# Cost of Congestion to the Trucking Industry: 2018 Undate 

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# Cost of Congestion to the Trucking Industry: 2018 Update 

October 2018

Alan Hooper<br>Research Associate<br>American Transportation Research Institute<br>Atlanta, GA

950 N. Glebe Road, Suite 210
Arlington, Virginia 22203
www.atri-online.org

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## LIST OF ACRONYMS

| AADTT | Average Annual Daily Truck Traffic |
| :---: | :---: |
| ArcGIS | Aeronautical Reconnaissance Coverage Geographic Information System |
| ATRI | American Transportation Research Institute |
| CBSA | Core Based Statistical Areas |
| CPH | Cost per Hour |
| EIA | Energy Information Administration |
| ELD | Electronic Logging Device |
| FAF | Freight Analysis Framework |
| FAF4 | Freight Analysis Framework Version 4 |
| FHWA | Federal Highway Administration |
| FPM | Freight Performance Measures |
| GDP | Gross Domestic Product |
| GMT | Greenwich Mean Time |
| GPS | Global Positioning System |
| IHS | Interstate Highway System |
| MPH | Miles per Hour |
| NDA | Non-Disclosure Agreement |
| NHS | National Highway System |
| NPMRDS | National Performance Management Research Data Set |
| P\&D | Pick-up and Delivery |
| RAC | Research Advisory Committee |
| TMC | Traffic Management Channel |
| UDOT | Utah Department of Transportation |
| VMT | Vehicle Miles Traveled |

## INTRODUCTION

Safe and reliable truck movements form the backbone of economic growth in the U.S., so it is critical to understand how traffic congestion on the United States (U.S.) roadway network impacts the trucking industry. Motor carriers are directly affected by congestion through increased operating costs; traffic congestion results in wasted fuel, increased labor costs, safety costs and vehicle wear and tear. Secondary impacts of congestion on trucking include inefficiencies in the nation's supply chain as pick-up and delivery schedules are impacted by traffic delays.

To quantify and monetize the impact of traffic congestion on the trucking industry, the American Transportation Research Institute (ATRI) commenced research in 2014 using U.S. Interstate Highway System (IHS) data from 2012 and 2013. ${ }^{1}$ Building on this research, ATRI unveiled a revised and standardized methodology in a report published in April 2016 to enable the monitoring of congestion impacts on an annual basis, and to expand the analysis beyond the IHS to include the entire National Highway System (NHS). ${ }^{2}$

This methodology was subsequently submitted to a rigorous academic peer review process by the Transportation Research Board of the National Academies of Sciences, and was selected for publication as a verified methodological standard for congestion monitoring and monetization. ${ }^{3}$

For this year's analysis, ATRI has made slight revisions to this methodology to account for annual fluctuations in truck GPS volumes, and has employed this revised methodology to estimate the congestion costs incurred by the trucking industry. This year's analysis utilized the following data sources:

- Federal Highway Administration (FHWA) Freight Analysis Framework Version 4 (FAF4), ${ }^{4}$
- FHWA's National Performance Management Research Data Set (NPMRDS) Version 2016Q2,
- ATRI's commercial motor vehicle GPS data from 2016, and
- ATRI's 2016 national average operational cost of trucking. ${ }^{5}$

[^0]One change of note this year was an expansion of ATRI's truck GPS data set. To account for the growing GPS database, ATRI revised the original Cost of Congestion methodology to account for these more robust data and re-calculated the 2015 congestion costs (originally reported in the May 2017 publication) in addition to producing estimates for congestion costs in 2016 (as described in this report).

This methodological update clarified the impact on congestion caused by work zones and road construction, e-commerce growth, and growing urban truck miles and national vehicle registrations. More specifically, some of the major contributors to increased congestion in 2016 include:

- A continued increase in traffic incidents, including a record 7.3 million policereported crashes and a 5.6 percent increase in fatalities from motor vehicle crashes on U.S. roadways. ${ }^{6}$
- Growing economic activity, as evidenced by annual U.S. Gross Domestic Product (GDP) growth of 1.5 percent ${ }^{7}$ and growth in e-commerce sales of 14.9 percent between 2015 and 2016. ${ }^{8}$
- Weather impacts such as Winter Storm Jonas - a record-breaking snowstorm which impacted the Northeast, Appalachians, and mid-Atlantic in January 2016. ${ }^{9}$

Similar to previous iterations of this report, this analysis focuses on trucking operation delays associated with weekday traffic congestion on the NHS. Specifically, this study analyzes congestion costs and annual changes in these costs for the trucking industry on a total and per-mile basis at the state, metropolitan area, and county levels. The results of these analyses are compared to the updated 2015 data to identify year-overyear congestion trends.

[^1]
## NATIONAL HIGHWAY SYSTEM ANALYSIS

## National Level

In 2016, the trucking industry experienced nearly 1.2 billion hours of delay on the NHS as a result of traffic congestion. This delay is the equivalent of 425,533 commercial truck drivers sitting idle for an entire working year. ${ }^{10}$ Applying ATRI's national average operational cost per hour (CPH) calculation of $\$ 63.66$ for 2016 , it is estimated that the additional operational costs incurred by the trucking industry due to traffic congestion were $\$ 74.5$ billion, an increase of 0.5 percent from the updated $2015{ }^{11}$ figure of $\$ 74.1$ billion. ${ }^{12}$

Distributing this cost across the 11.5 million registered large trucks in the U.S. results in an average congestion cost per truck of $\$ 6,478 .{ }^{13}$ While the actual cost for any one truck is dependent on a number of different factors, such as location of operation and industry sector, congestion delays were also normalized using the number of miles driven annually. Using FHWA's total truck vehicle miles traveled (VMT) figure for $2016,{ }^{14}$ congestion costs held steady at an average of $\$ 0.26$ per VMT (Table 1).

Table 1: Average Congestion Cost per Truck and VMT Changes, 2015-2016

|  | 2015 | $\mathbf{2 0 1 6}$ |
| :--- | ---: | ---: |
| Hours of Delay (billion hours) | 1.177 | 1.170 |
| Total Cost of Congestion (\$Billion) | $\$ 74.115$ | $\$ 74.493$ |
| Truck VMT (million miles) | $279,843.6$ | $287,894.9$ |
| Registered Trucks | $11,203,184$ | $11,498,561$ |
| Average Congestion Cost per VMT | $\$ 0.26$ | $\$ 0.26$ |
| Average Congestion Cost per Truck | $\$ 6,616$ | $\$ 6,478$ |

[^2]As depicted in Figure 1, the impact of congestion on marginal costs varied greatly depending on an individual truck's VMT for the year. These figures range from an average of $\$ 6,469$ for a truck traveling 25,000 miles to roughly $\$ 32,350$ for the average truck traveling 125,000 miles in 2016.

Figure 1: Average Congestion Cost per Truck Based on Miles Driven, 2016


The cost of congestion followed a similar seasonal pattern as it has in previous years, as the relative level of congestion was lowest during the first quarter of 2016 and reached the annual high during the third quarter of the year (Figure 2). However, congestion costs decreased during the latter half of 2016 on a year-over-year basis (Figure 3); congestion costs declined 3.7 percent from the third quarter of 2015 to the third quarter of 2016, and fell further during the fourth quarter. This roughly tracks with the pattern of U.S. GDP growth observed in 2016 - as GDP growth peaked during the second quarter of the year before decelerating to end the year. ${ }^{15}$

[^3]Figure 2: Cost of Congestion by Month, 2014-2016


Figure 3: Year-over-Year Change in Congestion Costs, 2015 to 2016


Spreading the total congestion cost figure across the entirety of the NHS network shows the average cost on any given mile of the NHS. This resulted in an average industry cost per mile of $\$ 152,585$ - a 0.6 percent increase from the $\$ 151,742$ per mile found in 2015. Looking at congestion costs across NHS segments also illuminates the growing concentration of traffic congestion on a relatively small proportion of the NHS. To this end, just 17.2 percent of NHS miles represented a sizable majority ( $86.7 \%$ ) of total congestion costs nationwide (Table 2). These NHS segments in particular are characterized by above-average costs per mile, with costs on these segments exceeding $\$ 155,000$ per mile.

Table 2: Cost and Mileage by Segment Network Intensity

|  | Share of Mileage |  | Share of <br>  <br>  <br>  <br> Congestion Cost |  |
| :--- | ---: | ---: | ---: | ---: |
| Cost of Congestion <br> Less than $\$ 55,000$ | $\mathbf{2 0 1 5}$ | $\mathbf{2 0 1 6}$ | $\mathbf{2 0 1 5}$ | $\mathbf{2 0 1 6}$ |
| $\$ 55,000$ to $\$ 155,000$ | $14.1 \%$ | $13.4 \%$ | $8.8 \%$ | $8.3 \%$ |
| More than $\$ 155,000$ | $17.4 \%$ | $17.2 \%$ | $85.9 \%$ | $86.7 \%$ |

This concentration of congestion can be best visualized by examining a national map of the NHS network with congestion levels presented on each roadway segment. Figure 4 displays the cost of congestion on a per-mile basis for all of the 203,780 roadway segments utilized in the NHS network analysis. Similar to 2015, this map highlights that congestion in 2016 remains concentrated in major urban areas, namely New York, Chicago, Los Angeles, and Miami.

Figure 4: Cost of Congestion on a per Mile Basis


## State Level

The top ten states by total congestion cost held steady in comparison to 2015 - with all ten states returning to the list in 2016. The ranking order changed slightly over the year, with growing congestion costs in Illinois moving the state up to sixth on the list (Table 3). The top two states in terms of total congestion costs - Texas and Florida - accounted for 16.1 percent of the national congestion costs, while the top ten states combined to account for over half (51.8\%) of the national figure (Figure 5).

Table 3: Top Ten States by Total Cost of Congestion

| $\mathbf{2 0 1 6}$ <br> Rank | State | Total Cost | Share of <br> Total Cost | 2015 <br> Rank |
| :---: | :--- | ---: | ---: | :---: |
| $\mathbf{1}$ | Texas | $\$ 6,370,989,505$ | $8.6 \%$ | 1 |
| 2 | Florida | $\$ 5,637,019,390$ | $7.6 \%$ | 2 |
| 3 | California | $\$ 5,059,865,608$ | $6.8 \%$ | 3 |
| 4 | New York | $\$ 4,347,935,258$ | $5.8 \%$ | 4 |
| 5 | New Jersey | $\$ 3,350,935,426$ | $4.5 \%$ | 5 |
| 6 | Illinois | $\$ 2,903,204,725$ | $3.9 \%$ | 8 |
| 7 | Pennsylvania | $\$ 2,885,361,948$ | $3.9 \%$ | 6 |
| 8 | Tennessee | $\$ 2,838,362,415$ | $3.8 \%$ | 7 |
| 9 | Ohio | $\$ 2,769,050,420$ | $3.7 \%$ | 9 |
| 10 | North Carolina | $\$ 2,429,355,868$ | $3.3 \%$ | 10 |

Figure 5: State Share of Total Cost of Congestion


Due to the high levels of congestion concentrated on a small number of NHS segment miles, the District of Columbia remained firmly atop the list in terms of the per-mile cost of congestion by state. In fact, the congestion costs per mile in D.C. were more than double the congestion costs per mile in New Jersey, which ranked second among all states in terms of this measure (Table 4). Similar to the District of Columbia, states in the Northeast and Mid-Atlantic region rank high on congestion costs per mile due to high congestion costs concentrated on relatively small road networks. Florida is the only state with more than 8,000 NHS segment miles to also rank high on congestion costs per mile.

Table 4: Top Ten States Based on Cost per NHS Segment Mile

| $\mathbf{2 0 1 6}$ <br> Rank | State | Miles of NHS <br> Segments | Total Cost of <br> Congestion | Cost per <br> Mile | $\mathbf{2 0 1 5}$ <br> Rank |
| :---: | :--- | ---: | ---: | ---: | :---: |
| 1 | District of Columbia | 59 | $\$ 82,809,558$ | $\$ 1,394,377$ | 1 |
| 2 | New Jersey | 6,172 | $\$ 3,350,935,426$ | $\$ 542,941$ | 2 |
| 3 | Maryland | 5,141 | $\$ 2,024,487,754$ | $\$ 393,816$ | 3 |
| 4 | Connecticut | 3,573 | $\$ 1,275,606,923$ | $\$ 356,975$ | 6 |
| 5 | Utah | 6,097 | $\$ 2,112,323,433$ | $\$ 346,464$ | 5 |
| 6 | Delaware | 1,036 | $\$ 356,919,653$ | $\$ 344,610$ | 4 |
| 7 | Florida | 18,396 | $\$ 5,637,019,390$ | $\$ 306,421$ | 7 |
| 8 | Massachusetts | 5,991 | $\$ 1,806,188,142$ | $\$ 301,459$ | 8 |
| 9 | Rhode Island | 1,214 | $\$ 352,723,384$ | $\$ 290,556$ | 11 |
| 10 | Louisiana | 7,999 | $\$ 2,300,465,910$ | $\$ 287,587$ | 9 |

Although some of the biggest increases in congestion costs during this time period were concentrated in the most populous U.S. states - Texas, California, and Florida congestion costs increased sizably in less densely populated areas as well (Table 5).

For instance, trucks operating in Wisconsin experienced the third-largest increase in congestion costs, coinciding with the implementation of the state's Statewide Transportation Improvement Program for 2016 through 2019. ${ }^{16}$ The roughly $\$ 1.2$ billion in highway development and rehabilitation projects budgeted for the 2016 fiscal year contributed to the worsening of congestion conditions throughout the state, while the additional $\$ 3.5$ billion budgeted for similar projects through the 2019 fiscal year means that truck drivers and motor carriers operating in Wisconsin may incur more construction-related congestion in the years ahead.

[^4]Also of note is the relatively large increase in congestion costs incurred by motor carriers operating in Hawaii during 2016. Congestion costs more than doubled to $\$ 98.9$ million over the year, as construction projects like the Kalanianaole Highway Improvements Project ${ }^{17}$ and temporary bridge weight restrictions on Kamehameha Highway ${ }^{18}$ created adverse traffic conditions for freight transportation at various times throughout the year.

Table 5 details the remaining states with the largest increases in congestion costs, while Table 6 shows those states that experienced the most significant decrease in congestion costs.

Table 5: Top Ten States with Largest Congestion Cost Increases

| State | 2015 <br> Congestion <br> Cost | 2016 <br> Congestion <br> Cost | Cost Increase | Percent <br> Change |
| :--- | ---: | ---: | ---: | ---: |
| Texas | $\$ 6,057,365,603$ | $\$ 6,370,989,505$ | $\$ 313,623,902$ | $5.2 \%$ |
| California | $\$ 4,756,368,563$ | $\$ 5,059,865,608$ | $\$ 303,497,045$ | $6.4 \%$ |
| Wisconsin | $\$ 2,013,095,351$ | $\$ 2,164,660,873$ | $\$ 151,565,522$ | $7.5 \%$ |
| West Virginia | $\$ 718,084,606$ | $\$ 822,761,736$ | $\$ 104,677,130$ | $14.6 \%$ |
| Louisiana | $\$ 2,198,503,688$ | $\$ 2,300,465,910$ | $\$ 101,962,222$ | $4.6 \%$ |
| Mississippi | $\$ 574,980,316$ | $\$ 666,678,919$ | $\$ 91,698,603$ | $15.9 \%$ |
| Georgia | $\$ 2,150,236,972$ | $\$ 2,217,832,693$ | $\$ 67,595,722$ | $3.1 \%$ |
| Hawaii | $\$ 40,197,226$ | $\$ 98,926,894$ | $\$ 58,729,668$ | $146.1 \%$ |
| Florida | $\$ 5,584,344,521$ | $\$ 5,637,019,390$ | $\$ 52,674,869$ | $0.9 \%$ |
| Rhode Island | $\$ 303,144,871$ | $\$ 352,723,384$ | $\$ 49,578,513$ | $16.4 \%$ |

[^5]Table 6: Top Ten States with Largest Congestion Cost Decreases

| State | 2015 <br> Congestion <br> Cost | 2016 <br> Congestion <br> Cost | Cost Decrease | Percent <br> Change |
| :--- | ---: | ---: | ---: | ---: |
| Pennsylvania | $\$ 3,088,889,916$ | $\$ 2,885,361,948$ | $-\$ 203,527,968$ | $-6.6 \%$ |
| Ohio | $\$ 2,921,798,579$ | $\$ 2,769,050,420$ | $-\$ 152,748,158$ | $-5.2 \%$ |
| Tennessee | $\$ 2,954,638,992$ | $\$ 2,838,362,415$ | $-\$ 116,276,577$ | $-3.9 \%$ |
| Utah | $\$ 2,226,632,929$ | $\$ 2,112,323,433$ | $-\$ 114,309,496$ | $-5.1 \%$ |
| Maryland | $\$ 2,100,402,789$ | $\$ 2,024,487,754$ | $-\$ 75,915,036$ | $-3.6 \%$ |
| Indiana | $\$ 1,517,846,182$ | $\$ 1,456,572,097$ | $-\$ 61,274,085$ | $-4.0 \%$ |
| Virginia | $\$ 1,668,820,334$ | $\$ 1,609,019,148$ | $-\$ 59,801,186$ | $-3.6 \%$ |
| Michigan | $\$ 624,679,029$ | $\$ 574,359,585$ | $-\$ 50,319,445$ | $-8.1 \%$ |
| Oklahoma | $\$ 798,420,429$ | $\$ 748,415,006$ | $-\$ 50,005,423$ | $-6.3 \%$ |
| Alabama | $\$ 1,086,683,377$ | $\$ 1,038,713,652$ | $-\$ 47,969,724$ | $-4.4 \%$ |

To illustrate the intensity of congestion changes, regardless of the size of the state's network, ATRI researchers normalized the total congestion cost changes by the number of NHS miles contained in each state. As detailed in Table 7, motor carriers operating in the District of Columbia experienced the most significant per-mile increase in congestion costs, while carriers operating in other states with relatively small NHS roadway networks like Hawaii, Rhode Island, and Virginia also experienced more concentrated congestion costs relative to 2015.

Table 7: Top Ten States with Largest Per-Mile Cost Increases

| State | Miles of <br> NHS <br> Segments | Congestion <br> Cost Change | Per-Mile <br> Increase | Per- <br> Mile <br> Percent <br> Change |
| :--- | ---: | ---: | ---: | ---: |
| District of Columbia | 59 | $\$ 8,472,707$ | $\$ 143,222$ | $11.4 \%$ |
| Hawaii | 921 | $\$ 58,729,668$ | $\$ 57,505$ | $115.2 \%$ |
| Rhode Island | 1,214 | $\$ 49,578,513$ | $\$ 41,438$ | $16.6 \%$ |
| West Virginia | 4,753 | $\$ 104,677,130$ | $\$ 22,224$ | $14.7 \%$ |
| California | 21,053 | $\$ 303,497,045$ | $\$ 14,259$ | $6.3 \%$ |
| Louisiana | 7,999 | $\$ 101,962,222$ | $\$ 13,202$ | $4.8 \%$ |
| Connecticut | 3,573 | $\$ 31,606,125$ | $\$ 10,945$ | $3.2 \%$ |
| Mississippi | 14,720 | $\$ 91,698,603$ | $\$ 10,649$ | $16.2 \%$ |
| Wisconsin | 37,419 | $\$ 313,623,902$ | $\$ 8,354$ | $5.2 \%$ |
| Texas |  |  | $\$ 10,473$ | $7.6 \%$ |

The full state congestion table can be found in Appendix B of this report.

## Metropolitan Level

Slightly more than 91 percent of the total congestion costs in 2016 occurred in metropolitan areas, with just $\$ 6.4$ billion of the $\$ 74.5$ billion in congestion costs occurring outside of these urban areas. The New York/ Newark/ Jersey City, NY/NJ/PA metropolitan area remained at the top the list with nearly $\$ 4.9$ billion in total congestion costs - more than double the next closest metropolitan area (Table 8).

Table 8: Top Ten Metropolitan Areas by Total Cost of Congestion

| Metropolitan Area | Total Cost |
| :--- | ---: |
| New York/ Newark/ Jersey City, NY/NJ/PA | $\$ 4,932,953,308$ |
| Chicago/ Naperville-Elgin, IL/IN/WI | $\$ 2,277,859,370$ |
| Miami/ Fort Lauderdale/ West Palm Beach, FL | $\$ 2,242,273,959$ |
| Philadelphia/ Camden/ Wilmington, PA/NJ/DE/MD | $\$ 1,662,591,597$ |
| Los Angeles/ Long Beach/ Anaheim, CA | $\$ 1,634,100,369$ |
| Washington/ Arlington/ Alexandria, DC/VA/MD/WV | $\$ 1,408,773,540$ |
| Dallas/ Fort Worth/ Arlington, TX | $\$ 1,381,875,845$ |
| Houston/ The Woodlands/ Sugar Land, TX | $\$ 1,359,055,852$ |
| Atlanta-Sandy Springs-Roswell, GA | $\$ 1,114,969,029$ |
| Nashville/ Davidson/ Murfreesboro/ Franklin, TN | $\$ 1,105,626,725$ |

Analyzing congestion costs in metropolitan areas on a per-mile basis highlights the rapid increase in congestion costs observed on smaller roadway networks like the 176 NHS roadway miles in the Elizabethtown/ Fort Knox, KY metropolitan area. Specifically, congestion costs in this area surged in 2016 due to the confluence of the I-65 widening project and a flurry of vehicle crashes recorded in the construction zones, bringing traffic to a standstill numerous times throughout the year. ${ }^{19}$

A similar pattern can be observed on the relatively small NHS roadway network in Utah, which is home to three of the top 10 metropolitan areas in terms of congestion costs per mile (Table 9). A full depiction of the concentration of congestion costs in metropolitan areas can be seen in Figure 6.

[^6]Table 9: Top Ten Metropolitan Areas Based on Cost per NHS Segment Mile

| Metropolitan Area | Miles of <br> NHS <br> Segments | Total Cost of <br> Congestion | Cost per <br> Mile |
| :--- | ---: | ---: | ---: |
| Elizabethtown/ Fort Knox, KY | 176 | $\$ 181,507,139$ | $\$ 1,029,420$ |
| Ogden/ Clearfield, UT | 619 | $\$ 628,824,811$ | $\$ 1,016,265$ |
| Miami/ Fort Lauderdale/ West Palm <br> Beach, FL | 2,432 | $\$ 2,242,273,959$ | $\$ 921,931$ |
| Arkadelphia, AR | 83 | $\$ 71,362,210$ | $\$ 855,795$ |
| Bridgeport/ Stamford-Norwalk, CT | 562 | $\$ 480,558,357$ | $\$ 855,772$ |
| Los Angeles/ Long Beach/ Anaheim, CA | 1,997 | $\$ 1,634,100,369$ | $\$ 818,124$ |
| Provo/ Orem, UT | 557 | $\$ 450,231,927$ | $\$ 807,713$ |
| San Francisco/ Oakland/ Hayward, CA | 945 | $\$ 713,670,924$ | $\$ 754,926$ |
| New York/ Newark/ Jersey City, <br> NY/NJ/PA | 7,288 | $\$ 4,932,953,308$ | $\$ 676,845$ |
| Salt Lake City, UT | 868 | $\$ 572,994,749$ | $\$ 660,232$ |

Figure 6: Metropolitan Area Cost of Congestion on a per Mile Basis


With congestion costs in rural areas declining nearly nine percent to $\$ 6.4$ billion between 2015 and 2016, it is clear that the congestion costs incurred by the trucking industry are increasingly an urban phenomenon. In fact, congestion costs in urban metropolitan areas increased by over $\$ 1$ billion during this time period, which provides further insight into the locations of freight congestion hotspots throughout a state.

For example, the Los Angeles/ Long Beach/ Anaheim, CA metropolitan area accounted for 57.4 percent of the $\$ 303.5$ million in new congestion costs in California (Table 10). Indeed, congestion increases in densely populated urban centers can have an outsized impact on overall congestion levels in a state.

Table 10: Top Ten Metropolitan Areas with Largest Congestion Cost Increases

| Metropolitan Area | Congestion <br> Cost | 2016 <br> Congestion | Cost Increase | Percent <br> Change |
| :--- | ---: | ---: | ---: | ---: |
| Los Angeles/ Long <br> Beach/ Anaheim, CA | $\$ 1,459,972,624$ | $\$ 1,634,100,369$ | $\$ 174,127,745$ | $11.9 \%$ |
| Miami/ Fort Lauderdale/ <br> West Palm Beach, FL | $\$ 2,133,023,928$ | $\$ 2,242,273,959$ | $\$ 109,250,031$ | $5.1 \%$ |
| Atlanta/ Sandy Springs/ <br> Roswell, GA | $\$ 1,017,680,472$ | $\$ 1,114,969,029$ | $\$ 97,288,557$ | $9.6 \%$ |
| Austin/ Round Rock, TX | $\$ 325,497,178$ | $\$ 413,240,797$ | $\$ 87,743,619$ | $27.0 \%$ |
| Lafayette, LA | $\$ 144,774,913$ | $\$ 227,150,176$ | $\$ 82,375,264$ | $56.9 \%$ |
| Memphis, TN/MS/AR | $\$ 327,149,123$ | $\$ 408,754,550$ | $\$ 81,605,427$ | $24.9 \%$ |
| McAllen/ Edinburg/ <br> Mission, TX | $\$ 215,565,167$ | $\$ 268,175,548$ | $\$ 52,610,382$ | $24.4 \%$ |
| Providence/ Warwick, <br> RI/MA | $\$ 429,624,474$ | $\$ 482,225,234$ | $\$ 52,600,760$ | $12.2 \%$ |
| Minneapolis/ St. Paul// <br> Bloomington, MN/WI | $\$ 510,540,981$ | $\$ 561,534,739$ | $\$ 50,993,758$ | $10.0 \%$ |
| San Diego/ Carlsbad, CA | $\$ 327,480,272$ | $\$ 375,865,733$ | $\$ 48,385,461$ | $14.8 \%$ |

Although urban metropolitan areas account for almost all of the increase in congestion costs observed nationwide in 2016, there were large metropolitan areas like Baltimore/ Columbia/ Towson, MD that experienced a decrease in congestion costs over the year.

Much of the decrease observed in this metropolitan area over the year is attributable to the completion of a resurfacing project along a stretch of MD-7 (Philadelphia Road) in
close proximity to I-95, I-695, and US-40. ${ }^{20}$ This project significantly worsened traffic conditions on this roadway segment during the second half of 2015, and the completion of this project in early 2016 alleviated much of the congestion observed in this construction zone.

Despite these congestion cost decreases from 2015, motor carriers operating in the metropolitan areas detailed in Table 11 must still contend with substantial congestion costs. In fact, overall congestion costs still exceed $\$ 1$ billion in four of the five metropolitan areas that posted the biggest decrease in congestion costs over the year (Table 11).

Table 11: Top Ten Metropolitan Areas with Largest Congestion Cost Decreases

| Metropolitan Area | 2015 <br> Congestion <br> Cost | 2016 <br> Congestion <br> Cost | Cost <br> Decrease | Percent <br> Change |
| :--- | :---: | :---: | :---: | :---: |
| Baltimore/ Columbia/ Towson, <br> MD | $\$ 942,376,361$ | $\$ 859,834,067$ | $-\$ 82,542,294$ | $-8.8 \%$ |
| Philadelphia/ Camden/ <br> Wilmington, PA/NJ/DE/MD | $\$ 1,741,641,291$ | $\$ 1,662,591,597$ | $-\$ 79,049,694$ | $-4.5 \%$ |
| Dallas/ Fort Worth/ Arlington, <br> TX | $\$ 1,436,623,279$ | $\$ 1,381,875,845$ | $-\$ 54,747,434$ | $-3.8 \%$ |
| New York/ Newark/ Jersey <br> City, NY/NJ/PA | $\$ 4,985,702,113$ | $\$ 4,932,953,308$ | $-\$ 52,748,805$ | $-1.1 \%$ |
| Nashville/ Davidson/ <br> Murfreesboro/ Franklin, TN | $\$ 1,156,419,908$ | $\$ 1,105,626,725$ | $-\$ 50,793,183$ | $-4.4 \%$ |
| Pittsburgh, PA | $\$ 469,323,430$ | $\$ 425,037,527$ | $-\$ 44,285,903$ | $-9.4 \%$ |
| Cincinnati, OH/KY/IN | $\$ 816,049,515$ | $\$ 774,194,909$ | $-\$ 41,854,606$ | $-5.1 \%$ |
| Allentown/ Bethlehem/ Easton, <br> PA/NJ | $\$ 231,449,348$ | $\$ 190,096,541$ | $-\$ 41,352,807$ | $-17.9 \%$ |
| Ogden/ Clearfield, UT | $\$ 663,239,555$ | $\$ 628,824,811$ | $-\$ 34,414,745$ | $-5.2 \%$ |
| Boston/ Cambridge/ Newton, <br> MA/NH | $\$ 1,097,886,985$ | $\$ 1,063,611,811$ | $-\$ 34,275,174$ | $-3.1 \%$ |

Although metropolitan areas with relatively small NHS roadway networks may not experience overall congestion cost increases of a similar magnitude to more densely traveled regions, the intensity of these increases can be equally severe when normalized on a per-mile basis. In fact, all but one of the metropolitan areas with the

[^7]largest per-mile congestion cost increases contain fewer than 500 miles of NHS segments (Table 12). Meanwhile, the 13.6 percent increase in per-mile congestion costs observed in Los Angeles/ Long Beach/Anaheim, CA highlights the extent to which traffic conditions continue to deteriorate in one of the most densely populated regions of the country.

Table 12: Top Ten Metropolitan Areas with Largest per Mile Congestion Cost Increases

| Metropolitan Area | Miles of NHS <br> Segments | Congestion <br> Cost Change | Per-Mile <br> Change | Percent <br> Change |
| :--- | ---: | ---: | ---: | ---: |
| Elizabethtown-Fort Knox, KY | 176 | $\$ 39,824,942$ | $\$ 229,182$ | $28.6 \%$ |
| Lafayette, LA | 436 | $\$ 82,375,264$ | $\$ 188,960$ | $56.9 \%$ |
| Oneonta, NY | 231 | $\$ 38,352,580$ | $\$ 165,748$ | $66.8 \%$ |
| Glasgow, KY | 55 | $\$ 7,811,098$ | $\$ 141,452$ | $51.5 \%$ |
| Morristown, TN | 353 | $\$ 42,150,866$ | $\$ 116,508$ | $108.2 \%$ |
| Urban Honolulu, HI | 270 | $\$ 25,355,263$ | $\$ 98,028$ | $41.3 \%$ |
| Lake Charles, LA | 1,997 | $\$ 174,127,745$ | $\$ 97,882$ | $13.6 \%$ |
| Los Angeles-Long Beach- <br> Anaheim, CA | 243 | $\$ 19,617,990$ | $\$ 81,233$ | $56.3 \%$ |
| Oshkosh-Neenah, WI | 166 | $\$ 13,354,285$ | $\$ 80,234$ | $31.4 \%$ |
| Sulphur Springs, TX |  |  | $\$ 127,124$ | $31.6 \%$ |

Due to the large number of metropolitan areas examined in this analysis, the congestion figures for all areas are not included in this report but are available upon request from ATRI.

## County Level

As can be seen in Table 13, the counties experiencing the highest total congestion costs were those within several of the major metropolitan areas discussed previously. Los Angeles County, California and Miami-Dade County, Florida, were among the top counties by this measure. Overall, congestion costs exceeded $\$ 1$ billion in only three counties during 2016, with Cook County, Illinois, home to Chicago, rounding out the top three counties in terms of total cost of congestion.

## Table 13: Top Ten Counties by Total Cost of Congestion

| County | Total Cost |
| :--- | ---: |
| Los Angeles, California | $\$ 1,260,469,613$ |
| Cook, Illinois | $\$ 1,181,207,854$ |
| Miami-Dade, Florida | $\$ 1,090,088,342$ |
| Harris, Texas | $\$ 874,282,816$ |
| Broward, Florida | $\$ 763,305,040$ |
| Davidson, Tennessee | $\$ 640,013,765$ |
| Salt Lake, Utah | $\$ 551,650,653$ |
| Suffolk, New York | $\$ 495,437,573$ |
| Fairfield, Connecticut | $\$ 482,557,550$ |
| Worcester, Massachusetts | $\$ 458,685,801$ |

Examining costs at the county level, on a cost-per-NHS mile basis, highlights the intensity of congestion in the New York/ Newark/ Jersey City, NY/NJ/PA metropolitan area: the top four counties make up four of the five counties that comprise New York City (Table 14). A county-level map of congestion costs per mile documents how truck traffic congestion tends to be confined to a handful of densely populated regions, with little-to-no congestion costs being measured in large swathes of the U.S (Figure 7).

Table 14: Top Ten Counties Based on Cost per NHS Segment Mile

| County | Miles of NHS <br> Segments | Total Cost of <br> Congestion | Cost per <br> Mile |
| :--- | ---: | :---: | :---: |
| New York, New York | 43 | $\$ 151,664,541$ | $\$ 3,548,952$ |
| Queens, New York | 141 | $\$ 347,476,406$ | $\$ 2,461,361$ |
| Kings, New York | 42 | $\$ 100,841,979$ | $\$ 2,429,307$ |
| Bronx, New York | 91 | $\$ 218,840,243$ | $\$ 2,414,285$ |
| Kenton, Kentucky | 105 | $\$ 192,001,794$ | $\$ 1,822,997$ |
| Hudson, New Jersey | 144 | $\$ 256,038,524$ | $\$ 1,782,863$ |
| San Francisco, California | 64 | $\$ 113,597,346$ | $\$ 1,773,560$ |
| Davis, Utah | 195 | $\$ 319,281,600$ | $\$ 1,635,756$ |
| Weber, Utah | 185 | $\$ 297,861,850$ | $\$ 1,613,965$ |
| Trimble, Kentucky | 16 | $\$ 23,910,887$ | $\$ 1,489,079$ |

Figure 7: County Cost of Congestion on a per Mile Basis


Due to the large number of counties examined in this analysis, the congestion figures for individual counties are not included in this report but are available upon request from ATRI.

## CONCLUSION

Utilizing a revised methodology and updated inputs for cost, travel time, and GPS data, this report monitors congestion trends, as well as localized changes in the congestionrelated delay costs incurred by motor carriers on the U.S. NHS network.

Delay on the NHS was calculated to be almost 1.2 billion hours. Between 2015 and 2016, delay costs increased by over $\$ 377$ million to $\$ 74.5$ billion. This change in congestion costs was heavily concentrated in urban areas, with congestion costs decreasing over the year in rural locations. Moreover, these cost increases remain concentrated on a relatively small portion of U.S. roadways, with just 17.2 percent of NHS segment miles representing almost 87 percent of total congestion costs nationwide in 2016.

The lost productivity in 2016 is the equivalent of 425,533 commercial truck drivers sitting idle for an entire working year, which in the context of the significant truck driver shortage (currently projected to exceed 174,000 by 2026), underscores the impact of congestion on industry capacity. ${ }^{21}$ Furthermore, this delay generated $\$ 6,478$ in congestion costs per truck, although this cost can vary significantly depending on the number of miles a truck traveled and the primary areas of operation.

Finally, as a direct result of this analysis, ATRI is able to provide a unique and strategic resource to transportation planners on congestion information at every jurisdiction level. Utilizing the output of this analysis, ATRI's congestion cost database has been updated with congestion data for 2016. This information includes hours of delay and associated costs on the NHS by major jurisdiction type, presented on an annual and month-bymonth basis. Table 15 presents an example of the type of information that can be extracted from the database for use by planning officials.

Table 15: Sample Cost of Congestion Database Information Interstates in Davidson County, Tennessee

| Road | Hours of Delay | Congestion Cost | Miles of NHS | Cost per Mile |
| :--- | ---: | ---: | :---: | :---: |
| I-24 | 676,978 | $\$ 43,094,502$ | 63 | $\$ 684,040$ |
| I-40 | 167,968 | $\$ 10,692,385$ | 59 | $\$ 181,227$ |
| I-440 | 73,870 | $\$ 4,702,376$ | 14 | $\$ 335,884$ |
| I-65 | 247,348 | $\$ 15,745,489$ | 37 | $\$ 425,554$ |

To request congestion information please contact ATRI at ATRI@trucking.org.

[^8]
## APPENDIX A: DETAILED METHODOLOGY, UPDATED 2018

Four data sources were used in this analysis to quantify the impact of traffic congestion on the trucking industry:
(1) Commercial truck travel times from the Federal Highway Administration (FHWA) National Performance Management Research Data Set (NPMRDS);
(2) Commercial truck volumes from FHWA's Freight Analysis Framework v4 (FAF4);
(3) Commercial truck GPS data from ATRI's Freight Performance Measures (FPM) database; and
(4) Industry financial data from ATRI's annual An Analysis of the Operational Costs of Trucking publication.

## Roadway Network

The NPMRDS network, published as a shape file in each monthly iteration of the NPMRDS, was utilized as the foundational network in this analysis. The network is made up of over 319,000 bi-directional roadway segments, the bulk of which are located in the U.S. (with some segments falling in Canada, Mexico, and Puerto Rico). Each roadway segment is identified by a unique traffic management channel (TMC) code, and each TMC contains information on various jurisdiction levels (country, state, county), the length in miles of the segment, the road name, the road direction, the route type, and the latitude and longitude of the center of the segment.

The first step in defining the roadway network was to extract only those TMCs corresponding to roads located within the 48 contiguous states as well as Alaska and Hawaii. This resulted in the network depicted in Figure A1.

Figure A1: United States NPMRDS NHS Roadway Network


Next, using a combination of the route type indicator and the road name, the NHS was defined and extracted from the full U.S. network for use in this analysis. This network consists of numbered interstate, federal, state, and county highways. Detailed in Table A1, this generated almost 204,000 roadway segments, totaling over 488,000 bidirectional miles.

Table A1: NHS Roadway Network Statistics

| NHS Road Network Profile |  |
| :--- | ---: |
| Total Segment Miles | 488,205 |
| Total Network Length (miles) ${ }^{22}$ | 244,103 |
| Total Number of Segments | 203,780 |
| Longest segment (miles) | 229.5 |
| Shortest segment (miles) | 0.002 |
| Average segment (miles) | 2.4 |
| Median segment (miles) | 1.3 |

The entirety of the network was spatially joined using ArcGIS software to reflect a variety of features including metropolitan area, ${ }^{23}$ county, and time zone for use in subsequent steps in this analysis.

## Marginal Truck Travel Time Delay

## Truck Speeds

New iterations of the NPMRDS are published each month and contain travel times in seconds for both passenger and commercial vehicles for each TMC across 288 fiveminute epochs which correspond to a certain time of day on a particular day of the month. For example, the average travel time for the 12:00-12:05 AM period corresponds to epoch 0 . For the purposes of this analysis, the truck travel times were extracted from the full data set.

Next, weekdays were extracted from the truck travel time dataset as the majority of truck traffic occurs during the week, and therefore are the days most impacted by congestion. Due to the nature of the NPMRDS, the five-minute travel times were aggregated into one-hour time periods yielding 24 average travel times in seconds for each roadway segment. The intent of this task is to reduce the impact of outliers and missing data. These average travel times were then converted from seconds to hours, and subsequently converted to speeds in miles-per-hour (MPH) using the distance corresponding to each TMC as follows:

[^9]\[

$$
\begin{gathered}
\overline{\text { travTıme }}_{t, h, m}=\frac{\frac{1}{n} * \sum_{i=0}^{n} \text { travTime }_{t, i, m}}{3600} \\
\overline{\text { speed }}_{t, h, m}=\frac{\text { distance }_{t}}{\overline{\text { travTıme }}_{t, h, m}}
\end{gathered}
$$
\]

Where:

- $t$ is TMC;
- $h$ is hour of the day;
- $m$ is month of the year;
- $i$ is epoch;
- $n$ is the number of observations in an hour bin;
- $\overline{\text { travTime }}_{t, h, m}$ is the calculated mean travel time in hours on TMC $t$ in hour bin $h$ for month $m$;
- $\quad$ travTime $_{t, i, m}$ is the travel time for TMC $t$ in epoch $i$ for month $m$;
- $\overline{\text { speed }}_{t, h, m}$ is the calculated mean speed in MPH on TMC $t$ in hour bin $h$ for month $m$; and
- distance $e_{t}$ is the distance of TMC $t$ in miles.


## Free-flow Speed

To facilitate the congestion level calculation, a free-flow speed was established for each roadway segment. While the posted speed limit of a particular segment can be used as free-flow speed, issues can arise with varying degrees of speed limit enforcement and truck speed governor usage. As such, the empirical speeds found by the above process were used in the establishment of a free-flow speed for each segment.

First, a maximum speed of 80 MPH was set to further reduce the impact of outlier speeds. The fastest hourly speed was then found for each segment of each month resulting in the 12 fastest speeds for each segment. Finally, the median of these 12 fastest speeds was set as the free-flow speed for the segment:

$$
\text { freeflow }_{t}=\max \widetilde{\overline{\text { speed }}}
$$

Where:

- $\quad$ rreeflow $_{t}$ is the calculated free flow speed for TMC $t$; and
- max $\overline{\text { speed }_{t, m}}$ is the median of the maximum average speeds for TMC $t$ in month $m$.


## Congestion Threshold

Shown in Figure A2 below, a congestion threshold was calculated to flag instances of congestion. The congestion threshold was set at 90 percent of the identified free-flow
speed as the trucking industry is generally flexible enough to adjust to minor congestion in daily operations. By using a more conservative threshold in calculating marginal delay, the results of the analysis provide a more accurate assessment of congestion that is having a noticeable impact on industry operations:

$$
\text { thresh }_{t}=\text { freeflow }_{t} * .90
$$

Where:

- $\quad$ thresh $h_{t}$ is the calculated congestion threshold for TMC $t$ in MPH.

Figure A2: Example Segment - Establishing Congested Conditions


Travel Time Delay
To quantify travel time delay, the observed speeds and congestion threshold speeds were first converted back to travel times in hours:

$$
\begin{gathered}
{\overline{\text { travTıme }_{t, h, m}}=\frac{\text { distance }_{t}}{\text { speed }_{t, h, m}}}_{\text {thresh }_{t}^{\prime}=\frac{\text { distance }_{t}}{\text { thresh }_{t}}}=\text {. }
\end{gathered}
$$

Where:

- thresh ${ }_{t}^{\prime}$ is the calculated congestion threshold travel time for TMC $t$ in hours.

The observed travel times were then compared to the congestion threshold to identify when congestion was present. In instances where congestion was present, the actual travel time was subtracted from the congestion threshold travel time to establish a marginal delay value (Figure A3):

$$
\operatorname{cong}_{t, h, m}=\overline{\operatorname{travTıme}_{t, h, m}}-\text { thresh }_{t}^{\prime} \leftrightarrow \overline{\operatorname{travTıme}_{t, h, m}}>\text { thresh }_{t}^{\prime}
$$

Where:

- $\operatorname{cong}_{t, h, m}$ is the calculated travel time delay in hours for TMC $t$ in hour bin $h$ for month $m$.

This resulted in 24 marginal delay values for each segment in each month of 2016. If no delay was present at a particular time of a month, that hour bin received a delay value of zero.

Figure A3: Example Segment - Establishing Marginal Delay Values


## Estimating Truck Volumes

Marginal delay values can tell a very important story about the severity of congestion at a certain place and time, however truck volume data is needed in order to quantify the impact on the industry as a whole. This allows the analysis to account for the fact that two segments may have the same amount of marginal delay, but one segment is more
heavily traveled by trucks than the other and therefore would result in a greater congestion impact on the industry.

## Linking the FAF and NPMRDS Networks

One of the most commonly used government sources of truck volume estimates is contained in FHWA's FAF network shape file. The FAF data provides volume estimates, or average annual daily truck traffic (AADTT), for large trucks with a gross vehicle weight rating greater than 10,000 pounds on approximately 204,000 U.S. roadway segments. However, due to FAF roadway segments differing in many ways from those found in the NPMRDS, it was necessary to spatially join the two networks. This resulted in each NPMRDS roadway segment with a TMC code receiving an AADTT value from the FAF network.

## Adjusting FAF Volume Estimates

Due to the nature of the FAF volume estimates associated with the NPMRDS network through this research process, a number of adjustments were needed to produce accurate hourly volume estimates for 2015. First, the AADTT estimates needed to be adjusted to 2016 values as the base-year FAF estimates in the most recent publication are for 2012. This was done by using truck vehicle miles traveled (VMT) figures produced by FHWA for urban and rural roadways ${ }^{24}$ to calculate an adjustment factor as follows:

$$
\Delta V M T_{r}=\frac{V M T_{r, 16}-V M T_{r, 16}}{V M T_{r, 12}}+1
$$

Where:

- $r$ is the roadway type; urban or rural;
- $\Delta V M T_{r}$ is the calculated adjustment factor for roadway type $r$;
- $V M T_{r, 15}$ is the total VMT for roadway type $r$ in 2016; and
- $V M T_{r, 12}$ is the total VMT for roadway type $r$ in 2012.

The FAF estimates were further adjusted by a factor of two to account for the FAF roadway segments being one-directional and the NPMRDS segments being bidirectional. While more nuanced methodologies could have been developed, constraints due to the national scope of this analysis as well as the lack of non-

[^10]proprietary national VMT data by direction led to the following calculation for determining AADTT for 2016 for each TMC:
$$
A A D T T_{t, r, 16}=\frac{A A D T T_{t, r, 12} * \Delta V M T_{r}}{2}
$$

Where:

- $t$ is TMC segment;
- $A^{-1 D T T} T_{t, r, 16}$ is the calculated AADTT for TMC $t$ with roadway type $r$ for 2016; and
- $A^{-1 D T T} T_{t, r, 12}$ is AADTT for TMC $t$ with roadway type $r$ in 2012.

To account for seasonality, FHWA's national volume statistics ${ }^{25}$ were used to estimate how total volume fluctuates seasonally. A monthly utilization factor was calculated for each month for urban and rural roadways by:

$$
u t i l_{m, r}=\frac{V M T_{m, r, 16}}{V M T_{r, 16}} * 12
$$

Where:

- $m$ is month of the year;
- util $l_{m, r}$ is the calculated monthly utility factor for month $m$ and roadway type $r$;
- $V M T_{m, r, 15}$ is VMT for month $m$ and roadway type $r$ in 2016; and
- $V M T_{r, 15}$ is the total VMT for roadway type $r$ in 2016.


## Calculating Hourly Truck Volumes

Due to the granularity of the NPMRDS, AADTT estimates needed to be distributed across the hours of the day for each month of the year. To perform this, ATRI's proprietary truck GPS database was utilized. A five weekday sample of GPS data was extracted from each month of 2016. Each truck ping data point contains a unique truck identification code, a date/time stamp recorded in Greenwich Mean Time (GMT), a latitude/longitude location, a heading, and a spot speed; the total data sample used equated to approximately 1.25 billion truck GPS points.

The NPMRDS network was then spatially joined with a U.S. time zone shape file ${ }^{26}$ resulting in each TMC receiving a time zone identifier. The truck GPS data was joined to this network which resulted in each GPS point receiving a TMC code and a time zone identifier. The date/time stamp of the GPS data was then converted from GMT to the

[^11]time zone in which the point fell, and binned hourly. Finally, the hourly volume distribution for each TMC per month was found by (Figure A4):
$$
\text { dist }_{t, h, m}=\frac{\text { trucks }_{t, h, m}}{\text { trucks }_{t, m}}
$$

Where:

- $h$ is hour of the day;
- $d i s t_{t, h, m}$ is the calculated volume distribution for TMC $t$ in hour bin $h$ for month $m$;
- trucks $s_{t, h, m}$ is the number of trucks on TMC $t$ in hour bin $h$ for month $m$; and
- trucks $_{t, m}$ is the total number of trucks on TMC $t$ for month $m$.

Figure A4: Example Segment - Hourly Truck Distribution



To account for continuing growth in GPS data coverage, the method for calculating hourly truck volumes was updated in 2018. Specifically, this new methodology now accounts for areas and times where hourly volume data were unavailable in ATRI's truck GPS data set by incorporating a robust methodology for estimating missing hourly truck volume distributions (i.e. dist $t_{t, m, h}=0$ ), TMCs on the NHS are grouped into four Research
categories that best define their operational characteristics. These TMC categories (c) are:

- Urban Interstate,
- Rural Interstate,
- Urban Other, and
- Rural Other.

Average and minimum volume distributions for each of these TMC categories are calculated by aggregating data from TMCs with complete data coverage as a preliminary step to fill in missing TMC-month-hour distributions.

If dist $_{t, m, h}=0$ for a TMC in TMC category c , then the missing data are filled in with the average hourly volume distribution for TMC category c. The average hourly volume distribution for TMC category c during hour $h$ is calculated as:

$$
\operatorname{avgDist}_{c, m, h}=\frac{\sum_{t=0}^{n} \text { pings }_{t, m, h}}{\sum_{t=0}^{n} \sum_{h=0}^{23} \text { pings }_{t, m, h}},
$$

Where:

- $n$ is the number of TMCs that meet the criteria of TMC category $c$.

A minimum volume distribution for TMC category c is also needed to serve as a lower bound for dist $_{t, m, h}$ during the redistribution process. The minimum volume distribution for TMC category c during hour h is calculated as:
$\operatorname{minDist}_{c, m, h}=$ dist $_{t, m, h}$ for the bottom $1^{\text {st }}$ percentile of TMCs in TMC category c

Prior to accounting for unavailable hourly volume data, the hourly volume distributions for a given TMC in a month sum to 100. After filling in the TMC-month-hour distributions where dist $_{t, m, h}=0$ with avgDist ${ }_{c, m, h}$, however, the sum of the hourly volume distributions for a given TMC in a month will exceed 100. For each TMC-month combination in which any dist $_{t, m, h}$ were filled in with $\operatorname{avgDist}_{c, m, h}$, the values for the $d i s t_{t, m, h}$ in which dist $_{t, m, h} \neq 0$ must be redistributed (reduced) such that the hourly volume distributions for a given TMC in a month sum back up to 100.

The redistribution factor for a TMC with missing data filled in is calculated as:

$$
\text { redistFactor }_{t, m}=\frac{\sum_{h=0}^{k} \text { dist }_{t, m, h}}{24-k}, \text { where }
$$

- $k$ is the number of TMC-hour combinations in which missing values were filled in with $\operatorname{avg}$ Dist $_{c, m, h}$ for TMC t .
redistFactor ${ }_{t, m}$ is then be applied to the remaining hourly volume distribution values for TMC t during month $m$ as long as:

$$
\operatorname{minDist}_{c, m, h} \leq \text { dist }_{t, m, h}-\text { redistFactor }_{t, m}
$$

If

$$
\text { minDist }_{c, m, h}>\text { dist }_{t, m, h}-\text { redistFactor }_{t, m}, \text { then }
$$

$d i s t_{t, m, h}$ retains its initial value in the final hourly truck volume distribution and redistFactor ${ }_{t, m}$ is recalculated as:

$$
\text { redistFactor } r_{t, m}=\frac{\sum_{h=0}^{k} d i s t_{t, m, h}}{24-k-j}, \text { where }
$$

- j is the number of TMC-hour combinations such that minDist $_{c, m, h}>$ dist $_{t, m, h}-$ redistFactor $r_{t, m}$

The redistribution process repeats on the remaining $24-k-j$ hourly distributions until the hourly volume distributions have been redistributed such that they sum to 100 for every TMC.

Once the hourly volume distributions have been calculated, the volume estimates were then multiplied by a factor equal to the number of weekdays in a month given that this analysis focuses on weekday congestion. Incorporating this factor, the final volume estimates are calculated as:

$$
\operatorname{vol}_{t, h, m, r}=A A D T T_{t, r, 16} *{u t i l_{m, r} * d i s t_{t, h, m} * \text { days }_{m}}
$$

Where:

- $v^{\circ} l_{t, h, m, r}$ is the calculated volume estimate for TMC $t$ in hour bin $h$ for month $m$ with road type $r$;
- $A^{\prime} D T T_{t, r, 16}$ is the calculated AADTT for TMC $t$ with roadway type $r$ for 2016;
- util $l_{m, r}$ is the calculated monthly utility factor for month $m$ and roadway type $r$;
- $d i s t_{t, h, m}$ is the calculated volume distribution for TMC $t$ in hour bin $h$ for month $m$; and
- days $_{m}$ is the number of weekdays in month $m$.


## Calculating Total Delay and Cost

With both marginal delay and volume estimates calculated for each TMC segment per hour of the day and month of the year, the total delay calculation simply becomes:

$$
\operatorname{delay}_{t, h, m}=\operatorname{cong}_{t, h, m} * \operatorname{vol}_{t, h, m, r}
$$

Where:

- delay $_{t, h, m}$ is the calculated total delay on TMC $t$ in hour bin $h$ for month $m$;
- $\operatorname{cong}_{t, h, m}$ is the calculated travel time delay in hours for TMC $t$ in hour bin $h$ for month $m$; and
- $v^{\circ} l_{t, h, m, r}$ is the calculated volume estimate for TMC $t$ in hour bin $h$ for month $m$ with road type $r$.

The final step of the analysis was to apply a monetary equivalent to the total delay figures. ATRI annually produces a national average operating cost figure which is derived from financial data obtained directly from representative motor carriers throughout the country. ${ }^{27}$ Applying this national per-hour cost of operation to the calculated hours of delay yields the total cost of delay incurred on the trucking industry by traffic congestion:

$$
\operatorname{cost}_{t, h, m}=\operatorname{delay}_{t, h, m} * C P H
$$

Where:

- $\operatorname{cost}_{t, h, m}$ is the calculated cost of delay on TMC $t$ in hour bin $h$ for month $m$;
- $\operatorname{delay}_{t, h, m}$ is the calculated total delay on TMC $t$ in hour bin $h$ for month $m$; and
- $\quad C P H$ is the national average cost per hour of operation.

These delay and cost figures were then aggregated across hours and months for each TMC segment to produce the total delay and cost experienced on a particular segment for the entire year. Further aggregation can produce national delay and cost figures which can then be stratified at the state, metropolitan area, and county level.

[^12]
## APPENDIX B: STATE CONGESTION TABLE

| State | 2015 <br> Congestion Cost | 2016 Congestion Cost | Congestion Cost Change (\$) | Miles of NHS Segments | $\begin{aligned} & \text { Cost per } \\ & \text { Mile } \\ & \text { Change (\$) } \end{aligned}$ | Percent Change |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Alabama | \$1,086,683,377 | \$1,038,713,652 | -\$47,969,724 | 10,979 | -\$4,358 | -4.4\% |
| Alaska | \$74,519,308 | \$77,750,152 | \$3,230,844 | 3,989 | \$727 | 3.9\% |
| Arizona | \$689,898,053 | \$716,642,518 | \$26,744,465 | 7,197 | \$3,887 | 4.1\% |
| Arkansas | \$806,122,718 | \$809,745,356 | \$3,622,638 | 8,874 | \$606 | 0.7\% |
| California | \$4,756,368,563 | \$5,059,865,608 | \$303,497,045 | 21,053 | \$14,259 | 6.3\% |
| Colorado | \$886,876,307 | \$879,352,435 | -\$7,523,873 | 10,346 | -\$686 | -0.8\% |
| Connecticut | \$1,244,000,798 | \$1,275,606,923 | \$31,606,125 | 3,573 | \$10,945 | 3.2\% |
| Delaware | \$380,166,836 | \$356,919,653 | -\$23,247,183 | 1,036 | -\$22,124 | -6.0\% |
| District of Columbia | \$74,336,851 | \$82,809,558 | \$8,472,707 | 59 | \$143,222 | 11.4\% |
| Florida | \$5,584,344,521 | \$5,637,019,390 | \$52,674,869 | 18,396 | \$3,204 | 1.1\% |
| Georgia | \$2,150,236,972 | \$2,217,832,693 | \$67,595,722 | 16,568 | \$4,132 | 3.2\% |
| Hawaii | \$40,197,226 | \$98,926,894 | \$58,729,668 | 921 | \$57,505 | 115.2\% |
| Idaho | \$220,459,058 | \$232,107,926 | \$11,648,867 | 5,531 | \$2,110 | 5.3\% |
| Illinois | \$2,928,208,863 | \$2,903,204,725 | -\$25,004,138 | 17,266 | -\$1,207 | -0.7\% |
| Indiana | \$1,517,846,182 | \$1,456,572,097 | -\$61,274,085 | 11,713 | -\$5,152 | -4.0\% |
| Iowa | \$395,843,994 | \$384,196,349 | -\$11,647,645 | 11,175 | -\$1,018 | -2.9\% |
| Kansas | \$369,264,454 | \$346,630,568 | -\$22,633,886 | 10,624 | -\$2,170 | -6.2\% |
| Kentucky | \$1,923,965,622 | \$1,897,927,170 | -\$26,038,452 | 7,889 | -\$3,553 | -1.5\% |
| Louisiana | \$2,198,503,688 | \$2,300,465,910 | \$101,962,222 | 7,999 | \$13,202 | 4.8\% |
| Maine | \$431,679,833 | \$441,427,393 | \$9,747,560 | 3,577 | \$2,788 | 2.3\% |
| Maryland | \$2,100,402,789 | \$2,024,487,754 | -\$75,915,036 | 5,141 | -\$14,067 | -3.4\% |
| Massachusetts | \$1,778,394,528 | \$1,806,188,142 | \$27,793,614 | 5,991 | \$5,246 | 1.8\% |
| Michigan | \$624,679,029 | \$574,359,585 | -\$50,319,445 | 10,819 | -\$4,551 | -7.9\% |
| Minnesota | \$819,916,376 | \$844,217,011 | \$24,300,635 | 12,814 | \$1,930 | 3.0\% |
| Mississippi | \$574,980,316 | \$666,678,919 | \$91,698,603 | 8,720 | \$10,649 | 16.2\% |
| Missouri | \$1,045,470,616 | \$1,024,013,704 | -\$21,456,913 | 15,014 | -\$1,445 | -2.1\% |
| Montana | \$210,179,726 | \$179,679,037 | -\$30,500,690 | 8,854 | -\$3,368 | -14.2\% |
| Nebraska | \$230,875,370 | \$235,221,291 | \$4,345,922 | 8,375 | \$537 | 2.0\% |
| Nevada | \$330,133,827 | \$293,020,612 | -\$37,113,215 | 5,456 | -\$6,762 | -11.2\% |
| New Hampshire | \$601,098,371 | \$596,732,782 | -\$4,365,589 | 2,537 | -\$914 | -0.4\% |
| New Jersey | \$3,313,022,934 | \$3,350,935,426 | \$37,912,492 | 6,172 | \$6,976 | 1.3\% |
| New Mexico | \$582,600,642 | \$579,136,081 | -\$3,464,562 | 6,565 | -\$409 | -0.5\% |
| New York | \$4,350,720,877 | \$4,347,935,258 | -\$2,785,620 | 16,985 | \$752 | 0.3\% |
| North Carolina | \$2,418,593,017 | \$2,429,355,868 | \$10,762,851 | 15,753 | \$725 | 0.5\% |
| North Dakota | \$210,259,488 | \$198,548,841 | -\$11,710,647 | 8,157 | -\$1,513 | -5.9\% |
| Ohio | \$2,921,798,579 | \$2,769,050,420 | -\$152,748,158 | 15,809 | -\$9,287 | -5.0\% |


| State | 2015 <br> Congestion <br> Cost | 2016 <br> Congestion <br> Cost | Congestion <br> Cost Change <br> $\mathbf{( \$ )}$ | Miles of <br> NHS <br> Segments | Cost per <br> Mile <br> Change $\mathbf{( \$ )}$ | Percent <br> Change |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| Oklahoma | $\$ 798,420,429$ | $\$ 748,415,006$ | $-\$ 50,005,423$ | 9,815 | $-\$ 5,879$ | $-7.2 \%$ |
| Oregon | $\$ 846,325,671$ | $\$ 864,162,204$ | $\$ 17,836,533$ | 9,227 | $\$ 1,663$ | $1.8 \%$ |
| Pennsylvania | $\$ 3,088,889,916$ | $\$ 2,885,361,948$ | $-\$ 203,527,968$ | 16,087 | $-\$ 12,014$ | $-6.3 \%$ |
| Rhode Island | $\$ 303,144,871$ | $\$ 352,723,384$ | $\$ 49,578,513$ | 1,214 | $\$ 41,438$ | $16.6 \%$ |
| South Carolina | $\$ 1,788,237,999$ | $\$ 1,807,419,337$ | $\$ 19,181,338$ | 9,101 | $\$ 2,379$ | $1.2 \%$ |
| South Dakota | $\$ 242,534,590$ | $\$ 243,382,312$ | $\$ 847,722$ | 8,183 | $\$ 66$ | $0.2 \%$ |
| Tennessee | $\$ 2,954,638,992$ | $\$ 2,838,362,415$ | $-\$ 116,276,577$ | 12,532 | $-\$ 8,877$ | $-3.8 \%$ |
| Texas | $\$ 6,057,365,603$ | $\$ 6,370,989,505$ | $\$ 313,623,902$ | 37,419 | $\$ 8,354$ | $5.2 \%$ |
| Utah | $\$ 2,226,632,929$ | $\$ 2,112,323,433$ | $-\$ 114,309,496$ | 6,097 | $-\$ 15,673$ | $-4.3 \%$ |
| Vermont | $\$ 180,210,175$ | $\$ 196,621,844$ | $\$ 16,411,669$ | 2,013 | $\$ 8,316$ | $9.3 \%$ |
| Virginia | $\$ 1,668,820,334$ | $\$ 1,609,019,148$ | $-\$ 59,801,186$ | 10,226 | $-\$ 5,476$ | $-3.4 \%$ |
| Washington | $\$ 1,143,963,200$ | $\$ 1,134,841,207$ | $-\$ 9,121,993$ | 8,055 | $-\$ 1,261$ | $-0.9 \%$ |
| West Virginia | $\$ 718,084,606$ | $\$ 822,761,736$ | $\$ 104,677,130$ | 4,753 | $\$ 22,224$ | $14.7 \%$ |
| Wisconsin | $\$ 2,013,095,351$ | $\$ 2,164,660,873$ | $\$ 151,565,522$ | 14,671 | $\$ 10,473$ | $7.6 \%$ |
| Wyoming | $\$ 212,226,905$ | $\$ 208,294,882$ | $-\$ 3,932,023$ | 6,888 | $-\$ 551$ | $-1.8 \%$ |

## 950 N Glebe Road

Arlington, VA
(703) 838-1966 atr@trucking.org
TruckingResearch.org


[^0]:    ${ }^{1}$ Pierce, Dave and Dan Murray. Cost of Congestion to the Trucking Industry. American Transportation Research Institute. Arlington, Virginia. April 2014.
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    ${ }^{4}$ Available online: https://ops.fhwa.dot.gov/freight/freight analysis/faf/
    ${ }^{5}$ Hooper, Alan and Dan Murray. An Analysis of the Operational Costs of Trucking: 2017 Update. American Transportation Research Institute. Arlington, Virginia. October 2017.

[^1]:    ${ }^{6}$ U.S. Department of Transportation. National Highway Traffic Safety Administration. Police-Reported Motor Vehicle Traffic Crashes in 2016. March 2018.
    ${ }^{7}$ Table 1.1.1 Percent Change from Preceding Period in Real Gross Domestic Product. National Income and Product Accounts Tables. Bureau of Economic Analysis. U.S. Department of Commerce. Last Revised September 27, 2018.
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[^2]:    ${ }^{10}$ A working year is defined as driving 11 hours a day, 5 days a week, for 50 weeks per year.
    ${ }^{11}$ The rationale for and explanation of the revisions made to ATRI's Cost of Congestion methodology are detailed in Appendix A on pages 31 through 33.
    ${ }^{12}$ Hooper, Alan and Dan Murray. An Analysis of the Operational Costs of Trucking: 2017 Update. American Transportation Research Institute. Arlington, Virginia. October 2017.
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    https://www.fhwa.dot.gov/policyinformation/statistics/2016/vm1.cfm
    ${ }^{14}$ Ibid.

[^3]:    ${ }^{15}$ Table 1.1.1 Percent Change from Preceding Period in Real Gross Domestic Product. National Income and Product Accounts Tables. Bureau of Economic Analysis. U.S. Department of Commerce. Last Revised September 27, 2018.

[^4]:    16 "Statewide Transportation Improvement Program." Wisconsin Department of Transportation. January 2016. Available online: https://wisconsindot.gov/Documents/doing-bus/local-gov/astnce-pgms/highway/stip/final-2016.pdf.

[^5]:    17 "Kalanianaole Highway Improvements Project Begins Monday, Aug. 29." Hawaii Department of Transportation. August 26, 2016. http://hidot.hawaii.gov/highways/kalanianaole-highway-improvements-project-begins-monday-aug29/.
    18 "Paumalu Stream Bridge Repairs Begin May 16, Lane Closure and Contraflow Necessary." Hawaii Department of Transportation. May 13, 2016. http://hidot.hawaii.gov/highways/paumalu-stream-bridge-repairs-begin-may-16-lane-closure-and-contraflow-necessary/.

[^6]:    ${ }^{19}$ Alves, Ryan. "I-65 traffic woes continue." The News-Enterprise. April 14, 2017. http://subscriber.thenewsenterprise.com/content/i-65-traffic-woes-continue.

[^7]:    20 "2015 Road Ready e-Brochure Mid-Summer Update." Maryland State Highway Administration. July 25, 2015. Available online: https://www.roads.maryland.gov/OC/Road Ready 2015.pdf.

[^8]:    ${ }^{21}$ Costello, Bob. "Truck Driver Shortage Analysis 2017." American Trucking Associations. Arlington, VA. October 2017.

[^9]:    ${ }^{22}$ Total network length in miles is estimated by dividing the total segment miles figure in half.
    ${ }^{23}$ Core Based Statistical Areas (CBSAs). United States Department of Commerce, United States Census Bureau. Available online: https://www.census.gov/geo/maps-data/data/cbf/cbf msa.html. For the purposes of this report micropolitan areas are referred to as metropolitan.

[^10]:    ${ }^{24}$ Table VM-1: Annual Vehicle Distance Traveled in Miles and Related Data by Highway Category and Vehicle Type - 2015. Highway Statistics Series 2015. U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information. January 2017. Available online: https://www.fhwa.dot.gov/policyinformation/statistics/2015/vm1.cfm

[^11]:    ${ }^{25}$ Traffic Volume Trends. Table - 1. Estimated Individual Monthly Motor Vehicle Travel in the United States. U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information. December 2015. Available online: https://www.fhwa.dot.gov/policyinformation/travel monitoring/15dectvt/15dectvt.pdf
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[^12]:    ${ }^{27}$ Hooper, Alan and Dan Murray. An Analysis of the Operational Costs of Trucking: 2017 Update. American Transportation Research Institute. Arlington, Virginia. October 2017.

