Freight-Specific Data Derived from Intelligent Transportation Systems

Potential Uses in Planning Freight Improvement Projects

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Freight planning is an increasingly visible topic in the arena of transportation planning. Freight planning metrics and benchmarks can help state agencies select and assess the impact of improvement projects with respect to freight mobility. Given the unique patterns of freight flow, freight metrics are most valuable when derived from freight-specific data. Extraction of timely freight-specific data to support freight planning efforts is not, however, always straightforward. Washington State, the primary focus of this study, has been developing potential methodologies for extracting and applying freight-specific data in benchmarking freight projects. The Freight Mobility Strategic Investment Board (FMSIB) of Washington State deployed intelligent transportation systems (ITS) technologies [Global Positioning Systems (GPS) and automated vehicle identification (AVI)] with the stated goal of collecting freight-specific data. An examination of the data collected for the FMSIB benchmarking test reveals that both sources of data—GPS and AVI—can support the freight planning process. This paper highlights results of the FMSIB study, the comparative accuracy of the two data sources, and the uses of each for planning purposes.

Freight planning is an increasingly visible topic in the arena of transportation planning. The federal government first mandated the inclusion of freight transportation in the planning process with the 1991 passing of the Intermodal Surface Transportation Efficiency Act (ISTEA) (*1*). This act required state and metropolitan planning entities to explicitly address and incorporate freight-specific transportation planning factors. This trend was continued in the Transportation Equity Act for the 21st Century (*2*). Besides politicians, planners also realize that including freight in the planning process prevents the unfortunate impact of freight gridlock on the economy and environment. However, freight transportation is often difficult to plan for and benchmark.

Private commercial entities are the organizations that execute freight movement, and public agencies often fund the roadway improvements and port activities affecting freight mobility. Therefore, freight planning requires interplay between these public and private entities. Generally, a "lack of understanding of business needs and public sector planning timelines hinders the effective integration of freight into many statewide and regional plans and transportation investment decisions" (*3*).

The FHWA advocates freight planning through courses, such as 139001–Integrating Freight in the Transportation Planning Process, Freight Data Made Simple (FHWA Resource Center course), and the Freight Studies Seminar (FHWA Resource Center course). These courses provide practical tools, techniques, and noteworthy practices to support the freight planning interests of state departments of transportations (DOTs), metropolitan planning organizations (MPOs), and local governments. Implementation of these tools and techniques varies widely from state to state and region to region.

Progressively more states are seeking to require accountability in the identification, selection, funding, and execution of transportation projects, especially projects contributing to the improved movement of freight. Freight-specific planning metrics and benchmarks can help predict areas of congestion, and thereby allow freight-dependent communities to plan freight-based improvements and private companies to improve their routing and scheduling practices. Furthermore, freight planning metrics and benchmarks can help state agencies assess the impact of selected improvement projects with respect to freight mobility.

The need for such metrics has long been recognized. A 1998 review of freight planning techniques performed by the University of Virginia reported on a survey of state DOTs that indicated the use of approximately 211 performance measures associated with freight planning (*4*). This same study also noted that the development and use of freight-specific planning metrics is dependent on data availability.

Given the unique patterns of freight flow, freight metrics must be based on freight-specific data. Extraction of timely freight-specific data to support freight planning efforts is not always straightforward. In some instances, public agencies deploy intelligent transportation systems (ITS) and collect general transportation mobility data. The Association of Metropolitan Planning Organizations (AMPO) regularly selects and reports on best practices in transportation planning (*5*). A recent review of AMPO's selection reveals three locations (Washington, D.C.; Baltimore, Maryland; and Hampton Roads, Virginia) heralded for their use of Global Positioning Systems (GPS) technology to derive origin–destination data, travel times, and travel speeds. In addition, AMPO's review of best practices noted plans of San Francisco, California, to use toll transponder data for collecting travel time data. Unfortunately, extracting freight-specific data from these general sources is not always feasible.

Many private companies use ITS technologies to track vehicles and optimize routing and scheduling; however, the issue of proprietary data often prevents the sharing of these data assets for planning

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purposes. Freight-specific data needs are noted by the TRB study recommending a framework for the development of a National Freight Data Program (6). The goal of the National Freight Data Program study is to identify specific types of freight data that users require. Another goal is to fill current gaps in modal coverage, particularly motor carrier flows. The current data sets for this area do not thoroughly cover routing and time of day. New data streams from the increased use of ITS technologies lend themselves well to the population of freight databases. Furthermore, the data provided by freight-based ITS systems (such as GPS trackers) can directly support the development and use of freight planning metrics and benchmarks. This is exemplified by a recent study performed at Oregon State University aimed at extracting freight-specific origin–destination data from GPS technologies placed in commercial motor vehicles (7). With the use of this methodology, the GPS data will serve to illustrate commodity flows in the Portland, Oregon, region.

Despite an existing technology's availability for data collection, there may still be challenges in transferring and analyzing the data. First, the data may not completely support the desired analysis. Second, there may be privacy or other issues preventing an organization from having unencumbered access to the data. Last, the analysis required to support the desired metrics may be time consuming or complex. These challenges were all found in a recent evaluation of the Freight Mobility Strategic Investment Board's (FMSIB) Benchmark Project. This project resulted in concepts concerning how data from freight-specific ITS could support the identification, selection, and benchmarking of freight improvement projects.

This paper highlights the innovative use of ITS data as uncovered in the case study of the Washington State FMSIB Benchmark Project. The paper begins with an overview of freight planning practices in Washington State. This overview is followed by a description of a specific test performed by the FMSIB to determine technology uses and data handling methodologies to promote freight data use in planning and benchmarking projects. Finally, the paper concludes with an analysis of two data sets: one from transponder-based Commercial Vehicle Information Systems and Networks' automated vehicle identification (CVISN–AVI), and one from GPS.

OVERVIEW OF FREIGHT PLANNING IN WASHINGTON STATE

The Washington State Department of Transportation (Washington State DOT) has an Office of Freight Strategy and Planning organized to work on issues related to freight transportation planning. This office ensures that decision makers are accurately informed with respect to the following:

- Customers of the state's freight system and their expectations of the system;
- Relationship between freight, jobs, and gross state revenues;
- Identification of key performance gaps; and
- How to make productive, strategic investments in the state's freight system.

In the *Freight Report,* a component of the Washington Transportation Plan (8), the Office of Freight Strategy and Planning recommends corridors and specific improvement projects with respect to four subcomponents of the freight system: international gateways, corridors (both east-west and north-south), transportation serving in-state producers and manufacturers, and wholesale distribution systems. The *Freight Report* identifies areas of productive investments with respect to Washington's global view of the freight system. Throughout the *Freight Report,* data-driven statistics support the arguments for the proposed projects; however, requirements for freight-specific data to support future planning activities are not articulated in this document.

At the state level, Washington State DOT has also answered the legislative and public demand for agency accountability in transportation system benchmarking through the publication of the *Gray Notebook* (9). The *Gray Notebook* reports on many areas, including moving goods and freight. The freight indicators used in the book include the following:

- Revenue from trucks (all weights and classes);
- Daily truck trips for major corridors in Washington: I-5, I-90, Highway 395, and US 97;
- Average monthly cross-border truck volumes;
- Road segment ranking (ranked by truck tonnage); and
- Current and projected mainline rail capacity (trains per day).

In addition to the Freight Planning Office, Washington State DOT has numerous partnerships tasked with exploring the issue of freight mobility, improvement, and planning. These include the Freight Action Strategy corridor; the FMSIB; the International Mobility and Trade Corridor project; and the Washington State legislature's Transportation Improvement Board. These Washington freight planning entities address the need for freight-related data and benchmarks that relate specifically to freight performance, particularly the impact of freight improvement projects. The FMSIB, for example, requires many quantitative freight metrics in its project application form, including the following:

- Current and projected truck delays (in hours) and
- Volume-to-capacity ratios for truck movements (at peak hour, measured in the number of trucks per peak hour).

The following section highlights FMSIB's efforts in the arena of deriving viable benchmarks from freight-specific data sources.

FMSIB BENCHMARK PROJECT

The Washington State legislature created Washington State's FMSIB in 1998, with the mission of creating a "comprehensive and coordinated state program to facilitate freight movement between and among local, national, and international markets which enhance trade opportunities" (10). The board comprises 11 representatives from the highest levels of state government and transportation-related industries, including rail, steamship, and trucking. The FMSIB's main activities are identifying, securing funding for, and overseeing the execution of freight-specific improvement projects. The FMSIB maintains a 6-year list of projects, and the board submits specific funding requests to the legislature annually; the FMSIB solicits project requests every other year. The FMSIB considers project requests from local, county, and regional (MPO) levels, as well as port authorities. The board sponsors projects that "promote strategic investments in a statewide freight mobility transportation system" (10), as well as those that "soften the impact of freight movement on local communities" (10).

In 2000 the Benchmark Committee of the Washington State Blue Ribbon Commission on Transportation (BRCT) tasked the FMSIB

with determining benchmarks applicable to freight operations and improvement projects. Because of the complexity involved in benchmarking freight operations, the BRCT charged the FMSIB with bringing predictability and certainty to these freight benchmarks. FMSIB collaborated with the Washington State Transportation Center (TRAC) affiliated with the University of Washington to ensure that the data used in the benchmarking project would be meaningful to other agencies. The benchmarks, or selected standards, are expected to become part of the board's freight improvement project selection process. These standards are also expected to support reporting on speed and volume improvements that resulted from completed FMSIB improvement projects. The FMSIB's goals for instituting freight benchmarks were to understand the following elements:

- Number of trucking movements that would be affected by each FMSIB improvement project,
- Freight travel time changes that would result from a particular FMSIB improvement project, and
- Frequency with which trucks experience severe, unexpected delays (TRAC referred to this element as "trip reliability").

The FMSIB had one specific requirement that was important to incorporate into its benchmarking process: ideally, the benchmarks would be derived from inexpensively collected data. This requirement caused FMSIB to investigate the use of an existing ITS whose data could support freight-related benchmarks. The FMSIB decided to examine the use of existing CVISN and border AVI electronic truck transponders that were mounted on approximately 20,000 trucks traveling in Washington. These transponders are read on major Interstate corridors. In addition to using the stored travel time information collected via the CVISN–AVI systems, the FMSIB decided to use in-vehicle GPS tags as a mechanism for collecting potential benchmarking data. Washington State DOT purchased approximately 25 new and used GPS tags and data recorders. Each GPS unit and recorder cost between $200 and $600; therefore, for this limited deployment, it was an inexpensive means of collecting data.

TRAC solicited the Washington Trucking Association for volunteers who would be willing to participate in the test. Five carriers agreed to participate. These carriers followed mainly urban routes, mainly on arterials.

The GPS units and data recorders were in use for nearly 1 year, from June 2003 to June 2004. TRAC provided the units to the trucking companies with a postage-paid envelope so the recorders could easily be collected monthly. The recorders were configured to log a latitude and longitude position every 5 s. The recorders do not highlight exact origins and destinations. TRAC analysts used in-house software to analyze the raw GPS data based on the assumption that if the vehicle speed was recorded at 0 mph for longer than 3 min, it would be interpreted as an origin/destination. The software alternated labeling these pauses as origins or destinations as it read each file, thus enabling TRAC analysts to compute approximate travel time segments for each carrier's routes.

Summary of TRAC Findings

After determining which technologies to use in the project, FMSIB used additional funding to support a TRAC study of its benchmarking project. The purpose of this study was to examine how data could be collected to support freight operational and improvement

benchmarks (*11*). The TRAC study documented the development of data collection methodologies and recommended additional elements that needed to be incorporated in a successful FMSIB benchmarking strategy. The TRAC study also estimated the costs of deploying a benchmark data collection program, should the FMSIB determine to do so.

The TRAC study found that both the CVISN–AVI and the GPS devices could be used to collect truck movement data, thus providing descriptions of the changes in truck performance that may result from FMSIB improvement projects. TRAC found that a key factor affecting the use of these technologies appears to be whether enough instrumented vehicles pass over the roadways for which data are required. Trucks equipped with CVISN–AVI transponders, for example, travel primarily on major Interstate corridors. If the FMSIB improvement project is on another state route or arterial, then the CVISN–AVI system is not likely to generate sufficient data. Similarly, TRAC found that although the data set collected via GPS was more robust than that collected by CVISN–AVI, the relatively few GPS instrumented trucks operating in a large metropolitan region yielded insufficient data to be collected on many routes. Hence, unless a fairly large sample of trucks is actively participating in the data collection effort, GPS may provide neither a statistically significant nor a robust sample (*11*).

TRAC recommended a benchmarking methodology dependent on existing ITS (i.e., GPS and CVISN–AVI) to collect data both before and after the improvement occurred. Specifically, the following ITS data–derived elements could support the FMSIB in meeting its benchmarking goals:

- Truck volumes by day and by time of day,
- Mean travel times by time of day,
- 80th and 95th percentile travel times by time of day,
- Select origin-to-destination travel time, and
- Select origin-to-destination route.

The origin-to-destination route element was recommended to support understanding how a particular roadway improvement affected a trucker's route selection.

Finally, FMSIB tasked TRAC to examine the potential costs of a benchmark data collection program. It was found that the estimated cost ranges are broad. For FMSIB projects on major Interstate corridors, transponder data are collected at no charge via the CVISN–AVI systems. Combining the semiportable readers owned by FMSIB with the additional semiportable readers owned by Washington State DOT could supplement this system at a cost of between $10,000 and $15,000, which could increase to approximately $80,000 if support materials such as power poles and sign bridges were necessary.

The 25 GPS units and recorders used to support the TRAC study were relatively inexpensive (approximately $200–$600 per unit); 25 units could support the data collection for a single isolated roadway at an estimated cost of $10,000 for both data collection and analysis. If the improvement affected a more complex area, the data collection area would be considerably larger. Although it is difficult to estimate how many GPS units and recorders would be required, TRAC felt that between 150 and 200 units would meet the minimal requirement. The TRAC-developed analysis and reporting software used for the limited GPS test would have to be refined to streamline the process of analyzing additional data. Thus, TRAC estimated these costs at between $150,000 and $200,000 as one-time costs, with $15,000 required to support each additional year.

Federal Evaluation

The U.S. Department of Transportation Joint Program Office selected the FMSIB benchmark project for a federal evaluation. Federal evaluations follow a rigorous methodology including a baseline data collection phase and a postdeployment data collection phase with a comparative analysis to determine improvements. The first phase of baseline data collection and analysis for the FMSIB project was completed in July 2005 and serves as the basis for this report (*12*). The evaluation team immediately recognized the value of the ITS data (CVISN–AVI and GPS) in supporting several operational areas, including planners, commercial vehicle companies, and law enforcement. The aim of the ongoing FMSIB benchmark evaluation is to determine how useful the data provided by GPS and CVISN–AVI are to these communities. In some cases, the baseline evaluation has already indicated how the data from these systems can support the planning process. This segment of the paper highlights these preliminary findings.

To date, the evaluation has relied on four primary data sources: a comprehensive review of the freight planning literature in Washington State, results from interviews with state and local planning personnel, archived GPS and AVI data, and results from surveys with industry personnel. Because of the potential innovative uses of ITS data discovered via the GPS and AVI analysis, this article highlights only those findings. The reader is referred to the final report of the baseline phase for the full study results (*12*).

GPS–AVI Data Collection

The GPS data were collected by equipping 52 trucks with a Geo-Logger GPS data-archiving device. Given the ease of reuse for the GeoLogger GPS devices, after the data were archived, the loggers were returned to the field. Originally, 25 GPS units and data loggers were purchased with FMSIB funds for the project. Hence, the reuse of the equipment allowed 52 different vehicles to be tracked during the year they were deployed. Each GPS unit and logger remained on a single vehicle for the span of about 1 month each. Despite being able to reuse the GPS loggers, 52 vehicles still do not represent a significant percentage of commercial vehicles operating in Washington State. As such, difficulty in soliciting commercial motor vehicle participation is the biggest shortcoming of this technology. Careful consideration of appropriate sample sizes and sets should be undertaken before using GPS for the collection of freight planning data.

In the FMSIB test, each of the 52 GPS-equipped trucks performed its regular pickup and delivery duties for a period of approximately 1 month. The data loggers were then submitted to TRAC, where the data were retrieved and stored in a database accessible via the Internet. The full data files were downloaded from the host server by the evaluation team at the end of the test.

The transponder data were collected by the CVISN–AVI–equipped weigh stations. As a truck passed one weigh station, its record was time stamped. As the truck continued to pass weigh stations downstream, subsequent records were made and time stamped. The records were then compared and the time required for travel between weigh stations was extracted and made available via a Web-based interface. In conjunction with the known distance between weigh stations, the travel time information was used to determine the speed of travel. The evaluation team downloaded raw travel time, speed, and distance information from the TRAC server for the dates of interest for analysis.

GPS–AVI Data Analysis

Once the evaluation team downloaded the GPS and AVI data, the files were converted from comma separated text files to Excel files. Given the large file size, data loss was of great concern in performing this conversion. Hence, care was taken so as not to lose any data; rather than convert the full files, data covering only very specific time periods were extracted. The time periods were selected on the basis of those dates for which both CVISN–AVI and GPS data were available and comparable.

The transponder data follow distinct routes along the CVISN–AVI corridors in Washington State. As such, it was necessary to sort the GPS data to identify truck trips on those same equipped corridors. Once an appropriate truck trip was identified in the GPS data, the date and times were noted, and the CVISN–AVI data for the same route, date, and time frame were requested.

The CVISN–AVI data contained fields for the date/time, travel time in minutes between the specified readers, sample size, and average speed. The GPS data contained fields for date/time, latitude, longitude, speed, heading, and number of satellites available for the reading. To determine the relative or comparative accuracy of these data, two elements were examined—the travel time and the speeds.

The travel times provided in the CVISN–AVI data were in 10-min increments. For example, the average number of minutes that it took a truck to travel from one weigh station to another was recorded on the basis of arrival in a specific 10-min time window. On average, for the trips and times examined, five trucks completed the specified route in each 10-min window. The GPS data did not provide the travel time specifically for each trip.

Travel time was computed from the GPS data by subtracting the time affiliated with the record indicating a GPS location at the first weigh station from the time affiliated with the record indicating a GPS location at the second weigh station. In this way, the GPS-based travel times and the CVISN–AVI–based travel time could be compared. The average speed of all trucks over the entire route in each 10-min increment was calculated and presented in the CVISN–AVI data based on a calculation—dividing the travel time by the preestablished distance between the given weigh stations.

The speed for the GPS data was recorded for each truck every 5 s. Hence, to extract speeds from the GPS comparable with speeds from the CVISN–AVI, the individual speed recordings were averaged for each 10-min increment.

The GPS and AVI data supported two main study areas: (*a*) data accuracy and (*b*) data usability for selecting and benchmarking freight projects. There was great interest in determining data accuracy as collected by the two test technologies. To accomplish that activity, the evaluation team examined the data from the two systems (CVISN–AVI and GPS) to gain a comparative understanding of the strengths and weaknesses of both data sets. To determine data usability for the selection of freight projects the evaluation team undertook a mapping process to visualize vehicle speeds and locations of high freight congestion.

Data Accuracy

The averaged incremental GPS-based speeds were then compared with the average CVISN–AVI speeds via a *t*-test. This approach does not yield an exact comparison because the CVISN–AVI data represent an average across several trucks across the full route, whereas the GPS data represent an average across a short time interval and

segment of the full route for only one truck. This comparison is the most similar that can be made based on the two differing data sets and sources.

Following the aforementioned data extraction and analysis methodology, one route emerged as having data from both CVISN–AVI and GPS data sources. This route includes the path along I-5 from the Vancouver (Ridgefield) (N) weigh station reader location to the Fort Lewis (N) weigh station transponder reader location. This route, depicted in Figure 1, is about 102 mi long.

For this one route, only three trucks made the trip a total of four times: 12/8/2003, 12/10/2003, 5/03/2004, and 5/11/2004. The average travel time was recorded in units of minutes. The average travel time for the GPS data was 133 min, and the average travel time for the CVISN–AVI data was 101 min. The GPS-based travel times ranged from 113 to 172 min, and the CVISN–AVI data ranged from only 94 to 115 min. This difference is likely the result of the CVISN–AVI data capturing an average travel time across several vehicles traveling the same corridor, whereas GPS data capture the travel time of only one vehicle traveling the same corridor. In that regard, if the first CVISN–AVI–equipped vehicles arriving at the weigh station did not encounter delay, the average across the CVISN–AVI vehicles will be lower; whereas the one GPS vehicle may have traveled the corridor moments after those first AVI–CVISN vehicles and as such encountered an accident or period of congestion.

The speed data for these trips was also examined. Given the dependency of speed data on roadway conditions (i.e., weather, lighting, construction, etc.), the comparison between CVISN–AVI and GPS data was performed individually for each specific trip. Table 1 summarizes the average speed for each comparison. In examining the table, it may be said that in general the GPS data reflect longer travel times than those expressed in the CVISN–AVI data. Admittedly, with such a small sample size for each trip, the results of a statistical comparison are questionable; despite that shortcoming, a *t*-test was performed. An analysis of variance revealed that the variances were consistent in only two of the four cases (12/08/2003 and 12/10/2003). That may be a result of construction affecting the I-5 speeds during May 2004. A *t*-test for the two December trips revealed that in one instance (12/10/2003), the calculated *t*-value was above the tabulated *t*-value; whereas in the other instance (12/08/2003), the calculated *t*-value was below the tabulated *t*-value. Thus, there is a significant difference between the means of the GPS and transponder data on 12/08/2003, whereas there is no significant difference between the means of the GPS and CVISN–AVI data on 12/10/2003. Results of these statistics are presented in Table 2. These differences in average
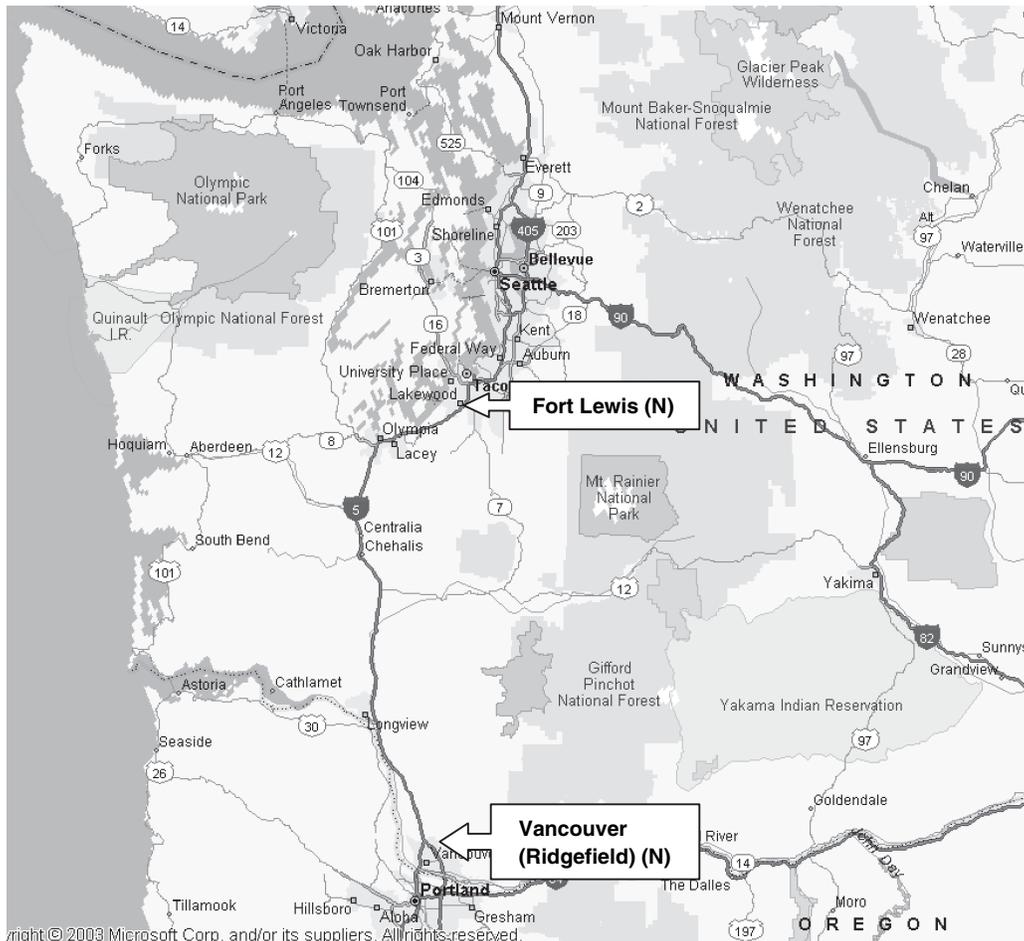

FIGURE 1   Route from Vancouver (Ridgefield) (N) along I-5 to Fort Lewis (N).

TABLE 1   Mean Speeds for Each Data Set
for Specified Date

Date	GPS Data	AVI Data
12/08/2003	61.76 mph	63.81 mph
12/10/2003	57.18 mph	64.90 mph
05/03/2004	55.22 mph	60.24 mph
05/11/2004	49.06 mph	61.38 mph

travel times most likely result from the fact that the CVISN–AVI data represent an average across several trucks across the full route, whereas the GPS data represent an average across a short time interval and segment of the full route for only one truck.

Figure 2 illustrates the comparison of CVISN–AVI speeds with GPS speeds on I-5 between Vancouver (Ridgefield) (N) and Fort Lewis (N) on May 3, 2004. In looking at this graph in Figure 2, it is interesting to note that the GPS data mirror the CVISN–AVI transponder data, yet reflect greater extremes. This pattern was similarly noted across all 4 days examined: 12/08/03, 12/10/03, 5/03/04, and 5/11/04. Again, this phenomenon most likely results from the fact that the transponder data represent an average across several trucks in a given interval across the full route; however, the GPS data represent an average across a small segment of the full route for only one truck in the given interval.

Given the rough similarities between the two data sets and the fact that no major outlying data had to be cleaned from either data set, it can be concluded that accurate freight data can be collected from both GPS and CVISN–AVI. However, several factors emerged that may play into the decision between using GPS or CVISN–AVI data. For example, the CVISN–AVI data are premised on averages across a full trip, whereas the GPS data are at the unit truck level. Hence, if one is interested in travel times for a given route in a wide time window, CVISN–AVI data may be the better choice. However, if travel time data for a small segment in a very specific interval is required, then GPS data would be the best choice. In this way, the two data sets work to complement each other—and neither can be said to be more or less accurate than the other.

Data Usability for Identifying Congested Areas

In this section the usability of GPS data for identifying areas of congestion to support freight planning is examined. Only GPS data are examined because they provide a more robust view of freight movement than the CVISN–AVI data. The CVISN–AVI data are limited to major Interstates and reflect averages across multiple trucks—properties that are helpful in determining main-line travel time reliability, but are less helpful in gauging specific areas of congestion.

Although previous and ongoing studies have focused on using GPS data to derive commodity flow information, that was not possible in the context of this test. The selected GPS loggers provided only the truck's location and no information on the load status (i.e., loaded or empty); it was not possible to determine pickup and drop-off locations or times. The analysis methodology was thus limited to examining consistent areas of delay. Hence, after extracting the raw GPS files from the TRAC server, the data were converted from comma-separated text files to Excel files. Once converted, the GPS data were mapped and coded on the basis of the speed of the vehicle. It was hoped that in this way specific truck trips (i.e., from pickup to drop-off) would be readily discernible.

With the described mapping approach, delay was not occurring over-the-road as frequently as it was occurring in commercial vehicle terminals. This phenomenon is most easily viewed in the data extracted for operations on 5/19/03. On that date, seven commercial vehicles were operating with GPS recorders (four in the Boeing fleet and three from the Harbor Freight fleet). These seven vehicles operated mostly in the I-5 corridor ranging from the Parkland area north to the Arlington area. From this process it was immediately obvious that multiple red dots indicating areas of delay were occurring throughout the Seattle region. Figure 3 shows a close-in view of the map highlighting delays in the city of Seattle.

From these visualizations the zones of commercial vehicle congestion are immediately apparent. One method by which GPS data may improve planning is through the identification of improvement projects targeting areas of high congestion. With this visualization method, these areas are readily identified as those areas with a significant number of "red dots," or points affiliated with the slowest GPS recorded speeds. Rigor can be added to the process of selecting congested areas via the application of a density metric. For example, depending on the scale of the area, congestion could be measured on the basis of a specified number of GPS reads for speeds between 0 and 5 mph (0 and 8 km/h) within 1 mi. In that way, selection could be justified in quantifiable terms.

Furthermore, once a project is complete, this approach can benchmark improvements in commercial vehicle flow. This approach is only as good as the number and types of trucks that are equipped with GPS. Hence, great care must be taken in selecting the number

TABLE 2   GPS versus AVI Speed Study Results

|	12/08/2003	12/10/2003
GPS	61.76 ± 0.78 (mean ± standard error; $n = 7$)	57.18 ± 1.14 (mean ± standard error; $n = 11$)
CVISN–AVI	63.81 ± 1.47 (mean ± standard error; $n = 7$)	64.90 ± 0.62 (mean ± standard error; $n = 11$)
Calculated t-value	1.23	5.95
Tabulated t-value ($p = .05$)	2.18	2.09
Outcome (null hypothesis: the means of the GPS and CVISN–AVI data sets do not differ significantly.)	Fail to reject null hypothesis	Reject null hypothesis
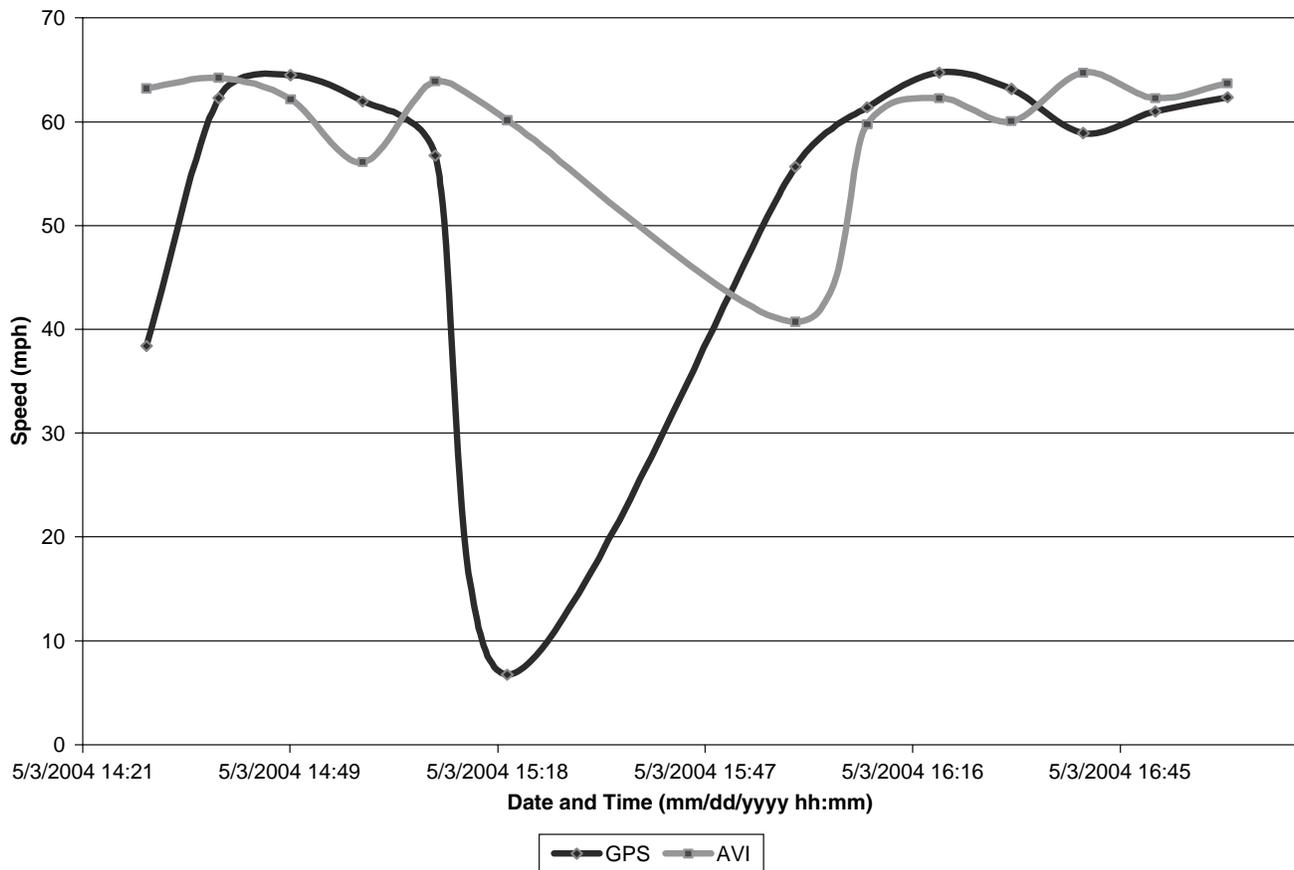
FIGURE 2   Speed graphs for four different trips on I-5 between Vancouver (Ridgefield) (N) and Fort Lewis (N).

and types of trucks to avoid skewing the data and an inappropriate set of improvement projects.

CONCLUSIONS

The FMSIB of Washington State deployed ITS technologies (GPS and AVI) with the goal of collecting freight-specific data. These freight-specific data then supported the development of freight-specific benchmarks. Furthermore, through the process of a federal evaluation, the accuracy of the data and additional uses were noted.

An examination of the data collected for the FMSIB benchmarking test reveals that both sources of data can support the freight planning process. Of the TRAC-recommended ITS-derived metrics, only travel times and preliminary route analysis are possible using the GPS and CVISN–AVI data. Volume measures were not possible with either data sources. Both data sources also pose trouble in ensuring a statistically significant data set—with GPS, it is often difficult to recruit motor carriers willing to participate, and with CVISN–AVI the number of data points is linked to the number of transponder-equipped vehicles. In addition, each data source demonstrated different strengths and weaknesses in the computation of the desired planning metrics. Table 3 provides an overview of the strengths and weaknesses of both types of data.

For example, if travel times for a given route in a wide time window are desired, CVISN–AVI data may be the better choice. If travel time data for a small segment in a very specific interval are required, then GPS data would be the best choice. Furthermore, GPS data mapped by speed category indicates a unique method by which policy makers and planners may identify areas of heavy freight congestion. By focusing on these areas, planners may be able to design projects to improve both roadway congestion and air quality.

Although this paper serves to highlight some methods by which ITS (CVISN–AVI and GPS) data may satisfy planning needs, the suggested approaches are by no means exhaustive. Specifically, additional uses of demographic data filed with CVISN–AVI transponder applications may be used to perform commodity flow studies on major Interstates. Furthermore the methodology for visualizing congestion via GPS reads (as introduced in this paper) may be expanded to support metrics of travel time reliability. This expansion is dependent on an in-depth study of the relationship between congestion and travel time reliability.

Freight planning has come a long way since the passing of ISTEA. Most states now incorporate freight in the planning process in a well-defined way. Many states, such as Washington State, host a dedicated freight planning office or freight advisory committee. Several states are moving toward a rigorous set of performance measures and prioritization methods for selecting and funding freight projects. At the forefront of these efforts is the work performed

FIGURE 3 Commercial vehicle speeds in Seattle on May 19, 2003.

TABLE 3 Comparison of GPS and CVISN–AVI Strengths and Weaknesses

Planning Metric	GPS Data Strengths	GPS Data Weaknesses	CVISN–AVI Data Strengths	CVISN–AVI Data Weaknesses
Truck volumes	N/A	N/A	Unlike GPS, CVISN–AVI provides a means by which to measure truck volumes at weigh stations.	Restricted to routes equipped with CVISN–AVI weigh stations.
Travel times	GPS data could be effectively mined to generate a robust data set of travel times for specific trips.	Extracting routes that encompass travel in a specific corridor is difficult. The effort required to mine the data may exceed the statistical significance garnered from the data mined. Statistical significance is closely tied to the number and types of motor carriers signed up to share GPS data.	AVI data can provide good, but gross estimates of travel time along specific corridors in Washington State.	Unfortunately, AVI data are limited to only specific corridors that do not generally encompass terminals or points of pickup or delivery. AVI data are based on averages; may mask specific areas of congestion.
Route considerations	GPS data do a very good job at exposing specific areas of congestion at specific times.		AVI data can provide routes to the extent they are limited to corridors equipped with AVI readers.	Data span multiple trucks across longer stretches of roadway—it is difficult to pinpoint segments of congestion. No data can be downloaded for specific terminals.

by Washington State in the arena of freight project benchmarks derived from the data streams of existing ITS technologies.

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