Literature Review:

Non-Oregon State Studies and Plans (Task 3.1)

ODOT Freight Highway Bottlenecks Project

TGM 2D-14: Technical Memo

March 2, 2016

Final

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1 INTRODUCTION AND EXECUTIVE SUMMARY

Seven (7) plans and reports are summarized in this memorandum. They represent non-Oregon, statewide bottleneck studies or highway bottleneck case studies and focus on various key data and emerging metrics of importance in the evaluation of highway freight systems performance and bottleneck assessment. To the extent possible, key findings from each study are introduced and summarized to note data sources used, available tools and methods, factors of success, lessons learned, and transferability.

To assist the reader, each of the plans and reports are briefly highlighted here, noting their key findings and chapter reference. General observations are noted at the end of this section.

Statewide Bottleneck Studies

- ✓ **Iowa** integrated statewide travel demand model and INRIX data and Bottleneck Ranking tool to list and prioritize statewide freight plan improvements (Chapter 2).
- ✓ **Florida** integrated statewide roadway characteristics inventory data, which has physical characteristics and ATR data, and INRIX traffic speed data. It also used the INRIX Bottleneck Ranking tool to identify and rank statewide bottlenecks on urban and rural freeways and highways (Chapter 3).

Highway Bottleneck Case Studies

- ✓ **University of Washington** summarizes research to compute freight performance measures (initially statewide, interstate highways only) using NPMRDS and noting its opportunities and weaknesses (Chapter 4).
- ✓ **American Highway Users Alliance** summarizes research to compute and rank freight bottlenecks (nationwide, interstate freeways only) using a combination of NPMRDS GPS probe data, freight vehicle speed data from American Transportation Research Institute and vehicle speed data from HERE North America (Chapter 5).
- ✓ **Cambridge Systematics** matched HPMS and FAF (Freight Analysis Framework) data to define and quantify truck freight bottlenecks on the national interstate system. It also references the ability to integrate general HPMS data source and methodology with FHWA's HERS model (Chapter 6).
- ✓ **University of Wisconsin** builds upon a HPMS-based data and analysis to develop a systematic framework to prioritize truck bottlenecks in the Mississippi Valley region (Chapter 7).
- ✓ **Minnesota DOT** – demonstrates use of truck GPS data, national data, local weigh-in-motion and count data sources to establish freight mobility performance measures and identify freight bottlenecks (Chapter 8).

General Observations

The studies reviewed in this report are varied in their methods, data sources and evaluation measures, which makes direct comparisons challenging. Each methodology and data source has its limitations,

which are not all summarized in this review. Some general observations about the trends and data sources include:

- The more recent studies reviewed rely, at least in part, on vehicle probe data, which is real time, all day and includes speed. Older studies use spot data sources from fixed or temporary sources.
- The newer probe data appears to provide more data coverage from a geographic perspective. But is still limited in rural locations with low volumes.
- HPMS combines data in both directions while NMPRDS does not.
- NMPRD, only available since 2013, is the only source that has a truck only data source (from ATRI).
- NMPRDS is only available for the National Highway System (NHS) although ATRI has it for a wider set of roads.
- Both probe and fixed data sources may miss delay on long roadway segments where sub segment performance may be masked by the average performance over the segment.
- Truck specific probe data has the potential to identify bottlenecks related to long steep grades rather than just congestion.
- Travel time reliability is a very applicable measure for freight evaluation and is encouraged by FHWA.
- Probe data, while providing a trove of new data potential is relatively newer and, therefore, less well understood than traditional data sources.

STATEWIDE BOTTLENECK STUDIES

2 FREIGHT PROJECT PRIORITIZATION: VALUE, CONDITION, AND PERFORMANCE (VCAP) MATRIX[1]

US DOT's *Guidance on State Freight Plans* recommends that prioritized freight project lists be developed for the multiple modes represented in the State's freight plan. From this guidance, Iowa DOT developed its methodology to prioritize its highway freight project list.

The study notes that *INRIX* traffic data for all vehicles can help identify "bottleneck" locations in Iowa and the number of times bottlenecks occurs throughout the year. INRIX data was retrieved for 2014 and overlaid with Iowa DOT truck traffic count data. INRIX bottleneck locations that occurred in each quarter of the year and had either 30 percent truck traffic *or* more than 5,000 total trucks per day were flagged as locations with potential freight mobility issues.

INRIX collects data from a variety of sources. Traffic sensors convey speed data (induction loop sensors, radar sensors, and toll tag readers), probe vehicles (with onboard GPS devices) transmit location and speed data, and INRIX Smart Dust Network, which uses a patented system to gather input points and weight information from physical sensors to calculate speed on a given road segment.

Iowa DOT also uses its iTRAM statewide travel model, which incorporates both passenger and freight rail movement components.

2.1 DATA SOURCES USED:

- INRIX
- ITRAM (Iowa's statewide travel demand model)

2.2 AVAILABLE TOOLS AND METHODOLOGY:

Iowa DOT documented a number of factors that contribute to ranking of statewide freight projects:

- Value ranking:
  - Truck vehicle travel hours
- (Roadway) Conditions ranking:
  - Pavement condition
  - International roughness index
  - Structure sufficiency rating
  - Passenger traffic
  - Single unit truck traffic
  - Combination truck traffic
  - Congestion

[1] *Source: IOWA DOT,*

- Performance (bottleneck) ranking:
    - Traffic data-occurrences of truck bottlenecks determined by analyzing INRIX traffic count data and then overlaying with IDOT truck traffic count data
- Final ranking:
    - Uses value, condition and performance rankings

Four tools are employed by the Iowa DOT:

- Iowa Travel Analysis Model (iTRAM) – value-based prioritization of known bottlenecks based on truck vehicle hours traveled (VHT). The model predicts VHT on the primary road network. An individual location's VHT can be determined by running the model with the location excluded and comparing the difference in overall VHT. The difference in overall VHT is the location's contribution.
- Infrastructure Condition Evaluation (ICE) – composite scoring of seven criteria (pavement condition, international roughness index, structure sufficiency, passenger traffic, single-unit truck traffic, combination truck traffic and congestion)
- INRIX Bottleneck Ranking tool – number of annual bottleneck occurrences
- VCAP Matrix - Final Ranking of Project Location based on an average of individual scoring and ranking using iTRAM, ICE and INRIX

2.3 SIGNIFICANT FACTORS OF SUCCESS OR *LESSONS LEARNED*:

No significant factors were readily identified.

2.4 TRANSFERABILITY (OR TRANSFERABLE MEASURES/TOOLS):

The bottleneck analysis was a small portion of a larger study and is not well documented. However, the entire study focused on freight, which makes it more applicable to the Oregon effort.

The INRIX Bottleneck Ranking tool cited by Iowa DOT identifies and ranks bottleneck locations. This tool uses detailed probe traffic data to identify and rank bottlenecks for all vehicles throughout the year. It was not based on truck only data. For a freight specific study, INRIX data requires additional analysis using unique, statewide travel demand modeling data relating to trucks. ODOT has a travel demand model similar to iTRAM, an infrastructure conditions database similar to ICE, which could be used along with INRIX or other probe traffic data to develop a similar ranking Matrix to the VCAP.

INRIX's multi-source data and Bottleneck Ranking tool would be available to ODOT by purchase. More detailed information about how the project team integrated its truck data would be necessary to replicate this methodology in Oregon but the data building blocks available in Oregon are similar.

3 BOTTLENECKS ON FLORIDA SIS, YEAR 2011[2]

Citing the *National Cooperative Highway Research Program (NCHRP) Report Volume 1: Quantifying Congestion*, FDOT defines methods to measure congestion on roadway systems, and then quantifies congestion and bottlenecks based on duration, extent, intensity, and reliability.

The study summarizes a methodology to identify bottlenecks on Florida's Strategic Intermodal System (SIS) using vehicle probe data and travel time reliability measures. Vehicle probe data was obtained from INRIX. The INRIX network includes hundreds of thousands of probe vehicles which include trucks, taxis, busses and passenger cars with onboard GPS devices. The study does not examine freight traffic data separately from passenger vehicle data. The data includes travel speed on roadways for an entire year at five-minute intervals.

Travel time reliability is a measure of consistency in travel time and is being encouraged by FHWA as a measure for managing and operating transportation systems. The top bottlenecks at the statewide and district-wide level are identified. This methodology can be used to update the bottleneck locations on Florida's SIS with the latest vehicle probe data on an annual basis.

The study notes that information about the roadway geometry at the identified bottleneck locations can help to determine the cause and suggest actions to correct bottlenecks. Identification of bottlenecks and estimation of their activation times and delay impact can aid the Department of Transportation in prioritizing relief efforts. Applying the methodology regularly, with the latest vehicle probe data, allows FDOT to track congestion trends over time.

3.1 DATA SOURCES USED:

The study used traffic data regularly collected by FDOT and purchased from INRIX.

FDOT data sources include the Roadway Characteristics Inventory (RCI) and the FDOT Traffic Monitoring Program. RCI is a computerized database of information related to the roadway network maintained by FDOT and additional roadway information as is required by federal and state reporting obligations. RCI identifies the different roadway segments with a unique roadway ID, with each segment containing information on roadway features, characteristics, and other data elements.

FDOT's Traffic Monitoring Program collects annual average daily traffic, vehicle classification, speed, and weight data from two types of sources: Telemetered (permanent) Traffic Monitoring Sites (TTMSs) and Portable Traffic Monitoring Sites (PTMSs).

INRIX collects data from a variety of sources as described in Chapter 2 of this technical memo..

[2] *Source: Florida Department of Transportation, 2011*

3.2 AVAILABLE TOOLS AND METHODOLOGY:

The study uses the following indicators of possible bottlenecks:

- a traffic queue upstream of the bottleneck;
- a beginning point for a queue;
- free flow traffic conditions downstream of the bottleneck;
- predictable recurring cause; and,
- traffic volumes that exceed capacity.

The following four (annual) performance measures were calculated for a whole year:

- **90th Percentile Travel Time –** This measure indicates that 90 percent of the time, the travel time on a roadway segment is lower than the 90th percentile value. The higher the 90th percentile travel time, the longer it takes to travel on a roadway.
- **Free-flow Travel Time –** This measure indicates the travel time on a roadway under free-flow conditions, with little to no interaction from traffic. To calculate this measure, the travel times during overnight hours are considered because of low traffic volumes.
- **Planning Time Index –** The planning time index is computed as the 90th percentile travel time divided by the free-flow travel time.
- **Frequency of Congestion –** Expressed as the percent of time that travel speeds fall below 75% of the free-flow speed during daytime. The higher the frequency of congestion, the longer the roadway is congested.

Bottlenecks were identified using a combination of the **planning time index** and **frequency of congestion**. Both congested roadways and bottlenecks were identified as follows:

- **Congested Roadways** – The portion of the roadway network with planning time index greater than 3.0 (for freeways) and 2.0 (for arterials) or frequency of congestion greater than 40 percent is identified as a *congested roadway*.
- **Bottleneck** – The portion of the congested roadway network which has the highest combination of planning time index and frequency of congestion is identified as a *bottleneck*.

The report provides a detailed description and summary of how INRIX data is processed and used to calculate the performance measures using *Oracle software.* The final step involves the statistical validation of performance measures.

3.3 SIGNIFICANT FACTORS OF SUCCESS OR *LESSONS LEARNED*:

Florida SIS includes both urban and rural freeways and highways, but not a comprehensive coverage of all state highways (urban and rural).

The study notes that, historically, the most common measures of congestion used by agencies were volume-to-capacity ratio, vehicle hours of delay and mean speed. Recent research efforts, including those by FDOT, identifies the importance of using **travel time** and **reliability** as measures of congestion. FHWA provides a methodical approach for agencies considering adoption of reliability measures. This methodology was used as the basis to identify bottlenecks and congestion on Florida's SIS network.

Bottlenecks were identified based on the following sets of parameters:

- Auto mode along the general purpose lanes and HOV lanes are considered.
- Bottlenecks are identified based on weekday travel patterns along the SIS network. For the purpose of bottleneck identification, weekday is considered as Monday through Friday.
- Travel time reliability measures are used to identify bottlenecks. Travel time reliability allows agencies to evaluate the performance of a facility beyond just the peak hour, and to consider operations over a longer period of time. Travel time reliability is defined as how much travel times vary over a specified duration.
- Annual trends of travel time reliability measures will be prepared.

3.4 TRANSFERABILITY (OR TRANSFERABLE MEASURES/TOOLS):

The FDOT bottleneck methodology is more clearly outlined than Iowa's, would more easily be implemented in Oregon and could cover all Oregon's urban and rural highways. However, it was a general bottleneck study and not limited to freight.

The INRIX data and Bottleneck Ranking tool cited by FDOT identifies and ranks bottleneck locations. ODOT has an infrastructure conditions database similar to RCI and a traffic monitoring system, both of which could be used along with INRIX or other probe traffic data to develop a similar ranking Matrix.

The INRIX multi-source data and Bottleneck Ranking tool would be available to ODOT by purchase.

The travel time based measures used in this study speak to travel reliability, which is important for freight operations.

HIGHWAY BOTTLENECK CASE STUDIES

4 DEVELOPING A SYSTEM FOR COMPUTING AND REPORTING MAP-21 AND OTHER FREIGHT PERFORMANCE MEASURES, 2015[3]

This report documents the use of the National Performance Monitoring Research Data Set (NPMRDS) for the computation of freight performance measures on Interstate highways in Washington State. The report documents the data availability and issues identified with NPMRDS. It then describes a recommended initial set of tests that are needed before WSDOT begins producing freight performance measures. A subset of those metrics was tested using NPMRDS data, including delay and frequency of congestion, to illustrate how WSDOT could use the freight performance measures. Finally, recommendations and the next steps that WSDOT needs to take are discussed.

This report describes the outcome of the initial exploration of the National Performance Research Monitoring Data Set (NPMRDS), supplied by the Federal Highway Administration (FHWA) to state transportation agencies and metropolitan planning organizations for use in computing roadway performance measures. The report describes the availability, attributes and limitations of the NPMRDS data on the Interstates in the state of Washington.

On the basis of the review of the NPMRDS data, this report recommends a set of performance metrics for WSDOT's use that report and assess the travel conditions that trucks moving freight within the state experience. It describes specific steps for computing those measures. And it uses a subset of those measures produced with the NPMRDS to illustrate how WSDOT can use those measures in its reporting and decision making procedures.

4.1 DATA SOURCES USED:

National Performance Research Monitoring Data Set (NPMRDS) vehicle probe data

4.2 AVAILABLE TOOLS AND METHODOLOGY:

The NPMRDS provides roadway performance data for the national highway system (NHS). The intent of the NPMRDS was to provide a travel time estimate for every 5-minute time interval (epoch) of the year for all roadway segments in the NHS. The NPMRDS data are derived from instantaneous vehicle probe speed data supplied by a variety of GPS devices carried by both trucks and cars. The data are supplied on a geographic information system (GIS) roadway network, which divides the NHS into directional road segments based on the Traffic Message Channel (TMC) standard.

The NPMRDS is supplied by a combination of HERE (the company that was once Traffic.com and was also known as NAVTEC) and the American Trucking Research Institute (ATRI). HERE supplies the data used to estimate 'car' vehicle travel times, and ATRI provides the data for 'truck' travel time estimates. HERE then combines the data from these two data sets into a single travel time statistic meant to be an estimate of 'average vehicle travel time' for both cars and trucks. The intent of the NPMRDS data set is

[3] *Source: University of Washington, Seattle, 2015.*

to provide one travel time statistic for each 5-minute interval, for each TMC segment (TMC/epoch), for each type of vehicle (truck, car, or combined).

The NCHRP 08-98 (Guide for Identifying, Classifying, Evaluating, and Mitigating Truck Freight Bottlenecks, Cambridge Systematics, 2015) project recommends that four different delay computations be performed and reported using different threshold values. Each delay computation describes delay from the perspective of a different road user or operator. Three of those thresholds are applicable to WSDOT: 1) delay based on the speed limit, 2) delay based on 70 percent of the posted speed, and 3) delay based on a locally set target value. NPMRDS data were used to compute these values.

4.3 SIGNIFICANT FACTORS OF SUCCESS OR *LESSONS LEARNED*:

The research identified the following challenges of the NPMRDS data:

- The use of instantaneous GPS speeds when there are relatively few data points in a roadway segment makes the reported data more variable than actual roadway performance, as vehicle speed can vary considerably within a roadway segment.
- Roadway performance reporting on road segments that contain long steep grades should be evaluated carefully based on how congestion is defined. On those road segments, heavily loaded trucks may drive slowly because of their limited power-to-weight ratio. Thus, the actual speed is a function of their power-to-weight ratio, not a function of the road's congestion level.

The research identified the following opportunities for application and requirements for further research:

- Possibility to compute delay statistics (veh-hrs of delay) by TMC segment.
- Possibility to compute frequency of congestion statistics with the NPMRDS data and thus describe the reliability of travel through specific road sections, with two limitations:
    1. There are challenges of interpretation in the NPMRDS speed values on long steep grades (described above)
    2. For TMC segments longer than one mile, it becomes difficult to identify the occurrence of congestion when other sections of the segment may experience free flow conditions. The research team recommends that frequency of congestion be reported only for TMC segments of 1 mile or shorter.
- The NPMRDS can also be used to compute travel time and travel time reliability statistics. The researchers note, however, that additional work is needed before this capability is available for statewide application by WSDOT, including:
    1. The limited number of data points in some segments or times of day makes computing travel times at a 5-minute interval level somewhat problematic. The authors recommend that travel times be computed on a 15-minute interval until data gaps are filled.

- The researchers suggest that additional steps be taken before WSDOT establish a long term performance monitoring system for the entire state. Including:
    1. Work with FHWA as it works towards the next version of the NPMRDS.
    2. Determine the average travel time of heavily loaded trucks on segments where trucks have slow travel times because of power-to-weight ratio limits.
    3. Code the travel time algorithms described in this report.
    4. Test and refine the travel time algorithms, with specific attention paid to the ability to compute travel times for heavily loaded vehicles.
    5. Determine the accuracy of arterial travel times from the NPMRDS data.
    6. Determine how to extend the volume count estimation process to state routes that are not monitored by a specific Permanent Traffic Recorder (PTR) that can be used to estimate changing traffic volumes by day of week and time of day.
    7. Complete more extensive computer programming and calculations to refine the traffic volume count process. (Researchers employed the DriveNet programming software (Digital Roadway Interactive Visualization and Evaluation Network)).

4.4 TRANSFERABILITY (OR TRANSFERABLE MEASURES/TOOLS):

NPRMDS is available at no cost for Oregon and the methodology developed by the University of Washington is transferable to Oregon. The researchers identified effort to better account for data limitations and gaps, which likely also exist in the Oregon data set.

As a research project which was focused on an on-going performance monitoring system, the authors focus on data and evaluation gaps that may be beyond the level of detail needed for the more limited purpose of identification and evaluation of freight bottlenecks in Oregon. Further, some of the concerns the authors note regarding NMPRDS relate to differences between model or count based analysis and probe data in general. For example, while researchers identify the reporting of heavily loaded truck speeds on long steep grades as a limitation, the reporting of actual truck operations in real conditions could be an opportunity for the Oregon study to identify bottlenecks related to grades rather than congestion. Similarly, while segments that have a limited number of reference points creates some gaps, this is an issue of interpretation that is likely to be similar with any probe data set that report real time data with frequent/small time increments and there are advantages to having this rich data set.

5 AMERICAN HIGHWAY USERS ALLIANCE - UNCLOGGING AMERICA'S ARTERIES 2015, PRESCRIPTIONS FOR HEALTHIER HIGHWAYS[4]

This report is largely a trucking industry statement of interest by the American Highway Users Alliance (AHUA). The report's emphasis is on national bottleneck abatement. However, it is supported by bottleneck identification analytics.

The American Transportation Research Institute (ATRI) and HERE North America, LLC (HERE) provided data and technical assistance in data preparation. ATRI, the not-for-profit research arm of the trucking industry, supplied freight movement data for this report. HERE passenger vehicle speed data.

The authors used vehicle speed data from the HERE/ATRI data to develop weekday speed profiles for over 350,000 urban highway segments across the U.S. Delay estimates were generated by comparing the observed speed profile for each highway segment to an ideal speed profile for the same segment. Delay estimates were then adjusted for the relative lengths of highway segments, as well as the estimated volume of vehicles (both cars and trucks) on those segments. The resulting delay metric is Daily Total Delay, measured in hours.

5.1 DATA SOURCES USED:

The study uses:

- GPS probe data that feeds the Federal Highway Administration's National Performance Management Research Data set (NPMRDS).
- Passenger vehicle and freight vehicle spot speed data collected from GPS probes, provided by HERE/ATRI

In the combined data sets, the GPS probe-based speeds are allocated to a road network layer called Traffic Message Channel (TMC). Other highway characteristic data from the HPMS system is combined through a process termed 'conflation', described in the report.

5.2 AVAILABLE TOOLS AND METHODOLOGY:

Researchers noted that the aggregate estimate of delay for freeway segments requires vehicle speed profiles and volume. The speed data for each section of freeway (HERE/ATRI) was tied to expected vehicle volumes (i.e. AADT) and number of lanes from the HPMS data for the same section. *Network conflation* is the process of combining these two separate spatial data sets. Geographic Information System (GIS) models were used to accomplish the conflation.

The HPMS combines data in both directions while HERE/ATRI data set has separate directional flows, denoted by Traffic Messaging Channel (TMC) identifiers. The report does not identify any potential problems with directional versus non-directional data. Since both HPMS and HERE/ATRI data were used, the researchers needed to combine the two data sets into one format. The researchers chose to convert the directional data into non-directional data. The benefit of doing it this way was they were able to avoid the potential for errors in the data from estimating the number of lanes, which is necessary when separating non-directional data into directional data. Another benefit of using the

[4] *Source: American Highway Users Alliance, 2015*

HPMS format was shorter freeway segments which allow greater ability to pinpoint the bottleneck locations. The report provides more detail on the conversion methodology. The researchers:

- combined average observed speeds from the directional TMCs with the HPMS non-directional vehicle volume and lane data
- translated daily vehicle volumes to hourly volumes using Texas A&M Transportation Institute's published daily traffic distribution data to allocate Annual Average Daily Traffic (AADT) to each hour of the day in the weekday speed profile for each freeway segment
- estimated length-normalized, hour-indexed delays (in hours per mile) for every urban freeway segment, and
- ranked bottlenecks for both trucks and passenger vehicles by the metric *Daily Total Delay* (hours), defined as the sum of the estimated delays in all hours experienced by all vehicles entering and leaving a congestion queue on a representative non-holiday weekday.

While the study's focus was on bottlenecks of the overall roadway network affecting both trucks and passenger vehicles, the researchers noted that there are benefits of examining truck bottlenecks separately. The report includes a brief summary of a methodology developed in a separate study by ATRI that identifies truck-specific bottlenecks. This involves:

- Identification of study population through extraction of relevant commercial truck data during all weekdays of the year 2014 at 250 specific locations using an extensive truck GPS database;
- Application of data quality tools and techniques;
- Application of a four-step analysis process that utilizes vehicle time, date and speed information;
- Calculation of total freight congestion values and ranking (congestion index); and
- Production of detailed congestion profiles for the 100 top ranked locations

5.3 SIGNIFICANT FACTORS OF SUCCESS OR *LESSONS LEARNED*:

No significant factors are readily identified in review of the study.

5.4 TRANSFERABILITY (OR TRANSFERABLE MEASURES/TOOLS):

ATRI, HERE and NPMRDS data are available for Oregon. The methodology developed by AHUA applies specifically to trucks. It may be transferable to Oregon; however it was developed for a national network application.

6 AN INITIAL ASSESSMENT OF FREIGHT BOTTLENECKS ON HIGHWAYS, 2005 WHITE PAPER [5]

This paper was completed in 2005 and its purpose was to identify and quantify (on a national basis) highway freight bottlenecks, resulting in truck delay and increase costs to businesses and consumers. The paper was one of the first efforts to look specifically at the impacts and costs of highway bottlenecks on truck freight shipments. These highway truck bottlenecks are identified and differentiated from general traffic bottlenecks using available FHWA Highway Performance Monitoring System (HPMS) and Freight Analysis Framework (FAF) data. The impact of these bottlenecks are measured by *total truck hours* of delay, *hours of delay to large trucks* making longer-distance trips, and the *tonnage and value of commodities* in the trucks.

For the purposes of this paper, the authors recommend that highways bottlenecks for trucks be defined by a combination of three features: the type of constraint, the type of roadway, and the type of freight route. The paper details each element used to describe bottlenecks by feature:

Table 3.1 Truck Bottleneck Typology

Constraint Type	Roadway Type	Freight Route Type
Lane-Drop	Freeway	Intercity Truck Corridor
Interchange	Arterial	Urban Truck Corridor
Intersection/Signal	Collectors/Local Roads	Intermodal Connector
Roadway Geometry		Truck Access Route
Rail Grade Crossing		
Regulatory Barrier		

6.1 DATA SOURCES USED:

The project integrated FAF and HPMS data, which the authors suggest provides a relatively comprehensive inventory of truck highway bottlenecks. The FAF is a database of county-to-county freight flows over the national highway, railroad, water, and air freight networks. HPMS data is based on information reported by state DOTs and compiled by FHWA annually.

6.2 AVAILABLE TOOLS AND METHODOLOGY:

The paper outlines the general methodology as follows.

First, HPMS data is scanned to identify bottleneck intersections based on the *volume-to-capacity ratio of all vehicles*. Next, the researchers calculated the truck hours of delay passing through the bottlenecks

[5] *Source: Prepared for Federal Highway Administration Office of Transportation Policy Studies, Cambridge Systematics, 2005*

using FAF data at interchange bottlenecks and HPMS data for other types of bottlenecks. To estimate the truck hours of delay at previously identified highway freight bottleneck locations, the study used a simplified queuing-based model, QSIM, developed by Margiotta et al, 1998. The equations use only a few, readily available independent variables for each bottleneck: annual average daily traffic (AADT), roadway capacity, signal density, and signal progression.

The output variable for these equations is "hours of delay per 1,000 vehicle-miles" at each bottleneck. Total truck delay was found by multiplying this value by truck vehicle miles of travel for the bottleneck location. Only the "daily" delay for weekday/weekend combined was considered in this analysis.

The methodology identifies general traffic bottlenecks and then estimates truck delay. The authors note four key limitations:

1. ***Delay at Interchange Bottlenecks:*** At interchanges, the scan identified only the critically congested roadway and the corresponding two-way truck traffic volumes on that roadway.
2. ***Incident Delay:*** The author indicates the analysis does not account adequately for variability in delay, especially for variability caused by nonrecurring congestion (i.e., congestion caused by incidents and crashes).
3. ***Truck Exposure to Delay:*** The authors also note that the calculation of truck hours of delay does not account for actual truck exposure to congestion.
4. ***Expansion of Delay Estimates Based on HPMS Sample Data:*** The statistical-sample framework that underlies the HPMS database is based on volume, mileage, road classification, and state. Volume-related data such as truck hours of delay for the HPMS sample section bottlenecks can be expanded statistically to estimate total truck hours of delay for all HPMS roadways for all states, but data such as the number of bottlenecks cannot be expanded. This means that while the analysis can identify the number of bottlenecks within the HPMS Sample sections, calculate the truck hours of delay at these bottlenecks, and extrapolate the delay hours to estimate the total national truck hours of delay for a category of bottlenecks, it cannot identify the total number of bottlenecks or the location of bottlenecks other than those in sample sections.

The FAF data produces reasonably accurate estimates of the number of longer-distance, large truck trips along major highway corridors. However, it does not accurately estimate the volume of trucks moving on specific roadways, especially on lower-volume roads. To ensure that data collection and computation were manageable at the national level, the FAF was constructed using county-to-county commodity flow data, which does not include many local, intra-county truck trips, and assumed that all freight shipments originate or terminate at a single central point (centroid) in a county.

6.3 SIGNIFICANT FACTORS OF SUCCESS OR *LESSONS LEARNED*:

The bottlenecks were located by scanning the FHWA Highway Performance Monitoring System (HPMS) database for highway sections that were highly congested as indicated by a high volume of traffic (all vehicles) in proportion to the available roadway capacity (the volume-to-capacity ratio).

The HPMS database describes physical and traffic conditions for all major roads in the United States. For reporting purposes, the roadways are divided into sections. The average HPMS roadway section in urban areas is 0.7 miles long. In rural areas HPMS roadway sections average 2 miles long and can range up to 20 miles or more in length in very isolated areas.

The HPMS 2002 Universe database was used to scan for interchange bottlenecks on urban Interstate highway sections. Almost all urban Interstate interchanges or their adjoining sections were represented in the Universe database. The HPMS Universe database reports traffic volumes for each section but not highway capacity. Capacity was calculated from information on the type of roadway, number of lanes, and default values for lane width, shoulder width, and percent trucks.

Most of the lane-drop, signalized-intersection, and steep-grade bottlenecks are on lower-volume highways and arterials, and so the HPMS Sample database was used to calculate truck volumes for these bottlenecks.

The paper notes that the accuracy and reliability of the HPMS estimates vary by state and type of roadway.

The method has been incorporated into the FHWA's Surface Transportation Efficiency Analysis Model (STEAM) and Highway Economic Requirements System (HERS) models.

6.4 TRANSFERABILITY (OR TRANSFERABLE MEASURES/TOOLS):

Though focused on interstate freight bottlenecks, the paper demonstrates the researchers' ability to integrate components of the general data source (HMPS) and methodology with FHWA's HERS model(s). The authors were able to identify several types of bottlenecks based on causes. The HPMS uses state data and is available for Oregon on major roadways but limited or unavailable off major roadways.

The authors noted several significant limitations of the HPMS data as used. These include the calculation of delay on only the most critically congested roadway at an interchange, the lack of information on non-recurring delay, the fact that truck delay is estimated based on overall volume to capacity ratio for all vehicles and the reliance on a sample of HMPS to identify bottlenecks. Further, in assessing travel delay on long rural segments, changes in performance within the segment can be masked by average performance for the full segment.

7 FREIGHT BOTTLENECKS IN THE UPPER MIDWEST: IDENTIFICATION, COLLABORATION, AND ALLEVIATION, 2009 [6]

In an effort to alleviate the impact of traffic bottlenecks to freight movement through the Upper Midwest, the study author defined an analysis framework to identify, characterize, and prioritize *regional truck bottlenecks*. The study investigated highway freight bottlenecks in 10 states in the Mississippi Valley region. The authors used GPS data to identify existing bottleneck locations and then confirmed their findings with bottleneck databases of the states' DOTs. Once identified and confirmed with the DOTs, the authors performed an analysis of known truck bottleneck locations to categorize them by type and calculate the truck delay associated with the existing locations.

The authors built upon a HPMS-based analysis approach and developed a systematic framework to identify, characterize, and prioritize truck bottlenecks in the Mississippi Valley region. They applied the analysis methodology to arrive at a master list of regional freight bottlenecks. Then the bottlenecks were sorted and tagged with all constraints types applicable from the following categories: interchange, signalized intersection, lane drop, and steep grade. After this categorization process, the bottlenecks were prioritized by truck unit delay associated with the existing conditions.

The researchers' delay estimation is based on equations borrowed from a previous study by Margiotta et al. (1999), who developed a series of equations to estimate hours of delay and speed on each section by using a simplified queuing-based model, QSIM. This model incorporates several advanced features, including the use of queuing analysis, accounting for temporal distribution and daily variation of traffic flow, and so on.

Because interchange bottlenecks usually cause system congestion, simply examining the sections with significant truck unit delay on freeways would identify many separate bottlenecks, which are actually located on a congested corridor as a result of one interchange bottleneck.

Realizing that the interchange configuration varies significantly from case to case and the most congested location caused by an interchange might be out of its physical scope, the maximum searching length was determined through a sensitivity analysis. Researchers investigated all constraints identifiable from HPMS data on each bottleneck, to explain the potential causes.

7.1 DATA SOURCES USED:

The study uses a combination of local data:

- Loop detectors along major corridors (Vehicle counts, occupancy of detector, speed)
- GPS-based data

and,

- 2006 Highway Performance Monitoring System (HPMS) data for 10 states in the MV region

7.2 AVAILABLE TOOLS AND METHODOLOGY:

This study uses HMPS data and methodology for identifying and characterizing truck bottlenecks that was developed in a 2005 Cambridge Systematics, Inc. study. The present study builds upon the previous framework to categorize delay that causes a bottleneck (interchange, lane drop, steep grade, and

[6] *Source: University of Wisconsin, Madison, 2009*

signalized intersection). The method allows bottlenecks to be categorized into one or more categories. Delay estimation is based on equations borrowed from a previous study by Mariotta et al. (1999) that uses a simplified queuing-based model, QSIM. This model incorporates several advanced features, including the use of queuing analysis, accounting for temporal distribution and daily variation of traffic flow, and so on.

The study notes that three conditions lead to significant truck unit delay:

1. Presence of exceptionally high truck volume
2. Presence of exceptionally high hours of delay per vehicle mile
3. Combinations of 1 and 2, above.

Further, the study outlines three general approaches to bottleneck analysis that differ by the types of data used for analysis:

1. Rich traffic data obtained from loop detectors along major corridors including: count of vehicles, occupancy of detector, and speed.
2. GPS data, i.e. from portable GPS devices distributed to trucking companies
3. HPMS data: preferred in this study because it is available to all states, consists of the Universe database and the Sample database

7.3 Significant Factors of Success or *Lessons Learned*:

The author believes this method is more suitable method for screening highway sections for potential bottleneck locations than what was outlined in the Cambridge Systematics/FHWA White Paper (2005).

In the White Paper (2005), highway sections with high V/C ratios during peak hour were selected as candidate bottleneck locations. This University of Wisconsin analysis uses truck unit delay (total hours of delay for trucks per mile) instead. Truck unit delay is considered a more suitable measure for the study because it captures the delay for all commercial motor vehicle drivers' use per mile of a given highway segment. It was considered to more directly capture the congestion impact to freight movement.

This study identified a limitation with the Margiotta et al. (1999) study's delay estimation that was used as the basis for estimating delay in this study. The equations have a potential to overestimate the exposure of truck trips to delay. By multiplying the truck volume with the unit delay estimated from the equations, it is assumed that truck trips follow the similar temporal distribution as passenger car trips. However, most commercial motor carriers make great efforts developing strategies to reschedule and/or reroute picking up and delivering works in order to avoid known recurring bottleneck. This might lead to the underlying difference in temporal distribution patterns between truck trips and passenger car trips, which suggests an overestimate of truck delay.

7.4 Transferability (or transferable measures/tools):

Statewide HPMS data is available in Oregon. Using this data source, ODOT may follow the identified systematic framework developed by researchers in this study to identify, characterize, and prioritize truck bottlenecks on urban and rural highways statewide. The limitation noted earlier, with respect to over-estimating truck delay due to the assumption that the temporal distribution is like cars, applies.

8 USING TRUCK GPS DATA FOR FREIGHT PERFORMANCE ANALYSIS IN THE TWIN CITIES METRO AREA, 2014 [7]

This study used 12 months of American Transportation Research Institute's (ATRI) GPS-based truck data that was collected in 2012 along 38 key freight corridors collected in the Twin Cities metropolitan area (TCMA). Truck speed and hourly volume percentage computed from GPS data were compared with data from weigh-in-motion (WIM) sensors.

Building on previous efforts to analyze freight mobility and reliability, the study developed a data processing and analysis methodology to study freight performance. Several performance measures, such as truck mobility and delay and the reliability index, were computed and statistically analyzed by route, roadway segment (1-mile) and time of day.

The MnDOT research team identified key freight corridors by comparing percentage of miles with Heavy Commercial Annual Average Daily Traffic (HCAADT) greater than 7,500 and HCAADT per lane greater than 1,500 in the TCMA. The HCAADT is the theoretical estimate of the total number of heavy commercial vehicles using a specific segment of roadway (in both directions) on any given day of the year. This estimate is derived from the total number of heavy commercial vehicles per year divided by 365 and adjusted for seasonality.

The study identified truck bottlenecks and ranked their severity based on average delay hours and number of hours with speed less than the target speed during the AM and PM peak periods.

The study also estimated the financial impact of traffic mobility deficiencies by expressing the economic costs of congestion. These congestion cost measures can have utility to both transportation decision-makers and system users if they accurately reflect the tangible costs of transportation use on congested facilities.

Finally, the MnDOT researchers measured network reliability of the 38 freight corridors, using an 80th percentile travel time reliability index (RI). The reliability measure was further divided into three categories: reliable (RI < 1.5), moderately reliable (1.5 ≤ RI < 2.0) and unreliable (RI ≥ 2.0) to visualize the system performance.

8.1 DATA SOURCES USED:

MnDOT used the following data in the analysis:

- ATRI Truck GPS data
- National Corridors Analysis & Speed Tool (N-CAST)
- National Performance Management Research Data Set (NPMRDS)
- MnDOT WIM Data
- Automatic Traffic Recorder (ATR) Data
- MnDOT Online Mapping Application,
- Metro trunk highway HCAADT map, and
- Greater MN trunk highway HCAADT map

[7] *Source: Minnesota Department of Transportation (MnDOT), Research Services & Library, Office of Transportation System Management, 2014*

8.2 AVAILABLE TOOLS AND METHODOLOGY:

Two mobility measures, (1) average speed, and (2) number of hours in peak periods with average speed below threshold speed, were used to analyze the freight mobility.

Performance measures derived from GPS data offer promising opportunities for freight planners and managers to generate reliable measures in a timely manner. Most of the identified freight bottlenecks are located within or near interchanges.

Three key **performance measures** are identified and calculated in the study: truck mobility, delay, and a reliability index.

Key freight corridors were identified by comparing the percentage of miles with heavy commercial annual average daily traffic (HCAADT) greater than 7,500 and HCAADT per lane greater than 1,500 in the TCMA.

Truck bottlenecks were also identified and ranked based on hours of truck delay and number of hours with speed less than the target speeds (set by MnDOT) during the AM and PM peak periods.
The analysis indicates routes with the **highest combined truck delay** and quantifies the lengths of those delays.

Total truck congestion cost in the TCMA was about 0.8 million per weekday using the hourly operational cost from ATRI. The corresponding annual congestion cost was about $212 million (assuming no delays on weekends). When using the TTI's congestion cost rate, the total truck congestion cost in the TCMA was about 1.1 million per weekday with corresponding annual congestion cost around $286 million (assuming no delays on weekends).

8.3 SIGNIFICANT FACTORS OF SUCCESS OR *LESSONS LEARNED*:

No significant factors are readily identified in the review of the study.

8.4 TRANSFERABILITY (OR TRANSFERABLE MEASURES/TOOLS):

MnDOT's custom methodology to identify freight bottlenecks involves combining multiple commercial (ATRI truck GPS, N-CAST), FHWA (NPMRDS) and state (WIM and ATR) data and appears to be transferable, at least, on urban highways and freeways. The MnDOT study did not target rural highways and freeways. Further inquiry with MnDOT would be needed to determine if the methodology is suitable for rural systems analysis where a lower volume of probe data is available.

The study does not make clear the extent to which FHWA's NPMRDS data is used. Also, direct investigation with MnDOT would be required to better understand their application of NPMRDS data.

The delay and travel time reliability measures used in this study could be applicable to Oregon. However, with just-in-time delivery strategies prevalent today, reliability in the 90 to 95 percent range, rather than the 80 percent range used in this study, is the industry standard .