (million hours)	7	116	307	308
Public transportation (million hours)	290	455	622	646
Congestion costs saved by				
Operational treatments (billions of 2007 dollars)	$.02	$2.3	$6.4	$6.5
Public transportation (billions of 2007 dollars)	$6.3	$9.3	$13.1	$13.7

Travel Time Index (TTI) – The ratio of travel time in the peak period to travel time at free-flow conditions. A Travel Time Index of 1.35 indicates a 20-minute free-flow trip takes 27 minutes in the peak.
Delay per Peak Traveler – The extra time spent traveling at congested speeds rather than free-flow speeds divided by the number of persons making a trip during the peak period.
Wasted Fuel – Extra fuel consumed during congested travel.
Vehicle-miles – Total of all vehicle travel (10 vehicles traveling 9 miles is 90 vehicle-miles).
Expansion Needed – Either lane-miles or annual riders to keep pace with travel growth (and maintain congestion).

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The Congestion Trends

(And Why A Few Numbers Are Different than Previous Reports)

Each *Urban Mobility Report* reviews procedures, processes, and data used to develop the best estimates of the costs and challenges of traffic congestion, improving them when possible. The methodology was revised in 2008/9 to improve the public transportation methodology. In addition, the benefits from operations treatments were estimated throughout the extent of the study database to improve the relevance of the long-term trends. This caused some numbers from previous reports to change. All of the congestion statistics in the *2009 Urban Mobility Report* have been revised using the new calculation procedures for all years from 1982 so that true trends can be identified (Exhibit 2).

Congestion, by every measure, has increased substantially over the 25 years covered in this report. The most recent two years of the report, however, have seen slower growth or even a decline in congestion. Delay per traveler – the number of hours of extra travel time that commuters spend during rush hours – was 1.3 hours lower in 2007 than 2005. This change would be more hopeful if it was associated with something other than rising fuel prices (which occurred for a short time in 2005 and 2006 before the sustained increase in 2007 and 2008) and a slowing economy. This same kind of slow growth/decline over a few years occurred in the early 1990s when spending and growth in the high-tech and defense sectors of the economy declined dramatically.

The decline means congestion is near the levels recorded in 2003, not exactly a year remembered for trouble-free commuting.

Changes to Congestion Methodology – Highlights

- Public transportation – An improved method for transferring riders back into the roadway network to simulate the effect of eliminating public transportation service resulted in larger delay reduction benefits in the 2009 report. The new methodology was reapplied for all previous years as well. Improvements include using the transit modes in each region to determine the peak travel mileage and alternative routes.
- Operations benefits - The 2009 report estimates the benefits from programs that reduce congestion without adding roadway lanes for every year since 1982. Previous reports included these programs only since 2000. There are fewer data for the pre-2000 period, but general trend information and project-specific reports were used to smooth out what had been a disruptive element in the urban area congestion trends.

The base data for this report are from the Federal Highway Administration's Highway Performance Monitoring System (*1*). More information on the methodology is included on the website at: http://mobility.tamu.edu/ums/report/methodology.stm

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Exhibit 2. National Congestion Measures, 1982 to 2007

						Hours Saved (million hours)		Gallons Saved (million gallons)		Dollars Saved (billions of $2007)	
Year	Travel Time Index	Delay per Traveler (hours)	Total Delay (billion hours)	Total Fuel Wasted (billion gallons)	Total Cost ($2007 billion)	Operational Treatments & High-Occupancy Vehicle Lanes	Public Transp	Operational Treatments & High-Occupancy Vehicle Lanes	Public Transp	Operational Treatments & High-Occupancy Vehicle Lanes	Public Transp
1982	1.09	13.8	0.79	0.50	16.7	7	290	4	163	0.2	6.3
1983	1.09	14.7	0.87	0.54	18.0	9	296	5	167	0.2	6.4
1984	1.10	15.8	0.95	0.60	19.7	12	306	7	174	0.3	6.6
1985	1.11	12.0	1.10	0.70	22.6	17	324	9	187	0.3	6.9
1986	1.13	20.2	1.27	0.81	25.2	22	306	12	181	0.4	6.3
1987	1.14	21.6	1.41	0.92	27.9	28	315	16	186	0.6	6.5
1988	1.16	24.2	1.62	1.06	32.0	37	384	20	228	0.7	7.9
1989	1.17	25.9	1.78	1.17	35.3	45	411	24	246	0.9	8.5
1990	1.18	26.8	1.88	1.25	37.3	51	409	28	248	1.0	8.4
1991	1.18	26.5	1.93	1.29	38.1	54	404	30	247	1.1	8.3
1992	1.18	27.4	2.05	1.37	40.6	61	397	34	241	1.2	8.1
1993	1.18	28.5	2.17	1.43	42.6	68	391	38	237	1.3	8.0
1994	1.18	28.8	2.26	1.49	44.3	76	407	42	246	1.5	8.3
1995	1.19	30.0	2.42	1.61	47.8	89	427	49	262	1.8	8.8
1996	1.19	31.0	2.58	1.72	51.0	102	442	56	272	2.0	9.1
1997	1.20	31.7	2.73	1.82	53.6	116	455	64	280	2.3	9.3
1998	1.21	31.9	2.83	1.91	55.0	131	482	72	299	2.5	9.7
1999	1.22	33.3	3.04	2.05	58.9	151	511	82	319	2.9	10.3
2000	1.22	33.4	3.18	2.14	63.1	166	538	109	327	3.3	10.9
2001	1.23	34.2	3.33	2.25	65.7	187	559	123	341	3.7	11.3
2002	1.24	35.0	3.52	2.38	69.3	208	566	138	346	4.1	11.4
2003	1.24	35.4	3.73	2.53	73.3	238	558	156	341	4.7	11.2
2004	1.25	36.5	3.97	2.69	79.4	258	591	171	362	5.2	12.1
2005	1.25	37.4	4.18	2.82	85.6	278	595	182	365	5.7	12.4
2006	1.25	36.6	4.20	2.85	87.1	307	622	200	384	6.4	13.1
2007	1.25	36.1	4.16	2.81	87.2	308	646	202	398	6.5	13.7

Note: For more congestion information see Tables 1 to 7 and http://mobility.tamu.edu/ums

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One Page of Congestion Problems

Travelers and freight shippers must plan around traffic jams for more of their trips, in more hours of the day and in more parts of town than in 1982. In some cases, this includes weekends and rural areas. Until 2007, mobility problems worsened at a relatively consistent rate during the more than two decades studied.

Congestion costs are increasing. The congestion "invoice" for the cost of extra time and fuel in 439 urban areas (all values in constant 2007 dollars):

- In 2007 – $87.2 billion
- In 2000 – $63.1 billion
- In 1982 – $16.7 billion

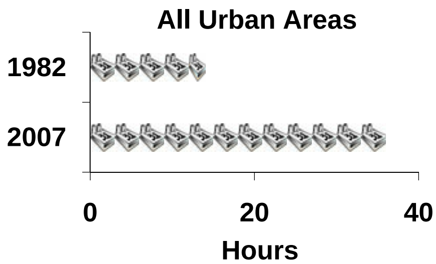
Congestion wastes a massive amount of time, fuel and money. In 2007:

- 2.8 billion gallons of wasted fuel (enough to fill 370,000 18-wheeler fuel delivery trucks – bumper-to-bumper from Houston to Boston to Los Angeles)
- 4.2 billion hours of extra time (enough to listen to *War and Peace* being read 160 million times through your car stereo)
- $87.2 billion of delay and fuel cost (The negative effect of uncertain or longer delivery times, missed meetings, business relocations and other congestion results are not included)

Congestion affects the people who typically make trips during the peak period.

- Yearly delay for the average peak-period traveler was 36 hours in 2007 – almost one week of vacation – an increase from 14 hours in 1982 (Exhibit 3).
- That traveler wasted 24 gallons of fuel in 2007 – three weeks worth of fuel for the average U.S. resident – up from 9 gallons in 1982 (Exhibit 4).
- The value for the delay and wasted fuel was almost $760 per traveler in 2007 compared to an inflation-adjusted $290 in 1982.
- Congestion effects were even larger in areas over one million persons – 46 hours and 31 gallons in 2007.

Exhibit 3. Hours of Travel Delay per Peak-Period Traveler



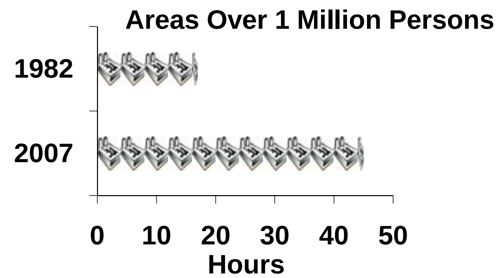
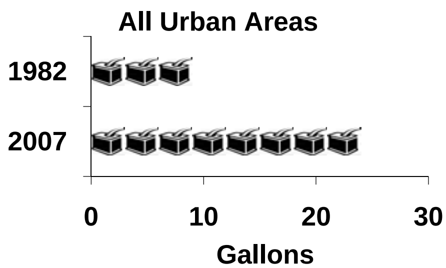
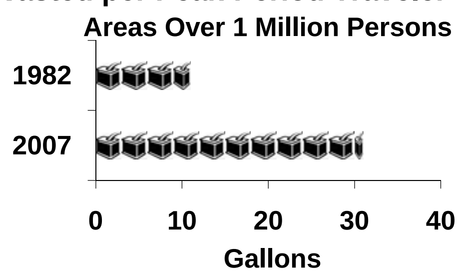


Exhibit 4. Gallons of Fuel Wasted per Peak-Period Traveler





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Won't Higher Fuel Prices and the Economic Slowdown Help Solve Congestion Problems?

The *2009 Urban Mobility Report* suggests a tentative "yes" to the fuel price question above, if…
- By "higher" you mean very high – above $4 per gallon for more than a year
- By "solve" you mean slower growth or modest declines in congestion (don't expect to drive at the speed limit on your way to work)

The way most people understand congestion, then, the answer is "no, higher fuel prices are not the answer."

The economic solution, likewise, doesn't hold much hope for those wishing to find the easy answer. Travel may grow slower than in the past, but that will only mean "things get worse slower" – hardly a positive goal statement. The Urban Mobility Report database includes a few similar periods from regional recessions in the past (the northeastern states in the early-to-mid 1980s, Texas in the mid 1980s, California in the early-to-mid 1990s). In every case, when the economy rebounded, so did the congestion problem. An examination of recent fuel price, traffic volume, transit ridership and congestion trends shows (Exhibit 5):
- There is a cycle to traffic volume and fuel prices – they generally go up in the summer and down in the winter.
- There was a small but varying decline in traffic volume in 2008. The largest declines were in rural areas and on the weekends. The smallest declines were in the urban areas on weekdays – where most of the congestion exists.
- Traffic volume began to increase when prices declined in the Fall of 2008.
- Traffic volume and congestion trends during the economic downturn in the last half of 2008 were consistent with previous recessions – slow or no growth in areas with job losses.
- Public transportation ridership was up in early and mid-2008 when fuel prices were at their highest levels (*2*).

None of these events suggest that price increases which are modest and take a long time or price increases that are rapid but decline after a few months will cause any substantial change in travel behavior or cause a dramatic slowdown in congestion growth trends.

Data collected on freeways in 23 urban regions (see Exhibit 5) as part of a 2008 study for the Federal Highway Administration (*3*) found:
- Weekday traffic volumes were down between 2% and 4% from June to December 2008 compared to June to December 2007.
- Traffic congestion for these same time periods was down between 3% and 5%.
- Weekend traffic volumes were down between 4% and 7% between June and November 2008 and the same period in 2007.
- Weekend traffic volumes were down only 2% to 3% in December 2008 (with lower fuel prices).

These values show that dramatic fuel price increases and a falling job market will "solve" only part of the congestion problem.

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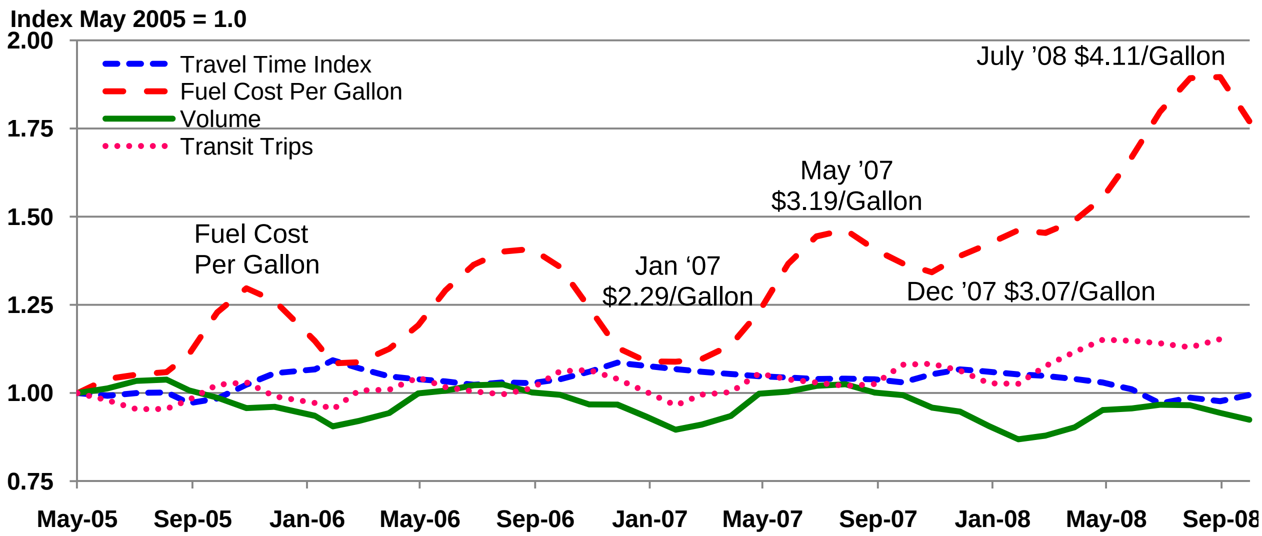
The reason why the travel decline was relatively small (in relation to the price increase) may have been due to the fact that people could adopt several coping strategies:

- Cut back spending in other areas to pay for fuel
- Reduce their percentage of drive-alone trips
- Combine trips, for example, stopping at the store on the way home from work
- Avoid optional trips in "rush hours" (but in many areas this time period was already congested – one would be hard pressed to find a lot of "joy-riding" in rush hour)

Over a relatively short time period, many people are "locked in" to many of their choices and cannot respond rapidly. Consider these factors that made it difficult for people to react to short-term fuel price increases in 2007 and 2008:

- Cannot sell a large car or SUV for the amount of the loan, because trade-in value was low
- Cannot ride public transportation for trips that are not served by transit systems
- Cannot change jobs – many employers were not hiring because the economy was expected to slow down
- Cannot move homes because prices had slipped and it was difficult to obtain a mortgage

Exhibit 5. Congestion, Traffic Volume, Transit Ridership and Fuel Cost – 2005 to 2008



Note: Trends are based on 3-month running averages.

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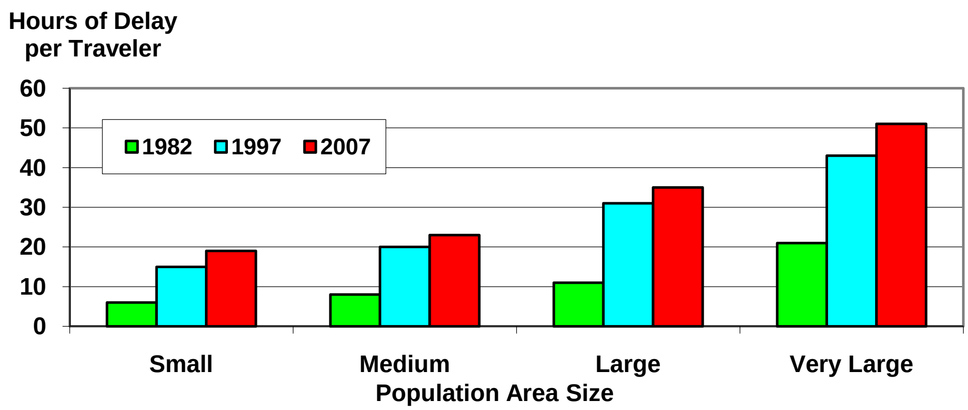
More Detail about Congestion Problems

Congestion is worse in areas of every size – it is not just a big city problem. The growing time delays hit residents of smaller cities as well (Exhibit 6). Regions of all sizes have problems implementing enough projects, programs and policies to meet the demand of growing population and jobs. Major projects, programs and funding efforts take 10 to 15 years to develop. In 2020, at this rate, congestion problems in cities with 500,000 to 1 million people will resemble today's traffic headaches for areas over 1 million people.

Exhibit 6. Congestion Growth Trend



Small = less than 500,000 **Large** = 1 million to 3 million
Medium = 500,000 to 1 million **Very Large** = more than 3 million

Think of what else could be done with the 36 hours of extra time suffered in congestion by the average urban traveler in 2007:

- Almost 5 vacation days
- Almost 13 big league baseball games
- More than 600 average online video clips

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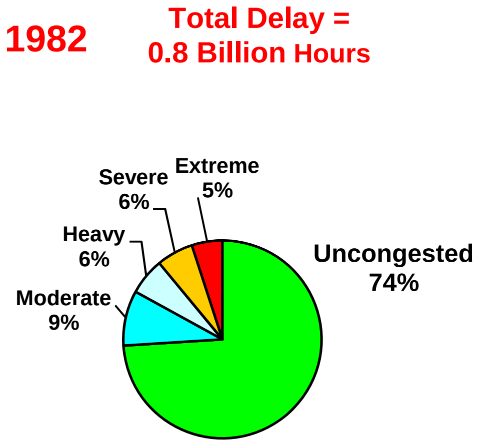
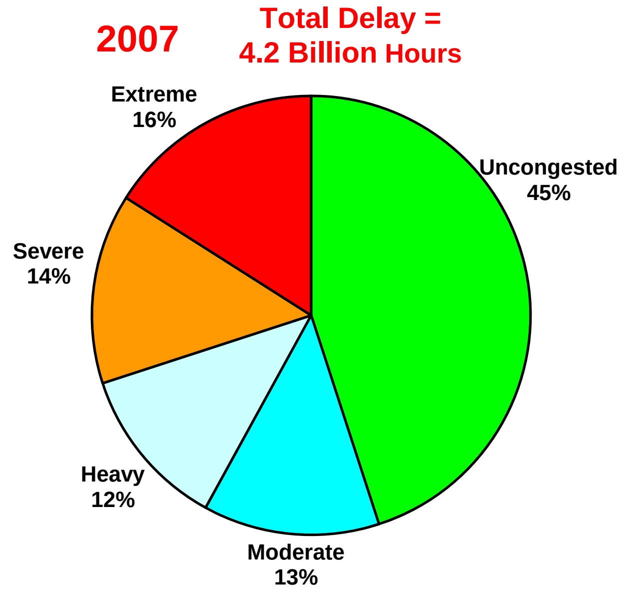
Travelers and shippers must plan around congestion more often.

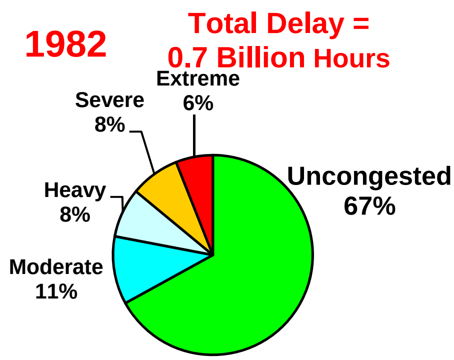
- In all 439 urban areas, the worst congestion levels affected only 1 in 9 trips in 1982, but almost 1 in 3 trips in 2007 (Exhibits 7 and 8).
- Free-flowing traffic is seen less than one-third of the time in urban areas over 1 million population.
- Delay has grown five times larger overall since 1982 and more than four times higher in regions with more than 1 million people.

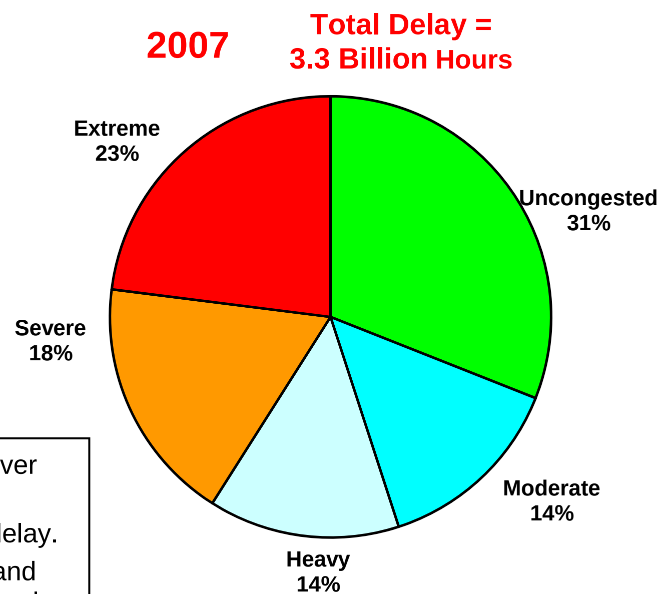
Exhibit 7. Congestion Growth – 1982 to 2007





Urban Areas Over 1 Million Population





But the problem could be even worse in the regions over 1 million population.

- Operational treatments save 278 million hours of delay.
- And if there were no public transportation service and travelers used their cars, there would be an additional 616 million hours of delay.

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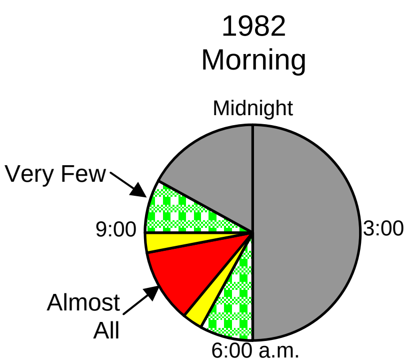
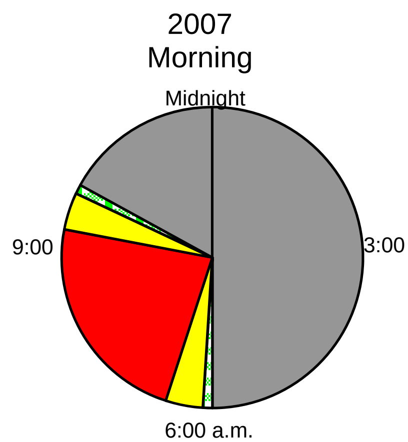
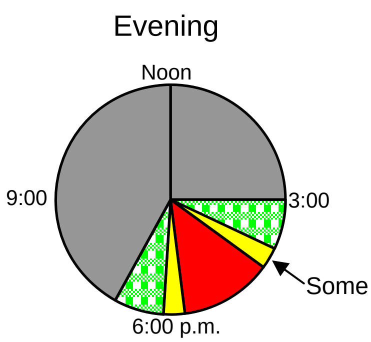
The Jam Clock (Exhibit 8) depicts the growth of congested periods within the morning and evening "rush hours."

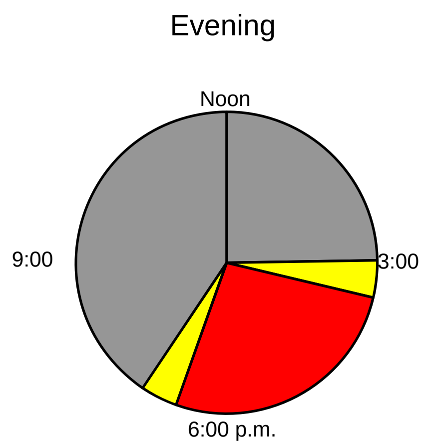
Exhibit 8. The Jam Clock Shows That It Is Hard To Avoid Congestion in Urban Areas with More than 1 Million Persons



The concept of "rush hour" definitely does not apply in areas with more than 1 million people. Congestion might be encountered three hours in each peak. And very few travelers are "rushing" anywhere.







Red – Almost all regions have congestion
Yellow – Some regions have congestion
Green Checked– Very few regions have congestion
Gray – Time period not analyzed

Note: The *2009 Urban Mobility Report* examined 6 to 10 a.m. and 3 to 7 p.m.

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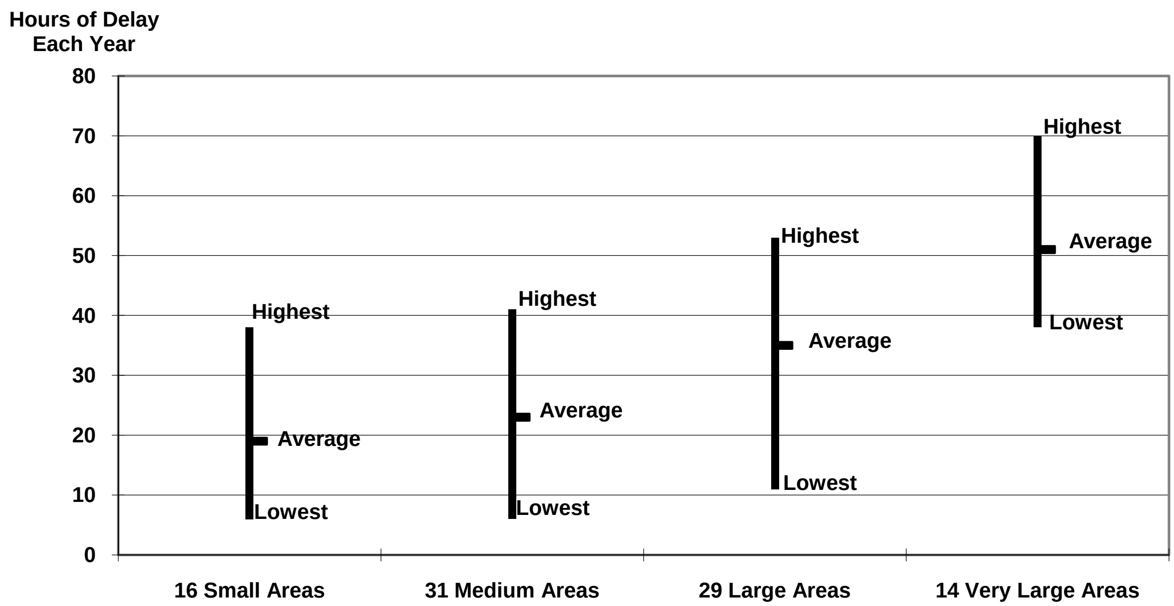
Congestion levels vary in cities of the same size. Exhibit 9 shows the wide range in congestion problems in each of the four urban size groups. In all four groups, there is a difference of at least 30 hours of delay per traveler between the most and least congested regions. There are many causes for this range – some natural, some man-made. And some of the differences are the result of investment decisions.

The public and decision-makers at all levels should consider whether there is a match between transportation funding levels, mobility goals and the projects, programs and policies they support to address congestion problems. Every city is different, but the data suggest the current trends are not acceptable.

Exhibit 9. Congestion and Urban Area Size, 2007



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Congestion Solutions – An Overview of the Portfolio

We recommend a ***balanced and diversified approach*** to reduce congestion – one that focuses on more of everything. It is clear that our current investment levels have not kept pace with the problems. Population growth will require more systems, better operations and increased number of travel alternatives. And most urban regions have big problems now – more congestion, poorer pavement and bridge conditions and less public transportation service than they would like. There will be a different mix of solutions in metro regions, cities, neighborhoods, job centers and shopping areas. Some areas might be more amenable to construction solutions, other areas might use more travel options, productivity improvements, diversified land use patterns or redevelopment solutions. In all cases, the solutions need to work together to provide an interconnected network of transportation services.

More information on the possible solutions, places they have been implemented, the effects estimated in this report and the methodology used to capture those benefits can be found on the website http://mobility.tamu.edu/solutions.

- **Get as much service as possible from what we have** – Many low-cost improvements have broad public support and can be rapidly deployed. These management programs require innovation, constant attention and adjustment, but they pay dividends in faster, safer and more reliable travel. Rapidly removing crashed vehicles, timing the traffic signals so that more vehicles see green lights, improving road and intersection designs, or adding a short section of roadway are relatively simple actions.
- **Add capacity in critical corridors** – Handling greater freight or person travel on freeways, streets, rail lines, buses or intermodal facilities often requires "more." Important corridors or growth regions can benefit from more road lanes, new streets and highways, new or expanded public transportation facilities, and larger bus and rail fleets.
- **Change the usage patterns** –There are solutions that involve changes in the way employers and travelers conduct business to avoid traveling in the traditional "rush hours." Flexible work hours, internet connections or phones allow employees to choose work schedules that meet family needs and the needs of their jobs.
- **Provide choices** – This might involve different routes, travel modes or lanes that involve a toll for high-speed and reliable service – a greater number of options that allow travelers and shippers to customize their travel plans.
- **Diversify the development patterns** – These typically involve denser developments with a mix of jobs, shops and homes, so that more people can walk, bike or take transit to more, and closer, destinations. Sustaining the "quality of life" and gaining economic development without the typical increment of mobility decline in each of these sub-regions appear to be part, but not all, of the solution.
- **Realistic expectations** are also part of the solution. Large urban areas will be congested. Some locations near key activity centers in smaller urban areas will also be congested. But congestion does not have to be an all-day event. Identifying solutions and funding sources that meet a variety of community goals is challenging enough without attempting to eliminate congestion in all locations at all times.

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Congestion Solutions – The Effects

The *2009 Urban Mobility Report* database includes the effect of several widely implemented congestion solutions. These provide more efficient and reliable operation of roads and public transportation using a combination of information, technology, design changes, operating practices and construction programs.

Benefits of Public Transportation Service

Regular-route public transportation service on buses and trains provides a significant amount of peak-period travel in the most congested corridors and urban areas in the U.S. If public transportation service had been discontinued and the riders traveled in private vehicles in 2007, the 439 urban areas would have suffered an additional 646 million hours of delay and consumed 398 million more gallons of fuel (Exhibit 10), 40% more than a decade ago. The value of the additional travel delay and fuel that would have been consumed if there were no public transportation service would be an additional $13.7 billion, a 16% increase over current levels in the 439 urban areas.

There were approximately 55 billion passenger-miles of travel on public transportation systems in the 439 urban areas in 2007 (*2*). The benefits from public transportation vary by the amount of travel and the road congestion levels (Exhibit 10). More information on the effects for each urban area is included in Table 3.

Exhibit 10. Delay Increase in 2007 if Public Transportation Service Were Eliminated – 439 Areas

Population Group and Number of Areas	Average Annual Passenger-Miles of Travel (Million)	Delay Reduction Due to Public Transportation		
		Hours of Delay (Million)	Percent of Base Delay	Dollars Saved ($ Million)
Very Large (14)	41,602	557	18	11,874
Large (29)	6,180	59	6	1,226
Medium (31)	1,718	13	4	259
Small (16)	289	2	3	31
Other (349)	6,033	16	3	339
National Urban Total	55,822	646	16	$13,729

Source: Reference (*2*) and Review by Texas Transportation Institute

Better Operations

Five prominent types of operational treatments are estimated to relieve a total of 308 million hours of delay (7% of the total) with a value of $6.5 billion in 2007 (Exhibit 11). If the treatments were deployed on all major freeways and streets, the benefit would expand to about 504 million hours of delay (11% of delay) and more than $10.5 billion would be saved. These are significant benefits, especially since these techniques can be enacted much quicker than significant roadway or public transportation system expansions can occur. The operational treatments, however, do not replace the need for those expansions.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit 11. Operational Improvement Summary for All 439 Urban Areas

Operations Treatment (Number of Regions with Treatment)	**Delay Reduction from Current Projects**		**Delay Reduction if In Place on All Roads (Million Hours)**
	Hours Saved (Million)	**Dollars Saved ($ Million)**	
Ramp Metering (25)	39.8	851	98.5
Incident Management (272)	143.3	3,060	199.5
Signal Coordination (439)	19.6	404	45.8
Access Management (439)	68.7	1,370	159.7
High-Occupancy Vehicle Lanes (16)	37.0	779	Not Known
TOTAL	308	$6,464	504

Note: This analysis uses nationally consistent data and relatively simple estimation procedures. Local or more detailed evaluations should be used where available. These estimates should be considered preliminary pending more extensive review and revision of information obtained from source databases.(*1*,*4*)

More information about the specific treatments and examples of regions and corridors where they have been implemented can be found at the website http://mobility.tamu.edu/resources/

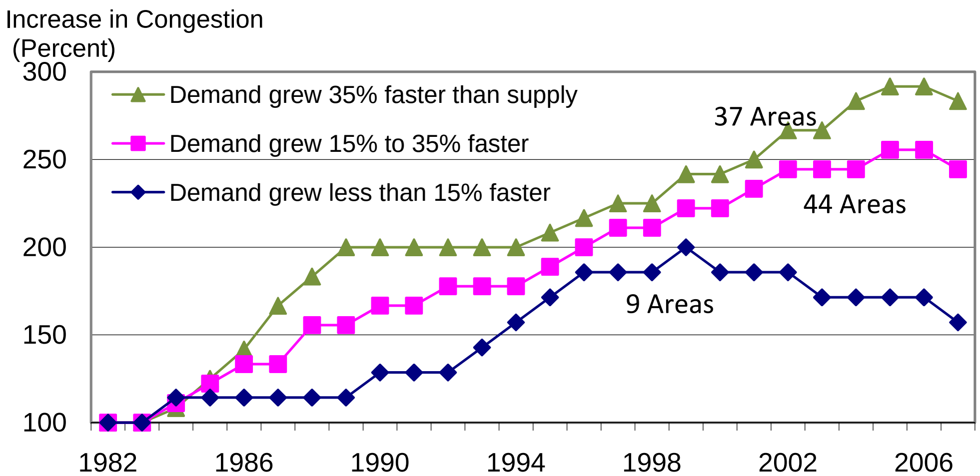
More Capacity

Projects that provide more road lanes and more public transportation service are part of the congestion solution package in most growing urban regions. New streets and urban freeways will be needed to serve new developments, public transportation improvements are particularly important in congested corridors and to serve major activity centers, and toll highways and toll lanes are being used more frequently in urban corridors. Capacity expansions are also important additions for freeway-to-freeway interchanges and connections to ports, rail yards, intermodal terminals and other major activity centers for people and freight transportation.

Additional roadways reduce the rate of congestion increase. This is clear from comparisons between 1982 and 2007 (Exhibit 12). Urban areas where capacity increases matched the demand increase saw congestion grow much more slowly than regions where capacity lagged behind demand growth. It is also clear, however, that if only 9 areas were able to accomplish that rate, there must be a broader and larger set of solutions applied to the problem. Most of these 9 regions (listed in Table 7) were not in locations of high economic growth, suggesting their challenges were not as great as in regions with booming job markets.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit 12. Road Growth and Mobility Level



Source: Texas Transportation Institute analysis, see Table 7 and http://mobility.tamu.edu/ums/report/methodology.stm

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

All Congestion Solutions Are Needed

Most large city transportation and planning agencies are pursuing all of these strategies as well as others. The mix of programs, policies and projects may be different in each city and the pace of implementation varies according to overall funding, commitment, location of problems, public support and other factors. Addressing the range of different problems with an overall strategy that chooses transportation and land development solutions with the greatest benefit for the least cost recognizes the diversity of the problems and opportunities in each region.

Policy-makers and big city residents have learned to expect congestion for 1 or 2 hours in the morning and in the evening. However, agencies should be able to improve the performance and reliability of the service at other hours. But they have not been able to combine the leadership, technical and financial support to expand the system, improve operations and change travel patterns to keep congestion levels from increasing in times of economic growth.

The involvement of business leaders in crafting a set of locally supported solutions would seem to be a very important element in the future. At the strategic end, business leader actions take the form of information development and communication with the public and decision-makers to emphasize the role of transportation in the state and regional economy. On the tactical end, business and community leaders can make the case for small-scale improvements that may not be evident to the operating agencies. And they can support individual workers who wish to choose carpooling, public transportation, flexible work hours, telecommuting or other route or mode options.

Addressing the congestion problems can provide substantial benefits and provide improvements in many sectors of society and the economy. A Texas study (*5*) estimated that solving the congestion problems in the state's urban regions would generate more than $6.50 in economic benefits for every $1.00 spent. Rebuilding transportation facilities to provide more capacity also addresses the need for roadway repair and infrastructure renewal.

Methodology

The base data for the *2009 Urban Mobility Report* come from the U.S. Department of Transportation and the states (*1,4*). Several analytical processes are used to develop the final measures. These are described in a series of technical reports (*6*) that are posted on the mobility report website: http://mobility.tamu.edu/ums/report/methodology.stm.

- The travel and road inventory statistics are analyzed with a set of procedures developed from computer models and studies of real-world travel time and traffic congestion data. The congestion methodology creates a set of base statistics developed from traffic density values. The density data (daily traffic volume per lane of roadway) are converted to average peak-period speeds using a set of estimation curves based on relatively ideal travel conditions – no crashes, breakdowns or weather problems – for the years 1982 to 2007.
- The base estimates, however, do not include the effect of many transportation improvements. The 2009 report addresses this estimation deficiency with methodologies designed to identify the effect of operational treatments and public transportation services. The delay, cost and index measures for all years include these treatments.
- The new estimation procedures for public transportation benefits include more detail than previous reports and provide additional information to analyze the effect of public transportation services.

Future Changes

There will be other changes in the report methodology over the next few years. There is more information available every year from freeways, streets and public transportation systems that provides more descriptive travel time and volume data. Travel time information is being collected from travelers and shippers on the road network by a variety of public and private data collection sources. Some advanced transit operating systems monitor passenger volume, travel time and schedule information and share those data with freeway monitoring and traffic signal systems. Traffic signals can be retimed immediately by the computers to reduce person congestion (not just vehicle congestion). These data can also be used to more accurately describe congestion problems on public transportation and roadway systems.

Combining Performance Measures

Table 6 illustrates an approach to understanding several of the key measures. The value for each statistic is rated according to the relationship to the average value for the population group. The terms "higher" and "lower" than average congestion are used to characterize the 2007 values and trends from 1982 to 2007. These descriptions do not indicate any judgment about the extent of mobility problems. Urban areas that have better than average rankings may have congestion that residents consider a significant problem. What Table 6 does, however, is provide the reader with some context for the mobility discussion.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Concluding Thoughts

Congestion has gotten worse in many ways since 1982:

- Trips take longer.
- Congestion affects more of the day.
- Congestion affects weekend travel and rural areas.
- Congestion affects more personal trips and freight shipments.
- Trip travel times are unreliable.

The *2009 Urban Mobility Report* points to an $87.2 billion congestion cost – and that is only the value of wasted time and fuel. Congestion causes the average peak-period traveler to spend an extra 36 hours of travel time and use 24 gallons of fuel consumption, which amounts to a cost of $760 per traveler. The report includes a comprehensive picture of congestion in all 439 U.S. urban areas and provides an indication of how the problem affects travel choices, arrival times, shipment routes, manufacturing processes and location decisions.

The recent rise and then fall in fuel prices and the economic slowdown has disrupted the steady climbing trend seen in the last few congestion reports. Before victory is declared on the congestion or imported fuel issues, however, a few points should be considered:

- The decline in driving after more than a doubling in the price of fuel was the equivalent of about 1 mile per day for the person traveling the average 12,000 annual miles.
- Previous recessions in the 1980s and 1990s saw congestion declines that were reversed as soon as the economy began to grow again.
- The “recovery” in miles traveled in Fall 2008 when fuel prices dropped before the economy turned down suggests historical patterns are still in place and congestion will grow again.

Anyone who thinks the congestion problem has gone away should check the past.

The good news is that there are solutions that work. There are significant benefits from solving congestion problems – whether they are large or small, in big metropolitan regions or smaller urban areas and no matter the cause. There are performance measures that provide accountability to the public and decision-makers and improve operational effectiveness. Mobility reports in coming years will use more comprehensive datasets and improved analysis tools to capture traveler experiences (and frustration).

All of the potential congestion-reducing strategies are needed. Getting more productivity out of the existing road and public transportation systems is vital to reducing congestion and improving travel time reliability. Businesses and employees can use a variety of strategies to modify their times and modes of travel to avoid the peak periods or to use less vehicle travel and more electronic “travel.” In many corridors, however, there is a need for additional capacity to move people and freight more rapidly and reliably.

Future program decisions should focus on how to use each project, program or strategy to attack the problems, and how much transportation improvement to pursue. The solutions will require more funding – this report clearly describes the shortfall in projects, programs and policies. Focusing on the broad areas of agreement and consensus funding arrangements will provide a base of implementable strategies. Besides the congestion benefits, the construction projects also help rebuild infrastructure elements, a need noted in many analyses over the past decade. The U.S. should begin fixing these problems while crafting an all-encompassing long-term solution.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

National Congestion Tables

Table 1. Key Mobility Measures, 2007

Urban Area	Annual Delay per Traveler		Travel Time Index		Wasted Fuel per Traveler	
	Hours	Rank	Value	Rank	Gallons	Rank
Very Large Average (14 areas)	**51**		**1.37**		**35**	
Los Angeles-Long Beach-Santa Ana CA	70	1	1.49	1	53	1
Washington DC-VA-MD	62	2	1.39	4	42	2
Atlanta GA	57	3	1.35	10	40	3
Houston TX	56	4	1.33	11	40	3
San Francisco-Oakland CA	55	5	1.42	3	40	3
Dallas-Fort Worth-Arlington TX	53	6	1.32	12	36	8
Detroit MI	52	9	1.29	20	34	11
Miami FL	47	11	1.37	5	33	12
New York-Newark NY-NJ-CT	44	14	1.37	5	28	20
Phoenix AZ	44	14	1.30	17	31	14
Seattle WA	43	19	1.29	20	30	15
Boston MA-NH-RI	43	19	1.26	25	29	19
Chicago IL-IN	41	21	1.43	2	28	20
Philadelphia PA-NJ-DE-MD	38	29	1.28	24	24	34
Large Average (29 areas)	**35**		**1.23**		**24**	
San Jose CA	53	6	1.36	8	37	7
Orlando FL	53	6	1.30	17	35	9
San Diego CA	52	9	1.37	5	40	3
Tampa-St. Petersburg FL	47	11	1.31	14	30	15
Denver-Aurora CO	45	13	1.31	14	30	15
Riverside-San Bernardino CA	44	14	1.36	8	35	9
Baltimore MD	44	14	1.31	14	32	13
Las Vegas NV	44	14	1.30	17	30	15
Charlotte NC-SC	40	23	1.25	26	27	23
Sacramento CA	39	24	1.32	12	28	20
Austin TX	39	24	1.29	20	27	23
Minneapolis-St. Paul MN	39	24	1.24	28	27	23
Jacksonville FL	39	24	1.23	32	27	23
Indianapolis IN	39	24	1.21	34	27	23
San Antonio TX	38	29	1.23	32	27	23
Portland OR-WA	37	34	1.29	20	26	31
Raleigh-Durham NC	34	36	1.17	43	22	37
Columbus OH	30	40	1.18	39	21	39
Virginia Beach VA	29	41	1.18	39	19	41
Providence RI-MA	29	41	1.17	43	18	42
St. Louis MO-IL	26	47	1.13	52	17	46
Cincinnati OH-KY-IN	25	51	1.18	39	18	42
Memphis TN-MS-AR	25	51	1.12	57	15	52
New Orleans LA	20	61	1.17	43	12	65
Milwaukee WI	18	67	1.13	52	13	60
Pittsburgh PA	15	70	1.09	70	9	71
Kansas City MO-KS	15	70	1.07	80	9	71
Cleveland OH	12	76	1.08	77	8	74
Buffalo NY	11	79	1.07	80	7	77
90 Area Average	**41**		**1.29**		**28**	
Remaining Areas						
48 Urban Areas Over 250,000 Popn	24		1.16		15	
301 Urban Areas Under 250,000 Popn	18		1.10		10	
All 439 Urban Areas	**36**		**1.25**		**24**	

Very Large Urban Areas—over 3 million population. Large Urban Areas—over 1 million and less than 3 million population.

Annual Delay per Traveler – Extra travel time for peak-period travel during the year divided by the number of travelers who begin a trip during the peak period (6 to 9 a.m. and 4 to 7 p.m.). Free-flow speeds (60 mph on freeways and 35 mph on principal arterials) are used as the comparison threshold.

Travel Time Index – The ratio of travel time in the peak period to the travel time at free-flow conditions. A value of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak

2007 values include the effects of operational treatments.

Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.

Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

Table 1. Key Mobility Measures, 2007, Continued

Urban Area	Annual Delay per Traveler		Travel Time Index		Wasted Fuel per Traveler	
	Hours	Rank	Value	Rank	Gallons	Rank
Medium Average (31 areas)	**23**		**1.14**		**15**	
Tucson AZ	41	21	1.24	28	26	31
Oxnard-Ventura CA	38	29	1.24	28	27	23
Louisville KY-IN	38	29	1.20	35	26	31
Nashville-Davidson TN	37	34	1.15	48	23	35
Albuquerque NM	34	36	1.18	39	22	37
Bridgeport-Stamford CT-NY	33	38	1.25	26	27	23
Birmingham AL	32	39	1.15	48	21	39
Salt Lake City UT	27	45	1.19	37	18	42
Oklahoma City OK	27	45	1.12	57	17	46
Honolulu HI	26	47	1.24	28	18	42
Omaha NE-IA	26	47	1.16	47	17	46
Sarasota-Bradenton FL	25	51	1.19	37	15	52
Colorado Springs CO	23	54	1.13	52	14	56
Allentown-Bethlehem PA-NJ	22	55	1.14	50	14	56
Grand Rapids MI	22	55	1.10	64	13	60
Tulsa OK	22	55	1.10	64	13	60
Hartford CT	21	60	1.12	57	15	52
Fresno CA	20	61	1.13	52	13	60
Richmond VA	20	61	1.09	70	13	60
El Paso TX-NM	19	64	1.12	57	12	65
New Haven CT	19	64	1.11	63	14	56
Albany-Schenectady NY	19	64	1.10	64	12	65
Poughkeepsie-Newburgh NY	17	68	1.09	70	10	68
Dayton OH	14	73	1.09	70	10	68
Toledo OH-MI	14	73	1.08	77	9	71
Indio-Cathedral City-Palm Springs CA	13	75	1.14	50	8	74
Bakersfield CA	12	76	1.09	70	7	77
Springfield MA-CT	11	79	1.06	85	7	77
Rochester NY	10	83	1.06	85	6	83
Akron OH	9	85	1.07	80	6	83
Lancaster-Palmdale CA	6	89	1.10	64	3	89
Small Average (16 areas)	**19**		**1.10**		**11**	
Charleston-North Charleston SC	38	29	1.20	35	23	35
Cape Coral FL	29	41	1.17	43	17	46
Pensacola FL-AL	28	44	1.13	52	16	50
Knoxville TN	26	47	1.12	57	16	50
Columbia SC	22	55	1.10	64	14	56
Little Rock AR	22	55	1.09	70	15	52
Salem OR	16	69	1.10	64	10	68
Laredo TX	15	70	1.12	57	8	74
Boulder CO	12	76	1.09	70	7	77
Eugene OR	11	79	1.08	77	7	77
Beaumont TX	11	79	1.05	87	7	77
Anchorage AK	10	83	1.07	80	6	83
Corpus Christi TX	9	85	1.05	87	5	86
Spokane WA	9	85	1.05	87	5	86
Brownsville TX	8	88	1.07	80	5	86
Wichita KS	6	89	1.02	90	3	89
90 Area Average	**41**		**1.29**		**28**	
Remaining Areas						
48 Urban Areas Over 250,000 Popn	24		1.16		15	
301 Urban Areas Under 250,000 Popn	18		1.10		10	
All 439 Urban Areas	**36**		**1.25**		**24**	

Medium Urban Areas—over 500,000 and less than 1 million population. Small Urban Areas—less than 500,000 population.

Annual Delay per Traveler – Extra travel time for peak-period travel during the year divided by the number of travelers who begin a trip during the peak period (6 to 9 a.m. and 4 to 7 p.m.). Free-flow speeds (60 mph on freeways and 35 mph on principal arterials) are used as the comparison threshold.

Travel Time Index – The ratio of travel time in the peak period to the travel time at free-flow conditions. A value of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak

2007 values include the effects of operational treatments.

Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.

Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Table 2. What Congestion Means to Your Town, 2007 Urban Area Totals

Urban Area	Travel Delay (1000 Hours)	Rank	Excess Fuel Consumed (1000 Gallons)	Rank	Congestion Cost ($ million)	Rank
Very Large Average (14 areas)	**166,900**		**115,654**		**3,549**	
Los Angeles-Long Beach-Santa Ana CA	485,022	1	366,969	1	10,328	1
New York-Newark NY-NJ-CT	379,328	2	238,934	2	8,180	2
Chicago IL-IN	189,201	3	129,365	3	4,207	3
Atlanta GA	135,335	6	95,936	6	2,981	4
Miami FL	145,608	4	101,727	4	2,955	5
Dallas-Fort Worth-Arlington TX	140,744	5	96,477	5	2,849	6
Washington DC-VA-MD	133,862	7	90,801	8	2,762	7
San Francisco-Oakland CA	129,393	8	94,295	7	2,675	8
Houston TX	123,915	9	88,239	9	2,482	9
Detroit MI	116,981	10	76,425	10	2,472	10
Philadelphia PA-NJ-DE-MD	112,074	11	71,262	11	2,316	11
Boston MA-NH-RI	91,052	12	60,986	13	1,996	12
Phoenix AZ	80,456	14	57,200	14	1,891	13
Seattle WA	73,636	15	50,541	15	1,591	15
Large Average (29 areas)	**31,778**		**22,024**		**661**	
San Diego CA	85,392	13	65,734	12	1,786	14
Baltimore MD	56,964	18	41,777	16	1,276	16
Denver-Aurora CO	61,345	16	40,492	17	1,240	17
Tampa-St. Petersburg FL	61,018	17	39,612	18	1,205	18
Minneapolis-St. Paul MN	55,287	19	38,534	20	1,148	19
Riverside-San Bernardino CA	48,135	21	38,537	19	1,083	20
San Jose CA	51,070	20	35,630	21	1,013	21
Orlando FL	41,791	22	27,842	23	850	22
Sacramento CA	39,197	23	28,358	22	806	23
Portland OR-WA	34,418	25	23,969	24	712	24
Las Vegas NV	34,521	24	23,425	25	705	25
St. Louis MO-IL	32,863	26	20,660	27	697	26
San Antonio TX	31,026	27	21,973	26	621	27
Charlotte NC-SC	24,237	29	16,046	31	525	28
Indianapolis IN	23,505	31	16,135	30	522	29
Cincinnati OH-KY-IN	23,832	30	17,307	28	508	30
Virginia Beach VA	24,665	28	16,324	29	501	31
Austin TX	22,777	32	15,578	33	471	32
Jacksonville FL	22,491	33	15,711	32	457	33
Columbus OH	20,428	34	14,519	34	424	35
Raleigh-Durham NC	19,588	37	12,716	37	421	36
Providence RI-MA	19,937	36	12,114	39	386	39
Memphis TN-MS-AR	14,633	43	8,975	44	311	41
Milwaukee WI	14,860	42	10,651	41	307	42
Pittsburgh PA	15,334	41	8,753	45	304	43
Kansas City MO-KS	12,703	47	8,085	49	267	47
New Orleans LA	11,327	50	7,147	51	244	49
Cleveland OH	12,037	49	8,166	48	241	51
Buffalo NY	6,185	66	3,929	67	134	65
90 Area Total	**3,592,338**		**2,473,532**		**75,761**	
90 Areas Average	**39,915**		**27,484**		**842**	
Remaining Areas						
48 Areas Over 250,000 - Total	247,046		161,607		5,387	
48 Areas Over 250,000 - Average	5,147		3,367		112	
301 Areas Under 250,000 - Total	319,331		179,223		6,074	
301 Areas Under 250,000 - Average	1,061		595		20	
All 439 Areas Total	**4,158,715**		**2,814,363**		**87,222**	
All 439 Areas Average	**9,473**		**6,411**		**199**	

Very Large Urban Areas—over 3 million population. Large Urban Areas—over 1 million and less than 3 million population.
Travel Delay – Travel time above that needed to complete a trip at free-flow speeds.
Excess Fuel Consumed – Increased fuel consumption due to travel in congested conditions rather than free-flow conditions.
Congestion Cost – Value of travel time delay (estimated at $15.47 per hour of person travel and $102.12 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon).

Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.
Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Table 2. What Congestion Means to Your Town, 2007 Urban Area Totals, Continued

Urban Area	Travel Delay (1000 Hours)	Rank	Excess Fuel Consumed (1000 Gallons)	Rank	Congestion Cost ($ million)	Rank
Medium Average (31 areas)	**9,002**		**5,879**		**186**	
Nashville-Davidson TN	20,215	35	12,487	38	426	34
Louisville KY-IN	19,015	38	13,024	35	409	37
Tucson AZ	17,321	39	10,883	40	393	38
Bridgeport-Stamford CT-NY	16,077	40	12,759	36	350	40
Oxnard-Ventura CA	14,258	45	10,017	42	298	44
Salt Lake City UT	14,557	44	9,468	43	287	45
Birmingham AL	12,605	48	8,395	46	267	46
Oklahoma City OK	12,826	46	8,262	47	257	48
Albuquerque NM	11,095	51	7,070	52	244	49
Hartford CT	10,147	53	7,201	50	203	53
Richmond VA	10,212	52	6,557	54	202	54
Honolulu HI	10,076	54	7,051	53	199	55
Tulsa OK	9,826	56	5,589	57	192	56
Omaha NE-IA	9,298	57	5,864	56	184	57
Sarasota-Bradenton FL	9,030	58	5,418	58	176	58
Allentown-Bethlehem PA-NJ	7,571	59	4,664	60	154	59
Fresno CA	7,032	64	4,436	61	151	61
Grand Rapids MI	7,324	61	4,335	63	148	62
El Paso TX-NM	7,185	62	4,691	59	147	63
Albany-Schenectady NY	6,082	67	3,842	69	131	66
Colorado Springs CO	6,457	65	3,860	68	129	67
Dayton OH	5,800	68	4,000	66	120	69
New Haven CT	5,728	69	4,225	65	117	70
Poughkeepsie-Newburgh NY	4,739	72	2,886	73	95	73
Toledo OH-MI	3,916	77	2,480	74	83	74
Indio-Cathedral City-Palm Springs CA	4,049	74	2,338	77	82	75
Rochester NY	4,038	75	2,441	75	81	76
Springfield MA-CT	3,989	76	2,422	76	77	77
Bakersfield CA	3,359	78	2,091	79	73	78
Akron OH	3,031	79	2,172	78	63	79
Lancaster-Palmdale CA	2,208	80	1,314	80	44	80
Small Average (16 areas)	**3,444**		**2,090**		**71**	
Charleston-North Charleston SC	9,944	55	6,090	55	207	52
Cape Coral FL	7,451	60	4,347	62	152	60
Knoxville TN	7,166	63	4,295	64	147	64
Columbia SC	5,478	70	3,516	70	121	68
Pensacola FL-AL	5,469	71	3,122	72	106	71
Little Rock AR	4,652	73	3,298	71	97	72
Salem OR	2,069	81	1,224	81	41	81
Laredo TX	1,806	82	1,005	83	37	82
Spokane WA	1,714	83	1,056	82	36	83
Corpus Christi TX	1,629	84	970	84	32	84
Anchorage AK	1,616	85	903	85	32	85
Eugene OR	1,481	86	903	85	30	86
Beaumont TX	1,425	87	866	87	28	87
Wichita KS	1,404	88	793	88	27	88
Boulder CO	953	89	562	89	18	89
Brownsville TX	841	90	486	90	17	89
90 Area Total	**3,592,338**		**2,473,532**		**75,761**	
90 Areas Average	**39,915**		**27,484**		**842**	
Remaining Areas						
48 Areas Over 250,000 - Total	247,046		161,607		5,387	
48 Areas Over 250,000 - Average	5,147		3,367		112	
301 Areas Under 250,000 - Total	319,331		179,223		6,074	
301 Areas Under 250,000 - Average	1,061		595		20	
All 439 Areas Total	**4,158,715**		**2,814,363**		**87,222**	
All 439 Areas Average	**9,473**		**6,411**		**199**	

Medium Urban Areas—over 500,000 and less than 1 million population. Small Urban Areas—less than 500,000 population.

Travel Delay – Travel time above that needed to complete a trip at free-flow speeds.

Excess Fuel Consumed – Increased fuel consumption due to travel in congested conditions rather than free-flow conditions.

Congestion Cost – Value of travel time delay (estimated at $15.47 per hour of person travel and $102.12 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon).

Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.

Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Table 3. Solutions to Congestion Problems, 2007

Urban Area	Operational Treatment Savings				Public Transportation Savings		
	Treatments	Delay (1000 Hours)	Rank	Cost ($ Million)	Delay (1000 Hours)	Rank	Cost ($ Million)
Very Large Average (14 areas)		**15,413**		**324.6**	**39,784**		**848.2**
Los Angeles-Long Beach-Santa Ana CA	r,i,s,a,h	60,576	1	1,286.1	32,348	3	588.8
New York-Newark NY-NJ-CT	r,i,s,a,h	40,466	2	863.7	319,247	1	6,929.2
San Francisco-Oakland CA	r,i,s,a,h	17,675	3	360.8	31,835	4	658.9
Houston TX	r,i,s,a,h	15,201	4	300.8	5,902	13	103.0
Miami FL	i,s,a,h	13,443	5	269.2	10,026	10	191.1
Dallas-Fort Worth-Arlington TX	r,i,s,a,h	11,186	6	221.8	5,486	14	111.1
Washington DC-VA-MD	r,i,s,a,h	10,517	7	216.1	26,285	5	521.1
Atlanta GA	r,i,s,a,h	9,426	8	215.0	10,474	9	224.8
Chicago IL-IN	r,i,s,a	8,038	10	179.5	48,751	2	1,121.1
Philadelphia PA-NJ-DE-MD	r,i,s,a	7,856	11	165.1	22,538	7	472.6
Seattle WA	r,i,s,a,h	6,802	12	145.6	12,521	8	261.4
Phoenix AZ	r,i,s,a,h	5,359	15	121.4	2,566	21	59.8
Boston MA-NH-RI	i,s,a	4,929	16	106.7	26,266	6	573.8
Detroit MI	r,i,s,a	4,313	19	92.9	2,732	19	57.4
Large Average (29 areas)		**2,149**		**44.6**	**2,029**		**42.3**
San Diego CA	r,i,s,a	8,309	9	170.0	7,832	12	161.7
Riverside-San Bernardino CA	r,i,s,a,h	5,505	13	123.5	1,397	30	27.7
Minneapolis-St. Paul MN	r,i,s,a,h	5,457	14	109.6	3,900	17	79.4
San Jose CA	r,i,s,a	4,396	17	86.4	2,375	22	46.9
Tampa-St. Petersburg FL	i,s,a	4,378	18	86.5	1,250	32	24.3
Sacramento CA	r,i,s,a,h	3,877	20	80.7	1,865	25	37.0
Baltimore MD	i,s,a	3,568	21	79.8	9,474	11	216.0
Denver-Aurora CO	r,i,s,a,h	3,554	22	71.3	5,033	15	101.6
Portland OR-WA	r,i,s,a,h	2,922	23	61.6	4,771	16	98.0
Orlando FL	i,s,a	2,613	24	53.0	1,572	27	31.7
Virginia Beach VA	i,s,a,h	1,947	25	39.5	913	38	18.6
Las Vegas NV	i,s,a	1,661	26	33.0	1,723	26	35.4
Jacksonville FL	i,s,a	1,475	27	30.1	511	43	10.4
San Antonio TX	i,s,a	1,386	28	27.8	1,455	29	29.0
St. Louis MO-IL	i,s,a	1,323	29	27.9	2,031	23	43.2
Milwaukee WI	r,i,s,a	1,296	30	26.7	1,071	35	22.1
Austin TX	i,s,a	1,209	31	25.1	1,472	28	30.6
Columbus OH	r,i,s,a	1,002	32	21.8	451	45	9.5
Memphis TN-MS-AR	i,s,a	965	34	21.2	372	50	7.9
Charlotte NC-SC	i,s,a	910	35	19.8	946	37	20.4
Cincinnati OH-KY-IN	r,i,s,a	793	37	17.1	1,328	31	28.4
Indianapolis IN	i,s,a	697	42	15.5	431	48	9.5
New Orleans LA	i,s,a	675	44	14.6	1,075	34	23.4
Cleveland OH	i,s,a	505	49	10.3	1,227	33	24.6
Raleigh-Durham NC	i,s,a	491	50	10.9	723	39	15.5
Kansas City MO-KS	i,s,a	486	51	10.1	240	55	5.0
Pittsburgh PA	i,s,a	431	55	8.7	1,957	24	39.1
Providence RI-MA	i,s,a	324	57	6.5	989	36	19.1
Buffalo NY	i,s,a	160	65	3.6	451	45	9.8
90 Area Total		**290,824**		**6,105.3**	**630,149**		**13,390.7**
90 Area Average		**3,231**		**68.0**	**7,002**		**149.0**
Remaining Areas							
48 Areas Over 250,000 - Total		8,165		178.9	6,891		150.9
48 Areas Over 250,000 - Average		170		3.7	144		3.1
301 Areas Under 250,000 - Total		9,239		179.6	8,874		187.9
301 Areas Under 250,000 - Average		31		0.6	29		0.6
All 439 Areas Total		**308,319**		**6,463.8**	**645,914**		**13,729.5**
All 439 Areas Average		**702**		**14.7**	**1,471**		**31.3**

Very Large Urban Areas—over 3 million population. Large Urban Areas—over 1 million and less than 3 million population.

Operational Treatments – Freeway incident management (i), freeway ramp metering (r), arterial street signal coordination (s), arterial street access management (a) and high-occupancy vehicle lanes (h).
Public Transportation – Regular route service from all public transportation providers in an urban area.
Delay savings are affected by the amount of treatment or service in each area, as well as the amount of congestion and the urban area population.
Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.

Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

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Table 3. Solutions to Congestion Problems, 2007, Continued

	Operational Treatment Savings				Public Transportation Savings		
Urban Area	Treatments	Delay (1000 Hours)	Rank	Cost ($ Million)	Delay (1000 Hours)	Rank	Cost ($ Million)
Medium Average (31 areas)		**354**		**7.4**	**414**		**8.4**
Tucson AZ	i,s,a	994	33	22.3	571	41	12.9
Nashville-Davidson TN	i,s,a	893	36	19.6	407	49	8.6
Omaha NE-IA	i,s,a	765	38	15.2	161	67	3.2
Bridgeport-Stamford CT-NY	i,s,a	744	39	16.4	248	53	5.4
Albuquerque NM	i,s,a	734	40	15.8	237	56	5.2
Birmingham AL	i,s,a	723	41	16.6	160	68	3.4
Louisville KY-IN	i,s,a	682	43	14.9	501	44	10.9
Sarasota-Bradenton FL	i,s,a	564	45	10.9	135	73	2.6
Fresno CA	r,i,s,a	529	46	11.3	224	58	4.7
El Paso TX-NM	i,s,a	515	47	10.3	546	42	11.1
Salt Lake City UT	r,i,s,a	513	48	10.5	2,672	20	52.9
Oxnard-Ventura CA	i,s,a	468	52	9.3	257	52	5.3
Hartford CT	i,s,a	440	54	8.9	670	40	13.4
Richmond VA	i,s,a	274	58	5.4	435	47	8.6
Honolulu HI	i,s,a	245	59	4.8	3,045	18	59.2
Allentown-Bethlehem PA-NJ	r,i,s,a	204	61	4.3	202	60	4.1
Colorado Springs CO	i,s,a	197	62	3.8	222	59	4.4
New Haven CT	i,s,a	197	62	4.0	138	71	2.8
Grand Rapids MI	s,a	188	64	3.7	245	54	5.0
Albany-Schenectady NY	i,s,a	145	66	3.2	271	51	5.8
Indio-Cathedral City-Palm Springs CA	i,s,a	145	66	3.0	118	76	2.4
Bakersfield CA	i,s,a	144	68	3.0	175	63	3.8
Oklahoma City OK	i,s,a	131	69	2.7	95	79	1.9
Rochester NY	i,s,a	113	72	2.3	146	69	2.9
Dayton OH	s,a	85	74	1.6	169	65	3.6
Poughkeepsie-Newburgh NY	s,a	82	75	1.6	199	61	4.0
Tulsa OK	i,s,a	78	76	1.6	51	86	1.0
Lancaster-Palmdale CA	s,a	64	78	1.3	190	62	3.7
Springfield MA-CT	i,s,a	64	78	1.3	119	75	2.3
Akron OH	i,s,a	24	86	0.5	73	82	1.5
Toledo OH-MI	i,s,a	23	87	0.5	141	70	3.0
Small Average (16 areas)		**110**		**2.3**	**95**		**2.0**
Cape Coral FL	i,s,a	456	53	9.3	137	72	2.8
Knoxville TN	i,s,a	373	56	8.0	48	87	1.0
Little Rock AR	i,s,a	213	60	4.7	12	90	0.2
Charleston-North Charleston SC	i,s,a	122	70	2.7	117	77	2.4
Pensacola FL-AL	s,a	114	71	2.2	57	84	1.2
Columbia SC	i,s,a	98	73	2.4	170	64	3.9
Spokane WA	i,s,a	75	77	1.6	168	66	3.6
Salem OR	s,a	54	80	1.0	111	78	2.3
Eugene OR	i,s,a	52	81	1.1	230	57	4.7
Anchorage AK	s,a	50	82	1.0	120	74	2.4
Laredo TX	i,s,a	36	83	0.8	94	80	1.9
Wichita KS	i,s,a	32	84	0.6	45	88	0.9
Boulder CO	s,a	26	85	0.5	52	85	1.0
Corpus Christi TX	s,a	23	87	0.5	65	83	1.3
Brownsville TX	s,a	18	89	0.4	75	81	1.5
Beaumont TX	s,a	13	90	0.2	15	89	0.3
90 Area Total		**290,824**		**6,105.3**	**630,149**		**13,390.7**
90 Area Average		**3,231**		**68.0**	**7,002**		**149.0**
Remaining Areas							
48 Areas Over 250,000 - Total		8,165		178.9	6,891		150.9
48 Areas Over 250,000 - Average		170		3.7	144		3.1
301 Areas Under 250,000 - Total		9,239		179.6	8,874		187.9
301 Areas Under 250,000 - Average		31		0.6	29		0.6
All 439 Areas Total		**308,319**		**6463.8**	**645,914**		**13,729.5**
All 439 Areas Average		**702**		**14.7**	**1,471**		**31.3**

Medium Urban Areas—over 500,000 and less than 1 million population. Small Urban Areas—less than 500,000 population.

Operational Treatments – Freeway incident management (i), freeway ramp metering (r) arterial street signal coordination (s), arterial street access management (a) and high-occupancy vehicle lanes (h).

Public Transportation – Regular route service from all public transportation providers in an urban area.

Delay savings are affected by the amount of treatment or service in each area, as well as the amount of congestion and the urban area population.

Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.

Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

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Table. 4. Congestion Trends – Wasted Hours (Annual Delay per Traveler, 1982 to 2007)

Urban Area	Annual Hours of Delay per Traveler				Long-Term Change 1982 to 2007	
	2007	2006	1997	1982	Hours	Rank
Very Large Average (14 areas)	**51**	**52**	**43**	**21**	**30**	
Washington DC-VA-MD	62	59	52	16	46	1
Dallas-Fort Worth-Arlington TX	53	55	34	10	43	2
Atlanta GA	57	59	56	19	38	5
Miami FL	47	48	35	15	32	11
New York-Newark NY-NJ-CT	44	45	32	12	32	11
San Francisco-Oakland CA	55	58	47	23	32	11
Boston MA-NH-RI	43	44	32	12	31	15
Seattle WA	43	45	52	12	31	15
Detroit MI	52	53	48	24	28	21
Houston TX	56	56	39	29	27	22
Chicago IL-IN	41	43	35	15	26	23
Los Angeles-Long Beach-Santa Ana CA	70	72	69	44	26	23
Philadelphia PA-NJ-DE-MD	38	38	28	16	22	36
Phoenix AZ	44	45	35	35	9	70
Large Average (29 areas)	**35**	**36**	**31**	**11**	**24**	
San Diego CA	52	54	36	12	40	3
Riverside-San Bernardino CA	44	45	26	5	39	4
Orlando FL	53	55	59	18	35	6
Las Vegas NV	44	43	34	10	34	7
Baltimore MD	44	44	32	11	33	9
Minneapolis-St. Paul MN	39	40	38	6	33	9
San Antonio TX	38	40	24	6	32	11
Charlotte NC-SC	40	39	25	10	30	17
San Jose CA	53	55	44	23	30	17
Austin TX	39	39	32	10	29	19
Denver-Aurora CO	45	48	41	16	29	19
Columbus OH	30	32	31	4	26	23
Providence RI-MA	29	26	15	3	26	23
Raleigh-Durham NC	34	32	31	8	26	23
Portland OR-WA	37	38	35	13	24	28
Sacramento CA	39	42	35	15	24	28
Tampa-St. Petersburg FL	47	48	37	24	23	32
Jacksonville FL	39	38	39	17	22	36
Cincinnati OH-KY-IN	25	26	29	5	20	40
Indianapolis IN	39	42	56	19	20	40
Memphis TN-MS-AR	25	28	23	6	19	44
Virginia Beach VA	29	30	31	14	15	56
St. Louis MO-IL	26	30	39	12	14	57
Kansas City MO-KS	15	17	19	3	12	64
Milwaukee WI	18	18	19	7	11	67
Cleveland OH	12	13	18	3	9	70
Buffalo NY	11	12	7	3	8	72
Pittsburgh PA	15	15	18	11	4	82
New Orleans LA	20	20	21	17	3	87
90 Area Average	**41**	**42**	**36**	**16**	**25**	
Remaining Areas						
48 Urban Areas Over 250,000 Popn	24	23	19	7	17	
301 Urban Areas Under 250,000 Popn	18	18	16	5	13	
All 439 Urban Areas	**36**	**37**	**32**	**14**	**22**	

Very Large Urban Areas—over 3 million population. Large Urban Areas—over 1 million and less than 3 million population.
Annual Delay per Traveler – Extra travel time for peak-period travel during the year divided by the number of travelers who begin a trip during the peak period (6 to 9 a.m. and 4 to 7 p.m.). Free-flow speeds (60 mph on freeways and 35 mph on principal arterials) are used as the comparison threshold.
Data for all years include effects of operational treatments.
Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.
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Table. 4. Congestion Trends – Wasted Hours (Annual Delay per Traveler, 1982 to 2007), Continued

Urban Area	Annual Hours of Delay per Traveler				Long-Term Change 1982 to 2007	
	2007	2006	1997	1982	Hours	Rank
Medium Average (31 areas)	**23**	**24**	**20**	**8**	**15**	
Oxnard-Ventura CA	38	36	21	4	34	7
Birmingham AL	32	33	24	8	24	28
Bridgeport-Stamford CT-NY	33	33	24	9	24	28
Albuquerque NM	34	33	33	11	23	32
Oklahoma City OK	27	24	20	5	22	36
Omaha NE-IA	26	28	19	5	21	39
Louisville KY-IN	38	40	39	18	20	40
Colorado Springs CO	23	26	16	4	19	44
Salt Lake City UT	27	26	28	8	19	44
Hartford CT	21	21	15	4	17	49
Nashville-Davidson TN	37	38	36	20	17	49
Tucson AZ	41	43	29	24	17	49
Albany-Schenectady NY	19	17	9	3	16	52
El Paso TX-NM	19	21	10	3	16	52
Grand Rapids MI	22	23	21	6	16	52
New Haven CT	19	19	15	5	14	57
Richmond VA	20	20	21	6	14	57
Tulsa OK	22	22	18	8	14	57
Allentown-Bethlehem PA-NJ	22	21	25	9	13	61
Honolulu HI	26	24	22	14	12	64
Toledo OH-MI	14	15	14	2	12	64
Sarasota-Bradenton FL	25	27	22	14	11	67
Bakersfield CA	12	13	7	2	10	69
Fresno CA	20	20	18	12	8	72
Akron OH	9	11	13	2	7	74
Poughkeepsie-Newburgh NY	17	18	14	10	7	74
Rochester NY	10	9	8	3	7	74
Dayton OH	14	17	22	10	4	82
Springfield MA-CT	11	12	10	7	4	82
Lancaster-Palmdale CA	6	5	6	12	-6	89
Indio-Cathedral City-Palm Springs CA	13	15	15	20	-7	90
Small Average (16 areas)	**19**	**18**	**15**	**6**	**13**	
Charleston-North Charleston SC	38	35	27	15	23	32
Pensacola FL-AL	28	28	22	5	23	32
Cape Coral FL	29	28	26	9	20	40
Columbia SC	22	19	12	4	18	47
Little Rock AR	22	19	10	4	18	47
Knoxville TN	26	25	39	10	16	52
Laredo TX	15	12	9	2	13	61
Salem OR	16	17	12	3	13	61
Beaumont TX	11	12	6	4	7	74
Boulder CO	12	14	14	6	6	78
Brownsville TX	8	7	4	2	6	78
Spokane WA	9	8	10	3	6	78
Eugene OR	11	11	9	6	5	81
Corpus Christi TX	9	8	7	5	4	82
Wichita KS	6	5	5	2	4	82
Anchorage AK	10	10	9	10	0	88
90 Area Average	**41**	**42**	**36**	**16**	**25**	
Remaining Areas						
48 Urban Areas Over 250,000 Popn	24	23	19	7	17	
301 Urban Areas Under 250,000 Popn	18	18	16	5	13	
All 439 Urban Areas	**36**	**37**	**32**	**14**	**22**	

Medium Urban Areas—over 500,000 and less than 1 million population. Small Urban Areas—less than 500,000 population.
Annual Delay per Traveler – Extra travel time for peak-period travel during the year divided by the number of travelers who begin a trip during the peak period (6 to 9 a.m. and 4 to 7 p.m.). Free-flow speeds (60 mph on freeways and 35 mph on principal arterials) are used as the comparison threshold.
Data for all years include effects of operational treatments.
Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6^{th} and 12^{th}. The actual measure values should also be examined.
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Table 5. Congestion Trends – Wasted Time (Travel Time Index, 1982 to 2007)

Urban Area	Travel Time Index				Point Change in Peak-Period Time Penalty	
	2007	2006	1997	1982	Points	Rank
Very Large Average (14 areas)	**1.37**	**1.38**	**1.30**	**1.14**	**23**	
Chicago IL-IN	1.43	1.45	1.33	1.12	31	2
San Francisco-Oakland CA	1.42	1.44	1.30	1.14	28	4
Washington DC-VA-MD	1.39	1.37	1.32	1.11	28	4
New York-Newark NY-NJ-CT	1.37	1.38	1.26	1.10	27	6
Dallas-Fort Worth-Arlington TX	1.32	1.33	1.17	1.05	27	6
Miami FL	1.37	1.37	1.26	1.11	26	8
Los Angeles-Long Beach-Santa Ana CA	1.49	1.51	1.45	1.24	25	10
Atlanta GA	1.35	1.34	1.27	1.10	25	10
Seattle WA	1.29	1.30	1.31	1.07	22	15
Boston MA-NH-RI	1.26	1.27	1.20	1.08	18	24
Philadelphia PA-NJ-DE-MD	1.28	1.27	1.20	1.11	17	26
Detroit MI	1.29	1.29	1.27	1.13	16	27
Phoenix AZ	1.30	1.29	1.21	1.15	15	29
Houston TX	1.33	1.34	1.23	1.19	14	31
Large Average (29 areas)	**1.23**	**1.24**	**1.19**	**1.07**	**16**	
Riverside-San Bernardino CA	1.36	1.36	1.18	1.03	33	1
San Diego CA	1.37	1.38	1.23	1.07	30	3
Sacramento CA	1.32	1.33	1.21	1.06	26	8
Baltimore MD	1.31	1.31	1.20	1.07	24	12
Las Vegas NV	1.30	1.30	1.23	1.06	24	12
San Jose CA	1.36	1.37	1.23	1.13	23	14
Denver-Aurora CO	1.31	1.31	1.26	1.09	22	15
Austin TX	1.29	1.29	1.22	1.07	22	15
Portland OR-WA	1.29	1.29	1.24	1.07	22	15
Orlando FL	1.30	1.31	1.30	1.10	20	20
Minneapolis-St. Paul MN	1.24	1.25	1.21	1.04	20	20
San Antonio TX	1.23	1.23	1.13	1.04	19	22
Charlotte NC-SC	1.25	1.24	1.16	1.07	18	24
Jacksonville FL	1.23	1.22	1.18	1.07	16	27
Columbus OH	1.18	1.19	1.16	1.03	15	29
Cincinnati OH-KY-IN	1.18	1.18	1.18	1.04	14	31
Providence RI-MA	1.17	1.15	1.10	1.03	14	31
Indianapolis IN	1.21	1.21	1.25	1.08	13	36
Raleigh-Durham NC	1.17	1.16	1.12	1.04	13	36
Tampa-St. Petersburg FL	1.31	1.30	1.26	1.20	11	42
Virginia Beach VA	1.18	1.18	1.18	1.07	11	42
Milwaukee WI	1.13	1.12	1.12	1.05	8	54
Memphis TN-MS-AR	1.12	1.13	1.12	1.04	8	54
New Orleans LA	1.17	1.17	1.15	1.11	6	67
St. Louis MO-IL	1.13	1.16	1.19	1.07	6	67
Cleveland OH	1.08	1.09	1.13	1.03	5	72
Kansas City MO-KS	1.07	1.08	1.08	1.02	5	72
Buffalo NY	1.07	1.08	1.04	1.03	4	79
Pittsburgh PA	1.09	1.09	1.09	1.06	3	83
90 Area Average	**1.29**	**1.29**	**1.23**	**1.10**	**19**	
Remaining Areas						
48 Urban Areas Over 250,000 Popn	1.16	1.15	1.11	1.05	11	
301 Urban Areas Under 250,000 Popn	1.10	1.11	1.09	1.03	7	
All 439 Urban Areas	**1.25**	**1.25**	**1.20**	**1.09**	**16**	

Very Large Urban Areas—over 3 million population. Large Urban Areas—over 1 million and less than 3 million population.
Travel Time Index – The ratio of travel time in the peak period to the travel time at free-flow conditions. A value of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak. Free-flow speeds (60 mph on freeways and 35 mph on principal arterials) are used as the comparison threshold.
Data for all years include the effects of operational treatments.
Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.
Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Table 5. Congestion Trends – Wasted Time (Travel Time Index, 1982 to 2007), Continued

Urban Area	Travel Time Index				Point Change in Peak-Period Time Penalty	
	2007	2006	1997	1982	Points	Rank
Medium Average (31 areas)	**1.14**	**1.14**	**1.11**	**1.05**	**9**	
Oxnard-Ventura CA	1.24	1.23	1.12	1.03	21	19
Bridgeport-Stamford CT-NY	1.25	1.25	1.17	1.06	19	22
Tucson AZ	1.24	1.25	1.16	1.10	14	31
Salt Lake City UT	1.19	1.18	1.18	1.05	14	31
Honolulu HI	1.24	1.23	1.19	1.11	13	36
Albuquerque NM	1.18	1.17	1.18	1.05	13	36
Omaha NE-IA	1.16	1.17	1.11	1.04	12	40
Birmingham AL	1.15	1.15	1.10	1.04	11	42
Colorado Springs CO	1.13	1.14	1.09	1.02	11	42
El Paso TX-NM	1.12	1.13	1.07	1.02	10	46
Oklahoma City OK	1.12	1.10	1.08	1.02	10	46
Louisville KY-IN	1.20	1.22	1.19	1.11	9	51
Sarasota-Bradenton FL	1.19	1.20	1.18	1.10	9	51
Hartford CT	1.12	1.12	1.09	1.03	9	51
Allentown-Bethlehem PA-NJ	1.14	1.13	1.16	1.06	8	54
Fresno CA	1.13	1.13	1.11	1.05	8	54
New Haven CT	1.11	1.11	1.09	1.03	8	54
Albany-Schenectady NY	1.10	1.09	1.04	1.02	8	54
Bakersfield CA	1.09	1.09	1.04	1.01	8	54
Tulsa OK	1.10	1.10	1.09	1.03	7	63
Grand Rapids MI	1.10	1.10	1.10	1.03	7	63
Nashville-Davidson TN	1.15	1.16	1.14	1.09	6	67
Indio-Cathedral City-Palm Springs CA	1.14	1.16	1.12	1.08	6	67
Toledo OH-MI	1.08	1.09	1.08	1.02	6	67
Richmond VA	1.09	1.09	1.08	1.04	5	72
Poughkeepsie-Newburgh NY	1.09	1.09	1.07	1.04	5	72
Akron OH	1.07	1.08	1.08	1.02	5	72
Lancaster-Palmdale CA	1.10	1.10	1.06	1.06	4	79
Rochester NY	1.06	1.07	1.06	1.02	4	79
Dayton OH	1.09	1.10	1.12	1.07	2	86
Springfield MA-CT	1.06	1.07	1.05	1.04	2	86
Small Average (16 areas)	**1.10**	**1.09**	**1.08**	**1.03**	**7**	
Charleston-North Charleston SC	1.20	1.18	1.14	1.08	12	40
Cape Coral FL	1.17	1.15	1.14	1.07	10	46
Pensacola FL-AL	1.13	1.13	1.10	1.03	10	46
Laredo TX	1.12	1.10	1.07	1.02	10	46
Salem OR	1.10	1.10	1.07	1.02	8	54
Columbia SC	1.10	1.08	1.05	1.02	8	54
Knoxville TN	1.12	1.11	1.14	1.05	7	63
Little Rock AR	1.09	1.08	1.04	1.02	7	63
Boulder CO	1.09	1.11	1.10	1.04	5	72
Brownsville TX	1.07	1.07	1.05	1.02	5	72
Eugene OR	1.08	1.08	1.05	1.04	4	79
Beaumont TX	1.05	1.05	1.03	1.02	3	83
Spokane WA	1.05	1.04	1.05	1.02	3	83
Corpus Christi TX	1.05	1.05	1.04	1.03	2	86
Anchorage AK	1.07	1.07	1.06	1.06	1	89
Wichita KS	1.02	1.02	1.02	1.01	1	89
90 Area Average	**1.29**	**1.29**	**1.23**	**1.10**	**19**	
Remaining Areas						
48 Urban Areas Over 250,000 Popn	1.16	1.15	1.11	1.05	11	
301 Urban Areas Under 250,000 Popn	1.10	1.11	1.09	1.03	7	
All 439 Urban Areas	**1.25**	**1.25**	**1.20**	**1.09**	**16**	

Medium Urban Areas—over 500,000 and less than 1 million population. Small Urban Areas—less than 500,000 population.
Travel Time Index – The ratio of travel time in the peak period to the travel time at free-flow conditions. A value of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak. Free-flow speeds (60 mph on freeways and 35 mph on principal arterials) are used as the comparison threshold.
Data for all years include the effects of operational treatments.
Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference in congestion between areas ranked (for example) 6th and 12th. The actual measure values should also be examined.
Also note: The best congestion comparisons use multi-year trends and are made between similar urban areas.

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Table 6. Summary of Congestion Measures and Trends

Urban Area	Congestion Levels in 2007: Delay per Traveler (Hours)	Congestion Levels in 2007: Travel Time Index	Congestion Levels in 2007: Total Delay (1000 Hours)	Congestion Increase 1982 to 2007: Delay per Traveler (Hours)	Congestion Increase 1982 to 2007: Total Delay (1000 Hours)
Very Large Average (14 areas)	**51**	**1.37**	**166,900**	**30**	**129,322**
New York-Newark NY-NJ-CT	-	0	++	0	F+
Los Angeles-Long Beach-Santa Ana CA	++	++	++	S	F+
Chicago IL-IN	L-	+	+	S	F+
Miami FL	-	0	-	0	S
Philadelphia PA-NJ-DE-MD	--	--	--	S-	S-
San Francisco-Oakland CA	+	+	-	0	S-
Dallas-Fort Worth-Arlington TX	0	-	-	F+	0
Atlanta GA	+	0	-	F+	S
Washington DC-VA-MD	++	0	-	F+	S-
Boston MA-NH-RI	--	--	--	0	S-
Detroit MI	0	--	--	0	S-
Houston TX	+	-	-	S	S-
Phoenix AZ	-	-	--	S-	S-
Seattle WA	--	--	--	0	S-
Large Average (29 areas)	**35**	**1.23**	**31,778**	**24**	**26,944**
San Diego CA	++	++	++	F+	F+
Minneapolis-St. Paul MN	+	0	++	F+	F+
Baltimore MD	++	++	++	F+	F+
Tampa-St. Petersburg FL	++	++	++	0	F+
St. Louis MO-IL	--	--	0	S-	S
Denver-Aurora CO	++	++	++	F	F+
Riverside-San Bernardino CA	++	++	++	F+	F+
Sacramento CA	+	++	+	0	F+
Pittsburgh PA	--	--	--	S-	S-
Portland OR-WA	0	+	0	0	F
Cleveland OH	--	--	--	S-	S-
San Jose CA	++	++	++	F	F+
Cincinnati OH-KY-IN	--	-	-	S	S-
Virginia Beach VA	-	-	-	S-	S-
Kansas City MO-KS	--	--	--	S-	S-
Milwaukee WI	--	--	--	S-	S-
San Antonio TX	+	0	0	F+	F
Las Vegas NV	++	+	0	F+	F+
Orlando FL	++	+	+	F+	F+
Providence RI-MA	-	-	-	0	S-
Columbus OH	-	-	-	0	S-
Buffalo NY	--	--	--	S-	S-
New Orleans LA	--	-	--	S-	S-
Charlotte NC-SC	+	0	-	F	S-
Indianapolis IN	+	0	-	S	S-
Jacksonville FL	+	0	-	0	S-
Austin TX	+	+	-	F	S-
Memphis TN-MS-AR	--	--	--	S	S-
Raleigh-Durham NC	0	-	--	0	S-
Interval Values – Very Large and Large	5 hours	5 index points	(5 hours x average popn. for group)	5 hours	(5 hours x average popn. for group)

0 – *Average congestion levels or average congestion growth (within 1 interval)*
(Note: Interval – If the difference in values is less than this, it may not indicate a difference in congestion level).

Between 1 and 2 intervals above or below the average
+ *Higher congestion*; F *Faster congestion growth*;
- *Lower congestion*; S *Slower congestion growth*;

More than 2 intervals above or below the average
++ *Much higher congestion*; F+ *Much faster growth*
-- *Much lower congestion*; S- *Much slower growth*

Table 6. Summary of Congestion Measures and Trends, Continued

Urban Area	Congestion Levels in 2007			Congestion Increase 1982 to 2007	
	Delay per Traveler (Hours)	Travel Time Index	Total Delay (1000 Hours)	Delay per Traveler (Hours)	Total Delay (1000 Hours)
Medium Average (31 areas)	**23**	**1.14**	**9,002**	**15**	**7,295**
Nashville-Davidson TN	++	0	++	F	F+
Salt Lake City UT	+	++	++	F	F+
Richmond VA	-	--	+	0	F+
Louisville KY-IN	++	++	++	F+	F+
Hartford CT	-	-	+	F	F+
Bridgeport-Stamford CT-NY	++	++	++	F+	F+
Oklahoma City OK	+	-	++	F+	F+
Tulsa OK	0	-	0	0	F
Tucson AZ	++	++	++	F	F+
Dayton OH	--	--	--	S-	S-
Rochester NY	--	--	--	S-	S-
Birmingham AL	++	0	++	F+	F+
Lancaster-Palmdale CA	--	-	--	S-	S-
Honolulu HI	+	++	+	S	S
El Paso TX-NM	-	-	-	0	S
Oxnard-Ventura CA	++	++	++	F+	F+
Sarasota-Bradenton FL	+	++	0	S-	0
Springfield MA-CT	--	--	--	S-	S-
Omaha NE-IA	+	+	0	F+	F
Fresno CA	-	0	-	S-	S-
Allentown-Bethlehem PA-NJ	0	0	-	S	S-
Akron OH	--	--	--	S-	S-
Grand Rapids MI	0	-	-	0	S
Albany-Schenectady NY	-	-	-	0	S-
Albuquerque NM	++	+	+	F+	F+
New Haven CT	-	-	--	0	S-
Indio-Cathedral City-Palm Springs CA	--	0	--	S-	S-
Toledo OH-MI	--	--	--	S	S-
Poughkeepsie-Newburgh NY	--	--	--	S-	S-
Bakersfield CA	--	--	--	S-	S-
Colorado Springs CO	0	0	-	F	S-
Small Average (16 areas)	**19**	**1.10**	**3,444**	**13**	**2,881**
Knoxville TN	++	+	++	F	F+
Charleston-North Charleston SC	++	++	++	F+	F+
Cape Coral FL	++	++	++	F+	F+
Columbia SC	+	0	++	F+	F+
Wichita KS	--	--	--	S-	S-
Little Rock AR	+	0	+	F+	F+
Spokane WA	--	--	--	S-	S-
Pensacola FL-AL	++	+	++	F+	F+
Corpus Christi TX	--	--	--	S-	S-
Anchorage AK	--	-	--	S-	S-
Eugene OR	--	-	--	S-	S-
Salem OR	-	0	-	0	S-
Beaumont TX	--	--	--	S-	S-
Laredo TX	-	+	--	0	S-
Brownsville TX	--	-	--	S-	S-
Boulder CO	--	0	--	S-	S-
Interval Values – Medium and Small	5 hours	5 index points	(5 hours x average popn. for group)	5 hours	(5 hours x average popn. for group)

0 – *Average congestion levels or average congestion growth (within 1 interval)*
(Note: Interval – If the difference in values is less than this, it may not indicate a difference in congestion level).

Between 1 and 2 intervals above or below the average
\+ *Higher congestion*; F *Faster congestion growth*;
\- *Lower congestion*; S *Slower congestion growth*;

More than 2 intervals above or below the average
++ *Much higher congestion*; F+ *Much faster growth*
-- *Much lower congestion*; S- *Much slower growth*

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Table 7. Urban Area Demand and Roadway Growth Trends

Less Than 15% Faster (9)	15% to 35% Faster (44)	More Than 35% Faster (37)
Anchorage AK	Allentown-Bethlehem PA-NJ	Akron OH
Dayton OH	Bakersfield CA	Albany-Schenectady NY
Indio-Cathedral City-Palm Springs CA	Beaumont TX	Albuquerque NM
Lancaster-Palmdale CA	Boulder, CO	Atlanta GA
New Orleans LA	Boston MA-NH-RI	Austin TX
Pittsburgh PA	Brownsville TX	Baltimore MD
Poughkeepsie-Newburgh NY	Buffalo NY	Birmingham AL
St. Louis MO-IL	Charleston-North Charleston SC	Bridgeport-Stamford CT-NY
Wichita KS	Charlotte NC-SC	Cape Coral, FL
	Cleveland OH	Chicago IL-IN
	Corpus Christi TX	Cincinnati OH-KY-IN
	Denver-Aurora CO	Colorado Springs CO
	Detroit MI	Columbia SC
	El Paso TX-NM	Columbus, OH
	Eugene OR	Dallas-Fort Worth-Arlington TX
	Fresno CA	Hartford CT
	Grand Rapids MI	Jacksonville FL
	Honolulu HI	Laredo TX
	Houston TX	Las Vegas NV
	Indianapolis IN	Little Rock AR
	Kansas City MO-KS	Los Angeles-L Bch-Santa Ana CA
	Knoxville TN	Miami FL
	Louisville KY-IN	Minneapolis-St. Paul MN
	Memphis TN-MS-AR	New Haven CT
	Milwaukee WI	New York-Newark NY-NJ-CT
	Nashville-Davidson TN	Orlando FL
	Oklahoma City OK	Oxnard-Ventura CA
	Omaha NE-IA	Pensacola FL-AL
	Philadelphia PA-NJ-DE-MD	Providence RI-MA
	Phoenix AZ	Raleigh-Durham NC
	Portland OR-WA	Riverside-San Bernardino CA
	Richmond VA	Sacramento CA
	Rochester NY	San Antonio TX
	Salem OR	San Diego CA
	Salt Lake City UT	San Francisco-Oakland CA
	San Jose CA	Sarasota-Bradenton FL
	Seattle WA	Washington DC-VA-MD
	Spokane WA	
	Springfield MA-CT	
	Tampa-St. Petersburg FL	
	Toledo OH-MI	
	Tucson AZ	
	Tulsa, OK	
	Virginia Beach VA	

Note: See Exhibit 12 for comparison of growth in demand, road supply and congestion.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

References

1 Federal Highway Administration. "Highway Performance Monitoring System," 1982 to 2007 Data. November 2008.

2 National Transit Database. Federal Transit Administration. 2008. Available: http://www.ntdprogram.gov/ntdprogram/

3 Urban Congestion Report: National Executive Summary. Federal Highway Administration. Unpublished monthly data, 2008.

4 ITS Deployment Statistics Database. U.S. Department of Transportation. 2008. Available: http://www.itsdeployment.its.dot.gov/

5 2030 Committee Texas Transportation Needs Report. Texas 2030 Committee, Austin Texas. February 2009. Available: http://texas2030committee.tamu.edu/

6 Urban Mobility Report Methodology. Texas Transportation Institute, College Station, Texas. 2009. Available: http://mobility.tamu.edu/ums/report/methodology.stm

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

APPENDIX A
Methodology for the 2009 Urban Mobility Report

The data source for most of the calculations is the Highway Performance Monitoring System from the Federal Highway Administration (*1*). A detailed description of that dataset can be found at: http://www.fhwa.dot.gov/policy/ohpi/hpms/index.htm. The procedures used in the 2009 Urban Mobility Report have been developed by the Texas Transportation Institute over several years and several research projects. The congestion estimates for all study years are recalculated every time the methodology is altered to provide a consistent data trend. The estimates and methodology from this report should be used in place of any other previous measures. All the measures and many of the input variables for each city of every year are provided in a spreadsheet that can be downloaded at http://mobility.tamu.edu/ums/congestion_data/.

This appendix summarizes the methodology utilized to calculate many of the statistics shown in the Urban Mobility Report. The methodology is divided into three main sections containing information on the constant values, variables and calculation steps of the main performance measures of the mobility database.

1. **National Constants**
2. **Urban Area Constants and Inventory Values**
3. **Variable and Performance Measure Calculation Descriptions**
    1) Roadway Congestion Index
    2) Percent of Daily Travel in Congested Conditions
    3) Travel Speed
    4) Travel Delay
    5) Incident-Related Travel Delay
    6) Annual Person Delay
    7) Travel Time Index
    8) Fuel Economy
    9) Wasted Fuel
    10) Congestion Cost
    11) Percent of Congested Cost
    12) Lane-Miles and Passenger Trips Required to Hold Congestion Constant

Generally, the sections are listed in the order that they will be needed to complete all calculations.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

NATIONAL CONSTANTS

The congestion calculations utilize the values in Exhibit A-1 as national constants—values used in all urban areas to estimate the effect of congestion.

Exhibit A-1. National Congestion Constants for 2009 Urban Mobility Report

Constant	Value
Vehicle Occupancy	1.25 persons per vehicle
Working Days	250 days per year
Percent of Daily Travel in Peak Periods 6 – 10 a.m. 3 -7 p.m.	50 percent
Average Cost of Time ($2007)*	$15.47 per person hour[1]
Commercial Vehicle Operating Cost ($2007)	$102.12 per vehicle hour[1, 2]

[1] Adjusted annually using the Consumer Price Index.

[2] Adjusted periodically using industry cost and logistics data.

*Source: (Reference *7,8*)

Vehicle Occupancy

The average number of persons in each vehicle during peak period travel is 1.25.

Working Days

Cost calculations were based on 250 working days per year.

Percent of Daily Travel in the Peak Period

The hours of the day outside of the peak-period are typically uncongested. Even though some sections of road in larger areas can be congested for 10 to 12 hours of the day, the Mobility Report methodology only examines the peak-periods—estimated as 6:00 to 10:00 a.m. and 3:00 to 7:00 p.m. These time periods are estimated to include 50 percent of the daily vehicle travel. The rationale for eliminating the remainder of the day is that an area's mobility statistics should not be "credited" for having an uncongested system at 3:00 a.m.

Average Cost of Time

The 2007 value of person time used in the report is $15.47 per hour based on the value of time, rather than the average or prevailing wage rate (*7*).

Commercial Vehicle Operating Cost

Truck travel time is valued at $102.12 per hour (*8*).

URBAN AREA VARIABLES

In addition to the national constants, four urbanized area or state specific values 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 and Peak Travelers

Population data were obtained from a combination of U.S. Census Bureau estimates and the Federal Highway Administration's Highway Performance Monitoring System (HPMS) (*1,9*). Estimates of peak period travelers are derived from the National Household Travel Survey (*10*) data on the time of day when trips begin. Any resident who begins a trip, by any mode, between 6 a.m. and 10 a.m. or 3 p.m. and 7 p.m. is counted as a peak-period traveler. Data are available for many of the major urban areas and a few of the smaller areas. Averages for areas of similar size are used in cities with no specific data. The traveler estimate for some regions, specifically high tourism areas, may not represent all of the transportation users on an average day.

Fuel Costs

Statewide average fuel cost estimates were obtained from daily fuel price data published by the American Automobile Association (AAA) (*11*). Values for different fuel types used in motor vehicles, i.e., diesel and gasoline, did not vary enough to be reported separately.

Truck Percentage

The percentage of passenger cars and trucks for each urban area was estimated from the Highway Performance Monitoring System dataset (*1*). The values are used to estimate congestion costs and are not used to adjust the capacity or vehicle speed estimating procedures.

VARIABLE AND PERFORMANCE MEASURE CALCULATION DESCRIPTIONS

The major calculation products are described in this section. In some cases the process requires the use of variables described elsewhere in Appendix A.

Roadway Congestion Index

Early versions of the Urban Mobility Report used the roadway congestion index as a primary measure. While other measures that define congestion in terms of travel time and delay have replaced the RCI, it is still used as part of the calculation of delay. The RCI measures the density of traffic across the urban area using generally available data. Urban area estimates of vehicle-miles of travel (VMT) and lane-miles of roadway (Ln-Mi) are combined in a ratio using the amount of travel on each portion of the system. The combined index measures conditions on the freeway and arterial street systems according to the amount of travel on each type of road (Eq. A-1). This variable weighting factor allows comparisons between areas that carry different percentages of regional vehicle travel on arterial streets and freeways. The resulting ratio indicates an undesirable level of areawide congestion if the index value is greater than or equal to 1.0.

The traffic density ratio (VMT per lane-mile) is divided by a value that represents congestion for a system with the same mix of freeway and street volume. The RCI is, therefore, a measure of both intensity and duration of congestion. 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.

$$\begin{matrix}\text{Roadway}\\\text{Congestion}\\\text{Index}\end{matrix} = \frac{\begin{matrix}\text{Freeway}\\\text{VMT/Ln.Mi.}\end{matrix} \times \begin{matrix}\text{Freeway}\\\text{VMT}\end{matrix} + \begin{matrix}\text{Prin Art Str}\\\text{VMT/Ln.Mi.}\end{matrix} \times \begin{matrix}\text{Prin Art Str}\\\text{VMT}\end{matrix}}{14{,}000 \times \begin{matrix}\text{Freeway}\\\text{VMT}\end{matrix} + 5{,}000 \times \begin{matrix}\text{Prin Art Str}\\\text{VMT}\end{matrix}}$$

(Eq. A-1)

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 treatments designed to give a travel speed advantage to transit and carpool riders. The urban area may see several of the following effects:

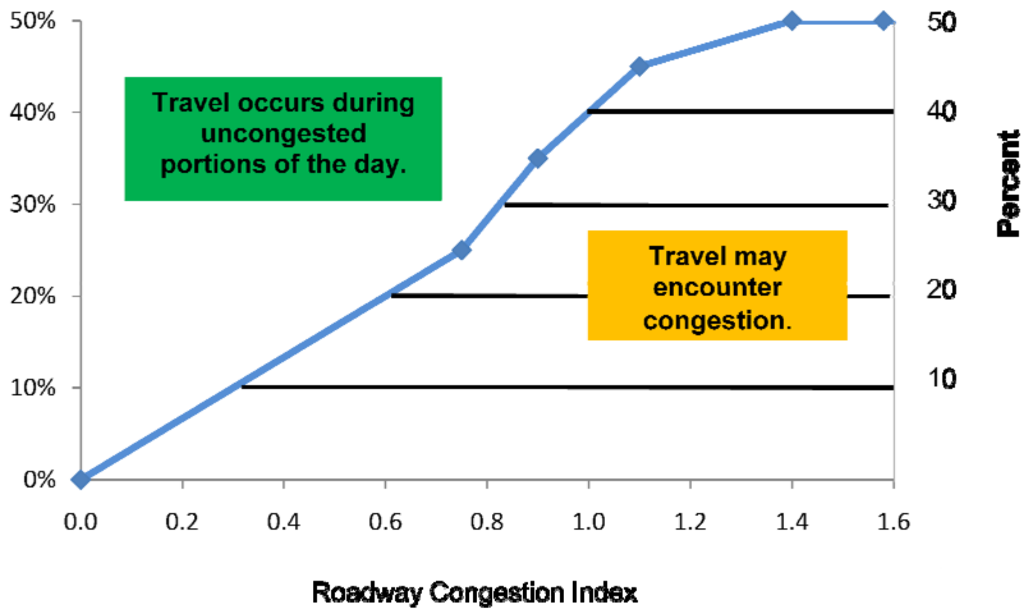
- Typical commute time 25% longer than off-peak travel time.
- Slower moving traffic during the peak period on the freeways, but not sustained stop-and-go conditions.
- Moderate congestion for 1 1/2 to 2 hours during each peak-period.
- Wait through one or two red lights at heavily traveled intersections.
- The RCI includes the effect of 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 over a short section of road (e.g., a narrow bridge or tunnel crossing a harbor or river), or missing capacity due to a gap in the system.
- The urban area congestion index averages all the developments within an urban area; there will be locations where congestion is much worse or much better than average.

Percent of Daily Travel in Congested Conditions

Peak travel periods in urban areas are the morning and evening "rush hours" when slow speeds are most likely to occur. The length of the peak period is held constant—essentially the most traveled four hours in the morning and evening—but the amount of the peak period that may suffer congestion is estimated separately. Large urban areas have peak periods that are typically longer than smaller or less congested areas because not all of the demand can be handled by the transportation network during a single hour. The congested times of day have increased since the start of the Urban Mobility Report. The maximum value is 50% of daily vehicle-miles of travel.

Exhibit A-2 illustrates the estimation procedure used for all urban areas. The Urban Mobility Report procedure uses the roadway congestion index (RCI)—a ratio of daily traffic volume to the number of lane-miles of arterial street and freeway—to estimate the length of the peak period. In this application, the RCI acts as an indicator of the number of hours of the day that might be affected by congested conditions (a higher RCI value means more traffic during more hours of the day). Exhibit A-2 illustrates the process used to estimate the amount of the day (and the amount of travel) when travelers might encounter congestion. Exhibit A-3 presents the results of the 2007 data analysis. Travel during the peak period, but outside these possibly congested times, is considered uncongested and is assigned a free-flow speed.

Exhibit A-2. Percent of Daily Travel in Congested Conditions



CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit A-3. Percentage of Daily Travel Used in Delay Estimation Procedure for 2009 Urban Mobility Report

Urban Area	2007 Roadway Congestion Index	% of Daily Travel in Congested Conditions	Urban Area	2007 Roadway Congestion Index	% of Daily Travel in Congested Conditions
Very Large			Medium		
Atlanta, GA	1.31	48.5	Akron, OH	0.88	33.6
Boston, MA-NH-RI	1.09	44.4	Albany-Schenectady, NY	0.83	30.4
Chicago, IL-IN	1.18	46.4	Albuquerque, NM	1.00	40.2
Dallas-Fort Worth-Arlington, TX	1.21	46.9	Allentown-Bethlehem, PA-NJ	0.94	37.1
Detroit, MI	1.23	47.2	Bakersfield, CA	0.83	30.2
Houston, TX	1.29	48.2	Birmingham, AL	1.02	40.8
Los Angeles-LBch-Santa Ana, CA	1.58	50.0	Bridgeport-Stamford, CT-NY	1.19	46.4
Miami, FL	1.39	49.9	Colorado Springs, CO	0.85	31.9
New York-Newark, NY-NJ-CT	1.15	45.8	Dayton, OH	0.91	35.3
Philadelphia, PA-NJ-DE-MD	1.11	45.1	El Paso, TX-NM	0.86	32.6
Phoenix, AZ	1.25	47.6	Fresno, CA	0.91	35.3
San Francisco-Oakland, CA	1.39	49.8	Grand Rapids, MI	0.87	33.1
Seattle, WA	1.12	45.4	Hartford, CT	0.97	38.3
Washington, DC-VA-MD	1.34	49.1	Honolulu, HI	1.10	45.1
			Indio-Cat. City-Palm Springs, CA	0.92	36.2
Large			Lancaster-Palmdale, CA	0.91	35.4
Austin, TX	1.19	46.5	Louisville, KY-IN	1.09	44.3
Baltimore, MD	1.21	46.8	Nashville-Davidson, TN	0.99	39.6
Buffalo, NY	0.77	26.0	New Haven, CT	1.00	39.8
Charlotte, NC-SC	1.11	45.2	Oklahoma City, OK	0.92	35.9
Cincinnati, OH-KY-IN	1.06	42.8	Omaha, NE-IA	0.96	37.8
Cleveland, OH	0.89	34.4	Oxnard-Ventura, CA	1.22	47.0
Columbus, OH	1.10	44.8	Poughkeepsie-Newburgh, NY	0.89	34.3
Denver-Aurora, CO	1.17	46.1	Richmond, VA	0.83	30.3
Indianapolis, IN	1.09	44.7	Rochester, NY	0.77	26.1
Jacksonville, FL	1.17	46.2	Salt Lake City, UT	1.06	42.9
Kansas City, MO-KS	0.79	27.5	Sarasota-Bradenton, FL	1.23	47.2
Las Vegas, NV	1.41	50.0	Springfield, MA-CT	0.83	30.1
Memphis, TN-MS-AR	0.91	35.3	Toledo, OH-MI	0.84	31.1
Milwaukee, WI	0.95	37.5	Tucson, AZ	1.15	45.9
Minneapolis-St. Paul, MN	1.17	46.1	Tulsa, OK	0.83	30.3
New Orleans, LA	0.98	39.0			
Orlando, FL	1.24	47.3	Small		
Pittsburgh, PA	0.78	26.8	Anchorage, AK	0.76	25.5
Portland, OR-WA	1.20	46.6	Beaumont, TX	0.80	28.1
Providence, RI-MA	0.95	37.3	Boulder, CO	0.89	34.3
Raleigh-Durham, NC	1.01	40.4	Brownsville, TX	0.85	31.5
Riverside-San Bernardino, CA	1.45	50.0	Cape Coral, FL	1.31	48.5
Sacramento, CA	1.33	48.9	Charleston-No. Charleston, SC	1.14	45.7
San Antonio, TX	1.16	46.0	Columbia, SC	0.94	36.8
San Diego, CA	1.37	49.5	Corpus Christi, TX	0.70	23.4
San Jose, CA	1.34	49.0	Eugene, OR	0.88	33.4
St. Louis, MO-IL	0.89	34.6	Knoxville, TN	1.08	44.0
Tampa-St. Petersburg, FL	1.29	48.2	Laredo, TX	0.82	29.6
Virginia Beach, VA	1.01	40.5	Little Rock, AR	0.94	37.1
			Pensacola, FL-AL	1.12	45.3
			Salem, OR	0.91	35.5
			Spokane, WA	0.72	18.8
			Wichita, KS	0.56	18.8

Note: 2007 data used in 2009 Urban Mobility Report.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Travel Speed

The volume and speed data that is collected by freeway operations centers in many metropolitan regions is used along with computer simulation modeling to adjust the Urban Mobility Report congestion estimation procedures. The speed functions used for the 2009 Urban Mobility Report are shown in Exhibits A-4 and A-5. More details on the supporting research are in a technical memorandum on the Urban Mobility Report website (*12*). The speed equations in Exhibit A-6 are linear within a congestion range and together the equations form a continuous line as shown in Exhibits A-4 and A-5.

Exhibit A-6. Daily Traffic Volume per Lane and Speed Estimating Used in Delay Calculation

Facility and Congestion Level	Daily Traffic Volume per Lane	Speed Estimate Equation[1]	
		Peak Direction	Off-Peak Direction
Freeway			
Uncongested	Under 15,000	60	60
Medium	15,001-17,500	70-(0.9* ADT/Lane)	67-(0.6* ADT/Lane)
Heavy	17,501-20,000	78-(1.4* ADT/Lane)	71-(0.85* ADT/Lane)
Severe	20,001-25,000	96-(2.3* ADT/Lane)	88-(1.7* ADT/Lane)
Extreme	Over 25,000	76-(1.46* ADT/Lane)	85.7-(1.6* ADT/Lane)
		Lowest speed is 35 mph	Lowest speed is 40 mph
Arterial Street			
Uncongested	Under 5,500	35	35
Medium	5,501-7,000	33.58-(0.74 ADT/Lane)	33.82-(0.59 ADT/Lane)
Heavy	7,001-8,500	33.80-(0.77 ADT/Lane)	33.90-(0.59 ADT/Lane)
Severe	8,501-10,000	31.65-(0.51 ADT/Lane)	30.10 (0.15 ADT/Lane)
Extreme	Over 10,000	32.57-(0.62 ADT/Lane)	31.23-(0.27 ADT/Lane)
		Lowest speed is 20 mph	Lowest speed is 27 mph

Note: [1]ADT/Lane in thousands.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit A-4. 2009 Urban Mobility Report – Freeway Speed Estimates

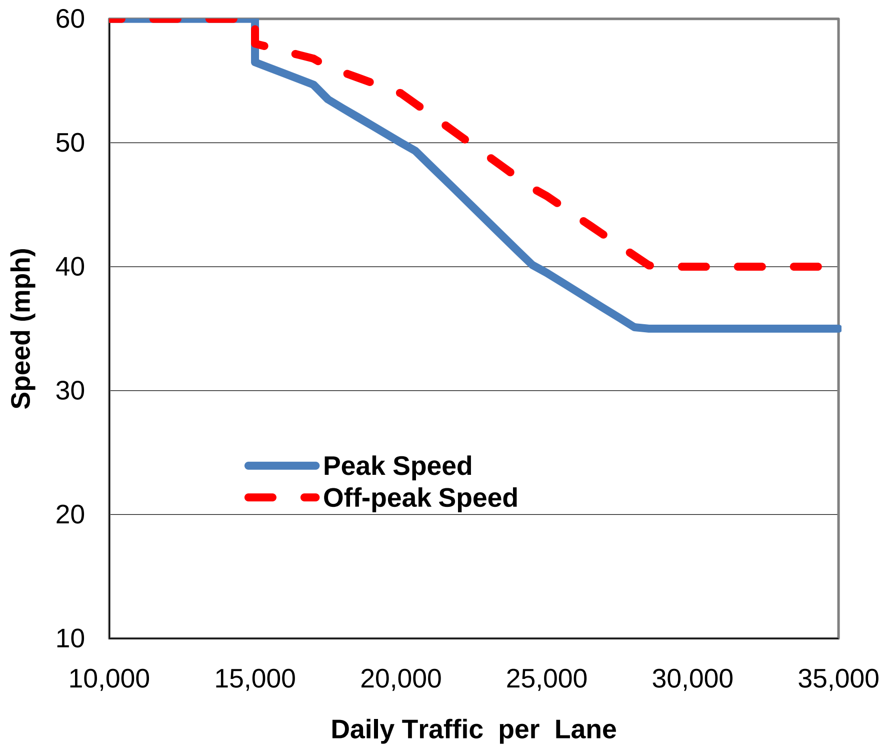
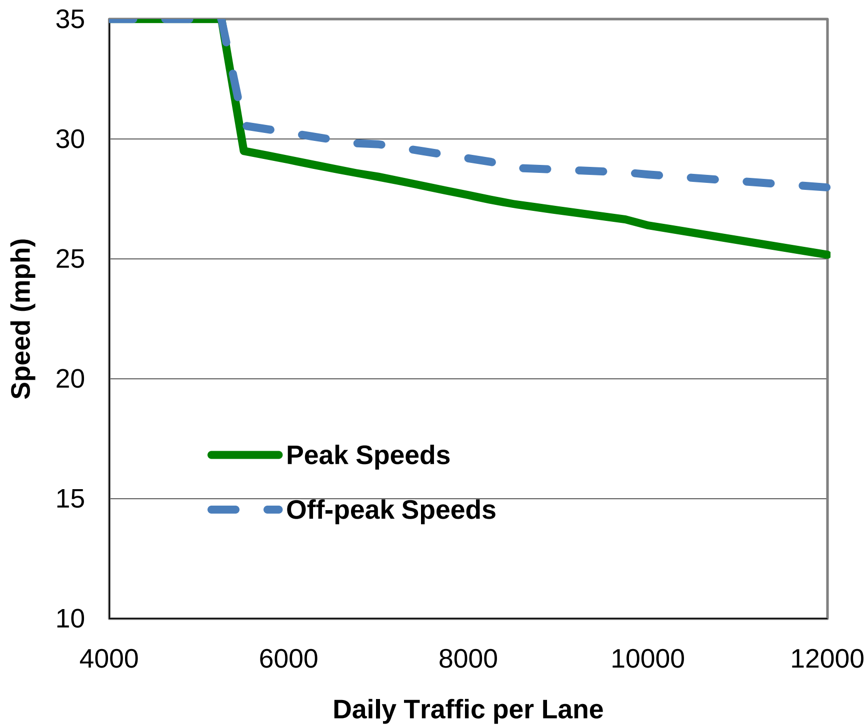


Exhibit A-5. 2009 Urban Mobility Report – Arterial Speed Estimates



The amount of travel (measured in vehicle-miles for each roadway link) is summed for each congestion level and direction. The average daily traffic volume per lane for each congestion level and direction is determined by dividing the group total VMT by the sum of lane-miles for all the links in that group. The average speed for each roadway type is obtained by weighting the speed in each congestion level by the total amount of travel at that level. The uncongested category includes travel on the uncongested portions of roadway, as well as travel during portions of the day that are estimated to rarely have congestion. The uncongested portion of the day varies for each city. The total amount of travel included in the speed averaging procedure, however, is 50 percent of the average daily vehicle-miles of travel for all urban areas.

Equation A-2 shows the calculation for a weighted average of speed. The average speed for each element of the road system is multiplied by the amount of travel on that set of roads. Using the amount of travel as a weighting factor provides a way to get an average "system experience" of travelers based on the amount of travel that occurs within each portion of the road system. This fundamental concept is used elsewhere in the Urban Mobility Report methodology. The resulting freeway and arterial speeds are shown in Exhibit A-7.

$$\begin{matrix}\text{Average Speed}\\ \text{(mph)}\end{matrix} = \frac{\begin{matrix}\text{Average}\\ \text{Freeway Speed}\end{matrix}\begin{pmatrix}\text{Freeway}\\ \text{VMT}\end{pmatrix} + \begin{matrix}\text{Average Arterial}\\ \text{Street Speed}\end{matrix}\begin{pmatrix}\text{Arterial}\\ \text{VMT}\end{pmatrix}}{\begin{matrix}\text{Freeway}\\ \text{VMT}\end{matrix} + \begin{matrix}\text{Street}\\ \text{VMT}\end{matrix}} \qquad \text{(Eq. A-2)}$$

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit A-7. 2007 Traffic Speed Estimates

Urban Area	Freeway	Arterial Street	Urban Area	Freeway	Arterial Street
Very Large			Medium		
Atlanta, GA	41.9	26.7	Akron, OH	56.2	32.8
Boston, MA-NH-RI	45.7	28.4	Albany-Schenectady, NY	56.3	30.7
Chicago, IL-IN	41.0	24.7	Albuquerque, NM	49.3	29.9
Dallas-Fort Worth-Arlington, TX	42.5	27.9	Allentown-Bethlehem, PA-NJ	56.3	29.0
Detroit, MI	47.5	26.4	Bakersfield, CA	55.0	31.9
Houston, TX	41.6	27.3	Birmingham, AL	53.4	29.0
Los Angeles-LBch-Santa Ana, CA	34.6	25.8	Bridgeport-Stamford, CT-NY	45.8	29.9
Miami, FL	41.6	25.5	Colorado Springs, CO	52.5	31.2
New York-Newark, NY-NJ-CT	41.5	26.1	Dayton, OH	55.9	31.5
Philadelphia, PA-NJ-DE-MD	45.2	27.6	El Paso, TX-NM	52.4	31.3
Phoenix, AZ	42.2	28.5	Fresno, CA	53.7	30.3
San Francisco-Oakland, CA	38.5	26.0	Grand Rapids, MI	58.0	30.8
Seattle, WA	43.8	27.9	Hartford, CT	53.7	30.8
Washington, DC-VA-MD	41.5	25.1	Honolulu, HI	48.8	27.3
			Indio-Cat. City-Palm Springs, CA	59.6	29.7
Large			Lancaster-Palmdale, CA	57.8	31.0
Austin, TX	46.1	26.6	Louisville, KY-IN	50.6	28.3
Baltimore, MD	43.9	27.7	Nashville-Davidson, TN	53.8	29.1
Buffalo, NY	56.2	32.5	New Haven, CT	54.2	31.1
Charlotte, NC-SC	49.6	26.7	Oklahoma City, OK	55.6	30.5
Cincinnati, OH-KY-IN	50.3	30.1	Omaha, NE-IA	51.1	29.8
Cleveland, OH	55.6	32.0	Oxnard-Ventura, CA	48.2	28.1
Columbus, OH	50.5	29.3	Poughkeepsie-Newburg, NY	58.4	30.2
Denver-Aurora, CO	45.1	26.5	Richmond, VA	55.5	31.6
Indianapolis, IN	51.6	27.7	Rochester, NY	57.2	32.4
Jacksonville, FL	50.1	26.9	Salt Lake City, UT	54.0	27.4
Kansas City, MO-KS	56.4	32.2	Sarasota-Bradenton, FL	57.5	27.8
Las Vegas, NV	44.8	27.1	Springfield, MA-CT	58.0	32.0
Memphis, TN-MS-AR	50.9	31.8	Toledo, OH-MI	55.0	32.4
Milwaukee, WI	49.6	32.2	Tucson, AZ	50.6	27.6
Minneapolis-St. Paul, MN	45.6	29.4	Tulsa, OK	58.1	30.6
New Orleans, LA	52.6	29.3			
Orlando, FL	48.6	25.2	Small		
Pittsburgh, PA	56.2	31.6	Anchorage, AK	59.8	31.2
Portland, OR-WA	44.6	27.4	Beaumont, TX	57.9	33.1
Providence, RI-MA	51.6	29.8	Boulder, CO	58.5	30.7
Raleigh-Durham, NC	53.4	28.7	Brownsville, TX	59.6	31.5
Riverside-San Bernardino, CA	39.9	28.8	Cape Coral, FL	57.7	28.7
Sacramento, CA	43.3	26.8	Charleston-No Charleston, SC	54.3	27.8
San Antonio, TX	48.8	27.7	Columbia, SC	56.9	30.4
San Diego, CA	42.1	25.7	Corpus Christi, TX	58.9	32.3
San Jose, CA	43.7	25.1	Eugene, OR	58.2	31.3
St. Louis, MO-IL	53.4	30.1	Knoxville, TN	55.6	30.3
Tampa-St. Petersburg, FL	49.4	25.3	Laredo, TX	59.3	30.4
Virginia Beach, VA	51.3	28.9	Little Rock, AR	55.9	31.3
			Pensacola, FL-AL	58.4	30.2
			Salem, OR	58.5	30.1
			Spokane, WA	58.0	33.2
			Wichita, KS	59.6	33.7

Note: 2007 data used in 2009 Urban Mobility Report.

Travel Delay

Most of the basic performance measures presented in the Urban Mobility Report are developed as part of calculating travel delay—the amount of extra time spent traveling due to congestion. An overview of the process is followed by more detailed descriptions of the individual steps.

Travel delay calculations are performed in two steps—recurring (or usual) delay and incident delay (due to crashes, vehicle breakdowns, etc.). Recurring delay estimates are developed using a process designed to identify peak period congestion due to traffic volume and capacity. Delay caused by other events is not included in the recurring delay estimate. Generally, these events can be categorized as one of the seven sources of unreliability (*13*).

- Traffic Incidents
- Work Zones
- Weather
- Fluctuation in Demand
- Special Events
- Traffic Control Devices
- Inadequate Base Capacity

The 2009 Urban Mobility Report methodology only includes estimates of travel delay from incidents, demand fluctuations and base capacity inadequacy.

Recurring Travel Delay - Summary Version

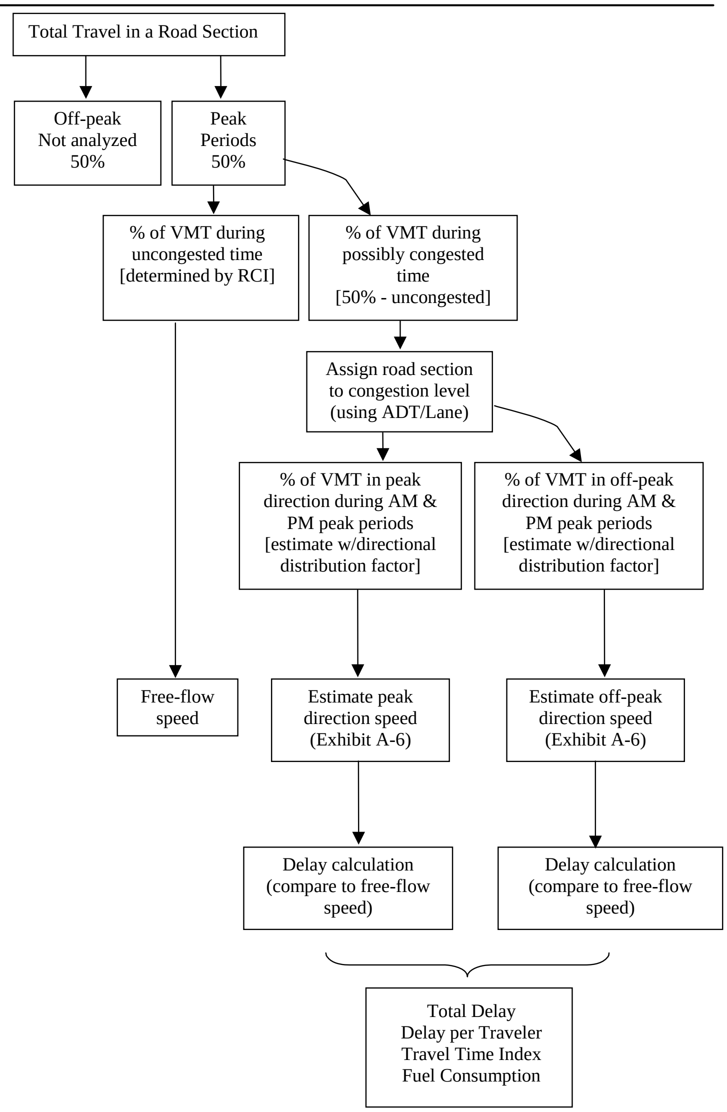
Travel delay is estimated from equations relating vehicle traffic volume per lane and traffic speed. The calculation proceeds through the following steps (displayed in Exhibit A-8):

- Estimate peak period travel miles.
- Estimate the amount of travel in times that might encounter congestion; place remainder of the travel in the uncongested group.
- Separate congested travel into peak and off-peak directions.
- Place each road section in a congestion group (one of four congestion levels for peak and off-peak or the uncongested group).
- Calculate a speed for each congestion group.
- Calculate average speed on each road type (e.g. freeways or arterial streets).

Exhibit A-8. Overview of Speed and Delay Calculation Process

Step	Why? or What
Collect travel and roadway characteristics	Get data for an average day
Isolate peak-period travel	Remove off-peak, uncongested travel (50% of day)
Identify the usually congested time of day	Varies for each area; congestion usually lasts longer in larger areas
Identify congestion level of each section of roadway	Use daily traffic/lane and Exhibit A-6
Assign travel to peak/off-peak directions	Accumulate VMT by congestion level and direction, determine average VMT per lane-mile
Apply speed estimates to each congestion level and direction	Using speed curves, determine average speed for each direction and level
Calculate delay	Compare average speeds to free-flow speeds
Calculate other measures	Use VMT, speeds and remaining methodology to determine other measures

The 'Process'



For Each Road Section

Collect Travel and Roadway Characteristics

Information for each section of roadway includes daily traffic volume, length and number of lanes.

Isolate Peak-Period and Congested Travel

Fifty percent of the daily vehicle travel occurs in the peak period and is used in the speed and delay estimates. The calculation procedure to estimate the congested portions of the peak (described previously) is used to initially distribute travel to the uncongested portions of the day and those hours that may be congested.

Separate Peak and Off-Peak Direction Travel Volume

The directional distribution factor in the Highway Performance Monitoring System database is used to divide the traffic on each link to the peak and off-peak directions. There is a different speed estimating equation for each direction (*12*). The delay reduction equation for arterial street traffic signal coordination is also different for the two directions.

Congestion Level of Each Section of Roadway

Each roadway link is assigned to one of five congestion levels—uncongested, moderate, heavy, severe or extreme, based on the daily traffic volume per lane. These assignments are used in the estimation of both the peak period travel speed and the delay reducing effects of the operational treatments.

Estimate Travel Speed in Each Congestion Group

Previous steps have separated the roadway links into freeway or arterial, congestion level, and peak or off-peak direction. The speed calculation is applied for each combination of congestion level/road type/direction for each group.

Estimate Travel Time

The travel time for each combination of road/direction/congestion level is calculated by dividing the miles traveled in each group by the average speed. The travel time at free-flow conditions is calculated by dividing the travel distance by the free-flow speed.

Estimate Travel Delay Using Speed and Travel Volume

The amount of delay incurred in the peak period is the difference between the time to travel at the average speed and the travel time at the free-flow speed, multiplied by the distance traveled in the peak period.

Estimate Travel Delay

The difference between the amount of time it takes to travel the peak-period vehicle-miles at the average speed and at free-flow speeds is termed delay.

Incident-Related Travel Delay

Another type of delay encountered by travelers is the delay that results from a collision or disabled vehicle. Incident delay is related to the frequency of crashes or vehicle breakdowns, how easily those incidents are removed from the traffic lanes and shoulders and the "normal" amount of recurring congestion. The basic procedure used to estimate incident delay in this study is to multiply the recurring delay by a ratio (Equation A-3).

$$\begin{matrix}\text{Daily Incident}\\ \text{Vehicle – Hours of Delay}\end{matrix} = \begin{matrix}\text{Daily Recurring}\\ \text{Vehicle – Hours of Delay}\end{matrix} \times \begin{matrix}\text{Recurring to Incident}\\ \text{Delay Factor Ratio}\end{matrix} \qquad \text{(Eq. A-3)}$$

The process used to develop the delay factor ratio is a detailed examination of the freeway characteristics and volumes. In addition, a methodology developed by FHWA is used to model the effect of incidents based on the design characteristics and estimated volume patterns (*14*). The procedure involves the random assignment of crashes to the roadway system based on the distribution of frequency and severity of collisions. Each type of collision has a different capacity reducing effect and depending on the traffic volume at the "time" of the collision, travel delay can increase by very little (for minor crashes during low volume conditions) to a large amount if the collision blocks a lane or lanes during high traffic volume periods. The resulting ratios are presented in Exhibit A-9.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit A-9. Incident Delay Ratios

Urban Area	Freeway Incident Delay Ratio	Arterial Street Incident Delay Ratio	Urban Area	Freeway Incident Delay Ratio	Arterial Street Incident Delay Ratio
Very Large			Medium		
Atlanta, GA	1.2	1.1	Akron, OH	1.4	1.1
Boston, MA-NH-RI	1.6	1.1	Albany-Schenectady, NY	2.3	1.1
Chicago, IL-IN	0.8	1.1	Albuquerque, NM	1.1	1.1
Dallas-Fort Worth-Arlington, TX	1.3	1.1	Allentown-Bethlehem, PA-NJ	1.6	1.1
Detroit, MI	1.2	1.1	Bakersfield, CA	1.8	1.1
Houston, TX	0.9	1.1	Birmingham, AL	2.0	1.1
Los Angeles-LBch-Santa Ana, CA	0.7	1.1	Bridgeport-Stamford, CT-NY	1.5	1.1
Miami, FL	1.0	1.1	Colorado Springs, CO	2.2	1.1
New York-Newark, NY-NJ-CT	2.5	1.1	Dayton, OH	1.4	1.1
Philadelphia, PA-NJ-DE-MD	2.2	1.1	El Paso, TX-NM	1.7	1.1
Phoenix, AZ	0.9	1.1	Fresno, CA	2.3	1.1
San Francisco-Oakland, CA	0.9	1.1	Grand Rapids, MI	2.1	1.1
Seattle, WA	1.2	1.1	Hartford, CT	2.1	1.1
Washington, DC-VA-MD	1.0	1.1	Honolulu, HI	1.3	1.1
			Indio-Cat. City-Palm Springs, CA	2.5	1.1
Large			Lancaster-Palmdale, CA	2.5	1.1
Austin, TX	1.6	1.1	Louisville, KY-IN	1.5	1.1
Baltimore, MD	1.3	1.1	Nashville-Davidson, TN	1.7	1.1
Buffalo, NY	2.1	1.1	New Haven, CT	1.4	1.1
Charlotte, NC-SC	1.2	1.1	Oklahoma City, OK	2.0	1.1
Cincinnati, OH-KY-IN	1.3	1.1	Omaha, NE-IA	2.3	1.1
Cleveland, OH	1.5	1.1	Oxnard-Ventura, CA	1.3	1.1
Columbus, OH	1.3	1.1	Poughkeepsie-Newburgh, NY	2.5	1.1
Denver-Aurora, CO	1.2	1.1	Richmond, VA	2.2	1.1
Indianapolis, IN	1.1	1.1	Rochester, NY	2.3	1.1
Jacksonville, FL	1.5	1.1	Salt Lake City, UT	1.3	1.1
Kansas City, MO-KS	2.5	1.1	Sarasota-Bradenton, FL	2.5	1.1
Las Vegas, NV	1.1	1.1	Springfield, MA-CT	1.9	1.1
Memphis, TN-MS-AR	1.6	1.1	Toledo, OH-MI	2.1	1.1
Milwaukee, WI	1.1	1.1	Tucson, AZ	1.5	1.1
Minneapolis-St. Paul, MN	1.4	1.1	Tulsa, OK	2.1	1.1
New Orleans, LA	1.4	1.1			
Orlando, FL	1.3	1.1	Small		
Pittsburgh, PA	2.5	1.1	Anchorage, AK	2.5	1.1
Portland, OR-WA	1.4	1.1	Beaumont, TX	2.5	1.1
Providence, RI-MA	2.2	1.1	Boulder, CO	2.5	1.1
Raleigh-Durham, NC	1.6	1.1	Brownsville, TX	2.5	1.1
Riverside-San Bernardino, CA	0.9	1.1	Cape Coral, FL	2.5	1.1
Sacramento, CA	1.0	1.1	Charleston-No. Charleston, SC	2.0	1.1
San Antonio, TX	1.2	1.1	Columbia, SC	1.9	1.1
San Diego, CA	0.9	1.1	Corpus Christi, TX	2.4	1.1
San Jose, CA	1.2	1.1	Eugene, OR	2.4	1.1
St. Louis, MO-IL	1.2	1.1	Knoxville, TX	2.3	1.1
Tampa-St. Petersburg, FL	1.5	1.1	Laredo, TX	2.5	1.1
Virginia Beach, VA	2.1	1.1	Little Rock, AR	1.6	1.1
			Pensacola, FL-AL	2.5	1.1
			Salem, OR	2.5	1.1
			Spokane, WA	2.4	1.1
			Wichita, KS	2.5	1.1

Incident delay occurs in different ways on streets than freeways. While there are driveways that can be used to remove incidents, the crash rate is higher and the recurring delay is lower on streets. Arterial street designs are more consistent from city to city than freeway designs. For the purpose of this study, incident delay for arterial streets is estimated as 110 percent of arterial street recurring delay.

Annual Person Delay

This calculation is performed to expand the daily recurring and incident delay estimates for freeways and arterial streets to a yearly estimate in each study area. The daily vehicle-hours of delay is the sum of the delay resulting from recurring and incident delay in all four congestion levels on both types of facilities. To calculate the annual person-hours of delay, multiply the daily delay estimates by the average vehicle occupancy (1.25 persons per vehicle) and by 250 working days per year (Equation A-4).

$$\begin{matrix}\text{Annual}\\ \text{Persons} - \text{Hours}\\ \text{of Delay}\end{matrix} = \begin{matrix}\text{Daily Vehicle} - \text{Hours of}\\ \text{Incident and Recurring}\\ \text{Delay on Frwys and Arterial Streets}\end{matrix} \times \begin{matrix}\text{250 Working Days}\\ \text{per Year}\end{matrix} \times \begin{matrix}\text{1.25 Persons}\\ \text{per Vehicle}\end{matrix} \qquad \text{(Eq. A-4)}$$

Annual delay per traveler is a measure of the extra travel time endured by persons who make trips during the peak period. The procedure used in the Urban Mobility Report applies estimates of the number of people and trip departure times during the morning and evening peak periods from the American Community Survey to the urban area population estimate to derive the average number of travelers during the peak periods (*15*). Total delay is divided by the number of travelers to get the annual delay per peak traveler.

Annual Peak Period Travel Time

Total travel time can be used as both a performance measure and as a component in other calculations. The 2009 Urban Mobility Report used travel time as a component; future reports will incorporate other information and improve on the use of total travel time as a performance measure.

Total travel time is the sum of travel delay and free-flow travel time. Both of the quantities are only calculated for freeways and arterial streets. Free-flow travel time is the amount of time needed to travel the peak period miles at the free-flow speeds (60 mph on freeways and 35 mph on streets) (Equation A-5).

$$\begin{array}{c}\text{Annual Free–flow}\\ \text{Travel Time}\\ \text{(vehicle–hours)}\end{array} = \frac{1}{\begin{array}{c}\text{Free–flow}\\ \text{Travel Speed}\\ \left(\begin{array}{c}\text{60 mph–freeway}\\ \text{35 mph–arterial}\end{array}\right)\end{array}} \times \begin{array}{c}\text{Peak Period}\\ \text{Vehicle–Miles}\\ \text{of Travel}\end{array} \times \begin{array}{c}250\\ \text{Working}\\ \text{Days}\end{array} \qquad \text{(Eq. A-5)}$$

$$\begin{array}{c}\text{Annual}\\ \text{Travel Time}\end{array} = \underbrace{\left(\begin{array}{c}\text{Freeway}\\ \text{Delay}\end{array} + \begin{array}{c}\text{Arterial}\\ \text{Street Delay}\end{array}\right)}_{\text{(Eq. A–4)}} + \underbrace{\left(\begin{array}{c}\text{Freeway}\\ \text{Free–flow}\\ \text{Travel Time}\end{array} + \begin{array}{c}\text{Arterial}\\ \text{Free–flow}\\ \text{Travel Time}\end{array}\right)}_{\text{(Eq. A–5)}} \qquad \text{(Eq. A-6)}$$

Travel Time Index

The Travel Time Index (TTI) illustrates the comparison of peak period travel time to free-flow travel time. The Travel Time Index includes both recurring and incident conditions and is, therefore, an estimate of the conditions faced by urban travelers. Equation A-5 illustrates the ratio used to calculate the TTI. The ratio is time divided by time and the Index, therefore, has no units. This “unitless” feature allows the Index to be used to compare trips of different lengths to estimate the travel time in excess of that experienced in free-flow conditions.

The index is calculated with a procedure consistent with the methods and data that will be used in the automated travel management centers. The free-flow travel time for each functional class is subtracted from the average travel time to estimate delay. The recurring delay is multiplied by the incident-to-recurring delay ratio to estimate incident delay. For each congestion level, the incident delay is added to the recurring delay to estimate total delay. The Travel Time Index is calculated by comparing total travel time to the free-flow travel time (Equations A-7 and A-8).

$$\text{Travel Time Index} = \frac{\text{Peak Travel Time}}{\text{Free–Flow Travel Time}} \qquad \text{(Eq. A-7)}$$

$$\text{Travel Time Index} = \frac{\text{Delay Time} + \text{Free–Flow Travel Time}}{\text{Free–Flow Travel Time}} \qquad \text{(Eq. A-8)}$$

Fuel Economy

The average fuel economy calculation is used to estimate the fuel consumption of the vehicles operating in congested and uncongested conditions. Equation A-9 is a linear regression applied to a modified version of fuel consumption reported by Raus (*16*).

$$\begin{array}{c}\text{Average Fuel}\\ \text{Economy}\\ \text{in Congestion}\end{array} = 8.8 + 0.25\left(\begin{array}{c}\text{Average Peak}\\ \text{Period Congested}\\ \text{System Speed}\end{array}\right) \qquad \text{(Eq. A-9)}$$

Wasted Fuel

The Urban Mobility Report calculates the wasted fuel due to vehicles moving at speeds slower than free-flow during peak period travel. Equation A-10 calculates the fuel wasted in recurring and incident delay conditions from Equation A-4, the average peak period speed (Equation A-2), and the average fuel economy associated with the peak speed (Equation A-9).

$$\begin{array}{c}\text{Annual}\\ \text{Fuel Wasted}\end{array} = \begin{array}{c}\text{Travel Time}\\ \text{(vehicle hours)}\\ \text{(Eq. A–5)}\end{array} \times \begin{array}{c}\text{Average Peak Period System}\\ \text{"Congested Speed"}\\ \text{(Eq. A–2)}\end{array} \div \begin{array}{c}\text{Average Fuel}\\ \text{Economy}\\ \text{(Eq. A–9)}\end{array} \times \begin{array}{c}\text{250 Working}\\ \text{Days per year}\end{array} \qquad \text{(Eq. A-10)}$$

Equation A-11 incorporates the same factors to calculate fuel that would be consumed in free-flow conditions. The fuel that is deemed “wasted due to congestion” is the difference between the amount consumed at peak speeds and free-flow speeds (Equation A-10).

$$\begin{array}{c}\text{Annual Fuel That Would}\\ \text{be Consumed in}\\ \text{Free-flow Conditions}\end{array} = \begin{array}{c}\text{Travel Time}\\ \text{(Eq. A–5)}\end{array} \times \begin{array}{c}\text{Free-flow Speed}\\ \text{(35 mph-arterial,}\\ \text{60 mph-freeway)}\end{array} \div \begin{array}{c}\text{Average Fuel}\\ \text{Economy for}\\ \text{Free-flow Speeds}\\ \text{(Eq. A–9)}\end{array} \qquad \text{(Eq. A-11)}$$

$$\begin{array}{c}\text{Annual Fuel}\\ \text{Wasted in Congestion}\end{array} = \begin{array}{c}\text{Annual Fuel}\\ \text{Consumed in}\\ \text{Peak Conditions}\end{array} - \begin{array}{c}\text{Annual Fuel That}\\ \text{Would be Consumed}\\ \text{in Free-flow Conditions}\end{array} \qquad \text{(Eq. A-12)}$$

Congestion Cost

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 and Equations A-13 through A-15 show how to calculate the cost of delay and fuel effects of congestion.

Passenger Vehicle Delay Cost

The delay cost is an estimate of the value of lost time in passenger vehicles and the increased operating costs of commercial vehicles in congestion. Equation A-13 shows how to calculate the passenger vehicle delay costs that result from lost time.

$$\begin{matrix}\text{Annual Passenger} \\ \text{Vehicle Delay Cost}\end{matrix} = \begin{matrix}\text{Daily Passenger Vehicle} \\ \text{Hours of Delay} \\ \text{(Eq. A-4)}\end{matrix} \times \begin{matrix}\text{Value of} \\ \text{Person Time} \\ \text{(\$ / hour)}\end{matrix} \times \begin{matrix}\text{Vehicle} \\ \text{Occupancy} \\ \text{(persons/vehicle)}\end{matrix} \times \begin{matrix}\text{250 Working} \\ \text{Days}\end{matrix} \quad \text{(Eq. A-13)}$$

Passenger Vehicle Fuel Cost

Fuel cost due to congestion is calculated for passenger vehicles in Equation A-14. This is done by associating the peak period congested speeds, the average fuel economy, and the fuel costs with the vehicle-hours of delay.

$$\begin{matrix}\text{Annual} \\ \text{Fuel Cost}\end{matrix} = \begin{matrix}\text{Annual Fuel} \\ \text{Wasted} \\ \text{(Eq. A–12)}\end{matrix} \times \begin{matrix}\text{Percent of} \\ \text{Passenger} \\ \text{Vehicles}\end{matrix} \times \begin{matrix}\text{Fuel} \\ \text{Cost}\end{matrix} \times \begin{matrix}\text{250} \\ \text{Working Days}\end{matrix} \quad \text{(Eq. A-14)}$$

Commercial Vehicle Cost

The cost of both wasted time and fuel are included in the value of commercial vehicle time ($102.12 in 2007). Thus, there is not a separate value for wasted time and fuel. The equation to calculate commercial vehicle cost is shown in Equation A-15.

$$\begin{matrix}\text{Annual} \\ \text{Commercial} \\ \text{Cost}\end{matrix} = \begin{matrix}\text{Delay Vehicle} \\ \text{Hours of Delay} \\ \text{(Eq. A–4)}\end{matrix} \times \begin{matrix}\text{Percent of} \\ \text{Commercial} \\ \text{Vehicles}\end{matrix} \times \begin{matrix}\text{Value of} \\ \text{Commercial Vehicle} \\ \text{Time (\$/hour)}\end{matrix} \times \begin{matrix}\text{250 Working} \\ \text{Days}\end{matrix} \quad \text{(Eq. A-15)}$$

Total Congestion Cost

Equation A-16 combines the cost due to travel delay and wasted fuel to determine the annual cost due to congestion resulting from incident and recurring delay.

$$\begin{matrix}\text{Annual Cost}\\ \text{Due to}\\ \text{Congestion}\end{matrix} = \left(\begin{matrix}\text{Annual Passenger}\\ \text{Vehicle Delay Cost}\\ \text{(Eq. A–13)}\end{matrix} + \begin{matrix}\text{Annual Passenger}\\ \text{Fuel Cost}\\ \text{(Eq. A–14)}\end{matrix}\right) + \begin{matrix}\text{Annual}\\ \text{Commerical Cost}\\ \text{(Eq. A–15)}\end{matrix} \qquad \text{(Eq. A-16)}$$

Percent of Congested Travel

The percentage of travel in each urban area that is congested both for peak travel and daily travel can be calculated. The equations are very similar with the only difference being the amount of travel in the denominator. For calculations involving only the congested periods (Equations A-17 and A-18), the amount of travel used is half of the daily total since the assumption is made that only 50 percent of daily travel occurs in the peak driving times. For the daily percentage (Equation A-19), the factor in the denominator is the daily miles of travel. Exhibit A-10 shows the 2007 percent of congested travel values.

$$\begin{matrix}\text{Peak Period}\\ \text{Congested Travel}\end{matrix} = \begin{matrix}\text{Percent of Congested}\\ \text{Peak Period Travel}\end{matrix} \times \begin{matrix}\text{VMT for}\\ \text{Roadway Type}\end{matrix} \qquad \text{(Eq. A-17)}$$

$$\begin{matrix}\text{Percent Congested}\\ \text{Peak Period Travel}\end{matrix} = \begin{matrix}\text{Percent Congested}\\ \text{Daily Travel}\end{matrix} \div \text{50 percent} \qquad \text{(Eq. A-28)}$$

$$\begin{matrix}\text{Percent Congested}\\ \text{Daily Travel}\end{matrix} = \frac{\begin{matrix}\text{Freeway}\\ \text{Congested Travel}\end{matrix} + \begin{matrix}\text{Arterial}\\ \text{Congested Travel}\end{matrix}}{\text{Daily Travel}} \qquad \text{(Eq. A-39)}$$

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit A-10. Percentage of Congested Travel in 2007

Urban Area	Percent of Peak Period Travel that is Congested	Percentage of Daily Travel that is Congested	Urban Area	Percent of Peak Period Travel that is Congested	Percentage of Daily Travel that is Congested
Very Large			Medium		
Atlanta, GA	75	38	Akron, OH	28	14
Boston, MA-NH-RI	58	29	Albany-Schenectady, NY	28	14
Chicago, IL-IN	79	39	Albuquerque, NM	46	23
Dallas-Fort Worth-Arlington, TX	66	33	Allentown-Bethlehem, PA-NJ	38	19
Detroit, MI	71	35	Bakersfield, CA	27	14
Houston, TX	73	36	Birmingham, AL	44	22
Los Angeles-LBch-Santa Ana, CA	86	43	Bridgeport-Stamford, CT-NY	64	32
Miami, FL	82	41	Colorado Springs, CO	32	16
New York-Newark, NY-NJ-CT	69	34	Dayton, OH	34	17
Philadelphia, PA-NJ-DE-MD	63	32	El Paso, TX-NM	34	17
Phoenix, AZ	68	34	Fresno, CA	38	19
San Francisco-Oakland, CA	82	41	Grand Rapids, MI	29	14
Seattle, WA	66	33	Hartford, CT	38	19
Washington, DC-VA-MD	81	40	Honolulu, HI	57	29
			Indio-Cat. City-Palm Springs, CA	38	19
Large			Lancaster-Palmdale, CA	30	15
Austin, TX	70	35	Louisville, KY-IN	55	27
Baltimore, MD	69	35	Nashville-Davidson, TN	41	20
Buffalo, NY	22	11	New Haven, CT	38	19
Charlotte, NC-SC	60	30	Oklahoma City, OK	36	18
Cincinnati, OH-KY-IN	51	25	Omaha, NE-IA	45	23
Cleveland, OH	28	14	Oxnard-Ventura, CA	59	29
Columbus, OH	57	29	Poughkeepsie-Newburgh, NY	27	13
Denver-Aurora, CO	67	33	Richmond, VA	29	14
Indianapolis, IN	60	30	Rochester, NY	19	10
Jacksonville, FL	64	32	Salt Lake City, UT	54	27
Kansas City, MO-KS	21	11	Sarasota-Bradenton, FL	49	25
Las Vegas, NV	72	36	Springfield, MA-CT	21	11
Memphis, TN-MS-AR	32	16	Toledo, OH-MI	25	12
Milwaukee, WI	39	20	Tucson, AZ	61	30
Minneapolis-St. Paul, MN	58	29	Tulsa, OK	26	13
New Orleans, LA	45	23			
Orlando, FL	74	37	Small		
Pittsburgh, PA	24	12	Anchorage, AK	21	10
Portland, OR-WA	68	34	Beaumont, TX	14	7
Providence, RI-MA	39	20	Boulder, CO	27	14
Raleigh-Durham, NC	51	25	Brownsville, TX	22	11
Riverside-San Bernardino, CA	78	39	Cape Coral, FL	45	23
Sacramento, CA	76	38	Charleston-No. Charleston, SC	51	25
San Antonio, TX	63	31	Columbia, SC	33	16
San Diego, CA	84	42	Corpus Christi, TX	15	8
San Jose, CA	81	40	Eugene, OR	25	12
St. Louis, MO-IL	36	18	Knoxville, TN	32	16
Tampa-St. Petersburg, FL	76	38	Laredo, TX	31	15
Virginia Beach, VA	51	25	Little Rock, AR	33	17
			Pensacola, FL-AL	35	18
			Salem, OR	29	15
			Spokane, WA	17	8
			Wichita, KS	8	4

Lane-Miles and Passenger Trips Required To Hold Congestion Constant

The lane-miles of roadway and the transit trips that would be needed every year to maintain a constant congestion level are calculated to illustrate the amount of improvement required to address growing travel needs. The average growth rate is calculated for the previous five years of growth in vehicle-miles of travel. For example, the 2007 statistics are based on the growth rate calculated from changes between 2002 and 2007. If vehicle travel grows at a higher rate than capacity (measured in lane-miles or transit trips), congestion will increase. Thus, in order to hold congestion constant, capacity must be added at the same rate as vehicle travel growth.

The following equation is used to calculate the average annual growth rate for vehicle travel and is key for calculating both the lane-miles and transit passenger trips that are needed to hold congestion constant.

$$\begin{matrix}\text{Annual Average}\\ \text{VMT Growth}\end{matrix} = \left(\frac{(2007\ \text{VMT} - 2002\ \text{VMT})}{2002\ \text{VMT}}\right) 1/5 - 1 \qquad \text{(Eq. A-20)}$$

The "needed" lane-miles are based on applying the average annual growth rate in travel during the analysis period (2002 to 2007) to the existing 2007 lane-miles. This estimates the amount of roadway lane-miles that would be needed to match the travel demand growth rate.

The calculation for the number of passenger trips needed on public transportation each year to hold congestion constant is very similar to the "needed" lane-miles. The annual average growth rate in vehicle-miles of travel is multiplied by the 2007 passenger-miles of travel on the roadways in 2007. This gives the amount of expected passenger travel growth if trends continue. To convert this annual travel mileage growth into transit trips, the person-miles of travel are divided by 9 miles, the approximate length of the average transit trip in the U.S.(*10*). This value represents the number of trips that would need to occur on public transportation to hold the congestion level constant.

It should be noted that these statistics can be calculated for any period of time. The five-year period is used in these calculations as a description of recent trends, but the same statistics could be calculated for the entire time series in the Urban Mobility Report by changing the factor (e.g., 1/5) in the equation above to one over the number of years in the time series.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

What Causes Congestion?

In a word, "you." Most of the Mojave Desert is not congested. But the rural portions also support very few jobs, has hardly any schools and provides a very small contribution to the nation's economic production. The 100 largest metropolitan regions, on the other hand, contribute 70 percent of the gross domestic product and have 69 percent of the jobs (*17*). It is not surprising that congestion exists in large areas given the number of people and the amount of freight moving in many directions over the course of two peak periods of two or three hours each. *So the first cause—many people and lots of freight moving at the same time.*

The second cause is the slow growth in supply—both roads and public transportation—in the last 20 years. Congestion has increased even though there are more roads and more transit service. Travel by public transportation riders has increased 47 percent in the 90 urban areas studied in this report. The contribution of the road growth effect to the congestion problem is difficult to estimate. The data files used for the Urban Mobility Report include the growth in urban roadway and travel that results from job and population growth, transportation investments **and** expanding urbanized area boundaries. Roads in areas that were rural are re-designated as urban, causing the "urban" lane-miles to grow even if there are no roads constructed. But even given this shortcoming, the differences are dramatic— travel has increased 72 percent in big metro regions while road capacity on freeways and major streets has grown by only 40 percent (the actual new capacity is much smaller). *Too many people, too many trips over too short of a time period on a system that is too small—not really a new observation* (*1,2*).

A third factor causes many trips to be delayed by events that are irregular, but frequent. Crashes, vehicle breakdowns, improperly timed traffic signals, special events and weather are factors that cause a variety of traffic congestion problems. The effect of these events are made worse by the increasing travel volumes. *The solutions to each of these problems are different and are usually a combination of policies, practices, equipment and facilities.*

The commuting *uber reference*, *Commuting in America III* (*18*) confirmed the lengthening commute times, with average travel time to work growing 2 minutes (to 25.5 minutes) from 1990 to 2000, following a 1.7 minute increase in the decade before. This two-decade trend in commuting time growth raises concerns when compared to the growth in commuter volume—23 million more solo drivers in the 1980s, but only 13 million more single drivers in the 1990s. A greater growth in travel time with substantially fewer additional trips suggests that the transportation capacity built in earlier decades is being "used up."

The proportion of commute trips going from one county to another and from one suburb to another has increased significantly. The long commutes—*Commuting in America III* labels a one-way trip over 1 hour as "extreme"—increased from 6 percent of commute trips to 8 percent. Over 12 percent of commuters in the largest metropolitan regions (over 5 million) had trips lengths beyond 60 minutes. With this as an alternative, it is not surprising that working at home and leaving for work before 6 a.m. also saw substantial increases.

WHAT IS THE SOURCE OF DATA FOR THIS REPORT?

This report uses data from federal, state, and local agencies to develop estimates of congestion and mobility within an urban area. The methodology developed by several previous research studies (*19,20,21,22,23*) 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 (*1*). The HPMS database is used because of its relative consistency and comprehensive nature. State departments of transportation collect, review, and report the data annually. Since each state classifies roadways in a slightly different manner, TTI reviews and adjusts the data to make it comparable and then state and local agencies familiar with each urban area review the data.

The Urban Mobility Report procedures have been modified to take advantage of special issue studies that provide more detailed information, but the assumptions used in the Annual Mobility Report do not fully account for the effect of all operational improvements. Comparisons between cities are always difficult and the local and state studies are typically more detailed and relevant for specific areas. The Urban Mobility Report is more applicable for comparisons of trends for individual cities, rather than any value for a particular year.

Urban Area Boundary Effects

Urban boundaries are redrawn at different intervals in the study states. Official realignments and local agency boundary updates are sometimes made to reflect urban growth. These changes may significantly change the size of the urban area, which also causes a change in system length, travel and mobility estimates. The effect in the Urban Mobility Report database is that travel and roadways that previously existed in rural areas are added to the urban area statistics. It is important to recognize that newly constructed roads are only a portion of the "added" roads.

When the urban boundary is not altered every year in fast growth areas, the HPMS data items take on a "stair-step appearance." The Urban Annual Report process closely re-examines the most recent years to see if any of the trends or data should be altered (e.g., smoothing some of the stair steps into more continuous curves) to more closely reflect actual experience. This changes some data and measures for previous years. Any analysis should use the most recent report and data—they include the best estimates of the mobility statistics.

Why Is Free-Flow Travel Speed the Congestion Threshold?

The conditions in the middle of the day (or middle of the night) are the ones that travelers generally identify as desirable and use for comparison purposes. It is also relatively easy to understand that those conditions are not achievable during the peak travel periods without significant funding, environmental concerns and social effects. The decisions to make substantial improvements to achieve some desirable condition using investments in road, transit, operations, demand management or other strategies are products of detailed studies—studies that are not replicated in this report.

For the purposes of a national study, therefore, it is reasonable to set a congestion measurement baseline that everyone generally understands. Free-flow speed—which we estimate is 60 mph on freeways and 35 mph on major streets—is such a baseline. Speeds less than that will be an indication of delay. It is not intended to be the target for peak-hour conditions in urban corridors. The target setting exercise is discussed in more detail in a report section addressing "acceptable conditions" as targets.

Why Use Traffic Counts and Estimates Instead of "Real" Traffic Speeds?

Because there are not enough cities collecting enough high quality traffic speed data on enough roads, estimates are necessary. The Urban Mobility Report series seeks to understand congestion and mobility levels in many urban areas, and unfortunately, the best common database is one that has roadway design and traffic information. The estimation procedures are used to develop travel time and speed measures that can be used to communicate to a variety of audiences. This Annual Report also has some travel speed data from urban traffic operations centers, but until that information is more widely available, estimates will be required.

In the near future, these reports will also include estimates of the effects from several key improvements such as incident management, ramp metering, traffic signal coordination and high-occupancy vehicles lanes. The benefits of these projects are only indirectly included in the current methodology. When more cities and states conduct thorough evaluation studies and the comparison techniques are improved, the operations and demand management programs will be more completely characterized.

Detailed Speed Data and Reliability Information

The high quality speed data that are available were collected as part of the Mobility Monitoring Program (http://mobility.tamu.edu/mmp), a joint research effort of Texas Transportation Institute and Cambridge Systematics for the Federal Highway Administration (*24*). The MMP collected and analyzed detailed traffic volume and speed data for freeways in 29 cities for 2003. The data are prepared for 5-minute time intervals for sections of freeway between one-half and three miles in length. The base data sets were examined for quality and reasonable values and analyzed for a few key performance measures.

The continuous nature of this database provides a very good picture of the variation in conditions through the year—significantly better information than was available before. Variation or reliability in transportation conditions was studied with 2003 data. Some of that data is used in this report.

The detailed traffic operations center data also does not cover very much of the transportation system of the travel even in the most highly monitored cities. The percentage of the freeway system that was monitored during 2003 in the 29 Mobility Monitoring Program cities averaged around 50 percent. There was very little arterial street condition data. It is difficult to construct a set of city to city comparison measures or interpret the meaning of data under these conditions. While the data are very useful for examining issues, they are less useful for area or trend comparisons. Even the evaluation of incidents is hampered by the lack of arterial street data. Traffic that changes route from the freeway to a street experiences delay, but that delay is not counted because there is no monitoring equipment. So the “real” traffic data does not include all of the delay that occurs. Estimates are required to obtain a full picture of the congestion situation.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

MEASURES AND RANKINGS WITHIN POPULATION GROUPS—WHICH MEASURE SHOULD BE USED?

We recommend that several measures, as well as the trend in the measures over several years, be considered before any "official rank" is determined. Just as the report indicates there is no single "solution" to the mobility problems in most areas, there is also no single "best" measure. The measures illustrate different aspects of the congestion problems and improvement strategies.

There is a temptation to choose one measure to make the interpretations and message easy. As a minimum two of the "intensity" measures and one "magnitude" measure should be used to assess the mobility situation at an areawide level. At the corridor level, where solutions are implemented, more measures and more detailed analyses are needed to identify the most appropriate solution and evaluate the resulting effects. The measures reflect travel time concerns and can be applied to a variety of strategies. More information on these measures is available on the website: http://mobility.tamu.edu.

- Travel Time Index—the ratio of peak period travel time to free-flow travel time. The TTI expresses the average amount of extra time it takes to travel in the peak relative to free-flow travel. A TTI of 1.3, for example, indicates a 20-minute free-flow trip will take 26 minutes during the peak travel periods, a 6-minute (30 percent) travel time penalty. Free-flow travel speeds are used because they are an easy and familiar comparison standard, not because they should be the goal for urban transportation system improvements.
- Delay per Traveler—the hours of extra travel time divided by the number of urban area peak period travelers. This is an annual measure indicating the sum of all the extra travel time that would occur during the year for the average traveler. All urban travelers are used as the comparison device to better relate the delay statistics to those affected on the roadways.
- Cost of Congestion—the value of the extra time and fuel that is consumed during congested travel. The value of time for 2007 is estimated for passenger vehicles and trucks. The fuel costs are the per-gallon average price for each state. The value of a person's time is derived from the perspective of the individual's value of their time, rather than being based on the wage rate. Only the value of truck operating time is included; the value of the commodities is not. The value of time is the same for all urban areas.
- Change in Congestion—not a particular measure, but a concept used in many analyses. The trends in congestion are often more important than the absolute mobility levels, because they indicate if the right projects are selected and the proper amount of improvement is being funded to achieve the goals.

The mobility performance measures and the rankings based on them are useful for a variety of purposes. They are especially good at identifying multi-year trends and in comparing relative levels of congestion. As evidenced by the continual refinement of the measures, estimation procedures and data, however, this series of reports is still a "work-in-progress." One element of this uncertainty is that the measure values have an element of variation in them. All estimation procedures have simplifying assumptions that are not correct for every situation. And traffic data reflects the day-to-day variation in activity that affects traveler experiences. There are also locations or corridors in each urban area, especially those over one million population, where mobility levels are much lower than any average value. Those who frequently travel in these places may get a biased view of the urban areawide mobility level.

HOW SHOULD THE MEASURES AND RANKINGS BE INTERPRETED?

Most of the measures presented in the report address roadway systems. While the problems and solutions are not solely focused on roads, much of the data that are available relate to roads and vehicle travel. This year's report also includes operational improvement information and public transportation data at an areawide level. While this expands the scope of the data and measures, the effect of these strategies is often at a corridor or activity center area level where they are applied. So, while the road statistics may provide a picture of urban mobility levels, the addition of the public transportation data and operational treatment effects improve the usefulness of the comparisons.

On the "solution" side of the measures, the current database and methodology include roadway lanes, public transportation and traffic volumes for the database years, and statistics on a few operational improvements for 2000 through 2007. Most larger urban areas are expanding their use of these improvements and are also increasing the data and evaluation studies. The methodologies and more detailed description of estimating the mobility effect of the operational solutions and public transportation service is also investigated in a separate report also on the Urban Mobility Report website.

The estimates are not a replacement, a substitute or a better method of evaluating these strategies at the corridor or project level. The estimates included in this report are a way to understand the comparative mobility contributions of various strategies using a consistent methodology.

Another key manifestation of uncertainty is the ranking of the measures. Estimating the measures creates one set of variations—the "real" measure could be higher or lower—and the relatively close spacing of the measures mean that the rankings should be considered as an indication of the range within which the true measure lies. There are many instances where one or two hours of delay or one or two index points could move an urban area several ranking spots.

Rankings, whether with or without the operational improvements or public transportation service, should be examined by comparing the values for cities with similar population, density, geography or other key elements. The rankings of values with strategies are available for only the most recent year, and the performance measures are presented for mobility levels with and without the strategy contributions.

HOW CONGESTED ARE THE ROADS? ARE THEY GETTING WORSE?

Congestion levels and the trends in congestion growth are important aspects of the database. Where and when congestion occurs is important within an urban network, as well as for comparing urban areas to each other. Comparisons should include considerations such as, areawide congestion levels tend to be worse in the larger urban areas, but there are some isolated pockets of very bad traffic congestion in smaller urban areas that rival some locations in larger cities. Comparisons with areas of similar population are usually more informative than broader comparisons.

Conclusions

In general, traffic congestion is worse in the larger urban areas than in the smaller ones. Traffic congestion levels have increased in every area since 1982. Congestion extends to more time of the day, more roads, affects more of the travel and creates more extra travel time than in the past. And congestion levels have risen in all size categories, indicating that even the smaller areas are not able to keep pace with rising demand.

The need for attention to transportation projects is illustrated in these trends. Major projects or programs require a significant planning and development time—10 years is not an unrealistic timeframe to go from an idea to a completed project or to an accepted program. At recent growth rates, the urban area average congestion values will jump to the next highest classification—medium areas in 2017 will have congestion problems of large areas in 2007.

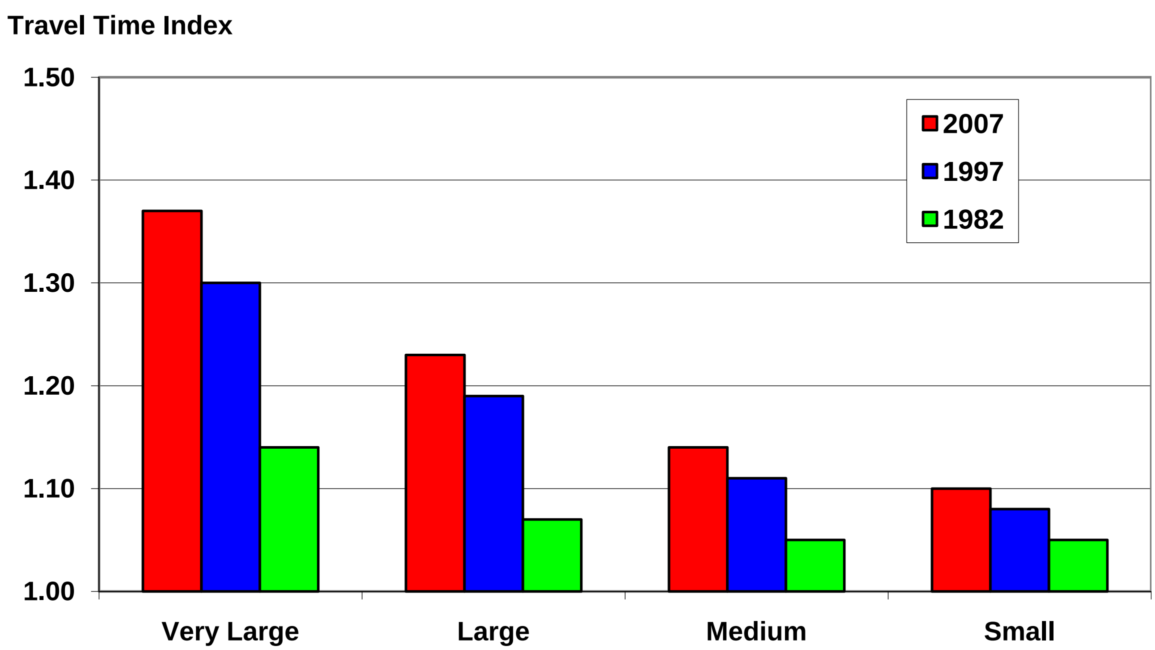
The Travel Time Index is one of two primary measures of extra travel time for travelers. (See Exhibit B-1). It measures the amount of additional time needed to make a trip during a typical peak travel period in comparison to traveling at free-flow speeds.

Travel delay per peak traveler is the other individual measure that provides estimates of the mobility levels (see Exhibit B-2). The extra travel time per year can be related to many other activities and may be more relevant for some discussions.

The extra travel time each year is a combination of the extra travel time for each trip (as measured by the TTI), the trip distance and the number of trips. The effect of this difference is relatively modest in most areas—that is, the TTI and delay per traveler tell basically the same story. The rankings are similar and the pattern of growth or decline are about the same. In some areas, however, the two values lead to different conclusions.

Portland is one area where the multiple performance measures help illustrate the effect of the transportation and land use policies that are being pursued to create a denser urban area that is better served by public transportation. The Travel Time Index and the delay per traveler values have both increased since 1982, indicating an increase in congestion. The Travel Time Index for Portland grew faster from 1982 to 2007 than it has for the majority of the other areas in the Large urban group. Delay per traveler, however, has grown at a rate closer to the Large area average, indicating that delay has not grown as rapidly as the per-minute travel time penalties have declined. Perhaps the urban growth and transportation policies are encouraging shorter trips and travel on light rail and other modes.

Exhibit B-1. Travel Time Index Trends

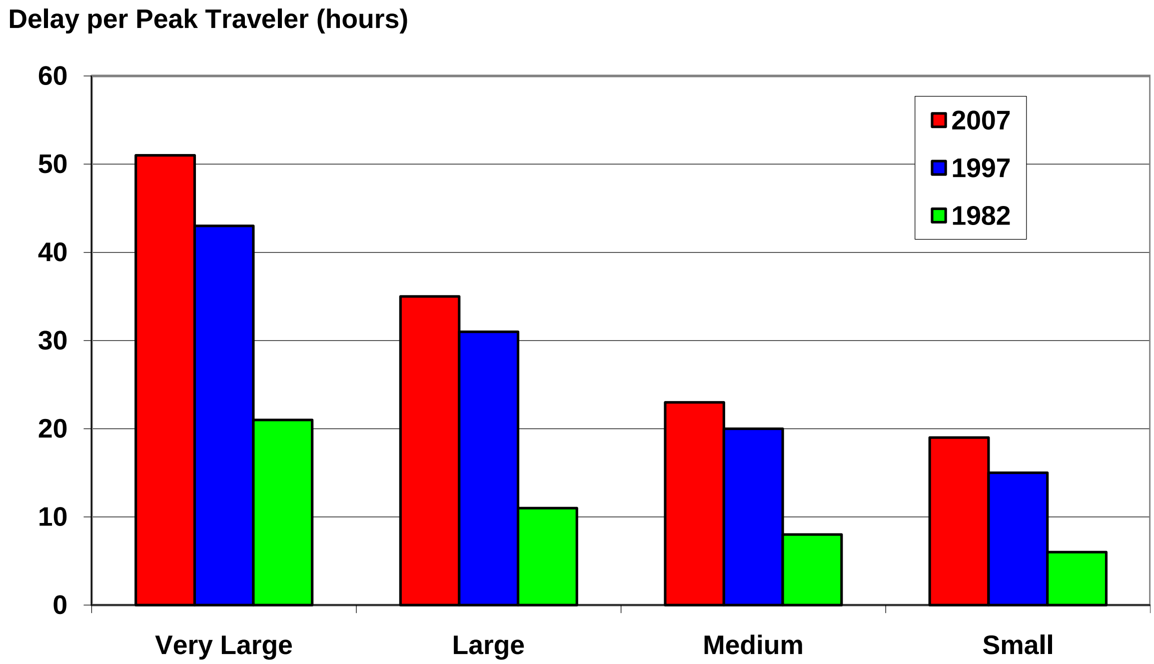


Note: The Travel Time Index is a ratio of average peak period to free-flow travel time. A value of 1.30 indicates a free-flow trip of 20 minutes takes 26 minutes in the peak due to heavy traffic demand and incidents.

- The average TTI for all 439 urban areas is 1.25. Thus, an average 20-minute off-peak trip takes 25 minutes to complete during the peak due to heavy traffic demand and incidents.
- Congestion problems tend to be more severe in larger cities. The average TTI for each individual population group ranges from 1.37 in the Very Large areas down to 1.10 in the Small urban areas.
- The average increase in the travel time penalty was 19 points (1.10 to 1.29) between 1982 and 2007. This gap ranges from 23 points in the Very Large group to 7 points in the Small population group.
- Nineteen of the 439 urban areas have a TTI of at least 1.30. All of these urban areas are in the Very Large and Large population groups—they have populations greater than one million.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-2. Delay per Peak Traveler Trends



- The average delay per peak traveler in the 439 urban areas is 36 hours.
- There are 9 urban areas with delay per peak traveler values in excess of 50 hours, showing the effect of the very large delays in the areas with populations larger than 1 million.
- The average delay per peak traveler in the Medium population group is about the same as the average delay in the Very Large population group in 1982.

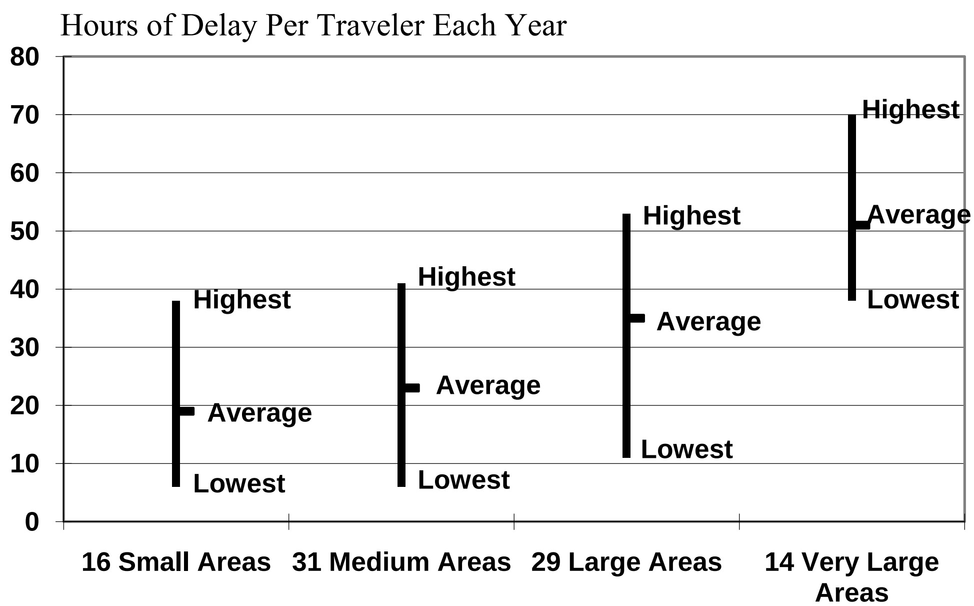
The average delay per peak traveler in the Small population group is about the same as the average delay in the Medium group in 1997.

WHAT CONGESTION LEVEL SHOULD WE EXPECT?

Congestion travel time penalties are related to size of the area, and Exhibit B-3 illustrates this. The Delay per Traveler decreases as population does, but there is a significant amount of variation within the groups. Areas that have seen high rates of growth in recent years are more likely to be near the top of their population group because demand will increase much faster than the roadway, public transportation service, operational treatments and land use patterns.

- Areas with populations over 3 million (Very Large) should expect a minimum delay per traveler of 38 hours.
- Areas over 1 million (Large and Very Large) should expect a delay per traveler of at least 11 hours with a more likely value of around 35 hours.
- Areas over one-half million (all except Small) should expect at least 6 hours with typical values being closer to 23 to 51 hours.
- Areas less than a half million (Small) should expect a delay per traveler of up to 38 hours.

Exhibit B-3. Congestion and Urban Area Size, 2007



CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

HOW FAR HAS CONGESTION SPREAD?

Traffic congestion affects a broader segment of the transportation system each year. Several dimensions are explored within this report. Congestion has spread to **more cities** to **more** of the **road system** and **trips** in cities to **more time** during the day and to **more days** of the week in some locations.

Conclusions

Congestion has spread significantly over the 20 years of the study. A few notable changes from 1982 to 2007 include:

- Nineteen urban areas have a Travel Time Index above 1.30 compared with no areas in 1982.
- Sixty-three percent of the peak period travel is congested compared to 29 percent in 1982.
- Forty-eight percent of the major road system is congested compared to 29 percent in 1982.
- The number of hours of the day when congestion might be encountered has grown from about 4.2 hours to about 7.0 hours.

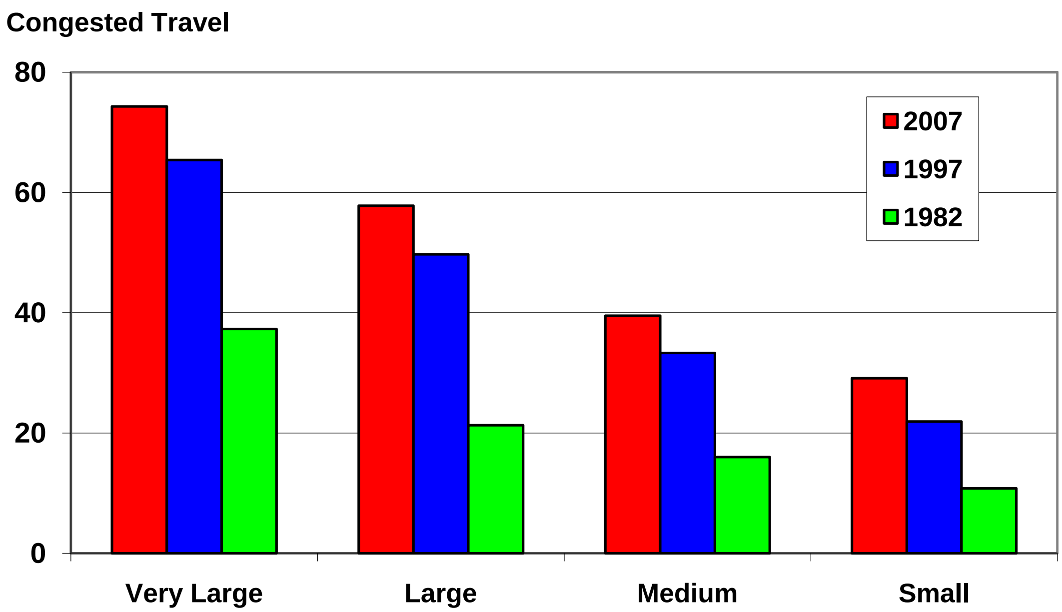
Most of the trend information indicates that the 2007 average values for each population group are above the 1997 value for the next highest population group. This is also the case for the 1997 and 1982 comparison. This suggests that congestion problems grow at about the rate of one population group every 10 or 15 years. So in the time it takes to enact solutions for one size of problem, congestion has worsened.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Congested Travel

The amount of traffic experiencing congested conditions in the peak travel periods (three hours in the morning and three hours in the afternoon) has doubled in 20 years of the study from 29 percent in 1982 to 63 percent in 2007. This means that two of every three cars experience congestion in their morning or evening trip. Exhibit B-4 provides more information on this trend.

Exhibit B-4. Percent of Travel in Congested Conditions

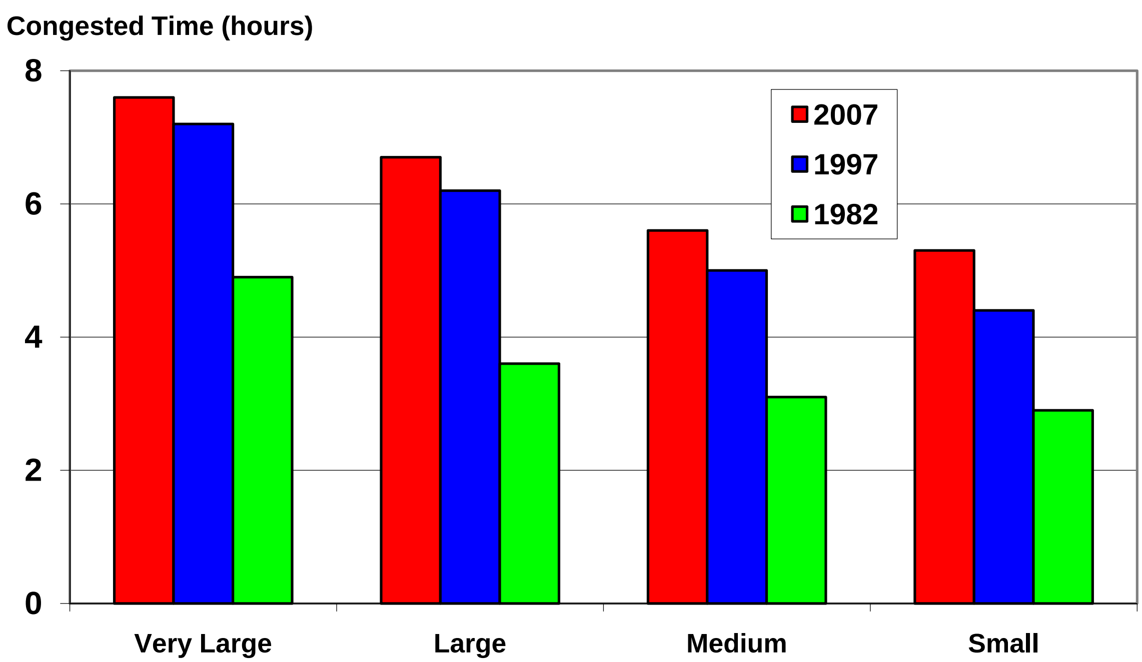


- The range of travel experiencing congestion grew from between 11 percent and 37 percent in 1982 to between 29 percent and 74 percent in 2007.
- The average percentage has increased to the next highest population group approximately each decade.

Congested Time

From the traffic database that is used for this study, it is uncertain exactly how long the congested periods last in each urban area. We can estimate, however, the amount of travel that occurs during times of the day when travelers **may** encounter congestion. This is not the amount of time when congestion occurs on a particular segment of road, but rather is the time when congestion occurs on some part of the road system. Exhibit B-5 shows the average length of the congested periods for each population group for 1982, 1997 and 2007.

Exhibit B-5. Hours of Day When Congestion May Occur

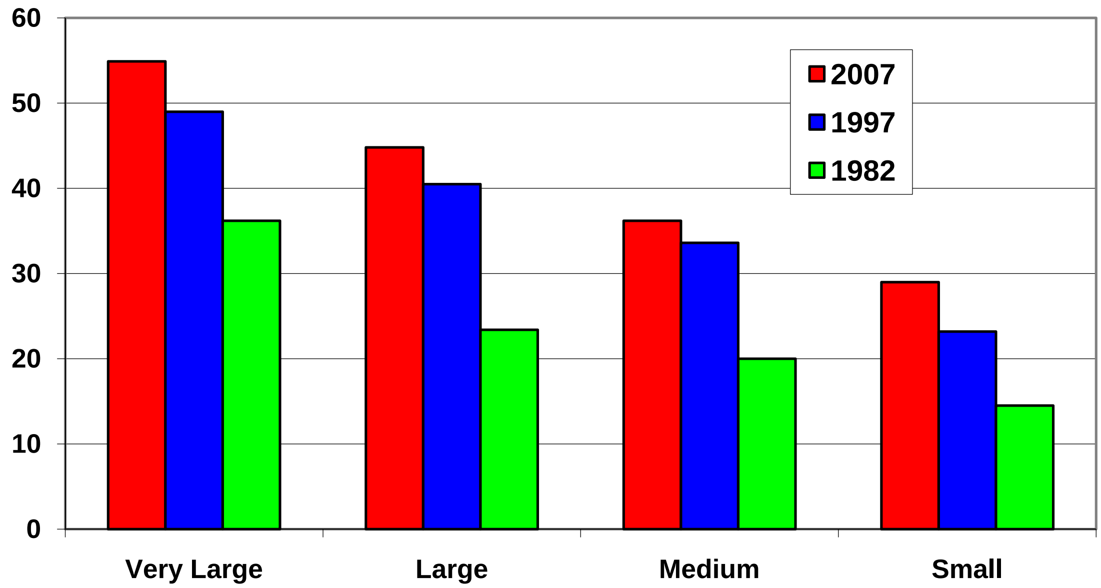


- The time when congestion might be encountered on major urban roads has grown in all population categories.
- The congested time in the morning and evening is near 3 hours in even the Small group—indicating that in many areas the term "rush hour" does not convey the length of time travelers may suffer slowdowns.
- Slow conditions might be encountered for 3 hours in each peak period in areas above 500,000. The amount of slowdown does not appear to be as great in the smaller areas.
- Three hours of congestion in each peak does not extend to the entire urban area, but some travelers must allow for extra time during a substantially longer portion of the day.

Congested Roads

The amount of roadways (freeways and principal arterial streets) that is congested during the peak period is shown in Exhibit B-6 for 1982, 1997 and 2007. The percentage of the major roadway system that is congested has risen from 29 percent in 1982 to 48 percent in 2007.

Exhibit B-6. Percentage of Roads that Experience Some Congestion During Peak Periods



- The percentage of roads where congestion might occur in the peak period has about doubled in the Small, and nearly doubled in the Medium and Large areas since 1982.
- The largest percentage point increase has occurred in the Large areas.
- Each of the population groups has a 2007 value close to the 1997 value for the next highest population group.

Growth in Delay and Congested Travel

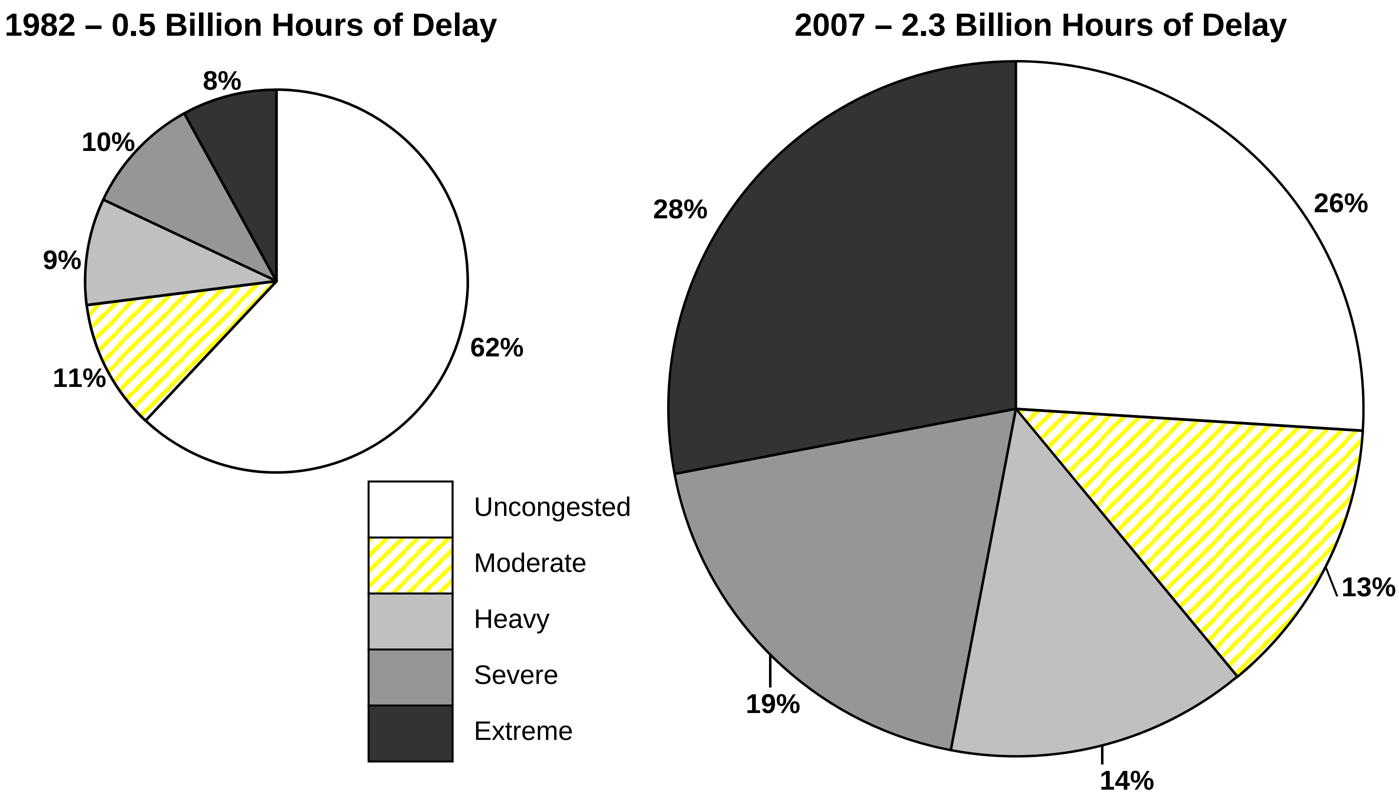
This section provides a graphical comparison for each of the four population groups in the Urban Mobility Report. There are two circles on each page representing conditions in 1982 and 2007.

- The growth in the area of the circle represents the growth in travel delay for all the cities in the group from 1982 to 2007.
- The amount of miles traveled during the peak period in each of five congestion levels is also displayed for each year to give a perspective on the change in conditions experienced by travelers.

Exhibits B-7 through B-10 illustrates conditions for the four population groups.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

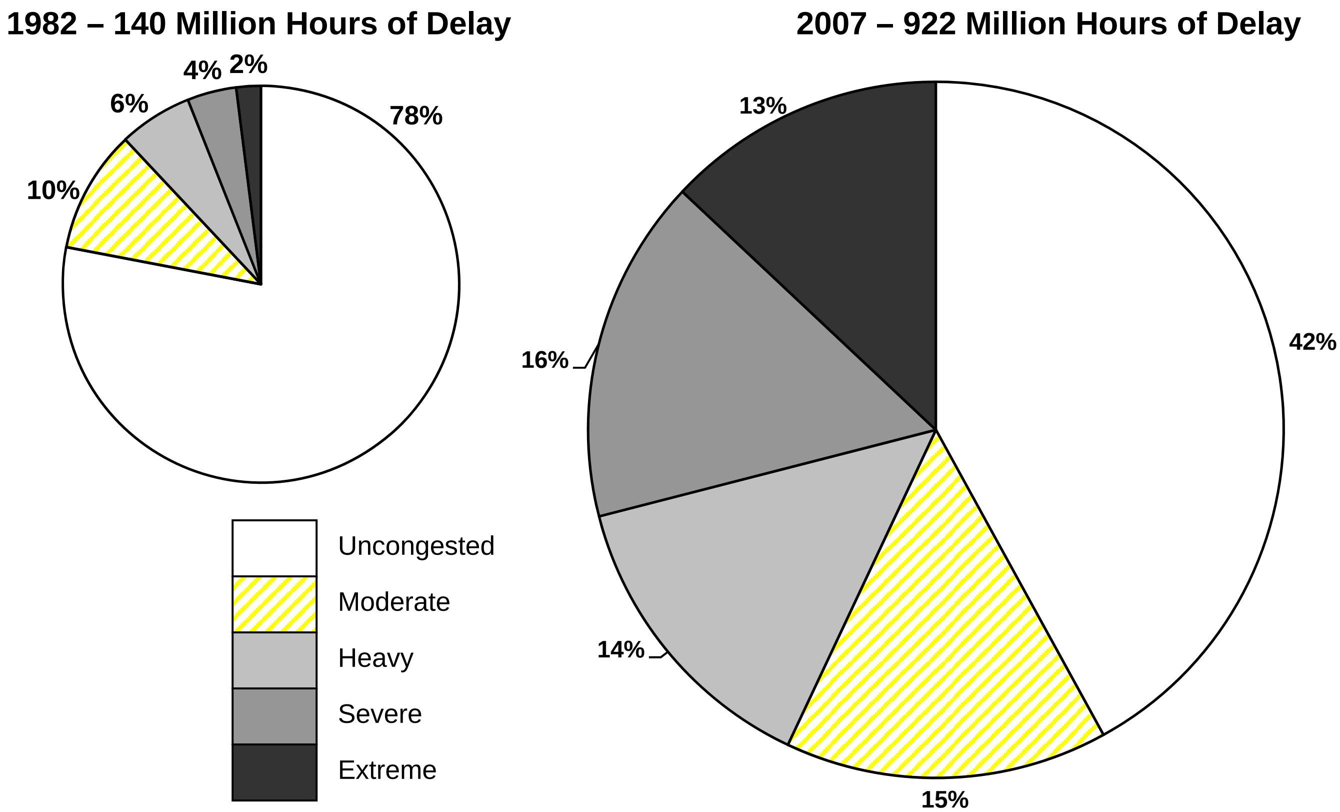
Exhibit B-7. Very Large Urban Area Travel Conditions



- Fourteen urban areas are included in this group representing 54 percent of the population and 65 percent of the travel delay in 2007.
- Delay grew approximately 340 percent from 1982 to 2007.
- There was significant growth in the severely and extremely congested volume ranges with travel increasing from about 18 percent to almost 50 percent.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

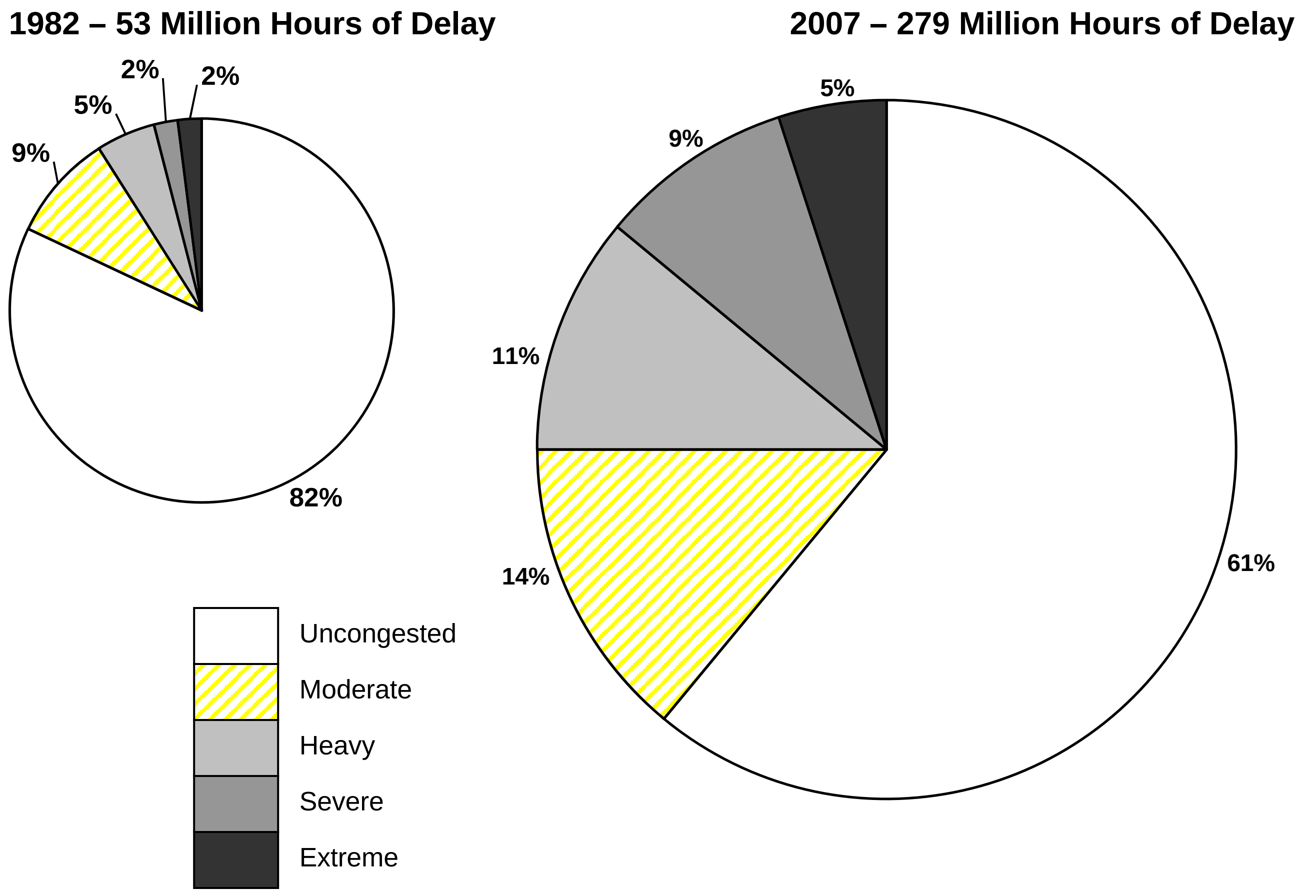
Exhibit B-8. Large Urban Area Travel Conditions



- Twenty-nine urban areas are included in this group representing 29 percent of the population and 26 percent of the travel delay in 2007.
- Delay grew 555 percent from 1982 to 2007.
- There was almost no travel in the two most congested categories in 1982, while those ranges now account for almost 1/3 of peak travel.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

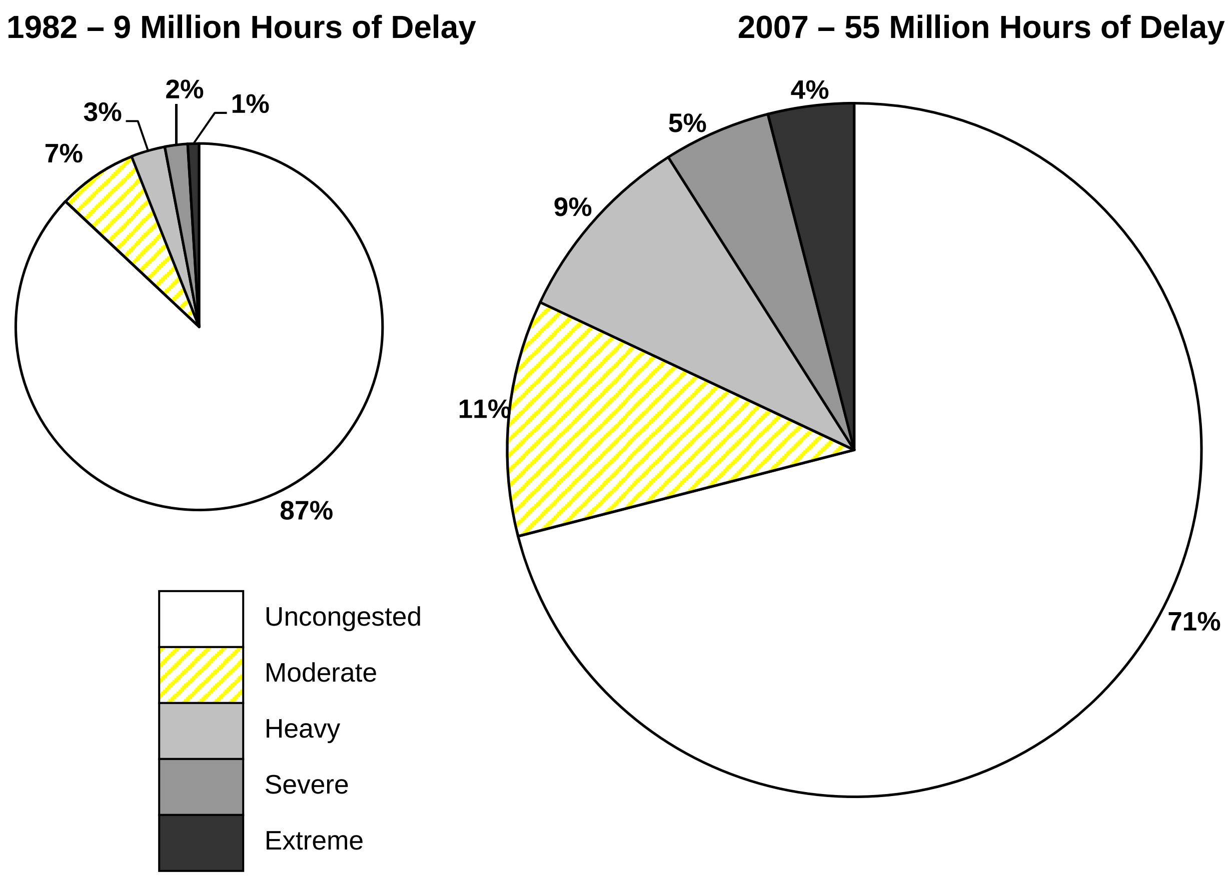
Exhibit B-9. Medium Urban Area Travel Conditions



- Thirty urban areas are included in this group representing 14 percent of the population and 8 percent of the travel delay in 2007.
- Delay grew 425 percent from 1982 to 2007.
- Travel in the congested regions now accounts for almost 40 percent of travel during the peak, compared to less than half this amount in 1982.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-10. Small Urban Area Travel Conditions



- Sixteen urban areas are included in this group representing 3 percent of the population and 2 percent of the travel delay in 2007.
- Delay grew 510 percent from 1982 to 2007.
- Congestion, although not a significant problem for most peak period travel, has increased to about 30 percent of peak travel miles.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

WHAT DOES CONGESTION COST US?

Congestion has several effects on travelers, businesses, agencies and cities. One significant element is the value of the additional time and wasted fuel. The top 14 urban areas include about two-thirds of the delay estimated for 2007, and the top 20 areas account for over 75 percent of annual delay. Some other highlights include:

- In 2007, congestion (based on wasted time and fuel) cost about $87.2 billion in the 439 urban areas, compared to $87.1 billion (in constant dollars) in 2006. (See Exhibits B-11 and B-12).
- The average cost per traveler in the 439 urban areas was $757 in 2007, down from $758 in 2006 (using constant dollars). The cost ranged from an average of $1,084 per traveler in Very Large urban areas down to $384 per traveler in the Small areas.
- Exhibits B-13 and B-14 show that 2.8 billion gallons of fuel were wasted in the 439 urban areas. This amount of fuel would fill 56 super-tankers or 370,000 gasoline tank trucks.
- The urban areas with populations greater than 3 million accounted for 1.6 billion gallons (almost two-thirds of the national estimate) of wasted fuel.
- The amount of wasted fuel per traveler ranges from 35 gallons per year in the Very Large urban areas to 11 gallons per year in the Small areas.

Exhibit B-11. Congestion Effects on the Average Traveler – 2007

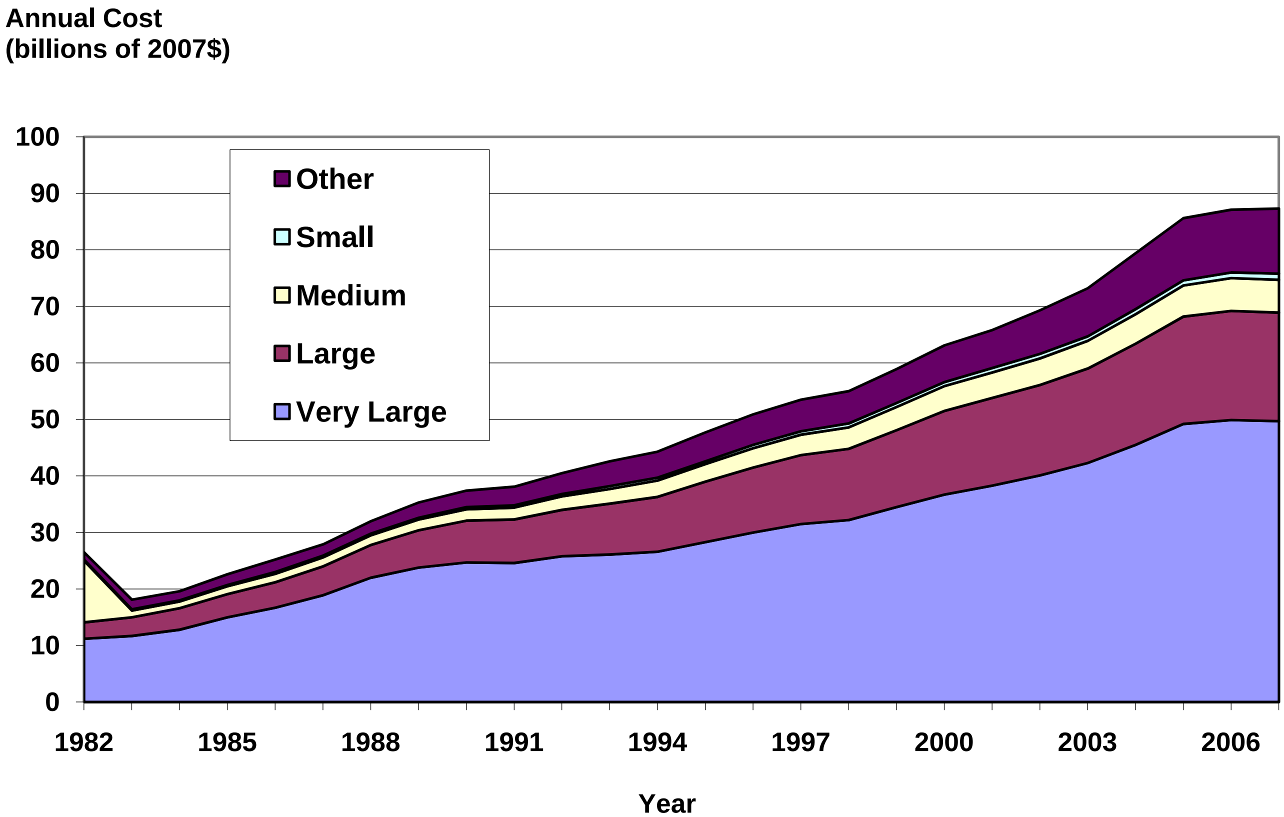
	Congestion Statistics per Traveler		
Population Group	**Average Cost ($)**	**Average Delay (hours)**	**Average Fuel (gallons)**
Very Large areas	1,084	51	35
Large areas	734	35	24
Medium areas	481	23	15
Small areas	384	19	11
Other Urban Areas	404	20	12
439 Area Average	757	36	24
439 Area Total	$87.2 billion	4.2 billion	2.8 billion

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

What is the Total Cost of Congestion?

The total cost of congestion for each population size group is shown in Exhibit B-12. This cost accounts for the amount of wasted time and fuel due to traffic congestion. The total cost of congestion in the urban areas is $87.2 billion in 2007 or an average of $757 per peak period traveler.

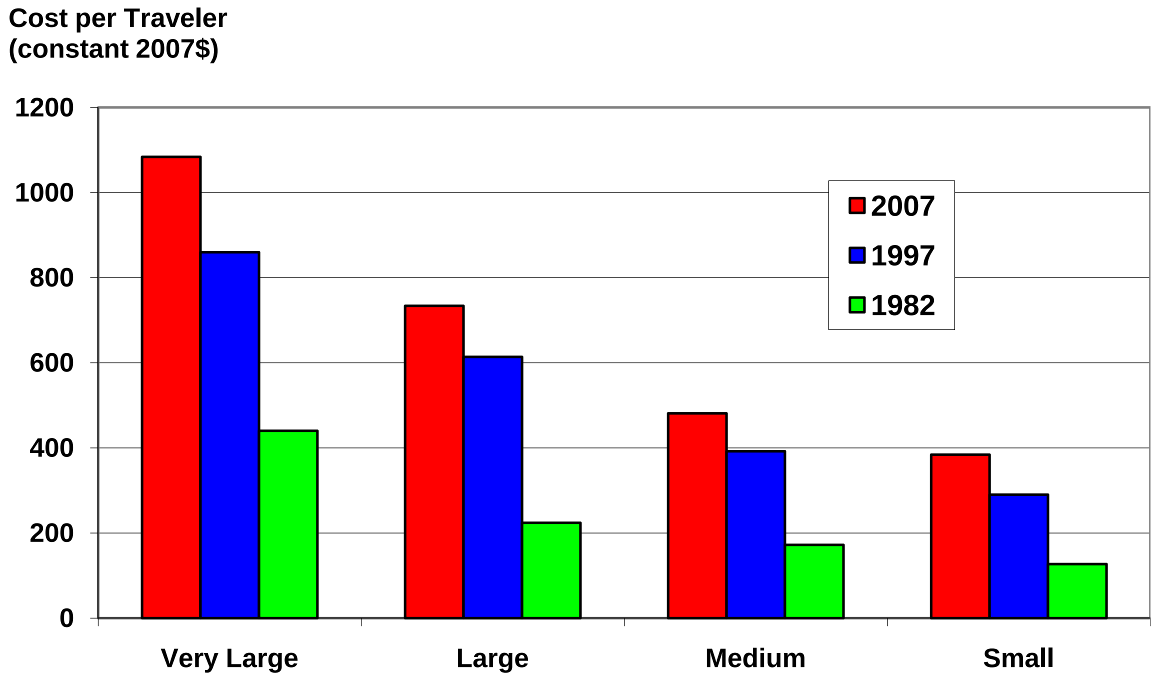
Exhibit B-12. Annual Cost of Congestion



- Twenty-one urban areas had a total annual congestion cost of at least $1 billion each.
- The areas with populations over 3 million persons account for about 57 percent of the congestion cost.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-13. Annual Cost of Congestion per Traveler



What is the cost of congestion for me?

The total cost of congestion is divided by the number of peak period travelers to determine the effect of congestion on an individual (Exhibit B-13). The average annual cost to each of these travelers in the 439 urban areas is about $757.

- Travelers of 74 areas are "paying" more than $1 per workday in congestion costs; 45 areas have a congestion value exceeding $2 per workday.

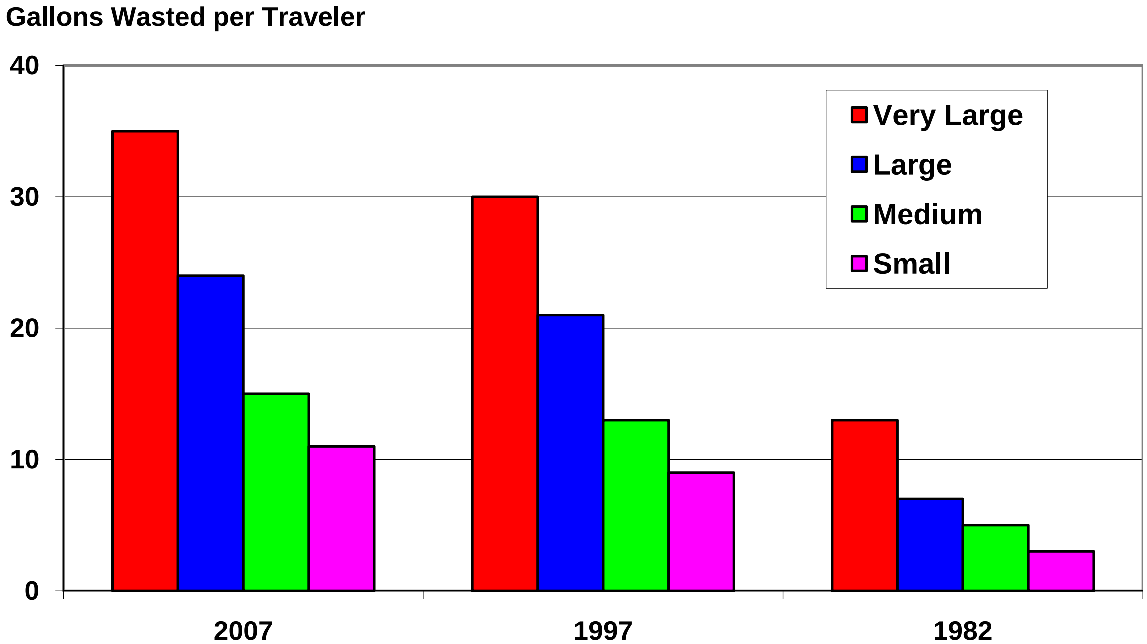
- The average cost of congestion per traveler ranged from $1,084 in the Very Large population group to $384 in the Small population group in 2007.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

How Much Fuel is Wasted in Congestion?

As with cost, the amount of fuel wasted in congestion is divided by the estimated number of persons in the urban area. This provides an estimate of the amount of fuel consumed for each individual because of congestion (Exhibit B-14), a quantity that can be compared to other per capita consumptions. More than 28 gallons are wasted per traveler in the 439 urban areasThe average amount of wasted fuel per traveler in 2007 in the 439 study areas was 28 gallons.

Exhibit B-14. Wasted Fuel per Traveler



- The amount of wasted fuel per traveler ranged from 11 gallons in the Small population group to 35 gallons in the Very Large population group in 2007.

- The total amount of wasted fuel in the 439 urban areas was approximately 2.8 billion gallons in 2007.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

CAN MORE ROAD SPACE REDUCE CONGESTION GROWTH?

Conclusions

The analysis shows that **changes** in roadway supply have an effect on the **change** in delay. Additional roadways reduce the rate of increase in the amount of time it takes travelers to make congested period trips. In general, as the lane-mile "deficit" gets smaller, meaning that urban areas come closer to matching capacity growth and travel growth, the travel time increase is smaller. It appears that the growth in facilities has to be at a rate slightly greater than travel growth in order to maintain constant travel times, if additional roads are the only solution used to address mobility concerns. It is clear that adding roadway at about the same rate as traffic grows will slow the growth of congestion.

It is equally clear, however, that only nine of the 90 intensively studied urban areas were able to accomplish that rate. There must be a broader set of solutions applied to the problem, as well as more of each solution than has been implemented in the past, if more areas are to move into the "maintaining conditions or making progress on mobility" category.

Analyses that only examine comparisons such as travel growth vs. delay change or roadway growth vs. delay change are missing the point. The only comparison relevant to the question of road, traffic volume and congestion growth is the relationship between all three factors. Comparisons of only two of these elements will provide misleading answers.

The analysis in this section (shown in Exhibit B-15) addresses the issue of whether or not roadway additions made significant differences in the delay experienced by drivers in urban areas. These years saw a range of economic conditions but a relatively consistent pattern between demand or population growth and increase in congestion. Rapid population growth was usually accompanied by significant congestion growth, while slow growth saw less congestion growth. The length of time needed to plan and construct major transportation improvements, however, means that very few areas see a rapid increase in economic activity and population without a significant growth in congestion. It also reinforces the idea that congestion is not a problem that can be addressed and then ignored for a decade.

Two measures are used to answer this question.

1. The Travel Time Index (TTI) is a mobility measure that shows the additional time required to complete a trip during congested times versus other times of the day. The TTI accounts for both recurrent delay and delay caused by roadway incidents.
2. The difference between lane-mile increases and traffic growth compares the change in supply and demand. If roadway capacity has been added at the same rate as travel, the deficit will be zero. The two changes are expressed in percentage terms to make them easily comparable. The changes are oriented toward road supply because transportation agencies have more control over changes in roadway supply than over demand changes. In most cases in the Urban Mobility Report database, traffic volume grows faster than lane-miles.

Exhibit B-15 shows the ratio of changes in demand (miles traveled) and supply (roadway) and the resulting change in the mobility level measured by the Travel Time Index. If road growth is a useful strategy for reducing the growth of congestion, lane-mileage increases that are faster than the traffic growth should improve conditions. If adding roads is not an effective strategy, the relationship between added roads and added demand will not indicate lower congestion growth for a demand-supply balance.

The 90 intensively studied urban areas were divided into three groups based on the differences between lane-mile growth and traffic growth. If an area's traffic volume grew relatively slowly, the road capacity would need to only grow slowly to maintain a balance. Faster traffic growth rates would require more road capacity growth. The key analysis point is to examine the **change** in demand, the **change** in supply and the **change** in congestion levels. This allows fast growth cities that have built roads in approximately the same rate that demand has grown to be judged against other areas where demand and supply changes have been balanced.

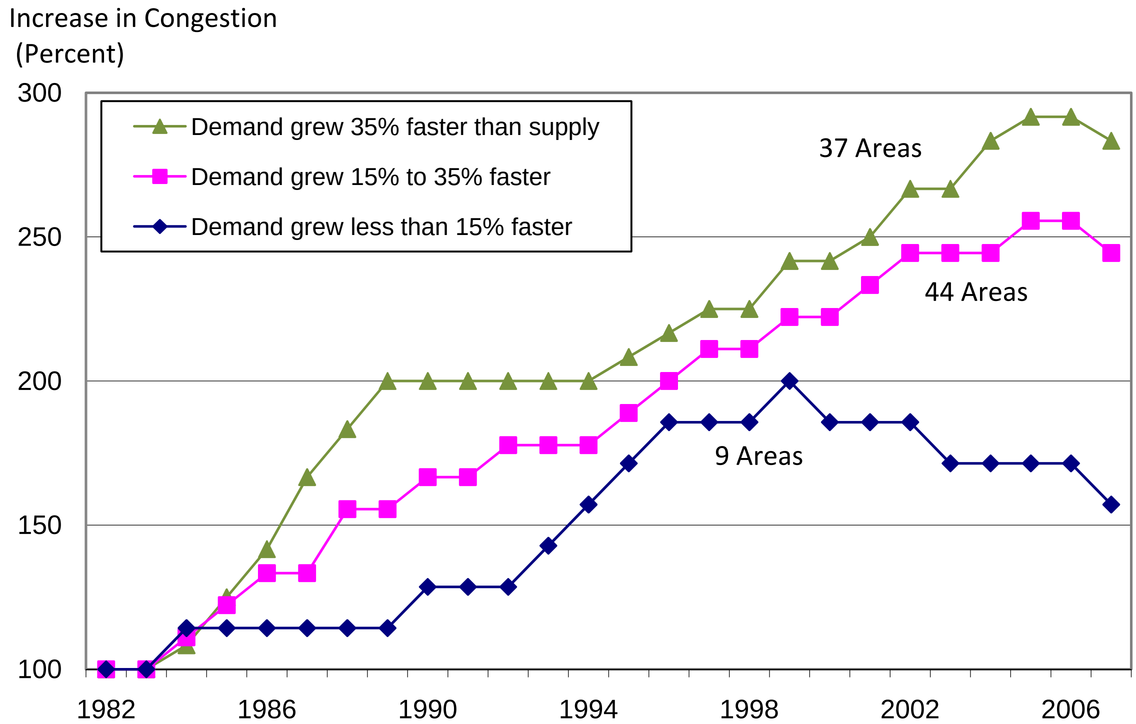
The four groups were arranged using data from 1982 to 2007:

- **Significant mismatch** – Traffic growth was more than 355 percent faster than the growth in road capacity for the 37 urban areas in this group.
- **Moderate mismatch** – Traffic growth was between 15 and 35 percent greater than road growth. There were 44 urban areas in this group.
- **Narrow gap** – Road growth was within 15 percent of traffic growth for the 9 urban areas in this group.

The resulting growth in congestion is charted in Exhibit B-15, and the cities in each group are listed in Exhibit B-16. The Travel Time Index values were compared to the 1982 values to examine the growth in extra travel time each year (in a manner similar to the Consumer Price Index).

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-15. Road Growth and Mobility Level



Note: Legend represents difference between traffic growth and road additions.

- A general trend appears to hold—the more that travel growth outpaced roadway expansion, the more the overall mobility level declined.
- The nine urban areas with a demand-supply growth balance had their congestion levels increase at a much lower rate than those areas where travel increased at a much higher rate than capacity expansion. The demand increases in some of these areas was also relatively low compared to other areas in the study, which made it easier to add roads at the needed rate.
- The recession in California in the early 1990s and the combination of the economy and increased road construction efforts in Texas in the late 1980s and early 1990s affects the change in congestion levels during that time.
- The number of areas in each group is another significant finding. Only nine urban areas were in the Narrow Gap group. Three of those, St. Louis, Pittsburgh and New Orleans, had populations greater than 1 million. Dayton, Palm Springs, Lancaster, Poughkeepsie, Allentown are in the Medium population group. Anchorage is from the Small population group. Most of these areas had relatively low population growth rates, indicating that the low demand growth may have been responsible for their inclusion in this group, rather than rapid road construction.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-16. Urban Area Demand and Roadway Growth Trends

Less Than 15% Faster (9)
- Anchorage AK
- Dayton OH
- Indio-Cathedral City-Palm Springs CA
- Lancaster-Palmdale CA
- New Orleans LA
- Pittsburgh PA
- Poughkeepsie-Newburgh NY
- St. Louis MO-IL
- Wichita KS

15% to 35% Faster (44)
- Allentown-Bethlehem PA-NJ
- Bakersfield CA
- Beaumont TX
- Boulder, CO
- Boston MA-NH-RI
- Brownsville TX
- Buffalo NY
- Charleston-North Charleston SC
- Charlotte NC-SC
- Cleveland OH
- Corpus Christi TX
- Denver-Aurora CO
- Detroit MI
- El Paso TX-NM
- Eugene OR
- Fresno CA
- Grand Rapids MI
- Honolulu HI
- Houston TX
- Indianapolis IN
- Kansas City MO-KS
- Knoxville TN
- Louisville KY-IN
- Memphis TN-MS-AR
- Milwaukee WI
- Nashville-Davidson TN
- Oklahoma City OK
- Omaha NE-IA
- Philadelphia PA-NJ-DE-MD
- Phoenix AZ
- Portland OR-WA
- Richmond VA
- Rochester NY
- Salem OR
- Salt Lake City UT
- San Jose CA
- Seattle WA
- Spokane WA
- Springfield MA-CT
- Tampa-St. Petersburg FL
- Toledo OH-MI
- Tucson AZ
- Tulsa, OK
- Virginia Beach VA

More Than 35% Faster (37)
- Akron OH
- Albany-Schenectady NY
- Albuquerque NM
- Atlanta GA
- Austin TX
- Baltimore MD
- Birmingham AL
- Bridgeport-Stamford CT-NY
- Cape Coral, FL
- Chicago IL-IN
- Cincinnati OH-KY-IN
- Colorado Springs CO
- Columbia SC
- Columbus, OH
- Dallas-Fort Worth-Arlington TX
- Hartford CT
- Jacksonville FL
- Laredo TX
- Las Vegas NV
- Little Rock AR
- Los Angeles-L Bch-Santa Ana CA
- Miami FL
- Minneapolis-St. Paul MN
- New Haven CT
- New York-Newark NY-NJ-CT
- Orlando FL
- Oxnard-Ventura CA
- Pensacola FL-AL
- Providence RI-MA
- Raleigh-Durham NC
- Riverside-San Bernardino CA
- Sacramento CA
- San Antonio TX
- San Diego CA
- San Francisco-Oakland CA
- Sarasota-Bradenton FL
- Washington DC-VA-MD

HOW MUCH MORE TRANSPORTATION CAPACITY WOULD BE NEEDED?

This is a difficult question to answer for at least two reasons.

- Most urban areas implement a wide variety of projects and programs to deal with traffic congestion. Each of these projects or programs can add to the overall mobility level for the area. Thus, isolating the effects of roadway construction is difficult because these other programs and projects are making a contribution at the same time.
- The relevancy of the analysis is questionable. Many areas focus on managing the growth of congestion, particularly in rapid growth areas. The analysis presented here is not intended to suggest that road construction is the best or only method to address congestion, but some readers will interpret it that way.

Conclusions

This analysis shows that it would be almost impossible to attempt to maintain a constant congestion level with road construction only. Over the past 2 decades, less than 50 percent of the needed mileage was actually added. This means that it would require at least twice the level of current-day road expansion funding to attempt this road construction strategy. An even larger problem would be to find suitable roads that can be widened, or areas where roads can be added, year after year. Most urban areas are pursuing a range of congestion management strategies, with road widening or construction being only one of them.

How Much Roadway has been Added?

Before we discuss the road growth issue, a word about our data. One answer to the question "How much roadway has been added?" is "not as much as our statistics indicate." The roadway growth in the Urban Mobility Report database includes the roads that were added because the urban boundary grew to include areas that previously were classified as rural. These existing, but newly urbanized, roads appear as additions to the urban databases, but do not have the same effect as new roadway. Even including these redesignated roads, however, the amount of added roadway is considerably less than that needed to match travel volume growth.

Estimating the Needed Road Growth

This analysis uses the premise that enough road construction should take place so that the areawide congestion level is kept constant. For every percent increase in vehicle-miles of travel, it is assumed that there should be a similar percent increase in the lane-miles of roadway. For example, if a region's vehicle-miles of travel were to increase by five percent per year, roadway lane-miles would need to increase by five percent each year to maintain the initial congestion level. Based on these assumptions, the percentage of the "Needed" roadway that has been "Added" can be calculated (Exhibit B-17). The 1982 to 2007 statistics show:

- Over the 26-year period, less than half of the roadway that was needed to maintain a constant congestion level was added. These percentages are actually higher than the amount that was "constructed" since they also include roadway mileage that was added through shifting urban boundaries and not just new construction.
- Exhibit B-18 also shows that the larger urban areas have done a little better, on average, at maintaining pace with the growth of travel.

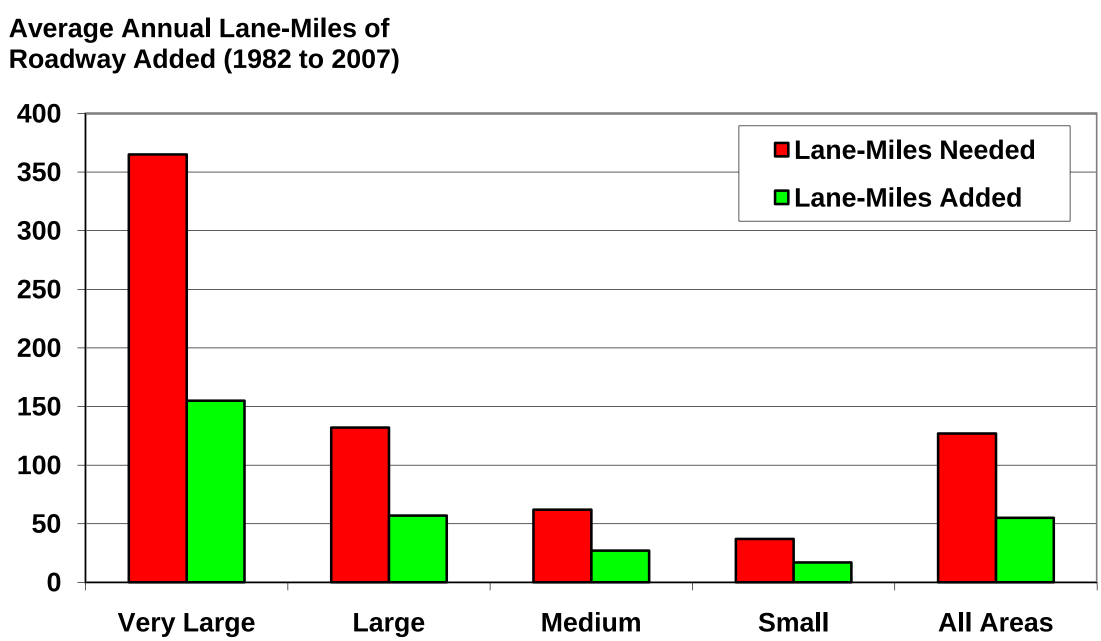
Exhibit B-17. Vehicle Travel and Roadway Additions

2007 Population Group Average	Avg. Annual Growth in Vehicle-Miles of Travel (1982 to 2007)	Percentage of Needed Roadway Added[1]
Very Large areas	2.9	43
Large areas	3.5	43
Medium areas	3.3	43
Small areas	3.8	47
90 area average	3.2	43

[1] Lane-miles added divided by lane-miles needed. "Lane-miles needed" are based on matching the VMT growth rate.

Note: Assumes that all added lane-miles are roadway system expansion. The database does not include data concerning the number of lane-miles added because of changing urban boundaries.

Exhibit B-18. Comparison of Roadway Added to Needed



- Over the 26-year period, less than half (43 percent) of the roadway that was needed to maintain a constant congestion level was actually added.
- There is very little difference between the roadway added percentage values for any of the population groups. Areas of all sizes are approximately equal in ability to add lane-miles.

HOW MANY NEW CARPOOLS OR BUS RIDERS WOULD BE NEEDED IF THEY WERE THE ONLY SOLUTION?

Another method of examining the role and potential of public transportation is to examine the amount of service that would be required to address the growing delay problem if this were the only solution. Just as with the "roadway construction" only solution, this analysis will focus on the changes in occupancy level needed to accommodate travel growth. The results from this analysis show the increase in occupancy level in order to maintain existing congestion levels. But they are not intended to suggest that this is a realistic solution.

Conclusions

The 90 urban areas in the Urban Mobility Report added almost 60 million additional miles of daily person travel in 2007. To accomplish a goal of maintaining a constant congestion level in these areas by only adding transit riders of carpoolers, there would have to be a substantial growth in these modes. The growth would be equivalent to an additional 3 or 4 percent of all vehicles becoming carpools, or expanding transit systems by more than one-third of the current ridership each year.

It may be very difficult to convince this many persons to begin ridesharing or riding transit. As indicated elsewhere in this report, some success with this solution, in conjunction with other techniques may give an urban area the opportunity to slow the mobility decline.

Vehicle travel growth is estimated with the annual growth rate for the previous five years. Passenger-miles of travel are estimated using the standard 1.25 persons per vehicle value used elsewhere in the study. The growth in demand is estimated and the number of added passenger-miles of travel is divided by a simple national average trip length to estimate the number of additional trips that would have to be made by carpool or transit. Average trip lengths vary by metropolitan area. The length of a trip can have an effect on how much exposure a traveler has to congestion. For purposes of comparison, however, this report assumes one trip length for all areas.

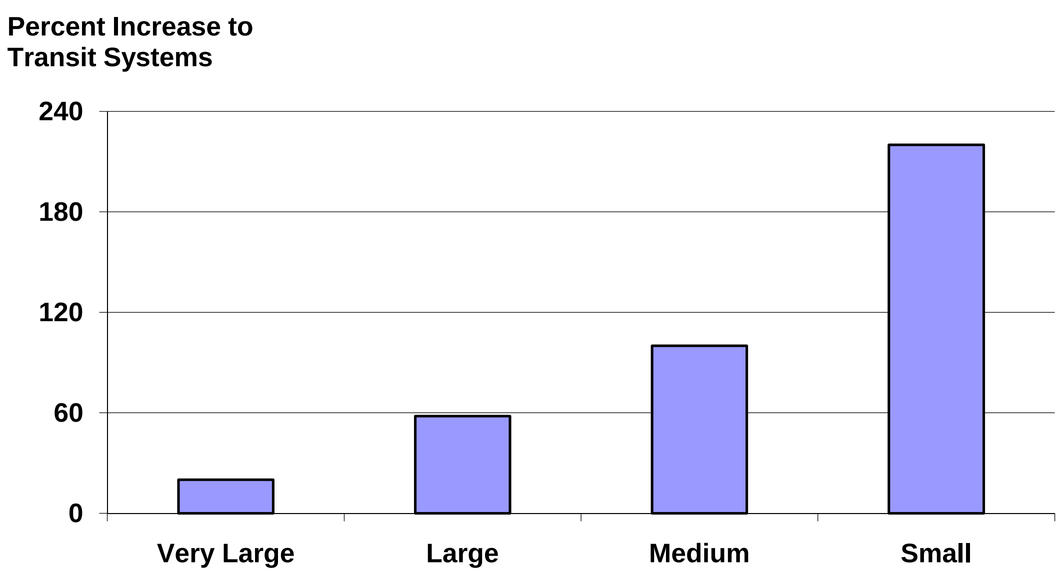
- 6.1 million trips per day would have to be made as carpools or bus trips in the 90 urban areas to handle the 55 million additional person-miles of travel if congestion levels are to remain constant.
- On average, the occupancy of each vehicle in the 90 urban areas would have to rise by about 0.03 persons or, in other words, 3 out of every 100 vehicles would have to become a new 2-person carpool to handle one year's growth.

How Many Trips Would be Needed on Transit?

Transit, like ridesharing, park-and-ride lots and high-occupancy vehicle lanes, typically have a greater effect on the congestion statistics in a corridor, rather than across a region. Transit and these other elements "compete" very well with the single-occupant vehicle in serving dense activity centers and congested travel corridors. But it is also useful to examine the data at the urban area level. Ridership statistics were gathered for the 90 intensively studied urban areas to determine how much more travel the systems would have to handle to offset congestion growth—again, if transit expansion was the only method to address travel growth. The additional passenger-miles of travel (or estimated trips) from the roadway were compared with the number of trips from existing transit service.

There are no other U.S. cities with ridership like New York City. Approximately one out of four U.S. transit trips are made in the New York area. Including these statistics would not present a useful comparison for typical cities over 3 million population; the New York data were removed from this comparison. The transit ridership increase that would be needed for each year in the remaining areas is shown in Exhibit B-19.

Exhibit B-19. Increase in Existing Transit System to Hold Congestion Constant



Note: The New York urban area statistics have been removed from the calculation.

- The Very Large urban areas would have to increase transit trips by over 20 percent to maintain a constant congestion level.
- The Large urban areas would have to add half the number of transit trips that they already have to maintain a constant congestion level.
- The Small and Medium urban areas would have to add at least 100% more than their existing transit ridership to maintain their congestion level.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

INCORPORATING THE EFFECT OF OPERATIONAL TREATMENTS – 90 URBAN AREAS

Many state and local transportation agencies, as well as the federal transportation program, have invested substantial funding in operational treatments and the future will include more of these programs in more cities. Technologies, operating practices, programs and strategies provide methods to get the most efficiency out of the road or transit capacity that is built, typically for relatively modest costs and low environmental effects. In some cases, the operational improvements are some of the few strategies that can be approved, funded and implemented.

For the Urban Mobility Report database, the operational treatments were assessed for the delay reduction that results from the strategy as implemented in the urban area. A separate report, *Six Congestion Reduction Strategies and Their Effects on Mobility* (*25*), describes the process of estimating the delay reduction in more detail. The ITS deployment analysis system (*26*) model was used as the basis for the estimates of the effect of the operational treatments. The ITS deployment database (*4*) and the Highway Performance Monitoring System (*1*) include data on the deployment of several operational improvements. These two databases provide the most comprehensive and consistent picture of where and what has been implemented on freeways and streets in urban areas.

The delay reduction estimates are determined by a combination of factors:

- extent of the treatments
- congestion level of the location
- density of the treatment (if it applies)
- effect of the treatment

These factors are estimated from the databases, the inventory information found and applied within the existing Urban Mobility Report structure, and the delay reduction has been incorporated into several of measures calculated in the study.

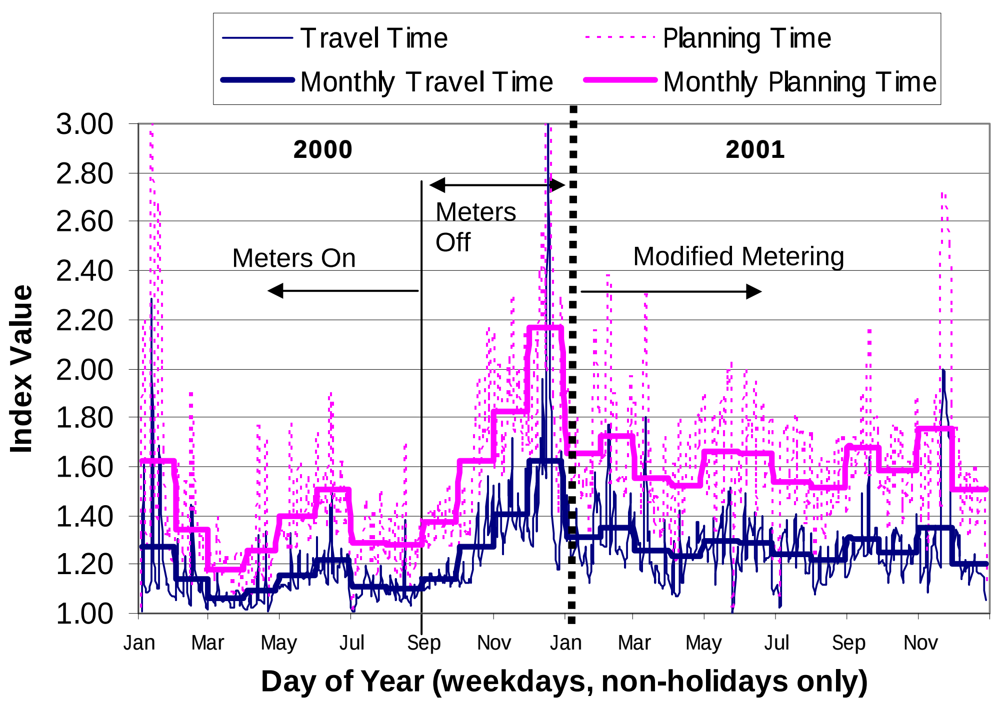
CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Freeway Entrance Ramp Metering

Entrance ramp meters regulate the flow of traffic on freeway entrance ramps. They are designed to create more space between entering vehicles so those vehicles do not disrupt the mainlane traffic flow. The signals, just as traffic signals at street intersections, allow one vehicle to enter the freeway at some interval (for example, every two to five seconds) They also somewhat reduce the number of entering vehicles due to the short distance trips that are encouraged to use the parallel streets to avoid the ramp wait time.

The effect of ramp metering was tested in Minneapolis-St. Paul in October 2000 when the extensive metering system was turned off and the freeway operated as it does in most other cities. The basic system was relatively aggressive in that ramp wait times of five minutes were not uncommon. The results of this systemwide experiment are clearly visible in the peak period data in Exhibit B-20. The Travel Time Index (average travel time) and the Planning Time Index (travel time that includes 19 out of every 20 trips) are plotted with each monthly average highlighted. Except for snowstorms, the highest values are during the shut-off experiment period. The metering experiment report produced by Cambridge Systematics (*27*) refers to a 22 percent increase in freeway travel time and the freeway system travel time becoming twice as unpredictable without the ramp meters. Congestion reductions are seen in January 2001 when a modified, less aggressive metering program was implemented. It might be interpreted that turning off the ramp meter system had the effect of a small snowstorm.

Exhibit B-20. Minneapolis-St. Paul Freeway System Congestion Levels

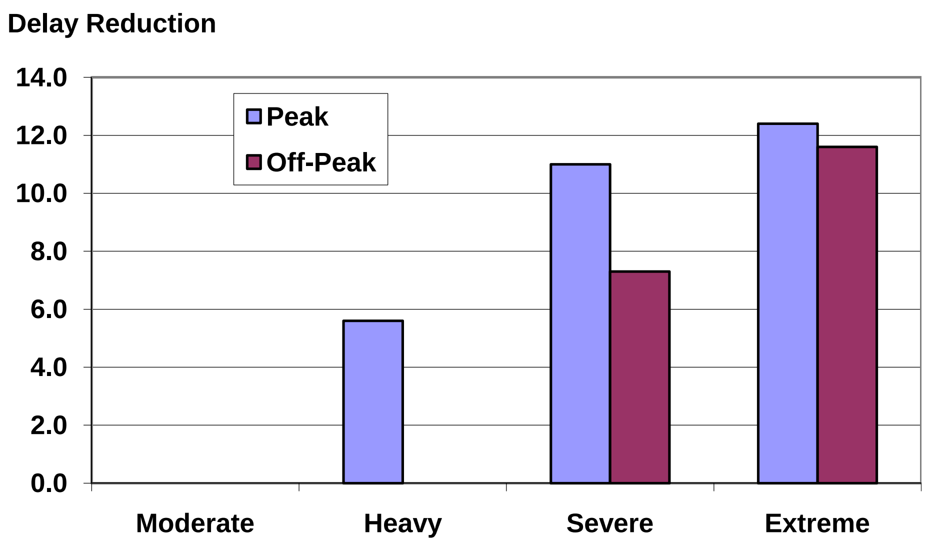


CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Delay Reduction Effects

The results of the Minneapolis experiment and simulation modeling performed for the Intelligent Transportation System Deployment Analysis System (IDAS) (*26*) have been combined into a relatively simple delay reduction estimation procedure for use in the Urban Mobility Report. Exhibit B-21 illustrates the delay reduction percentage for each of the four congestion ranges. More delay is subtracted from the more congested sections because there is more effect, particularly if the metering program can delay the beginning of stop-and-go conditions for some period of time.

Exhibit B-21. Ramp Metering Delay Reduction



Twenty-five of the urban areas reported ramp metering on some portion of their freeway system in 2007 (*1*,*4*). The average metered distance was 683 lane-miles which represents just over one-third of all the miles in the 25 cities. The effect was to reduce delay by 39.8 million person hours, approximately 2.8 percent of the freeway delay (Exhibit B-22). This value is combined in the operational effects summary at the end of this section.

- Los Angeles has the largest delay reduction estimate in the Very Large group.
- Minneapolis-St. Paul, Riverside-San Bernardino and San Diego have the most extensive metering benefits in the Large group.
- Of the 47 areas studied with under one million population, only three reported any metering.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-22. Freeway Ramp Metering Delay Reduction Benefits - 2007

Population Group	Average Covered Freeway Lane-miles		Freeway Hours of Delay (million)
	Lane-miles	Percentage	Reduction
Very Large (12)	745	28	30.7
Large (10)	619	54	9.0
Medium (3)	151	35	0.1
Small (0)	0	0	0.0
25 Area Average	683	35	--
25 Area Total	17,069	35	39.8

Source: HPMS, IDAS, and TTI Analysis

Note: This analysis uses nationally consistent data and relatively simplistic estimation procedures. Local or more detailed evaluations should be used where available. These estimates should be considered preliminary pending more extensive review and revision of base inventory information obtained from source databases.

Freeway Incident Management Programs

Freeway Service Patrol, Highway Angel, Highway Helper, The Minutemen and Motorists Assistance Patrol are all names that have been applied to the operations that attempt to remove crashed and disabled vehicles from the freeway lanes and shoulders. They work in conjunction with surveillance cameras, cell phone reported incident call-in programs and other elements to remove these disruptions and decrease delay and improve the reliability of the system. The benefits of these programs can be significant. Benefit/cost ratios from the reduction in delay between 3:1 and 10:1 are common for freeway service patrols (*28*). An incident management program can also reduce "secondary" crashes—collisions within the stop-and-go traffic caused by the initial incident. The range of benefits is related to traffic flow characteristics as well as to the aggressiveness and timeliness of the service.

Addressing these problems requires a program of monitoring, evaluation and action.

- Monitoring—Motorists calling on their cell phones are often the way a stalled vehicle or a crash is reported, but closed circuit cameras enable the responses to be more effective and targeted. Shortening the time to detect a disabled vehicle can greatly reduce the total delay due to an incident.

- Evaluation—An experienced team of transportation and emergency response staff provide ways for the incident to be quickly and appropriately addressed. Cameras and on-scene personnel are key elements in this evaluation phase.

- Action—Freeway service patrols and tow trucks are two well-known response mechanisms that not only reduce the time of the blockage but can also remove the incident from the area and begin to return the traffic flow to normal. Even in states where a motorist can legally move a wrecked vehicle from the travel lanes, many drivers wait for enforcement personnel dramatically increasing the delay. Public information campaigns that are effective at changing motorists' behavior (that is, move vehicles from the travel lanes when allowed by law) are particularly important.

An active management program is a part of many cities comprehensive strategy to get as much productivity out of the system as possible. Removing incidents in the off-peak periods may also be important particularly in heavily traveled corridors or those with a high volume of freight movement. Commercial trucks generally try to avoid peak traffic hours, but the value of their time and commodities, as well as the effect on the manufacturing and service industries they supply can be much greater than simple additional minutes of travel time.

Delay Reduction Effects

The basic Urban Mobility Report methodology includes an estimate of the delay due to incidents. This estimate is based on roadway design characteristics and incident rates and durations from a few detailed studies. These give a broad overview, but an incomplete picture of the effect of the temporary roadway blockages. They also use the same incident duration patterns for all urban areas. Incidents are estimated to cause somewhere between 52 and 58 percent of total delay experienced by motorists in all urban area population groups. A more complete understanding of how incidents affect travelers will be possible as continuous travel speed and traffic count monitoring equipment is deployed on freeways and major streets in U.S. cities. Unfortunately, that equipment is in place and recording data in only a few cities. These can, however, give us a view of how travel speeds and volumes change during incidents.

The results of incident management program evaluations conducted in several cities and simulation modeling performed for the Intelligent Transportation System Deployment Analysis System (IDAS) (*26*) have been used to develop a delay reduction estimation procedure. The process estimates benefits for monitoring cameras and service patrol vehicles (Exhibits B-23 and B-24) with the cameras receiving less benefit from the identification and verification actions they assist with than the removal efforts of the service patrol. As with the ramp metering programs, more delay is subtracted from the more congested sections because there is more effect.

Exhibit B-23. Benefits of Freeway Service Patrols

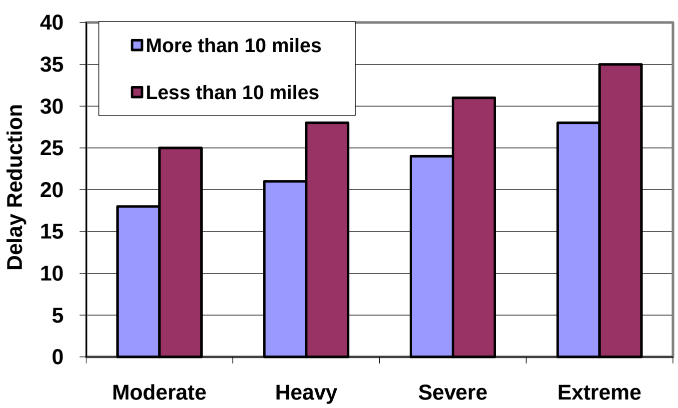
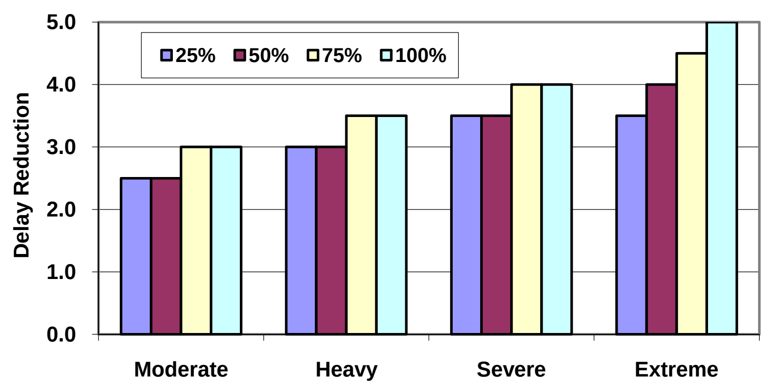


Exhibit B-24. Benefits of Freeway Surveillance Cameras



More than 79 areas reported one or both treatments in 2007, with the coverage representing from one-third to two-thirds of the freeway miles in the cities (*1,4*). The effect was to reduce delay by 137 million person hours, over seven percent of the freeway delay (Exhibit B-25). This value is combined in the operational effects summary at the end of this section.

Incident Management

- The New York City and Los Angeles regions are estimated to derive the most benefit from incident management.
- Minneapolis-St. Paul, San Diego, and Baltimore are estimated to have the most benefit in the Large group.
- Nashville and Bridgeport are the areas within the Medium group with the highest delay reduction benefit.

Exhibit B-25. Freeway Incident Management Delay Reduction Benefits

Population Group	Average Covered Freeway Lane-miles		Freeway Hours of Delay (million)
	Lane-miles	Percentage	Delay Reduction
Surveillance Cameras			
Very Large (14)	1,520	52	Delay Reduction Included Below
Large (27)	413	37	
Medium (25)	181	34	
Small (7)	110	39	
73 Area Average	517	44	
73 Area Total	37,732	44	
Service Patrols			
Very Large (14)	2,208	76	102.7
Large (29)	668	63	29.5
Medium (18)	312	49	4.3
Small (8)	212	74	0.6
69 Area Average	832	68	1.7
69 Area Total	55,743	68	137.1

Source: HPMS, IDAS, and TTI Analysis
Note: This analysis uses nationally consistent data and relatively simplistic estimation procedures. Local or more detailed evaluations should be used where available. These estimates should be considered preliminary pending more extensive review and revision of base inventory information obtained from source databases.

Traffic Signal Coordination Programs

Traffic signal timing can be a significant source of delay on the major street system. Much of this delay is the result of the managing the flow of intersecting traffic, but some of the delay can be reduced if the streams arrive at the intersection when the traffic signal is green instead of red. This is difficult in a complex urban environment, and when traffic volumes are very high, coordinating the signals does not work as well due to the long lines of cars already waiting to get through the intersection.

There are different types of coordination programs and methods to determine the arrival of vehicles, but they all basically seek to keep moving the vehicles that approach intersections on the major roads, somewhat at the expense of the minor roads. On a system basis, then, the major road intersections are the potential bottlenecks.

Delay Reduction Estimates

Some of the delay reduction from signal coordination efforts that have been undertaken in the U.S. is the attention that is given to setting the signal timing to correspond to the current volume patterns and levels and to recalibrate the equipment. It is often difficult to identify how much of the benefit is due to this "maintenance" function and how much is due to the coordination program itself. The Urban Mobility Report methodology draws on the evaluations and simulation modeling performed for the Intelligent Transportation System Deployment Analysis System (IDAS) (*26*) to develop the delay reduction estimation procedure shown in Exhibits B-26 and B-27. There is less benefit for the more heavily congested sections of the street system due to the conflicting traffic flows and vehicle queues. The benefits of an actuated system (where the signals respond to demand) are about one-third of the benefits of a centrally controlled system that monitors and adapts the signals to changes in demand.

All 90 areas reported some level of traffic signal coordination in 2007, with the coverage representing slightly over half of the street miles in the cities (*1,4*). Signal coordination projects, because the technology has been proven, the cost is relatively low and the government institutions are familiar with the implementation methods, have the highest percentage of cities and road miles with a program. The evolution of programs is also evident in the lower percentage of advanced progressive systems. These systems require more planning, infrastructure, and agency coordination.

Exhibit B-26. Signal Coordination Benefits (actuated)

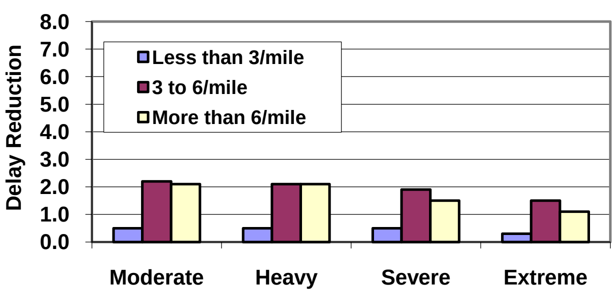
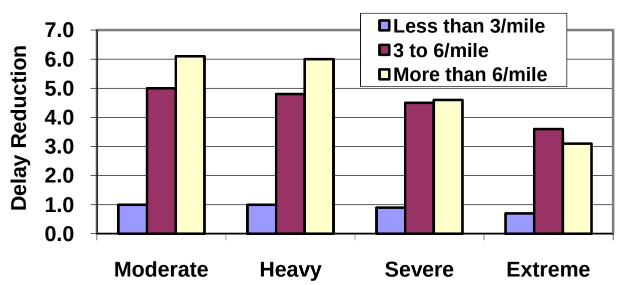


Exhibit B-27. Signal Coordination Benefits (progressive)



The effect of the signal coordination projects was to reduce delay by 16.3 million person hours, approximately one percent of the street delay (Exhibit B-28). This value is combined in the operational effects summary at the end of this section.

While the total effect is relatively modest, the relatively low percentage of implementation should be recognized, as should the relatively low cost and the amount of benefit on any particular road section. The modest effect does not indicate that the treatment should not be implemented—why would a driver wish to encounter a red light if it were not necessary? The estimates do indicate that the benefits are not at the same level as a new travel lane, but neither are the costs or the implementation difficulties or time. It also demonstrates that if there are specific routes that should be favored—due to high bus ridership, an important freight route or parallel route road construction—there may be reasons to ignore the system or intersecting route effects.

- Los Angeles and New York are the Very large areas with the highest benefits.
- Denver, Tampa, and Las Vegas are the Large areas with the most hours of delay benefit from signal coordination in areas between one and three million population.
- Tucson, Honolulu, and Louisville in the Medium areas and Cape Coral in the Small areas lead their population group.

Exhibit B-28. Principal Arterial Street Traffic Signal Coordination Delay Reduction Benefits - 2007

Population Group	Average Covered Lane-miles		Principal Arterial Hours of Delay (million)
	Lane-miles	Percentage	Reduction
Very Large (14)	5,985	63	10.3
Large (29)	1,517	55	4.1
Medium (31)	640	46	1.6
Small (16)	378	49	0.3
90 Area Average	1,707	57	0.2
90 Area Total	153,654	57	16.3

Source: HPMS, IDAS, and TTI Analysis

Note: This analysis uses nationally consistent data and relatively simplistic estimation procedures. Local or more detailed evaluations should be used where available. These estimates should be considered preliminary pending more extensive review and revision of base inventory information obtained from source databases.

Arterial Street Access Management Programs

Providing smooth traffic flow and reducing collisions are the goal of a variety of individual treatments that make up a statewide or municipal access management program. Typical treatments include consolidating driveways to minimize the disruptions to traffic flow, median turn lanes or turn restrictions, acceleration and deceleration lanes and other approaches to reduce the potential collision and conflict points. Such programs are a combination of design standards, public sector regulations and private sector development actions. The benefits of access management treatments are well documented in National Cooperative Highway Research Program (NCHRP) Report 420 (*29*).

Delay Reduction Estimates

NCHRP Report 395 analyzed the impacts of going from a TWLTL to a raised median for various access point densities and traffic volumes (*30*). Tables produced in NCHRP Report 395 were used in the Urban Mobility Report methodology to obtain delay factors for both recurring and incident delay.

There is an increase in recurring delay for through and left-turning traffic when going from a TWLTL to a raised median. This increase is primarily due to the storage limitations of select turn bay locations with the raised median treatments. As the turn bays become full, traffic spills out into the through lanes and increases the delay of through vehicles. This situation worsens with increased congestion levels and increased signal density (*31,32*). The percent increase factors shown in Exhibit B-29 are applied to the recurring delay on the principal arterial streets to account for this increased delay.

Raised medians can increase roadway safety by reducing the number of conflict points and managing the location of the conflict points. The reduction in conflict points equates to a reduction in crashes. This benefit of the raised medians was included in the methodology. The delay factors were generated for roadways going from a TWLTL to a raised median. Exhibit B-30 shows the percent reduction factors that range from 12 percent at low signal density (≤ signals/mile) and the lowest congestion level to 22 percent at high signal density (>3 signals/mile) and the highest congestion level (*30*). These percent reduction values are applied to the incident delay on the principal arterial streets in the methodology.

All 90 areas reported some level of access management in 2007, with the coverage representing about 30 percent of the street miles in the cities (*1,41*). The effect of access management was to reduce delay by 60.6 million person hours, approximately 3 percent of the principal arterial street delay (Exhibit B-31). The percent reduction drops as the size of the urban area gets smaller.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-29. Access Management Recurring Delay Effects

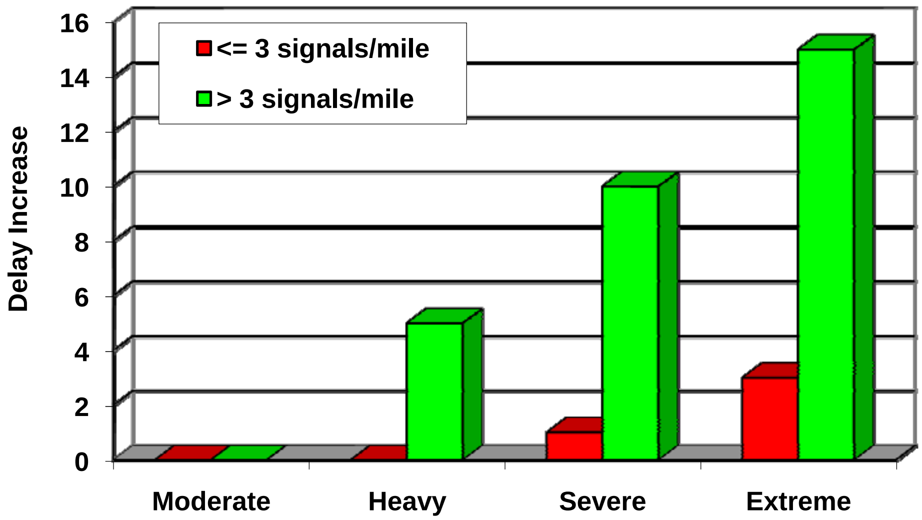
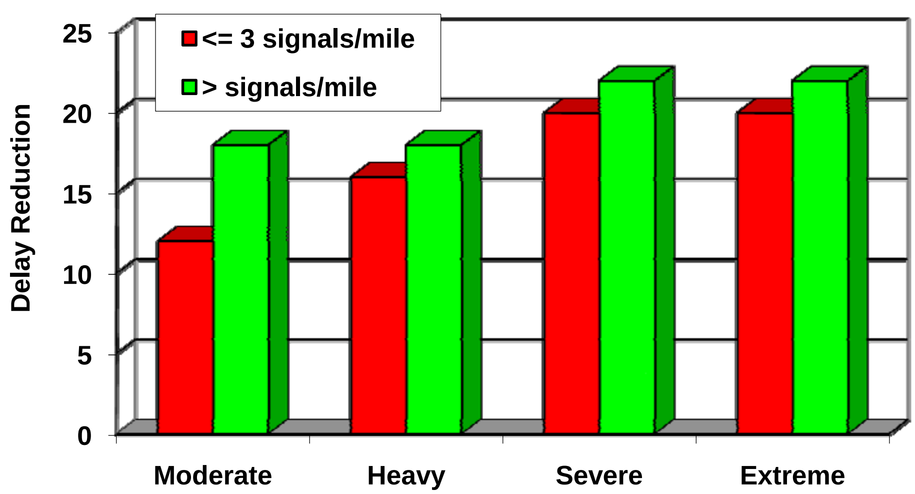


Exhibit B-30. Access Management Incident Delay Effects



Source: (1) and Texas Transportation Institute Analysis

Exhibit B-31. Principal Arterial Street Access Management Delay Reduction Benefits

Population Group	Average Covered Lane-miles		Principal Arterial Hours of Delay (million)
	Lane-miles	Percentage	Reduction
Very Large (14)	3,207	34	38.1
Large (29)	823	30	16.6
Medium (31)	315	23	5.1
Small (16)	115	15	0.8
90 Area Average	893	30	0.7
90 Area Total	80,393	30	60.6

Source: HPMS and TTI Analysis

Note: This analysis uses nationally consistent data and relatively simplistic estimation procedures. Local or more detailed evaluations should be used where available. These estimates should be considered preliminary pending more extensive review and revision of base inventory information obtained from source databases.

Combined Effect of Operational Treatments

The delay reduction benefits of four operational treatments analyzed in this edition of the Urban Mobility Report are combined into an estimate of the total effect of the deployed projects in the 90 urban areas. The inventory of all projects is identified in Exhibit B-32 by the percentage of miles on freeways and streets that have one of the programs or projects implemented. Exhibit B-32 shows the relatively low percentage of not only cities that have some treatments but also the low percentage of roads that have any treatment.

The total effect of the delay reduction programs represents 7.1 percent of the delay in the 90 cities. Again, the value seems low but when the low percentage of implementation is factored in, the benefit estimates are reasonable. The programs are also important in that the benefits are on facilities that have been constructed. The operating improvements represent important efficiencies from significant expenditures that have already been made.

Exhibit B-32. Total Operational Improvement Delay Reduction

Operations Treatment	Number of Cities	Percent of System Covered	Delay Reduction Hours (millions)
Ramp Metering	25	35	40
Incident Management	74	44-68	137
Signal Coordination	90	57	16
Access Management	90	30	61

Note: This analysis uses nationally consistent data and relatively simplistic estimation procedures. Local or more detailed evaluations should be used where available. These estimates should be considered preliminary pending more extensive review and revision of base inventory information obtained from source databases.

MOBILITY BENEFITS FROM PUBLIC TRANSPORTATION SERVICE

Buses and trains carry a significant number of trips in many large areas, and provide important benefits in many smaller ones. Peak period public transportation service during congested hours can improve the transportation capacity, provide options for travel mode and allow those without a vehicle to gain access to jobs, school, medical facilities, and other destinations. In the case of public transportation lines that do not intersect roads, the service can be particularly reliable as they are not affected by the collisions and vehicle breakdowns that plague the roadway system and are not as affected by weather, road work, and other unreliability-producing events. Early versions of the Urban Mobility Report included examples of the amount of public transportation improvements needed to address congestion. Later versions included public transportation service in the general measures and analysis. This paper provides an estimate of the mobility benefits associated with general public transportation service.

Public Transportation Service

The Urban Mobility Report methodology for roadways uses person volume and speed as the two main elements of the measurement analysis (*6*). While this is consistent with the goals of the public transportation service, there are differences between several aspects of road and transit operations. Regular route bus transit service stops frequently to allow riders to enter and leave the vehicles. Train service in many cases also makes more than one stop per mile. The goal of the service is to provide access to the area near the stops as well as move passengers to other destinations. A comparison with road transportation systems, therefore, cannot use the same standards or comparison methods.

The data sources for this type of analysis are a combination of locally collected and nationally consistent information. The nationally consistent public transportation data is supplied by the American Public Transportation Association (APTA) and includes ridership, passenger miles of travel, service mileage and hours (*2*). Consistent roadway data, in the form of the Highway Performance Monitoring System (HPMS) from Federal Highway Administration (FHWA) is available for similar statistics, but the relationship between volume and speed on the roadway side is more studied and more easily estimated than for the transit service (*1*). Some simplifying assumptions have been made to initiate the analysis. There is an ongoing effort to improve the data and statistics in order to reduce the number of assumptions that are needed, as well as improving the estimates that are made.

The Mobility Measures

Travel Delay Savings

The delay benefits associated with public transportation service were calculated using the "what if many of the transit riders were in the general traffic flow" case. Additional traffic on already crowded road networks would affect all the other peak period travelers as well. This is an artificial case in the sense that the effects of a transit service shutdown would be much more significant and affect more than just the transit riders or roadway travelers. Public transportation patrons who rely on the service for their basic transportation needs would find travel much more difficult, making jobs, school, medical, or other trip destinations much harder to achieve. Businesses that count on the reliable service and access to consumers and workers that public transportation provides would suffer as well.

Travel Time Index

The method used in this analysis to estimate a revised Travel Time Index focuses on "similar expectations". Transit service is operated according to a schedule. When buses and trains stop to pick up and discharge passengers, their average speed is generally slower than vehicles on the road. Riders and potential riders evaluate the service and make choices according to either the departure and arrival times or in the case of operations that run very frequently, the travel time to the destination with the expectation that the departure time will be relatively soon after arrival in the station. In transit operations this can be thought of as similar to an uncongested roadway trip. Public transportation service that operates on-time according to the schedule, then, would be classified by the patrons as uncongested roadway travel.

It may seem odd to disregard travel speed in this sense, but the service differences are important. Attempting to estimate the slower speeds on transit routes and incorporating them into the analysis would, in essence, double penalize the service. Many travelers already use the longer travel times to make their decision to not use transit and the longer times are one of the reasons ridership is relatively low during off-peak hours. Transit routes could gain speed by decreasing stops, but at the risk of losing ridership. This relationship between speed and convenience is constantly adjusted by transit agencies seeking to increase transit performance and ridership. Our approach to defining a different standard for transit routes is similar to the different speed threshold used for surface streets and freeways.

The "reward" for public transportation in this revised Travel Time Index estimate comes from gain in ridership and on-time operation. If the route travel times become unreasonably long, ridership will decline, and the amount of "uncongested" passenger-miles contributed by public transportation will also decline. The beneficial effects of faster route times, better access or improved service from interconnected networks or high-speed bus or rail links would result in higher ridership values, which would increase the amount of "uncongested" travel in the mobility measure calculations.

Revisions to Public Transportation Methodology

Since the release of the *2003 Urban Mobility Report* (UMR) (*33*) the Texas Transportation Institute (TTI) has included several statistics that show the estimated reduction in traffic congestion attributed to public transportation. Following the release of the *2007 Urban Mobility Report* (*34*)*,* the decision was made to take an in-depth look at the public transportation methodology to determine if any improvements could be made to the statistics produced in the analysis. The American Public Transportation Association (APTA) was helpful in supplying support and industry contacts to this effort in addition to the transit statistics necessary to produce the congestion estimates. Three key items were identified for improvement.

- Incorporate transit modal share—determine the percentage of transit travel associated with bus, light rail, heavy rail, and commuter rail in each urban area.
- Transit ridership in the peak periods—determine the amount of daily transit travel occurring in the peak commuting periods.
- Account for location of transit routes on the roadway network—determine how to account for the fact that transit routes often operate in congested roadway corridors.

Incorporate Transit Modal Share

The purpose for this addition to the methodology is to allow the ridership from the different public transportation modes to be assigned to specific roadway functional classes based on the type of service provided by the mode. The modal share information is obtained from the public transportation operating statistics (*2*) supplied annually by APTA for inclusion into the Urban Mobility Report analysis. The passenger-miles of travel for each urban area are classified as light rail, heavy rail, commuter rail, or bus. No differentiation is made between service that is owned by the company and service that is purchased. Any other mode is placed in the bus category. These other modes include service such as vanpools and taxis. The reason for placing these into the bus category is that the service uses the surface streets and provides a similar type of service as buses.

- The transit vehicle-miles of travel from commuter rail are assigned to freeways because commuter rail typically travels longer distances into centrally located activity centers similar to freeway commuting. Arterial streets tend to handle shorter commutes than the freeway system, therefore, none of the commuter rail travel is assigned to the arterial streets.
- Travel from the remainder of the modes—light rail, heavy rail, and bus—is assigned to the roadway system in the same proportions that already exist on the roadway. For example, if 60 percent of the roadway travel in a city occurs on the freeway system, then 60 percent of the light rail, heavy rail, and bus travel is added to the freeway system and 40 percent of the transit travel is assigned to the arterial streets.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Public Transportation Ridership in the Peak Periods

The peak period transit ridership statistics were obtained from APTA who conducted a survey of the transit companies operating in approximately twenty urban areas across the U.S. APTA surveyed the majority of the Very Large urban areas—those with populations over 3 million—because the transit companies in these larger regions comprise a significant percentage of the public transportation usage in the U.S. Surveys were only sent to a sample of transit companies in the smaller urban area population groups to create a representative set of statistics that can be applied to all urban areas of similar size. Exhibit B-33 shows the results of the survey.

In some cases, an incomplete survey was returned to APTA by a transit agency. The transit agency may have reported a peak period modal share for one or two rail modes operating in their area but not all of the rail modes. In some areas, the survey was not returned by all transit operators. When this occurred, the urban area was assigned the average response for the modes from returned surveys. An area was assigned the population group average when no information was submitted.

Exhibit B.33. Peak Period Ridership Percentages by Mode

Urban Area	Percentage of Daily Modal Ridership in Peak Period			
	Bus	Commuter Rail	Heavy Rail	Light Rail
Very Large Area Average	60	75	65	60
	58	--	59	--
Atlanta	63	75	61	63
Boston	59	83	67	--
Chicago	60	74	--	68
Dallas-Fort Worth	65	--	63	63
Los Angeles	56	65	73	--
New York	70	--	68	--
Philadelphia	62	68	81	58
San Francisco-Oakland	63	75	--	60
Seattle	--	--	59	--
Washington DC				
Large Area Average	55	75	65	60
Denver	55	--	--	60
San Jose	55	--	--	55
Medium and Small Area Average	55	75	65	55
Charleston	54	--	--	--
Colorado Springs	54	--	--	--
Grand Rapids	55	--	--	--

Notes: -- denotes data is unavailable
Very Large Areas have populations over 3 million
Large Areas have populations between 1 and 3 million
Medium and Small Areas have populations under 1 million

Location of Public Transportation Routes

Many of the public transportation routes either utilize or run parallel to congested roadway corridors. In the prior version of the methodology, transit travel was assigned to all roadways throughout the urban area rather than being placed onto more congested corridors. Areas of a city that had little or no transit service were assigned some of the transit travel from portions of the city which had significant transit service. In reality, if transit service were eliminated, some traffic would shift to other corridors but much of it would continue to use the same corridor because of proximity to homes and jobs. In order to account for the location of transit routes along these congested corridors, researchers used two steps to alter the approach from "spread the transit travel like the road travel" to "peak period travel is more concentrated on highly traveled and congested corridors to major job centers."

Transit Travel on Congested Roads

Exhibit B-34 shows how the additional travel is added in urban areas with a range of congested roadways. For example, Urban Area 2 has roadway travel in the moderate, heavy, and severe congestion levels. The additional transit travel would be added only in the heavy and severe congestion levels to replicate the heavier congestion levels on transit routes. The percentage of transit travel assigned to uncongested roadways would be the same as with existing road travel. Thus, the same amount of transit travel is assigned to the roadway network as the previous methodology, but now it is applied to some of the more congested roadways.

Exhibit B-34. Accounting for Location of Transit Service on Roadway Network

Example Urban Area	Existing Roadway Travel by Congestion Level				Roadway Travel Following Addition of Transit Travel by Congestion Level			
	Moderate	Heavy	Severe	Extreme	Moderate	Heavy	Severe	Extreme
Area 1	X	X	X	X	X	X + T	X + T	X + T
Area 2	X	X	X		X	X + T	X + T	
Area 3	X	X			X	X + T		
Area 4	X				X + T			

Note: 'X' denotes existing roadway travel, 'T' denotes transit travel that is added to roadway system

Effect of Transit Travel

Another change to the previous methodology was to adjust the way the transit travel is added to roadways in the various congestion levels. Exhibit B-35 shows the traffic densities associated with the five congestion levels—uncongested, moderate, heavy, severe, and extreme—for both the freeways and arterial streets (*6*). If the additional transit travel assigned to a level causes the traffic density to surpass the highest traffic density allowed in that level, the amount of the travel above the highest allowable traffic density is allowed to "spill over" into the next more congested level. For example, if the average VMT per lane-mile in the freeway heavy congestion level is 19,970 and the additional transit travel assigned to the heavy level increases this average to 20,050, the 50 VMT per lane-mile "spills" into the severe level to lower the heavy level average to 20,000 (the ceiling for the heavy freeway level). The effect of this "spillage" is that the travel that shifts into the severe bin would be subjected to lower speeds (more delay) than the travel in the heavy level.

Exhibit B-35. Congestion Level Bins and Traffic Density

Functional Class and Traffic Density (VMT/Lane-mile)	Traffic Density by Congestion Level				
	Uncongested	Moderate	Heavy	Severe	Extreme
Freeways	under 15,000	15,000 to 17,499	17,500 to 19,999	20,000 to 24,999	over 25,000
Arterial Streets	under 5,500	5,501 to 6,999	7,000 to 8,499	8,500 to 9,999	over 10,000

Source: (*6*)

In a perfect world, the transit travel would be assigned to the corridors where the transit service was provided and the traffic volumes on the roadway would be adjusted accordingly. The methodology used to produce the Urban Mobility Report, however, does not function at such a microscopic level. The two changes that deal with location of transit service provide a first step at emulating where much of the transit travel occurs and what would happen if the additional travel was added to roadways that are already congested.

Summary of Changes

Exhibit B-36 shows the steps for calculating the traffic delay reduction provided by public transportation. A comparison is made of the "old" methodology used in the *2007 Urban Mobility Report* (*34*) and the "new" methodology used in the *2009 Urban Mobility Report* (*6*). The changes to the methodology occur in Steps 2, 3, 6, and 7 of the calculation process.

- The Urban Mobility Report methodology has the following new features for calculating the delay reduction effects of public transportation.
- Public transportation ridership is assigned to the roadway system based on the travel in each of the existing transit modes.
- The percentage of the daily public transportation ridership that occurs in the peak periods is used in the roadway delay calculations.
- Public transportation ridership is assigned to more congested roadways to estimate the effect of public transportation routes that utilize congested roadway corridors.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-36. Changes to the Urban Mobility Report Methodology

Computation Step	2007 Urban Mobility Report	2009 Urban Mobility Report
1. Convert annual transit passenger-miles of travel (pmt) to daily vehicle-miles of travel (vmt)	Passenger miles / 300 days / 1.25 persons per auto = transit daily vmt	Passenger miles / 300 days / 1.25 persons per auto = transit daily vmt
2. Assign vmt from Step 1 to transit mode	Not used	Using mode splits in APTA transit ridership report, assign vmt to commuter rail, heavy rail, light rail, or bus
3. Assign vmt to roadway facility	Assign transit vmt from Step 1 to freeways and arterials based on existing roadway vmt proportions	Assign modal vmt from Step 2 to freeways and arterials. Commuter Rail vmt is assigned entirely to freeways. The other 3 modes are assigned to freeways and arterials based on existing vmt proportions.
4. Re-calculate percentage of travel occurring in peak periods	Re-calculate with additional transit travel added to roadways	Re-calculate with additional transit travel added to roadways (Unchanged)
5. Calculate amount of transit vmt added to existing roadway vmt	Use recalculated percentage from Step 4.	Use results from survey of transit companies by APTA to determine percentage of ridership by mode occurring in peak periods
6. Assign transit vmt to congestion levels (buckets)	Assign transit vmt in same proportions as existing roadway travel	Assign transit travel for moderate congestion category to more congested categories unless moderate is only current roadway congestion level.
7. Add peak period transit vmt to existing roadway vmt	Add transit vmt in same proportions as existing roadway travel	Add transit vmt to road vmt based on results of Step 6 and allow for travel to spill over into more congested levels.
8. Re-calculate peak period operating speeds	Use combined volumes from Steps 6 and 7	Use combined volumes from Steps 6 and 7
9. Re-calculate delay	Use combined volumes and new speeds to calculate delay	Use combined volumes and new speeds to calculate delay

Source: (*6*)

These changes have improved the methodology for analyzing the delay reduction benefits derived from public transportation. A comparison was made of the results of the "old" and "new" methodologies for the year 2005 (the latest year reported with the old methodology). The results of the comparison show that the delays savings from public transportation increased from the reported 540 million hours in all 439 urban areas under the "old" methodology to about 610 million hours under the "new" methodology. The improvements to the methodology show that public transportation has an even greater effect on delay savings than was reported in *2007 Urban Mobility Report* (*34*).

Summary of the Mobility Effects of Public Transportation

The mobility effects from public transportation are shown for both of the key performance measures—travel delay and Travel Time Index. The differences between the two measures are important to understand:

- The travel delay shows an estimate of the amount of additional delay that would occur if public transportation did not exist and the transit riders were added onto the roadways.
- The Travel Time Index shows the effects of including the public transportation travel with the roadway travel, but assumes that all of the public transportation service is uncongested travel for purposes of calculating the benefits to the entire transportation system. Additional research and data collection are needed to develop a consistent "on-time reliability" measure for the public transportation industry.

Travel Delay

Exhibit B-37 shows that in the 439 urban areas studied, there were approximately 56 billion passenger-miles of travel on public transportation systems in 2007 (*6*). The annual average ridership ranged from about 16 million passenger-miles in the Small urban areas to about 3 billion in the Very Large areas. Overall, if these riders were not handled on public transportation systems they would contribute an additional roadway delay of almost 646 million hours or about a 14 percent increase in the total delay. Some additional effects include:

- The range of benefits derived from public transportation in the 90 intensely studied urban areas ranged from about 18 percent in the Very Large Urban Areas down to about 3 percent in the Small Areas.
- Of the 646 million hours of potential extra delay, 630 million are in the 90 urban areas studied in detail.

Exhibit B-37. Delay Increase if Public Transportation Service Were Eliminated – 439 Areas

Population Group and Number of Areas	Population Group Average Annual Passenger-miles of Travel (million)	Delay Reduction Due to Public Transportation	
		Hours of Delay (million)	Percent of Base Delay
Very Large (14)	2,972	557.0	17.9
Large (29)	213	58.8	5.6
Medium (31)	55	12.8	4.2
Small (16)	16	1.5	2.8
90 Area Total	49,790	630.1	14.9
Other Areas (349)	6,032	15.8	2.8
All Areas	55,822	645.9	13.5

Source: (*6*)

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Travel Time Index

The Travel Time Index values are shown with and without the effects of public transportation in Exhibit B-38 for the 90 Urban Areas studied extensively in the Urban Mobility Report. In the 90 urban areas, the mobility effect of public transportation lowered the average TTI value by almost 2 points from approximately 1.31 to 1.29. The delay reduction was greatest in the Very Large urban areas which have the most extensive transit systems. The TTI values in the Very Large areas were lowered by almost 4 points.

Exhibit B-38. Effects of Public Transportation Service on the Travel Time Index – 90 Areas

Population Group and Number of Areas	Travel Time Index		
	Base (without public transportation)	With Public Transportation Effect	Reduction in TTI (Points)
Very Large (14)	1.403	1.367	0.036 (4)
Large (29)	1.248	1.243	0.005 (1)
Medium (31)	1.145	1.143	0.002 (0)
Small (16)	1.102	1.101	0.001 (0)
90 Area Average	1.309	1.291	0.018 (2)

Note: A TTI "point" is 0.01 on the Travel Time Index
Source: (*6*)

MOBILITY BENEFITS FROM HIGH-OCCUPANCY VEHICLE LANES

High-occupancy vehicle lanes (also known as diamond lanes, bus and carpool lanes, transitways) provide a high-speed travel option to buses and carpools as an incentive to share a vehicle and reduce the number of vehicle trips. The lanes are most used during the peak travel periods when congestion is worst and the time savings compared to the general travel lanes is most significant. In addition to saving time on an average trip, the HOV lanes also provide more reliable service as they are less affected by collisions or vehicle breakdowns.

The HOV lanes provide service similar to freeway mainlanes in that there are relatively few lanes that have stations on the route. The buses on the lanes can either pickup patrons on regular bus routes before entering the HOV lane, or they can provide service to a park-and-ride lot that allows patrons to drive their private vehicle to a parking lot and use a bus to their destination. The high-speed lanes are also open to use by carpools (although there are some bus-only lanes) which provide additional flexibility for use by travelers.

Another version of high-occupancy vehicle lane involves allowing single-occupant vehicles to use the lane for a fee. These have been labeled high-occupancy/toll lanes (HOT lanes) and, while fewer than ten of these projects exist, many more are being planned and studied. The advantages of high speed and reliable transportation service can be extended to another user group. If a variable tolling system is used to maintain high-speed operations (e.g., by charging a higher toll when the freeway mainlanes are congested) more vehicles can be allowed to use the lane without the possibility of speed decreases or congestion.

Delay Reduction Estimate

HOV lane service is similar to the general freeway operation, and because HOV lane data is not included in the regular freeway data, the operating statistics (e.g., speed, person volume and miles traveled) can be added to the freeway and street data. Exhibit B-39 is a summary of HOV lane operations in several urban corridors from the year 2005. While this is only a partial list of HOV projects, it provides a view of the usefulness of the data, as well as an idea of the mobility contribution provided by the facilities. The exhibit includes information about the typical peak period operating conditions (three hours in the morning and evening) on the HOV lane. The statistics from six peak hours of operation may appear to show relatively low ridership, but in some corridors the significant benefits may only be for one hour in each peak. Some other aspects of the corridor operations such as the variation in travel time and the effects of park-and-ride service or transit operations are also not fully explored in these statistics.

The data for freeway mainlanes and HOV lanes in a city or region can be combined to produce an improved Travel Time Index. This index and other statistics can provide a multimodal mobility estimate.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-39. Mobility Levels in HOV Corridors in 2005

		Peak Period Operations	
	Miles	**Person Volume**	**Average Speed (mph)**
Atlanta			
I-75	20.0	6,340	54
I-85	20.0	7,890	52
I-20	8.5	7,240	49
Dallas			
I-30 East	5.5	6,350	60
I-35 North	7.3	4,850	60
I-35 South	9.0	6,000	60
I-635 North	6.7	9,410	62
Denver			
I-25	7.0	9,700	57
Houston			
I-10 West	12.3	23,290	52
I-45 North	19.3	26,660	54
I-45 South	15.0	17,940	56
US 290	13.4	23,050	52
US 59 South	11.5	22,680	59
US 59 North	19.9	12,380	60
Los Angeles			
LA/Ventura Counties			
I-10	20.1	13,740	53
SR-14	35.9	9,880	66
SR-57	4.5	8,700	27
SR-60	7.5	8,770	54
SR-91	14.3	10,390	55
I-105	16.0	11,360	32
I-110	10.7	24,170	58
SR-118	11.4	9,510	69
SR-134	12.8	7,110	67
SR-170	6.1	6,770	42
I-210	27.2	22,930	39
I-405	16.7	20,700	35
I-605	20.7	11,500	59
Orange County♦			
I-5	35.3	N/A♦	53
SR-55	10.3	N/A♦	56
SR-57	12.1	N/A♦	50
SR-91	22.2	N/A♦	53
I-405	23.6	N/A♦	55
Miami			
I-95 North	31.4	4,450	57
I-95 South	22.7	5,600	52
Minneapolis-St. Paul			
I-394	10.4	9,920	65
I-35W	7.5	5,590	58
New York			
Long Island Expressway	40.0	3,150	60

♦Passenger-miles of travel estimated from Caltrans PEMS data.

Exhibit B-39. Mobility Levels in HOV Corridors in 2005, continued

		Peak Period Operations	
	Miles	Person Volume	Average Speed (mph)
Phoenix			
I-10 West	21.0	4,000	60
I-10 East	5.0	4,000	60
SR-202	9.0	3,000	60
I-17	7.0	3,000	60
Portland			
I-5/I-405	6.7	7,700	34
Riverside-San Bernardino♦			
SR-60	13.3	N/A♦	58
SR-91	17.6	N/A♦	52
I-10	8.4	N/A♦	58
I-210	10.4	N/A♦	58
SR-71	7.7	N/A♦	57
Sacramento			
US-50	11.5	1,710	63
I-80	9.6	1,970	63
SR-99	14.3	3,070	47
San Francisco-Oakland			
I-80 (Alameda County)	5.3	16,760	53
I-84 (Alameda County)	2.0	4,900	60
SR-92 (Alameda County)	3.0	5,060	60
I-680 (Alameda County)	14.0	3,840	65
I-880 (Alameda County)	20.5	5,920	65
SR-4 (Contra Costa County)	7.0	4,930	65
I-80 (Contra Costa County)	9.9	10,670	48
I-680 (Contra Costa County)	12.9	6,080	65
US-101 (Marin County)	6.1	4,810	47
SR-85 (Santa Clara County)	23.8	3,750	65
US-101 (Santa Clara County)	34.8	3,790	64
Seattle			
I-5 South	16.5	51,880	55
I-5 North	18.4	77,330	54
I-405 South	12.9	42,260	55
I-405 North	15.9	60,890	57
I-90	7.4	30,010	60
SR-520	7.0	21,550	55
SR-167	9.2	51,960	59
Virginia Beach			
I-64	14.0	1,500	64
I-64 SS	9.0	3,620	64
I-264	9.0	3,070	59
Washington, DC			
I-395	28.4	26,010	63
I-66	27.9	14,010	40
I-270	18.4	5,920	49
VA 267	24.2	6,550	51
US 50	9.1	4,010	64

♦Passenger-miles of travel estimated from Caltrans PEMS data.

COMBINED EFFECT OF PUBLIC TRANSPORTATION AND OPERATIONAL IMPROVEMENTS

Analytical improvements will continue to be developed and incorporated into the Urban Mobility Report. The values and approach may change, but the goal is to include all the types of transportation improvements in a comprehensive areawide mobility assessment. The use of the information may also encourage local and state transportation officials to develop their own databases and procedures to maximize the flexibility and inclusiveness of corridor and sub-regional evaluations, as some agencies are doing now.

The expanded version of the methodology used in this report (*6*) is available on the website (http://mobility.tamu.edu/ums). The summary statistics at the population group level for 2007 are illustrated in Exhibit B-40. Most of the delay in the 439 urban areas is in the 14 areas with populations above three million, so it should not be surprising that the majority of the operational treatment benefits are in those areas as well. Large areas not only have had large problems for longer, and thus more incentive to pursue a range of solutions, but the expertise needed to plan and implement innovative or complex programs are also more likely to be readily accessible.

Several of the areas with populations between one million and three million also have significant contributions from four or five of the six treatments identified in the report. Some of the delay reduction estimates are as large, or larger than the above three million population areas. The medium group areas have relatively small overall contributions due to the low congestion level, but they are also implementing and refining techniques that will be more valuable as congestion grows.

The Travel Time Index change from the base value to the "inclusive" value follows the same pattern as the delay reduction—much more change in the Very Large group than in the others. The TTI values are presented with three decimal places to better illustrate the amount of change. The amount of change should be gauged against the base TTI value—small areas with less congestion that have implemented more operational treatments or a more extensive transit system may have larger changes as a percentage of the base value than larger areas that have not used these options.

Several other observations about this initial attempt to include a broader set of mobility treatments in the regular mobility data reporting are listed below.

- The significant investment in operations treatments in states that are widely judged to be among the leaders in these technologies is evident. California, Minnesota, Illinois, Arizona, Oregon and Washington have relatively large delay reductions, in several case for cities outside the "most congested" list.

- The delay reduction estimate for public transportation service should be considered as "delay avoided" because the calculation involves comparing current operations to conditions that might exist if the service were not in operation.

- Almost three-fourths of delay reduction from incident management and ramp meters is in the Very Large group.

- Although the percentage of "treated" streets and freeways is relatively low, the combined effects are equal to several years of growth in the Very Large group, and one or two years in the Large and some of the Medium group cities.

Exhibit B-40. Summary of Public Transportation and Operational Improvement Delay Reduction Effects - 2007

Delay Reduction Element	Population Group – Annual Hours Saved (million)					
	Very Large	**Large**	**Medium**	**Small**	**Intensively Studied**	**All 439**
Number of Cities	14	29	31	16	90	439
Delay Reduction from:						
Ramp Metering	30.7	9.0	0.1	0.0	40	40
Incident Management	102.7	29.5	4.3	0.6	137	143
Signal Coordination	10.3	4.1	1.6	0.3	16	20
Access Management	38.1	16.6	5.1	0.8	61	69
High-Occupancy Vehicles	33.8	3.2	0.0	0.0	37	37
Delay Savings from Public Transportation	557	59	13	2	630	646

HOW SHOULD WE ADDRESS THE MOBILITY PROBLEM?

Just as congestion has a number of potential causes, there are several ways to address the problem. Generally, the approaches can be grouped under four main strategies—adding capacity, increasing the efficiency of the existing system, better management of construction and maintenance projects, and managing the demand. The benefits associated with these improvements include reduced delay, and more predictable and lower trip times. Emissions may be reduced due to the reduction in demand or congestion, improved efficiencies and the change in the way travelers use the system. The locations of congestion may also move over time due to the new development that occurs or is encouraged by the new transportation facilities.

More Travel Options

While not a specific improvement, providing more options for how a trip is made, the time of travel and the way that transportation service is paid for may be a useful mobility improvement framework for urban areas. For many trips and in many cities, the alternatives for a peak period trip are to travel earlier or later, avoid the trip or travel in congestion. Given the range of choices that Americans enjoy in many other aspects of daily life, these are relatively few and not entirely satisfying options.

The Internet has facilitated electronic "trips." There are a variety of time-shift methods that involve relationships between communication and transportation. Using a computer or phone to work at home for a day, or just one or two hours, can reduce the peak system demand levels without dramatically altering lifestyles.s

Using information and pricing options can improve the usefulness of road space as well as offering a service that some residents find very valuable. People who are late for a meeting, a family gathering or other important event could use a priced lane to show that importance on a few or many occasions—a choice that does not exist for most trips.

The diversity of transportation needs is not matched by the number of travel alternatives. The private auto offers flexibility in time of travel, route and comfort level. Transit can offer some advantages in avoiding congestion or unreliable travel conditions. But many of the mobility improvements below can be part of creating a broader set of options.

Add Capacity

Adding capacity is the best known, and probably most frequently used, improvement option. Pursuing an "add capacity" strategy can mean more traffic lanes, additional buses or new bus routes, new roadways or improved design components as well as a number of other options. Grade separations and better roadway intersection design, along with managed lanes and dedicated bus and carpool priority lanes, can also contribute to moving more traffic through a given spot in the same or less time. The addition of, or improvements to heavy rail, commuter rail, bus system, and improvement in the freight rail system all can assist in adding capacity to varying degrees. In growing areas, adding capacity of all types is essential to handle the growing demand and avoid rapidly rising congestion.

Manage the Demand

Demand management strategies include a variety of methods to move trips away from the peak travel periods. These are either a function of making it easier to combine trips via ridesharing or transit use, or providing methods to reduce vehicle trips via tele-travel or different development designs.

The fact is, transportation system demand and land use patterns are linked and influence each other. There is a variety of strategies that can be implemented to either change the way that travelers affect the system or the approaches used to plan and design the shops, offices, homes, schools, medical facilities and other land uses.

Relatively few neighborhoods, office parks, etc. will be developed for auto-free characteristics—that is not the goal of most of these treatments. The idea is that some characteristics can be incorporated into new developments so that new economic development does not generate the same amount of traffic volume as existing developments. Among the tools that can be employed are better management of arterial street access, incorporating bicycle and pedestrian elements, better parking strategies, assessing transportation impact before a development is approved for construction, and encouraging more diverse development patterns. These changes are not a congestion panacea, but they are part of a package of techniques that are being used to address "quality-of-life" concerns—congestion being only one of many.

Increase Efficiency of the System

Sometimes, the more traditional approach of simply adding more capacity is not possible or not desirable. However, improvements can still be made by increasing the efficiency of the existing system. These treatments are particularly effective in three ways. They are relatively low cost and high benefit which is efficient from a funding perspective. They can usually be implemented quickly and can be tailored to individual situations making them more useful because they are flexible. They are usually a distinct, visible change; it is obvious that the operating agencies are reacting to the situation and attempting improvements.

In many cases, the operations improvements also represent a "stretching" of the system to the point where the margin of error is relatively low. It is important to capitalize on the potential efficiencies – no one wants to sit through more traffic signal cycles or behind a disabled vehicle if it is not necessary – but the efficiency improvements also have limits. The basic transportation system—the roads, transit vehicles and facilities, sidewalks and more—is designed to accommodate a certain amount of use. Some locations, however, present bottlenecks, or constraints, to smooth flow. At other times, high volume congests the entire system, so strategies to improve system efficiency by improving peak hour mobility are in order. The community and travelers can benefit from reduced congestion and reduced emissions, as well as more efficiently utilizing the infrastructure already in place.

Among the strategies that fall into this category are tools that make improvements in intersections, traffic signals, freeway entrance ramps, special event management (e.g., managing traffic before and after large sporting or entertainment events) and incident management. In addition such strategies as one-way streets, electronic toll collection systems, and changeable lane assignments are often helpful.

Freeway entrance ramp metering (i.e., traffic signals that regulate the traffic flow entering the freeway) and incident management (i.e., finding and removing stalled or crashed vehicles) are two operations treatments highlighted in this report. When properly implemented, monitored and aggressively managed, they can decrease the average travel time and significantly improve the predictability of transportation service. Both can decrease vehicle crashes by smoothing traffic flow and reducing unexpected stop-and-go conditions. Both treatments can also enhance conditions for both private vehicles and transit.

Manage Construction and Maintenance Projects

When construction takes place to provide more lanes, new roadways, or improved intersections, or during maintenance of the existing road system, the effort to improve mobility can itself cause congestion. Better techniques in managing construction and maintenance programs can make a difference. Some of the strategies involve methods to improve the construction phase by shortening duration of construction, or moving the construction to periods where traffic volume is relatively low. Among the strategies that might be considered include providing contractor incentives for completing work ahead of schedule or penalties for missed construction milestones, adjustments in the contract working day, using design-build strategies, or maintenance of traffic strategies during construction to minimize delays.

Role of Pricing

Urban travelers pay for congestion by sitting in traffic or on crowded transit vehicles. Anthony Downs (*35*), among many, has suggested this is the price that Americans are willing to pay for the benefits that they derive from the land development and activity arrangements that cause the congestion. But for most Americans there is no mechanism that allows them to show that they place a higher value on certain trips. Finding a way to incorporate a pricing mechanism into some travel corridors could provide an important option for urban residents and freight shippers.

A fee has been charged on some transportation projects for a long time. Toll highways and transit routes are two familiar examples. An extension of this concept would treat transportation services like most other aspects of society. There would be a direct charge for using more important system elements. Price is used to regulate the use and demand patterns of telephones, movie seats, electricity, food and many other elements of the economy. In addition to direct charges, transportation facilities and operations are typically paid for by per-gallon fees, sales taxes or property taxes. One could also include the extra time spent in congestion as another way to pay for transportation.

Electronic tolling methods provide a way for travelers to pay for their travel without being penalized by stopping to pay a fee. Electronics can also be used to reduce the fee for travelers in certain social programs (e.g., welfare to work) or to vary the fee by time of day or congestion level. Implementing these special lanes as an addition to roads (rather than converting existing lanes) has been the most common method of instituting pricing options in a corridor. This offers a choice of a premium service for a fee, or lower speed, less reliable travel with no additional fee.

Importance of Evaluating Transportation Systems

Providing the public and decision-makers with a sufficient amount of understandable information can help "make the case" for transportation. Part of the implementation and operation of transportation projects and programs should be a commitment to collecting evaluation data. These statistics not only improve the effectiveness of individual projects, but they also provide the comparative data needed to balance transportation needs and opportunities with other societal imperatives whether those are other infrastructure assets or other programs.

Change the Usage Pattern - Examples

The way that travelers use the transportation network can be modified to accommodate more demand and reduce congestion. Using the telephone or internet for certain trips, traveling in off-peak hours and using public transportation and carpools are examples. Projects that use tolls or pricing incentives can be tailored to meet transportation needs and also address social and economic equity concerns.

Any of these changes will affect the way that travelers, employers and shippers conduct their lives and business; these may not be inconsequential effects. The key will be to provide better conditions and more travel options primarily for work commutes, but there are also opportunities to change trips for shopping, school, health care and a variety of other activities.

Although comprising slightly less than 20 percent of all vehicular trips in the average urban area, commute trips generally cluster around the most congested peak periods and are from the same origin to the same destination at the same time of day(*10*). These factors make commute trips by carpooling, vanpooling, public transit, bicycling and walking more likely. Furthermore, alternative work arrangements—including flexible work hours, compressed work weeks and teleworking—provide another means of shifting trips out of the peak periods. This "triple divergence"—moving away from congested roads—is described in much more detail by Anthony Downs in his book, "Still Stuck in Traffic" (*35*).

The goal of all of these programs is to move trips to uncongested times, routes or modes so that there is less congestion during peak hours and so that more trips can be handled on the current system. Carrying more trips can be thought of in the same way as increasing production in a manufacturing plant. If the current buses, cars and trains can carry more people to the places they want to go, there are benefits to society and the economy.

The role of phones, computers and the internet cannot be overlooked as the future role of commute options are examined. New technologies are being used along with changes in business practices to encourage employers to allow jobs to be done from home or remote locations—and these might allow workers to avoid their commute a few days each month, or travel to their jobsites after a few hours of work at home in the morning.

Atlanta's "Cash for Commuters" program is one example of the newer, more aggressive commute option programs. Built around a Clean Air Campaign, the program involved payment of cash incentives to driver-only commuters who switched to another mode. Participants earned up to $60 per month (for three months) by choosing and using an eligible alternative mode of transportation. During the program, participants used alternative modes an average of more than four days each week compared to less than one day per week before. A year and one-half after the program, participants still used a commute alternative an average of 2.4 days per week. Overall, program participants decreased their single-occupant commute modes from 84 percent to 53 percent. This type of change has benefits in less vehicle travel and fewer parking spaces needed and participants have reported lower frustration levels and better on-time arrival. Decreasing each commuter's peak-period personal vehicle trips by one per week could have substantial congestion benefits, if employers and employees choose these options (*36*).

Relieve Chokepoints - Examples

Congestion does not come in one size or shape and neither do solutions. Some congestion problems start as just a few too many cars trying to get through an intersection or onto a freeway. The slowdowns that begin there penalize travelers and shippers in at least two ways. First, the trips take longer because traffic is moving slower. Secondly, a stop-and-go system is inefficient and fewer travelers can get through the constriction. This double penalty was depicted by Washington State DOT as rice flowing (or not) through a funnel—pour slowly and the rice tumbles through; pour quickly and the constriction point is overwhelmed and rice clogs the funnel (*37*).

Eliminating these problem locations could have huge benefits. A 2004 study of the largest highway bottlenecks by the American Highway Users Alliance (*38*) estimated that there were more than 210 congested locations in 33 states with more than one million hours of travel delay. The top 24 most congested freeway bottlenecks each accounted for more than 10 million hours of delay; these were located in 13 different metropolitan regions. The study noted that progress had been made in the five years since the previous study with seven of the top 20 locations dropping off the worst bottlenecks list through construction improvements.

Similar studies focusing on freight bottlenecks were conducted for the Ohio DOT and expanded to national examinations of freight travel and congestion problems (*39*,*40*,*41*). Several metropolitan regions have also conducted analyses of public transportation service bottlenecks. All the conclusions have been similar—there are significant returns on investment from addressing the locations of most severe congestion. The solutions range from the simple, quick and cheap to the complex, lengthy and expensive. For example, about 250 miles of freeway shoulder in Minneapolis are used to allow buses to bypass stop-and-go traffic, thereby saving time and providing a much more reliable time schedule for public transportation riders. The routes that use the shoulders had a 9.2 percent ridership increase over a two-year period when the overall system ridership decreased 6.5 percent, illustrating the favorable passenger reaction to improved speed and reliability attributes (*42*).

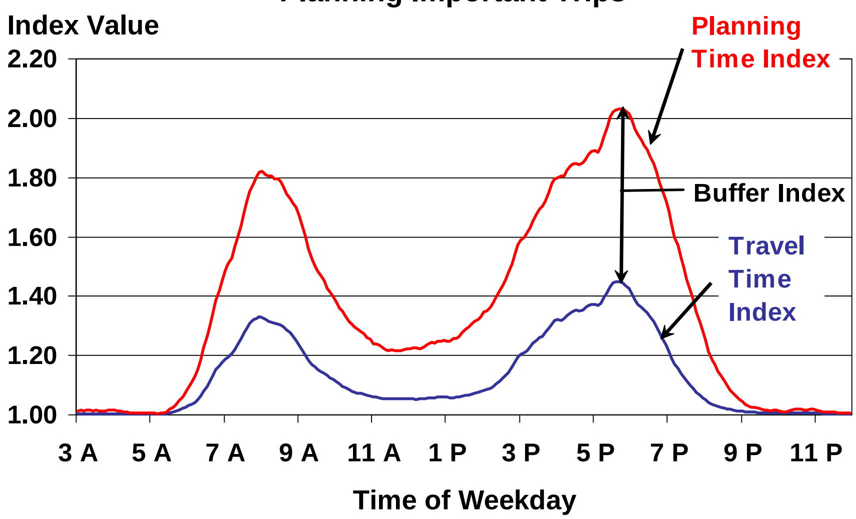
CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Unreliable Travel Times – One of the Congestion Problems

You have an important family event at home at 5:45 p.m. Your normal commute time is 30 to 35 minutes. But you also know that your travel time varies. The problem is that crashes, vehicle breakdowns, road work, weather and variations in daily traffic volume all change the commute from day to day. In order to arrive before the event starts, you must plan for extra travel time. This extra time, or "buffer time," is part of the congestion problem—unreliability.

The Planning Time Index is similar to the Travel Time Index except that the PTI indicates the travel time needed to make your destination on time 19 days out of 20—essentially the worst weekday of the month (*3*). An Index value of 2.0, for example, would mean that you should allow twice as much time for an important trip as your travel time in uncongested conditions. The difference between the average time and the planning time is a reliability measure termed the "Buffer Index." (Exhibit B-41) In general, the Buffer Index goes up in the peak periods, indicating reliability problems and congestion occur at the same time and explaining why so much extra travel time has to be planned.

Exhibit B-41. The Extra "Buffer" Time Needed When Planning Important Trips



Source: Reference (*3*)

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

According to data from some of the freeways in 19 metropolitan regions (Exhibit B-42), travelers and freight shippers should plan on twice as much extra travel time if they have an important trip as they would allow in average conditions. For example, in Phoenix a 20-minute free-flow trip takes an average of almost 28 minutes. On one weekday out of 20 (essentially the worst travel day of the month) that trip will take 36 minutes. The frustrating and economically damaging part of this doubling of the extra travel time (16 minutes vs. 8 minutes more than the free-flow travel time of 20 minutes) is that we cannot know which day that is and how it might affect important trips or deliveries.

This distinction between "average" and "important" is crucial to understanding the role of the solutions described in the next few pages. Some strategies reduce congestion for all travelers and at all times on every day. Other strategies provide options that some travelers, manufacturers or freight shippers might choose for time-sensitive travel. Some solutions target congestion problems that occur every day and others address irregular events such as vehicle crashes that cause some of the longest delays and greatest frustrations.

Exhibit B-42. You Should Plan for Much Longer Travel Times if You Wish to Arrive On-Schedule, 2007 Data

Region	Multiply the free-flow travel time by this factor to estimate the time to reach your destination:	
	In Average Conditions (Travel Time Index)	For an Important Trip (Planning Time Index)
Chicago, IL	1.48	2.07
Detroit, MI	1.24	1.65
Houston, TX	1.43	2.01
Los Angeles, CA	1.47	1.92
Minneapolis-St. Paul, MN	1.29	1.70
Orange County, CA	1.40	1.77
Philadelphia, PA	1.29	1.76
Phoenix, AZ	1.38	1.80
Pittsburgh, PA	1.28	1.70
Portland, OR	1.34	1.87
Providence, RI	1.14	1.43
Riverside-San Bernardino, CA	1.34	1.77
Sacramento, CA	1.26	1.61
Salt Lake City, UT	1.16	1.52
San Antonio, TX	1.22	1.61
San Diego, CA	1.31	1.66
San Francisco, CA	1.25	1.51
Seattle, WA	1.44	2.06
Tampa, FL	1.23	1.55

Source: Reference (*3*)

Note: Index values are a ratio of travel time in the peak to free-flow travel time. A Travel Time Index of 1.40 indicates a 20-minute off-peak trip takes 28 minutes on average. A Planning Time Index of 1.80 indicates the 20-minute off-peak trip might take 36 minutes one day each month.

Note: In most regions only a few freeways are included in this dataset. This difference in coverage and differences in the data collection devices make comparisons between the regional values in Exhibit B-42 impossible. These 2007 data are only for freeways and, thus, not comparable with the areawide data.

COMMUNICATING MOBILITY AND RELIABILITY ISSUES

The transportation profession is adopting a distinction between mobility—the ease of getting to a destination—and reliability—the predictability of travel times for usual trips. Travelers, elected leaders, the media and decision-makers may question the relevance of this distinction since problems with both elements cause increases in travel times and costs. The two concepts are clearly related, but the difference is useful when discussing solutions. Most of the computerized simulation and planning tools are not equipped to fully handle this issue, and so a significant amount of the data on congestion relates to the average of fairly good conditions—midweek day, clear weather and pavement, no collisions or lane-blocking roadwork, etc.—rather than the conditions that travelers and shippers must allow for to arrive on-time for important trips.

There are some strategies that focus on improving "mobility"—improving travel time—by adding capacity, improving the operational efficiency or managing demand in such way as to reduce the peak load. But there are also transportation improvements that reduce average travel time by reducing the amount of irregular problems or the influence of them on travel time. Incident management is the most obvious of these, but others such as providing bus or road routing information, improving interagency or interjurisdictional cooperation and communication and partnerships with private companies can pay huge benefits in reduction of incident clearance times and travel time variations.

The ability to predict travel times is highly valued by travelers and businesses. It affects the starting time and route used by travelers on a day-to-day basis, and the decisions about travel mode for typical trips and for day-to-day variations in decisions. Reliability problems can be traced to seven sources of travel time variation in both road and transit operations. Some are more easily addressed than others and some, such as weather problems, might be addressed by communicating information, rather than by agency design or operations actions.

- Incidents—collisions and vehicle breakdowns causing lane blockages and driver distractions.
- Work Zones—construction and maintenance activity that can cause added travel time in locations and times where congestion is not normally present.
- Weather—reduced visibility, road surface problems and uncertain waiting conditions result in extra travel time and altered trip patterns.
- Demand Changes—traffic volume varies from hour-to-hour and day-to-day and this causes travel time, crowding and congestion patterns to disappear or to significantly worsen for no apparent reason in some locations.
- Special Events—an identifiable case of demand changes where the volume and pattern of the change can frequently be predicted or anticipated.

- Traffic Control Devices—poorly timed of inoperable traffic signals, drawbridges, railroad grade crossing signals or traveler information systems contribute to irregularities in travel time.

- Inadequate Road or Transit Capacity—actually the interaction of capacity problems with the other six sources causes travel time to expand much faster than demand.

The profession is only at the start of understanding the precise mechanisms by which these sources contribute to congestion problems. Both public and private sectors undoubtedly see a cost from unreliable travel times, but those values can be very different for many situations. It is clear that there are several strategies to reduce the problem. There are construction, operations, management, operational practices, education and information components to these strategies. As more research is performed, there will be more detail about the effectiveness of the solutions as well as an idea of how much of the problem has a "solution." If drivers insist on slowing down to look at a collision on the other direction, incident management techniques will be less effective. If road construction zones are allowed to close busy rural roads, there will be problems during holiday travel. There will always be trade-offs between operational efficiencies and the costs necessary to obtain them.

Measuring Reliability

If travelers assume each trip will take the average travel time, they will be late for half of their trips. It has not been determined what level of certainty should be used for trip planning purposes, but it seems reasonable to start with an assumption that a supervisor might allow an employee to be late one day per month. This translates into a need to be on time for approximately 19 out of 20 days, or 95 percent of the time.

The difference between the average conditions and the 95th percentile conditions is the extra time that has to be budgeted, an illustration of the Buffer Time Index measure (Equation B-1). In the middle of the peak in most cities studied in the Mobility Monitoring Program, the sources of travel time variation are more significant than in the midday.

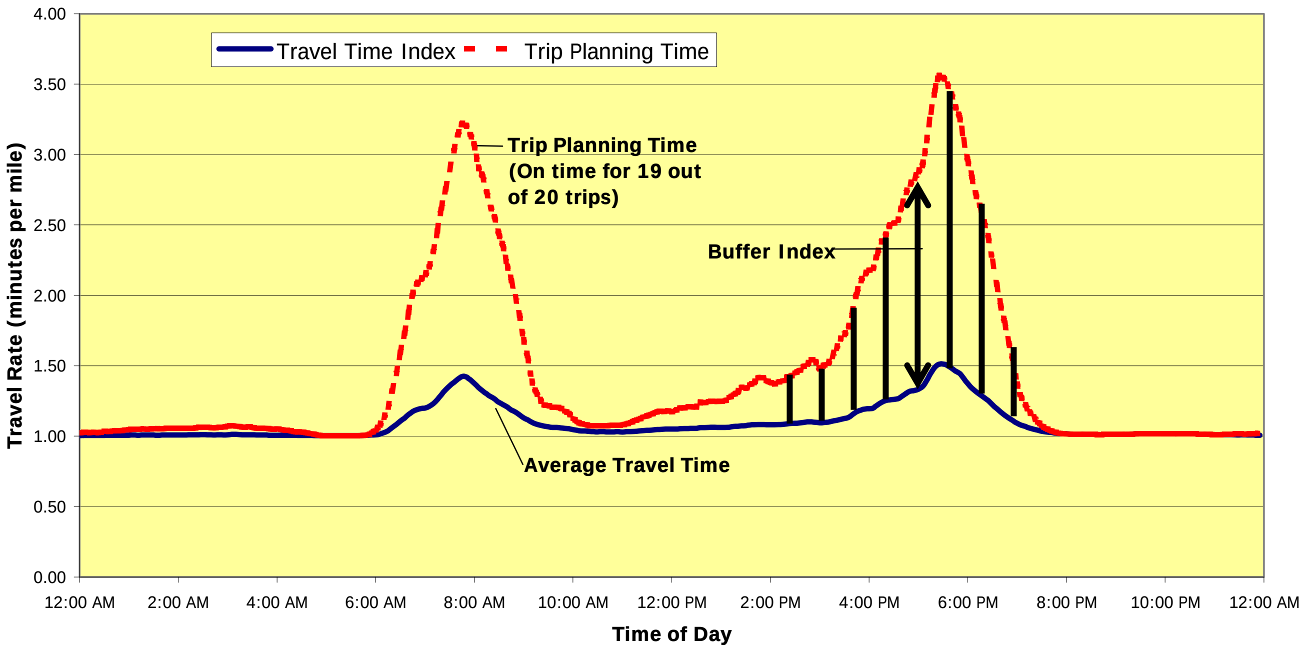
$$\text{Buffer Time Index (BTI)} = \frac{\begin{matrix}\text{95th percentile travel rate} \\ \text{(in minutes per mile)}\end{matrix} - \begin{matrix}\text{Average travel rate} \\ \text{(in minutes per mile)}\end{matrix}}{\begin{matrix}\text{Average travel rate} \\ \text{(in minutes per mile)}\end{matrix}} \times 100\%$$

Eq. B-1

What does all this mean? If you are a commuter who travels between about 7:00 a.m. and 9:00 a.m., Exhibit B-43 indicates your trip takes an average of about 30 percent longer (that is, the TTI value is 1.3) than in the off peak. A 20-mile, 20-minute trip in the off-peak would take an average of 26 minutes in a typical home-to-work trip. The Buffer Time Index during this time is between 50 and 100 percent resulting in a Trip Planning Time of 2.1 minutes per mile. So if your boss wants you to begin work on time 95 percent of the days, you should plan on 42 minutes of travel time (20 miles times an average of 2.1 minutes per mile of trip for the peak period). But, to arrive by 8:00 a.m., you might have to leave your home around 7:00 a.m. because the system is even less reliable in the period between 7:30 a.m. and 8:00 a.m.

CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

Exhibit B-43. Trip Planning Travel Times



The mobility measure, the Travel Time Index, can be thought of as the time penalty for traveling in the peak period. The reliability measure, the Buffer Time Index, describes how much more time above the average should be budgeted to make an on-time trip. Reliability problems can be caused by simple variations in demand, as well as by vehicle crashes or breakdowns, weather, special events, construction, maintenance and other regular and irregular events. It can present difficulties for commuters and off-peak travelers, and for individuals and businesses (*24*).

With both of these measures one can tell how congested a transportation system is and how much variation there is in the congestion. This is particularly important when evaluating the wide range of improvement types that are being implemented. Traditional roadway and transit line construction and some operating improvements such as traffic signal system enhancements are oriented toward the typical, daily congestion levels. Others, such as crash and vehicle breakdown detection and removal programs, address the reliability issue. Most projects, programs and strategies have some benefits for each aspect of urban transportation problems. Future reports will explore the subject in greater depth. For more information about the reliability database, see: http://mobility.tamu.edu/mmp.