Project Title: Using Truck GPS Data for Freight Performance Analysis in the Twin Cities Metro Area
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TASK #1 DELIVERABLE: SUMMARY OF LITERATURE SEARCH

Introduction

The Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law by President Obama on July 6, 2012. As outlined in the MAP-21, the States are required to establish performance targets that reflect the performance measures established by the U.S. Department of Transportation (DOT). Improving efficiency of freight movement is identified as one of the key national goals for performance management. The objective of freight performance management is *to improve freight networks, strengthen the ability of rural communities to access national and international trade markets, and support regional and national economic development* (FHWA, 2012).

The American Association of State Highway and Transportation Officials (AASHTO) established a Standing Committee on Performance Management (SCOPM) to support performance-based management and outcome-driven environment by providing necessary expertise and resources to DOTs and other stakeholders. The NCHRP 20-24(37)G report (2011) has identified and made recommendations for critical performance measures, methodologies and standards for data collection, potential issues related to deployment, and usability of performance measures in addressing issues at local, state and federal levels. However, there is still ongoing debate over concerns and issues with the proposed measures, such as selection of reliability measure, data consistency, availability and adequacy, and federal vs. state role and responsibilities.

NCHRP (2003) synthesis 311 studied highway segments and system performance measures that included a survey of state DOTs and MPOs. The report indicated the need for a national set of core performance measures that consider data quality and collection, system coverage, and the aggregation of results. Key findings from the report include:

- A variety of different definitions of reliability measures are used by different states and MPOs.
- Need to provide a complete explanation of the measure and the data required to make the calculation.
- No standard way to evaluate and collect information in an operational setting and thus making comparison of operational scenarios difficult.
- Need to develop an effective way to present performance measure results.
- Relatively little work on forecasting performance measures and assessing their sensitivity to policy and changes in travel behavior.

Surface Freight Performance Measures

In the U.S., the trucking industry represents the largest portion of domestic freight movement. According to the *U.S. Freight Transportation Forecast to 2021* published by the American Trucking Associations (ATA) in 2010, the trucking industry shares about 68% of total tonnage and trucks move more than 80% of freight revenue. Safe, efficient, and reliable trucking services are essential, not only to provide door-to-door freight transportation, but also to ensure the effective operation of other freight modes and facilities.

Trucks usually occupy more than twice of the space of passenger vehicles on the roadway. Truck delays from traffic congestion or adverse weather conditions can have significant impact on truck travel time reliability. Federal Highway Administration (FHWA) has developed national congestion monitoring program that uses archived traffic detector data for measuring traffic congestion and travel time reliability (Pu, 2011; Turner et al., 2004). NCHRP Synthesis Report 384 (Kuzmyak, 2008) identified the challenges that many metropolitan planning organizations (MPOs) are facing in forecasting freight activities and modeling freight movements. NCFRP report #10 (2011) emphasized the importance of freight performance measures to support investment, operations, and policy decisions for both public and private stakeholders.

Many MPOs model heavy trucks as an alternative for modeling freight activity because trucks account for more than 80% of freight movement in most metropolitan areas. FHWA and American Transportation Research Institute (ATRI) released the findings on level of truck congestion at 250 freight significant highway locations in 2011. Five highway interchanges located in the Twin Cities Metro Area (TCMA) were identified in the study (ATRI, 2011).

Schofield and Harrison (2007) reported the status of freight performance measures used in DOTs nationally and suggested a set of relatively broad performance measures including mobility, reliability, economic, safety/environment, and infrastructure for emerging users. Varmar (2008) compiled, organized, and analyzed freight data by mode, performance measure and indicator categories. The report suggested that there are needs to, (1) determine what performance measures or indicators are relevant and most important for freight planning support, and (2) identify freight significant strategic corridors and nodes.

The Minnesota Department of Transportation (MnDOT), Office of Freight and Commercial Vehicle Operations (OFCVO) has identified and included travel time by mode as one of the four performance indicators in the statewide freight plan (MnDOT, 2005). Currently, the MnDOT has also deployed Automatic Traffic Recorders (ATR) and Weigh-In-Motion (WIM) systems statewide for measuring truck weight and classifications with varying axle configurations at highway speeds (MnDOT traffic data, http://www.dot.state.mn.us/traffic/data/index.html). Existing ATR and WIM sensors collect truck volume and speed information at selected locations statewide. However, they do provide truck travel time information.

Probe Vehicle Based Performance Measures

With the prevalence of GPS receivers on vehicles and portable navigation devices, probe vehicle based data collection has been increasingly attractive to transportation community. The GPS based vehicle location data has been used to estimate traffic states and derive travel time information for traffic monitoring (Lund and Pack, 2010; Guo et al., 2008; Smith, 2006; Nanthawichit et al., 2003). Probe vehicle data, when fused with loop detector data and other data sources, can provide more complete and continuous coverage of traffic monitoring. Turner et al. (2011) outlined the primary data requirements for congestion-related performance measures and introduced core data elements and various metadata to ensure data consistency among data providers. They also examined legal and institutional issues related to privacy and Freedom of Information (FOIA) with regard to implementation.

Travel time reliability is one of the key measures of freight performance along interstates or interregional corridors in the nation (Lomax et al., 2003; TTI, 2006). Pu (2011) examined several reliability measures and recommended a median-based buffer index or a failure rate estimate is more appropriate to handle heavily skewed travel time distributions.

Majority of commercial vehicles are equipped with on-board Automatic Vehicle Location (AVL) systems that collect truck locations at a fixed polling rate. The continuous trajectory information presents an excellent data source for monitoring travel time and reliability. However, GPS-based truck trip data usually are not available and are more difficult to collect due to the proprietary nature of the data. Commercially available travel time information (for example, from INRIX) provides some coverage using aggregated general traffic speed data from loop detectors and other probe vehicle based data sources. However, heavy commercial vehicles are considerably underrepresented in this type of data source.

Since 2002, FHWA has established a partnership with the American Transportation Research Institute (ATRI) and the trucking industry to measure average truck travel speed on major freight-significant corridors using more than 400,000 commercial trucks in North America (Jones et al., 2005). A spatial data processing methodology was evaluated, refined, and assisted by Liao (2008) to improve the effectiveness of generating freight performance measures (FPM). Analyzing truck speed, volume and travel time by location can also help identify network impediments and variations of seasonal flow changes (Liao, 2009). Derived vehicle speed and travel time from the GPS and/or terrestrial wireless systems used by the trucking industry provide potential opportunities to support freight planning and operation on the surface transportation system.

McCormack and Hallenbeck (2006) used 25 portable GPS data collection units with 1-second polling rate to gather truck positioning data for measuring freight movements along freight significant corridors in Washington State. 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 initiative is to measure average travel rates on five freight-significant corridors (Jones et al., 2005). ATRI analyzed the severity of 30 key freight bottlenecks in the U.S. interstate system (Short et al., 2009). Freight bottlenecks occurred at highway interchanges were analyzed using a freight congestion index. Possible causes for the bottlenecks may include roadway geometry (e.g., grade, curvature, and sight distance), capacity (number of lanes), toll booths, speed limit, weather, truck volume vs. general traffic volume, and available lane of travel for trucks.

The MnDOT 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 et al., 2010). 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 conducted a study to address the need to reduce the hours of delay for commercial motor vehicles passing through ports-of-entry (FHWA, 2002). However, manually truck data collection at border crossing plaza is labor intensive and expensive.

Recently, FHWA is leading the effort to asses and validate the appropriateness of using GPS data from commercial vehicles to derive mobility and reliability performance measures and to support congestion monitoring on the highway system. Four key factors, including average daily traffic (ADT) per lane, percent of heavy vehicle, grade, and congestion level, were investigated. The preliminary findings indicated that (1) estimates of speed from FPM data are sufficiently accurate for performance measurement on most roadways in the United States, (2) FPM speed estimates show a consistent negative bias due to differences in operating characteristics of trucks and autos, and (3) grade and congestion have the greatest effect on FPM data accuracy among the four key factors evaluated (FHWA, 2012).

National Corridors Analysis & Speed Tool (N-CAST)

ATRI in coordination with the FHWA recently announced (10/22/2012) a beta release of Freight Performance Measures (FPM) tool that expands on the scope and functionality of the original FHWA-sponsored "FPMWeb" application (www.freightperformance.org/). The National Corridors Analysis & Speed Tool (N-CAST, www.atri-online.org/n-cast) provides key roadway performance and truck mobility information for the U.S. Interstate Highway System. The N-CAST database includes average speed and share of total position reads of each one-mile segment in four periods in a day, i.e., AM peak (6-10AM), mid-day (10AM-3PM), PM peak (3PM-7PM), and off peak (7PM-6AM) periods. The N-CAST tool has the potential to be integrated with existing truck data sources to generate critical performance measures (such as delay and reliability) to provide technical guidance to stakeholders in the freight industry.

For example, the vehicle-hours of delay for trucks on Interstate and NHS corridor can be computed as,

$$Daily\ Delay = \sum_{Period} \sum_{Segment} \left(\frac{Segment\ Length}{Travel\ Speed} - \frac{Segment\ Length}{Threshold\ Speed}\right) \times HCAADT_{Period} \qquad \text{(Eq. 1)}$$

The Reliability Index (RI) for 80th percentile travel time can be defined as,

$$RI_{80} = \frac{80^{\,th}\ percentile\ Travel\ Time}{Travel\ Time\ at\ Agency{-}Specified\ Threshold\ Speed} \qquad \text{(Eq. 2)}$$

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APPENDIX A: Suggested Freight Performance Measures for an Emerging User (Schofield & Harrison, 2007)

Category	Potential Indicators
Mobility	Intercity Travel Times
	Average Speed on Freeways, by Route and Time of Day
	Major City Congestion Levels Compared to Other Metro Areas
	Volume/Capacity of All Vehicles on Freeway Segments
Reliability	Deviation of Travel Times or Speeds from the Average
	Density of Nonrecurring Delays
	Portion of On-Time Motor Carrier Arrivals
Economic	State Transportation Investment vs. Gross State Product
Public Impact	Emissions
	Freight Related Accident Rates
Infrastructure	Pavement and Bridge Quality
	Delay at Border Crossings

APPENDIX B: List of Reliability Measures (Lomax et al., 2003; Pu, 2011)

- Percentile

For example, $P(80\%)$ represents 80th percentile

- Standard Deviation (σ), Median and Mean (μ)
- Coefficient of Deviation (C_σ)

$$C_\sigma = \frac{\sigma}{\mu}$$

- Percent Deviation (C_p)

$$C_p = C_\sigma \times 100\%$$

- Skew Statistics (S_k)

$$S_k = \frac{P(90\%) - \text{median}}{\text{median} - P(10\%)}$$

- Mean Based Buffer Index (BI_μ)

$$BI_\mu = \frac{P(95\%) - \text{mean}}{\text{mean}}$$

- Median Based Buffer Index (BI_m)

$$BI_m = \frac{P(95\%) - \text{median}}{\text{median}}$$

- Planning Time Index (PTI)

$$\text{PTI} = \frac{P(95\%)\ \text{TT}}{\text{free\_flow TT}}$$

- Travel Time Index (TTI)

$$\text{TTI} = \frac{actual\ \ \text{TT}}{\text{free\_flow TT}}$$

- Frequency of Congestion (F_c)

F_c: Probability that TT ≥ 2× free_flow TT

- Failure Rate (or Percent On-Time Rate):

R_F: 100% - % of on-time arrival

Note[1]: The Urban Congestion Report suggests,

- Using 15th percentile travel time as free-flow travel time
- Using 95th percentile travel time for calculating planning time index
- Using 45 mph as the threshold for computing congestion delay

[1] The Urban Congestion Report (UCR): Documentation and Definitions, http://www.ops.fhwa.dot.gov/perf_measurement/ucr/documentation.htm

APPENDIX C: Key Freight Corridors in Twin Cities 8-County Area