SEPTEMBER 2011

2011 URBAN MOBILITY REPORT

Texas Transportation Institute

POWERED BY INRIX TRAFFIC

UTCM
University Transportation Center for Mobility
Texas Transportation Institute

TTI's 2011 URBAN MOBILITY REPORT
Powered by INRIX Traffic Data

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September 2011

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

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Acknowledgements

Pam Rowe and Michelle Young—Report Preparation
Lauren Geng, Nick Koncz and Eric Li—GIS Assistance
Greg Larson—Methodology Development
Tobey Lindsey—Web Page Creation and Maintenance
Richard Cole, Rick Davenport, Bernie Fette and Michelle Hoelscher—Media Relations
John Henry—Cover Artwork
Dolores Hott and Nancy Pippin—Printing and Distribution
Rick Schuman, Jeff Summerson and Jim Bak of INRIX—Technical Support and Media Relations

Support for this research was provided in part by a grant from the U.S. Department of Transportation University Transportation Centers Program to the University Transportation Center for Mobility (DTRT06-G-0044).

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2011 Urban Mobility Report

For the complete report and congestion data on your city, see: http://mobility.tamu.edu/ums.

Congestion is a significant problem in America's 439 urban areas. And after the economic recession and slow recovery of the last few years, congestion is again a growing problem. Readers and policy makers may have been distracted by the economy-based congestion reductions. The 2010 data indicate the problem will not go away by itself – action is needed.

- First, the problem is very large. In 2010, congestion caused urban Americans to travel 4.8 billion hours more and to purchase an extra 1.9 billion gallons of fuel for a congestion cost of $101 billion.
- Second, 2008 was the best year for congestion in recent times (see Exhibit 2); congestion was worse in 2009 and 2010.
- Third, there is only a short-term cause for celebration. Prior to the economy slowing, just 4 years ago, congestion levels were much higher than a decade ago; these conditions will return with a strengthening economy.

There are many ways to address congestion problems; the data show that these are not being pursued aggressively enough. The most effective strategy is one where agency actions are **complemented** by efforts of businesses, manufacturers, commuters and travelers. There is no **rigid prescription** for the "best way"—**each region** must identify the projects, programs and policies that achieve goals, solve problems and capitalize on opportunities.

Exhibit 1. Major Findings of the 2011 Urban Mobility Report (439 U.S. Urban Areas)
(Note: See page 2 for description of changes since the 2010 Report)

Measures of…	1982	2000	2005	2009	2010
… Individual Congestion					
Yearly delay per auto commuter (hours)	14	35	39	34	34
Travel Time Index	1.09	1.21	1.25	1.20	1.20
Commuter Stress Index	--	--	--	1.29	1.30
"Wasted" fuel per auto commuter (gallons)	6	14	17	14	14
Congestion cost per auto commuter (2010 dollars)	$301	$701	$814	$723	$713
… The Nation's Congestion Problem					
Travel delay (billion hours)	1.0	4.0	5.2	4.8	4.8
"Wasted" fuel (billion gallons)	0.4	1.6	2.2	1.9	1.9
Truck congestion cost (billions of 2010 dollars)	--	--	--	$24	$23
Congestion cost (billions of 2010 dollars)	$21	$79	$108	$101	$101
… The Effect of Some Solutions					
Yearly travel delay saved by:					
Operational treatments (million hours)	8	190	312	321	327
Public transportation (million hours)	381	720	802	783	796
Fuel saved by:					
Operational treatments (million gallons)	1	79	126	128	131
Public transportation (million gallons)	139	294	326	313	303
Yearly congestion costs saved by:					
Operational treatments (billions of 2010$)	$0.2	$3.1	$6.5	$6.7	$6.9
Public transportation (billions of 2010$)	$6.9	$12.0	$16.9	$16.5	$16.8

Yearly delay per auto commuter – The extra time spent traveling at congested speeds rather than free-flow speeds by private vehicle drivers and passengers who typically travel in the peak periods.
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 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak period.
Commuter Stress Index – The ratio of travel time for the peak direction to travel time at free-flow conditions. A TTI calculation for only the most congested direction in both peak periods.
Wasted fuel – Extra fuel consumed during congested travel.
Congestion cost – The yearly value of delay time and wasted fuel.

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The Congestion Trends

(And the New Data Providing a More Accurate View)

The 2011 *Urban Mobility Report* is the 2nd prepared in partnership with INRIX, a leading private sector provider of travel time information for travelers and shippers. This means the 2011 Urban Mobility Report has millions of data points resulting in an average speed on almost every mile of major road in urban America for almost every hour of the day. For the congestion analyst, this is an awesome amount of information. For the policy analyst and transportation planner, these congestion problems can be described in detail and solutions can be targeted with much greater specificity and accuracy.

The INRIX speed data is combined with traffic volume data from the states to provide a much better and more detailed picture of the problems facing urban travelers. This one-of-its-kind data combination gives the Urban Mobility Report an unrivaled picture of urban traffic congestion.

INRIX (*1*) anonymously collects traffic speed data from personal trips, commercial delivery vehicle fleets and a range of other agencies and companies and compiles them into an average speed profile for most major roads. The data show conditions for every day of the year and include the effect of weather problems, traffic crashes, special events, holidays, work zones and the other congestion causing (and reducing) elements of today's traffic problems. TTI combined these speeds with detailed traffic volume data (*2*) to present an estimate of the scale, scope and patterns of the congestion problem in urban America.

The new data and analysis changes the way the mobility information can be presented and how the problems are evaluated. Key aspects of the 2011 report are summarized below.

- Hour-by-hour speeds collected from a variety of sources on every day of the year on most major roads are used in the 101 detailed study areas and the 338 other urban areas. For more information about INRIX, go to www.inrix.com.
- The data for all 24 hours makes it possible to track congestion problems for the midday, overnight and weekend time periods.
- Truck freight congestion is explored in more detail thanks to research funding from the National Center for Freight and Infrastructure Research and Education (CFIRE) at the University of Wisconsin (http://www.wistrans.org/cfire/).
- A new wasted fuel estimation process was developed to use the more detailed speed data. The procedure is based on the Environmental Protection Agency's new modeling procedure-Motor Vehicle Emission Simulator (MOVES). While this model does not capture the second-to-second variations in fuel consumption due to stop-and-go driving, it, along with the INRIX hourly speed data, provides a better estimate than previous procedures based on average daily traffic speeds.
- One new congestion measure is debuted in the 2011 Urban Mobility Report. Total travel time is the sum of delay time and free-flow travel time. It estimates the amount of time spent on the road. More information on total travel time can be found at: http://mobility.tamu.edu/resources/

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Exhibit 2. National Congestion Measures, 1982 to 2010

						Hours Saved (million hours)		Gallons Saved (million gallons)		Dollars Saved (billions of 2010$)	
Year	Travel Time Index	Delay per Commuter (hours)	Total Delay (billion hours)	Fuel Wasted (billion gallons)	Total Cost (2010$ billion)	Operational Treatments & HOV Lanes	Public Transp	Operational Treatments & HOV Lanes	Public Transp	Operational Treatments & HOV Lanes	Public Transp
1982	1.09	14.4	0.99	0.36	20.6	8	381	1	139	0.2	6.9
1983	1.09	15.7	1.09	0.40	22.3	10	389	3	142	0.2	7.1
1984	1.10	16.9	1.19	0.44	24.3	14	403	5	149	0.3	7.3
1985	1.11	19.0	1.38	0.51	28.0	19	427	6	160	0.3	7.6
1986	1.12	21.1	1.59	0.60	31.2	25	404	8	156	0.4	7.0
1987	1.13	23.2	1.76	0.68	34.6	32	416	11	161	0.6	7.2
1988	1.14	25.3	2.03	0.79	39.7	42	508	14	197	0.7	8.8
1989	1.16	27.4	2.22	0.87	43.8	51	544	17	214	0.8	9.5
1990	1.16	28.5	2.35	0.93	46.4	58	542	20	216	0.9	9.4
1991	1.16	28.5	2.41	0.96	47.4	61	536	21	216	1.0	9.3
1992	1.16	28.5	2.57	1.02	50.5	69	527	24	211	1.1	9.1
1993	1.17	29.6	2.71	1.07	53.1	77	520	27	208	1.2	9.0
1994	1.17	30.6	2.82	1.12	55.4	86	541	30	217	1.4	9.4
1995	1.18	31.7	3.02	1.21	59.7	101	569	35	232	1.7	9.9
1996	1.19	32.7	3.22	1.30	63.8	116	589	40	241	1.9	10.3
1997	1.19	33.8	3.40	1.37	67.1	132	607	46	249	2.2	10.6
1998	1.20	33.8	3.54	1.44	68.9	150	644	52	267	2.4	11.0
1999	1.21	34.8	3.80	1.55	73.9	173	683	59	285	2.8	11.7
2000	1.21	34.8	3.97	1.63	79.2	190	720	79	294	3.1	12.0
2001	1.22	35.9	4.16	1.71	82.6	215	749	89	307	3.7	12.9
2002	1.23	36.9	4.39	1.82	87.2	239	758	101	314	4.2	13.2
2003	1.23	36.9	4.66	1.93	92.4	276	757	115	311	4.8	13.3
2004	1.24	39.1	4.96	2.06	100.2	299	798	127	331	5.5	14.8
2005	1.25	39.1	5.22	2.16	108.1	325	809	135	336	6.3	15.9
2006	1.24	39.1	5.25	2.18	110.0	359	845	150	354	7.2	17.3
2007	1.24	38.4	5.19	2.20	110.3	363	889	152	372	7.6	18.9
2008	1.20	33.7	4.62	1.88	97.0	312	802	126	326	6.5	16.9
2009	1.20	34.0	4.80	1.92	100.9	321	783	128	313	6.7	16.5
2010	1.20	34.4	4.82	1.94	100.9	327	796	131	303	6.9	16.8

Note: For more congestion information see Tables 1 to 9 and http://mobility.tamu.edu/ums.

One Page of Congestion Problems

In many regions, traffic jams can occur at any daylight hour, many nighttime hours and on weekends. The problems that travelers and shippers face include extra travel time, unreliable travel time and a system that is vulnerable to a variety of irregular congestion-producing occurrences. All of these are a much greater problem now than in 1982. Some key descriptions are listed below. See data for your city at mobility.tamu.edu/ums/congestion_data.

Congestion costs are increasing. The congestion "invoice" for the cost of extra time and fuel in 439 urban areas was (all values in constant 2010 dollars):

- In 2010 – $101 billion
- In 2000 – $79 billion
- In 1982 – $21 billion

Congestion wastes a massive amount of time, fuel and money. In 2010:

- 1.9 billion gallons of wasted fuel (equivalent to about 2 months of flow in the Alaska Pipeline).
- 4.8 billion hours of extra time (equivalent to the time Americans spend relaxing and thinking in 10 weeks).
- $101 billion of delay and fuel cost (the negative effect of uncertain or longer delivery times, missed meetings, business relocations and other congestion-related effects are not included).
- $23 billion of the delay cost was the effect of congestion on truck operations; this does not include any value for the goods being transported in the trucks.
- The cost to the average commuter was $713 in 2010 compared to an inflation-adjusted $301 in 1982.

Congestion affects people who make trips during the peak period.

- Yearly peak period delay for the average commuter was 34 hours in 2010, up from 14 hours in 1982.
- Those commuters wasted 14 gallons of fuel in the peak periods in 2010 – a week's worth of fuel for the average U.S. driver – up from 6 gallons in 1982.
- Congestion effects were even larger in areas with over one million persons – 44 hours and 20 gallons in 2010.
- "Rush hour" – possibly the most misnamed period ever – lasted 6 hours in the largest areas in 2010.
- Fridays are the worst days to travel. The combination of work, school, leisure and other trips mean that urban residents earn their weekend after suffering 200 million more delay hours than Monday.
- 60 million Americans suffered more than 30 hours of delay in 2010.

Congestion is also a problem at other hours.

- Approximately 40 percent of total delay occurs in the midday and overnight (outside of the peak hours of 6 to 10 a.m. and 3 to 7 p.m.) times of day when travelers and shippers expect free-flow travel. Many manufacturing processes depend on a free-flow trip for efficient production; it is difficult to achieve the most desirable outcome with a network that may be congested at any time of day.

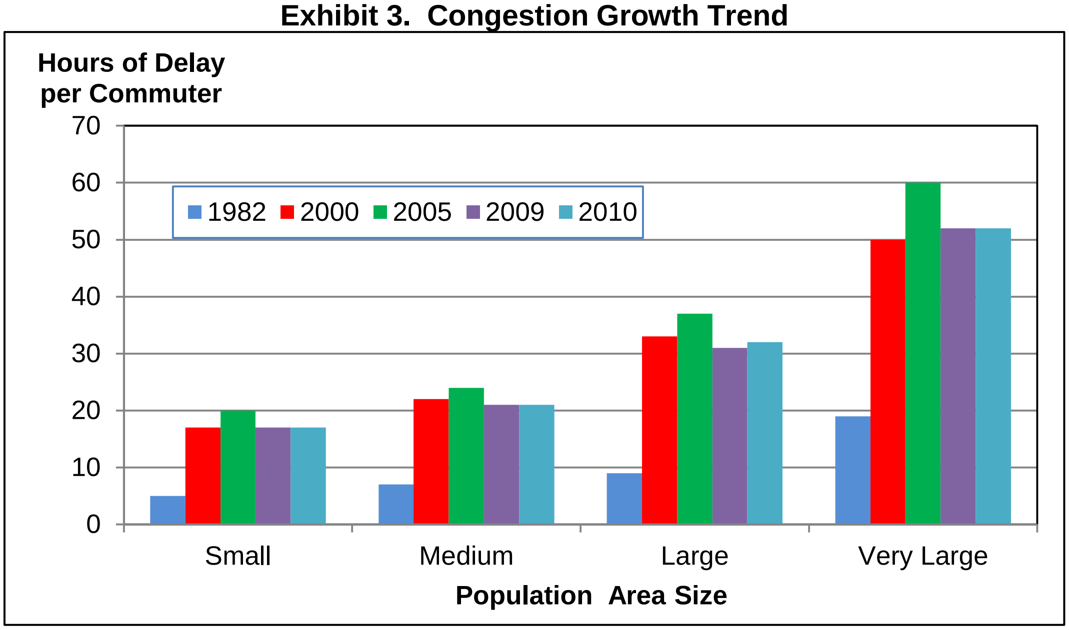
More Detail About Congestion Problems

Congestion, by every measure, has increased substantially over the 29 years covered in this report. The recent decline in congestion brought on by the economic recession has been reversed in most urban regions. This is consistent with the pattern seen in some metropolitan regions in the 1980s and 1990s; economic recessions cause fewer goods to be purchased, job losses mean fewer people on the road in rush hours and tight family budgets mean different travel decisions are made. As the economy recovers, so does traffic congestion. In previous regional recessions, once employment began a sustained, significant growth period, congestion increased as well.

The total congestion problem in 2010 was approximately near the levels recorded in 2004; growth in the number of commuters means that the delay per commuter is less in 2010. This "reset" in the congestion trend, and the low prices for construction, should be used as a time to promote congestion reduction programs, policies and projects.

Congestion is worse in areas of every size – it is not just a big city problem. The growing delays also hit residents of smaller cities (Exhibit 3). 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.

Exhibit 3. Congestion Growth Trend



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

Think of what else could be done with the 34 hours of extra time suffered by the average urban auto commuter in 2010:

- 4 vacation days
- The time the average American spends eating and drinking in a month.

And the 4.8 billion hours of delay is the equivalent of more than 1,400 days of Americans playing Angry Birds – this is a lot of time.

Congestion builds through the week from Monday to Friday. The two weekend days have less delay than any weekday (Exhibit 4). Congestion is worse in the evening but it can be a problem all day (Exhibit 5). Midday hours comprise a significant share of the congestion problem (approximately 30% of total delay).

Exhibit 4. Percent of Delay for Each Day

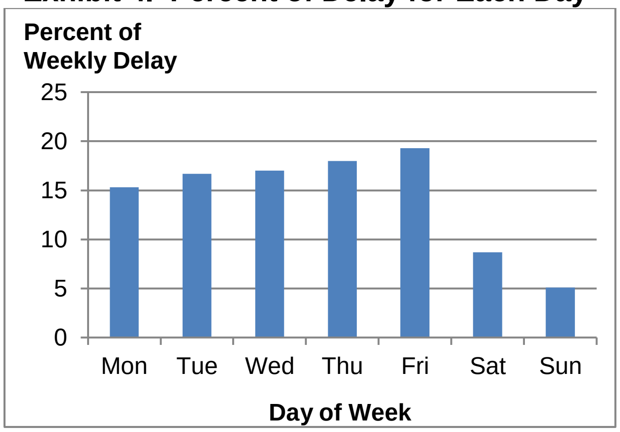
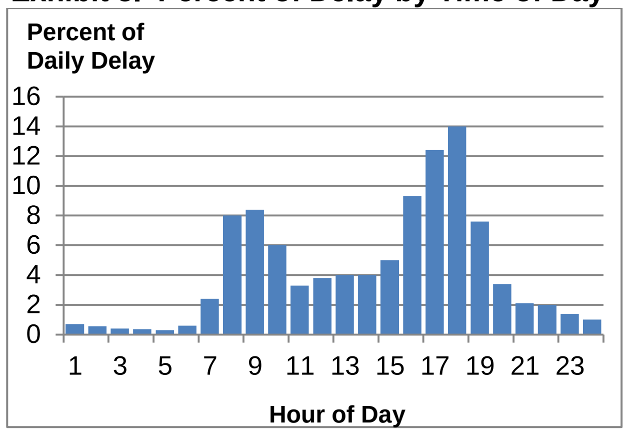
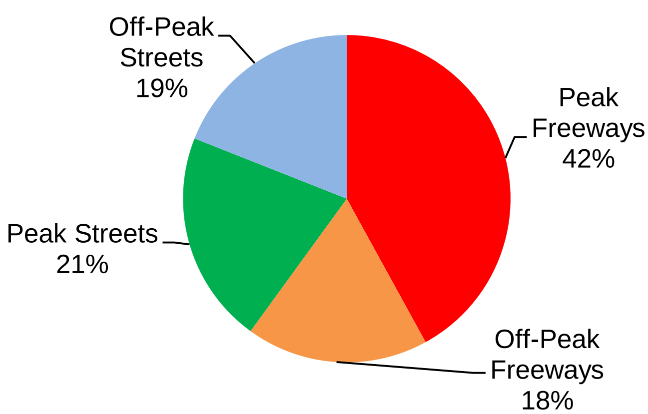


Exhibit 5. Percent of Delay by Time of Day



Freeways have more delay than streets, but not as much as you might think (Exhibit 6).

Exhibit 6. Percent of Delay for Road Types



The "surprising" congestion levels have logical explanations in some regions.

The urban area congestion level rankings shown in Tables 1 through 9 may surprise some readers. The areas listed below are examples of the reasons for higher than expected congestion levels.

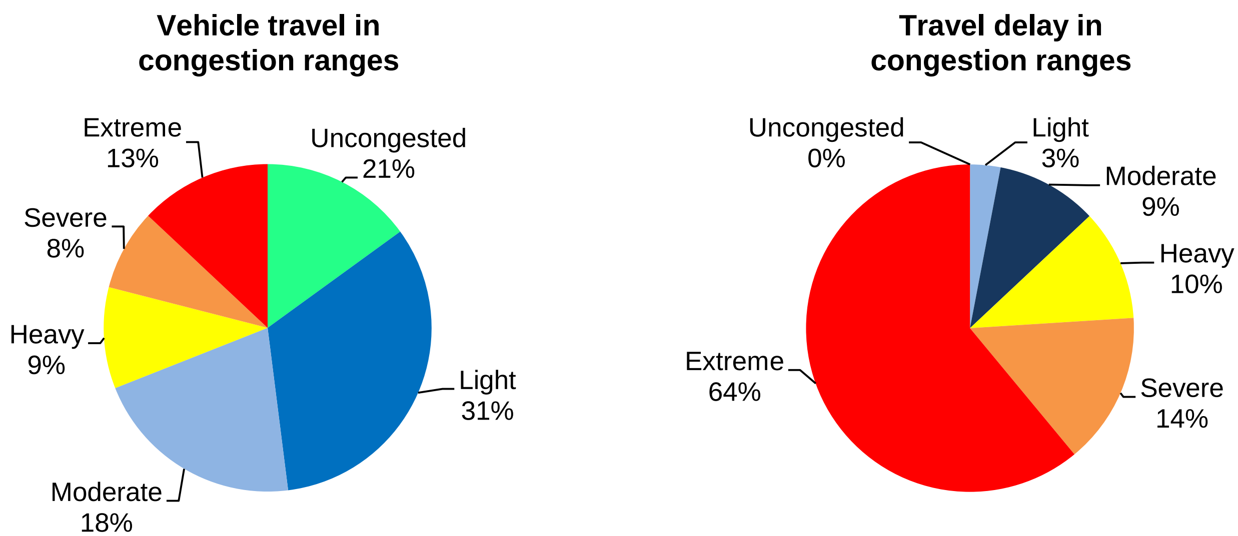
- *Work zones* – Baton Rouge. Construction, even when it occurs in the off-peak, can increase traffic congestion.
- *Smaller urban areas with a major interstate highway* – Austin, Bridgeport, Salem. High volume highways running through smaller urban areas generate more traffic congestion than the local economy causes by itself.
- *Tourism* – Orlando, Las Vegas. The traffic congestion measures in these areas are divided by the local population numbers causing the per-commuter values to be higher than normal.

- *Geographic constraints* – Honolulu, Pittsburgh, Seattle. Water features, hills and other geographic elements cause more traffic congestion than regions with several alternative routes.

Travelers and shippers must plan around congestion more often.

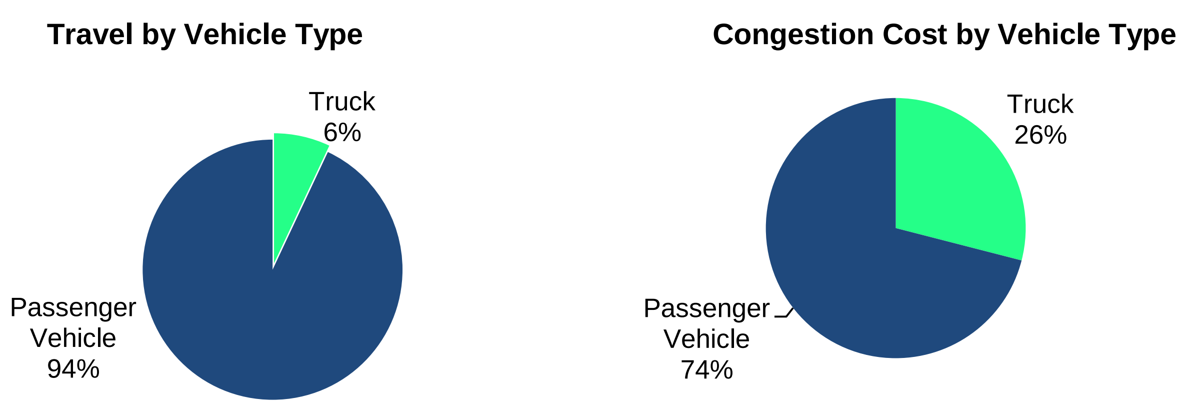
- In all 439 urban areas, the worst congestion levels affected only 1 in 9 trips in 1982, but almost 1 in 4 trips in 2010 (Exhibit 7).
- The most congested sections of road account for 78% of peak period delays, with only 21% of the travel (Exhibit 7).
- Delay has grown about five times larger overall since 1982.

Exhibit 7. Peak Period Congestion and Congested Travel in 2010



While trucks only account for about 6 percent of the miles traveled in urban areas, they are almost 26 percent of the urban "congestion invoice." In addition, the cost in Exhibit 8 only includes the cost to operate the truck in heavy traffic; the extra cost of the commodities is not included.

Exhibit 8. 2010 Congestion Cost for Urban Passenger and Freight Vehicles



The Future of Congestion

As Yogi Berra said, "I don't like to make predictions, especially about the future…" But with a few clearly stated assumptions, this report provides some estimates of the near-future congestion problem. Basically, these assumptions relate to the growth in travel and the amount of effort being made to accommodate that growth, as well as address the current congestion problem. In summary, the outlook is not sunshine and kittens.

- Population and employment growth—two primary factors in rush hour travel demand—are projected to grow slightly slower from 2010 to 2020 than in the previous ten years.
- The combined role of the government and private sector will yield approximately the same rate of transportation system expansion (both roadway and public transportation). (The analysis assumed that policies and funding levels will remain about the same).
- The growth in usage of any of the alternatives (biking, walking, work or shop at home) will continue at the same rate.
- Decisions as to the priorities and level of effort in solving transportation problems will continue as in the recent past.
- The period before the economic recession was used as the indicator of the effect of growth. The years from 2000 to 2006 had generally steady economic growth in most U.S. urban regions; these years are assumed to be a good indicator of the future level of investment in solutions and the resulting increase in congestion.

If this "status quo" benchmark is applied to the next five to ten years, a rough estimate of future congestion can be developed. The congestion estimate for any single region will be affected by the funding, project selections and operational strategies; the simplified estimation procedure used in this report will not capture these variations. Combining all the regions into one value for each population group, however, may result in a balance between estimates that are too high and those that are too low.

- The national congestion cost will grow from $101 billion to $133 billion in 2015 and $175 billion in 2020 (in 2010 dollars).
- Delay will grow to 6.1 billion hours in 2015 and 7.7 billion hours in 2020.
- The average commuter will see their cost grow to $937 in 2015 and $1,232 in 2020 (in 2010 dollars). They will waste 37 hours and 16 gallons in 2015 and 41 hours and 19 gallons in 2020.
- Wasted fuel will increase to 2.5 billion gallons in 2015 and 3.2 billion gallons in 2020.
- If the price of gasoline grows to $5 per gallon, the congestion-related fuel cost would grow to $13 billion in 2015 and $16 billion in 2020.

Freight Congestion and Commodity Value

Trucks carry goods to suppliers, manufacturers and markets. They travel long and short distances in peak periods, middle of the day and overnight. Many of the trips conflict with commute trips, but many are also to warehouses, ports, industrial plants and other locations that are not on traditional suburb to office routes. Trucks are a key element in the just-in-time (or lean) manufacturing process; these business models use efficient delivery timing of components to reduce the amount of inventory warehouse space. As a consequence, however, trucks become a mobile warehouse and if their arrival times are missed, production lines can be stopped, at a cost of many times the value of the truck delay times.

Congestion, then, affects truck productivity and delivery times and can also be caused by high volumes of trucks, just as with high car volumes. One difference between car and truck congestion costs is important; a significant share of the $23 billion in truck congestion costs in 2010 was passed on to consumers in the form of higher prices. The congestion effects extend far beyond the region where the congestion occurs.

The 2010 Urban Mobility Report, with funding from the National Center for Freight and Infrastructure Research and Education (CFIRE) at the University of Wisconsin and data from USDOT's Freight Analysis Framework (*6*), developed an estimate of the value of commodities being shipped by truck to and through urban areas and in rural regions. The commodity values were matched with truck delay estimates to identify regions where high values of commodities move on congested roadway networks.

Table 5 points to a correlation between commodity value and truck delay—higher commodity values are associated with more people; more people are associated with more traffic congestion. Bigger cities consume more goods, which means a higher value of freight movement. While there are many cities with large differences in commodity and delay ranks, only 17 urban areas are ranked with commodity values much higher than their delay ranking.

The Table also illustrates the role of long corridors with important roles in freight movement. Some of the smaller urban areas along major interstate highways along the east and west coast and through the central and Midwestern U.S., for example, have commodity value ranks much higher than their delay ranking. High commodity values and lower delay might sound advantageous—lower congestion levels with higher commodity values means there is less chance of congestion getting in the way of freight movement. At the areawide level, this reading of the data would be correct, but in the real world the problem often exists at the road or even intersection level—and solutions should be deployed in the same variety of ways.

Possible Solutions

Urban and rural corridors, ports, intermodal terminals, warehouse districts and manufacturing plants are all locations where truck congestion is a particular problem. Some of the solutions to these problems look like those deployed for person travel—new roads and rail lines, new lanes on existing roads, lanes dedicated to trucks, additional lanes and docking facilities at warehouses and distribution centers. New capacity to handle freight movement might be an even larger need in coming years than passenger travel capacity. Goods are delivered to retail and commercial stores by trucks that are affected by congestion. But "upstream" of the store shelves, many manufacturing operations use just-in-time processes that rely on the ability of trucks to maintain a reliable schedule. Traffic congestion at any time of day causes potentially costly disruptions. The solutions might be implemented in a broad scale to address freight traffic growth or targeted to road sections that cause freight bottlenecks.

Other strategies may consist of regulatory changes, operating practices or changes in the operating hours of freight facilities, delivery schedules or manufacturing plants. Addressing customs, immigration and security issues will reduce congestion at border ports-of-entry. These technology, operating and policy changes can be accomplished with attention to the needs of all stakeholders and can produce as much from the current systems and investments as possible.

The Next Generation of Freight Measures

The dataset used for Table 5 provides origin and destination information, but not routing paths. The *2011 Urban Mobility Report* developed an estimate of the value of commodities in each urban area, but better estimates of value will be possible when new freight models are examined. Those can be matched with the detailed speed data from INRIX to investigate individual congested freight corridors and their value to the economy.

Congestion Relief – An Overview of the Strategies

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 an 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.

Congestion Solutions – The Effects

The *2011Urban Mobility Report* database includes the effect of several widely implemented congestion solutions. These strategies provide faster and more reliable travel and make the most of the roads and public transportation systems that have been built. These solutions use a combination of information, technology, design changes, operating practices and construction programs to create value for travelers and shippers. There is a double benefit to efficient operations-travelers benefit from better conditions and the public sees that their tax dollars are being used wisely. The estimates described in the next few pages are a reflection of the benefits from these types of roadway operating strategies and public transportation systems.

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 2010, the 439 urban areas would have suffered an additional 796 million hours of delay and consumed 300 million more gallons of fuel (Exhibit 9). 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 $16.8 billion, a 17% increase over current congestion costs in the 439 urban areas.

There were approximately 55 billion passenger-miles of travel on public transportation systems in the 439 urban areas in 2010 (*4*). The benefits from public transportation vary by the amount of travel and the road congestion levels (Exhibit 9). More information on the effects for each urban area is included in Table 3.

Exhibit 9. Delay Increase in 2010 if Public Transportation Service Were Eliminated – 439 Areas

Population Group and Number of Areas	Average Annual Passenger-Miles of Travel (Million)	Reduction Due to Public Transportation			
		Hours of Delay Saved (Million)	Percent of Base Delay	Gallons of Fuel (Million)	Dollars Saved ($ Million)
Very Large (15)	41,481	681	24	271	14,402
Large (33)	5,867	74	7	23	1,518
Medium (32)	1,343	12	3	2	245
Small (21)	394	3	3	1	62
Other (338)	5,930	26	5	6	584
National Urban Total	55,015	796	16	303	$16,811

Source: Reference (*4*) and Review by Texas Transportation Institute

Better Traffic Flow

Improving transportation systems is about more than just adding road lanes, transit routes, sidewalks and bike lanes. It is also about operating those systems efficiently. Not only does congestion cause slow speeds, it also decreases the traffic volume that can use the roadway; stop-and-go roads only carry half to two-thirds of the vehicles as a smoothly flowing road. This is why simple volume-to-capacity measures are not good indicators; actual traffic volumes are low in stop-and-go conditions, so a volume/capacity measure says there is no congestion problem. Several types of improvements have been widely deployed to improve traffic flow on existing roadways.

Five prominent types of operational treatments are estimated to relieve a total of 327 million hours of delay (6% of the total) with a value of $6.9 billion in 2010 (Exhibit 10). If the treatments were deployed on all major freeways and streets, the benefit would expand to almost 740 million hours of delay (14% of delay) and more than $15 billion would be saved. These are significant benefits, especially since these techniques can be enacted more quickly than significant roadway or public transportation system expansions can occur. The operational treatments, however, are not large enough to replace the need for those expansions.

Exhibit 10. Operational Improvement Summary for All 439 Urban Areas

Population Group and Number of Areas	Reduction Due to Current Projects			Delay Reduction if In Place on All Roads (Million Hours)
	Hours of Delay Saved (Million)	Gallons of Fuel Saved (Million)	Dollars Saved ($ Million)	
Very Large (15)	235	103	4,948	580
Large (33)	60	21	1,264	82
Medium (32)	12	3	245	31
Small (21)	3	1	62	7
Other (338)	17	3	356	36
TOTAL	327	131	$6,875	736

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 (*2,5*).

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/

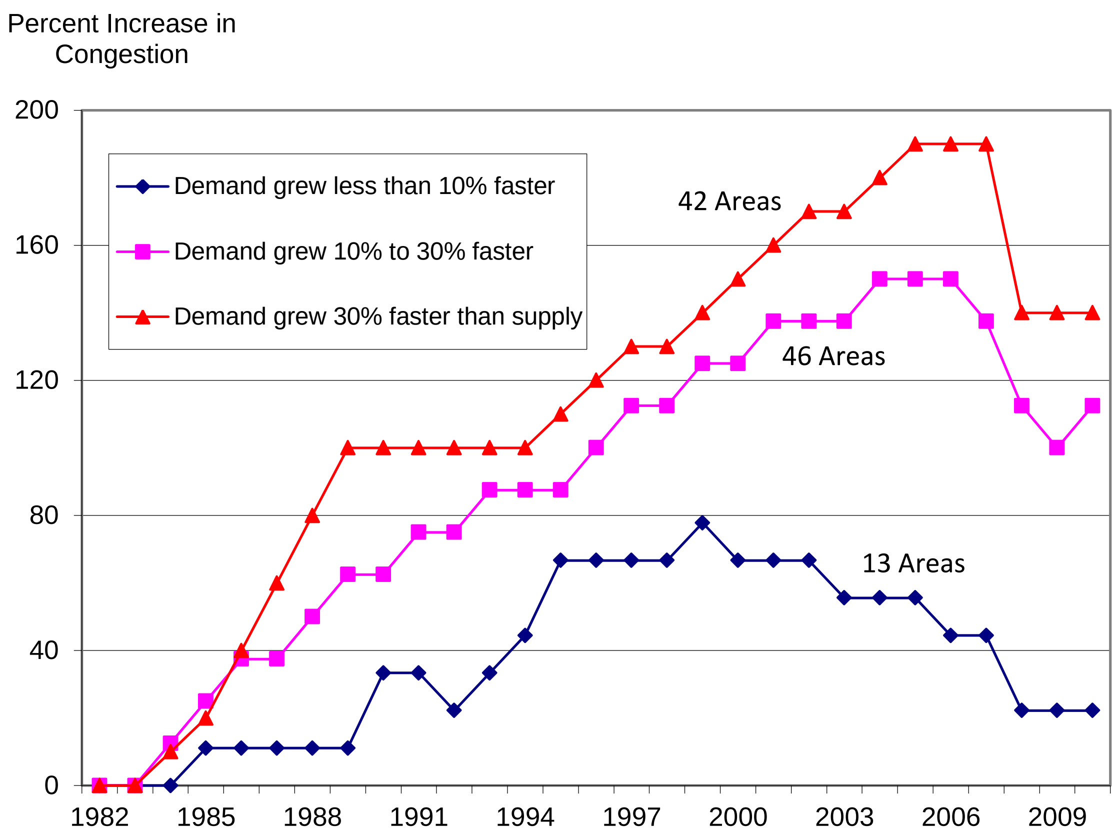
CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

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 2010 (Exhibit 11). 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 areas were able to accomplish that rate, there must be a broader and larger set of solutions applied to the problem. Most of these regions (listed in) were not in locations of high economic growth, suggesting their challenges were not as great as in regions with booming job markets.

Exhibit 11. Road Growth and Mobility Level



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

Total Travel Time

Another approach to measuring some aspects of congestion is the total time spent traveling in the peak periods. The measure can be used with other *Urban Mobility Report* statistics in a balanced transportation and land use pattern evaluation program. As with any measure, the analyst must understand the components of the measure and the implications of its use. In the *Urban Mobility Report* context where trends are important, values for cities of similar size and/or congestion levels can be used as comparisons. Year-to-year changes for an area can also be used to help an evaluation of long-term policies. The measure is particularly well-suited for long-range scenario planning as it shows the effect of the combination of different transportation investments and land use arrangements.

Some have used total travel time to suggest that it shows urban residents are making poor home and job location decisions or are not correctly evaluating their travel options. There are several factors that should be considered when examining values of total travel time.

- Travel delay – The extra travel time due to congestion
- Type of road network – The mix of high-speed freeways and slower streets
- Development patterns – The physical arrangement of living, working, shopping, medical, school and other activities
- Home and job location – Distance from home to work is a significant portion of commuting
- Decisions and priorities – It is clear that congestion is not the only important factor in the location and travel decisions made by families

Individuals and families frequently trade one or two long daily commutes for other desirable features such as good schools, medical facilities, large homes or a myriad of other factors.

Total travel time (see Table 4) can provide additional explanatory power to a set of mobility performance measures. It provides some of the desirable aspects of accessibility measures, while at the same time being a travel time quantity that can be developed from actual travel speeds. Regions that are developed in a relatively compact urban form will also score well, which is why the measure may be particularly well-suited to public discussions about regional plans and how investments support can support the attainment of goals.

Preliminary Calculation for 2011 Report

The calculation procedures and base data used for the total travel time measure in the *2011 Urban Mobility Report* are a first attempt at combining several datasets that have not been used for these purposes. There are clearly challenges to a broader use of the data; the data will be refined in the next few years. Any measure that appears to suggest that Jackson, Mississippi has the second worst traffic conditions and Baltimore is 67th requires some clarification. The measure is in peak period minutes of road travel per auto commuter, so some of the problem may be in the estimates of commuters. Other problems may be derived from the local street travel estimates that have not been extensively used. Many of the values in Table 4 are far in excess of the average commuting times reported for the regions (for example, one-way commute times two trips per day).

More information about total travel time measure can be found at:
http://mobility.tamu.edu/resources/

Using the Best Congestion Data & Analysis Methodologies

The base data for the *2011 Urban Mobility Report* come from INRIX, the U.S. Department of Transportation and the states (*1,2,4*). Several analytical processes are used to develop the final measures, but the biggest improvement in the last two decades is provided by INRIX data. The speed data covering most major roads in U.S. urban regions eliminates the difficult process of estimating speeds and dramatically improves the accuracy and level of understanding about the congestion problems facing US travelers.

The methodology is described in a series of technical reports (*7,8,9,10*) that are posted on the mobility report website: http://mobility.tamu.edu/ums/report/methodology.stm.

- The INRIX traffic speeds are collected from a variety of sources and compiled in their National Average Speed (NAS) database. Agreements with fleet operators who have location devices on their vehicles feed time and location data points to INRIX. Individuals who have downloaded the INRIX application to their smart phones also contribute time/location data. The proprietary process filters inappropriate data (e.g., pedestrians walking next to a street) and compiles a dataset of average speeds for each road segment. TTI was provided a dataset of hourly average speeds for each link of major roadway covered in the NAS database for 2007 to 2010 (approximately 1 million centerline miles in 2010).
- Hourly travel volume statistics were developed with a set of procedures developed from computer models and studies of real-world travel time and volume data. The congestion methodology uses daily traffic volume converted to average hourly volumes using a set of estimation curves developed from a national traffic count dataset (*11*).
- The hourly INRIX speeds were matched to the hourly volume data for each road section on the FHWA maps.
- An estimation procedure was also developed for the INRIX data that was not matched with an FHWA road section. The INRIX sections were ranked according to congestion level (using the Travel Time Index); those sections were matched with a similar list of most to least congested sections according to volume per lane (as developed from the FHWA data) (*2*). Delay was calculated by combining the lists of volume and speed.
- The effect of operational treatments and public transportation services were estimated using methods similar to previous Urban Mobility Reports.
- The trend in delay from years 1982 to 2007 from the previous Urban Mobility Report methodology was used to create the updated urban delay values.

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. The congested corridor data and the travel time reliability statistics are two examples of the improved data and analysis procedures for this year. In addition to the travel speed information from INRIX, some advanced transit operating systems monitor passenger volume, travel time and schedule information. These data can be used to more accurately describe congestion problems on public transportation and roadway systems.

Concluding Thoughts

Congestion has gotten worse in many ways since 1982:

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

The *2011 Urban Mobility Report* points to a $101 billion congestion cost, $23 billion of which is due to truck congestion—and that is only the value of wasted time, fuel and truck operating costs. Congestion causes the average urban resident to spend an extra 34 hours of travel time and use 14 extra gallons of fuel, which amounts to an average cost of $713 per commuter. 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 economic slowdown points to one of the basic rules of traffic congestion—if fewer people are traveling, there will be less congestion. Not exactly "man bites dog" type of findings. Before everyone gets too excited about the decline in congestion, consider these points:

- 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. And we think 2008 was the best year for mobility in the last several; congestion was worse in 2009 and 2010.

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

Solutions and Performance Measurement

There are solutions that work. There are significant benefits from aggressively attacking congestion problems—whether they are large or small, in big metropolitan regions or smaller urban areas and no matter the cause. Performance measures and detailed data like those used in the *2011 Urban Mobility Report* can guide those investments, identify operating changes that should be made and provide the public with the assurance that their dollars are being spent wisely. Decision-makers and project planners alike should use the comprehensive congestion data to describe the problems and solutions in ways that resonate with traveler experiences and frustrations.

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.

The good news from the *2011 Urban Mobility Report* is that the data can improve decisions and the methods used to communicate the effects of actions. The information can be used to study congestion problems in detail and decide how to fund and implement projects, programs and policies to attack the problems. And because the data relate to everyone's travel experiences, the measures are relatively easy to understand and use to develop solutions that satisfy the transportation needs of a range of travelers, freight shippers, manufacturers and others.

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

National Congestion Tables

Table 1. What Congestion Means to You, 2010

Urban Area	Yearly Delay per Auto Commuter		Travel Time Index		Excess Fuel per Auto Commuter		Congestion Cost per Auto Commuter	
	Hours	Rank	Value	Rank	Gallons	Rank	Dollars	Rank
Very Large Average (15 areas)	**52**		**1.27**		**25**		**1,083**	
Washington DC-VA-MD	74	1	1.33	2	37	1	1,495	2
Chicago IL-IN	71	2	1.24	13	36	2	1,568	1
Los Angeles-Long Beach-Santa Ana CA	64	3	1.38	1	34	3	1,334	3
Houston TX	57	4	1.27	6	28	4	1,171	4
New York-Newark NY-NJ-CT	54	5	1.28	3	22	7	1,126	5
San Francisco-Oakland CA	50	7	1.28	3	22	7	1,019	7
Boston MA-NH-RI	47	9	1.21	20	21	11	980	9
Dallas-Fort Worth-Arlington TX	45	10	1.23	16	22	7	924	11
Seattle WA	44	12	1.27	6	23	6	942	10
Atlanta GA	43	13	1.23	16	20	12	924	11
Philadelphia PA-NJ-DE-MD	42	14	1.21	20	17	18	864	14
Miami FL	38	15	1.23	16	18	16	785	19
San Diego CA	38	15	1.19	23	20	12	794	17
Phoenix AZ	35	23	1.21	20	20	12	821	16
Detroit MI	33	27	1.16	37	17	18	687	26

Very Large Urban Areas—over 3 million population.
Large Urban Areas—over 1 million and less than 3 million population.
Medium Urban Areas—over 500,000 and less than 1 million population.
Small Urban Areas—less than 500,000 population.
Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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 period.
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 $8 per hour of person travel and $88 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon for gasoline and diesel).
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 1. What Congestion Means to You, 2010, Continued

Urban Area	Yearly Delay per Auto Commuter		Travel Time Index		Excess Fuel per Auto Commuter		Congestion Cost per Auto Commuter	
	Hours	Rank	Value	Rank	Gallons	Rank	Dollars	Rank
Large Average (32 areas)	**31**		**1.17**		**11**		**642**	
Baltimore MD	52	6	1.19	23	22	7	1,102	6
Denver-Aurora CO	49	8	1.24	13	24	5	993	8
Minneapolis-St. Paul MN	45	10	1.23	16	20	12	916	13
Austin TX	38	15	1.28	3	10	27	743	23
Orlando FL	38	15	1.18	26	12	23	791	18
Portland OR-WA	37	19	1.25	9	10	27	744	22
San Jose CA	37	19	1.25	9	13	22	721	25
Nashville-Davidson TN	35	23	1.18	26	10	27	722	24
New Orleans LA	35	23	1.17	34	11	26	746	20
Virginia Beach VA	34	26	1.18	26	9	31	654	30
San Juan PR	33	27	1.25	9	12	23	665	29
Tampa-St. Petersburg FL	33	27	1.16	37	18	16	670	28
Pittsburgh PA	31	31	1.18	26	8	36	641	32
Riverside-San Bernardino CA	31	31	1.18	26	17	18	684	27
San Antonio TX	30	34	1.18	26	9	31	591	35
St. Louis MO-IL	30	34	1.10	56	14	21	642	31
Las Vegas NV	28	36	1.24	13	7	41	532	42
Milwaukee WI	27	38	1.18	26	7	41	541	38
Salt Lake City UT	27	38	1.11	51	7	41	512	45
Charlotte NC-SC	25	42	1.17	34	8	36	539	39
Jacksonville FL	25	42	1.09	68	7	41	496	50
Raleigh-Durham NC	25	42	1.14	43	9	31	537	40
Sacramento CA	25	42	1.19	23	8	36	507	46
Indianapolis IN	24	49	1.17	34	6	49	506	47
Kansas City MO-KS	23	52	1.11	51	7	41	464	55
Louisville KY-IN	23	52	1.10	56	6	49	477	52
Memphis TN-MS-AR	23	52	1.12	48	7	41	477	52
Cincinnati OH-KY-IN	21	60	1.13	45	6	49	427	60
Cleveland OH	20	64	1.10	56	5	58	383	65
Providence RI-MA	19	67	1.12	48	7	41	365	71
Columbus OH	18	72	1.11	51	5	58	344	79
Buffalo NY	17	77	1.10	56	5	58	358	73

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Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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 period.
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 $16 per hour of person travel and $88 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon for gasoline and diesel).
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 1. What Congestion Means to You, 2010, Continued

Urban Area	Yearly Delay per Auto Commuter		Travel Time Index		Excess Fuel per Auto Commuter		Congestion Cost per Auto Commuter	
	Hours	Rank	Value	Rank	Gallons	Rank	Dollars	Rank
Medium Average (33 areas)	**21**		**1.11**		**5**		**426**	
Baton Rouge LA	36	21	1.25	9	9	31	832	15
Bridgeport-Stamford CT-NY	36	21	1.27	6	12	23	745	21
Honolulu HI	33	27	1.18	26	6	49	620	33
Colorado Springs CO	31	31	1.13	45	9	31	602	34
New Haven CT	28	36	1.13	45	7	41	559	36
Birmingham AL	27	38	1.15	41	10	27	556	37
Hartford CT	26	41	1.15	41	6	49	501	49
Albuquerque NM	25	42	1.10	56	4	66	525	44
Charleston-North Charleston SC	25	42	1.16	37	8	36	529	43
Oklahoma City OK	24	49	1.10	56	4	66	476	54
Tucson AZ	23	52	1.11	51	5	58	506	47
Allentown-Bethlehem PA-NJ	22	57	1.07	79	4	66	432	59
El Paso TX-NM	21	60	1.16	37	4	66	427	60
Knoxville TN	21	60	1.06	85	5	58	423	62
Omaha NE-IA	21	60	1.09	68	4	66	389	64
Richmond VA	20	64	1.06	85	5	58	375	68
Wichita KS	20	64	1.07	79	4	66	379	67
Grand Rapids MI	19	67	1.05	94	4	66	372	69
Oxnard-Ventura CA	19	67	1.12	48	6	49	383	65
Springfield MA-CT	18	72	1.08	73	4	66	355	75
Tulsa OK	18	72	1.08	73	4	66	368	70
Albany-Schenectady NY	17	77	1.08	73	6	49	359	72
Lancaster-Palmdale CA	16	79	1.10	56	3	81	312	84
Sarasota-Bradenton FL	16	79	1.09	68	4	66	318	82
Akron OH	15	83	1.05	94	3	81	288	85
Dayton OH	14	87	1.06	85	3	81	277	88
Indio-Cathedral City-Palm Springs CA	14	87	1.11	51	2	89	279	87
Fresno CA	13	91	1.07	79	3	81	260	92
Rochester NY	13	91	1.05	94	2	89	241	94
Toledo OH-MI	12	93	1.05	94	3	81	237	95
Bakersfield CA	10	96	1.07	79	2	89	232	96
Poughkeepsie-Newburgh NY	10	96	1.04	99	2	89	205	97
McAllen TX	7	101	1.10	56	1	100	125	101

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Small Urban Areas—less than 500,000 population.
Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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 period.
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 $16 per hour of person travel and $88 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon for gasoline and diesel).
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 1. What Congestion Means to You, 2010, Continued

Urban Area	Yearly Delay per Auto Commuter		Travel Time Index		Excess Fuel per Auto Commuter		Congestion Cost per Auto Commuter	
	Hours	Rank	Value	Rank	Gallons	Rank	Dollars	Rank
Small Average (21 areas)	**18**		**1.08**		**4**		**363**	
Columbia SC	25	42	1.09	68	8	36	533	41
Little Rock AR	24	49	1.10	56	6	49	490	51
Cape Coral FL	23	52	1.10	56	4	66	464	55
Beaumont TX	22	57	1.08	73	4	66	445	58
Salem OR	22	57	1.09	68	5	58	451	57
Boise ID	19	67	1.10	56	3	81	345	78
Jackson MS	19	67	1.06	85	4	66	418	63
Pensacola FL-AL	18	72	1.08	73	3	81	350	77
Worcester MA	18	72	1.06	85	6	49	354	76
Greensboro NC	16	79	1.06	85	4	66	358	73
Spokane WA	16	79	1.10	56	4	66	329	80
Boulder CO	15	83	1.14	43	5	58	288	85
Brownsville TX	15	83	1.04	99	2	89	321	81
Winston-Salem NC	15	83	1.06	85	3	81	314	83
Anchorage AK	14	87	1.05	94	2	89	272	90
Provo UT	14	87	1.08	73	2	89	274	89
Laredo TX	12	93	1.07	79	2	89	264	91
Madison WI	12	93	1.06	85	2	89	246	93
Corpus Christi TX	10	96	1.07	79	2	89	194	98
Stockton CA	9	99	1.02	101	1	100	184	99
Eugene OR	8	100	1.06	85	2	89	171	100
101 Area Average	**40**		**1.21**		**17**		**829**	
Remaining Areas	**16**		**1.12**		**3**		**327**	
All 439 Urban Areas	**34**		**1.20**		**14**		**713**	

Very Large Urban Areas—over 3 million population.
Large Urban Areas—over 1 million and less than 3 million population.
Medium Urban Areas—over 500,000 and less than 1 million population.
Small Urban Areas—less than 500,000 population.
Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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 period.
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 $16 per hour of person travel and $88 per hour of truck time) and excess fuel consumption (estimated using state average cost per gallon for gasoline and diesel).
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.
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, 2010

Urban Area	Travel Delay		Excess Fuel Consumed		Truck Congestion Cost		Total Congestion Cost	
	(1000 Hours)	Rank	(1000 Gallons)	Rank	($ million)	Rank	($ million)	Rank
Very Large Average (15 areas)	**187,872**		**90,718**		**895**		**3,981**	
Los Angeles-Long Beach-Santa Ana CA	521,449	1	278,318	1	2,254	2	10,999	1
New York-Newark NY-NJ-CT	465,564	2	190,452	2	2,218	3	9,794	2
Chicago IL-IN	367,122	3	183,738	3	2,317	1	8,206	3
Washington DC-VA-MD	188,650	4	95,365	4	683	5	3,849	4
Dallas-Fort Worth-Arlington TX	163,585	5	80,587	5	666	6	3,365	5
Houston TX	153,391	6	76,531	6	688	4	3,203	6
Miami FL	139,764	7	66,104	7	604	9	2,906	7
Philadelphia PA-NJ-DE-MD	134,899	8	55,500	8	659	7	2,842	8
Atlanta GA	115,958	11	53,021	10	623	8	2,489	9
San Francisco-Oakland CA	120,149	9	53,801	9	484	11	2,479	10
Boston MA-NH-RI	117,234	10	51,806	11	459	13	2,393	11
Phoenix AZ	81,829	15	47,180	12	467	12	1,913	12
Seattle WA	87,919	12	46,373	13	603	10	1,905	13
Detroit MI	87,572	13	43,941	14	382	15	1,828	15
San Diego CA	72,995	18	38,052	16	321	16	1,541	18

Very Large Urban Areas—over 3 million population.
Large Urban Areas—over 1 million and less than 3 million population.
Medium Urban Areas—over 500,000 and less than 1 million population.
Small Urban Areas—less than 500,000 population.
Travel Delay—Value of extra travel time during the year (estimated at $16 per hour of person travel).
Excess Fuel Consumed—Value of increased fuel consumption due to travel in congested conditions rather than free-flow conditions (estimated using state average cost per gallon).
Truck Congestion Cost—Value of increased travel time and other operating costs of large trucks (estimated at $88 per hour of truck time) and the extra diesel consumed (estimated using state average cost per gallon).
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Table 2. What Congestion Means to Your Town, 2010, Continued

Urban Area	Travel Delay		Excess Fuel Consumed		Truck Congestion Cost		Total Congestion Cost	
	(1000 Hours)	Rank	(1000 Gallons)	Rank	($ million)	Rank	($ million)	Rank
Large Average (32 areas)	**33,407**		**11,968**		**148**		**688**	
Baltimore MD	87,199	14	36,303	17	449	14	1,853	14
Denver-Aurora CO	80,837	16	40,151	15	319	17	1,659	16
Minneapolis-St. Paul MN	78,483	17	34,689	18	300	18	1,595	17
Tampa-St. Petersburg FL	53,047	19	28,488	19	210	21	1,097	19
St. Louis MO-IL	47,042	21	23,190	20	283	19	1,034	20
San Juan PR	50,229	20	17,731	22	174	25	1,012	21
Riverside-San Bernardino CA	40,875	25	22,387	21	229	20	902	22
Pittsburgh PA	41,081	24	10,951	25	200	23	850	23
Portland OR-WA	41,743	23	10,931	26	185	24	850	23
San Jose CA	42,846	22	14,664	23	133	28	842	25
Orlando FL	38,260	26	11,883	24	207	22	811	26
Virginia Beach VA	36,538	27	9,301	28	98	40	693	27
Austin TX	31,038	28	8,425	30	119	32	617	28
Sacramento CA	29,602	30	9,374	27	123	30	603	29
San Antonio TX	30,207	29	8,883	29	105	37	593	30
Nashville-Davidson TN	26,475	33	6,971	34	142	26	556	31
Milwaukee WI	26,699	32	7,086	33	127	29	549	32
Las Vegas NV	27,386	31	7,428	31	83	45	530	33
Kansas City MO-KS	24,185	34	7,147	32	119	32	501	34
Cincinnati OH-KY-IN	23,297	35	5,889	38	120	31	486	35
New Orleans LA	20,565	39	6,218	37	135	27	453	36
Indianapolis IN	20,800	38	5,253	43	119	32	443	37
Raleigh-Durham NC	19,247	40	6,586	36	75	46	418	39
Cleveland OH	21,380	36	5,530	40	115	35	417	40
Charlotte NC-SC	17,730	43	5,228	44	101	39	378	41
Jacksonville FL	18,005	42	5,461	41	84	44	371	42
Memphis TN-MS-AR	17,197	44	5,038	45	87	42	358	43
Louisville KY-IN	17,033	45	4,574	47	61	50	357	44
Salt Lake City UT	18,366	41	4,713	46	85	43	353	45
Providence RI-MA	15,539	48	5,335	42	45	59	302	49
Columbus OH	14,651	51	3,904	48	53	51	289	51
Buffalo NY	11,450	56	3,257	52	51	54	234	56

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Urban Area	Travel Delay		Excess Fuel Consumed		Truck Congestion Cost		Total Congestion Cost	
	(1000 Hours)	Rank	(1000 Gallons)	Rank	($ million)	Rank	($ million)	Rank
Medium Average (33 areas)	**9,513**		**2,216**		**42**		**193**	
Bridgeport-Stamford CT-NY	21,233	37	6,857	35	102	38	441	38
Baton Rouge LA	14,577	52	3,295	51	66	49	331	46
Oklahoma City OK	16,848	46	2,847	57	110	36	329	47
Birmingham AL	15,832	47	5,639	39	71	47	326	48
Hartford CT	15,072	49	3,462	50	52	52	295	50
Honolulu HI	15,035	50	2,774	58	42	61	287	52
Tucson AZ	11,412	57	2,342	61	39	64	262	53
Richmond VA	13,800	53	3,105	53	92	41	262	53
New Haven CT	11,643	55	3,032	54	49	56	235	55
Albuquerque NM	10,477	58	1,724	69	37	66	231	57
Colorado Springs CO	11,897	54	3,552	49	69	48	228	58
El Paso TX-NM	10,452	59	1,971	64	52	52	214	59
Allentown-Bethlehem PA-NJ	9,777	60	1,777	66	43	60	197	60
Charleston-North Charleston SC	9,160	62	2,852	56	51	54	195	61
Oxnard-Ventura CA	9,009	64	2,869	55	39	64	184	62
Tulsa OK	9,086	63	1,861	65	42	61	183	63
Omaha NE-IA	9,299	61	1,737	68	23	78	173	65
Sarasota-Bradenton FL	8,015	67	2,240	62	32	69	161	66
Springfield MA-CT	8,305	66	1,975	63	27	76	161	66
Albany-Schenectady NY	7,467	71	2,384	60	32	69	156	69
Grand Rapids MI	7,861	68	1,595	72	35	67	155	70
Knoxville TN	7,518	70	1,622	70	32	69	151	71
Dayton OH	7,096	73	1,470	73	28	74	140	73
Lancaster-Palmdale CA	6,906	74	1,069	80	22	80	132	74
Wichita KS	6,858	75	1,460	74	21	81	131	75
Fresno CA	5,999	78	1,200	77	21	81	124	77
Rochester NY	6,377	76	1,229	76	29	73	123	78
Akron OH	6,198	77	1,042	81	21	81	120	79
Indio-Cathedral City-Palm Springs CA	5,633	80	983	82	28	74	116	80
Bakersfield CA	4,005	90	925	84	31	72	91	84
Poughkeepsie-Newburgh NY	4,271	85	809	88	20	85	87	87
Toledo OH-MI	4,223	86	951	83	18	88	85	88
McAllen TX	2,598	96	475	96	9	99	50	96

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Table 2. What Congestion Means to Your Town, 2010, Continued

Urban Area	Travel Delay (1000 Hours)	Rank	Excess Fuel Consumed (1000 Gallons)	Rank	Truck Congestion Cost ($ million)	Rank	Total Congestion Cost ($ million)	Rank
Small Average (21 areas)	**4,166**		**881**		**21**		**86**	
Columbia SC	8,515	65	2,723	59	47	57	181	64
Cape Coral FL	7,600	69	1,366	75	41	63	158	68
Little Rock AR	7,345	72	1,615	71	33	68	149	72
Jackson MS	5,488	81	1,124	78	47	57	128	76
Worcester MA	5,639	79	1,777	66	19	86	111	81
Provo UT	5,056	82	695	90	18	88	97	82
Pensacola FL-AL	4,699	83	888	86	19	86	93	83
Greensboro NC	4,104	87	1,110	79	26	77	90	85
Spokane WA	4,306	84	923	85	23	78	90	85
Winston-Salem NC	4,054	89	837	87	21	81	84	89
Salem OR	3,912	91	787	89	18	88	80	90
Beaumont TX	3,814	92	615	91	17	92	77	91
Boise ID	4,063	88	578	92	10	98	75	92
Madison WI	3,375	93	533	94	18	88	70	93
Anchorage AK	3,013	94	512	95	13	96	61	94
Stockton CA	2,648	95	394	98	15	93	55	95
Brownsville TX	2,323	98	326	100	15	93	50	96
Corpus Christi TX	2,432	97	469	97	13	96	50	96
Laredo TX	2,041	99	378	99	15	93	46	99
Boulder CO	1,612	100	541	93	3	101	30	100
Eugene OR	1,456	101	315	101	7	100	30	100
101 Area Total	**4,288,547**		**1,835,371**		**19,989**		**89,881**	
101 Area Average	**42,461**		**18,172**		**198**		**890**	
Remaining Area Total	**534,712**		**107,964**		**2,846**		**11,011**	
Remaining Area Average	**1,582**		**319**		**8**		**33**	
All 439 Areas Total	**4,823,259**		**1,943,335**		**22,835**		**100,892**	
All 439 Areas Average	**10,987**		**4,427**		**52**		**230**	

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Table 3. Solutions to Congestion Problems, 2010

	Operational Treatment Savings				Public Transportation Savings		
Urban Area	Treatments	Delay (1000 Hours)	Rank	Cost ($ Million)	Delay (1000 Hours)	Rank	Cost ($ Million)
Very Large Average (15 areas)		**15,636**		**$330.0**	**45,381**		**$960.0**
Los Angeles-Long Beach-Santa Ana CA	r,i,s,a,h	63,652	1	1,342.6	33,606	4	708.8
New York-Newark NY-NJ-CT	r,i,s,a,h	46,192	2	971.7	377,069	1	7,932.1
Houston TX	r,i,s,a,h	15,896	3	332.0	7,082	12	147.9
Chicago IL-IN	r,i,s,a	15,821	4	353.6	91,109	2	2,036.5
Washington DC-VA-MD	r,i,s,a,h	14,922	5	304.5	35,567	3	725.7
San Francisco-Oakland CA	r,i,s,a,h	14,679	6	302.9	28,431	6	586.6
Miami FL	i,s,a,h	12,065	7	250.9	9,276	10	192.9
Dallas-Fort Worth-Arlington TX	r,i,s,a,h	10,334	8	212.6	6,137	15	126.2
Philadelphia PA-NJ-DE-MD	r,i,s,a,h	8,851	9	186.5	26,082	7	549.5
Seattle WA	r,i,s,a,h	7,411	11	161.3	14,377	8	312.8
San Diego CA	r,i,s,a	6,340	12	133.8	6,460	13	136.3
Atlanta GA	r,i,s,a,h	5,603	13	120.3	8,589	11	184.4
Boston MA-NH-RI	i,s,a	4,988	14	101.8	32,477	5	662.9
Phoenix AZ	r,i,s,a,h	4,619	17	107.5	2,519	22	58.6
Detroit MI	r,i,s,a	3,170	22	66.2	1,937	25	40.4

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Public Transportation—Regular route service from all public transportation providers in an urban area.
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Table 3. Solutions to Congestion Problems, 2010, Continued

Urban Area	Operational Treatment Savings				Public Transportation Savings		
	Treatments	Delay (1000 Hours)	Rank	Cost ($ Million)	Delay (1000 Hours)	Rank	Cost ($ Million)
Large Average (32 areas)		**1,934**		**$40.0**	**2,304**		**$47.0**
Minneapolis-St. Paul MN	r,i,s,a,h	7,593	10	154.3	5,360	18	109.0
Denver-Aurora CO	r,i,s,a,h	4,720	15	96.8	6,376	14	130.8
Baltimore MD	i,s,a	4,644	16	98.7	13,924	9	295.8
Tampa-St. Petersburg FL	i,s,a	3,873	18	80.1	1,021	36	21.1
Portland OR-WA	r,i,s,a,h	3,701	19	75.4	5,581	17	113.7
Riverside-San Bernardino CA	r,i,s,a,h	3,636	20	80.2	1,140	35	25.2
San Jose CA	r,i,s,a	3,501	21	68.8	1,896	26	37.2
Virginia Beach VA	i,s,a,h	2,936	23	55.7	1,300	33	24.7
Sacramento CA	r,i,s,a,h	2,750	24	56.0	1,367	30	27.8
Orlando FL	i,s,a	2,254	25	47.8	1,399	29	29.7
Milwaukee WI	r,i,s,a	2,033	26	41.8	1,849	28	38.0
St. Louis MO-IL	i,s,a	1,975	27	43.4	2,805	21	61.7
Austin TX	i,s,a	1,541	28	30.6	1,941	24	38.5
Las Vegas NV	i,s,a	1,526	29	29.5	1,317	32	25.5
Pittsburgh PA	i,s,a	1,482	30	30.7	5,058	19	104.7
New Orleans LA	i,s,a	1,280	31	28.2	1,879	27	41.4
San Juan PR	s,a	1,217	32	24.5	5,798	16	116.8
Kansas City MO-KS	i,s,a	1,145	33	23.7	442	47	9.2
San Antonio TX	i,s,a	1,095	34	21.5	1,366	31	26.8
Jacksonville FL	i,s,a	1,055	35	21.8	398	51	8.2
Nashville-Davidson TN	i,s,a	1,040	36	21.9	509	45	10.7
Charlotte NC-SC	i,s,a	803	39	17.1	665	42	14.2
Raleigh-Durham NC	i,s,a	796	40	17.3	685	41	14.8
Salt Lake City UT	r,i,s,a	759	42	14.8	3,251	20	63.3
Cleveland OH	i,s,a	729	44	14.3	2,098	23	41.1
Cincinnati OH-KY-IN	r,i,s,a	715	45	14.9	1,255	34	26.2
Memphis TN-MS-AR	i,s,a	662	49	13.8	414	49	8.6
Columbus OH	r,i,s,a	472	54	9.3	310	56	6.1
Louisville KY-IN	i,s,a	449	55	9.3	426	48	8.8
Indianapolis IN	i,s,a	447	56	9.5	360	54	7.7
Providence RI-MA	i,s,a	324	62	6.3	747	40	14.5
Buffalo NY	i,s,a	287	65	5.9	804	38	16.4

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Table 3. Solutions to Congestion Problems, 2010, Continued

Urban Area	Operational Treatment Savings				Public Transportation Savings		
	Treatments	Delay (1000 Hours)	Rank	Cost ($ Million)	Delay (1000 Hours)	Rank	Cost ($ Million)
Medium Average (33 areas)		**363**		**$7.0**	**263**		**$5.0**
Bridgeport-Stamford CT-NY	i,s,a	887	37	18.4	306	57	6.4
Baton Rouge LA	i,s,a	872	38	19.7	140	82	3.2
Honolulu HI	i,s,a	767	41	14.6	463	46	8.8
Birmingham AL	i,s,a	745	43	15.3	198	72	4.1
Albuquerque NM	i,s,a	705	46	15.3	212	67	4.6
Omaha NE-IA	i,s,a	687	47	12.8	152	79	2.8
Tucson AZ	i,s,a	673	48	15.5	362	53	8.3
El Paso TX-NM	i,s,a	659	50	13.5	764	39	15.7
Hartford CT	i,s,a	625	51	12.2	957	37	18.7
Richmond VA	i,s,a	544	52	10.3	571	43	10.8
Sarasota-Bradenton FL	i,s,a	509	53	10.2	116	85	2.3
Fresno CA	r,i,s,a	429	57	8.8	185	74	3.8
Colorado Springs CO	i,s,a	411	59	8.0	389	52	7.6
New Haven CT	i,s,a	384	60	7.8	269	58	5.4
Knoxville TN	i,s,a	318	63	6.4	51	93	1.0
Charleston-North Charleston SC	i,s,a	298	64	6.3	106	87	2.2
Oxnard-Ventura CA	i,s,a	239	66	4.9	156	78	3.2
Allentown-Bethlehem PA-NJ	r,i,s,a	235	67	4.7	254	59	5.1
Wichita KS	i,s,a	231	68	4.4	211	68	4.0
Albany-Schenectady NY	i,s,a	211	70	4.4	323	55	6.7
Indio-Cathedral City-Palm Springs CA	i,s,a	193	73	4.0	157	77	3.2
Oklahoma City OK	i,s,a	184	76	3.6	113	86	2.2
Rochester NY	i,s,a	167	78	3.2	221	64	4.3
Grand Rapids MI	s,a	163	79	3.2	250	61	5.0
Bakersfield CA	i,s,a	157	80	3.6	200	70	4.6
Dayton OH	s,a	157	80	3.1	198	72	3.9
Springfield MA-CT	i,s,a	154	83	3.0	240	62	4.7
Lancaster-Palmdale CA	s,a	147	84	2.8	571	43	10.9
Tulsa OK	i,s,a	58	93	1.2	44	96	0.9
Poughkeepsie-Newburgh NY	s,a	54	94	1.1	173	76	3.5
Toledo OH-MI	i,s,a	48	95	1.0	146	80	2.9
Akron OH	i,s,a	43	96	0.8	143	81	2.8
McAllen TX	s,a	16	101	0.3	25	100	0.5

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	Operational Treatment Savings				Public Transportation Savings		
Urban Area	Treatments	Delay (1000 Hours)	Rank	Cost ($ Million)	Delay (1000 Hours)	Rank	Cost ($ Million)
Small Average (21 areas)		**142**		**$3.0**	**132**		**$3.0**
Little Rock AR	i,s,a	428	58	8.7	21	101	0.4
Cape Coral FL	i,s,a	382	61	8.0	132	83	2.7
Provo UT	i,s,a	225	69	4.3	49	94	0.9
Greensboro NC	i,s,a	205	71	4.5	118	84	2.6
Winston-Salem NC	i,s,a	203	72	4.2	39	97	0.8
Spokane WA	i,s,a	193	73	4.1	406	50	8.5
Jackson MS	s,a	189	75	4.4	53	92	1.2
Worcester MA	s,a	179	77	3.5	54	91	1.1
Columbia SC	i,s,a	155	82	3.3	254	59	5.4
Stockton CA	i,s,a	120	85	2.5	178	75	3.7
Salem OR	s,a	91	86	1.8	203	69	4.2
Beaumont TX	s,a	89	87	1.8	37	99	0.7
Anchorage AK	s,a	84	88	1.7	214	66	4.3
Eugene OR	i,s,a	78	89	1.6	217	65	4.5
Pensacola FL-AL	s,a	74	90	1.5	45	95	0.9
Boise ID	i,s,a	72	91	1.3	39	97	0.7
Madison WI	s,a	71	92	1.5	227	63	4.7
Brownsville TX	s,a	43	96	0.9	199	71	4.3
Laredo TX	i,s,a	40	98	0.9	102	88	2.3
Boulder CO	s,a	36	99	0.7	84	90	1.6
Corpus Christi TX	s,a	23	100	0.5	94	89	1.9
101 Area Total		**309,455**		**6,518.0**	**765,886**		**16,151.0**
101 Area Average		**3,095**		**65.0**	**7,583**		**160.0**
All Urban Areas Total		**327,157**		**6,875.0**	**795,668**		**16,811.0**
All Urban Areas Average		**745**		**15.0**	**1,812**		**39.0**

Very Large Urban Areas—over 3 million population.
Large Urban Areas—over 1 million and less than 3 million population.
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.
Congestion Cost Savings—Value of delay, fuel and truck congestion cost.
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. Other Congestion Measures, 2010

Urban Area	Total Peak Period Travel Time		Delay per Non-Peak Traveler		Commuter Stress Index	
	Minutes	Rank	Hours	Rank	Value	Rank
Very Large Area (15 areas)	**107**		**13**		**1.38**	
Washington DC-VA-MD	120	4	17	2	1.48	2
Chicago IL-IN	102	26	19	1	1.34	11
Los Angeles-Long Beach-Santa Ana CA	107	18	16	3	1.57	1
Houston TX	106	20	14	6	1.40	4
New York-Newark NY-NJ-CT	116	6	11	13	1.39	5
San Francisco-Oakland CA	105	21	12	9	1.42	3
Boston MA-NH-RI	109	15	11	13	1.31	19
Dallas-Fort Worth-Arlington TX	96	37	14	6	1.34	11
Seattle WA	101	28	10	22	1.39	5
Atlanta GA	127	1	11	13	1.34	11
Philadelphia PA-NJ-DE-MD	105	22	12	9	1.29	22
Miami FL	106	19	12	9	1.32	18
San Diego CA	94	42	10	22	1.29	22
Phoenix AZ	99	32	10	22	1.30	21
Detroit MI	109	16	11	13	1.20	44

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Commuter Stress Index—The ratio of travel time in the peak period to the travel time at free-flow conditions for the peak directions of travel in both peak periods. A value of 1.40 indicates a 20-minute free-flow trip takes 28 minutes in the most congested directions of the peak periods.
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Table 4. Other Congestion Measures, 2010, Continued

Urban Area	Total Peak Period Travel Time		Delay per Non-Peak Traveler		Commuter Stress Index	
	Minutes	Rank	Hours	Rank	Value	Rank
Large Area Average (32 areas)	**93**		**9**		**1.25**	
Baltimore MD	83	67	16	3	1.28	26
Denver-Aurora CO	90	52	15	5	1.34	11
Minneapolis-St. Paul MN	100	30	10	22	1.33	17
Austin TX	82	69	8	45	1.38	8
Orlando FL	120	3	13	8	1.23	35
Portland OR-WA	85	62	8	45	1.38	8
San Jose CA	82	70	9	29	1.39	5
Nashville-Davidson TN	114	8	11	13	1.25	31
New Orleans LA	84	65	10	22	1.20	44
Virginia Beach VA	96	38	12	9	1.29	22
San Juan PR	61	91	9	29	1.34	11
Tampa-St. Petersburg FL	104	24	11	13	1.22	36
Pittsburgh PA	80	74	11	13	1.21	40
Riverside-San Bernardino CA	88	58	9	29	1.29	22
San Antonio TX	95	40	8	45	1.27	28
St. Louis MO-IL	109	13	9	29	1.15	62
Las Vegas NV	92	48	10	22	1.34	11
Milwaukee WI	88	59	8	45	1.27	28
Salt Lake City UT	76	79	9	29	1.20	44
Charlotte NC-SC	110	12	7	60	1.26	30
Jacksonville FL	108	17	8	45	1.14	63
Raleigh-Durham NC	115	7	8	45	1.20	44
Sacramento CA	82	68	7	60	1.28	26
Indianapolis IN	112	10	9	29	1.22	36
Kansas City MO-KS	101	29	7	60	1.17	53
Louisville KY-IN	88	56	8	45	1.17	53
Memphis TN-MS-AR	95	39	9	29	1.17	53
Cincinnati OH-KY-IN	93	45	6	74	1.20	44
Cleveland OH	91	49	5	85	1.16	58
Providence RI-MA	85	63	6	74	1.18	49
Columbus OH	86	61	5	85	1.18	49
Buffalo NY	92	46	6	74	1.14	63

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Table 4. Other Congestion Measures, 2010, Continued

Urban Area	Total Peak Period Travel Time		Delay per Non-Peak Traveler		Commuter Stress Index	
	Minutes	Rank	Hours	Rank	Value	Rank
Medium Area Average (33 areas)	**83**		**7**		**1.16**	
Baton Rouge LA	91	51	11	13	1.31	19
Bridgeport-Stamford CT-NY	92	47	8	45	1.35	10
Honolulu HI	73	83	9	29	1.24	32
Colorado Springs CO	81	73	11	13	1.17	53
New Haven CT	79	75	9	29	1.21	40
Birmingham AL	102	25	9	29	1.22	36
Hartford CT	94	41	7	60	1.21	40
Albuquerque NM	82	72	8	45	1.21	40
Charleston-North Charleston SC	88	57	9	29	1.24	32
Oklahoma City OK	117	5	10	22	1.16	58
Tucson AZ	113	9	9	29	1.18	49
Allentown-Bethlehem PA-NJ	79	76	9	29	1.09	83
El Paso TX-NM	69	88	7	60	1.24	32
Knoxville TN	112	11	8	45	1.09	83
Omaha NE-IA	94	43	8	45	1.13	67
Richmond VA	102	27	8	45	1.08	92
Wichita KS	84	64	6	74	1.12	71
Grand Rapids MI	94	44	6	74	1.10	79
Oxnard-Ventura CA	73	82	6	74	1.18	49
Springfield MA-CT	89	53	8	45	1.12	71
Tulsa OK	97	35	7	60	1.11	75
Albany-Schenectady NY	75	80	7	60	1.11	75
Lancaster-Palmdale CA	37	101	6	74	1.14	63
Sarasota-Bradenton FL	73	84	7	60	1.12	71
Akron OH	67	89	5	85	1.07	97
Dayton OH	89	55	5	85	1.09	83
Indio-Cathedral City-Palm Springs CA	54	97	5	85	1.22	36
Fresno CA	77	78	4	95	1.11	75
Rochester NY	82	71	4	95	1.08	92
Toledo OH-MI	87	60	4	95	1.08	92
Bakersfield CA	57	94	4	95	1.09	83
Poughkeepsie-Newburgh NY	72	86	5	85	1.05	100
McAllen TX	60	92	3	100	1.13	67

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

Table 4. Other Congestion Measures, 2010, Continued

Urban Area	Total Peak Period Travel Time		Delay per Non-Peak Traveler		Commuter Stress Index	
	Minutes	Rank	Hours	Rank	Value	Rank
Small Area Average (21 areas)	**80**		**7**		**1.11**	
Columbia SC	104	23	9	29	1.12	71
Little Rock AR	109	14	7	60	1.16	58
Cape Coral FL	89	54	9	29	1.13	67
Beaumont TX	96	36	8	45	1.13	67
Salem OR	66	90	9	29	1.11	75
Boise ID	71	87	7	60	1.17	53
Jackson MS	126	2	7	60	1.09	83
Pensacola FL-AL	98	33	8	45	1.10	79
Worcester MA	100	31	7	60	1.10	79
Greensboro NC	98	34	7	60	1.09	83
Spokane WA	91	50	6	74	1.14	63
Boulder CO	52	98	6	74	1.16	58
Brownsville TX	56	96	6	74	1.08	92
Winston-Salem NC	83	66	5	85	1.07	97
Anchorage AK	50	100	6	74	1.07	97
Provo UT	73	81	7	60	1.09	83
Laredo TX	56	95	5	85	1.08	92
Madison WI	73	85	5	85	1.09	83
Corpus Christi TX	78	77	5	85	1.10	79
Stockton CA	52	99	4	95	1.03	101
Eugene OR	59	93	3	100	1.09	83
101 Area Average	**90**		**11**		**1.30**	
Remaining Area Average			**7**		**1.12**	
All 439 Area Average			**10**		**1.30**	

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Table 5. Truck Commodity Value and Truck Delay, 2010

Urban Area	Total Delay		Truck Delay			Truck Commodity Value	
	(1000 Hours)	Rank	(1000 Hours)	Rank	Congestion Cost ($ million)	($ million)	Rank
Very Large Average (15 areas)	**187,872**		**12,120**		**895**	**206,375**	
Chicago IL-IN	367,122	3	31,378	1	2,317	357,816	3
Los Angeles-Long Beach-Santa Ana CA	521,449	1	30,347	2	2,254	406,939	2
New York-Newark NY-NJ-CT	465,564	2	30,185	3	2,218	475,730	1
Houston TX	153,391	6	9,299	4	688	230,769	4
Washington DC-VA-MD	188,650	4	9,204	5	683	95,965	17
Dallas-Fort Worth-Arlington TX	163,585	5	9,037	6	666	227,514	5
Philadelphia PA-NJ-DE-MD	134,899	8	8,970	7	659	172,905	7
Atlanta GA	115,958	11	8,459	8	623	189,488	6
Miami FL	139,764	7	8,207	9	604	153,596	9
Phoenix AZ	81,829	15	8,139	10	603	129,894	12
San Francisco-Oakland CA	120,149	9	6,558	11	484	130,852	11
Seattle WA	87,919	12	6,296	12	467	150,998	10
Boston MA-NH-RI	117,234	10	6,227	13	459	128,143	13
Detroit MI	87,572	13	5,186	15	382	159,328	8
San Diego CA	72,995	18	4,316	17	321	85,686	20

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Small Urban Areas—less than 500,000 population.
Travel Delay—Travel time above that needed to complete a trip at free-flow speeds for all vehicles.
Truck Delay—Travel time above that needed to complete a trip at free-flow speeds for large trucks.
Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the urban area.
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 5. Truck Commodity Value and Truck Delay, 2010, Continued

Urban Area	Total Delay		Truck Delay			Truck Commodity Value	
	(1000 Hours)	Rank	(1000 Hours)	Rank	Congestion Cost ($million)	($ million)	Rank
Large Average (32 areas)	**33,407**		**2,024**		**148**	**62,310**	
Baltimore MD	87,199	14	6,103	14	449	94,943	19
Denver-Aurora CO	80,837	16	4,324	16	319	76,023	22
Minneapolis-St. Paul MN	78,483	17	4,073	18	300	95,819	18
St. Louis MO-IL	47,042	21	3,841	19	283	107,010	15
Riverside-San Bernardino CA	40,875	25	3,080	20	229	108,218	14
Orlando FL	38,260	26	2,856	21	207	63,106	32
Tampa-St. Petersburg FL	53,047	19	2,842	22	210	61,906	33
Pittsburgh PA	41,081	24	2,755	23	200	69,290	25
Portland OR-WA	41,743	23	2,546	24	185	64,964	30
San Juan PR	50,229	20	2,417	25	174	23,130	60
Nashville-Davidson TN	26,475	33	1,961	26	142	65,449	29
New Orleans LA	20,565	39	1,859	27	135	34,270	50
San Jose CA	42,846	22	1,815	28	133	52,079	36
Milwaukee WI	26,699	32	1,746	29	127	66,629	28
Sacramento CA	29,602	30	1,688	30	123	51,883	37
Cincinnati OH-KY-IN	23,297	35	1,660	31	120	64,323	31
Indianapolis IN	20,800	38	1,657	32	119	83,984	21
Kansas City MO-KS	24,185	34	1,641	33	119	72,545	23
Austin TX	31,038	28	1,636	34	119	32,824	52
Raleigh-Durham NC	19,247	40	1,569	35	115	49,468	40
San Antonio TX	30,207	29	1,428	37	105	50,600	39
Charlotte NC-SC	17,730	43	1,383	38	101	68,196	26
Virginia Beach VA	36,538	27	1,344	40	98	43,056	42
Memphis TN-MS-AR	17,197	44	1,195	42	87	98,356	16
Louisville KY-IN	17,033	45	1,170	43	85	55,226	35
Jacksonville FL	18,005	42	1,158	44	84	41,508	44
Las Vegas NV	27,386	31	1,141	45	83	35,458	49
Cleveland OH	21,380	36	1,016	46	75	67,808	27
Salt Lake City UT	18,366	41	823	50	61	56,160	34
Columbus OH	14,651	51	727	51	53	69,664	24
Buffalo NY	11,450	56	698	55	51	48,387	41
Providence RI-MA	15,539	48	610	59	45	21,633	61

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Truck Delay—Travel time above that needed to complete a trip at free-flow speeds for large trucks.
Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the urban area.
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 5. Truck Commodity Value and Truck Delay, 2010, Continued

Urban Area	Total Delay (1000 Hours)	Total Delay Rank	Truck Delay (1000 Hours)	Truck Delay Rank	Congestion Cost ($ million)	Truck Commodity Value ($ million)	Truck Commodity Value Rank
Medium Average (33 areas)	**9,513**		**578**		**42**	**18,478**	
Baton Rouge LA	14,577	52	1,519	36	110	32,636	54
Bridgeport-Stamford CT-NY	21,233	37	1,380	39	102	11,205	73
Tucson AZ	11,412	57	1,287	41	92	28,654	58
Birmingham AL	15,832	47	971	47	71	38,401	45
Albuquerque NM	10,477	58	963	48	69	14,035	67
Oklahoma City OK	16,848	46	912	49	66	37,779	46
Hartford CT	15,072	49	716	52	52	42,403	43
El Paso TX-NM	10,452	59	714	53	52	31,703	55
Charleston-North Charleston SC	9,160	62	701	54	51	10,552	76
New Haven CT	11,643	55	676	56	49	8,276	86
Allentown-Bethlehem PA-NJ	9,777	60	597	60	43	15,827	65
Honolulu HI	15,035	50	595	61	42	10,125	78
Tulsa OK	9,086	63	562	63	42	28,827	57
Richmond VA	13,800	53	530	64	39	37,643	47
Oxnard-Ventura CA	9,009	64	529	65	39	9,187	83
Colorado Springs CO	11,897	54	509	66	37	6,546	91
Albany-Schenectady NY	7,467	71	484	67	35	32,655	53
Grand Rapids MI	7,861	68	446	69	32	37,551	48
Sarasota-Bradenton FL	8,015	67	446	69	32	7,591	89
Knoxville TN	7,518	70	439	71	32	11,989	72
Bakersfield CA	4,005	90	425	72	31	10,838	75
Fresno CA	5,999	78	396	73	29	9,474	81
Indio-Cathedral City-Palm Springs CA	5,633	80	389	74	28	5,455	94
Dayton OH	7,096	73	382	75	28	33,645	51
Springfield MA-CT	8,305	66	378	76	27	9,238	82
Omaha NE-IA	9,299	61	314	79	23	8,668	85
Lancaster-Palmdale CA	6,906	74	303	80	22	2,728	99
Rochester NY	6,377	76	295	81	21	26,077	59
Akron OH	6,198	77	290	82	21	9,828	80
Wichita KS	6,858	75	280	84	21	7,901	87
Poughkeepsie-Newburgh NY	4,271	85	272	85	20	13,714	68
Toledo OH-MI	4,223	86	247	90	18	10,950	74
McAllen TX	2,598	96	125	99	9	7,678	88

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Table 5. Truck Commodity Value and Truck Delay, 2010, Continued

Urban Area	Total Delay		Truck Delay			Truck Commodity Value	
	(1000 Hours)	Rank	(1000 Hours)	Rank	Congestion Cost ($ million)	($ million)	Rank
Small Average (21 areas)	**4,166**		**288**		**21**	**12,275**	
Columbia SC	8,515	65	651	57	47	12,404	70
Jackson MS	5,488	81	648	58	47	16,984	64
Cape Coral FL	7,600	69	567	62	41	5,962	93
Little Rock AR	7,345	72	457	68	33	15,221	66
Greensboro NC	4,104	87	362	77	26	50,964	38
Spokane WA	4,306	84	323	78	23	7,230	90
Winston-Salem NC	4,054	89	287	83	21	8,679	84
Pensacola FL-AL	4,699	83	261	86	19	6,339	92
Worcester MA	5,639	79	259	87	19	10,115	79
Salem OR	3,912	91	256	88	18	3,864	97
Madison WI	3,375	93	252	89	18	17,361	63
Provo UT	5,056	82	240	91	18	12,681	69
Beaumont TX	3,814	92	236	92	17	20,504	62
Laredo TX	2,041	99	212	93	15	30,799	56
Brownsville TX	2,323	98	206	94	15	2,380	100
Stockton CA	2,648	95	203	95	15	10,264	77
Anchorage AK	3,013	94	183	96	13	4,454	96
Corpus Christi TX	2,432	97	172	97	13	12,327	71
Boise ID	4,063	88	137	98	10	4,772	95
Eugene OR	1,456	101	98	100	7	3,658	98
Boulder CO	1,612	100	47	101	3	820	101
101 Area Average	**42,461**		**2,690**		**198**	**58,981**	
Remaining Area Average	**1,582**		**119**		**9**	**3,183**	
All 439 Area Average	**10,987**		**710**		**52**	**16,021**	

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Table 6. State Truck Commodity Value, 2010

State	Total Truck Commodity Value ($ million)	Rural Truck Commodity Value ($ million)	Urban Truck Commodity Value ($ million)
Alabama	225,316	140,281	85,035
Alaska	17,161	12,082	5,079
Arizona	266,930	102,058	164,872
Arkansas	160,049	130,440	29,609
California	1,235,308	295,145	940,164
Colorado	153,998	62,081	91,917
Connecticut	110,515	7,578	102,937
Delaware	35,030	12,397	22,633
Florida	552,621	138,470	414,151
Georgia	417,906	182,728	235,178
Hawaii	16,307	5,592	10,715
Idaho	57,974	47,004	10,970
Illinois	548,431	174,621	373,810
Indiana	368,446	199,151	169,296
Iowa	157,013	130,758	26,255
Kansas	142,534	100,076	42,458
Kentucky	222,880	146,951	75,929
Louisiana	217,425	101,396	116,029
Maine	44,693	36,143	8,550
Maryland	205,976	51,098	154,878
Massachusetts	164,871	10,433	154,438
Michigan	348,470	101,493	246,977
Minnesota	189,643	86,720	102,923
Mississippi	155,821	121,572	34,249
Missouri	297,147	150,722	146,425
Montana	41,673	39,489	2,184
Nebraska	96,020	84,448	11,572
Nevada	78,514	37,075	41,440
New Hampshire	38,649	23,312	15,338
New Jersey	295,927	12,901	283,026
New Mexico	111,128	91,403	19,725
New York	482,018	111,566	370,451
North Carolina	373,822	146,171	227,652
North Dakota	47,109	42,718	4,391

Total Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the state.
Rural Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the rural areas of the state.
Urban Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the urban areas of the state.

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

Table 6. State Truck Commodity Value, 2010, Continued

State	Total Truck Commodity Value ($ million)	Rural Truck Commodity Value ($ million)	Urban Truck Commodity Value ($ million)
Ohio	447,564	177,760	269,805
Oklahoma	205,346	137,892	67,453
Oregon	153,382	82,144	71,239
Pennsylvania	443,946	195,660	248,286
Rhode Island	21,139	3,786	17,353
South Carolina	192,648	97,765	94,883
South Dakota	44,693	39,879	4,813
Tennessee	349,114	156,776	192,337
Texas	1,150,012	441,184	708,828
Utah	143,138	60,146	82,992
Vermont	24,158	21,648	2,510
Virginia	253,058	110,587	142,471
Washington	273,611	91,855	181,756
West Virginia	85,762	62,040	23,722
Wisconsin	326,741	190,205	136,536
Wyoming	48,921	46,372	2,549
District of Columbia	9,059	-	9,059
Puerto Rico	38,653	3,494	35,159

Total Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the state.
Rural Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the rural areas of the state.
Urban Truck Commodity Value—Value of all commodities moved by truck estimated to be traveling in the urban areas of the state.

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Table 7. Congestion Trends – Wasted Hours (Yearly Delay per Auto Commuter, 1982 to 2010)

Urban Area	Yearly Hours of Delay per Auto Commuter					Long-Term Change 1982 to 2010	
	2010	2009	2005	2000	1982	Hours	Rank
Very Large Average (15 areas)	**52**	**52**	**60**	**50**	**19**	**33**	
Washington DC-VA-MD	74	70	83	73	20	54	1
Chicago IL-IN	71	70	77	55	18	53	2
New York-Newark NY-NJ-CT	54	42	51	35	10	44	3
Dallas-Fort Worth-Arlington TX	45	48	51	40	7	38	6
Boston MA-NH-RI	47	48	57	44	13	34	8
Seattle WA	44	44	51	49	10	34	8
Houston TX	57	58	55	45	24	33	10
Atlanta GA	43	44	58	52	13	30	11
Philadelphia PA-NJ-DE-MD	42	39	42	32	12	30	11
San Diego CA	38	37	46	35	8	30	11
San Francisco-Oakland CA	50	49	74	60	20	30	11
Miami FL	38	39	45	38	10	28	16
Los Angeles-Long Beach-Santa Ana CA	64	63	82	76	39	25	23
Detroit MI	33	33	41	36	14	19	36
Phoenix AZ	35	36	44	34	24	11	79

Very Large Urban Areas—over 3 million population.
Large Urban Areas—over 1 million and less than 3 million population.
Medium Urban Areas—over 500,000 and less than 1 million population.
Small Urban Areas—less than 500,000 population.
Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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 7. Congestion Trends – Wasted Hours (Yearly Delay per Auto Commuter, 1982 to 2010), Continued

Urban Area	Yearly Hours of Delay per Auto Commuter					Long-Term Change 1982 to 2010	
	2010	2009	2005	2000	1982	Hours	Rank
Large Average (32 areas)	**31**	**31**	**37**	**33**	**9**	**22**	
Baltimore MD	52	50	57	41	11	41	4
Minneapolis-St. Paul MN	45	43	54	48	6	39	5
Denver-Aurora CO	49	47	53	47	12	37	7
Austin TX	38	39	52	36	9	29	15
Riverside-San Bernardino CA	31	30	37	24	3	28	16
San Juan PR	33	33	34	26	5	28	16
Orlando FL	38	41	44	47	11	27	19
Portland OR-WA	37	36	42	38	11	26	21
San Antonio TX	30	30	33	30	4	26	21
Las Vegas NV	28	32	32	24	5	23	26
Salt Lake City UT	27	28	25	27	6	21	27
Charlotte NC-SC	25	26	25	19	5	20	31
Raleigh-Durham NC	25	25	31	26	5	20	31
San Jose CA	37	35	54	53	17	20	31
Virginia Beach VA	34	32	41	37	14	20	31
Kansas City MO-KS	23	21	30	33	4	19	36
St. Louis MO-IL	30	31	38	44	11	19	36
Tampa-St. Petersburg FL	33	34	34	27	14	19	36
Memphis TN-MS-AR	23	24	28	24	5	18	43
Milwaukee WI	27	25	31	32	9	18	43
Nashville-Davidson TN	35	35	43	36	17	18	43
New Orleans LA	35	31	26	25	17	18	43
Cincinnati OH-KY-IN	21	19	28	29	4	17	50
Cleveland OH	20	19	17	20	3	17	50
Providence RI-MA	19	19	26	19	2	17	50
Columbus OH	18	17	19	15	2	16	56
Sacramento CA	25	24	35	27	9	16	56
Jacksonville FL	25	26	31	26	10	15	61
Indianapolis IN	24	25	30	31	10	14	68
Louisville KY-IN	23	22	25	25	9	14	68
Buffalo NY	17	17	21	16	4	13	74
Pittsburgh PA	31	33	37	35	18	13	74

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Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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 7. Congestion Trends – Wasted Hours (Yearly Delay per Auto Commuter, 1982 to 2010), Continued

Urban Area	Yearly Hours of Delay per Auto Commuter					Long-Term Change 1982 to 2010	
	2010	2009	2005	2000	1982	Hours	Rank
Medium Average (33 areas)	**21**	**21**	**24**	**22**	**7**	**14**	
Baton Rouge LA	36	37	37	31	9	27	19
Bridgeport-Stamford CT-NY	36	35	47	44	11	25	23
Colorado Springs CO	31	31	53	45	6	25	23
Hartford CT	26	24	27	26	5	21	27
New Haven CT	28	29	34	34	7	21	27
Birmingham AL	27	28	31	30	7	20	31
Honolulu HI	33	31	32	25	14	19	36
Oklahoma City OK	24	25	23	23	5	19	36
El Paso TX-NM	21	21	28	20	3	18	43
Omaha NE-IA	21	20	18	16	3	18	43
Oxnard-Ventura CA	19	19	23	16	2	17	50
Albuquerque NM	25	26	33	30	9	16	56
Richmond VA	20	19	17	13	4	16	56
Allentown-Bethlehem PA-NJ	22	22	24	24	7	15	61
Charleston-North Charleston SC	25	27	28	25	10	15	61
Grand Rapids MI	19	19	19	18	4	15	61
Knoxville TN	21	21	23	26	6	15	61
Albany-Schenectady NY	17	18	19	14	3	14	68
Tulsa OK	18	18	16	15	4	14	68
Wichita KS	20	20	19	19	6	14	68
Akron OH	15	16	19	22	3	12	77
Tucson AZ	23	23	28	19	11	12	77
Rochester NY	13	12	13	12	3	10	83
Toledo OH-MI	12	12	17	19	2	10	83
Bakersfield CA	10	11	7	4	1	9	86
Springfield MA-CT	18	19	19	18	9	9	86
Dayton OH	14	15	15	19	7	7	89
Sarasota-Bradenton FL	16	17	20	19	9	7	89
Fresno CA	13	14	16	18	7	6	93
McAllen TX	7	7	7	6	1	6	93
Poughkeepsie-Newburgh NY	10	11	10	8	5	5	96
Lancaster-Palmdale CA	16	18	17	12	19	-3	100
Indio-Cathedral City-Palm Springs CA	14	14	20	15	22	-8	101

Very Large Urban Areas—over 3 million population.
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Yearly Delay per Auto Commuter—Extra travel time during the year divided by the number of people who commute in private vehicles in the urban area.
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Table 7. Congestion Trends – Wasted Hours (Yearly Delay per Auto Commuter, 1982 to 2010), Continued

Urban Area	Yearly Hours of Delay per Auto Commuter					Long-Term Change 1982 to 2010	
	2010	2009	2005	2000	1982	Hours	Rank
Small Average (21 areas)	**18**	**18**	**20**	**17**	**5**	**13**	
Columbia SC	25	25	20	17	4	21	27
Little Rock AR	24	24	23	17	5	19	36
Salem OR	22	24	32	30	4	18	43
Beaumont TX	22	21	26	18	5	17	50
Boise ID	19	21	24	20	2	17	50
Jackson MS	19	19	20	12	3	16	56
Cape Coral FL	23	23	28	23	8	15	61
Pensacola FL-AL	18	19	21	16	3	15	61
Brownsville TX	15	14	10	8	1	14	68
Greensboro NC	16	15	19	24	3	13	74
Laredo TX	12	12	8	7	1	11	77
Winston-Salem NC	15	16	20	13	4	11	79
Worcester MA	18	20	22	22	7	11	79
Spokane WA	16	16	17	22	6	10	83
Provo UT	14	14	14	11	5	9	86
Madison WI	12	11	7	6	5	7	89
Stockton CA	9	9	10	7	2	7	89
Boulder CO	15	15	28	28	9	6	93
Corpus Christi TX	10	10	11	9	5	5	96
Eugene OR	8	9	14	15	5	3	98
Anchorage AK	14	14	21	20	16	-2	99
101 Area Average	**40**	**40**	**46**	**40**	**14**	**26**	
Remaining Area Average	**16**	**18**	**20**	**20**	**10**	**6**	
All 439 Area Average	**34**	**34**	**39**	**35**	**14**	**20**	

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Table 8. Congestion Trends – Wasted Time (Travel Time Index, 1982 to 2010)

Urban Area	Travel Time Index					Point Change in Peak-Period Time Penalty 1982 to 2010	
	2010	2009	2005	2000	1982	Points	Rank
Very Large Average (15 areas)	**1.27**	**1.26**	**1.32**	**1.27**	**1.12**	**15**	
Washington DC-VA-MD	1.33	1.30	1.35	1.31	1.11	22	1
Seattle WA	1.27	1.24	1.33	1.31	1.08	19	4
Dallas-Fort Worth-Arlington TX	1.23	1.22	1.27	1.20	1.05	18	6
New York-Newark NY-NJ-CT	1.28	1.27	1.37	1.28	1.10	18	6
Los Angeles-Long Beach-Santa Ana CA	1.38	1.38	1.42	1.39	1.21	17	12
Chicago IL-IN	1.24	1.25	1.29	1.21	1.08	16	15
San Francisco-Oakland CA	1.28	1.27	1.40	1.34	1.13	15	16
Atlanta GA	1.23	1.22	1.28	1.25	1.08	15	17
San Diego CA	1.19	1.18	1.25	1.20	1.04	15	17
Miami FL	1.23	1.23	1.31	1.27	1.09	14	20
Boston MA-NH-RI	1.21	1.20	1.32	1.26	1.09	12	25
Philadelphia PA-NJ-DE-MD	1.21	1.19	1.22	1.18	1.09	12	25
Phoenix AZ	1.21	1.20	1.21	1.18	1.10	11	29
Houston TX	1.27	1.25	1.33	1.26	1.18	9	38

Very Large Urban Areas—over 3 million population.
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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 period.

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 8. Congestion Trends – Wasted Time (Travel Time Index, 1982 to 2010), Continued

Urban Area	Travel Time Index					Point Change in Peak-Period Time Penalty 1982 to 2010	
	2010	2009	2005	2000	1982	Points	Rank
Large Average (31 areas)	**1.17**	**1.17**	**1.21**	**1.19**	**1.07**	**10**	
Austin TX	1.28	1.28	1.32	1.23	1.08	20	2
Portland OR-WA	1.25	1.23	1.27	1.26	1.06	19	4
Las Vegas NV	1.24	1.26	1.29	1.25	1.06	18	6
Minneapolis-St. Paul MN	1.23	1.21	1.33	1.31	1.05	18	6
San Juan PR	1.25	1.25	1.24	1.21	1.07	18	6
Denver-Aurora CO	1.24	1.22	1.28	1.26	1.07	17	12
Riverside-San Bernardino CA	1.18	1.16	1.19	1.13	1.01	17	12
San Antonio TX	1.18	1.16	1.21	1.18	1.03	15	17
Baltimore MD	1.19	1.17	1.19	1.14	1.05	14	20
Sacramento CA	1.19	1.18	1.26	1.20	1.05	14	20
San Jose CA	1.25	1.23	1.31	1.30	1.12	13	23
Milwaukee WI	1.18	1.16	1.17	1.18	1.06	12	25
Charlotte NC-SC	1.17	1.17	1.20	1.19	1.06	11	29
Indianapolis IN	1.17	1.18	1.15	1.15	1.06	11	29
Orlando FL	1.18	1.20	1.22	1.23	1.07	11	29
Cincinnati OH-KY-IN	1.13	1.12	1.14	1.15	1.03	10	34
Raleigh-Durham NC	1.14	1.13	1.17	1.13	1.04	10	34
Columbus OH	1.11	1.11	1.11	1.09	1.02	9	38
Providence RI-MA	1.12	1.14	1.18	1.15	1.03	9	38
Virginia Beach VA	1.18	1.19	1.24	1.21	1.09	9	42
Cleveland OH	1.10	1.10	1.12	1.15	1.03	7	49
Kansas City MO-KS	1.11	1.10	1.15	1.18	1.04	7	49
Memphis TN-MS-AR	1.12	1.13	1.18	1.18	1.05	7	49
Nashville-Davidson TN	1.18	1.15	1.20	1.18	1.11	7	54
Buffalo NY	1.10	1.10	1.13	1.11	1.04	6	57
Salt Lake City UT	1.11	1.12	1.16	1.18	1.05	6	57
Louisville KY-IN	1.10	1.10	1.12	1.11	1.06	4	72
Jacksonville FL	1.09	1.12	1.17	1.13	1.06	3	79
New Orleans LA	1.17	1.15	1.19	1.19	1.14	3	79
Pittsburgh PA	1.18	1.17	1.22	1.22	1.15	3	79
Tampa-St. Petersburg FL	1.16	1.16	1.18	1.15	1.13	3	79
St. Louis MO-IL	1.10	1.12	1.17	1.21	1.08	2	93

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Table 8. Congestion Trends – Wasted Time (Travel Time Index, 1982 to 2010), Continued

Urban Area	Travel Time Index					Point Change in Peak-Period Time Penalty 1982 to 2010	
	2010	2009	2005	2000	1982	Points	Rank
Medium Average (33 areas)	**1.11**	**1.11**	**1.12**	**1.11**	**1.04**	**7**	
Bridgeport-Stamford CT-NY	1.27	1.25	1.26	1.24	1.07	20	2
Baton Rouge LA	1.25	1.24	1.21	1.19	1.07	18	6
El Paso TX-NM	1.16	1.15	1.18	1.16	1.03	13	23
Oxnard-Ventura CA	1.12	1.12	1.12	1.08	1.01	11	28
Birmingham AL	1.15	1.14	1.15	1.12	1.04	11	29
Colorado Springs CO	1.13	1.12	1.18	1.18	1.03	10	34
Hartford CT	1.15	1.13	1.17	1.18	1.05	10	34
McAllen TX	1.10	1.09	1.08	1.07	1.01	9	38
Honolulu HI	1.18	1.18	1.18	1.15	1.09	9	42
New Haven CT	1.13	1.15	1.15	1.15	1.04	9	42
Oklahoma City OK	1.10	1.09	1.07	1.07	1.02	8	46
Omaha NE-IA	1.09	1.08	1.10	1.08	1.02	7	49
Charleston-North Charleston SC	1.16	1.15	1.17	1.16	1.09	7	54
Bakersfield CA	1.07	1.08	1.08	1.05	1.01	6	57
Tulsa OK	1.08	1.07	1.05	1.06	1.02	6	57
Albany-Schenectady NY	1.08	1.10	1.10	1.07	1.03	5	65
Albuquerque NM	1.10	1.13	1.16	1.17	1.05	5	65
Indio-Cathedral City-Palm Springs CA	1.11	1.13	1.12	1.08	1.06	5	65
Fresno CA	1.07	1.07	1.08	1.10	1.03	4	72
Toledo OH-MI	1.05	1.05	1.07	1.08	1.01	4	72
Tucson AZ	1.11	1.11	1.15	1.12	1.07	4	72
Wichita KS	1.07	1.08	1.06	1.06	1.03	4	72
Akron OH	1.05	1.05	1.08	1.09	1.02	3	79
Allentown-Bethlehem PA-NJ	1.07	1.08	1.08	1.09	1.04	3	79
Grand Rapids MI	1.05	1.06	1.05	1.06	1.02	3	79
Lancaster-Palmdale CA	1.10	1.11	1.10	1.07	1.07	3	79
Richmond VA	1.06	1.06	1.07	1.06	1.03	3	79
Sarasota-Bradenton FL	1.09	1.10	1.11	1.11	1.06	3	79
Springfield MA-CT	1.08	1.09	1.09	1.09	1.05	3	79
Knoxville TN	1.06	1.06	1.09	1.10	1.04	2	93
Rochester NY	1.05	1.07	1.07	1.06	1.03	2	93
Dayton OH	1.06	1.06	1.07	1.08	1.05	1	97
Poughkeepsie-Newburgh NY	1.04	1.04	1.05	1.04	1.03	1	97

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Table 8. Congestion Trends – Wasted Time (Travel Time Index, 1982 to 2010), Continued

Urban Area	Travel Time Index					Point Change in Peak-Period Time Penalty 1982 to 2010	
	2010	2009	2005	2000	1982	Points	Rank
Small Average (21 areas)	**1.08**	**1.08**	**1.08**	**1.08**	**1.03**	**5**	
Boulder CO	1.14	1.13	1.14	1.15	1.05	9	42
Boise ID	1.10	1.12	1.15	1.12	1.02	8	46
Little Rock AR	1.10	1.10	1.08	1.07	1.02	8	46
Columbia SC	1.09	1.09	1.07	1.06	1.02	7	49
Beaumont TX	1.08	1.08	1.06	1.05	1.02	6	57
Laredo TX	1.07	1.07	1.06	1.05	1.01	6	57
Provo UT	1.08	1.06	1.05	1.04	1.02	6	57
Salem OR	1.09	1.10	1.12	1.12	1.03	6	57
Greensboro NC	1.06	1.05	1.07	1.08	1.01	5	65
Pensacola FL-AL	1.08	1.07	1.10	1.09	1.03	5	65
Spokane WA	1.10	1.10	1.10	1.14	1.05	5	65
Winston-Salem NC	1.06	1.06	1.07	1.05	1.01	5	65
Corpus Christi TX	1.07	1.07	1.07	1.06	1.03	4	72
Jackson MS	1.06	1.07	1.09	1.06	1.02	4	72
Cape Coral FL	1.10	1.12	1.12	1.10	1.07	3	79
Madison WI	1.06	1.06	1.05	1.05	1.03	3	79
Worcester MA	1.06	1.07	1.09	1.09	1.03	3	79
Brownsville TX	1.04	1.04	1.07	1.07	1.02	2	93
Eugene OR	1.06	1.07	1.13	1.13	1.05	1	97
Stockton CA	1.02	1.02	1.05	1.03	1.01	1	97
Anchorage AK	1.05	1.05	1.06	1.05	1.05	0	101
101 Area Average	**1.21**	**1.20**	**1.25**	**1.22**	**1.09**	**12**	
Remaining Areas	**1.08**	**1.09**	**1.12**	**1.10**	**1.04**	**4**	
All 439 Urban Areas	**1.20**	**1.20**	**1.25**	**1.21**	**1.09**	**11**	

Very Large Urban Areas—over 3 million population.
Large Urban Areas—over 1 million and less than 3 million population.
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 period.
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 9. Urban Area Demand and Roadway Growth Trends

Less Than 10% Faster (13)	10% to 30% Faster (46)	10% to 30% Faster (cont.)	More Than 30% Faster (40)	More Than 30% Faster (cont.)
Anchorage AK	Allentown-Bethlehem PA-NJ	Memphis TN-MS-AR	Akron OH	Minneapolis-St. Paul MN
Boulder CO	Baton Rouge LA	Milwaukee WI	Albany-Schenectady NY	New Haven CT
Dayton OH	Beaumont TX	Nashville-Davidson TN	Albuquerque NM	New York-Newark NY-NJ-CT
Greensboro NC	Boston MA-NH-RI	Oklahoma City OK	Atlanta GA	Omaha NE-IA
Indio-Cath City-P Springs CA	Brownsville TX	Pensacola FL-AL	Austin TX	Orlando FL
Lancaster-Palmdale CA	Buffalo NY	Philadelphia PA-NJ-DE-MD	Bakersfield CA	Oxnard-Ventura CA
Madison WI	Cape Coral FL	Phoenix AZ	Baltimore MD	Providence RI-MA
New Orleans LA	Charleston-N Charleston SC	Portland OR-WA	Birmingham AL	Raleigh-Durham NC
Pittsburgh PA	Charlotte NC-SC	Richmond VA	Boise ID	Riverside-S Bernardino CA
Poughkeepsie-Newburgh NY	Cleveland OH	Rochester NY	Bridgeport-Stamford CT-NY	Sacramento CA
Provo UT	Corpus Christi TX	Salem OR	Chicago IL-IN	San Antonio TX
St. Louis MO-IL	Detroit MI	Salt Lake City UT	Cincinnati OH-KY-IN	San Diego CA
Wichita KS	El Paso TX-NM	San Jose CA	Colorado Springs CO	San Francisco-Oakland CA
	Eugene OR	Seattle WA	Columbia SC	San Juan PR
	Fresno CA	Spokane WA	Columbus OH	Sarasota-Bradenton FL
	Grand Rapids MI	Springfield MA-CT	Dallas-Ft Worth-Arlington TX	Stockton CA
	Honolulu HI	Tampa-St. Petersburg FL	Denver-Aurora CO	Washington DC-VA-MD
	Houston TX	Toledo OH-MI	Hartford CT	
	Indianapolis IN	Tucson AZ	Jacksonville FL	
	Jackson MS	Tulsa OK	Laredo TX	
	Kansas City MO-KS	Virginia Beach VA	Las Vegas NV	
	Knoxville TN	Winston-Salem NC	Little Rock AR	
	Louisville KY-IN	Worcester MA	Los Angeles-L Bch-S Ana CA	
	McAllen TX		Miami FL	

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

References

1 *National Average Speed Database*, 2007, 2008, 2009, 2010. INRIX. Bellevue, WA. www.inrix.com

2 *Highway Performance Monitoring System*. 1982 to 2008 Data. Federal Highway Administration. Washington D.C. November 2009.

3 *Time Management Company Calculates Time You Spend Online…* Techuncover. June 4, 2010. http://techuncover.com/?tag=amazon

4 *National Transit Database*. Federal Transit Administration. 2009. Available: http://www.ntdprogram.gov/ntdprogram/

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

6 *Freight Analysis Framework (FAF) Version 2.2, User Guide – Commodity Origin-Destination Database 2002 to 2035.* Federal Highway Administration. Washington D.C. November 2006.

7 *Urban Mobility Report Methodology*. Prepared by Texas Transportation Institute For University Transportation Center for Mobility, College Station, Texas. 2009. Available: http://mobility.tamu.edu/ums/report/methodology.stm

8 *An Early Look at the 2010 Urban Mobility Report: "Change" is Improving the Information.* Prepared by Texas Transportation Institute For University Transportation Center for Mobility, College Station, TX. September 2010. http://mobility.tamu.edu/ums/resources/umr2010_preview.pdf

9 *Developing a Total Travel Time Performance Measure: A Concept Paper.* Prepared by Texas Transportation Institute For Mobility Measurement in Urban Transportation Pooled Fund Study. College Station, TX. August 2010. http://mobility.tamu.edu/resources/ttt_measure_2010.pdf

10 *Incorporating Sustainability Factors Into The Urban Mobility Report: A Draft Concept Paper.* Prepared by Texas Transportation Institute For Mobility Measurement in Urban Transportation Pooled Fund Study. College Station, TX. August 2010. http://mobility.tamu.edu/resources/sustainability_factors.pdf

11 *Development of Diurnal Traffic Distribution and Daily, Peak and Off-Peak Vehicle Speed Estimation Procedures for Air Quality Planning.* Final Report, Work Order B-94-06, Prepared for Federal Highway Administration, April 1996.

Appendix A
Methodology for the 2011 Urban Mobility Report

The procedures used in the 2011 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 year and every city are provided in a spreadsheet that can be downloaded at http://mobility.tamu.edu/ums/congestion-data/.

This memo documents the analysis conducted for the methodology utilized in preparing the 2011 Urban Mobility Report. This methodology incorporates private sector traffic speed data from INRIX for calendar year 2010 into the calculation of the mobility performance measures presented in the initial calculations. The roadway inventory 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.

Methodology Changes to the 2011 UMR

There are several changes to the UMR methodology for the 2011 report. The largest changes have to do with how wasted fuel is calculated and how commercial vehicle operating costs are calculated. These changes are documented in more detail in the following sections of the Methodology. Here are brief summaries of what has changed:

- New fuel efficiency equations have been incorporated that are based on the more fuel efficient fleets that we operate in the U.S. as compared with 10 and 20 years ago. The previous fuel efficiency equation used in the UMR was based on 1980's data. Separate fuel efficiency equations for passenger cars and commercial vehicles are now being used in calculating the UMR statistics. In the past, one efficiency equation was used for all vehicle types.
- Diesel costs are now being utilized to calculate commercial vehicle operating costs. In the past, the fuel costs were rolled into the hourly operating costs of commercial vehicles. Now the fuel costs are separated out for commercial vehicles just like passenger vehicles and the diesel prices are applied to the commercial vehicle wasted fuel. The commercial vehicle hourly operating costs in the 2011 UMR only reflect such items as wasted time and operating/maintenance costs; fuel is no longer a component.

Summary

The Urban Mobility Report (UMR) procedures provide estimates of mobility at the areawide level. The approach that is used describes congestion in consistent ways allowing for comparisons across urban areas or groups of urban areas. As with the last several editions of the UMR, this report includes the effect of several operational treatments and to public transportation. The goal is to include all improvements, but good data is necessary to accomplish this.

The previous UMR methodology used a set of estimation procedures and data provided by state DOT's and regional planning agencies to develop a set of mobility measures. This memo describes the congestion calculation procedure that uses a dataset of traffic speeds from INRIX, a private company that provides travel time information to a variety of customers. INRIX's 2010 data is an annual average of traffic speed for each section of road for every hour of each day for a total of 168 day/time period cells (24 hours x 7 days).

The travel speed data addresses the biggest shortcoming of previous editions of the UMR – the speed estimation process. INRIX's speed data improves the freeway and arterial street congestion measures in the following ways:

- "Real" rush hour speeds used to estimate a range of congestion measures; *speeds are measured not estimated.*
- Overnight speeds were used to identify the free-flow speeds that are used as a comparison standard; *low-volume speeds on each road section were used as the comparison standard.*
- The volume and roadway inventory data from FHWA's Highway Performance Monitoring System (HPMS) files were used with the speeds to calculate travel delay statistics; *the best speed data is combined with the best volume information to produce high-quality congestion measures.*

The Congestion Measure Calculation with Speed and Volume Datasets

The following steps were used to calculate the congestion performance measures for each urban roadway section.

1. Obtain HPMS traffic volume data by road section
2. Match the HPMS road network sections with the traffic speed dataset road sections
3. Estimate traffic volumes for each hour time interval from the daily volume data
4. Calculate average travel speed and total delay for each hour interval

5. Establish free-flow (i.e., low volume) travel speed
6. Calculate congestion performance measures
7. Additional steps when volume data had no speed data match

The mobility measures require four data inputs:

- Actual travel speed
- Free-flow travel speed
- Vehicle volume
- Vehicle occupancy (persons per vehicle) to calculate person-hours of travel delay

The 2010 private sector traffic speed data provided a better data source for the first two inputs, actual and free-flow travel time. The UMR analysis required vehicle and person volume estimates for the delay calculations; these were obtained from FHWA's HPMS dataset. The geographic referencing systems are different for the speed and volume datasets, a geographic matching process was performed to assign traffic speed data to each HPMS road section for the purposes of calculating the performance measures. When INRIX traffic speed data was not available for sections of road or times of day in urban areas, the speeds were estimated. This estimation process is described in more detail in Step 7.

Step 1. Identify Traffic Volume Data

The HPMS dataset from FHWA provided the source for traffic volume data, although the geographic designations in the HPMS dataset are not identical to the private sector speed data. The daily traffic volume data must be divided into the same time interval as the traffic speed data (hour intervals). While there are some detailed traffic counts on major roads, the most widespread and consistent traffic counts available are average daily traffic (ADT) counts. The hourly traffic volumes for each section, therefore, were estimated from these ADT counts using typical time-of-day traffic volume profiles developed from continuous count locations or other data sources. The section "Estimation of Hourly Traffic Volumes" shows the average hourly volume profiles used in the measure calculations.

Volume estimates for each day of the week (to match the speed database) were created from the average volume data using the factors in Exhibit A-1. Automated traffic recorders from around the country were reviewed and the factors in Exhibit A-1 are a "best-fit" average for both freeways and major streets. Creating an hourly volume to be used with the traffic speed values, then, is a process of multiplying the annual average by the daily factor and by the hourly factor.

Exhibit A-1. Day of Week Volume Conversion Factors

Day of Week	Adjustment Factor (to convert average annual volume into day of week volume)
Monday to Thursday	+5%
Friday	+10%
Saturday	-10%
Sunday	-20%

Step 2. Combine the Road Networks for Traffic Volume and Speed Data

The second step was to combine the road networks for the traffic volume and speed data sources, such that an estimate of traffic speed and traffic volume was available for each roadway segment in each urban area. The combination (also known as conflation) of the traffic volume and traffic speed networks was accomplished using Geographic Information Systems (GIS) tools. The INRIX speed network was chosen as the base network; an ADT count from the HPMS network was applied to each segment of roadway in the speed network. The traffic count and speed data for each roadway segment were then combined into areawide performance measures.

Step 3. Estimate Traffic Volumes for Shorter Time Intervals

The third step was to estimate traffic volumes for one-hour time intervals for each day of the week. Typical time-of-day traffic distribution profiles are needed to estimate hourly traffic flows from average daily traffic volumes. Previous analytical efforts[1,2] have developed typical traffic profiles at the hourly level (the roadway traffic and inventory databases are used for a variety of traffic and economic studies). These traffic distribution profiles were developed for the following different scenarios (resulting in 16 unique profiles):

- Functional class: freeway and non-freeway
- Day type: weekday and weekend
- Traffic congestion level: percentage reduction in speed from free-flow (varies for freeways and streets)

[1] *Roadway Usage Patterns: Urban Case Studies*. Prepared for Volpe National Transportation Systems Center and Federal Highway Administration, July 22, 1994.

[2] *Development of Diurnal Traffic Distribution and Daily, Peak and Off-peak Vehicle Speed Estimation Procedures for Air Quality Planning*. Final Report, Work Order B-94-06, Prepared for Federal Highway Administration, April 1996.

- Directionality: peak traffic in the morning (AM), peak traffic in the evening (PM), approximately equal traffic in each peak

The 16 traffic distribution profiles shown in Exhibits A-2 through A-6 are considered to be very comprehensive, as they were developed based upon 713 continuous traffic monitoring locations in urban areas of 37 states.

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

Exhibit A-2. Weekday Traffic Distribution Profile for No to Low Congestion

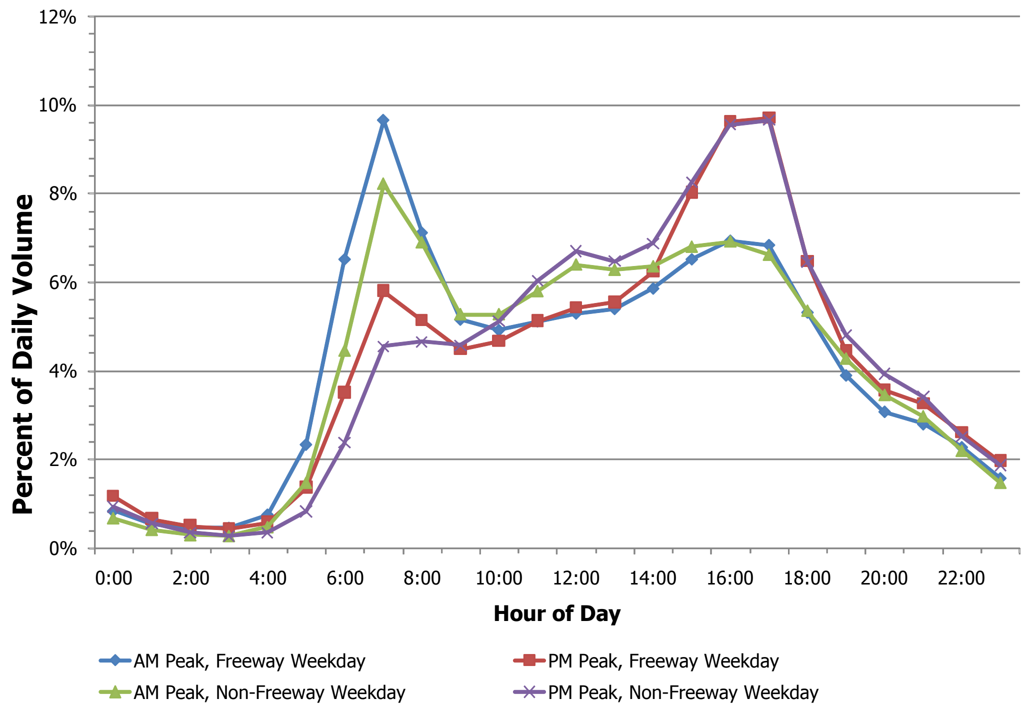
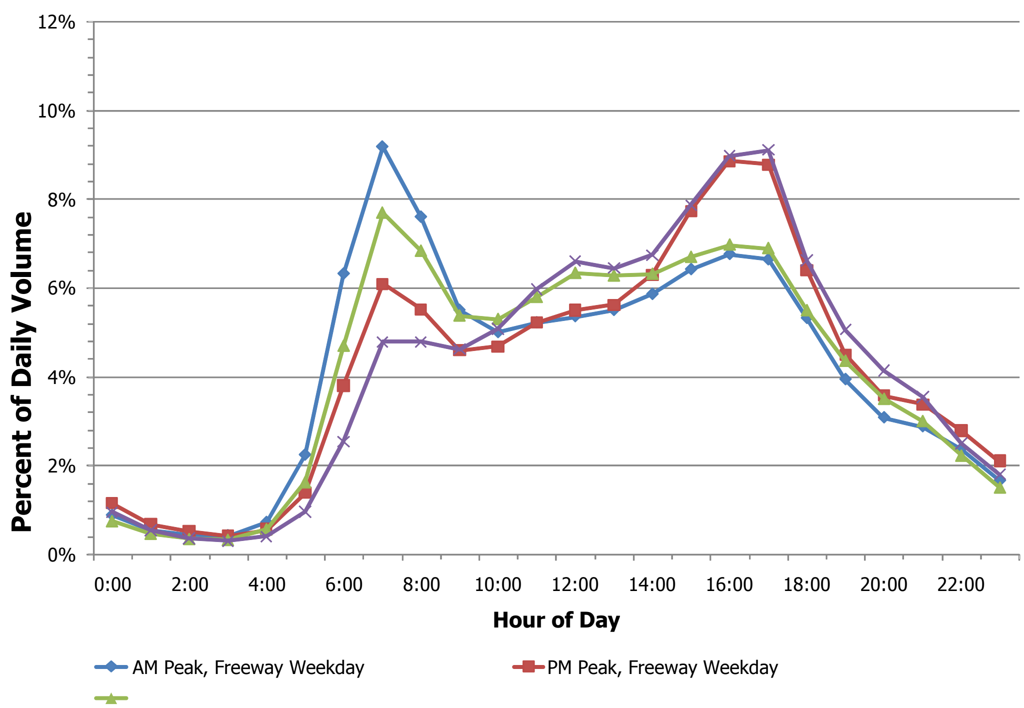


Exhibit A-3. Weekday Traffic Distribution Profile for Moderate Congestion



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

Exhibit A-4. Weekday Traffic Distribution Profile for Severe Congestion

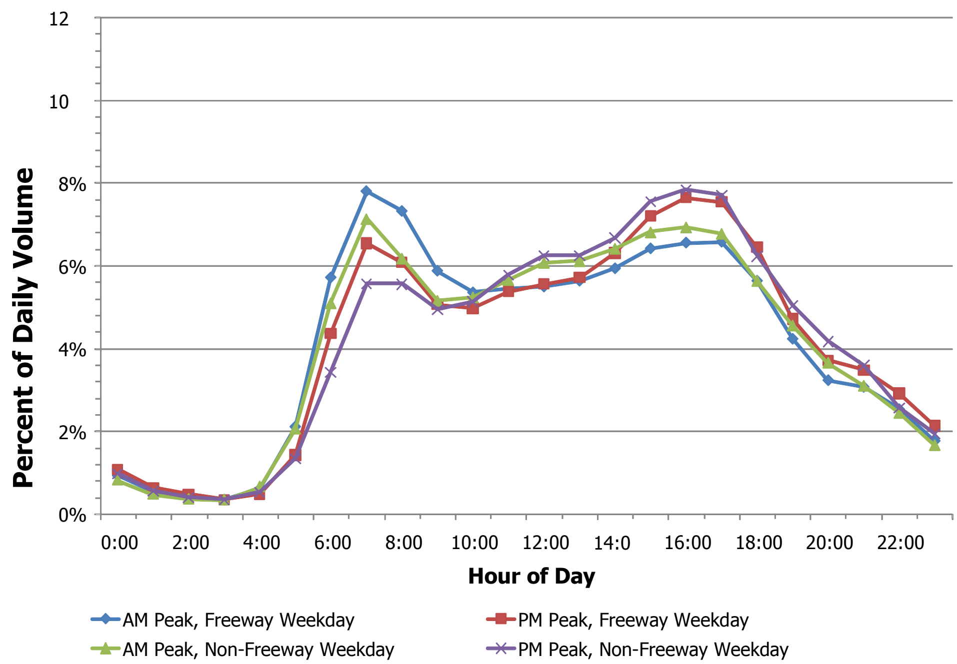


Exhibit A-5. Weekend Traffic Distribution Profile

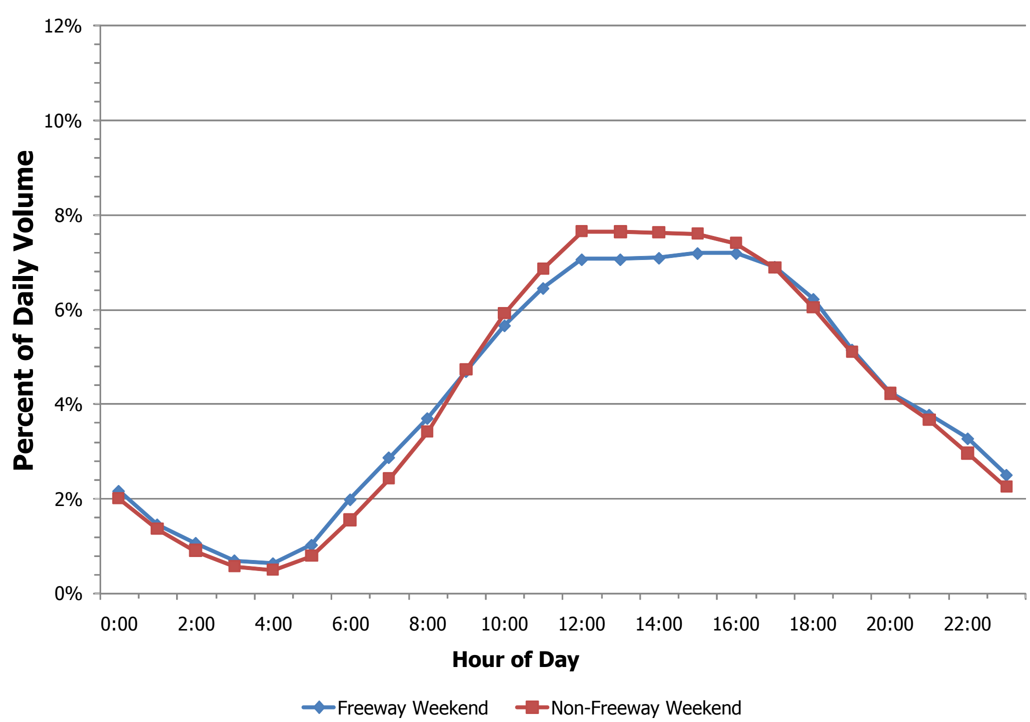
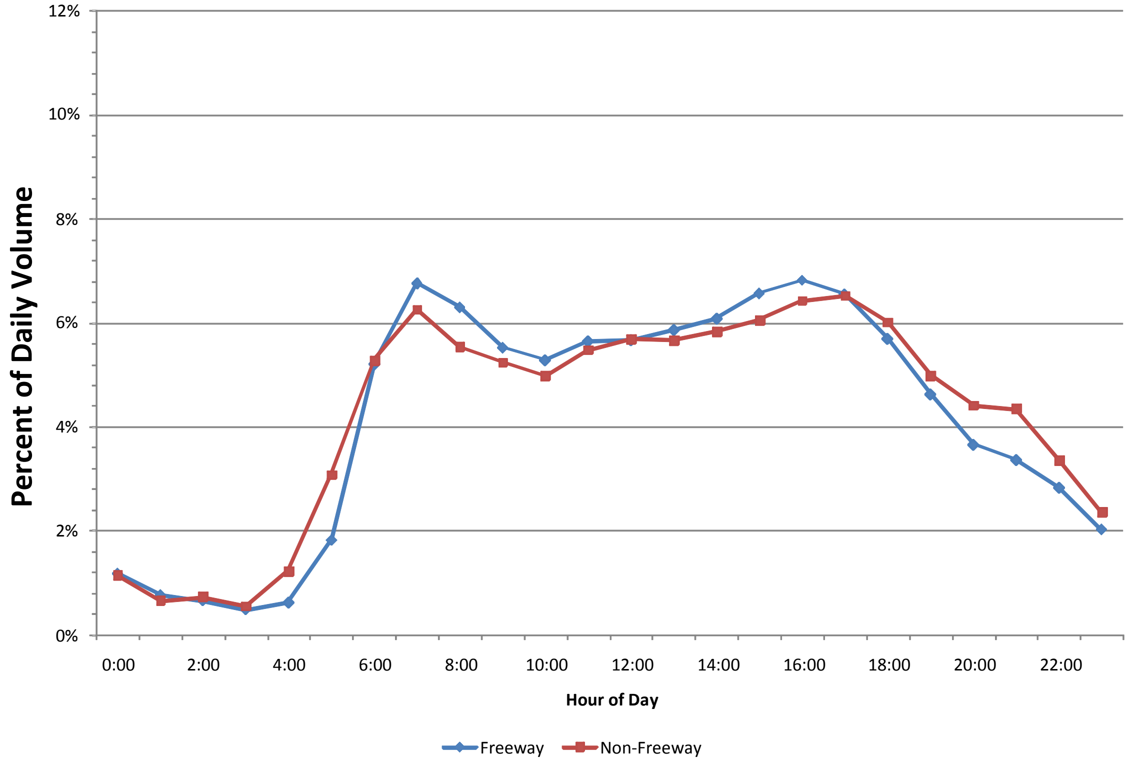


Exhibit A-6. Weekday Traffic Distribution Profile for Severe Congestion and Similar Speeds in Each Peak Period



The next step in the traffic flow assignment process is to determine which of the 16 traffic distribution profiles should be assigned to each Traffic Message Channel (TMC) path (the "geography" used by the private sector data providers), such that the hourly traffic flows can be calculated from traffic count data supplied by HPMS. The assignment should be as follows:

- Functional class: assign based on HPMS functional road class
  - Freeway – access-controlled highways
  - Non-freeway – all other major roads and streets
- Day type: assign volume profile based on each day
  - Weekday (Monday through Friday)
  - Weekend (Saturday and Sunday)
- Traffic congestion level: assign based on the peak period speed reduction percentage calculated from the private sector speed data. The peak period speed reduction is calculated as follows: 1) Calculate a simple average peak period speed (add up all the morning and evening peak period speeds and divide the total by the 8 periods in the eight peak hours) for each TMC path

using speed data from 6 a.m. to 10 a.m. (morning peak period) and 3 p.m. to 7 p.m. (evening peak period).

2) Calculate a free-flow speed during the light traffic hours (e.g., 10 p.m. to 5 a.m.) to be used as the baseline for congestion calculations.

3) Calculate the peak period speed reduction by dividing the average combined peak period speed by the free-flow speed.

$$\begin{matrix}\text{Speed} \\ \text{Reduction Factor}\end{matrix} = \frac{\begin{matrix}\text{Average Peak} \\ \text{Period Speed}\end{matrix}}{\begin{matrix}\text{Free-Flow Speed} \\ (10\ \text{p.m. to } 5\ \text{a.m.})\end{matrix}} \qquad \text{(Eq. A-1)}$$

For Freeways:

- speed reduction factor ranging from 90% to 100% (no to low congestion)
- speed reduction factor ranging from 75% to 90% (moderate congestion)
- speed reduction factor less than 75% (severe congestion)

For Non-Freeways:

- speed reduction factor ranging from 80% to 100% (no to low congestion)
- speed reduction factor ranging from 65% to 80% (moderate congestion)
- speed reduction factor less than 65% (severe congestion)

- Directionality: Assign this factor based on peak period speed differentials in the private sector speed dataset. The peak period speed differential is calculated as follows:
  1) Calculate the average morning peak period speed (6 a.m. to 10 a.m.) and the average evening peak period speed (3 p.m. to 7 p.m.)
  2) Assign the peak period volume curve based on the speed differential. The lowest speed determines the peak direction. Any section where the difference in the morning and evening peak period speeds is 6 mph or less will be assigned the even volume distribution.

Step 4. Calculate Travel and Time

The hourly speed and volume data was combined to calculate the total travel time for each one hour time period. The one hour volume for each segment was multiplied by the corresponding travel time to get a quantity of vehicle-hours; these were summed across the entire urban area.

Step 5. Establish Free-Flow Travel Speed and Time

The calculation of congestion measures required establishing a congestion threshold, such that delay was accumulated for any time period once the speeds are lower than the congestion threshold. There has been considerable debate about the appropriate congestion thresholds, but for the purpose of the UMR methodology, the data was used to identify the speed at low volume conditions (for example, 10 p.m. to 5 a.m.). This speed is relatively high, but varies according to the roadway design characteristics. An upper limit of 65 mph was placed on the freeway free-flow speed to maintain a reasonable estimate of delay; no limit was placed on the arterial street free-flow speeds.

Step 6. Calculate Congestion Performance Measures

The mobility performance measures were calculated using the equations shown in the next section of this methodology once the one-hour dataset of actual speeds, free-flow travel speeds and traffic volumes was prepared.

Step 7. Estimate Speed Data Where Volume Data Had No Matched Speed Data

The UMR methodology analyzes travel on all freeways and arterial streets in each urban area. In many cases, the arterial streets are not maintained by the state DOT's so they are not included in the roadway network GIS shapefile that is reported in HPMS (all roadway classes will be added to the GIS roadway shapefiles within the next few years by the state DOTs as mandated by FHWA). A technique for handling the unmatched sections of roadway was developed for the 2010 UMR. The percentage of arterial streets that had INRIX speed data match ranged from about 20 to 40 percent across the U.S. while the freeway match percentages ranged from about 80 to 100 percent.

After the original conflation of the volume and speed networks in each urban area was completed, there were unmatched volume sections of roadway and unmatched INRIX speed sections of roadway. After reviewing how much speed data was unmatched in each urban area, it was decided that unmatched data would be handled differently in urban areas over under one million in population versus areas over one million in population.

Areas Under One Million Population

The HPMS volume data for each urban area that was unmatched was separated into freeway and arterial street sections. The HPMS sections of road were divided by each county in which the urban area was located. If an urban area was located in two counties, the unmatched traffic volume data from each county would be analyzed separately. The volume data was then aggregated such that it was treated like one large traffic count for freeways and another for street sections.0.

The unmatched speed data was separated by county also. All of the speed data and freeflow speed data was then averaged together to create a speed profile to represent the unmatched freeway sections and unmatched street sections.

The volume data and the speed data were combined and Steps 1 through 6 were repeated for the unmatched data in these smaller urban areas.

Areas Over One Million Population

In urban areas with populations over one million, the unmatched data was handled in one or two steps depending on the area. The core counties of these urban areas (these include the counties with at least 15 to 20 percent of the entire urban area's VMT) were treated differently because they tended to have more unmatched speed data available than some of the more suburban counties.

In the suburban counties (non-core), where less than 15 or 20 percent of the area's VMT was in a particular county, the volume and speed data from those counties were treated the same as the data in smaller urban areas with populations below one million discussed earlier. Steps 1 through 6 were repeated for the non-core counties of these urban areas.

In each of the core counties, all of the unmatched HPMS sections were gathered and ranked in order of highest traffic density (VMT per lane-mile) down to lowest for both freeways and arterial streets. These sections of roadway were divided into three groups. The top 25 percent of the lane-miles, with highest traffic density, were grouped together into the first set. The next 25 percent were grouped into a second set and the remaining lane-miles were grouped into a third set.

Similar groupings were made with the unmatched speed data for each core county for both functional classes of roadway. The roadway sections of unmatched speed data were ordered from most congested to least congested based on their Travel Time Index value. Since the lane-miles of roadway for these sections were not available with the INRIX speed data, the listing was divided into the same splits as the traffic volume data (25/25/50 percent). (The Travel Time Index was used instead of speed because the TTI includes both free-flow and actual speed).

The volume data from each of the 3 groups was matched with the corresponding group of speed data and steps 1 through 6 were repeated for the unmatched data in the core counties.

Calculation of the Congestion Measures

This section summarizes the methodology utilized to calculate many of the statistics shown in the Urban Mobility Report and 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) Travel Speed
    2) Travel Delay
    3) Annual Person Delay
    4) Annual Delay per Auto Commuter
    5) Annual Peak Period Travel Time
    6) Travel Time Index
    7) Commuter Stress Index
    8) Wasted Fuel
    9) Total Congestion Cost and Truck Congestion Cost
    10) Truck Commodity Value
    11) Roadway Congestion Index
    12) Number of Rush Hours
    13) Percent of Daily and Peak Travel in Congested Conditions
    14) Percent of Congested Travel

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

National Constants

The congestion calculations utilize the values in Exhibit A-7 as national constants—values used in all urban areas to estimate the effect of congestion.

Exhibit A-7. National Congestion Constants for 2011 Urban Mobility Report

Constant	Value
Vehicle Occupancy	1.25 persons per vehicle
Average Cost of Time ($2010)*	$16.30 per person hour[1]
Commercial Vehicle Operating Cost ($2010)	$88.12 per vehicle hour[1, 2]
Working Days (5x50)	250 days
Total Travel Days (7x52)	364 days

[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 and Weeks

With the addition of the INRIX speed data in the 2011 UMR, the calculations are based on a full year of data that includes all days of the week rather than just the working days. The delay from each day of the week is multiplied by 50 work weeks to annualize the delay. The weekend days are multiplied by 57 to help account for the lighter traffic days on holidays. Total delay for the year is based on 364 total travel days in the year.

Average Cost of Time

The 2010 value of person time used in the report is $16.30 per hour based on the value of time, rather than the average or prevailing wage rate (*7*).

Commercial Vehicle Operating Cost

Truck travel time and operating costs (excluding diesel costs) are valued at $88.12 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, Peak Travelers and Commuters

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 (NHTS) (*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. These same data from NHTS was also used to calculate an estimate of commuters who were traveling during the peak periods by private vehicle—a subset of the peak period travelers.

Fuel Costs

Statewide average fuel cost estimates were obtained from daily fuel price data published by the American Automobile Association (AAA) (*11*). Values for gasoline and diesel are 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 roadway capacity.

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 this methodology.

Travel Speed

The peak period average travel speeds from INRIX are shown in Exhibit A-8 for the freeways and arterial streets. Also shown are the freeflow travel speeds used to calculate the delay-based measures in the report. These speeds are based on the "matched" traffic volume/speeds datasets as well as the "unmatched" traffic volume/speed datasets described in Step 7 of the "Process" description.

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

Exhibit A-8. 2010 Traffic Speed Data

Urban Area	Freeway		Arterial Streets	
	Peak Speed	Freeflow Speed	Peak Speed	Freeflow Speed
Very Large Areas				
Atlanta GA	56.0	63.3	34.5	42.4
Boston MA-NH-RI	55.3	62.5	29.8	35.9
Chicago IL-IN	49.4	58.2	29.0	35.5
Dallas-Fort Worth-Arlington TX	53.0	61.3	31.3	37.4
Detroit MI	56.7	61.7	31.4	37.4
Houston TX	51.8	61.9	34.7	42.8
Los Angeles-Long Beach-Santa Ana CA	47.3	60.3	29.9	37.1
Miami FL	58.3	62.9	32.5	37.8
New York-Newark NY-NJ-CT	52.3	60.6	32.5	40.8
Philadelphia PA-NJ-DE-MD	55.3	61.5	34.0	40.6
Phoenix AZ	58.1	62.2	37.2	42.6
San Diego CA	55.9	62.3	34.0	40.5
San Francisco-Oakland CA	51.8	60.5	29.8	36.4
Seattle WA	49.1	58.9	30.6	37.0
Washington DC-VA-MD	48.2	60.8	33.4	41.5
Large Areas				
Austin TX	48.4	61.2	39.2	49.5
Baltimore MD	54.0	61.2	34.0	40.9
Buffalo NY	55.4	58.9	36.4	41.1
Charlotte NC-SC	56.8	62.2	35.8	42.5
Cincinnati OH-KY-IN	56.7	59.9	38.8	42.7
Cleveland OH	56.1	59.3	38.8	42.7
Columbus OH	58.1	60.5	43.1	48.2
Denver-Aurora CO	51.1	60.4	31.1	37.3
Indianapolis IN	41.8	52.7	35.4	39.6
Jacksonville FL	59.1	61.9	40.4	45.3
Kansas City MO-KS	57.1	61.4	36.0	40.5
Las Vegas NV	56.0	61.0	34.7	40.0
Louisville KY-IN	57.5	60.3	36.0	41.6
Memphis TN-MS-AR	55.5	59.5	39.8	44.1
Milwaukee WI	54.1	60.4	39.7	43.2
Large Areas				
Minneapolis-St. Paul MN	51.4	60.1	35.1	42.1
Nashville-Davidson TN	57.2	62.1	39.6	46.0
New Orleans LA	51.5	60.8	31.1	38.2
Orlando FL	57.3	62.5	33.7	40.8
Pittsburgh PA	53.5	58.8	41.3	46.6
Portland OR-WA	48.6	56.5	36.2	42.0
Providence RI-MA	56.7	60.8	34.7	38.9
Raleigh-Durham NC	59.1	63.3	41.0	46.9
Riverside-San Bernardino CA	53.8	59.8	34.2	39.8
Sacramento CA	53.2	59.6	32.2	38.7
San Antonio TX	56.3	62.5	37.5	44.5
Salt Lake UT	59.2	62.5	50.6	55.1
San Jose CA	52.9	61.4	37.3	42.7
San Juan PR	55.0	61.7	35.8	39.1
St. Louis MO-IL	57.4	60.0	35.1	40.3
Tampa-St. Petersburg FL	60.4	63.8	36.0	42.5
Virginia Beach VA	54.6	60.0	36.9	43.2

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

Exhibit A-8. 2010 Traffic Speed Data, continued

Urban Area	Freeway		Arterial Streets		Urban Area	Freeway		Arterial Streets	
	Peak Speed	Freeflow Speed	Peak Speed	Freeflow Speed		Peak Speed	Freeflow Speed	Peak Speed	Freeflow Speed
Medium Areas					Medium Areas				
Akron OH	58.4	59.2	36.7	40.3	Toledo OH-MI	59.2	60.1	37.5	41.6
Albany-Schenectady NY	59.8	62.0	33.1	38.4	Tucson AZ	60.7	60.0	35.8	41.3
Albuquerque NM	59.5	61.0	42.4	47.5	Tulsa OK	58.4	62.0	50.7	52.7
Allentown-Bethlehem PA-NJ	60.6	61.5	41.4	46.0	Wichita KS	58.3	60.4	45.1	51.3
Bakersfield CA	57.0	58.6	32.8	39.6					
Baton Rouge LA	53.5	61.7	39.5	47.2	Small Areas				
Birmingham AL	58.5	62.3	35.3	43.1	Anchorage AK	59.7	62.9	32.9	39.1
Bridgeport-Stamford CT-NY	51.9	62.0	28.9	34.7	Beaumont TX	60.4	63.5	45.7	50.0
Charleston-North Charleston SC	57.0	61.4	38.8	45.6	Boise ID	58.4	60.4	35.5	41.8
Colorado Springs CO	55.3	59.5	34.4	39.8	Boulder CO	47.1	55.0	31.9	37.6
Dayton OH	59.6	59.9	46.4	48.8	Brownsville TX	61.7	63.5	36.7	43.3
El Paso TX-NM	54.1	60.2	55.0	56.3	Cape Coral FL	67.4	65.0	40.1	46.3
Fresno CA	58.0	58.3	37.0	41.4	Columbia SC	60.9	63.1	32.8	38.3
Grand Rapids MI	60.4	61.0	41.2	46.9	Corpus Christi TX	62.7	64.0	63.0	63.9
Hartford CT	57.3	62.3	38.5	43.8	Eugene OR	54.6	56.8	43.1	46.9
Honolulu HI	0.0	0.0	34.1	41.9	Greensboro NC	59.5	61.5	35.6	41.8
Indio-Cathedral City-Palm Springs CA	58.5	59.5	35.9	38.9	Jackson MS	62.3	63.8	46.8	52.4
Knoxville TN	58.2	59.9	43.7	48.0	Laredo TX	58.1	60.8	32.6	38.6
Lancaster-Palmdale CA	59.7	60.5	43.6	47.9	Little Rock AR	59.8	63.1	33.8	38.4
McAllen TX	59.4	63.4	44.7	48.1	Madison WI	60.5	62.7	44.8	49.2
New Haven CT	59.1	63.0	40.3	47.2	Pensacola FL-AL	63.6	63.3	37.9	43.4
Oklahoma City OK	58.3	61.5	39.3	45.2	Provo UT	58.9	64.2	33.7	38.4
Omaha NE-IA	57.5	59.8	32.5	37.5	Salem OR	55.3	57.1	38.0	41.2
Oxnard-Ventura CA	56.4	60.6	46.3	49.5	Spokane WA	57.6	59.2	29.4	33.2
Poughkeepsie-Newburgh NY	61.5	62.3	42.6	46.8	Stockton CA	58.2	58.6	49.6	51.4
Richmond VA	61.1	62.5	37.1	42.3	Winston-Salem NC	59.4	61.5	38.4	43.7
Rochester NY	58.8	60.9	32.9	39.0	Worcester MA	61.2	62.7	37.5	41.8
Sarasota-Bradenton FL	67.8	65.0	39.0	44.2					
Springfield MA-CT	60.9	62.6	34.6	38.9					

Travel Delay

Most of the basic performance measures presented in the Urban Mobility Report are developed in the process of calculating travel delay—the amount of extra time spent traveling due to congestion. The travel delay calculations have been greatly simplified with the addition of the INRIX speed data. This speed data reflects the effects of both recurring delay (or usual) and incident delay (crashes, vehicle breakdowns, etc.). The delay calculations are performed at the individual roadway section level and for each hour of the week. Depending on the application, the delay can be aggregated into summaries such as weekday peak period, weekend, weekday off-peak period, etc.

$$\text{Daily Vehicle-Hours of Delay} = \frac{\text{DailyVehicle-Miles of Travel}}{\text{Speed}} - \frac{\text{DailyVehicle-Miles of Travel}}{\text{Free-Flow Speed}} \qquad \text{(Eq. A-2)}$$

Annual Person Delay

This calculation is performed to expand the daily vehicle-hours of delay estimates for freeways and arterial streets to a yearly estimate in each study area. To calculate the annual person-hours of delay, multiply each day-of-the-week delay estimate by the average vehicle occupancy (1.25 persons per vehicle) and by 50 working weeks per year (Equation A-3).

$$\text{Annual Persons-Hours of Delay} = \text{Daily Vehicle-Hours of Delay on Frwys and Arterial Streets} \times \text{Annual Conversion Factor} \times \text{1.25 Persons per Vehicle} \qquad \text{(Eq. A-3)}$$

Annual Delay per Auto Commuter

Annual delay per auto commuter is a measure of the extra travel time endured throughout the year by auto commuters 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 National Household Travel Survey (10) to the urban area population estimate to derive the average number of auto commuters and number of travelers during the peak periods (*15*).

The delay calculated for each commuter comes from delay during peak commute times and delay that occurs during other times of the day. All of the delay that occurs during the peak hours of the day (6:00

a.m. to 10:00 a.m. and 3:00 p.m. to 7:00 p.m.) is assigned to the pool of commuters. In addition to this, the delay that occurs outside of the peak period is assigned to the entire population of the urban area. Equation A-4 shows how the delay per auto commuter is calculated. The reason that the off-peak delay is also assigned to the commuters is that their trips are not limited to just peak driving times but they also contribute to the delay that occurs during other times of the weekdays and the weekends.

$$\begin{matrix}\text{Delay per} \\ \text{Auto Commuter}\end{matrix} = \frac{\text{Peak Period Delay}}{\text{Auto Commuters}} + \frac{\text{Remaining Delay}}{\text{Population}} \qquad \text{(Eq. A-4)}$$

Annual Peak Period Major Road Travel Time

Total travel time can be used as both a performance measure and as a component in other calculations. The 2010 Urban Mobility Report used travel time as a component; future reports will incorporate other information and expand 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 roadway section length at the free-flow speeds (provided by INRIX for each roadway section) (Equation A-5).

$$\begin{matrix}\text{Annual Free-Flow} \\ \text{Travel Time} \\ \text{(Vehicle-Hours)}\end{matrix} = \frac{1}{\begin{matrix}\text{Free-Flow} \\ \text{Travel Speed}\end{matrix}} \times \begin{matrix}\text{Daily} \\ \text{Vehicle-Miles} \\ \text{of Travel}\end{matrix} \times \begin{matrix}\text{Annual} \\ \text{Conversion} \\ \text{Factor}\end{matrix} \qquad \text{(Eq. A-5)}$$

$$\begin{matrix}\text{Annual} \\ \text{Travel Time}\end{matrix} = \underbrace{\begin{matrix}\text{Freeway} \\ \text{Delay}\end{matrix} + \begin{matrix}\text{Arterial} \\ \text{Street Delay}\end{matrix}}_{\text{Eq. A-3}} + \underbrace{\begin{matrix}\text{Freeway} \\ \text{Free-Flow} \\ \text{Travel Time}\end{matrix} + \begin{matrix}\text{Arterial} \\ \text{Free-Flow} \\ \text{Travel Time}\end{matrix}}_{\text{Eq. A-5}} \qquad \text{(Eq. A-6)}$$

Travel Time Index

The Travel Time Index (TTI) compares 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 has units of 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 free-flow travel time for each functional class is subtracted from the average travel time to estimate delay. The Travel Time Index is calculated by comparing total travel time to the free-flow travel time (Equations A-7 and A-8).

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

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

Commuter Stress Index

The Commuter Stress Index (CSI) is the same as the TTI except that it includes only the travel in the peak directions during the peak periods; the TTI includes travel in all directions during the peak period. Thus, the CSI is more indicative of the work trip experienced by each commuter on a daily basis.

Wasted Fuel

The average fuel economy calculation is used to estimate the difference in fuel consumption of the vehicles operating in congested and uncongested conditions. Equations A-9 and A-10 are the regression equations resulting from fuel efficiency data from EPA/FHWA's MOVES model (*16*).

$$\begin{matrix}\text{Passenger Car} \\ \text{Fuel Economy}\end{matrix} = -0.0066 \times (\text{speed})^2 + 0.823 \times (\text{speed}) + 6.1577 \qquad \text{(Eq. A-9)}$$

$$\begin{matrix}\text{Truck Fuel} \\ \text{Economy}\end{matrix} = 1.4898 \text{ x In } \text{speed} - 0.2554 \qquad \text{(Eq. A-10)}$$

The Urban Mobility Report calculates the wasted fuel due to vehicles moving at speeds slower than free-flow throughout the day. Equation A-11 calculates the fuel wasted in delay conditions from Equation A-3, the average hourly speed, and the average fuel economy associated with the hourly speed (Equation A-9 and A-10).

$$\text{Annual Fuel Wasted} = \begin{matrix}\text{Travel Time}\\ \text{vehicle hours}\\ \text{Eq. A–5}\end{matrix} \times \begin{matrix}\text{Average Hourly}\\ \text{Speed}\\ \text{Eq. A–2}\end{matrix} \div \begin{matrix}\text{Average Fuel}\\ \text{Economy}\\ \text{Eq.A–9,10}\end{matrix} \times \begin{matrix}\text{Annual}\\ \text{Conversion Factor}\end{matrix} \quad \text{(Eq. A-11)}$$

Equation A-12 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-11).

$$\begin{matrix}\text{Annual Fuel}\\ \text{Consumed in}\\ \text{Free-Flow Conditions}\end{matrix} = \begin{matrix}\text{Travel Time}\\ \text{Eq. A-5}\end{matrix} \times \begin{matrix}\text{Free-Flow Speed}\\ \text{from INRIX Data}\end{matrix} \div \begin{matrix}\text{Average Fuel}\\ \text{Economy for}\\ \text{Free-Flow Speeds}\\ \text{Eq. A–9,10}\end{matrix} \times \begin{matrix}\text{Annual}\\ \text{Conversion}\\ \text{Factor}\end{matrix} \quad \text{(Eq. A-12)}$$

$$\begin{matrix}\text{Annual Fuel}\\ \text{Wasted in Congestion}\end{matrix} = \begin{matrix}\text{Annual Fuel}\\ \text{Consumed in}\\ \text{Congestion}\end{matrix} - \begin{matrix}\text{Annual Fuel That}\\ \text{Would be Consumed}\\ \text{in Free-flow Conditions}\end{matrix} \quad \text{(Eq. A-13)}$$

Total Congestion Cost and Truck 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-14 through A-16 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 in congestion. Equation A-14 shows how to calculate the passenger vehicle delay costs that result from lost time.

$$\begin{matrix}\text{Annual Psgr-Veh}\\ \text{Delay Cost}\end{matrix} = \begin{matrix}\text{Daily Psgr Vehicle}\\ \text{Hours of Delay}\\ \text{(Eq. A-4)}\end{matrix} \times \begin{matrix}\text{Value of}\\ \text{Person Time}\\ \text{(\$ / hour)}\end{matrix} \times \begin{matrix}\text{Vehicle}\\ \text{Occupancy}\\ \text{(pers vehicle)}\end{matrix} \times \begin{matrix}\text{Annual}\\ \text{Conversion}\\ \text{Factor}\end{matrix} \quad \text{(Eq. A-14)}$$

Passenger Vehicle Fuel Cost. Fuel cost due to congestion is calculated for passenger vehicles in Equation A-15. This is done by associating the wasted fuel, the percentage of the vehicle mix that is passenger, and the fuel costs.

$$\text{Annual Fuel Cost} = \begin{matrix}\text{Daily Fuel}\\ \text{Wasted}\\ \text{(Eq. A–13)}\end{matrix} \times \begin{matrix}\text{Percent of}\\ \text{Passenger}\\ \text{Vehicles}\end{matrix} \times \begin{matrix}\text{Gasoline}\\ \text{Cost}\end{matrix} \times \begin{matrix}\text{Annual}\\ \text{Conversion Factor}\end{matrix} \qquad \text{(Eq. A-15)}$$

Truck or Commercial Vehicle Delay Cost. The delay cost is an estimate of the value of lost time in commercial vehicles and the increased operating costs of commercial vehicles in congestion. Equation A-16 shows how to calculate the passenger vehicle delay costs that result from lost time.

$$\begin{matrix}\text{Annual Comm-Veh}\\ \text{Delay Cost}\end{matrix} = \begin{matrix}\text{Daily Comm Vehicle}\\ \text{Hours of Delay}\\ \text{(Eq. A-4)}\end{matrix} \times \begin{matrix}\text{Value of}\\ \text{Comm Vehicle Time}\\ \text{(\$ / hour)}\end{matrix} \times \begin{matrix}\text{Annual}\\ \text{Conversion}\\ \text{Factor}\end{matrix} \qquad \text{(Eq. A-16)}$$

Truck or Commercial Vehicle Fuel Cost. Fuel cost due to congestion is calculated for commercial vehicles in Equation A-16. This is done by associating the wasted fuel, the percentage of the vehicle mix that is commercial, and the fuel costs.

$$\text{Annual Fuel Cost} = \begin{matrix}\text{Daily Fuel}\\ \text{Wasted}\\ \text{(Eq. A–13)}\end{matrix} \times \begin{matrix}\text{Percent of}\\ \text{Commercial}\\ \text{Vehicles}\end{matrix} \times \begin{matrix}\text{Diesel}\\ \text{Cost}\end{matrix} \times \begin{matrix}\text{Annual}\\ \text{Conversion Factor}\end{matrix} \qquad \text{(Eq. A-17)}$$

Total Congestion Cost. Equation A-18 combines the cost due to travel delay and wasted fuel to determine the annual cost due to congestion resulting from incident and recurring delay.

$$\begin{matrix}\text{Annual Cost}\\ \text{Due to}\\ \text{Congestion}\end{matrix} = \begin{matrix}\text{Annual Passenger}\\ \text{Vehicle Delay Cost}\\ \text{Eq. A-14}\end{matrix} + \begin{matrix}\text{Annual Passenger}\\ \text{Fuel Cost}\\ \text{Eq. A-15}\end{matrix} + \begin{matrix}\text{Annual Comm}\\ \text{Veh Delay Cost}\\ \text{Eq. A-16}\end{matrix} + \begin{matrix}\text{Annual Comm}\\ \text{Veh Fuel Cost}\\ \text{(Eq A-17)}\end{matrix} \qquad \text{(Eq. A-18)}$$

Truck Commodity Value

The data for this performance measure came from the Freight Analysis Framework (FAF) and the Highway Performance Monitoring System (HPMS) from the Federal Highway Administration. The basis of this measure is the integration of the commodity value supplied by FAF and the truck vehicle-miles of travel (VMT) calculated from the HPMS roadway inventory database.

There are 5 steps involved in calculating the truck commodity value for each urban area.

1. Calculate the national commodity value for all truck movements
2. Calculate the HPMS truck VMT percentages for states, urban areas and rural roadways

3. Estimate the state and urban commodity values using the HPMS truck VMT percentages
4. Calculate the truck commodity value of origins and destinations for each urban area
5. Average the VMT-based commodity value with the origin/destination-based commodity value for each urban area.

Step 1 - National Truck Commodity Value. The FAF (version 3) database has truck commodity values that originate and end in 131 regions of the U.S. The database contains a 131 by 131 matrix of truck goods movements (tons and dollars) between these regions. Using just the value of the commodities that originate within the 131 regions, the value of the commodities moving within the 131 regions is determined (if the value of the commodities destined for the 131 regions was included also, the commodity values would be double-counted). The FAF database has commodity value estimates for different years. The base year for FAF-3 is 2007 with estimates of commodity values in 2010 through 2040 in 5-year increments. The 2008 and 2009 commodity value was estimated using a constant percentage growth trend between the 2007 and 2010 FAF values.

Step 2 – Truck VMT Percentages. The HPMS state truck VMT percentages are calculated in Equation A-19 using each state's estimated truck VMT and the national truck VMT. This percentage will be used to approximate total commodity value at the state level.

$$\begin{matrix}\text{State Truck}\\ \text{VMT Percentage}\end{matrix} = \frac{\text{State Truck VMT}}{\text{U.S. Truck VMT}} \times 100\% \qquad \text{(Eq. A-19)}$$

The urban percentages within each state are calculated similarly, but with respect to the state VMT. The equation used for the urban percentage is given in Equation A-20. The rural truck VMT percentage for each state is shown in Equation A-21.

$$\begin{matrix}\text{State Urban}\\ \text{Truck VMT Percentage}\end{matrix} = \frac{\begin{matrix}\text{State Urban}\\ \text{Truck VMT}\end{matrix}}{\begin{matrix}\text{State Truck}\\ \text{VMT}\end{matrix}} \times 100\% \qquad \text{(Eq. A-20)}$$

$$\begin{matrix}\text{State Rural Truck}\\ \text{VMT Percentage}\end{matrix} = 100\% - \begin{matrix}\text{State Urban Truck}\\ \text{VMT Percentage}\end{matrix} \qquad \text{(Eq. A-21)}$$

The urban area truck VMT percentage is used in the final calculation. The truck VMT in each urban area in a given state is divided by all of the urban truck VMT for the state (Equation A-20).

$$\text{Urban Area Truck VMT Percentage} = \frac{\text{Urban Area Truck VMT}}{\text{State Urban Truck VMT}} \quad \text{(Eq. A-22)}$$

Step 3 – Estimate State and Urban Area VMT from Truck VMT percentages. The national estimate of truck commodity value from Step 1 is used with the percentages calculated in Step 2 to assign a VMT-based commodity value to the urban and rural roadways within each state and to each urban area.

$$\text{State Urban Truck VMT-Based Commodity Value} = \text{U.S. Truck Commodity Value} \times \text{State Urban Truck Percentage} \quad \text{(Eq. A-23)}$$

$$\text{State Rural Truck VMT-Based Commodity Value} = \text{U.S. Truck Commodity Value} \times \text{State Rural Truck Percentage} \quad \text{(Eq. A-24)}$$

$$\text{Urban Area Truck VMT-Based Commodity Value} = \text{State Urban Truck VMT-Based Commodity Value} \times \text{Urban Area Truck VMT Percentage} \quad \text{(Eq. A-25)}$$

Step 4 – Calculate Origin/Destination-Based Commodity Value. The results in Step 3 show the commodity values for the U.S. distributed based on the truck VMT flowing through states in both rural portions and urban areas. The Step 3 results place equal weighting on a truck mile in a rural area and a truck mile in an urban area. Step 4 redistributes the truck commodity values with more emphasis placed on the urban regions where the majority of the truck trips were originating or ending.

The value of commodities with trips that began or ended in each of the 131 FAF regions was calculated and the results were combined to get a total for the U.S. The percentage of the total U.S. origin/ destination-based commodity values corresponding to each of the FAF regions, shown in Equations A-26 and A-27, was calculated and these percentages were used to redistribute the national freight commodity value estimated in Step 1 that were based only on the origin-based commodities. Equation A-28 shows that this redistribution was first done at the state level by summing the FAF regions within each state. After the new state commodity values were calculated, the commodity values were assigned to each urban area within each state based on the new percentages calculated from the origin/destination-based commodity data. Urban areas not included in a FAF region were assigned a commodity value based on their truck VMT relative to all the truck VMT which remained unassigned to a FAF region (Equation A-29).

$$\text{FAF Region O/D-Based Commodity Value \%} = \frac{\text{FAF Region O/D-Based Commodity Value}}{\text{U.S. O/D-Based Commodity Value}} \times 100\% \qquad \text{(Eq. A-26)}$$

$$\text{FAF Region O/D-Based Commodity Value} = \text{FAF Region O/D-Based Commodity Value \%} \times \text{U.S. O/D-Based Commodity Value} \qquad \text{(Eq. A-27)}$$

$$\text{O/D-Based Commodity Value for State 1} = \text{FAF Region 1 Value from State 1} + \text{FAF Region 2 Value from State 1} \qquad \text{(Eq. A-28)}$$

$$\text{Non-FAF Region Urban Area O/D-Based Commodity Value from State 1} = \text{Remaining Unassigned State 1 FAF O/D-Based Commodity Value} \times \frac{\text{Non-FAF Urban Area Truck VMT Percentage}}{\text{Remaining Unassigned State 1 Truck VMT Percentage}} \qquad \text{(Eq. A-29)}$$

Step 5 – Final Commodity Value for Each Urban Area. The VMT-based commodity value and the O/D-based commodity value were averaged for each urban area to create the final commodity value to be presented in the Urban Mobility Report.

$$\text{Final Commodity Value for Urban Area} = \left(\text{Urban Area VMT-Based Commodity Value} + \text{Urban Area O/D-Based Commodity Value}\right) \div 2 \qquad \text{(Eq. A-30)}$$

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 a useful performance measure in some applications. 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-31). 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.

$$\text{Roadway Congestion Index} = \frac{\text{Freeway VMT / Ln. Mi.} \times \text{Freeway VMT} + \text{Prin Art Str VMT / Ln. Mi.} \times \text{Prin Art Str VMT}}{14{,}000 \times \text{Freeway VMT} + 5{,}000 \times \text{Prin Art Str VMT}} \qquad \text{(Eq. A-31)}$$

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.

Number of "Rush Hours"

The length of time each day that the roadway system contains congestion is presented as the number of "rush hours" of traffic. This measure is calculated differently than under previous methodologies. The average Travel Time Index is calculated for each urban area for each hour of the average weekday. The TTI for each hour of the day and the population of the urban area determ*ine the number of "rush hours".*

For each hour of the average weekday in each urban area, the TTI values are analyzed with the criteria in Exhibit A-9. For example, if the TTI value meets the highest criteria, the entire hour is considered congested. The TTI values in these calculations are based on areawide statistics. In order to be considered a "rush hour" the amount of congestion has to meet a certain level of congestion to be considered areawide. In the case of Very Large urban areas, the minimum TTI value for a portion of an hour to be considered congested is 1.12.

Exhibit A-9. Estimation of Rush Hours

Population Group	TTI Range	Number of Hours of Congestion
Very Large	Over 1.22	1.00
	1.17-1.22	0.50
	1.12-1.17	0.25
	Under 1.12	0.00
Large	Over 1.20	1.00
	1.15-1.20	0.50
	1.10-1.15	0.25
	Under 1.10	0.00
Medium/Small	Over 1.17	1.00
	1.12-1.17	0.50
	1.07-1.12	0.25
	Under 1.07	0.00

The following two measures are not based on the INRIX speeds and the new methodology. Due to some low match rates in some of the urban areas between the INRIX speed network and the HPMS roadway inventory data and because we currently use hourly speed and volume data instead of 15-minute, these measures are based on the previous methodology with estimated speeds. In the future as the match rate improves, these measures will be based on the new methodology with measured speeds.

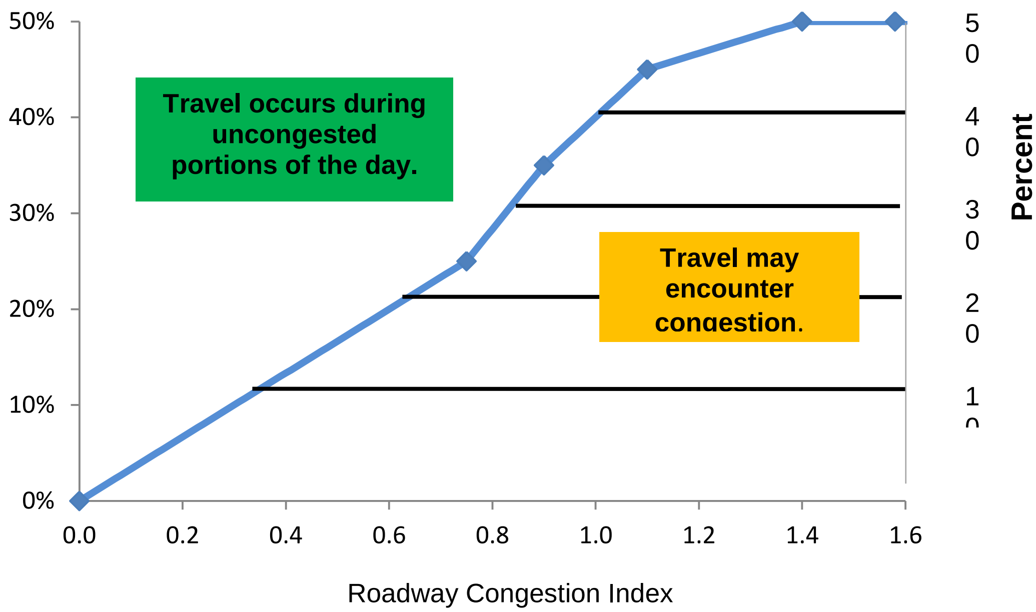
Percent of Daily and Peak Travel in Congested Conditions

Traditional 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 UMR.

These percentages have been estimated again for the 2010 UMR. The historical measured speed data will make it possible in future reports to calculate the travel that occurs at a speed that is under a certain congestion threshold speed. However, in this report, the travel percentages were estimated using the process described below as changes to the methodology were not incorporated prior to this release.

Exhibit A-10 illustrates the estimation procedure used for all urban areas. The UMR 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-10 illustrates the process used to estimate the amount of the day (and the amount of travel) when travelers might encounter congestion. Travel during the peak period, but outside these possibly congested times, is considered uncongested and is assigned a free-flow speed. The maximum percentage of daily travel that can be in congestion is 50 percent which is also the maximum amount of travel that can occur in the peak periods of the day. The percentage of peak period travel that is congested comes from the 50 percent of travel that is assigned to the peak periods.

Exhibit A-10. Percent of Daily Travel in Congested Conditions



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-32 and A-33), 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-34), the factor in the denominator is the daily miles of travel.

$$\begin{matrix}\text{Peak Period} \\ \text{Congested Travel}\end{matrix} = \begin{matrix}\text{Percent of Congested} \\ \text{Peak Period Travel}\end{matrix} \times \begin{matrix}\text{VMT for} \\ \text{Roadway Type}\end{matrix} \qquad \text{(Eq. A-32)}$$

$$\begin{matrix}\text{Percent Congested} \\ \text{Peak Period Travel}\end{matrix} = \begin{matrix}\text{Percent Congested} \\ \text{Daily Travel}\end{matrix} \div 50 \text{ percent} \qquad \text{(Eq. A-33)}$$

$$\begin{matrix}\text{Percent Congested} \\ \text{Daily Travel}\end{matrix} = \frac{\begin{matrix}\text{Freeway} \\ \text{Congested Travel}\end{matrix} + \begin{matrix}\text{Arterial} \\ \text{Congested Travel}\end{matrix}}{\text{Daily Travel}} \qquad \text{(Eq. A-34)}$$

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 40 percent in the 101 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 54 percent in big metro regions while road capacity on freeways and major streets has grown by only 36 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 as well as a private company 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 traffic volume data from 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 speed data used in the Urban Mobility Report comes from INRIX. The methodology used in previous Urban Mobility Reports was a combination of data from several freeway speed monitoring systems and empirically derived procedures. Sources such as the Highway Capacity Manual and travel time and speed studies conducted in several cities were adapted for use with the base dataset obtained from the states and FHWA. In summary, the large amount of speed data directly collected from vehicles using the roads provides a much better source of speed data than the previous estimation process.

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 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 Mobility 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.

The INRIX Speed Dataset

TTI has conducted several evaluations of INRIX historical travel speeds and has confirmed the accuracy of the archived information included in the datasets. These evaluations compared the INRIX datasets to speed data obtained independently from a variety of other sources and showed good correlation in both the peak and off-peak periods. Other independent evaluations of INRIX real-time data have documented its quality. For example, as of mid-2010, more than 22,000 hours and 475 miles of INRIX travel speed data have been evaluated by the University of Maryland in the I-95 corridor (*43*). Based on these independent evaluations, INRIX has never failed to meet the contract requirements for accuracy.

INRIX uses sophisticated statistical analysis techniques, originally developed by Microsoft Research, to aggregate and enhance traffic-related information from hundreds of public and private sources and traditional road sensors. Traffic speed information is collected from more than 2 million GPS-enabled vehicles and mobile devices (referred to as "crowd-sourcing"). They provide real-time and historical traffic information for every major U.S. metropolitan area and 15 other countries across North America and Europe. Their information is delivered to a variety of private companies, mobile devices (including 8 of the top 10 iPhone navigation apps) and for real-time conditions in the I-95 corridor in several U.S. states.

The location and time data that INRIX collects for the entire U.S. is compiled into a dataset of speed for each hour of each day of the week. The 168 cells of this matrix (7 days, 24 hours) have data for the entire year with the following characteristics:

- All high volume roads and many low volume streets
- All daylight hours and most nighttime hours
- All major urban areas
- Data on heavier volume road sections in small urban regions and rural areas

The speed data is less prevalent, although still much better than previous estimates, in the following situations:

- Late-night and early-morning hours
- Low volume minor streets
- Small urban areas

In most cases, these "less covered" portions of the network are not congested sections of road.

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.

With the addition of the INRIX data, the freeflow speed values were provided with the speed data for each section of roadway in the INRIX database. The freeflow speeds were generally based on overnight speeds when demand is low. The freeflow speeds were used as provided except that speeds on freeways were capped at 65 mph. Hourly speeds that are less than the freeflow speed will be an indication of delay. These freeflow speeds are 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.

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 Auto Commuter—the hours of extra travel time divided by the number of urban area peak period auto commuters. This is an annual measure indicating the sum of all the extra travel time that would occur during the year for the average commuter. All urban commuters 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 2010 is estimated for passenger vehicles and trucks. The fuel costs are the per-gallon average price (gasoline and diesel) 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.

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

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 area wide 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 2007 through 2010. 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 2020 will have congestion problems of large areas in 2010.

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.

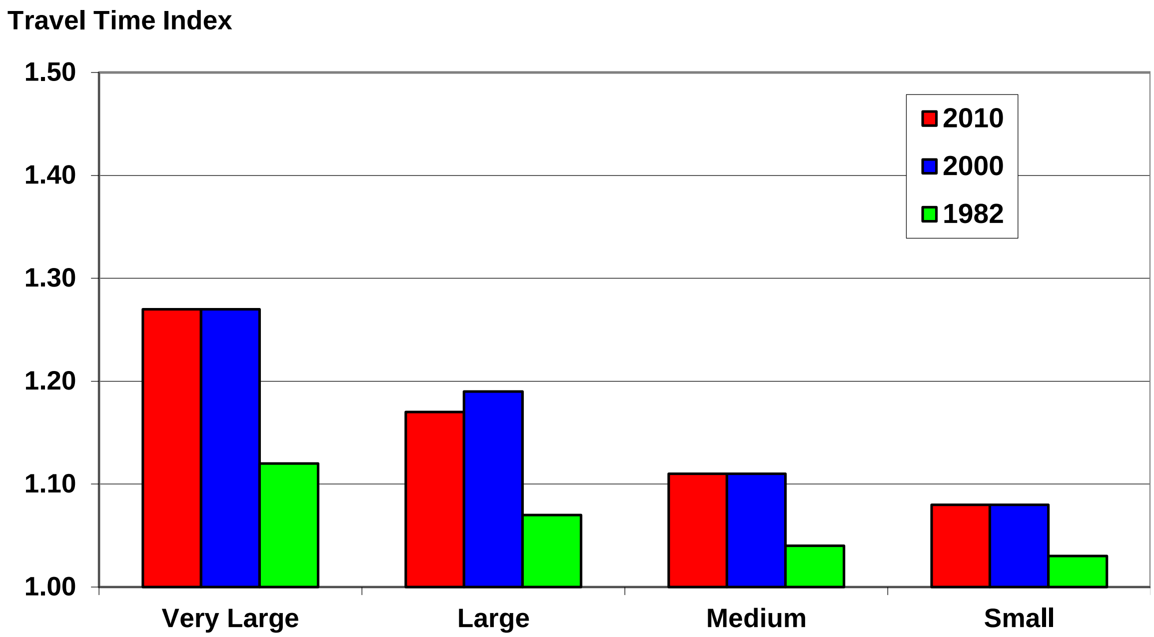
Travel delay per peak auto commuter is the other individual measure that provides estimates of the mobility levels (see Exhibit B-2). The extra travel time per year can be related to many other activities and may be more relevant for some discussions.

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 auto commuter 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 auto commuter values have both increased since 1982, indicating an increase in congestion. The Travel Time Index for Portland grew faster from 1982 to 2010 than it has for the majority of the other areas in the Large urban group. Delay per auto commuter, 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

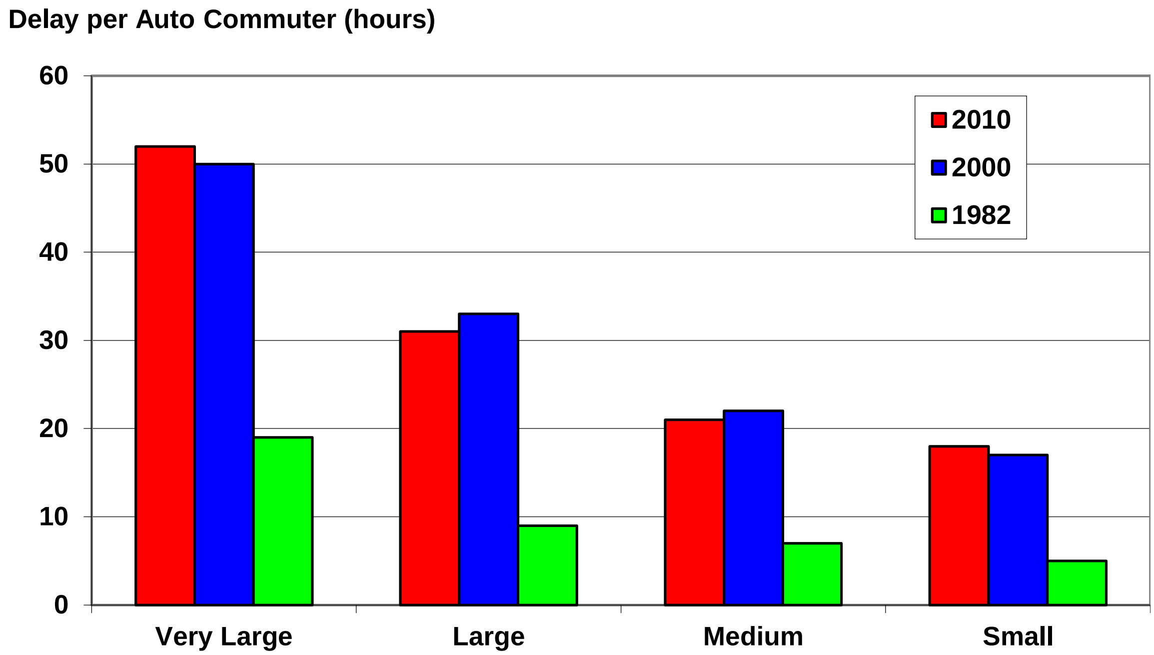


Note: The Travel Time Index is a ratio of average peak period to free-flow travel time. A value of 1.30 indicates a free-flow trip of 20 minutes takes 26 minutes in the peak due to heavy traffic demand and incidents.

- The average TTI for all 439 urban areas is 1.2. Thus, an average 20-minute off-peak trip takes 24 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 1.27 in the Very Large areas down to 1.08 in the Small urban areas.
- The average increase in the travel time penalty was 12 points (1.09 to 1.20) between 1982 and 2010. This gap ranges from 15 points in the Very Large group to 5 points in the Small population group.
- Twenty-two of the 439 urban areas have a TTI of at least 1.20. All but 2 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 Auto Commuter Trends



- The average delay per auto commuter in the 439 urban areas is 34 hours.
- There are 7 urban areas with delay per auto commuter 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 auto commuter in the Small population group is about the same as the average delay in the Very Large population group in 1982.

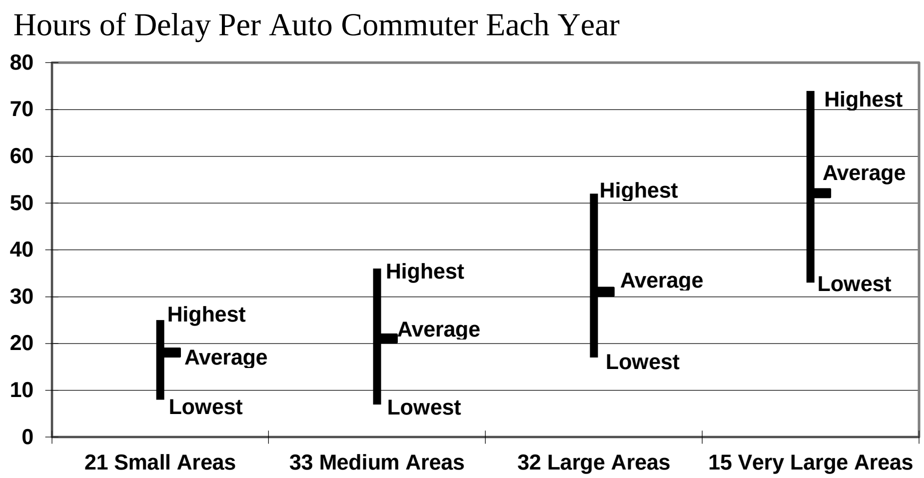
CAUTION: See http://mobility.tamu.edu/ums for improved performance measures and updated data.

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 Auto Commuter 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 auto commuter of 33 hours.
- Areas over 1 million (Large and Very Large) should expect a delay per auto commuter of at least 17 hours with a more likely value of around 31 to 52 hours.
- Areas over one-half million (all except Small) should expect at least 7 hours with typical values being closer to 21 to 52 hours.
- Areas less than a half million (Small) should expect a delay per auto commuter of up to 25 hours.

Exhibit B-3. Congestion and Urban Area Size, 2010



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. The detailed speed data from INRIX by hour of the day and day of the week allows for a more detailed analysis of the delay picture.

Conclusions

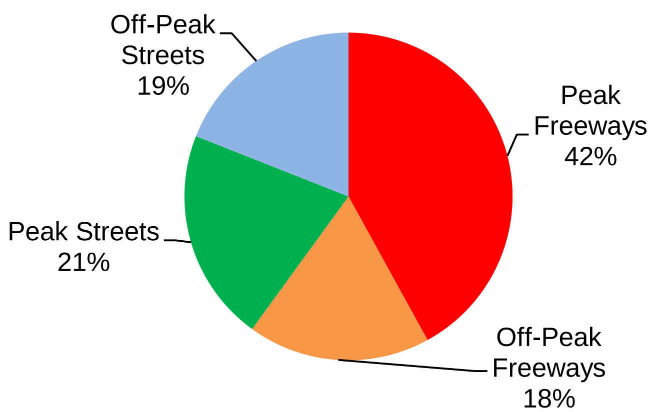
Congestion has spread significantly over the 20 years of the study. A few notable changes from 1982 to 2010 include:

- Two urban areas have a Travel Time Index above 1.30 compared with no areas in 1982.
- Friday has the most congestion of any day of the week.
- 5:00-6:00p.m. has the greatest amount of delay of any hour of the day followed by 4:00-5:00p.m.
- The freeways during the peak periods have the greatest percentage of the total delay.

Congested Travel

Exhibit B-4 shows that the freeway system has the greatest amount of delay as compared to the arterial streets. About 42 percent of the nation's delay occurs on the freeways during the peak periods. Another 18 percent of total delay occurs on the freeways during the other 16 hours of the day. The arterial street system accounts for 40 percent of total delay. There is about twice as much delay on the freeway during the peak periods than on the arterial streets. There is, however, slightly more delay on the arterial street system during the off-peak periods than on the freeways.

Exhibit B-4. Percent of Travel by Road Type



Congested Time

An analysis of the delay by day of the week in Exhibit B-5 shows that delay increases with each weekday. Monday has the least amount of delay (just over 15 percent) of any of the weekdays while Friday has the greatest amount (almost 20 percent). The delay that occurs on Saturday and Sunday do not add up to the delay that occurs on Monday by itself. Sunday has the least amount of delay of any day of the week with about 5 percent.

Exhibit B-5. Percent of Delay by Day of Week

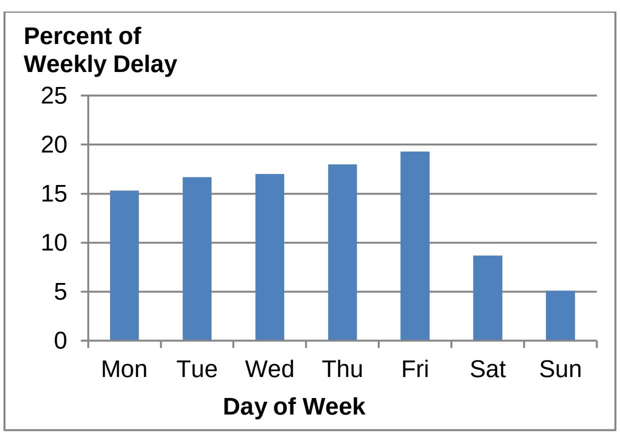
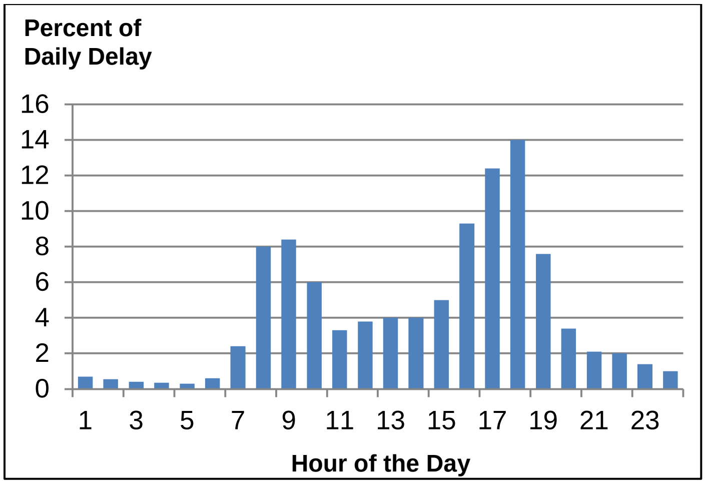


Exhibit B-6 shows the delay by hour of the day. Congestion is worse in the evening peak period than the morning peak period. The 5:00-6:00p.m. hour has the greatest amount of the daily delay with about 14 percent. This one hour has almost as much delay as the two most congested morning peak period hours 7:00-9:00 a.m. There is a significant amount of delay that occurs during the mid-day hours which shows that congestion is not just a peak period problem. The timeframe of midnight to 6:00a.m. is the time with the least amount of delay on the roadways.

Exhibit B-6. Percent of Delay by Time of Day



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 15 urban areas include about 58% of the delay estimated for 2010, and the top 20 areas account for over 65 percent of annual delay. Some other highlights include:

- In 2010, congestion (based on wasted time and fuel) cost about $115 billion in the 439 urban areas, compared to $113 billion (in constant dollars) in 2006. (See Exhibits B-7 and B-8).
- The average cost per auto commuter in the 439 urban areas was $713 in 2010, down from $723 in 2009 (using constant dollars). The cost ranged from an average of $1,083 per auto commuter in Very Large urban areas down to $363 per auto commuter in the Small areas.
- Exhibits B-9 and B-10 show that 1.9 billion gallons of fuel were wasted in the 439 urban areas. This amount of fuel would fill 38 super-tankers or 210,000 gasoline tank trucks.
- The urban areas with populations greater than 3 million accounted for 1.6 billion gallons (about 70% of the national estimate) of wasted fuel.
- The amount of wasted fuel per auto commuter ranges from 25 gallons per year in the Very Large urban areas to 3 gallons per year in the Small areas.

Exhibit B-7. Congestion Effects on the Average Commuter – 2010

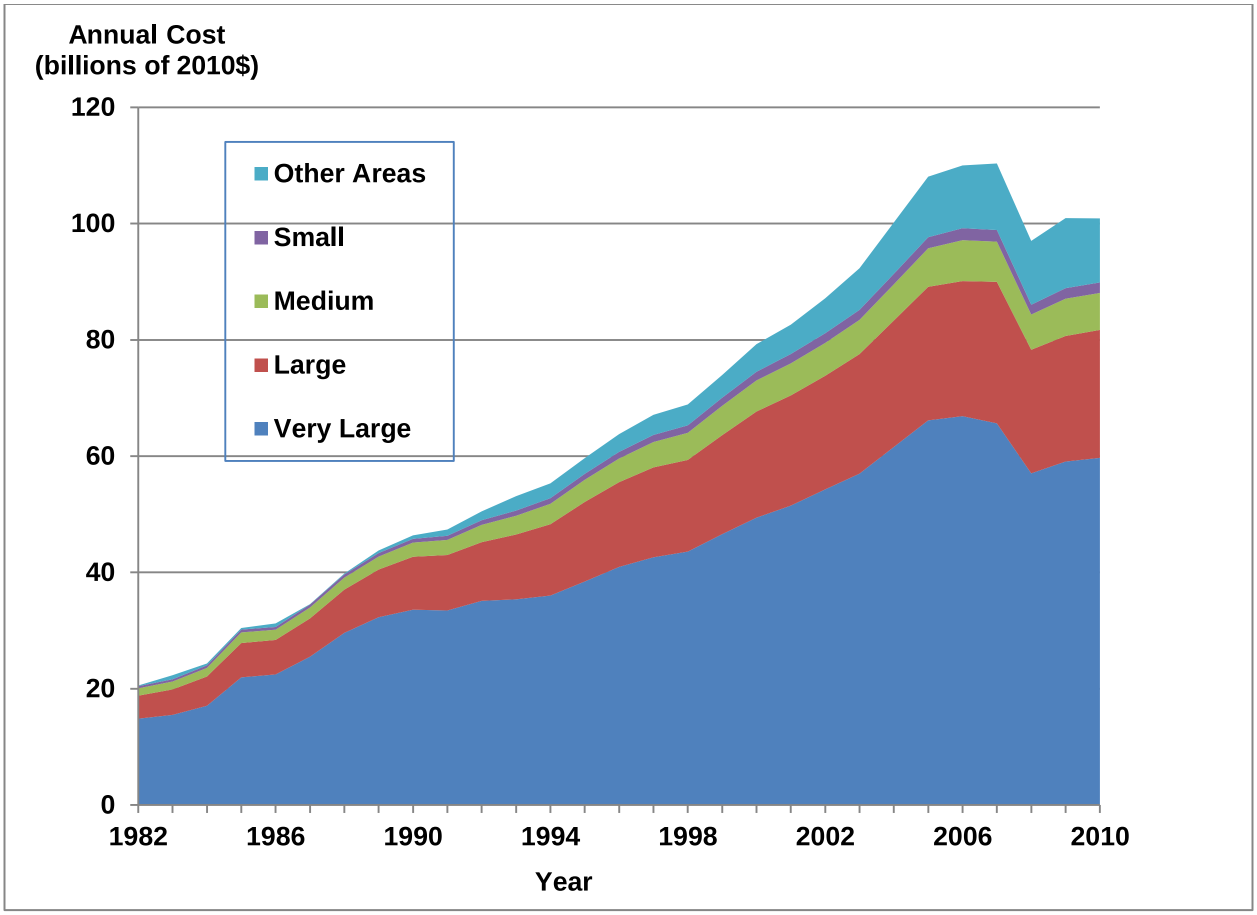
	Congestion Statistics per Auto Commuter		
Population Group	**Average Cost ($)**	**Average Delay (hours)**	**Average Fuel (gallons)**
Very Large areas	1083	52	25
Large areas	642	31	11
Medium areas	426	21	5
Small areas	363	18	4
Other Urban Areas	327	16	3
439 Area Average	713	34	14
439 Area Total	$100.9 billion	4.8 billion	1.9 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-8. 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 $100.9 billion in 2010 or an average of $713 per auto commuter.

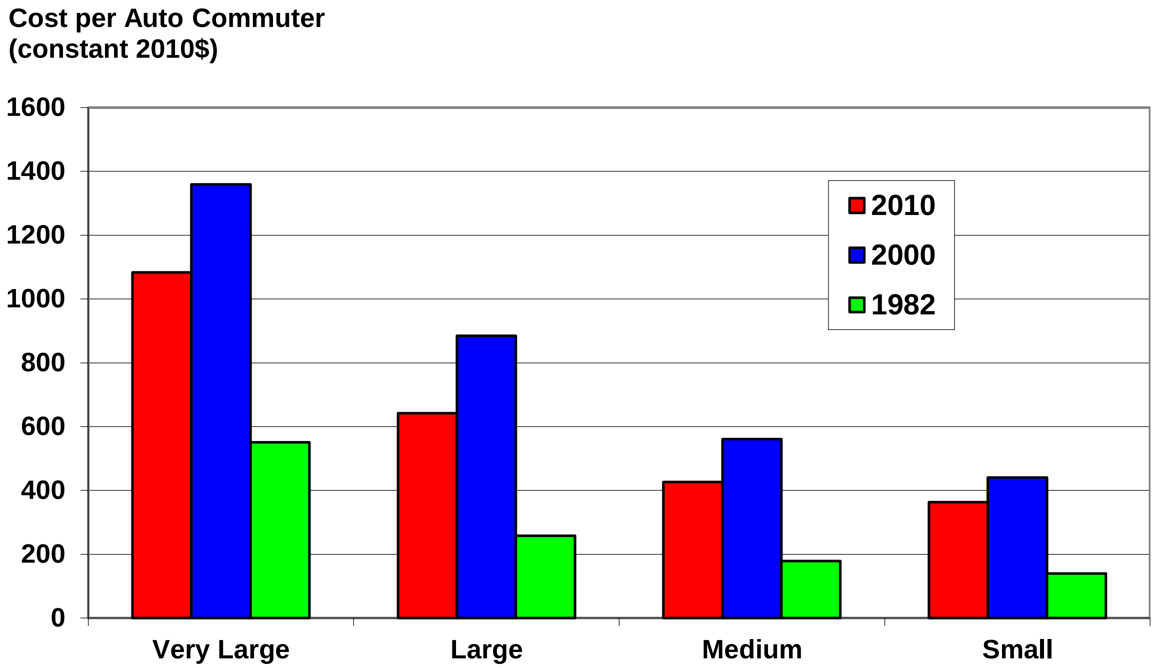
Exhibit B-8. Annual Cost of Congestion



- 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 59 percent of the congestion cost.

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

Exhibit B-9. Annual Cost of Congestion per Auto Commuter



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-9). The average annual cost to each of these travelers in the 439 urban areas is about $713.

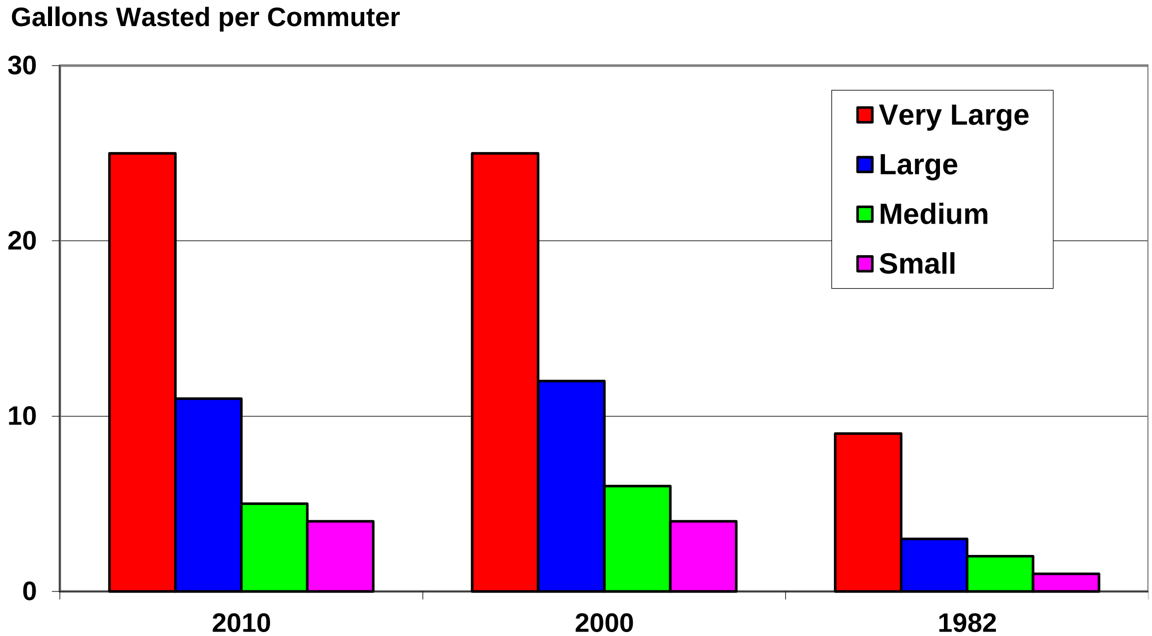
- Commuters of 96 areas are "paying" more than $1 per workday in congestion costs; 59 areas have a congestion value exceeding $2 per workday.
- The average cost of congestion per auto commuter ranged from $1,083 in the Very Large population group to $363 in the Small population group in 2010.

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 commuters in the urban area. This provides an estimate of the amount of fuel consumed for each individual because of congestion (Exhibit B-10), a quantity that can be compared to other per capita consumptions. More than 14 gallons are wasted per auto commuter in the 439 urban areas.

Exhibit B-10. Wasted Fuel per Traveler



- The amount of wasted fuel per traveler ranged from 4 gallons in the Small population group to 25 gallons in the Very Large population group in 2010.
- The total amount of wasted fuel in the 439 urban areas was approximately 1.9 billion gallons in 2010.

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 13 of the 101 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-11) 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-115 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 101 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.

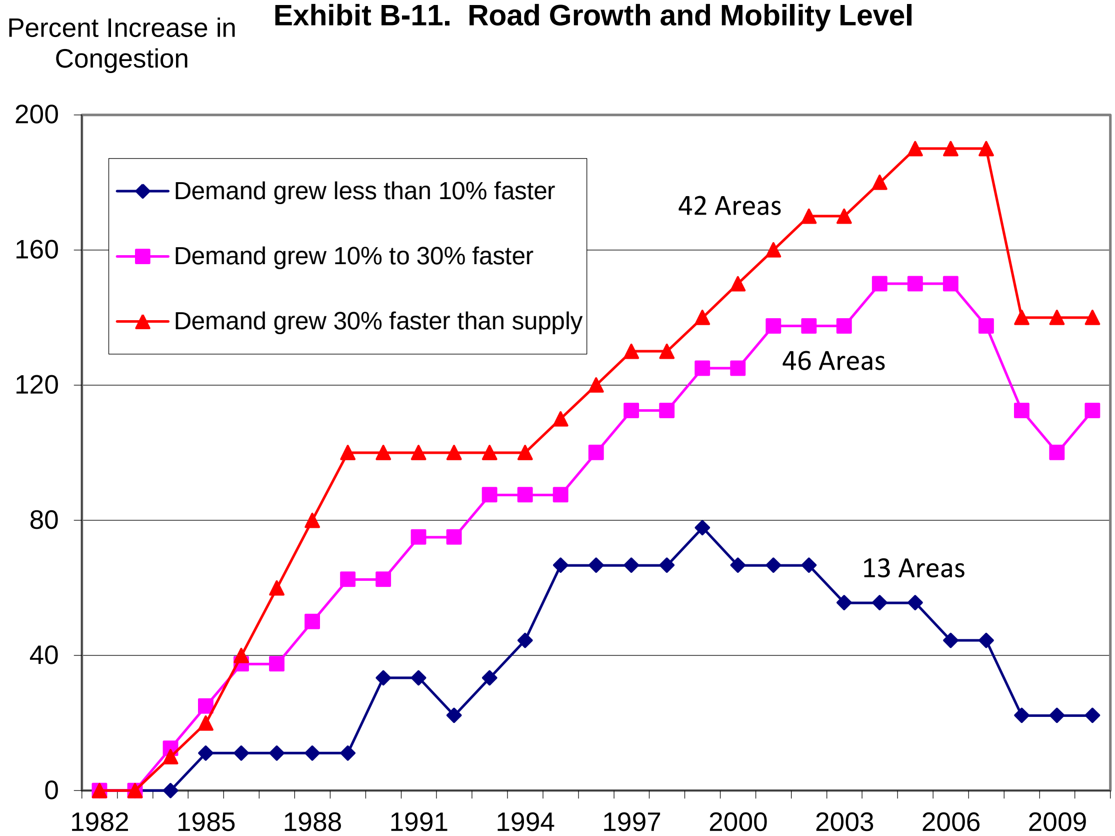
The four groups were arranged using data from 1982 to 2010:

- **Significant mismatch** – Traffic growth was more than 30 percent faster than the growth in road capacity for the 42 urban areas in this group.
- **Moderate mismatch** – Traffic growth was between 10 and 30 percent greater than road growth. There were 46 urban areas in this group.
- **Narrow gap** – Road growth was within 10 percent of traffic growth for the 13 urban areas in this group.

The resulting growth in congestion is charted in Exhibit B-11, and the cities in each group are listed in Exhibit B-12. 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-11. 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, Wichita are in the Medium population group. Anchorage, Boulder, Greensboro, Madison, Provo 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-12. Urban Area Demand and Roadway Growth Trends

Less Than 10% Faster (13)	10% to 30% Faster (46)	10% to 30% Faster (cont.)	More Than 30% Faster (40)	More Than 30% Faster (cont.)
Anchorage AK	Allentown-Bethlehem PA-NJ	Memphis TN-MS-AR	Akron OH	Minneapolis-St. Paul MN
Boulder CO	Baton Rouge LA	Milwaukee WI	Albany-Schenectady NY	New Haven CT
Dayton OH	Beaumont TX	Nashville-Davidson TN	Albuquerque NM	New York-Newark NY-NJ-CT
Greensboro NC	Boston MA-NH-RI	Oklahoma City OK	Atlanta GA	Omaha NE-IA
Indio-Cath City-P Springs CA	Brownsville TX	Pensacola FL-AL	Austin TX	Orlando FL
Lancaster-Palmdale CA	Buffalo NY	Philadelphia PA-NJ-DE-MD	Bakersfield CA	Oxnard-Ventura CA
Madison WI	Cape Coral FL	Phoenix AZ	Baltimore MD	Providence RI-MA
New Orleans LA	Charleston-N Charleston SC	Portland OR-WA	Birmingham AL	Raleigh-Durham NC
Pittsburgh PA	Charlotte NC-SC	Richmond VA	Boise ID	Riverside-S Bernardino CA
Poughkeepsie-Newburgh NY	Cleveland OH	Rochester NY	Bridgeport-Stamford CT-NY	Sacramento CA
Provo UT	Corpus Christi TX	Salem OR	Chicago IL-IN	San Antonio TX
St. Louis MO-IL	Detroit MI	Salt Lake City UT	Cincinnati OH-KY-IN	San Diego CA
Wichita KS	El Paso TX-NM	San Jose CA	Colorado Springs CO	San Francisco-Oakland CA
	Eugene OR	Seattle WA	Columbia SC	San Juan PR
	Fresno CA	Spokane WA	Columbus OH	Sarasota-Bradenton FL
	Grand Rapids MI	Springfield MA-CT	Dallas-Ft Worth-Arlington TX	Stockton CA
	Honolulu HI	Tampa-St. Petersburg FL	Denver-Aurora CO	Washington DC-VA-MD
	Houston TX	Toledo OH-MI	Hartford CT	
	Indianapolis IN	Tucson AZ	Jacksonville FL	
	Jackson MS	Tulsa OK	Laredo TX	
	Kansas City MO-KS	Virginia Beach VA	Las Vegas NV	
	Knoxville TN	Winston-Salem NC	Little Rock AR	
	Louisville KY-IN	Worcester MA	Los Angeles-L Bch-S Ana CA	
	McAllen TX		Miami FL	

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

INCORPORATING THE EFFECT OF OPERATIONAL TREATMENTS – 101 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

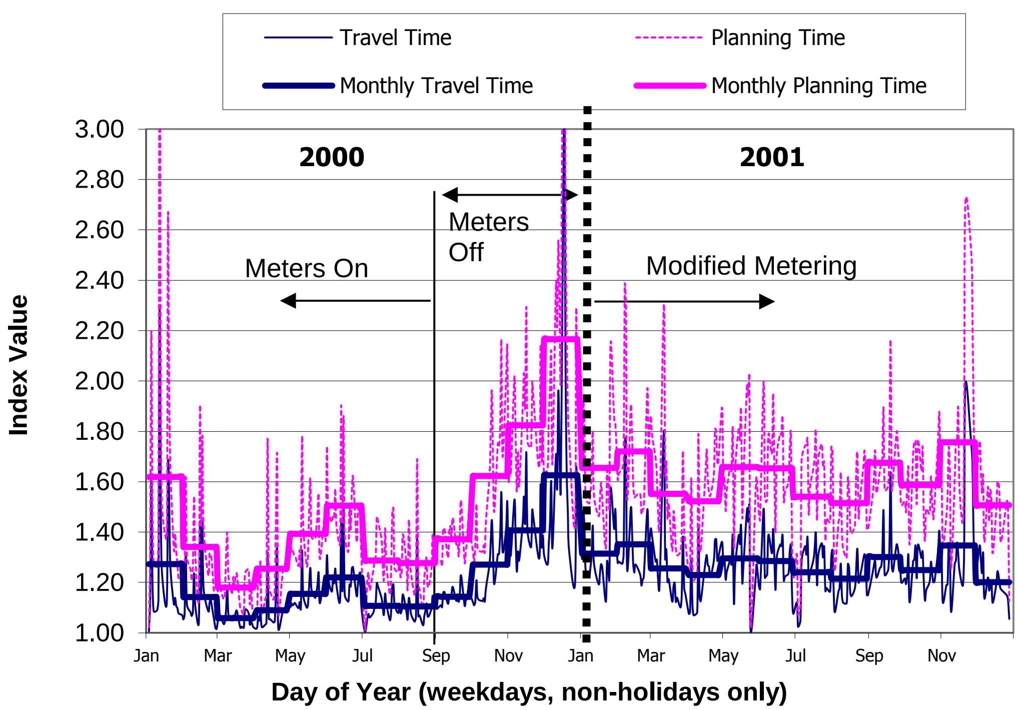
These factors are estimated from the databases, the inventory information found and applied within the existing Urban Mobility Report structure, and the delay reduction has been incorporated into several of measures calculated in the study.

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-13. 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.

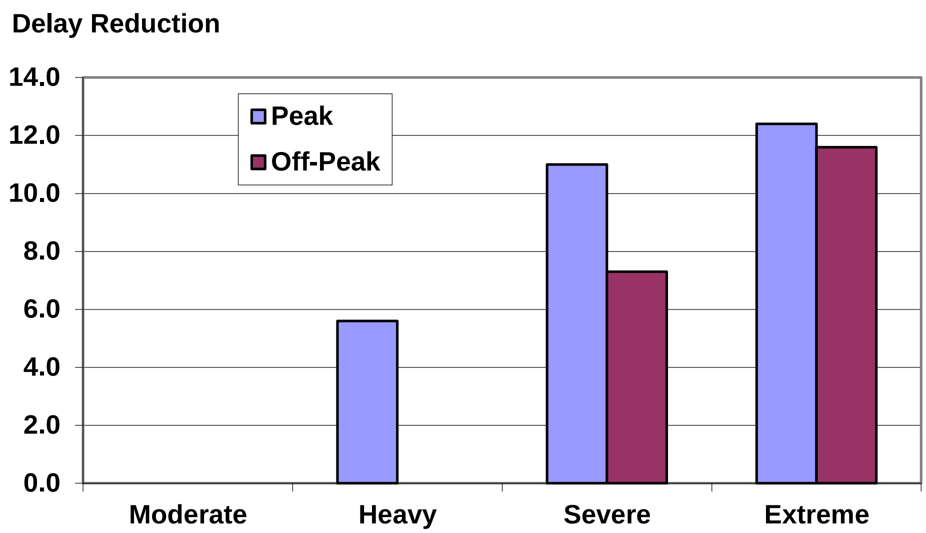
Exhibit B-13. Minneapolis-St. Paul Freeway System Congestion Levels



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-14 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-14. Ramp Metering Delay Reduction



Twenty-eight of the urban areas reported ramp metering on some portion of their freeway system in 2010 (*1*,*4*). The average metered distance was about one-quarter. The effect was to reduce delay by 38.7 million person hours (Exhibit B-15). 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 has the most extensive metering benefits in the Large group.
- Of the 55 areas studied with under one million population, only three reported any metering.

Exhibit B-15. Freeway Ramp Metering Delay Reduction Benefits - 2010

Population Group	Percentage of Covered Freeway Lane-miles	Freeway Hours of Delay (million) Reduction
Very Large (15)	35	33.7
Large (32)	20	6.2
Medium (33)	2	0.2
Small (21)	0	0
101 Area Average	25	0.4
101 Area Total	25	39.5

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-16 and B-17) 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-16. Benefits of Freeway Service Patrols

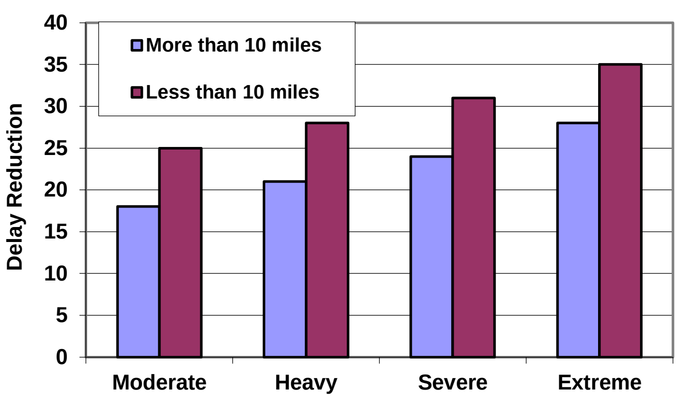
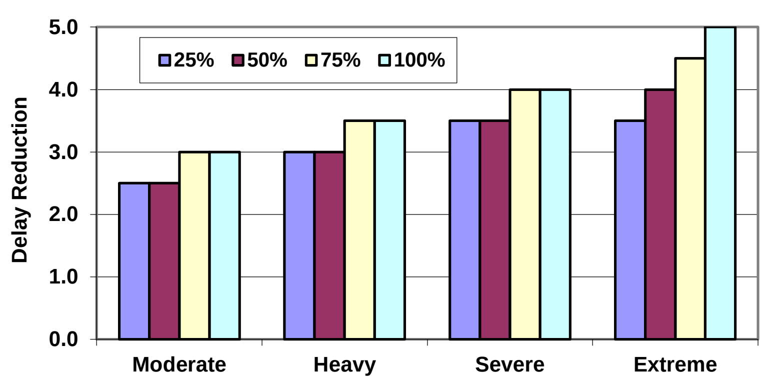


Exhibit B-17. Benefits of Freeway Surveillance Cameras



More than 85 areas reported one or both treatments in 2010, 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 135 million person hours (Exhibit B-18). 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 and Baltimore are estimated to have the most benefit in the Large group.
- Bridgeport is the area within the Medium group with the highest delay reduction benefit.

Exhibit B-18. Freeway Incident Management Delay Reduction Benefits

Population Group	Percentage of Miles Covered Freeway Lane-miles	Freeway Hours of Delay (million) Delay Reduction
Surveillance Cameras		
Very Large (15)	59	Delay Reduction Included Below
Large (32)	51	
Medium (33)	30	
Small (21)	39	
101 Area Average	52	
101 Area Total	52	
Service Patrols		
Very Large (15)	82	101.9
Large (32)	67	28.0
Medium (33)	35	4.0
Small (21)	46	1.0
101 Area Average	70	1.3
101 Area Total	70	134.9

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-19 and B-20. 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 101 areas reported some level of traffic signal coordination in 2010, 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-19. Signal Coordination Benefits (actuated)

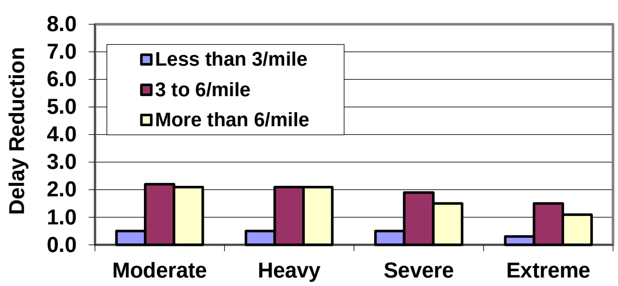
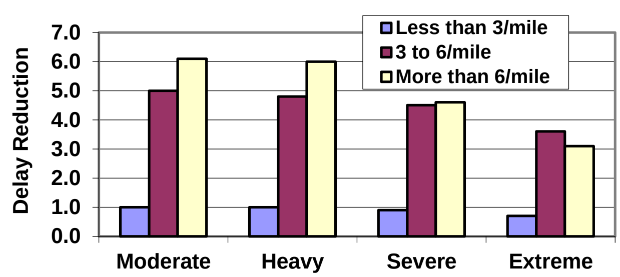


Exhibit B-20. Signal Coordination Benefits (progressive)



The effect of the signal coordination projects was to reduce delay by 21.7 million person hours, approximately one percent of the street delay (Exhibit B-21). 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 and Baltimore are the Large areas with the most hours of delay benefit from signal coordination in areas between one and three million population.
- Honolulu and Richmond in the Medium areas and Cape Coral in the Small areas lead their population group.

Exhibit B-21. Principal Arterial Street Traffic Signal Coordination Delay Reduction Benefits - 2010

Population Group	Percentage of Mileage Covered Lane-miles	Principal Arterial Hours of Delay (million)
		Reduction
Very Large (15)	66	13.8
Large (32)	57	45.2
Medium (33)	53	2.2
Small (21)	52	0.5
101 Area Average	61	0.2
101 Area Total	61	21.7

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-22 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-23 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 101 areas reported some level of access management in 2010, with the coverage representing about 33 percent of the street miles in the cities (*1,41*). The effect of access management was to reduce delay by 77 million person hours (Exhibit B-24). 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-22. Access Management Recurring Delay Effects

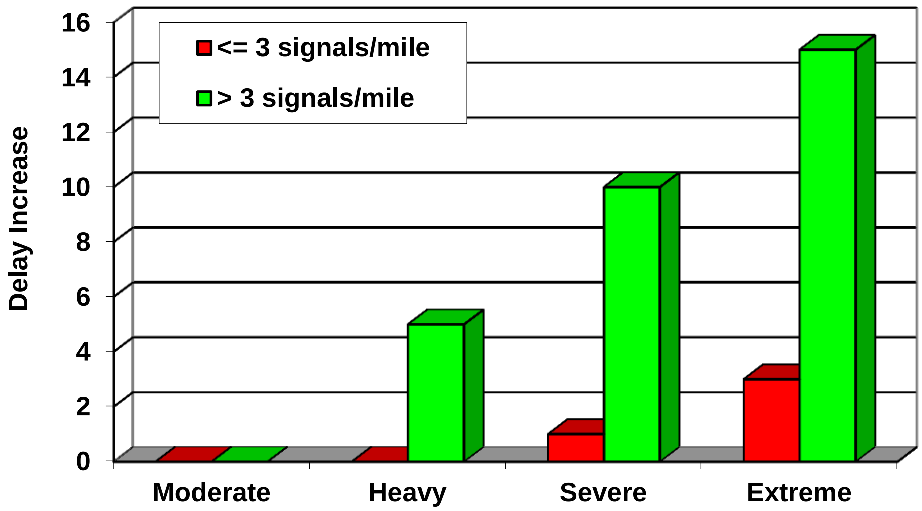
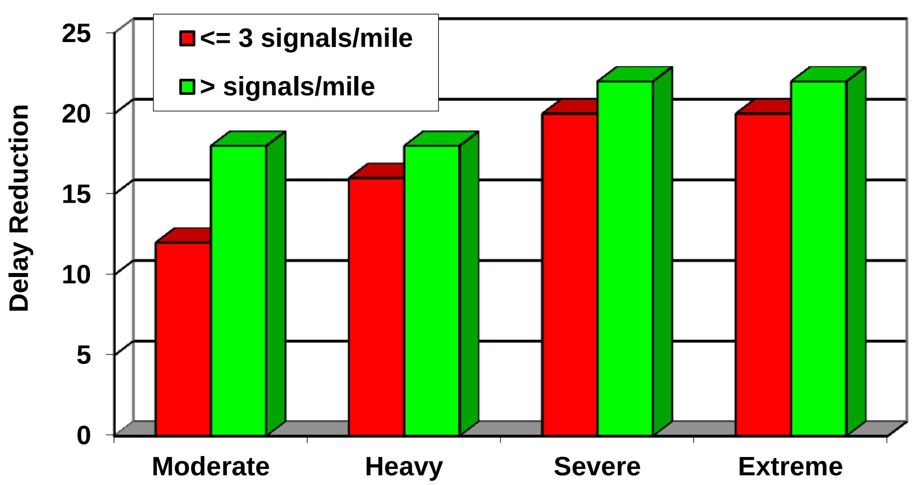


Exhibit B-23. Access Management Incident Delay Effects



Source: (1) and Texas Transportation Institute Analysis

Exhibit B-24. Principal Arterial Street Access Management Delay Reduction Benefits

Population Group	Percentage of Mileage Covered Lane-miles	Principal Arterial Hours of Delay (million) Reduction
Very Large (15)	37	49.7
Large (32)	32	20.2
Medium (33)	26	5.8
Small (21)	19	1.4
101 Area Average	33	0.8
101 Area Total	33	77.1

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 101 urban areas. The inventory of all projects is identified in Exhibit B-25 by the percentage of miles on freeways and streets that have one of the programs or projects implemented. Exhibit B-25 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 about 6 percent of the delay in the 101 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-25. Total Operational Improvement Delay Reduction

Operations Treatment	Number of Cities	Percent of System Covered	Delay Reduction Hours (millions)
Ramp Metering	28	25	40
Incident Management	85	52-70	135
Signal Coordination	101	61	22
Access Management	101	33	77

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-26 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-26. 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-27 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-27. 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-28 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-28. 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-29 shows the steps for calculating the traffic delay reduction provided by public transportation.

- 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.

Exhibit B-29. Changes to the Urban Mobility Report Methodology

Computation Step	2010 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
2. Assign vmt from Step 1 to transit mode	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 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 (Unchanged)
5. Calculate amount of transit vmt added to existing roadway vmt	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 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 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
9. Re-calculate delay	Use combined volumes and new speeds to calculate delay

Source: (*6*)

Summary of the Mobility Effects of Public Transportation

The mobility effects from public transportation are shown for the key performance measure—travel delay. 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.

Travel Delay

Exhibit B-30 shows that in the 439 urban areas studied, there were approximately 55 billion passenger-miles of travel on public transportation systems in 2010 (*6*). The annual average ridership ranged from about 19 million passenger-miles in the Small urban areas to about 2.8 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 784 million hours or about a 16 percent increase in the total delay. Some additional effects include:

- The range of benefits derived from public transportation in the 101 intensely studied urban areas ranged from about 24 percent in the Very Large Urban Areas down to about 3 percent in the Small Areas.
- Of the 796 million hours of potential extra delay, 766 million are in the 101 urban areas studied in detail.

Exhibit B-30. 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 (15)	2,765	681	24
Large (32)	183	74	7
Medium (33)	41	9	3
Small (21)	19	3	3
101 Area Total	49,085	766	20
Other Areas (338)	5,930	30	5
All Areas	55,015	796	16

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-31 is a summary of HOV lane operations in several urban corridors from the year 2007. 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.

Exhibit B-31. Mobility Levels in HOV Corridors in 2007

		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-31. Mobility Levels in HOV Corridors in 2007, 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 area wide 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 2010 are illustrated in Exhibit B-32. Most of the delay in the 439 urban areas is in the 15 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.

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-32. Summary of Public Transportation and Operational Improvement Delay Reduction Effects - 2010

Delay Reduction Element	**Population Group – Annual Hours Saved (million)**					
	Very Large	**Large**	**Medium**	**Small**	**Intensively Studied**	**All 439**
Number of Cities	15	32	33	21	101	439
Delay Reduction from:						
Ramp Metering	33.7	5.8	0.1	0.0	40	40
Incident Management	101.9	28.0	4.0	1.0	135	138
Signal Coordination	13.8	5.2	2.2	0.5	22	26
Access Management	49.7	20.2	5.8	1.4	77	86
High-Occupancy Vehicles	35.4	2.3	0.0	0.0	38	38
Delay Savings from Public Transportation	680.7	73.7	8.7	2.8	766	796

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*).

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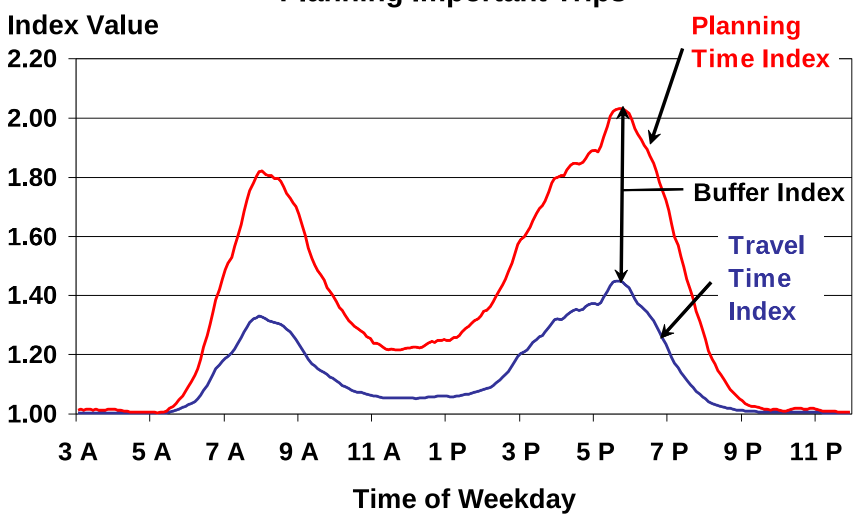
Unreliable Travel Times – One of the Congestion Problems

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-33) 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-33. The Extra "Buffer" Time Needed When Planning Important Trips



Source: Reference (*3*)

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According to data from some of the freeways in 19 metropolitan regions (Exhibit B-34), 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-34. 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.

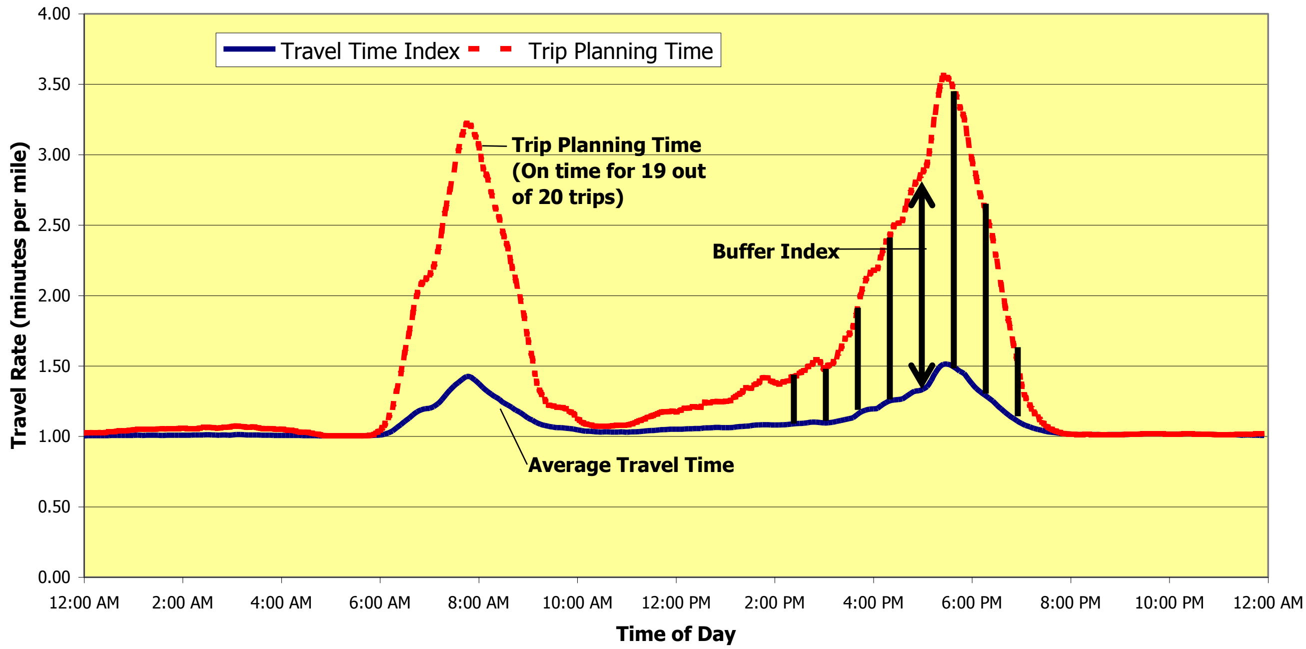
The difference between the average conditions and the 95th percentile conditions is the extra time that has to be budgeted, an illustration of the Buffer Time Index measure (Equation B-1). In the middle of the peak in most cities studied in the Mobility Monitoring Program, the sources of travel time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

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

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-35 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.

Exhibit B-35. 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.

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

Multiple-State Urban Areas

How much of the delay is from each state when an urban area crosses state boundaries? Exhibit B-35 shows the percentage of the urban area's travel and delay that occurs within each state.

Exhibit B-35. Delay and VMT Percentages for Multiple-State Urban Areas

Urban Area	State	Percent by State	
		Travel	Delay
Allentown-Bethlehem PA-NJ	NJ PA	3 97	11 89
Boston MA-NH-RI	MA RI	98 2	98 2
Charlotte NC-SC	NC SC	96 5	92 8
Chicago IL-IN	IL IN	95 5	94 6
Cincinnati OH-KY-IN	IN KY OH	2 34 64	0 25 75
Kansas City MO-KS	KS MO	47 53	38 62
Louisville KY-IN	IN KY	10 90	1 99
Memphis TN-MS-AR	AR MS TN	3 11 86	5 9 86
New York-Newark NY-NJ-CT	NJ NY	27 73	46 54
Omaha NE-IA	IA NE	7 93	9 91
Philadelphia PA-NJ-DE-MD	DE MD NJ PA	5 1 17 77	11 1 35 53
Portland OR-WA	OR WA	92 8	82 18
Providence RI-MA	MA RI	19 82	27 73
Springfield MA-CT	CT MA	17 83	23 77
St. Louis MO-IL	IL MO	27 73	36 64
Toledo OH-MI	MI OH	2 98	0 100
Washington DC-VA-MD	DC MD VA	6 56 38	2 63 35
Worcester MA-CT	CT MA	2 98	1 99

Source: TTI Analysis

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2011 URBAN MOBILITY REPORT

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