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Comparing Perceptions and Measures of Congestion

Final Report

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16. Abstract

People's perception of congestion and the actual measured congestion do not always agree. Measured congestion relates to the delay resulting from field measurements of traffic volume, speed, and travel time. People's perception of congestion can be influenced by relative year to year growth in congestion, improved or new transportation infrastructure, and societal attitudes on transportation.

IBM publishes an annual study on the attitudes of commuters from across the world on their daily travel (known as the *Commuter Pain Survey*). The Texas A&M Transportation Institute (TTI) publishes an annual *Urban Mobility Report* that measures urban mobility based on public and private traffic data for highways, streets, and transit.

This research attempts to connect the relationships between perceived congestion as determined by IBM's *Commuter Pain Survey* results and measured congestion from the *Urban Mobility Report* (UMR) in 10 cities across the United States. The raw Pain Index values (the unadjusted index values based entirely on survey responses) had higher correlation with TTI-based measures than the published Pain Index. The Raw Pain Index was found to correspond to a composite model of two of the four core UMR measures examined—the Travel Time Index and the Roadway Congestion Index.

This study also examines the correlation of measured congestion between the UMR and two measures of the INRIX National Traffic Scorecard. The Travel Time Tax (T^3) and the Worst Hour T^3 were found to correspond to a model of the Travel Time Index of the UMR. The Travel Time Tax correlates especially well with the Travel Time Index.

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NOTE: Color figures in this report may not be legible if printed in black and white. A color PDF copy of this report may be accessed via the UTCM website at http://utcm.tamu.edu, the Texas A&M Transportation Institute website at http://tti.tamu.edu, or the Transportation Research Board's TRID database at http://trid.trb.org.

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Executive Summary

This study compares perceptions and measurements of congestion based on qualitative commuter survey data and quantitative traffic data. This study shares findings about the relationships between these data and makes recommendations on future research to better understand these relationships.

This research attempts to connect the relationships between perceived congestion as determined by IBM's *Commuter Pain Survey* results and measured congestion from Texas A&M Transportation Institute (TTI)'s *Urban Mobility Report* (UMR) in 10 cities across the United States. While these studies have different approaches there are some elements that can be linked and provide an opportunity for a collaborative assessment that uses both observed traffic data and driver self-assessments to provide a more comprehensive measure of the impacts of congestion. Both the Commuter Pain Index and the four core UMR measures examined in this study pertain to various aspects of congestion. Many of the survey questions that form the basis of the Pain Index primarily target congestion intensity and secondarily target congestion duration. Two of the UMR measures, the Travel Time Index and Roadway Congestion Index are also associated with the same aspects of congestion.

Based on 2008 and 2009 data on 10 US cities, the IBM raw Pain Index values (the unadjusted index values based entirely on survey responses) had higher correlation with TTI-based measures than the published Pain Index values. In particular, the Raw Pain Index was found to correspond to a composite model of two of the four core UMR measures examined—the Travel Time Index and the Roadway Congestion Index. These are the two measures focused on intensity of congestion.

Based on other TTI research, researchers hypothesize that commuter perception of congestion may be more related to travel time reliability in the sense that some motorist's base their expectations on how often they must plan for a worst case commute. TTI introduced the Planning Time Index and the Buffer Index with the Congested Corridors Report in September 2011 to quantify travel time reliability. However, these measures have not yet been calculated for entire metropolitan areas; thus any survey questions related to travel time reliability may be used to link qualitative or perceived congestion to measured congestion only for major corridors within a metropolitan area. Survey-based information on travel time reliability, especially perceived reliability, may be easier to obtain, so this is one area where commuter perception surveys can enhance performance measure reporting.

This study also compares different measures of congestion based on private sector data such as in INRIX's annual National Traffic Scorecard (Scorecard) to measures published in the UMR. Because both reports use different approaches to calculate congestion, this research investigates the correlation, if any, between congestion measures as determined by both the Scorecard and the UMR. The Travel Time Tax (T^3) and the Worst Hour T^3 of the Scorecard were found to correlate to a model of the Travel Time Index of the UMR. The Travel Time Tax correlates especially well with the Travel Time Index despite the different methodologies used to measure congestion.

Introduction

People's perception of congestion and the actual measured congestion do not always agree. Measured congestion relates to the delay resulting from field measurements of traffic volume, speed, and travel time. People's perception of congestion has historically been gathered through surveys. Perceptions of congestion can be influenced by relative year to year growth in congestion, improved or new transportation infrastructure, and societal attitudes on transportation. By examining both the perceived and measured congestion, performance reporting could help establish a clearer context for congestion in the daily experience of commuters.

IBM has published a study the last four years on the attitudes of commuters from across the world on their daily travel. The *Commuter Pain Survey* is based on a survey intended to gather drivers' opinions about local traffic issues. The daily commute in some of the world's most economically important international cities is longer and more grueling than previously imagined, reflecting the failure of transportation infrastructure to keep pace with economic activity. Each year, IBM conducts the online survey with approximately 400 participants in each city. The 2011 survey included over 8,000 drivers from 20 cities in 15 countries. Each City's Pain Index is ranked by a composite score of 10 key questions aimed at quantifying the time, stress, costs, and other aspects related to their typical commute.

Since 1984, the Texas A&M Transportation Institute (TTI) has published an annual *Urban Mobility Report* (UMR) that measures urban mobility based on public traffic data for highways, streets, and transit. The *Urban Mobility Report* provides information on long-term congestion trends, the most recent congestion comparisons, and a description of many congestion improvement strategies for over 75 urban cities in the US. TTI started incorporating private sector data from INRIX in the 2010 UMR, which expanded the analysis to 100 cities. TTI has also published its first *Congested Corridors Report* in 2011, which identifies reliability problems at specific stretches of highway responsible for significant traffic congestion at different times and different days.

In this project, TTI researchers collaborated with IBM to examine the relationships between perceived congestion as determined by IBM's survey results and measured congestion from the UMR, in 10 cities across the United States.

Background

Relation of Pain Index to Congestion Aspects

While it is difficult to conceive of a single value that will describe all of the travelers' concerns about congestion, many of the measures in the UMR deal with four aspects that interact in a congested roadway or system:

- Duration – This is defined as the length of time during which congestion affects the travel system. The measurement concept that illustrates duration is the amount of time during the day that the travel speed indicates congested travel on a system element or the entire system. The travel speed might be obtained in several ways depending on data sources or travel mode being studied. For example, how many hours in the day is the average speed along a freeway section below 30 mph?

- Extent – This is described by estimating the number of people or vehicles affected by congestion and by the geographic distribution of congestion. The person congestion extent may be measured by person-miles of travel or person-trips that occur during congested periods. The percent, route-miles, or lane-miles of the transportation system affected by congestion may be used to measure the geographic extent of mobility problems. For example, how many persons/vehicles traveled that freeway section when the average speeds were below 30 mph?
- Intensity – The severity of congestion that affects travel is a measure from an individual traveler's perspective. In concept, it is measured as the difference between the desired condition and the conditions being analyzed. For example, the intensity can be described as a stop-and-go condition that is considered heavy or severe congestion.
- Variation or Reliability – This key mobility component describes the change in the other three elements. Recurring delay (the regular, daily delay that occurs when traffic volumes exceed roadway capacity) is relatively stable. Non-recurring delay that occurs due to incidents such as crashes, construction, special events, or weather, however, is less easy to predict. The variation in travel time is a factor that conceptually can be measured as a standard deviation from the average travel time.

Both the Commuter Pain Index and the four core UMR measures examined in this study pertain to the various aspects of congestion. These UMR measures are generally ascribed as each relating to one or more aspects as shown in Table 1.

Table 1. Core Measures of the UMR and Their Relation to Aspects of Congestion

UMR Measure*	Relevant Aspect(s) of Congestion
Travel Time Index	Intensity
Annual Hours of Delay	Extent/Intensity
Roadway Congestion Index	Intensity/Duration
Congested Travel (% VMT or % Lane Miles)	Extent

*more details can be found at http://tti.tamu.edu/documents/mobility-report-2011-wappx.pdf

Many of the survey questions that form the basis of the Pain Index primarily target congestion intensity and secondarily target congestion duration, as shown in Table 2. This is corroborated by the correspondence of the Raw Pain Index with the core UMR measures of Travel Time Index and Roadway Congestion Index in the linear model described in the analysis section. As shown in Table 1, the Travel Time Index and Roadway Congestion Index are themselves associated with the same aspects of congestion, namely, intensity and duration.

Table 2. Survey Questions used in the IBM Commuter Pain Index and Their Relation to Aspects of Congestion

IBM Commuter Pain Index Component Survey Question (and applicable answers)	Relevant Aspect(s) of Congestion
How long does your typical one-way commute take?	Duration, Extent
In the past three years, has roadway traffic in the area you live gotten worse?	Intensity
In the past three years, what is the longest you have been stuck in roadway traffic in the area where you live?	Duration, Intensity
What is the most frustrating thing about your commute? Start/stop traffic.	Intensity
Has roadway traffic negatively affected your health? Yes, it causes stress.	Intensity
Has roadway traffic negatively affected your health? Yes, it causes anger.	Intensity
Has roadway traffic negatively affected your performance at work or school? Yes.	Intensity
What value would you place on any extra time you could save from your commute? (Value for 15 minutes scaled up to an hour.)	Not Applicable
In the last three years, has the roadway traffic ever been so bad that you turned around and went home? Yes.	Intensity
In the last month, have you decided not to make a driving trip due to anticipated traffic conditions? Yes.	Intensity, Duration, Extent

To begin the analysis, TTI examined both the Computer Pain Index and Raw Pain Index from the IBM survey data. Figure 1 and Table 3 show the comparison of these indices. It was chosen to perform the remaining analysis on the Raw Pain Index because it had greater consistency over time, thus, allowing for more stable analysis.

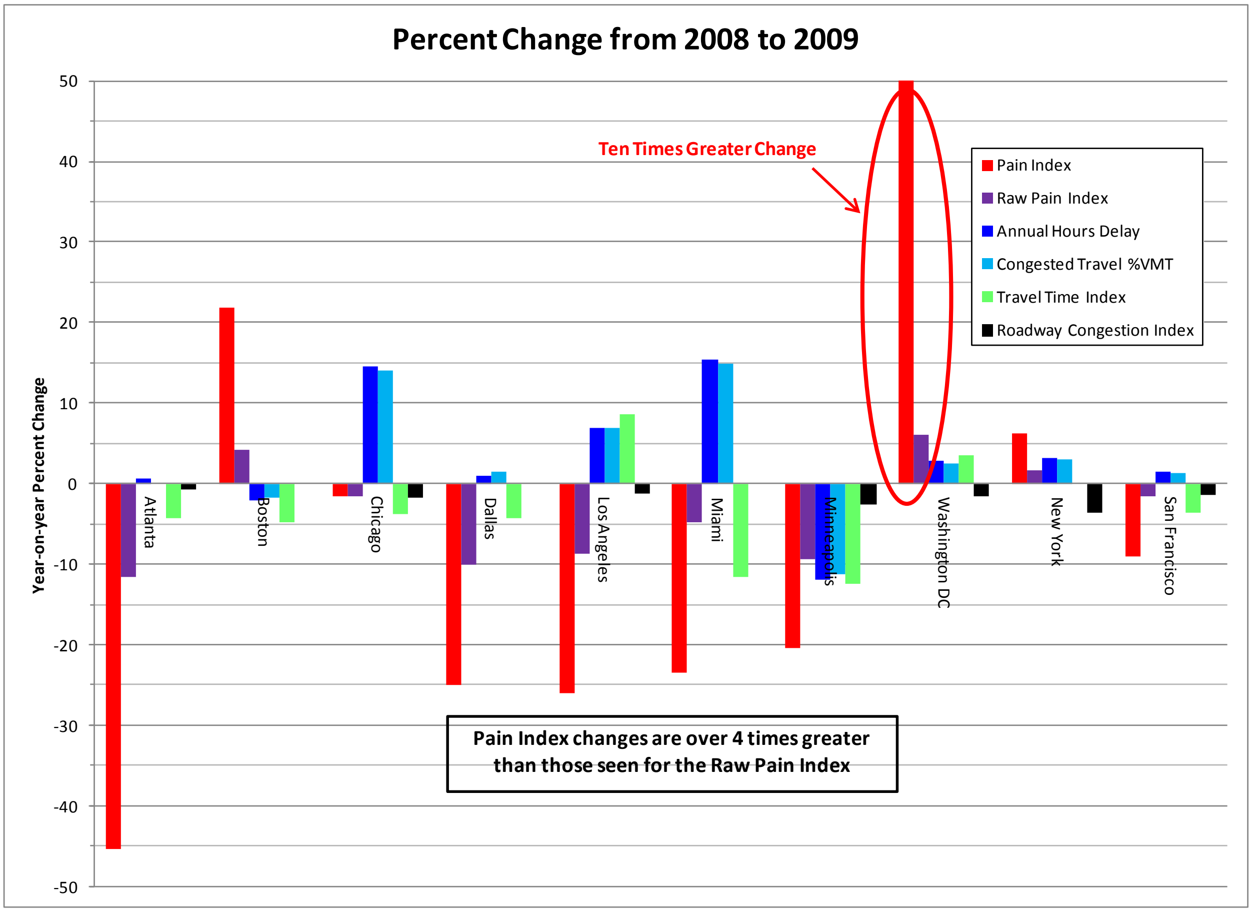

Figure 1. Year-to-Year Percent Change in Pain Index, Raw Pain Index, and UMR Measures

Table 3. Year-to-Year Percent Changes in the Pain Index and Raw Pain Index and Ratio of Changes

UMR Metropolitan Area	2008–2009 Change (%)		Ratio of Changes in Pain Index and Raw Pain Index (%)
	Pain Index	Raw Pain Index	
Atlanta	−45.4	−11.6	392
Boston	21.8	4.1	527
Chicago	−1.5	−1.5	100
Dallas – Ft. Worth	−25.0	−10.1	247
Los Angeles	−26.0	−8.6	301
Miami	−23.4	−4.9	483
Minneapolis – St. Paul	−20.5	−9.4	218
Washington, DC	55.2	6.0	920
New York	6.3	1.7	373
San Francisco	−9.1	−1.5	584

Analysis and Results – Raw Pain Index

Based on 2008 and 2009 data on 10 US cities, the Raw Pain Index was found to correspond to a composite model of two of the four core UMR measures examined: Travel Time Index and Roadway Congestion Index. The fitted model for the 2008 and 2009 RPI values is given as:

$$RPI = 19.7932 \times TTI + 13.4185 \times RCI$$

where RPI, TTI and RCI are the Raw Pain Index, UMR Travel Time Index and Roadway Congestion Index, respectively. Estimates of the Raw Pain Index based on this robust regression model were found to have a mean absolute percent error (MAPE) of 4.5 percent across both years; see Table 4 for more detail. The estimation accuracy of the fitted model for RPI was considerably better than that obtained for the un-modified Pain Index, which had a MAPE of 18.8 percent.

Note the 2010 and 2011 Pain Indices for three of these cities were based on a slightly different set of questions; they were not examined here.

Table 4. Model Performance for Raw Pain Index Values

UMR Metropolitan Area	2008 Raw Pain Index Values			2009 Raw Pain Index Values		
	Observed	Predicted	Absolute Percent Error (APE)	Observed	Predicted	Absolute Percent Error (APE)
Atlanta	45.9	41.3	10.12	40.6	40.9	0.84
Boston	38.7	38.4	0.67	40.3	38.2	5.10
Chicago	42.0	40.6	3.24	41.4	40.2	2.87
Dallas – Ft. Worth	43.2	40.0	7.30	38.8	39.8	2.65
Los Angeles	49.8	47.7	4.31	45.5	48.0	5.45
Miami	44.5	42.7	4.15	42.3	42.1	0.67
Minneapolis – St. Paul	37.3	39.7	6.45	33.8	38.7	14.53
Washington, DC	41.7	43.4	4.03	44.2	43.3	2.01
New York	39.3	40.3	2.55	40.0	39.8	0.49
San Francisco	41.3	43.3	4.88	40.7	42.8	5.39
	Mean Absolute Percent Error (MAPE)		**4.77**	**Mean Absolute Percent Error (MAPE)**		**4.00**

Figure 2 and Figure 3 show the simultaneous 90 percent confidence limits for the Raw Pain Index model estimates for 2008 and 2009, respectively. The many overlapping confidence bands in both figures (e.g., confidence bands for six of the ten cities examined include a Raw Pain Index value of 42) indicate that many metropolitan areas have Raw Pain Indices that are not significantly different from each other; on average, the threshold for significant Raw Pain Index differences is approximately 4 points.

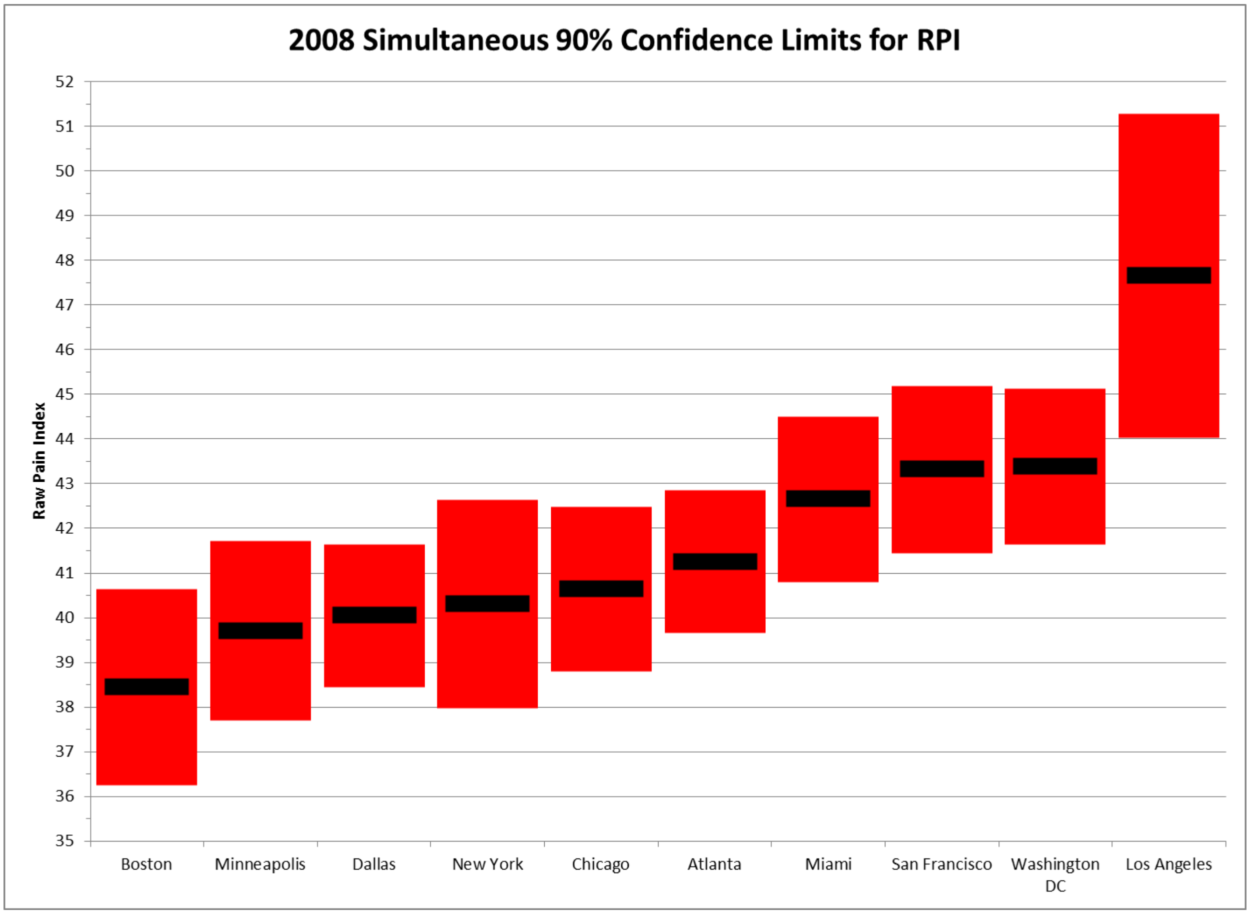

Figure 2. 2008 Confidence Limits (Red Box) for Raw Pain Index Estimates (Black Line)

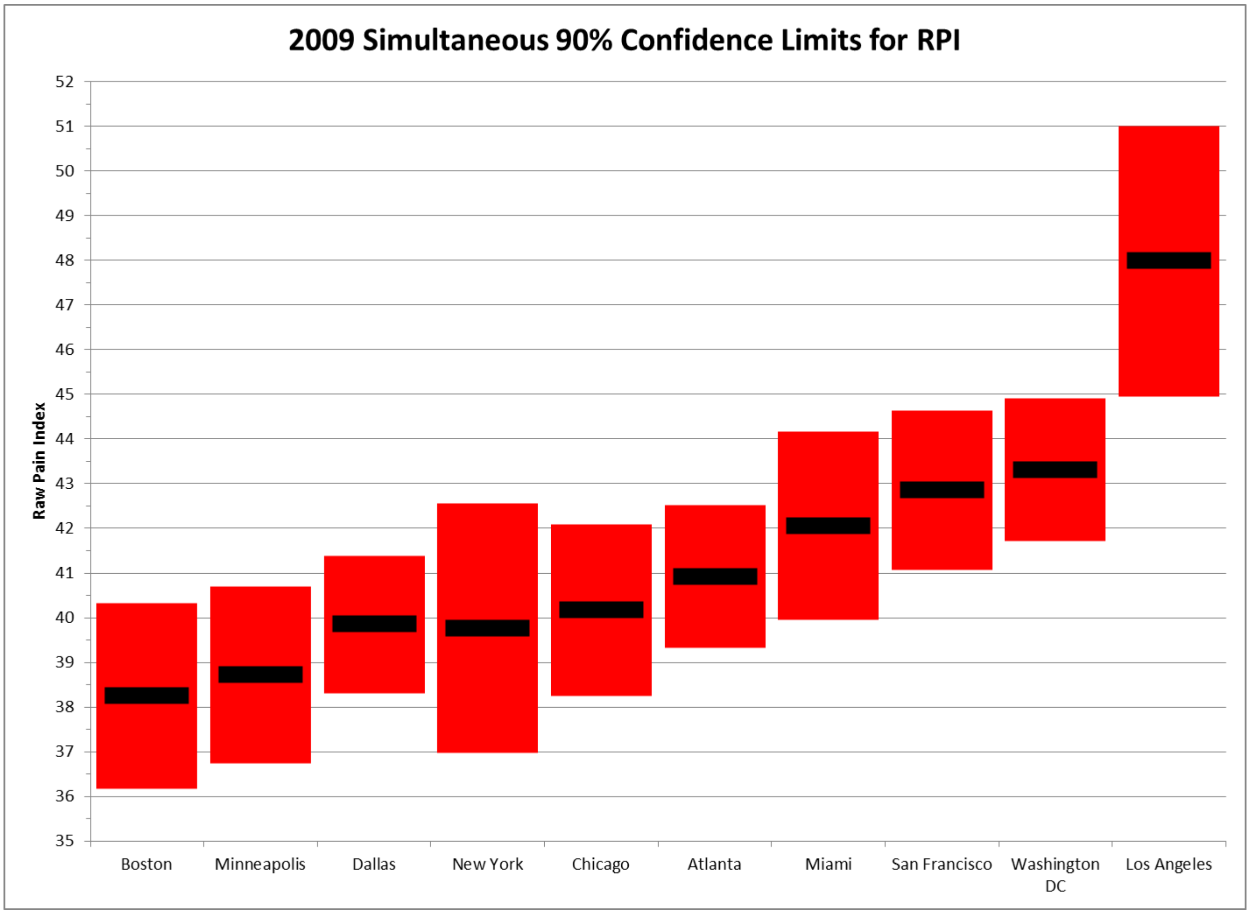

Figure 3. 2009 Confidence Limits (Red Box) for Raw Pain Index Estimates (Black Line)

Conclusions on Commuter Pain Index

This research attempts to connect the relationships between perceived congestion as determined by IBM's *Commuter Pain Survey* results and measured congestion from TTI's *Urban Mobility Report* in 10 cities across the United States. While these studies have different approaches there are some elements that can be linked and provide an opportunity for a collaborative assessment that uses both observed traffic data and driver self-assessments to provide a more comprehensive measure of the impacts of congestion.

Based on 2008 and 2009 data on 10 US cities, the IBM raw Pain Index values (the unadjusted index values based entirely on survey responses) had higher correlation with TTI-based measures than the published Pain Index values. In particular, the Raw Pain Index was found to correspond to a composite model of two of the four core UMR measures examined: the Travel Time Index and the Roadway Congestion Index. These are the two measures focused on intensity of congestion.

Researchers hypothesize that commuter perception of congestion is more related to travel time reliability in the sense that motorist's base their expectations on how often they must plan for a worst case commute. TTI researchers on the Strategic Highway Research Program 2 project "Effectiveness of Different Approaches to Disseminating Traveler Information on Travel Time Reliability" observed this behavior by study participants. When asked how they currently plan a trip, most focus group participants indicated that they used an online mapping tool to give them an initial travel time estimate, then added time to the mapping tool estimate. Similarly, in usability studies for a prototype online traveler information system, most participants indicated that when given a reasonably conservative total trip time estimate by the system, they added time to the estimate. A majority of participants chose to leave earlier than the departure time provided by the fictional website. These results were seen by the researchers to indicate either a lack of understanding or a lack of trust in the departure times provided by such a system. Travel time reliability is therefore an important component of the commuting experience. Information in this area may be obtained by including appropriate questions in future surveys such as "How much earlier do you need to leave to ensure that you arrive at your commute destination on time?" and "How many days a week do you experience heavy or severe congestion during your commute?" TTI introduced the Planning Time Index and the Buffer Index with the *Congested Corridors Report* in September 2011 to quantify travel time reliability. However, these measures have not yet been calculated for entire metropolitan areas; thus any survey questions related to travel time reliability may be used to link qualitative or perceived congestion to measured congestion only for major corridors within a metropolitan area. Survey-based information on travel time reliability, especially perceived reliability, may be easier to obtain, so this is one area where commuter perception surveys can enhance performance measure reporting.

Correlation of Measured Congestion between UMR and INRIX

This study also examines the correlation of measured congestion between the UMR and the INRIX National Traffic Scorecard (Scorecard).

INRIX® is a leading provider of real-time and historical traffic information. INRIX Traffic Services leverage sophisticated statistical analysis techniques, originally developed by Microsoft Research, to aggregate and enhance traffic-related information from hundreds of public and private sources, including traditional road sensors and the company's unique network of over 1.5 million GPS-enabled vehicles and mobile devices. INRIX has published its annual National Traffic Scorecard since 2007. This study analyzes and compares the status of traffic congestion for the top 100 metropolitan areas in the US as well as the nation as a whole.

Two measures from the INRIX National Traffic Scorecard are examined in this study. The first measure is the Travel Time Tax, which corresponds to the Travel Time Index in the UMR. The second is the Worst Hour T^3, which measures the most highly congested hour observed. This measure is a more extreme version of the Commuter Stress Index in the UMR (same as the Travel Time Index except that it includes only the travel in the peak direction during the peak periods; whereas the Travel Time Index includes travel in both directions during the peak period). All of these measures are exclusively related to the intensity of congestion.

There are some important differences in how congestion is calculated in the Scorecard and in the UMR. These differences can explain some of the difference in the results and the urban area rankings in each report. The main differences are as follows:

- Travel Time Tax is based on the average travel time whereas the Travel Time Index is the average travel time weighted by traffic volumes.
- Travel Time Tax uses reference speed, or the 85th percentile speeds during overnight hours, instead of a flat free flow speed such as 60 mph in the 2009 UMR (2008 data). However, the 2010 UMR (2009 data) uses the same reference speeds as the T^3.
- Travel Time Tax focuses on the major limited access roads (i.e., freeways) whereas the UMR includes both freeways and principal arterials for an urban area.
- Travel Time Tax uses the US Census Bureau definition of Core Based Statistical Area for urban areas whereas the UMR is based on the Urban Area boundary.

Analysis and Results – Travel Time Tax

Based on 2008 and 2009 data on 86 US cities, the INRIX Travel Time Tax was found to have a quadratic relationship to the UMR Travel Time Index. The fitted model for the 2008 and 2009 T^3 values is given as:

$$T^3 = 4.0347 - 5.8285 \times TTI + 2.8174 \times TTI^2$$

where TTI is the UMR Travel Time Index. Estimates of the T^3 based on this polynomial regression model were found to have a mean absolute percent error (MAPE) of 1.3 percent across both years; see Table 5 for more detail. The largest errors occur for the Las Vegas, NV (12.17 percent and 8.75 percent for 2008 and 2009, respectively), Oxnard-Ventura, CA (5.79 percent and 4.24 percent for 2008 and 2009, respectively) and Orlando, FL (4.26 percent and 5.1 percent for 2008 and 2009, respectively) metropolitan areas. The model explains 86 percent of the observed variation in the T^3.

Table 5. Model Performance for INRIX T^3 Values

UMR Metropolitan Area	2008 INRIX T^3 Values			2009 INRIX T^3 Values		
	Observed	Predicted	APE	Observed	Predicted	APE
Akron OH	1.016	1.02	0.48	1.012	1.02	0.88
Albany-Schenectady NY	1.023	1.03	0.58	1.025	1.03	0.72
Albuquerque NM	1.029	1.06	2.81	1.035	1.05	1.06
Allentown-Bethlehem PA-NJ	1.025	1.03	0.11	1.034	1.03	0.76
Atlanta GA	1.101	1.13	2.46	1.106	1.12	1.02
Austin TX	1.211	1.18	2.84	1.207	1.19	1.39
Bakersfield CA	1.013	1.02	1.07	1.022	1.03	0.40
Baltimore MD	1.093	1.06	2.59	1.104	1.07	2.89
Baton Rouge LA	1.122	1.13	0.54	1.121	1.14	1.64
Birmingham AL	1.046	1.05	0.54	1.061	1.05	0.88
Boise ID	1.039	1.05	1.22	1.042	1.04	0.11
Boston MA-NH-RI	1.132	1.11	2.20	1.124	1.10	2.36
Bridgeport-Stamford CT-NY	1.216	1.13	7.23	1.180	1.15	2.44
Buffalo NY	1.034	1.03	0.49	1.040	1.03	0.73
Cape Coral FL	1.031	1.05	1.45	1.020	1.04	2.05
Charleston-North Charleston SC	1.043	1.06	1.43	1.047	1.06	1.04
Charlotte NC-SC	1.067	1.09	2.01	1.063	1.07	0.85
Chicago IL-IN	1.184	1.16	1.72	1.164	1.15	1.10
Cincinnati OH-KY-IN	1.053	1.05	0.67	1.052	1.04	1.06
Cleveland OH	1.039	1.03	0.97	1.044	1.03	1.11
Colorado Springs CO	1.029	1.05	2.20	1.039	1.04	0.18
Columbia SC	1.016	1.03	0.99	1.021	1.03	0.78
Columbus OH	1.027	1.03	0.09	1.025	1.04	1.11
Dallas-Fort Worth-Arlington TX	1.116	1.13	1.08	1.116	1.12	0.12
Dayton OH	1.025	1.02	0.28	1.018	1.02	0.40
Denver-Aurora CO	1.088	1.11	1.76	1.093	1.12	2.22
Detroit MI	1.076	1.08	0.37	1.052	1.06	0.56
El Paso TX-NM	1.072	1.06	1.32	1.058	1.06	0.01
Fresno CA	1.020	1.02	0.20	1.028	1.02	0.41
Grand Rapids MI	1.026	1.02	0.49	1.026	1.02	0.38
Greensboro NC	1.010	1.02	1.08	1.014	1.02	0.68
Hartford CT	1.067	1.06	0.85	1.062	1.05	1.51
Houston TX	1.156	1.19	2.96	1.131	1.15	1.79
Indianapolis IN	1.023	1.08	5.57	1.034	1.08	4.45
Jackson MS	1.019	1.03	0.70	1.019	1.02	0.47
Jacksonville FL	1.042	1.05	0.38	1.039	1.04	0.18
Kansas City MO-KS	1.034	1.04	0.23	1.036	1.03	0.35
Knoxville TN	1.022	1.02	0.18	1.019	1.02	0.30
Las Vegas NV	**1.049**	**1.18**	**12.17**	**1.070**	**1.16**	**8.75**
Little Rock AR	1.025	1.03	0.11	1.035	1.03	0.25
Los Angeles-Long Beach-Santa Ana CA	1.325	1.30	1.82	1.347	1.36	0.72
Louisville KY-IN	1.032	1.03	0.57	1.046	1.03	1.30
Madison WI	1.019	1.02	0.19	1.025	1.02	0.28
McAllen TX	1.030	1.02	0.60	1.029	1.03	0.00
Memphis TN-MS-AR	1.029	1.05	1.65	1.039	1.05	0.67
Miami FL	1.131	1.16	2.89	1.132	1.13	0.35
Milwaukee WI	1.078	1.07	0.55	1.066	1.06	0.12
Minneapolis-St. Paul MN	1.133	1.14	0.56	1.118	1.11	0.97
Nashville-Davidson TN	1.042	1.05	0.93	1.049	1.06	0.85
New Haven CT	1.081	1.05	3.24	1.086	1.06	2.59
New Orleans LA	1.080	1.08	0.00	1.077	1.06	1.77
New York-Newark NY-NJ-CT	1.195	1.18	1.54	1.197	1.18	1.70
Oklahoma City OK	1.033	1.03	0.39	1.036	1.03	0.68

Table 5. Model Performance for INRIX T^3 Values *(cont'd.)*

UMR Metropolitan Area	2008 INRIX T^3 Values			2009 INRIX T^3 Values		
	Observed	Predicted	APE	Observed	Predicted	APE
Omaha NE-IA	1.024	1.04	1.21	1.032	1.03	0.57
Orlando FL	1.044	1.09	4.26	1.044	1.10	5.13
Oxnard-Ventura CA	1.100	1.04	5.79	1.087	1.04	4.24
Philadelphia PA-NJ-DE-MD	1.100	1.09	1.05	1.103	1.09	1.32
Phoenix AZ	1.082	1.07	0.92	1.068	1.10	2.76
Pittsburgh PA	1.070	1.10	2.57	1.072	1.07	0.00
Portland OR-WA	1.125	1.13	0.27	1.122	1.13	0.54
Poughkeepsie-Newburgh NY	1.025	1.02	0.46	1.046	1.02	2.45
Providence RI-MA	1.061	1.06	0.29	1.055	1.05	0.32
Raleigh-Durham NC	1.041	1.05	0.48	1.040	1.05	0.58
Richmond VA	1.014	1.02	0.80	1.014	1.02	0.80
Riverside-San Bernardino CA	1.087	1.06	2.05	1.088	1.06	2.14
Rochester NY	1.025	1.02	0.12	1.027	1.02	0.31
Sacramento CA	1.068	1.09	1.92	1.074	1.08	0.56
Salt Lake City UT	1.024	1.04	1.21	1.039	1.04	0.18
San Antonio TX	1.058	1.06	0.63	1.059	1.06	0.54
San Diego CA	1.133	1.10	3.13	1.107	1.08	2.44
San Francisco-Oakland CA	1.229	1.19	3.16	1.215	1.18	3.16
San Jose CA	1.156	1.16	0.66	1.142	1.13	1.22
Sarasota-Bradenton FL	1.013	1.03	1.57	1.015	1.03	1.71
Seattle WA	1.202	1.16	3.19	1.185	1.14	3.85
Springfield MA-CT	1.017	1.02	0.67	1.034	1.03	0.49
St. Louis MO-IL	1.051	1.04	0.96	1.051	1.04	0.96
Stockton CA	1.028	1.02	0.70	1.023	1.02	0.21
Tampa-St. Petersburg FL	1.082	1.06	1.60	1.080	1.06	1.42
Toledo OH-MI	1.008	1.02	1.22	1.009	1.02	1.18
Tucson AZ	1.029	1.04	1.16	1.024	1.04	1.21
Tulsa OK	1.019	1.02	0.19	1.029	1.02	0.50
Virginia Beach VA	1.115	1.09	2.38	1.113	1.09	2.21
Washington DC-VA-MD	1.203	1.20	0.11	1.224	1.22	0.41
Wichita KS	1.012	1.02	1.00	1.020	1.03	0.60
Worcester MA	1.032	1.03	0.57	1.031	1.02	0.70
	Mean Absolute Percent Error (MAPE)		1.25	**Mean Absolute Percent Error (MAPE)**		1.37

Figure 4 and Figure 5 show the simultaneous 90 percent confidence limits for the T^3 model estimates for 2008 and 2009, respectively. For comparative purposes, only a subset of the 86 cities that correspond to the same metro areas used for the Raw Pain Index are shown. The narrow confidence bands indicate reasonable precision in the model estimates. On average, the threshold for significant T^3 differences is approximately 0.012. Significant differences are observed between most of the metro areas in the subset; note that the model has sufficient precision to detect significant T^3 differences among mid-ranked metropolitan areas.

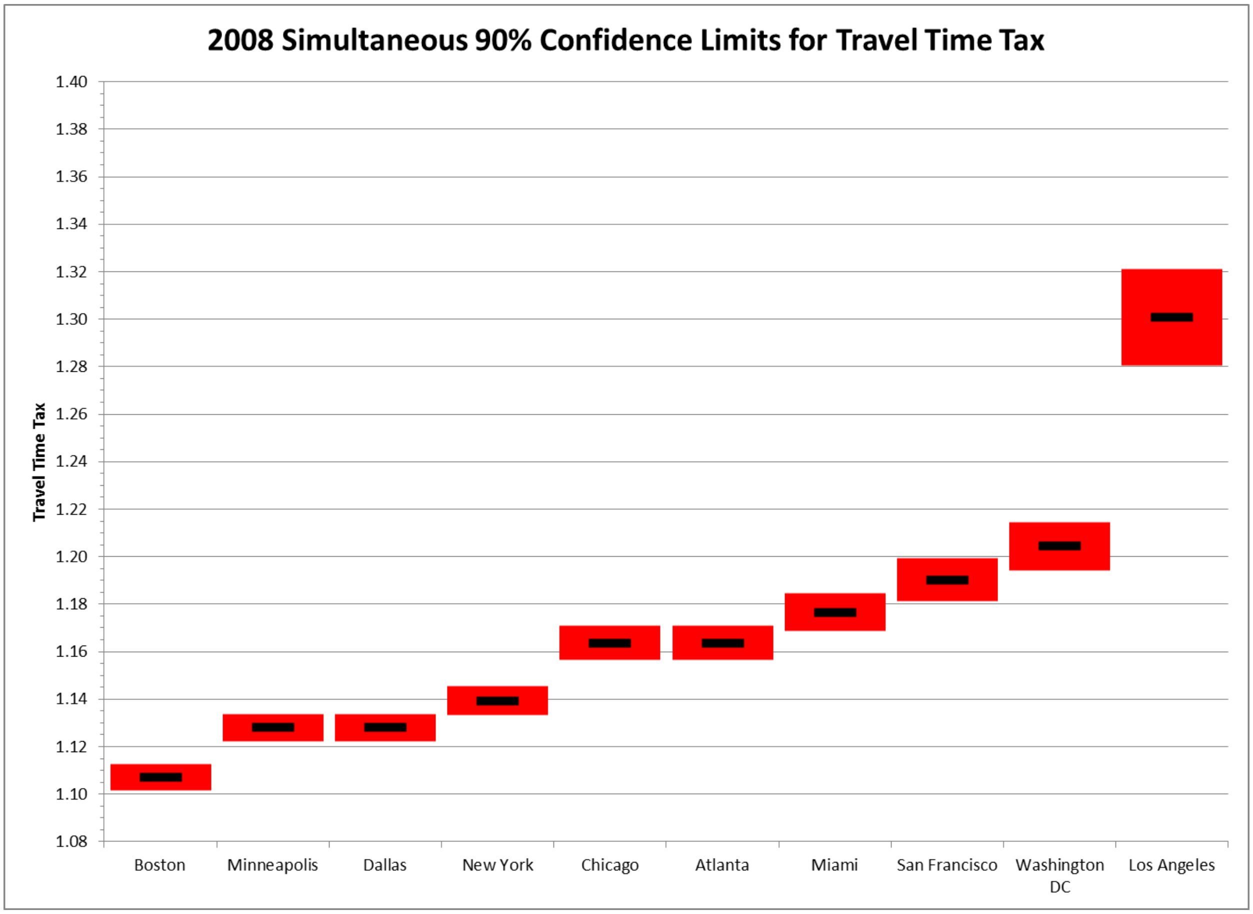

Figure 4. 2008 Confidence Limits (Red Box) for T^3 Estimates (Black Line)

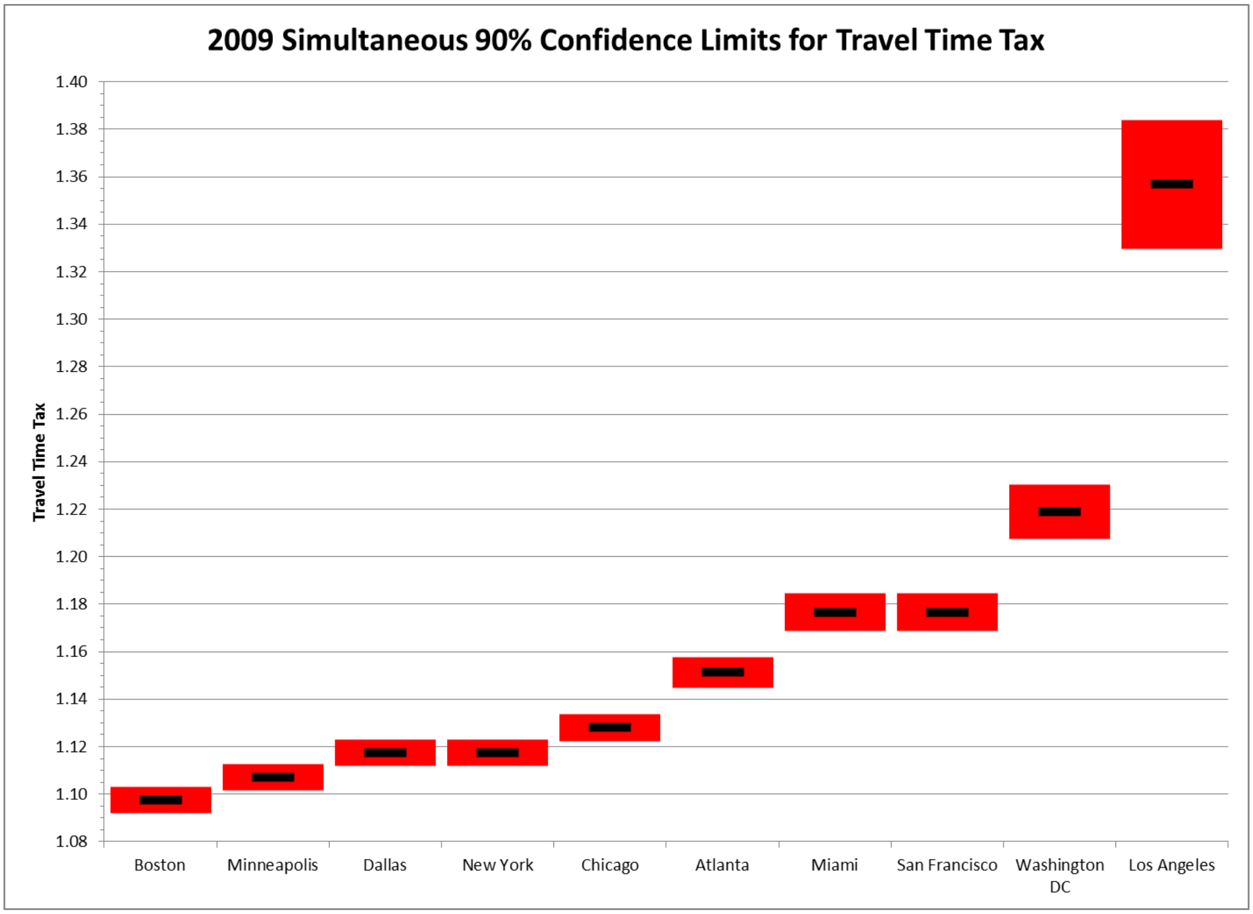

Figure 5. 2009 Confidence Limits (Red Box) for T^3 Estimates (Black Line)

Analysis and Results – Worst Hour Travel Time Tax

Based on 2008 and 2009 data on 85 US cities, the INRIX Worst Hour Travel Time Tax was found to have a quadratic relationship to the UMR Travel Time Index. The fitted model for the 2008 and 2009 Worst Hour T^3 values is given as:

$$Y = -0.9848 + 0.9745 \times TravelTimeIndex$$

Here, Y is a power transformation of Worst Hour T^3:

$$Y = \frac{X^{-2} - 1}{2.3359}$$

with X denoting Worst Hour T^3.

Estimates of the Worst Hour T^3 based on this regression model were found to have a mean absolute percent error (MAPE) of 3.8 percent across both years; see Table 6 for more detail. Several metropolitan areas exhibit over 10 percent absolute prediction error: Austin, TX; Bridgeport-Stamford, CT-NY; Las Vegas, NV; New Haven, CT; and Oxnard-Ventura, CA. This is to be expected since the Worst Hour T^3 is an extreme statistic and thus much more variable than estimates of central tendency such as the mean. The model nevertheless explains 79 percent of the observed variation in the Worst Hour T^3.

Table 6. Model Performance for INRIX Worst Hour T^3 Values

UMR Metropolitan Area	2008 INRIX Worst Hour T^3 Values			2009 INRIX Worst Hour T^3 Values		
	Observed	Predicted	APE	Observed	Predicted	APE
Akron OH	1.07	1.04	2.90	1.03	1.04	0.87
Albany-Schenectady NY	1.05	1.08	2.43	1.06	1.08	2.19
Albuquerque NM	1.09	1.15	5.71	1.06	1.13	6.96
Allentown-Bethlehem PA-NJ	1.07	1.06	0.90	1.08	1.07	1.12
Atlanta GA	1.27	1.27	0.24	1.29	1.26	2.29
Austin TX	**1.68**	**1.34**	**20.11**	**1.55**	**1.36**	**12.43**
Bakersfield CA	1.03	1.06	2.95	1.04	1.07	2.68
Baltimore MD	1.24	1.18	4.70	1.26	1.19	5.39
Baton Rouge LA	1.31	1.36	3.61	1.33	1.30	2.30
Birmingham AL	1.07	1.14	6.81	1.13	1.15	1.97
Boise ID	1.13	1.18	4.58	1.09	1.12	3.20
Boston MA-NH-RI	1.33	1.26	5.23	1.27	1.24	2.65
Bridgeport-Stamford CT-NY	**1.61**	**1.34**	**16.64**	**1.56**	**1.31**	**15.82**
Buffalo NY	1.07	1.08	1.24	1.09	1.09	0.11
Cape Coral FL	1.12	1.10	1.84	1.09	1.10	0.86
Charleston-North Charleston SC	1.20	1.15	3.98	1.11	1.15	3.81
Charlotte NC-SC	1.24	1.21	2.13	1.21	1.18	2.33
Chicago IL-IN	1.36	1.34	1.32	1.36	1.33	2.40
Cincinnati OH-KY-IN	1.16	1.14	1.47	1.14	1.13	0.55
Cleveland OH	1.09	1.09	0.11	1.11	1.09	1.69
Colorado Springs CO	1.13	1.13	0.33	1.17	1.11	5.33
Columbia SC	1.05	1.07	1.70	1.06	1.08	1.46
Columbus OH	1.10	1.08	2.23	1.11	1.12	1.34
Dallas-Fort Worth-Arlington TX	1.31	1.30	0.81	1.27	1.29	1.26
Dayton OH	1.08	1.06	1.81	1.06	1.05	0.65
Denver-Aurora CO	1.16	1.26	8.66	1.2	1.25	4.02
Detroit MI	1.19	1.19	0.18	1.13	1.13	0.33
El Paso TX-NM	1.13	1.15	1.97	1.13	1.17	3.69
Fresno CA	1.05	1.05	0.39	1.04	1.05	1.26
Grand Rapids MI	1.07	1.05	2.25	1.07	1.05	2.25
Greensboro NC	1.02	1.03	1.18	1.04	1.04	0.10
Hartford CT	1.23	1.15	6.32	1.2	1.12	6.26
Houston TX	1.32	1.41	6.54	1.31	1.34	2.45
Indianapolis IN	1.09	1.17	7.49	1.08	1.15	6.69
Jackson MS	1.05	1.06	0.99	1.04	1.05	1.26
Jacksonville FL	1.10	1.12	2.26	1.08	1.12	3.35
Kansas City MO-KS	1.08	1.11	2.56	1.08	1.10	1.79
Knoxville TN	1.09	1.07	2.03	1.05	1.05	0.30
Las Vegas NV	**1.09**	**1.37**	**25.97**	**1.12**	**1.33**	**18.52**
Little Rock AR	1.06	1.08	1.46	1.08	1.10	1.79
Los Angeles-Long Beach-Santa Ana CA	1.63	1.65	0.92	1.69	1.70	0.77
Louisville KY-IN	1.09	1.08	1.33	1.09	1.09	0.11
Madison WI	1.04	1.05	0.57	1.05	1.05	0.30
McAllen TX	1.06	1.05	0.65	1.05	1.07	1.70
Memphis TN-MS-AR	1.07	1.12	5.13	1.08	1.12	4.15
Miami FL	1.23	1.16	5.54	1.23	1.27	3.50
Milwaukee WI	1.20	1.20	0.23	1.17	1.18	1.00

Table 6. Model Performance for INRIX Worst Hour T^3 Values *(cont'd.)*

UMR Metropolitan Area	2008 INRIX Worst Hour T^3 Values			2009 INRIX Worst Hour T^3 Values		
	Observed	Predicted	APE	Observed	Predicted	APE
Minneapolis-St. Paul MN	1.32	1.31	0.52	1.3	1.25	3.98
Nashville-Davidson TN	1.27	1.15	9.27	1.13	1.16	2.82
New Haven CT	**1.27**	**1.14**	**10.01**	**1.28**	**1.17**	**8.46**
New Orleans LA	1.17	1.29	9.91	1.17	1.15	1.52
New York-Newark NY-NJ-CT	1.48	1.36	8.29	1.42	1.36	4.41
Oklahoma City OK	1.09	1.08	0.62	1.08	1.09	1.04
Omaha NE-IA	1.05	1.11	5.49	1.06	1.07	0.74
Orlando FL	1.11	1.18	6.46	1.1	1.19	8.37
Oxnard-Ventura CA	**1.24**	**1.11**	**10.67**	**1.26**	**1.11**	**12.09**
Philadelphia PA-NJ-DE-MD	1.23	1.19	3.08	1.26	1.20	4.55
Phoenix AZ	1.15	1.18	2.76	1.12	1.25	11.45
Pittsburgh PA	1.14	1.22	7.44	1.13	1.17	3.69
Portland OR-WA	1.35	1.33	1.67	1.31	1.30	0.81
Poughkeepsie-Newburgh NY	1.05	1.03	1.71	1.08	1.03	5.06
Providence RI-MA	1.15	1.15	0.20	1.12	1.14	2.05
Raleigh-Durham NC	1.12	1.13	1.23	1.11	1.12	1.34
Richmond VA	1.04	1.05	0.57	1.04	1.05	0.57
Riverside-San Bernardino CA	1.21	1.19	1.48	1.23	1.19	3.08
Rochester NY	1.06	1.06	0.04	1.05	1.06	0.99
Sacramento CA	1.19	1.21	1.99	1.16	1.20	3.68
Salt Lake City UT	1.07	1.12	4.31	1.07	1.12	5.13
San Antonio TX	1.17	1.19	1.89	1.16	1.19	2.77
San Diego CA	1.26	1.22	2.79	1.23	1.19	3.08
San Francisco-Oakland CA	1.48	1.42	3.80	1.46	1.37	5.95
San Jose CA	1.36	1.37	0.96	1.33	1.31	1.27
Sarasota-Bradenton FL	1.04	1.07	2.68	1.07	1.07	0.20
Seattle WA	1.44	1.36	5.74	1.4	1.31	6.20
Springfield MA-CT	1.07	1.05	1.58	1.09	1.08	1.33
St. Louis MO-IL	1.10	1.12	2.26	1.11	1.11	0.21
Stockton CA	1.07	1.01	5.40	1.05	1.01	3.60
Tampa-St. Petersburg FL	1.19	1.15	3.17	1.2	1.15	3.98
Toledo OH-MI	1.03	1.03	0.20	1.03	1.04	0.87
Tucson AZ	1.08	1.11	2.56	1.07	1.10	2.74
Tulsa OK	1.06	1.04	1.99	1.06	1.06	0.04
Virginia Beach VA	1.32	1.24	6.33	1.35	1.24	8.42
Washington DC-VA-MD	1.42	1.44	1.55	1.45	1.44	0.55
Wichita KS	1.02	1.04	1.86	1.03	1.05	2.24
Worcester MA	1.11	1.07	3.80	1.07	1.06	0.90
	Mean Absolute Percent Error (MAPE)		3.26	**Mean Absolute Percent Error (MAPE)**		3.49

Conclusions on INRIX National Traffic Scorecard

This study compares different measures of congestion based on private sector data such as in INRIX's annual National Traffic Scorecard to measures published in TTI's annual *Urban Mobility Report*.

Because both reports use different approaches to calculate congestion, this research investigates the correlation, if any, between congestion measures as determined by both the

Scorecard and the UMR. The Travel Time Tax and the Worst Hour T^3 of the Scorecard were found to correlate to a model of the Travel Time Index of the UMR. The Travel Time Tax correlates especially well with the Travel Time Index despite the different methodologies used to measure congestion.

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