Assessment of Multimodal Freight Bottlenecks and Alleviation Strategies for the Upper Midwest Region

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Department of Civil and Environmental Engineering
College of Engineering
University of Wisconsin–Madison

Authors:
Jessica Y. Guo, Qi Gong, and Andrew Obernesser
University of Wisconsin–Madison

Principal Investigator:
Jessica Y. Guo
Assistant Professor, Transportation and Urban Systems Analysis Laboratory
Department of Civil and Environmental Engineering
University of Wisconsin–Madison

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16. Abstract

The freight that passes through the Mississippi Valley Region is high volume and has a substantial impact on the economy of the region. According to the BTS-sponsored Commodity Flow Survey, trucks carried almost 2.5 billion tons of freight across the highways of the ten states of the Mississippi Valley region in 2002. During that same year, the region's rails moved 540 million tons of freight, and the region's waterways moved approximately 250 million tons of freight. Efficient movement of freight through this region is critical to the economic competitiveness of the nation.

The Upper Midwest Freight Corridor Study, completed by the Midwest Regional University Transportation Center (MRUTC) and six states, revealed that major bottlenecks exist in all modes of the freight transportation system throughout the region. According to the 2005 FHWA-sponsored report "An Initial Assessment of Freight Bottlenecks on Highways", more than 60 highway-related freight bottlenecks exist in our region. Three of the largest bottlenecks in the country are in Chicago and total over 38.4 million annual hours of delay for all vehicles. With current estimates indicating that by the year 2020 a 62 percent and 44 percent increase in the amount of freight carried on the nation's highways and rail, respectively, it is clear that steps must be taken to improve the efficiency of the freight network. Bottlenecks also account for long delays at the ports of entry, intermodal freight terminals and yards, and locks and dams. These delays result directly in additional expenditures for shippers, carriers and for the public in general.

Furthermore, as global economic competitors have invested heavily in their transportation infrastructure, the transportation cost advantages historically held by the United States are beginning to decline. Bottlenecks in all modes are significantly increasing the cost of transporting goods through the region, which in turn is contributing to the decline of the nation's transportation cost advantage. The MVFC Executive Committee agreed at its July 10th, 2007 meeting that addressing regional freight bottlenecks is one of the most significant projects for the coalition to undertake.

17. Key Words

Freight, trucking, rail, maritime, bottlenecks, traffic, highways, delays, freight network

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Project Summary

The freight that passes through the Mississippi Valley Region is high volume and has a substantial impact on the economy of the region. Addressing regional freight bottlenecks is considered as one of the most important tasks for the Mississippi Valley Freight Coalition. This project aims to identify high priority freight bottlenecks in the Mississippi Valley Region, assess their relative severity, and recommend strategies for alleviating the bottlenecks.

Background

According to the BTS-sponsored Commodity Flow Survey, trucks carried almost 2.5 billion tons of freight across the highways of the ten states of the Mississippi Valley region in 2002. During that same year, the region's rails moved 540 million tons of freight, and the region's waterways moved approximately 250 million tons of freight. Efficient movement of freight through this region is critical to the economic competitiveness of the nation. The Upper Midwest Freight Corridor Study revealed that major bottlenecks exist in the freight transportation system throughout the region. With current estimates indicating that by the year 2020 a 62 percent and 44 percent increase in the amount of freight carried on the nation's highways and rail, respectively, it is clear that steps must be taken to improve the efficiency of the freight network. Bottlenecks also account for long delays at intermodal freight terminals and yards, as well as some locks and dams. These delays result directly in additional expenditures for shippers, carriers, and for the public in general.

This project identifies and assesses highway, waterborne, and rail bottlenecks in the MVFC region based on quantitative data describing the freight transportation systems and qualitative data reflecting DOT experts' opinion and private-sector users' experience. An inventory of congestion alleviation projects across the region is also developed to determine gaps where potential freight bottlenecks exist and are yet to be addressed. Finally, additional bottleneck solutions for the region are proposed.

Process

This research began with three major information gathering activities: (a) collecting public, quantitative data that describes the performance of freight transportation modes; (b) soliciting input from MVFC state DOTs regarding their knowledge of freight bottlenecks within their respective states and any planned projects for alleviating the known bottlenecks; and (c) soliciting input from operators and carriers in the private sector regarding their experience with freight bottlenecks in the region. Highway freight bottlenecks were identified using a HPMS-based analysis method and verified against qualitative data available about known bottlenecks. The analysis yielded a ranked list of truck freight bottlenecks within the MVFC region. Port bottlenecks were identified based on data describing the freight tonnage and barge delay conditions throughout the port and inland waterway system. Rail bottlenecks were identified primarily based on interviews with freight rail operators.

As part of this project, state-by-state congestion alleviation projects (as well as multi-state projects) are inventoried based on interviews with state DOTs. Additional bottleneck alleviation strategies were developed for high priority highway bottlenecks found in the region. These proposed strategies are to be further assessed with regard to individual bottleneck characteristics.

Findings and Conclusions

The application of the proposed methodology to the Mississippi Valley area results in a prioritized list of truck bottlenecks on the regional urban and rural freeways and other principle arterials, a series of locations considered by rail operators to be their worst bottlenecks, and ranked lists of heavily trafficked ports and delays throughout the lock network.

In the truck bottleneck list, interchanges account for the highest proportion of bottleneck constraints, followed by lane drops and signalized intersection constraints. Steep grades are associated with the smallest number of bottleneck locations and relatively marginal truck unit delay because steep grade sections are usually found in rural areas where traffic demand is not as high and congestion is not as severe as that in the urban areas. The rail bottleneck locations discussed are largely the result of delays associated with shared tracks and river crossings. For waterborne freight transportation, a review of the data available through the US Army Corps of Engineers indicates that a comprehensive quantifiable connection between the physical characteristics of freight infrastructure and systematic delays cannot be established without further measures and research. Even so, the waterborne delays identified contribute to the general landscape of freight congestion. This broad snapshot of regional freight bottlenecks serves to stimulate cross-state and cross-sector dialogue among freight planners and operators and provides a basis for devising optimal alleviation plans for the greatest benefit of the region.

It should be noted that, since the HPMS data used in this study represent the conditions of year 2006, the analysis results may not accurately represent the regional bottlenecks of today. In fact, several of the top-ranked highway bottlenecks have been addressed by their respective states since 2006. The 2006 data was used because it was the latest publically available version at the time this research was conducted.

Not surprisingly, bottlenecks tend to be found throughout the beltways and central corridors serving urban areas. On balance, results of the truck freight bottleneck analysis trend heavily toward the major metropolitan areas in the eastern portion of the study area, although substantial delay is found in St. Louis, Kansas City, and Minneapolis. Metropolitan Chicago is the regional center for freight bottlenecks, a result of the combination of its regional prominence as a center of both population and industry and a large number of physical constraints throughout its highway network.

A series of qualitative comparisons have been conducted as a part of this study to verify analysis results to the truck freight bottlenecks identified by previous studies, local experts and roadway users. There is general agreement between study results and other sources to suggest that the proposed methodology is capable of identifying the most prevalent truck bottlenecks while also revealing additional locations that warrant further investigation. The discrepancy found between our results and those from other sources points out the sensitivity of bottleneck analysis results to the bottleneck criteria and threshold values used. These analysis parameters have varied from study to study and from one analyst to another. This study contributes to the general body of knowledge in congestion research by proposing a different set of parameters and by presenting one of the first comparative evaluations of truck bottlenecks identified through different channels.

Recommendations for Further Action

Due to the inherent limitations of the HPMS data, it is not possible to pinpoint the exact location of highway bottlenecks using this data. Rather, one can only use the data to identify their general locality at a regional level. Similarly, our interchange bottleneck assessment is limited to identifying the most likely interchange location that may have triggered the delays experienced on the corresponding corridor. We are unable to pinpoint the exact cause of the bottleneck, which could be anything from poor ramp entering/exiting design to insufficient weaving/merging length. In order to help guide investments in bottleneck alleviation, more refined diagnoses at the state or local levels are warranted. Such further analyses would require more detailed information, including project-level traffic and roadway data, knowledge of local experts, and microscopic traffic simulation models.

Because at-grade intersection traffic control information (i.e. number of yield signs, stop signs and signals) and highway geometry information (i.e. curves and grades) are available only in the HPMS Sample dataset, signalized intersection and steep grade conditions can be assessed only for sampled roadway sections. The limited number of roadway sections covered by the HPMS Sample database means that a significant portion of these two types of bottlenecks would be missing from the final results. In order to improve the success rate of the HPMS-based approach, a higher sampling rate for the HPMS Sample dataset is desired.

The state of rail and waterborne freight transportation are not represented with the depth that would be required to more accurately measure bottlenecks throughout these modes. The lack of suitable data presents a major obstacle in freight bottleneck research for these modes. In order to establish an in depth and accurate understanding of these modal performances, more coordinated and comprehensive freight data programs at the federal, regional and state levels are needed. Steps towards such data programs may include:

- Develop state and national freight advisory committees to improve data collection for freight planning efforts.
- Establish a federal requirement to report / collect freight modal data.
- Create a regional data standardization project to support corridor planning.

Another interesting research direction is the examination of size and type of commodities carried by trucks. Combined with truck traffic data, this information would allow us to quantify the types, amount, and values of goods movement stuck at bottleneck locations. Bottlenecks, and their corresponding alleviation projects, could therefore be prioritized in terms of their economic impacts on freight movements. For example, a bottleneck experienced predominately by empty trucks could be ranked as of a lower priority than a bottleneck experienced predominately by high-value, time-sensitive goods.

1. Introduction

1.1. Background

The freight that passes through the Mississippi Valley Region is high volume and has a substantial impact on the economy of the region. According to the BTS-sponsored Commodity Flow Survey, trucks carried almost 2.5 billion tons of freight across the highways of the 10 states of the Mississippi Valley region in 2002. During that same year, the region's rails moved 540 million tons of freight, and the region's waterways moved approximately 250 million tons of freight. Efficient movement of freight through this region is critical to the economic competitiveness of the nation.

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Furthermore, as global economic competitors have invested heavily in their transportation infrastructure, the transportation cost advantages historically held by the United States are beginning to decline. Bottlenecks in all modes are significantly increasing the cost of transporting goods throughout the region, which in turn is contributing to the decline of the nation's transportation cost advantage. The MVFC Executive Committee agreed at its July 10, 2007 meeting that addressing regional freight bottlenecks is one of the most significant projects for the coalition.

1.2. Objectives and Scope

The overall goal of this project is to develop a prioritized list of freight bottlenecks in the Mississippi Valley Region and to identify effective strategies for alleviating the bottlenecks. Here, a bottleneck is defined as a localized clogging spot constricting traffic movement, leading to the buildup of a queue. Once vehicles pass the clogging spot, they could accelerate away from congestion and resume to a desired speed.

The project was initially set out to meet the following objectives:

1. To identify freight bottlenecks on regionally significant routes and modes including highway, rail, and water;
2. To identify and apply criteria to rank the bottlenecks within each mode;
3. To assess bottleneck rankings across the multiple modes of transportation;
4. To develop an inventory of planned projects across the region for addressing identified bottlenecks;
5. To recommend additional bottleneck solutions for the region.

During the course of the project, it was found that information about the current performance of rail and water modes in supporting freight transportation is scarce. Not only does little public data exist that describe the level of service of these modes; private operators of these modes are often reluctant in sharing their experiences and proprietary data. Therefore, the state of rail and waterborne freight transportation was not represented with the desired depth, thus limiting the research team's ability to more accurately measure bottlenecks within these modes. As a result, the cross-modal comparison as suggested in research objective 3 was not possible. These issues and limitations were raised in MVFC technical committee meetings. The research scope was subsequently adjusted to focus on case studies of rail and water freight bottlenecks while addressing highway bottlenecks in a more systematic and comprehensive manner.

1.3. Research Approach and Report Outline

Figure 1 illustrates the various research activities undertaken to meet the goal of this project. These activities and the resulting products are reported in this document as follows.

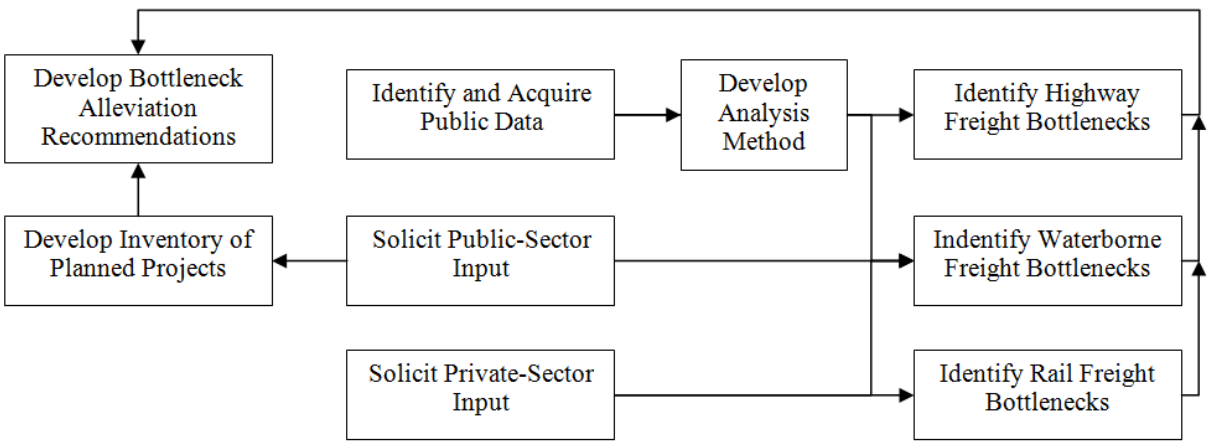


Figure 1. Research Approach

CHAPTER 2 describes the information gathering activities undertaken to obtain the quantitative and qualitative data used in the subsequent research activities. These activities include (a) collecting public, quantitative data that describe the performance of freight transportation modes; (b) soliciting input from MVFC state DOTs regarding their knowledge of freight bottlenecks within their respective states and any planned projects for alleviating the known bottlenecks; and (c) soliciting input from operators and carriers in the private sector regarding their experience with freight bottlenecks in the region.

CHAPTER 3 presents the methodology through which this research analyzes truck freight bottlenecks throughout the Upper Midwest, the results of which can be found in the Appendices, in the form of a ranked table of 100 truck freight bottlenecks within the study area.

CHAPTER 4 provides a description of the freight tonnage and delay conditions throughout the port and inland waterway system, and features a list of lock locations ranked according to barge delays experienced.

CHAPTER 5 examines the rail bottlenecks as suggested by freight rail operators.

CHAPTER 6 provides a regional snapshot of projects with the potential to alleviate known freight bottlenecks in the region. State-by-state projects (as well as multi-state projects) are inventoried and discussed in detail, including the identification of areas of freight congestion found within or near each project's boundaries.

CHAPTER 7 presents the bottleneck alleviation recommendations developed in this research project. Freight-specific strategies are examined with regard to suggested implementation criteria and considerations. Case studies are presented to show how the strategies can be assessed with regard to individual bottleneck locations.

CHAPTER 8 concludes the report by reviewing the research methodology, discussing the trends found in analysis results, describing potential limitations posed by the research, and suggesting directions for future research.

2. Information Collection Process

A number of quantitative and qualitative data sources were consulted and utilized in analyzing the freight networks throughout the study area. Information and numerous data sets were collected from federal and state agencies, as well as local stakeholders, through downloads of publicly available data, phone interviews, and a web survey.

Phone interviews were conducted with various transportation agencies and freight operators for the purpose of assessing their network bottlenecks. Two primary objectives drove the collaboration process. The first objective was to provide an indication as to the current state of freight planning throughout the region, or more specifically, the state of comprehensive bottleneck identification programs. Second, to collect whatever statewide capacity and volume data was available. Upon completion of the bottleneck assessment, interview participants and other state-level freight planners received thematic maps of the ten-state region and each particular state, along with a description of the calculation process, for their review. The collaboration process was used to verify the results of the assessment and adjust the models as necessary.

Data sources and collection methods are described in further detail below according to the source of information sought and obtained.

2.1. National-Level Public Data

One of the first steps in this project is to explore national databases supporting the freight bottleneck analysis for highway, waterway and rail system. The data at national level helps guaranteeing the consistency of analysis across ten member states to the greatest extent. In addition, it provides a basis to compare the regional bottleneck condition with that in a nation or other regions. This comparison could further illustrate the severity and scope of bottleneck condition in Mississippi Valley region.

- Highway Performance Monitoring System (HPMS). Data provided and maintained by State Departments of Transportation and submitted to the Federal Highway Administration, 2006. Attributes represent calendar year 2006.
- Freight Analysis Framework (FAF) 2.2. Spatial network of principal roadways within the United States with long-haul and local truck traffic information, provided by FHWA, 2002.
- National Highway Planning Network (NHPN). Spatial network of principle roadways within the United States, provided by FHWA, 2002.
- Geofreight Intermodal Freight Display Tool. A tool to display freight flows assigned on various component of transportation network, provided by Bureau of Transportation Statistics, Federal Highway Administration and the Office of the Secretary, 2003.
- Lock Performance Monitoring System (LPMS). US Army Corps of Engineers (USACE) Navigable Waterway Network provided and maintained by USACE, 2006.
- Railway Network. Spatial network of rail lines within the United States, provided and maintained by Federal Railroad Administration, 2008.

All listed databases above are of potential value for the freight bottleneck analysis. The selection and usage of various databases depend on the content, spatial coverage, and network representation of data. For the purpose of this study, the HPMS database and LPMS data are selected for the highway and waterway freight bottleneck analyses and the reason these two databases are favored is explained in chapters 4 and 5, respectively.

2.2. Public-Sector Input

State-agency phone interview participants were selected from a list of available contacts. These included members of the MVFC Technical and Customer Committees, as well as a number of contacts developed through other freight-related research at TUSA Lab and CFIRE. Original contacts often provided further contacts regarding specific projects and/or data-related inquiries. These interviews followed a general outline, but varied considerably in both the breadth and depth of information obtained throughout the conversation. Several of these conversations continued on through periodic email contacts. The basic interview format was written in advance of the interviews, and while certain details were added or subtracted from the outline, the overall structure of the conversation was maintained as much as possible, with an emphasis on four main aspects: an introduction to the research (and to the Coalition, if necessary); requests for data (or additional data to supplement that which had been provided previously); a review of that state's bottleneck identification and freight planning initiatives; and a brief recap of the information provided and confirmation of other appropriate contacts within the agency.

The interviews began with a brief introduction of the interviewer and the purpose of the research. After introducing the research assistant, the purpose of the conversation may have been described (according to the research needs particular to that state) as follows:

> "This MVFC study aims to prioritize freight bottlenecks in the Mississippi Valley region and to identify effective strategies for improving the conditions that contribute to them. We've received some data from the <state> DOT in the last few months, but we have some information that we still need to complete the truck freight research."

The results of these data collection efforts varied between states; some had no additional data to offer aside from the HPMS data already available from the FHWA, others offered a wealth of additional data points for our use. Ideal data included volume, capacity, and physical design information throughout the entire network. Unfortunately, the variation of data fields and collection methodology prevented the use of some of these rich data sets.

Regarding their freight planning strategies, interviewees were first asked whether or not their state had undertaken comprehensive efforts to identify bottlenecks. Interviewees were also asked about the progress of these efforts where they existed, such as whether or not the studies had been completed by the time of the interview, had there been other agencies involved, and/or were there any publicly available reports written about the effort. Very few member states had completed such comprehensive reviews, but most offered at least anecdotal evidence of bottlenecks within their borders.

Interviews offered an initial glimpse of the varied landscape for freight planning and bottleneck identification throughout the region. Some were fruitful in both their collection of data and information regarding alleviation strategies. All interview participants were willing to participate according to their ability to do so, and some offered other more appropriate contacts when unable to answer particular questions. The interviews showed substantial variance among the states in their bottleneck identification efforts as seen in Table 1, and also in their current and future alleviation strategies. Interviews with public sector transportation agencies provided some anecdotal information regarding rail congestion, but offered little quantitative data for analytical use. Information regarding ports and inland waterways was similarly obtained through state-level interviews, which pointed to a limited number of locations where waterborne freight might be congested. An interview with an associate at the Great Lakes Commission indicated no systematic congestion issues related to physical capacity throughout the ports of the study area.

Table 1. Condensed Summary of Comprehensive Bottleneck Identification Efforts

State	Bottleneck Analysis
Iowa	No specific statewide analysis of freight bottlenecks.
Illinois	Metropolitan Chicago has been identified as severe rail bottleneck, and alleviation strategies are in place. Chicago Metropolitan Agency for Planning's Regional Freight Snapshot is currently under development.
Indiana	No specific statewide analysis of freight bottlenecks.
Kansas	Eleven truck freight bottleneck locations analyzed as of 2008. Statewide Freight Plan published in June 2009.
Kentucky	KTC freight congestion report is currently under development.
Michigan	No specific statewide analysis of freight bottlenecks.
Minnesota	No specific statewide analysis of freight bottlenecks. Metropolitan Freeway System 2007 Congestion Report identifies segments of severe congestion in the Twin Cities area.
Missouri	The Missouri Statewide Freight Study (2005) specifically identifies four truck bottleneck locations.
Ohio	Ohio Freight Rail Choke Point Study (2007) and Ohio Freight Mobility, Access, and Safety Strategies (2006) identify specific bottleneck locations for rail and truck freight, respectively.
Wisconsin	Ten truck freight bottleneck locations analyzed as of 2006.

A similar discussion focused on alleviation strategies. DOT interviewees were asked to identify plans, projects, and studies (either underway or being planned) focused on alleviating bottleneck conditions. For the purpose of these conversations, an effort was made to distinguish freight-specific initiatives from more general efforts to combat highway congestion; however, because uncongested highways were assumed to be beneficial to all highway traffic (freight included), these general decongestion strategies were welcome offerings in the data collection interviews.

In closing, a basic recap of the interview was offered, and other contacts provided by the interviewees were clarified. Several interviewees requested follow-up emails so that they could pass along data requests, and these were provided shortly thereafter.

2.3. Private-Sector Input

Throughout the course of this research, information and opinions from stakeholders was used to supplement, verify, and improve the analysis. In particular, a motor carrier survey and discussions with private-sector stakeholders were important tools for checking the analytical results against the “ground truth” as perceived by the trucking industry, and interviews with private sector rail operators provided a useful insight into the congestion conditions that could not be located through data-driven research. These efforts are detailed below.

2.3.1. Motor Carrier Survey

A survey was created whereby highway users identified spatial and temporal characteristics of the locations of recurring congestion. This web-based Motor Carrier Survey was originally distributed through industry contacts, then made available on the Internet and also administered in person at three industry events throughout the Midwest. The survey allowed highway freight operators to nominate congested locations, which served as useful qualitative data for comparison to our systematic analysis as presented in Chapter 4.

Two Motor Carrier Survey forms were designed, one for drivers and another for dispatchers. Both followed the same general structure and question sequence. Both required basic personal identification information to be entered prior to taking the survey. Once such information was submitted, the user elected to take either the Driver or Dispatcher survey. The Driver survey featured seven questions, each with a pre-selected group of answers, as outlined in Appendix A.

In an effort to increase the visibility of the survey and collect additional data, the research team attended three trucking industry events: the Walcott Truckers Jamboree (Walcott, IA; July 10-11, 2008), Waupun Truck-N-Show (Waupun, WI; August 8-9, 2008), and Mid-West Truck Show and Convention (Peoria, IL; February 5-7, 2009). Researchers at the trucking events collected data through attendees’ self-submission at laptop locations, and also through verbal question-and-answer sessions following the format of the survey.

The Motor Carrier Survey resulted in 134 total responses, summarized in the following figures. Most respondents (i.e., 84 percent) were truck drivers and the major type of vehicles driven is tractor and trailer, as shown in Figure 2. The respondents represented a good mix of industry sectors and service providers, as shown in Figure 3 through Figure 7.

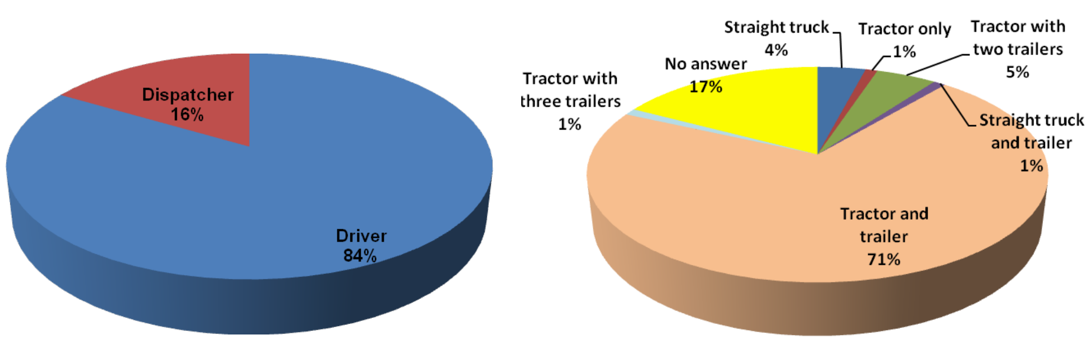


Figure 2. Role of Respondents in Company and Type of Vehicle Driven

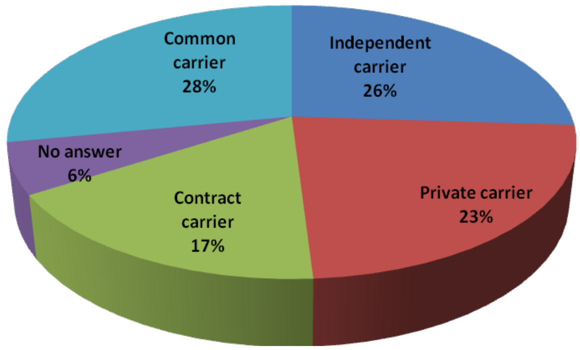


Figure 3. Type of Company

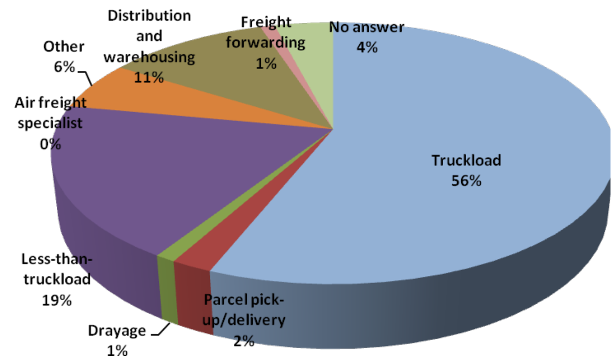


Figure 4. Type of Transportation Services Provided

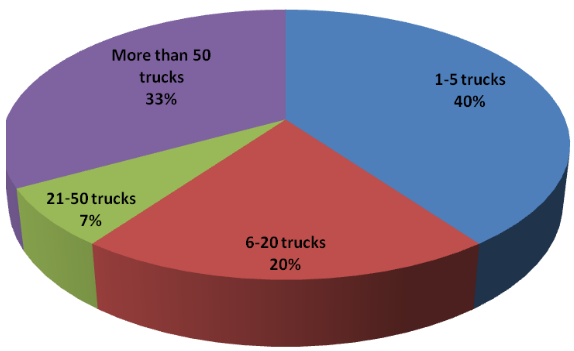


Figure 5. Size of Company's Vehicle Fleet

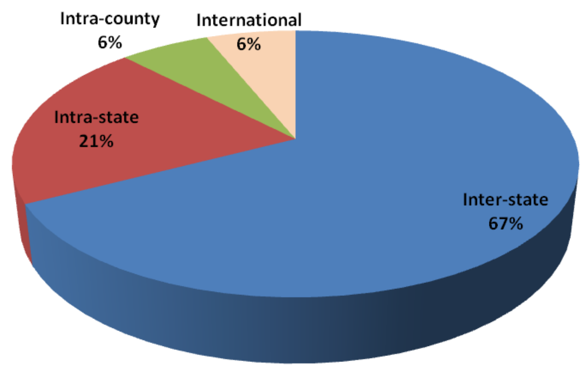


Figure 6. Geographic Area of Typical Operation

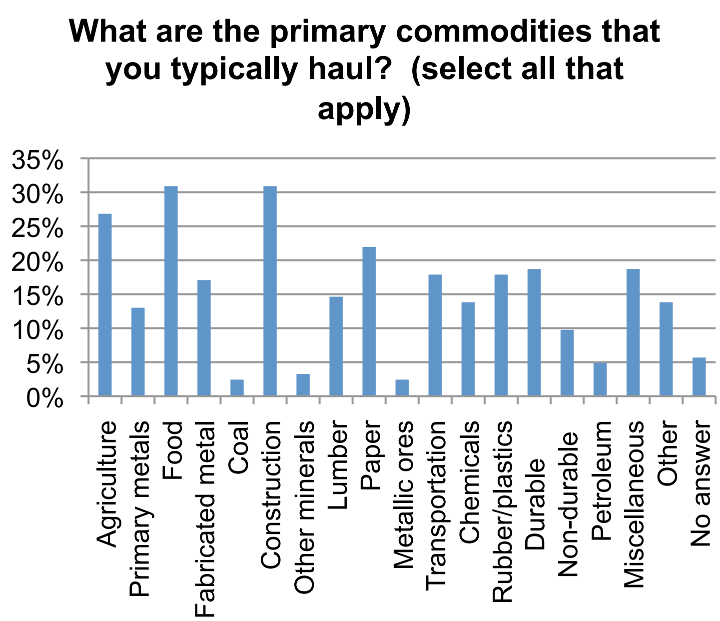


Figure 7. Primary Commodities Transported

Regarding bottleneck locations, respondents at the industry events often indicated an entire city or region (e.g. Chicago) prior to identifying a more specific location. Once a specific location had been identified, the reported temporal characteristics of the bottleneck often indicated congestion that was substantially linked to daily/weekly commuting patterns as opposed to yearly weather patterns (see Figure 8 and Figure 9).

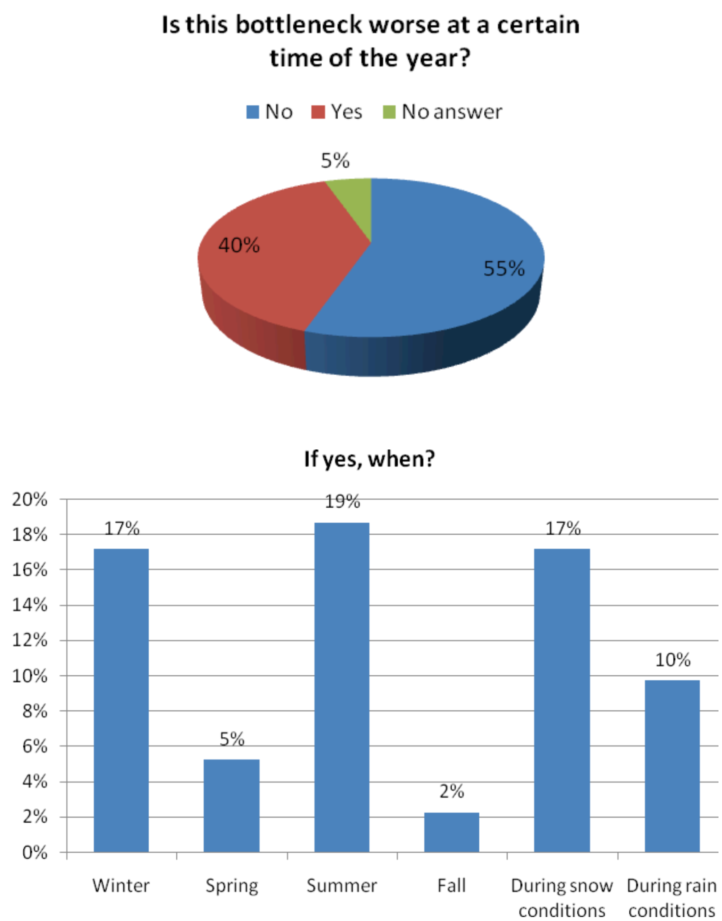


Figure 8. Temporal Distribution of Bottlenecks Nominated Within a Year

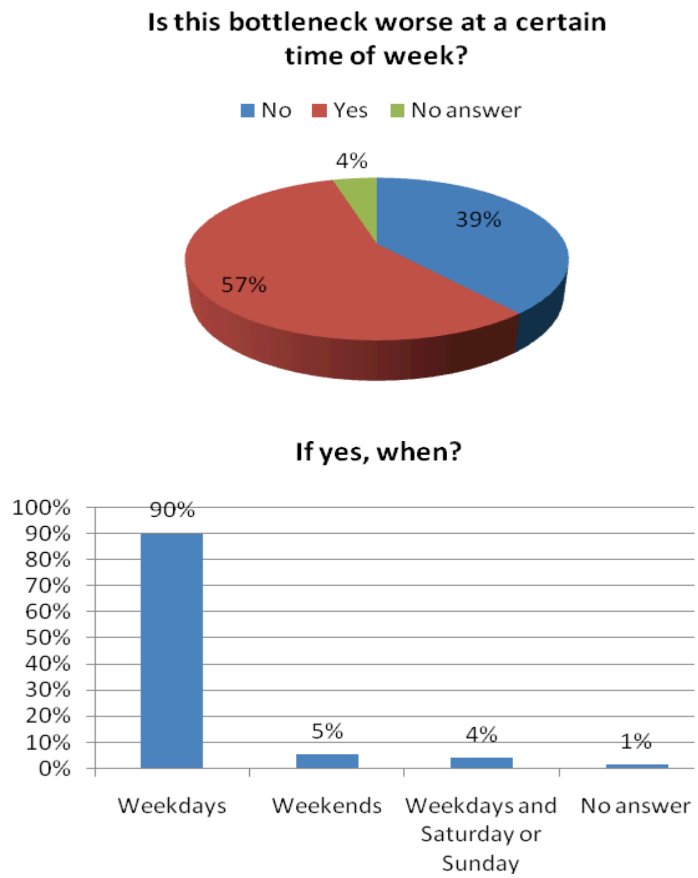


Figure 9. Temporal Distribution of Bottlenecks Nominated Within a Week

The bottlenecks identified through the Motor Carrier Survey were reported to be particularly congested as far as the speed of travel is concerned. As indicated in Figure 10, most respondents reported average speeds of no more than 10 miles per hour while traveling through the identified bottleneck locations. Of the physical characteristics identified at the suggested locations, inadequate capacity, lane drops, and insufficient merging lanes were the most frequently reported causes of bottleneck conditions (see Figure 11). Poor ramp design and frequent incidents were also reported as common causes.

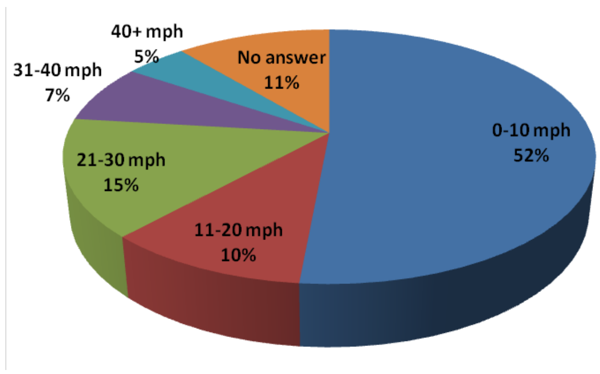


Figure 10. Speed Specified at Bottleneck Location

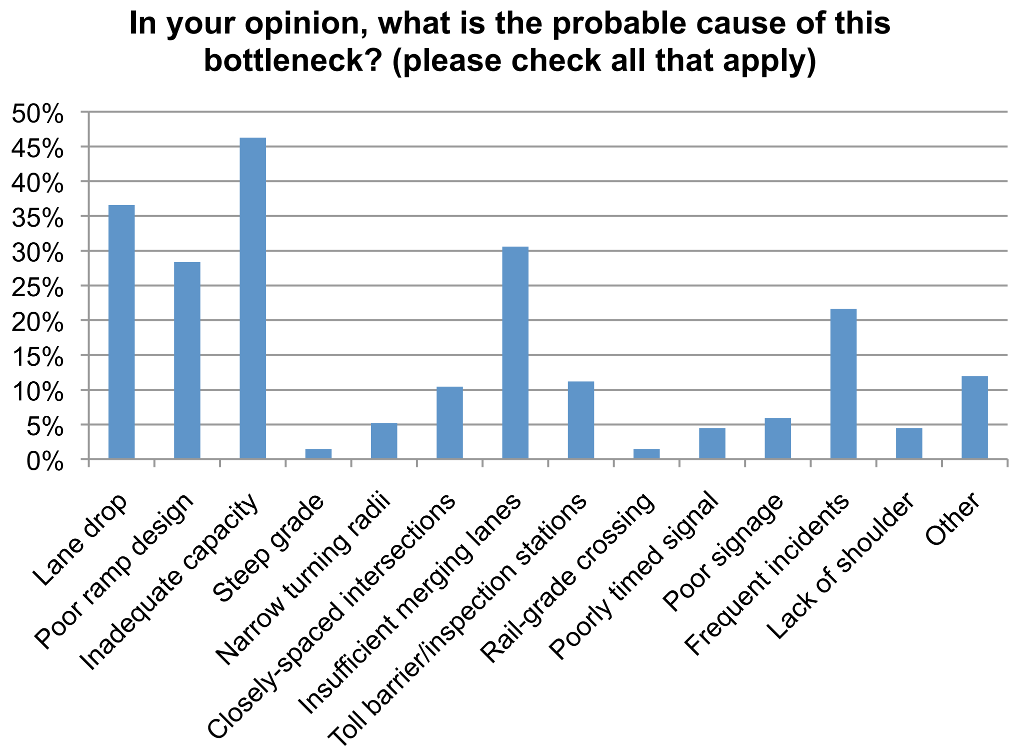


Figure 11. Cause of Bottlenecks Nominated by Respondents

2.3.2. Freight Rail Operators

Interviews with freight rail operators followed an introduction similar to the highway-related interview format. Following the introduction, questions focused on the bottleneck identification metrics and processes. Due to a number of circumstances and characteristics of the freight rail industry, interviews produced substantially less data in comparison to truck-related interviews, in both qualitative and quantitative terms. These issues are enumerated in further detail in Chapter 5.

3. Highway Bottleneck Analysis

According to Commodity Flow Survey, trucks carried almost 2.5 billion tons of freight across the highways of the ten states in Mississippi Valley region during 2002. This accounts for 69 percent of total weight of freight movement in the region. Therefore efficient truck traffic is of significant importance for the regional freight movement. This chapter is designed to examine the performance of freight movement on highway network within the study region. Built on a typology of freight bottlenecks defined in previous research, the study conduct an analysis to identify, characterize and prioritize highway freight bottlenecks of regional concerns.

3.1. Scan of Past Studies

Most of the previous studies about highway bottlenecks focus on the examination of locations constricting highway traffic. Past efforts in this area have focused on identifying the temporal and spatial distribution of highway bottlenecks. A few studies have also attempted to assess the causes and relative severities of bottleneck conditions. The investigation of previous studies provides a comprehensive knowledge about bottleneck identification and prioritization methods, especially about highway freight bottlenecks. Based on the type of data used for analysis, there are generally three different approaches to bottleneck analysis. These approaches are discussed in detail below.

3.1.1. Loop Detector-based Method

The first approach is based on the rich traffic data – such as vehicle counts, traffic speed, and occupancy of detector over a time interval – obtained from loop detectors. One way of using such data entails first constructing curves of cumulative vehicle counts and occupancy of detectors for each loop detector. Bottlenecks are then identified from visual inspection and comparison of the two types of curves for neighboring loop detectors. The process is repeated for multiple observation days and the results are compared across days to confirm the locations of bottlenecks (Cassidy & Bertini, 1999; Bertini & Myton, 2004).

An alternative to using single loop detector data is to develop 'speed contour maps' based on speed measures derived from adjacent loop detectors placed along a corridor. For example, Chen et al. (2004) identify freeway bottlenecks by using aggregated five-minute speed information obtained from Freeway Performance Measurement System (PeMS). Speed measures from neighboring pair of upstream-downstream loop detectors (i.e. within 2 miles) are examined for active bottlenecks in between. In their study, a bottleneck is characterized by a 40 mph of maximum speed at the upstream station and an increase of at least 20 mph in speed at the downstream station. These threshold values are selected to achieve the best match between their identification results and visual evaluations of contour plots. Similarly, Wiezorek et al. (2009) use the Portland Transportation Archive Listing (PORTAL) data to develop an automated tool for identifying recurrent freeway bottlenecks. Recognizing that the selection of speed threshold values should depend on the location and period of study, Wiezorek et al. test a series of combinations of three key parameters: maximum upstream speed, minimum speed differential, and aggregation level. The optimal parameter values are determined based on a statistical analysis of success and false rates, which respectively are the proportions of correctly and incorrectly identified bottlenecks according to ground truth. Ban et al. (2007) argue that the single day traffic data typically used in previous studies may vary significantly due to incidents and/or events. Instead, they propose to use multi-day, percentile speed to represent the traffic condition at each loop detector station. The 50th percentile speed is compared with 35 mph threshold to identify bottlenecks on a freeway and a smoothing procedure is performed to fill the minor gap between two periods of sustained bottleneck.

3.1.2. GPS-based Method

Very recently, researchers began to explore the use of vehicle global positioning system (GPS) data for bottleneck analysis. For example, in Washington state, GPS data points obtained from 25 portable GPS devices installed on trucks are used to develop a series of benchmarks to examine roadway segment performance, including speed, mean speed, and speed of various percentile (McCormack & Hallenbeck, 2006). Also, the data points from four of the GPS devices placed on Boeing trucks traveling on a routine route are used to identify the locations where delay occurs, as indicated by a slower speed. More recently, a freight performance study conducted by the American Transportation Research Institute (Short et al., 2009) attempts to quantify truck delay on the 30 worst US freight bottlenecks based on the difference between the free flow speed and the average speed measured from GPS data. Bottleneck interchange delay at a freeway interchange is computed as the accumulative delay over a 1 to 3 mile stretch from the interchange location. As demonstrated in (Short et al., 2009), GPS data represents a rich source of roadway performance information, especially when more and more fleets become equipped with automated vehicle tracking devices. However, the success in using such data for performance monitoring and bottleneck identification purposes depends on the size and spatial coverage of the sampled truck data.

3.1.3. HPMS-based Method

The third bottleneck analysis approach utilizes the Highway Performance Monitoring System (HPMS) data. The HPMS is a national transportation data program that provides data on the extent, condition, performance, use, and operating characteristics of the nation's highways. The data are collected and submitted to the FHWA Office of Highway Policy Information by state departments of transportation, metropolitan planning organizations, and local governments such as counties and cities. Historically, the HPMS data is used mainly in the production of the biennial Condition and Performance Reports to Congress and the determination of the scope and size of the federal-aid highway program and the level of federal highway taxation.

Due to its public availability and nation-wide coverage, the HPMS data has also become a popular source of data for bottleneck identification. As one of the earliest studies to identify bottlenecks on a national basis, Cambridge Systematics, Inc. (1999) scans the HPMS database for freeway segments with high ratios of traffic volume to available highway capacity to develop a preliminary list of candidate bottlenecks for the nation. A subsequent study (Cambridge Systematics, Inc., 2005) develops a typology of freight bottlenecks and identifies the priority freight bottlenecks for the nation using the HPMS data and Freight Analysis Framework (FAF) data. Four types of freight bottlenecks are identified: interchange, lane drop, steep grade, and signalized intersection bottlenecks. In both 1999 and 2005 studies, an interchange bottleneck is identified as a point on the map and its severity is characterized by the delay estimated for the "critical leg" of the interchange. While their methodologies help locate the interchange bottlenecks, they do not provide information on the actual causes of bottleneck condition. To overcome this limitation, Cambridge Systematics, Inc. (2007) supplements the HPMS and FAF data with Google Earth satellite photos, which provide detailed configurations and geometrics of interchanges. A procedure is developed to split and assign interchange traffic movements to more accurately identify the specific clogging spots on an interchange.

3.2. Discussion

The three aforementioned bottleneck analysis approaches utilize data of very different nature and are therefore suitable for different applications. As loop detectors record traffic information at fixed sites and usually at a high temporal resolution of 30-seconds to 5-minutes, the dynamic data allow the examination of the detailed variation in traffic patterns within a day. This makes the data most suitable for the detailed temporal and spatial analysis of bottlenecks at a local scale once the general locations of the bottlenecks are known. In comparison, current GPS data are typically available to researchers at lower and differing temporal resolutions (ranging from seconds to hours). Using GPS data to analyze the temporal variation in travel speed and in the presence of bottleneck condition is therefore subject to the careful treatment of data points. Furthermore, since the currently available GPS data represent only a fraction of all truck travel, several sample bias issues are yet to be resolved. The advantage of GPS data over loop detector data is spatial coverage. This is because, once installed, GPS devices can provide data for as far as the trucks can reach, whereas loop detectors are stationary and their wide deployment is relatively more costly.

Compared to the other two data sources, the HPMS database is the more appropriate for large-scale bottleneck analysis as it is a national data program. As the traffic data contained in the HPMS are annual measures (e.g. average annual daily traffic), the data are not subject to day-to-day variations or random events, rendering the data more suitable for identifying recurring delays. However, this lack of temporal details also means that any dynamic variation in the bottleneck condition at a given site cannot be identified. Similarly, as the HPMS data are available for highway segments that may range from a few yards to several miles, the lack of spatial details means that the data is best used for a preliminary scan of the general vicinity and severity of bottlenecks, but not their exact locations or causes.

3.3. Definition of Highway Freight Bottleneck

A clear definition of highway freight bottleneck is essential for shaping the scope and determining the data and methodology used for the analysis. The review of existing literature reveals that there are few bottleneck studies specifically addressing freight movement. Among these studies, the primary focus is to investigate the impact of generally recognized bottlenecks to truck traffic and the definition of freight bottleneck is relatively vague.

In fact, due to the maneuver characteristics and route choice of trucks, some types and/or locations of bottleneck might be exclusive for trucks. For example, truck drivers usually have to slow down to accommodate continuous upgrades, blocking traffic and building a queue. In terms of the location, trucks are more likely to experience congestion within the vicinity of a warehouse than general traffic due to the route choice, making the location a bottleneck particularly for trucks rather than a general one. FHWA concludes that “a freight bottleneck is ‘freight stuck in traffic’ but more to the point.” Therefore, it’s necessary to establish freight bottleneck as a separate topic in order to study congestion impact to freight movement.

In this freight-oriented study, the highway freight bottleneck definition should combine both the factors of truck traffic and inherent highway constraints causing congestion. Realizing this requirement, the freight bottleneck is defined as the segment of highway that constricts the efficient movement of trucks and leads to significant delay for freight transportation on highway network. This definition highlights the specific locations causing delay of truck traffic and is therefore favorable in this study.

3.4. Data for Analysis

The freight bottleneck analysis relies on consistent and uniform traffic data across the study region. Previous studies also reveal that the data employed determines the analysis approach and final output of bottleneck study. Realizing the importance of data, the study of highway freight bottleneck starts from exploring potential data sources and compares data availability and coverage for the entire region to determine the major data source on which the freight bottleneck analysis is conducted basing.

3.4.1. Data Source

As one of the first steps in data collection, DOT representatives of the MVFC member states were contacted and interviewed regarding the availability of physical and operational data about their respective state highway networks. During the interviews with each state, a great amount of state-specific data is collected and some of them are quite valuable for the study of freight bottleneck conditions on the highway network. For example, the Illinois DOT provides a comprehensive roadway data inventory database with ArcGIS layer, which covers not only the freeways, arterials and local highways, but also the ramps and interchange designs for freeways. However, the data collection results vary among states and some states have no additional data asides from the HPMS data annually submitted to FHWA. The variation of data fields and coverage among state-specific datasets limits the use of these datasets in this regional bottleneck study.

Compared with the state-specific data, the HPMS database provides a consistent source of information for the national level highway. In the database, each record represents a highway section, whose length varies from 0.01 mile in urban area to 20 miles in some rural area. The database consists of two datasets: (a) the Universe dataset, which provides basic physical and traffic information on all sections of the national highway network; and (b) the Sample dataset, which contains detailed geometry and operation information for a sampled subset of highway sections. The most recent available HPMS version is the 2006 including both the Universe and Sample datasets in database format.

Another potential datasets for the study of freight movement is the FAF 2.2 data, which provides the comprehensive highway link and truck data over National Highway System (NHS), National Network (NN) and several intermodal connectors. The major data sources to develop the network include 2005 National Highway Planning Network (NHPN) offering the spatial component, 2002 HPMS database providing general traffic count data and FAF 2.2 O-D database, from which the FAF truck flow is derived. Although the data favors the analysis of freight movement by providing the specific long distance and local truck traffic volume for each link, the aggregated segment (i.e., much longer segment than that in HPMS) and lack of geographic information prevent the further use of this dataset.

By comparing several available datasets, the research team decided to use the 2006 HPMS data as the major data source to analyze the highway traffic condition and freight bottlenecks for this regional level study. At this point, the merits of the state-specific data should not be overlooked as they provide detailed local traffic-related information. Bringing these data back to the study might help understanding the spot-specific situation and motivate appropriate solution to local traffic problem.

3.4.2. Data Characteristics

For the purpose of identifying and characterizing candidate freight bottlenecks, this study focuses on highways supporting truck traffic as they serve the ground freight movement. The data item “designated truck route” in HPMS database describes whether a section is on or off a truck route designated under Federal regulatory authority, providing a good indication to determine the coverage of study. By examining the distribution of designated truck route length among different functional classes, which is shown in Figure 12 , it’s found that the majority of truck routes are on highways of following three functional classes in the study region:

- Rural principal arterials. Over 25,000 miles of rural principal arterials are designated as truck routes, accounting for 78 percent of total highway length within the functional class.
- Rural minor arterials. Approximately 13,500 miles of rural minor arterials are covered by truck routes, accounting for 33 percent of total highway length within the functional class.
- Urban principal arterials. Over 10,000 miles of urban principal arterials are covered by truck routes, accounting for 48 percent of total highway length within the functional class

Roadways of functional classes other than these three types barely have links designated as truck route and consequently they are not included within the scope of this study. Further inspection reveals that comparing to urban and rural principal arterials, rural minor arterials only carries a marginal proportion of truck traffic. And considering the fact that traffic congestion in rural area is not as severe as that in urban area, the rural minor arterials are eliminated from the consideration.

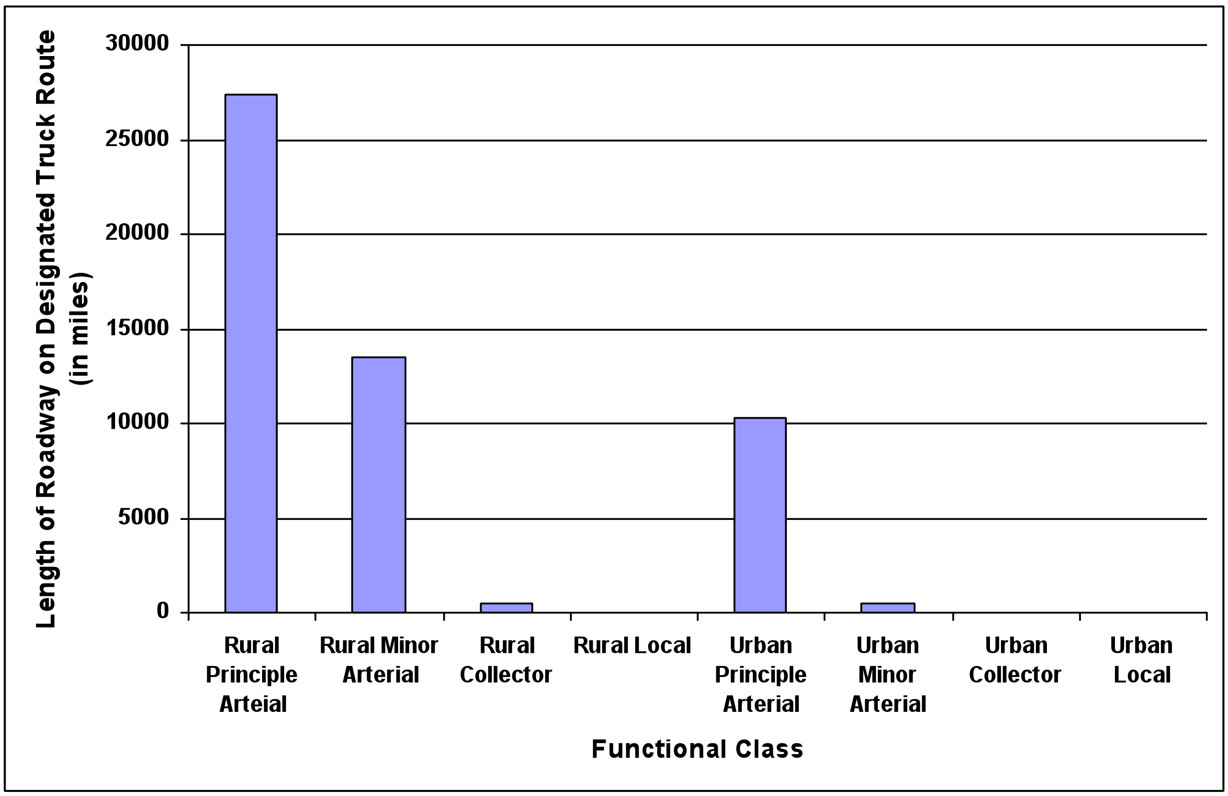


Figure 12. Distribution of Truck Route Length among Functional Class

The urban principal arterial can be further stratified into urban interstate freeway, urban other freeway and expressway, urban other principal arterial. Similarly, rural principal arterials could be classified as rural interstate freeway and rural other principal arterials. This disaggregated classification supports the detailed examination of traffic patterns and is therefore employed in discussions hereafter.

Figure 13 is a box plot showing the average annual daily traffic (AADT) distribution among different functional class groups in the Mississippi Valley region, derived from the HPMS 2006 universe dataset. It’s clear that the greatest traffic volume falls on urban interstate freeways, followed by urban other freeways/expressways. Because the freeways are designed to serve the highest traffic volume corridors, the majority of traffic accessing/exiting or going through the urban area uses these urban freeways. In comparison, the traffic volume on the urban/rural other principle arterials are much smaller.

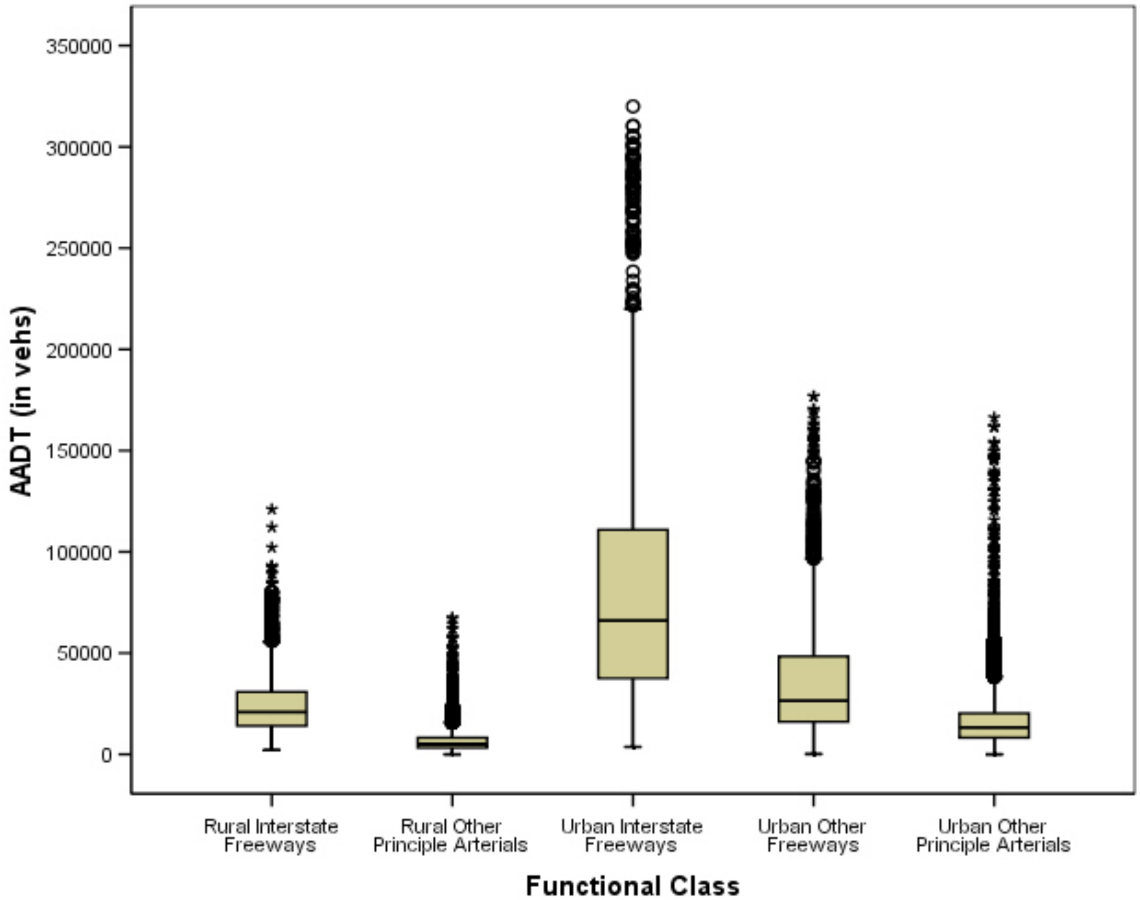


Figure 13. AADT by Functional Class

Because the truck percentage data (i.e. average daily percent single unit trucks and average daily percent combination trucks) is only available for sampled sections, the preliminary examination of the distribution of truck traffic volume is based on the sample data. The truck average annual daily truck traffic (AADTT) is calculated as:

$$AADTT = AADT \times (daily\ percent\ single\ unit\ trucks + daily\ percent\ combination\ trucks)$$

Figure 14 is a box plot showing the AADTT distribution in different functional class groups in the Mississippi Valley region, derived from the HPMS 2006 sample dataset. The similar trend is observed as the AADT distribution. Overall, the truck traffic volume on urban/rural freeways are much higher than that on urban/rural other principal arterials. One difference from the AADT distribution is that the mean of truck traffic volume on rural interstate freeways is higher than that on urban other freeways/expressways. This is because almost all the rural interstate freeways are designated truck routes. But trucks are prohibited to access a lot of urban traffic facilities.

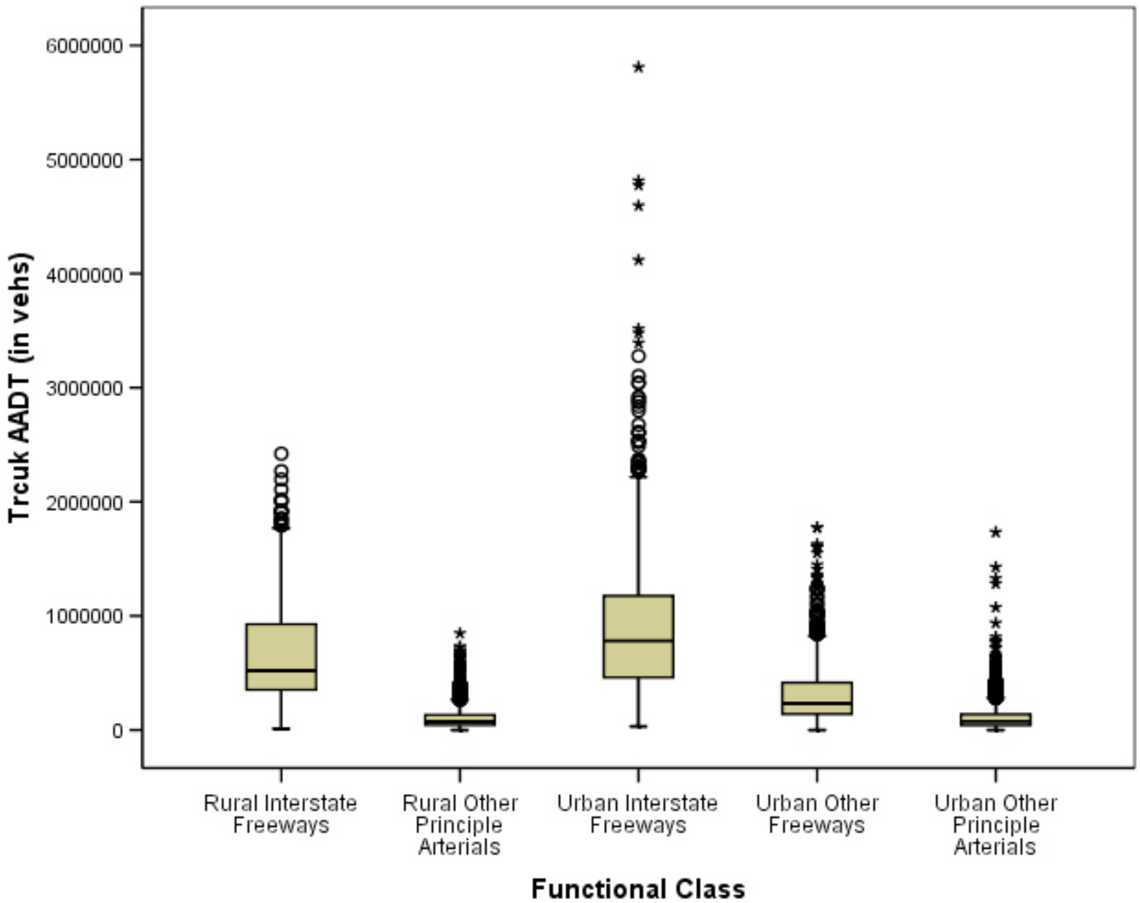


Figure 14. Sample Truck AADT by Functional Class

Figure 15 is a histogram showing the percentage of sampled sections out of total number of universe sections in each functional class for the Mississippi Valley region. The highest percentage of sampling is observed in urban other freeways group, which is more than 35 percent. The percent of sampled sections is higher than 15 for all freeway groups. However, this percentage is barely over 10 for urban other principal arterials and less than 10 for rural other principal arterials.

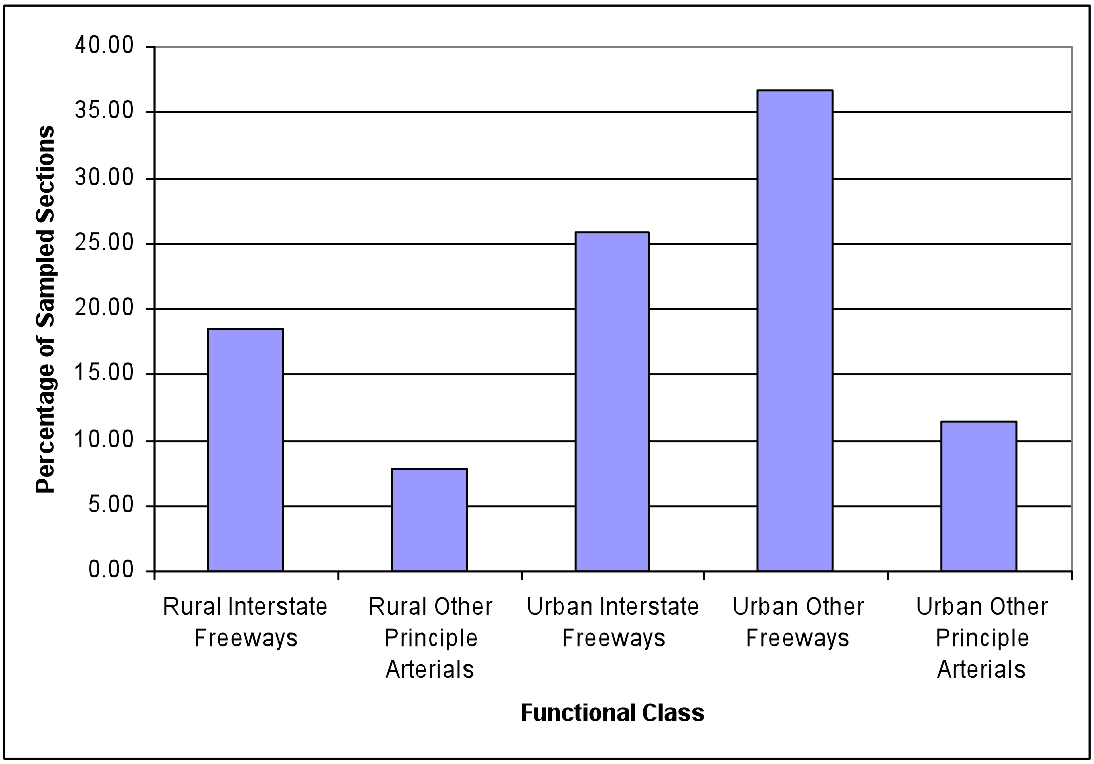


Figure 15. Percentage of Sampled Sections among Functional Class

The percentage of sampled sections also varies among states. Table 2 shows the distribution of number of sampled sections among ten states. The percentage of sampled sections out of universe sections ranges from 4.5 percent in Iowa to 40.3 percent in Kentucky. Due to the fact that certain roadway attributes are available only for the sampled sections and that the sampling rate varies across roadway classes and states, our analysis of certain types of highway bottlenecks result in incomplete and biased coverage of bottleneck locations. This limitation will be further discussed in sections 3.4 and 3.5.

Table 2. Distribution of Number of Sampled Sections among States

State	Number of Sampled Sections		Total Number of Sampled Sections	Total Number of Universe Sections	Sample Rate
	On Freeway	On Other Principle Arterials			
Illinois	346	736	1082	15716	6.9%
Indiana	315	862	1177	3313	35.5%
Iowa	455	740	1195	26700	4.5%
Kansas	252	483	735	2429	30.3%
Kentucky	230	755	985	2443	40.3%
Michigan	482	819	1301	4574	28.4%

Minnesota	242	706	948	3262	29.1%
Missouri	321	480	801	6334	12.7%
Ohio	916	1277	2193	12987	16.9%
Wisconsin	372	1066	1438	16345	8.8%

3.4.3. Data Processing

3.4.3.1. Mapping HPMS Data onto NHPN Layer

In order to analyze the HPMS data in a geographic information system (GIS) environment, it's necessary to integrate the original HPMS in database format into an ArcGIS format. When submitting the annually collected data to the FHWA, each state is required to provide the linear referencing system (LRS) inventory ID, and a begin and end mile point for each section. This linear referencing system data allows mapping sections in HPMS datasets onto the NHPN, which is a comprehensive network database that covers the rural arterials, urban principal arterials, and all national highways system routes. By sharing the same linear reference system with HPMS database, the NHPN permits the visualization of the HPMS database and GIS analyses of the data.

The dynamic segmentation process is used to map the sections in HPMS to the NHPN dataset, by which sections stored in a table can be transformed into a feature that is visible in a GIS layer. The information required to matching two datasets, as mentioned above, includes the LRS inventory ID, and begin and end mile points. However, in both datasets, a LRS inventory road might have renumbered begin and end miles when crossing counties or states, resulting in the situation where two or more sections with identical LRS inventory ID and overlapping begin and end mile points exist in different counties or states. To uniquely identify one section in both datasets, the county ID and state ID were added to the end of the original LRS inventory ID. After creating the unique LRS inventory ID, each freeway section in HPMS data was added as an event to the NHPN coverage network.

However, not all the freeway sections in HPMS data have the corresponding route in NHPN database. Both the missing route and milepost discrepancy contribute to the non-matching between two datasets. As indicated by Battelle Co. (2007), "The route system on the NHPN was built in the 1990's from State submitted LRS data sources (maps, link/node files, GIS files) as explained in the HPMS Field Manual, Chapter 5 and Appendix H. As part of the annual HPMS submittal to FHWA, States are requested to provide LRS updated maps showing the location of new, deleted, and revised inventory routes." The updated HPMS inventory system by each state might employ new route name, or redefine the milepost system, resulting in the inconsistency to the original LRS system. The efforts from both FHWA and each State are required to fix the inconsistency.

The percentage of matched sections out of total number of freeway sections for each state are showed in Table 3. The percentage of matched freeway sections varies among states, ranging from 93.65 percent for Indiana to 99.95 percent for Iowa. In total, 97.33 percent of the sections on urban interstate freeways, urban other freeways/expressways and rural interstate freeways are successfully mapped onto the NHPN. The remaining 2.67 percent are then excluded from subsequent analysis.

Table 3. The Matching Percentage of Freeway Sections in Ten States

State	Number of Matched Freeway Sections	Number of Freeway Sections	Percentage of Matching
Illinois	2255	2283	98.77%
Indiana	560	598	93.65%
Iowa	3889	3891	99.95%
Kansas	429	451	95.12%
Kentucky	226	230	98.26%
Missouri	858	885	96.95%
Minnesota	699	732	95.49%
Michigan	1377	1464	94.06%
Ohio	3125	3248	96.21%
Wisconsin	1512	1558	97.05%
Ten states	14930	15340	97.33%

3.4.3.2. Extrapolation of Information on Sample Section

As stated before, the detailed geometry information and traffic characteristics data are only available in the sample dataset. Yet, many of these data fields are critical to the analysis of freight bottlenecks. For instance, the geometric attributes are needed for the estimation of highway capacity and the identification of possible traffic constraints on the respective highway sections. The data field, percentage of truck volume, is particularly necessary in determining the presence of truck traffic and the impact of bottleneck condition on truck movement. In order to perform bottleneck analysis on the non-sampled sections as well as the sampled sections, this study extrapolates the data values of the sampled sections onto the non-sampled sections using the following procedure.

The basic assumption underlying the extrapolation process is that traffic pattern and geometry characteristics vary little along a LRS route made up of connected roadway sections with the same LRS ID and in the same county. As such, non-sampled highway sections on a given LRS route would inherit the attribute values of their nearby sampled sections on the same route. The attributes favoring extrapolation include lane width, left/right shoulder width, speed limit, percentage of trucks, etc. However, it's not reasonable to extrapolate the traffic operation data items, such as number of at-grade signals and geographic information like curves and grades, because they are primarily subject to the change of location. Without further information, simply extrapolating these data items according to spatial relationship would introduce great bias into data.

Specifically, there are three different cases for which extrapolation are performed. In the case where only one sampled sections is found on a given LRS route (see Figure 16(a)), all non-sampled sections on the route are assigned with the attribute values of the sampled section. If more than one sampled section are found on a LRS route but are all on the same side of a given non-sampled section (see Figure 16(b)), then the non-sampled section is assigned with the attribute values of the nearest sampled section. If a non-sampled section is found between two sampled sections on the same LRS route (see Figure 16(c)), then the attribute values of the non-sampled section are computed according to the operations summarized in Table 4. Essentially, for attributes describing the traffic characteristics (e.g. percentage of trucks in traffic), the average of the two sampled values is used as the value for the non-sampled section. For attributes that describe the roadway geometry (e.g., lane width), the non-sampled section inherits either the minimum or the maximum of the two sampled values that correspond to a more conservative traffic capacity or more intense demand. Therefore the extrapolation is performed in such a way that traffic delays tend to be overestimated according to information extrapolated.

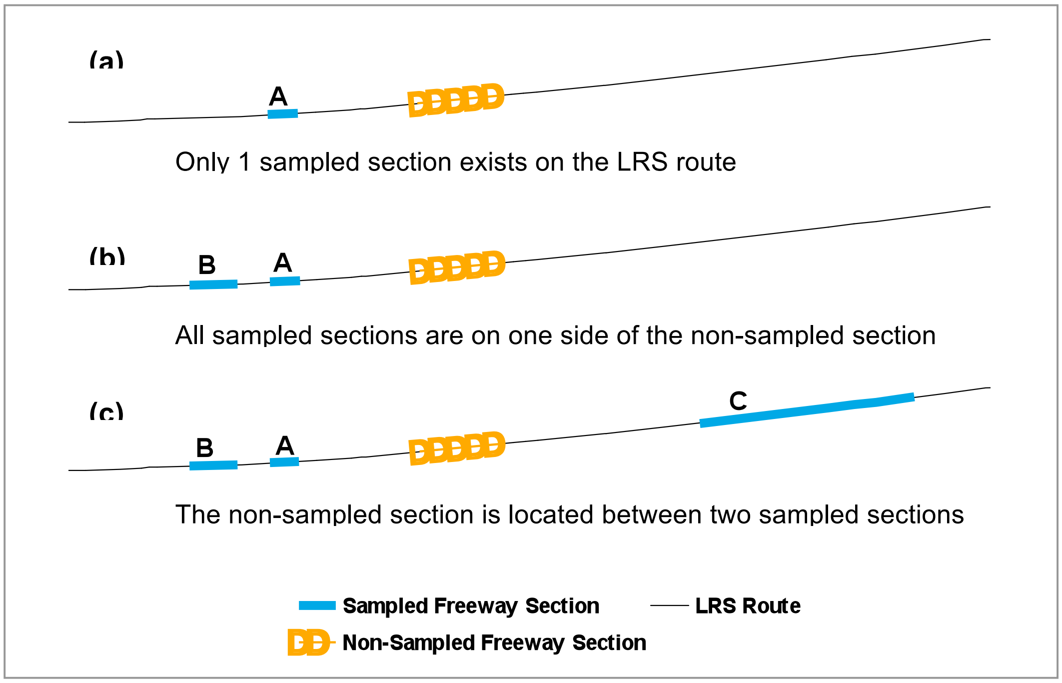


Figure 16. Extrapolation of attribute values from sampled to non-sampled HPMS sections

Table 4. Operations for determining the attribute value of a non-sampled section located between two sampled sections

Attribute Name	Operation
Lane Width	Min
Speed Limit	Min
Median Width	Min
Right Shoulder Width	Min
Left Shoulder Width	Min
Percent Passing Sight Distance	Min
Number of Peak Lanes	Min
Left Turning Lanes	Min
Right Turning Lanes	Min
Typical Peak Percent Green Time	Min
Access Control	Max
Median Type	Max
Type of Terrain	Max
Percent Peak Single Unit Trucks	Average
Percent Average Daily Single Unit Trucks	Average
Percent Peak Combination Trucks	Average
Percent Average Daily Combination Trucks	Average
K Factor	Average
Directional Factor	Average

The extrapolation process outlined above requires that LRS routes contain with at least one sampled section. Clearly, the proportion of LRS routes without any sampled section depends on the HPMS' sampling rate for its Sample dataset. It is found that this sampling rate varies significantly across functional classes. While 25 percent and 18.5 percent of urban and rural freeways are respectively included in the Sample dataset, the proportion of urban other principal arterials and rural other principal arterials are below 10 percent. Therefore, the data extrapolation is performed to the freeway sections only. This limits subsequent analysis to all freeway sections in the study region, plus the sampled principle arterial sections. The non-sampled principle arterials – both urban and rural – are excluded in the analysis due to the lack of needed attribute values.

After the extrapolation, link capacity of freeway sections is estimated according to the extrapolated geometry information and several data items in Universe database (i.e., functional system, type of facility, section length, number of through lanes, and AADT). The measure of capacity follows the procedure described in Appendix N of HPMS Field Manual. This procedure uses the capacity calculation method developed from Highway Capacity Manual 2000 (HCM, 2000). It estimates capacity based on service flow rates for level of service E. By employing this procedure, both the two-way link capacity and capacity for peak direction could be obtained.

3.5. Bottleneck Analysis Methodology

The proposed bottleneck analysis method is built on a past FHWA freight bottleneck study (Cambridge Systematics, 2005) because of the same HPMS database employed. In order to explore freight bottlenecks of regional concern and take advantage of the processed HPMS data, several underlying changes are made to the original method, including:

- Characterization of bottlenecks. The proposed methodology adopts the four-way freight bottleneck classification developed previously (Cambridge Systematics, 2005), including interchange, lane drop, steep grade, and signalized intersection bottlenecks. However, as opposed to assigning each bottleneck location to exactly one of the four types of bottlenecks, this study recognizes the limitation of the HPMS data and considers the possibility of a highway section being associated with more than one bottleneck conditions. Therefore, for all freight bottlenecks identified, the presence of each type of constraint is examined to explore any potential cause leading to the activation of bottleneck. As the interaction between multiple constraints tends to complicate the bottleneck condition and aggravate delay (Cambridge Systematics, Sep 2005), full investigation of bottleneck sources provides more insights by which one can gain a better understanding of local traffic conditions.
- Freight bottleneck indicator. Instead of utilizing the ratio of traffic volume to capacity during peak hour as in the previous study (Cambridge Systematics, 2005), this study uses truck unit delay, measured by hours of delay for trucks per 1,000 miles, to scan candidates of freight bottleneck locations. Truck unit delay is considered a more suitable measure for the purpose of this study because it captures the delay for all commercial motor drivers using per mile of a given highway segment. It is considered to more directly capture the congestion impact to freight movement.
- Interchange bottleneck identification. As part of our methodology development for identifying interchange bottlenecks, this study also proposes a congestion corridor approach that is not found in previous studies. The congestion caused by geometry design constraints at interchange is more severe in terms of both spatial extent and duration than that which results from other types of constraints (Cambridge Systematics, 2005). And the traffic queue developed from an interchange could reach several miles during peak period. These features of interchange bottleneck put challenges on identifying the specific bottleneck location along a congested highway. In order to address the challenges, a congestion corridor growing method is incorporated in the method.
- Prioritization method. The total hours of delay is usually employed as a measure to prioritize bottlenecks in previous studies (Cambridge Systematics, 1999; Cambridge Systematics, 2005; Cambridge Systematics, 2008; Short et al., 2009), however, an important question not well addressed is the spatial scope incorporated in calculation of total delay for bottlenecks. For interchange bottlenecks, various assumptions are found about the stretch from interchange location to be included in delay calculation, ranging from 1 mile to 5 miles. For

other types of bottlenecks identified from HPMS data, because the information on each section represents the prevailing condition, the actual congestion might not cover entire bottleneck section, or spread to neighboring sections. To avoid introducing bias when calculating the total delay, the prioritization is performed based on truck unit delay without considering the impact scope of bottleneck.

3.5.1. Overall Framework

Figure 17depicts the sequence of steps involved in the bottleneck analysis method. In general, the procedure depicted on left side of the figure is used to identify interchange bottlenecks while the right side of the figure shows how highway sections are checked for the presence of the other three types of bottlenecks.

The identification of interchange bottlenecks begins with extrapolating attribute values from sampled freeway sections to non-sampled ones in the Universe dataset using the procedure described in Section 3.3.3. Truck unit delay is then estimated for each of these sections using the process described in more details in Section 3.4.2. If the delay is found to exceed a pre-selected threshold value θ (the process by which the threshold value is determined is discussed in Section 3.4.3), then the section is considered as being part of a congested corridor. The following entails constructing a congestion corridor around each congested section using the method described in Section 3.4.4. When multiple congested sections are close to each other, their corresponding congested corridors are merged into one. For each corridor identified, the section with the highest truck unit delay is considered as the worst section. If this worst section is within ε distance of an interchange (the selection of ε is discussed in Section 3.4.5), then that interchange is considered as the root of the congestion along the corridor and is labeled as an interchange bottleneck.

The assessment of the remaining three types of bottlenecks is performed for all freeway sections and sampled principle arterial sections, but not the non-sampled principle arterial sections. This is because the HPMS has a low sampling rate for principle arterials and extrapolation cannot be applied to most of these arterial roads to derive the additional attribute values needed for bottleneck analysis. As show on the right side of Figure 17, we first estimate the truck unit delay for the target sections using the same procedure as applied to interchange bottleneck analysis. Similarly, if the delay on a given section exceeds a pre-selected threshold value θ, the section is then checked for the following three types of traffic constraints:

1. Is there an at-grade traffic signal on the section?
2. Does the section include a stretch of more than 1 mile of steep grade (i.e. grade greater than 4.5 percent)?
3. Is there a decrease in number of lanes between this section and its neighboring sections?

If the answer is “yes” to any of the above questions, then the section is labeled as a signalized intersection bottleneck, steep grade bottleneck, and/or lane drop bottleneck.

When the two paths of the analysis converge towards the end of the analysis procedure, all four types of bottlenecks are merged into one list and ranked according to their respective truck unit delay values. The end product is a prioritized list of bottlenecks identified for the study region.

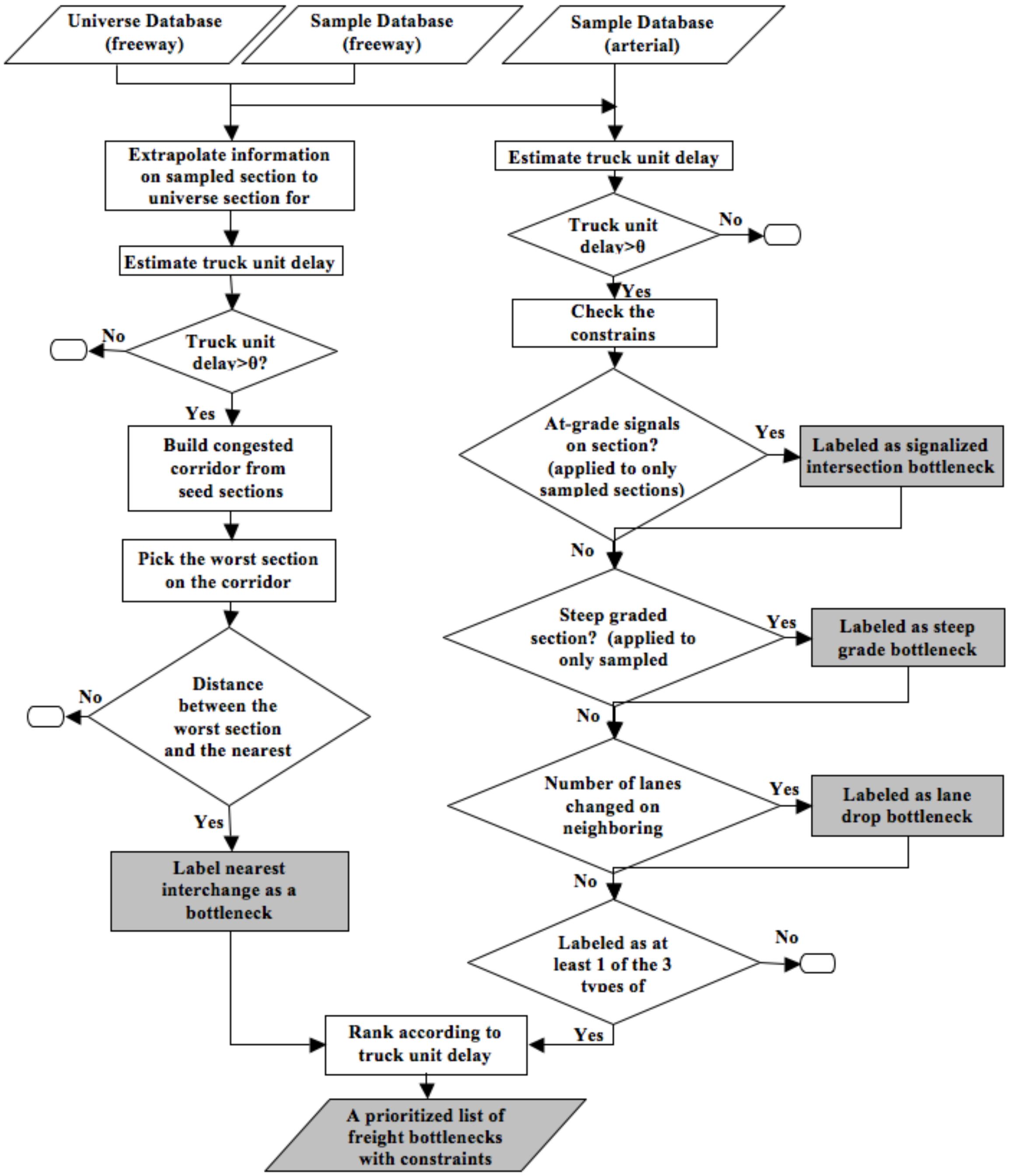


Figure 17. Flowchart depicting the proposed bottleneck analysis methodology

3.5.2. Estimation of Truck Unit Delay

Our delay estimation is based on the empirical models developed in a previous study (Margiotta et al., 1999), allowing the calculation of delay and speed in peak hour, peak period and entire day. Also, different models are available for weekdays, weekend and holidays, and an average day. In this analysis, only the delay estimation model for an average day is used. The delay model requires as input the annual average daily traffic (AADT), capacity, signal density, and signal progression type of a given section. These attributes are all readily available in the HPMS database.

Specifically, following equations are primarily employed to estimate unit delay, measured as hours of delay for two-way traffic per 1,000 miles per vehicle.

For freeways:

$$\text{Unit Delay} = 0.0461854203 * AADT/C^3 - 0.0154380323 * AADT/C^4 + 0.0018559670 * AADT/C^5 - 0.0000887095 * AADT/C^6 + 0.0000014614 * AADT/C^7$$

For signalized arterials:

To consider the effect of progression signals, the signal density *n* should be adjusted before calculating the hours of delay. The adjusted signal density *n'* is calculated as:

$n' = 2n/(n+2)$

If AADT/C <= 7

$$\text{Unit Delay} = (1- e^{-0.3n}) * (32.5177 + 0.19583856 * AADT/C^2 - 0.00728030 * AADT/C^3 + 0.0007935231 * AADT/C^4)$$

If AADT/C > 7

$$\text{Unit Delay} = 0.1586415772 * (AADT/C - 7)^2 + 0.1211710141 * (AADT/C - 7)^2 * (1 - e^{-0.3n}) + \{(1 - e\ e^{-0.3n}) * (32.5177 + 0.19583856 * AADT/C^2 - 0.00728030 * AADT/C^3)\}$$

As unit delay measures the hours of delay per 1,000 vehicle-miles, it describes how bad the congestion condition is on a given section. By multiplying the unit delay with the truck volume on a given section, one can obtain the hours of delay for trucks per 1,000 miles.

This method incorporates several advanced features as summarized by Cambridge Systematics, Inc. (2005), including the use of queuing analysis, accounting for temporal distribution, and daily variation of traffic flow. On the other hand, there are limitations by using this method to estimate hours of delay for trucks, one of which is the potential overestimate of exposure of truck trips to delay. By multiplying the truck volume with the unit delay, it's assumed that truck trips follow the similar temporal distribution as passenger car trips. However, most commercial motor carries make great efforts developing strategies to re-schedule and/or re-route picking-up and delivering works in order to avoid known recurring bottlenecks. This might lead to the underlying difference in temporal distribution patterns between truck trips and passenger car trips, suggesting an overestimate of truck delay.

At the same time, it should be noted that the estimate of delay is based on two-way link volume. Although the HPMS Sample database reports the directional factor describing the percent of design hour volume flowing in the peak direction, which supports the estimation of delay at peak direction, the peak traffic direction is not explicitly specified. This lack of information prevents the further directional analysis of traffic congestion issues.

3.5.3. Delay Threshold

When does a section qualify as a bottleneck? In this study, a section becomes a candidate bottleneck location if its corresponding truck unit delay exceeds a threshold value, θ. The choice of θ is based on an empirical assessment of the calculated truck unit delay values across the study region. As shown in Figure 18, the range of truck unit delay values varies significantly for sections of different functional classes. The box plot in Figure 18 shows that the highest truck unit delays occur mostly on urban interstate freeways.

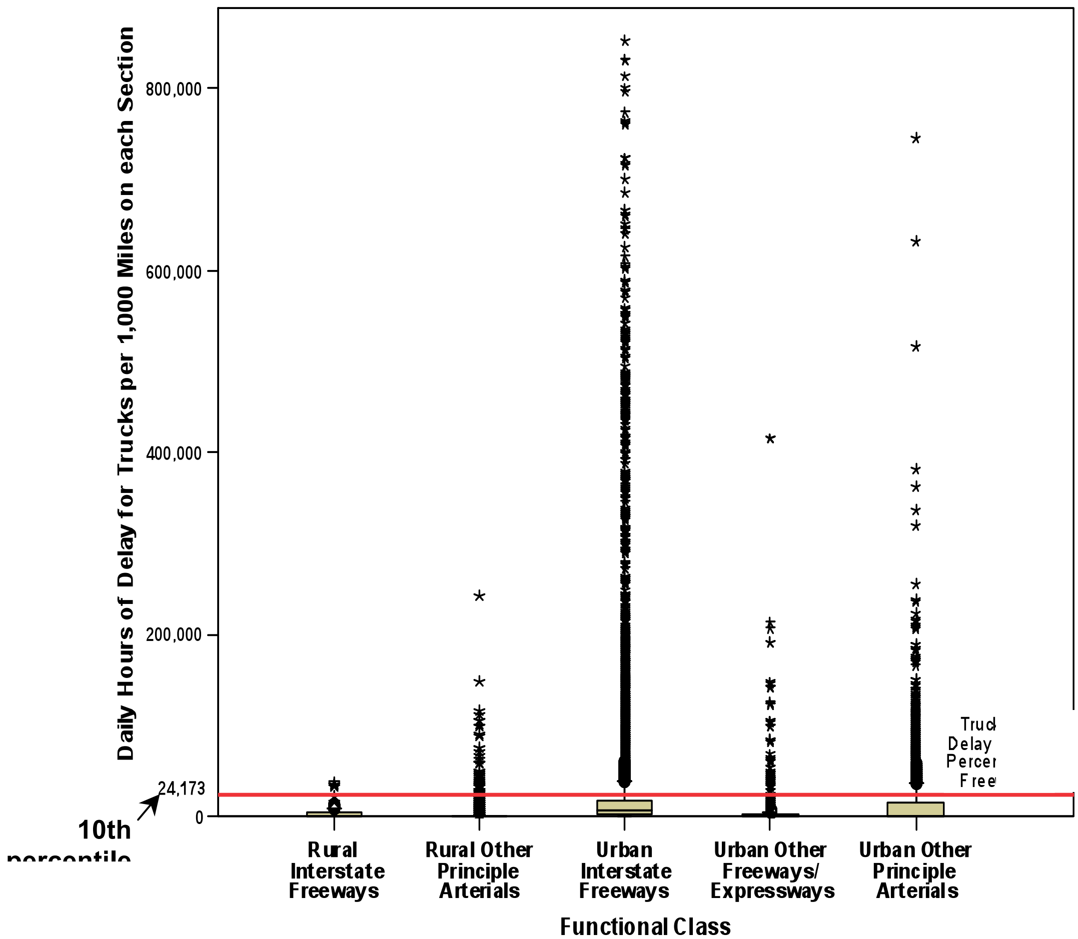


Figure 18. Distribution of Truck Unit Delay among Different Functional Classes

For the purpose of this regional freight bottleneck analysis, the 10th percentile of the combined truck unit delay distribution for all five functional classes is selected as the threshold value for bottleneck criterion (this corresponds to a threshold value of 24,173 truck hours per 1,000 miles). This cut off point captures the top 25 percent of urban interstate freeway and urban other principal arterial sections. It also allows the inclusion of the worst delayed sections on the remaining three functional classes.

Because the truck unit delay is determined by the truck volume and traffic conditions, three elements contribute to a significant truck unit delay,

(a) High Truck Volume

This case describes the situation where slight traffic congestion happens, but a high volume of trucks accumulates the unit truck delay. The appropriate example would be a distribution center producing and attracting a great amount of truck trips. The high volume of trucks within the vicinity would not only accumulate the total unit truck delay, but also cause a decrease in speed of traffic when accessing or exiting the warehouse locations, which aggravates the congestion. The congestion of this category is usually more localized and easy to be fixed.

(b) High Unit Delay

This case describes the situation where slight truck activities exist, but these trucks experience great delay due to the severe traffic congestion. A lot of state DOTs and metropolitan planning organizations have performed extensive highway congestion studies to such bottlenecks of public concern. By examining truck volumes at these locations one can examine the impact of generally bottlenecks to freight movement and identify the freight bottlenecks clogged with great proportion of trucks.

(c) Combination of Conditions

The presence of both high truck volume and high hours of delay per vehicle-mile inevitably produce the great truck unit delay, which is usually observed on the urban principal arterials serving the major centers of activities for both freight and general traffic. This is the most commonly case and usually causes the most significant truck unit delays.

As previous freight bottleneck studies focus on examining truck traffic on generally recognized bottlenecks, this analysis supplements current knowledge with the information about particular trouble locations for truck traffic by considering the freight bottleneck of first type. But this truck unit delay oriented scanning process is not appropriate for general bottleneck study since it overlooks bottlenecks for passenger vehicle traffic but with few trucks.

It should be noted that the selection of high truck unit delay threshold depends on the study area. For example, the 10th percentile truck unit delay value found for a state with little truck activities could be considerably different from that for a heavily urbanized state with intense truck traffic demands. Furthermore, the threshold value should also be selected to reflect what freight carriers and policy makers' perceive as bottleneck conditions.

3.5.4. Construction of Congestion Corridor

It is conceivable that, in reality, a given interchange bottleneck could trigger a system impact that lead to a traffic queue reaching miles away from the interchange location and affecting interchanges further up- or down-stream. Therefore, simply picking out sections with high truck unit delay on freeways is not an effective way for locating their root interchange bottlenecks. For this reason, we have developed a process of constructing congestion corridors to establish possible interdependency among sections of similar levels of delay that are in close proximity to each other. In order to explain the process, a step-by-step explanation is provided with the figures showing the implantation results of each step in Detroit urban area in Michigan to help illustrating the process.

The construction of a congestion corridor begins with given seed sections that have high truck unit delay (see Figure 19(a)). Neighboring sections to those selected ones are examined to confirm if a similar traffic patterns exist (see Figure 19 (b).). These immediately adjacent sections are included into the corridor if the following measure is no more than 0.1:

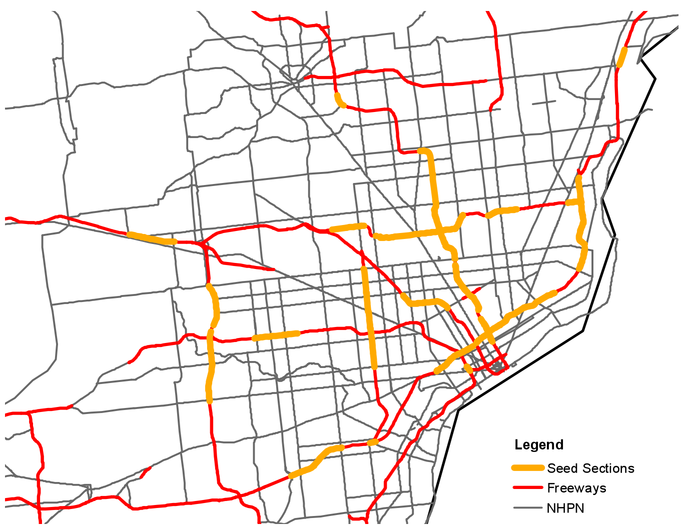
$$D = \frac{\left| AADT_1 / C_1 - AADT_2 / C_2 \right|}{AADT_1 / C_1 + AADT_2 / C_2}$$

where $AADT_1$ and C_1 denote the annual average daily traffic and capacity on the section already included in the congestion corridor; $AADT_2$ and C_2 denote the annual average daily traffic and capacity on the new section being examined, respectively. The AADT/C is selected as critical measure because this is the basis to estimate unit delay. And in consequence, the measure D indicates the relative difference in level of congestion between two immediately adjacent sections. A low value of D means similar level of traffic congestion on both sections. From the views of both roadway users going through the corridor and planners examining the traffic performance, a uniform traffic queue pattern exists on these two sections and consequently they are included in the same congested corridor. On the other hand, a high value of D indicates the following two cases for traffics on opposing directions, respectively:

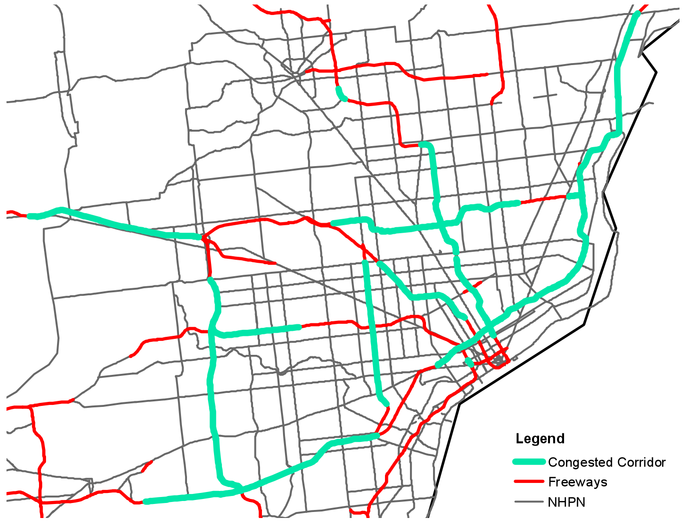
- Vehicles traveling from a section with lower AADT/C to one with higher AADT/C have to slow down on average to accommodate more congested traffic. These vehicles are considered as entering the end of a traffic queue from a regular traffic movement.
- Vehicles traveling from a section with higher AADT/C to one with lower AADT/C could speed up as density of traffic becomes less and more favorable to free flow conditions. These vehicles are considered as being discharged from congestion condition and getting back to normal speed.

In both cases, it's necessary to cut off the growth of the congestion corridor because of the interruption in traffic queue. At the end of the corridor construction process, it is possible for a congested corridor to include multiple seed sections that are of similar magnitude of delay and are located close to each other. This is particularly prevalent in urban areas and the corridor approach allows us to treat these congested sections not as separate bottleneck locations themselves, but as indicators of the presence of a nearby freeway interchange bottleneck.

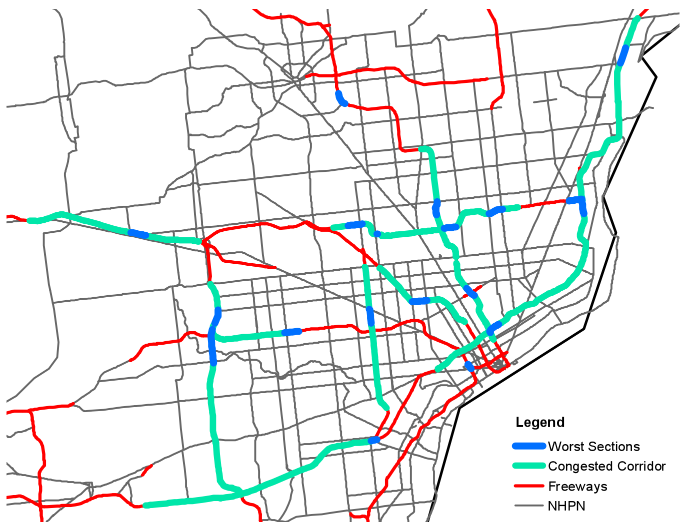
Once a congested corridor is identified, the section on a corridor where the truck unit delay is the highest is selected (see Figure 19 (c)). This most severely congested section is reasonably assumed to be the origin of the congestion corridor. If this worst section is located within close vicinity of a freeway interchange, the congestion on this corridor is attributed to the bottleneck at the interchange (see Figure 19 (d) and Figure 19 (e)). Here the one-mile threshold is selected to characterize interchange bottleneck. The selection of threshold for "vicinity" is a key issue of the algorithm, which is explained in detail in the following section.



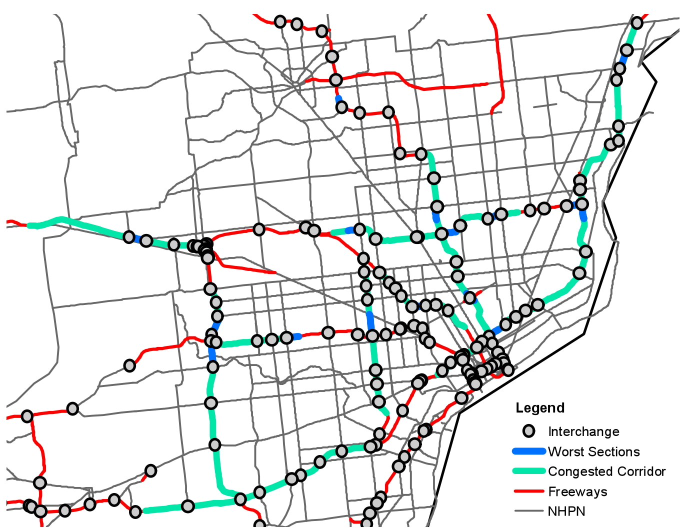
(a)


Legend
Congested Corridor
Freeways
NHPN

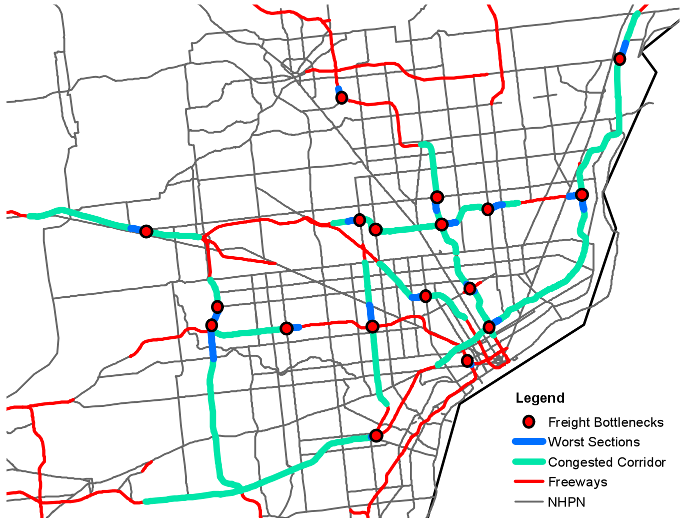
(b)


Legend
Worst Sections
Congested Corridor
Freeways
NHPN

(c)


Legend
Interchange
Worst Sections
Congested Corridor
Freeways
NHPN

(d)



(e)

Figure 19. Illustration of Interchange Bottleneck Identification

In conclusion, this method uses a progressive refining procedure to first expand selected sections with high truck unit delay and then zoom-into the possible locations from where the traffic builds. By implementing the method, unique interchange bottleneck location is identified on a corridor. In addition, as the intermediate output of the method, the created congestion corridors provide an initial clue to investigate the congestion coverage of interchange bottlenecks.

3.5.5. Distance Threshold for Interchange Bottleneck

An important issue in the congestion corridor method developed here is how to quantitatively define the concept of "vicinity". Conceptually, the distance threshold ε used to determine whether an interchange is close enough to the worst section on the corridor is subject to the spatial extent of interchange. If the most severely congested section is within the coverage of interchange (i.e. the section is a part of the frontage road/ramp/distributor-collector road of the interchange), the interchange is considered to have a dominating impact to traffic movements and the bottleneck is characterized as interchange bottleneck. However, the land area covered by interchanges may vary considerably depending on the different interchange configurations. The distance from the center location of an interchange, represented by a point on HPMS network, to its farthest end of ramp ranges from hundreds of feet to half a mile and it might be even longer for some extremely complicated interchanges. The difference in extents of interchanges brings up the first challenge in deciding the search length.

Another major challenge comes from the fact that the most congested location caused by interchange may not be within the extent of interchange. For example, a diamond interchange with poor off ramp design builds traffic queue on sections ahead of the ramp location as vehicles experience difficulties in exiting the freeway. In this sense, the most severe congestion might happen out of the land use covered by an interchange.

Realizing these challenges, the selection of ε should serve to reflect the limit by which a traffic queue could build up from a true interchange bottleneck. In order to establish a reasonable value for ε, this study first conduct a sensitivity analysis of how the total delay estimated for an interchange varies as ε increases from 0.5 to 3 miles. Here, the total delay at an interchange is calculated as the vehicle-hours of delay summed across all sections within a given distance threshold on all approaches. The calculation is based on Freight Analysis FAF 2.2 database, which provides AADT, AADTT, and HCM-based link delay on segments through the national highways. This database is selected instead of the original HPMS database because the detailed capacity and link delay measure are available on both freeways and arterials, where the HPMS database only allows one to estimate such measures in extrapolated freeways and sampled arterials. However, the fact that traffic data in FAF are developed from HPMS database assures the consistency when applying the sensitivity analysis result to interchange bottleneck identification method. All freeway interchanges within our study region are included in this sensitivity analysis.

Figure 20 shows how the increase in total interchange delay and the increase in total vehicle miles traveled (VMT) vary as a function of ε, the distance threshold. The graphs reveal that, as ε increases from 0.5 to 1 mile, there is a clear dive in the additional interchange delay that could be accumulated from the additional sections. This is not because there are fewer vehicles traveling on the outer ring of the interchange (as reflected by the consistent VMT trend), but because less and less delay is experienced on the sections as the distance threshold increases to 1 mile. Beyond the value of 1 mile, the trend becomes quite flat for both graphs. Based on these observations, we choose ε = 1 mile as the distance threshold for assessing the presence and location of interchange bottlenecks.

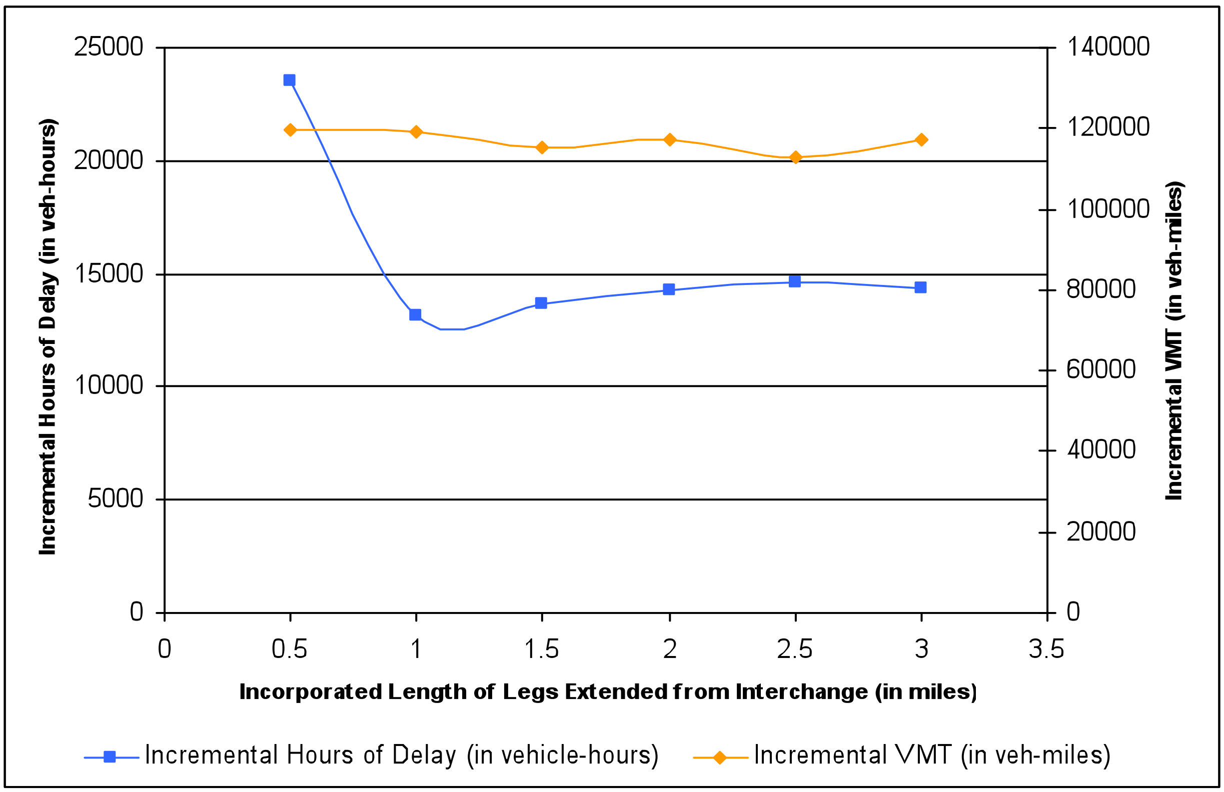


Figure 20. The change in traffic characteristics at varying distances from interchanges

3.5.6. Limitations and Issues

By taking advantages of the sampled structure of HPMS database, the method starts from extrapolating information on sampled section to universe sections to make best use of the data. The method is built on a previous study completed by Cambridge Systematics, Inc. and improves it to match the purpose of this study. Particularly, the method incorporated several features including the use of truck unit delay to scan candidate freight bottlenecks and prioritize identification results, exploration of constraints at bottleneck locations, and development of a congestion corridor growing approach to account for system impact of interchange bottlenecks. These features provide another dimension to examine freight bottleneck issues and therefore complete the related studies.

Although the present study utilizes the HPMS database and develops a method to arrive at best estimates of bottleneck locations and severities with the data available, the methodology is subject to a number of limitations, mostly associated with the nature of the HPMS data:

- As mentioned earlier, the HPMS database has a section-based structure, in which each record represents a two-way link on the national highway network. Since data are available only for these linear structures that vary greatly in length, it is impossible to pinpoint the exact location of bottlenecks using the data. Rather, one can only use the data to identify their general locality at a regional level.
- Because at-grade intersection traffic control information (i.e. number of yield, stop sign and signals) and highway geometry information (i.e. curves and grades) are available only in the HPMS Sample dataset, signalized intersection and steep grade conditions can be assessed only for sampled roadway sections. The limited number of roadway sections covered by the HPMS Sample database means that a significant portion of these two types of bottlenecks would be missed from the final results.
- Our interchange bottleneck assessment is limited to identifying the most lastly interchange location that may have triggered the delays experienced on the corresponding corridor. We are unable to pin point the exact cause of the bottleneck, which could be anything from poor ramp entering/exiting design to insufficient weaving/merging length. In order to make further diagnosis, additional information about the physical design of the interchanges and micro-level analysis of the traffic behavior around the interchanges will be needed.

3.6. Results

After applying the proposed bottleneck analysis method to the 2006 HPMS data for the ten states in the Mississippi Valley region, a master list of regional freight bottlenecks with all constraints checked for each bottleneck is produced. After obtaining the results, the truck unit delay measure is scaled by timing 365 and dividing by 1,000 to reflect annual hours of delay for trucks on a per-mile basis.

3.6.1. Summary of Results

A total number of 1,107 locations are identified throughout the region. Table 5 shows the breakdown by bottleneck types. The bottlenecks identified on freeways are mainly constrained by geometry design of interchange and drops in number of lanes between neighboring sections. Most of the bottlenecks on other principle arterials are characterized as signalized intersection bottlenecks.

Table 5. Number of freight bottlenecks identified from 2006 HPMS data for the Mississippi Valley region

Bottleneck Type	On Freeways	On Other Principle Arterials	Total
Interchange	246	0	246
Signalized Intersection	3	726	729
Lane Drop	283	192	475

Steep Grade	4	0	4

The freight bottlenecks are further prioritized by the truck unit delay associated with the existing conditions. Figure 21depicts the distribution of truck unit delay across all bottlenecks identified and specifies the range of value for each type of constraints. The interchange bottleneck is associated with the highest truck unit delay, followed by the lane drop constraint. The steep grade bottlenecks are only associated with a marginal truck unit delay because such sections are usually located in rural areas in the study region where general traffic demand is not intense and congestion is not as severe as in urban areas. However, the great length of sections with steep grade tends to aggravate this issue and might warrant the concerns when the travel demand increases. A list of top 100 freight bottlenecks with constraints identified is presented in Appendix B.

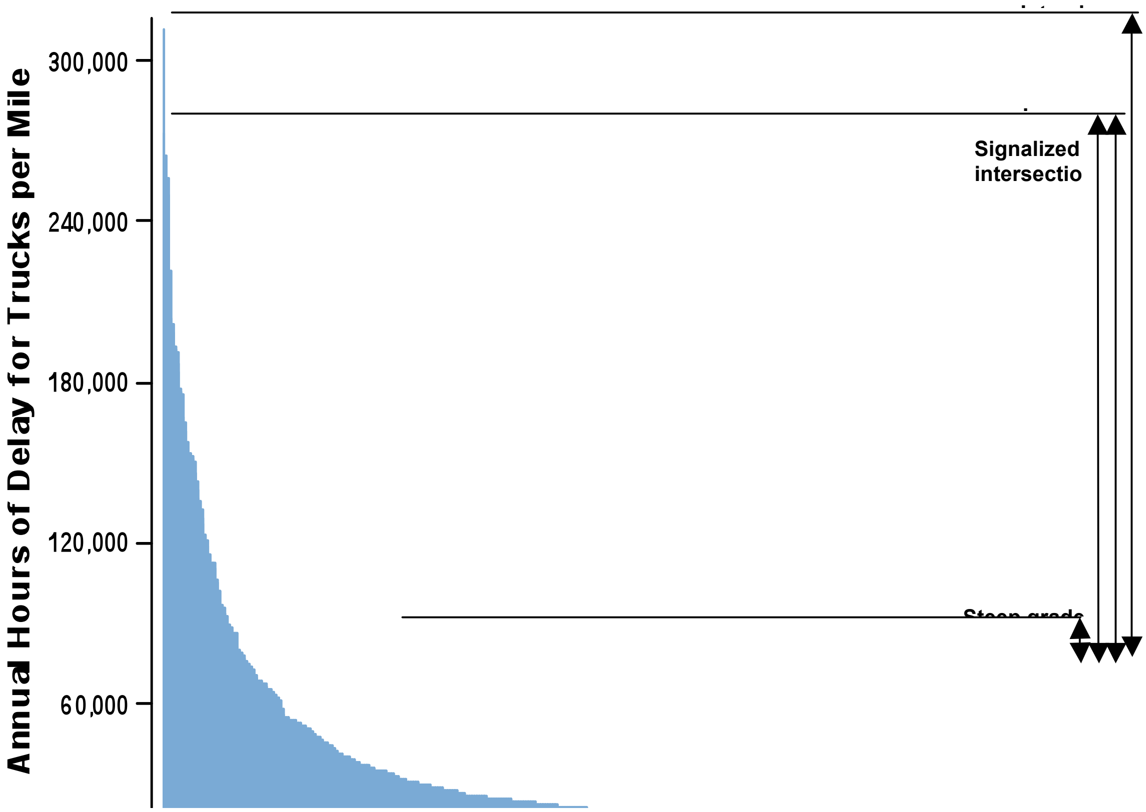


Figure 21. Distribution of Truck Unit Delay across All Types of Bottlenecks

3.6.2. Interchange Bottlenecks

Figure 22 shows the locations of interchange bottlenecks identified in ten states with the count of bottlenecks in each state. Because the interchange bottlenecks are identified from HPMS Universe database (as opposed to the Sample database), the analysis result represents a relatively complete list of bottlenecks of interchange constraints within the region, subject to the coverage and quality of the HPMS data. Most of the interchange bottlenecks are located on urban freeways accessing to major intermodal freight terminals including Chicago, Minneapolis, and Detroit, etc. These urban freeways usually serve intense freight movement activities and daily travels of the public as well. It is necessary to collaborate with various freight transportation sectors for addressing bottleneck issues.

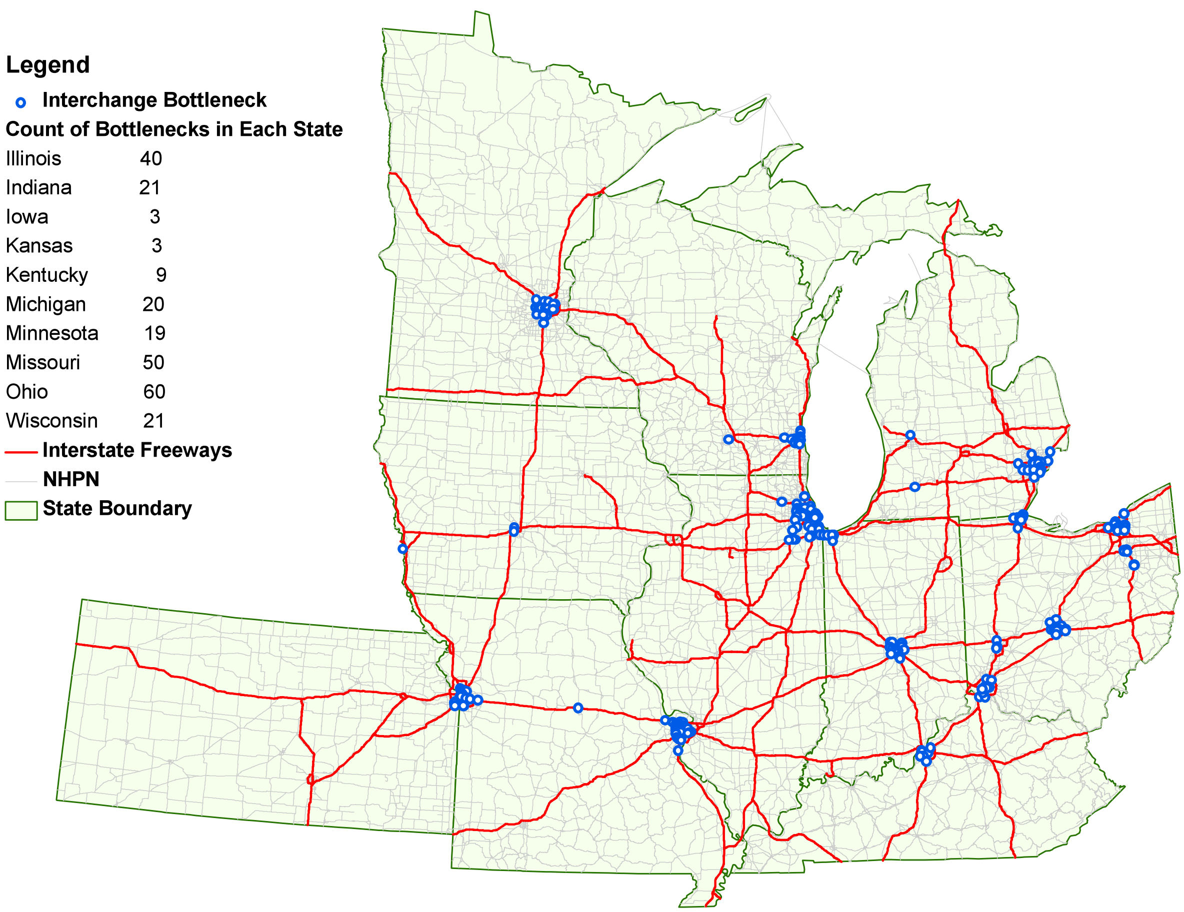


Figure 22. Interchange Bottlenecks Identified from HPMS Data

Figure 23 shows the distribution of truck unit delay for all interchange bottlenecks. Each individual bottleneck is represented on the horizontal axis by an identification number sorted in descending order of truck unit delay, which is measured on the vertical axis. This truck unit delay is measured on the most severely congested section as the interchange bottleneck is developed from it. Among the 246 interchange bottlenecks identified, 60 cause more than 200,000 hours of truck unit delay. By comparison, only a few of all the other types of bottlenecks cause more than 200,000 hours of truck unit delay. The interchange bottleneck is a dominating type of bottlenecks—not only building longer traffic queues, but also leading to severer congestion. It should be noted, however, that many of the top-ranked interchange bottlenecks identified in our analysis, which is based on 2006 data, have subsequently been addressed.

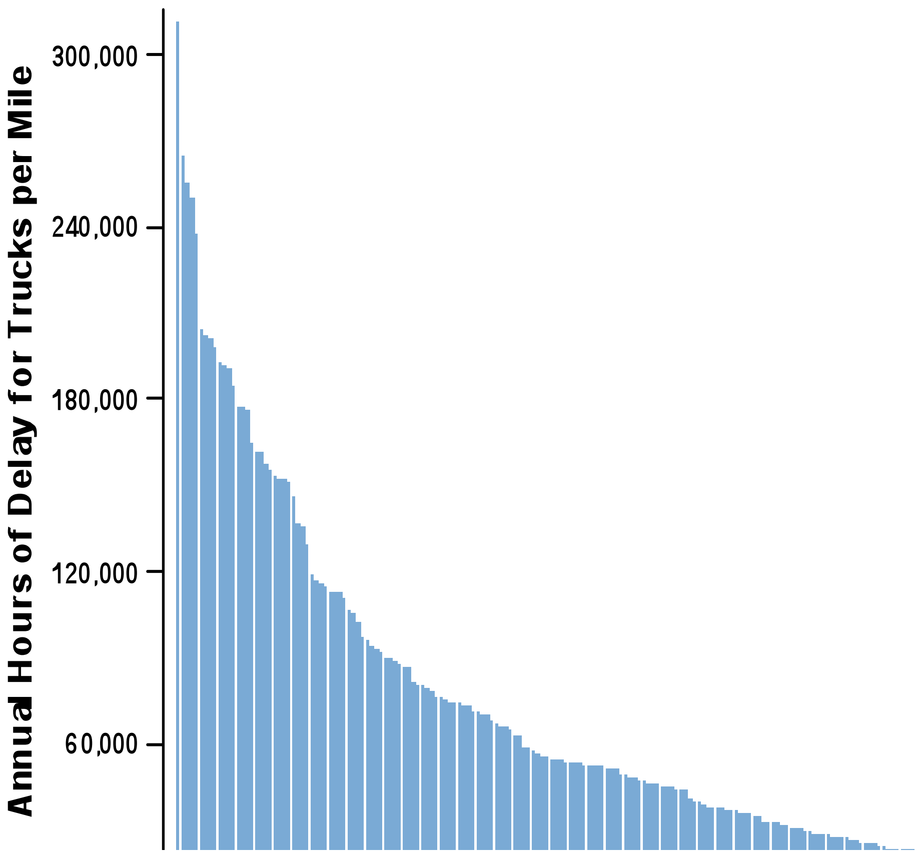


Figure 23. Distribution of Truck Unit Delay at Interchange Bottlenecks

3.6.3. Signalized Intersection Bottlenecks

Figure 24 shows the locations of signalized intersection bottlenecks identified in ten states with the count of bottlenecks in each state. Nearly all signalized intersection bottlenecks are on other principal arterials. The absence of signalized intersection bottlenecks on freeways is because freeways are designed to serve continuous through movement with less interruption by traffic control devices. It should be noted that because the bottlenecks are identified from HPMS Sample database, its distribution among states largely depends on the sample rates of Universe sections in each state. A significant number of arterials sections sampled in the Kentucky and Wisconsin (i.e. 755 and 1066, respectively) contributes to the larger presence of signalized intersection bottlenecks in these two states.

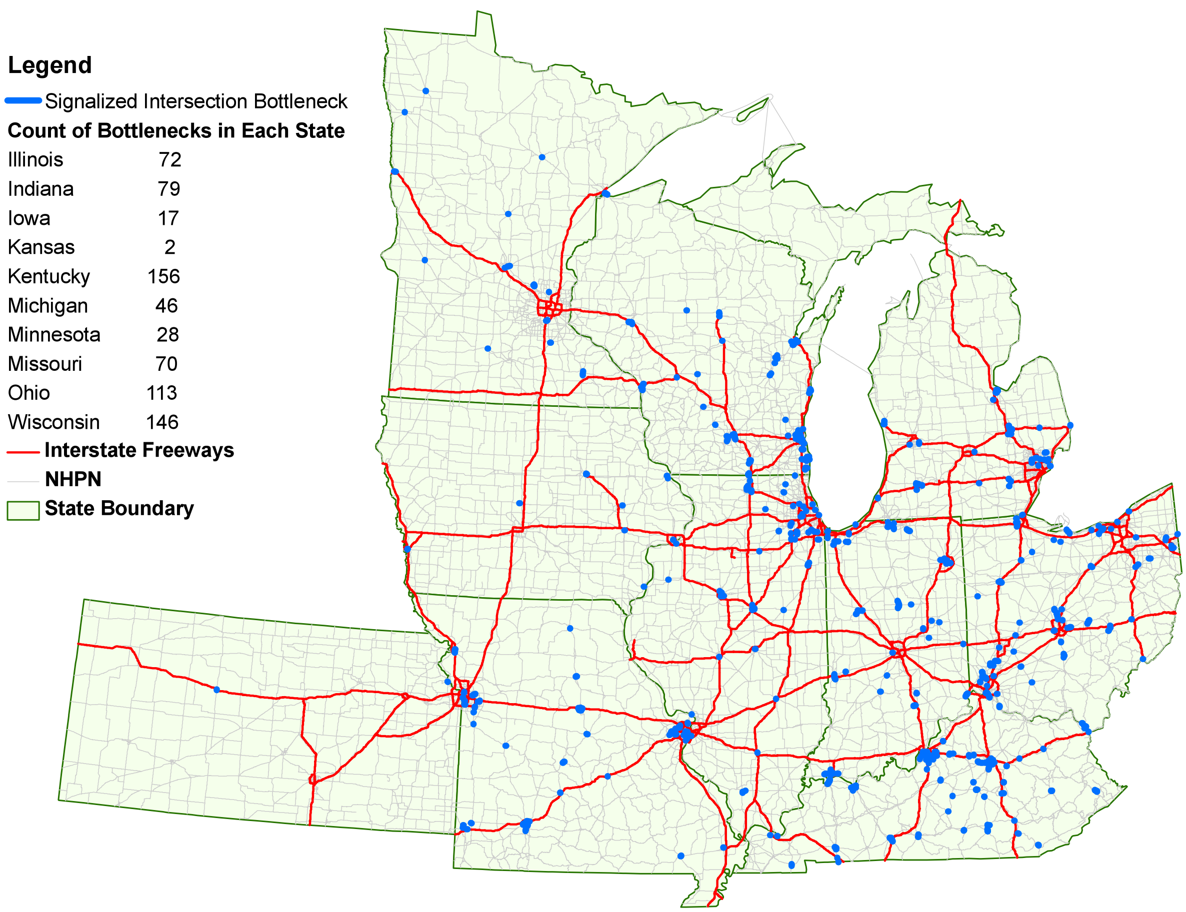


Figure 24. Signalized Intersection Bottlenecks Identified from HPMS Data

Figure 25 shows the distribution of truck unit delay for all signalized intersection bottlenecks. Each individual bottleneck is represented on the horizontal axis by an identification number sorted in descending order of truck unit delay, which is measured on the vertical axis. The majority of signalized intersection bottlenecks have a truck unit delay less than 100,000 hours. However, the existence of lane drop constraint on some of the signalized sections aggravates the traffic congestion and leads to high truck unit delays associated with the sections.

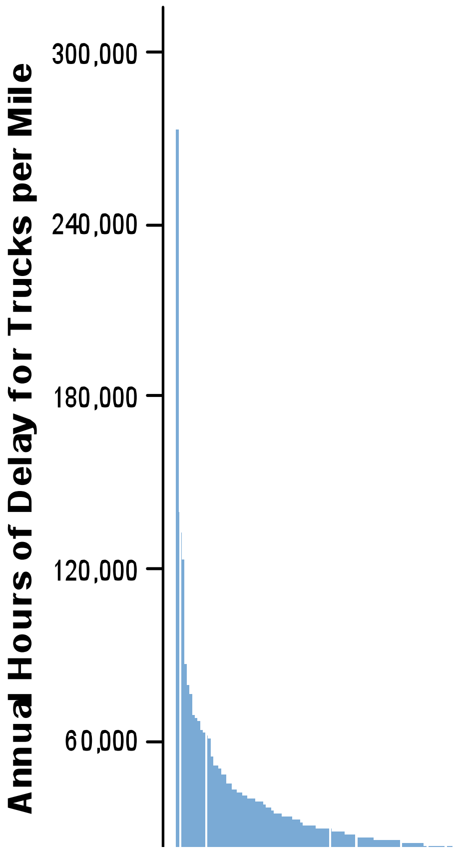


Figure 25. Distribution of Truck Unit Delay at Signalized Intersection Bottlenecks

3.6.4. Lane Drop Bottlenecks

Figure 26 shows the locations of lane drop bottlenecks identified in ten states with the count of bottlenecks in each state. This type of bottleneck identifies the situation where vehicles have difficulties in merging/diverging at the location with changed number of lanes. Among the 695 bottlenecks in the region, 496 are located on freeways due to the fact that they carry a great amount of traffic volumes. And most of those bottlenecks are on the congested corridor grown for identifying interchange bottlenecks. The fact that the change of number of lanes usually happens around interchanges explains the overlapping between lane drop bottleneck location and congested corridor.

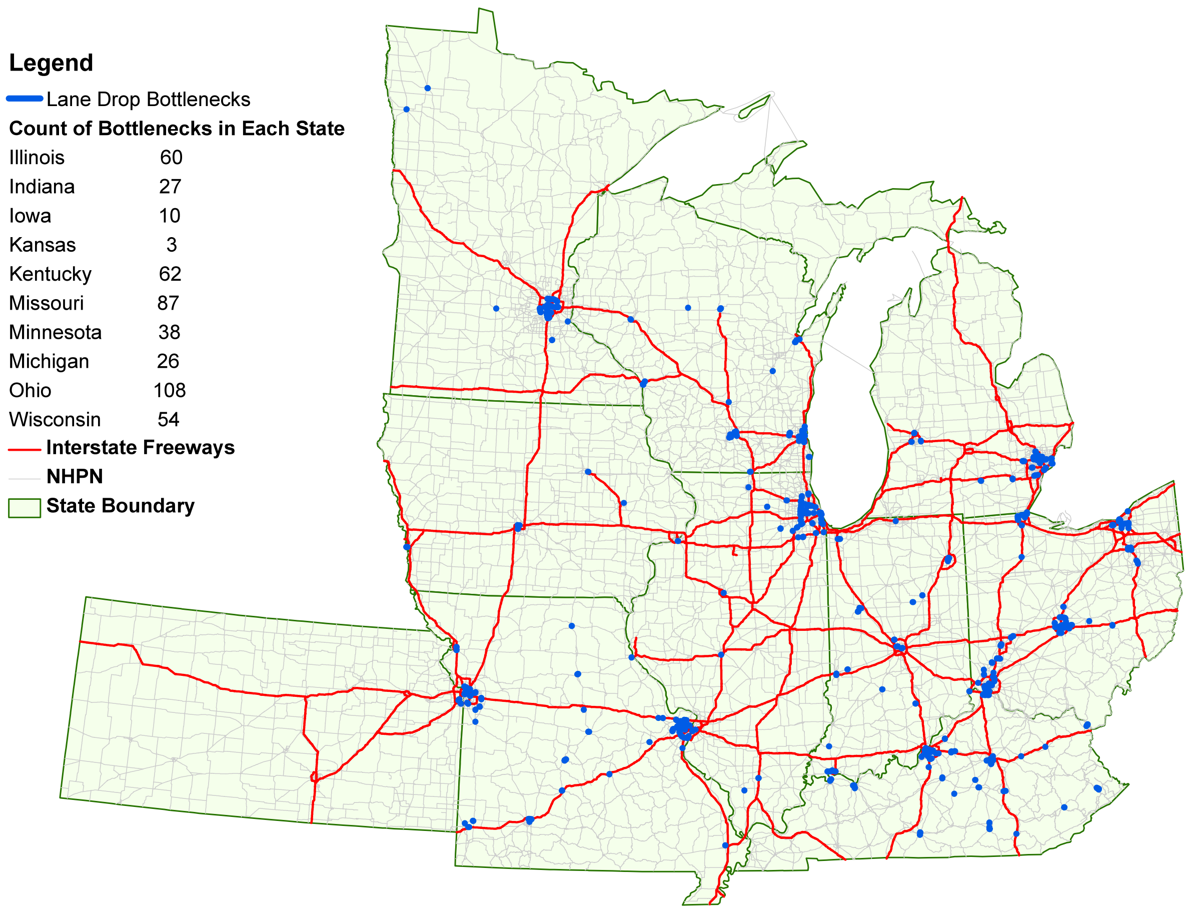


Figure 26. Lane Drop Bottlenecks Identified from HPMS Data

Figure 27 shows the distribution of truck unit delay for all lane drop bottlenecks. Each individual bottleneck is represented on the horizontal axis by an identification number sorted in descending order of truck unit delay, which is measured on the vertical axis. Among the 695 interchange bottlenecks identified, 93 cause more than 200,000 hours of truck unit delay. The frequent presence of high truck unit delay makes the lane drop the second type of bottlenecks in terms of severity.

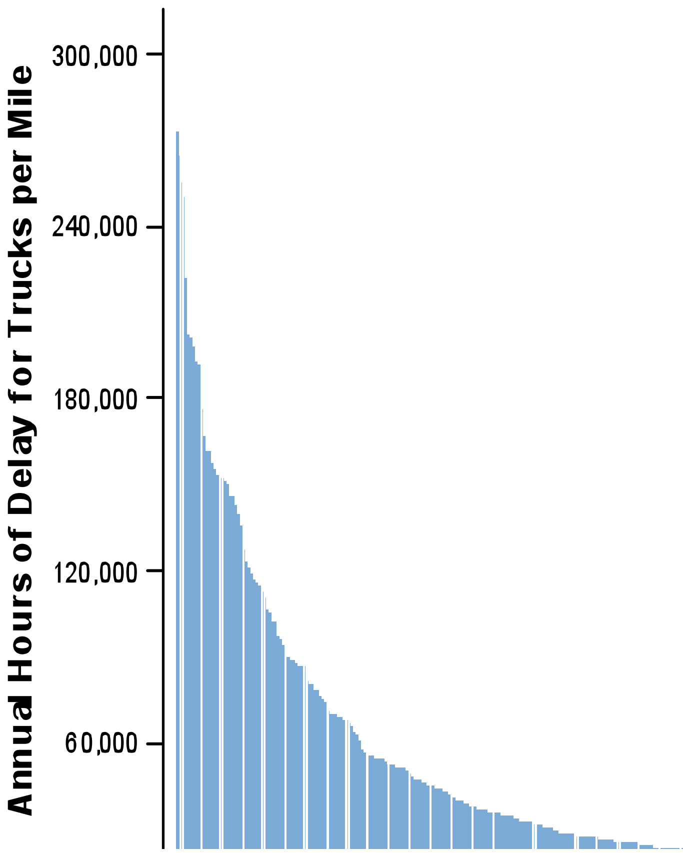


Figure 27. Distribution of Truck Unit Delay at Lane Drop Bottlenecks

3.6.5. Steep Grade Bottlenecks

Figure 28 shows the locations of steep grade bottlenecks identified in ten states with the count of bottlenecks in each state. Only four steep grade bottlenecks are located on the interstate freeways. Most steep grade sections are in rural areas with relatively lower traffic volume. And this congestion situation is not severe as that in urban areas. Therefore the truck unit delay estimated on these sections is significantly lower than that of other types of constraints. However, the continuous steep grades with sufficient length usually aggravate the grade effect, leading to a considerable drop in speed for trucks.

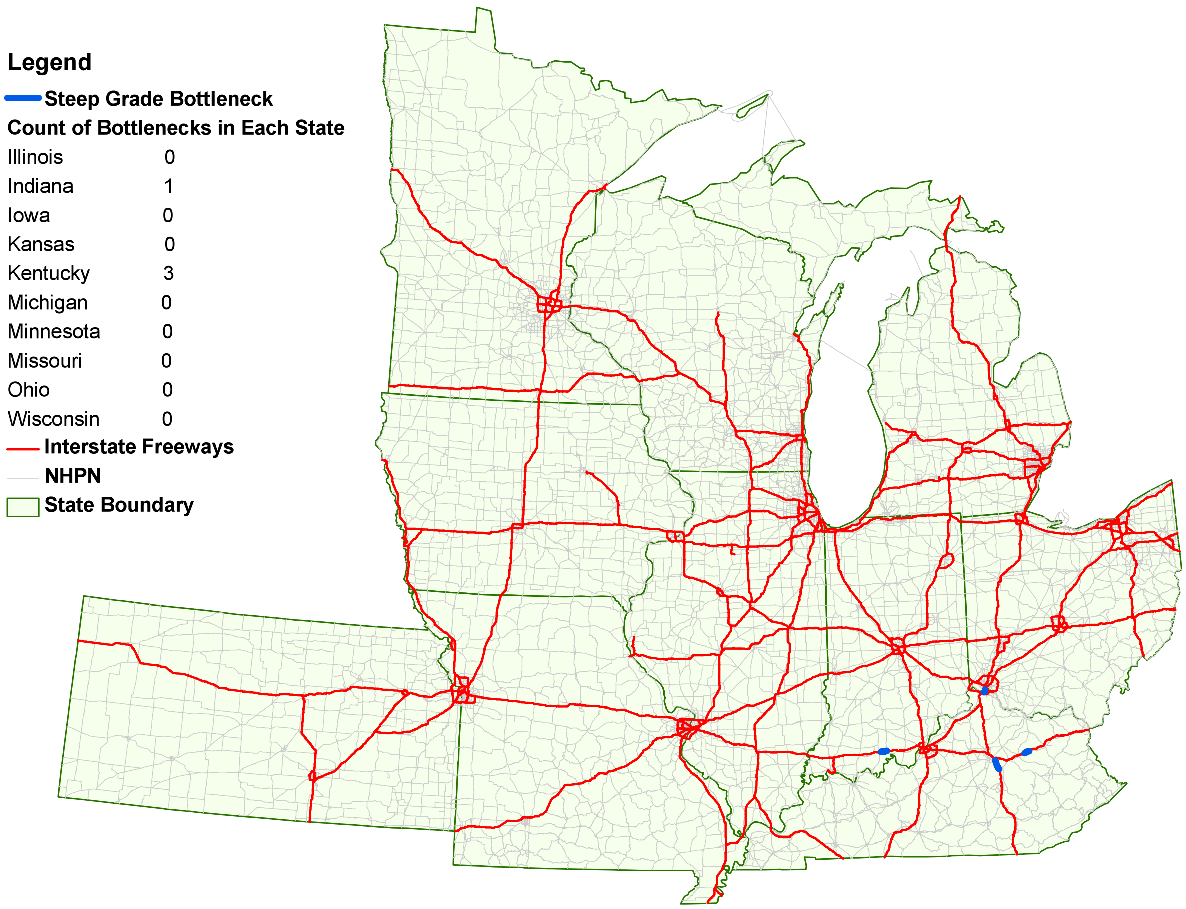


Figure 28. Steep Grade Bottlenecks Identified from HPMS Data

Figure 29 shows the distribution of truck unit delay for all steep grade bottlenecks. Each individual bottleneck is represented on the horizontal axis by an identification number sorted in descending order of truck unit delay, which is measured on the vertical axis. The lower volume of both passenger cars and trucks results in less truck unit delay for steep grade bottlenecks as compared with other types of bottlenecks.

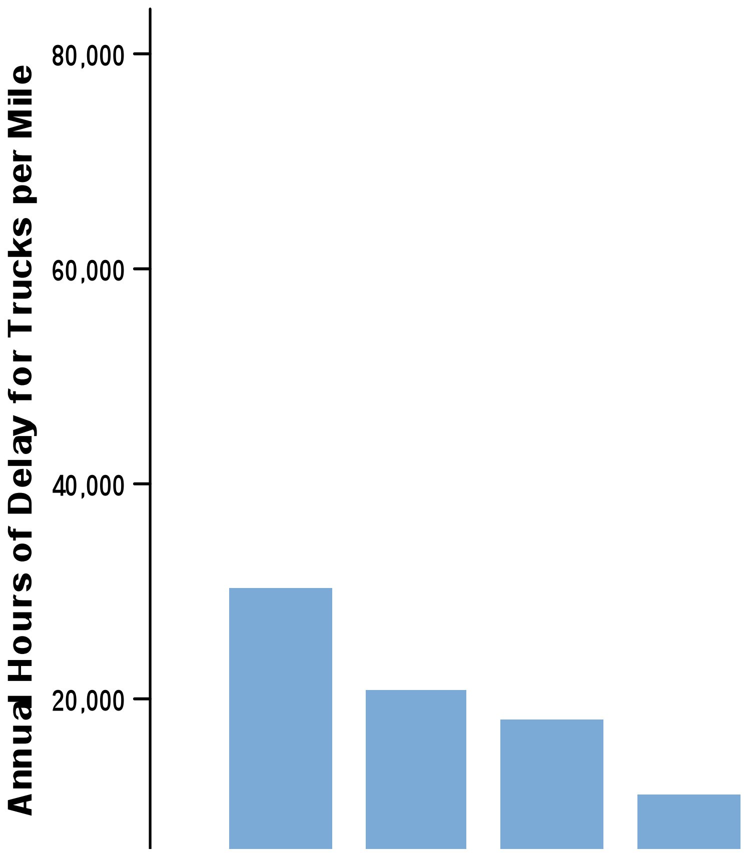


Figure 29. Distribution of Truck Unit Delay at Steep Grade Bottlenecks

3.7. Validation

As a way to check the validity of the proposed methodology and to verify the accuracy of analysis results for the Mississippi Valley region, the list of bottlenecks are compared against bottlenecks identified from three different sources, including previous study results, freight carriers' nominations, and knowledge from state transportation engineers and planners. It should be noted that the comparisons are primarily qualitative. Section 3.6.1 compares the identification results against previous study results. Section 3.6.2 compares the identification results against bottlenecks nominated by roadway users. Section 3.6.3 verifies the identification results according to the knowledge from local experts.

3.7.1. Comparison Against Previous Study

A potential source appropriate for the comparison is the FHWA freight bottleneck study (Cambridge Systematics, 2005) because we follow the typology defined in this study. However, the unavailability of its complete analysis results prevents a systematic comparison between two studies. As one of its succeeding studies, Cambridge Systematics, Inc. (2008) uses the HPMS 2006 database to analyze freight bottlenecks on a national level for FHWA, in which the previous typology of bottlenecks is inherited except that the lane drop bottleneck type is incorporated as interchange capacity bottlenecks. Because of the same database employed and availability of comprehensive lists of top national freight bottlenecks, this 2008 study is selected as the major source to verify the bottleneck analysis results.

3.7.1.1. Interchange Bottleneck

The previous study reveals 43 interchange bottlenecks in Mississippi Valley region. Thirty-six of those are among the interchange bottlenecks identified in our results and the remaining seven fall on the congested corridors constructed with different interchanges identified as bottleneck locations. The general agreement on the spatial distribution suggests that the proposed congestion corridor growing method is capable of capturing the congestion area for freight movement and reasonably estimate the locations of interchange bottlenecks of prevalent interest.

The agreement of locations identified for interchange bottlenecks also facilitates a quantitative comparison of prioritization results between two studies. Specifically, a rank correlation analysis is used to examine the similarity in rank ordering among interchange bottlenecks identified in the two studies. By re-ranking the 43 interchange bottlenecks according to truck unit delay value on worst sections identified in this study, another set of order is generated. The rank correlation analysis compares the orders of each bottleneck in two sets and reveals a correlation coefficient value of 0.66 (statistically significant at 0.01 level). This suggests that, due to the many differences between the two studies in how interchange bottlenecks are identified, the results are similar but with some differences in how bottlenecks are ranked.

3.7.1.2. Signalized Intersection Bottleneck

For the signalized intersection bottlenecks, 39 of the 73 bottlenecks identified by Cambridge Systematics, Inc. for the study region show up in our final ranked list. The discrepancy in results can be attributed to the different scanning criteria used. As this study use truck unit delay instead of the volume to capacity ratio in peak hour to select freight bottleneck locations, the proposed method puts more emphasis on truck bottlenecks as opposed to general traffic bottlenecks.

3.7.1.3. Steep Grade Bottleneck

For steep grade bottlenecks, our results coincide with previous results at 4 out of 127 locations. This is again due to the different selection criteria used in the two studies. In the Cambridge Systematics, Inc. study, the total truck delay on a section is used to represent the severity of bottleneck condition. In the present study, however, we opt for truck unit delay, which by design is normalized by section length. This is because this study wants to avoid the analysis results being confounded by the non-standardized lengths across HPMS sections.

3.7.2. Comparison Against User Nominated

The survey of motor carrier nominated bottlenecks, which is described in Section 2.3.1, provides a good basis to understand how truck drivers perceive bottleneck issues. Bottlenecks pinpointed by these roadway users directly reflect the locations where trucks experience significant delay. Therefore these nominated bottlenecks are considerable as a desired source to verify this freight bottleneck identification results.

The most common constraints identified by respondents are inadequate capacity, lane drop, poor ramp design, and insufficient merging lanes. These constraints are considered to reflect deficiency in geometry design of interchanges and therefore bottlenecks with such constraints specified are characterized as nominated interchange bottlenecks.

Because of the survey method, the spatial distribution of samples collected shows a clear localization trend. Eighty-one bottleneck locations are specified in Illinois and twenty bottleneck locations are found in Wisconsin. States other than these two have only a few bottlenecks identified by commercial vehicle drivers.

Based on the fact that most nominated bottlenecks are located within Illinois and the common presence of bottlenecks with interchange constraints, the comparison is accomplished for this type of bottlenecks in Illinois. Realizing the fact that the bottleneck location pinpointed on the map by users has a spatial deviation from the actual interchange location, a 1-mile buffer is created for each user nominated interchange bottleneck to accommodate it.

The spatial distribution of the two sets of findings is shown in Figure 30. Out of the 45 locations nominated for the state of Illinois as interchange bottlenecks, 30 are found in our final list of truck interchange bottlenecks. The discrepancy is likely attributable to the fact that the survey respondents are from all over the region and may have very different perception of what qualifies as bottleneck condition. In fact, 26 percent of the respondents report that their typical goods delivery tasks are within state. Therefore, the bottlenecks nominated by them are more likely to be a local concern rather than a regional interest.

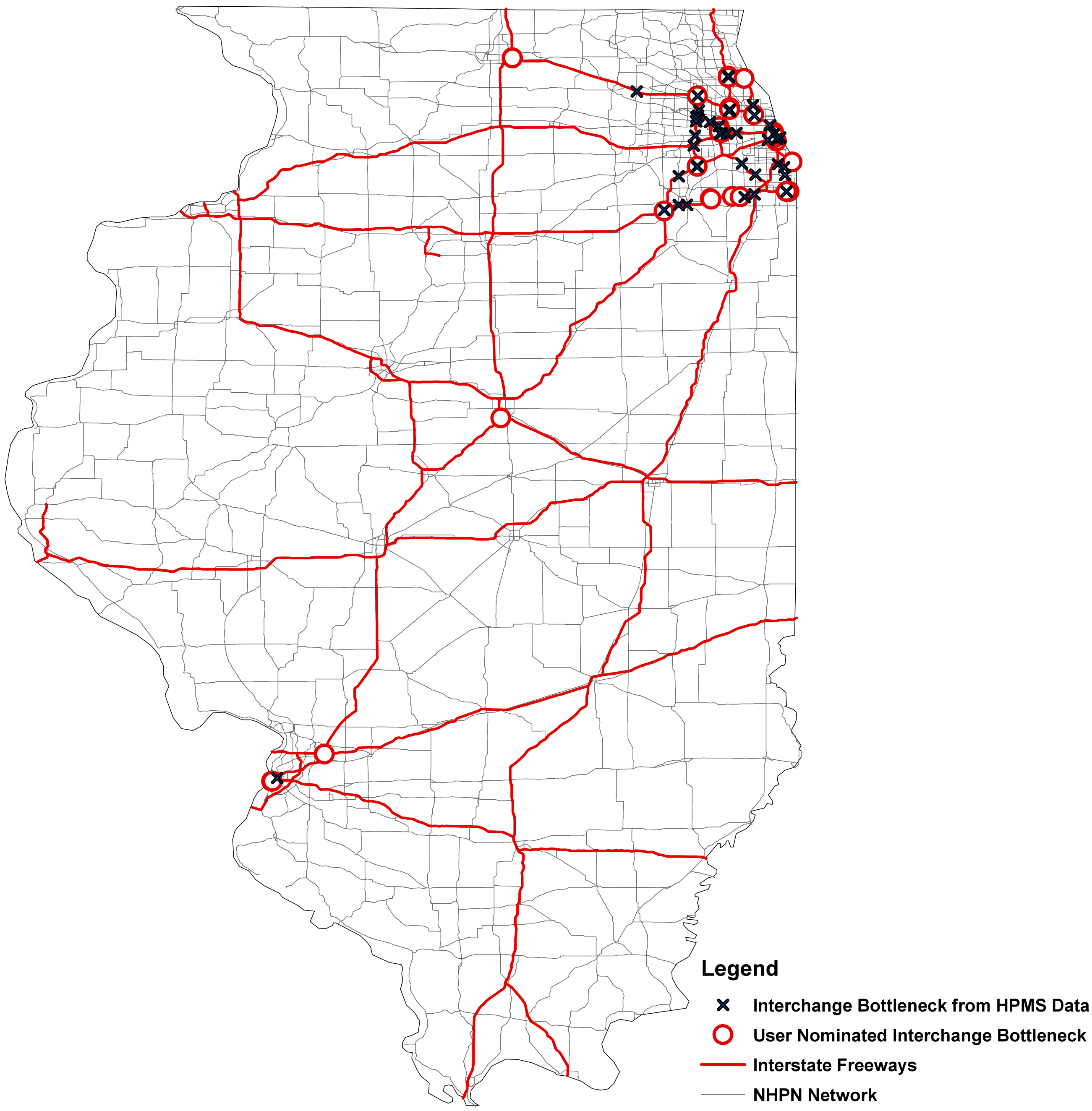


Figure 30. Comparison between bottlenecks nominated by freight carriers for Illinois and the bottlenecks identified using the proposed HPMS-based method

A zoom in the map comparing the interchange bottlenecks nominated by freight carriers and those from data analysis in Chicago area is shown in Figure 31. In this area, all the interchange bottlenecks that connect two interstate freeways are reasonably located. This map reveals that in the severely congested urban area, the proposed HPMS-based bottleneck analysis method is able to capture the major locations constricting the truck traffic.

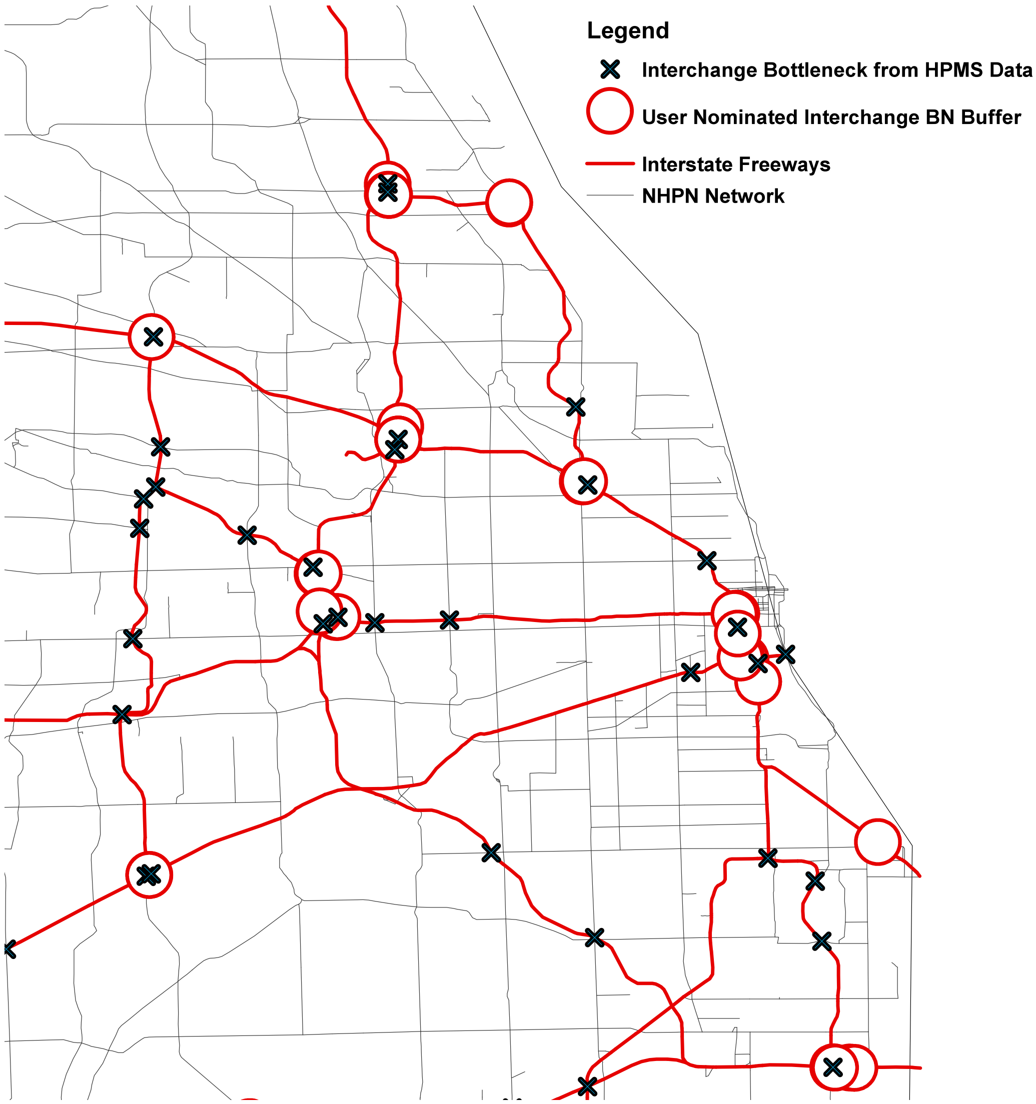


Figure 31. Comparison between bottlenecks nominated by freight carriers for Illinois and the bottlenecks identified using the proposed HPMS-based method for Chicago area

3.7.3. Comparison Against Local Knowledge

As a part of our collaborative effort with the MVFC, transportation planners and engineers from the member state DOTs have been asked to help verify and comment on the bottleneck analysis results. The feedback is found to vary from state to state. For example, the responses from the Indiana DOT indicate that the analysis results cover the majority of the bottlenecks that they are aware of in their state. However, the local experts in Kentucky point out that the methodology developed in this study fails to identify certain bottleneck locations that reside on their highway network. The further investigation reveals that the discrepancy between our results and Kentucky's expert knowledge is primarily due to two factors. First, the limited coverage of sampled HPMS sections doesn't allow examining all sections for all types of bottlenecks in Kentucky. Second, the various threshold values selected for this analysis differ from the benchmarks that the local experts would use in their own assessment. This reflects a difference in perspective and sensitivity to traffic delay due to the range of traffic conditions experienced in different areas.

The discrepancy found also suggests the value of local knowledge. Bottleneck analysis relying on data is always limited by the data coverage, attribute availability, method adopted, and various assumptions involved. Taking local knowledge as a starting point and/or a source for verification would supplement the analysis procedure with empirical recognition. And this in-depth understanding of bottleneck conditions helps refining the characterization and therefore proposing effective alleviation strategies.

4. Port Bottleneck Analysis

The waterborne freight transportation network in the Mississippi Valley consists of the Great Lakes and Great Lakes port system, along with the locks and dams associated with four major inland waterways (the Mississippi, Missouri, Ohio, and Illinois Rivers) and their associated navigable tributaries. According to a number of stakeholders, the waterborne freight system throughout the region suffers mainly from either climate-related constraints or delays associated with intermodal transfer facilities. Winter conditions close the inland waterway system to freight traffic for a substantial portion of the year, forcing waterborne freight onto rail lines or highways while the waterways are frozen.

4.1. Port Conditions

Figure 32 and Table 6 describe the freight tonnage processed in 2006 throughout the ten-state region's principal ports (as determined by the US Army Corps of Engineers). In terms of total tonnage, Michigan and Ohio process the bulk of all regional port freight, at 50 percent combined.

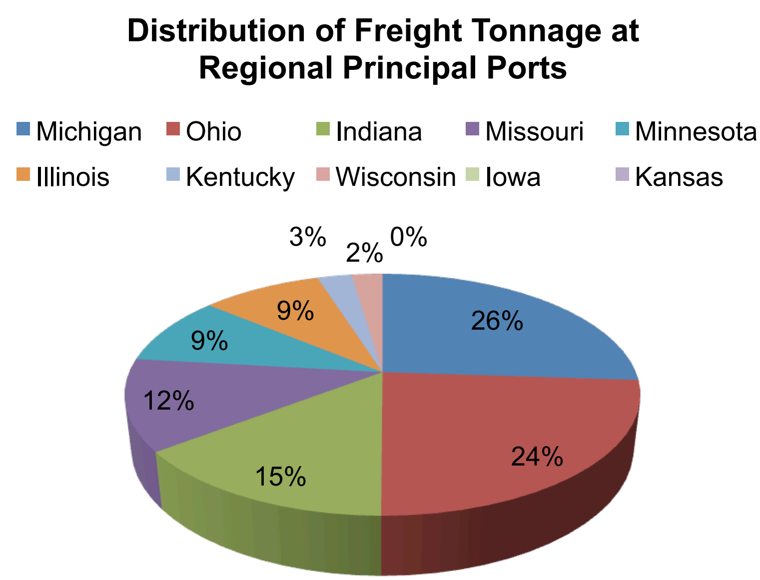


Figure 32. Distribution of Freight Tonnage at Regional Principle Ports

Table 6. Principal Mississippi Valley Regional Ports- 2006 tonnage

Port Name	State	Total	Domestic	Foreign	Imported	Exported
St. Louis	MO	31,317,323	31,317,323	0	0	0
Chicago	IL	25,706,302	22,541,183	3,165,119	1,547,949	1,617,170
Detroit	MI	17,352,767	12,974,601	4,378,166	3,788,289	589,877
Indiana Harbor	IN	16,163,799	15,659,530	504,269	481,363	22,906
Cleveland	OH	15,186,819	11,467,131	3,719,688	3,598,998	120,690
Two Harbors	MN	13,419,526	13,361,941	57,585	0	57,585
Cincinnati	OH	13,334,351	13,334,351	0	0	0
Toledo	OH	11,161,545	2,293,546	8,867,999	4,946,436	3,921,563
Gary	IN	9,111,679	8,428,557	683,122	604,310	78,812
Presque Isle	MI	9,073,545	6,937,525	2,136,020	0	2,136,020
Burns Waterway Hbr.	IN	8,953,865	6,586,578	2,367,287	2,115,841	251,446
Louisville	KY	7,373,428	7,373,428	0	0	0
Conneaut	OH	7,368,475	4,604,612	2,763,863	137,349	2,626,514
Stoneport	MI	6,865,321	6,753,361	111,960	21,466	90,494
Ashtabula	OH	6,822,084	2,306,562	4,515,522	464,667	4,050,855
Calcite	MI	6,427,868	5,455,817	972,051	40,957	931,094
Mount Vernon	IN	5,738,656	5,738,656	0	0	0
Escanaba	MI	5,689,337	5,672,611	16,726	16,726	0
Port Inland	MI	5,522,893	4,790,705	732,188	16,137	716,051
Silver Bay	MN	5,188,175	5,188,175	0	0	0
St. Clair	MI	4,901,346	4,901,346	0	0	0
St. Paul	MN	4,656,035	4,656,035	0	0	0
Marine City	MI	4,018,613	3,919,566	99,047	99,047	0
Milwaukee	WI	4,007,146	2,588,516	1,418,630	921,629	497,001
Sandusky	OH	3,789,693	1,687,185	2,102,508	0	2,102,508

Marblehead	OH	3,757,580	2,978,545	779,035	75,890	703,145
Lorain	OH	3,617,050	2,915,041	702,009	613,529	88,480
Kansas City	MO	3,580,000	3,580,000	0	0	0
Alpena	MI	3,329,565	2,985,204	344,361	181,557	162,804
Green Bay	WI	2,617,768	2,130,828	486,940	486,940	0
Port Dolomite	MI	2,582,211	1,983,158	599,053	0	599,053
Fairport Harbor	OH	2,411,464	1,604,584	806,880	441,028	365,852
Muskegon	MI	2,229,817	2,003,471	226,346	226,346	0
Taconite	MN	2,088,999	2,088,999	0	0	0
Buffington	IN	1,489,134	972,897	516,237	483,177	33,060
Charlevoix	MI	1,420,314	1,322,954	97,360	97,360	0
Monroe	MI	1,379,042	1,336,469	42,573	42,573	0
Marysville	MI	1,316,253	786,339	529,914	529,914	0
Drummond Island	MI	1,237,590	1,000,156	237,434	0	237,434
Kelleys Island	OH	1,116,021	1,116,021	0	0	0
Minneapolis	MN	1,092,230	1,092,230	0	0	0
Grand Haven	MI	987,803	750,018	237,785	234,373	3,412

This list indicates the volume of freight processed throughout the port system; however, these volumes do not necessarily equate with bottleneck conditions. While physical attributes of the ports (such as depth alongside operational elements, and berthing distance) are available through data provided by the Corps of Engineers, the relationship between these characteristics and any resulting freight delays could not be established within the limits of the data. Some state-agency freight planners suggested that a dredging backlog continues to be a problem throughout the Great Lakes port system, but that while this affects the available loading depth of vessels, it has not resulted in systematic bottleneck conditions.

4.2. Lock conditions

Insufficient chamber length can inhibit the efficient movement of freight through lock locations throughout the inland waterway system. Frequently, towboats are capable of handling more barges (15) than the locks they pass through, requiring the shipment to be broken up into smaller sections at each lock. Long lock chambers (those which are 1200 feet or greater in length) can allow the passage of such shipments in one lockage, while shorter chambers (typically 600 feet long) cannot. However, the length of lock chambers is not necessarily indicative of bottleneck conditions. Many of the facilities with longer chambers routinely experience long average delay times, as shown below in Table 7, and some feature additional main or auxiliary chambers capable of processing heavier traffic flows.

The Corps of Engineers reports the delay experienced by vessels at lock locations along all navigable waters throughout the study area, as shown in Figure 7. The lock locations experiencing average tow delays of greater than one hour are listed below, in Table 7. Figures are taken from calendar year 2006 for consistency with highway data sources, although it should be noted that this represents a snapshot that may have changed in the interim, due in part to both economic shifts and a number of construction projects. Lock 52 on the Ohio River, though perhaps an extreme example, demonstrates the changing nature of these delays. Tow delays increased tenfold between 2004 and 2005 (from 0.41 hrs. to 4.27 hrs, respectively), when major repairs were undertaken on both the miter gates and the hydraulic system. Average delay at this location was not as severe in 2008 as it had been in 2006, although this reduction may be heavily influenced by economic, rather than physical, factors (as discussed below). Further clouding the effect of physical constraints on delay, this lock is beside a “wicket” dam which generally allows traffic to pass without requiring the locks to raise/lower the water levels; the average delay may be driven high by the extremely long delays only experienced when low water levels necessitate the operation of the locks. Construction of the 1200-foot chambers at the Olmsted facility will replace both Locks 52 and 53 within the coming years.

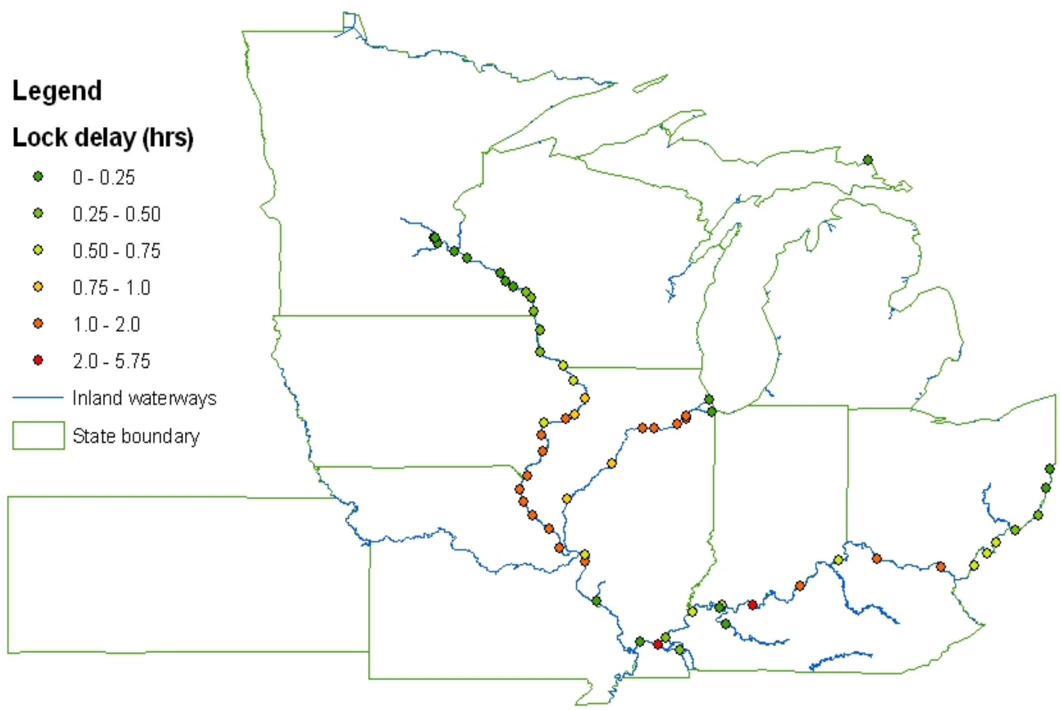


Figure 33. Lock delays throughout the inland waterway system (2006).

Interviews with state agencies indicated a potential bottleneck at the locks at Sault Ste. Marie (MI), located at the Canadian border between Lakes Superior and Huron, due to its unique capacity to process long (1000-foot) lake-bound freighters. According to these interviews this location does not suffer severe congestion at present, but because several vessels are built to match the size capacity of this passageway, it is of critical importance that their operation remains uninterrupted throughout the commercial shipping season (traditionally March 26-January 14). The Sault Locks feature two operational facilities with chambers of 1200 feet or more; the Poe and Davis locks measure 1200 feet and 1320 feet, respectively. Another is currently under construction.

Table 7. Lock Locations Experiencing Average Delays Greater than One Hour (2006)

Delay rank	Waterway	Lock Name	Total # Barges	Average Delay (hours)	Main Chamber Length	Additional Chambers
1	Ohio	Lock 52	91,344	5.68	1200	yes
2	Ohio	Cannelton	55,747	2.31	1200	yes
3	Mississippi	Lock 25	28,037	1.84	600	no
4	Illinois	Marseilles	18,601	1.75	600	no
5	Illinois	Brandon Rd	17,895	1.71	600	no
6	Ohio	Greenup	69,393	1.64	1200	yes
7	Ohio	Captain Anthony Meldahl	55,258	1.58	1200	yes
8	Illinois	Lockport	17,430	1.56	600	no
9	Mississippi	Lock 21	26,457	1.52	600	no
10	Mississippi	Lock 22	26,758	1.5	600	no
11	Mississippi	Lock 27	63,056	1.46	1200	yes
12	Mississippi	Lock 24	28,044	1.38	600	no
13	Mississippi	Lock 15	20,039	1.37	600	yes
14	Illinois	Starved Rock	19,691	1.36	600	no
15	Mississippi	Lock 20	24,788	1.22	600	no
16	Illinois	Dresden Island	19,180	1.22	600	no
17	Ohio	McAlpine	49,569	1.11	1200	yes
18	Mississippi	Lock 17	21,319	1.09	600	no
19	Mississippi	Lock 18	22,530	1.08	600	no
20	Mississippi	Lock 19	23,502	1.07	1200	no

Although chamber length and the presence of additional main or auxiliary chambers are two key characteristics used to determine the capacity of individual facilities to accommodate freight traffic, these (along with other characteristics) are not enough to establish a clear picture of systemic bottlenecks as they are defined for the purposes of this research. The primary obstacle preventing the identification of waterborne bottleneck conditions as such is the myriad of complicating factors affecting both supply and demand.

Though the capacity of individual locks may be determined through existing data, a more complete view of the waterborne freight landscape requires a comprehensive review of the demand placed on the system. Origin-destination factors and shifts in the economic landscape play a major role in the use of waterway facilities, not only because of the inflexibility of facility location and the relatively fewer numbers of facility users, but also because of the global nature of commodity markets (Train,, 2006; Wang, 2007). According to a representative with the Corps of Engineers, recent lock usage may be a poor representative of historic usage, as global economic patterns have been associated with a sharp decline in grain exports, which are one of the primary uses of the waterway system. While it is necessary to dissect this sensitivity to demand factors for the purpose of freight planning, such an exercise is beyond the scope of this research.

On the supply side, short lock chambers notwithstanding, a number of sources indicate that the greatest threat to the efficient long-term operation of the inland waterway system is the quality of waterway infrastructure. The declining condition of locks is a consistent concern throughout the region and beyond, as locks that are 50 (or even 70) years old continue to deteriorate. Funding for maintenance and repair has not kept pace with the decline in conditions, which has further complicated facility operations (IHUB, 2005-2008; Grier, 2004).

5. Freight Rail Bottlenecks

Freight rail congestion is a critical transportation issue throughout the Mississippi Valley region, which contains several of the most severely congested rail lines in the country. The Association of American Railroads' (2007) "National Rail Freight Infrastructure Capacity and Investment Study" illustrates current locations of recurring congestion, and forecasts future capacity and levels of service throughout the national rail network. After forecasting demand growth out to 2035, this analysis shows levels of service decreasing sharply throughout the ten-state region if no improvements are made to the physical conditions of the rail lines (Cambridge Systematics, Inc., 2007).

While useful in terms of qualitative and anecdotal evidence of bottleneck conditions, interviews with the Association of American Railroads and a sampling of Class I railways (Burlington Northern Santa Fe and Union Pacific) did not produce the quantitative data that would allow for a comprehensive analysis of the freight rail network throughout the region. The nature of proprietary data and the privacy concerns of private-sector freight operators is a substantial obstacle in the analysis of the freight rail network. As the rail industry is intensely competitive and largely deregulated, region-wide volume and capacity data is very difficult to obtain. Freight rail operators are hesitant to share comprehensive quantitative data that would demonstrate chronic congestion problems at particular segments of their rail network, largely because other service providers could potentially take advantage of such information. Further, the lack of volume- and capacity-related detail in publicly available data is at least in part a consequence of the deregulation of the industry. Several data sources provide the physical extent to the rail network, but very few offer comprehensive volume data, and none of the publicly available sources offer capacity data. What little volume-related data is available is presented in tonnage ranges too broad for a detailed analysis of network constraints.

As a result, interviews with private sector freight operators focused on a particular selection of bottleneck locations that the operators were able to discuss publicly. These locations have been publicly identified previously, allowing rail operators to provide information about the congested locations without risking competitive disadvantage. In an effort to shape future research on rail bottlenecks, these case studies also provide insight into the processes of bottleneck identification and alleviation from the perspective of the private sector. These locations include three in Illinois (Chicago, Joliet, and Galesburg), as well as three river crossings in Iowa (at Clinton, Burlington, and Ft. Madison).

5.1. Chicago

The chronic rail congestion problem associated with the metropolitan Chicago area is the most widely recognized and far-reaching issue facing many rail freight operators in the United States. As the freight rail hub of the nation, Chicago sees more rail traffic on a daily basis than any city in the United States[1]. Freight rail congestion in the area is further complicated by the presence of two passenger train systems: Amtrak and Metra. As a condition of the deregulation process, freight rail operators must yield right-of-way to passenger trains, and as both services have increased in volume over the years, the capacity for the rail network to accommodate both types of service has decreased.

Union Pacific (UP), like many other freight rail operators, must make way for commuter trains throughout the day, while also carrying 50 to 60 freight trains per day on their tracks. The weekday delays associated with Chicago's congestion have been known to require the entire

[1] http://www.createprogram.org/about-history.html

weekend to clear; in the meantime, UP trains are held up throughout the country, idle and waiting to pass through the nation's rail hub. As a result, UP has at times instituted curfews, preventing their trains from even entering the metropolitan area when passenger rail traffic will cause unmanageable bottlenecks.

In an effort to estimate the cost associated with this region-wide bottleneck, UP calculates train "tow": the amount of delay associated with each train, regardless of location, that is directly caused by the backup in Chicago. These records are assigned to the train's electronic travel logs for analysis. UP also considers the re-crew percentage, which measures the number of crews required to move a given train from origin to destination. Since crew shifts are time-limited, a substantial delay in the network will require additional crews to accommodate the increased travel time, adding to the operating expense of each train that passes through the bottleneck. These delay metrics are monetized and considered in UP's process of calculating return on investments for physical improvements.

Burlington Northern Santa Fe (BNSF) faces the same difficulties as UP and other freight rail operators throughout northern Illinois. Commuter traffic that operates on, or crosses paths with, BNSF freight lines can pose a substantial impediment to the timely transport of freight throughout the region. BNSF shipments experience recurring congestion at a number of locations, specifically at the Corwith intermodal facility and the McCook and Cicero yards, both in the southwestern portion of metropolitan Chicago. Prior to recent construction projects at the Corwith facility (which will be discussed in Chapter 6), which processes approximately 750,000 intermodal trailers each year, BNSF's rail line was bisected by a Canadian National rail line, which itself carried both freight and commuter traffic. Such occurrences are a common problem throughout the greater Chicago network, and severely limit the effective passage of both freight and rail service. At McCook, for example, BNSF crosses rail lines operated by the Indiana Harbor Belt Railroad to access a line operated by CSX and Norfolk Southern. The current condition of the crossing slows trains down to approximately 10 miles per hour.

The Cicero bottleneck is a unique situation resulting in enormous delays on a daily basis. BNSF trains traveling from the Corwith to Cicero yards, though only moving approximately three miles, often require up to twelve hours for the short trip, requiring an entire second crew shift. Much of this delay is associated with the physical layout of the route, which requires trains to back up onto tracks twice from origin to destination.

5.2. Other Illinois Locations

Freight rail congestion in Chicago complicates rail travel outside of the metropolitan region as well. Joliet (IL) contains one of the closest rail bottlenecks to Chicago, and although it is located within close proximity to the metro region, it is not under the purview of the CREATE program. The bottleneck occurs at the Metra/Amtrak station in downtown Joliet, where four main lines are bisected by a single Metra line. Approximately forty Metra trains originate at the station every day, and two of the main lines carry eight Amtrak trains and a limited number of Metra trains, as well as other freight traffic. BNSF's lines, which carry 60-70 freight trains per day, are held at a stand-still for more than fifty commuter trains per day at this location.

Galesburg (IL) also presents a congestion problem for freight traffic. Passenger train service in Galesburg, which is served by three Amtrak trains en route to Chicago, was doubled in 2006 through an agreement between the State of Illinois, Amtrak, and BNSF. This agreement also included provisions for the construction of additional storage tracks for BNSF, for whom Galesburg is a critical facility for many required inspections. Although the storage track construction was originally scheduled to be funded by 2008, no funding has been committed as of yet.

5.3. Mississippi River Crossings

The Mississippi River crossing at Clinton (IA) presents severe congestion problems for Union Pacific's freight traffic. The crossing consists of a swing-span bridge, which closes for rail traffic to accommodate barge passage on the river. Because of the time required to stop trains, open the bridge for river traffic, return the bridge to its original position, and re-start rail passage, UP estimates that the bridge is responsible for 8 hours of train delay each day. The transcontinental rail line that crosses the Mississippi at this location handles a substantial amount of freight, from 60 to 80 trains each day. The train delay per hundred train miles and cost of the delay are estimated for proprietary use only.

BNSF's two Mississippi-related bottlenecks occur at Burlington and Ft. Madison (IA). The former is a swing-span bridge connecting Burlington to Gulf Port (IL) en route to Chicago. This bridge consists of piers dating back to 1868, along with a superstructure dating to 1891, and carries 35-40 trains per day (including coal, grain, and intermodal shipments, as well as passenger service). The condition of the bridge is such that freight traffic must slow to 10 miles per hour as it crosses the river. In addition to the delay caused by the structural condition of the bridge, BNSF's trains are also delayed up to fifty minutes each time the bridge must open to accommodate waterborne freight traffic. The latter is a swing-span structure dating back to 1927, with similar requirements for accommodating waterborne traffic. The bridge at Ft. Madison carries approximately 70-75 freight trains per day, along with a limited number of Amtrak passenger trains.

6. Inventory of Planned Bottleneck Alleviation Projects

Throughout the process of locating and measuring bottleneck locations, an inventory of various planned projects was developed in an effort to demonstrate the current landscape for congestion alleviation throughout the study area. Conversations with state transportation agencies and private operators contributed several suggestions for projects with potential benefit for freight transportation, and a review of state-level project records produced still others. Many of the projects and programs listed below were suggested through the interview process as having substantial impacts on highway congestion in general, if not particular bottlenecks specifically. Others were collected through state-by-state searches of projects and studies.

While few are freight-specific, all were verified for their potential to influence freight transportation through congested areas either through the affirmative agreement of DOT contacts or through specific passages indicating spatially-explicit congestion relief as found in the project's "Purpose and Need" (or similar) statement. A summary of the highway alleviation projects is provided in Table 8. Rail projects were obtained through conversations with state agencies and private operators, with the operators supplying the majority of the details. No substantial port or inland waterway projects were suggested throughout the interviews, though the eventual expansion of the Sault Ste. Marie locks and the Panama Canal are likely to influence waterborne transportation once those projects are realized. Projects described in further detail below are segregated by mode and location, beginning with state-by-state highway projects, followed by multi-state highway projects and rail projects.

Table 8. Summary of Highway Congestion Alleviation Projects

State	Project	Goal(s)	Time Frame*										
			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
IA	I-29 Improvement	Safety, efficiency, capacity, road conditions											
IA	I-80 Council Bluffs Interstate	Capacity		■	■	■	■	■					
IL	Illinois Tollway Congestion Relief Program	Linkage, capacity				■	■	■	■	■	■		
IN	Accelerate 465	Capacity, safety, design standards	← ■	■	■	■	■	■					
IN	I-80/94 Borman Expressway	Capacity, design standards	← ■	■	■	■							
IN	Hoosier Heartland Highway	Capacity, safety, design standards	■	■	■	■	■	■					
IN	465/69 Northeast	Capacity, safety, design standards					■	■	■	■	■		
IN	I-69 Evansville to Indianapolis	Linkage, accessibility, capacity, safety											
MI	Ambassador Bridge Gateway	Capacity	■	■									
MI	Detroit River Int'l Crossing	Capacity, linkage, security			■	■	■	■					
MI	Detroit Intermodal Freight Terminal	Capacity, linkage											

MN	St. Croix River Crossing	Capacity, safety	
MN	Crosstown Commons	Capacity, safety, design standards	←
MN	I-494 Woodbury to Maplewood	Capacity, safety	
MN	I-90 Bridge at Dresbach	Bridge condition, capacity, safety	
MO	Improve I-70	Capacity, safety, design standards	
MO	The New I-64	Design standards, capacity, safety	←
MO	kcICON	Bridge condition, safety, linkage, capacity	
OH	Cleveland Innerbelt Plan	Roadway conditions, capacity, design standards, safety	
WI	US-51/WI-29	Capacity, efficiency	←
WI	US-41 Expansion	Capacity, safety, design standards	
WI	I-94 North-South Corridor	Safety, capacity, linkage, roadway conditions	
Multi-State	US-24 "Fort to Port"	Capacity, efficiency, safety, linkage	
Multi-	I-70	Capacity,	

State	Dedicated Truck Lanes	mobility, reliability of supply chain	
Multi-State	Ohio River Bridges	Capacity, safety, linkage	← →
Multi-State	Brent Spence Bridge	Capacity, safety, design standards, linkage	
Multi-State	New Mississippi River Bridge	Capacity	

* May not be available prior to funding commitments. Subject to change.

6.1. Iowa Highway Projects

6.1.1. I-29 Improvement Project

Extent: This project consists of three segments within Woodbury County. Segment 1 originates south of the I-29/1st St. interchange in Sergeant Bluff, and Segment 3 terminates at the South Dakota border. I-29 is the principal thoroughfare through the Sioux City area.

Goal: The stated goals of the project are: improved safety; improved traffic operations; provisions for driver expectancy; and improved surface conditions. Strategies for achieving these goals include adding travel lanes and upgrading interchanges throughout the study area.

Time Frame: Slated to begin construction in early 2009, dependent on the availability of funding.

Current Status: Segment 3 is due to begin prior to other improvements. All improvements will depend on funding and the schedule of other related improvements throughout the study area.

Bottlenecks Addressed: This improvement project may help alleviate general traffic congestion as it is experienced by all highway users throughout the project area; however, the segments in and around the project are not found to present substantial freight bottlenecks.

For additional *project information:* http://www.iowadot.gov/i29/index.htm

6.1.2. I-80 Council Bluffs Interstate Project

Extent: The five segments that comprise the project area include 14 interchanges and 18 miles of mainline highway throughout Council Bluffs, a city on the east bank of the Missouri River, directly across from Omaha, NE. Construction will occur on Interstates 80, 29, and 480, as well as several connections to local highways. Iowa DOT is collaborating with the Nebraska DOT on this project, as some of the interstates cross the river at Council Bluffs.

Goal: Iowa DOT aims to improve mobility through improvements to road condition, reduced congestion, and additional capacity. The efforts will be the first major reconstruction of the highways, which handle substantially more daily traffic (including 11-25 percent truck traffic) than they were designed to carry.

Time Frame: Construction has been underway on the improvements since 2008. Construction schedules for Sections 2 and 3 are due to continue beyond 2013; schedules for Sections 4 and 5 are not complete at this time.

Current Status: The 24th St. bridge portion of the project was completed in the fall of 2008. Iowa DOT is currently in the property acquisition process for the second phase of the project.

Bottlenecks Addressed: The confluence of I-29 and I-80 features freight congestion associated with the interchange and lane drops. The interchange carries an average of more than 11,000 trucks per day, and is associated with 14,620 annual hours of truck delay per mile.

For additional project information: http://www.iowadot.gov/cbinterstate/index.asp

6.2. Illinois Highway Projects

6.2.1. Illinois Tollway Congestion Relief Program

Extent: This program includes several congestion relief projects affecting major freight routes throughout Illinois. The first phase, known as "Open Roads for a Faster Future," is more than 80 percent complete; the Open Road toll plazas associated with this program have been completed in full. Other projects in the first phase include several widening efforts and interchange improvements on I-39/90, I-94 (the Tri-State Tollway), I-88, I-355 (Veteran's Memorial Tollway), and I-294.

The second phase, "Tomorrow's Transportation Today," includes the addition of High-Occupancy Tolling lanes and interchange improvements at two critical locations (I-294/I-57, and I-90 at I-290/IL-53). The I-294/I-57 Interchange project would construct an interchange between two substantial freight routes where none currently exists. The proposed termini of the project would extend from the two interstates' interchanges at US-6 in Markham to IL-83 in Posen. Interstates 294 and 57 cross one another between these two routes, but access between the two currently requires travel on local roads. The improvements to the I-90/ I-290 interchange in Schaumburg will address recurring congestion in this heavily congested area.

Goal: The primary goals of the I-294/I-57 project are to improve transportation system linkage between the two interstates and relieve congestion on local routes. The goal of the I-90/I-290 project is to alleviate one of the most congested interchanges throughout the entire Tollway system.

Time Frame: Groundbreaking for the I-294/I-57 and I-90/I-290 interchange projects could occur in 2011 and 2013, respectively. The I-294/I-57 interchange could be completed by 2013-2014; the I-90/I-290 interchange could be completed by 2015-2016.

Current Status: The I-294/I-57 project is currently in the second (design) phase of the environmental assessment/ environmental impact statement process. The I-90/I-290 interchange project is in the preliminary phase of the environmental evaluation.

Bottlenecks Addressed: As with most of the major routes in and around Chicago, the highways covered within this project suffer from heavy freight congestion. Although not directly within the bounds of the project area, the I-294/IL-50 interchange, which carries more than 21,000 trucks per day and features approximately 13,000 annual hours of truck delay per mile, could experience secondary benefits from the project. The confluence of I-90 and I-290, which carries more than 17,000 trucks per day, is associated with more than 152,000 annual hours of truck delay per mile. Congestion at this location is compounded by a lane drop on I-290.

For additional project information: http://www.dot.state.il.us/projects.html#District_1 ; http://www.illinoistollway.com

6.3. Indiana Highway Projects

6.3.1. Accelerate 465

Extent: Accelerate 465 is a project by the Indiana DOT to update 7 interchanges along the western stretch of I-465, between Mann Road and I-65. InDOT's expected improvements include (but are not limited to) increased capacity, decreased weaving, signal upgrades, and alignment changes. Construction costs are estimated at $550M.

Goal: InDOT's objective is to bring the 47-year old interstate up to its current standards for ramp design. Originally built in the early 1960s, interchanges along this major thoroughfare cannot process current capacity levels because of several outdated design issues, including: shoulder widths; ramp acceleration, deceleration, and taper lengths; clear zone and barrier requirements, and vertical curves.

Time Frame: Limited construction began in the 2007 construction season, and the full construction process is expected to continue through 2012.

Current Status: At the time of writing, of the nine contracts involved with the project, one has been completed (at the 34th and 46th Street Bridges), five are active, and the remaining three are yet to be let.

Bottlenecks Addressed: The Accelerate 465 project includes several points of freight congestion. The confluence of I-865 and I-465 in the northern reach of the project is both an interchange and lane drop bottleneck, carrying an average of 7,820 trucks per day and experiencing annual truck delays of approximately 11,462 hours per mile. The interchange at I-465 and W. 56th St. carries an average of almost 19,200 trucks per day and sees annual truck delays of approximately 9,760 hours per mile. The interchange at US-40 carries an average of almost 22,000 trucks per day, and is associated with annual truck delays of approximately 30,600 hours per mile.

For additional project information:
http://www.in.gov/indot/div/projects/accelerate465/design/index.html

6.3.2. Northwest Indiana I-80/94 Borman Expressway Reconstruction

Extent: This interchange modification project is an effort within Indiana's Major Moves initiative. The project, located at the confluence of I-80/94 and I-65, completes a series of recent overhauls of I-80/94 from the Illinois border to I-65. This portion of the Borman Expressway improvements includes the construction of new ramps, rehabilitation of existing bridges, and construction of additional travel and connector lanes. The estimated project cost is $189M.

Goal: InDOT's objective for the reconstruction is to increase the capacity of the interchange in line with expected travel demand for the next 20 years, allowing for increased mobility and vehicle flow.

Time Frame: Reconstruction efforts began in 2003, and are expected to continue through 2011.

Current Status: At the time of writing, InDOT anticipates that the efforts of the 2009 construction season will address the eastbound lanes on I-80/94. Current restrictions and detours are available on the project website.

Bottlenecks Addressed: The project area is located in a very congested area for freight traffic. Interchanges within the bounds of the project carry an average of between 42,000 and 58,000 trucks per day, and are associated with annual truck delays of up to 176,817 hours per mile.

For additional project information: http://www.in.gov/indot/div/projects/borman/index.html

6.3.3. Hoosier Heartland Highway- State Route 25

Extent: The Hoosier Heartland Highway connects Toledo (OH) to Lafayette (IN). The 35-mile SR25 section runs through Tippecanoe, Carroll, and Cass counties from Lafayette to Logansport, an area known as the Heartland Industrial Corridor. The project has qualified for $18.75M in TEA-21 funding from the federal government.

Goal: According to InDOT, the purpose of the project is to provide a safe link featuring current design standards, built to handle regional traffic through this industrial/agricultural corridor.

Time Frame: The Lafayette-to-Logansport section of highway has been studied for update potential since at least 1995. The current project began with a Draft Environmental Impact Statement in 2002, and construction is expected to finish in 2013.

Current Status: Groundbreaking occurred in October of 2008, and several bridge construction projects associated with the reconstruction are slated for the 2009 construction season.

Bottlenecks Addressed: This improvement project may help alleviate general traffic congestion as it is experienced by all highway users throughout the project area; however, the segments in the project area are not found to present substantial freight bottlenecks.

For additional project information: http://www.in.gov/indot/div/projects/sr25study/index.htm

6.3.4. 465/69 Northeast

Extent: As part of InDOT's Major Moves initiative, the Northeast section of I-465 and its connection to I-69 will see additional travel, auxiliary, and collector/distributor lanes, as well as four new interchanges. The project begins west of the I-465/College Ave. overpass, and extends to the south of the I-465/71st street overpass. Work continues north on I-69 toward the 96th street interchange. The estimated project cost is $567 million, which will be paid through both state and federal transportation funds.

Goal: InDOT's goals for this project are to improve the level of service on one of Indiana's most frequently traveled highway sections, and to enhance mobility in the area. InDOT has found that the project area currently operates at or below the lowest acceptable level of service, and that forecasted travel demand would decrease the level of service still further.

Time Frame: The first phase of the project is expected to be awarded in 2012, and the final (fourth) phase is expected to be awarded in 2015.

Current Status: Surveying, soil testing, design, and community meetings have been underway since 2008.

Bottlenecks Addressed: The 465/69 Northeast project includes the I-465/I-69 interchange, which carries an average of approximately 31,200 trucks per day and is associated with almost 190,800 annual hours of truck delay per mile.

For additional project information: http://www.465-69northeast.in.gov/index.html

6.3.5. I-69 Evansville to Indianapolis

Extent: This project will eventually construct a direct, 142-mile interstate highway connection between Indianapolis and Evansville. The project will be constructed in six segments, from the I-64/I-164 interchange to I-465 between the I-70 and I-65 interchanges. The I-69 project is currently in developmental stages. Indiana has earmarked $700M for the project thus far.

Goal: InDOT's goal is to improve the transportation network between the southwestern portion of the state with Indianapolis, a significant regional transportation hub. Currently, the connection between Evansville and Indianapolis is through Louisville (KY), a route that is approximately 80 miles longer than the proposed interstate will be.

Time Frame: Construction is anticipated to begin in 2014-2015.

Current Status: The public comment period on the Draft Environmental Impact Statement is currently underway, and the Final Environmental Impact Statement is scheduled to be published in fall 2009.

Bottlenecks Addressed: This future interstate has the potential to draw freight traffic off of I-70 and I-65, but as this route is not featured within 2006 HPMS data, it is not possible to determine an accurate estimate for that alleviation potential.

For additional project information: http://www.i69indyevn.org/index.html

6.4. Michigan Highway Projects

6.4.1. I-75 Ambassador Bridge Gateway

Extent: Upon completion, this project will include the reconstruction of Interstates 75 and 96, a new interchange for improved access to a critical trade route to and from Canada, the reconstruction of several other bridges along the two interstate highways, and a pedestrian bridge at Bagley Avenue.

Goal: The primary purpose for the project is to manage current congestion and to ensure adequate capacity for forecasted traffic volumes at this international border crossing.

Time Frame: Major construction began in 2008. Roadways currently closed to traffic are expected to reopen ahead of the original December 2009 completion date.

Current Status: The project is currently ahead of schedule and nearing completion.

Bottlenecks Addressed: The complex and congested approach to the Ambassador Bridge includes an interchange at I-96 and Martin Luther King, Jr. Blvd., which carries an average of 14,170 trucks per day and features annual truck delays of approximately 23,150 hours per mile.

For additional project information: http://www.michigan.gov/gateway

6.4.2. Detroit River International Crossing Project

Extent: The Detroit River International Crossing (DRIC) Project will construct an international crossing near Zug Island, south of Detroit. The project will consist of a new bridge, inspection plaza, and interchange. The selected alternative for the plaza is located between I-75 and Fort Wayne, a short distance from the Detroit-Windsor Truck Ferry dock.

Goal: The primary goals of the DRIC are to provide adequate border crossing capacity to meet anticipated demand, improve the transportation network for the movement of goods and passengers, improve border operations, and increase security.

Time Frame: Construction of the crossing could begin in 2010, and the project could be open to traffic in 2013.

Current Status: The Canadian Ministry of the Environment is currently accepting public comments on the proposal for the Windsor-Essex Parkway, the Canadian portion of the DRIC.

Bottlenecks Addressed: This future border crossing has the potential to reduce both general and freight congestion in the area, but as this route is not featured within 2006 HPMS data, it is not possible to determine an accurate estimate for that alleviation potential.

For additional project information: http://www.partnershipborderstudy.com/index.asp

6.4.3. Detroit Intermodal Freight Terminal

Extent: MDOT is currently studying the feasibility of an intermodal facility in the southwestern portion of the city, which contains a high concentration of industry and railroad service. The study area is bounded by M-39, I-94, 14th St., and the Detroit River. Though it is currently not a planned project, this facility has the potential to alleviate freight congestion by improving modal shift options in the region.

Goal: The primary goal of this proposal is to enhance the regional intermodal network at a critical geographic juncture.

Time Frame: No time frame has yet been established for the proposal, as it is still in the study phase.

Current Status: MDOT is currently in the environmental impact study phase.

Bottlenecks Addressed: Freight congestion is found at one of the corners of the study area, along I-94 at the M-39 interchange. This segment of highway carries an average of 14,410 trucks per day, and is associated with annual truck delays of approximately 36,850 hours per mile.

For additional project information:

http://www.michigan.gov/mdot/0,1607,7-151-9621_11058_26215-75037--,00.html

6.5. Minnesota Highway Projects

6.5.1. St. Croix River Crossing Project

Extent: This partnership between Mn/DOT and WisDOT aims to replace the current river crossing, a lift bridge connecting Stillwater (MN) to Houlton (WI), with a higher-capacity bridge downriver. No funding has yet been committed to the bridge project. Total project costs (including both WI and MN portions) are estimated at approximately $668.5 million.

Goal: There are two general goals associated with the St. Croix project: first, to decrease the severe congestion currently experienced both on the bridge and on bridge approaches; and second, to increase safety, as both sides of the bridge experience high crash rates.

Time Frame: The Stillwater Lift Bridge has been the object of studies and replacement scenarios for many years. If the current plans are adopted in full, construction could be completed by 2012.

Current Status: The Sierra Club has brought suit against the Federal Highway Authority and National Park Service in response to the Environmental Impact Statement. Community Open Houses are being held to address the future of the Lift Bridge as a pedestrian facility. Mn/DOT, WisDOT, and FHWA are currently working to develop a Project Management Plan.

Bottlenecks Addressed: This improvement project may help alleviate general traffic congestion as it is experienced by all highway users throughout the project area; however, the segments in the project area are not found to present substantial freight bottlenecks.

For additional project information: http://www.dot.state.mn.us/metro/projects/stcroix/index.html

6.5.2. Crosstown Commons Reconstruction

Extent: The Crosstown Commons Reconstruction project involves improvements to I-35W and MN-62. Construction on I-35W spans between 42nd St. and 66th St., and construction on MN-62 spans from Penn Ave. to Portland Ave. Estimated project costs total $288 million.

Goal: Currently, these heavily congested sections require weaving between travel lanes, which contributes to a large number of crashes every year. Mn/DOT aims to decrease the congestion through added capacity, improved access, and the addition of a high occupancy vehicle lane.

Time Frame: Construction on the project began in mid-2007 and is expected to continue through December 2010.

Current Status: Several ramps and bridges are currently closed as a result of the project.

Bottlenecks Addressed: Substantial freight delays are found at both interchanges and lane drop locations associated with the confluence of I-35W and MN-62. The eastern portion of the interchange carries an average of 6,086 trucks per day and is associated with annual truck delays of 74,000 hours per mile.

For additional project information: http://www.dot.state.mn.us/projects/crosstown/index.html

6.5.3. I-494 Woodbury, Oakdale, Maplewood

Extent: This pavement and capacity project extends from south of the I-494/Century Avenue overpass to north of the I-694/4th St. underpass. The additional lanes constructed will create continuous three-lane capacity in each travel direction throughout the section. The estimated project costs are $40 million.

Goal: Though primarily a pavement preservation project, this reconstruction effort also aims to alleviate the growing congestion between Valley Creek Rd. and Lake Rd. Mn/DOT studies associated with the Valley Creek Rd. interchange have identified this section as a bottleneck in need of alleviation.

Time Frame: The project is expected to be completed by Fall 2010.

Current Status: Early construction efforts will include work on the I-494 median, Century Ave. Bridge, and drainage issues.

Bottlenecks Addressed: This improvement project may help alleviate general traffic congestion as it is experienced by all highway users throughout the project area; however, the segments in the project area are not found to present substantial freight bottlenecks.

For additional project information:
http://www.dot.state.mn.us/metro/projects/i494and94/index.html

6.5.4. Interstate 90 Bridge at Dresbach

Extent: The Dresbach Bridge, constructed in 1967, connects Dresbach (MN) to LaCrosse (WI) over the Mississippi River. The project will replace the bridge and reconfigure the interchange with US-14/61. Minnesota's share of the replacement project is estimated at $100 million.

Goal: The primary goal of the project is to replace the aging bridge due to the condition of its sub- and superstructure, which (although currently satisfactory) are demonstrating signs of wear. Capacity is a secondary issue, but the replacement structure will be designed to better accommodate the projected travel demand.

Time Frame: Construction is anticipated to begin in 2012, with an anticipated conclusion in 2015.

Current Status: Preliminary engineering is expected to be completed by late 2009.

Bottlenecks Addressed: This bridge project could help alleviate freight congestion as it is experienced on the Wisconsin-side of the bridge approach. A signalized intersection and lane drop freight bottleneck is found on US-53 in La Crosse, which carries an average of approximately 2,820 trucks per day and is responsible for 14,327 annual hours of truck delay per mile.

For additional project information:
http://www.dot.state.mn.us/d6/projects/dresbachbridge/index2.html

6.6. Missouri Highway Projects

6.6.1. Improve I-70

Extent: Improve I-70 is a second-tier study assessing the widening and reconstruction of I-70 from the interchange at I-470 (east of Kansas City) to the interchange at US-40 (west of St. Louis). The widening effort is aimed at the addition of dedicated truck lanes along the length of the interstate. Improve I-70 is not currently funded for construction.

Goal: The I-70 project is intended to reduce congestion along the heavily-traveled interstate, which is a significant freight route through the region. The widening effort is expected to increase roadway capacity and safety, and improve the movement of goods through the state.

Time Frame: As there is no funding currently allocated to the project, the time frame for its construction is not yet established.

Current Status: The public hearings scheduled for comments regarding the Draft Supplemental Impact Statement concluded in March, 2009.

Bottlenecks Addressed: The I-70 project spans much of the length of one of the most significant transportation corridors through Missouri. The western end of the project includes the interchange at MO-7 in Blue Springs, which carries an average of 18,700 trucks per day and is associated with 9,580 annual hours of truck delay per mile. The project may also alleviate freight congestion around Columbia. For example, the signalized intersection at Old Route 63 and I-70 carries an average of 4,132 trucks per day, and is associated with annual truck delays of 68,800 hours per mile.

For additional project information: http://www.improvei70.org/

6.6.2. The New I-64

Extent: This reconstruction effort spans approximately eleven miles on I-64/US-40, from Spoede Rd. to Kingshighway Blvd. in St. Louis County. The project involves a major rebuild of all existing pavement, bridges and interchanges, the addition of new lanes for added travel capacity, and enhanced designs aimed at improving interchange merge patterns. When complete, the project will also feature wider shoulders than the previous design, and dedicated exit lanes.

Goal: The project addresses several goals as identified by MoDOT: replace deteriorating facilities and substandard interchange designs; increase capacity; improve safety; improve traffic flow; and promote community redevelopment.

Time Frame: Construction on the I-64 project began in 2007, and MoDOT expects that it should be completed by the end of the 2010 construction season.

Current Status: The project is approximately halfway complete. At the time of writing, the western section has re-opened up to the I-70 interchange, with the eastern section between I-70 and Kings highway expected to remain closed through December 2009.

Bottlenecks Addressed: The I-64 project addresses a number of highly congested points for freight travel. The interchange at I-270 carries an average of more than 16,000 trucks per day, and is associated with approximately 69,950 annual hours of truck delay per mile. The interchange at US-67 carries an average of almost 19,000 trucks per day, and is associated with approximately 72,865 annual hours of truck delay per mile.

For additional project information: http://www.thenewi64.org/index.jsp

6.6.3. kcICON (I-29/35 Connections)

Extent: The kcICON project is anticipated to involve lane expansion, reconstruction and rehabilitation efforts throughout the 4.7-mile I-29/35 corridor in Kansas City, while also replacing the Paseo Bridge with a new cable-stayed structure, directly east of the existing bridge. Missouri has dedicated $195 million to the project, and the federal government has dedicated $50 through SAFETEA-LU funds.

Goal: The goal of the project is to update the corridor according to forecasted traffic volumes, and to replace the aging Paseo Bridge structure, which MoDOT scheduled for replacement in June, 2005.

Time Frame: Construction broke ground in Spring 2008, and the project is expected to be completed by the end of July, 2011.

Current Status: The 2009 construction season features several improvements to Armour Rd. in both travel directions.

Bottlenecks Addressed: The southern approach to the Paseo Bridge, which features both lane drop and interchange bottlenecks, carries an average of 4,720 trucks per day and is associated with annual truck delays of approximately 15,450 hours per mile.

For additional project information: http://www.kcrivercrossings.org/

6.7. Ohio Highway Projects

6.7.1. Cleveland Innerbelt Plan

Extent: The Ohio Department of Transportation's Cleveland Innerbelt Plan consists of a series of projects throughout the core of the city. The primary projects, as identified by ODOT, include: E. 55th St. Bridge; Innerbelt Curve and Innerbelt Trench; Central Interchange and Central Viaduct; I-77 Access; Southern Innterbelt; Quigley Rd. Extension; and the W. 7th St./I-490 Interchange.

Goal: Projects within the Innerbelt share a number of broad objectives, organized into ten categories: increased accessibility (including access to industrial areas); improved mobility; community and economic development; improved quality of life; preservation of environmental quality; improved transportation safety; increased operational efficiency; increased cost effectiveness; constructability; and improved physical condition of transportation infrastructure.

Time Frame: Construction could begin on the new westbound bridge in 2010, and it is anticipated to be complete within three years from the beginning of construction.

Current Status: ODOT is in the process of preparing the Final Environmental Impact Statement. The Record of Decision is expected in August 2009.

Bottlenecks Addressed: The interstates serving Cleveland's "Industrial Valley" experience substantial freight congestion in a number of locations. The most significant of these is an interchange and lane drop bottleneck located at the confluence of I-90 and I-77, which carries an average of approximately 9,550 trucks per day and is associated with annual truck delays of more than 116,300 hours per mile. Segments around the I-70/I-490 interchange are also found to be interchange/lane drop bottlenecks, featuring between 9,700 and 14,100 average trucks per day and up to 93,000 annual truck hours of delay per mile. Similar conditions exist at the I-71/I-490 interchange, which is associated with annual truck delays of approximately 27,220 hours per mile.

For additional project information:
http://www.dot.state.oh.us/projects/ClevelandUrbanCoreProjects/Innerbelt/Pages/default.aspx

6.8. Wisconsin Highway Projects

6.8.1. US-51 / WI-29

Extent: The US-51/WI-29 alleviation project will aims to address known bottleneck locations throughout a corridor that is seeing increasing congestion problems. The project involves additional capacity in both travel directions, as well as the redesign of several interchanges throughout a seven mile stretch in Marathon County. Reconstruction efforts on US-51 commence just north of Foxglove Rd. interchange and continue north to the Bridge St. interchange. WI-29 improvements start at the approach to the bridge at the southern tip of Lake Wausau and continue east, concluding just east of the 48th St. overpass. Project expenditures are expected to have totaled $291 million upon completion.

Goal: The goals of the project are to remove existing bottlenecks caused by capacity deficiencies, and to increase the capacity of ramps throughout the corridor, thereby improving the free flow of highway traffic.

Time Frame: Project improvements, underway since 2004, are anticipated to come to an end in 2010.

Current Status: The 2009 construction season is expected to involve improvements to US-51 from Exit 191B to Exit 192, WI-29 at Exit 164, 28th Ave. from Sherman St. to WI-52, and Stewart Ave. from WI-52 to 24th Ave.

Bottlenecks Addressed: No substantial freight bottlenecks are found directly on the routes targeted for construction, but the project could help to alleviate a freight bottleneck found at the signalized intersection of US-51 and WI-29, close to the eastern terminus of the project. This intersection carries an average of 1,840 trucks per day, and is associated with annual truck delays of 11,822 per mile.

For additional project information:
http://www.dot.wisconsin.gov/projects/d4/us51wis29/index.htm

6.8.2. US-41 Expansion

Extent: WisDOT's plan for improvements to US-41 is expected to be one of the state's largest ever highway projects. Improvements are slated for segments of this important trucking route throughout Brown, Winnebago, Marinette, and Oconto Counties. Improvements include, but are not limited to: several reconfigurations of interchanges from signalized intersections to roundabout designs; grade separation of congested intersections; the construction of frontage roads; bridge reconstruction; construction of additional lanes; and the potential development of Intelligent Transportation System technologies.

Goal: Major goals of the project include upgrading transportation facilities to meet anticipated traffic demand, increased safety, and upgrading designs to meet current design standards. US-41 is a priority highway in WisDOT's Corridors 2020 plan, and the segment of US-41 from Milwaukee to Green Bay is eligible for interstate designation upon completion of the design upgrades.

Time Frame: Construction is expected to start in 2009 and continue through 2016.

Current Status: The 2009 season is expected to involve major construction efforts focused on US-41 in Winnebago County, from WI-26 to US-45.

Bottlenecks Addressed: Signalized intersections in close proximity to US-41 throughout Green Bay, Appleton, and Neenah are found to result in annual truck delays of between 9,000 and 19,000 hours per mile. A signalized intersection in Appleton near the US-41/College Ave. interchange is found to carry an average of about 2,450 trucks per day and experience annual truck delays of approximately 41,800 hours per mile. The US-41 project has the potential to alleviate many points of freight congestion found on such routes that feed into the highway.

For additional project information: http://www.dot.wisconsin.gov/projects/ne.htm

6.8.3. I-94 North-South Corridor

Extent: The I-94 North-South Corridor project involves substantial reconstruction of a 35-mile segment of the interstate between the Russell Rd. interchange south of the Wisconsin/Illinois border, north to Howard Ave. and 27th St. in Milwaukee County. The project includes the construction of additional travel lanes in each direction, redesign of roadways to meet current standards, and the reconstruction of left-side exists to the right side of the freeway. As part of its goal to increase safety throughout the segment, WisDOT will replace all crisscrossing "scissor" ramps with diamond ramps, which more effectively separate freeway traffic from frontage road traffic.

Goal: WisDOT aims to increase safety and ease congestion throughout this interstate artery.

Time Frame: Construction starts in 2009 and is expected to continue through 2017.

Current Status: The 2009 construction season will see efforts underway at eight interchanges (27th St., Grange Ave., the Westbound Airport Spur, College Ave., County Highways G, E, and C, and WI-158), and two sections (between County Highway K and 7 Mile Rd. in Racine Co., and between the Illinois border and US-50 in Kenosha Co.).

Bottlenecks Addressed: The northern section of the I-94 project may help to alleviate substantial freight congestion in the Milwaukee area. The lane drop and interchange bottlenecks around the I-94/894/43 and I-94/West Layton Ave. interchanges account for significant freight delays in the area. The I-94/894/43 interchange carries an average of approximately 12,920 trucks per day, and is associated with between 146,000 and 157,000 annual hours of truck delay per mile. A similar amount of truck traffic is found at the I-94/West Layton Ave. interchange, as well as more than 43,500 annual hours of truck delay per mile.

For additional project information: http://www.plan94.org/

6.9. Multi-State Projects

6.9.1. U.S. 24 Fort to Port

Extent: The Fort to Port project is a partnership between the ODOT and INDOT, involving realignments, capacity expansion, and several grade separations along more than 90 miles of US-24 between the I-469 interchange in New Haven (IN) and Toledo (OH). US-24 is an important truck route through an industrial region, and has struggled to meet the demands of increasing capacity in recent years. Project cost estimates, combined over the length of the improvements, total more than $615 million.

Goal: The goal of the realignments and reconstruction of existing segments is to improve traffic flow and reduce congestion, increase facility efficiency, eliminate systematic delays, improve safety, enhance the regional transportation network, and accommodate future regional growth.

Time Frame: Most sections of the project are anticipated to be open to traffic by 2012; construction is expected to be completed in full by 2013.

Current Status: Current new construction and improvements are underway throughout Paulding, Defiance, and Henry Counties (OH).

Bottlenecks Addressed: Although this project will improve conditions for freight travel throughout this corridor, only one freight bottleneck is identified that may be directly mitigated by the project. US-24, which carries an average of 1,618 trucks per day through the segment crossing I-475, exhibits annual truck delays of 8,866 hours per mile that are associated with the signalized intersections located to the northeast of the I-475 interchange. These may be alleviated through the Fort to Port project. The most substantial freight bottlenecks in the area occur on I-75 in Toledo, which is beyond the limits of this project.

For additional project information: http://www.us24.org/ ; http://www.in.gov/indot/div/projects/us24/

6.9.2. I-70 Dedicated Truck Lanes

Extent: Though the I-70 Dedicated Truck Lanes concept is currently still in the study phase, it deserves mention as a potential project for freight congestion alleviation due to its freight-specific focus. This FHWA Corridors of the Future proposal would segregate truck traffic through an 800-mile corridor from the I-435 beltway in Kansas City (MO) through to the eastern Ohio border at Bridgeport, traveling through Illinois and Indiana en route. The proposal would add four truck-only lanes throughout the length of the corridor. The study suggests that a dedicated trucking corridor throughout the region would attract east-west freight traffic from the heavily congested I-80 corridor, and provide new opportunities for intermodal freight connections along the route.

Goal: The primary goals of this proposal are to reduce traffic congestion, enhance the mobility of both freight and passenger transportation, improve the reliability of the supply chain, and to improve safety. Further, this proposal aims to promote multimodal freight connectivity.

Time Frame: As this proposal is still being studied, no time frame is yet available.

Current Status: The assessment of environmental impact is underway.

Bottlenecks Addressed: Given the length of this potential project, it is difficult to quantify the amount of freight congestion that could be mitigated. Thirty interchange bottlenecks are found directly on I-70 within the project area, as well as at least fourteen lane drop bottlenecks. Many other freight bottleneck locations in close proximity to I-70 are likely influence by the traffic directly on it, including several bottlenecks in the Kansas City, St. Louis, Indianapolis, and Columbus metropolitan areas.

For additional project information: http://www.corridors.dot.gov/i70.htm ; http://www.in.gov/indot/2355.htm

6.9.3. Ohio River Bridges

Extent: The Ohio River Bridges project will construct two new bridge connections between Louisville and southern Indiana, as well as rebuild the Kennedy Interchange (a.k.a. “Spaghetti Junction”) at the confluence of Interstates 65, 71, and 64. The new Downtown Bridge will be located immediately east of the existing Kennedy Bridge, and the new East End Bridge will connect KY-841 to IN-265.

Goal: The primary purpose of the project is to improve mobility throughout the regional transportation network, as well as to alleviate the recurring congestion associated with the Kennedy Bridge and Kennedy Interchange and improve cross-river system linkage.

Committed Funding: The financial plan approved by the Federal Highway Administration estimates a total project cost of $4.068 billion, split between Kentucky and Indiana at 72% and 28%, respectively.

Time Frame: Preliminary construction began in 2006. All phases of the project are expected to be completed by 2024.

Current Status: Currently the project is in the pre-construction phase, with right-of-way and utility tasks underway.

Bottlenecks Addressed: This bridge project is likely to alleviate several points of substantial freight delays throughout Louisville. The most significant of these is the I-71 approach to the I-65 bridge. The bridge itself carries an average of 10,840 trucks per day, and sees approximately 17,625 annual hours of truck delay per mile. But greatest benefit may be realized at the southern terminus of I-71 at I-65, which is estimated to account for 255,645 annual hours of truck delay per mile.

For additional project information: http://www.kyinbridges.com/

6.9.4. Brent Spence Bridge

Extent: The Brent Spence Bridge is one of two Interstate bridges crossing the Ohio River at Cincinnati/Northern Kentucky. This bridge connects Cincinnati and the city of Covington (KY) via I-71/75, an important trucking corridor in the Upper Midwest region. The Ohio Department of Transportation and the Kentucky Transportation Cabinet, along with the Federal Highway Authority and several regional stakeholders, have been working together to replace the severely congested bridge, which has been identified by the National Bridge Inventory as functionally obsolete.

Goal: The primary goals of the project are to improve traffic flow and safety, update design standards of geometry, and provide better linkage to transportation corridors.

Time Frame: Construction could begin in 2015.

Current Status: ODOT and KTC have recently held public meetings regarding the Conceptual Alternatives Study. The Assessment of Feasible Alternatives Report is currently scheduled for submittal in early August of this year.

Bottlenecks Addressed: The Brent Spence Bridge is found to carry more than 30,000 trucks per day on average, and is associated with nearly 21,000 annual hours of truck delay per mile.

For additional project information: *http://www.brentspencebridgecorridor.com/Home.html*

6.9.5. New Mississippi River Bridge

Extent: A collaborative effort between MoDOT and IDOT, the New Mississippi River Bridge project aims to relocate the I-70 crossing (from St. Louis, MO to East St. Louis, IL) to a new location north of the current bridge at Poplar St. The proposed 8-lane bridge will require several new interchanges and sections of interstate, as well as improvements to existing ramps at the current I-55/64/70 Poplar St. Bridge. The total project estimate is $640 million, comprised of state and federal funds (estimated at $313 million, $88 million, and $239 million for Illinois, Missouri, and the Federal government, respectively).

Goal: The primary consideration in relocating the I-70 crossing is the severe congestion at the Poplar St. Bridge and its corresponding approach roadways, which is more than thirty years old and operating at or over capacity. Travel demand projections indicate that the capacity limitations of the current river crossing will hamper efficient travel elsewhere in the city as well.

Time Frame: Estimated project costs have been calculated based on an estimated construction time frame of four to six years, beginning in 2010.

Current Status: The deadline for bids on the bridge proposal was Spring 2009. Construction is expected to begin shortly thereafter, and the bridge should be completed in 2012.

Bottlenecks Addressed: Interchange construction at the St. Louis approach to the Poplar St. Bridge (at the confluence of I-64/70/55) has the potential to alleviate 53,945 annual hours of truck delay per mile at this location, which carries approximately 12,745 trucks per day.

For additional project information: http://www.newriverbridge.org/default.asp

6.10. Rail Projects

In response to the severe congestion throughout northeastern Illinois, the Class I railways operating in the area have partnered with key public transportation agencies to address improvements in cooperation with one another. This partnership, the Chicago Region Environmental and Transportation Efficiency Program (CREATE), supports numerous projects aimed at physical improvements that will benefit both the public and private sectors. The partnership includes:

- United States Department of Transportation
- Illinois Department of Transportation
- Chicago Department of Transportation
- American Association of Railroads membership:
    - BNSF Railway
    - Canadian Pacific Railway
    - CN
    - CSX Transportation
    - Norfolk Southern Corporation
    - Union Pacific Railroad
    - Metra
    - Amtrak

Because of the highly co-dependent nature of rail infrastructure, and indeed all transportation infrastructure, throughout the metropolitan region, the partners involved with CREATE have agreed on methods to invest in a number of improvements to remove the constraints that ultimately overwhelm the entire rail network. Several of these improvements are described below. Figure 34 shows the spatial organization of CREATE projects.

Figure 34. Map of CREATE Corridors available at CREATE program website

Two projects are currently active on Union Pacific-owned tracks: on the Beltway Corridor, in Melrose, at the Proviso North Departure Yard; and on the Western Ave. Corridor, in Chicago, at Ogden Junction. At Proviso, CREATE is adding a third main line to connect UP with the Inner Harbor Beltline via a grade-separated flyover. The project at Ogden involves a reconfiguration of the junction's lines to allow for a more fluid throughput. The benefits of these improvements are assessed for internal purposes only, but UP and its partners in CREATE are confident that they will be realized far beyond UP alone.

Similarly, BNSF stands to gain substantial efficiencies through its partnership in the CREATE program. The company has already begun to realize the benefits associated with construction at the Corwith facility. The junction at Corwith, once controlled via an attended tower on site, is now controlled remotely from BNSF's facility in Ft. Worth (TX), giving operators a much broader picture of regional freight movements. This reconfiguration has allowed for a much more efficient junction for both freight and commuter traffic.

Projects at the McCook and Cicero yards are also included in the CREATE program. Construction efforts now underway will expand the connection at McCook from a single track to a double track, increasing both the speed and capacity of the connection. BNSF estimates that the new connection will allow for traffic to pass through at 40 miles per hour. The Cicero project, though not yet funded, will decrease the amount of time required for BNSF intermodal trains to travel between the Cicero and Corwith yards. The proposed solution would provide BNSF an easement for new tracks along the Western corridor, where four main lines are currently located with ample space for a fifth. If constructed, this improvement could reduce the travel time between the two intermodal yards from twelve hours to two, alleviating one of the worst rail bottlenecks in the area.

Outside of the CREATE program, the railways are partnering with the public sector to relieve freight congestion at their Mississippi River crossings. In response to recent Orders to Alter from the US Coast Guard, BNSF is planning the replacement of the swing span bridges at Burlington and Ft. Madison (IA) with vertical lift bridges. The process of replacement will involve the partnership of government agencies under the Truman-Hobbs Act of 1940, which requires the federal government to share in the cost of bridge replacement when navigation channels are compromised by the structure. BNSF is currently investigating the potential for funding through the American Recovery and Reinvestment Act of 2009 for the Burlington project, with construction costs estimated at approximately $60 million. Once funding is obtained, construction of the new bridge may be complete within 2-3 years. After construction is complete, the delays associated with barge traffic in Burlington may be reduced to 20-25 minutes, and train speed across the river could increase up to 35 miles per hour. While funds have not yet been appropriated for a replacement of the bridge at Ft. Madison, its construction should also be completed within 2-3 years once funds are available.

The swing span bridge in Clinton (IA) is also under an Order to Alter notice, and plans are underway to replace the swing span bridge with a clear span bridge, which would allow enough clearance for barge freight to pass without the need for closing the bridge to rail traffic at all. Union Pacific is investigating the potential for a multimodal clear span bridge, the estimated cost of which is on the order of $300-600 million, a capital expenditure too great for the rail operator to assume on its own. Whereas the combination of auto and rail traffic on a single structure will complicate the design and construction of the bridge, the partners involved believe that it may prove to be the most cost-effective method for eliminating this bottleneck.

7. Recommended Bottleneck Alleviation Strategies

As traffic bottlenecks have been highlighted as a major congestion problem, which significantly jeopardize the efficiencies of both passenger and freight movement, they have warranted special attention from transportation analysts. Many strategies have been proposed by transportation agencies, industry groups, and researchers to alleviate and/or mitigate constraints throughout the nation's transportation networks, and many of them have proven to be effective. By using the previous efforts as a starting point, a systematic bottleneck alleviation strategy was developed in this study to map various mitigation measures with specific bottleneck types. To develop the strategy we reviewed relevant studies and project reports from several sources:

- Federal Highway Administration, Traffic Bottlenecks: A Primer Focus on Low-Cost Operational Improvements, U.S Department of Transportation, July 2007.
- Federal Highway Administration, Congestion Reduction Toolbox. Available at http://www.fhwa.dot.gov/congestion/toolbox/index.htm. Accessed Jun 2009.
- Cambridge Systematics, Inc., Unclogging America's Arterials-Prescriptions for Healthier Highways, American Highway Users Alliance, Nov 1999.
- Cambridge Systematics, Inc., Unclogging America's Arterials-Effective Relief for Highway Bottlenecks, American Highway Users Alliance, 1999-2004.
- Denver Regional Council of Governments. Congestion Mitigation Toolkit, June 2008.

The mapping between mitigation measures and bottleneck types is summarized in Section 7.1 with clear definitions of each measure. Section 7.2 provides case studies to describe how to apply mitigation measures to different types of bottlenecks. Section 7.3 discusses practical issues of implementing bottleneck alleviation measures.

7.1. Mapping Mitigation Measures and Bottleneck Types

By reviewing the existing studies both from highway transportation practice and academic research, a series of highway bottleneck alleviation measures is identified. These measures are categorized into three groups based on how they affect freight movement. The three groups include:

- Exclusive: strategies that are specifically applied to freight transport;
- Potential: strategies that are applied to both freight and passenger travel that could have substantial benefit toward freight bottlenecks; and
- General: strategies that are most frequently applied to passenger travel congestion, but could have ancillary benefits toward freight transport while mitigating passenger-travel congestion.

Each type has the potential to alleviate truck freight congestion, but the benefits may vary in accordance to the purpose of the strategy and specific constraints associated with bottlenecks. For example, the congestion pricing strategy, which is expected to reduce travel demand and mitigate congestion through economic policy, has little effect on addressing steep grade bottlenecks as the inherent geographic constraints are not improved. A table describing all measures with the specific bottleneck causes is presented in Table 9, in which the applicability of each measure is indicated. Also the implementation considerations for each strategy are specified in the table, which helps determining the feasibility of the measures at specific bottleneck locations and eliminating unreasonable ones. The measures that have exclusive or potentially direct impact to truck movements are explained in detail below. And the implementation considerations are illustrated in detail by case studies in Section 7.2.

Table 9. Mapping Mitigation Measures to Bottleneck Causes

Bottleneck type	Specific Concerns	Exclusive	Potential					General						
		Truck lane dedication	Access control	Pre-travel/ In-travel information	Congestion pricing	Vehicle-Infrastructure Integration	Modal shift	Shoulder pavement	HOV lanes	Express lanes	Collector-Distributor road	Additional turning lane	Signal optimization	Widening
Signalized intersection	Poor signal progression, Signal timing design, Intersection geometry design			+	+		+					+	++	+
Steep grade	No passing lanes, Too long steep grade segment	++[*]		+		+	+	++	+	+	-			+
Interchange	Ramp design Insufficient merging/ diverging area	+	++	+	+	+	+	+	+	++	++			+
Lane drop	Intense demand, Insufficient merging length	+	++	+	+	+	+	++	+	++				++
Implementation Considerations		Number of lanes ≥ 6[**] Truck percentage >20% Urban freeway	No metered ramp exist Length of ramp Number of ramp lane	Alternative route/roads available	Number of lanes≥ 8 for interchange and lane drop bottlenecks on urban freeways	Extent of technology adoption	Alternative mode available with adequate capacity	Shoulder width>10 feet on either side Freeway	Number of lanes ≥ 6 No HOV operation exist Freeway	Number of lanes ≥ 8 Freeway	Original geometric design of the interchange Land use around interchange location	Absence of turning lane Turning movement volume	Type of signalizatio n, Typical peak percent green time	Widening feasibility,

[*]. ++ Strongly recommended. + Recommended
[**]. Number of lanes on both directions

7.1.1. Congestion Pricing by Time of Day

Congestion pricing is one of the most commonly suggested demand side approaches to solve the congestion problem. By charging motorists according to the additional congestion they cause during peak periods, the redistribution of vehicle trips in terms of spatial scope, temporal and modal selection is encouraged to relieve automotive travel congestion. Four main types of pricing strategies are used in practical implementation, which are cordon charges, area wide charges, city center toll rings and corridor- or single-facility congestion pricing. This mechanism is almost exclusively implemented in urban areas, where traffic congestion is most likely to happen.

The strategy has been successfully implemented abroad in central London, Singapore and Stockholm, where the drop in vehicle trips, increase in traffic speed and shift from private passenger cars to public transit have been reported since the implementation of the toll mechanism. In the US, there has been an increase in the number of toll freeways to combat the congestion. One of the earliest domestic examples is the tolled 4-lane SR 91 express highways in California, which is a part of 12-lane freeway connecting Anaheim and Orange/Riverside County. The reduction in peak period travel has released a significant amount of capacity from congestion for both the toll lanes and free lanes. As a result, trucks save a great amount of travel time as well, even though they are prohibited from the toll lanes. Research has shown that trucks would further benefit if the toll lanes were open to heavy vehicles (Kawanura, 2003).

Another toll express lane strategy encourages the use of high occupancy vehicles through toll exemptions. Some segments of I-95 feature variably priced express 2-lanes, converted from a single HOV lane, to allow the free use of express lanes for vanpools, registered carpools of three or more passengers, registered hybrid vehicles, and motorcycles.

Although the congestion pricing concept is extensively advocated by transportation researchers, practical implementation depends heavily on demand distribution effects and the social and political acceptability of the additional charge. In order to take advantage of the congestion pricing mechanism, careful examination should be performed about the following factors before implementing the charge:

- Temporal distribution of travel demand on the facility;
- Number and width of lanes available; and
- Public opinion and socioeconomic impacts.

The cordon area and area-wide charging strategy could potentially be applied to limit vehicles entering a restricted area within a city center and alleviate network congestion. Therefore, this type of congestion pricing mechanism generally applies to the signalized intersection bottlenecks within urban areas. Variable pricing on a single facility, as another type of congestion pricing mechanism, is considered appropriate for urban corridors suffering severe congestion. Because the scope of the study and data availability, only an initial check is performed on the number of lanes to determine the feasibility of this type of strategy to each lane drop and interchange bottlenecks bottleneck located on urban freeways. Since most of the cases applying congestion pricing to single facilities have at least 6 lanes other than toll lanes available in both travel directions, usually 10-12 lanes available in total, the existence of 8 lanes is determined as the minimum requirement to qualify the consideration of applying variably tolling lanes.

7.1.2. Pre-travel/In-travel Information

By developing schedules and routes out of peak periods and congested areas in advance, motor carriers could reduce the exposure of trucks to the impact of peak period congestion.

However, the optimal schedule and route are often derived from past experience and typical traffic patterns, which might be inaccurate. In addition, general traffic patterns are subject to the change caused by nonrecurring factors such as road construction, accidents and severe weather. Patterns can vary significantly among months, days and even time periods within a day. Recent advancements in Intelligent Transportation System (ITS) technology enable motor carriers to re-schedule or re-route movement according to real time traffic information to avoid congestion.

As one of the earliest applications, TRANSCOM (Transportation Operations Coordinating Committee) provides real-time traffic information to its member agencies and other transportation agencies in New York and New Jersey metropolitan area. TRANSCOM has also collaborated with the American Trucking Association and twelve commercial motor carriers to demonstrate the benefits of the system to the trucking industry. With the advantage of advance awareness of nonrecurring incidents, dispatchers are able to reroute and reschedule shipments around incident locations, allowing truck drivers to select alternative routes to avoid traffic jams.

An empirical study conducted in 2002 quantifies the benefit of real-time traffic information to the trucking industry (Kim et al, 2006). In Southeast Michigan, an average of 7% cost savings and an 11% decrease in travel time for truck was observed after the access to real-time traffic information was provided during times of congestion. The study also indicated that this information was more valuable under severe congestion than under normal traffic conditions.

An example of the successful implementation of pre-travel or in-travel information systems can be found in Oregon, where the state's Department of Transportation has created TripCheck, an online and telephone service providing travelers with real time traffic conditions and transit arrival times (Coffman and Makler, 2007). The TripCheck system allows travelers to identify actual congested highways and obtain updated arrival times of regional bus or light rail train services. This information helps travelers to select alternative routes or times before departing. In addition, the aggravation of existing congestion caused by more vehicles joining the traffic jam is avoided. As illustrated by the visiting statistics of the website, this real time information system is widely used by the residents of the region as a reference for travel planning.

As a demand-side bottleneck mitigation measure, providing pre-travel/in-travel information is universally applicable to all types of bottlenecks. However, the impact of this measure depends on the capability of travelers or motor carriers to re-schedule trips and the availability of alternative routes. If drivers lack the flexibility to rearrange trips and/or the bottleneck is on the fixed route, only marginal benefits could be received by implementing this measure.

7.1.3. Access Control

Traffic signals at freeway on-ramps can control the flow of vehicles onto the roadway and thus decrease the interruptions experienced by freeway traffic. The metering rate could be fixed or responsive to actual traffic conditions on mainline freeway and ramps.

As trucks have a slower rate of acceleration than passenger cars, making a truck enter the highway from a dead-stop leads to additional delay for both trucks and other vehicles. In order to improve the commercial vehicle operating efficiencies at on-ramps, some Australian transportation agencies have instituted a separate lane without metering control. The separation of heavy vehicles and passenger cars not only eliminates the time lost to the deceleration and acceleration of trucks, but also prevents passenger cars from being blocked by the slowly accelerating trucks.

Scheduled closure of on-ramps is an alternative to reduce the interruption of traffic to the mainline of freeways where the ramp metering is not applicable because of insufficient acceleration and storage lengths and high ramp demand volumes. This strategy may also work to divert vehicles from using the freeway when it is already operating at capacity, or when roadway incidents have caused severe backups.

The access control strategy improves travel conditions on the freeway but might transfer the congestion to on-ramps and create even more delay if designed inappropriately. Therefore it is important to develop effective metering rates to optimize traffic flow condition. Usually the successful implementation of ramp metering system depends on the following factors:

- Travel demand on entrance ramps and mainline
- Acceleration length of ramps
- Storage length of ramps
- Number of lanes of ramps
- Real-time traffic data collected from loop detector on mainline and ramps
- Enforcement mechanisms.

As an initial effort to identify potential solutions to bottlenecks, this study examines the operational pattern of on-ramps. If metered signal are already placed on entrance ramp, this measure would be filtered out from the candidate solution list; otherwise the measure is qualified for further inspection, which relies on detailed input about the temporal and spatial distribution of travel demand on both mainline and on-ramps, and the geometric designs of on-ramps as well.

7.1.4. Truck Lane Dedication

As a strategy for bottleneck alleviation, designated lanes for freight traffic (also known as Exclusive Truck Facilities, Exclusive Truck Lanes, or Dedicated Truck Lanes) could have a highly positive impact on freight congestion. Though there are currently few functioning examples of dedicated truck lanes in operation in the United States, those examples, in combination with several research studies regarding the operational feasibility of such facilities, provide a foundation for the conceptual framework for constructing and managing these projects.

While it is not a truly exclusive truck facility, the New Jersey Turnpike does feature a dual-dual design that segregates a large portion of passenger traffic from freight and commercial traffic. The dual-dual layout (two separated sets of lanes in each travel direction) and truck-only toll lanes help to separate these often-competing uses of the roadway, and offer substantial management benefits to the Turnpike Authority. Among the many ancillary benefits, such segregation also allows designers and engineers to tailor roadways toward their specific use, instead of applying one-size-fits-all pavement types, lane widths, etc. indiscriminately to all travel lanes.

The New Jersey model is only one example of several potential operational models for controlling and improving freight traffic on highways. Middleton et al. (2006) describe a series of “special truck treatments” that could be used in segregating freight from general traffic, including reserve capacity lanes, bypass facilities, and exclusive truck lanes (no physical barrier between general and freight traffic) and exclusive truck facilities (with a physical barrier). A number of studies and technical reports (Burke, 2008; Battelle, Co. 2007; Jones, 2007) provide a list of factors to consider in examining whether or not lane dedication strategies may be an appropriate and/or feasible alleviation strategy for a given bottleneck location. These include, but are not limited to:

- Present ownership and width of right-of-way;
- Percent truck traffic;

- Level of access control (including the presence of hard barriers);
- Shared vs. segregated access ramps;
- Distance between roadway exits; and
- Tolling options.

It should be noted that the most significant factor determining the feasibility of lane dedication strategies may be the financial aspect, though a recent study by Burke et al. determined that the construction of truck-only lanes along a 164-mile segment of Interstate 80 in Iowa would likely cost less than the corresponding addition of general purpose lanes.

Some of the largest obstacles to implementing dedicated truck lanes are related to operational and political feasibility. Exclusive facilities would go a long way toward relieving freight bottlenecks if implemented in major metropolitan areas, which feature the heaviest freight congestion. Unfortunately, these are also the areas where such facilities might be least feasible. The density of access points, ownership of neighboring property, and public opposition pose considerable impediments to practical implementation within urbanized areas. However, concerns of political feasibility are beyond the scope of this research.

Therefore, as these dedicated truck facilities represent a direct alleviation of freight congestion through the segregation of freight from passenger travel, they are recommended as an appropriate strategy for bottleneck alleviation in metropolitan areas, where the overwhelming majority of freight congestion occurs. In this analysis, dedicated truck lanes are suggested for freight bottlenecks on urban freeways with three or more lanes in each direction, and where truck traffic accounts for 20 percent or more of the total traffic.

7.1.5. Modal Shift

Another strategy for alleviating freight bottlenecks is to distribute freight between modes in the most efficient combinations achievable. For example, under certain circumstances (see below) a truck freight shipment slated for passage through a point (or points) of recurring congestion may be more efficiently routed via other freight modes where and when those alternatives are operating under capacity. In this manner, modal shifts in freight transportation could have a more substantial impact on general highway congestion than corresponding shifts in passenger travel (Bryan et al., 2008). However, whether or not they are directed toward specific modal shift objectives, the effects of transportation policy on modal choice may exhibit substantial variation, and must be critically examined before any significant changes are enacted (Knoflacher, 2001).

Changes in freight mode decision-making require the examination of many economic factors, as modal choice has significant ramifications throughout industry, transportation, and the public sector. Blauwens et al. (2006) discusses several of these factors at length, including:

- Transportation cost;
- Inventory cost;
- Economies of scale;
- Speed of transport; and
- Reliability.

The applicability of modal shift policies and/or incentives may vary widely between bottlenecks, states, or regions. Any number of combinations of these or other factors, (e.g. fluctuations in transportation fuel prices, passenger travel alternatives, demographics) will necessarily change the landscape surrounding efficient freight modal choices. Local concerns may have the largest influence on the applicability of modal shift policies, as the proximity and capacity of inland waterways and/or rail networks will obviously alter the available alternatives. Thus, the number of alternatives is not likely to be uniform throughout a large region such as the Mississippi Valley.

Perhaps the largest caveat regarding the potential for modal shifts to alleviate bottleneck conditions is the amount of control (or lack thereof) that federal, state, regional and local governments have over the transportation choices of the private sector. The transportation choices of the private sector are largely determined by market forces. Should government agencies pursue modal shift policies or incentive programs, policymakers must carefully consider not only the infrastructural investments that would be required in order to sufficiently handle increases in demand (Cambridge Systematics, Inc., 2007; Beshers, 2007), but also needs of commercial transportation operators (Golob et al., 2000) and the measures by which success would be evaluated (Woodburn, 2007).

Modal shift is considered here to be an appropriate strategy for bottleneck alleviation in all cases. In theory, any reduction in roadway freight shipments would necessarily reduce roadway freight congestion. On a site-by-site basis this theory may be challenged and modal shift may be less appropriate, largely dependent on the proximity and capacity of alternative freight networks. However, in those cases that all (or most) criteria align in favor of a modal shift, it should be considered as an effective strategy to combat freight bottlenecks.

7.1.6. Vehicle-Infrastructure Integration

Vehicle-Infrastructure Integration (VII) is perhaps less immediately feasible than the balance of current strategies as outlined here. Nonetheless, it continues to receive some attention in transportation research, and shows promise as a potential long-range concept for freight congestion alleviation. VII represents a series of technological advances toward the automation of highway travel, through both vehicle-to-vehicle and vehicle-to-command center communication, and may have substantial benefit for freight transportation providers, transportation planners and designers, and passenger travel (Shladover, 2005).

In general, VII employs communications devices to connect infrastructural systems with a given means of transportation. Freight transportation applications of VII technologies might include (US DOT RITA, 2009):

- Driver communication;
- Intelligent speed control;
- Lane keeping assistance;
- Roll stability control;
- Precision docking;
- Coupling/decoupling; and
- On-board monitoring.

These applications could have a positive impact on the efficiency of freight shipments, improving both roadway operations and freight transfer facilities. Research has demonstrated the applicability and cost-benefit advantages of some of these technologies in the heavily congested Chicago area (Schladover, 2004).

A substantial body of research has been conducted on a number of VII initiatives. The California Partners for Advanced Transit and Highways (PATH) program has performed a number of studies of the ways in which VII can be implemented, and the U.S. Department of Transportation's Research and Innovative Technology Administration (RITA) has compiled a wide variety of VII research in an overview of the applications of such programs[13]. RITA has also published an exhaustive online resource guide for ITS (US DOT RITA, 2009).

Without further “proof of concept” investigations demonstrating the implementation considerations for VII as a freight bottleneck alleviation strategy, it is difficult to outline the specific criteria that may be required for its successful implementation. Although VII covers a broad range of technologies, conversations with various transportation agencies indicated that VII may hold the greatest benefit as a method of “platooning” truck fleets (i.e. coordinating the close movement of several trucks in succession). This would suggest that VII is most applicable to freight movements outside of heavily congested urban areas, wherein closely-spaced interchanges would require the break-up and reassembly of platoons. Rural sections of highway could serve as more preferable staging areas for such platoons, although other logistical concerns for the platoons and other highway users must be accounted for. Such controls could be combined with dedicated truck lanes, but in the absence of such facilities they are recommended more favorably for rural highways.

7.2. Case Studies

As discussed above, the mapping matrix between mitigation measures and bottleneck types suggests the potential solutions worthy of consideration. The successful implementation of various measures largely depends on the specific traffic conditions and feasibility of improvement at each bottleneck location. The case studies described below is not designed to present a project-level analysis of bottleneck mitigation solutions, which requires detailed geometry information along with current and projected traffic data, and is therefore not within the scope of the study. However, they do provide an introductory framework upon which a more thorough analysis may be built. The appropriate bottleneck alleviation strategies are developed through the following steps for each bottleneck:

- Bottleneck description: a detailed inspection of the geometry and operation characteristics at and/or near the bottleneck locations from the input gathered from Google Map, HPMS data. This step aims to provide more insights about the bottleneck formation and identify local traffic geometry and operational features that might restrict the implementation of some mitigation measures.
- Identification of potential mitigation measures: a listing of those strategies, as described above, that may be effective in alleviating the congestion conditions at the particular location.
- Feasibility examination: the elimination of any inappropriate measures due to the specific limitations of geometry and operational design, which are based on the information identified in the first step.

The second and third steps are based on the information provided in Table 9. In order to demonstrate the procedure of bottleneck alleviation strategy analysis, four case studies are presented in the following sections for each type of bottleneck, respectively. A supplemental explanation about some of the criteria used to filter out inappropriate strategies is also provided.

7.2.1. I64@US61/67 Interchange Bottleneck

Figure 35. I64@US61/US67 Interchange Bottleneck in St Louis, MO

7.2.1.1. Bottleneck Description

This cloverleaf interchange connects the six-lane Interstate 64 freeway to the six-lane US 61/67 (South Lindbergh Blvd) arterial in St. Louis, MO. The following features are identified at the location through HPMS database and Google Map:

1. One lane off ramp splits from the mainline for right-turn vehicles on I64 and US 61/67.
2. One lane on ramp adds back to the mainline on I64 and US 61/67.
3. The cloverleaf interchange allows the left-turning vehicles to go through the interchange without stopping.
4. 2-foot shoulders exist on both sides of roadway for each direction of I64 freeway.
5. Trucks account for 12 percent of the total amount of traffic.
6. K factor 9 Directional factor 50
7. Widening is not feasible at this location

Although the cloverleaf configuration makes good use of the limited land, the close spatial distribution of the left-turn on-ramp and off-ramp on the mainline (i.e. I64 freeway) tends to increase the interference between the merging vehicles from on-ramps and diverging vehicles to off-ramps, which leads to congestion at the interchange. With the presence of significant proportion of large vehicles, which require more space for lane changes, the bottleneck problem is likely to be aggravated.

7.2.1.2. Mitigation Measures Identification

The potential measures to eliminate the bottleneck include:

- Truck lane dedication
- Access control
- Congestion pricing
- Pre-travel/In-travel information
- Vehicle-infrastructure integration
- Modal shift
- Shoulder pavement
- HOV lanes
- Express lanes
- Collector-Distributor road
- Widening

7.2.1.3. Feasibility Examination

Truck lane dedication

According to the criteria presented here, truck traffic does not account for a sufficient percentage (12 percent, as opposed to the recommended 20 percent) for the consideration of dedicated lanes along this route.

Access control

By imposing the metered signals on entrance ramps to the I64 freeway, the interference among weaving vehicles could be reduced, which improves the smooth flow on the mainline. However, due to the limited length of ramps and the signalized intersection close to the interchange on the southern (i.e. about 1 mile to the interchange), the implementation of access control mechanism might be reserved in avoidance of shifting congestion from I64 freeway to the intersecting US61/67 highway.

Congestion pricing

As the bottleneck is located on the major accessing corridor to St Louis city and it carries large traffic, charging variable price to vehicles is considered to control the total demand and keep a reasonable speed on the I64 facility. However, without any widening construction, the limited number of lanes (i.e. 6 lanes on both directions on the I64) does not support the application of this measure.

Pre-travel/In-travel information

The successful implementation of offering pre-travel/in-travel information to mitigate bottleneck depends on the availability of other route. The value of the bottleneck activation information diminishes if the bottleneck is on the facility that a traveler or a truck driver has to pass. Therefore, it's necessary to examine whether additional routes are available to accommodate route-shifted vehicles. However, the route shifted is determined by the origin and destination, which vary from trip to trip. In order to simplify the procedure, only the parallel and close sections to the bottleneck are examined. By examining the network around the interchange location, it's found that vehicles traveling east-west bound between Chesterfield and Richmond Heights have few alternatives route besides the I64 highway. The only parallel road to the I64 within two 2 miles is Ladue road on the south of I64 and only one lane is provided for each direction, which does not favor the operation of heavy vehicles. The lack of alternative road limits the effect of pre-travel/in-travel information to alleviate bottleneck condition.

Vehicle-infrastructure integration

As discussed above, VII technology (as considered here, concerning the platooning of truck fleets) may not be appropriate for this location, as it is located in a congested corridor within a major metropolitan area. The proximity of this bottleneck to several other access points would require platoons to accommodate too many merging and weaving vehicles, reducing the efficiency of such a “train on wheels”. Other VII applications, such as anti-rollover technologies, could be of beneficial use, however.

Modal shift

In theory, modal shift can be an effective strategy in any location where bottlenecks feature appropriate proximity to other modes of freight transport with adequate capacity. This location is approximately five miles from the nearest potential container yards or transfer facilities (in Maplewood and Fenton), but the ownership, use, and capacity of these facilities would determine whether or not any shift from truck to rail freight would be appropriate. Other factors to consider would be the origin/destination of individual shipments and scheduling concerns.

Shoulder pavement

The shoulder pavement is a low-cost measure to increase freeway capacity by using the wide-enough shoulder as an addition travel lane during either the peak period or throughout the entire day. Restriping of the lanes is usually necessary to re-distribute width of the remaining shoulder and/or re-assign the width of lanes for more narrow lanes. According to the NCHRP report (1995), the combination of the use of shoulders and narrow lanes is not recommended in the presence of significant truck traffic proportion during peak periods (i.e., 5 to 10 percent). Because our study focuses on the freight bottleneck where large truck traffic volume exists, only the shoulder pavement is considered as a mitigation measure, not lane narrowing. Considering the safety issues and operation features, roadway shoulders of more than 12 feet in width at either side can be potentially converted into additional travel lanes to accommodate more traffic. Shoulders of between 10 and 12 feet in width are also worthy of consideration as travel lanes to increase capacity. However, due to the limited width, truck traffic might be prohibited on these lanes. Careful planning and design should be performed when implementing the shoulder pavement to avoid any potential safety problems.

As 2-foot shoulders are available on both sides of the mainline in this case, the paved shoulder is not considered appropriate as an additional travel lane. This potential measure is eliminated from the solution list for this interchange bottleneck.

HOV lanes

As a measure to encourage the car pooling by providing separate lane for passenger cars with a driver and one or more passengers, the high occupancy vehicle lane is usually implemented in urban areas. In order to ensure the smooth flow on general traffic lanes, HOV lanes are more likely to be considered where 4 or more lanes exist in each direction before separating the HOV lane. Because only 3 lanes are available for each direction at the I64 bottleneck location, the HOV lane is not recommended to mitigate congestion here.

Express lanes

The express lane, separated from general-purpose lanes and managed with limited number of entrance and exit points, facilitates through traffic along the highway. Similar to HOV lanes, express lanes are usually implemented in urban areas where more than 3 general purpose lanes are present in each direction prior to the implementation of the special-use lane. The 3-lane roadway here indicates that the express lanes measure is not appropriate in this case.

Collector-Distributor road

At the interchange location, vehicles attempting to turn left on the westbound mainline freeway and intersected northbound arterials, as well as on the eastbound mainline freeway and intersected southbound arterials, share the same sections, respectively. The merging and diverging traffic flows conflict, and vehicles with difficulties entering and exiting the freeways slow down and block the traffic behind them. In order to eliminate the impact of weaving vehicles to through vehicles on the mainline freeway, a collect-distributor road, as a separated parallel road to the mainline, is recommended to carry the weaving vehicles.

Widening

As indicated by the data item Widening Feasibility in the HPMS sample database, no room is available to add additional lanes to the original facility. The aerial photo derived from Google Map confirms the infeasibility of widening highway, showing that residential and business facilities locate close to the interstate highway, which will restrict the ability to add more lanes to the highway.

7.2.2. I270 Lane Drop Bottleneck

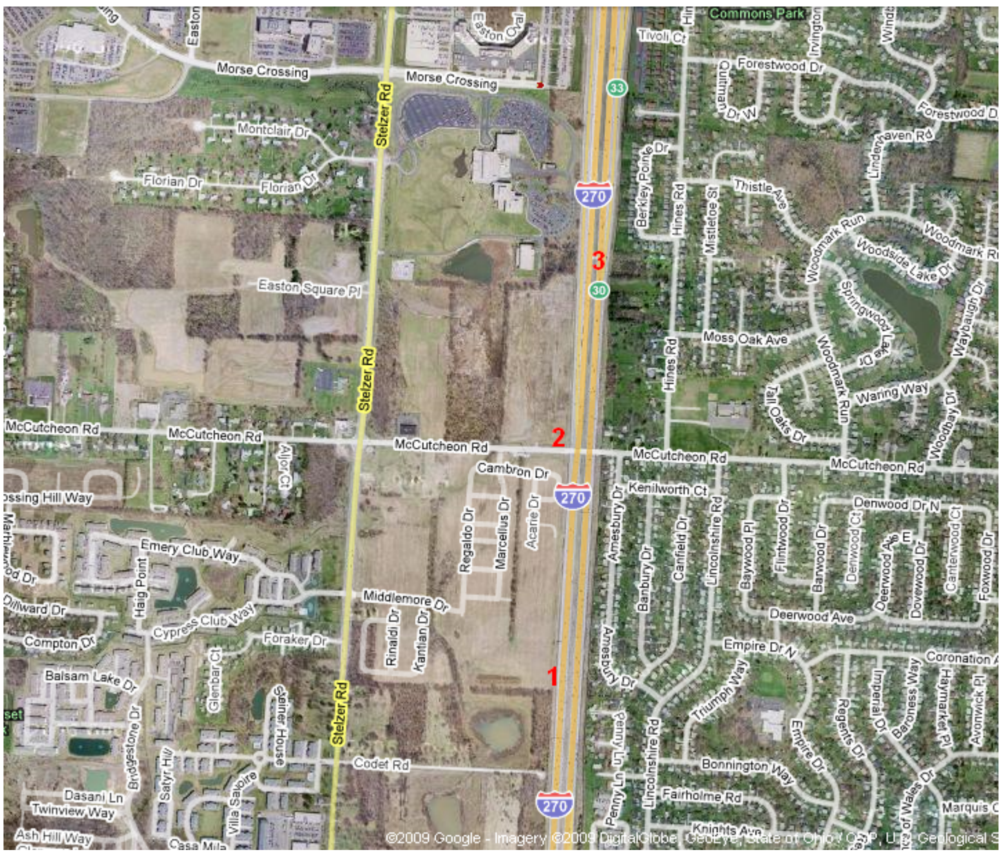


Figure 36. Lane Drop Bottleneck on I270 in Columbus, OH

7.2.2.1. Bottleneck Description

Through the inspection of HPMS database and Google Map, the following geometric and operational conditions are identified at a lane drop bottleneck on I270 in Columbus, OH:

1. 6-lanes corridor merges into 5 lanes on the southbound I270 freeway.
2. 3-lanes separated highways, including 1 on-ramp lane, add back to the 3 lane mainline I270 freeway on the southbound.
3. 3-lanes, one of which serves as off-ramp to Easton way, splits from the 6 lanes corridor on the southbound I270 freeway.
4. 10-foot shoulders exist on both sides of roadway for each direction.

5. Widening of lanes is feasible and 3 lanes or more could be added when considering the physical features along the roadway section, medians and other areas already within the right-of-way to be available for widening.
6. Trucks take up significant proportion of the total traffic volume (i.e. 10%).
7. No HOV lane exists on the facility
8. Lane width is 12 feet

According to the geometric information above, the major bottleneck is most likely to happen at the location where 6 lanes corridor merges into 5 lanes on the southbound of I270 freeway. As number of vehicles increases, vehicles compete for the decreased right-of-ways, speed becomes slow down and a traffic queue develops.

7.2.2.2. Mitigation Measures Identification

The potential measures to eliminate the bottleneck include:

- Truck lane dedication
- Pre-travel/In-travel information
- Congestion pricing
- Access control
- Vehicle-Infrastructure Integration
- Modal shift
- Shoulder pavement
- HOV lanes
- Widening

7.2.2.3. Feasibility Examination

Truck lane dedication

According to the criteria presented here, truck traffic does not account for a sufficient percentage (10 percent, as opposed to the recommended 20 percent) for the consideration of dedicated lanes along this route.

Pre-travel/In-travel information

By examining the traffic network around the bottleneck location, it is found that north-south traffic has few alternative roadways other than I270, especially for the southbound traffic heading toward Whitehall. Therefore the lack of alternative roadways would limit the effect of pre-travel/in-travel information on mitigating bottleneck conditions.

Congestion pricing

The major through traffic is carried by the I70 and I71 freeways for east-west and north-south travel, respectively. The I270 freeway primarily serves as a beltline around the Columbus metropolitan area. In addition, only 6 total lanes are available in both directions on I270. Therefore the congestion pricing strategy is not recommended to alleviate congestion on this facility.

Access control

Along the I270 highway between the interchanges at US 161 and US 62, two on ramps are provided allowing traffic from Morse Road and Easton Way to enter the I270 freeway. In order to reduce the impact of on-ramp traffic to the through smooth traffic, metered signals could be implemented at the on-ramps to restrict the number of vehicles entering the mainline. Under the severe congestion condition or during the peak period, the two on ramps could be temporarily shut down to divert the north-south traffic and eliminate the impact to mainline traffic.

Vehicle-Infrastructure Integration

As with the I64/US61-67 bottleneck, this location is most likely too heavily congested for the practical implementation of VII technology as it pertains to truck platooning.

HOV lane

Because only 3 lanes are available for each direction at the I270 bottleneck location, the HOV lane is not recommended to mitigate congestion.

Modal shift

Although the capacity of the network is unknown within the context of this research, Columbus is served by north-south and east-west rail lines, which are accessible within 5 to 7 miles of this bottleneck location. Standard considerations for cost effectiveness, etc., as previously discussed, obviously apply to this location. Columbus is not located in a convenient place for truck to waterborne modal shift.

Shoulder pavement

It is recommended to convert the shoulder on one side of the roadway into an additional travel lane at the segments where only 5 travel lanes are available. The use of shoulders as travel lanes could be restricted during the peak period since the travel demand during off-peak periods is not very intense and the original 5 lanes might accommodate them. Because the shoulder width on both sides is 10 feet, it is possible to use this space for passenger vehicles (but not large trucks) when the facility is over capacity.

Express lanes

The three-lane roadway indicates that the express lanes measure is not appropriate in this case.

Widening

As indicated by the data item Widening Feasibility in the HPMS sample database, three lanes or more could be added to the original roadway. By examining the land use around the bottleneck location, it is further confirmed that the widening of the facility is feasible.

7.2.3. West Irving Park Rd Signalize Intersection Bottleneck

Figure 37. Signalized Intersection Bottleneck on West Irving Park Rd in Chicago, IL

7.2.3.1. Bottleneck Description

On the 0.49 mile 4-lanes section of West Irving Park road, the following geometry and operation design characteristics exist:

1. At-grade signal controlled intersection at West Irving Park road and North Kedzie avenue
2. At-grade signal controlled intersection at West Irving Park road and North Sacramento avenue
3. At-grade signal controlled intersection at West Irving Park road and North California avenue
4. Intersected with N Troy St, N Albany Ave, N Whipple St, N Richmond St, N Francisco Ave and N Mozart St, which are one-way streets controlled by stop sign.
5. The traffic signals have uncoordinated fixed time (may include pre-programmed changes for peak or other times) and the typical percent green time of traffic signals at peak period is 50 percent.
6. Exclusive left-turn lanes are available at each intersection where through movements are prohibited in these lanes.
7. Street parking is allowed on both sides of the road. Barrier curbs exist, with no shoulders in front of the curb
8. Widening of lanes is feasible and three lanes or more could be added when considering the physical features along the roadway section, medians and other areas already within the right-of-way to be available for widening.
9. Trucks account for a significant proportion of the total traffic volume (i.e. 27%)
10. AADT: 39796 K factor 8 Direction factor 55
11. Curbed median type, whose width is 12.

7.2.3.2. Mapping the Mitigation Measures

The potential measures to eliminate the bottleneck include:

- Pre-travel/In-travel information
- Congestion pricing
- Modal shift
- Additional general lane
- Signal optimization
- Widening

7.2.3.3. Feasibility Examination

Pre-travel/In-travel information

According to the visual inspections of traffic networks in Chicago area, two alternative routes, West Montrose Avenue and West Addison Street, are identified, which are four blocks away from the congested West Irving Park Road, respectively. To justify the use of the alternative routes and avoid shifting congestion from original bottleneck to alternative sections, traffic conditions on them should be examined. However, due to the lack of traffic information on local streets, the examination is left to local traffic agencies for further inspections.

Congestion pricing

For this signalized intersection bottleneck on urban arterial in Chicago, the condor area or area wide charging is a potential solution to reduce the total traffic demand and encourage the use of public transit by charging vehicles entering the Chicago metropolitan area. But a careful inspection on public acceptability should be conducted, as well as on charging patterns and the distribution of revenue, which all significantly influence the effect of the mechanism.

Modal shift

The Chicago area is served by a number of major freight rail operators, and several rail facilities exist in close proximity to this bottleneck location. However, rail congestion in the area is notoriously severe, which will reduce the effectiveness of truck to rail modal shifts until such congestion is alleviated through rail improvement projects. Depending on all of the standard considerations for cost-effectiveness, some shipments could also be diverted via waterborne transport along the Chicago River, which is not far from this bottleneck.

Additional turning lane

The exclusive left-turn lanes exist as additional lanes to the four lanes at each intersection and street parking is allowed on the both sides of the roadway. However, the close distribution of intersections restricts the length of left-turn lanes and there is no exclusive right-turn lane on this section. If the left-turn and right-turn traffic volume are high, the traffic queues waiting for turning left/right tends to propagate to the through traffic lanes. Especially, the high percent of truck volume (27 percent) aggravates the bottleneck problem due to the difficult turning maneuverability of trucks. Therefore the additional general lanes are necessary if large volume of left-turn and/or right-turn traffic exists.

Signal optimization

According to the HPMS database, the traffic signals on this section are uncoordinated and have fixed time, whose typical green time at peak period is 50 percent. In order to improve the operational efficiency, continuous traffic signals are suggested to achieve a progressive traffic flow. In addition, even though green time is currently 50 percent, the large volume of passenger cars and trucks suggests the optimizing traffic signal timing could potentially improve the bottleneck condition.

Widening

According to the data item “widening feasibility”, which exams the physical features along the roadway section, medians and other areas already within the right-of-way, three lanes or more could be added to the original roadway. The increase in traffic capacity introduced by the additional lanes would accommodate the large volume of the traffic and alleviate the bottleneck condition.

7.2.4. I64 Steep Grade Bottleneck

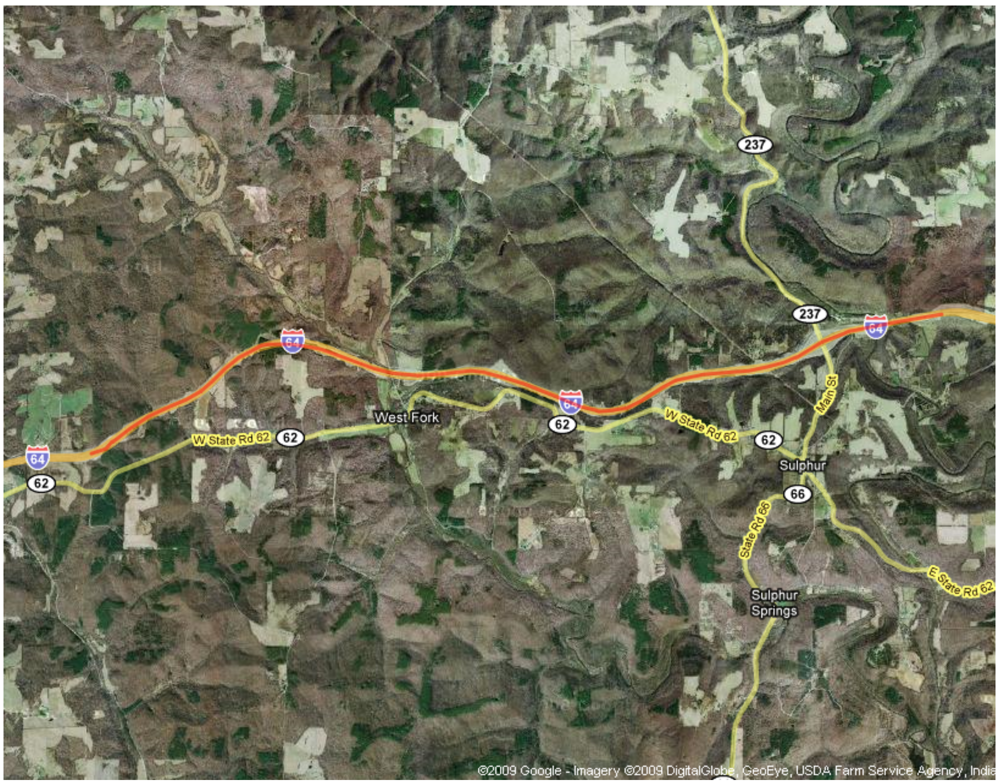


Figure 38. Steep Grade Bottleneck on I64 in IN

7.2.4.1. Bottleneck Description

This 7.01 mile section of 4lane highway on I64 in Indiana consists of 1.61 miles of roadway with grade 0.0-0.4, 0.71 miles of roadway with 0.5-2.4, 2.29 miles of roadway with grade 2.5-4.4, 0.4 miles of roadway with and grade 4.5-6.4 and 2 miles of roadway with grade 6.5-8.4. Besides the varying grade distribution on this section, the following features are identified:

1. For the both directions, 12-foot shoulders exist on the right-hand side of the roadway and 4-foot left shoulders exist on the left-hand side of the roadway.
2. Trucks account for 38 percent of the total amount of traffic.
3. Widening of lanes is feasible and three lanes or more could be added when considering the physical features along the roadway section, medians and other areas already within the right-of-way to be available for widening.

The continuous steep grade condition at the facility makes it difficult for the operations of heavy vehicles. This is compounded by the significant proportion of heavy trucks (38%), which limits the speed of overall traffic.

7.2.4.2. Mapping the Mitigation Measures

The potential measures to eliminate the bottleneck include:

- Truck lane dedication
- Vehicle-infrastructure integration
- Pre-travel/In-travel information
- Modal shift
- Shoulder pavement
- HOV lanes
- Express lanes
- Additional general lane
- Widening

7.2.4.3. Feasibility Examination

Truck lane dedication

The presence of large proportion of truck traffic leads to the consideration of truck dedicated lane. However, the high truck percentage alone does not warrant the implementation of this mitigation measure. By examining the number of lanes on the facility, it's found that there are two lanes on each direction. Without the construction of additional lanes, the implementation of a dedicated truck lane would leave only one lane for the general traffic, resulting in the difficulties in passing for passenger cars. Given that additional lanes are possible in this location (according to HPMS data), dedicated truck climbing lanes could be an appropriate strategy.

Vehicle-infrastructure integration

VII technology could be used to build truck platoons near this location, as it is in a rural area removed from dense access points. This technology could be used in combination with truck lanes (if they were to be implemented) to make climbing and drafting more efficient, as well.

Modal shift

Given the proximity to the Ohio River, truck to waterborne modal shift is an appropriate strategy for this bottleneck location, provided the standard considerations for cost efficiency are met. Rail facilities may be within a reasonable distance to shift modes, but they are not in immediate proximity to this location.

Pre-travel/In-travel information

Drivers traveling on I64 could divert to state highway 62, which is a parallel road to the I64 highway, to avoid potential congestion on I64. But it should be noted that because only one lane is provided on the state highway for each direction, this road is not able to accommodate large traffic volumes and the route-shift is only a temporary alternative.

Shoulder pavement

The 10-foot right shoulder could carry passenger cars and therefore supports the shoulder pavement measure. But heavy vehicles should be prohibited to use the this additional lane due to safety and operational concerns.

HOV lanes

Because the bottleneck is located in a rural area with 2 lanes available on each direction, the HOV lane is not considered as an appropriate measure.

Express lanes

Similar to the HOV lane measure, the implementation of express lane is not considered due to the limited number of lanes and location of the bottleneck.

Widening

As indicated by the data item Widening Feasibility in the HPMS sample database, three lanes or more could be added to the original roadway. By examining the land use around the bottleneck location, it is further confirmed that the widening of facility is feasible.

7.2.5. Examination of Top Freight Bottlenecks

The same analysis approach is applied to each of the freight bottlenecks ranked within top 100 to identify appropriate bottleneck alleviation strategies. It should be noted that some strategies, such as pre-travel/in-travel information, almost applies to everywhere, but the effectiveness is determined largely by the behavior characteristics of travelers and truck drivers. Without further information, it would be aggressive to eliminate or advocate strongly the strategy. Therefore they are just recommended for consideration for each bottleneck. The results are shown in Appendix B.

7.3. Discussion about Implementation of Alleviation Strategies

Besides the physical constraints determining the feasibility and applicability, the successful implementation of alleviation strategies also relies on the following actors.

7.3.1. Work Zone

One issue of primary concern during roadway construction is setting-up of work zones. Due to the capacity lost for work zones, usually additional delay is triggered at the construction site. As indicated by FHWA (FHWA, 2005), approximately 10 percent of highway congestion results from work zones. Without appropriate design, the congestion caused during construction could outweigh the benefits of roadway improvement for single project.

Safety issue has long been recognized as another concern of work zones. In 2003, motor vehicle crashes in work zones cause 1,095 fatalities, and 41,000 people injured (National Work Zone Safety Information Clearinghouse Work Zone Fatalities; US Department of Transportation, 2002). Most of the crashes are resulted from poor signage, lack of public awareness and inappropriate setting-up at work zone locations.

In order to improve mobility and safety of motorist at construction site, and minimize the effect of work zones to daily travels, FHWA have identified various work zone traffic management strategies, and indicates that the implementation should take into account of project constraints, construction phasing/staging plan, type of work zone and anticipated work zone impacts (FHWA Work Zone Mobility and Safety Program). Among the strategies developed, the following are highlighted and encouraged as new ways of designing and building roads:

- Accelerated construction to complete the roadwork in a timely fashion
- Full road closure and lane closure to eliminate the exposure of motorists to work zones
- Night work/off peak work to alleviate the disruption in traffic flow
- Positive separation balancing the need for traveler mobility

7.3.2. Benefit-Cost Analysis

The roadway constructions not only cause extra delay, they also require vast investment as well. In this sense, a comprehensive benefit-cost analysis is essential to justify taxpayer dollars. The analysis needs to identify a diverse range of economic, social, and environmental impacts from both positive and negative sides to the greatest extent possible. During the identification process, a clear typology is helpful to avoid double counting benefits or costs. The second task is to quantify the impacts in terms of monetary values accurately. And a discounting rate is used to account for the difference between the perceived value of a dollar at presence and past.

7.3.3. Generated Traffic

The induced traffic is known as a notorious side-effect of new roadway constructions. It consists of diverted traffic shifted from other times, routes and destinations, and induced vehicle travel shifted from other modes, longer trips and new vehicle trips. These new demands usually company the additional capacity and tend to increase until a new congestion is reached. As estimated by Hansen and Huang (1997), every 10 percent increase in lane mile capacity results in 9 percent of traffic. The induced traffic diminishes benefits of highway improvement and therefore traffic planners and engineers have been conservative to solving traffic congestion by widening original roadways or constructing new highways.

The intuitive approach to avoid the vicious cycle of induced traffic is to use alternative solutions instead of simply expanding roadways. The site-specific improvement strategies and demand decrease measures are of potential considerations. However, when the increase of lane-miles is identified to be necessary, it’s important to take into account of induced traffic demand and provide an accurate estimate of it based on effective model and/or dedicated surveys.

7.3.4. Social and Political Concern

The implementation of some bottleneck alleviation strategies is more limited by public and political concerns rather than construction concern. For example, the congestion pricing strategies, as an economic solution to encourage car sharing and travelling in transits, has been advocated widely by researchers for long time. However, it’s another story in making the public to realize and appreciate the benefits of implementing congestion pricing. Usually, people would only recognize that they are charged extra money without understanding the potential value of time saved.

Also, there are some political issues regarding with the implementation of congestion pricing strategy, including the distribution of revenues, the equity between the rich and the poor, and so on. Without satisfyingly addressing these issues, some bottleneck mitigation measures could easily fail to serve the purpose or be called off soon.

7.4. Summary

In conclusion, the bottleneck alleviation strategies should be identified based on the bottleneck constraints, geometric and operational designs of the original network, and budget plan. Besides these factors, the implementation of bottleneck alleviation strategies is also of social and political concerns. In order to achieve the maximum benefits in a cost-effective way in addressing bottlenecks, the coordination and cooperation among various sectors is encouraged.

8. Conclusion

General congestion throughout the nation's roadways has received considerable attention throughout the years, whether in academic research, transportation planning and practice, or the popular media. But this attention, while certainly justified, has rarely examined freight congestion explicitly. Recognizing this gap, this research develops a framework to identify, characterize and prioritize regional freight bottlenecks. Such an analysis is of critical importance for the economic competitiveness and general standard of living throughout the region. The results of this analysis demonstrate a number of trends and outliers, and point to several directions for future research.

The methods and analysis presented here comprise a valuable tool for freight transportation authorities and operators in the assessment of network efficiency and services. Freight congestion has been a concern throughout the Upper Midwest for some time, and it warrants an intense and comprehensive analysis of its causes and solutions. Cooperation, not only between states but also between the public and private sectors, is vital to ensuring that valuable and limited resources are distributed such that they reduce freight congestion in a prudent and cost-effective manner. The resultant easing of freight congestion, regardless of mode, will have substantial benefit for all travelers, consumers, and the business community.

8.1. Summary

8.1.1. Research Methodology

This research is based on data analysis and collaborative efforts with public agencies and stakeholders. The methodology developed to examine highway freight bottlenecks employs HPMS data, which is selected after an extensive exploration of available data and comparisons among various data sources. The original HPMS database is mapped onto the NHPN network through a dynamic segmentation process, and detailed traffic information on sampled sections is extrapolated to universe sections for freeways. This research adopted the bottleneck typology developed in a previous FHWA study, which classify bottlenecks by the type of constraints, including interchange, lane drop, signalized intersection, and steep grade.

The truck unit delay measure is proposed as an indicator of freight bottleneck. The use of this measure allows for the capture of general bottlenecks for passenger cars but also specific locations constricting the freight movement, reflected by truck traffic. This feature enables the method developed to be consistent with the study purpose and bridge the gaps in the existing literature.

In order to account for the systematic congestion caused by interchange bottlenecks, a congestion corridor growing method is incorporated in the analysis framework. The method uses each selected section with high truck unit delay as a starting point, ensuring that all congested sections are included in analysis. The congestion corridor is expanded from these sections by connecting neighboring sections with similar severity of congestion. The presence of an interchange is examined in the vicinity of most severely congested locations on each corridor built to characterize bottlenecks. Particularly, this study conducts a sensitivity analysis to quantify the concept of vicinity to interchange bottlenecks.

The analysis of rail bottlenecks is significantly limited by the absence of comprehensive regional data indicating volume, capacity, and physical constraints to the efficient transport of goods. The private and deregulated nature of the freight rail industry limits the depth of publicly available data regarding their operations. In light of this obstacle, a sampling of industry representatives are interviewed for whatever information, qualitative or quantitative, they are able to provide regarding the physical constraints to their operations.

Waterborne freight bottlenecks are similarly reviewed through a series of interviews and an examination of the available data indicating physical characteristics and delay. Measures for capacity throughout ports and the inland waterway system are limited. Anecdotal evidence of potential bottlenecks, as well as LPMS data regarding delays at locks, is examined.

8.1.2. Results and Trends

The application of the proposed methodology to the Mississippi Valley area results in a prioritized list of truck bottlenecks on the regional urban and rural freeways and other principle arterials, a series of locations considered by rail operators to be their worst bottlenecks, and ranked lists of heavily trafficked ports and delays throughout the lock network. In the truck bottleneck list, interchanges account for the highest proportion of bottleneck constraints, followed by lane drops and signalized intersection constraints. Steep grades are associated with the smallest number of bottleneck locations and relatively marginal truck unit delay because steep grade sections are usually found in rural areas where traffic demand is not as high and congestion is not as severe as that in the urban areas. The rail bottleneck locations discussed are largely the result of delays associated with shared tracks and river crossings. For waterborne freight transportation, a review of the data available through the US Army Corps of Engineers indicates that a comprehensive quantifiable connection between the physical characteristics of freight infrastructure and systematic delays cannot be established without further measures and research. Even so, the waterborne delays identified contribute to the general landscape of freight congestion. This broad snapshot of regional freight bottlenecks serves to stimulate cross-state and cross-sector dialogue among freight planners and operators and provides a basis for devising optimal alleviation plans for the greatest benefit of the region.

Not surprisingly, bottlenecks tend to be found throughout the beltways and central corridors serving urban areas. On balance, results of the truck freight bottleneck analysis trend heavily toward the major metropolitan areas in the eastern portion of the study area, although substantial delay is found in St. Louis, Kansas City, and Minneapolis. Metropolitan Chicago is the regional center for freight bottlenecks, a result of the combination of its regional prominence as a center of both population and industry and a large number of physical constraints throughout its highway network.

A series of qualitative comparisons have been conducted as a part of this study to verify analysis results to the truck freight bottlenecks identified by previous studies, local experts and roadway users. There is general agreement between study results and other sources to suggest that the proposed methodology is capable of identifying the most prevalent truck bottlenecks while also revealing additional locations that warrant further investigation. The discrepancy found between our results and those from other sources points out the sensitivity of bottleneck analysis results to the data sources used, bottleneck criteria considered, and threshold values applied. These analysis parameters have varied from study to study and from one analyst to another. This study contributes to the general body of knowledge in congestion research by proposing a different set of parameters and by presenting one of the first comparative evaluations of truck bottlenecks identified through different channels.

8.2. Limitations of Methodology

The comparative evaluation also reveals the fact that the proposed methodology is subject to the following limitations.

- As mentioned earlier, the HPMS database has a section-based structure, in which each record represents a two-way link on the national highway network. Since data are available only for these linear structures that vary greatly in length, it is impossible to pinpoint the exact location of bottlenecks using the data. Rather, one can only use the data to identify their general locality at a regional level. Similarly, our interchange bottleneck assessment is limited to identifying the most likely interchange location that may have triggered the delays experienced on the corresponding corridor. We are unable to pinpoint the exact cause of the bottleneck, which could be anything from poor ramp entering/exiting design to insufficient weaving/merging length. In order to help guide investments in bottleneck alleviation, more refined diagnoses at the state or local levels are warranted. Such further analyses would require more detailed information, including project-level traffic and roadway data, knowledge of local experts, , and microscopic traffic simulation models.
- Because at-grade intersection traffic control information (i.e. number of yield signs, stop signs and signals) and highway geometry information (i.e. curves and grades) are available only in the HPMS Sample dataset, signalized intersection and steep grade conditions can be assessed only for sampled roadway sections. The limited number of roadway sections covered by the HPMS Sample database means that a significant portion of these two types of bottlenecks would be missing from the final results. In order to improve the success rate of the HPMS-based approach, a higher sampling rate for the HPMS Sample dataset is needed.
- Since the HPMS data used in this study represent the conditions of year 2006, the analysis results may not accurately represent the regional bottlenecks of today. In fact, several of the top-ranked highway bottlenecks have been addressed by their respective states since 2006. The 2006 data was used because it was the latest publically available version at the time this research was conducted.
- This study relies on truck traffic to represent freight movements across the region. However, the bottleneck impact to freight movements is quite different between the cases where trucks are fully loaded and empty. The accurate estimation of truck loading condition requires sophisticated commodity flow models, which indicate the tons and type of commodities carried by trucks. Without such information, it’s impossible to further assess how freight flow is affect by the presence of bottlenecks.
- The state of rail and waterborne freight transportation are not represented with the depth that would be required to more accurately measure bottlenecks throughout these modes. As a result, the cross-modal comparison as suggested in the research objectives is not possible. For example, though this research achieves a preliminary identification of rail bottleneck locations, these are subject to the subjective willingness of private operators to provide such information. The locations listed here present only that portion of rail bottlenecks that have already been publicly identified through other initiatives (such as CREATE). It is more than likely that many other bottleneck conditions exist, but until more comprehensive data becomes widely available this constraint will continue to be a substantial obstacle in freight research.

8.3. Directions for Future Work

The research team has identified a number of future research directions as a result of this study.

- Because of its inherent limitations, the HPMS database prevents the comprehensive identification of bottlenecks with certain types of constraints and the ability to pinpoint exact locations of bottlenecks. Additional individual state roadway databases providing greater coverage and more detailed data, some of which already exist, are desirable to supplement national level database. A possible solution is to supplement national database with high-resolution aerial photos, from which the detailed roadway information including ramp design, intersection position, weaving patterns, etc. could be identified. Meanwhile, it is important to incorporate project-level data and local knowledge to refine bottleneck identification results from data analysis.

- The lack of suitable data regarding rail and waterway use for freight transportation presents a major obstacle in freight bottleneck research for these modes. In order to establish an in depth and accurate understanding of these modal performances, more coordinated and comprehensive freight data programs at the federal, regional and state levels are needed. Steps towards such data programs may include:
    - Develop state and national freight advisory committees to improve data collection for freight planning efforts.
    - Establish a federal requirement to report / collect freight modal data.
    - Create a regional data standardization project to support corridor planning.
- Another interesting research direction is the examination of size and type of commodities carried by trucks. Combined with truck traffic data, this information would allow us to quantify the types, amount, and values of goods movement stuck at bottleneck locations. Bottlenecks, and their corresponding alleviation projects, could therefore be prioritized in terms of their economic impacts on freight movements. For example, a bottleneck experienced predominately by empty trucks could be ranked as of a lower priority than a bottleneck experienced predominately by high-value, time-sensitive goods.

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Appendix A: Web-Based Survey Questionnaire

1. How would you characterize your company?
   a. Independent Carrier: You are an individual owner-operator/trucker.
   b. Private Carrier: Your company owns and operates its own private fleet.
   c. Common Carrier: Your company offers transportation service to the general public over regular and irregular routes.
   d. Contract Carrier: Your company offers transportation service to certain shippers under specific contract.
2. What kind of transportation services does your company provide?
   a. Truckload
   b. Less-than-truckload
   c. Distribution and warehousing
   d. Parcel pickup/delivery
   e. Air freight specialist
   f. Freight forwarding
   g. Drayage
   h. Other (please specify)
3. What kind of vehicle do you drive?
   a. Straight truck
   b. Straight truck and trailer
   c. Tractor only
   d. Tractor and trailer
   e. Tractor with two trailers
   f. Tractor with three trailers
   g. Other (please specify)
4. What types of technology is your truck equipped with? (please specify all that apply)

    a. Radio (one way or two way?)
    b. GPS
    c. internet
    d. On-board remote communications
    e. Other (please specify)
5. What geographic area do you typically operate in? (please select all that apply)
    a. Intra-county (please specify county)
    b. Intra-state (please specify state)
    c. Inter-state (please specify states)
    d. International (please specify border)
6. How time-sensitive are the typical loads that you haul?
    a. Not time-sensitive
    b. Must be delivered within ___ hours (please specify) within scheduled time
7. What are the primary commodities that you typically haul?
    a. Agriculture (e.g. farm/ forest/ fish/ marine products)
    b. Primary metals
    c. Food
    d. Fabricated metal products
    e. Coal
    f. Construction materials (including clay, concrete, glass, stone products)
    g. Other minerals (e.g. non-metallic minerals, ordinance or accessories)
    h. Lumber (excluding furniture)
    i. Paper
    j. Rubber/plastics
    k. Metallic ores
    l. Transportation equipment
    m. Chemicals
    n. Durable manufacturing (e.g. leather products, electrical machinery, optical goods, watches, clocks)
    o. Non-durable manufacturing (e.g. tobacco, textile, furniture, printed matter)
    p. Petroleum
    q. Miscellaneous freight (e.g. including hazardous materials, parcels, waste substances)
    r. Other (please specify)

The Dispatcher version followed the same format and featured most of the same questions. Question #6 was extracted from the Dispatcher version, and Question #3 was replaced with the following:

3. What size is your company's vehicle fleet (power units)?
    a. 1-5 trucks
    b. 6-20 trucks
    c. 21-50 trucks
    d. More than 50 trucks

The second portion of the survey asked respondents to for the spatial and temporal identification of bottleneck conditions, through a map of the region and several questions regarding the response.

The map allowed the user to pan and zoom through the region, so that he or she could pinpoint the exact problem location. Locations could also be found through a series of menus along the left side of the screen; users could search by State, City, City and Highway, Interchange Name, or Landmark. Once the location was found, users added a bottleneck marker to the map and answered a series of questions about the characteristics of congestion associated with that location:

1. When bottleneck conditions occur at this location, what is the average speed that you could travel?
2. In your opinion, what is the probable cause of this bottleneck? (please check all that apply)
    a. Lane drop
    b. Poor ramp design
    c. Inadequate capacity
    d. Steep grade
    e. Narrow turning radii
    f. Closely-spaced intersections/interchanges
    g. Insufficient weaving/ merging length/ lanes
    h. Toll barrier/ inspection stations
    i. Rail-grade crossing
    j. Poorly timed signal
    k. Poor signage
    l. Frequent incidents
    m. Lack of shoulder
    n. Other (please specify)
3. Is this bottleneck location on a route that you regularly travel?
    a. No (please skip to Question #6)
    b. Yes
4. If this bottleneck is on a regular route, what are the origin and destination of this route?
    a. Origin: City _______ State__
    b. Destination: City _______ State__
5. If this bottleneck is on a regular route, how often to you haul along this route?
    a. A few times a day- How many? ____
    b. A few times a week- How many? ____
    c. A few times a month- How many? ____
    d. A few times a year- How many? ____
6. Is the bottleneck condition at this location worse at a certain time of the year?
    a. No
    b. Yes- When is that? (please select all that apply)
        i. Winter
        ii. Spring
        iii. Summer
        iv. Fall
        v. Snowy/icy times
        vi. Rainy times
        vii. Other (please specify)
7. Is the bottleneck condition at this location worse at a certain time of the week?

    a. No
    b. Yes- When is that? (please select all that apply)
        i. Weekdays
        ii. Saturday
        iii. Sunday

8. Is the bottleneck condition at this location worse at a certain time of the day?
    a. No
    b. Yes- When is that? (please select all that apply)
        i. Early morning
        ii. Morning rush hour
        iii. Midday
        iv. Afternoon rush hour
        v. Late evening
        vi. Night time
9. Do you, as a driver, have any alternatives to avoid the bottleneck identified above?
    a. No
    b. Yes- What do you do? (please select all that apply)
        i. Re-schedule
        ii. Re-route
        iii. Other (please specify)
10. What improvement would you suggest to help alleviate this bottleneck?

Appendix B: Highway Bottleneck Identification Results and Recommendation of Alleviation Strategies

Rank	Bottleneck Location	State	AADT	AADTT	Truck Unit Delay	Existing Constraints				Alleviation Strategies Recommended												
						Inter-change	Lane drop	Signal control	Steep grade	A·	B	C	D	E	F	G	H	I	J	K	L	M
1	I-90/I-94 at W North Ave. Interchange	IL	319,968	25,597	311,046	X						+	+		+		+	++				+
2	W 14 Mile Rd Begin Milepost: 1.04	MI	55,934	17,340	272,392		X	X				+			+						++	
3	I-88 at I-290 Interchange	IL	199,626	17,966	264,096	X	X					+			+	++						++
4	I-71 at I-65 Interchange	KY	141,927	22,708	255,645	X	X					+			+	++						
5	I-90 at I-94 Interchange Edens Interchenge	IL	295,626	19,216	250,138	X	X					+			+		+		+			++
6	I-80/I-94 at SR 912 Interchange	IN	159,500	55,825	237,519	X				+		+			+	+	+					+
7	I-90/I-94 Begin Milepost: 93.62	IL	228,074	18,246	221,771		X					+			+		+					++
8	I-290 at SR 12/20/45 Interchange	IL	208,718	18,785	203,947	X						+			+	+	+		+			+
9	I-71/75 at I-275 Interchange	KY	179,640	28,742	201,863	X	X			+		+			+		+					++
10	I-75 at I-280 Interchange	OH	88,388	19,003	201,208	X	X					+			+	++						
11	I-57 at I-94 Interchange	IL	146,347	16,830	198,018	X	X					+			+							++
12	I-290 at I-355 Interchange	IL	204,905	18,441	192,597	X	X					+			+	++	+					++
13	I-35 @ Avenida Cesar Chavez	MO	141,958	17,035	191,846	X	X					+			+				+			
14	I-465 at I-69 Interchange	IN	173,320	31,198	190,752	X				+		+			+	+	+		+			+
15	I-75 Begin Milepost: 11.88	OH	138,690	17,336	186,992		X					+			+	++						++
16	I-290 at SR 171 Interchange	IL	202,168	18,195	184,181	X						+			+	+	+					+
17	I-290 at SR 64 Interchange	IL	199,919	17,993	177,144	X						+			+	+	+		+			+
18	I-80/94 at SR 53 Interchange	IN	148,980	58,102	176,817	X				+		+			+	+	+					+

·The characters represent truck lane dedicate, access control, pre-travel/in-travel information, congestion pricing, vehicle-infrastructure integration, modal shift, shoulder pavement, HOV lanes, express lanes, collector-distributor road, additional turning lane, signal optimization and widening, respectively

Rank	Bottleneck Location	State	AADT	AADTT	Truck Unit Delay	Existing Constraints				Alleviation Strategies Recommended												
						Inter-change	Lane drop	Signal control	Steep grade	A	B	C	D	E	F	G	H	I	J	K	L	M
19	I-290 Begin Milepost: 13.88	IL	199,626	17,966	176,221		X					+			+	++	+					++
20	I-94/90 at W Roosevelt Rd. Interchange	IL	294,746	26,527	175,595	X						+	+		+		+	++				+
21	I-70 Begin Milepost: 13.21	OH	133,920	16,740	166,817		X					+			+	++						++
22	I-55 at S Damen Ave Interchange	IL	196,107	17,650	165,056	X						+			+	+	+					+
23	I-670 at I-70/SR-40 Interchange	MO	134,344	16,121	161,912	X	X					+			+							
24	I-43 at I-94/I-794 Interchange	WI	155,300	13,201	161,447	X	X					+			+	++						++
25	I-94 Begin Milepost: 62.98	IL	229,540	26,397	157,044		X					+			+		+					++
26	I-94 at W Layton Ave Interchange	WI	152,000	12,920	157,011	X	X					+			+	++			+			++
27	I-75 at W 7th /W 9th St. Interchange	OH	136,102	14,971	155,062	X	X					+			+	++						++
28	I-70 at I-71 Interchange	OH	137,530	14,441	153,060	X	X					+			+	++						++
29	I-94E Begin Milepost: 304.13	WI	145,500	13,095	152,972		X					+			+							++
30	I-290/SR 53 at SR-58 Interchange	IL	192,196	17,298	152,573	X	X					+			+	++	+		+			++
31	I-71 at I-670 Interchange	OH	155,340	12,427	151,993	X	X					+			+	++						++
32	I-94 @ I-894/US 45 Interchange	WI	155,000	12,400	151,626	X	X					+			+							++
33	I-71 Begin Milepost: 16.83	OH	134,690	14,816	149,737		X					+			+	++						++
34	I-90/I-94 Begin Milepost: 95.70	IL	284,188	25,577	146,266		X					+	+		+		+	++				++
35	I-43/I-894 at I-94 Interchange	WI	142,800	12,852	146,143	X	X					+			+							++
36	I-290 Dwight Exwy Begin Milepost: 17.65	IL	189,263	17,034	143,244		X					+			+	++	+					++
37	McMasters Ave Begin Milepost: 60.88	MO	37,556	14,271	139,304		X	X				+			+						++	
38	I-80/I-94 at SR 41 Interchange	IN	148,240	45,954	136,312	X				+		+			+	+	+		+			+
39	I-94/I-43 Begin Milepost: 72.05	WI	139,000	12,510	135,541		X					+			+							+

Rank	Bottleneck Location	State	AADT	AADTT	Truck Unit Delay	Existing Constraints				Alleviation Strategies Recommended												
						Inter-change	Lane drop	Signal control	Steep grade	A	B	C	D	E	F	G	H	I	J	K	L	M
40	Irving Park Rd Begin Milepost: 30.42	IL	39,796	10,745	132,524			X				+			+						++	+
41	I-94 at Stony Island Ave Interchange	IL	126,726	15,207	129,657	X	X					+			+							++
42	I-90/I-94 Begin Milepost: 93.35	IL	189,361	15,149	127,604		X					+			+		+					++
43	SR 60 Begin Milepost: 17.93	OH	42,070	6,311	123,187			X				+			+					+	++	
44	I-90/I-94 Begin Milepost: 94.32	IL	275,097	24,759	123,126		X					+	+		+		+	++				++
45	I-270 Begin Milepost: 8.98	OH	120,360	16,850	120,542		X					+			+	++						++
46	I-55 at Weber Rd Interchange	IL	117,508	18,214	119,029	X	X					+			+	++						++
47	I-77 at I-90 Interchange	OH	79,559	9,547	116,306	X	X					+			+	++			+			++
48	I-90 at I-294 Interchange	IL	170,689	11,095	115,772	X	X					+			+							++
49	I-294 Tri-State Tollway Begin Milepost: 12.23	IL	162,966	24,445	114,821		X					+			+		+					++
50	I-75 at 3rd St Interchange	OH	138,690	22,190	114,434	X	X					+			+	++						++
51	I-70 at Union Blvd Interchange	MO	88,220	10,586	112,464	X	X					+			+	++						
52	I-65 at I-70 Interchange	IN	151,370	34,058	112,376	X				+		+			+	+	+					+
53	I-75 at US 35 Interchange	OH	138,690	10,402	112,195	X						+			+	+						+
54	I-35 @ Southwest Trafficway Interchange	MO	122,216	14,666	110,834	X	X					+			+							
55	I-70 Begin Milepost: 232.25	MO	167,456	20,095	106,432		X					+			+	+	+					
56	I-90/I-94 at La Salle Ave Interchange	IL	222,893	20,060	105,467	X	X					+	+		+		+	++	+			++
57	I-270 Begin Milepost: 12.26	OH	116,307	16,283	102,205		X					+			+	++						++
58	I-170 at Olive Blvd Interchange	MO	120,058	14,407	102,116	X	X					+			+	++						++
59	I-480	OH	173,764	15,639	96,608		X					+			+	++	+					++

Rank	Bottleneck Location	State	AADT	AADTT	Truck Unit Delay	Existing Constraints				Alleviation Strategies Recommended												
						Inter-change	Lane drop	Signal control	Steep grade	A	B	C	D	E	F	G	H	I	J	K	L	M
	Begin Milepost: 18.26																					
60	I-170 at Olive Blvd Interchange	MO	206,652	25,832	95,820	X						+	+		+	+	+	++				+
61	I-270 Begin Milepost: 19.83	MO	164,118	19,694	95,483		X					+			+	++	+					++
62	I-80/I-294 Begin Milepost: 160.33	IL	103,723	24,894	94,080		X					+			+	+						+
63	I-77 at SR 14/SR 43 Interchange	OH	117,738	14,129	93,034	X	X					+			+	++						++
64	I-71 Begin Milepost: 14.96	OH	113,960	15,954	92,191		X					+			+	+						+
65	I-64 at I-264 Interchange	KY	156,000	23,400	89,585	X	X					+			+		+		+			++
66	I-35 at I-29/US 71 Interchange	MO	101,414	5,071	89,345	X	X					+			+	++						++
67	I-75 at US 27 Interchange	OH	170,911	15,382	88,821	X	X					+			+	++	+					++
68	US 50 Begin Milepost: 166.85	IN	31,980	5,756	88,418		X	X				+		+	+							
69	I-43 at I-894/US 45 Interchange	WI	80,600	7,254	87,745	X	X					+			+							++
70	Nicholasville Rd Begin Milepost: 2.04	KY	85,300	7,677	86,921		X	X				+			+						++	++
71	I-76/I-77 at SR 8 Interchange	OH	117,057	13,462	86,664	X	X					+			+							++
72	I-290 Begin Milepost: 23.09	IL	176,164	13,212	86,158		X					+			+	++	+					++
73	I-64 at I-170 Interchange	MO	68,434	8,212	86,134	X	X					+			+	++						++
74	US 62/SR 73 Begin Milepost: 14.86	OH	14,260	6,417	86,000			X				+			+					+	++	+
75	I-70 at I-435 Interchange	MO	114,566	13,748	81,197	X	X					+			+	++						
76	I-71 at I-275 Interchange	OH	121,303	10,917	80,338	X	X					+			+				+			++
77	I-74/US 52 at I-75 Interchange	OH	114,225	13,707	79,969	X	X					+			+	++						++
78	SR 60 Begin Milepost: 18.00	OH	42,070	6,311	79,446			X				+			+					+	++	

Rank	Bottleneck Location	State	AADT	AADTT	Truck Unit Delay	Existing Constraints				Alleviation Strategies Recommended												
						Inter-change	Lane drop	Signal control	Steep grade	A	B	C	D	E	F	G	H	I	J	K	L	M
79	I-65 at I-70 Interchange	IN	143,030	32,182	79,081	X				+		+			+	+	+					+
80	I-480 at US 422 Interchange	OH	144,064	12,966	78,461	X	X					+			+	++						++
81	John F Kennedy Exwy Begin Milepost: 79.34	IL	199,501	7,980	78,145		X					+			+		+					++
82	US 250 Begin Milepost: 2.20	OH	23,290	7,220	76,592			X				+			+					+	++	+
83	US 250 Begin Milepost: 3.15	OH	23,290	7,220	76,311			X				+			+						++	+
84	I-88 at I-290/I-294 Interchange	IL	117,214	11,721	75,858	X						+			+				+			+
85	I-70/I-71 at SR 315 Interchange	OH	72,420	6,518	75,682	X	X					+			+	++						++
86	I-70 at I-270 Interchange	OH	130,010	19,502	74,688	X	X					+			+	++			+			++
87	I-76 at I-77 Interchange	OH	122,472	9,798	74,589	X						+			+							+
88	I-465/US 421 at Shadeland Ave	IN	162,000	16,200	74,065	X						+			+	+	+					+
89	I-35W at SR 62 Interchange	MN	152,156	6,086	74,001	X	X					+			+	++						++
90	I-75 at Lewis Ave Interchange	OH	109,879	14,834	73,295	X	X					+			+							
91	I-64/US 40 at US 67 Interchange	MO	156,444	18,773	72,865	X						+			+	+	+		+			+
92	I-94 at I-294 Tri-State Interchange	IL	152,701	20,615	71,065	X	X					+			+	++	+		+			++
93	I-80 at US 6/SR 7 Interchange	IL	99,617	22,912	70,800	X						+			+	+			+			+
94	I-70 at I-270 Interchange	OH	124,520	8,716	70,216	X	X					+			+	++			+			++
95	I-270 at I-64/US 40 Interchange	MO	160,356	16,036	69,950	X	X					+			+		+					
96	I-270 Begin Milepost: 33.62	OH	158,770	16,671	69,418		X					+			+	++	+					++
97	I-270 Begin Milepost: 2.32	KY	64,883	5,839	69,002		X	X				+			+						++	++
98	Old 63 Rd	MO	25,828	4,132	68,798			X				+			+					+	++	+

Rank	Bottleneck Location	State	AADT	AADTT	Truck Unit Delay	Existing Constraints				Alleviation Strategies Recommended												
						Inter-change	Lane drop	Signal control	Steep grade	A·	B	C	D	E	F	G	H	I	J	K	L	M
	Begin Milepost: 0.77																					
99	I-270 Begin Milepost: 12.66	MO	194,326	25,262	68,592		X					+	+		+	++	+	++				++
100	East-West Tollway Begin Milepost: 139.51	IL	117,214	10,549	68,272		X					+			+							++