Fusing Public and Private Truck Data to Support Regional Freight Planning and Modeling

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Abstract
In the past, regional transportation planners primarily focused on passenger traffic demand and forecast modeling. Many metropolitan areas were unable to include freight in regional planning due to lacking of data. With the growing freight movement and its significant impact on regional and national economy, many planning agencies are investing more resources on integrating freight into transportation planning and using freight models to better support transportation decision making. Data is critical to derive parameters and support analysis processes in developing a model. However, freight data acquisition, due to the proprietary nature of data, has been an ongoing challenge. Existing public freight data is insufficient to support advanced freight modeling. Collecting additional data or identifying new data sources is essential to support effective freight modeling and planning. The FHWA has established a partnership with the American Transportation Research Institute (ATRI) to measure truck travel speed on freight-significant corridors since 2002. This paper explores the feasibility of generating truck performance measures that can be fed to freight models. As an example, 12-month of private truck GPS data from ATRI and traffic data from state DOTs were utilized to study trucking activity, level of congestion, and travel time reliability along the I94/90 corridor between the Twin Cities and Chicago. The data analysis methodology demonstrated the capability of using truck GPS data to generate performance measures for potential applications such as measuring truck travel time reliability, evaluating impact of congestion on cost of freight, identifying truck stop or parking facility needs, and studying the impact of traffic volume with respect to speed gap difference between passenger vehicles and trucks. Resulting performance indices can thereafter be utilized to support freight modeling, planning and decision making.

Introduction
Data is critical for deriving model parameters and model validation. Reliable and timely freight data on freight activity is vital for freight planning, forecasting and infrastructure investment decision making. Integrating commodity type, weight, and GPS-based trip information becomes essential to develop a comprehensive freight model. Currently, different freight activity data are regularly collected by public and private sectors. Private data is generally more difficult to obtain due to its proprietary nature and thus requires substantial effort to coordinate different data from various sources. Nationally, no standardized freight data collection methodology is practiced by public and private sectors. Texas Transportation Institute recently completed a project (NCFRP 12) on specifications of freight data architecture to address the needs of data collection standard and institutional strategy for freight decision making at national, regional and local level. To create an effective freight model for forecasting and planning, traffic flow and commodity flow data are both important. Commodity flow data is useful in understanding the freight value, finance impact and economic activity. And performance indices derived from traffic flow data can be used for infrastructure maintenance and investment decision support.

For example, Washington State deployed 25 portable data collection GPS systems to collect truck data for measuring freight movements and identify bottleneck along corridors (McCormack & Hallenbeck, 2006; McCormack et al., 2010). The study concluded that GPS data can be collected cost effectively and can provide an indication of roadway performance. Based on processed truck speed data, a route model including analyses of truck travel time, delay and reliability can be developed to better understand current freight network performance, freight origin to destination flows, and to study possible solutions to future freight demand growth (Short & Jones, 2008). Initial phase of the FHWA FPM initiatives measures average travel rates on five freight-significant corridors (Jones et al., 2009). ATRI also analyzed the severity of 30 key freight bottlenecks in the US interstate system (Short et al., 2009). Freight bottlenecks occurred at highway interchanges were analyzed using the freight congestion value. The study concluded that possible causes for the bottlenecks may include roadway geometry, capacity, toll booths, speed limit, weather, truck volume vs. general traffic volume, and required lane of travel for trucks. Minnesota State DOT (Mn/DOT) recently completed a study on truck parking analysis. The goal was to develop the information necessary to support decisions regarding future approaches to the truck parking issues in Minnesota (Maze, 2008). Short and Murray (2008) demonstrated the capability of utilizing FPM data for truck parking analysis. Another application is to utilize the FPM data to evaluate the travel time and delay at border crossing. FHWA (2002) conducted a study to address the need to reduce the hours of delay for commercial motor vehicles passing
through ports-of-entry. However, manually truck data collection at border crossing plaza is labor intensive and expensive (FHWA, 2002).

With the massive truck data gathered by FHWA and ATRI, processed FPM data presents tremendous opportunities for developing new and relevant measures for truck performance on highways and freight mobility, including congestion and capacity bottlenecks (MnDOT, 2005). Processing FPM data can generate truck traveling information needed to study the variations of freight traffic, travel time reliability, stop location, congestion trend, and bottlenecks. Truck location data collected by private data providers from May 2008 to April 2009 were obtained from the ATRI. Travel Time Index (TTI) is proposed to measure the level of congestion and Buffer Time Index (BTI) is used to measure the travel time reliability along the freight corridor. Truck speed, speed variation, truck volume variation, distribution of destinations, stop location, and rest duration derived from each individual trip were processed and analyzed using open source statistical software.

Data Processing

A route geo-spatial database of I-94/90 from the Twin Cities to Chicago was created using the ArcGIS software. Monthly raw truck GPS data obtained from private sector were imported into the ArcGIS software to snap the GPS latitude-longitude points to nearest route and locate linear referencing measurements and distances. Individual vehicle trip speed was then computed by grouping vehicle ID and sorting the location data by time. Average speed of a network segment is calculated by dividing the linear distance difference over time difference between two consecutive GPS data points within the same trip. Processed data does not meet the speed filtering parameters (potential anomalies) are stored in a separate database for later truck stop location and stop duration analyses.

Truck speed variations by location and by hour of day were analyzed. Speed and volume variations at specified mile marker were analyzed to compare the changes over the hour of day. Computed truck speed versus the general traffic speed gathered by state DOTs were compared to evaluate the speed difference between trucks and passenger vehicles. Raw truck GPS data did not pass through the data quality filter were trucks that might stop for service or rest. Truck stop locations along the I-94/90 corridor and their stop durations were also derived to better understand truck parking activity and service availability.

Performance Indices and Analysis Results

Performance measures of truck congestion and travel time reliability were developed and discussed as follows. In addition, inference of trip destination and truck stop locations were derived from the raw truck GPS data.

Buffer Time Index (BTI) and Travel Time Index (TTI)

The Buffer Time Index (BTI), as defined in Equation (1), measures the travel time reliability by comparing the 95th percentile travel time to average travel time. The Travel Time Index (TTI) is introduced to measure level of congestion as defined in Equation (2). TTI is the ratio of peak period travel time to free flow travel time. The free flow travel time is computed as the minimum travel time within a given travel distance during a day. The TTI measure represents the average amount of time it requires to travel within a highway segment with respect to free-flow travel speed. In addition to current Buffer Time Index (BTI) and Travel Time Index (TTI), segment level travel time model can be developed based on the empirical performance measurement data to study the travel time reliability and delay for any given origin and destination pair in a network.

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Buffer Time Index \ (BTI) = \frac{95\text{ Percentile Travel Time} - \text{Average Travel Time}}{\text{Average Travel Time}} \quad \text{Eq. (1)}
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Travel Time Index \ (TTI) = \frac{\text{Peak Travel Time}}{\text{Free Flow Travel Time}} \quad \text{Eq. (2)}
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The travel time index between IL-53 and O’Hare airport in Jan. 2009 was plotted against the free flow travel time as shown in Figure 1. In average, the primary peak index (congestion) occurred around 8AM in eastbound direction with travel time 2.2 times of the free flow travel time. In westbound, the peak congestion occurred at 5PM which took almost twice the free flow travel time to travel from O’Hare airport to IL-53. There is also secondary peak value around 5PM in eastbound (9AM in westbound), but the congestion level is less severe (TTI value around 1.45 and 1.3 respectively). As defined in Equation (1), a smaller buffer time index (smaller variability) represents higher trip travel reliability. Truck BTI in Jan. 2009 along the I-94/90 corridor, as displayed in Figure 2, indicated that at 95th percentile of travel time, it averagely takes 2.5 to 3 times of the average travel time within each 3-mile segment between mile marker 18 (St. Paul) and 378 (Elgin toll plaza). Truck travels nearby O’Hare airport (mile marker 380~400) has higher reliability (Figure 2) but lower average speed.
Trip Destination Inference

Truck trip destinations were also derived from each trip record with identical vehicle ID assigned to the record within each month between the Twin Cities and Chicago. For westbound trip destinations, all trucks originated east of mile marker 402 (or east of O'Hare airport) were queried from the database. The histogram of corresponding ending destination of 3,698 trucks originated from east of O'Hare in Jan. 2009 was plotted as shown in Figure 3(a). For eastbound trip destinations, all trucks originated west of mile marker 18 (or west of St. Paul) were queried from the database. The histogram of corresponding ending destination of 4,631 trucks originated from west of St. Paul in Jan. 2009 was plotted as shown in Figure 3(b). The WB destination histogram, as displayed in Figure 3(a), indicated that most of the WB trucks (over 60%) ended before Madison, while there were only about 15% of WB trucks ended in the Twin Cities area. The EB destination histogram, as displayed in Figure 3(b), indicated that 40% of the EB trucks originated from west of St. Paul ended in Chicago area. There were about 22% of EB trucks ended in the Madison area which may include trucks continuing on I-94 to Milwaukee area.
Truck Stop Locations
In January 2009, for example, there were over 65,000 truck stops along the I-94/90 corridor in both EB and WB directions. Truck stop count at location along the corridor is visualized using GIS software as illustrated in Figure 4. Within each 3-mile segment, number of truck stops ranging from 2001 to 4000 is plotted with a larger red dot. The medium orange dot represents 1001 to 2000 truck stops in both directions.

Potential Applications, Challenges and Opportunities
With the advancement of satellite-based technology and Automatic Vehicle Location (AVL) system equipped on most trucking fleets, tremendous amount of truck data were gathered at trip level with relatively high resolution. The FPM system can automate the data processing analysis systematically and thereafter generates performance measures that provide opportunities for potential freight applications such as estimation of commodity flow patterns for smaller geographic unit, timely updates of demand and variations of network flows by season. Results from our analysis can be used to better understand freight flow characteristics and model freight demand.

In the past, small amount of heavy truck data were collected at trip level due to limited resources. Typically, truck volume and limited speed information were only collected at selected wayside to estimate the annual average truck volume. Truck speed and travel time derived from FPM can be used to support decision making on infrastructure investment for the public agencies and freight scheduling and routing for truck carriers. Even though current FPM does not include freight data from all trucks, it represents a good sample from the reality when comparing to other data collected by state or local agencies. The average travel speed at each segment and volume counts can then be modeled and calibrated to forecast future demand. We currently are working on a project to automate the data quality filtering of Automatic Traffic Recorder (ATR) and Wight-In-Motion (WIM) systems that are installed at fixed locations. There is opportunity to calibrate and validate the derived measures from truck GPS data with ATR/WIM data. There might be opportunity to fuse public and private dataset to generate reliable measures to identify freight bottlenecks and evaluate freight mobility.

In addition, land use on industrial development or warehouse facilities has significant impact on freight demand and movement. The resulting measure from our analysis can be linked to land use data and use spatial analysis to study the truck traffic pattern, trip length, and origin to destinations. The result of integrated analysis with land use data can provide key inputs to calibrate and validate freight models.

Truck activity and commodity flow data are vital in developing effective surface freight model. However, the challenges of integrating both are significant. With the flexibility and effectiveness of modern supply chain logistics that one commodity may be shipped with many trips or a single truck may carry multiple commodities, it is difficult to track commodity through truck trips without intelligent data collection systems. Carriers typically do not have much knowledge about the commodity in the cargo. The Commodity flow Survey (CFS) is a shipper based survey, not carrier based. Studying the interrelationship and interaction between commodity flows and modal vehicle traffic flows becomes very important. We believe there are opportunities to link commodity flow with truck traffic flow data by using the Intelligent Transportation Systems (ITS) technology and by developing innovative data fusion methodologies.

Concluding Remarks
In US, Metropolitan Planning Organization (MPO) and state department of transportation in each region have the responsibility to forecast future regional transportation needs and develop transportation improvement plan. With the growing freight movement and its potential impact on regional and national economy, many MPOs are investing more resources on integrating freight into transportation planning and including freight model to support decision making. A data processing methodology was developed to process massive truck data and produce measures for freight performance analysis. Analyses, such as truck speed, speed variation, truck volume variation, truck destination inference, stop location and rest duration derived from individual trip, were processed in this study. Performance measures including truck travel time reliability and level of congestion along the corridor were analyzed.

This freight analysis on heavy trucks can support surface freight planner in identifying freight bottleneck, truck stop locations, destinations, infrastructure improvement needs, and operational strategy to promote efficient freight movement. Current Travel Time Index (TTI) and Buffer Time Index (BTI) provide important performance indices at route or link level. However, performance indices based on given origin and destination region, i.e., from user’s perspective, will provide more valuable measures to public and private agencies for freight modeling, scheduling, planning and operation. Freight demand
and travel time resulting from the FPM calculations can potentially provide more timely updates and calibrations to the FAF at regional or interregional level. National freight data collection standard is needed to coordinate various freight data collected by the public and private sectors.

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