Creating a New Method to Identify the Worst Bottlenecks in Texas

by

David L. Schrank, Ph.D.
Associate Research Scientist
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135
Phone: (979)845-7323, Fax: (979)845-6008

Timothy J. Lomax, Ph.D., P.E.
Research Engineer
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135
Phone: (979)845-9960, Fax: (979)845-6008

Shannon Crum, Ph.D.
Director of Data Management
Texas Department of Transportation
Austin, Texas 78701-2483
Phone: (512)486-5054

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ABSTRACT

Since 2009 the Texas Department of Transportation (TxDOT) has posted a list of the most congested roadway sections in the state on its website (1). This list is produced annually by TxDOT and the Texas Transportation Institute (TTI) using a jointly-developed methodology. The two agencies have developed an approach that combines traffic speed data from annual archives of private sector data companies, basic roadway geometry, and traffic counts published in the TxDOT statewide roadway inventory file (RHiNo) (2) to calculate congestion-related performance measures. A set of volume distribution curves, combined with daily traffic counts, is used to estimate 15-minute volumes for each average day of the week. These estimated 15-minute volumes are combined with 15-minute speed data to calculate delay. Performance measures such as annual delay per mile, congestion cost, and the Travel Time Index are produced from this analysis and are used to rank the congested segments across Texas. This paper describes the process used to produce these statistics.

INTRODUCTION

In 2009, the Texas Department of Transportation (TxDOT) was required by the Texas Legislature to produce a list of the 100 most congested roadway sections in the state of Texas. TxDOT contracted with the Texas Transportation Institute (TTI) to help produce the list since TTI had produced traffic congestion statistics for decades in its annual Urban Mobility Report (UMR) (3).

This paper 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 data is an annual average of traffic speed for each section of road for every 15 minutes of each day of the week for a total of 672 day/time-period cells (24 hours x 7 days a week x 4 times per hour).

The travel speed data addresses the greatest shortcoming of older methodologies—the speed estimation process. INRIX’s speed data has improved the freeway and arterial street congestion measures in the following ways:

- “Real” rush hour speeds are used to estimate a range of congestion measures; speeds are measured not estimated.

- Overnight speeds are used to identify the free-flow speeds that are used as a comparison standard; low-volume conditions on each road section are used as the comparison standard.

- The volume and roadway inventory data from TxDOT’s files are 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.

BACKGROUND

The initial methodology used for the 2009 100 most congested section list used a set of estimation procedures and data provided by TxDOT and regional planning agencies to develop a set of mobility measures. This procedure was based on the methodology that had been used in the Urban Mobility Report for decades. It generally assumed that certain traffic density levels produced similar operating characteristics. With the availability of large national traffic speed datasets, it became possible to use the data produced by private-sector companies for navigation purposes in conjunction with TxDOT data to produce a more accurate assessment of traffic congestion based on actual performance.

THE NEW CONGESTION MEASURE CALCULATIONS

The following steps describe the new process used to calculate the congestion performance measures and identify the 100 most congested road sections in Texas.

1. Obtain TxDOT Roadway-Highway Inventory (RHiNo) traffic volume data by road section
2. Match the RHiNo road network sections with the traffic speed dataset road sections
3. Estimate traffic volumes for each 15-minute time interval from the daily volume data
4. Establish free-flow (i.e., low volume) travel speed
5. Calculate congestion performance measures

The mobility measures require four data inputs:
- Actual travel speed
- Free-flow travel speed
- Vehicle volume (15-minute)
- Vehicle occupancy (persons per vehicle) to calculate person-hours of travel delay

The private sector traffic speed data provided a very detailed data source for the first two inputs, actual and free-flow travel time. The top 100 congestion analysis required vehicle volume estimates for the delay calculations. While the geographic referencing systems are different for the speed and volume datasets, a conflation process was performed to assign traffic speed data to each TxDOT RHiNo road section for the purposes of calculating the 100 most congested section performance measures.

**Process Description**

The following sections describe the details for the six calculation steps and the performance measures that were generated for the determination of the 100 most congested road sections.

### Step 1. Create Traffic Volume Data by Day-of-Week

The RHiNo dataset from TxDOT provides the source for traffic volume data, although the geographic designations in the RHiNo dataset are not identical to the private sector speed data. While there are some detailed traffic counts on major roads, the most widespread and consistent traffic counts available are average annual daily traffic (AADT) counts. Volume estimates for each day of the week (to match the speed database) are created from the annual average volume data using the factors in Table 1. Automated traffic recorders from the Texas metropolitan areas were reviewed and the factors in Table 1 are a “best-fit” average for both freeways and major streets.

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Adjustment Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday to Thursday</td>
<td>+5%</td>
</tr>
<tr>
<td>Friday</td>
<td>+10%</td>
</tr>
<tr>
<td>Saturday</td>
<td>-10%</td>
</tr>
<tr>
<td>Sunday</td>
<td>-20%</td>
</tr>
</tbody>
</table>

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

The second step is to combine the road networks for the traffic volume and speed data sources, such that an estimate of traffic speed and traffic volume are available for each desired roadway segment. Freeway segments with traffic densities of over 15,000 per lane per day and arterial streets with more than 5,500 vehicles per lane per day are included in the analysis so that the effort focused on the roads most likely to be seriously congested.

The combination (also known as conflation) of the traffic volume and traffic speed networks is accomplished using Geographic Information Systems (GIS) tools. Another decision to be made is which network should be used as the “control” network during conflation. In other words, should the private sector Traffic Message Channel (TMC) network be used as the base network or should the TxDOT traffic volume network be used? In this case, the RHiNo network is chosen as the base network. Each road...
segment that met the traffic density requirements was coded as part of an analysis section by TxDOT (multiple RHiNo segments make up a section). The RHiNo network is reviewed annually to identify new sections for analysis and refine section definitions as physical changes occur to the roadway network.

**Step 3. Estimate Traffic Volumes for Shorter Time Intervals**

The 15-minute traffic volumes for each section were estimated from the AADT counts using typical time-of-day traffic volume profiles developed from local continuous count locations. Typical time-of-day traffic distribution profiles are needed to estimate 15-minute traffic flows from average daily traffic volumes. Previous analytical efforts (4,5) have developed typical traffic profiles at the 15-minute 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: severe, moderate and low based on the percentage reduction in speed from free-flow (varies for freeways and streets)
- 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 Figure 1 through Figure 5 are considered to be very comprehensive, as they were based upon 713 continuous traffic monitoring locations in urban areas of 37 states. TTI compared these reported traffic profiles with readily-available, recent empirical traffic data in Houston, San Antonio and Austin to confirm that these reported profiles remain valid. The profiles in these graphics represent hourly profiles but the percentages can easily be adjusted for 15-minute periods.

![FIGURE 1 Weekday Traffic Distribution Profile for No to Low Congestion.](image-url)
FIGURE 2 Weekday Traffic Distribution Profile for Moderate Congestion.

FIGURE 3 Weekday Traffic Distribution Profile for Severe Congestion.
FIGURE 4 Weekend Traffic Distribution Profile.

FIGURE 5 Weekday Traffic Distribution Profile for Similar Speeds in Each Peak Period.
There are several substeps within Step 3. The first substep is to determine which of the 16 traffic distribution profiles should be assigned to each Traffic Message Channel (TMC) path within each RHiNo analysis segment, such that the 15-minute traffic flows can be calculated from TxDOT’s RHiNo data. The assignment should be as follows:

- Functional class: assign based on roadway functional class (data contained in the RHiNo file)
  - 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 using 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 24 15-minute periods in the six peak hours) for each TMC path
  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.

\[
\text{Speed Reduction Factor} = \frac{\text{Average Peak Period Speed}}{\text{Free-flow Speed (e.g., 10 p.m. to 5 a.m.)}}
\]

For Freeways (roads with a free-flow (baseline) speed more than 55 mph):
- 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 (roads with a free-flow (baseline) speed less than 55 mph):
- 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 using the 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 9 a.m.) and the average evening peak period speed (4 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 to the even volume distribution.

**Step 4. Calculate Peak Period Travel Speed and Time**

The 15-minute speed and volume data are combined to calculate the weighted average peak-period statistics. Time periods with more volume should “count for more” than time periods with less volume. For delay calculation, a simple average of all the speeds in the peak period (as was done in Step 3) is inappropriate. The 15-minute volume for each segment is multiplied by the corresponding travel time to get a quantity of vehicle-minutes. The twelve values (four 15-minute values for each of the three peak hours) are summed and divided by the total volume to obtain a weighted average travel time and speed for each peak period.
Step 5. Establish Free-Flow Travel Speed and Time

The calculation of congestion measures requires establishing a congestion threshold, such that delay is accumulated for any time period once the congestion threshold has been crossed. There has been considerable debate about the appropriate congestion thresholds, but for the purposes of the 100 most congested list, the data is used to identify the speed at low volume conditions. The threshold was set by examining the non-peak periods (for example, 10 p.m. to 5 a.m.) and identifying the 85th percentile speed during those hours. This speed is relatively high, but varies according to the roadway design and operating characteristics. An upper limit of 65 mph was placed on the freeway free-flow speed to maintain a reasonable estimate of congestion. Typical street free-flow speeds ranged between 30 and 40 mph.

Step 6. Calculate Congestion Performance Measures

Once the dataset of 15-minute actual speeds, free-flow travel speeds and traffic volumes are prepared, the mobility performance measures are calculated using the equations in Table 2. For the purposes of the top 100 list, the measures are calculated in person terms.

- Texas Congestion Index – The TCI (also known as the Travel Time Index) is a unitless measure that indicates the amount of extra time for any trip. A TCI value of 1.40 indicates a 20-minute trip in the off-peak will take 28 minutes in the peak.
- Total delay – The best measure of the size of the congestion problem is the annual travel delay. This measure combines elements of the TCI (intensity of congestion on any section of road) with a magnitude element (the amount of people suffering that congestion). This combination will prioritize highly traveled sections above those that are less heavily traveled. For example, a four-lane freeway can operate at the same speed (and have the same TCI value) as a 10-lane freeway. But the higher volume on the 10-lane freeway will mean it has more delay and, thus, is a bigger problem for the region.
- Total delay per mile of road – One combination of a delay measure and the “indexed” approach is to divide total section delay by the road length. So the measure of “hours of delay per mile of road” indicates the level of congestion problem without the different section lengths affecting the ranking. **This is the performance measure that best identifies most congested segments.**
- 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 cost of delay and fuel in the equation in Table 2 is a simplified version of the procedure used in TTI’s 2011 Urban Mobility Report. In 2010, the most recent year of data, the average congestion cost (for delay and fuel) for an hour of person delay was approximately $21 per hour. This value can be adjusted to other dollar-years based on the Consumer Price Index.
- Commuter Stress Index – Most of the road and public transportation network operates with much more volume or ridership (and more congestion) in one direction during each peak period. Averaging the conditions for both directions in both peaks (as with the Texas Congestion Index) provides an accurate measure of congestion, but does not always match the perception of the majority of commuters. The CSI measure uses the travel speed from the direction with the most congestion in each peak period to illustrate the conditions experienced by the commuters traveling in the predominant directions (for example, inbound from suburbs in the morning and outbound to the suburbs in the evening). The calculation is conducted with the TCI formula, but only for the peak directions.
- Time of Congestion – Providing the time when congestion might be encountered is one method of explaining both the congestion problem and illustrating some of the solutions. The times of day when each road direction speed is below 80 percent of the street free-flow speed or 90 percent of the freeway free-flow speed is shown for each of the 100 most congested sections (for example, below 54 mph on a 60 mph freeway). The time is displayed in 15-minute increments with a minimum of 30 minutes used to decide which times to include.
Table 2  Equations for Selected Mobility Measures

<table>
<thead>
<tr>
<th>INDIVIDUAL MEASURES(^1)</th>
<th>Delay per Mile annual hours per mile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[\text{Delay per Mile} = \frac{\text{Actual Travel Time}}{\text{Free-Flow Travel Time}} \times \frac{\text{Vehicle Volume}}{\text{Vehicle Occupancy}} \times \frac{\text{hour}}{60 \text{ minutes}}]</td>
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<table>
<thead>
<tr>
<th>Texas Congestion Index(^2)</th>
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<tbody>
<tr>
<td>[\text{Texas Congestion Index} = \frac{\text{Actual Travel Time}}{\text{Free-Flow Travel Time}}^{3}]</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>AREA MOBILITY MEASURES(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Segment Delay (person - minutes)</td>
</tr>
<tr>
<td>[\text{Total Segment Delay} = \frac{\text{Actual Travel Time}}{\text{Free-Flow Travel Time}}^{4} \times \frac{\text{Vehicle Volume}}{\text{Vehicle Occupancy}} \times \frac{\text{(persons/vehicle)}}{\text{(minutes)}}]</td>
</tr>
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<table>
<thead>
<tr>
<th>Congested Time</th>
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</thead>
<tbody>
<tr>
<td>Defined as any 15-minute period with a speed less than 80% of the arterial free-flow speed or 90% of freeway free-flow speed.</td>
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</table>

<table>
<thead>
<tr>
<th>Congestion Cost</th>
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<tbody>
<tr>
<td>[\text{Annual Passenger Vehicle Delay Cost} = \frac{\text{Annual Passenger Vehicle Hours of Delay}}{\text{Value of Delay}} \times \frac{\text{Person Time}}{\text{Occupancy}} \times \frac{\text{($21/hr)}}{\text{(pers/vehicle)}}]</td>
</tr>
</tbody>
</table>

\(^1\)“Individual” measures are those measures that relate best to the individual traveler, whereas the “area” mobility measures are more applicable beyond the individual (e.g., corridor, area, or region). Some individual measures are useful at the area level when weighted by PMT (Passenger Miles Traveled) or VMT (Vehicles Miles Traveled).

\(^2\)Can be computed as a weighted average of all sections using VMT or PMT.

\(^3\)Computed as the 85\textsuperscript{th} percentile speed of low-volume conditions (e.g., 10 p.m. to 5 a.m.)

CONCLUSION

The Texas Transportation Institute has been producing traffic congestion estimates for many years. Until recently, these congestion estimates relied heavily on traffic counts and assumptions on how various levels of traffic performed in order to complete the calculations. As more travel speed data has become available in recent years, the assumptions made to produce the congestion estimates have become more focused on the traffic counts and how to estimate the appropriate traffic volumes to associate with the disaggregated speed data. TTI has developed a method to estimate traffic volume information (whether hourly or based on 15-minute time periods) to match with detailed speed data to produce extremely detailed traffic congestion estimates. The improvements in both data sources and analytic methods facilitate a more granular examination of congestion, providing focus for policy-makers in a time of limited resources. For the past two years, this method has helped TxDOT and TTI produce a list of the 100 most congested roadway segments in Texas.

REFERENCES

1. Texas 100 Most Congested Roadway Segments. Texas Department of Transportation (http://apps.dot.state.tx.us/apps/top_100/)


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