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OPTIONS FOR BENCHMARKING PERFORMANCE IMPROVEMENTS ACHIEVED FROM CONSTRUCTION OF FREIGHT MOBILITY PROJECTS

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16. ABSTRACT

This report documents the development of data collection methodologies that can be used to cost effectively measure truck movements along specific roadway corridors selected by transportation agencies in Washington State. The intent of this study was to design and test methodologies that could be used to measure the performance of freight mobility roadway improvement projects against benchmarks, or selected standards, that would be used both as part of the project selection process and to report on speed and volume improvements that resulted from completed freight mobility projects.

One technology tested was Commercial Vehicle Information System and Networks (CVISN) electronic truck transponders, which are mounted on the windshields of approximately 20,000 trucks in Washington. By using software to link the transponder reads from sites anywhere in the state, the transponder-equipped trucks could become a travel-time probe fleet. The second technology tested involved global positioning systems (GPS) placed in volunteer trucks to collect specific truck movement data at 5-second intervals. With GPS data it was possible to understand when and where the monitored trucks experienced congestion and to generate useful performance statistics.

The study found that both data collection technologies could be useful; however, the key to both technologies is whether enough instrumented vehicles pass over the roadways for which data are required. This basic condition affects whether the technologies will be effective at collecting the data required for any given benchmark project. The report also recommends the traffic data that should be collected for a benchmark program and the potential costs of using either data collection technology.

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INTRODUCTION

This report documents the development and testing of data collection methodologies intended to cost effectively measure truck movements along specific roadway corridors selected for freight mobility improvements. As part of the effort, the project considered ways to create benchmarks, or standards against which roadway performance could be compared, in order to both prioritize potential projects and measure the success of projects that were constructed. The examined benchmarks included a variety of speed and volume statistics that would describe the improvements that might result from completed projects. This study concentrated on methods for collecting data that could describe these improvements. The study was performed with considerable assistance from both the Freight Mobility Strategic Investment Board (FMSIB) and the Washington State Department of Transportation (WSDOT) and was intended to serve the needs of both agencies. The recommended benchmarks are similar for both agencies.

Understanding changes in truck trip reliability requires fairly extensive data collection. Unfortunately, data specific to truck movements can be difficult to collect, especially on urban arterials, where many truck-oriented roadway construction projects are located. In fact, most traditional data collection systems cannot cost-effectively provide information about changes in truck performance and route choice that result from such roadway projects. To address these data collection limitations, this project tested two technologies for collecting robust performance information specific to trucks.

One technology tested was Commercial Vehicle Information System and Networks (CVISN) electronic truck transponders, which are mounted on the windshields of approximately 20,000 trucks traveling in Washington. These transponders are used at weigh stations across the state, some ports, and the Canadian border to improve the efficiency of truck regulatory compliance checks for both trucks and agency staff. By using software to link the transponder reads from sites anywhere in the state, the transponder-equipped trucks could become a travel time probe fleet. By linking the time of arrival for individual trucks at adjacent readers, it would be possible to determine the travel time between those locations. This information could be used to report on inter-city travel times and travel reliability. The advantage of using the CVISN transponder readers is that the data would be essentially free, as they are already collected for regulatory purposes.

The second technology tested involved the use of global positioning systems (GPS). GPS devices with on-board data storage capabilities were placed in trucks recruited for this project, and data were collected at 5-second intervals. With GPS data it was possible to understand when and where the monitored trucks experienced congestion. By aggregating this information over time, it was possible to generate performance statistics related to the reliability of truck trips, and even examine changes in route choice for trips between high volume origin/destination pairs.

The main difficulty with using GPS for data collection is that truckers need to be recruited and devices installed in their trucks. Because of privacy concerns, some truck drivers object to the GPS devices. In addition, a mechanism is needed to store, extract, and analyze the large volumes of output data. Thus the ability to analyze complex changes in trucking behavior is offset by the even more complex analysis process.

RESULTS

The transponder and GPS technologies were tested in four different applications (detailed within the report). The results of the field tests indicated that it is possible to use both CVISN truck transponders and GPS devices to collect truck movement data and to provide detailed descriptions of changes in truck performance that result from roadway improvements.

The key to both data collection technologies is whether enough instrumented vehicles pass over the roadways for which data are required. This basic condition significantly affects whether the transponder and GPS technologies will be effective at collecting the data required for any given freight mobility benchmark project.

CVISN Transponders

The tests showed that for routes with a large number of transponder-equipped trucks (typically Interstate routes) it is possible to compute roadway performance with a level of accuracy that meets benchmarking needs. However, unless a roadway improvement will directly affect a major Interstate corridor, use of transponders will require the placement of semi-portable CVISN transponder readers at either end of the relevant road segment. In addition, the WSDOT will need to confirm with trucking firms that a significant proportion of trucks using the route are transponder equipped. WSDOT may need to recruit trucking participants and provide them with CVISN transponders to ensure a large enough vehicle fleet sample.

GPS

The GPS devices also show promise for providing a data set that will meet WSDOT's needs. The advantage of the GPS devices is that they can monitor the actual route taken by instrumented vehicles. This makes the GPS data set far more robust than the transponder data. The major problem with the GPS technique is ensuring that enough trucks traveling the facility being monitored carry GPS devices from which data can be obtained, and that those trucking firms are willing to share those data with WSDOT. Gaining access to more than a few GPS instrumented trucks is a significant challenge, and in a large metropolitan region, insufficient data will be collected on many routes unless a fairly large sample of trucks is actively participating in the data collection effort. Changes measured along arterials studied as part of this test were inconclusive in large part because of a lack of GPS equipped trucks traversing those road segments. Therefore, if trucks routinely operating over the subject arterials cannot be identified and equipped with GPS, this is not a technique that should be adopted for freight benchmarking.

BENCHMARK PROGRAM

A freight mobility benchmark program aimed at measuring the benefits gained from freight mobility projects should collect information both before and after roadway improvements have been made. The following before-and-after statistics should developed as part of the data collection effort and used as freight mobility benchmarks:

- 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.

Information on total trip reliability (origin to destination travel times and routes) should also be collected if the roadway improvement is likely to affect truckers' route selection. Both volume and travel time data should be reported for at least four time periods: morning peak period, midday, evening peak period, and night time.

For most projects in areas with non-congested traffic, truck volume data can be accurately collected with automatic roadside vehicle classification counters. However, if trucks using the road sections in the study area do not travel at a constant speed because of congestion and/or traffic signals, truck counts will have to be performed manually.

Several methods of data collection are recommended to meet WSDOT's benchmark reporting needs. For isolated improvements that are unlikely to cause changes in truckers' route choices, either of the two data collection procedures can be used. First, if a limited number of trucks travel the facility, placing GPS devices on those trucks will provide an excellent measure of changes in the length and location of delays that result from the roadway improvement. Data collection should start at least six months before construction of the project and should be performed for at least six months after the project's completion.

Second, where the trucking population that travels the facility is diverse and not easily outfitted with GPS devices, a more conventional floating car study will have to be performed. This will involve hiring drivers to follow trucks as they use the road and record their travel times. If truck trip reliability is one of the expected improvements of the project, a fairly extensive number of floating car runs will have to be performed both before and after the improvement has been completed. If a significant percentage of trucks uses transponders, semi-portable transponder readers can possibly be installed instead to collect travel time data.

Another data collection method is recommended to measure truck-oriented improvements to dense roadway networks that are likely to cause significant changes in truckers' route choices. In this situation, floating car runs may not provide a complete understanding of the truck travel time savings that result from an improvement. The diversity of trucks using such an improvement also may make it impossible to select a set of trucks that can be instrumented with GPS devices to effectively collect performance information. Consequently it is recommended that WSDOT work with other agencies to investigate the feasibility of implementing an ongoing, region-wide truck performance data collection project. Attention should be paid to recruiting trucking firms that operate frequently over the roadways where improvements are planned or are being considered.

In either data collection situation, the use of GPS technology will require the cooperation of truck drivers and their trucking firms. Specifically, the trucks using these facilities (both before and after the construction project) must be outfitted with GPS, and trucking firm personnel must periodically replace the GPS data loggers and mail them back to the benchmark analysis team. This level of cooperation can be difficult to achieve and could be a considerable shortcoming. A key in gaining cooperation will be for trucking firms to understand the mobility benefits they might gain in return for their cooperation. For isolated improvements that will directly benefit a select set of users, these benefits will tend to be far more obvious than in large urban areas where a given trucking firm uses a variety of roads during any given day.

PROGRAM COST

The cost of a benchmark data collection program focused on truck-oriented roadway improvements would depend on the type and location of the improvement. For a roadway improvement on a major state route there might be enough transponder-equipped trucks to collect data with roadside transponder readers. If newly developed, low-cost portable readers were purchased, a system could be set up for roughly $10,000 to $15,000, assuming that appropriate structures already existed on which to hang the equipment. If power pole and sign bridges were needed, the cost could increase up to $80,000.

GPS data collection has the same broad range of costs. As a result of this field test, WSDOT has enough GPS devices to instrument 25 trucks. For a benchmark on an improvement involving a single, isolated roadway, these devices could be placed on volunteer trucks at relatively little expense. As a result, the project costs would involve only the administration of the transponders and analysis of the GPS data and would be relatively insignificant (roughly $10,000 per site).

For roadway projects in the Puget Sound region that involve more complex changes in trucking performance, GPS data collection would allow the collection of the comprehensive trucking data necessary to compute performance measures. However, such a program would have to be considerably larger than the field test performed as part of this study. At an absolute minimum, between 150 and 200 GPS devices would need to be in trucks active in the Puget Sound metropolitan region, and these devices would need to be effectively distributed around the region. The software currently used to store, analyze, and report on the GPS data would have to be improved and refined to streamline the analysis of the GPS data. This area-wide, GPS-based monitoring program would require an estimated $150,000 to $200,000 in one-time expenses, and then continuing costs of around $150,000 per year.

CHAPTER 1
BACKGROUND AND GOALS

This report documents the development and testing of alternative data collection methodologies that can be used to cost effectively measure truck movements along specific roadway corridors selected by the Freight Mobility Strategic Investment Board (FMSIB.) The intent of the project was to complete the design and testing of potential methodologies that could be used to measure the performance of roadway improvement projects against selected standards. These benchmarks, while developed for FMSIB, could be used both as part of WSDOT's project selection/prioritization process and to report on the freight mobility benefits that resulted from the selected roadway projects.

This report is divided into four chapters. This first chapter describes the background and goals of the project. It also describes the types of data required to measure the performance of roadway improvements designed to improve freight mobility and compare that performance with a defined standard—termed benchmarking—and introduces the constraints to collecting those data. The second chapter then describes the technologies that were tested to overcome those constraints. The third chapter describes the results of those tests. The final chapter describes the conclusions obtained from this project and makes recommendations for meeting freight mobility benchmark needs.

BACKGROUND

Accountability of government expenditures is a major issue in the state of Washington. To accomplish greater accountability, task forces and committees such as the Blue Ribbon Commission on Transportation have recommended, and state legislators have adopted requirements for, more active reporting on the performance of the state's transportation system and the effects that funded improvements to that system have generated.

To meet those reporting requirements and to more effectively identify and prioritize transportation infrastructure improvements, the FMSIB has begun the process of developing performance standards, or benchmarks, that describe freight mobility. This project is one effort to support that development process. It looked specifically at the potential for new intelligent transportation systems (ITS) technology to inexpensively provide data about the roadway delays trucks experience as they use the Interstate system and the Puget Sound freight network.

"Freight mobility" involves many issues. It can rightly be considered to include topics as diverse as the cost of moving freight, the availability of alternative modes for carrying commodities, the travel time required to move freight between various points, the reliability of those movements, and the volume of those movements. Many key attributes of freight mobility lie within the private sector and are outside of the control of the state government to significantly change. As a result, the study was framed to examine the changes in truck volumes, along with changes in average travel time (speed) and truck trip reliability, that result from publicly funded roadway improvements.

Although these basic measures (speed and volume) are common to many traffic studies, the collection of truck volumes and truck travel time performance are not typically obtained by existing data collection systems. In addition, many truck-oriented projects are on urban, arterial roadways, roads that are currently not instrumented to routinely collect traffic congestion information and that are also places where truck data are difficult to collect. In addition, many urban roadway improvement projects are likely to influence truck drivers' choice of routes for picking up or delivering goods and, consequently, can have far broader impacts on truck trip reliability than simple measurements of the affected roadway segments will capture.

Therefore, the heart of the study was to investigate new ways to collect truck travel performance information that were both low in cost and robust in their ability to describe that travel. More specifically, given the limited funding available for this study, efforts were concentrated on measuring the travel times experienced by trucks operating in normal service, so that travel time changes that resulted from truck-focused improvements could be measured.

Although truck volumes are also important, little new research has been conducted in the collection of truck volume data, so testing and evaluation of new truck counting techniques was not required as part of this project. This report does include a discussion of how to use the state-of-the-art to collect the truck volume information needed to measure the performance of truck-oriented projects.

TRADITIONAL TRAVEL TIME DATA COLLECTION PROGRAMS

Travel time data on urban arterials are most commonly collected with the "floating car" technique. A person is hired to drive a car along a defined route. The time taken to make the defined trip (and any sub-segments of interest) is recorded at specific time points during each trip. A number of techniques exist for actually collecting the time point information.

While this approach works reasonably well for estimating the average travel conditions along the defined route, it has several major drawbacks. First, it is fairly expensive, as the travel time study must pay for at least one staff person (the driver), possibly other staff people (someone who records or analyzes the data), and vehicle rental and mileage. More importantly, these expenses expand quickly if a number of travel corridors need to be studied, if travel times are needed at different times of the day, or if data are needed for many days in succession to determine the reliability trips made along that the roadway. Unfortunately for WSDOT, in the Puget Sound region, many of these conditions exist, making floating car data collection quite expensive.

While the WSDOT freeway surveillance and control system can supply excellent travel time data on the region's freeway system, WSDOT collects very few data on urban arterials and currently has no mechanism to convert the data it does collect into travel time estimates. The Puget Sound Regional Council (PSRC) and various city and county road authorities also collect some roadway performance related data as part of their existing transportation planning, programming, and operating efforts. However, these data are not collected in a manner, depth, timeframe, or location that would allow their use for freight mobility benchmarking.

Consequently, this project looked at the potential use of two technologies for collecting roadway performance data (travel times and delays). These technologies are discussed in the next chapter.

BENCHMARK REQUIREMENTS AND COLLECTION METHODS

As noted above, this project assumed that the primary interest of WSDOT is the evaluation of roadway mobility improvements. Consequently, the selected measurements, or benchmarks, needed to describe both the number of trucking movements that would be affected by each roadway improvement and the travel time changes that would result from those improvements.

However, it is important to recognize that such benchmarks can not always reveal a clear cause and effect relationship between a roadway improvement and the measured changes in volume and travel times. This is because many factors outside of roadway improvements affect the volumes of vehicles using a specific set of roads, and those vehicle volumes have considerable effect on the speeds at which trucks travel.

Factors such as population growth, changes in the economy, and other physical changes in the transportation system (e.g., the loss of a bridge) can significantly change roadway performance. These changes would need to be reflected in the benchmark measurements used to describe the effects of WSDOT's freight mobility improvements.

While such external factors will affect our ability to directly measure the results of WSDOT-funded improvements, the volume and travel time performance benchmarks described in this paper will provide an excellent means of defining the freight mobility that exists both before and after the improvements have been made. These benchmark measures will describe the state of freight mobility and whether that mobility has improved after each roadway project has been completed. In addition, taking the steps discussed below can account for many, if not all, of the externalities that affect freight mobility, thus leaving a reasonably strong level of confidence that any measured changes in freight productivity and mobility are the result of the improvements being studied.

Measuring Volumes

The number of trucks affected by a freight-mobility improvement can be simply measured and reported as the volume of trucks using the improved sections of roadway. . The number of trucks that use a road improved as part of a freight mobility project is the number of trucks assumed to directly benefit from those projects. Measuring the volume of trucks before the improvement indicates use before the improvement. Measuring again after the improvement has been completed describes “current” use.

However, it is not acceptable to simply subtract the “before” volume from the “after” volume and assume that the difference in volumes is *caused by* the improvement. In part this is because changes in the economy can easily cause freight volume changes, which could overwhelm any changes caused by the improvement. This can be seen by looking at truck volume measurements recorded by WSDOT on SR 167 in southern King County. Figure 1[1] shows that combination truck volumes routinely vary by more than 30 percent on SR 167 during the course of a year. These changes in truck volumes are caused in large part by changes in the business cycle. For the example shown in Figure 1, SR 167 is heavily influenced by the delivery of goods to the Puget Sound region. Truck freight movements routinely increase in the summer and early fall as inventories increase before the Christmas shopping season. (This causes the seasonal factor to be low.) By late fall, these goods have all been delivered, and trucking volumes drop significantly. (This causes the seasonal factor in Figure 1 to spike in January.)

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[1] Figure 1 plots the “seasonal factor” for combination trucks by month for this site. The seasonal factor is computed as the average annual daily combination truck volume, divided by the average day of month combination truck volume. Thus, a seasonal factor of 1.20 for January means that if a daily count were taken during January, it would be necessary to multiply the daily volume from that count by 1.2 to estimate the average daily volume for the year.

Consequently, to control for seasonal changes in truck movements, it is important that any "before" and "after" truck volume measurement be performed at similar times of the year.

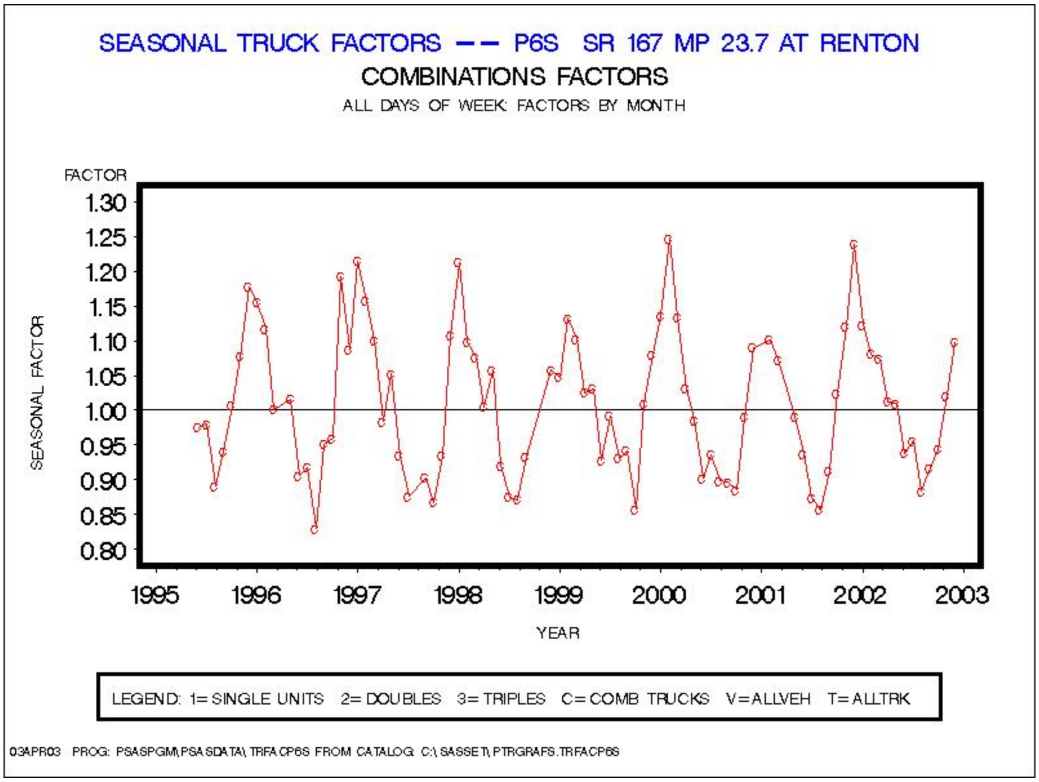

Figure 1: Monthly Seasonal Factors That Describe Combination Truck Volume Patterns on SR 167

In addition to counting truck volumes on improved road sections, it is also important to count truck volumes on parallel routes that serve similar truck movements.[2] By counting on these parallel routes, the benchmarking process will be able to determine whether truck volumes have actually increased or trucks have chosen to use the improved route in place of alternative routes. This will yield a far better understanding of the

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[2] If there are no obvious alternatives to the route being improved, these counts are not necessary.

overall impact the roadway project has had, not only on truck mobility but on the surrounding road network.

If a more complete understanding of a freight mobility improvement's effect on freight routing decisions and on changes in economic activity is needed, a survey of trucking firms whose vehicles use the improved facility should be undertaken. Such a survey would need to obtain information on how the truck improvements affected the business decisions of the firm or driver. The volume and travel time benchmark data would then be used to support the reasoning behind these decisions. (For example, a firm might expand its operation at a nearby manufacturing plant because materials could now be obtained more reliably.)

Measuring Travel Times and Trip Reliability

The second major roadway performance benchmark is travel time.[3] Two major components of truck freight travel time need to be measured to understand the effect of a truck-oriented roadway improvement. The first is the change in average travel times that trucks experience as they make routine trips. The second is how frequently trucks experience unusually severe, unexpected delays and the severity of those unexpected delays. Improving the reliability of a freight trip (reducing the frequency and severity of unexpected delays) can be very important to trucking firms, as it can allow them to more cost effectively schedule and use both labor and equipment.

Direct measurement of the travel time on a link is the simplest way to measure the travel time benefits from any improvement. Average link travel times can be measured

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[3] Note that "travel time" and "speed" are frequently used interchangeably in this paper. In both the GPS and CVISN data analysis systems described in this paper, the initial calculation of roadway performance is made in terms of travel time. Speed is then computed by determining the actual travel distance covered in the measured travel time and dividing that distance by the travel time.

by running floating car surveys repeatedly over the improved roadway link. However, this technique is not a practical method for collecting enough data to determine changes in the reliability of that trip. In addition, restricting the data collection effort to the improved roadway segment prevents the benchmark from accounting for changes in travel time and travel time reliability that result from changes in route choice as trucks adjust their behavior to take advantage of the improved facility.

As a result, the project team looked at more robust travel time benchmarks. The benchmarks should describe not only the changes in travel time on an improved segment but how the improvement affects the total trip travel time of trucks. Thus, in addition to the average travel time and reliability for the improved segment, the proposed benchmarks report on the average travel time and reliability of trips between key truck trip origins and destinations (O/Ds) within the region, with emphasis on the O/D pairs that might benefit from a particular roadway improvement. This will allow the benchmark process to describe the outcome of the roadway improvements, not only in terms of link speed but also in how speed improvements affect the entire truck trip.

Examining both the time trucks take to travel between O/D pairs and the routes selected to make those trips will provide insight into which truck trips are taking advantage of the roadway improvements and how significant the new travel time benefits are in terms of decreased trip delay.

TESTS PERFORMED

To test the recommended benchmarking process, as well as the proposed data collection methods, the project team selected two improvements that received funding through FMSIB's freight mobility program (and were constructed by WSDOT) and two additional "pre-emptive monitoring" locations.

The two improvements to be examined were a railroad grade separation project on South 180th Street in Kent, and a new freeway access ramp that by-passed an at-grade rail crossing on Royal Brougham Avenue just south of downtown Seattle. The two "preemptive monitoring" tests were to examine the frequency and severity of delays experienced by 1) Boeing trucks moving airplane components between a plant in Fredrickson, Washington (near Tacoma) and the Everett 747 assembly plant, and 2) trucks using I-5 between Ridgefield and Olympia.

The first two of these tests involved both vehicle volume and truck travel performance data collection. The second two tests examined only travel time and delay information.

The Boeing movement test was included to provide a demonstration of whether the benchmarking data collection process could be used to 1) effectively identify road segments that were contributing significant delay to specific, regional trucking movements and 2) provide accurate measurements of the size and scope of those delays.

The I-5 test was included to explore whether existing Commercial Vehicle Information System and Networks (CVISN[4]) data resources maintained by WSDOT and the Washington State Patrol (WSP) could be used to provide performance information on major state highways.

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[4] For more information on CVISN, please see the following Web sites. http://www.jhuapl.edu/cvisn/Introcvisn/index.html, or http://cvisn.wsdot.wa.gov/

CHAPTER 2
TECHNOLOGIES BEING TESTED

Two ITS technologies were tested for use in measuring truck travel times, CVISN truck tags and GPS devices carried by volunteer trucks. No new technologies were tested for the collection of truck volume data.

CVISN TAGS

As part of its efforts to improve the productivity of interstate trucking, the U.S. Department of Transportation has encouraged the development and implementation of a series of technologies under the banner of Commercial Vehicle Information Systems and Networks. Trucks participating in CVISN carry a windshield-mounted electronic tag that can be read at highway speeds by a special “reader.” The truck identification information obtained by the reader allows regulatory enforcement personnel to automatically look up that vehicle in a secure database to check that vehicle’s safety record and current regulatory status (e.g., Have the taxes been paid for this vehicle? How much weight is it permitted to carry?).

This information is then combined with other information collected at weight enforcement sites (e.g., axle weight and spacing information from weigh-in-motion scales, the last recorded safety inspection for that vehicle, and the current number of vehicles waiting in the queue to be inspected) to determine whether a given vehicle should be stopped for closer regulatory inspection.

The automated vehicle check helps enforcement officers differentiate vehicles that are likely to be in full regulatory compliance from potentially less compliant vehicles, allowing officers to concentrate on examining vehicles less likely to be in compliance. The results are better regulatory control, safer commercial vehicles (more identified violators), and more efficient use of enforcement officers' time.

In return for cooperating with these automated compliance checks, CVISN-tag equipped trucks that are in good standing are permitted on most occasions to bypass truck enforcement stations, thus saving time, fuel, and vehicle wear.

CVISN tag readers have been placed at truck weight enforcement sites around the state, as well as at key trucking facilities, such as the ports of Seattle and Tacoma and the Canadian border. More than 20,000 trucks operating in the state use CVISN transponders.

CVISN tag data can be obtained from two sources, WSDOT and TransCore. WSDOT collects and stores all CVISN reads taken at WSDOT enforcement facilities. The data are maintained on a secure server to which the research team was given access. TransCore operates a compatible data collection system in conjunction with a number of federal government initiatives that are promoting freight productivity improvements. TransCore readers are commonly located at ports and other terminal facilities. These data, too, are stored on a secure server that was made accessible to the project team.

If software is used to link the data obtained by each of these readers, the CVISN-equipped vehicle fleet can become an inexpensive probe vehicle fleet. By computing the time trucks take to travel between adjacent CVISN readers, it is possible to determine the travel time between those two locations for trucks. This information can be used, in turn, to report on inter-city travel times and travel reliability.

The ability to compute these intercity truck travel times was developed as part of this project.

The great advantage of using the CVISN readers for computing truck travel times is that the data are essentially “free.” That is, the data that describe when CVISN tagged trucks pass CVISN reader locations are already collected for regulatory enforcement purposes. The cost of converting those data into estimates of travel time is minimal. The question answered in Chapter 4 of this report is whether these data provide useful measures of roadway performance.

The known factors that limit the ability to use CVISN tag reads for performance monitoring are

- the relatively small number of reader locations
- the large distances between readers
- the location of those readers on mostly major rural routes.

The small number of readers, combined with the fact that most current readers are located on major state routes, means that relatively few roadway segments in the state can be monitored with CVISN tags, and very few of those roadway segments are in urban areas or on smaller roads.

The small number of readers also results in large distances between readers. With these large distances, trucks often make stops between readers to get fuel or food, or to pick up or deliver goods. If a vehicle stops, the travel time computed between those readers is still an accurate measure of the time a truck took to travel between the readers, but that time is not a good measure of roadway performance. Thus, the computed travel time is useful for the trucking company (because it describes the number of labor hours needed to make that trip), but it is a poor measure of roadway performance because it includes "delays" that are not caused by road conditions.

To help resolve some of these issues, the project team worked with WSDOT and the FMSIB to purchase several semi-portable CVISN readers. These readers can be transported to selected locations and installed so that they provide CVISN tag reads at locations of WSDOT's choosing. This will allow WSDOT to define short roadway segments that cover roads of interest and that are short enough that the potential for vehicles stopping between readers is not significant. If CVISN-equipped trucks use the road segments instrumented with portable readers, WSDOT will be able to collect large quantities of travel performance data on these segments without having to pay drivers to perform floating car surveys.

GPS DEVICES

One limitation of the portable CVISN readers is that they provide information on only the defined roadway segment. While this may meet the need for benchmarks on a specific road section that has been improved, it does not describe where delays are occurring within the segment defined by the two readers. Neither does it provide information about the effects roadway improvements have had on route choice, or on road conditions just outside of the defined roadway improvement.

Consequently, a second type of low cost data collection technology, global positioning systems (GPS), was explored as part of this project.

GPS devices use satellite technology to obtain very accurate location data. By collecting GPS position data frequently (in our case, every 5 seconds) and then storing and analyzing those data points, it is possible to gain an understanding of when and where monitored trucks are experiencing congestion. By collecting GPS data over a large number of days and then aggregating the roadway performance information over time, analysts can generate excellent performance statistics related to the reliability of truck trips. For example, it is possible to measure where delays take place routinely, how often those delays take place, and how severe those delays are when they do occur.

There are three primary difficulties with using GPS for data collection:

1) GPS devices are not already being carried by most trucks.
2) Even if GPS devices are carried by trucks, a mechanism is needed (and is often not present) to extract the GPS data and send them to a group that will develop the benchmarks.
3) Because of the detailed record GPS devices provide, some truck drivers object to their presence out of a concern that the collection of this level of detailed data invades their privacy.

GPS devices are not overly expensive. GPS receivers with significant data storage capability can be purchased for between $500 and $750 each. Whether this price per unit makes GPS a reasonable data collection option for meeting benchmarking needs is a function of the number of devices needed to measure roadway performance. This project explores this subject in detail in Chapters 3 and 4.

More importantly, before GPS data collection can be effective, trucks and truck drivers must be available who are willing to carry GPS devices on vehicles that routinely use the roads of interest.. The Washington Trucking Association (WTA) helped to recruit volunteer trucking firms to participate in this study by carrying GPS devices. WTA was instrumental in providing contacts with various trucking companies, assisting in the recruitment of trucks for the study, and providing guidance to the study. The project would not have been possible without its support and assistance. The importance of recruiting trucks to participate in the study and the characteristics of those trucks are also covered in Chapter 3 of this report.

In an earlier test[5] of GPS technology for roadway performance monitoring, researchers used five GPS devices connected to wireless communications devices to gather real-time truck position information. While this proved the basic functionality of the GPS concept, it also showed that wireless, real-time data collection was too expensive for simple performance monitoring data collection. Although costs for wireless data transmission have decreased recently, they are not low enough to make real-time wireless data transmission cost effective.

Because this project's goal was to cost-effectively collect freight performance measures, real-time data collection was not necessary. As a result, the project team took a very different approach to obtaining the GPS data. For this project, the purchased GPS device included a rugged, removable, on-board data storage system. Truck dispatchers working for the companies that volunteered to participate in this study simply removed one data storage device, replaced it with an "empty" device, and mailed the "full" one back to the project team. This resulted in a very cost effective method for obtaining the GPS data. The advantages and disadvantages of this approach to data collection are discussed in Chapter 3.

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[5] Hallenbeck, M. E., E. D. McCormack, J. Nee, and D. Wright. 2003. Freight Data from Intelligent Transportation System Devices. Research report, WA.RD 566.1

CHAPTER 3
TEST RESULTS

CVISN TAGS

This section of Chapter 3 discusses the use of CVISN truck tags for monitoring roadway performance in Washington.

The CVISN Tag Travel Time Database

The software system necessary for automatically obtaining and storing CVISN tags was successfully constructed as part of a related research project.[6] While the Web site and underlying software are still subject to revision, their functionality was sufficient to test the use of CVISN tags in meeting the needs of WSDOT. All results presented in this paper are drawn from that software.

The tag-based travel time computations are available to anyone who is aware of the Web site. At this writing, the site can be accessed at http://trac24.trac.washington.edu:8080/trucks/index.jsp, although this URL is subject to change. The database itself, the reports that it generates, and the software that underlies it are all expected to change over time as new uses for the tag data are developed and implemented.

Currently, the CVISN tag database performs the following tasks.

1. Obtains truck tag read information periodically from WSDOT and TransCore as those respective databases receive data from the field. (Data collection

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[6] The project is called "Database Design for Performance Monitoring (Data Archive)" and is funded by WSDOT.

from the field can be delayed as much as 45 minutes[7] by various limitations in the current CVISN communications network.)

2. Truck tag IDs are given anonymity[8] as they are obtained from WSDOT and TransCore.
3. The data obtained along with each anonymous tag ID comprise the location (including direction) where, the time when, and date when the tag was observed.
4. Anonymous tag IDs are then matched from one reader to every other reader for the next 24-hour period.
5. Travel times between readers are then computed for each matched pair of tag observations.
6. Average speed for each matched trip is then computed by dividing the distance between readers by the computed travel time.
7. Travel time and average speed[9] for each matched pair of IDs are then stored in the database.
8. Queries of the database can then be used to produce statistics about travel time between any pair of tag reader locations and for any given period.

To query the database, the user must specify both 1) the period for reporting roadway performance (e.g., every 15 minutes) and 2) the beginning and ending dates that define which days of data are included in the report. The user can also specify whether data are to be output for each day individually or for all days in the data set combined.

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[7] This value is subject to change as communications capabilities and protocols in the field change.

[8] That is, IDs are converted into a new value that prevents tracking of any specific vehicle from this database. The ID conversion changes every 24 hours, so for example, today tag 123ABC might become 987XYZ, but tomorrow tag 123ABC would be converted into 321ZXY.

[9] For the rest of this section, the terms travel time and speed are used interchangeably.

The user can also select from a series of filtering routines that help remove "spurious" matches from the data set, as well as from different output formats (graphical, Excel compatible files, ASCII files).

The travel times reported for each selected reporting period are associated with the upstream tag reader. So a truck that passed the upstream detector at 8:00 AM and the downstream detector at 8:22 AM would have a travel time of 22 minutes and would be categorized as an "8:00 AM trip." If a single day of data were processed and a 15-minute reporting period were selected, the speed reported for the 8:00 AM to 8:15 AM time period would be the fastest speed observed for all trucks that passed the upstream reader location between 8:00 AM and 8:15 AM and then passed the downstream reader. This "fastest truck algorithm" assumes that if one vehicle can make the trip in that stated time, other vehicles can also make the trip in that time interval, and any vehicle traveling slower than this does so by choice of the driver.

The database allows the user to either 1) obtain one number per time period per day, or 2) compute specific statistics (e.g., mean and 90th percentile) for each time period by comparing the values reported for that time period among all days in the selected sample. If 60 days of data were selected for analysis and the mean and 90th percentile speed were requested, the database would report the mean speed for the 60 reported speeds for the 8:00 AM to 8:15 AM time period, as well as the 54th slowest speed from those 60 samples (0.90 x 60 = 54).

When truck volumes that pass both readers are moderately high, the "fastest truck" algorithm is good at removing from the travel time dataset those vehicle travel times that are affected by a stop between readers. However, the fastest truck algorithm has significant limitations when truck volumes passing both readers are light. At those times, slow travel times reported by the system can signify either congestion or that the few (often singular) vehicles observed at both readers stopped at some point between those readers.

Although high truck volumes can help ensure that the reported travel times and speeds reflect roadway congestion rather than the effects of stops, placing two readers close together on the same road can significantly improve the performance of the CVISN tag system. Placing the readers close to each other reduces the opportunities for a truck to exit and re-enter the roadway between readers.

Also helpful for counting purposes is if the majority of trucks passing an upstream reader are likely to continue on that same road past the second reader. One advantage of using the CVISN system is that many trucks stay on the Interstate freeways until they reach the major metropolitan regions, thus providing a reasonably large number of matches.

Results of CVISN Tag Travel Time Testing

Use of CVISN tags to measure roadway performance produced mixed results. The tests showed that for routes with large numbers of CVISN tag-equipped trucks, it is possible to compute roadway performance with a level of accuracy that meets WSDOT's needs. However, few State Routes currently carry sufficient CVISN-equipped trucks. In addition, the fairly sparse CVISN tag reader network severely limits the number of roadway segments for which travel times can be computed. And finally, the long distances between most current CVISN tag readers means that many measured travel times are poor estimates of roadway performance because the reported travel times computed from CVISN tags include time that trucks spent parked at rest areas, truck stops, and other locations.

While the CVISN system can provide sufficient data for roadway performance monitoring for a limited number of important Interstate road segments, even within those segments, the tag system does not provide a mechanism for real-time roadway performance measurement and traveler information. There are simply too many holes in the CVISN tag reader data set to use the data for real-time performance measurement. This situation will improve, as WSDOT's CVISN group plans to install a number of data readers along Interstate–5.

The following section discusses these and other findings in more detail.

Detailed CVISN Test Results

Table 1 shows the key statistics for June 2004 tag reads and matches for all northbound CVISN readers on I-5. The first northbound reader on I-5 is near Ridgefield, just north of Vancouver, Washington. The second northbound reader is at Ft. Lewis, just north of Olympia, followed by the SeaTac weigh station in Federal Way, the Stanwood weigh station north of Everett, and finally a reader located at the border crossing into Canada.

As can be seen in Table 1, almost 50 percent more trucks carried CVISN tags past the Ridgefield and Ft. Lewis readers than past the Seatac reader. The number of tagged trucks then declined further by the Stanwood site, and only a few tagged vehicles crossed into Canada.

Table 1: CVISN Site and Segment Statistics

Location	Number of Tag Reads in June 2004	Distance From Previous Reader	Matches with Previous Reader
Ridgefield	21,900		
Ft. Lewis	21,500	100 miles	9,200 (43%)
Seatac Northbound	14,700	24 miles	6,700 (45%)
Stanwood	11,900	70 miles	1,800 (15%)
Blaine Port of Entry	1,420	65 miles	144 (10%)

In addition to the number of tag reads decreasing with northward location, the percentage of read tags that could be matched against an upstream tag read also declined. The drop in matches was primarily a function of the origin/destination patterns associated with trucks that are participating in the CVISN program. The majority of CVISN participants are trucking companies involved in interstate commerce. Therefore, most CVISN truck O/D patterns center on major city to major city movements, or port to major city (and vice versa) movements. For example, a large percentage of trucks observed at Ridgefield pass the Ft. Lewis scale because they are likely headed to the Seattle and Tacoma metropolitan areas. The same is true for the Ft. Lewis to Seatac segment. However, because many of these trucks stop in either Seattle of Tacoma, a much lower percentage of matches was found between the Seatac reader (south of Seattle) and the Stanwood reader (north of Seattle.) Matching rates farther north dropped still more, as many of the CVISN trucks do not currently operate into Canada.

While Table 1 shows that an average of over 220 matches occurred each day (just under 10 per hour) on the Ft. Lewis to Seatac segment and over 300 occurred each day (over 12.5 each hour) for the Ridgefield to Ft. Lewis trip, tag reads and tag matches were not evenly distributed throughout the day. Figure 2 shows the number of matches by time of day for the Ridgefield to Ft. Lewis road segment.

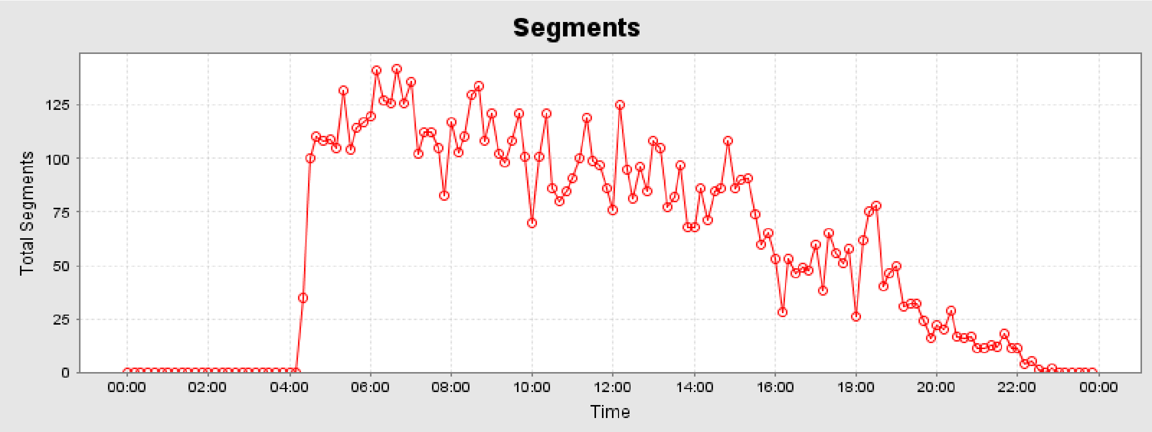

Figure 2: Segment Matches by Time of Day[10]
June 2004, Ridgefield – Ft. Lewis

Trucks traveling north from Vancouver basically do not use I-5 between 11:30 PM and 4:15 AM. This is in part because those with destinations in Seattle would arrive in the middle of the night when businesses are not open to load and unload cargo. Northbound truck travel picks up markedly at 4:15 AM, a time that allows trucks leaving Vancouver to beat the worst of the early morning congestion in Seattle but still arrive when most businesses are open for freight delivery and/or pick up. CVISN tag matches on this roadway segment peaked early in the morning and declined slightly through the day, dropping significantly as the afternoon commute period began, and then falling off even further after 7:00 PM.

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[10] Note that the time represented on this graphic is the time when the vehicle passed the upstream CVISN reader, in this case, the Ridgefield site.

The time of day distribution for the next road segment (Ft. Lewis to Seatac) has a shape very similar to that of the Ridgefield-Ft. Lewis segment, but the closer proximity of the site to the urban delivery destination of many of the CVISN trucks resulted in some minor variations in the distribution (see Figure 3).

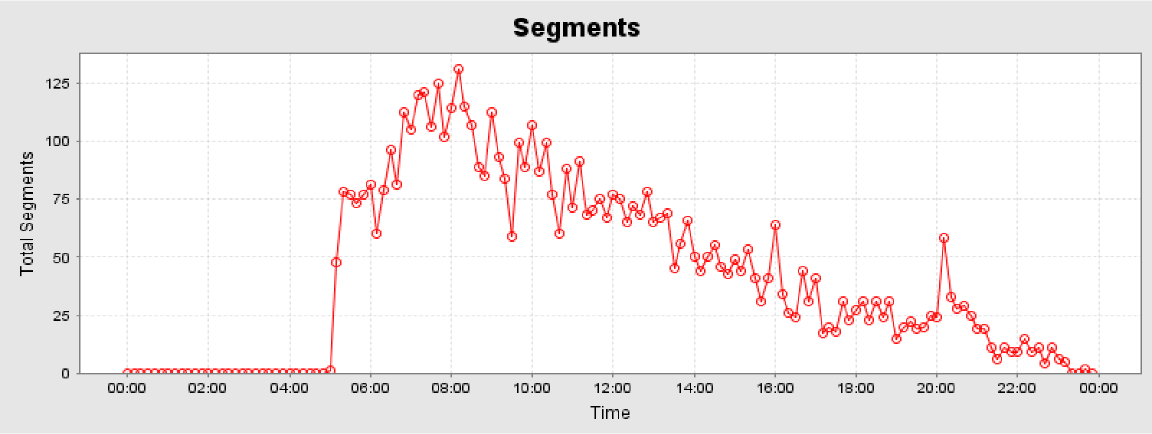

Figure 3: Segment Matches by Time of Day
June 2004, Ft. Lewis – Seatac North

This road segment (which passes through the city of Tacoma) showed a sharper AM peak and a more dramatic afternoon decline than the more rural segment previously discussed. The peak of matches started later than on the Ridgefield-Ft. Lewis segment, in large part because the "time" reported for each travel time on these graphics is the time the truck passed the <u>first</u> CVISN reader. Thus a truck that passed the Ridgefield reader at 4:30 AM still needed to drive for about 2 hours before it reached its destination in the Seattle area, while a truck passing the Ft. Lewis scale at 4:30 AM could easily be at its destination in 45 minutes or less. As a result, the first Ft. Lewis-Seatac matches occurred roughly 50 minutes later in the day than those for the Ridgefield –Ft. Lewis segment.

If the Seatac to Stanwood road segment is examined (see Figure 4), the time-of-day pattern of tag matches changes more dramatically. In addition to having fewer matches altogether, the percentage of matches that occurred very early in the day were much lower at this site. The majority of trucks making this movement travel during the business day.

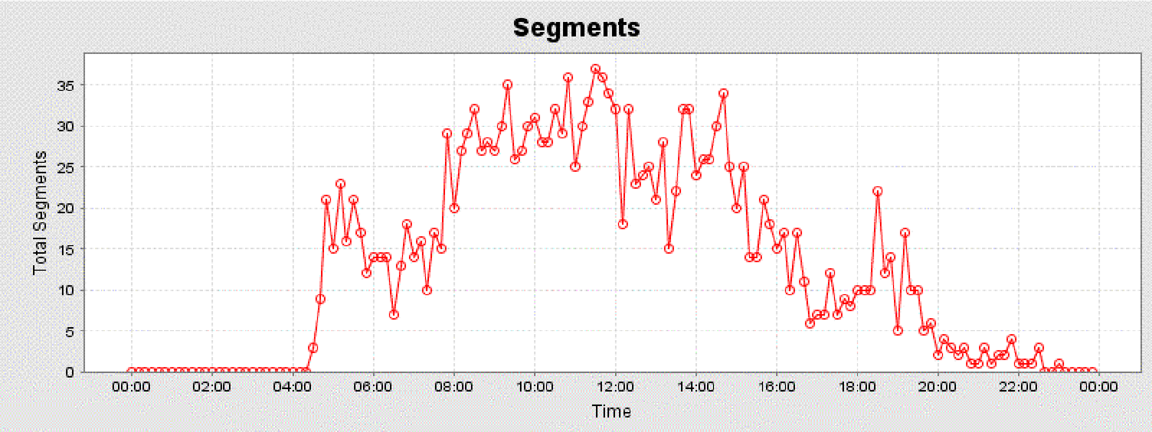

Figure 4: Segment Matches by Time of Day
June 2004, Seatac North–Stanwood

A more logical "upstream" reader for Stanwood would be the either the Port of Tacoma or the Port of Seattle, as trucks carrying cargo from these ports across the Canadian border are likely to pass the Stanwood reader. Unfortunately, the number of tags reads for these sites is very modest in comparison to the number of reads at WSDOT weigh stations on I-5. (The APL gate at the Port of Seattle typically reports about 700 to 800 tags reads per month, whereas the MSK gate at the Port of Tacoma reports only 50 to 150 tags reads in a month.) These readers are located at the exit gates to two specific container terminals, and the gates simply do not have the truck volumes seen on I-5.

In addition, the port gates are open only between 7:30 AM and 4:30 PM. Therefore, travel times can only be computed for trips that leave during those limited hours. Figure 5 summarizes the measured travel times from the Port of Seattle to the Canadian border computed from all CVISN tag matches for the last seven months of

2003, based on a 10-minute reporting interval. Figure 6 shows the same information with a 15-minute reporting interval.

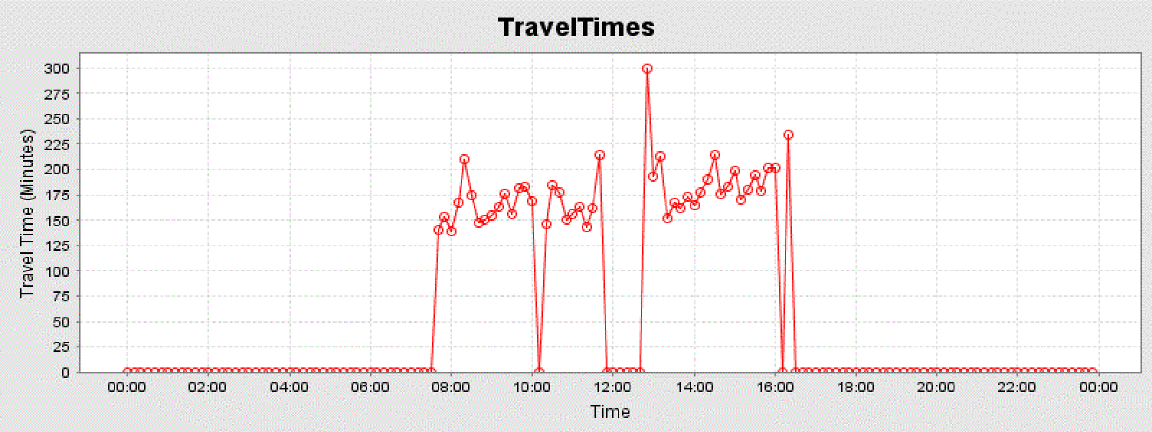

Figure 5: Measured Travel Times, Port of Seattle Exit Gate to Canadian Border June 1–December 31, 2003, at 10-Minute Interval Start Times

The 15-minute reporting period chosen for Figure 6 allows more truck measurements to be grouped into each reporting period and, consequently, allows a greater chance that a "fast" trip occurred during that period. The result is a "smoother" travel time estimate by time of day.

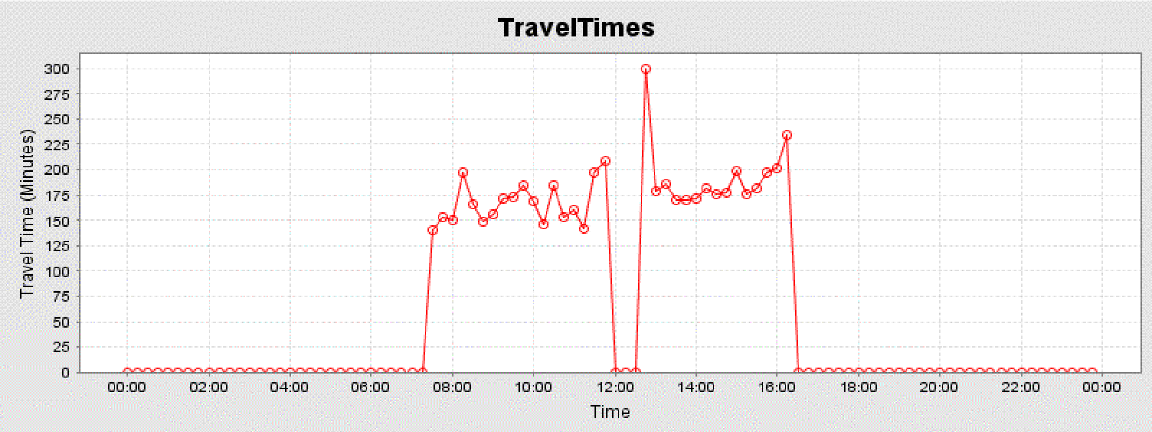

Figure 6: Measured Travel Times, Port of Seattle Exit Gate to Canadian Border June 1–December 31, 2003, at 15-Minute Interval Start Times

The graphs in both figures 5 and 6 show that the CVISN tag system does not provide data on this route segment during the morning, evening, or nighttime portions of the day. Both graphs also show a hole in the middle of the day, when the port gates are closed during lunch. Finally, both show a very “slow” travel time (over 300 minutes) immediately after the gates are reopened in the afternoon. This reported travel time is based on a single data point for the entire seven-month period. It is likely that this truck stopped along the way (the driver may have stopped for a bite to eat), but since no other truck was observed during this period, no “faster” vehicle masks this slow travel time.

This if these graphs represented a single day of data, then the “smoother” graph would be a good thing. It would show that travel conditions had not really changed over the course of the day. However, these graphs were made with seven months of data. During those seven months, some of these trips would have been delayed. To show those delays, a similar graphic analysis was developed. It computes the “fastest truck” by time of day for each day used in the analysis. It then determines the average travel time (or speed) for each period and the 85th percentile for each period.

This version of the travel time graph is shown in Figure 7 for the Ft. Lewis to Seatac roadway segment. The graph displays both average speed for each time of day (in red) and the speed for the 85th percentile (slowest) travel time (in blue) for this 24-mile section of road for May 2004.

The graph shows that it is definitely possible to observe the delays that trucks can expect as they pass through the Tacoma metropolitan core. The slow downs routinely present in both the morning and evening commute periods are readily apparent. But even though just under 5,000 vehicle travel times are included in Figure 7, few or no data represent the late-night period. As a congestion measurement process that describes the impact of congestion on freight, this is not an issue, as few trucks travel the roadway during those times. However, it would be an issue if the CVISN tags were used for more general congestion measurement and if night time construction delays were an issue for which data were desired.

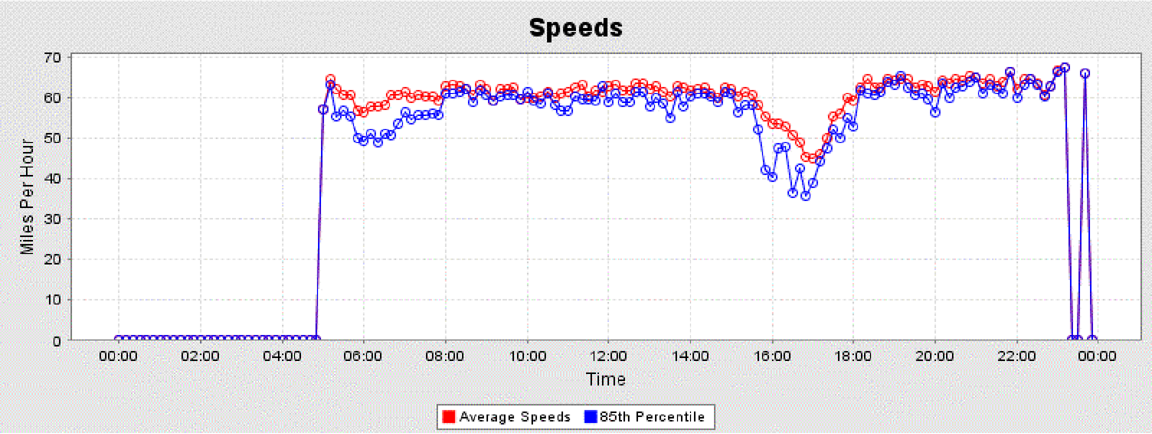

Figure 7: I-5 Northbound, Ft. Lewis to SeaTac: Average Speed for the Mean and 85th Percentile (Slowest) Trip by Time of Day for All Weekdays in May 2004

Alternative Roadway Performance Reports

While the graphs displayed above are useful for analyzing the data collected and are necessary for understanding the strengths and weaknesses of the CVISN tag-based monitoring system, the graphics themselves may not be the best freight mobility benchmark. Instead, the project team recommends a simplified summary table. Such a table would include easily computed measures. Table 2 shows our recommended benchmark measures for road segments monitored with CVISN tags.

Table 2: Recommended Benchmarks When Data from CVISN Tags Are Used, I-5 From Ft. Lewis to SeaTac

Time Period	Average Speed (mph)	85th Percentile Speed (mph)	95th Percentile Speed (mph)
Early Morning	62	59	54
AM Peak	59	53	44
Midday	61	59	48
PM Peak	56	46	36

The recommended benchmarks are based on a day divided into summary time periods and the mean travel timed reported for each summary period. This measure provides an excellent estimate of the 'routine' condition that can be expected by a truck driver traveling over the monitored road segment. As measures of reliability, the project team recommends that the 85th and 95th percentile slowest travel times (converted to speed) be reported for these periods. These measures represent the level of congestion that can be expected at least three times per month (the 85th percentile) or once per month (95th percentile).

(Note that Table 2 is based on three months of data, from mid-March 2004 through mid-June 2004. For this table, "early morning" is defined as all trips through the roadway segment starting before 6:00 AM. "AM Peak" is defined as trips starting between 6:00 AM and 9:00 AM. "Midday" is between 9:00 AM and 3:00 PM, and "PM Peak" is from 3:00 PM until 7:00 PM. The definitions of these periods could be adjusted to meet specific benchmarking interests and do not need to be the same from one location to another.)

Detailed analysis of the travel times used to compute Table 2 did raise one bias issue that must be considered before the CVISN tags are used for travel time computation. The travel time data through the Tacoma area suggest that when a major incident on I-5 creates very significant congestion, trucks may change their routes to avoid I-5 altogether. (This makes perfect sense, as most truck drivers have some form of communication in the cab and frequently share congestion information among themselves.) The result is that the CVISN travel time data may understate the “worst” I-5 travel time conditions because CVISN-equipped trucks simply avoid using I-5 during those periods. Therefore, while the data accurately represent the worst travel times experienced by tagged CVISN trucks on I-5, they may not accurately represent the worst days of congestion on this section of freeway.

Whether truck re-routing during congestion is an issue that will bias the data collection results is a function of whether alternative routes exist for trucks. In the case of the Ft. Lewis to Seatac movement, trucks using I-5 to travel to Seattle can detour at SR 512 and then travel SR 167 to avoid major congestion in the Tacoma area if they are destined for locations in Seattle, the Kent Valley, the eastern suburbs of Seattle, or points north of Seattle. When trucks take this alternative route, they bypass the Seatac weigh station, their tags are not read by the CVISN tag reader, and their travel times are not recorded.

On the other hand, a trip segment such as Ridgefield to Ft. Lewis does not have routing alternatives. But this route segment also has fewer major congestion problems on weekdays. (The worst congestion occurs in the urban areas just north and south of the measured route segment.) This route segment’s worst congestion is on holiday weekends, a time when few trucks use the road and, therefore, when travel time computations based on CVISN tags are unreliable.

Figure 8 shows the average and 85th (slowest) percentile speeds for this inter-city I-5 corridor segment. The graph shows that a truck using this roadway can expect to travel at the speed limit on most days. Slowdowns do occur on this route, as is evidenced by the 85th percentile (blue) speeds near 55 mph for much of the afternoon. (A 55 mph average speed for this trip translates into a 10-minute delay for the road segment starting just north of Vancouver and ending just north of Olympia.)

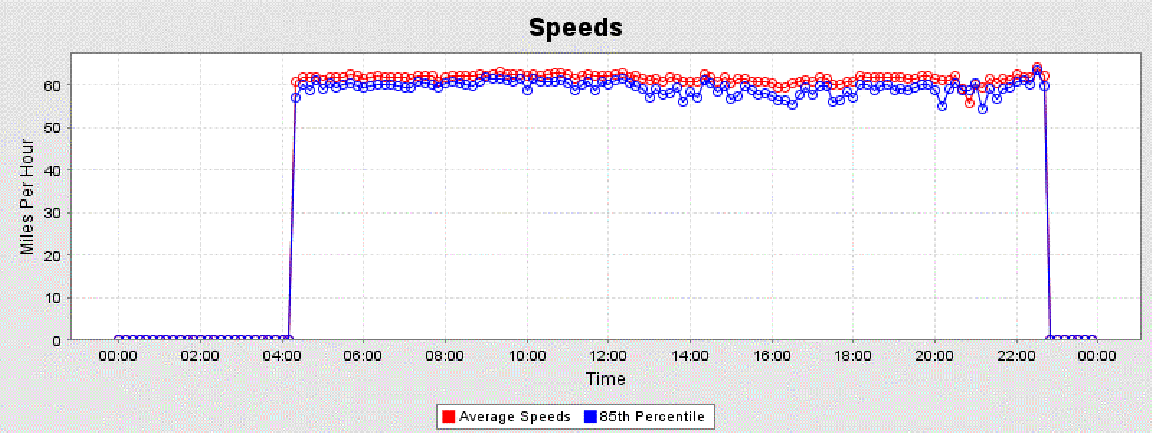

Figure 8: I-5 Northbound, Ridgefield–Ft. Lewis: Average Speed for the Mean and 85th Percentile (Slowest) Trip by Time of Day for All Weekdays March to June 2004

Table 3 shows the recommended benchmarks for this trip.

Table 3: Recommended Benchmarks When Data from CVISN Tags Are Used, I-5 From Ridgefield to Ft. Lewis

Time Period	Average Speed (mph)	85th Percentile Speed (mph)	95th Percentile Speed (mph)
Early Morning	62	59	54
AM Peak	59	53	44
Midday	61	59	48
PM Peak	56	46	36

Availability of CVISN Readers

One of the biggest constraints with using data from the CVISN tags for benchmarking projects is the lack of CVISN readers around the state. Figure 9 illustrates the location of tag readers at the time of this writing and the planned implementation of readers at WSDOT/WSP weight enforcement sites. Planned expansion of the CVISN reader system for both weigh-in-motion and data collection will allow monitoring of additional key roadway segments by the end of 2005. Unfortunately, many of these weigh stations only monitor traffic in one direction. Therefore, CVISN readers associated with those weigh stations only record tags passing the site in that direction. As a result, even after 2005, many of the roadway segments can be monitored in only one direction with data from CVISN readers at weigh stations. Sites such as Ft. Lewis only observe northbound traffic, and it is not possible to compute travel times from Seatac to Ft. Lewis. (CVISN tag readers at Seatac observe traffic in both directions.)

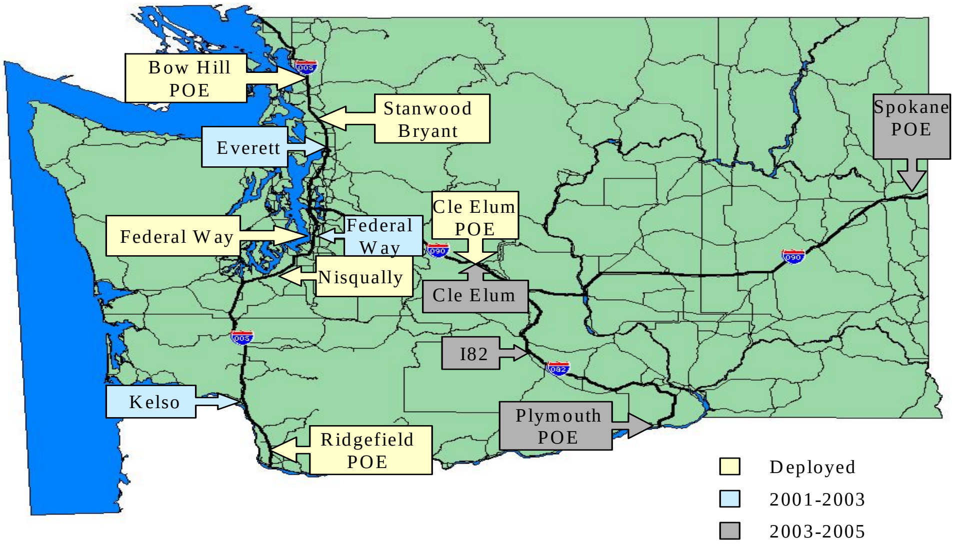

Figure 9: Schedule for Adding CVISN Tags to WSDOT/WSP Weight Enforcement Sites

To increase the data collection potential of the CVISN system, WSDOT and the FMSIB worked together as part of this project to purchase CVISN tag readers that are semi-portable. These readers can be placed on available structures (bridges, electrical poles) and operated at those sites indefinitely. However, these readers can also be easily removed and taken to other sites if data collection needs change. The availability of these readers will allow CVISN tag-based travel times to be used to monitor road segments of specific interest to WSDOT for its benchmarking needs.

The first test of the portable readers was intended to be studied as part of this project. Unfortunately, a variety of technical delays have prevented the installation of these semi-portable readers until just recently. A full-scale test of five readers placed in the Vancouver, Washington, area will begin in August 2004. The five readers will placed to observe passing CVISN tagged trucks as follows:

- north- and southbound on I-205 at the Columbia river bridge
- north- and southbound on I-5 at the Columbia river bridge
- southbound on I-5 at the Ridgefield weigh station.

These five readers, combined with the existing northbound Ridgefield reader, will allow monitoring of freeway performance between Washington and Oregon through the Vancouver metropolitan area. The readers cover both major freeway corridors and should provide the first continuous travel time monitoring of the major freeway corridors in the area.

Costs and Considerations for CVISN Reader Use

The cost of readers has declined markedly since this project was started. If the Vancouver travel monitoring experiment is successful, and if WSDOT decides both that additional monitoring is required and that the CVISN tags are the most effective way to perform that monitoring, it may be possible to expand the collection of CVISN tags more quickly than is currently planned and to add sites not connected to the current CVISN weigh station efforts.

Because these sites would not be part of the budgeted CVISN effort, new funding would be needed to purchase, install, and operate the new data collection sites. Estimated costs for expansion of the CVISN tag read sites are given below.

The equipment required to set up a CVISN tag reader site now costs about $1,500 per lane per direction, assuming that electrical power is available at the data collection site. If power is not available, a $500 solar panel must also be purchased.

The cost of installing the equipment is primarily dependent on whether a bridge, road sign, or power pole already exists on which the reader can be mounted. If so, installation costs are roughly $5,000 per site. If a pole must be provided upon which the reader is mounted, an additional $1,500 should be budgeted. Current WSDOT CVISN reader expansion efforts are averaging about $7,000 per site for all tasks combined.

Communications to the site can be performed by either land-line telephone connection or cellular telephone. The choice of communications at each location will affect equipment, installation, and operations costs. (A conventional telephone connection is less expensive per month but has a higher initial cost because the phone line has to be run to the roadside cabinet.) For budgeting purposes, communications are assumed to be performed via cellular phone, with monthly charges of roughly $50 per month per location.

The final cost is for the analysis of collected data. The software system is already constructed and can be used in its current form to output statistics for any pair of CVISN readers that report tag observations to the WSDOT CVISN data collection system. No additional costs are required to maintain or operate that system. However, there will be costs associated with the actual extraction, analysis, and reporting of those statistics for benchmarking purposes. These costs will be dependent on the number and sophistication of reports required. A simple report comparing travel trends for a specific pair of CVISN reader location could be performed for under $1,000, whereas a more detailed reporting process featuring a large number of new reader locations (for example, a detailed analysis of travel times in the Vancouver area for an entire year) might cost $25,000 or more, depending on the scope of the analysis.

GLOBAL POSITIONING SYSTEM TAGS

Although the CVISN tags may provide an interesting and “free” data source for use in freight mobility benchmarking projects, their geographic limitations are considerable. Unless a roadway improvement will directly affect a major Interstate corridor, use of CVISN tags will require the placement of the semi-portable CVISN tag readers at either end of the road segment for which monitoring will be required. In addition, WSDOT will need to confirm with trucking firms that a significant number of trucks using the route are CVISN tag equipped. If the traffic movement affected by a planned improvement will primarily benefit trucking firms operating within the state, then it is unlikely that many trucks will already be carrying CVISN tags. In that case, these trucks will need to be equipped with tags. Thus, if the long-term study of roadway reliability is required for benchmarking purposes, WSDOT will need to recruit trucking participants.

Even if WSDOT makes such an effort, the CVISN tag reader system will provide only a limited amount of information: the travel time between readers. While this roadway performance statistic is key to a freight mobility benchmarking effort, the CVISN system does not provide much of the detailed travel information that would be necessary to accurately describe any changes in truck travel behavior that occur after many truck-oriented roadway projects have been constructed. That is, the CVISN tag data do not describe any routing changes that might be occurring (as noted above, in the case of severe congestion on I-5 through Tacoma) and do not provide data on when and where measured delays are occurring.

Global positioning system (GPS) devices with on-board storage units have the potential to collect the type of data not available through the use of CVISN tags. The following section discusses the results of the FMSIB-sponsored tests on the use of these devices.

The GPS Devices and Data

For this project, 25 GPS devices were supplied to trucking companies recruited by the WTA and FMSIB to participate in this test. The GPS devices were connected to DC power sources (the cigarette lighter power output) in those companies' trucks. Each GPs device recorded the vehicle's position every 5 seconds while the vehicle's engine was on. Data were stored on the truck in a "data logger."[11] Once every month or two, the trucking firm's dispatch office replaced the data logger in each vehicle with a fresh data logger and mailed the full logger back to the project team. The project team then downloaded the truck position data onto a computer for analysis. Figure 10 shows the GPS device and logger .

Each record stored on the logger contained an identification number, the location of the device (latitude, longitude, altitude), the time at which that position information was determined, the speed the vehicle was traveling at the time the data were recorded, and the heading of the vehicle at the time its position was recorded. These data were recorded sequentially and downloaded from the logger to computers at the project team's office.

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[11] A data logger is a solid-state device capable of storing large amounts of data without the need for a hard disk. It is comparable to flash memory on a computer but is a stand-alone device.

Figure 10: GPS Device and Data Logger

Once the data were available in the office, the analytical process illustrated in Figure 11 was undertaken. The analytical process followed two separate tracks: trip measures and road segment measures. The GPs data had to be processed twice to develop both sets of measures.

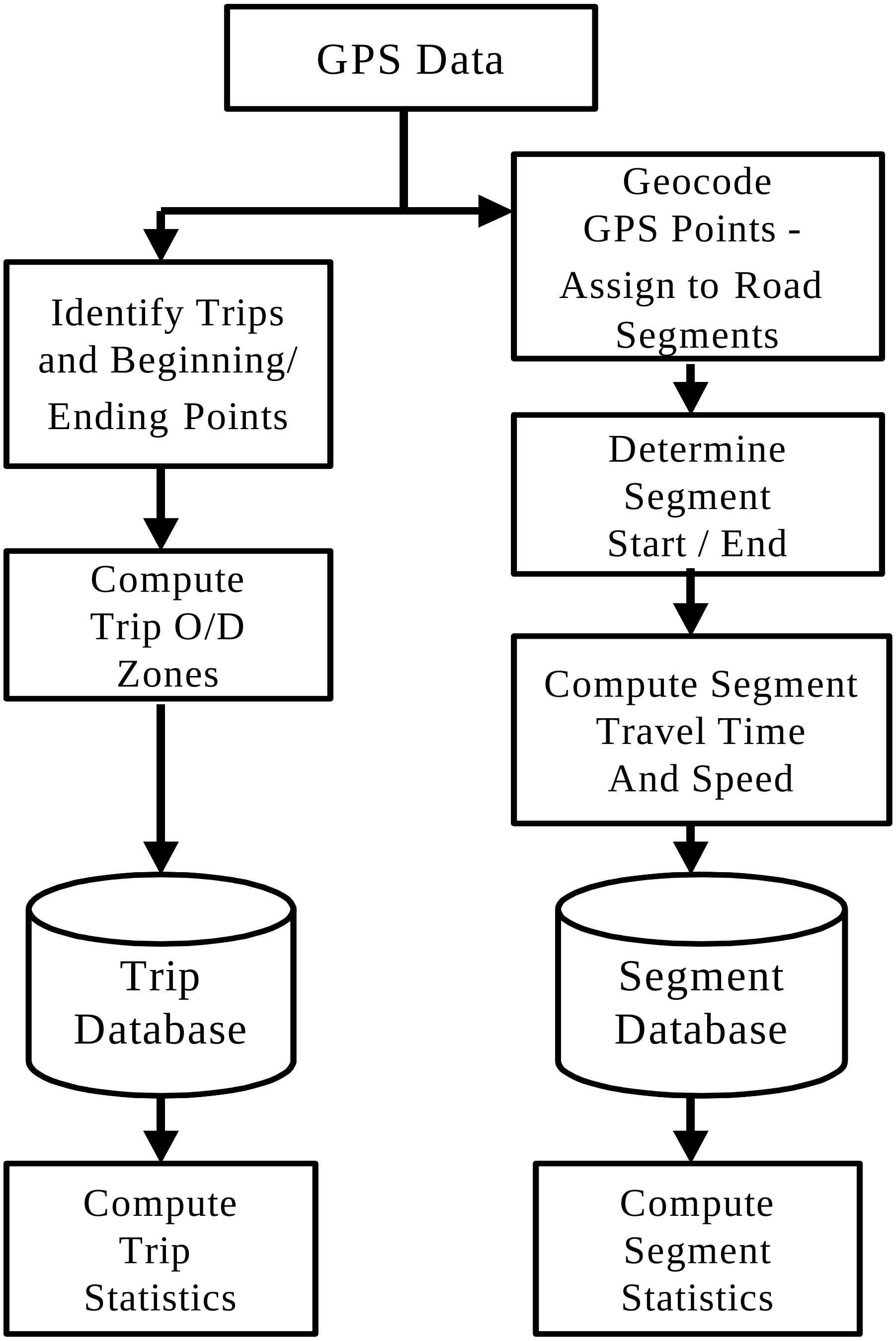

Figure 11: GPS Data Processing Flow Chart

Trip Performance Measures Development

The first task in developing trip performance measures was to identify ‘trips’ in the GPS data set. For this study’s purposes, ‘trips’ were defined by the locations where trucks either picked up or delivered goods. So a truck that started at a warehouse, delivered goods to Store A, then Store B, and then Store C before returning to the warehouse made four trips. (In urban planning terminology these are called “unlinked trips.”)

Unfortunately, the GPS devices did not record specific start and end points for trips. Neither did drivers enter specific trip information. Consequently, ‘trips’ had to be determined solely by examining the GPS data record. To do this, the GPS record for each unique GPS device ID, ordered by time of day, was read sequentially by a software program. The first point in the file for that device ID was assumed to be the origin of a trip. The remaining points were then scanned until a break in that record of 3 minutes or longer was found, or when the vehicle remained stationary for more than 3 minutes.[12] At that point, the ‘trip’ was considered to have ended, and the last point before the time break was recorded as the ‘trip destination.’ Once the vehicle started moving again, that first point was considered the ‘origin’ of the next trip. This process continued until the entire GPS file was segmented into a series of trips.

For each trip identified above, a single data record was written. It consisted of the origin and destination points (and their time stamps), followed by the points traversed between the origin and destination for that trip. (Time and location were also stored for each of these points.) Total trip travel time was computed by subtracting the time at the

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[12] Some modifications to this rule to account for delays at at-grade railroad crossings and draw bridges have been written into the software. It is also possible to subtract out stationary time the vehicle spends at the very beginning or ending of its trip, as it waits with its engine running but not moving.

origin point from the time at the destination point. The time the trip occurred was defined as the time at the origin point. Each trip was then assigned an identification number. The trip records were then read back into the GIS, where the origin and destinations for each trip could be geocoded to the census tract level. All geocoded trip records were then saved as the “Trip Database.” This file served as the primary input to analyses about trip making behavior. It could be analyzed within the GIS or exported into statistical analysis software for the production of travel statistics, such as the example benchmarks described below.

Figure 12 illustrates mean travel times by time of day recorded between the Kent Valley and the census tract containing many of the Port of Seattle terminals. Figure 13 illustrates the average speeds for the mean, median, and 80th percentile travel times for three time periods for this same trip. (The 80th percentile travel time represents those travel conditions so poor that the trucking firm should expect to experience such travel times only once per week.)

The mean and/or median travel times (by time of day) are both good descriptors of “the expected” travel time between two zones. The mean is defined as the mathematical average of all trips, while the median is the trip for which half of all trips are faster and half are slower. Both are reasonable measures of “expected” or “normal” travel times. (The mean is more commonly reported by statistical measurements used to detect changing conditions but can be affected by one or two very slow trips. Median times are excellent measures of “the middle” but don’t reflect the importance of changes in the size or frequency of extreme conditions.) Similarly, the 80th percentile travel time is a good descriptor of the travel time a truck driver (or carrier) It reflects a condition that will be exceeded only about once a week. The 95th percentile travel time reflects the worst trip a driver could expect to experience during a month.

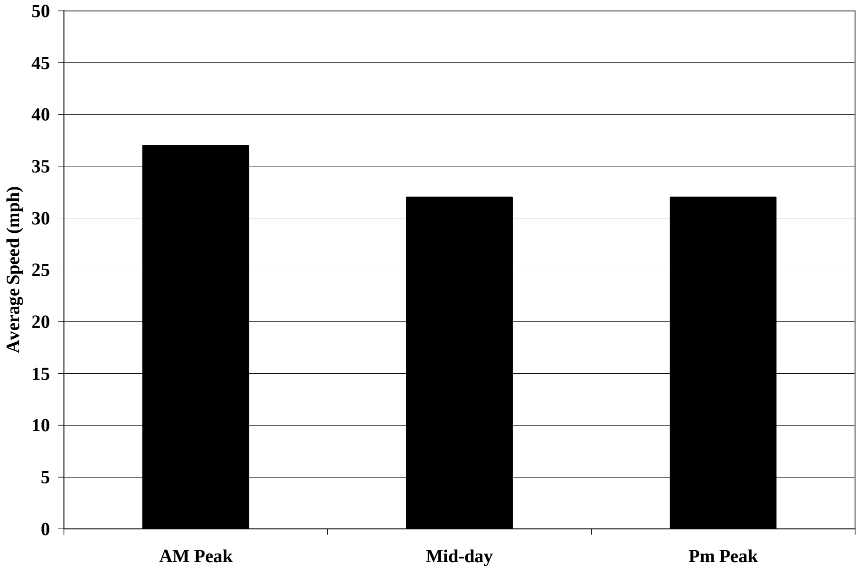

**Figure 12: Mean Travel Times,
Kent Valley to Duwamish by Time of Day**

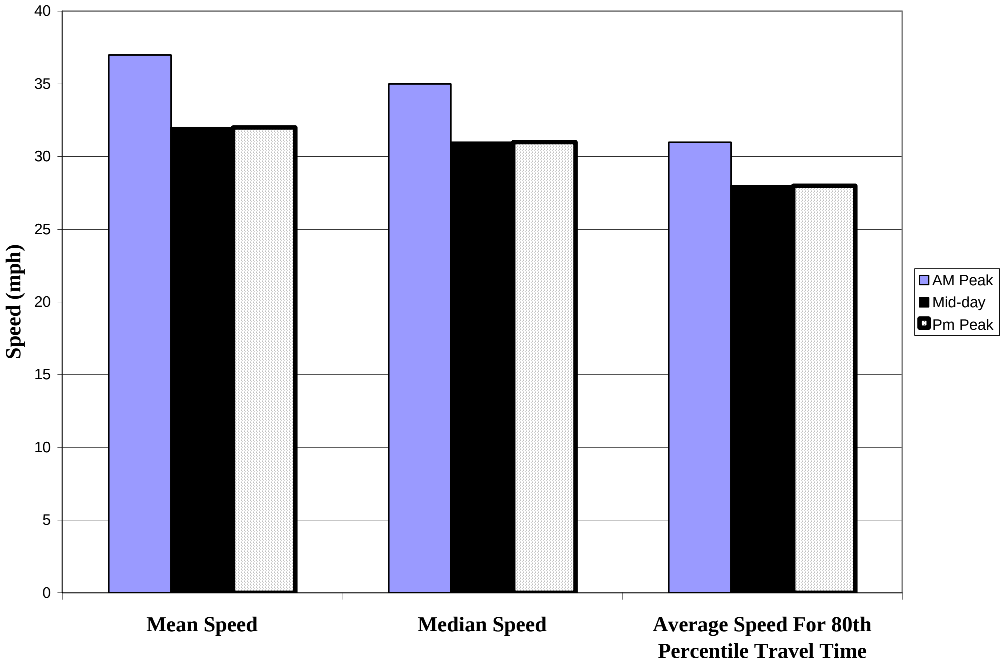

**Figure 13: Median and 80th Percentile Travel Times,
Kent Valley to the Duwamish**

Monitoring changes in all of these statistics would allow WSDOT to track the effect of congestion (and WSDOT improvements) on the time taken to deliver goods, as well as on the reliability of those movements. They would also provide an excellent understanding of the effects that traffic congestion has on a company’s ability to efficiently schedule labor and equipment.

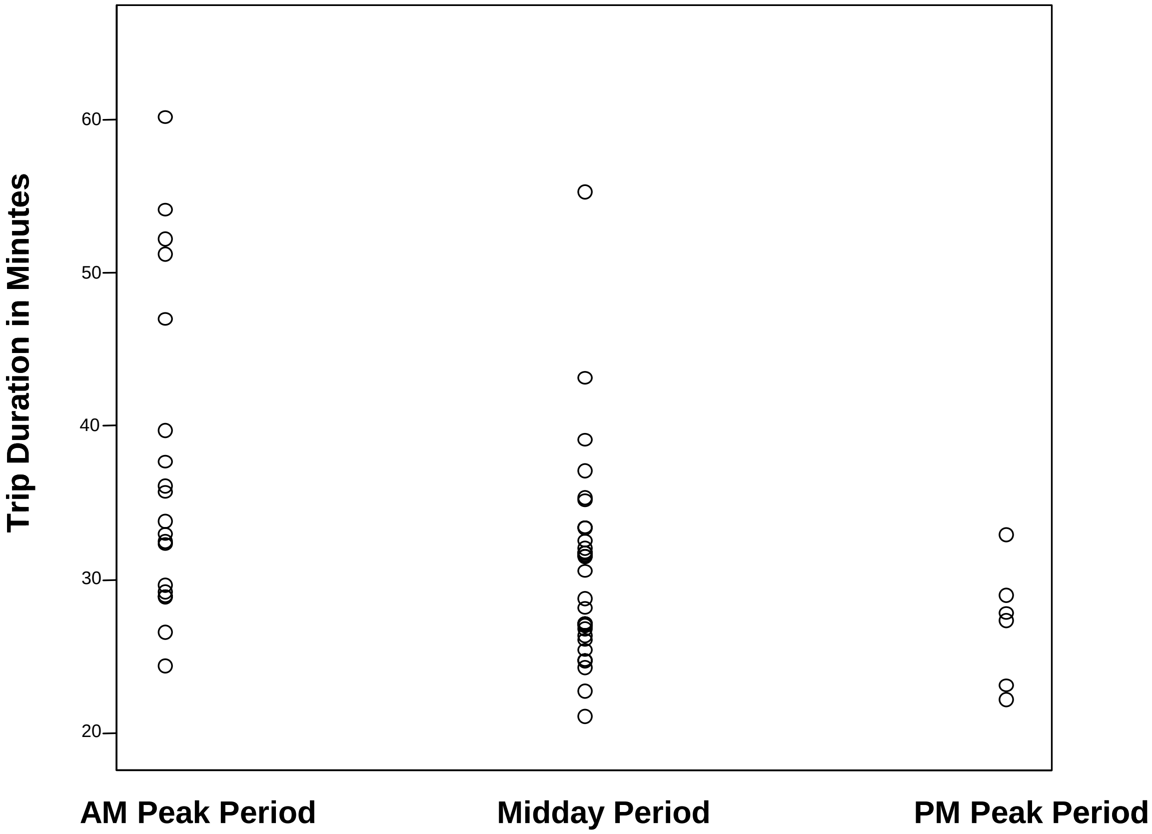

Figure 14: Distribution of Travel Times between the Duwamish Area and the Kent Valley

The reliability of a given truck trip is a key aspect in the efficient use of equipment and labor. The 80th and 95th percentile travel times are excellent descriptive statistics for examining reliability. Other ways to describe reliability are to examine the distribution of travel times associated with zone-to-zone movements. Figure 14 illustrates how travel times by time of day can be plotted to provide a more intuitive sense of the variability of travel time between two zones. Mathematically, this distribution is commonly expressed as the standard deviation of the travel time. However, examining the actual distribution of travel times can be very helpful in understanding how often very slow trips occur and how slow those trips are relative to the "routine" travel times that trucks experience.

It is also possible to set a standard (or benchmark) for acceptable travel time between any two zones and then track the percentage of trips that are able to travel between those two zones within the time associated with that standard. For example, if WSDOT adopted a standard that stated "in order to promote the economic vitality of the region, travel between the Kent Valley and the Duwamish Industrial Area should take no longer than 45 minutes during the business day," it would be possible to use the Trip Database to monitor compliance with those standards. Figure 15 illustrates how the data above could be presented to report on how effectively the road system met this example standard.

Almost any basic statistical software package can use the Trip Database as input and produce the statistics and graphics shown above (as well as a large number of additional statistics) to illustrate the variability in travel times for specific zone to zone movements. All of the statistics mentioned above can be placed in tables and compared over time to determine how travel times are changing as a result of roadway improvements, changes in vehicle volumes, and other factors.

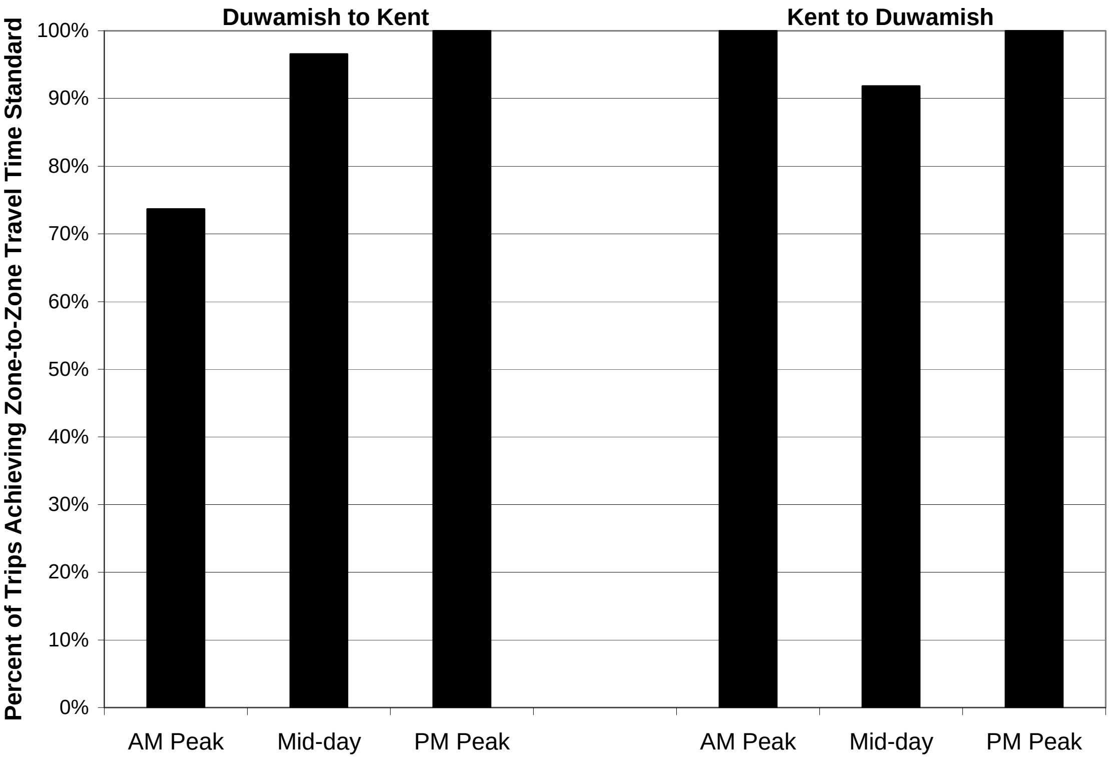

Figure 15: Example of Performance Reporting Against an Example Travel Time Standard

If a representative sample of trucks is recruited to participate in the GPS data collection effort, the Trip Database can also be used to describe the geographic distribution of truck travel in the Puget Sound metropolitan region. However, if the sample of trucks participating in the GPS tests is not representative (only a few trucking companies participate, and their movements are concentrated in specific geographic areas), then an analysis of the spatial distribution of truck trips based on that limited sample will provide a biased view of Puget Sound trucking patterns. Note that this bias is not important if the only goal of the data collection program is to monitor travel time. In this case, the only concern that truck selection bias raises is whether the participating trucks actually drive often enough between key origin/destination pairs to provide reliable travel time estimates.

One other concern is that zone-to-zone travel times will change slightly if the starting and ending points within the two zones are significantly different. Figure 16 illustrates the variety of locations within the Kent Valley census tract where trips start. (The Kent tract is the shaded area in Figure 16, and the dots are the specific start points.)

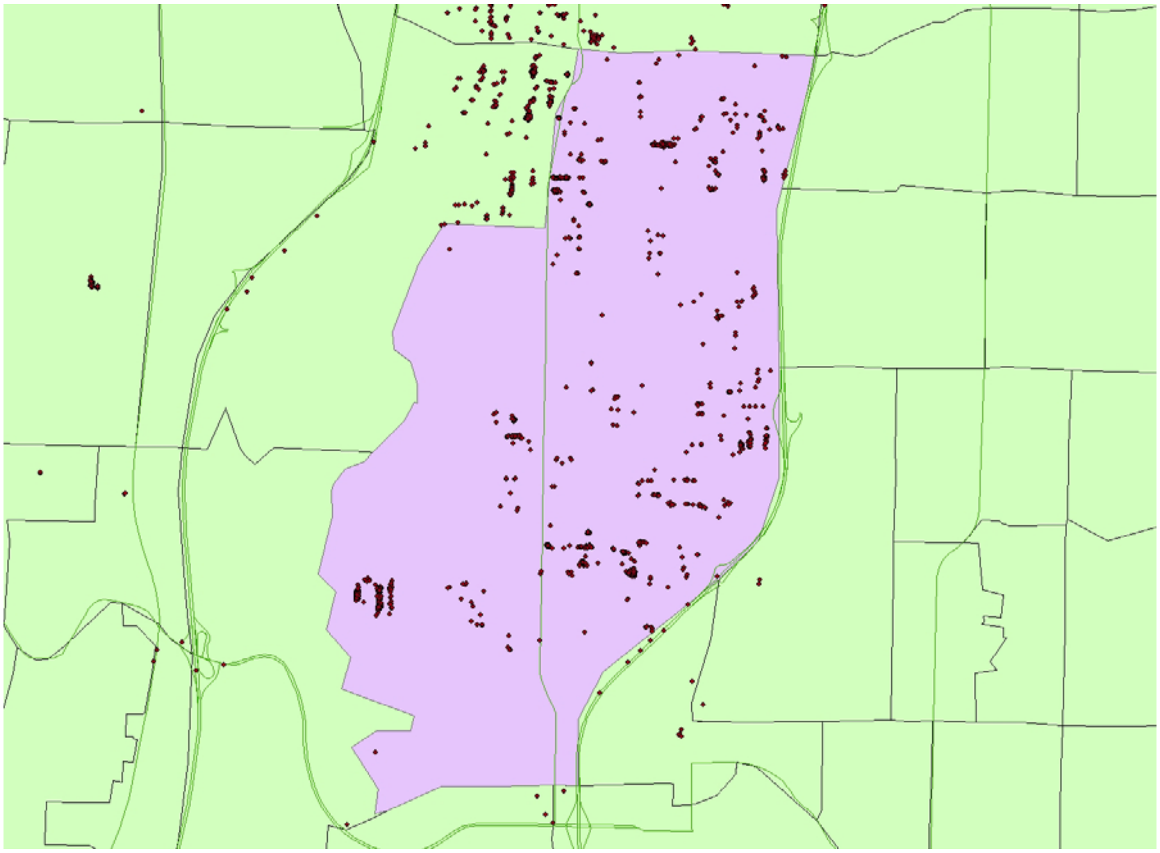

Figure 16: Locations of Trip Start Points in the Kent Valley

Trips leaving from the upper (northern) portion of the zone shown in Figure 16 will likely take somewhat different routes and have somewhat different travel times than trips leaving from the lower left (southwestern) portion of the zone. Consequently, analysts must be aware that small changes in average travel time are just as likely to result from changes in the distribution of origins and destinations within a zone as they are to result from changes in roadway conditions.

However, just because the exact start and end point of trips can affect travel time and route selection does not mean that zone to zone travel times are not an effective measure of roadway performance. A variety of factors affect travel time, including congestion, traffic signals on arterials, and the availability of alternative routes. The longer the zone-to-zone trip, the less significant any minor changes in origin/destination within a zone will become. Therefore, only for very short trips is the distribution of trips within a zone of significant concern.

One great advantage of the use of GPS for data collection is that if the distribution of trip start and end points becomes a concern, the location of these points is known and can be accounted for through more detailed analysis.

For example, a review of trips between the Kent Valley and the Duwamish area of Seattle (Figure 17 shows all routing points for all trips between these two zones) shows that all trips between these two zones pass through the I-5/SR 599 interchange. Therefore, if WSDOT were looking at the effect of roadway modifications near downtown Seattle on the Kent to Duwamish trip, it could remove the effect of the exact starting/ending point in the Kent Valley by examining only that portion of the trip between the I-5/SR 599 and the Duwamish.

Nevertheless, the routing information itself provides significant insight into truck freight movements. From the I-5/SR 599 interchange, trucks routinely use one of three routes into the industrial areas south of the city. They can take

- SR 599 north
- I-5 to one of the downtown exits

- I-5 to Airport Way and then travel north using arterials (usually Airport Way).

Analysis of the routing choices for specific trips shows that the location of the trip end within the Duwamish census tract appears to have only a modest impact on this route choice. Instead, other factors (most likely congestion on I-5) appear to determine route choice.

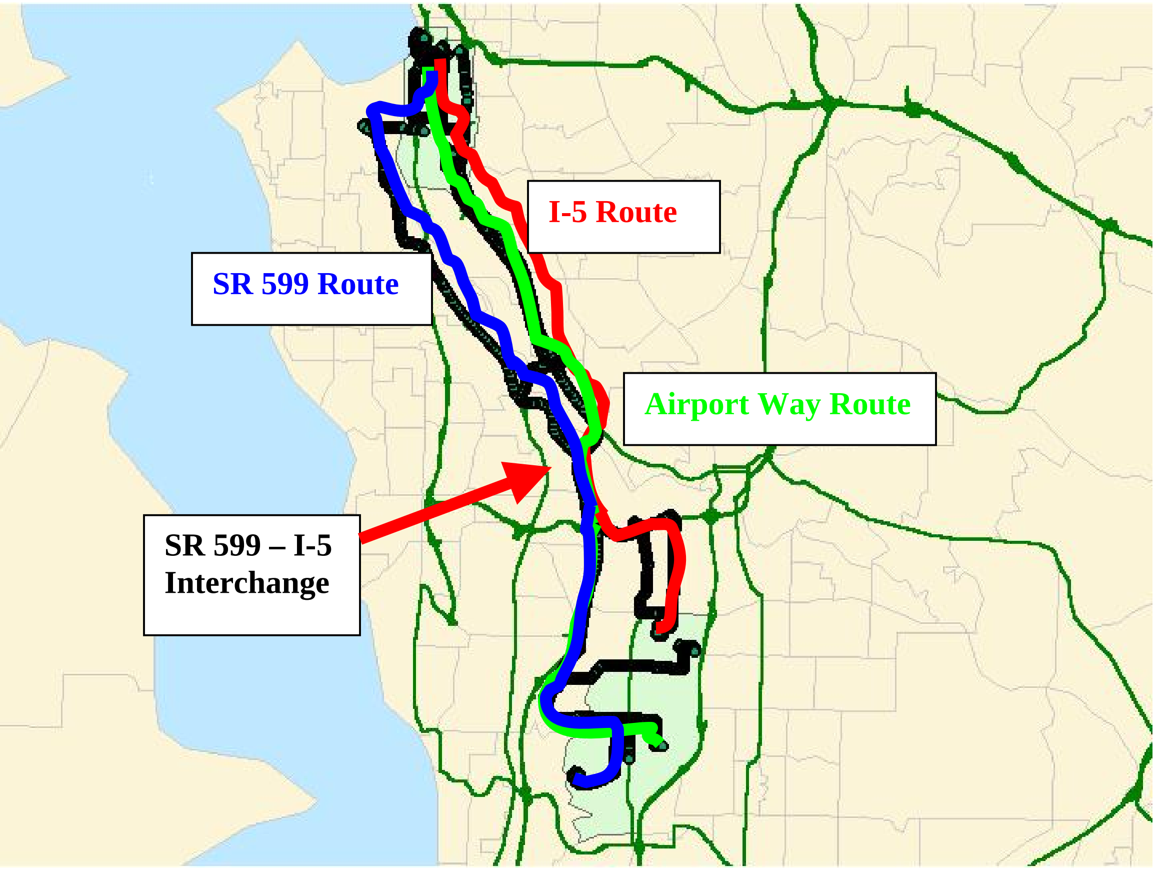

Figure 17: Three Commonly Used Routes from Kent to South of Downtown Seattle

The use of GPS in volunteer trucks would allow WSDOT to monitor how route choice changes over time. GPS data from in-service trucks would provide an excellent source for determining changes in truck routing decisions.

Road Segment Performance Measures Development

Truck trip travel time is not the only benchmark that can be used for a freight mobility program. Such a program also needs benchmarks on specific roadway segments, as well as total trip movements. The roadway segment data are needed to describe the specific, localized performance changes that result from roadway projects. The GPS data described above can also be used to provide these road segment-specific benchmarks. To perform these calculations, the raw data collected from the volunteer trucks are processed into the roadway Segment Database following the steps illustrated in Figure 11 (above).

To compute segment statistics, the raw GPS data had to be processed differently than they were processed to produce the Trip Database. To begin with, the origin and destination of truck trips are unimportant for examining road segment performance. What is important is that every trip that traverses a specified road segment is tracked so that as much information as possible about travel along a road segment is available to describe the performance of that road segment. This segment-specific travel information was stored in the Segment Database. This database contained one record for each truck movement along a defined road segment of interest to WSDOT. The technical steps required to create this database are described below.

The initial step for creating the Segment Database was to read the “raw” GPS data point files (still in time sequential order by device ID) into the geographic information system. GIS tools were then used to assign each GPS data point to a specific roadway segment on the Puget Sound Regional Council’s (PSRC) freight priority road network. (Note: this was a very complex process that required considerable effort to ensure adequate quality control. For example, some data points were assigned as “off network” during this step because they were located too far from a road segment to be considered “on” that road segment. In most of these cases, the vehicle carrying the tag had entered a parking lot or was traveling a local road not included in the PSRC freight network. These data points were not included in the Segment Database.)

All data points were then exported to a new file. Each reported truck location was a single record in the file, and that record included all of the data that described that location (longitude, latitude, time of observation, heading, GPS device ID), including a road segment identifier extracted from the GIS.

This file was then processed sequentially (by time of day for each GPS tag ID) by a program written in C++ to produce the base records that made up the Segment Database. This program identified when each truck passed from one road segment to another. Each time a vehicle passed onto a new road segment, the data from the previous segment were written onto a single record.

Consequently, each new record contained data for an entire “trip” on a single roadway segment. (So if Truck A used NE 45th Street between 11th and 12th avenues twice during a day, two different records would exist, one for the first trip on that road segment and one for the second trip.) Each record contained the all GPS data points on that segment for that specific trip by that specific truck, along with the road segment ID. Associated with each GPS data point included in the record were the latitude and longitude of that specific point, the time the truck was observed at that point, and the heading of the truck at that time.

From the data points stored on each record it was possible to compute the total distance the truck traveled while on that road segment for that specific trip. To do this required that the distance between each GPS data point be computed and that those distances be added together. These steps were necessary because the truck may have entered or exited the defined road segment at some point other than the end points of the segment. (See Figure 18 for an illustration of how a truck may use only a portion of a defined link.) A truck may only travel a portion of a defined road segment because it enters/exits that link to/from a minor street intersection or a driveway in the middle of the defined roadway segment. In addition, the road segment may curve, which makes a straight line computation from the first data point to the last data point within the link a poor estimate of total distance traveled.

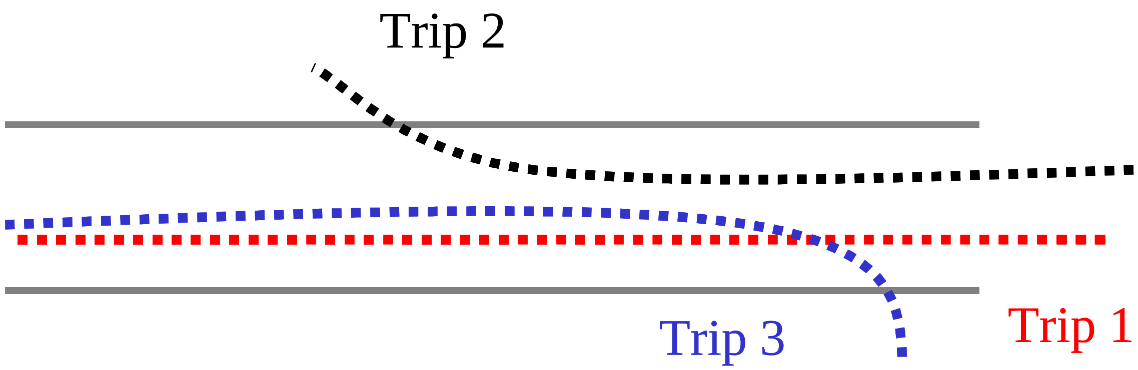

Figure 18: Illustration of Trips Covering Only Part of a Road Segment

The total travel time the truck spent on that road segment was computed by subtracting the time the truck was first observed on the segment from the time the truck was last observed on that segment. Dividing the total distance traveled on the link by the total time on the link produced a measure of the average speed of the truck while on that link. All three of these variables were then written as part of the database record.

This process was repeated for all GPS data points collected. The result was a new file with records that described the performance of all truck trips along all freight network roadway segments. This file was the Segment Database. To obtain performance information on specific segments it was necessary only to use the GIS to identify the road segment ID of the road segment of interest, select those records that included this identifier, and compute the statistics of interest from that sample of records.

All travel time related benchmarks specific to roadway links of interest can be generated from this database. An example of what those benchmarks might include is presented below as Table 4. The primary concern with this database is that the statistics generated by it are valid only if a substantial number of participating trucks have used this roadway segment.

How the Segment database might be used, and how sample size affects the utility of the database, are described below, with the data contained in Table 4 as examples. Table 4 presents data for four freeway and six arterial road segments. Summary statistics are presented for each road segment for four time periods, the AM peak period (6:01 AM to 9:00 AM), midday (9:01 AM – 3:00 PM), the PM peak (3:01 PM – 7:00 PM), and night (7:01 PM – 6:00 AM). Figure 19 illustrates the location of the roadway segments whose performance is shown in Table 4.

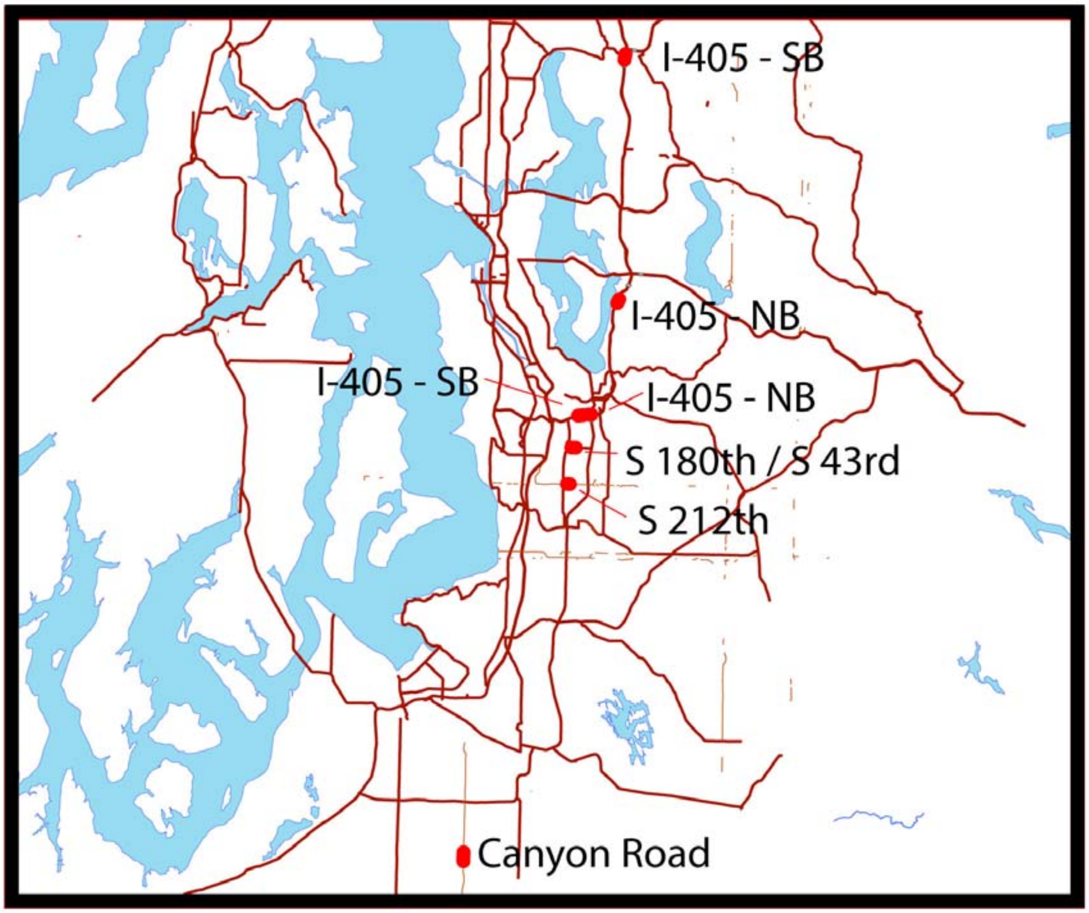

Figure 19: Location of Road Segments Included in Benchmark Examples

Table 4: Illustration of Potential Road Segment Benchmarks

Roadway			Mean Speed	Number of Observations	Median Speed	Standard Deviation	5th Percentile Speed	25th Percentile Speed	95th Percentile Speed
S I-405 NB	PERIOD	**AM_Pk**	**34**	**16**	**32**	**7**	**21**	**49**	**57**
South of SR 167		Mid_Day	53	88	56	24	54	59	65
		PM_Pk	**50**	**9**	**55**	**30**	**52**	**55**	**60**
		Night	58	43	58	55	56	60	63
N I-405 SB	PERIOD	**AM_Pk**	**29**	**40**	**21**	**9**	**16**	**49**	**54**
South of SR 522		Mid_Day	52	76	55	23	51	57	63
		PM_Pk	**53**	**19**	**52**	**39**	**49**	**57**	**64**
		Night	52	9	54	43	50	55	58
S I-405 SB	PERIOD	**AM_Pk**	**28**	**64**	**23**	**14**	**9**	**20**	**51**
South of SR 167		Mid_Day	31	154	28	12	12	22	52
		PM_Pk	**27**	**36**	**24**	**10**	**12**	**21**	**48**
		Night	35	23	36	11	22	25	47
N I-405 NB	PERIOD	**AM_Pk**	**45**	**42**	**49**	**13**	**21**	**39**	**58**
South of I-90		Mid_Day	42	153	43	24	31	51	57
		PM_Pk	**37**	**19**	**34**	**23**	**30**	**48**	**51**
		Night	57	8	57	51	54	61	63
212th EB	PERIOD	**AM_Pk**	**25**	**4**	**30**	**3**	**15**	**34**	**35**
		Mid_Day	16	25	13	10	7	8	38
		PM_Pk	**20**	**45**	**18**	**11**	**7**	**11**	**37**
		Night	.	0	.	.	.	.	.
212th WB	PERIOD	**AM_Pk**	**19**	**8**	**19**	**16**	**1**	**2**	**41**
		Mid_Day	22	21	18	13	4	11	40
		PM_Pk	**20**	**25**	**21**	**11**	**6**	**10**	**37**
		Night	28	3	25	7	23	23	37
Canyon SB	PERIOD	**AM_Pk**	**33**	**15**	**36**	**8**	**22**	**25**	**48**
		Mid_Day	32	84	31	9	17	25	45
		PM_Pk	**36**	**13**	**35**	**9**	**15**	**31**	**51**
		Night	35	4	37	8	24	29	43
Canyon NB	PERIOD	**AM_Pk**	**36**	**27**	**37**	**5**	**24**	**33**	**42**
		Mid_Day	35	64	35	5	27	31	44
		PM_Pk	**37**	**7**	**35**	**4**	**34**	**34**	**43**
		Night	36	26	38	6	27	30	42
S. 180th / SW 43rd (EB)	PERIOD	**AM_Pk**	.	0	.	.	.	.	.
		Mid_Day	.	0	.	.	.	.	.
		PM_Pk	**25**	**2**	**25**	**17**	**13**	**13**	**38**
		Night	35	2	35	0	35	35	35
S. 180th / SW 43rd (WB)	PERIOD	**AM_Pk**	.	0	.	.	.	.	.
		Mid_Day	.	0	.	.	.	.	.
		PM_Pk	**21**	**4**	**21**	**12**	**7**	**13**	**37**
		Night	29	2	29	7	24	24	34

For the Segment database to be effective for performance monitoring, enough data must be collected on each road segment to provide average speed estimates that are representative of facility performance. This means that enough trucks must travel along each road so that random chance does not result in the database reporting unusually fast or slow travel speeds for that segment.

While small sample sizes can still produce speed estimates, statistical confidence in how well those estimates represent actual conditions remains modest until sample sizes approach at least 30 trips. Statistical confidence that differences in measured speeds accurately reflect real changes in roadway performance grows slowly with sample size larger than 30 trips. Confidence declines rapidly with sample sizes smaller than 30, as the potential effects of random error become more significant.

Examining the sample sizes by time of day in Table 4 (see the column labeled "Number of Observations") shows which time periods and road segment locations had enough data to provide speed estimates statistically representative of that road segment's performance.

In general, eight of the ten locations had reasonable sample sizes during the middle of the day. The availability of AM peak, PM peak, and night measurements tended to vary considerably from location to location. Interestingly, the South 180th/SW 43rd roadway segment had no trips during either the midday or the AM peak periods, times when most trucks are operating. Not surprisingly, because their truck volumes are higher and they serve as the preferred route choice between a vast number of origins and destinations in the region, the freeway segments generally had considerably more data points than the arterial segments. Because performance data on most freeway segments are already available from the WSDOT freeway surveillance system, the remainder of this discussion will focus on the arterial data available from this study's 62 truck-months of GPS data collection, as those data have the potential to fill a major hole in the state's ability to monitor roadway performance. However, it is important to note that whereas these data are an excellent source of data for truck performance on freeways, truck performance will be different than general roadway performance.

Arterial data in Table 4 illustrate the performance of three different roads. Monitored speeds are presented for both directions of all three arterials. The first arterial is South 212th St in Kent. It is one of the major east/west arterials that cross the Kent Valley. It is the next major east/west arterial south of S. 180th, which is an FMSIB freight mobility project being studied.

The second road, Canyon Road, is a major north/south road that is on the route commonly driven by Boeing trucks to connect to SR 512 as they move freight between the Boeing Fredrickson facility and the Everett assembly plant.

The last arterial presented is S. 180th/S 43rd St. in Kent. It is the site of a recently constructed railroad grade separation project. (An underpass was constructed to allow road traffic to continue while trains are present.) This roadway connects the Southcenter Parkway and West Valley Highway on the west side of the Kent Valley with SR 167 on the east side of the Valley, and it provides access to a large number of businesses in this area.

A reasonable number of truck trips were observed traveling the first two arterials in both directions. In fact, considerably more instrumented trucks used S. 212th (131 trips) than the newly constructed railroad grade separation on S. 180th (10 trips) during the GPS data collection period. While the data collected on S 212th allowed us to examine the performance of that road, the very limited number of data on S. 180th made it difficult to accurately determine the performance of the road segment containing the S. 180th Street railroad grade crossing. The lack of data is not because trucks do not use this road but rather because the trucks that routinely use this facility were not recruited for this project’s GPS pilot test.

Truck volume counts collected during this study showed that roughly 20 large trucks per hour (and 40 commercial vehicles) traveled this roadway throughout the business day. Unfortunately, none of these trucks appeared to have been carrying a project-supplied GPS device. (This underscores the importance of the recruitment process if GPS data collection will be used to monitor freight mobility projects. It is absolutely necessary that trucks recruited for benchmarking purposes routinely use the facility for which benchmark data are required.)

Table 4 shows that a reasonably high percentage of trips traveled S. 212th during the middle of the day and evening peak periods, while relatively few trucks were observed on this road during the AM peak and at night. On the other hand, a significant number of trucks used Canyon Road northbound late at night and in the morning, as well as during the middle of the day in both directions.

The reason for these differences is partly the nature of the usage of these roads but also the result of which trucks were participating in the data collection effort. Boeing instrumented four trucks for the project, and those trucks frequently carried airplane parts between its Fredrickson facility and the Everett assembly plant very early in the morning (before 6:00 AM) along Canyon Road northbound.[13] Conversely, few of the trucks participating in the study were active in the Kent Valley either late at night or very early in the morning, as the majority of businesses in that area are closed during those times. (The three westbound "night trucks" on S. 212th in Table 4 all made those trips just before the 6:00 AM deadline that separated "Night" from "AM Peak" in our summarization process.)

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[13] Interestingly, the southbound movement of those trucks occurs late in the morning commute period, or early in the midday period and thus the southbound Canyon Road segment does not have many night time trips.

The effect of these differences in data availability is that statistically meaningful benchmarks could not be created for some road segments and/or some time periods. For example, a benchmark could not be created for eastbound S 212th during the night period, and the AM peak period (based on four trips) has little statistical reliability. The lack of data also meant that performance statistics could not be reliably reported for the S. 180th Street project.

So how many trips are needed to create a statistically valid benchmark?

Where the number of truck trips along a route exceeds 30 during a specific period of interest, statistics allow greater confidence in being able to say that measured differences in travel time are statistically significant. Samples sizes below 30 can still be used for computing changes in performance, but they require larger differences in those travel times if the resulting differences are to be considered more than random variation. Larger sample sizes are usually required on arterials because arterial travel times tend to vary as a result of traffic signals.

With a sample size of 30 “before” and 30 “after” measurements and the standard deviations of the average segment speed of between 9 and 13 mph taken from Table 4, a difference of 4 to 5 mph in the measured “before” and “after” mean speeds would be necessary to be confident that an observed change in speed had actually occurred, rather than being the result of random variations in the measured samples. A sample size of only 20 truck trips in each of the “before” and “after” periods would mean that the before/after difference would have to be closer to 5.5 to 6.5 mph for WSDOT to be confident that performance changes on that road segment had occurred after the roadway improvement had taken place.

Costs and Considerations for Using GPS Data Collection

WSDOT currently owns 25 operational GPS devices and over 50 data loggers. Newer GPS devices with better positional accuracy, increased data capacity, and improved downloading speeds are currently on the market and cost roughly $500 each. Additional loggers are $340. A minimum of one additional data logger is needed for each GPS device purchased.

Unlike the CVISN tag reader system, the GPS data collection system requires considerable staff effort to collect and process the GPS data. These project tasks include

- distributing the GPS devices to participating trucking firms and ensuring that they are installed correctly
- the office functions of sending out “empty” data loggers, obtaining and downloading “full” data loggers, replacing each logger’s battery, and corresponding with participating trucking companies’ representatives to make sure the data collection and transfer process is working smoothly
- performing periodic site visits to each company to maintain participation and to resolve problems with GPS devices, loggers, and retrieval of data loggers.

These administrative tasks require about one hour of staff time per logger per month. These tasks also require a modest “supply/miscellaneous” budget to pay for new batteries and postage to mail loggers back and forth between the administrator and the participating trucking firms.

In addition, it is necessary to have a mechanism for recruiting trucking company participation. This approach to data collection will not work without strong support from the trucking community. WSDOT, perhaps working with the FMSIB, is in an excellent position (with the help of the Washington Trucking Association) to recruit trucking firms for this task. If the data collection task focuses on a specific road segment, it is imperative that trucking firms that use that road segment be identified and agree to participate, or this type of data collection will not be successful.

Considerable analytical effort is also required to convert the GPS data into useful statistics. The process developed for this project is considered an early prototype. Additional programming is needed to convert the current software into a "production" system that can be used routinely with a minimum of staff intervention. This task, estimated to cost $40,000 would be a one-time expense.

The amount of time required to actually run the data through the new software system, deal with quality control issues, and create the Trip and Segment databases and produce summary reports will depend highly on the number of trucks participating in the GPS system. This effort could be as small as two hours per logger per month, or if the system were expanded to provide region-wide freight performance statistics, it could cost over $150,000 per year.

EXAMPLE FREIGHT MOBILITY PERFORMANCE REPORTS

As part of this study, four specific examples of benchmarks of freight performance, two related to recent FMSIB-funded projects and two related to freight movements of interest, were explored. This section provides examples of what those benchmark reports might look like. Two of the examples are intended to illustrate how before/after studies would describe the magnitude of benefits achieved by freight mobility projects. The last two examples are intended to show how ongoing monitoring efforts could be used to describe the delays freight movements currently experience.

<u>South 180th / SW 43rd Underpass Improvement Example</u>

It has been noted that this pilot test of GPS data collection using volunteer trucks did not succeed in collecting sufficient truck travel data on the South 180th / SW 43rd Street road segment. A second problem is that the road construction project was begun before the start of the GPS pilot test. Therefore, no "before" truck performance information was collected before the start of the grade separation project. This combination of problems made it impossible to actually compute benefits. However, it is possible to use data collected and some simple assumptions to illustrate what such a benefit calculation would look like.

Truck volume counts performed at the new underpass as part of this project indicated that on the order of 17 combination[14] trucks per hour used this facility in each direction during the business day (6:00 AM to 6:00 PM.) Truck volumes appeared to be much lighter during the remaining 12 hours of the day. An additional 28 single-unit trucks also used this facility in each direction, each hour, during the business day.

The value to trucking firms of lost time is assumed to be $53.07[15] per hour nationally.

If the savings from the grade separation project are assumed to be 1 minute per trip, then <u>the savings to trucking firms only</u> from the project can be computed as being

12 hours/wkday
x 45 trucks/dir-hr
x 2 directions

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[14] "Combination trucks" are defined as all tractor trailer vehicles, full trucks pulling trailers, and multi-unit vehicles.

[15] This value is used by WSDOT when calculating benefits from mobility improvement projects. See Mobility Project Prioritization Process, Benefit/Cost User's Guide, May 2000, by Dowling Associates, et. al.

x 261 weekdays

x \$53.07/hr

x 1 min

<u>x 1 hr/60 min.</u>

~ \$249,000 / year[16]

The 1-minute savings used in the above equation would be obtained by computing the mean travel time savings along the road segment that contains the new grade crossing. Additional savings could be computed by adding in the savings to cars using this same facility. (Travel time savings for passenger cars is assumed to be worth \$9.87 per hour. Per trip time savings can be assumed to be equal to those for trucks, although they may differ slightly.)

Additional benefit could be computed if truck volumes increased on this facility after completion of the grade separation. (This is a likely outcome of such a project, as the street becomes a more convenient and reliable route for crossing the railroad tracks.) This additional benefit could be estimated by using the GPS data to compute changes in total trip travel time for zone to zone movements that previously did not use this roadway but that used it after the improvement.

The benchmark tables for the report might look something like those shown below. Table 5 illustrates how benefits that accrued to trucks using the roadway on which the improvement was made (based on changes in average travel speed on the segment) might be shown. (Note that benefits are calculated for both directions, but directional volumes are shown.)

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[16] Note that this computation is simply an **example** and is not based on actual before and after data.

Table 5: Example Benchmark Report for Road Segment Truck Travel Savings

Road Segment	Time Period	Mean Speed After Project	Before Travel Time (Min)	After Travel Time (min)	Travel Time Savings (min)	Truck Volume (Per Hour)	Value of Truck Time (per year)
S. 180th	AM Peak (6 AM - 9 AM)	25.4	3.4	2.4	1	45	$62,331
	Midday (9 AM - 3 PM)	34.7	2.7	1.7	1	45	$124,661
	PM Peak (3 PM - 6 PM)	21.5	3.8	2.8	1	45	$62,331
	Night (6 PM - 6 AM)	40.1	2	2	0	5	$0
						TOTAL	$249,323

Table 6 provides an illustrative table that includes travel time savings for automobile traffic for these same roadway segment improvements. As with Table 5, Table 6 would also need to be computed for both directions of travel.

Table 6: Example Benchmark Report for Total Road Segment Travel Benefits

Road Segment	Time Period	Travel Time Savings	Truck Volume (Per Hour)	New Truck Trip Time Savings	New Truck Trips	Value of Truck Time (per year)	Passenger Car Volume (Per Hour)	Value of Car Time (per year)	Total Annual Value of Time Savings
S. 180th	AM Peak (6 AM - 9 AM)	1	45	1.6	5	$73,412	1450	$373,530	$446,942
	Midday (9 AM - 3 PM)	1	45	1.1	10	$155,134	1020	$262,759	$417,893
	PM Peak (3 PM - 6 PM)	1	45	0.7	5	$67,179	1510	$388,987	$456,165
	Night (6 PM - 6 AM)	0	5	0.5	2	$1,385	320	$0	$1,385
								TOTAL	$1,322,386

Table 7 shows how the benefits gained by truck trips attracted to the improved road might be calculated and shown. These benefits are based on improved travel times between zones involved in key freight movements.

Table 7: Example Benchmark for Savings from Attracted Trips

Zone to Zone Movement	Time Period	Mean Speed After Project	Before Travel Time	After Travel Time	Travel Time Savings	Truck Volume (Per Hour)	Value of Truck Time (per year)
Kent - Duwamish	AM Peak (6 AM - 9 AM)	25.4	37.1	35.5	1.6	5	$11,081
	Midday (9 AM - 3 PM)	34.7	32.2	31.1	1.1	10	$30,473
	PM Peak (3 PM - 6 PM)	21.5	32.5	31.8	0.7	5	$4,848
	Night (6 PM - 6 AM)	29.3	26.5	26	0.5	0.5	$1,385
						TOTAL	$47,787

Table 8 provides an example of what a summary table might look like describing the changes in travel time reliability that resulted from a truck-oriented roadway improvement.

Table 8: Example Benchmark Summary of Improvements in Freight Reliability

Zone to Zone Movement	Time Period	New Mean Travel Time (min)	New Mean Speed (mph)	80th Percentile Travel Time (min)	95th Percentile Travel Time (min)	Percent of Trips That Require More that 40 minutes
Kent - Duwamish	AM Peak (6 AM - 9 AM)	37	24.3	45	55	26%
	Midday (9 AM - 3 PM)	32	28.0	34	39	2%
	PM Peak (3 PM - 6 PM)	33	27.7	37	42	7%
	Night (6 PM - 6 AM)	27	34.0	28	30	0%
Duwamish - Kent	AM Peak (6 AM - 9 AM)	32	28.0	35	39	3%
	Midday (9 AM - 3 PM)	33	27.4	36	38	3%
	PM Peak (3 PM - 6 PM)	39	22.8	43	52	24%
	Night (6 PM - 6 AM)	27	34.0	28	30	0%

Royal Brougham By-Pass Improvement

The Royal Brougham test of data collection procedures experienced many of the same problems as the S 180th St. railroad grade separation project test. The biggest problem was a lack of data collected on the facility. For the Royal Brougham case, the "after" data collection showed very few trucks using the desired roadways.

Like the S. 180th St improvement project, the Royal Brougham improvement involved a grade separation. In this case, a new freeway entrance ramp was constructed from Atlantic Avenue leading to both I-5 and I-90. The new ramp includes a structure that passes over the existing railroad tracks and allows trucks traveling from the Seattle waterfront (and Port of Seattle) to access the freeways without being delayed by trains crossing Royal Brougham. The improvement should decrease travel times to destinations south of downtown Seattle. The improvement is also likely to produce a shift in routes used by trucks traveling to and from just south of downtown Seattle.

Data on the use of Royal Brougham and the new ramp were to be collected by volunteer trucks. Initial tests of the data collected in the summer of 2003 indicated that a reasonable number of trips were made on Royal Brougham as it crossed the railroad tracks near Safeco Field. (During the initial month of data collection, twenty trips westbound and nine eastbound used Royal Brougham.) Unfortunately, unbeknownst to the project team, all of these data came from trucks provided by a single participating trucking firm. After an initial period of participating in the study, the truck drivers for this firm became concerned about data from the GPS devices being used to violate their privacy. The trucking firm then pulled out of the study.

Because data were not actively processed during the middle months of the study (the process initially performed manually was converted to a more automated system, and data were not processed during this transition), the lack of data to and from these zones was not noticed until late in the analysis phase of the project. The result is that insufficient data on travel times between zones were available after the completion of the new ramp. This not only prevented the computation of travel time savings, it prevented any analysis of how the new ramp affected route choice for trucks serving this part of the city. Thus, just as with the S. 180th St. underpass, this project was unable to accurately describe the effects of the new Atlantic Street ramp.

What the collected data makes apparent about the use of Royal Brougham Way before the completion of the Atlantic Street ramp is that the trucks that used that facility accessed it from a variety of directions and roads. Trucks using Royal Brougham to cross the railroad tracks accessed Royal Brougham not only from the freeway but from 4th Avenue South, Airport Way, and even 6th Avenue South (see Figure 20). Trucks using the freeway to reach Royal Brougham (usually via the 4th Avenue ramp) came from north, south, and east.

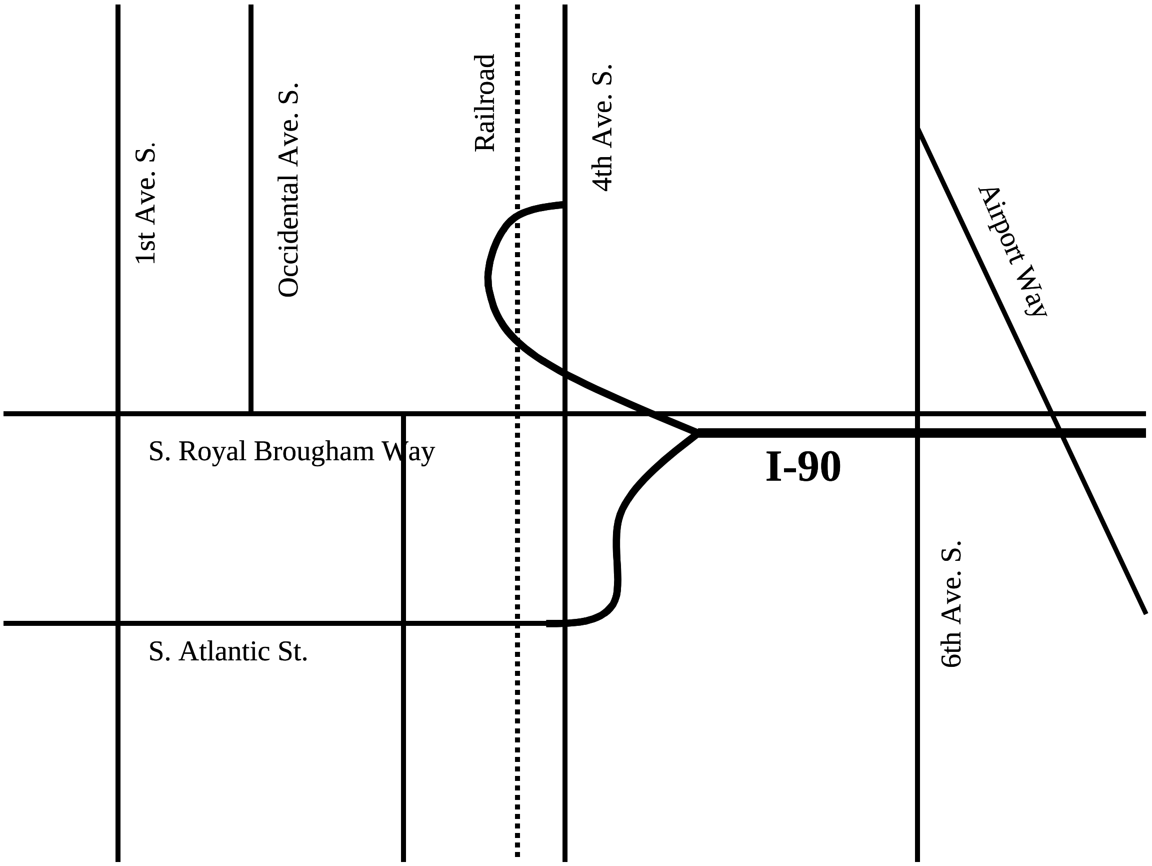

Figure 20: Alternative Routes for Accessing Royal Brougham Way

While alternative routes to the freeway approaches from the north and east are relatively few, drivers wishing to avoid either congestion on I-5 or train delays on Royal Brougham can choose from a large number of alternative routes to the approach from the south. Among the major alternatives that exist, truckers can exit I-5 at

- the freeway ramps to downtown
- Exit #158 and use Airport way northbound
- Exit #163 and use 4th Avenue South northbound
- Exit #156 and use SR 599 and Marginal Way to completely avoid using Royal Brougham while accessing Port of Seattle terminals.

The very low level of “after” data collected means that it was impossible to determine how the new Atlantic Street overpass affected driver route choice and, consequently, the amount of delay experienced as a result of the railroad track crossing at Royal Brougham Way. The same statistics used to describe zone to zone movements between Kent and the Duwamish census tract would also be used to describe the effects a project such as this would have on truck trip travel time and travel time reliability.

In addition, if sufficient data had been collected, it would be possible to observe changes in the percentage of trips using the various routes to access the Port of Seattle terminals just south of downtown. Thus in addition to tables similar to tables 5 through 8, a table such as Table 9 might be used to describe the effects a freight mobility project had on truck routing.

Table 9: Example Benchmark Report for Route Selection

		Before			**After**				
Trip	**Route**	**Percent of Trips**	**Mean Trip Time (min)**	**80th Percentile Trip Time (min)**	**Percent of Trips**	**Mean Trip Time (min)**	**80th Percentile Trip Time (min)**	**Change in Mean Travel Time (min)**	**Change in Percent of Trips**
Kent to Port of Seattle	4th Ave. S. Ramp	50%	34.9	46.2	5%	35.1	46.2	0.2	-45%
	Atlantic Ramp	NA	NA	NA	58%	34.1	41.5	NA	NA
	SR 599	35%	36.4	50.9	30%	36.2	50.3	-0.2	-5%
	Airport Way	10%	39.8	54.3	5%	39.4	54.3	-0.4	-5%
	4th Ave. S.	5%	42	54.5	2%	42.1	54.5	0.1	-3%
Port of Seattle to Kent	4th Ave. S. Ramp	55%	37.4	44.2	6%	35.8	44.2	-1.6	-49%
	Atlantic Ramp	NA	NA	NA	55%	33.5	38.5	NA	NA
	SR 599	32%	36.5	44.2	28%	36.7	44.2	0.2	-4%
	Airport Way	8%	41	50.6	8%	40.5	50.6	-0.5	0%
	4th Ave. S.	5%	44.5	51.3	3%	44.3	51.3	-0.2	-2%

The example illustrated in Table 9 is written as if truck travel times were dependent only on travel route. On the contrary, the small number of data collected for this trip indicated (not surprisingly) that trip travel times changed by time of day, even within a specific route.

Thus, ideally, enough data need to be collected to estimate trip travel times by route, by time of day. The problem with using travel time information by route by time of day is that this essentially quintuples the number of data required to perform before/after studies. However, having good time-of-day data does allow the benefits calculation to be performed by time of day. This is particularly important for a facility such as Royal Brougham Way, where truck volumes are less constant than those found at S. 180th St. On Royal Brougham, truck volumes are negligible before 6:30 AM and after 5:15 PM, as many of the businesses near the waterfront (such as the Port of Seattle) keep limited business hours. This means that truck trips are concentrated during these time periods.

Boeing Movement: Fredrickson – Everett

This report example describes the effect of congestion on movements of freight between Boeing's Fredrickson facility and its aircraft assembly plant in Everett. The use of GPS data collection would allow WSDOT to understand the size and frequency of delays being experienced by Boeing vehicles, as well as to pin-point where those delays are taking place. The analysis consisted of two specific parts, a review of the overall trip statistics for truck movements between these two locations, and a description of the points where congestion most significantly affected the congestion occurring at those points.

During the study, 61 trips were monitored traveling northbound from Fredrickson to Everett. Southbound, 48 trips were monitored. If the GPS data are used to compute travel times between these two facilities, it can be seen that an "uncongested" trip took just over 80 minutes. Converted to average speed (and remembering that even in uncongested conditions, trucks still must stop at traffic signals, spend some time moving slowly at either end of the trip, and accelerate slowly), the fastest measured truck trip averaged just over 50 miles per hour from beginning to end. However a significant number of monitored trips took far longer than the 80-minute free flow travel time. Not surprisingly, the start time and direction of the trip played a significant role in determining the travel time required to make this trip.

Figure 21 compares the distribution of travel times against the start time of the trip for all monitored northbound trips between Fredrickson and Everett. This figure suggests why Boeing has adopted the practice of frequently shipping goods from Fredrickson to Everett very early in the morning.

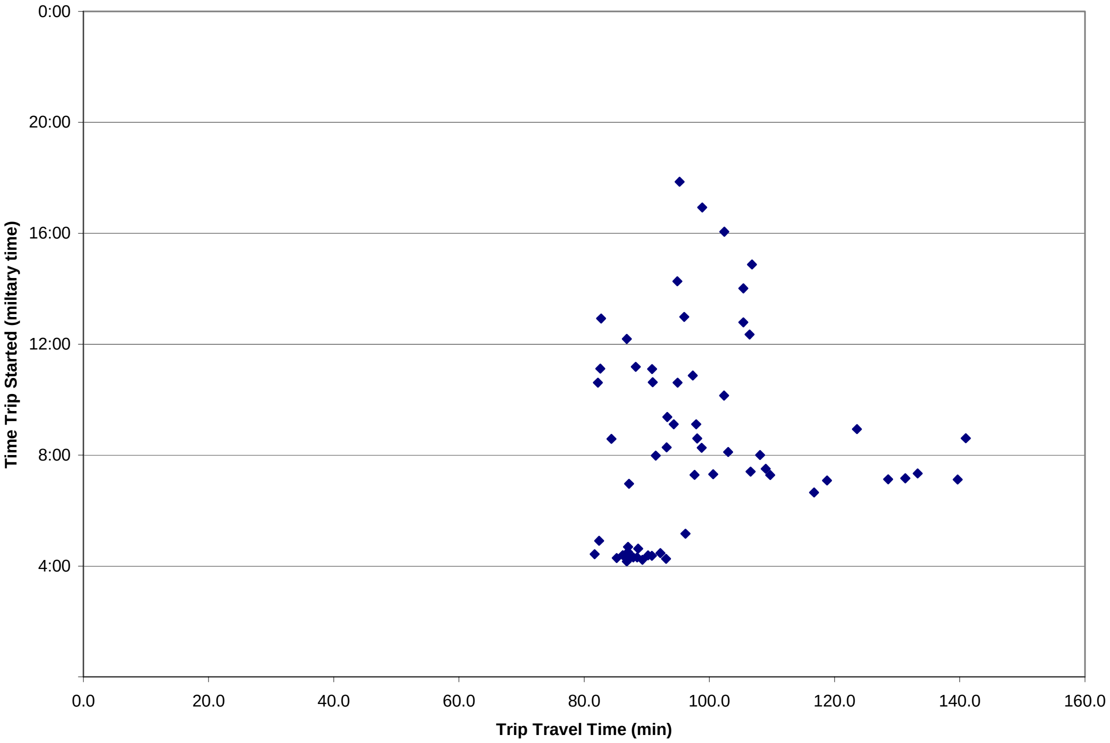

**Figure 21: Trip Travel Time versus Trip Start Time
Northbound Fredrickson – Everett**

As can be seen in Figure 21, a significant number of trips left Fredrickson just after 4:00 AM. This allowed them to pass through the SR 167 and I-405 corridors before the on-set of morning peak period congestion. Even the slowest of the trips that left near 4:00 AM completed the trip in just over 96 minutes. Monitored trips that left close to 7:00 or 8:00 AM took as much as 140 minutes and frequently took more than 110 minutes.

If data for all northbound trips are combined, they show that roughly 40 percent of northbound trips were completed within 10 minutes of "free flow" conditions. However, only 15 percent of peak period trips could be made within 10 minutes of the free flow travel time, while 55 percent of all other trips could be made within those travel time bounds.

Southbound travel between Everett to Fredrickson had additional variation not found in the northbound movements (see Figure 22). The two most obvious differences were the lack of very early morning trips (only one trip started before 7:00 AM) and the presence of long duration trips in both the AM and PM peak periods, with the slowest trips taking place during the afternoon commute.

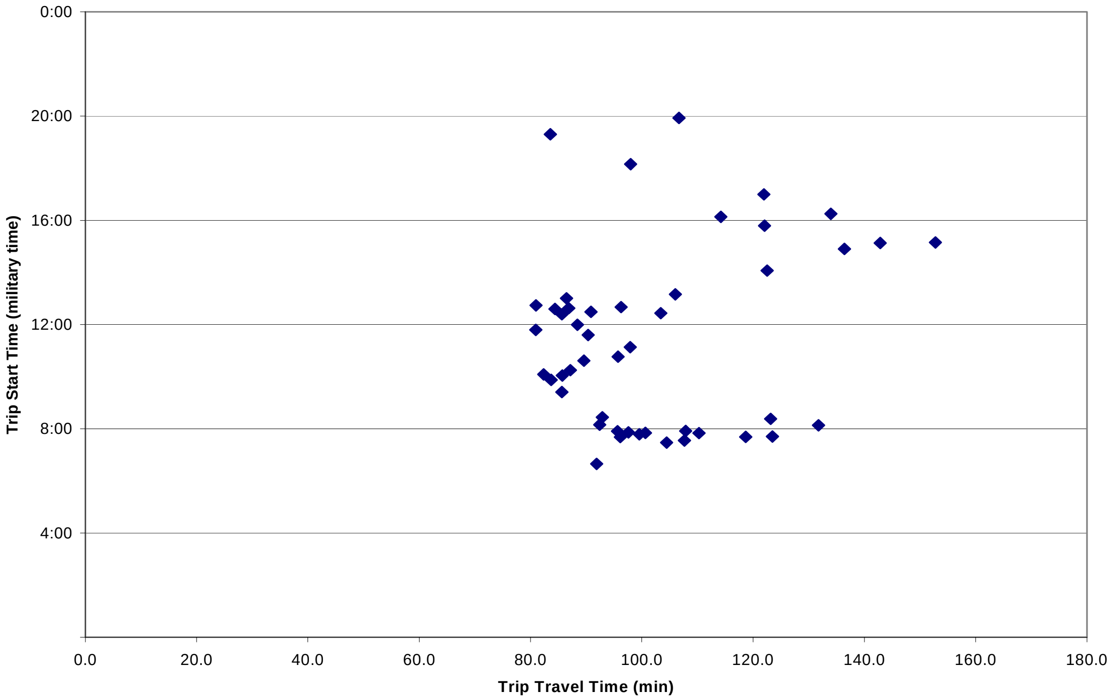

Figure 22: Trip Travel Time versus Trip Start Time
Southbound Everett – Fredrickson

In fact, only one southbound trip that started between 2:00 and 6:00 PM was completed in less than 114 minutes. While northbound traffic in the afternoon could be congested (experiencing trip times of over 100 minutes), the southbound traffic often experienced very heavy congestion in more than one location. As a result, travel times were frequently more than 50 percent of free flow travel times. Some semblance of travel time reliability did not re-occur until after 6:00 PM, when delays of 10 to 20 minutes could be expected. The time of day variability for travel times was not a surprise, since the southbound movements in the afternoon on both I-405 and SR 167 are among the most congested in the metropolitan region.

The collected GPS data can also be used to examine where delays occurred between Fredrickson and Everett. Figures 23 and 24 illustrate the routes taken by monitored Boeing trips. (Figure 23 illustrates the northbound trip, and Figure 24 shows the southbound trip.) In these figures, GPS data points are color coded to show the instrumented truck's speed at the time when the GPS data points were collected. Speeds above 45 mph are colored green. Speeds between 25 and 45 mph are yellow, while speeds below 25 mph are red.

The first thing that can be seen on Figure 23 is that two basic routes exist between Fredrickson and Everett. Both routes use Canyon Road to connect to SR 512. Going northbound, drivers can then turn west to reach I-5 and proceed north to the SR 526 exit to the Everett Boeing plant. The alternative is to turn east on SR 512, to where it joins SR 167, following that road to I-405, then I-5, and finally SR 526. While it is not obvious from Figure 23, only ten trips, all leaving between 7:00 and 9:10 AM, used the I-5 route. Figure 24 shows that no southbound trips used the I-5 route.

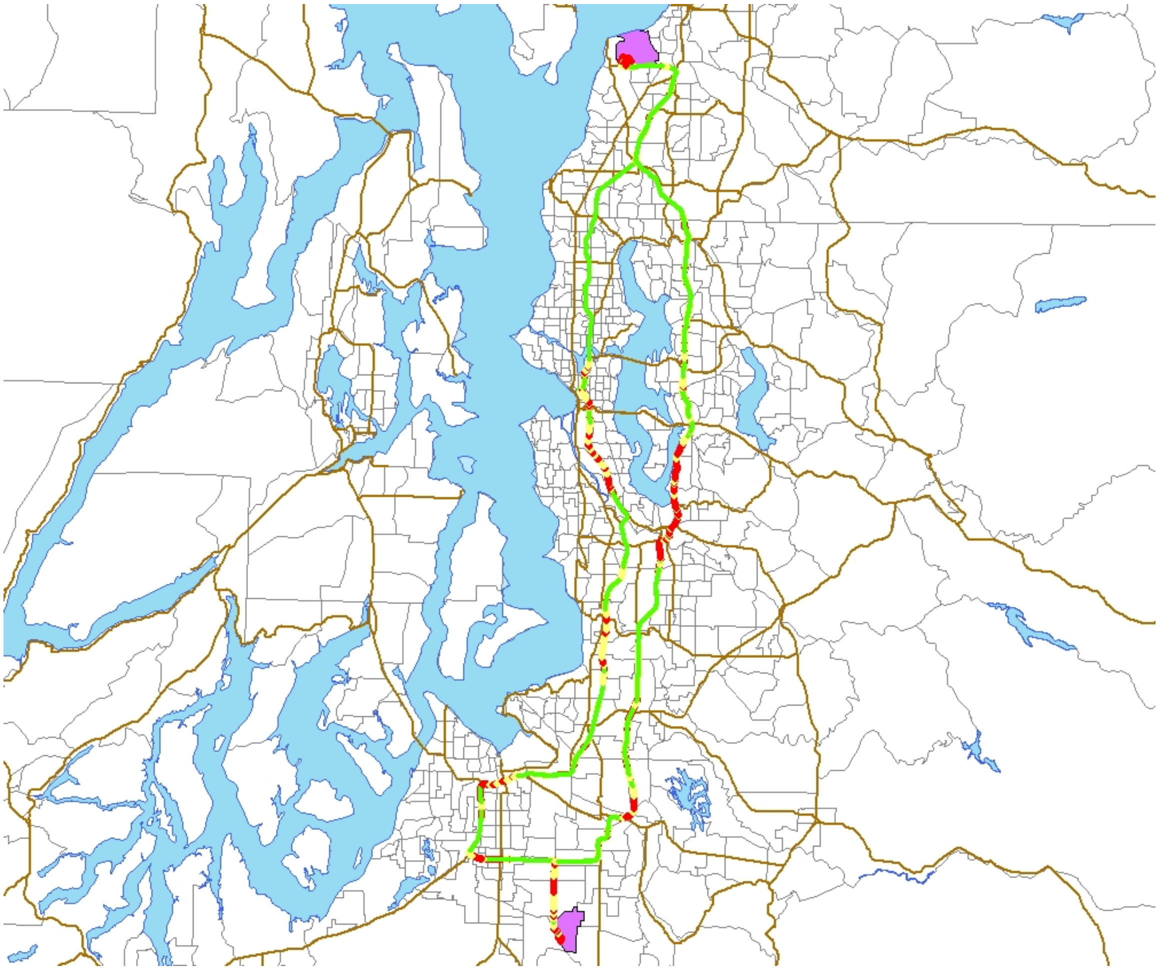

Figure 23: Locations of Delays Experienced between Fredrickson and Everett

The choice of I-5 over SR 167 and I-405 in the heart of the peak period is understandable. Northbound SR 167 and the southern half of I-405 are both renowned for their congestion, and Boeing staff related that they use radio communications with Boeing trucks, as well as other information sources, to identify congestion so that they can avoid it if possible. However, a quick review of WSDOT's historical freeway data archive indicated that congestion on SR 167 and I-405 was frequently no worse than normal on the ten days when I-5 was used, and on at least two occasions I-5 could easily have been the more congested of the two routes. This indicates that better congestion information might indeed improve the reliability of Boeing truck movements, even though the trucks already track congestion.

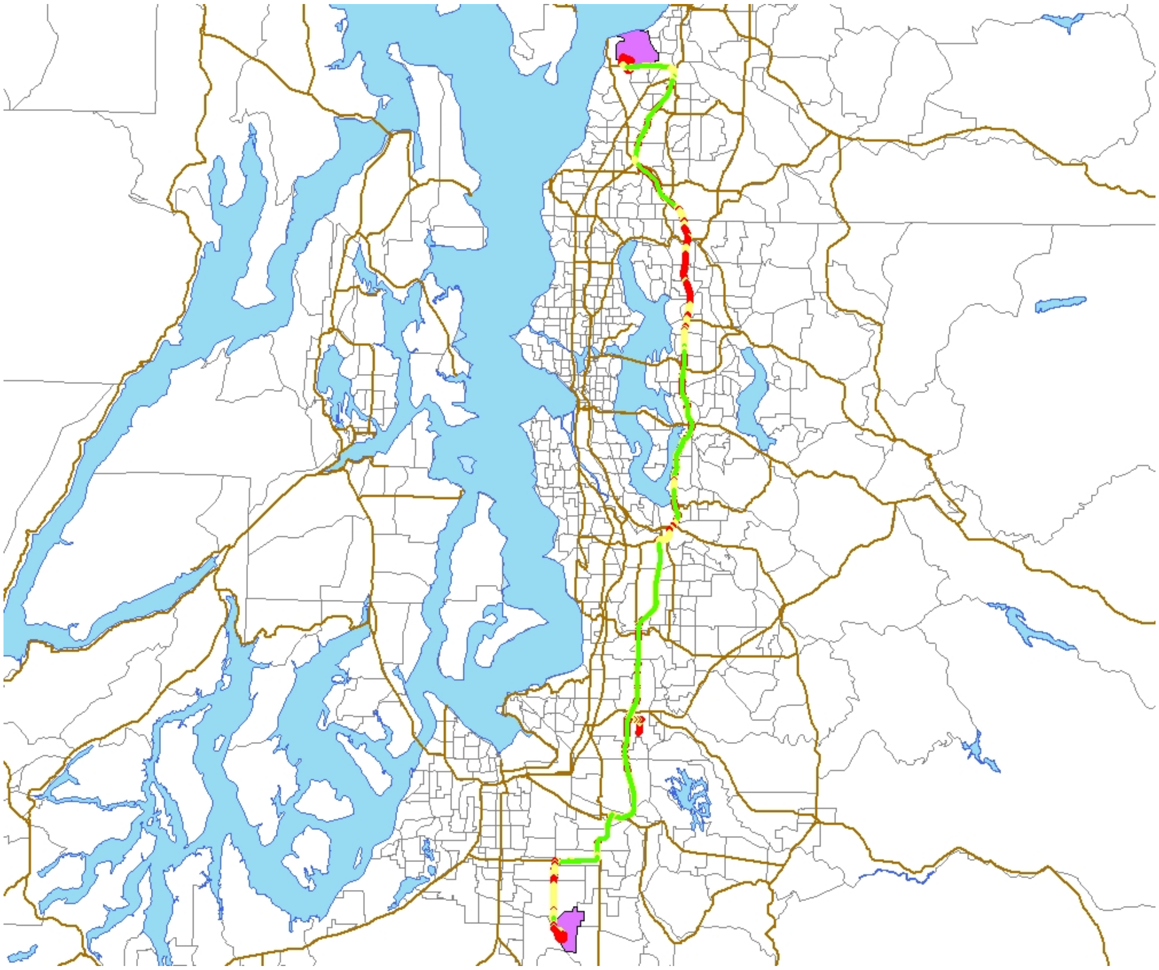

Figure 24: Locations of Delays Experienced between Everett and Fredrickson

The color-coded GPS data allow a quick determination of where during this trip delays took place. However, while these graphics serve as an excellent first cut at identifying the location of delays, these locations must be used with caution. For example, the several small "red" spots at the beginning and end of the trip are associated with the slow speed of trucks as they enter and drive through the facilities on either end of each trip. In addition, on Canyon Road in the far south end are several red spots; these correspond to the location of traffic signals and are not necessarily indications of congestion related delay.

On the freeway segments, red spots are generally indications of congestion, although at interchanges, red may simply mean that trucks had to slow while using the various ramps. ‘Slivers’ of ‘spots’ of red, such as on SR 167 in Figure 23, indicate a location mostly free of congestion but where congestion was experienced during a small number of trips.

Looking at Figure 23, congestion is apparent on northbound I-5

- through Tacoma
- near the Southcenter Hill
- just south of downtown Seattle.

On I-405, northbound congestion is commonly found between the SR 167 and I-90 interchanges. On SR 167, congestion is found near the SR 512 and I-405 interchanges.

The picture of southbound congestion given by the GPS devices (Figure 24) is very different. The most significant congestion point is on I-405 between the King/Snohomish county line and SR 900 (roughly downtown Kirkland).

If these data were to be used for regional roadway monitoring, the data underlying those roadway sections of interest could be extracted and analyzed by roadway segment, just as they were for the analysis of South 180th St.

However, before too much is read into the ability to monitor roadway performance from GPS data, the key caveat to the use of these data must be restated. The images and statistics obtained from the GPS devices describe the performance of roadways when monitored trucks are actually present on the roadway. Thus, data are not available when trucks are not present. This can create some important holes in the traffic monitoring data set, as can be seen in Table 10, which illustrates how the collected GPS data might be used to describe key monitored freight movements.

Table 10: Example Benchmark Report for Fredrickson – Everett Truck Movements

	Southbound			**Northbound**		
Time Period	**Mean Travel Time (min)**	**Standard Deviation (min)**	**Number of Trips Monitored**[17]	**Mean Travel Time (min)**	**Standard Deviation (min)**	**Number of Trips Monitored**[17]
Early AM	N.A.	N.A.	0	88.3	3.6	17
AM Peak	105.9	12.5	16	110.5	17.1	21
Midday	93.1	13.7	22	94.7	8.1	19
PM Peak	126.6	18.3	7	98.8	3.6	3
Late Night	95.1	16.3	2	N.A	N.A	0

Here, no data are present at all from southbound I-5 south of the Swamp Creek interchange with I-405. Similarly, the image of southbound congestion on I-405 is dominated by the large number of trips that occurred in the morning peak period and the late morning, when most of the monitored southbound trips took place. Only nine southbound trips (18 percent) took place during the evening peak period, and thus if only

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[17] Note that the limited number of trips during some time periods make it difficult to estimate statistics such as the 80th or 95th percentile travel time for these trips.

one image/statistic were produced for that facility (as is the case in Figure 24), afternoon facility performance would be significantly overshadowed by the large number of trips during less congested periods of the day.

I-5 Freight Performance

The last of the performance reports is intended to explore the potential for monitoring the reliability of truck traffic on Interstate 5. Ideally, the increasing use of CVISN tags by interstate trucking firms and the increasing number of Washington weight enforcement sites equipped with CVISN tag readers will provide a mechanism for monitoring the reliability of truck travel on all major interstate corridors in the state. This section describes the initial attempt to use CVISN tags for this purpose.

As noted earlier in this chapter, only two northbound sections of I-5 currently have a sufficient number of CVISN-equipped trucks and sufficient density of CVISN tags readers to allow this method to be used for analysis of truck travel time reliability computations on I-5. (Note that the GPS devices discussed above were placed on truck operating primarily in the Puget Sound region, and not enough GPS-equipped truck trips are available outside of the Puget Sound region for use in review of I-5 performance.)

Many of the details of these two trips were provided earlier in this report and will not be repeated here. Instead, this section will simply explore what an ongoing performance report might look like.

Table 11 illustrates what a performance reliability report based on the CVISN tag data might look like. This report highlights what the project team believes to be the key performance statistics: the “routine” travel speeds and measures that describe the reliability of the trip, the 80th and 95th percentile trip speeds. (These correspond to the slowest travel speeds that can be expected once per week and once per month.) The speed for the 95th percentile travel time could also be reported as a ratio of 95th percentile travel time to mean travel time. This statistic is commonly called the Buffer Time Index. (A Buffer Index of 1.5 means that it takes 50 percent more time to make a trip on the worst day of the month than it does at "normal" times.)

Table 11: Example Benchmark Summary of I-5 Performance

Roadway Segment	Time Period	Mean Speed	Median Speed	Stand Deviation of Speed	Speed For 80th Percentile Travel Time	Speed for 95th Percentile Travel Time
Fort Lewis to SeaTac	Early AM	57	62	13	49	35
	AM Peak	58	63	14	57	24
	Mid Day	58	63	14	56	20
	PM Peak	58	63	14	57	25
	Evening	58	63	14	53	22
Vancouver to Fort Lewis	Early AM	61	63	5	60	53
	AM Peak	61	63	6	61	56
	Mid Day	61	63	8	60	50
	PM Peak	60	63	10	60	39
	Evening	61	62	7	60	49

Statistics like those in Table 11 would be tracked over time to determine the extent to which changing levels of congestion were affecting trucking performance on this key road. Increases in mean and median speeds would indicate a change in routine travel conditions, while changes in the speeds associated with the 80th and 95th percentile travel time conditions would indicate changes in how reliable this trip was and whether traffic congestion was affecting the ability of companies to efficiently schedule their deployment of labor and equipment.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the findings of the various field tests conducted to collect truck performance information and relates those findings to the Freight Mobility Strategic Investment Board's needs to develop and maintain benchmarks on freight performance relative to projects it selects for funding.

CONCLUSIONS

Lessons Learned from the Field Tests

The results of the field tests described in earlier chapters of this report indicate that it is possible to use both GPS and CVISN truck tag technologies to collect the truck movement data required to provide detailed descriptions of changes in truck performance that result from freight mobility-oriented roadway improvements. However, successful use of these technologies will require considerable cooperation from the trucking firms and truck drivers that use the roads being improved. Without the ongoing cooperation of truck drivers and trucking firms, both technologies have considerable shortcomings that make their use problematic.

The cooperation required is simply that trucks using these facilities (both before and after the construction project) need to be outfitted with GPS (or CVISN) devices, and if GPS devices are used, data loggers[18] must be periodically replaced by trucking firm personnel and mailed back to the benchmark's analysis team. These tasks do not require a substantial investment of time, money, or staffing resources on the part of the trucking

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[18] The small electronic devices that store truck position data.

firms. However, they do require some effort, and this effort is difficult to sustain over long periods, as these tasks are not part of the routine duties of the trucking firm's personnel. As a result, they are easily ignored or forgotten by busy staff.

Unfortunately, the data collection process will not be successful if these tasks are not routinely carried out. A large proportion of the data problems experienced in the field tests were the direct result of declining rates of participation and lack of attention to these tasks by trucking company staff volunteered by their companies.

The first, and perhaps the most difficult, task in obtaining this cooperation and deploying these technologies is identifying and then recruiting the participation of trucks that routinely use a facility to be studied and that are willing to carry data collection devices. This task requires both knowledge of which trucking firms use the facility to be studied and the trust of those firms so that they can be convinced to participate in the data collection effort.

Identifying good candidate firms/trucks will be less of a problem for isolated facilities served by a limited number of trucking firms (e.g., projects that lead directly to specific industrial facilities or intermodal terminals served by a limited number of firms) than for projects in the middle of metropolitan areas that serve a variety of trucking uses and users. For truck-oriented roadway projects in metropolitan regions that serve diverse trucking interests, data collection may be more effectively performed as part of a regional effort than on a project basis. For more isolated projects, data collection will probably be more effectively performed on a project by project basis.

A key in gaining cooperation will be for trucking firms to understand the benefits they will gain in return for their cooperation. For isolated improvements that directly benefit a select set of users, the benefits tend to be far more obvious. (This is especially true if data collection is a requirement of project construction. If this is the case, WSDOT would be in the position of stating to the firms that directly stood to benefit from an improvement, "You won't get this improvement if you don't participate in proving its ultimate value.")

Once trucking firms that use a project facility have been identified, a necessary step to convincing them to participate will be answers to concerns those firms have about the application of the collected data. TRAC's experience suggests that both drivers and companies are likely to have data usage concerns.

Several drivers in the field test expressed concerns about invasion of privacy during the field test. This issue led to one trucking firm pulling out of the field test for this project after one month of participation. It is quite likely that privacy will be an issue on more than one occasion if GPS devices are used routinely for data collection.

Trucking firms are also likely to be concerned that allowing the collection of detailed truck performance information is not in their business interest. Their concerns are likely to range from potential liability problems (Was their GPS-equipped truck speeding the day it had an accident?) to employee relations (see the privacy issue above), to the potential loss of competitive advantage (many firms are extremely reluctant to share data that might be used in some way to provide their competitors with a business advantage).

While many actions can be taken to address the legitimate concerns of potential participants, these actions require additional administrative effort on the part of the data collection and analysis team. When added to the staffing effort required to recruit and retain trucking firms, drivers, and trucks, it is quite possible that more effort is required to administer the data collection program than is required to actually collect and analyze the data needed for analyses. However, the administrative tasks are key to maintaining the data collection process, and without it a sample of truck movements large enough to meet benchmarking needs is unlikely to be collected.

Applicability of Data Collection Techniques

As noted above, the key to both tested data collection technologies is that enough instrumented vehicles pass over the roadways for which data are required. This basic condition has a significant impact on whether the CVISN and GPS technologies are applicable for collecting the data required for any given benchmarking project.

The CVISN tag travel time system works and is inexpensive for those road segments instrumented as part of WSDOT's CVISN program. However, the current reader deployment for this program was not designed with the computation of travel time. The result is that the distances between readers is too long, and the travel times computed for those distance, while accurate, are often poor estimates of roadway performance, as they include various voluntary stops.

Therefore, WSDOT should only count on using the CVISN technology on roads on which a large number of CVISN tag equipped trucks are already operating, where the distances involved are modest (less than 25 miles), and where a significant percentage of trucks are expected to pass between readers without stopping. This combination of factors means that CVISN tags are probably only appropriately used on Interstate facilities, where the portable readers can be deployed.[19]

The GPS devices have the advantage of being able to monitor the actual route taken by instrumented vehicles. This makes the GPS data set far more robust than the CVISN tag data. The major problem with GPS is the small number of instrumented vehicles that actively collect data accessible to a benchmarking program.

While 15, 000 to 20,000 CVISN tag equipped trucks pass weigh stations on I-5 and I-90 each month (roughly 500 to 650 each day), only 25 GPS-equipped trucks existed in the entire field test. Thus, the key to use of GPS data collection is to be able to instrument trucks that routinely use the study facility. For example, instrumenting a truck performing drayage activities would be an excellent way to collect data on arterials leading between a port and railhead served by that drayage company, as a single truck would make multiple trips each day over the roadway being monitored. Conversely, having that same drayage company volunteer to carry a GPS device would have almost no value if the roadway being studied was in a warehouse district on the other side of the metropolitan region.

The largest failure of the GPS field test was the lack of data collected on the arterials. A significant part of this failure was caused by the fact that trucks participating in the test simply did not use the roads being studied. Their business activities took them to other parts of the region. Therefore, if trucks routinely operating over the subject arterials can not be identified and instrumented, this is not a technique that should be adopted by WSDOT.

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[19] The planned test of the travel time system on I-5 and I-205 in Vancouver, Washington, should confirm this conclusion.

Cost of Travel Time Data Collection

The cost of data collection with either of the two tested techniques is a function of the size of the data collection effort. For CVISN tags, if the two existing FMSIB semi-portable readers are used along with two semi-portable readers maintained by the WSDOT CVISN office, a two-directional data collection system could be set up for roughly \$10,000 to \$15,000, assuming that appropriate structures exist on which to hang the readers and that CVISN tags are already being carried by trucks using that roadway. (This cost may be reduced by half as inexpensive portable CVISN readers become available.) If additional readers are needed and power poles and/or sign bridges do not already exist, the same system would cost around \$80,000.

GPS data collection has the same broad range of costs. As a result of this field test, WSDOT has GPS devices and data loggers to instrument 25 trucks. For aproject test involving a single, isolated roadway, these devices could be placed on volunteer trucks at relatively little expense. The costs experienced would involve the administration of the tags and analysis of the GPS data.

For simple, isolated roadway improvement projects, the cost of administering the project can be assumed to be around two staff hours per month per GPS device. Analysis of the data itself is dependent on the complexity of the project and whether refinements to the current analytical system are funded within the project, as part of other WSDOT work, or not funded at all.

For projects that involve more complex changes in trucking performance (i.e., major changes in routing, or a wide variety of trip making behaviors such as grade separation projects in the middle of major urban areas), GPS data collection allows the collection of the comprehensive trucking performance data needed to compute reliable performance measures. However, such a program needs to be considerably larger than the field test performed as part of this study. At an absolute minimum, between 150 and 200 GPS devices need to be in active use in the three-county (Pierce, King, Snohomish) metropolitan region, and these devices need to be far more effectively distributed around the region than was possible within this field test. Management of those devices needs to be more effective to ensure that these devices are actively used and report travel data. Lastly, the software currently used to store, analyze, and report on the GPS data needs to be improved and refined to streamline the analysis of the GPS data.

This urban area-wide GPS based monitoring program will require an estimated $150,000 to $200,000 in one-time expenses, and then continuing costs of around $150,000 per year. The output will be statistics on the travel times and delays experienced by trucks on the vast majority of major roads used for truck freight movements in the three-county region. The program's success will depend on the active participation of between 30 and 50 trucking firms located in different parts of the region.

RECOMMENDATIONS

As noted above, the mobility benchmark program will collect two basic pieces of information both before and after truck-oriented roadway improvements are made. These two basic statistics are

- truck volumes
- truck travel times on defined roadway segments.

Where the roadway improvement is likely to significantly affect route selection, information on total trip reliability (origin to destination travel times and routes) should be collected. Sufficient data need to be collected to describe the reliability of the truck trips made over the improved roadway.

Travel Time Program Data Collection Recommendations

The project team recommends two very different approaches to data collection to meet the mobility benchmark reporting recommendations described above. The first set of recommendations applies to projects where the roadway improvement occurs on a reasonably isolated roadway and is unlikely to cause changes in route choice behavior in the trucking community (Isolated Improvements). The second recommendation is for projects that occur in denser roadway networks and are likely to cause significant changes in truck route choice behavior (Dense Network Improvements). Both the S. 180th St and Royal Brougham improvements described in this report are examples of this type of project.

Data collection in both isolated locations and dense networks will benefit greatly from the cooperation of trucking firms that routinely operate over the roadway segments that will be improved. In fact, for dense network improvements successful data collection may be possible only with such cooperation. Gaining participation of the firms that use the facilities to be improved needs to be led by WSDOT or the FMSIB. The project team suggests that a prerequisite for obtaining support for a road project should be the willingness of companies that request that support to participate in the data collection needed to measure the benefits obtained from that improvement.

For isolated improvements the project team recommends that either of two data collection procedures be used. If a relatively limited number of trucks use the facility, placing GPS devices on those trucks will provide excellent measures of changes in the size and location of delays that result from the roadway improvement. Data collection should start at least six months before initial construction of the project. It should also be performed for at least six months after the completion of the roadway improvement.

Enough GPS devices should be distributed to trucks operating on the roadway improvement so that roughly one truck per day per reporting time period can be expected to use the facility. (For example, if the road connects a port to an off-site inter-modal terminal for drayage activity, this might be accomplished with one GPS device placed on a truck that makes this trip several times each day. For other facilities, reporting might require considerably more devices.)

Where the trucking population that uses the subject facility is very diverse and not easily outfitted with GPS devices (for example, the road improvement leads to a factory served only by long distance trucks), it will be necessary to perform a more conventional travel time study. If a significant percentage of trucks using that road consists of long distance haulers that belong to the CVISN program, the travel time data can be collected by using the semi-portable CVISN readers owned by WSDOT's CVISN program and the FMSIB or by purchasing newer technology portable readers. Readers should be placed on either side of the improved section to capture truck movements in both directions.

If CVISN use is not practical (or few CVISN tag-equipped trucks use the facility), drivers will have to be hired for floating car studies. Passenger cars can be used by these drivers to perform the study, but rather than driving at the average speed of traffic, they should follow trucks using the facility to measure the performance of those trucks. If truck trip reliability is one of the expected improvements of the project, floating car runs will have to be performed on enough days both before and after the improvement has been completed to measure changes in reliability. A minimum of 30 floating car runs should be made during each time period both before and after the improvement has been completed. Ideally, these runs would be spread over ten or more days to ensure an adequate measurement of the day-to-day variability found in this trip.

For improvements made in the middle of dense networks, floating car runs may not provide a complete understanding of the truck travel time savings that result from the improvement. The diversity of trucks using such an improvement may make it impossible to select a cost-effective set of trucks that can be instrumented with GPS devices to collect performance information on such a segment. Consequently, if performance measures are needed for such projects WSDOT should develop and implement an ongoing, region-wide truck performance data collection project. Specific attention would be paid to trucking firms that operate trucks over the roadway improvements of interest. (Note that WSDOT might recruit new truck firm participants specifically to bolster the number of trucks trips made over WSDOT-sponsored projects.) WSDOT would also be expected to request analysis output from that more general data collection and analysis process to meet its own project benchmark needs.

In addition to providing the data needed for WSDOT's benchmark efforts, the creation of a region-wide monitoring program would have the additional benefit of providing the performance information WSDOT needs for project prioritization. This same data set would be highly valued for its use in general WSDOT and regional planning needs.

Truck Volume Program Data Collection Recommendations

For both types of projects, it is necessary to collect truck volume information. For those projects with free flowing traffic leading up to or away from the improvement, truck counts can be made with automatic vehicle classification counters routinely used by WSDOT. Automated counts should last at least three days and provide truck volume information by hour.

Where truck traffic approaching and departing the road section containing the roadway improvement does not travel at a constant speed because of congestion and/or traffic signals, it is currently necessary to perform manual truck counts. As with data collected with automated counters, manual count data should cover at least three days and all time periods when a significant number of trucks actively use the roadway being improved. (Note: if little truck traffic uses the facility during night time hours, it is not necessary to manually count during those periods.)

Benchmark Reporting

Using the data collected with the systems described above, the following statistics should be used as freight mobility benchmarks:

- 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.

Where significant changes in route selection have occurred as a result of the improvement, these changes should also be reported. Combined with the above statistics, these data should provide a reasonably complete description of the changes in truck freight mobility that result from roadway projects. These statistics can also be used determine the economic impacts of these changes in freight mobility.

Finally, the TRAC-UW project team recommends that both volume and travel time data be reported for at least four summary time periods: morning peak period, midday, evening peak period, and night time. The actual definition of these time periods may be changed to reflect the unique traffic conditions of each FMSIB project. The definition of each period should be explicitly stated as part of the benchmark report. Additional time periods may also be necessary if significant differences in truck volumes and/or roadway delays occur during those periods.