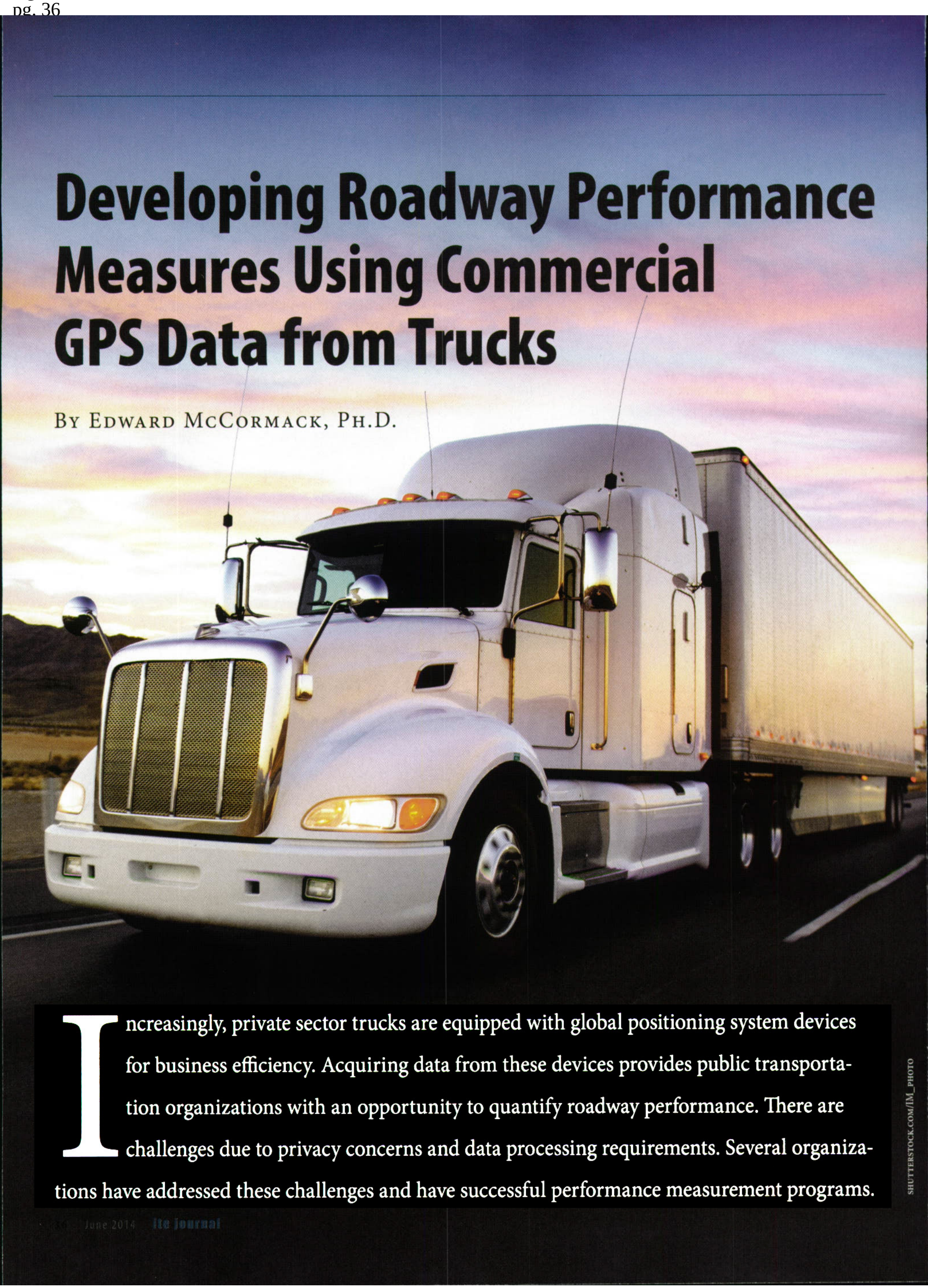

Developing Roadway Performance Measures Using Commercial GPS Data from Trucks

BY EDWARD MCCORMACK, PH.D.

Increasingly, private sector trucks are equipped with global positioning system devices for business efficiency. Acquiring data from these devices provides public transportation organizations with an opportunity to quantify roadway performance. There are challenges due to privacy concerns and data processing requirements. Several organizations have addressed these challenges and have successful performance measurement programs.

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Global positioning system (GPS) devices that are installed in trucks and used for fleet management are increasingly common. Raw data from these devices present an opportunity for public agencies to use these trucks as probe vehicles to better monitor roadway operations and to quantify transportation system efficiency. Several North American programs have demonstrated that these truck GPS data can be used for a variety of performance measurement applications including locating roadway bottlenecks for trucks, providing travel reliability data, and informing planning and engineering processes.

This paper discusses why these private sector GPS truck data are available, suggests how a public agency might acquire these data, provides some examples of the use of these data by transportation organizations, and covers some of the steps needed to make the GPS useful.

The Availability of Truck GPS Data

A growing number of commercial trucks have in-vehicle GPS devices. These GPS devices, while they may have the familiar navigation capabilities, are mainly used for business and fleet management functions. These devices, for example, provide dispatchers a truck location report for cargo pickup optimization and can monitor drivers for safety and fuel-efficient behavior. The fleet management GPS devices are linked to a wireless (cellular) system and periodically push out data to a vendor, who packages the data for reporting software that resides at a truck company. The reporting frequency is set to be effective for business reasons and to keep connection charges limited. Once the GPS data are used by a trucking company, they have limited private sector value.

As costs drop, these devices will be increasingly used by the trucking industry. One market research firm reports that in North America the penetration of these systems is estimated to increase from 7.9 percent in 2011 to 16.4 percent by 2016.[1] These data will also be increasingly important due to the freight reporting requirements of the U.S. Moving Ahead for Progress in the 21st Century Act as well as the increased availability of truck probe data from the Federal Highway Administration's new national GPS data set.[2,3]

What Information Can GPS Provide?

In a performance measurement program, the GPS-equipped trucks are a small subset of all trucks on the network. Fortunately for roadway measurement needs, a number of studies have concluded that a small percentage of all vehicles can be used as probes to effectively monitor overall performance. A study in Washington state indicated that GPS data from a few probe trucks could provide a reasonable indication of roadway performance.[4]

Data Acquisition Challenges and Approaches

A public organization interested in using truck GPS data needs to convince private sector data owners or systems vendors to share their data. One challenge to sharing is privacy concerns, since the data could be used to track individual drivers and may need to be protected because it includes business-sensitive information. Another challenge is resource limitations related to sharing the data. Why would a trucking company or vendor expend staff time and other resources to share the data? A recent freight data sharing guidebook suggests a range of motivators to address these concerns.[5]

The motivators include supporting a private sector company's involvement by identifying the purpose of the data sharing and clearly highlighting the benefit to the private sector if they share their data. For example, for a trucking company, sharing their data with a public transportation organization would encourage more effective truck-oriented roadway investments. Obtaining support from trucking and freight associations for performance measurement may be critical to convincing trucking companies or vendors to share data. It is important to indicate that the data will not be used for any regulatory enforcement such as for speeding citations.

Privacy concerns can be reduced by legal contracts such as nondisclosure agreements. Technical approaches can also address privacy, since individual or company identification in a database can be scrambled and sensitive variables can be blocked. If the data are released for public use, this can be done in an aggregated format that obscures individual business patterns but still provides usable information.

A strong motivator used in a Washington state performance measures program was simply paying a GPS vendor for their truck data. This arrangement had the benefit of establishing the data sharing as a business relationship.

Truck GPS Data Programs in North America

Several North American transportation organizations acquire truck GPS data from private sector companies. This section discusses these organizations' programs and some of the resulting performance measures.

American Transportation Research Institute

Since 2002, the American Transportation Research Institute (ATRI) has developed a large GPS database of truck activity.[6] The resulting Freight Performance Measures initiative uses raw data reads from different fleet management vendors and other sources to analyze and monitor truck travel. Their products include periodic reports ranking national congestion bottlenecks at 250 roadway locations based on peak and nonpeak period average travel speeds. ATRI has also produced truck travel speed performance information for longer (between states) freight corridors.

An aggregated version of the ATRI GPS data is accessible in a publically available, interactive tool known as the National Corridors Analysis and Speed Tool. This geographic information system (GIS)–based tool includes average speed measures by different time periods for 1-mile segments of the interstate system.[7]

Federal Highway Administration

The Federal Highway Administration recently initiated a GPS data program known as the National Performance Management Research Data Set. These data, acquired through the ATRI program, are from 400,000 probe trucks and cover the National Highway System. The data are aggregated into 5-minute periods for individual highway segments and include time, date, direction, travel time, segment length, and location for predefined roadway segments (around 1 mile in length) 24 hours a day, 7 days a week. Historical travel data will also be available. State departments of transportation and other public agencies will have free access to the data sets to use them to meet federal requirements related to performance measurement.[3]

Ontario Ministry of Transportation

The Ontario Ministry of Transportation has a sophisticated and long-term program that uses GPS data purchased from one fleet management vendor. The data have been used for a range of planning and engineering applications including the evaluation of historic traffic performance, developing truck congestion indices, and providing traveler information. The GPS data are also input into a public traveler Internet program known as I-Corridor, which has travel information for truckers.[8]

Washington State Department of Transportation

The Washington State Department of Transportation (WSDOT) and the University of Washington partnered on a truck performance measures program that used statewide GPS speed and location information. This program, initiated in 2007, collects and analyzes truck data purchased from a large national GPS vendor.[9] The vendor provided a raw data feed from around 8,000 probe trucks each day, with reads every 3 to 15 minutes from each truck. The trucks' IDs are scrambled, but this is done consistently so individual vehicles can be followed from their origin to destination. This simplifies travel time measurement and supports the analysis of regional freight flows.

Products include the identification and ranking of truck bottlenecks on every WSDOT-controlled road. Software was developed that segmented the WSDOT network into variable lengths based on the posted speed limits, road classification, major intersections, and other significant attributes. Within each segment, GPS-derived truck speeds were compared to posted speed limits. Any segments with large differences were identified as bottlenecks. Since reliability was determined to be important to the state's truckers, reliability metrics were developed based on trucks' average speed variability over time. The bottlenecks could then be ranked based on the measured speed differences, reliability, and truck volumes.[10] The resulting bottleneck information could be placed into an overview report oriented toward elected officials (Figure 1).

Figure 1. Example bottleneck report.

WSDOT also placed the GPS truck data into an interactive GIS planning tool with measures including average speeds and the percentage of trucks traveling below a speed threshold.

Using GPS Data

Any GPS device in a vehicle outputs a common set of variables including:

- latitude and longitude,
- a time/date stamp,
- a travel heading,
- a spot (instant) speed, and
- measures of signal strength.

Fleet management vendors often add useful data interpretation including parking and engine-on and -off events and information extracted from a truck's on-board computer.

One important data acquisition consideration is the GPS device's reporting rate. In general, the more frequent a device reports the truck's location and speed, the more usable the data. Since wireless connections have cost, and fleet management GPS devices are installed for business reasons, the read rate from each vehicle tends to be limited to every 5 to 15 minutes (even though GPS devices read continuously). For traffic engineering analysis, such as looking at intersections, a read rate on the order of every 5 seconds would be ideal, but for infrastructure planning and engineering read rates, every few minutes or more are usable.

There are different approaches to determining what GPS read rates and number of trucks result in useful data. One approach, used in several of the programs above, is to simply have categorical measures. The WSDOT program required at least 200 GPS reads (over time) on a segment before the data were used for analysis.[11] The ATRI program places their information in bins based on total position reads, and each bin is assigned a reliability grade (A, B, or C) based on the relative standard error.[6]

Another approach is to use statistical methods to calculate the required number of probe vehicles. Yim and Crayford present three methods to analyze probe sample size based on the number of probe reports, the acceptable level of errors, and what level of vehicle saturation for a time period is needed.[11]

Processing the GPS Data

Once a GPS device user or vendor has agreed to supply the data and the sample size is determined to be usable, the next step is to set up data acquisition arrangements. The GPS fleet management vendors are typically familiar with pushing out data to their clients, although in a processed format. Raw GPS data need several processing steps before they can be used for network measures. Multiple trucks outputting reads can generate large data sets, so any processing cannot be done manually and needs to be completed using software.

There are a number of error checks and adjustments (typically in GIS software) that should be completed as part of this processing. GPS signals may be lost when overhead obstructions such as tunnels prevent devices from receiving signals from GPS satellites.[12] Fortunately, many devices compensate for short-term signal loss by simply waiting until an adequate number of satellites are available before reporting a position. During a short period of signal loss, it is reasonable to assume that a truck continues to travel at a constant speed, and the GPS points recorded before and after the signal loss can be used to calculate performance statistics.

In many cases, due to signal inaccuracy, when a truck idles and the GPS points are mapped, the points fluctuate around a position (known as jiggle), creating a false report of movement. To address this issue, a minimum distance between consecutive GPS points can be used to determine if the movement is jiggle or is actual vehicle movement. In the WSDOT program, if the difference between two consecutive GPS points was less than 60 feet, the record was considered jiggle.

GPS data often contain erroneous trips caused by GPS multipath effects, in which the GPS signals are distorted by being reflected off objects such as buildings.[12] To address these errors, the WSDOT program developed an algorithm to remove:

- extremely short trips between GPS reads for an individual truck,
- false trips in which the elapsed travel time was zero, and
- trips with unreasonably high speeds.

A truck's location is determined by the latitude and longitude reported by the GPS. For this information to be useful for transportation applications, these coordinates have to be geocoded (matched) in GIS software onto a digital road network.[12] Often, geocoded data experience errors caused by spatial mismatches between the digital network and the latitude and longitude points. There can also be related problems such as assignment confusion due to overpasses and parallel roads. These mismatches require a software process to identify suspect points.

The Washington program developed a process where the heading of each GPS read was compared to the heading of the closest section of digital roadway. Points with a difference of greater than 15 degrees were eliminated. This filtered out trucks traveling along intersecting roads.[10]

Developing Performance Measures

A number of performance measures can be developed from truck GPS data.

Travel Time

There are several approaches where GPS data can be used to calculate trucks' travel times. One is a measure derived from spot speed, which is the speed of an individual truck as reported at the time of the GPS read. This information becomes useful in two general formats. One is when the spot speeds involve a large number of trucks at the same general location at approximately the same time, such as around a terminal. The other, more common situation, in which spot speeds can be used is when the speed data are accumulated over time to build a large sample. In this case, the overall average speed of trucks, perhaps disaggregated by time of day, can provide information on truck performance for roadway segments. The North American programs highlighted above use averaged spot speeds over time.

The other approach to calculate travel time is space mean speed, which is derived from the time it takes a truck to travel a known distance. This calculation is simple if IDs are consistently tagged to individual trucks so you can follow these trucks along the network. If you cannot follow individual trucks due to inconsistent travel patterns or a low number of trucks, or because IDs are suppressed for privacy, it also possible, but more complicated, to build up corridor travel times from different trucks on connected segments. Figliozzi suggests one approach to building truck analysis corridors using programming logic.[13]

Travel Reliability

Travel reliability is important for the trucking community for price setting and timely deliveries. There are a number of accepted reliability measures that can be derived from GPS data including percentile travel times and the buffer index. A measure developed for the WSDOT program and designed for use with spot speeds calculated reliability based on the finding that the speed distributions for a segment typically are either unimodal (distributed around one speed) or bimodal (distributed around two speeds). If truck speeds follow a bimodal distribution, the segment is classified as unreliable.[10]

Bottleneck Identification

Both the ATRI and the WSDOT programs located roadway segments in which trucks' averaged GPS speeds were below posted speeds. These bottlenecks can be caused by infrastructure limitations, which can be identified by slow truck travel at all times. If the averaged truck speed varies by time of day (during peak times), it is typically a congestion-based bottleneck.

Other Applications

GPS data have applications beyond performance measures. If a GPS device is tied to a truck's onboard computer, the operational parameters could be valuable as input for safety and air quality studies. The GPS devices provide real-world truck data that could support travel forecasting models. The value of data can be enhanced by combining them with data from tolling systems, smartphones, weigh-in-motion stations, and roadside classification devices.

Summary

An increasing number of trucks have in-vehicle fleet management GPS devices that are used by private sector trucking companies to improve business efficiency. Acquiring the data from these devices provides public transportation agencies with a unique opportunity to monitor network performance, to locate roadways that perform poorly for trucks, and to inform infrastructure investment decisions.

There are challenges to acquiring these data because the private sector owners of GPS data may need to be convinced that sharing their data will result in improved roadway infrastructure, and there may be limits on data use due to business and privacy concerns. The data also need to be processed and collected over time, since the read rates and output format are not always ideal for public sector planning and engineering decisions. Any resulting databases may be large, so automated processes have to be developed to remove bad data and to code trucks' locations to digital maps.

Several transportation organizations have addressed these challenges and have successful truck performance measure programs. These programs have created a range of usable metrics that evaluate and monitor truck travel speeds and reliability and that support their goal to build roadways that work better for trucks. **itej**

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