Evaluating the Accuracy of Spot Speed Data from Global Positioning Systems for Estimating Truck Travel Speed

Wenjuan Zhao, Anne V. Goodchild, and Edward D. McCormack

A number of trucking companies use Global Positioning System (GPS) devices for fleet management. Data extracted from these devices can provide valuable traffic information such as spot (instantaneous) speeds and vehicle trajectory. However, the accuracy of GPS spot speeds has not been fully explored, and there is concern about their use for estimating truck travel speed. This concern was addressed by initially comparing GPS spot speeds with speeds estimated from dual-loop detectors. A simple speed estimation method based on GPS spot speeds was devised to estimate link travel speed, and that method was compared with space mean speed estimation based on GPS vehicle location and time data. The analysis demonstrated that aggregated GPS spot speeds generally matched loop detector speeds and captured travel conditions over time and space. Speed estimation based on GPS spot speeds was sufficiently accurate in comparison with space mean speeds, with a mean absolute difference of less than 6%. It is concluded that GPS spot speed data provide an alternative for measuring freight corridor performance and truck travel characteristics.

A number of trucking companies use Global Positioning System (GPS) devices for vehicle tracking and fleet management. These devices are a source of truck probe data that can provide valuable traffic information. Data extracted from them include detailed information such as vehicle trajectory, spot speed, vehicle heading, location, time, and date.

A GPS spot speed is the instantaneous speed measured at a particular moment in time and reported by the GPS unit. Spot speeds collected by GPS have the following advantages over space mean speeds (which are calculated by using consecutive GPS data readings tagged with vehicle location and time stamp information):

- GPS spot speeds can be directly obtained from GPS devices and require minimal data processing, whereas space mean speeds require a number of processing steps.
- GPS spot speeds raise fewer privacy concerns than do space mean speeds, since the latter require a vehicle ID to identify and follow trips.
- Because GPS data available from trucking companies are designed for business efficiency, they typically have reading rates on the order of 15 to 60 min, and use of these data to estimate the space mean speed for a particular link can be difficult. This problem may occur if no readings were made on the link or if readings were not made near the beginning and end of the link. However, spot speed availability is not restricted by data reading frequency, and spot speeds can be collected on any link if a significantly large number of vehicles are in use.

While these benefits exist, there are concerns with regard to the accuracy of truck GPS spot speed measurements. The exact method used by GPS vendors for determining spot speeds is commercially sensitive and is often not readily available. Typically, GPS receivers take all the pseudorange data (distance from satellite to receiver) and pseudorange rate data (satellite frequency) from all satellites in view for the past several seconds and feed the data into a Kalman filter algorithm to calculate the spot speed (*1*). The speed is smoothed over past readings, with more weight given to the most recent readings. The GPS speed calculation method for a particular device is something of a "black box," and it is therefore uncertain whether the spot speed obtained from the GPS device accurately represents the actual speed at which the truck is traveling on the roadway.

To address these concerns, this study investigated whether GPS spot speed data are sufficiently accurate for estimating truck travel speed. In doing so, the study determined whether GPS spot speed data provide an alternative for measuring freight corridor performance and truck travel characteristics.

To answer this question, two analyses were conducted. First, GPS spot speeds were compared with speed estimates from in-road loop detectors. Second, a method for estimating speed on the basis of GPS spot speed data was developed and compared with space mean speed estimation based on GPS location and time data. The scope of work was limited to restricted-access freeways where no vehicle delays are caused by traffic signals or intersections.

Any speed measurement is an estimate and includes some error in comparison with the "true" speed. Although dual-loop detectors are widely accepted as sources of reliable speed data, they are subject to various malfunctions that can result in erroneous measurements, such as the dual-loop sensitivity discrepancy (*2*). Determining whether truck GPS spot speeds are sufficiently accurate means determining whether the absolute difference between a GPS spot speed measurement and another reliable speed measurement (loop detector speed measurement) is insignificant (less than 6%, for example). Comparing truck GPS data with loop detector data involves different populations because a loop detector measures general traffic, whereas a

W. Zhao, 135 More Hall; A. V. Goodchild, 121E More Hall; and E. D. McCormack, 121H More Hall, Department of Civil and Environmental Engineering, University of Washington, Box 352700, Seattle, WA 98195-2700. Corresponding author: W. Zhao, wz@u.washington.edu.

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GPS device measures only trucks. In addition, the two speed measurements may have differences because they are affected by many external factors such as traffic composition, loop detector location, and truck lane restrictions.

LITERATURE REVIEW

GPS data have attracted interest from academic researchers and are used for monitoring general traffic conditions. However, these studies have generally used space mean speeds, and only a few studies have considered the use of or have evaluated the accuracy of GPS spot speed data.

One relevant study was conducted by Quiroga and Bullock (*3*). They described an integrated GPS–geographic information system methodology for performing travel time studies. They devised a spatial model that used GPS to generate a network map with links to a database and a mathematical model that computed segment travel time and speed. The mathematical model used GPS spot speeds to calculate distance driven by integrating spot speeds over time intervals and computing the trapezoidal approximation. The segment speed was then derived by dividing the calculated distance by the travel time. This research used Trimble GPS equipment and took for granted that the GPS speed measurement has an accuracy of 0.1 mph. The proposed mathematical model was validated by comparing modeled segment travel times with actual travel times collected by GPS.

Another relevant research effort completed by Herrera et al. evaluated the accuracy of speed measurements calculated from GPS-enabled mobile phone data (*4*). They conducted a field experiment near Union City, California, which included 100 vehicles equipped with GPS-enabled cell phones, and collected data at fixed locations along a 10-mi stretch of freeway. First, the trajectory data collected from the cell phones were compared with the loop detector data. Vehicle trajectories were reconstructed both from GPS spot speed and position data and from loop detector speed measurements. Then the speed of the traffic stream was calculated by dividing the aggregated distance by the aggregated time spent by all vehicles traversing the given space–time domain. The traffic stream speed comparison indicated good agreement between the two data sources. Furthermore, the speed measurements collected from the loop detectors were compared with the space mean speed computations based on GPS measurements and assessed by actual travel times obtained from video cameras. The authors concluded that a low proportion of equipped vehicles can often provide more accurate speed measurements than can loop detectors.

Zito et al. discussed the accuracy of GPS spot speed data obtained from GPS devices installed in probe vehicles (*5*). Field trials were conducted under a variety of conditions, and the speed measurements from the GPS receivers were compared with the velocities collected from a travel time data acquisition system (TTDAS) installed in the same probe vehicles. TTDAS is capable of measuring vehicle speed and travel distance directly and has speed accuracy within 1 km/h. The researchers found that in a suburban area, the GPS and TTDAS speed measurements matched well. The average speed error of the GPS measurements was 0.21 km/h in comparison with the TTDAS measurements, and the standard deviation of the speed error was 1.35 km/h. In a downtown area, the mean speed error of the GPS data increased to 0.60 km/h, with a standard deviation of 4.2 km/h; however, the speed measurements were still good enough for the data to be useful. Zito et al. concluded that GPS can provide useful real-time data on vehicle position and speed, provided that the quality of the signals received is considered.

Although Quiroga and Bullock's (*3*) travel speed estimation model incorporated GPS spot speed measurement, it only used the speed measurement for calculating vehicle travel distance and required frequent (every second) and consecutive GPS data readings for segment speed calculation. In contrast, this study examined whether GPS spot speeds collected infrequently (every 15 min) can be used to estimate link travel speed. Herrera et al. (*4*) indirectly assessed the accuracy of spot speed measurements estimated from GPS-enabled cell phone data by evaluating the trajectory data and the space mean speeds calculated from GPS measurements, whereas this study directly assessed the accuracy of GPS spot speeds by comparing them with loop detector speed measurements. Although Zito et al. also addressed concerns about the accuracy of GPS spot speeds, they did not explore the application of GPS spot speeds to travel speed and time estimation.

A few studies have evaluated the use of GPS data for estimating the speeds of a subpopulation (trucks). These studies have used space mean speeds instead of GPS spot speed data for measuring freight corridor performance. Although these studies are not directly related to the research question considered here, they have discussed other speed calculation methods based on truck GPS data. For example, an ongoing project by FHWA (*6*) and the American Transportation Research Institute (*7*) has developed and tested a national system for monitoring freight performance measures on key Interstate corridors. GPS data purchased from technology vendors have been utilized to measure average travel speeds and travel time reliability on freight-significant corridors. Space mean speeds have been used to estimate travel speed, which is based on time difference and travel distance between GPS positions. McCormack and Hallenbeck (*8*) tested the use of GPS technology for measuring truck movements along specific roadway corridors in Washington State. In that research, truck data were collected every 5 s from 25 volunteer trucks equipped with GPS devices. McCormack and Hallenbeck first processed the raw GPS data into discrete trips and examined the distribution of zone-to-zone travel times and space mean speeds as trip performance measures. Then they assigned the GPS trip data to road segments to measure space mean speed variability and travel time reliability on specific segments, given GPS distance and time data. They found that GPS devices could provide highly accurate data on both travel routes and individual roadway segments if a sufficient number of instrumented trucks operated along the roadways of interest.

DATA ACQUISITION

The GPS data for this study were collected as part of an ongoing Washington State freight performance measure program and were purchased directly from GPS device vendors. To handle the large volumes of GPS data, a database system was developed to archive the data, and an automatic program was built within the database server to retrieve the data from vendors.

Because the GPS data set used for this research was originally collected for trucking industry operations, it had a low frequency of data readings (vehicle location information was collected and reported every 15 min as well as at every stop) but included approximately 2,500 trucks per day for 18 months in the Puget Sound, Washington, region. Because of the infrequent data readings, space mean speeds were not available for short road segments; however, the large fleet size and long duration of data collection compensated for the low data reading frequency and provided an extensive source of truck spot speeds over most road segments in the Puget Sound area. Other information obtained from this GPS data set included device ID, GPS status (moving or parking), truck mileage, truck heading, location (latitude and longitude), and time and date stamp.

To validate the GPS data against another data source, dual-loop detector data from the Washington State Department of Transportation's Central Puget Sound freeway network were acquired. The loop detector data were aggregated into 5-min intervals and provided vehicle speed and traffic volume data. A dual-loop detector system consists of two single loops separated by several feet. When a vehicle passes a dual-loop detector, the loop detects the time taken by the vehicle to travel from the upstream loop to the downstream loop and divides the distance between the two loops by this travel time to calculate vehicle speed.

CASE STUDY AND DATA PROCESSING

To determine whether GPS spot speeds are sufficiently accurate for estimating truck travel speed, GPS spot speeds were first compared with loop detector speed measurements from the same roadway. Travel speed estimates based on GPS spot speeds were then validated with space mean speeds calculated from GPS vehicle location and time data. However, before any data analysis could be conducted, the raw GPS data have to be geocoded to the road network. In addition, to obtain accurate space mean speeds for a specified roadway link, raw GPS data have to be processed into discrete trips. Only data readings from the same trip should be used for space mean speed calculation to exclude trucks with stops on the roadway link attributed to refueling, deliveries, or hour-of-service compliance. Before the GPS data processing procedures are discussed in detail, the case study roadway is introduced.

Washington's SR-167 was selected for the case study. SR-167 is south of Seattle and connects I-5 in Tacoma with I-405 in Renton (Figure 1*a*). This 28.6-mi route provides the Puget Sound region with an alternative to I-5. SR-167 is an important freight corridor in the Puget Sound region; it experiences high truck volumes and connects several warehouse districts and two Puget Sound ports.

The SR-167 link selected for analysis connects South Grady Way and SR-161/512 (highlighted in Figure 1*a*). This link is 20.8 mi long and includes three major interchanges. North from Auburn to Renton, SR-167 is a six-lane freeway and has one high-occupancy toll lane in each direction. South from Auburn to Puyallup it has four general lanes. There is no truck lane restriction on SR-167 except that trucks are not permitted to use the high-occupancy toll lanes. The speed limit on SR-167 is 55 mph.

As mentioned, the raw GPS data were processed into discrete trips. Detecting truck trip origins and destinations requires a rule-based algorithm that differentiates between traffic-based stops resulting from congestion or signals and intended stops at origins or destinations. An automatic trip end identification algorithm based on a dwell time plus a distance threshold was developed and implemented in Java (*9*). A dwell threshold of 180 s was used to filter most

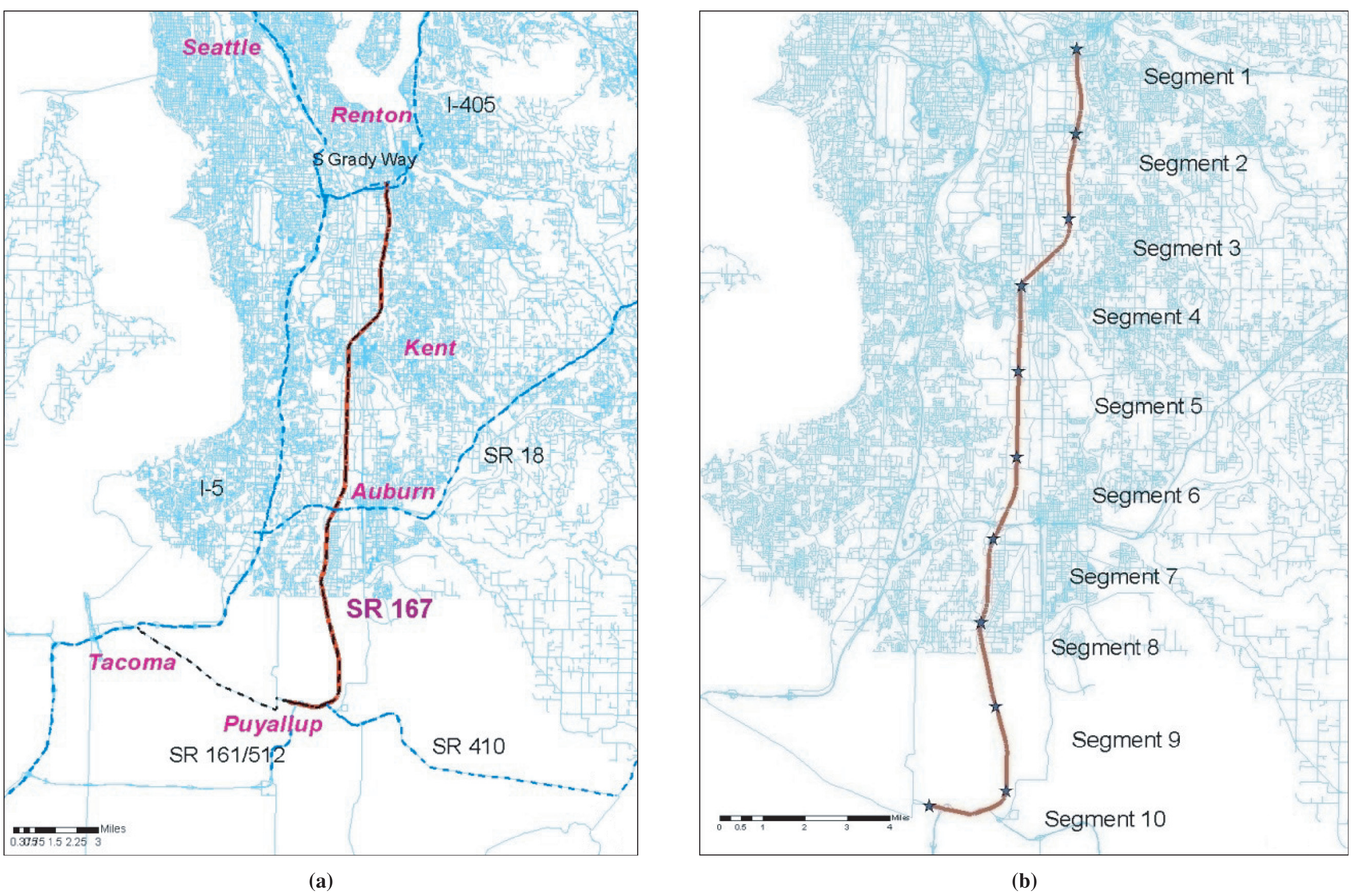


FIGURE 1 Case study: (*a*) area along SR-167 and surrounding road network and (*b*) SR-167 segmentation.

trucks' non-origin-destination stops for traffic signals or congestion, and a second screening process was incorporated to detect and flag abnormal trips such as extremely short trips, trips with extremely high speed, and trips with zero elapsed truck travel time.

Multiple data filtering procedures were used to locate (geocode) GPS data points to a road network and identify trucks traveling on SR-167. Since millions of data readings are received on a daily basis and sample size is not a major concern, strict processing methods were developed to eliminate data records that may not be on the specified freeway. First, a course filter area around SR-167 was defined to extract candidate data points from the database. These candidates were cleaned by removing duplicate records and erroneous records with abnormal readings, such as extremely high speeds. Then the remaining points were geocoded to a road network by using ArcGIS software and were further processed on the basis of the following data types:

1. Moving data points based on heading. These data points were first assigned to SR-167 by using a 70-ft buffer around the freeway. The remaining points were further filtered by comparing the truck heading with the heading of the road segment on which the truck was traveling. If the heading difference was larger than 15 degrees, the data point was considered to be outside the freeway (such as on an overpass or ramp) and was discarded.
2. Parking data points and other data types with a zero-heading direction. Zero heading was recorded when a truck was idle for a period of time and the GPS device was unable to record the direction of travel. Because these data points could not be cleaned by checking vehicle heading, a narrower buffer zone, with a boundary of 50 ft from the SR-167 centerline, was used to identify candidate data points. To avoid mistakenly capturing the data points on underpasses, overpasses, or connecting ramps, any data point falling within a 40-ft buffer zone around those features was discarded.

COMPARING TRUCK GPS DATA AND LOOP DETECTOR DATA

To validate truck GPS spot speeds, this study used dual-loop detector data collected from the same roadway segments as the GPS data. There are 25 detector stations along SR-167 spaced approximately every 0.5 mi. The first loop detector station is located at Milepost 13.27, and the last station is located at Milepost 25.62. This study used the 5-min aggregated speeds from loop detectors located in the rightmost lane to capture traffic conditions for trucks. Loop detector data from the rightmost lane were used because trucks are legally required to use the rightmost lane. To facilitate data comparison on shorter segments, the larger SR-167 section was divided evenly into 10 segments (Figure 1*b*), each 2.1 mi long. The loop detector data were available on Segments 2, 3, 4, 5, 6, and 7.

Loop and GPS data collected from October 2009 were used for comparing truck GPS spot speeds and loop detector vehicle speeds. Approximately 1,000 GPS truck data records were collected on each segment during this time, and the truck spot speeds were aggregated over segments and for 1-h periods. Similarly, the 5-min vehicle speeds collected from loop detectors were aggregated over each segment. Only weekday data were included in the analysis.

GPS spot speeds and loop detector vehicle speeds can be visually compared in Figures 2*a* and 2*b*. Figure 2*a* shows the hourly aggregated GPS spot speeds for different times of the day and over northbound freeway segments. It illustrates that trucks experienced recurrent congestion during the morning peak period, from 6:00 to 9:00 a.m., and traveled at free-flow speeds during the other periods. The severity of truck delay differed by spatial extent, and trucks experienced more severe morning delay on Segments 5 and 6. Figure 2*b* shows the monthly 5-min average loop detector speeds over the same segments. Although loop detectors in the rightmost lane also captured traffic conditions for general vehicles (predominantly passenger cars), Figure 2*b* shows traffic patterns similar to those in Figure 2*a*. The figure shows that general traffic also encountered recurrent congestion from 6:00 to 9:00 a.m., and the level of congestion was higher on Segments 5 and 6. A comparison of Figures 2*a* and 2*b* indicates that GPS spot speed data aggregated over long periods can capture freeway performance over time and space that is qualitatively comparable with freeway performance estimated by loop detector measurements.

To compare the GPS data and loop detector data quantitatively, the speed differences between hourly average GPS spot speeds and loop detector speeds over northbound segments were calculated and are shown in Figure 2*c*. The results indicate that in most cases, the speed difference was small, less than 5 mph. The speed difference was larger in the morning peak hours on Segments 4 and 6, at 14 mph. That is reasonable because truck travel characteristics are different from those of passenger cars. Trucks are more likely to travel in the rightmost lane, and they tend to travel more slowly than general vehicles, especially in congested traffic. They are also more likely to be affected by vehicle merging, lane changing, and other traffic dynamics because they cannot change lanes to avoid congestion, and they have to decelerate early when they encounter traffic congestion and accelerate slowly after being forced to slow down. It can be inferred from Figure 2*c* that the GPS spot speeds were consistent with loop detector speeds. On average the aggregated GPS spot speeds were slower than aggregated loop detector speeds by only 2.4% along northbound SR-167; the mean absolute difference between GPS spot speeds and loop detector speeds was 4.4%.

The GPS spot speeds and loop detector speeds collected from the southbound freeway direction were also examined and are presented in Figures 3*a* and 3*b*. Figure 3*a* illustrates that trucks experienced recurrent delay during the evening peak period, from 2:00 to 6:00 p.m., and evening congestion was most severe on Segments 6 and 7. Figure 3*b* shows that general vehicles in the rightmost lane also encountered recurrent congestion in the evening peak period, especially when they traveled through Segment 7. The qualitative agreement between Figures 3*a* and 3*b* is evident in terms of recurrent congestion location and its temporal and spatial extent.

The speed differences between GPS spot speeds and loop detector speeds along the southbound freeway are presented in Figure 3*c*; in most cases the speed difference was less than 5 mph. The speed differences increased during the evening peak period, especially on Segment 6, reaching 20 mph. This observation is similar to that in Figure 2*c*. The significant speed differences on certain segments might be related to roadway geometric characteristics. For example, there is a large interchange on Segment 6, where SR-167 meets SR-18 in Auburn, Washington. SR-167 also changes from three lanes to two lanes south of SR-18, near the end of Segment 6. All these factors might contribute to interrupted and slower truck traffic during peak periods. On average, the aggregated truck GPS speeds were slower than aggregated loop detector speeds by 4.1% along southbound SR-167, and the mean absolute difference between GPS spot speeds and loop detector speeds was 5.5%.

Therefore, aggregated GPS spot speed data and average loop detector speed data had a mean absolute difference of less than 6%.

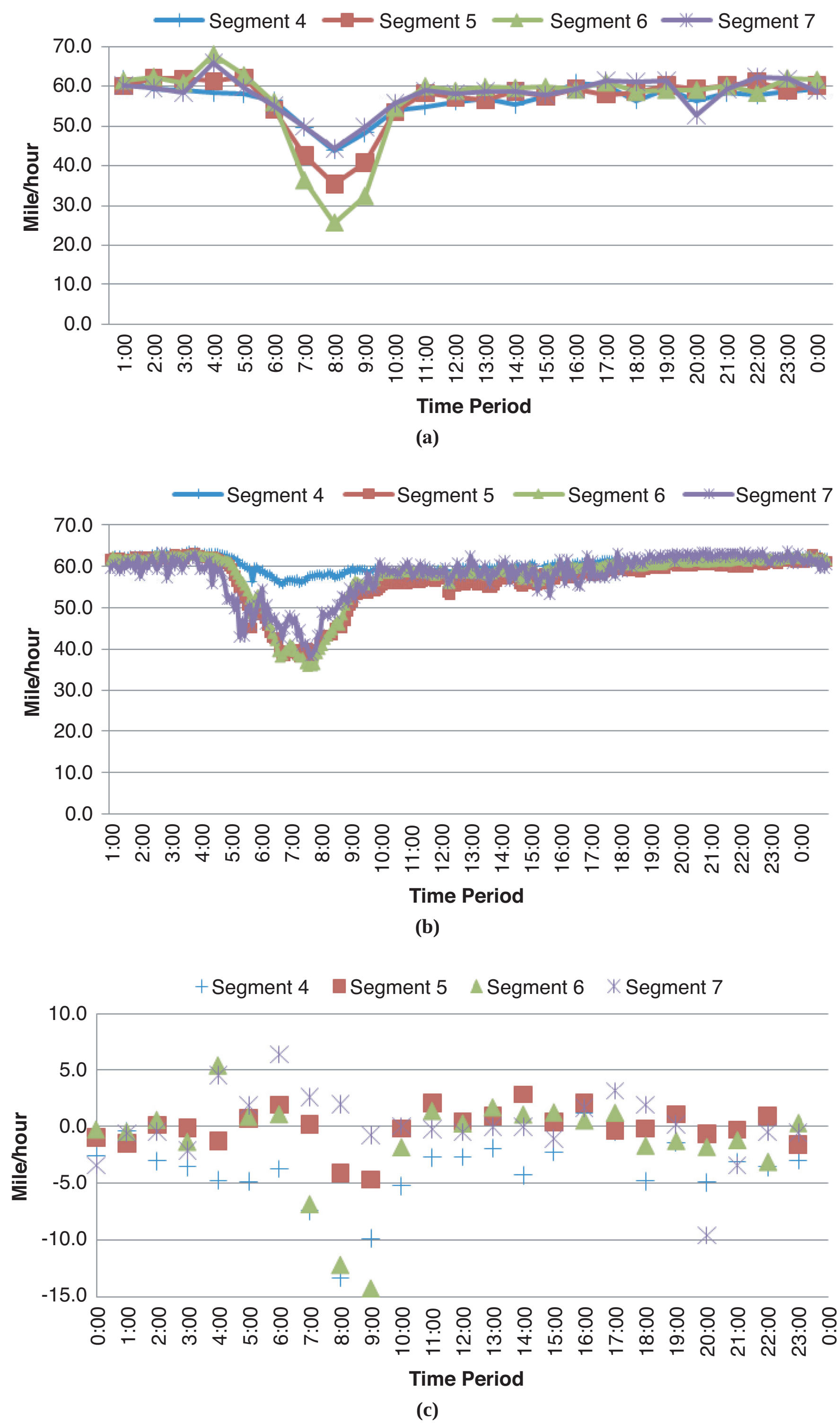


FIGURE 2 Comparison between GPS spot speeds and loop detector vehicle speeds along northbound SR-167: (*a*) average GPS spot speeds, (*b*) 5-min average loop detector speeds, and (*c*) difference between average GPS spot speeds and average loop detector speeds.

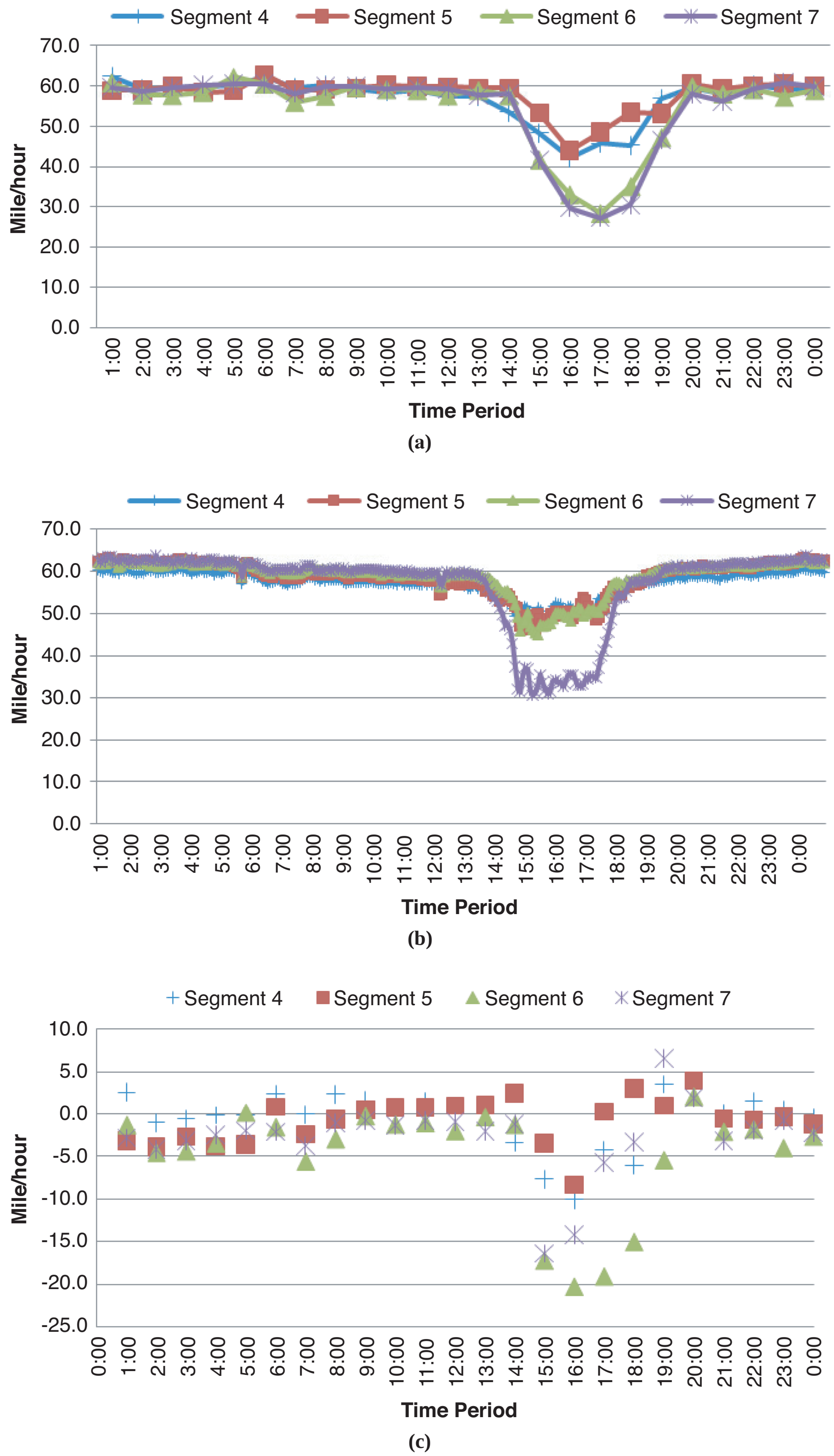


FIGURE 3 Comparison between GPS spot speeds and loop detector vehicle speeds along southbound SR-167: (*a*) average GPS spot speeds, (*b*) 5-min average loop detector speeds, and (*c*) difference between GPS spot speeds and loop detector speeds.

GPS truck speeds were less than loop detector speeds during peak hours, especially on certain freeway segments. However, this difference probably occurred because trucks have travel characteristics different from those of general vehicles, and they are more significantly affected by traffic congestion and geometric characteristics.

COMPARING METHODS FOR ESTIMATING TRUCK TRAVEL SPEED

In this section, the space mean speed estimation method based on vehicle location and time stamp data (which is widely used in GPS data studies and has been applied to measuring corridor performance and forecasting vehicle travel times) is compared with another travel speed estimation method based on GPS spot speeds.

The proposed method for estimating travel speed is to calculate the link speed on the basis of the GPS spot speeds averaged over segments. This will be called the "estimated link speed." Consider a freeway link, AB, with *n* segments (Figure 4). Here "link" refers to a stretch of freeway, and "segment" refers to one part of a link. One link can be composed of many segments. It is assumed that GPS spot speeds averaged across segments can reasonably represent general travel conditions on the segment. Thus the segment travel time can be calculated as the quotient of the segment length and average spot speed on a given segment. By summing all the segment travel times, the link travel time will be obtained, and the link travel speed can be derived. The estimated link speed can be expressed by the following equation:

$$V_e^j = \frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} \frac{L_i}{v_i^j}}$$

where

V_e^j = estimated link speed during the *j*th time period,
L_i = length of the *i*th segment, and
v_i^j = arithmetic mean of GPS spot speeds observed on the *i*th segment during the *j*th time period.

The most common method for estimating space mean speed is to calculate link travel speed on the basis of the travel time and distance between the starting point and the ending point. This will be referred to as the average link speed. The average speed is used instead of median speed because the average value was found to result in a better fit between the two speed estimation methods. To apply this method for computing travel speed on Link AB (Figure 4), first all the truck trips from which data readings have been collected near Points A and B must be identified, and then the average link speed can be calculated by the following equation:

$$V_a^j = \frac{\sum_{k=1}^{n} \frac{l_k^j}{t_k^j}}{n}$$

where

V_a^j = average link speed during the *j*th time period,
l_k^j = distance difference observed in vehicle locations of the *k*th trip with data collected near A and B during the *j*th time period,
t_k^j = travel time difference observed in vehicle time stamps of the *k*th trip during the *j*th time period, and
n = number of trips identified during the *j*th time period.

To compare and evaluate these two speed estimation methods, truck GPS data collected from September 2008 to January 2010 were used. At least 10,000 data points were collected on each segment. For southbound SR-167, the link including Segments 2 to 7 was analyzed (Figure 5*a*). All truck trips with data readings in Segments 2 and 7 were identified as through trips and were used for calculating the average link speed (1,278 trips identified). For northbound SR-167, the link including Segments 3 to 8 was analyzed (Figure 5*b*). All trucks trips with data readings in Segments 3 and 8 were identified and used for calculating the average link speed (1,383 trips identified).

The comparison between the estimated link speeds based on GPS spot speeds and average link speeds based on vehicle location and time data for the northbound direction is presented in Figure 6*a*. The 95% confidence interval of the average link speeds (the black bars displayed in Figure 6*a*) and the coefficient of variation of link speeds (calculated by dividing the standard deviation of link speed by the average link speed) are also provided in Figure 6*a* to illustrate speed reliability. Since no ground truth speed was available, the ultimate accuracy of the two methods cannot be evaluated. However, Figure 6*a* shows that the estimated link speed always falls within the 95% confidence interval of the average link speed. The coefficient of variation of link speed shows that the travel conditions of northbound trucks are reliable except in the morning peak hours (7:00 to 9:00 a.m.); however, this coefficient value never exceeds 22%, and the estimated link speed is consistent with the average link speed regardless of the variability of operations in the corridor. Figure 6*b* indicates that the absolute difference between the two speed estimations is less than 3.5 mph. On average, the estimated link speed is lower than the average link speed by 2.3% along the northbound freeway, and the mean absolute percentage error of estimated link speed is 3.0 in comparison with the average link speed.

A comparison of the two speed estimation methods applied to the southbound direction is shown in Figure 7. Again, the estimated link speed always falls within the 95% confidence interval of the average link speed. The coefficient of variation of link speed indicates that the

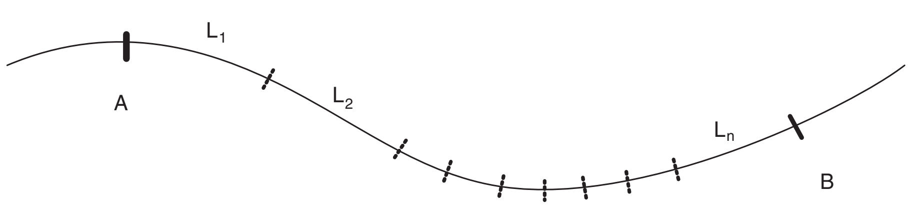
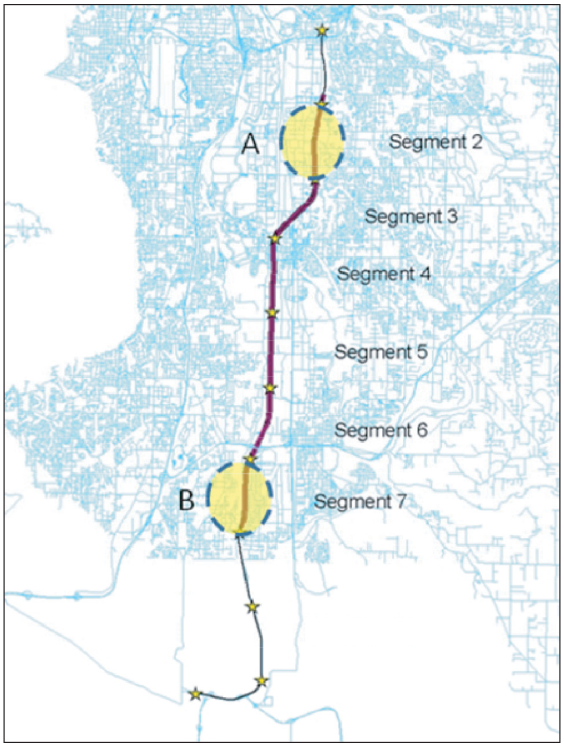
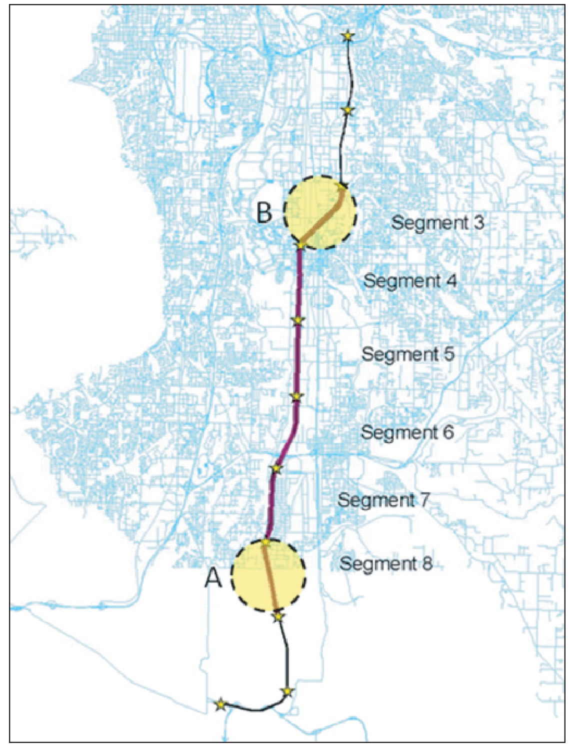


FIGURE 4 Freeway link and segments.

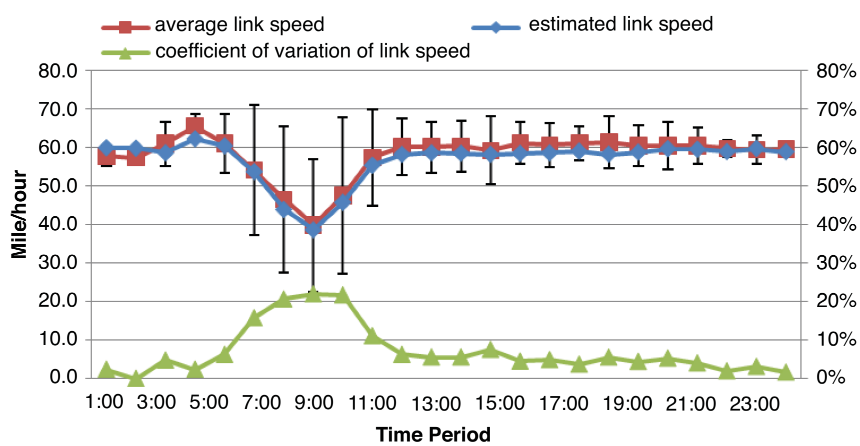


(a)

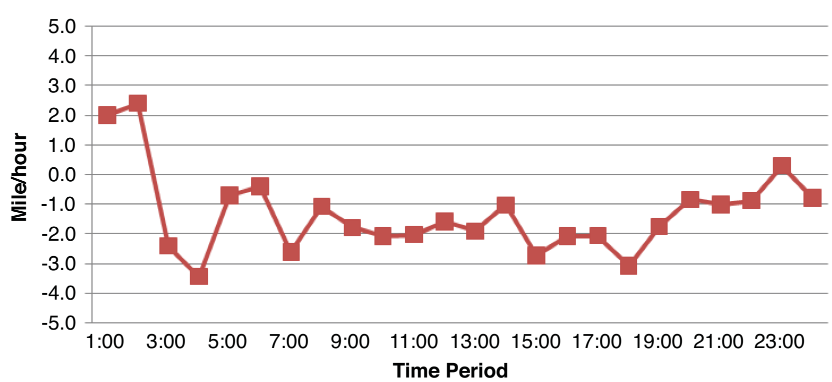


(b)

FIGURE 5 Link and segments under study on SR-167: link composition (*a*) southbound and (*b*) northbound.



(a)



(b)

FIGURE 6 Comparison of speed estimation methods on the basis of GPS data collected on northbound SR-167: (*a*) comparison between estimated link speed and average link speed and (*b*) absolute difference between estimated link speed and average link speed.

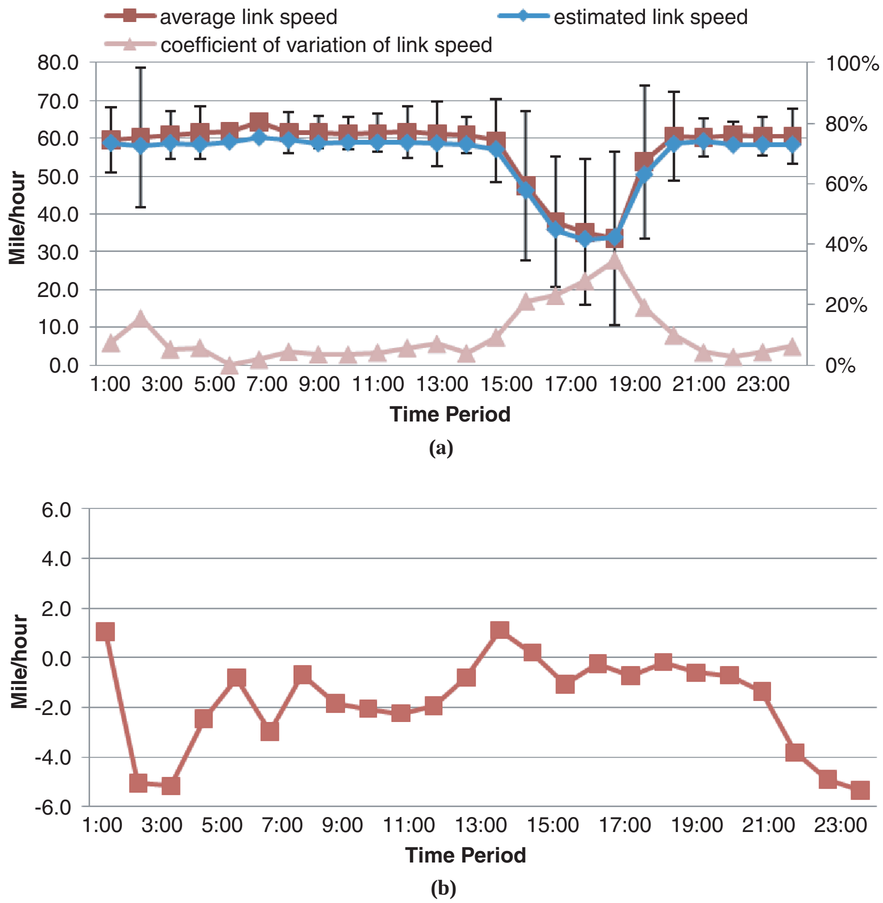


FIGURE 7 Comparison of speed estimation methods on the basis of GPS data collected on southbound SR-167: (*a*) comparison between estimated link speed and average link speed and (*b*) absolute difference between estimated link speed and average link speed.

truck travel conditions on the southbound freeway are reliable except during the evening peak period (3:00 to 7:00 p.m.); however, the two speed measurements are consistent regardless of the variability of freeway operations. Figure 7*b* shows that the difference between the estimated link speed and the average link speed is less than 5 mph in the southbound direction. On average, the estimated speed is lower than the average speed by 3.9%, and the mean absolute percentage error of estimated link speed is 4.0 in comparison with the average link speed.

This analysis indicates that estimating link speed on the basis of GPS spot speeds is also a reasonable speed estimation method, with a mean absolute percentage of error of less than 4.0. By using GPS data collected over long time periods, the proposed method can capture typical travel conditions. However, the estimated link speed is slightly lower than the average link speed. This is probably due to several factors. First, the data samples used for the two speed estimation methods were different. All the spot speeds observed on each segment were used to calculate estimated link speed, whereas only the through trips with data readings collected near the beginning and end of the freeway link were used to calculate average link speed, so the sample size was much smaller. Second, the average link speed calculation only included those through trips, whereas the estimated link speed calculation also considered trips that did not travel through the entire link but exited the freeway via ramps. Those vehicles needed to decelerate before exiting the freeway and could have brought about lower spot speed measurements, which might have contributed to a lower estimation of link travel speed.

CONCLUSION

This study addressed the question of whether GPS spot speeds are sufficiently accurate for estimating truck travel speeds. With Washington SR-167 as a case study, the accuracy of truck GPS spot speeds was first explored by comparing aggregated GPS spot speeds with speeds derived from roadway loop detectors. It was found that aggregated GPS spot speeds can capture freeway performance over time and space that is qualitatively comparable with freeway performance estimated from loop detector measurements. Although the speed difference between GPS spot speeds and loop detector speeds was greater during congested periods on certain freeway segments, this result was expected because trucks have travel characteristics different from those of general vehicles.

The study also developed a simple speed estimation method based on GPS spot speeds and compared it with another popular speed estimation method (calculation of space mean speed from travel distance and time). The analysis demonstrated that speed estimation based on GPS spot speed data collected over long periods can capture typical travel conditions and recurrent truck delay; results matched well with space mean speeds obtained from time and location data (the mean absolute difference between the two speed measurements was less than 4%).

The research methodology and results suggest that GPS spot speeds can be used for a wide range of truck GPS data applications, including measuring freight corridor performance, monitoring truck travel conditions on the roadway network, and estimating truck travel costs on network links. An advantage of using GPS spot speeds is that they can be directly obtained from GPS devices and require minimal data processing effort. In addition, they are not restricted by GPS data reading frequency, and because trucks IDs are not necessary, the method reduces privacy concerns. The speed estimation method based on GPS location and time data is constrained by the GPS data reading rate and is unable to calculate space mean speeds on roadway links if data readings are not available on the link or near the beginning or end of the link. GPS spot speeds, in contrast, can be used to estimate travel speeds on freeway links of any length, as long as they are traveled by enough GPS-equipped trucks.

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