Estimated Cost of Freight Involved in Highway Bottlenecks

Prepared for
Federal Highway Administration
Office of Transportation Policy Studies

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Executive Summary

Objectives of This Report

There are four objectives for this study:

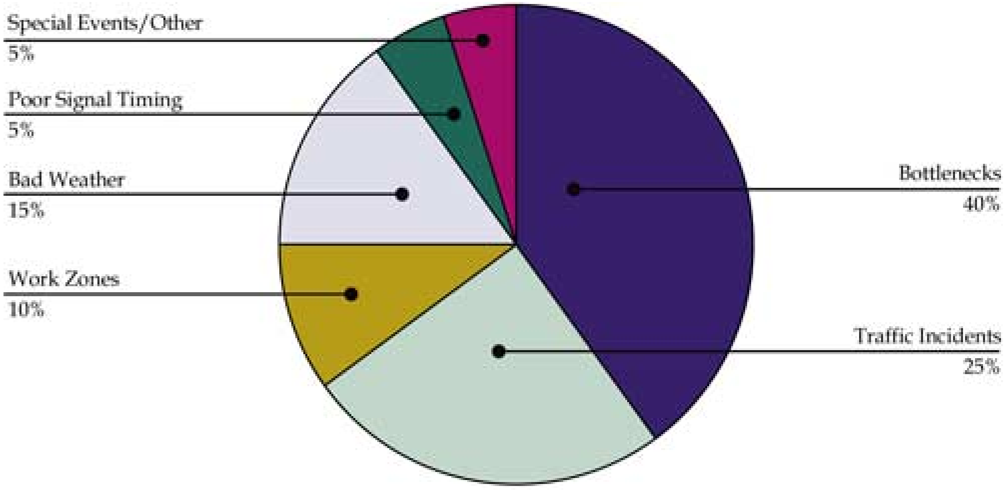
1. Identify the highway traffic bottlenecks in the country that delay truck freight, based on the total amount annual truck delay. Approximately 200 such locations should be identified. A sketch planning method is used to accomplish this task.
2. For the worst bottlenecks, identify the top 30 locations using a more refined methodology to derive truck annual truck delay.
3. Discuss trends in congestion related to trucks, especially with regard to the previous FHWA freight bottleneck study.[1]
4. Provide suggestions for how truck-related bottlenecks should be monitored in the future and provide options for FHWA in developing a freight bottleneck program.

The Congestion Problem in the U.S.

National estimates of how each of these sources contributes to total congestion have been made by FHWA (Figure ES.1). However, local conditions vary widely – the national estimates probably do not apply for individual facilities or areas. Studies of individual urban freeways indicate that the amount of congestion due to recurring (bottleneck) sources is higher, indicating that bottlenecks are a highly significant aspect of the congestion problem.

Highway bottlenecks affecting freight are a problem today because they delay large numbers of truck freight shipments. They will become increasingly problematic in the future as the U.S. economy grows and generates more demand for truck freight shipments. If the U.S. economy grows at a conservative annual rate of 2.5 to 3 percent over the next 20 years, domestic freight tonnage will almost double and the volume of freight moving through the largest international gateways may triple or quadruple.

Figure ES.1 The Sources of Congestion
National Summary



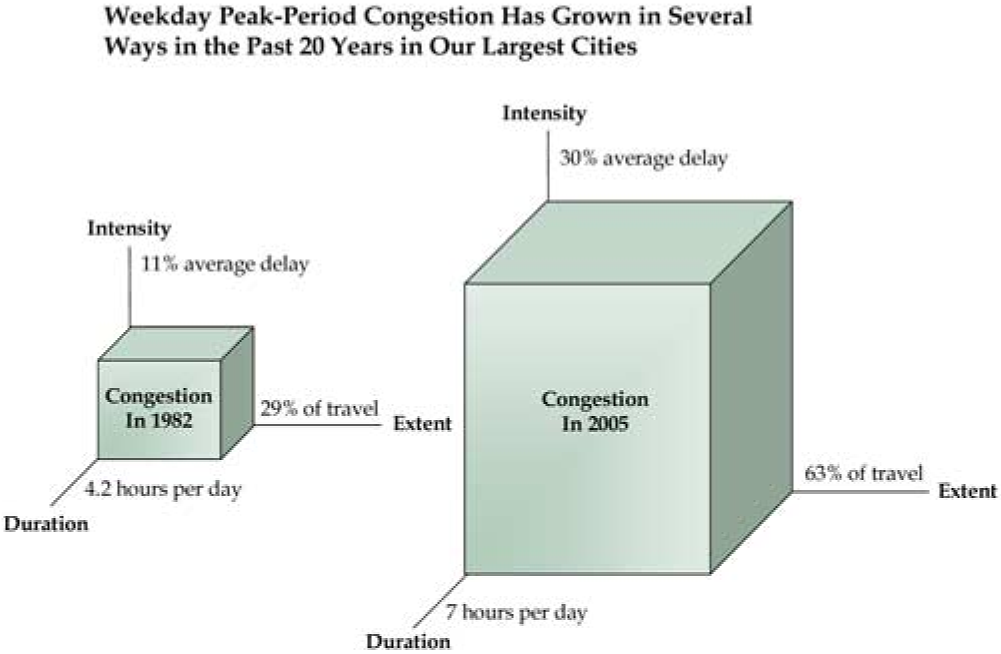
Source: http://www.ops.fhwa.dot.gov/aboutus/opstory.htm

Just in the past decade, traffic demand has increased significantly. The result has been considerable congestion and delays to automobiles and truck traffic, with potentially significant impacts on air quality and the natural environment. Figure ES.2 shows how congestion has expanded since 1982 on three dimensions; not only has the average delay increased, but congestion now affects significantly more roadways (travel) and is present for more hours of the day.

The Texas Transportation Institute's (TTI) 2007 Urban Mobility Report estimates that the cost of congestion in the 437 U.S. urban areas in 2005 was $78 billion. Corresponding to that dollar loss is 4.2 billion hours of delay and 2.9 billion gallons of excess fuel consumed. However, the TTI methodology is based on analyzing mainline segments of highway rather than specific bottlenecks.

The demand for freight transportation is driven by economic growth. The United States' economy is forecast to grow at a compound annual rate of 2.8 percent over the next 30 years. This means that the gross domestic product (GDP) – a measure of the market value of all final goods and services produced in the nation – will grow by 130 percent over the same period. This rate of growth is slightly lower than the rate of growth over the last decade, which averaged 3 percent, but about the same rate of growth experienced over the last 30 years.

Figure ES.2 Growth in Congestion
1982 to 2005

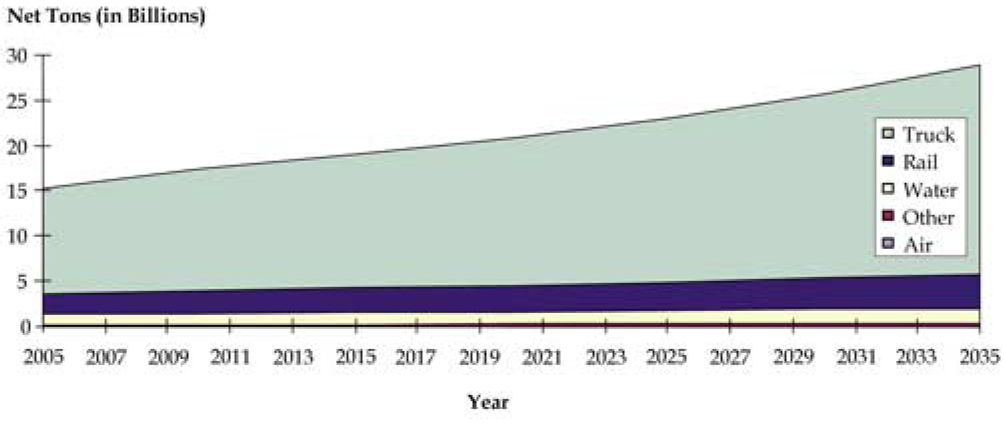


Source: Cambridge Systematics, Inc., and Texas Transportation Institute; *Traffic Congestion and Reliability Trends and Advanced Strategies for Congestion Mitigation*; September 1, 2005.

The demand for freight transportation to support this economic growth will nearly double between 2005 and 2035. Measured in tons, freight demand will grow from 15 billion tons today to 26 billion tons in 2035, an increase of 89 percent. Measured in ton-miles (a ton of freight moved a mile counts as one ton-mile), freight demand will grow from 6 trillion ton-miles today to 11 trillion ton-miles in 2035, an increase of 92 percent. Figure ES.3 shows the freight tonnage forecast by mode for 2005 through 2035; the most significant increase in demand is exhibited by trucks.

Delays to trucks are of particular concern to the nation because the national economy is highly dependent on reliable and cost-effective truck-freight transportation. Truck delays add to the cost of freight shipments, increasing the cost of doing business in the region and the cost of living. The delays come at a time when shippers and receivers are putting more pressure on motor carriers to reduce shipment costs and improve service to support fast cycle, on demand supply chains.

Figure ES.3 Freight Tonnage Forecast
By Mode – 2005 to 2035



Source: Global Insight, Inc., TRANSEARCH 2004.

The increase in freight demand and truck travel means that where today, on average, there are 10,500 trucks per day per mile on the Interstate Highway System, in 2035 there will be 22,700 trucks, with the most heavily used portions of the system seeing upwards of 50,000 trucks per day per mile.[2] The additional freight trucks will add to traffic congestion. The number of automobile and local truck trips also will grow with population and the economy. The result will be more traffic and more traffic congestion nationally.

Highway Bottlenecks — Background

In the past several years, transportation professionals have come to realize that highway bottlenecks – specific points on the highway system where traffic flow is restricted due to geometry, lane drops, weaving, or interchange-related merging maneuvers – demand special attention. The congestion caused by bottlenecks results from the interaction of traffic and these points of reduced capacity, and is usually referred to as "recurring congestion." In the past, recurring congestion was felt to be a systemic problem ("not enough lanes"), but the root cause of recurring congestion is in fact bottlenecks, not uniform highway segments.

The American Highway Users Alliance (AHUA) published two studies of national bottlenecks in 1999 and 2004.[3] The studies ranked the worst bottlenecks and highlighted locations where successful improvements had been made. These studies received extensive media attention and helped to galvanize interest in specifically addressing bottlenecks. On freeways, the AHUA study found that the predominant type of bottleneck was freeway-to-freeway interchanges. Lane-drop bottlenecks were far less common and interchanges with surface streets produced significantly less delay than freeway-to-freeway interchanges.

FHWA undertook a study of truck-related bottlenecks in 2005.[4] The study used the same methodology as the AHUA studies but calculated truck-only delay at the bottlenecks using truck volume information from HPMS and the Freight Analysis Framework. A study performed for the Ohio Department of Transportation[5] expanded on the bottleneck analysis approach used in both the AHUA and previous FHWA studies.

In 2006, CS applied the Ohio DOT methodology to national freight bottlenecks.[6] The I-95 Corridor Coalition has two truck-related bottleneck studies underway:

1. A regional study of bottlenecks for all states in the Coalition, which uses only the simple AHUA methodology; and
2. A subregion study of bottlenecks for the Mid-Atlantic states, which uses the methodology previously developed for FHWA in the 2005 study.

A key aspect of these studies was a survey of Coalition states to identify what they feel are their worst bottlenecks. As discovered in the original AHUA study, this local knowledge is indispensable in conducting the analysis, rather than relying blindly on HPMS or other inventory data.

Methodology

The significant aspects of these steps are further detailed in the subsections that follow.

1. **Assemble Initial List of Bottlenecks by "Scanning" HPMS –** The AHUA methodology was used with the 2006 HPMS data to make a first ranking of truck-related bottlenecks. This method is based on identifying HPMS segments where capacity is restricted, i.e., the AADT-to-capacity (AADT/C)[7] ratio is above 12.0.

2. **Compare Initial List of Bottlenecks in Those in the I 95 Corridor –** Concurrent with this study, the I 95 Corridor Coalition is identifying truck-related bottlenecks in Coalition states. In this study, Coalition states were asked to nominate their worst truck-related bottlenecks for consideration. Any Coalition state locations not identified by the HPMS scan were added to the list of national bottlenecks were located in HPMS, and the annual truck delay was estimated.
3. **Compare Initial List to FHWA Office of Operations Bottleneck Survey –** The 2006 survey of state bottlenecks conducted by the FHWA Office of Operations was used to further refine the initial list of bottleneck locations; these also were identified in HPMS and their annual truck delay was estimated.
4. **For Final List of National Bottlenecks, Identify the HPMS Segments representing the Bottleneck –** This step was a manual process of matching the bottleneck with corresponding HPMS data.
5. **Identify Top 40 Preliminary Bottlenecks –** From the combined list of preliminary bottlenecks, identify the top 40 (in terms of total truck delay) for detailed analysis. The concept is that the scan method is imprecise, so in order to get the top 30, a greater number of locations need to be analyzed.
6. **Identify the Geometric Characteristics for Each of the Top 40 Bottlenecks –** For each location, the key merge points where traffic is moving away from the center of the interchange were identified. At each merge point, the number of entering and exiting lanes was noted. The capacity of each merge juncture was determined by the minimum of either the number of exiting lanes or the number of lanes 1,500 feet downstream.
7. **Identify HPMS Traffic Data and FAF2 Truck Volumes –** On each leg of the interchange, identify HPMS-derived AADTs. Use FAF2 truck volumes from the previous FHWA Freight Bottleneck Study where available to derive truck percents. Where these are unavailable, use HPMS truck percents.
8. **Develop Daily Turning Movements** – Using the balancing procedure from NCHRP Report 255, directional AADT turning movements were synthesized. This was necessary because ramp volume counts were unavailable. (See Section 2.3 for details.)
9. **Conduct Delay Analysis for Each Merge Juncture, Weaving, and Other Capacity Restrictions at the Interchanges –** The equations developed for another FHWA study[8] were used to estimate total delay at each point. Truck percents were applied to derive truck delay.
10. **Compare Truck Speeds from the American Transportation Research Institute (ATRI) at the Bottlenecks –** ATRI provided to FHWA truck travel times on the approaches to the bottlenecks identified in this study. Delay values are compared.

National Inventory of Truck Bottlenecks

We located and estimated truck hours of delay for the various types of highway truck bottlenecks. Table ES.1 lists the types of bottlenecks and the annual truck hours of delay associated with each type. The bottleneck types are sorted in descending order of truck hours of delay by constraint type and then within each group by the truck hours of delay for each bottleneck type.

Table ES.1 also shows the delay values from Reference 1. It must be noted that the 2004 and 2006 numbers are not directly comparable, because the 2004 values are based on truck volumes from the FAF while the 2006 numbers are based on truck volumes from HPMS. Further, the number of bottlenecks is not directly comparable due to additional sources being used in 2006 (inclusion of the I 95 Corridor Coalition identified locations) and changes in HPMS data.

In 2006, the bottlenecks accrued 226 million hours of delay. At a delay cost of $32.15 per hour, the conservative value used by the FHWA's Highway Economic Requirements System model for estimating national highway costs and benefits, the direct user cost of the bottlenecks is about $7.3 billion per year.[9]

Table ES.1 Truck Hours of Delay by Type of Highway Freight Bottleneck

Constraint	Highway Type	Freight Route	National Annual Truck Hours of Delay, 2006 (Estimated)	National Annual Truck Hours of Delay, 2004 (Reference 1)
Interchange and Lane Drop	Freeway	Urban Freight Corridor	151,519,000	
Interchange and Lane Drop	Freeway	Intercity Freight Corridor	36,000	
Interchange and Lane Drop	Freeway	**Subtotal**	**151,555,000**	**134,517,000**
Steep Grade	Arterial	Intercity Freight Corridor	15,001,000	
Steep Grade	Arterial	Urban Freight Corridor	471,000	
Steep Grade	Freeway	Intercity Freight Corridor	10,697,000	
Steep Grade	Freeway	**Subtotal**	**26,169,000**	**32,859,000**
Signalized Intersections	Arterial	Urban Freight Corridor	43,462,000	
Signalized Intersections	Arterial	Intercity Freight Corridor	4,799,000	
Signalized Intersections	Arterial	**Subtotal**	**48,261,000**	**43,113,000**
		Total	**225,985,000**	**210,489,000**

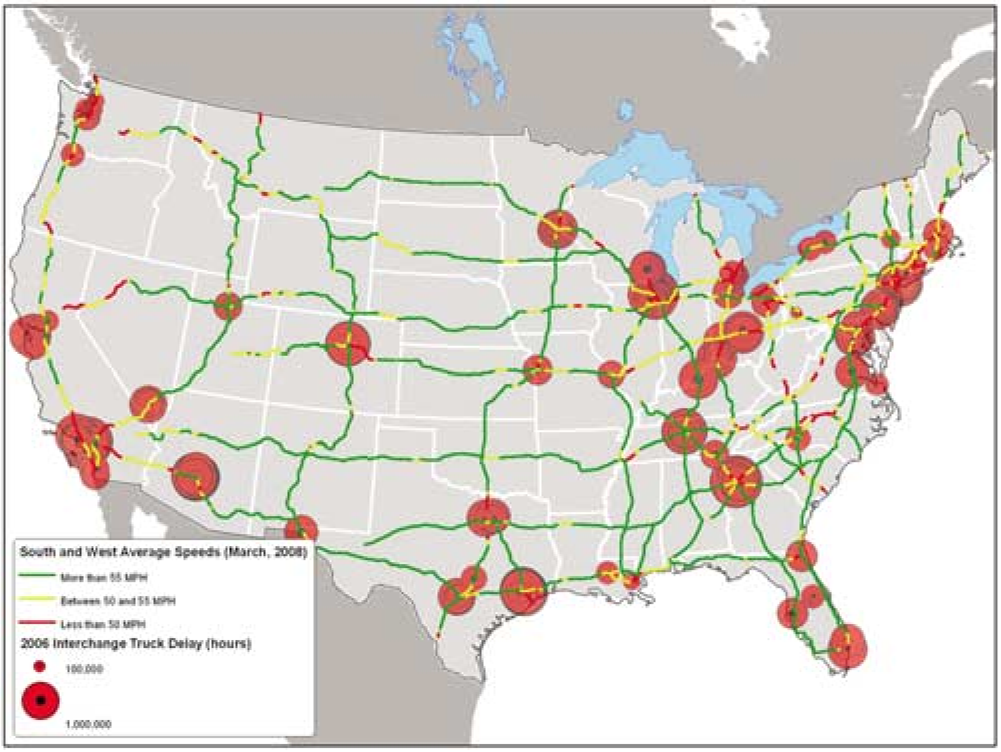
Notes:

1. **Interchange and Lane Drops –** The delay estimation methodology calculated delay resulting from queuing on the critically congested roadway of the interchange (as identified by the scan) and the immediately adjacent highway sections. Estimates of truck hours of delay are based on two-way traffic volumes. The bottleneck delay estimation methodology also did not account for the effects of weaving and merging at interchanges, which aggravates delay, but could not be calculated from the available HPMS data.
2. **Steep Grades and Signalized Intersections –** The total delay shown is the expanded delay, assuming that the HPMS Sample data used in the analysis does not cover all possible grades or signals. Unexpanded delay for steep grades and signalized intersections are 11,048,000 and 12,415,000, respectively.
3. **Steep Grades –** It is assumed that the delay is incurred only by trucks on the upgrade (one direction). The delay values in Reference 1 were computed for both directions, so they have been halved here.

Interchange Bottlenecks for Trucks

A total of 326 bottlenecks were identified. Figure ES.4 shows the locations of the bottlenecks overlaid on national speed data produced by the American Transportation Research Institute. Note that this shows only the South and West directions; Appendix F shows the map for the North and East directions.

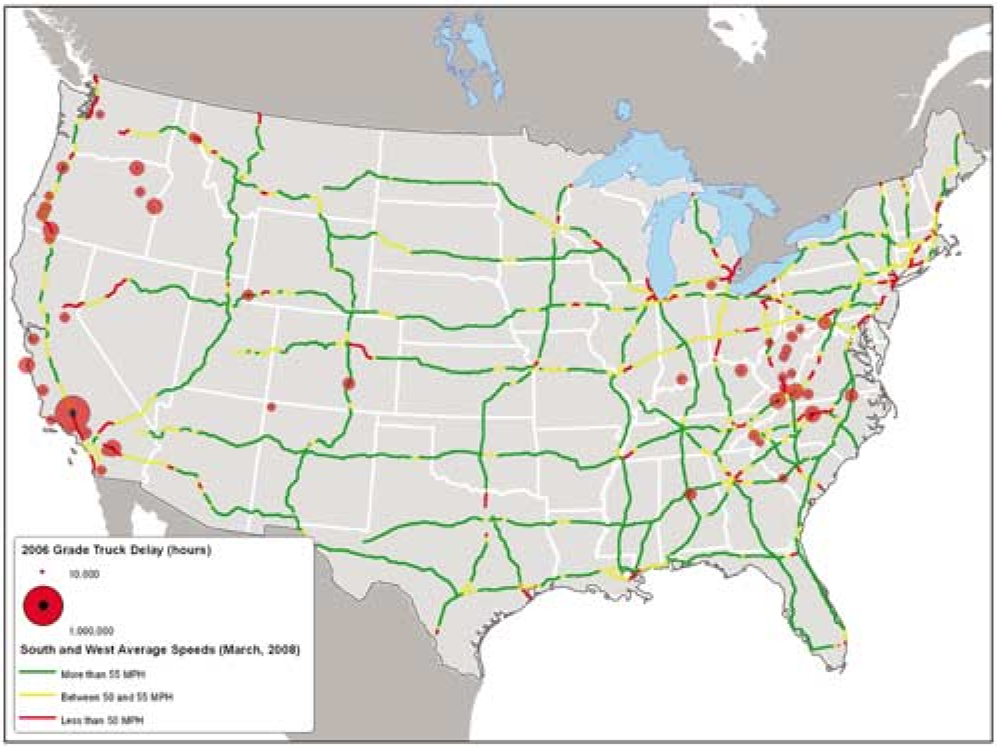
Figure ES.4 Interchange Bottlenecks Identified with the HPMS Scan Method and National Truck Speeds
2006 (South and West Directions)



Steep-Grade Bottlenecks for Trucks

We located 818 bottlenecks created by steep grades on freeways and arterials. These bottlenecks were located by scanning the HPMS Sample database for roadway sections with grades greater than 4.5 percent and more than a mile long. These bottlenecks represent a partial inventory of this type of bottleneck. Using HPMS expansion factors, we estimate that the total delay associated nationally with this type of bottleneck in 2006 was about 26 million truck hours or 12 percent of the total truck hours of delay. At a delay cost of $32.15 per hour, the direct user cost of the bottlenecks is about $836 million per year. Figure ES.5 shows the location of the steep-grade bottlenecks. Note that this shows only the South and West directions; Appendix F shows the map for the North and East directions.

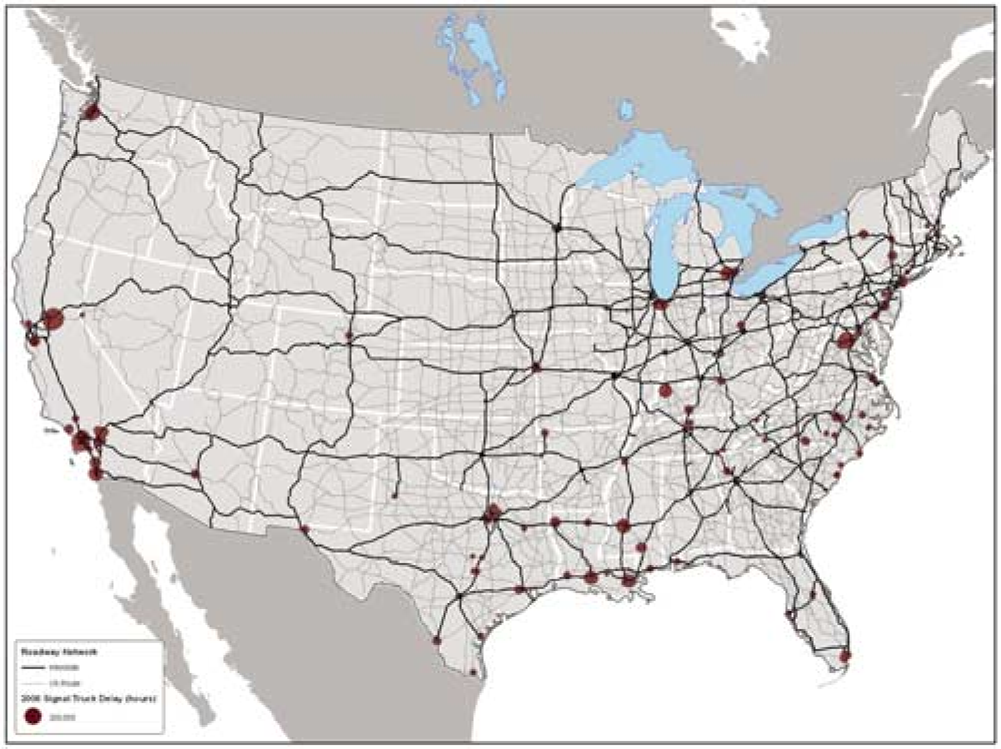
Figure ES.5 Grade Bottlenecks Identified with HPMS Scan Method and National Truck Speeds *2006 (South and West Directions)*



Signalized Intersection Bottlenecks for Trucks

We located 559 truck-related bottlenecks caused by signalized intersections on arterials. These bottlenecks were located by scanning the HPMS Sample database for signalized roadway sections with a volume-to-capacity ratio greater than 0.925. These bottlenecks also represent a partial inventory of this type of bottleneck. Expanding the sample, we estimate that the total delay associated nationally with this type of bottleneck in 2006 was about 48 million truck hours of delay. At a delay cost of $32.15 per hour, the direct user cost of the bottlenecks is about $1.5 billion per year. The truck volumes and highway capacity calculations were based on the HPMS Sample statistics. Figure ES.6 shows the location of the signalized intersection truck bottleneck locations.

Figure ES.6 Signal Bottlenecks Identified with the HPMS Scan Method
2006



Detailed Delay Analysis of the Top Bottlenecks

The national scan of bottlenecks produced a “short list” for more detailed examination. The main criterion for developing this short list was to look at locations with the highest truck delays. This resulted in considering freeway bottlenecks for the next level of analysis, because truck volumes are higher (i.e., more trucks are exposed to congestion on freeways). The bottleneck delay results from the ramp-based delay methodology are shown in Table ES.2. The bottlenecks are listed in order from the highest to the lowest based on the current delay estimates. The delay values for the previous FHWA study also are presented.

Table ES.2 Annual Delays, Based on Detailed Delay Method, at Major Truck Bottlenecks
2006

No.	Bottleneck Name	County/State	Annual Truck Delay (Hours) 2006[a]	Annual Truck Delay (Hours) 2004[a]	ATRI-Derived Truck Delay[b]	Number of ATRI Trucks Measured[b]	Caltrans HICOMP Congestion[c]
1	I-710 at I-105 Interchange	Los Angeles, California	1,550,000	425,200	1,240,000	27,488	4 of 4 legs
2	I-17 (Black Canyon Freeway): I-10 Interchange (the "Stack") to Cactus	Maricopa, Arizona	1,492,100	493,200	728,100	42,395	
3	I-285 at I-85 Interchange ("Spaghetti Junction")	De Kalb, Georgia	1,415,500	1,815,100	2,063,000	71,865	
4	I-20 at I-75/I-85	Fulton,	1,336,500	285,100	1,446,000	27,537	

	Interchange	Georgia					
5	I-80 at I-94 split in Chicago, Illinois	Cook, Illinois	1,300,000	1,365,300	1,368,400	227,578	
6	SR 60 at SR 57 Interchange	Los Angeles, California	1,259,700	*1,029,700*	705,000	52,140	2 of 3 legs
7	I-80 at I-580/I-880 in Oakland, California	Alameda, California	1,240,000	1,838,700	2,703,000	10,347	
8	I-405 (San Diego Freeway) at I-605 Interchange	Orange, California	1,221,500	2,662,600	273,500	4,426	4 of 4 legs
9	I-90 at I-94 Interchange ("Edens Interchange")	Cook, Illinois	1,185,700	1,600,300	1,266,800	49,923	
10	I-40 at I-65 Interchange (east)	Davidson, Tennessee	1,099,700	Not included	682,100	51,313	
11	I-290 at I-355 Interchange	DuPage, Illinois	1,039,400	263,600	117,000	49,546	
12	I-75 at I-85 Interchange	Fulton, Georgia	920,800	272,600	1,372,500	18,270	
13	I-95 at SR 9A (Westside Highway; George Washington Bridge approach)	New York, New York	919,200	*445,200*	3,095,050[a]	21,896	
14	I-71 at I-70 Interchange	Franklin, Ohio	905,900	*968,800*	354,000	40,718	
15	I-880 at I-238	Alameda, California	883,900	1,200,300	812,987	13,550	3 of 3 legs
16	I-110 at I-105 Interchange	Los Angeles, California	860,000	*910,000*	1,080,600		2 of 4 legs
17	SR 91 at SR 55 Interchange	Orange, California	816,700	(946,900)	458,356	8,163	Not congested
18	I-285 at I-75 Interchange	Cobb, Georgia	772,200	1,815,000	1,253,476	8,532	
19	I-695/I-70 and I-95 exit 11	Baltimore, Maryland	748,900	(616,800)	270,000	59,523	
20	I-95 at SR 4 (GW Bridge approach)	Bergen, New Jersey	734,600	Not included	(Note[a])	51,257	
21	I-10 at I-110/U.S.-54 Interchange	El Paso, Texas	664,700	(241,800)	105,900	49,672	
22	I-45 (Gulf Freeway) at U.S. 59 Interchange	Harris, Texas	644,700	(386,900)	778,223	32,627	
23	SR 134 at SR 2 Interchange	Los Angeles, California	598,700	267,600	109,000	4,603	1 of 4 legs
24	I-10 at SR 51/SR 202 Interchange ("Ministack")	Maricopa, Arizona	521,600	(982,600)	872,300	8,322	
25	I-10 at I-15	San	513,600	1,308,000	1,037,400	56,102	2 of 4 legs

	Interchange	Bernardino, California					
26	I-95/I-495	Prince Georges, Maryland	475,400	(1,020,100)	685,100	36,540	
27	I-45 at I-610 Interchange	Harris, Texas	450,600	(452,300)	378,300	46,856	
28	I-10 at I-410 Loop North Interchange	Bexar, Texas	450,200	(418,300)	346,600	15,243	
29	I-75 at I-275 Interchange	Kenton, Kentucky	435,600	(662,900)			
30	I-64 atI 65/I-71 Interchange	Jefferson, Kentucky	432,400	(375,900)			
31	I-94 (Dan Ryan Expressway) at I-90 Skyway	Cook, Illinois	292,300	584,500			
32	I-20 at I-285 Interchange	De Kalb, Georgia	215,600	(1,359,400)			
33	I-35E at I-94 Interchange ("Spaghetti Bowl") – East section	Ramsey, Minnesota	210,300	(230,300)			
34	I-95 at I-476 Interchange	Delaware, Pennsylvania	179,600	(437,300)			
35	I-75 at I-74 Interchange	Hamilton, Ohio	124,800	305,800		6,370	

[a] 2006 delay numbers based on the ramp-based method. 2004 delay numbers in parentheses indicate that the "scan" method was used; other values were estimated using the ramp-based method.
[b] ATRI data covers both sides of the George Washington Bridge, including SR 4 in New Jersey and the Westside Highway interchanges; ATRI data for individual locations may be found in Appendix F.
[c] The Caltrans HICOMP report (*State Highway Congestion Monitoring Program, Annual Data Compilation*, November 2007) maybe found at: http://www.dot.ca.gov/hq/traffops/sysmgtpl/HICOMP/pdfs/2006HICOMP.pdf.

Some 2006 bottlenecks were not identified in 2004, and the delay estimates for common bottlenecks vary widely. A number of reasons exist for this discrepancy, which makes the development of trend information impossible from these data:

- The previous study used FAF truck volumes while the current study uses HPMS truck volumes.
- The two studies used different national scans to get the short list, so some bottlenecks were inevitably left out.
- The HPMS data and satellite imagery used to derive the turning movements and geometric characteristics may have changed between the two studies. More importantly, the process of identifying bottleneck locations in HPMS and coding geometric features from satellite imagery is a manual and somewhat subjective process. Many interchange locations are extremely complex and require substantial judgment on how to assign turning movements and code merge areas.

A number of observations regarding the results obtained with the detailed delay analysis can be made:

As with the previous FHWA freight bottleneck study, the delay estimates change when the ramp-based method is used. The ramp-based method provides a more detailed picture of capacity restrictions at the interchanges. Also, as in the previous study, it was found that truck bottlenecks (in terms of total delay) occur at urban commuter bottlenecks.

The list of the highest delay bottlenecks in Table ES.2 is thought to be more accurate than the ones identified in the previous study. This is because the initial pool of locations has been expanded by using state-identified bottlenecks from the I 95 Corridor Coalition (CC) and FHWA's bottleneck survey. Also, more recent HPMS and geometric information has been used here.

As before, there is a much sharper drop off in delay as one proceeds down the list than the list produced by the simple scanning method. The reason for this is that in the original methodology, a single AADT/C value was used for the entire interchange. This value is based on HPMS data and the value tended to be very similar for the high-delay interchanges. In the current methodology, there is much more distinction between both the AADT/C values for the individual merge junctures and the volumes of trucks using them.

The worst bottleneck is the I 710/I 105 interchange in Los Angeles. I 710 is the major connector to the Port of Long Beach.

The area around the George Washington Bridge in New York and New Jersey requires special discussion. This is an extremely complex area from a geometric standpoint, with multiple highways merging just prior to the Bridge (eastbound, on the New Jersey side; Bottleneck number 19) and a major bottleneck on the eastern end (Bottleneck number 13). For all practical purposes, this probably should be considered a single bottleneck. Truck travel-time data from the American Transportation Research Institute being used in the I 95 CC bottleneck study indicates that annual truck delay on the approaches to the George Washington Bridge is 1,848,000 hours. If Bottleneck numbers 13 and 19 are added together, total delay is 1,654,000 hours, a close agreement.

Los Angeles has five of the top truck bottlenecks, Atlanta has four, and Chicago has three. This is roughly commensurate with the number of commuter bottlenecks found in the AHUA study.

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Several other discrepancies - Bottleneck numbers 8, 22, and 23 - may be occurring because the number of ATRI trucks in the sample is low. Other locations that show a high ramp-based method delay and low ATRI-based delay are Bottleneck numbers 11, 14, and 18.

Other discrepancies are difficult to explain without more detailed local knowledge. Several of these discrepancies are in the Los Angeles area (Bottleneck numbers 6, 8, 22, and 24). Of these, only number 24 has a higher ATRI-based estimate. A separate data source is available for the California bottlenecks; Caltrans publishes annual congestion statistics in their HICOMP report.[10] Caltrans uses a combination of floating car measurements (limited sample vehicle probe) and roadway detector measurements to estimate congestion, which is defined as speeds 35 mph or lower. The results are published as a series of maps showing congested roadway sections. From these maps the rightmost column in Table 3.5 was derived. Comparing HICOMP to the ramp-based and ATRI methods:

I-710 at I-105 – HICOMP verifies the high delay predicted by both methods.

SR 60 at SR 57 – HICOMP shows this section as being moderately to heavily congested, which would tend to verify the ramp-based method.

I-80 at I-580/I-880 (Bay Bridge approach) – HICOMP indicates that the high delay values shown by ATRI are justified.

I-405 at I-605 – HICOMP shows this location as heavily congested verifying the ramp-based method; the low number of trucks measured by ATRI is probably producing an underestimate of delay.

I-880 at I-238 – HICOMP verifies that this location has high delay as predicted by the two methods.

SR 91 at SR 55 – HICOMP indicates that the lower delay derived from the ATRI method is probably correct.

SR 134 at SR 2 – HICOMP shows a low level of congestion, which is probably between the ramp-based and ATRI methods.

I-10 at I-15 – HICOMP shows a moderate level of congestion, which is probably between the ramp-based and ATRI methods.

I-100 at I-105 – HICOMP shows a moderate level of congestion, which is indicated by both methods.

Recommendations for Future Bottleneck Monitoring (Freight and Nonfreight)

The study demonstrates that the basic information to monitor the performance of bottlenecks – interchange configuration/geometrics and traffic – can be cost effectively obtained from existing sources. However, a few improvements in the process are recommended. More refined traffic data may be obtained directly from state DOTs. This would include primarily directional AADTs on each of the approaches of the interchanges. If temporal traffic distributions could be obtained, then instead of applying the default delay equations (which are based on fixed temporal distributions) the queuing procedures used in the Ohio study could be applied directly to each merge juncture. Finally, data on the temporal distributions of trucks – ideally site-specific – would improve the estimates of truck delay.

The process used to determine the lane configurations and geometrics at merge areas (visual inspection of satellite imagery) is somewhat subjective, and becomes more so as the complexity of the ramp layouts become more complex. Many of these complex locations also are major bottlenecks. Verification of interchange configurations with local data – at least for bottlenecks thought to be of high value – should be undertaken.

Additional types of traffic flow restrictions at interchanges should be considered. The study focused on the worst delay bottlenecks, which tend to be major freeway-to-freeway interchanges. There may be some merit in examining simpler geometric bottlenecks, because they are more amenable to low-cost improvements. This study assumed that the “chokepoints” of the intersection are where two or more freeway ramps merge with each other or the mainline. Given the nature of the interchanges studied, nearly all of which are fully directional or mostly so, this assumption was adequate for our purposes. However, if the method is to be applied more universally, other types of restrictions need to be added, such as:

Restricted diverge areas;

Limited acceleration lanes; and

Other types of limited geometry (short radius loops).

For all of these, the way the method will assess them is through the estimate of capacity (to determine if queuing is occurring).

Along these same lines, coordination with FHWA's Office of Operations Bottleneck Initiative should be undertaken. The Bottleneck Initiative is focusing on low-cost improvements which will be beneficial to improving truck flows in the near term.

The HPMS scanning method (based on the original AHUA methodology) should only be used as a screening tool. It has proven to be an effective first cut at bottleneck delay estimation and ranking, but as this study has shown, interchanges are too unique in geometrics and traffic patterns for that method to produce operations-level rankings.

The restructured HPMS data set (i.e., once states start submitting in the new format) can be used directly by the methods developed here. The restructured HPMS will have ramp AADT, presumably directly measured, which will render the synthetic turning movement calculations unnecessary. However, the detail on the lane configurations at interchange merge points will not be collected by HPMS and will still require manual inspection of satellite photos.

The analytic procedures developed here should be considered for inclusion within the HERS model. Specifically, interchange deficiency analysis should be added to HERS as a companion to its current general capacity deficiency analysis (i.e., number of lanes on mainline, noninterchange-influenced segments). The interchange deficiency analysis would be based on the methodology used here. This inclusion will be particularly valuable when HERS migrates to a network-based (rather than sample section-based) framework. Since it is clear that interchanges and there immediate influence areas are the physical items that control congestion on urban freeways, performing delay analysis based on them will provide a much more realistic assessment of capacity deficiencies and needs.

The HERS delay equations should be reviewed. The data on which they were developed are now 15 years old. In particular, the assumptions about traffic variability need to be checked, particularly for congested highways. Some level of field validation also is probably in order.

Comparison of this study with past bottleneck studies reveals inconsistencies in the results, due to use of different data sources, updates to common data sources, additional locations identified by state personnel for the “pool” of candidate sites (e.g., the I 95 Corridor Coalition states), and the subjective nature of some of the analysis steps. These problems frustrate trends analysis, which could be very informative for policy development. Therefore, it is recommended that FHWA consider undertaking a formal program of bottleneck monitoring that would provide this valuable trend information. The Bottleneck Monitoring Program could span FHWA program areas (e.g., Offices of Policy, Operations, and Planning), especially considering the major overlap between commuter and freight bottlenecks. This program would identify a fixed set of bottlenecks to be analyzed every year, perhaps upward of 50. A selected few bottlenecks may be added from year-to-year. The initial list could be based on those bottlenecks identified here, adjusted to accommodate some from the commuter-only realm. With a finite number of locations to start with, the effort could be concentrated on obtaining the detailed data directly from the states, rather than relying on secondary sources. Where freeway surveillance data are available from FHWA's Mobility Monitoring Program, these could be used instead of the modeling approach discussed in this report. Annual trends in both total and truck-only delay (and travel-time reliability where freeway surveillance data are available) would be an excellent way to “take a pulse” of the system in terms of congestion and its impacts.

Probe-based travel time data – such as those from the ATRI project as well as those data available from other private vendors – represent a very valuable resource for congestion monitoring and bottleneck analysis. For example, vehicle probe data from Inrix is now being provided to several I 95 Corridor Coalition states, primarily as a real-time resource. However, the Coalition plans to use these data for monitoring the performance of long-distance trips and for bottleneck identification. Probe-based travel time data could be used in the Bottleneck Monitoring Program outlined above cost-effectively if the number of locations can be restricted. (Some firms will price the data on a coverage basis.)

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[1] Cambridge Systematics, Inc. and Battelle Memorial Institute, *An Initial Assessment of Freight Bottlenecks on Highways, prepared for Federal Highway Administration*, Office of Transportation Policy Studies, October 2005.
[2] Intercounty loaded and empty flows, calculated by truck miles over Interstate highway links divided by the length of the Interstate highway links used in the routes.
[3] *American Highway Users Alliance, Unclogging America's Arteries: Effective Relief for Highway Bottlenecks*, 2004, http://www.highways.org/pdfs/bottleneck2004.pdf.
[4] Cambridge Systematics, Inc. and Battelle Memorial Institute, *An Initial Assessment of Freight Bottlenecks on Highways*, prepared for Office of Transportation Studies, FHWA, October 2005.
[5] Maring, Gary; Margiotta, Rich; Hodge, Daniel; and Beagan, Dan, *Ohio Freight Mobility*, prepared for Ohio Department of Transportation, Office of Research and Development, December 30, 2005.
[6] Cambridge Systematics, Inc., *Application of Detailed Interchange Analysis to Top Freight Bottlenecks: Methods, Results, and Road Map for Future Research*, prepared for Office of Transportation Policy Studies, FHWA, September 1, 2006.
[7] Average Annual Daily Traffic.
[8] Cambridge Systematics, Inc., *Sketch Methods for Estimating Incident-Related Impacts*, prepared for FHWA Office of Planning, December 1998.
[9] The FHWA Highway Economic Requirements System model uses a current value of truck time of $32.15 per hour. Other researchers have suggested higher rates, typically between $60 and $70 per hour.
[10] Caltrans, State Highway Congestion Monitoring Program (HICOMP), Annual Data Compilation, November 2007