Estimating Urban Freight Congestion Costs: Methodologies, Measures, and Applications

by

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Submitted for presentation and publication for the
Transportation Research Board's 92nd Annual Meeting
January 2013
Washington, D.C.

Word Total = 4,821 (words) + (5 tables x 250 words/table = 1,250) + (4 figures x 250 words/table = 1,000) = 7,071 words

ABSTRACT

Congestion is a significant problem in America's 439 urban areas. According to the Texas A&M Transportation Institute's *2011 Urban Mobility Report (UMR)*, 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 (*1*). The *UMR* informs decision-making at the federal, state, and local levels. In 2011, the Texas A&M Transportation Institute released the inaugural *Congested Corridors Report* (*2*), which produces congestion statistics for the 328 most congested directional corridors in the United States. With the documented growth in freight shipments, particularly in the trucking sector, researchers were interested in developing methodologies and measures to help inform policy-makers and decision-makers characterize the impacts of congestion on urban. These methodologies and measures were developed and incorporated into the *UMR* and *CCR*.

The methodologies use inventory data from the Federal Highway Administration's (FHWA's) Highway Performance Monitoring System (HPMS) and historical speed data from INRIX® to estimate wasted time (delay in person-hours) and diesel fuel (gallons wasted), as well as the associated costs for trucks in urban congestion.

The results and rankings appear intuitive, and this information provides an important dimension to these reports for characterizing congestion levels in urban areas and along congested corridors in America. This information will help to inform trucking stakeholders by quantifying the congestion impact to the trucking community. Researchers will continue to include truck delay, wasted fuel, and associated costs for urban area trucks in future releases of the *UMR* and *CCR*.

INTRODUCTION

Congestion is a significant problem in America's 439 urban areas. According to the Texas A&M Transportation Institute's *2011 Urban Mobility Report (UMR)*, 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 (*1*). The *UMR* informs decision-making at the federal, state, and local levels for infrastructure decision-making. In 2011, the Texas A&M Transportation Institute released the inaugural *Congested Corridors Report* (*2*), which produces congestion statistics for the 328 most congested directional corridors in the U.S. Roadway congestion certainly impacts both commuters and goods movement; therefore, researchers developed methodologies and methods to estimate delay, wasted fuel and associated costs of urban congestion on trucks in both the *Urban Mobility Report* and the *Congested Corridors Report.*

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. Goods are delivered to retail and commercial stores by trucks that are affected by congestion. Traffic congestion at any time of day causes potentially costly disruptions. An improved understanding of congestion's impact on trucks on urban streets and highways in the United States can assist stakeholders in quantifying the problem and telling the freight "story" to interested stakeholders and decision-makers.

With the documented growth in freight shipments, particularly in the trucking sector, researchers were interested in developing methodologies and measures to help inform policy-makers and decision-makers about the impacts of congestion on urban trucking. There is a need for urban truck congestion methods and measures for use at both the areawide level and the individual roadway level. This information will help to inform trucking stakeholders by quantifying the congestion impact on the trucking community.

RESEARCH OBJECTIVES

Based on the need for information to better understand the extent of urban truck congestion impacts with measures such as urban freight delay, wasted fuel, and associated costs, researchers performed research with the following objectives:

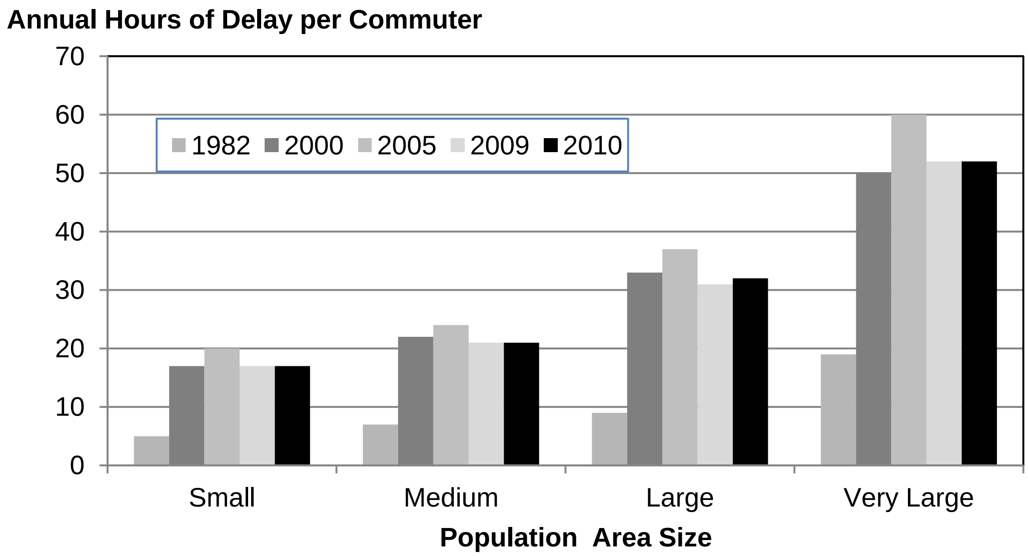
1. Develop a methodology and measures to use at the urban area level, and apply them to the Texas A&M Transportation Institute's *Urban Mobility Report (UMR),* and
2. Develop a methodology and measures to use at the corridor level, and apply them to the Texas A&M Transportation Institute's *Congested Corridor Report (CCR).*

BACKGROUND

TTI's *Urban Mobility Report* and *Congested Corridors Report*

Figure 1 shows the generally-increasing congestion trends in terms of the hours of delay per commuter for selected years from 1982 to 2010 as published in the 2011 *UMR*. The recent decline in congestion brought on by the economic recession has only provided a temporary respite from the growing congestion problem. As the economy recovers, so will traffic congestion. In previous regional recessions, once employment began a sustained, significant growth period, congestion increased as well.

Historically, the *UMR* has focused on passenger-car congestion (i.e., the average commuter). However, there are frequent questions about the impact of congestion on freight. Traffic congestion certainly impacts both commuters and goods movement albeit in differing economic and time valuations. With increased scrutiny and limited budgets facing public sector transportation officials, this type of information can assist project selection processes. For these reasons, researchers were interested in characterizing and including the amount of delay, wasted fuel, and associated truck costs into the *UMR.*



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

FIGURE 1 Congestion Trends (Adapted from Reference *1*).

TTI's *Congested Corridors Report* includes analysis along 328 specific (directional) freeway corridors in the United States. Whereas the *UMR* focuses on the congestion problem at the areawide level, the *CCR* focuses on specific corridors. The corridors include many of the worst places for congestion in the U.S., and the detailed data allow for more extensive analyses and a better picture of the locations, times and effects of stop-and-go traffic. Because congestion affects both passenger cars and trucks, researchers incorporated the delay, wasted fuel and associated costs of congestion on trucks in the inaugural *CCR*. The methods and measures are the subject of this paper.

It is also important to distinguish between urban freight and urban passenger car travel for system monitoring, system evaluation, and project selection because characteristics of travel differ, especially regarding congestion location and timing and the value of delay time. As one example, previous research found that travel times of commercial vehicles were nearly eight percent higher than vehicles in the traffic stream instrumented with toll tags (i.e., the general traffic stream) under free-flow conditions and six percent higher during congested conditions (i.e., speeds less than 30 mph) (*3,4*). The study was along an approximately two-mile corridor in Houston, and it is possible that over longer distances these differences could present more significant trucking problems (e.g., just-in-time operations). The researchers postulate that the increased travel time is due to slower starts, more difficulty changing lanes in heavier volumes, and more frequent lane restrictions in the urban area – either by policy and regulation or by routing needs.

Conceptualizing Freight for Investment Decisions

Researchers found that few analytical techniques fully incorporate freight aspects into transportation system monitoring, system evaluation, and project selection. Therefore, to give context to the truck delay and fuel cost methodology for incorporation into the *Urban Mobility*

Report, and to better understand general freight mobility and reliability issues, TTI researchers developed and tested a conceptual framework to help transportation professionals communicate, visualize, and understand factors that affect freight mobility and reliability (*5*). The analytical framework was needed to allow mobility and reliability of freight travel to be placed on equal footing with passenger travel for investment decision-making. Frequently, transportation decisions are made on the basis of typical performance measures of travel time and delay for passenger travel, and little, if any, attempt is made to incorporate goods movement into such analysis.

Figure 2 shows the previously-developed framework. The proposed framework in Figure 2 is applicable to all modes of freight (e.g., truck, rail, water, air, pipeline). The trucking mode is the focus of this paper, and it is shown by "Truck Type" in Figure 2. The three axes of the relationship for trucks are geographic area, commodity type, and time period. These axes directly relate to, and visually illustrate, the three critical issues under consideration: where is the study area?; what type of trucks are of interest?; and what are the time periods of interest?

As illustrated in Figure 2, each smaller cube within the box contains mobility information and reliability information by geographic area, commodity type, and time period for trucking operations. Note that the travel time index and buffer index mentioned in Figure 2 are typical measures to estimate average mobility (travel time index) and reliability (buffer index). More information on these measures can be found elsewhere (*2,6*). Each geographic area of interest would have its box populated with target cubes that incorporate local goals and establish targets for the mobility and reliability performance measures. In concept, there would also be a freight box of observed cubes for each geographic area of interest. This cube would include field observation of trucking mobility and reliability. The two boxes (target and observed) could then be compared to identify where operation is satisfactory or unsatisfactory.

Much more information about the geographic scalability and application of the framework for all freight modes, including trucking, is documented elsewhere (*5*). Clearly, the framework provides a method to visualize the temporal and spatial characteristics of freight movement to better guide decision-making. The methodology described in a later section of this paper identifies how freight value elements using the FAF data can be used to populate the commodity axis of the freight box for performance monitoring.

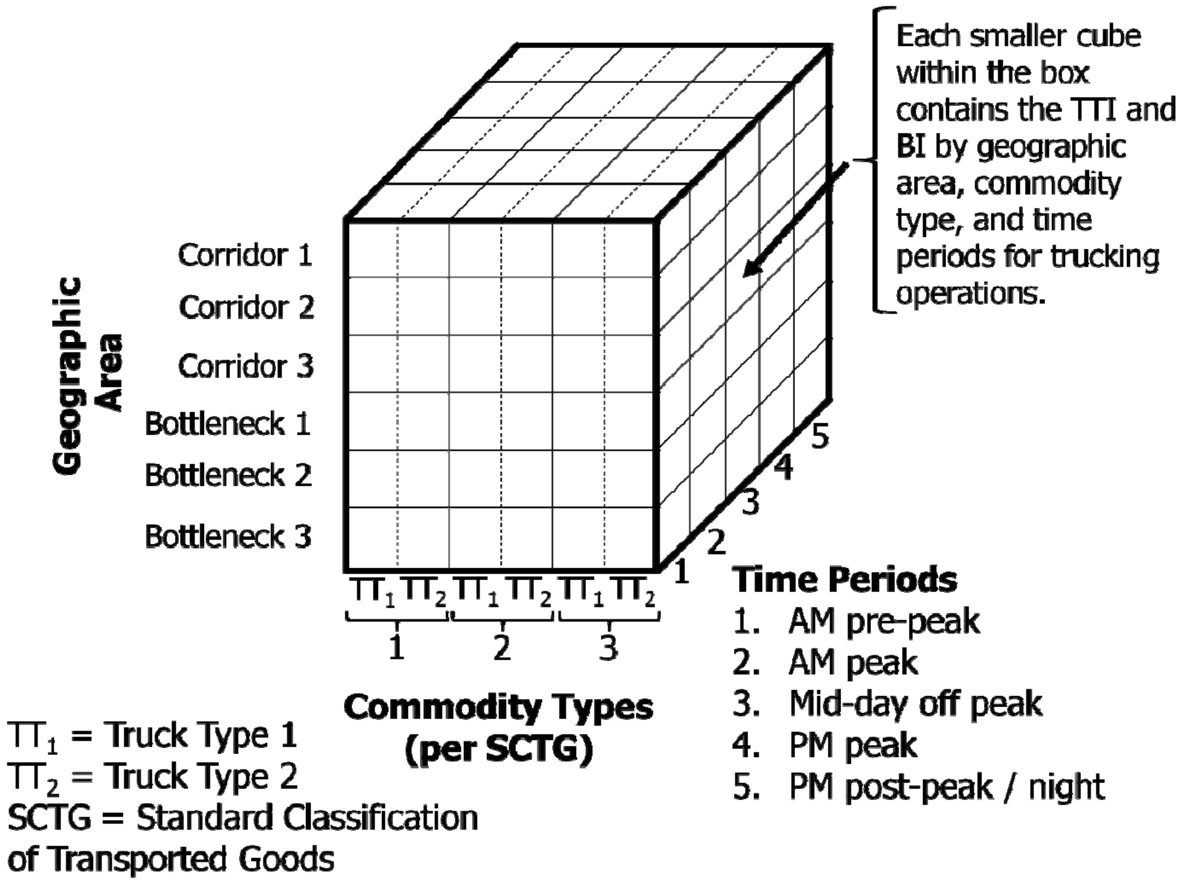


FIGURE 2 Freight Box Conceptual Framework Applied to Trucks (Adapted from Reference *5*).

Freight Growth

Freight transportation is growing. Figure 3 shows the value of shipments in billions of 2007 dollars, the baseline for the FAF forecasts. The value of shipments in 2010 and 2040 are shown in Figure 3. Trucking is the predominant transportation mode for freight shipments, and it accounts for 65 percent of shipment value in 2010 and 55 percent of shipment value in 2040. A 107 percent increase in shipment value is forecast for trucking and a 145 percent growth for all modes combined from 2010 to 2040. These projections are based on modest economic growth in the time period presented. Should economic growth substantially exceed these projects, the growth in truck freight would be expected to increase at a higher rate than the other modes.

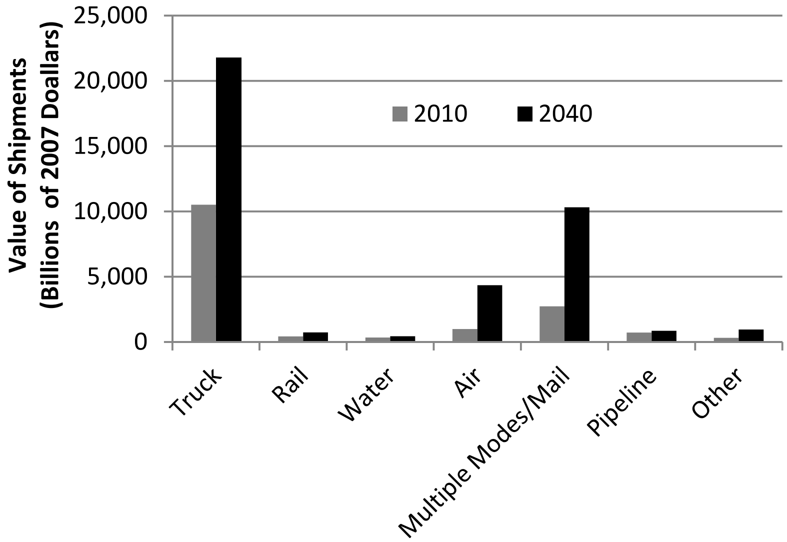


FIGURE 3 Value of Shipments by Transportation Mode (Adapted from Reference *7,8*).

Delay Performance Measures

Total delay in person-hours has been successfully used in the *Urban Mobility Report* for years to represent the magnitude of congestion. *The Keys to Estimating Mobility in Urban Areas* describes the importance and application of this measure in mobility analyses (*6*). Total delay is the sum of time lost due to congestion. Delay is typically expressed as a value relative to free-flow conditions. Total delay in an urban corridor is calculated as the sum of individual segment delays. This quantity is used as an estimate of the impact of improvements on transportation systems.

The values can be used to illustrate the effect of major improvements to one portion of a corridor that affects several other elements of the corridor. The quantity is particularly useful in economic or benefit/cost analyses that use information about the magnitude of the mobility improvements for cost-effectiveness decisions. While total delay is a valuable measure for urban area analyses, delay per mile of road is more meaningful for analyses of multiple corridors.

Incorporating Urban Truck Delay, Wasted Fuel, and Associated Congestion Costs

There is remarkable growth in value of shipments projected for all modes of travel including trucking. In 2010, trucking was the largest freight mode according to the latest figures from the Federal Highway Administration. Trucked value of goods is expected to more than double by 2040. Given the growth in all freight shipments, especially trucking, there is a need to better understand freight mobility and reliability issues.

Given these growth estimates, strong investment in freight infrastructure is needed to keep pace with growing demand. To provide a complete picture of the impact of congestion, performance monitoring must incorporate delay impacts and estimates for trucks separate from passenger cars. As shown by the work in Houston, Texas (*3,4*), the extent of the delay is not the same for urban trucks and passenger cars. The methodologies and applications discussed in this paper provide methods and measures to estimate the delay impacts of congestion and associated wasted time and fuel costs on trucks separate from passenger cars. This information is useful for telling the urban "trucking story" by quantifying truck delay in an urban area or along a specific corridor.

DATA SOURCES, METHODOLOGY, AND MEASURES

This section of the paper describes the methodologies and data sources to incorporate delay, wasted fuel and associated congestion costs for urban trucks into the *Urban Mobility Report (UMR)* and the *Congested Corridors Report (CCR).* Below are abbreviated versions of the methodologies and the interested reader can obtain more details elsewhere (*1*,*2*). Note that the methodology is first presented for the *UMR*, which is for areawide congestion statistics, and then the corridor-level methodology for the *CCR* is presented, which follows very closely to the computations for the *UMR* – the only difference being the geographic scale of the analysis.

Urban Mobility Report Methodology - Congestion Measure Calculations

The *Urban Mobility Report* congestion measure calculation procedure 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 hour of each day for a total of 168 day/time period cells (24 hours x 7 days). 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 are used to identify the free-flow speeds that are used as a comparison standard; *low-volume speeds on each road section are used as the comparison standard.*
- The volume and roadway inventory data from FHWA's Highway Performance Monitoring System (HPMS) (*9*) 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.*

The following general steps are 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

These steps are described elsewhere in much greater detail (*1*). The discussion that follows describes key national constants and urban area variables used in the analysis. Additional discussion provides a description of the applicable performance measures, including the urban truck freight delay, wasted diesel fuel, and associated costs due to congestion.

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 INRIX traffic speed data provide an excellent source for the first two inputs, actual and free-flow travel time. The *UMR* requires 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 is performed to assign traffic speed data to each HPMS road section for the purposes of calculating the performance measures. When INRIX traffic speed data are not available for sections of road or times of day in urban areas, the speeds are estimated.

National Constants

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

TABLE 1 National Congestion Constants for *2011 Urban Mobility Report* (Adapted from Reference *1*)

Constant	Value
Vehicle Occupancy	1.25 persons per vehicle
Average Cost of Time ($2010) (*10*)	$16.30 per person hour[1]
Commercial Vehicle Operating Cost ($2010) *(11)*	$88.12 per vehicle hour[1,2]
Working Days (5x50)	250 days[3]
Total Travel Days (7x52)	364 days

[1]Adjusted annually using the Consumer Price Index.
[2]Adjusted periodically using industry cost and logistics data.
[3]250 days per year (5 days per week x 50 weeks per year) are used to represent the "typical" work days (i.e., removing holidays).

Urban Area Variables

In addition to the national constants in Table 1, 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 is 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) (*12*,*13*). Estimates of peak period travelers are derived from the National Household Travel Survey (NHTS) (*14*) 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 were 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) (*15*). 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 (*12*). The values are used to estimate truck travel delay and congestion costs and are not used to adjust roadway capacity estimates.

Performance Measure Calculation Descriptions

The major calculations of the *UMR* methodology are described in this section of the paper.

Travel Delay Most of the basic performance measures presented in the *UMR* are developed in the process of calculating travel delay—the amount of extra time spent traveling due to congestion. The INRIX speed data reflect 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 as shown in Equation 1. Depending on the application, the delay can be aggregated into summaries such as weekday peak period, weekend, weekday off-peak period, etc.

$$\begin{matrix}\text{Daily Vehicle-Hours}\\\text{of Delay}\end{matrix} = \left(\frac{\begin{matrix}\text{DailyVehicle-Miles}\\\text{of Travel}\end{matrix}}{\text{Speed}}\right) - \left(\frac{\begin{matrix}\text{DailyVehicle-Miles}\\\text{of Travel}\end{matrix}}{\text{Free-Flow Speed}}\right) \qquad \text{(Equation 1)}$$

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, researchers multiply each day-of-the-week delay estimate by the average vehicle occupancy (1.25 persons per vehicle) and by 52 working weeks per year (Equation 2).

$$\begin{matrix}\text{Annual}\\\text{Persons-Hours}\\\text{of Delay}\end{matrix} = \sum_{i=1}^{7\text{ Days}} \left(\begin{matrix}\text{Daily Vehicle-Hours}\\\text{of Delay on}\\\text{Freeways}\end{matrix} \times \begin{matrix}\text{52 Work}\\\text{Weeks}\end{matrix} \times \begin{matrix}\text{1.25 Persons}\\\text{per Vehicle}\end{matrix}\right) \qquad \text{(Equation 2)}$$

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 *UMR* applies estimates of the number of people and trip departure times during the morning and evening peak periods from the National Household Travel Survey (*14*) to the urban area population estimate to derive the average number of auto commuters and number of travelers during the peak periods (*16*).

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 3 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.

$$\text{Delay per Auto Commuter} = \left(\frac{\text{Peak Period Delay}}{\text{Auto Commuters}}\right) + \left(\frac{\text{Remaining Delay}}{\text{Population}}\right) \qquad \text{(Equation 3)}$$

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 4 and 5 are the regression equations resulting from fuel efficiency data from EPA/FHWA's MOVES model (*17*).

$$\text{Passenger Car Fuel Economy} = -0.0066 \times (\text{speed})^2 + 0.823 \times (\text{speed}) + 6.1577 \qquad \text{(Equation 4)}$$

$$\text{Truck Fuel Economy} = 1.4898 \text{ x In(speed)} - 0.2554 \qquad \text{(Equation 5)}$$

Researchers calculate the wasted fuel due to vehicles moving at speeds slower than free-flow throughout the day. Equation 6 is used to calculate the fuel wasted in delay conditions from Equation 2, the average hourly speed, and the average fuel economy associated with the hourly speed (Equations 4 and 5).

$$\text{Annual Fuel Wasted} = \text{Travel Time (vehicle hours)} \times \text{Average Hourly Speed (Equation 1)} \div \text{Average Fuel Economy (Equations 4-5)} \times \text{Annual Conversion Factor} \qquad \text{(Equation 6)}$$

Equation 7 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 8 is used to estimate the annual fuel wasted in congestion.

$$\text{Annual Fuel Consumed in Free-Flow Conditions} = \text{Travel Time} \times \text{Free-Flow Speed from INRIX Data} \div \text{Average Fuel Economy for Free-Flow Speeds} \times \text{Annual Conversion Factor} \qquad \text{(Eq. 7)}$$

$$\text{Annual Fuel Wasted in Congestion} = \text{Annual Fuel Consumed in Congestion} - \text{Annual Fuel That Would be Consumed in Free-flow Conditions} \qquad \text{(Equation 8)}$$

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 9 through 13 show how researchers 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 of passenger vehicles in congestion. Equation 9 shows the calculation of passenger vehicle delay costs that result from lost time.

$$\text{Annual Psgr-Veh Delay Cost} = \text{Daily Psgr Vehicle Hours of Delay (Equation 3)} \times \text{Value of Person Time (\$ / hour)} \times \text{Vehicle Occupancy (pers/vehicle)} \times \text{Annual Conversion Factor} \qquad \text{(Equation 9)}$$

Passenger Vehicle Fuel Cost Fuel cost due to congestion is calculated for passenger vehicles in Equation 10. This is done by associating the wasted fuel, the percentage of the vehicle mix that is passenger, and the fuel costs.

$$\text{Annual Fuel Cost} = \text{Daily Fuel Wasted (Equation 8)} \times \text{Percent of Passenger Vehicles} \times \text{Gasoline Cost} \times \text{Annual Conversion Factor} \qquad \text{(Equation 10)}$$

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 11 shows how to calculate the commercial vehicle delay costs that result from lost time.

$$\text{Annual Comm-Veh Delay Cost} = \text{Daily Comm Vehicle Hours of Delay (Equation 3)} \times \text{Value of Comm Vehicle Time (\$ / hour)} \times \text{Annual Conversion Factor} \qquad \text{(Equation 11)}$$

Truck or Commercial Vehicle Fuel Cost Fuel cost due to congestion is calculated for commercial vehicles in Equation 12. This is done by associating the wasted fuel, the percentage of the vehicle mix that is commercial, and the fuel costs.

$$\text{Annual Fuel Cost} = \text{Daily Fuel Wasted (Eq. 8)} \times \text{Percent of Commercial Vehicles} \times \text{Diesel Cost} \times \text{Annual Conversion Factor} \qquad \text{(Equation 12)}$$

Total Congestion Cost Equation 13 combines the cost due to travel delay and wasted fuel to determine the annual cost due to congestion resulting from incident and recurring delay.

$$\begin{matrix}\text{Annual Cost}\\ \text{Due to}\\ \text{Congestion}\end{matrix} = \left(\begin{matrix}\text{Annual Passenger}\\ \text{Vehicle Delay Cost}\\ \text{(Eq. 9)}\end{matrix} + \begin{matrix}\text{Annual Passenger}\\ \text{Fuel Cost}\\ \text{(Eq. 10)}\end{matrix}\right) + \begin{matrix}\text{Annual Comm}\\ \text{Veh Delay Cost}\\ \text{(Eq. 11)}\end{matrix} + \begin{matrix}\text{Annual Comm}\\ \text{Veh Fuel Cost}\\ \text{(Eq. 12)}\end{matrix} \qquad \text{(Eq. 13)}$$

Congested Corridors Report Methodology - Congestion Measure Calculations

The *2011 Congested Corridors Report* includes analysis along 328 specific (directional) freeway corridors in the United States. Whereas the *UMR* focuses on the congestion problem at the urban area-level, the *CCR* focuses on specific corridors. The corridors include many of the worst places for congestion in the United States, and the detailed data allow for more extensive analysis and a better picture of the locations, times and effects of stop-and-go traffic. The report does not list every bad location for congestion, but the issues explored in the report advance the understanding of when, how and where congestion occurs.

In the *Congested Corridors Report*, researchers investigated all freeways in the United States. As first explored in the *2010 INRIX National Traffic Scorecard* (*18*), a short directional roadway segment (less than one mile) with congestion for more than 10 hours in a week was designated as the beginning of a congested corridor. ("Congestion" was having a speed less than half of the free-flow speed). Each directional, adjacent and upstream segment of roadway that was congested for four hours per week was included in the corridor. Four hours was chosen as the threshold after reviewing the data, which showed that many upstream segments had some congestion nearly every weekday. Since it typically did not constitute every day of the week, choosing four hours allows one day per week to have a different queuing pattern. A minimum corridor length was set at three miles. This resulted in 328 directional freeway corridors. Researchers combined traffic volume information from the states with the INRIX-derived speed data to compute the performance measures along these corridors.

The equations and mathematical steps shown previously for the *UMR* methodology were also used for corridors in the *CCR*. Ultimately, the delay values in person-hours are not reported as "total delay" as in the *UMR*, but as "delay per mile" because the corridors in the *CCR* are of different lengths.

RESULTS AND DISCUSSION

2011 Urban Mobility Report

This section presents and describes key findings from the 2011 *Urban Mobility Report* as they relate to urban trucks and the methodology presented in this paper. Figure 4 shows that while trucks account for only about six percent of the miles traveled in urban areas, they are almost 26 percent of the urban "congestion invoice" (i.e., the cost for wasted time and fuel due to congestion). In addition, the cost in Figure 4 only includes the cost to operate the truck in heavy traffic; the extra cost of the commodities and other business practice and investment changes caused by serious congestion are not included. The cost also does not include incurred costs/penalties due to late shipments.

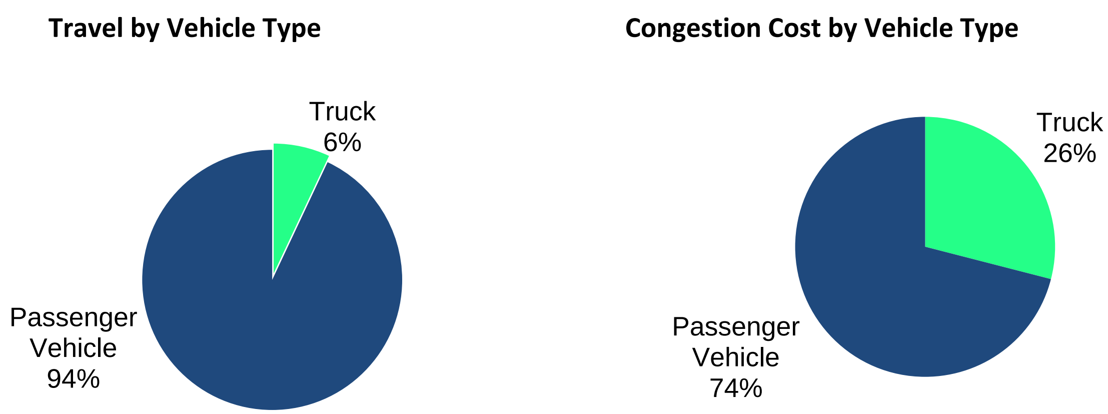


FIGURE 4 2010 Congested Cost for Urban Passenger and Freight Vehicles (Adapted from Reference *1*).

Table 2 shows the total and truck-only delay as presented in the *2011 Urban Mobility Report* for the "very large" urban areas – those with over three million in population. The results show that those areas with the highest total delay also have the highest truck delay and associated congestion cost. The congestion cost in Table 2 includes both wasted time and wasted diesel fuel while stuck in congestion. Similar tables are shown in the *UMR* for cities in all population ranges.

TABLE 2 Total and Truck Delay, 2010
(Adapted from Reference *1*)

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

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—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.
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

2011 Congested Corridors Report

The 2011 *Congested Corridors Report* found that the 328 directional corridors account for 33 percent of the urban freeway truck delay with only eight percent of the national urban freeway truck vehicle-miles of travel.

Researchers produced several tabular groupings to show that the corridors in the study have different peaking characteristics. For example, some corridors have a greater proportion of their daily delay in the morning peak period, while others have more delay occurring on the weekend. This paper only discusses the grouping from the *2011 CCR* of where the biggest truck delay was found. The interested reader can review results of other groupings in the full report (*2*).

Delay per mile is the primary ranking measure because the corridors in this analysis vary a great deal in length. This measure allows corridors of different lengths to be compared because this measure focuses on the intensity of the delay. The magnitude of the congestion problems in each corridor are further described with the total gallons of wasted fuel and the total congestion cost. Table 3 shows the delay per mile, wasted fuel, and congestion cost for the truck travel in the corridors that ranked highest for truck delay. Key findings of this table include:

- The northbound Harbor Freeway in Los Angeles between I-10 and Stadium Way has the most truck delay per mile at just under 100,000 hours per mile in 2010.
- The US-101 southbound in Los Angeles between Ventura Boulevard and Vignes Street ranked first for wasted diesel by trucks with over 1.5 million gallons.
- The Riverside Freeway (CA-91) eastbound in Los Angeles between CA-55 and McKinley Street ranked number one for truck congestion cost at over $67 million in 2010.
- The Los Angeles area had 16 corridors ranked in the top 40 for truck delay. New York had the second most corridors ranked for truck delay with nine, while Chicago was third with four corridors. Each of these regions has significant truck traffic due to large populations and proximity to ports and intermodal facilities.
- Significant truck congestion was not limited to corridors in the largest metropolitan regions. For example, Baton Rouge with eastbound I-12 and Austin with both northbound and southbound I-35 were included in the top 40 corridors.

TABLE 3 2010 All-Day Everyday Truck Congestion Leaders (Top 40) (Adapted from Reference *2*)

Urban Area	Corridor	Corridor Endpoints From To	Corridor Length (miles)	2010 All-day Everyday Truck Congestion					
				Delay Per Mile		Wasted Fuel		Congestion Cost	
				Person-hrs (x 1000)	Rank	Gallons (x 1000)	Rank	(x $1000)	Rank
Los Angeles	Harbor Fwy/CA-110 NB	I-10/Santa Monica Fwy Stadium Way/Exit 24C	3.1	98	1	469	34	22,655	33
Los Angeles	Harbor Fwy/I-110 NB	111th Pl I-110/I-10/Santa Monica Fwy	6.5	76	2	806	16	37,507	16
Los Angeles	San Diego Fwy/I-405 NB	I-105/Imperial Hwy Getty Center Dr	13.1	64	3	1,340	3	63,503	3
New York	Van Wyck Expy/I-678 NB	Belt Pkwy/Exit 1 Main St/Exit 8	3.1	52	4	244	78	12,200	65
New York	I-278 EB (Gowanus Expy/Brooklyn Queens)	92nd St/Exit 17 Apollo St/Meeker Ave/Exit 34	11.6	46	5	827	15	40,450	12
Los Angeles	San Gabriel River Fwy/I-605 SB	Beverly Blvd Florence Ave	4.8	45	6	365	50	16,435	49
Los Angeles	Riverside Fwy/CA-91 EB	CA-55/Costa Mesa Fwy McKinley St	20.7	43	7	1,485	2	67,672	1
New York	I-278 WB (Brooklyn Queens/Gowanus Expy)	NY-25A/Northern Blvd/Exit 41 NY-27/Prospect Expy/Exit 24	10.2	43	7	681	19	33,105	18
Los Angeles	Santa Monica Fwy/I-10 EB	CA-1/Lincoln Blvd/Exit 1B Alameda St	14.9	42	9	1,075	9	47,961	9
Los Angeles	Santa Monica Fwy/I-10 WB	I-5/Golden State Fwy National Blvd	12.6	42	9	893	12	39,895	13
Chicago	Stevenson Expy/I-55 SB	State St/Exit 293C Pulaski Rd/Exit 287	5.7	42	9	385	44	18,063	43
Chicago	Eisenhower Expy/I-290 WB	S Ashland Ave/Exit 28B 9th Ave/Exit 19B	8.9	40	12	606	25	26,869	24
New York	Van Wyck Expy/I-678 SB	Horace Harding Expy/Exit 12A Linden Blvd/Exit 3	6.2	40	12	377	47	18,496	38
Pittsburgh	Penn Lincoln Pkwy/I-376 EB	Lydia St/Exit 2 US-19 TK RT/PA-51/Exit 5	3.4	40	12	209	97	10,241	81

Delay Per Mile—Extra travel time during the year due to congestion, divided by the corridor length. Wasted Fuel—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 for person travel and $88 per hour for truck time) and excess fuel consumption (estimated using state average cost per gallon of gasoline and diesel). Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference between (for example) 5th and 10th. The actual measure values should also be examined.

TABLE 3 2010 All-Day Everyday Truck Congestion Leaders (Top 40) (Adapted from Reference *2*), Continued

Urban Area	Corridor	Corridor Endpoints From To	Corridor Length (miles)	2010 All-day Everyday Truck Congestion: Delay Per Mile Person-hrs (x 1000)	Delay Per Mile Rank	Wasted Fuel Gallons (x 1000)	Wasted Fuel Rank	Congestion Cost (x $1000)	Congestion Cost Rank
Austin	I-35 SB	US-183/Exit 239-240 Woodland Ave	6.7	38	15	397	40	19,202	37
Baton Rouge	I-12 EB	Essen Ln O'Neal Ln	5.8	38	15	343	52	16,632	47
Austin	I-35 NB	Shelby Ln/St Elmo Rd/Exit 230 Martin Luther King Blvd/19th St/Exit 235	4.7	38	15	293	61	13,596	57
Los Angeles	I-110 SB	W Vernon Ave 51st St	2.5	38	15	167	126	7,206	127
Chicago	Eisenhower Expy/I-290 EB	IL-72/Higgins Rd/Exit 1 Austin Blvd/Exit 23A	21.5	36	19	1,340	3	59,182	4
Chicago	I-90/I-94 EB (Kennedy/Dan Ryan Expys)	I-294/Tri State Tollway Ruble St/Exit 52B	15.9	36	19	903	11	42,869	11
New York	Major Deegan Expy/I-87 NB	I-278/Bruckner Expy I-95/Cross Bronx Expy/Exit 7	4.1	36	19	232	84	11,249	74
Los Angeles	I-5 SB (Santa Ana/Golden St Fwys)	East Cesar Chavez Ave Valley View Ave	17.5	35	22	1,017	10	46,126	10
New York	I-95 SB (NE Thwy, Bruckner/Cross Bronx Expys)	Conner St/Exit 13 Hudson Ter	22.7	34	23	1,153	8	57,540	5
Los Angeles	US-101 NB (Santa Ana/Hollywood Fwys)	I-5/CA-60 Haskell Ave	21.5	34	23	1,223	6	55,039	7
Philadelphia	Schuylkill Expy/I-76 WB	Oregon Ave/Passyunk Ave/Exit347 Belmont Ave/Exit 338	9.5	34	23	545	30	24,557	29
Los Angeles	CA-110 SB (Pasadena/Harbor Fwys)	Avenue 60 Olympic Blvd/9th St	6.6	34	23	375	48	17,134	45
Los Angeles	I-5 NB (Santa Ana/Golden St Fwys)	CA-39/Beach Blvd Riverside Dr	22.5	33	27	1,256	5	56,422	6
Boston	Southeast Expy/I-93 NB	MA-28/Randolph Ave/Exit 5 Columbia Rd/Exit 15	10.4	33	27	569	28	26,031	26
San Francisco	Grove Shafter Fwy/CA-24 WB	Saint Stephens Dr Caldecott Tunnel	3.5	33	27	181	115	8,815	103

<u>Delay Per Mile</u>—Extra travel time during the year due to congestion, divided by the corridor length. <u>Wasted Fuel</u>—Increased fuel consumption due to travel in congested conditions rather than free-flow conditions. <u>Congestion Cost</u>—Value of travel time delay (estimated at $16 per hour for person travel and $88 per hour for truck time) and excess fuel consumption (estimated using state average cost per gallon of gasoline and diesel). <u>Note</u>: Please do not place too much emphasis on small differences in the rankings. There may be little difference between (for example) 5th and 10th. The actual measure values should also be examined.

TABLE 3 2010 All-Day Everyday Truck Congestion Leaders (Top 40) (Adapted from Reference *2*), Continued

Urban Area	Corridor	Corridor Endpoints From To	Corridor Length (miles)	2010 All-day Everyday Truck Congestion: Delay Per Mile		Wasted Fuel		Congestion Cost	
				Person-hrs (x 1000)	Rank	Gallons (x 1000)	Rank	(x $1000)	Rank
Los Angeles	US-101 SB (Ventura/Hollywood Fwys)	Ventura Blvd/Shoup Ave Vignes St/Exit 2B	26.7	32	30	1,513	1	66,000	2
New York	Long Island Expy/I-495 EB	Maurice Ave/Exit 18 Mineola Ave/Willis Ave/Exit 37	16.0	32	30	855	14	39,269	14
Los Angeles	San Bernadino Fwy/I-10 EB	City Terrace Dr/Herbert Ave Baldwin Park Blvd	12.8	32	30	662	21	30,872	19
New York	Goethals Brg EB/I-278 EB	Meeker Ave/Forest Ave/Exit 4 Bradley Ave/Exit 11	3.3	32	30	169	124	7,946	117
Los Angeles	San Diego Fwy/I-405 NB	MacArthur Blvd Brookhurst St	7.8	31	34	416	38	18,489	39
Houston	N Loop W Fwy/I-610 EB	US-290 Yale St	4.0	31	34	216	92	9,446	95
San Francisco	I-80 EB (James Lick Fwy/Bay Brdg)	US-101 Treasure Island Rd	3.6	31	34	171	122	8,256	111
Seattle	I-5 SB	WA-523/145th St/Exit 175 Union St/Exit 165	9.0	30	37	469	34	20,537	35
Atlanta	I-285 EB	Riverside Dr/Exit 24 I-85/Exit 33	9.1	30	37	461	36	20,503	36
Los Angeles	San Diego Fwy/I-405 SB	Nordhoff St Mulholland Dr	8.1	30	37	382	46	18,151	42
New York	Major Deegan Expy SB	Van Cortlandt Park/Exit 11 I-95/Cross Bronx Expy/Exit 7	3.5	30	37	172	121	8,035	116
New York	I-95 NB (Cross Bronx/Bruckner Expys)	I-80/NJ Tpke Pelham Pkwy/Exit 8	11.5	29	41	538	31	25,256	27
New York	I-278 WB	New York Ave Slosson Ave/Exit 12	3.2	29	41	145	137	6,853	132

Delay Per Mile—Extra travel time during the year due to congestion, divided by the corridor length. Wasted Fuel—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 for person travel and $88 per hour for truck time) and excess fuel consumption (estimated using state average cost per gallon of gasoline and diesel). Note: Please do not place too much emphasis on small differences in the rankings. There may be little difference between (for example) 5th and 10th. The actual measure values should also be examined.

CONCLUSIONS

In this paper researchers document the development and application of measures and methodologies to inform policy-makers and decision-makers about the impacts of congestion on urban trucking. To help tell the "urban truck story," methods and measures for use at both the areawide level and the individual roadway level were developed to quantify the amount of wasted time and fuel and associated costs for truckers. This information will help to inform trucking stakeholders by quantifying the congestion impact to the trucking community. This information can be used to characterize the magnitude of congestion's impact on urban areas in the United States.

Researchers developed a methodology for areawide truck travel delay and congestion costs for inclusion in the *Urban Mobility Report*. Researchers also document a methodology for travel delay and congestion costs for specific corridors and share results from applying the methodology in the inaugural *2011 Congested Corridors Report*. The methodology uses volume and inventory data from FHWA's HPMS and speed data provided by INRIX.

The results in both the *UMR* and *CCR* appear intuitive and these truck statistics provide another dimension to the *UMR* and *CCR* to inform policy-makers and decision-makers related to truck delay and cost information due to congestion. This information helps to characterize the magnitude of congestion's impact on urban areas in the United States. Researchers will continue to include these truck statistics in future releases of the *Urban Mobility Report* and *Congested Corridors Report*.

ACKNOWLEDGMENTS

The authors would like to thank the following sponsors of the *Urban Mobility Report*: University Transportation Center for Mobility at Texas A&M University, INRIX®, Inc., National Center for Freight and Infrastructure Research and Education (CFIRE) at the University of Wisconsin, American Road & Transportation Builders Association – Transportation Development Foundation, American Public Transportation Association, and the Texas A&M Transportation Institute. The authors would like to thank the following sponsors of the *Congested Corridors Report*: University Transportation Center for Mobility at Texas A&M University, INRIX®, Inc., and Texas A&M Transportation Institute.

REFERENCES

1. Schrank, D., T. Lomax, and B. Eisele, *2011 Urban Mobility Report*. Texas Transportation Institute. September 2012. Available: http://mobility.tamu.edu
2. Eisele, W.L., D.L. Schrank, and T.J. Lomax, *2011 Congested Corridors Report*. November 2011. Available: http://mobility.tamu.edu/corridors.
3. Eisele, W.L., L. R. Rilett, K.B. Mhoon, and C. Spiegelman. Using Intelligent Transportation Systems Travel-Time Data for Multimodal Analyses and System Monitoring. In *Transportation Research Record 1768.* Transportation Researcher Board, National Research Council, Washington, D.C., 2001.
4. Eisele, W., *Estimating Corridor Travel Time Using Point and Probe Detector Data: Implications for Emerging Intelligent Transportation Systems Data Sources and*

Performance Measurement. LAP LAMBERT Academic Publishing, Saarbrucken, Germany, ISBN 978-3659116445. May 2012.

5. Eisele, W.L. and D.L. Schrank. Conceptual Framework and Trucking Application to Estimate the Impact of Congestion on Freight. *Transportation Research Record 2168.* Transportation Research Board, National Research Council, Washington, D.C., 2010.
6. Schrank, D., B. Eisele, and T. Lomax. *The Keys to Estimating Mobility in Urban Areas: Applying Definitions and Measures that Everyone Understands.* Developed under Transportation Performance Measures Pooled Fund Study. 2nd Edition, 2005. Available: http://mobility.tamu.edu/resources/related-tti-reports-and-presentations/estimating-mobility/
7. *Freight Facts and Figures 2011.* U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Report Number FHWA-HOP-12-002. Washington, D.C., November 2011. Available: http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/11factsfigures/index.htm
8. *The Freight Analysis Framework: Data and Documentation.* U.S. Department of Transportation, Federal Highway Administration, 2010. Available: http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm
9. *Highway Performance Monitoring System Field Manual.* U.S. Department of Transportation, Federal Highway Administration, September 2010. Available: http://www.fhwa.dot.gov/policyinformation/hpms/fieldmanual/
10. McFarland, W.F. and M. Chui. The Value of Travel Time: New Estimates Developed Using a Speed Choice Model. *Transportation Research Record 1116.* Transportation Research Board, National Research Council, Washington, D.C., 1987.
11. Ellis, D. *Cost Per Hour and Value of Time Calculations for Passenger Vehicles and Commercial Trucks for Use in the Urban Mobility Report.* Texas Transportation Institute, Unpublished White Paper, 2009.
12. Federal Highway Administration. *Highway Performance Monitoring System*, 1982 to 2007 Data. November 2008.
13. *Population Estimates.* U.S. Census Bureau. Available: www.census.gov
14. 2001 National Household Travel Survey, *Summary of Travel Trends.* Available: http://nhts.ornal.gov/2001/pub/stt.pdf
15. *Fuel Gauge Report*, American Automobile Association. 2009. Available: www.fuelgaugereport.com
16. *Means of Transportation to Work, Table S0802.* American Community Survey 2005. Available: www.census.gov/acs/www
17. *Motor Vehicle Emission Simulator (MOVES).* Federal Highway Administration. Available: http://www.fhwa.dot.gov/environment/air_quality/conformity/methodologies/moves.cfm.
18. *2010 National Traffic Scorecard.* INRIX, Inc. Bellevue, WA. Available: http://scorecard.inrix.com/scorecard/default.asp