

Identify and Quantify Truck Freight Bottlenecks

This chapter describes how to conduct analyses to identify and quantify truck bottlenecks. The first three subsections describe how to conduct this analysis for travel speed-based delay with the final subsection describing how to conduct this analysis for process-based delay. While many of the individual steps overlap, these delay calculations can be computed independently, in series, or in parallel. In most jurisdictions, delay will be larger for travel speed-based delay relative to process-based delay. However, calculating process-based delays will be important in certain circumstances where roadway geometric characteristics and operations are perceived to impede truck mobility.

5.1 Identifying Travel Speed-Based Truck Bottlenecks

The delay computations serve as the basis for the primary desktop analyses that should be performed to identify freight bottlenecks. The basic concept of the “desktop analysis” is that the state highway agency or MPO is able to perform an automated analysis that identifies the most significant bottlenecks across the state or region. The advantage of such an analysis is that it can be done relatively efficiently for a wide variety of locations. The disadvantage is that it requires data from across that wide range of locations. Therefore, such an analysis cannot account for detailed, site-specific data that can be collected only at individual locations (e.g., approach volumes and turning movements by lane group at a signal). Essentially, the desktop analysis takes the data available state-wide (or regionwide) and computes the variety of statistics mentioned above. Table 5-1 summarizes the statistics that should be computed and which will be used to identify travel speed-related freight bottlenecks. Further information on recommended performance measures, including cost calculations, is discussed in Appendix D.

All of these statistics also should be examined within the context of:

- The time of day,
- The day of week, and
- The time of year.

For example, just the total delay for a given roadway segment is not the only interest. Of interest also is:

- The size and proportion of delays that occur on weekdays versus weekends;
- Whether delays occur only during the a.m. or p.m. peak period or throughout the day;

Examples of Bottleneck Identification, Quantification, and Ranking

- Virginia’s Statewide Multimodal Freight Study, Phase I.
- Washington Department of Transportation Freight Mobility Plan.
- Using GPS Truck Data to Identify and Rank Bottlenecks in Washington State.
- I-95 Corridor Coalition: Bottleneck Performance in the I-95 Corridor.
- Columbus-Phoenix City MPO Congestion Management Process: 2007 Update.
- Identifying, Anticipating and Mitigating Freight Bottlenecks on Alabama Intersections.

Table 5-1. Measures recommended for bottleneck identification and quantification.

Measure	Short Description
Total Delay per segment	Vehicle-hours or person-hours per segment
Total Delay per Mile per Segment	Vehicle-hours or person-hours per mile of segment (which normalizes segments of different length when comparing across segments of varied length)
Hours of Delay per Truck	Vehicle-hours or person-hours of delay normalized by the number of trucks (typically reported weekly or yearly)
Frequency of Congestion per Segment	How often time intervals of speed data are congested
Total number of Hours When Congestion Is Present	Time that congestion occurs; in its simplest form it is a sum of time intervals meeting a congestion threshold
TTI	A dimensionless ratio of the actual travel time to the uncongested travel time
PTI	A dimensionless ratio of the 95 th percentile travel time to the uncongested travel time (reliability measure)
Planning-Time Index 80 th (PTI80)	A dimensionless ratio of the 80 th percentile travel time to the uncongested travel time (reliability measure)
Commuter Stress Index (CSI)	Same as TTI except for the peak direction rather than both peaks
Value of wasted time and fuel due to congestion for each segment	Computed as the difference in travel time and fuel use during congestion minus the travel time and fuel use during uncongested conditions and then multiplied by value of time and dollars per gallon of fuel to estimate costs

- Whether delays occur only during some times of the year (e.g., only during the summer) or throughout the year; and
- How these delays differ for trucks in comparison with all vehicles.

These detailed analyses can take into account key details about each study location (e.g., current local transportation improvement plans) that cannot be readily incorporated into an automated statewide analysis.

Understanding the temporal variation in the frequency of congestion formation is a major initial step in identifying and understanding freight bottlenecks, but it is just the start of the bottleneck analysis process.

The basic outputs from the desktop analysis define the size and scope of the travel speed-based congestion bottleneck problem throughout the state or region. Starting from these results, the roadway agency can then select a subset of the identified bottleneck locations to perform more detailed analyses to examine the effectiveness of different

approaches to mitigating those bottlenecks. These detailed analyses can take into account key details about each study location (e.g., current local transportation improvement plans) that cannot be readily incorporated into an automated statewide analysis.

This is very similar to the way that pavement management systems (PMSs) typically operate. PMSs typically estimate the size of the pavement deterioration problem, identify the locations most in need of repair, and provide crude cost estimates for making improvements to those deteriorating pavements. These estimates serve as useful planning information and as a means for prioritizing where more detailed analysis is needed. But additional, site-specific analysis is required to determine the “correct” engineering response for each deteriorated pavement section, as that correct response depends on a variety of factors outside of those included in the PMS. And because these detailed analyses require time and money, they are only performed for a limited subset of locations, which are selected in large part on the basis of the prioritization achieved with the initial outputs from the PMS.

Although the desktop system is designed to identify and quantify bottleneck locations throughout the state, the same process can be used for a much smaller geographic area—such as a corridor or region. The *Indiana Mobility Report* (129) analysis results shown in Figure 5-1 are an example of this type of desktop analysis performed for a specific corridor. Figure 5-1 shows that the largest congestion location on I-65 occurs between mileposts 0 and 2 (identified with a “d” in Figure 5-1) and that congestion at that location is far worse from September through December than during the rest of the year. Additional bottlenecks also are apparent near mileposts 113 (location “c”), 139 (location “b”), 260 and 262 (location “a”). These four locations are obvious places where additional, site-specific analysis would be performed to better understand the causes of that congestion and consequently the best strategies for mitigating that congestion.

5.2 Options for Computing Travel Speed-Based Delay

The key statistic that will be used to identify truck travel speed bottlenecks is the amount of delay trucks face on the defined road segments. The definition of delay is “the difference between the amount of time it actually takes and the amount of time the trip should have taken, whenever a trip takes longer than it should.” The “time a trip should take” also is called the “threshold” travel time, and any time beyond this threshold incurs delay. [It is suggested that delay be defined in terms of speed (when average speed drops below a specific value), but the computation of delay is actually a measure of time—meaning that computed delay uses the travel-time statistic, not the corresponding speed statistic. Use of speed as the threshold definition allows easier comparison of performance across roadway segments of different lengths.]

Delay can be computed from the origin to the destination of a trip, or it can be computed for any given road segment, where the “trip time” is simply the time to traverse that road segment. These are values that can be computed from the NPMRDS and similar data sets.

To effectively identify and rank truck bottlenecks, it is necessary to consider both delay and the number of trucks (or other vehicles) that experience that delay. The primary performance metric used to identify truck bottlenecks is therefore computed as:

$$[1] \text{ Truck Delay} = (\text{Truck Travel Time Threshold} - \text{Actual Truck Travel Time}) * \text{Truck Volume}$$

Where:

- *Truck Volume* is the volume of trucks experiencing that actual travel time;
- *Truck Travel-Time threshold* is the travel time at which that roadway segment “should” operate to not generate delay for the delay metric being computed; and

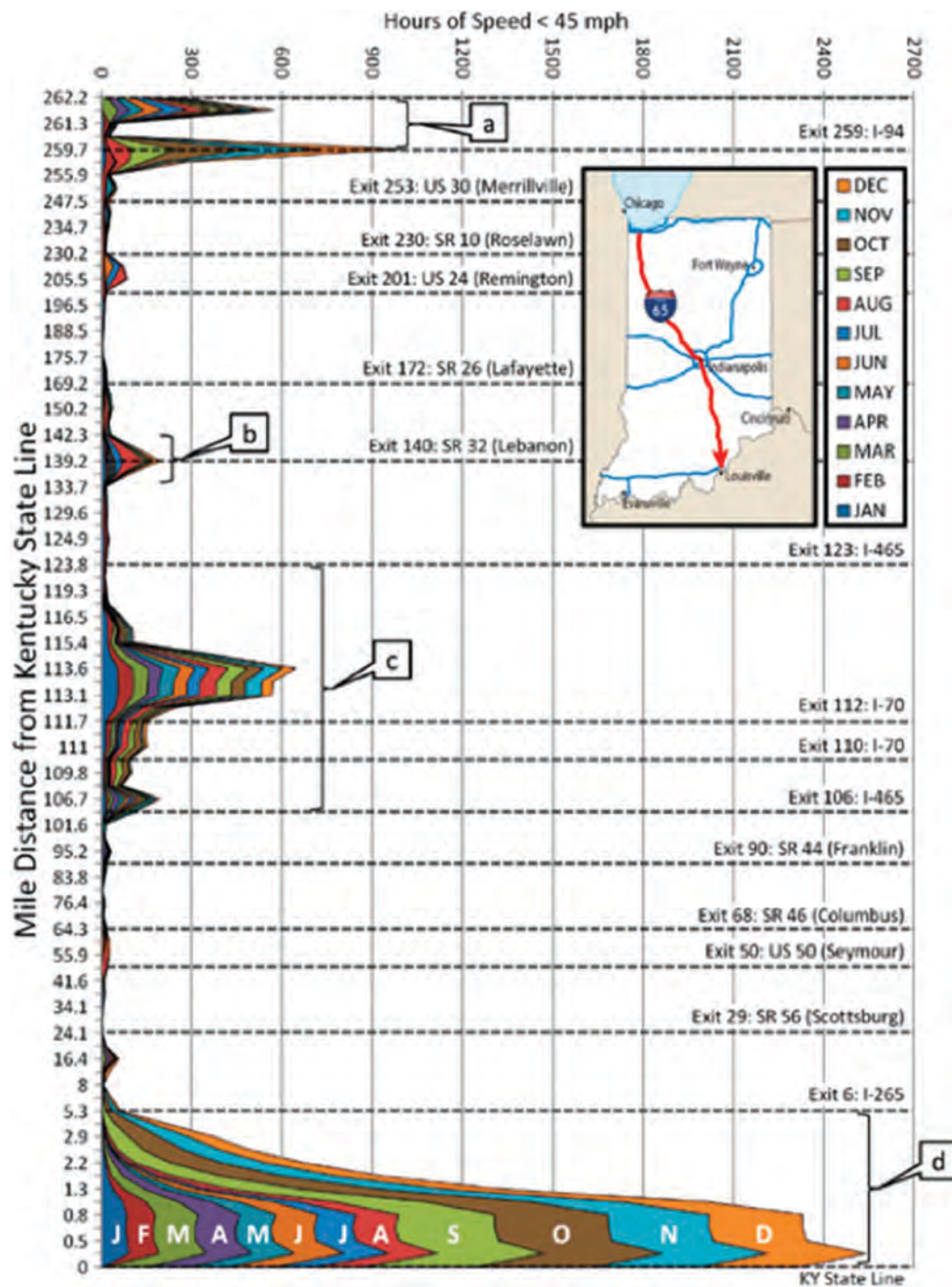


Figure 5-1. An example illustrating vehicle delay along a corridor—by month.

- *Actual Truck Travel Time* is the travel time experienced by trucks using that road segment for that time period.

Delay only occurs when formula [1] returns a positive value. A negative value means no delay is occurring, and it is discarded from further computations.

The computation of formula [1] can be accomplished by using the combined truck volume and NPMRDS data described above using the data structure shown in Figure 4-5.

Delay occurs whenever speed drops below a set threshold. A significant issue in identifying bottlenecks is defining the threshold at which delay occurs. The project team recommends computing delay for four different speed thresholds. The four recommended delay thresholds are as follows:

1. Delay from free-flow (uncongested) speeds (D_F):

$$[2] D_F = (\text{Truck Travel Time at Free-Flow}) - (\text{Actual Truck Travel Time})$$

2. Delay from the speed limit (D_S):

$$[3] D_S = (\text{Truck Travel Time at the Speed Limit}) - (\text{Actual Truck Travel Time})$$

3. Delay from the maximum efficiency (D_E):

$$[4] D_E = (\text{Truck Travel Time at the Speed that Maximizes Throughput}) \\ - (\text{Actual Truck Travel Time})$$

4. Delay from Target Value (D_T):

$$[5] D_T = (\text{Travel time at a Defined Speed Set as a Target}) - (\text{Actual Truck Travel Time})$$

Each of these thresholds has a different meaning and answers a different analytical question. One or more of these measures may be selected to rank and prioritize improvements. The determination of which threshold to use is generally a function of four interrelated considerations:

1. Local Policy—ensuring measures can be communicated in terms applicable to policy goals. Consideration should also be given to compatibility of threshold across agencies and U.S.DOT guidance related to performance measures for truck movement.
2. Sensitivity analysis that ensures computed delay matches public perception (e.g., if a selected threshold of 45 mph results in very little congestion in a large urban area, there could be perception concerns).
3. The relationship between a “threshold” (extent of the delay problem that exists) and a “target” (extent of delay that is unacceptable to community/region/state).
4. Data availability (e.g., statewide probe dataset or roadway inventory).

Delay at free-flow indicates the amount of travel occurring at speeds below which vehicles desire to travel on each road. It takes into account the fact that trucks and other motorists do not always desire to travel at the speed limit even when conditions are good. (Sometimes free-flow speed exceeds the speed limit. Sometimes free-flow speeds are slower than the speed limit, depending on the terrain and geometric conditions of the roadway.) When speeds drop below “free-flow” they indicate conditions are causing motorists to drive more slowly than they prefer.

Delay computed using the speed limit as the threshold value indicates that road conditions have dropped below the speed at which the road is legally intended to operate. This definition is particularly useful for comparing delay across roads operated by different agencies that might have different congestion relief policies as it allows an “apples to apples” comparisons of different roads.

Delay from maximum efficiency recognizes that maximum vehicle throughput typically occurs at speeds slightly below the speed limit. Thus, maximum use of the facility occurs at this speed, and agencies often use operational controls to maintain vehicle speeds at this value when

demand is very high to maximize use of the facility. This measure reports only that delay which represents a loss of roadway throughput efficiency.

Delay from a target value is specifically designed to allow an agency to analyze delay versus their adopted policies. Many agencies set specific operating targets for roads. In this last case *the adopted target performance value becomes the threshold used in the delay computation*. On very heavily congested urban freeways, these targets are often policy statements based on the level of improvements that are considered technically, financially, and politically feasible. The key is that “targets” are agency adopted values against which performance is intended to be compared locally. Consequently, they are very useful for reporting agency performance, and are readily compared across different agencies, but caution should be used in these comparisons because the target thresholds are likely to be very different.

The key is that “targets” are agency adopted values against which performance is intended to be compared locally.

When choosing between these four slightly different definitions of delay, the state or roadway agency should use whichever definition is appropriate for that specific analysis, report, or submission. Additional information about thresholds and target values, and their distinction, can be found elsewhere. (21) Table 5-2 summarizes the four delay thresholds including a brief description and some typical/specific examples of these thresholds in mobility analysis practice. Regarding the selection of the “correct” or “best” delay threshold, recent work sponsored by FHWA provides a recommendation as follows. (22) For congestion performance monitoring, the key outcome is the ability to track changes over time, that is, “are things better or worse?” If that is the case, any of the above strategies are reasonable if they are held constant over time. Reiterating the principle for performance measurement mentioned earlier—the best way to develop travel times is to measure them directly—the preference is an empirical approach using the data. If sufficient data are not present, then the speed limit is recommended.

In practice, it is important to be aware that the amount delay that is calculated is directly correlated to the reference speed that is used. The reference speed is the base speed below which all other speeds are considered to be delay. For example, if an Interstate reference speed is 55 miles per hour (mph), then a vehicle that travels at 54 mph would be considered to be a vehicle that experiences a minor level of delay.

The decision of which reference speed to use will be made separately by each transportation agency similar to how each agency will select the performance measures that work best for its organization. Use of a lower reference speed (e.g., 35 mph on an Interstate) implies that the agency is focused on extreme levels of congestion on the roadway of interest. Use of higher reference speeds is appropriate for agencies that are trying to identify congestion broadly across their roadway network of interest. Table 5-3 shows the general relationship between each of the four delay methods and the amount of calculated delay for a hypothetical 1-mile Interstate segment.

5.3 Sample Outputs of Truck Bottleneck Travel Speed-Based Delay Calculations

The cubic structure shown in Figure 4-5 allows simple computations of travel speed delay by location and time period for any given roadway for which volume and speed data are available. Delay data can then be summarized by roadway segment. For example, total annual truck delay by road segment can be computed for each segment of a corridor, and for each road segment in the NHS.

With the aid of a GIS, these statistics can be displayed on a map to highlight the key delay locations. An example of such a map is shown in Figure 5-1. This Figure shows the hours of delay on the x-axis and the miles from the Indiana-Kentucky state line on the y-axis. The multicolored peaks represent the amount of delay experienced on the corridor with each color representing a

Table 5-2. Characteristics of suggested delay thresholds.

Delay Threshold	Description	Typical/Specific Examples
Delay from Free-Flow (Uncongested) Speeds	Free-flow (uncongested) speed computed as: <ul style="list-style-type: none"> • Reference speed from private company data provider; • Percentage of free-flow speed (e.g., 85% of reference speed); and • Level of service (LOS) 	TTI's <i>Urban Mobility Scorecard</i> ^a and Texas 100 Most Congested Roadways ^b List (use private company reference speeds)
Delay From the Speed Limit	Speed limit	Speed limit is a common element of statewide roadway inventories
Delay From the Optimum Efficiency	Based on the optimum throughput or capacity at the location Sometimes referred to as maximizing "productivity" of the roadway	WSDOT's Gray Notebook ^c
Delay from Target Value	Incorporates community vision and goals into the delay computation and fixes the threshold as the community target of what constitutes unacceptable delay	Minnesota DOT arterial work computed unacceptable delay as that which exceeded an established target value ^d

^aSchrank, D, B. Eisele, T. Lomax, and J. Bak. 2015 *Urban Mobility Scorecard*, August 2015. Available: <http://mobility.tamu.edu/ums>. (49)

^bTexas 100 Most Congested Roadways List. Texas Department of Transportation. Available: <http://www.txdot.gov/inside-txdot/projects/100-congested-roadways.html>. Last Accessed: April 10, 2015. Note that the full ranking of all segments throughout Texas beyond the top 100 are available here: <http://mobility.tamu.edu/most-congested-texas/>. (23)

^cThe Gray Notebook, Washington State Department of Transportation, 2014, <http://www.wsdot.wa.gov/Accountability/GrayNotebook/SubjectIndex.htm>. (130)

^dDeveloping Twin Cities Arterial Mobility Performance Measures Using GPS Speed Data, Minnesota DOT, May 2013, <http://www.lrrb.org/media/reports/201314.pdf>. (131)

Table 5-3. Relationship between delay method and amount of calculated delay for hypothetical one-mile Interstate segment.

Delay Method	Reference Speed	Actual Speed	Amount of Calculated
	(mph)	(mph)	Delay per Vehicle (Minutes)
From Free-Flow Speeds	70	35	0.86
From the Speed Limit	55	35	0.62
From the Optimum Efficiency	45	35	0.38
From Target Value	50	35	0.51

separate month in the year. The delay is shown to peak in four urban areas labeled from “a” to “d” where “a” represents delay in the Indiana portion of the Chicago (IL) metropolitan area, “b” represents delay in the Lebanon metropolitan area, “c” represents the delay in the Indianapolis metropolitan region, and “d” represents the delay in the Indiana portion of the Louisville (KY) metropolitan area. Delay also can be summarized in tabular formats, such as in Table 5-4, taken from the Texas 100 Most Congested Roadways List (23) produced by the Texas A&M Transportation Institute for the Texas DOT every year.

Delay estimates produced for individual segments also can be combined to examine patterns along entire corridors. Figure 5-2 shows another Figure from the Indiana Mobility Report. (24) It illustrates the trajectory of a vehicle through space and time. The x-axis represents ten segments along a route, while the y-axis represents the progression of time. The shaded rectangles show which segment a vehicle is on during different points in time. For example, between 5:05 and 5:10, the vehicle moved along Segments 2, 3, and 4. Between 5:10 and 5:15, the vehicle moved from Segments 4 and 5.

Indiana used its delay analysis to understand not just the total amount of delay by location on I-65, but when it occurs during the year. This allows the state to better understand the cause of the congestion and thus apply strategies to mitigate that congestion.

Because trucks have different travel patterns than cars, it is important to compute delay separately for cars and trucks, as well as for both cars and trucks combined. The relative importance of locations where delays occur will differ for cars versus trucks. That is, the ranking of delay locations for trucks (worst to best) will be different than the ranking for cars or the ranking for both cars and trucks combined. The topic of ranking bottleneck locations is discussed in more detail in the next chapter of this Guidebook.

Table 5-4. Example table from Texas 100 Most Congested Roadways (23).

2014 Rank	2014 Rank Truck	Roadway	From	To	County	Annual Hrs of Delay per Mile	Annual Hrs of Truck Delay per Mile	TCI ?	PTI ?	CSI ?	Annual Congestion Cost (Millions)	Truck Congestion Cost (Millions)
1	4	IH 610	IH 10/ US 90	IH 69/ US 59	Harris	1,184,702	70,579	2.43	8.70	3.20	\$81.35	\$17.12
2	1	IH 35	US 290 N	SH 71	Travis	950,795	116,251	2.54	10.00	3.33	\$196.14	\$72.12
3	2	US 59	IH 610	SH 288	Harris	777,146	72,937	2.01	9.54	2.12	\$105.22	\$32.15
4	11	US 75	IH 635	Woodall Rodgers Freeway	Dallas	719,128	47,205	1.72	7.29	2.02	\$145.12	\$33.74
5	5	IH 35E/ US 77	SH 183	IH 30	Dallas	708,365	70,187	1.96	7.63	2.46	\$79.65	\$25.25
6	8	US 59	IH 10/ US 90	SH 288	Harris	666,494	55,325	2.34	10.73	3.48	\$50.26	\$13.9
7	7	IH 635	IH 35E/ US 77	US 75	Dallas	615,132	61,099	1.68	9.83	2.03	\$129.08	\$41.86
8	6	IH 35W/ US 287	28th St/ SH 183	IH 30	Tarrant	606,750	65,782	2.17	11.68	2.59	\$67.06	\$22.84
9	14	IH 45	IH 610	IH 10/ US 90	Harris	535,229	35,570	1.63	7.50	1.95	\$47.04	\$11.08
10	10	IH 35E/ US 77	IH 635	SL 12 N	Dallas	535,025	48,827	1.89	10.16	2.18	\$37.33	\$11.33

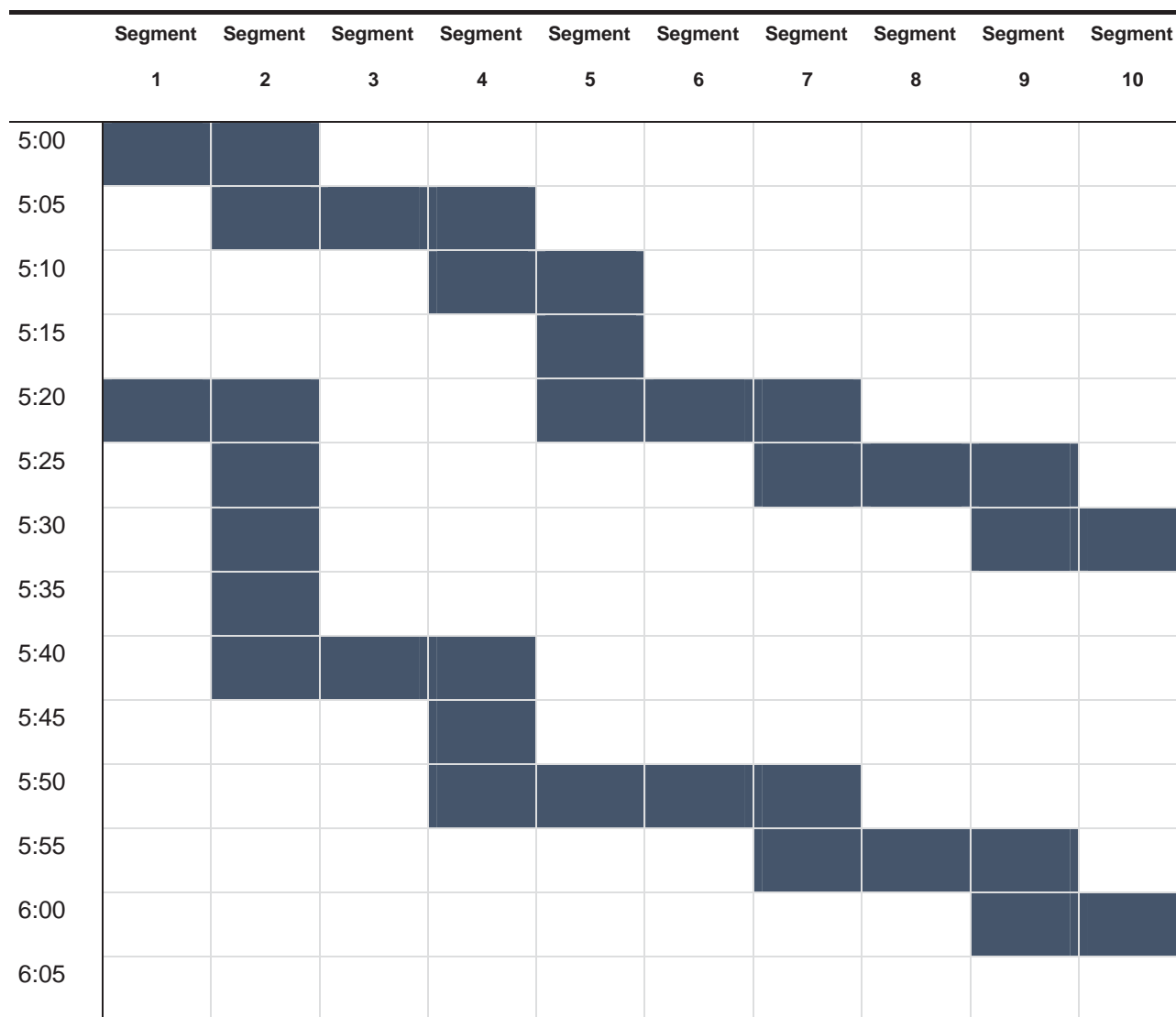


Figure 5-2. Travel-time matrix with trajectories shown.

The combined abilities to identify congestion locations on the basis of actual vehicle speeds and to compute and compare truck delays differently from passenger vehicle delays is one of the advantages of using the NPMRDS (or other datasets that provide truck-specific data) for congestion-related bottleneck identification.

Delay can be reported in many ways, and not simply in terms of truck-hours of delay versus passenger vehicle-hours of delay or total hours of delay. Each of the basic delay computations can be:

- Reported for each segment,
- Normalized to delay per mile for each segment, and
- Normalized to delay (hours) per vehicle or type of vehicle using a segment.

Segments also can be examined in terms of how reliable they are, that is, how frequently does delay occur? Does a road segment become congested only on rare occasions, or does it become congested routinely?

Each of these statistics can be computed from the basic cube data structure. Reporting and examining these different measures is part of evaluating the relative importance of a bottleneck, as well as determining what approaches should be applied to help mitigate that delay. This is because these different ways of reporting/describing delay provide insight into the conditions trucks actually experience and can be used to understand how each bottleneck affects the scheduling and cost of truck trips.

Delay also can be computed for trips that extend across more than one roadway segment. The travel-time/speed matrix structure shown in Figure 5-2 can be used to compute travel times for trips across multiple segments by using what is often called a “trajectory,” “trace,” or “stair step” algorithm (note that this is the method described in No. 4 of Section 4.4).

Each column in the Figure 5-2 matrix represents a road segment (e.g., TMC). The multi-segment trip traverses from Segment 1 to Segment 2 and on through Segment 10. The travel time in the first cell (5:00 for Segment S1) indicates when the “virtual vehicle” arrives in road Segment S2. The travel time in that segment at that arrival time is then used to compute when the virtual vehicle arrives in Segment 3. This process continues until the vehicle arrives at the final segment of the trip. In the schematic shown in Figure 5-2, the second trace (shown in blue) experiences significant congestion at Segment 2 relative to the first trace.

For example, by tracing the route from a major manufacturing center to the major port in the state, it would be possible to not only understand the travel-time distribution that trucks making that trip experience, but also to identify the specific congestion points that truck trip passes through and the delays experienced in comparison to the overall time.

By computing a secondary path between the origin and destination, the analyst also can determine the resiliency and redundancy of that road network between those important freight destinations, as well as the costs that are imposed on trucks that use the secondary path.

[Process-based truck bottlenecks] force trucks to use longer, more circuitous paths than passenger cars would take if making that same trip, or they require trucks to carry less cargo than they would otherwise carry if not legally restricted from doing so.

The total time for each trip can be determined for each virtual start time. These can then be aggregated to determine the mean travel time, the distribution of those travel times, and the reliability of that trip. These statistics can then be compared with the threshold or expected travel time for that trip, with the difference between the actual and threshold travel times defined as “delay.” This type of analysis allows the roadway agency to determine the effects of location-specific delays on longer trips and the effects of those delays on the overall travel reliability of trucks.

A good way to summarize the effects of bottlenecks on truck travel is for state agencies to define key truck trips and then monitor the reliability of those trips over time. This allows the impacts of the specific points located in the bottleneck identification process to be expressed in terms of increased travel time and travel-time reliability for key freight movements. For example, by tracing the route from a major manufacturing center to the major port in the state, it would be possible to not only understand the travel-time distribution that trucks making that trip experience, but also to identify the specific congestion points that truck trip passes through and the delays experienced in comparison to the overall trip time.

It is also possible to compute alternative travel paths from the selected origin (the manufacturing center in the above example) and the destination for that freight movement (the port). By computing a secondary path between the origin and destination, the analyst also can determine the resiliency and redundancy of that road network between those important freight destinations, as well as the costs (travel-time differentials and changes in travel reliability) that are imposed on trucks that use the secondary path.

5.4 Calculating Process-Based Delay

5.4.1 Overview of Process-Based Delay Categories

The second major category of causes of truck travel delay includes locations that either force trucks to use longer, more circuitous paths

than passenger cars would take if making that same trip, or they require trucks to carry less cargo than they would otherwise carry if not legally restricted from doing so. Both situations force trucks to travel additional miles, increasing the cost of freight delivery as a result of both additional labor hours and additional mileage driven. In addition, higher TMT increases fuel use and produces negative environmental emissions.

Four subcategories of problem locations, defined below, are identified within this broader classification of process-based delays. Each subcategory is defined by the type of adjustment a trucking firm must employ in response to a restriction on normal truck operations. The four selected subcategories consist of restrictions that require:

- Rerouting;
- Making additional trips;
- Changing the time of day when trucks operate or the type of truck that may be used; and
- Trucks having to search or wait for loading zones, terminal access, or parking because those facilities are not available or suitable.

The first subcategory includes restrictions such as low bridge heights or weight restrictions imposed on both bridges and entire roadway segments that cause trucks otherwise operating within normal truck height and weight regulations to reroute to less than optimal routes because the direct route does not meet height or load standards. Also included in this subcategory are hazardous materials restrictions that cause trucks carrying specific, high-impact cargo to travel additional distances to avoid road segments from which those hazardous materials are prohibited.

The second subcategory includes restrictions that cause trucks to make additional trips. For example, in northern tier states, spring thaw load restrictions may be applied to roads for which there are no “alternative routes.” As a result, more truck trips are needed to carry a given amount of cargo. Similarly, truck size (length) restrictions that limit otherwise legal trucks from using specific roads may require the use of smaller trucks, increasing freight costs and impacts (e.g., many urban areas limit both the size and weight of trucks operating on downtown streets, forcing delivery companies to off-load larger, long-haul trucks for the last-mile delivery process).

The third subcategory includes time-of-day restrictions. In this case, truck pick-ups and deliveries must be made in off-hours, increasing costs by decreasing a trucking firm’s ability to cost-effectively distribute their labor and equipment resources.

The final subcategory includes trucks having to make inefficient movements such as circling a block, because the last-mile facilities (e.g., parking, load zones) are not suitable, lack capacity, or are poorly managed. It also includes node-based delay that occurs at locations such as port gates, border crossings, intermodal rail yards, weigh stations, and toll plazas.

The “cubic data structure” described in Section 4.2 and shown in Figure 4-4 is an effective tool for identifying the costs of many of these delays. However, it must be used in concert with additional information that describes the size of truck movements, the nature of those movements, and data on the locations and attributes of the specific truck restrictions being evaluated.

For example, using GIS software, the cube analysis structure can help compute travel times and travel-time reliability over alternative travel paths. However, the cube structure does not contain information on the origins and destinations for which alternative paths must be computed, nor does it contain information describing the size of those movements. Similarly, although the cube structure can be used to compute the travel time and reliability of making trips at different times of the day (e.g., typical business hours versus off-hours delivery

Case Study Highlight

WSDOT recently completed a Freight Mobility Plan. In this Plan, WSDOT identifies five types of bottlenecks with associated criteria thresholds, and how these bottleneck types impact freight movement. The five bottleneck types are slow speed, reliability, resiliency, restricted access for legal loads, and clearance restriction for over-height loads. This bottleneck classification covers both travel speed-based and process-based delay truck bottlenecks. More details are available in Appendix B.

... the travel speed-based delay methodology (Chapter 5) can provide insights to the “trip-based” analysis performed for process-based delay analysis, and vice-versa. If the data, methods, and means are readily available to conduct the “facility-based” analysis described, it is encouraged and often beneficial.

timeframes), nothing in the cube analysis structure describes the nontravel-time costs associated with moving trips to late-night hours.

Therefore, analysis of many process-based delays requires information and tools in addition to the cube data structure. It should be noted that the travel speed-based delay methodology can provide insights to the “trip-based” analysis performed for process-based delay analysis, and vice-versa. If the data, methods, and means are readily available to conduct the “facility-based” analysis described, it is encouraged and often beneficial.

5.4.2 Process-Based Truck Bottleneck Methodology

A key difference between the methodology for process-based truck bottlenecks and travel speed-based truck bottlenecks is that process-based truck bottlenecks require an understanding of impacted truck trips, given the truck restriction. Therefore, the analysis for process-based truck bottlenecks is sometimes referred to as a “trip-based” analysis in contrast to the “facility-based” analysis described earlier for travel speed-based truck bottlenecks.

Figure 5-3 shows a flowchart of these steps showing both the bottleneck determination work flow at left and associated data sources at right. The system creation portion of the process refers to the estimation of total delay in the system, while the system operation portion of the process refers to the allocation of this delay to various causes, locations, vehicle types, and time of day. The identification of truck bottlenecks occurs in the system creation process. The classification, evaluation, and mitigation of truck bottlenecks occur in the system operation portion of the process.

Case Study Highlight

Recent research sponsored by VDOT used “trip-based” performance measures and analyses. VDOT sponsored the research to evaluate system performance on the statewide Interstate system to demonstrate how systemwide mobility and reliability measures can be computed and how targets can be set. Private-sector data were obtained for each 15-minutes of the entire analysis year (2012) and paired with traffic volumes and roadway inventory data. The analysis employed a “trip-based” analysis by computing reliability measures as a function of the distribution of travel time trajectories (as described in Chapter 5) through the analysis segments. More details are available in Appendix B.

5.4.3 Identify Affected Truck Trips

There are two keys to understanding and quantifying the impacts of process-related truck bottlenecks. The first is understanding the truck restrictions that exist and where they are located. The second is understanding the costs those restrictions impose on trucking movements. Therefore, the first requirement is understanding what types of truck restrictions need to be tracked and then collecting data on where and when those restrictions occur.

While many techniques can be used to illustrate where these restrictions occur, incorporating the restrictions into the cubic data analysis structure allows the agency to take advantage of the same analytical computations available for the travel speed-based bottlenecks. In particular, it is possible to use GIS software to not only show where truck restrictions are physically located but also to compute travel times.

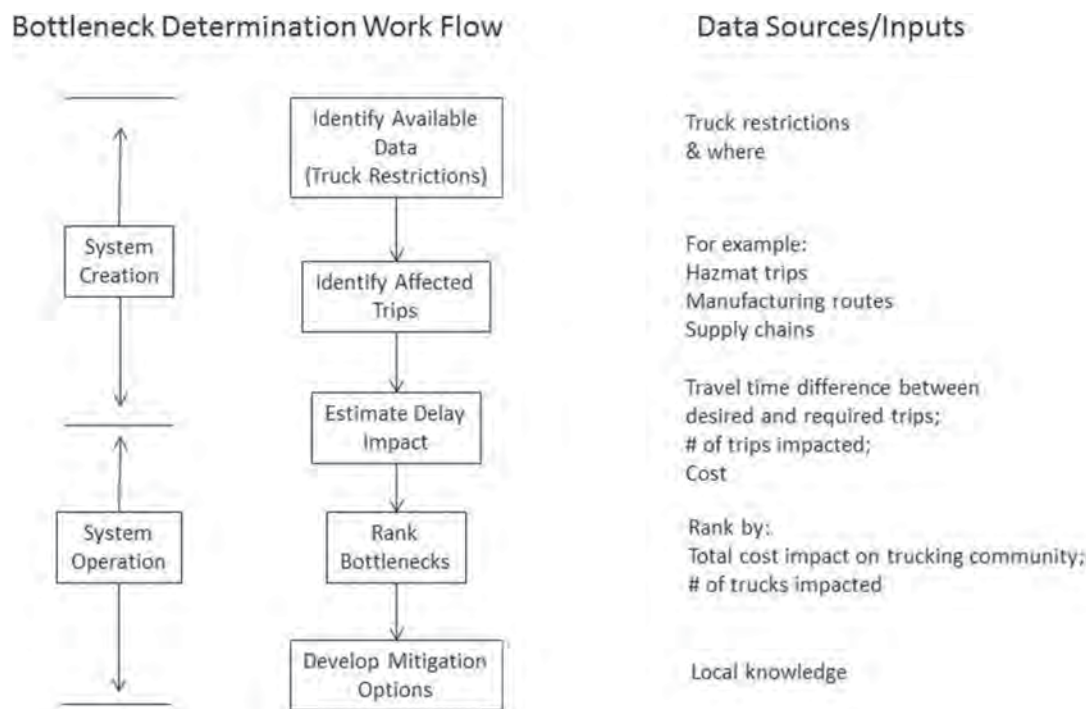


Figure 5-3. Process-based truck bottleneck identification and quantification methodology.

The discussion of desktop bottleneck analysis suggested that the state DOT identify key truck trips occurring in the state. For example, these can be from major manufacturing areas of the state to major ports, intermodal yards, or the state border on the Interstate connecting with major cities in neighboring states. For the analysis of truck restrictions, it is necessary to refine the identification of “key truck trips” to specifically include the types of truck trips that are affected by these restrictions.

For example, for hazardous materials shipments, there is a specific interest in the origins and destinations of hazardous materials shipments. For truck load restrictions, the interest is typically in specific commodities that move on the roads for which—and during the time periods when—load restrictions apply. It is also important to obtain an estimate of the number of these trips being made.

Using the same GIS that allows visualization of where truck restrictions are located, it is possible to compute travel paths for the truck trips that are affected by the various truck restrictions. Where these paths pass through the truck restrictions, this can now be visualized.

5.4.4 Quantitatively Measure Delay Impact

The determination of the path through the restricted roadway is just the first step in estimating the cost of that restriction. For truck restrictions that actually prohibit that movement (e.g., a low-height bridge or a hazardous materials prohibition preventing a truck from using a given

Case Study Highlight

An ongoing project for the Maryland State Highway Administration (SHA) is defining and implementing freight fluidity for Maryland to inform investments on the freight network. The project has developed a freight fluidity definition, trip-based calculation procedures for selected truck trips, and preliminary results. Future work will expand the methods to other modes, while investigating additional data sets for informing the process. More details are available in Appendix B on this project, and the calculation procedures are included in Appendix D.

road segment), the GIS must be used to determine the best alternative travel path from the origin to the destination that does not include the restricted roadway segment.

Comparing the [desired and actual path travel times allows for] the direct computation of the time and distance penalty imposed on the trucking community.

Once alternative paths have been developed, the analyst can then compute the travel distances, the travel times, and the trip reliability measures for both paths—the “desired” path and the “actual” path required by the restriction. Comparing the two paths and the differences in travel-time distance allows the direct computation of the time and distance penalty imposed on the trucking community.

Multiplying the dollar costs associated with the added travel time and mileage by the number of trips produces the increased trucking cost for the longer path required by the truck restriction. A wide range of dollar costs can be considered depending on which cost components are included in the analysis. (25)

For a “simple” restriction such as a low-height bridge, it is only necessary to estimate the number of vehicles that exceed the height limit, compute the cost of the reroute necessary for those trucks, and multiply those two values. It is not really necessary to understand the full trip paths of those trucks, unless the route is so long that many truck trips have to use entirely different roads to avoid the low-height bridge. In that case, it is necessary to understand the length of each of those alternative paths to estimate the trucking cost imposed by the low-height bridge.

For truck weight restrictions, trucking firms may be able to take one of two actions, depending on the location of the road restriction relative to the O/D of the affected trips. Trucks may react to load restrictions by continuing to use the weight-restricted roads while carrying lighter loads. Alternatively, they may take an alternative path with a full load. (This is possible only if such a path exists. That may not be possible if the only road leading to either the origin or the destination is one of the weight-restricted roads.) Discussing actual behavior with the trucking firms affected by the weight restriction will indicate which behavior to model for specific trips.

In either case, it is again a fairly simple matter to compute the trucking cost of the weight restriction. The cost is simply the added mileage and travel time required to make either longer or more trips as a result of the weight restrictions. The difficult part of this computation is determining the number of trips affected by the weight restriction. Note that analysis of OS/OW permitted loads is not addressed by this approach, but can be analyzed using similar techniques.