Methods of Travel Time Measurement in Freight-Significant Corridors

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ABSTRACT

In 2002 the Federal Highway Administration (FHWA) entered into partnership with the American Transportation Research Institute (ATRI) to explore methods and approaches for measuring freight performance on the nation's highways. This work is related to the United States Department of Transportation's (US DOT) and FHWA's strategic objective of global connectivity, aimed at facilitating a more efficient domestic and global transportation system that enables economic growth and development. This study is derived from a general understanding that our nation's freight transportation system is essential to the economy, and that the freight volume, especially that carried by the trucking industry, will increase dramatically over the next several decades. Measuring the performance of freight on the National Highway System (NHS) will allow Federal agencies, state and local planners, and industry to develop strategies and tactics for maintaining significant corridors and metrics that can be applied to the performance and reliability of the corridors. The processes associated with this phase include:

- Identification of Freight Significant Corridors
- Review of Data Collection Technologies
- System Alpha Test
- System Beta Test

The study concluded that positioning data from trucks can be processed in a confidential manner to provide average travel rates along major U.S. freight corridors. The research also suggests that the approach used for this study can be applied and expanded to establish a national system of freight performance measurement.

INTRODUCTION

In 2002 the Federal Highway Administration (FHWA) entered into a partnership with the American Transportation Research Institute (ATRI) to explore methods for measuring freight performance on the nation's highways. This effort is partially the result of the U.S. Department of Transportation's predictions that by the year 2020, the tonnage of goods hauled over the U.S. transportation system will increase almost 70%. *(1)*

The initial phase of this project uses a systematic approach to identify freight significant corridors and appropriate metrics for evaluating performance and reliability of the corridors. The processes associated with this phase included:

- Identification of Freight Significant Corridors
- Review of Data Collection Technologies
- System Alpha Test
- System Beta Test

Resultant from this initial phase is an understanding of Freight Performance Measures (FPM), and a second phase of more intense data collection. The second phase of data collection uses established methods of tracking highway freight to further understand opportunities associated with data collection and user requirements. Data for freight positions on five Freight Significant Corridors was collected over a 3-month period using satellite technology. As evidenced in the initial Beta Test, and during preliminary phase two data testing, an important finding is that average truck speed for corridor segments can be used to identify bottlenecks and/or congestion areas. .

IDENTIFICATION OF FREIGHT SIGNIFICANT CORRIDORS

The initial identification of freight significant corridors was determined through a process that weighted possible corridors against one another. To accomplish this, a qualitative method was utilized, relating usage of each corridor, appropriateness of tracking freight through each corridor, and identifying those that have flow interruption issues (i.e. bottlenecks, congestion)

The highest truck volume cities were determined through an ATRI partnership with a technology provider, which allowed for the collection of real-time location transmissions in order to identify traffic volumes on corridors. After analysis of these satellite-based position reports from a sample of the technology provider's fleet of trucking industry customers, ten cities were identified as highest volume cities based on one week of data collection (See Table 1).

The list of top truck traffic cities was compared to the list of freight-significant corridors identified in the report *Evaluation of Performance Measurement: Travel Times in Freight-Significant Corridors Phase 1 Final Report* prepared by Cambridge Systematics, and referenced against information derived from FHWA's Freight Analysis Framework. This effort yielded suggested corridors for further study of freight usage and travel times. Results are cross tabulated below (See Table 2).

ATRI supplemented this cross-tabulation by conducting a web-based motor carrier survey asking carriers to identify the most significant freight corridors based on usage and/or freight issues. The survey prompted carriers to provide information on their company and to rank the five U.S. corridors they considered most significant as defined by three criteria:

- the Interstate or travel route
- city and state of trip origin
- city and state of trip destination

Qualitative detail was also provided by survey respondents through responses concerning why specific corridor choices were made. The survey identified several sub-segments of larger interstate corridors – these reflect the predominantly shorter-haul mix of survey respondents. Though the overlap of freight-significant corridor segments was not substantial between the survey results and those identified in the first two steps, the survey-identified segments will be considered for study in subsequent phases of the project.

The systematic approach to corridor selection identified five candidate corridors (average length approximately 235 miles) for initial testing:

- Houston – Dallas via I-45
- Indianapolis – Chicago (Gary) via I-65
- Houston – San Antonio via I-10
- St. Louis – Kansas City via I-70
- Phoenix – San Bernardino via I-10

It was recognized by FHWA and the project team that information developed through this effort may be germane and timely to ongoing U.S. and Canada cross-border freight mobility and security initiatives. Therefore, I-5 in British Columbia/Washington State was included for study

REVIEW OF DATA COLLECTION TECHNOLOGIES

After the determination of corridors, a review was conducted of data collection technologies that are useful in tracking highway freight. Among the methods of collection analyzed are:

- Satellite-Based Systems;
- Terrestrial Wireless Systems;
- Hybrid Systems;
- On-Board Systems; and
- Fixed Site Systems

The purpose of the review was to identify the technologies that could provide the best combination of geographic and temporal coverage, density of observations, usability of data formats, and cost-effectiveness for collecting information on truck movements along the corridors.

Satellite tracking is done by an on-board mobile device that transmits a continuous or periodic signal to an earth orbit satellite. This method requires a Global Positioning Satellite (GPS) receiver which is used to determine location based on several potential algorithms or a signal triangulation. This technology was determined to offer superior service in rural areas, which is important in tracking vehicle movements on the NHS.

A second technology, terrestrial tracking, is based on either analog or digital cellular technology. Cellular systems are divided into multiple coverage base station areas referred to as cells. The benefit of cellular systems is the coverage provided within metropolitan areas where satellites are not as effective. Drawbacks include limited coverage in rural areas and on Interstate highways, less precise locating capabilities (50-150 meters) than satellite GPS, and multi-system interoperability issues.

Hybrid tracking systems were found to incorporate technologies and platforms from all or some of the previous two tracking technologies. Systems are being created that combine terrestrial wireless coverage in urban areas supported with satellite service reserved for those areas where terrestrial coverage is not available. This minimizes the overall system cost, when compared to a satellite tracking system, while providing the nationwide satellite coverage that is not apparent with terrestrial systems.

The fourth, and least advanced, technology is On-Board Computer tracking. It is the simplest and most labor-intensive form of vehicle tracking, consisting of cabin-mounted measuring/sensing devices (processors) that electronically or mechanically record data including truck speed, engine rpm, idle time, mileage, and other information utilized by motor carriers. Benefits include being the least costly tracking option (some variation of a system exists in most vehicles today) and a low cost alternative for users who need simple mileage, fuel, and vehicle performance data. Drawbacks include being the least sophisticated tracking option with limited data availability for the user. Additionally, it may involve substantial manual processing to extract and relate data to FPMs.

Finally, there are several major freight-related fixed site systems that could be used for vehicle tracking and FPM development. The most common form of this is the electronic toll collection systems that are in place today on many interstate segments. Several, such as PrePass and Green Light, were designed specifically for CVO processing; however other electronic toll collection systems such as EZ Pass provide similar functionality.

The primary FPM issue associated with fixed site systems is that the total number of available sites is limited by design, jurisdictional and financial issues. With a limited number of sites, it is more difficult to develop incremental and continuous corridor measures. It also greatly restricts tracking off the Interstate system. These limitations negate fixed site systems as a primary FPM collection tool, but make them useful for augmenting other systems.

Within these five technology categories, there are two capabilities that may be available to the user: Continuous Flow Technology and Data Burst Technology. Continuous Flow Technology enables the real-time updating of vehicle location tracking. Continuous Flow, as the name implies, is data that is transferred to the system user at all times. Data Burst Technology allows for near real-time updating of a vehicle's movement. Data is sent out as data packets at specified time intervals instead of as a constant stream of data.

SYSTEM ALPHA-TESTING

A system alpha-test was subsequently required to validate both the measurements and the methodology of ATRI-developed Freight Performance Measures. Before this took place, ATRI assessed the quality and scope of available tracking technologies and the customer base of those technologies. This assessment included a consideration of the geographic distributions of the study corridors to ensure the availability of truck data for those locations. A large technology provider was chosen who could offer data from a satellite-based system that could determine average travel speeds and times for finite segments of the study corridors.

The system itself is capable of contacting vehicles at regular, predetermined time intervals to determine the specific location of the asset, using latitude/longitude (lat/long) positioning. The locations are stamped with a time, date, and vehicle tracking number. For the purposes of this research, tracking numbers were altered so that they were unidentifiable, yet the random numbering was the same on each individual vehicle. Thus it is possible, using this data, to determine average speed of a vehicle between two or more points. After evaluating the capabilities of the data, a four-step initial system design was required to determine appropriate data acquisition, manipulation and analysis techniques.

The first step was to obtain permission from motor carriers to use position reports from their trucks as the data generated is the property of the motor carrier. Confidentiality, as noted above, was crucial to the agreements that were developed with six to eight carriers of various sizes. Those who did agree to participate played a major role in ensuring that data was cleansed and not traceable to the carrier.

A second step involved the development and testing of the 'snapping algorithm' that would be used in the research. The tracking system had several key, unique elements that were necessary to integrate prior to alpha-testing to allow for both accurate vehicle positioning on a known geographic database, as well as data conversion to speed and time.

- The first of these elements is the mobile terminal positioning mechanism. This allowed for the position polling of vehicles, mobile-initiated position reports for vehicles that had not sent reports, and finally polling of system activities, such as turning on or off the ignition switch. It was found that the system used was relatively robust in accuracy for this element: the lat/long positions were accurate within ¼ of a mile. One challenge that arose from this was matching a truck position with the more specific NHS points.
- A second element is transportation system mapping, which coordinated the lat/long vehicle positions with the NHS GIS points for the corridors. To do this, the research team created an SQL database of the NHS coordinates that encompassed the following:

  i. Known lat/long coordinates along I-5, I-10, I-45, I-65 and I-70 as provided by FHWA;
  ii. A ¼ mile "block" around each of the lat/long coordinates was developed by adding .0005 to each of the lat/long coordinates to arrive at an upper and lower limit range;
  iii. Each upper limit and lower limit range was assigned to available mile marker positions on a particular corridor as provided by FHWA and the Bureau of Transportation Statistics (BTS).

- The third element is position data collection, extraction and conversion. To identify if any of the received position reports fell within the upper and lower limits of known coordinates, a query was run comparing the data files of the technology provider with the highway coordinates developed above. Those that matched were placed in a file along with the following information: time and date; mobile terminal number; highway number; nearest highway mile marker; and lat/long position. A Visual Basic program (Cypher) was used to convert the mobile terminal numbers into unique five to seven random digit identifiers for each individual vehicle. Data received by ATRI was therefore not traceable to the carriers who provided data, and the original data with unaltered mobile terminal numbers was destroyed by the technology provider according to customer contracts.
- The granularity of position points found in the NHS data relating the truck lat/long coordinates to points along the NHS additionally required the development of a 'snapping algorithm,' or an algorithm that equates a position report's lat/long coordinate to the nearest NHS recorded coordinates. This allowed for the mapping of truck position along the transportation system, and more accurately than within ¼ mile of that system, and thus allowed for the calculation of travel speeds.
- The fourth element of the system developed for alpha-testing is the method of calculating travel speeds. The ATRI team determined the calculation of speed by dividing the distance traveled from position one to position two by the time between each position recording. A hypothetical query is shown below:
  i. Mile marker 206 minus mile marker 59 = 147 miles traveled
  ii. Time 16:42 minus time 05:43 = 10:59 travel time
  iii. 147 divided by 10:59 = 13.3 MPH
- It was therefore necessary for each vehicle to report at least two unique positions to not be excluded from the dataset. Average speeds during the sample period for individual corridors were calculated, and all speeds that fell outside one standard deviation of the mean were excluded. This is the initial way the project, during the alpha-test, accounted for common occurrences such as refueling, deliveries and hours-of-service compliance. This was the most readily available method for obtaining accurate average speeds for the corridors. This process is demonstrated in Table 3.
- The fifth element is the speed reporting system. The average speed for a particular corridor or corridor segment can therefore be reported on an aggregated basis as determined above.

The results of the alpha-test demonstrated the feasibility of the following:

- Associating vehicle identification/location with NHS geo-positions;
- Calculating average vehicle speeds through position point differentiation;
- Initial steps in extracting and eliminating confounding terminals/trucks that might otherwise negatively impact the statistical accuracy of speed estimation.

The alpha-test recommendations, listed below, led to improvements used in the next phase of research, system beta-testing:

- The ATRI team determined that a system should be deployed that reduces the amount of manual manipulation of data, especially for processing a larger scale of truck position reports over longer time periods and geographic ranges.
- It was also determined that greater uniformity and frequency of geo-coordinates is needed for NHS positions to improve speed measurement accuracy and consistency along corridors.
- Finally, graphic visualization of the travel time and average speed data was required to facilitate identification of temporal or infrastructure-based impediments to traffic flow.

System Beta-Testing

Based on the promise of alpha-test results, a beta-test of the system was designed. Objectives of this second test included the development of a new method to refine data processing, manipulation and analysis to allow for larger data collection, and additionally to map the truck positions using GIS software and a customized truck speed calculating tool. Resulting from the latter objective was an ability to visualize vast amounts of data in map formats, thus allowing for the identification of average speeds on segments of each corridor, and identification of slower segments that designate potential roadway bottlenecks.

The ATRI project team first addressed the limitations found in the NHS data, which does not provide incremental position points, such as mile markers, along a route. This lack of robustness resulted in an unwanted degree of variability in speed calculations when using the snapping algorithm. To address this concern the ATRI team developed 'virtual' mile markers with a GIS software developer. Thus, using the GIS software and a Visual Basic tool developed by the GIS software company (the truck speed calculating tool), the ATRI team had the ability to calculate more precise truck speeds by 'snapping' the trucks' reported lat/long position to the 'virtual mile markers' created for the software. This process also allowed for visualization of the data. (See visualization example in Figure 1)

The ATRI team ran a series of tests of data sets against the FPM system to ensure the accuracy of the snapping algorithm and mapping system. After several iterations, the ATRI team formally tested the validity and adaptability of the speed calculation and visualization methodologies for the five corridors across a 24-hour period, initially through the collection of 24-hours of data by the technology provider.

Using the vehicle number assignment method developed during the alpha-test, the ATRI team determined that full confidentiality existed. Therefore data from all trucks that generated position reports in a given time period along the corridors were extracted from the technology provider's network center and subsequently processed for the beta-test. Table 4 presents the number of trucks generating positions reports and the number of reports received along the test corridors for March 19, 2003.

Based on those position reports, speed calculations were developed for continuous 50-mile segments of the corridors. For the beta-test, segmentation of the corridors into 50-mile intervals was deemed to be the minimum interval length in which two or more position reports for a truck in transit would be received. This was due to the technology provider's standard hourly position reporting, a practice that is generally accepted in the trucking industry. Shorter segment lengths (i.e. 10, 20 or 30 mile increments) would require a more frequent position-polling rate than once hourly or a more robust data set of truck positions.

The speed calculations by corridor segment in the beta-test demonstrate the system's ability to translate speed and time calculations into average speeds per corridor segment, thus allowing identification of possible infrastructure bottlenecks. Additionally, the calculations can be further classified and compared across time-of-day intervals for the corridor segments to identify possible temporal bottlenecks.

MORE INTENSE DATA COLLECTION AND PROCESSING

A wider scale data collection was conducted as part of the second phase of this project. Truck positions on the five freight-significant corridors, I-5, I-10, 1-45, I-65 and I-70, were collected over a three-month period. The larger data set has been managed by distributing the information into several hundred spreadsheet files that are designed to allow for easy combining of data before it is entered into the GIS mapping tool. For instance, one could choose to combine every Friday for 3 months on the I-5 corridor between 3pm and 7pm, and the collection and compilation of that data would take minimal effort.

Preliminary results of this data collection and subsequent analysis and visualization indicate development of the Visual Basic truck speed calculator tool is necessary for more accurate results. It has been determined that with more robust results exist greater chances of including outliers within the 50 mile segments. Thus, if a segment has a particularly high number of outliers, such as a segment that has a great numbers of trucks stopping for routine deliveries, refueling and hours-of-service compliance, there exists a greater chance of falling outside the standard deviation. This is especially true in corridors that have vast expanses of rural areas interrupted by large urban areas, such as the I-5 corridor. Currently, the ATRI team is developing a truck calculator with the GIS software developer that will eliminate these factors from our data processing and visualization.

RECOMMENDATIONS AND CONCLUSIONS

This research has been successful in providing both an initial systematic identification of freight significant corridors, and in developing the metrics for evaluating the performance of full corridors as well as individual segments therein. The research has also created a viable methodology for integrating existing dynamic information flows with static points along the NHS to derive travel times and average speeds of freight movements along NHS corridors. The results of the research are promising and offer the opportunity for an expanded system that could potentially be real-time and more robust.

The beta-test has advanced the FHWA Freight Performance Measures concept beyond simply collecting numbers. The development of software packages and procedures has allowed the ATRI team to not only show travel times and average speeds on paper, but to visualize them using GIS software. The test has also shown that the data collected for these purposes can be rendered unidentifiable through cleansing techniques, can be assigned to specific locations along the NHS, and can be processed for speed estimation at the corridor or 50-mile segment level. This has been demonstrated in a relatively automated environment.

The ATRI team has, however, determined important areas for further research in order to enhance current FPM measures and offers the following conclusions:

- Additional statistical filters are needed to ensure the integrity of the speed estimates. In other words, future data analysis will require that our data processing tools are enhanced to establish a minimum number of observations per segmentation bin, to flag extreme values within defined bins for exception reporting, and to reference current estimates against historical estimates by bin to identify possible exceptions.
- Validation of the estimation methodology via probe vehicles with polling rates of greater frequency than the standard of once-per-hour may be necessary.
- Greater detail in the mapping of the NHS will ensure accurate identification, or replacement of ‘virtual’ mile markers.

Technological feasibility has been demonstrated through this initial FHWA-sponsored FPM research. The ATRI team has shown that it is possible to collect key roadway operational data using satellite technology, and has been effective in manipulating the data into useful and easily understood visual formats for the 5 corridors chosen. As a result, the following recommendations are made for an expanded operational test of the FPM system’s functionality and overall validity:

- Expansion of the number of test corridors from 5 to 25, using the original list of 50 corridors as a starting point, would multiply the number of end-to-end multi-corridor comparison possibilities.
- Utilizing truck probes with increased polling frequencies would validate the accuracy of the current FPM methods.
- Digitally mapping three to five of the original corridors would allow for assessment of research opportunities along those corridors, and also improve the functionality associated with dramatically improved location data.
- To improve visualization and data processing accuracy, an improvement in FPM presentation methods should occur that includes a revision of the existing GIS software system and associated customized software.

- An assessment of major transportation modeling systems should be conducted to determine whether, and how, FPM outputs could be used to improve the accuracy and functionality of traffic/transportation modeling systems.

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TABLE 1 Top Ten US Cities by Number of Truck Position Reports

City	Number of Reports from Units	Deviation from Highest City
Chicago, IL	774,728	
Atlanta, GA	689,248	13%
New York, NY	658,502	18%
San Bernardino, CA	561,947	38%
Ft. Worth/Dallas, TX	559,383	48%
Detroit, MI	552,052	96%
Cincinnati, OH	396,143	118%
Houston, TX	355,900	120%
Toledo, OH	350,854	121%

Table 2 Freight-Significant Corridors Cross Referenced with Top Ten Truck Traffic Cities

Top 10 City	Route	From	To
Chicago	I-80	Omaha	Chicago
		Chicago	**Cleveland**
	I-65	Indianapolis	Chicago
Atlanta	I-75	Miami	Atlanta
		Atlanta	Knoxville
New York	I-78	Harrisburg	New York
	I-95	Philadelphia	New York
		New York	Boston
San Bernardino	I-10	Los Angeles	Tucson
Ft. Worth/Dallas	US-287	Amarillo	Dallas
	I-35	San Antonio	Dallas
		Dallas	Oklahoma City
	I-45	**Galveston**	**Dallas**
Detroit	I-75	Dayton	Detroit
Cincinnati	I-75	Knoxville	Dayton
Houston	I-10	San Antonio	Houston
		Houston	New Orleans
	I-45	**Galveston**	**Dallas**
St. Louis	I-70	Kansas City	St. Louis
		St. Louis	Indianapolis
	I-24	Nashville	St. Louis
Toledo	**I-80**	**Chicago**	**Cleveland**

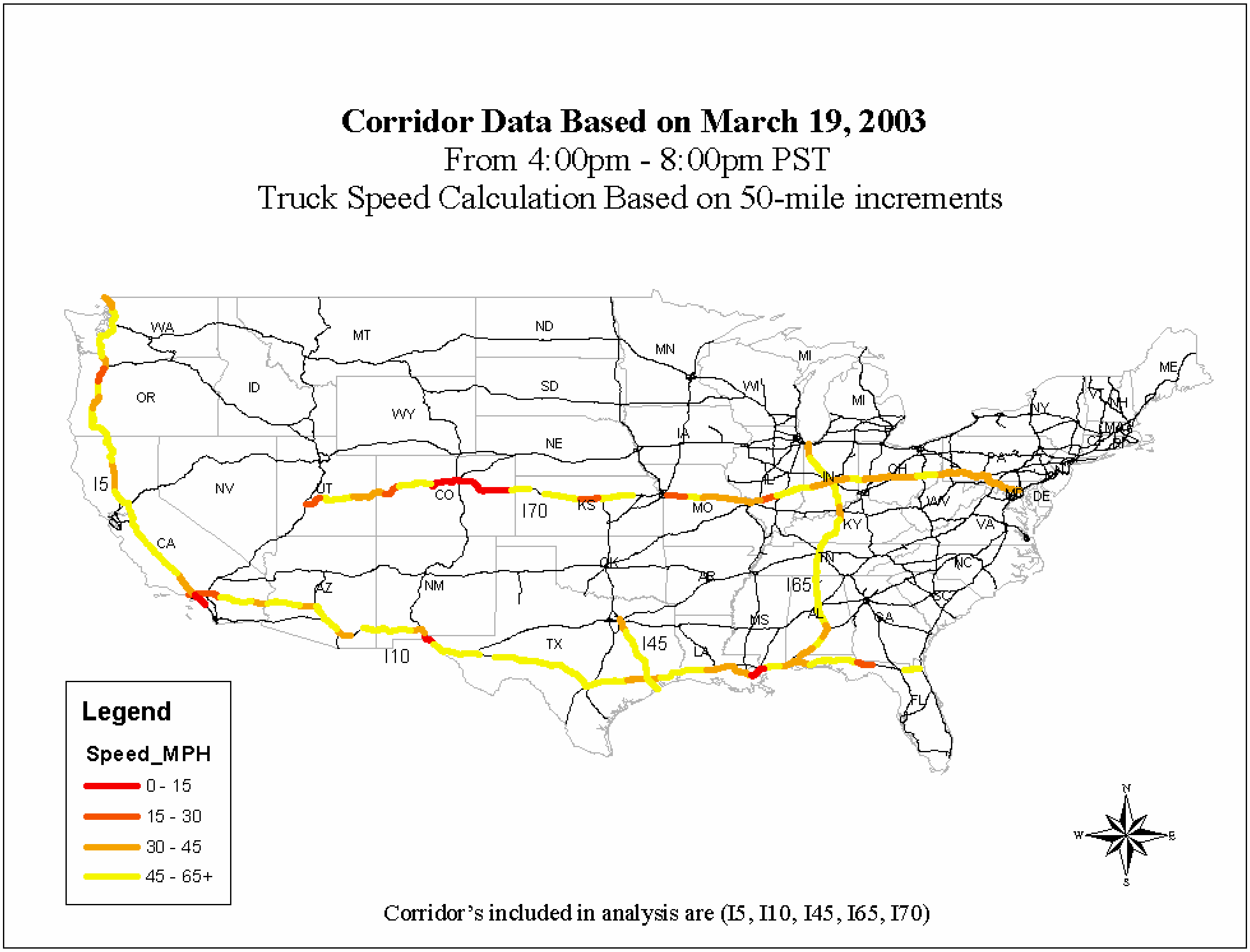
(Bolding indicates corridors covering more than one top ten city)

TABLE 3 Impact of Outliers on Calculated Travel Speeds

Mobile Unit Number	Average Speed (mph)
QQQYTR	50.8
BBCDEA	25.2
OPGGGT	55.0
YYTEEP	**66.0**
ABCFRD	45.5
ZZXASPL	50.2
WXYHCQ	**30.9**
PQDRKL	48.3
SWSSST	**44.8**
Average Speed for All Observations	***46.3*** *SD = +/- 12.19*
Average Speed Excluding Outliers	***49.1***

TABLE 4 Number of Trucks and Position Reports Processed for the Beta Test

Corridor	Trucks Per Corridor	Position Reports Per Corridor
I-5	3,781	7,954
I-10	5,603	12,117
I-45	819	1,558
I-65	4,891	8,701
I-70	7,136	16,528



Corridor Data Based on March 19, 2003
From 4:00pm - 8:00pm PST
Truck Speed Calculation Based on 50-mile increments

Corridor's included in analysis are (I5, I10, I45, I65, I70)

FIGURE 1 Beta Test Data Visualization Example