PORTLAND STATE UNIVERSITY
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
CENTER FOR TRANSPORTATION STUDIES

Techniques for Mining Truck Data to Improve Freight Operations and Planning

Robert L. Bertini
Zachary Horowitz
Kristin Tufte
Spicer Matthews

Sponsored by

OREGON DEPARTMENT OF TRANSPORTATION
TRANSPORTATION NORTHWEST (TransNow)

In cooperation with

U.S. Department of Transportation
Federal Highway Administration

Research Report

May 2006

TABLE OF CONTENTS

DISCLAIMER

LIST OF FIGURES

ACKNOWLEDGEMENTS

The authors thank the U.S. Department of Transportation and Transportation Northwest (TransNow) for providing funding for this project. In addition, the Portland State University Department of Civil & Environmental Engineering provided financial support for the work described here. Chansung Kim and Tarek Abou El-Seoud attempted early work on this project. The authors would particularly like to acknowledge the Oregon Department of Transportation for providing access to the video and sensor data that were critical to this project. Professor Yinhai Wang of the University of Washington also generously assisted the research team in the implementation of the long vehicle algorithm.

ABSTRACT

Freight plays an increasingly valuable role in the national economy, and a growing percentage of freight – measured by both total volume and market value - is being moved along the highway system by truck. An important part of the research process to fully understand the impacts of these increased truck volumes on the entire transportation network is by collecting and analyzing freight data. With the adoption of just-in-time supply chain management solutions, and increasing congestion on urban, rural and intercity motorways, better knowledge of freight movements can serve to improve highway operations. The real-time data generated by the development of travel time algorithms can be provided to commercial vehicle operators to enable them to minimize the delay associated with goods movement, and assist in streamlining the logistics planning process. Increased knowledge of truck travel patterns has the potential to increase overall highway safety, lead to better-managed maintenance operations, provide cost savings to public agencies, validate investments in intelligent transportation systems (ITS), and improve long-range planning and forecasting. Like other aspects of traffic engineering, efforts that result in higher quality data and improved collection methodologies generally lead to increased knowledge of the transportation system. This paper explores techniques that use current ITS technologies such as the Autoscope video processing system and loop detector data algorithms to collect and verify short and long vehicle count and length data. Three sets of traffic data for each time interval are created, and then compared using statistical analyses to produce results that that reveal new information about the freight transportation system in the Portland metropolitan region.

EXECUTIVE SUMMARY

Introduction

The growing volume of freight that is increasingly moved by trucks on the nation's transportation network make it more important than ever to develop a better understanding of the freight system's overall operational characteristics. This project attempts to establish a base level of knowledge regarding the characteristics of the movement of freight in the Portland region through the analysis of long vehicle volumes and speeds. A body of knowledge about the technical aspects of freight data collection has been established through experimentation with ITS subsystems such as CCTV networks, video image processing technologies, inductive loop detectors, traffic data storage networks, and data processing algorithms.

Research Objectives

This project has several objectives. First, the ability of researchers and public agencies to collect freight data using the existing ODOT CCTV camera network was tested. This was accomplished by coordinating camera positioning with the ODOT traffic management operation center and the successful connection of the fiber optic data feed to the Intelligent Transportation Systems (ITS) Laboratory at Portland State University. Second, it was demonstrated that traffic recorded on DVD-Rs could be processed with the Autoscope RackVision hardware unit and accompanying software, and done in such a way that a methodology was established that can be used for future data collection experiments. Third, the robustness of the Nihan-Wang algorithm was established for data collected in the Portland metropolitan region.

Project Benefits

The benefits of the project are as follows: it is possible to use the existing ODOT CCTV surveillance network to collect freight data in the Portland metropolitan region. The Nihan-Wang algorithm can be used to derive volume data for short and long vehicles using ODOT's existing loop detector infrastructure and the PORTAL data archive at Portland State University. The ITS lab at PSU now has the proper equipment, communication connections, hardware setup, software configuration and technical know-how to conduct future experiments with freight data. Over 45 hours of traffic video data has been archived, processed and can be used for future research projects, transportation coursework or further instructional use such as training for students, faculty and members of public agencies or private firms. The viability of video image processing using Portland data has been tested thoroughly and the results can be applied when considering or evaluating future applications for either research or practical use. Several students have been exposed to the technical, practical and theoretical aspects of current intelligent transportation system technologies, research project methodologies, modern traffic engineering practices and have gained knowledge in the fields of computer systems, report writing, statistical data analysis. In summary, the project has provided multiple stakeholders with verified data, technical knowledge, and learning opportunities. The project has also helped to raise additional research questions, has created room for future exploration in the field, and created additional partnerships with local agencies.

Study Areas

Four study areas were chosen for this project. They are:

- I-5 SB at Marine Drive in North Portland, OR
- I-84 WB at Sandy Blvd/37th Ave in Southeast Portland, OR
- I-5 NB at Lower Boones Ferry Road in Tualatin, OR
- OR-217 at SW Hall Blvd. in Tigard, OR

It was important to select locations that had high volumes of truck traffic, and were able to be recorded by ODOT's CCTV network in a manner that allowed the recorded video to be processed using the Autoscope RackVision and accompanying software package. Furthermore, it was necessary that the CCTV camera could be positioned in such a manner that enabled the field of vision to include the location of the inductive loop detectors that are located in each highway lane. The data fidelity of each loop detector was an important consideration in site selection, since high quality data was needed as an input into the Nihan-Wang algorithm. This was necessary so that the robustness of vehicle classification estimations produced by the algorithm could be adequately tested versus ground truth data.

The land use patterns near each location contribute to the high percentage of trucks observed at the study locations. The Marine Drive site is located near a large area of industrial-zoned land in the northern quadrant of Portland. There are many large warehousing and distribution facilities located in that section of the city, which produce a large number of truck trips. The site is also in close proximity to several Port of Portland marine terminals, and much of the traffic generated and attracted to this area travels past the Marine Drive interchange on I-5. Finally, this location serves interstate trucking routes that run through the states of Oregon, Washington and California. Similarly, the I-5 interchange at Lower Boones Ferry Road carries high volumes of truck traffic from the regions located south of Portland, and I-84 carries traffic entering Portland from the east. The location at SW Hall Blvd along Oregon-217 is along a prime freight route that connects the cities of Tigard, Tualatin, Lake Oswego and Beaverton. The OR-217 corridor serves dozens of large big-box retailers, warehouses and the Portland metropolitan region's largest shopping mall complex, Washington Square. OR-217 also is located in the fastest growing area of the metropolitan area, is congested for large parts of the day, and is currently being studied for lane expansion and other capacity improvements.

Data Analysis

The inductive loop detector recorded on highways in the Portland metropolitan region is stored in Portland State University' archived traffic database, the Portland Region Transportation Archival Listing, or PORTAL. The detectors in the freeway system are configured as dual-loop speed traps, but they are currently functioning as single loops. The detectors record volume and occupancy data aggregated at 20-second intervals. This current configuration does not allow direct measurement of speed or vehicle lengths. This paper explores the vehicle classification algorithm developed by Wang and Nihan at the University of Washington and compares it against ground truth data, and data created using video image processing. The results of these comparisons can be seen in the data summary table, Table 3. For each of the three data sets for a given period of observation, a series of eight plots were made to provide a graphical representation of the volume and speed data. Two types of graphs were made, the first showing the comparison between measured volumes for each data collection method, and the second type using a volume scaling factor to create an oblique plot which shows volume differences between the measured volume and the scaling factor.

In order to demonstrate some of the relationships between the differences found during the study, a number of graphical illustrations have been completed. These include comparing ground truth data versus the three count mechanisms, ground truth versus truck volumes, percent differences between count mechanisms, measured flow histograms, flow as related to total and percent count errors, and relationships between speed measurements and count errors. Finally, the possible sources of errors are identified, and specific issues in using the Wang-Nihan algorithm are presented.

Findings

It is shown that the Autoscope is an effective tool for determining truck and passenger vehicle volume counts. In addition, it can produce good estimates of individual vehicle speeds. This experiment has shown that the Autoscope, when used under the available CCTV camera conditions (the various positions, locations and heights of highway cameras located around the Portland region) in the Portland region does not produce accurate measurements of vehicle length. It is noted that while vehicle lengths are overall incorrect, in many circumstances a histogram of all vehicle lengths measured during a time period conforms closely to a generalized histograms made based on manual observations of vehicle lengths. It is possible to use such histograms in a way that makes it worthwhile to estimate long and short vehicle volumes with the Autoscope video processing system.

The Wang-Nihan algorithm results are less clear. In certain situations, the algorithm does a good job of predicting long vehicle volumes. In others, the algorithm over or underestimates truck volumes. The analysis of the estimation error patterns is inconclusive – there are inconsistencies during period of heavy traffic and light traffic, both when the volume of trucks is low, and when trucks constitute a larger percentage of the traffic stream. Sources of error may lie in the choice of study locations when they correspond to areas with poor detector performance. Further research needs to be undertaken in order to understand where the errors are coming from and if it is possible to tweak detector performance to result in more accurate truck counts.

Conclusions

It is shown that there is a current need for collecting freight data. One method for doing so is by using the existing ITS infrastructure readily available in metropolitan regions around the country – inductive loop detectors, surveillance cameras, data processing algorithms and software programs, communication networks and data archiving and retrieval technologies. These technologies can produce favorable results – good, useable data – when care is taken to design data collection experiments and implement methodologies that produce verifiable data. Coordination and cooperation between researchers, state and local DOTs, and other stakeholders helps to speed the data collection process and to enable worthwhile data to be collected. Overall, the technologies used in this experiment show some promise in terms of their long-range abilities to produce freight data in an automated way.

1.0 INTRODUCTION

It is seen that congestion on the overall highway network is negatively impacting the efficient and effective freight movement, and that this is having a deleterious effect on our national and regional economies. Despite investments in intelligent transportation systems (ITS) in many regions, we still do not have a comprehensive understanding of how our freight transportation system operates. This is complicated by the presence of many private operators with complex needs traveling on publicly operated highways with a complex permitting and regulatory environment. There is a heightened need to improve our knowledge of freight flows in order to improve the overall transportation system, the freight component in particular, and to respond to new and emerging security concerns. The objective of this project was to build upon past and ongoing research in the area of identifying techniques for collecting freight transportation data by designing two specific data collection experiments using an existing ITS infrastructure and equipment. The objective was be met by carefully reviewing the literature, developing unique and comprehensive data sampling strategies, working with regional transportation agency partners to clearly define their data needs, and implementing a data collection experiment to demonstrate the capabilities of two existing ITS surveillance system for freight data collection. The results of the experiment are documented here and results are being disseminated via project reports, website outreach and presentation of results at regional and national conferences.

1.1 Problem Statement

The efficient, safe and secure movement of goods through the transportation network is critical for our economy and quality of life. As freight transportation has evolved, trucks have become the dominant mode of transport. Trucks travel with passenger transport vehicles and they impact and are impacted by traffic congestion, incidents and highway safety. Of the Portland area's highway mileage on the State Highway Freight System, about 60 percent is congested according to mobility standards in the 1999 Oregon Highway Plan (Oregon Department of Transportation, *Freight Moves the Oregon Economy*, 1999). Recognizing the impact of this congestion and understanding truck travel patterns and trends is critical for planning, designing and operating our transportation system in an integrated manner. In order to remain competitive, departments of transportation, port authorities and private transportation firms must begin to work together to understand how truck travel patterns impact other users of the system. Despite the investment in major traffic surveillance systems, there are very little detailed, continuous data available describing truck travel movements.

Currently, freight planners rely on simple truck counts collected manually at a very small number of locations at very infrequent intervals. Even for this relatively limited data quality and quantity, high costs are involved. The Oregon Department of Transportation (ODOT) has limited information on truck trips, their origins and estimations, routes traveled and commodities carried. Traffic count data are inadequate for understanding truck freight movements and little is known about truck trip chaining and the use of distribution centers. Planners really need more than just counts—they need origin-destination flows, commodity details, and the proportion of empties, among other details. The rationale behind this project is to examine the automation of truck count procedures in the Portland metropolitan area so that the scarce resources that are currently applied to truck counting can be applied to the more important work behind obtaining detailed truck flow data on a continuing basis. Casavant and Jessup at Washington State University are completing a study *Methods to Collect and Analyze Truck Trip Information* that will provide a basis for moving beyond our reliance on solely truck counts. The truck count automation attempted in this project could be robust enough to rely upon for studying trends due to changes in season, weather and longitudinally across many years.

Recent trends in transportation planning have changed our way of coping with increased traffic demands from building new capacity to improved operation of our current highway facilities. Effective management of these facilities for freight movement requires reliable data on their use by trucks. In order to develop a greater understanding of truck travel patterns, this project explores a unique opportunity to leverage existing surveillance investments through a marginal investment in additional truck surveillance features. The 485 inductive freeway loop detectors in the Portland Metropolitan area installed as part of the overall advanced traffic management system provide vehicle count, speed and loop occupancy every 20-seconds. The loop detectors, roadside controllers and communications system that operate the ramp metering system are also capable of providing vehicle classification information in each lane, every 20 seconds. However, the "firmware" that is installed in the controllers is not currently set to activate the classification feature. Further, the 60 freeway closed circuit television cameras provide a rich set of views into the freeway traffic flow. Using a video image processor (Autoscope's Rackvision, already acquired as part of the PSU Intelligent Transportation Systems Laboratory), multiple segments of video can be archived simultaneously and post-processed to provide counts and classifications (e.g., truck counts). This project has designed a sampling plan for the Portland area and has selected a number of locations for activating the loop detector vehicle classification feature and for using the video processing system. A careful process was used for selecting key locations for providing continuous truck counts to ensure that counts would be available on key highway routes.

As an example, Interstate 5 was a key route, as was Interstate 84. The project has attempted to include development of robust methods for analyzing the truck count data and also for making relevant data available to stakeholders such as ODOT, Metro and the Port of Portland. The truck counts collected have been validated using video surveillance and an image processing system that was already in place. These new data sources have enhanced and could potentially replace other data collection programs that are limited by cost to small samples of truck counts at a small number of locations over very limited time periods. This could allow for developing a long term understanding of truck movements, seasonal effects, time of day effects, and changes over time.

This research has uses the existing ODOT Region 1 CCTV network currently available at Portland State University and a software interface to test and expand the capability of video imaging to capture and classify truck movements. Earlier use of this technology provided the percent trucks on a facility (measured at a point in space), but no further refinement research was done. The video imaging software outputs have been compared with the actual retained video for validation purposes. Technical issues addressed have included coordination with Region 1 camera mobility requirements, a determination through experimentation of matching trucks at multiple locations and coordination with Port of Portland

1.2 Project Objectives

The objective of this project is to build upon past and ongoing research in the area of identifying techniques for collecting freight transportation data by designing two specific data collection experiments using an existing ITS infrastructure and equipment. The objective has beenff met by carefully reviewing the literature, developing unique and comprehensive data sampling strategies, working with regional transportation agency partners to clearly define their data needs, and implementing a data collection experiment to demonstrate the capabilities of two existing ITS surveillance system for freight data collection.

1.3 Background

This project builds on previous and on-going work in the Portland region. First, a recently completed project funded by TransNow, the Oregon Department of Transportation (ODOT) and Portland State University has investigated and used the freeway surveillance infrastructure to assess the ramp metering and incident response programs in the Portland metropolitan area. These projects have included components for validation of the loop detector data for use in counting collections of vehicles and estimating their speeds. Also, ODOT has recently completing an SPR project entitled, "Methods to Collect & Analyze Truck Trip Information," which analyzed the effectiveness of transportation projects or polices on freight movements to help ODOT understand freight movements, characteristics and needed infrastructure. The methodologies, data and truck generation, distribution and routing relationships will be able to be quantified and to be incorporated into metropolitan models and the statewide transportation model. This project has attempted to advance the possibility of obtaining vehicle count and classification data in the Portland metropolitan area, and has thus benefited from and has been performed in coordination with these past projects. Finally, a project funded by the National Science Foundation has been mining the freeway and arterial surveillance systems in Portland toward improving the ways in which we monitor, model and evaluate transportation plans and improvements. The extension of those efforts to specifically address vehicle classification and freight movements has been very appropriate.

1.4 Expected Project Benefits

With limited investment, taking advantage of past investments in freeway surveillance, this project has sought to achieve a greater understanding of truck movement in the Portland area. Establishing the volumes and type of trucks on the highway network with temporal and spatial dimensions can help planners understand through-trip and local trip truck trends. In addition, the continuous nature of the data could allow for validation of simulation models, such as TRANSIMS, and other truck models currently being applied in the Portland metro area and in the state of Oregon. By developing a program for systematically sampling truck types and flows over time and space, a robust definition of truck travel can be determined. The results of this research could be used to capture and archive truck activity to better understand movements by time of day, season, direction, vehicle type, etc., and to track these trends over time. It is hoped that this will contribute toward the planning, design and operation of the freight transportation system in the state. Further, as Oregon moves to eliminate its Automatic Traffic Recorders (ATRs), the data processing system developed in this study could replace and augment the valuable vehicle classification data provided by the ATR system. Through technology transfer, it is hoped that practitioners will gain a better understanding of the impact of truck flows on the overall safety, efficiency and security of the transportation network. Also, students have gained hands-on experience working with truck flow data in the PSU Intelligent Transportation Systems laboratory, which should help them in their careers and increase the visibility for freight-related research to the many visitors to the laboratory and its web site.

1.5 Organization of the Report

Following this introduction, this report includes a brief literature review that focuses on past empirical research aimed at improving the truck data collection possibilities from automated intelligent transportation systems (ITS) infrastructure. The next chapter contains a detailed description of the data sources used in this research, including a discussion of the steps used to select the data collection sites, the use of archived ITS data from the PORTAL system, the manual data collection, image processing using streaming surveillance video and the data formatting and processing in preparation for analysis. The next chapter describes the analysis of the empirical truck count/classification data as well as the graphical representations used to aid in this analysis. The final chapter of the report provides some conclusions and recommends directions for future research.

2.0 LITERATURE REVIEW

Detecting and counting long vehicles on the freeway system requires a number of technical and statistical tools that are implemented in conjunction with standard statistical sampling methodologies. A literature review was completed to better understand the existing knowledge base about the technologies used to complete this task. It was important to understand several different aspects of the data collection experiment, primarily the underlying technologies involved, such as the operation and data archiving components of inductive loop detectors, and the procedures for extracting virtual loop detector data from recorded traffic streams using video image processing. Next, a series of papers describing algorithms for estimating truck volumes using the volume and occupancy data produced by single-loop detectors were studied to provide the comparison set of data. Primarily, the algorithm developed by Wang and Nihan (8) is tested using data from the Portland metropolitan area. Lastly, the literature describing various truck data collection concepts that was had information on the various statistical techniques used to collect and analyze data including sample sizes, site selection, days and times used for data collection and other common variables considered during the experimental design process.

An algorithm has been developed based on volume and occupancy data from single loop measurements to estimate the volume of long and short vehicles in a given time period. Short vehicles are classified as being less than 39 feet in length, long vehicles are greater than 39 feet. Sample data was collected from dual-loop detectors to create histograms of the distribution of vehicle lengths. This distribution was later used to calibrate the model. Two fundamental assumptions were made: 1) vehicle speeds are considered constant, and 2) there are at least two intervals that do not have any long vehicles present in each period. The first step in developing the truck counting algorithm was to take various 5-minute periods and screen out intervals without long vehicles. Next, a formula for predicting truck volumes was developed. A computer program was written that accepts raw volume and occupancy data and return the predicted counts of short and long vehicles. The algorithm was tested on a 24-hour set of data from Thursday, May 13, 1999. It was determined that the algorithm fit the data well, especially during the nighttime and early morning periods. It was concluded that the algorithm works best under un-congested conditions. [1]

Kwon's paper expands on the work done by Wang and Nihan. One of the biggest improvements is that the parameters for the model can be determined generically and do not need to be fitted from the data. The Wang-Nihan algorithm needs the mean effective vehicle length dataset for calibration. The Kwon algorithm uses observed occupancy standardized by the vehicle count as the signal-to-noise ratio that is a function of the ratio of long vehicles and does not depend on speed. [3] Statistical methodology is applied to derive the explicit estimator of the ratio of long vehicles as the maximum likelihood estimator. [9] This ratio can then be used to estimate the MEVL and speed. The model is calibrated by using data from dual-loop sped traps so true vehicle lengths and speeds are known. From this data, the mixture of long and short vehicles is derived and the speed distribution measured. Using the distribution of the standardized occupancy, the proportion of long vehicles can be estimated. When compared to the Wang-Nihan algorithm, the MEVL and speed predictions are not as accurate, but are better than an assumed constant MEVL.

Similar to other truck counting algorithms, this one uses the volume and occupancy measurements from single-loop detectors. An estimation of the mean effective vehicle length is calculated from a set of sample data collected during a 24-hour period and only the lane where truck traffic is expected is used in the analysis. Similar to the other studies, two peaks are visible, one near 17 feet, representing cars, and the second at 61 feet for trucks. Two assumptions are needed to proceed: 1) on multilane freeways, vehicle speeds over different lanes tend to be synchronized. This is called lane-to-lane speed correlation. The second assumption is that the proportion of trucks in the inner lanes (first or second lane from the median) is zero. Data was collected from 10 Mondays between March 22 and May 24, 1999 and are aggregated to 5-minute intervals. The results show that the predicted truck volumes are within 5.7% of the true values. In different travel lanes, the algorithm both over and under-estimated truck volumes. The algorithm was applied to data from I-710 in Long Beach, CA during the dockworkers strike in 2002 and determined that the number of trucks traveling through the corridor decreased 32% during the duration of the strike. Some difficulties with this model are similar to the others reviewed – the presence of trucks in the supposedly truck-free lanes and a lack of lane-to-lane speed correlation can both throw off the model. The onset of periods of congestion also present difficulties due to the effect on the change in speed and occupancy measurements from the loop-detectors. [7]

The objectives of this study were to quantitatively evaluate the accuracy of dual-loop measurements of volumes and vehicle classifications, to identify the causes of loop detector inaccuracies and to recommend methods for improving the quality of real-time dual-loop measurements. [4] This was done through a combination of loop detectors measurements and ground-truth data collected using video images. Similar to other work, 4 vehicle classification bins were identified

1. < 26 feet
2. 26 – 39 feet
3. 39 to 65 feet
4. > 65 feet

A study site was chosen so that a video camera could be placed directly over the roadway, with the dual-loop detectors within the camera's field of vision. Video data was collected on both weekdays and weekends, and under varying travel conditions (congested and un-congested). Official Pacific Standard Time was used for clock synchronization and to place a timestamp on the video data. Both the loop detector data and the video data had a 40-second period in which no vehicles were present. From this period, it was possible to synchronize the two clocks, with an accuracy of approximately 4 seconds. The recorded video data was manually processed and each passing vehicle was placed in one of the four vehicle length bins. By using the total volume present in each of the 20-second intervals, the two data sets were compared. Next, the data sets were compared using volume totals over a one-hour period. Similar analyses were completed for vehicle classification data, and for data in both peak and off-peak times. The conclusions of the project were that dual-loop detectors tend to underestimate total vehicle volumes, that Bin 3 vehicles often were considered as being in Bin 4, though the reverse never occurs, and that dual-loop detectors have difficulties identifying Bin 2 vehicles.

3.0 DATA SOURCES

Three sets of volume count data were collected:

PORTAL Data
Intelligent Transportation Systems (ITS) are known for producing large amounts of data. Data can come from many different sources: from loop detectors installed in roadways, to bus dispatch systems, and even Global Positioning Systems installed in motor vehicles. Often such data are used only in a real-time fashion; however, archiving and mining such data can greatly enhance transportation system management. The Portland Transportation Archive Listing (PORTAL) project at Portland State University (PSU) has been archiving speed, volume, and occupancy data from 485 loop detectors on the Portland metropolitan freeway system since July 2004. The archive as well as performance metrics derived from the archive, such as hours of delay, travel time, and vehicle miles traveled, are available to individuals and agencies such as transportation planners, metropolitan planning organizations (MPOs), state transportation planners, traffic management operators, transit operators, and transportation researchers.

For this study, PORTAL has been used to generate truck counts using an algorithm designed by Wang and Nihan [5]. The Wang-Nihan algorithm and its implementation in PORTAL are described in Section 4.1. In this section, PORTAL's architecture, user interface and capabilities are described in the context of this study.

Autoscope Video Image Processing
Using the ODOT CCTV surveillance network, traffic was recorded on DVD. Using the Autoscope hardware and software package, this video was processed by creating virtual traffic counters using the supplied detector editor included in the software. Two types of detectors were used: one that measured the speed and length of vehicles and a second detector that merely counted vehicles as they passed. The detector file was then uploaded to then running a data collection poll while the prerecorded traffic video played in the DVD player. The output was a semicolon-delimited file that contained the data. This file was imported into Microsoft Excel for further data processing.

Manual Counts
Traffic flow characteristics were measured manually by watching the recorded traffic videos on a television while simultaneously noting the passage of short and long vehicles on a computer using a small Windows executable file named timer.exe. The data was recorded to a text file, which was later imported into Excel for further data processing.

3.1 Site Selection

Three locations were chosen to collect data for the project. To be chosen, a location had to meet the selection criteria. The selection criteria included the following:

- ODOT CCTV cameras needed to be near existing loop detectors (loop detector within field of camera vision)
- Loop detectors at locations had to have high data fidelity
- Locations needed a high percentage of truck traffic
- Locations needed to be high volume, with a high degree of variability in volume
- Camera height needed to be a minimum of 25 feet, 35 feet or greater was ideal to avoid vehicle occlusion
- ODOT video camera quality needed to be sharp and constantly available
- Cameras needed to be able to PTZ into a favorable position for both Autoscope and manual data collections
- Lighting conditions needed to be accommodating during the majority of the day
- Freeways need to be relatively straight for entire field of view
- Preferable daytime only, under varying traffic conditions

Figure 1: Site Map

After examining all of the possible locations available using the existing ODOT surveillance camera network, three sites were selected to begin recording video and collecting data using manual counting techniques and the Autoscope video image processing system. The sites are shown in Figure 1 and described below:

3.1.1 Site 1: Southbound I-5 at North Marine Drive

Site 1 is located at the interchange of I-5 and Marine Drive in North Portland. This interchange is just south of the Interstate Bridge that forms of the two main highway connection between Oregon and Washington. From Washington traveling southbound, the freeway first crosses the Columbia River and across the state border, then travels over Hayden Island, where an interchange provides access to a large complex of big box retail stores popular with Washington residents due to the lack of a sales tax in Oregon. A short causeway connects the highway to Oregon. Marine Drive is the next interchange after Hayden Island, and this first on the Oregon mainland.

Figure 2: North Marine Drive Camera Image

Marine Drive parallels the southern shore of the Columbia River and is a major freight route that provides access west of I-5 to the Port of Portland's Terminal 6, the largest container port in Oregon. Other Port terminals are located west of I-5 along Marine Drive in addition to large numbers of manufacturing facilities and warehouses. The onramps and off-ramps at the Marine Drive/I-5 interchange have large turning radii to accommodate the high volume of truck traffic in the area. East of I-5, Marine Drive provides access to a collection of townhouses along the river, the Colombia Edgewater Country Club and the further east, to Portland International Airport.

As shown in Figure 2, the ODOT CCTV camera is positioned on the west side of Interstate 5, north of the merge between the southbound Marine Drive onramp. For purposes of this project, the camera was aimed so that it faced south, and captured southbound moving traffic. Therefore, vehicles were receding from the camera in the field of vision. ODOT inductive loop detectors are present in all three travel lanes, and are located approximately 300 feet back of the on-ramp merge gore point

3.1.2 Site 2: Westbound I-84 at NE 37th Avenue

Site 2 is located near the interchange of I-84 and Sandy Blvd in Northeast Portland's Hollywood neighborhood. The onramp to I-84 is accessed from Sandy Blvd, with a large percentage of traffic connecting to Sandy Blvd from NE 37th Avenue. I-84 is the main route into Portland from the east. Travel congestion is at its peak most often during the morning commute.

Figure 3: NE 37th Ave. Camera Image

As shown in Figure 3, the CCTV camera at this location is mounted on a pole on the Sandy Blvd overpass. For the purposes of this experiment, the camera is pointed westward, capturing westbound moving traffic that is receding from the camera's field of view. The loop detectors at this location are present in all three travel lanes, and are located approximately 300 feet back of the onramp gore point.

3.1.3 Site 3: I-5 at SW Lower Boones Ferry Road

Site three is located in southwest suburban Washington County, approximately 9 miles from downtown Portland. SW Lower Boones Ferry Rd. and Interstate 5 form a diamond-shaped interchange that is roughly equidistant from the recently upgraded interchange at Oregon Highway 217 and I-5 in the north, and I-5 and I-205 in the south. Just west of the freeway, off Lower Boones Ferry is Bridgeport Village, a new, outdoor, "lifestyle" mall that caters to the suburban communities of Tigard, Lake Oswego, and Tualatin. East of I-5, Lower Boones Ferry extends northeast towards Lake Oswego and southwestern Portland. A large light manufacturing and warehousing district lies west of I-5 and south of 217, northwest of the interchange. Many of the retailers in the area are 'big box' type: home improvement centers, supermarkets, and furniture stores.

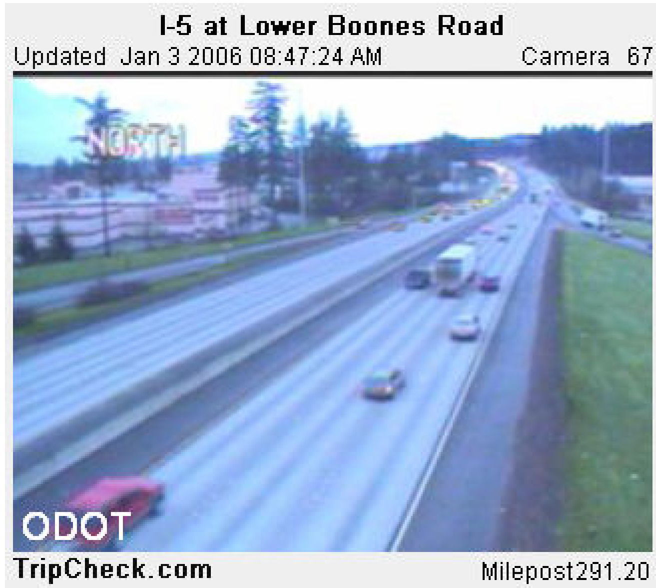


Figure 4: Lower Boones Ferry Road Camera Image

As shown in Figure 4, the camera used for data collection at this site is located on the northbound side of the freeway at the overpass. Northbound travel in the center and right hand shoulder lanes was captured for the data collection. The ODOT camera was pointed in both directions for separate data collections: upstream to record oncoming traffic and downstream to capture receding vehicles. The loop detectors at this location are located just south of the merge gore point for the onramp.

3.1.4 Site 4: Oregon 217 at SW Hall Blvd

As shown in Figure 5, the fourth location is located in Washington County, near the Portland region's largest mall complex, Washington Square. Oregon 217 is a seven-mile long state expressway that connects I-5 at the southern end to US-26 at the northern end. The highway connects to communities of Lake Oswego and Tigard with Beaverton. Each of these cities is seeing population growth that is much higher than in the city of Portland, and they are expected to continue to grow quickly in the next 20 years. Except for a small section immediately south of US-26, 217 has two lanes in each travel direction. This highway has undergone a series of improvements over the years, mostly involving converting old at-grade interchanges into grade-separated crossings. The southernmost interchange is still signal-controlled. Due to the changes over the years, many of the interchanges are closer to together than is desirable. This causes additional congestion. The highway is currently under study for additional capacity improvements such as the addition of a third travel lane and reconfiguration of a number of the interchanges to improve traffic flow. Since the highway connects a number of light manufacturing, big-box retails and warehouse commercial areas, it was thought to be a source of a high volume of trucks.

Figure 5: Hall Blvd. Camera Image

The ODOT CCTV camera at this location is located north of the SW Hall Blvd interchange. The loop detectors are located in travel lanes 1 (the lane closest to the center concrete median) and Lane 2, the center lane. There is a third lane in the weaving area between Hall Blvd and Denney Blvd to the north. This lane is used for vehicles entering the highway from the Denney interchange, and for vehicle exiting onto Hall Blvd. There are no loop detectors in this lane, and counts were not taken for it.

3.2 Camera Positioning

ODOT CCTV camera surveillance network were originally built alongside the freeways in the Portland metropolitan region (see map) and connected to ODOT's Region 1 Traffic Management Operations Center (TMOC) in order to expedite emergency service operations and to reduce travel delays. They are located along all major highways in the Portland region and are strategically placed to maximize the amount of high volume or high crash freeway locations that can be watched. All cameras have pan, tilt and zoom (PTZ) functionality which enables dispatchers to see both travel directions. In December 2005, there were approximately 80 cameras located along Portland's highways. The camera network functions well for its stated purpose, however, it poses some difficulties when being used for video image processing.

For the purposes of collecting data using video image processing with the Rackvision, ODOT CCTV cameras would ideally be mounted at least 35 feet above the freeway surface and positioned directly over the center lane of traffic. This camera height creates the most advantageous viewing angle by allowing the camera to be pointed downward to reduce downstream sun glare and to create a field of vision that allows the video imaging software the best circumstances to calculate vehicle speeds and length. When the camera is positioned it the suggested downstream or upstream viewing angle includes between 200-250 feet of pavement can be seen. Small deviations from the ideal camera position produce large errors in the processed speed and length data.

Counting vehicles requires vehicles to remain in sight just long enough to process their existence. The camera angle is less important when measuring vehicle counts. The largest effect the camera position has on vehicle count accuracy is when it is aimed in such a manner where smaller vehicles can be obscured by larger ones (occlusion), or when the camera angle makes it difficult for the video processing software to determine if a vehicle is following closely behind another vehicle is in fact a second vehicle. This is particularly noticeable when a smaller car is tailgating a truck.

In general, surveillance cameras are placed in way that best suits ODOT's needs, and the traffic that can be recorded from the best possible angle with the majority of the cameras in the field does not work well for video image processing.

Approximately 70 'channels' of traffic are available through Portland State's fiber-optic connection to ODOT. These channels can be viewed in a similar manner to cable television. A camera guide from ODOT with location of each camera by freeway number and closest street was provided. In addition, maps showing the exact location of both the ODOT cameras and inductive loop detectors were available.

It was necessary to flip through the traffic channels and identify the exact locations of the camera. It took in depth knowledge of Portland geography to be able to identify exact camera sitings.

3.3 ITS Data Archive for Portland

3.3.1 PORTAL Architecture

PORTAL is the Portland metropolitan area's transportation data archive and is based on the Archived Data User Service (ADUS) framework [9] developed by the U.S. Department of Transportation (DOT) as part of the National ITS Architecture. As defined in the National ITS Architecture [6], ADUS provides the historical data archive for all relevant ITS data and incorporates the planning, safety, operations, and research communities. ADUS provides the data collection, manipulation, and dissemination functions of these groups, as they relate to all ITS data. PORTAL is the Portland area's ADUS and has been has designated by the Portland ITS and operations agencies as the official ITS data archiving entity for the Portland region. The Federal Highway Administration (FHWA) maintains a website with links to other online ADUS projects (see http://www.fhwa.dot.gov/policy/ohpi/travel/adus.htm), including implementations in Arizona, California, Maryland, Minnesota, Texas, Virginia and Washington.

As PORTAL has been developed, compliance with the national ITS Architecture has been a major design goal. Given PORTAL's status as a research project and its current limitation to freeway data, it is not possible to claim that the entire ADUS Architecture umbrella is fully implemented in PORTAL. The ITS Architecture functions satisfied under PORTAL include:

- Store data in format received from ITS subsystems.

- Accommodate aggregation and reduction of the data flows, depending on the type of data represented.
- Sample raw data flows for permanent storage in accordance with user specifications. Permanent storage of the sampled data should be either online, offline, or both.
- Apply quality control procedures to the data, including the flagging of suspect data and the editing of data
- Distinguish between the following data types: unprocessed (raw), edited, aggregated, and transformed.

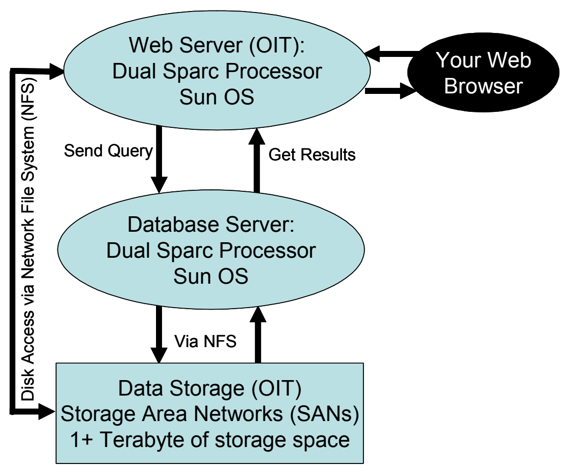


Figure 6: PORTAL Architecture

The PORTAL system currently focuses primarily on freeway data. Portland State University (PSU) receives a live stream of loop detector data from the Oregon Department of Transportation (ODOT) Region 1 Traffic Management and Operations Center (TMOC) located in downtown Portland. Currently, the data come from 485 inductive loop detectors installed in the freeway mainline and on-ramps in the Portland region. As shown in Figure 6, these data are transferred over a secure direct fiber optic connection between ODOT and PSU. Every 20 seconds XML data are pulled down from the ODOT servers to the PSU archiving servers. Once retained at PSU, the 20-second data are inserted into a PostgreSQL relational database management system (RDBMS). The raw 20-second data are not altered. Every morning at 3 a.m., the 20-second data from the previous day are aggregated to 5-minute, 15-minute, and 1-hour aggregates in order to allow for faster processing via the web interface described in the next section. The PORTAL RDBMS stores data physically on a redundant array of independent disks (RAID) providing both high-speed access and increased reliability through redundancy in the event of hardware failure. Currently PORTAL has a capacity of 1.2 TB, with approximately 200 MB of new freeway data added each day.

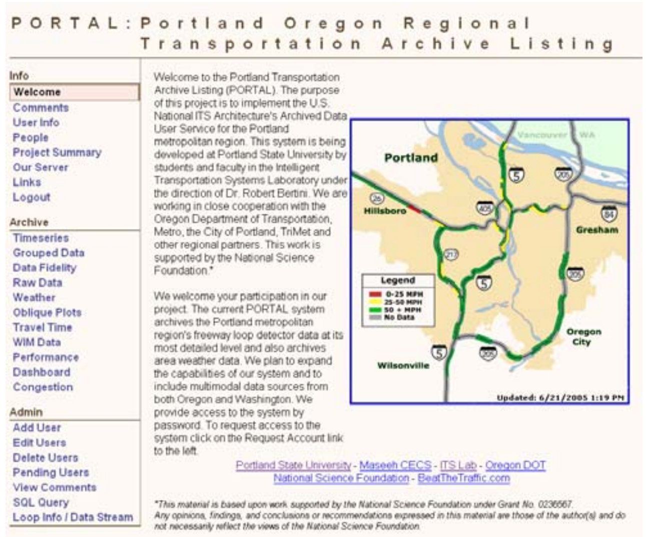


Figure 7: PORTAL Homepage

As part of the regional ITS backbone, the transportation agencies in the Portland region are finalizing the installation of a new private high speed ITS fiber network linking the key regional ITS organizations. Some of the major nodes on the network are ODOT, the City of Portland, the Port of Portland, TriMet and PSU. This network is designed to be a private and secure way for ITS organizations to share data in real time.

3.3.2 PORTAL User Interface

As suggested in the ITS Guidelines from the FHWA [7], user access to the PORTAL data archive is through a web-based interface providing easy access to both raw data sets and a wide range of common summary data and performance measures. Users have the option of graphically viewing data or outputting the data in tabular form. Additionally, PORTAL allows users to download all queried data as a comma separated text (CSV) file, since users may want to perform individualized manipulations off-line. The raw 20-second data are also available to users.

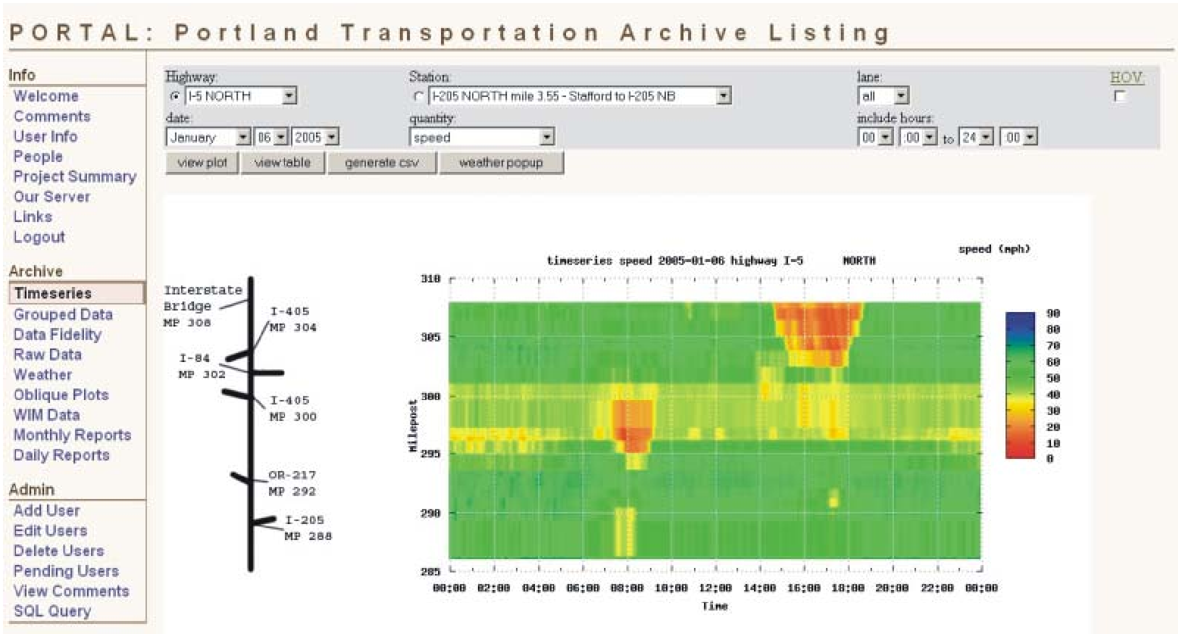


Figure 8: Timeseries Speed-Contour

Figure 7 shows the PORTAL home page (http://portal.its.pdx.edu). Persons interested in using PORTAL simply request an account so that access to the data can be understood and controlled. As of this writing there are over 110 registered PORTAL users ranging from students using the data to supplement their classroom education, ODOT traffic managers and engineers, planners from the Portland Metropolitan Planning Organization (Metro) as well as researchers from other universities around the globe. As shown in Figure 7, when a user logs onto PORTAL, there are several menu options, including Timeseries, Grouped Data, Data Fidelity, Raw Data and Weather. Each section allows users to fine tune a particular query. New functionality is being developed, and details are provided below.

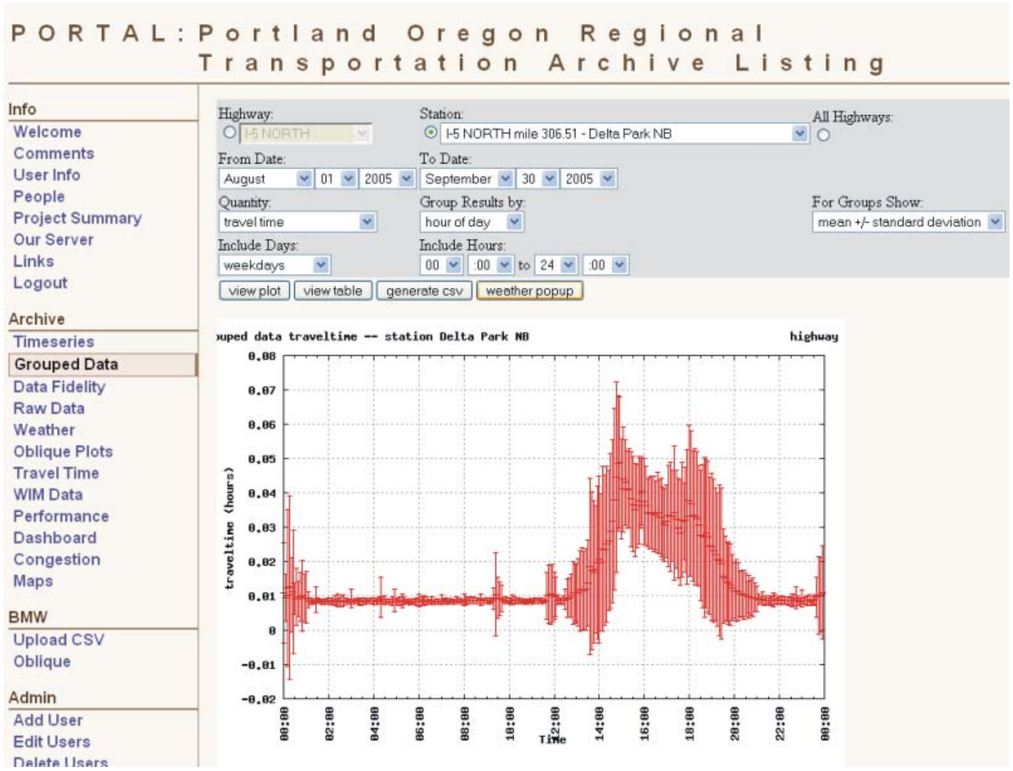


Figure 9: Grouped Data: Traveltime Plot

3.3.2.1 Time Series

The time series section allows the user to perform queries on the 5 minute aggregated data to extract volume, speed, occupancy, vehicle miles traveled, vehicle hours traveled, travel time, and delay. Figure 8 shows a speed-contour plot for highway I-5 North in Portland for January 6, 2005. In addition to plotting data for a whole highway, the user can plot data for a specific loop detector station. Additionally, the user can choose the time period and specific travel lanes. The user has the option of plotting the data as shown in the figure, viewing the data in a table, or exporting that data as a comma separated text file.

3.3.2.2 Grouped Data

The Grouped Data section of the PORTAL user interface allows the user to display summaries of data from multiple days. The data can be grouped by hour of day, day of week, or week of year. The user can also determine the particular statistics that are of most interest or relevance, including the mean, minimum value, maximum value, and standard deviation. As in the time series section, the user has the choice of plotting the data, displaying a table of the data, or downloading a comma separated text file. Figure 9 shows an example of grouped data for travel time at one particular detector station over a two-month period. The plot shows the mean and plus/minus one standard deviation.

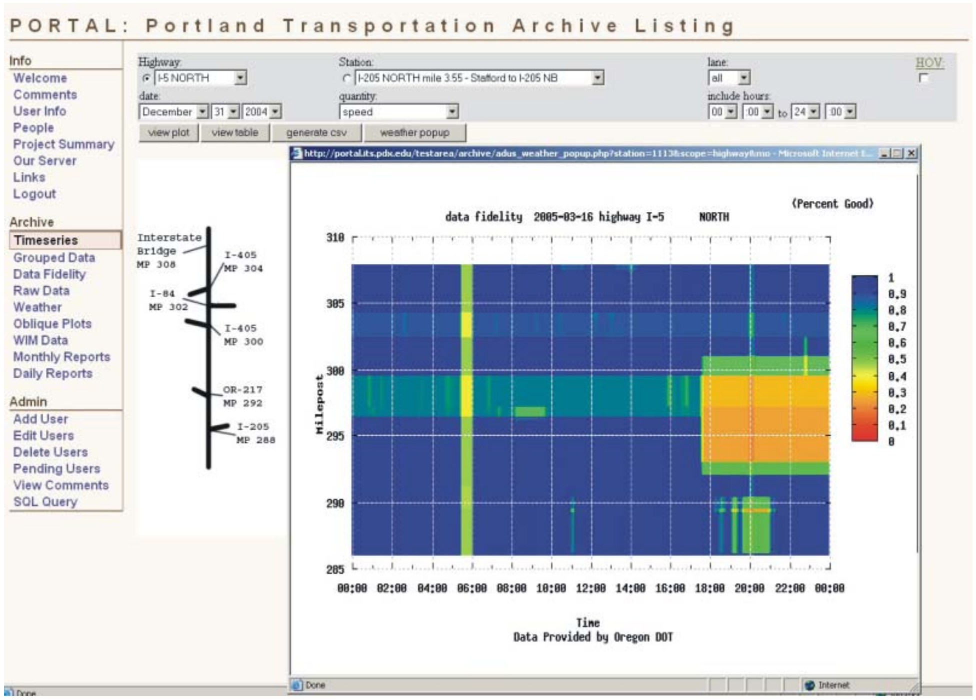


Figure 10: Data Fidelity Pop-up

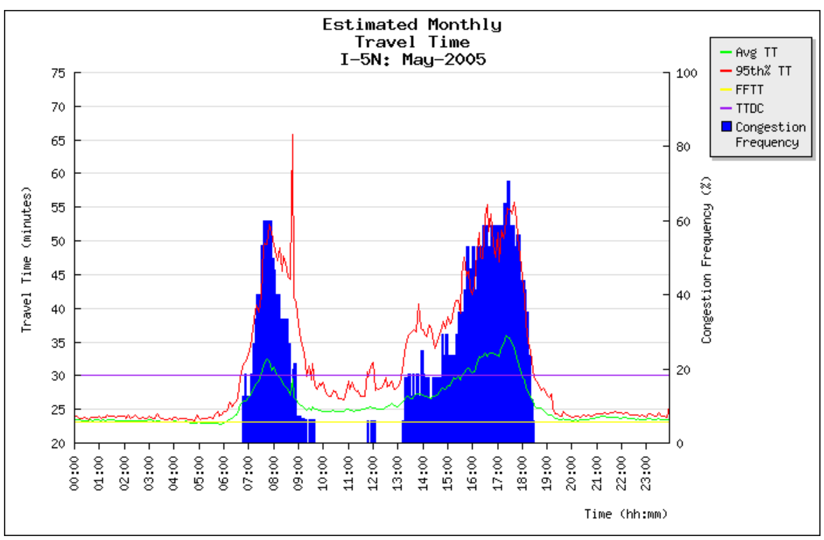


Figure 11: Monthly Reliability Report for Northbound I-5

3.3.3.3 Data Fidelity

For any data archive, understanding, documenting and communicating the data quality characteristics is critical. The National ITS Architecture emphasizes the importance of meta-data that clearly describes any known problems with the data that is distributed. This section of the PORTAL site allows the user to determine whether particular loop detectors reported valid data according to the data fidelity algorithm. Data fidelity is currently based on data quality measures from ODOT's system wide adaptive ramp metering system (SWARM) system. The user can either acquire information on the health of a specific detector, or can obtain the percentage of healthy loop readings on a specified highway section. Figure 10 is an example of data fidelity "pop-up" showing information for highway I-5 North.

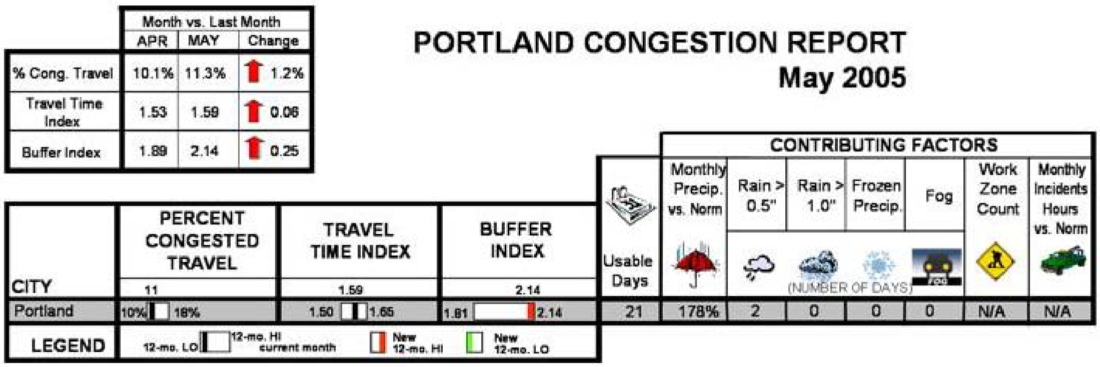


Figure 12: Sample Urban Congestion Report, May 2005 Portland Data

3.3.3.4 Daily and Monthly Reports

This section of PORTAL was requested by the various agencies around Portland, so that they could assimilate a gauge of the total system health for a specific day or month. This includes the average congested travel time for a road segment, the percent of time that a segment was congested during the peak period, and the buffer index (the 95th percentile travel time for the month for a road segment). These performance measures can provide traffic managers and transportation planners a good idea of the system's health at any time. Figure 11 shows a sample travel time reliability plot for northbound I-5 for May 2005. The mean and 95th percentile travel times are shown along with the percentage of time that each 5-min time slice was congested for that month. Figure 12 shows a sample monthly report developed by the FHWA to be a national report card for ten key cities. Currently, the FHWA must extract large raw data files and perform their own calculations. If FHWA desired Portland data, they could display the monthly report shown in Figure 12 with one click of the mouse.

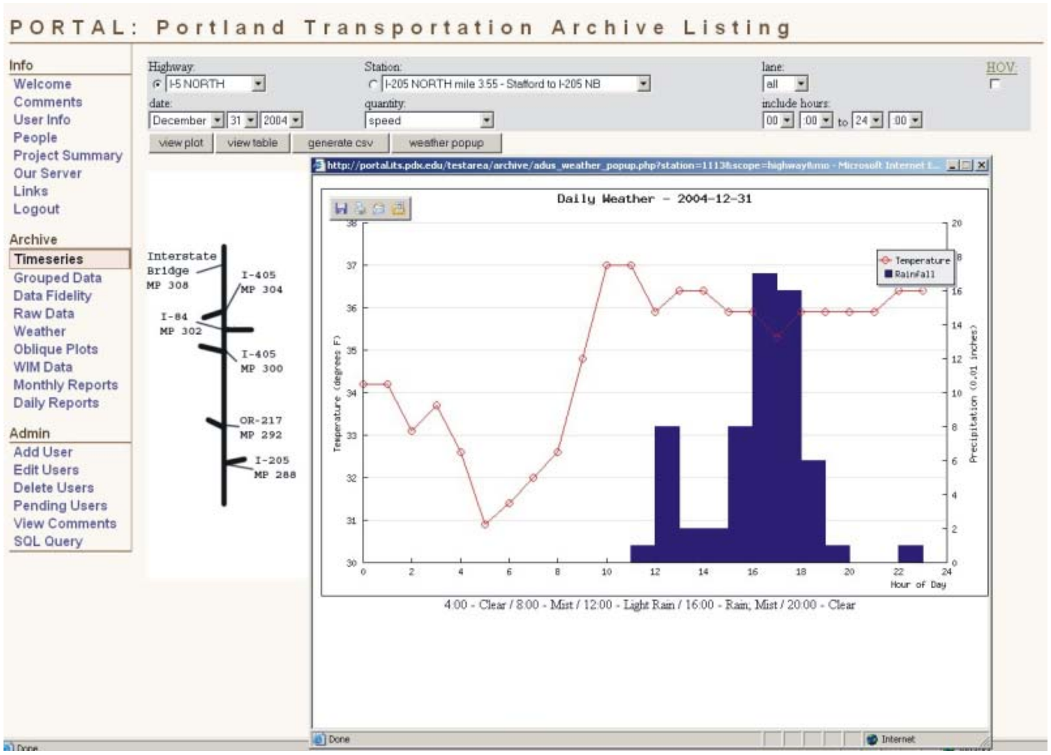


Figure 13: Weather Data for Dec 31, 2004

3.3.3.5 Weather

In an effort to provide additional information about traffic and freeway conditions, weather data are also archived on PORTAL Archived data includes rainfall and temperature collected by the National Oceanic and Atmospheric Administration, (NOAA). These weather stations are located at the Portland International Airport, as well as at the airports in suburban Hillsboro and Troutdale. Figure 13 shows an example of weather data from one day. The line graph shows the hourly temperature variation over the day (left hand axis) while the bar chart (right hand axis) shows the hourly measured precipitation. A weather "pop up" button appears on many PORTAL report screens so the user can rapidly view the weather on the day in question.

3.4 Manual Data Collection

Data was collected manually by playing the recorded traffic video on a television and using a small executable program named timer.exe. This computer program functions as a keystroke recorder. As vehicles passed a determined point on the freeway, a student was able to record this passage by pressing a key on the keyboard. For each segment of traffic video, four different keys were used to denote a different type of vehicle and the lane in which it traveled. Two keys were used to mark short vehicles and long vehicles in the center travel lane (all freeways surveyed

The student was required to make an informed judgment as to the length of each vehicle. Vehicles were divided into two classes: short vehicles (less than 39 feet) and long vehicles (greater than 39 feet). These lengths correspond to the lengths used by the Wang algorithm. The output file of a completed period of data capture contains a two column, hyphen-delimited list, as shown in Table 1. The first column containing the key pressed, the second denoted the time at which the key was pressed, as measured by the PC's internal clock. The output file was imported into Microsoft Excel for further data processing. It is clear that this manual count method is not free from error. Future research should include efforts to examine the magnitude of this error rate, and to compare it to the error rates of other methods. In addition, further segregation of the data by vehicle type (e.g., domestic trailer, 20-foot marine trailer, etc.) could further illuminate error rates; however this was not done as part of this project.

No.	Time	Vehicle
1	13:02:15	S
2	13:02:15	L
3	13:02:16	L
4	13:02:17	L
5	13:02:18	S
6	13:02:20	S
7	13:02:20	L
8	13:02:22	S
9	13:02:23	S
10	13:02:23	L
11	13:02:25	S
12	13:02:26	S
13	13:02:29	L
14	13:02:30	L
15	13:02:31	S
16	13:02:34	L
17	13:02:37	L
18	13:02:39	S
19	13:02:41	S
20	13:02:41	S
21	13:02:43	S
22	13:02:44	S
23	13:02:45	S
24	13:02:46	S

Table 1: Sample Manual Count Data Output From time.exe

3.5 Video Image Processing Using the Autoscope Rackvision

The recorded traffic video was processed by the Autoscope Rackvision hardware and accompanying software is described in the data sources section. Virtual detectors were first created using the software program. Next, a data collection poll was setup and executed. The video processing began when a DVD containing traffic video was played. As the segment played, traffic flow data began to be processed inside the Rackvision and was subsequently downloaded and stored as a text file on the computer. The following section will provide a detailed overview of the methodology used to collect traffic data by video image processing technology.

3.5.1 Equipment Needed and Hardware Configuration

The following equipment was used to collect video data using the Autoscope:

- Television
- DVD player/recorder
- Autoscope software version 8.1 installed on a PC
- Autoscope RackVision
- Cables to connect hardware

The setup for recording and processing video at the Intelligent Transportation Laboratory at Portland State University was as follows:

ODOT's fiber optic feed from their TMOC was dampened by a hardware device at PSU and connected to the ITS Lab via a coaxial cable connection. It was necessary to damp the fiber signal because it was, unexpectedly, too strong and produced a snowy feed. A second coaxial cable connected the incoming camera feed to the Philips DVD player/recorder. A DVD player was used for this project since a prior experiment using a VCR and VHS tapes did not produce a video quality that was high enough to use the Rackvision. The DVD machine was in turn connected via coaxial cable to a 27" television monitor. This enabled students to view the multiple channels of surveillance video (one channel for each of the 80 cameras in the field) by switching channels on the DVD player. It was necessary to use the television to work with the video: creating manuals counts, accessing the DVD option menus, and configuring the Autoscope data polling. The DVD player was connected with an RCA cable to the Autoscope Rackvision unit. The Rackvision was in turn connected to the serial port on the PC via the 'Supervisor' cable that was provided with the Rackvision. The Rackvision runs on standard AC power and needs to be plugged into a wall outlet.

3.5.2 Software Installation and Network Setup

Autoscope version 8.1 was installed on a PC in the ITS Lab. The standard software setup options were selected. When the software is run, it opens the Network Browser to the user (Figure 14)

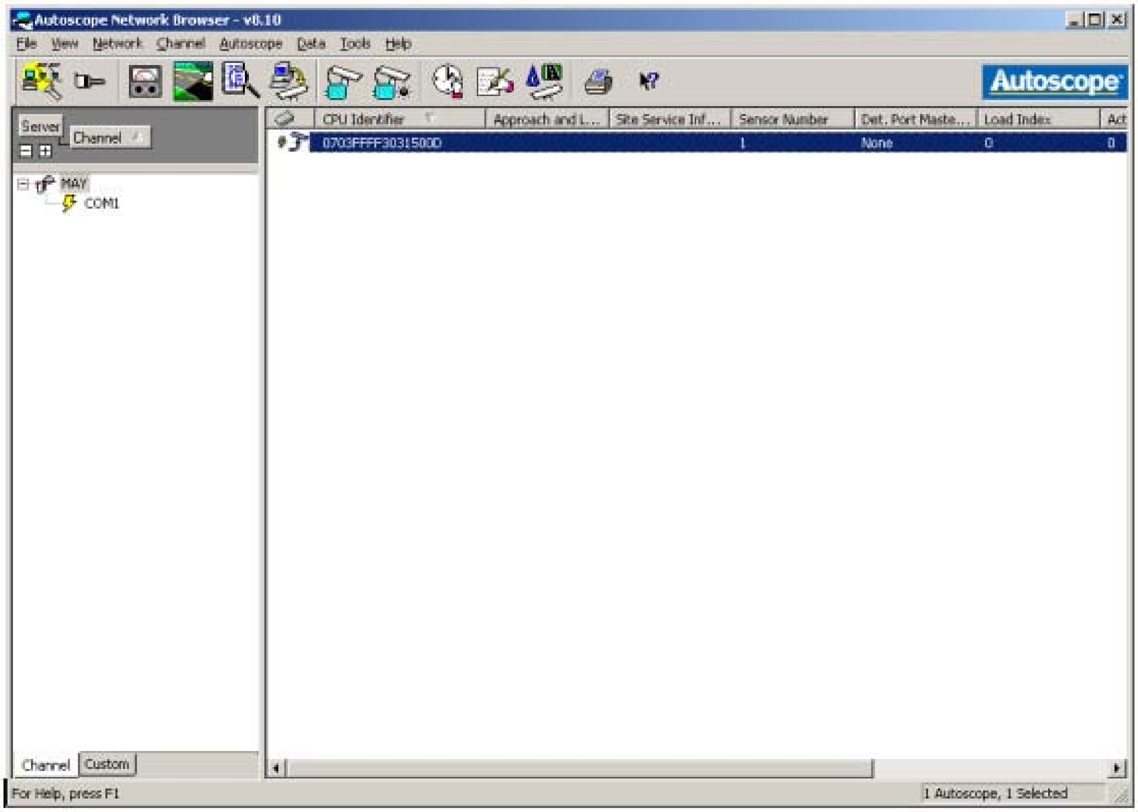


Figure 14: Autoscope Network Browser

The Network Browser is the centerpiece of the Autoscope software application. After the software loads, a second, smaller window opens and prompts the user to start the Communication Server and to 'Learn the Network'. The process of 'Learning the Network' serves to open the connection between the PC running the application software and the firmware installed in the Rackvision hardware unit. If the Rackvision is detected the 'learn' was successful. It is necessary to reboot the Rackvision if the 'learn' fails to make a connection. This can be done by pulling the handle of the Rackvision outward, disconnecting the card from the rest of the unit, and then reinserting the card back into the slot. Relearn the network. Once the Autoscope is 'found' its identification will be listed in the Network Browser window. A lighting bolt icon indicates that the Rackvision is functioning properly; a red exclamation make indicates that an error of some type exists. With the hardware and software connected, installed and configured, video image processing and data collection can begin

3.5.3 Calibration

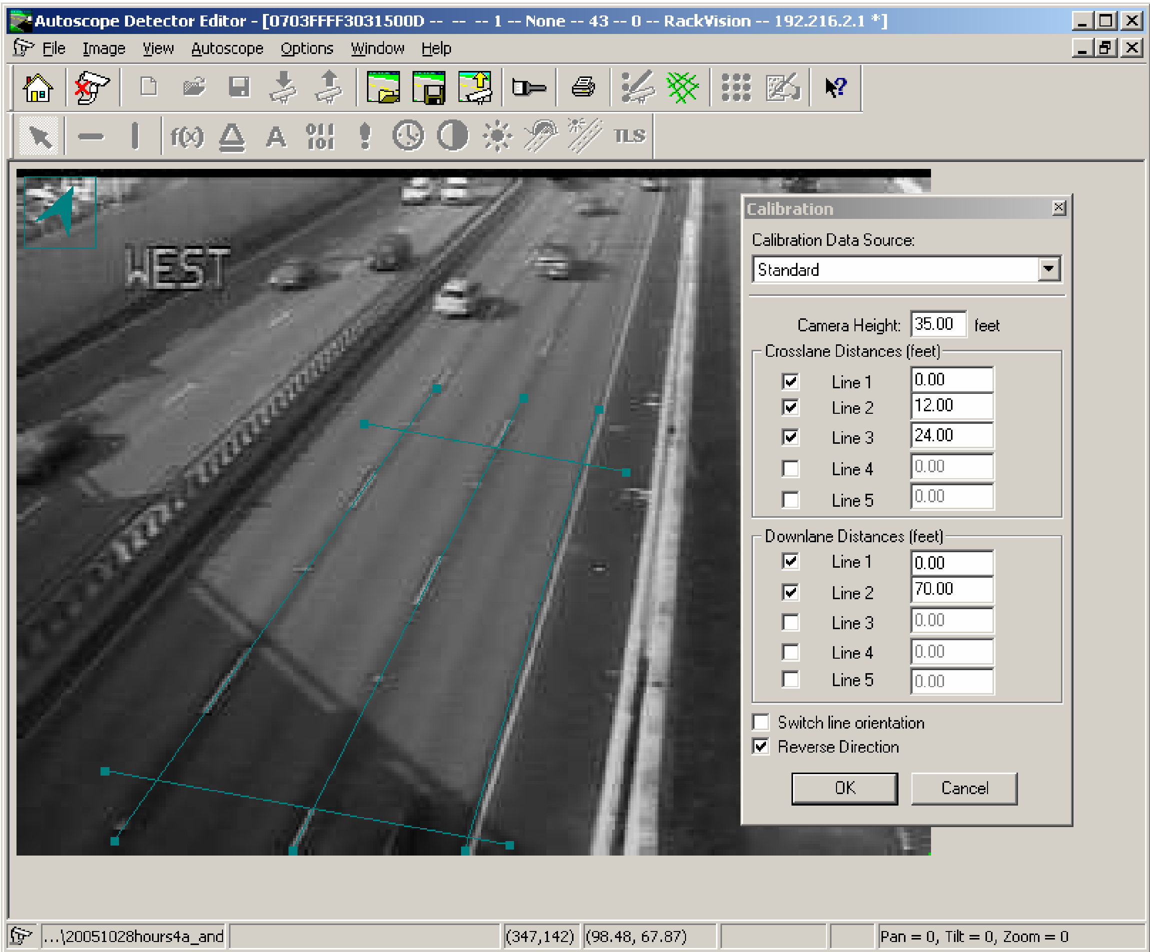


Figure 15: Autoscope Network Browser

To set up a detector file, choose the 'Set up Detectors' option under the 'Autoscope' menu. An Autoscope Detector Editor Window opens. The first step is to import an image of the section of freeway under analysis. After the image has loaded, it is necessary to calibrate the field of vision. Choosing the calibration option from the 'View' menu brings up a grid of lines and a calibration window as shown in Figure 15. Several lines are created to correspond with the lane lines on the freeway. The distances between these lines are known: 12 feet. Two calibration lines are shown drawn perpendicular to the direction of travel. These lines are 70 feet apart, and are based on the pattern of dashes and gaps in the lane striping. In Oregon, these lines are painted with 10-foot dashes and 30-foot gaps. To complete the calibration process, the camera height is entered and the arrow in the top left is checked to make sure it points in the same direction as traffic. Once the image is calibrated, detectors can be created.

3.5.4 Creating Detector Files

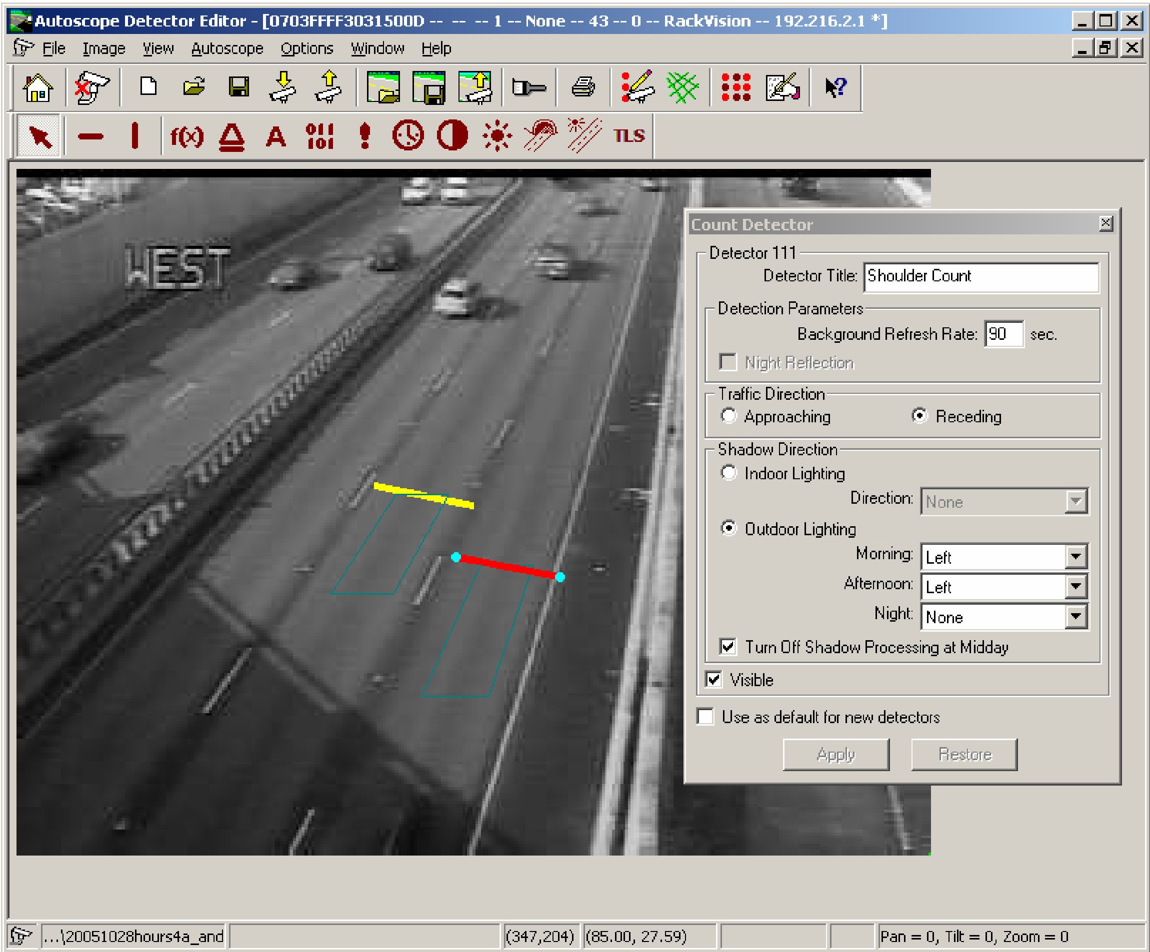


Figure 16: Autoscope Network Browser

A number of different detector types can be created with the Autoscope detector editor. These virtual detectors are meant to mimic the loop detectors that are in the field.

For the purposes of this project, it was only necessary to use speed detectors because they include the count detector functionality. The speed detectors that are used for the data collection section of this project collect the following time stamped information: vehicle presence, speed, and length measurements. When placing speed detectors, it is important to determine which part of the lane vehicles generally travel in. Ideally, the speed detectors should be placed in such a manner as to capture the front part of the hood of a vehicle. This will produce the most accurate measurements of speed and length. Speed detectors are the rectangular section seen in the center and right hand shoulder lane in Figure 16 above. The larger lines at the end of each speed detector represent the presence of count detectors. The count detector portion of a speed detector is the on the downstream side of the speed detector. When vehicles travel over a detector during video image processing, a detector will change its status to ‘on’. When vehicles leave the influence area of a detector, it turns off. Speed and length are calculated when the vehicle leaves the detector zone of the speed detector. The presence of the vehicle is noted at this time by both the speed and count detectors. This functionality creates the ability to plot two separate sets of cumulative curves. Once the detectors are created, named and configured for the direction of traffic, lighting conditions and vehicle classifications, the file is saved and the uploaded to the Rackvision. The next step in the video image process is to set up a data collection poll and execute it while the recorded traffic video plays on the DVD player.

3.5.5 Creating and Running a Data Collection Poll

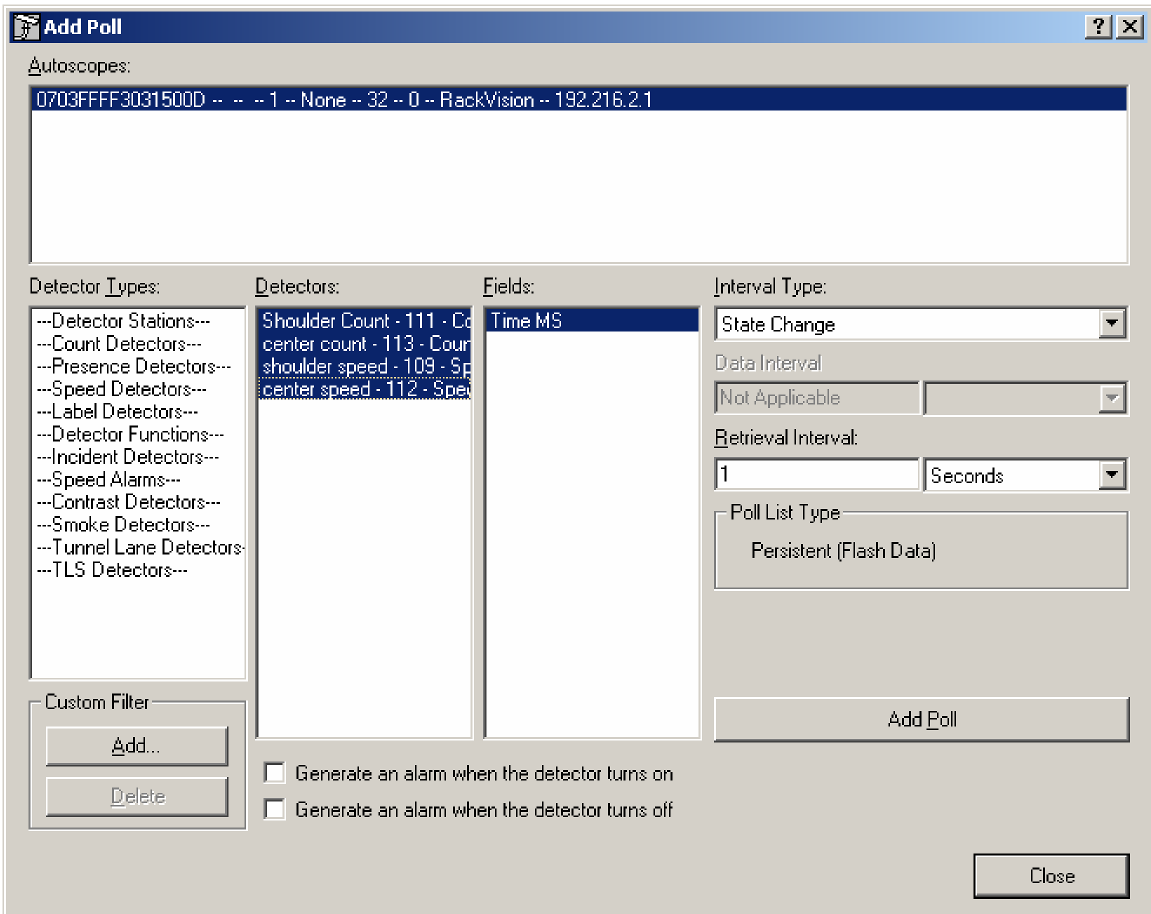
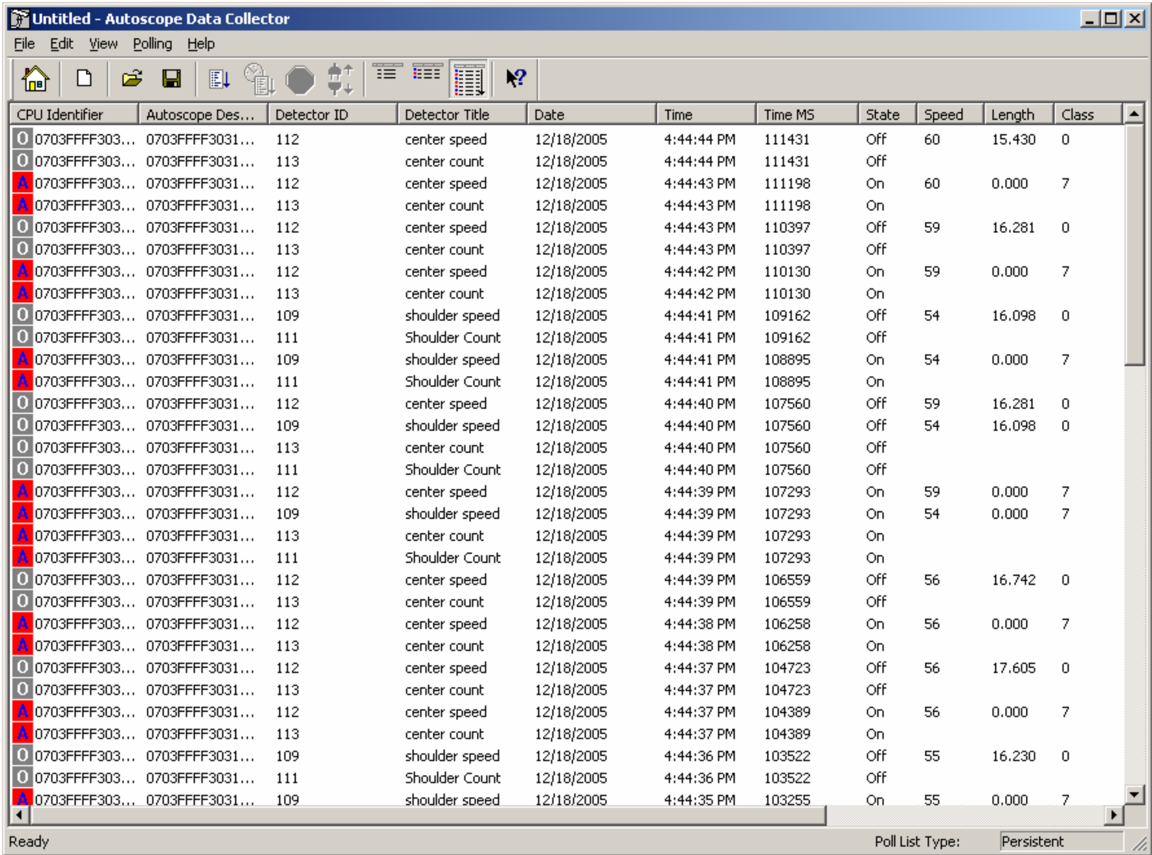


Figure 17: Add Poll Window

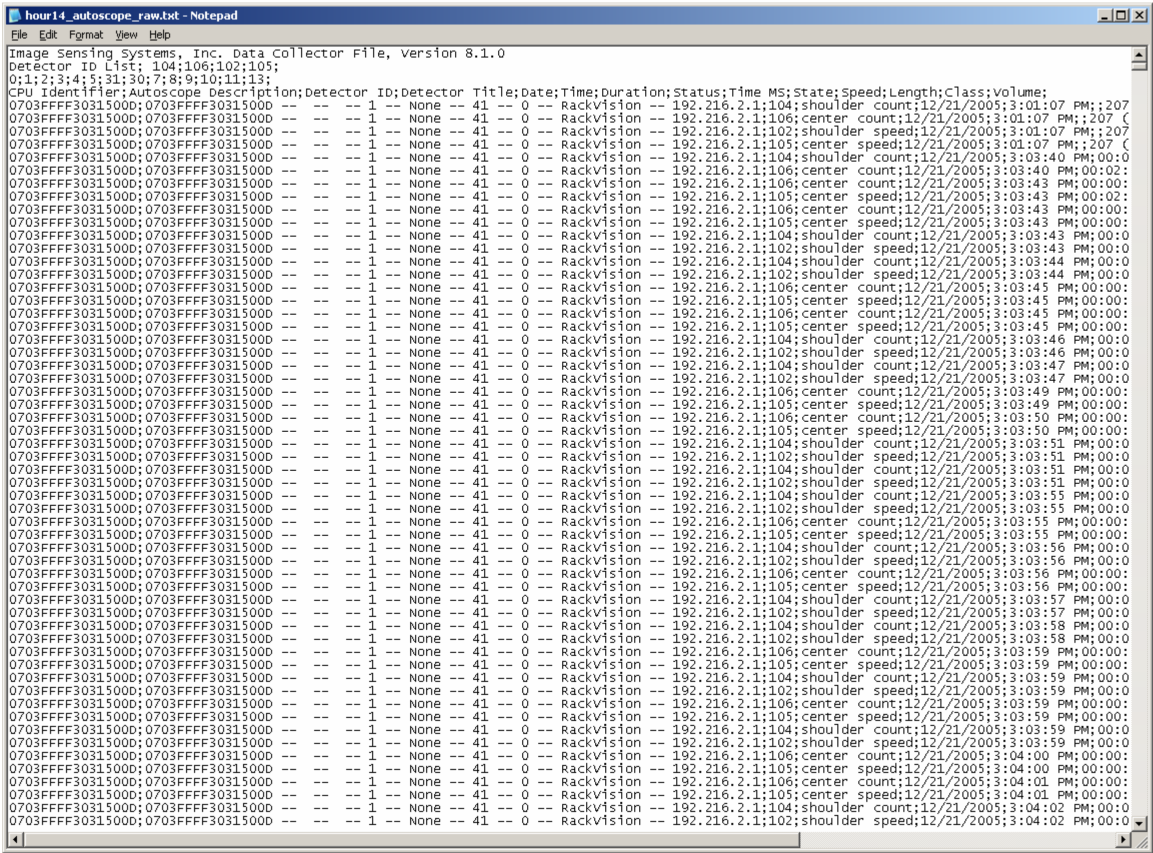
From the Network Browser screen, select 'Data Collector' from the 'Data' menu. This opens up the 'Add Poll' window in the Autoscope Data Collector. The detector section of the window lists the detectors that were created in the editor. To collect the data necessary for this project, all four detectors need to be selected. The interval type for each detector is 'State Change'. This indicates that the video image processing unit will create a new record of data whenever a detector changes its state from 'on' to 'off' or vice versa. The retrieval interval was chosen to be 1 second, the minimum allowed. This level of data collection allowed the processing to be monitored carefully, and made detector file calibration easier. Once the poll options are set, clicking the 'Add Poll' button prepares the software to begin data collection.



	CPU Identifier	Autoscope Des...	Detector ID	Detector Title	Date	Time	Time MS	State	Speed	Length	Class
O	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:44 PM	111431	Off	60	15.430	0
O	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:44 PM	111431	Off			
A	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:43 PM	111198	On	60	0.000	7
A	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:43 PM	111198	On			
O	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:43 PM	110397	Off	59	16.281	0
O	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:43 PM	110397	Off			
A	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:42 PM	110130	On	59	0.000	7
A	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:42 PM	110130	On			
O	0703FFFF303...	0703FFFF3031...	109	shoulder speed	12/18/2005	4:44:41 PM	109162	Off	54	16.098	0
O	0703FFFF303...	0703FFFF3031...	111	Shoulder Count	12/18/2005	4:44:41 PM	109162	Off			
A	0703FFFF303...	0703FFFF3031...	109	shoulder speed	12/18/2005	4:44:41 PM	108895	On	54	0.000	7
A	0703FFFF303...	0703FFFF3031...	111	Shoulder Count	12/18/2005	4:44:41 PM	108895	On			
O	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:40 PM	107560	Off	59	16.281	0
O	0703FFFF303...	0703FFFF3031...	109	shoulder speed	12/18/2005	4:44:40 PM	107560	Off	54	16.098	0
O	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:40 PM	107560	Off			
O	0703FFFF303...	0703FFFF3031...	111	Shoulder Count	12/18/2005	4:44:40 PM	107560	Off			
A	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:39 PM	107293	On	59	0.000	7
A	0703FFFF303...	0703FFFF3031...	109	shoulder speed	12/18/2005	4:44:39 PM	107293	On	54	0.000	7
A	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:39 PM	107293	On			
A	0703FFFF303...	0703FFFF3031...	111	Shoulder Count	12/18/2005	4:44:39 PM	107293	On			
O	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:39 PM	106559	Off	56	16.742	0
O	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:39 PM	106559	Off			
A	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:38 PM	106258	On	56	0.000	7
A	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:38 PM	106258	On			
O	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:37 PM	104723	Off	56	17.605	0
O	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:37 PM	104723	Off			
A	0703FFFF303...	0703FFFF3031...	112	center speed	12/18/2005	4:44:37 PM	104389	On	56	0.000	7
A	0703FFFF303...	0703FFFF3031...	113	center count	12/18/2005	4:44:37 PM	104389	On			
O	0703FFFF303...	0703FFFF3031...	109	shoulder speed	12/18/2005	4:44:36 PM	103522	Off	55	16.230	0
O	0703FFFF303...	0703FFFF3031...	111	Shoulder Count	12/18/2005	4:44:36 PM	103522	Off			
A	0703FFFF303...	0703FFFF3031...	109	shoulder speed	12/18/2005	4:44:35 PM	103255	On	55	0.000	7

Figure 18: Data Collection Window

Figure 18 shows a sample of the data collector window while a poll is running. As the traffic video plays, the Rackvision processes the data and outputs it to both the data collector window and to a text file. This enables real time monitoring of the data. The data poll and the traffic video continue to run for the duration of the segment, either one hour or 30 minutes. Upon the end of the hour, the completed text file (Figure 19) is ready to import into Excel to await the clock synchronization, formatting and analysis steps.



```
Image Sensing Systems, Inc. Data Collector File, Version 8.1.0
Detector ID List; 104;106;102;105;
0;1;2;3;4;5;31;30;7;8;9;10;11;13;
CPU Identifier;Autoscope Description;Detector ID;Detector Title;Date;Time;Duration;Status;Time MS;State;Speed;Length;Class;Volume;
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:01:07 PM;;207
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:01:07 PM;;207 (
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:01:07 PM;;207
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:01:07 PM;;207 (
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:40 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:40 PM;00:02:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:43 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:43 PM;00:02:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:43 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:43 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:43 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:43 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:44 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:44 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:45 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:45 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:45 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:45 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:46 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:46 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:47 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:47 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:49 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:49 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:50 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:50 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:51 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:51 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:51 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:51 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:55 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:55 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:55 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:55 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:56 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:56 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:56 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:56 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:57 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:57 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:58 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:58 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:59 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:59 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:59 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:59 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:03:59 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:03:59 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:03:59 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:03:59 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:04:00 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:04:00 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;106;center count;12/21/2005;3:04:01 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;105;center speed;12/21/2005;3:04:01 PM;00:00:
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;104;shoulder count;12/21/2005;3:04:02 PM;00:0
0703FFFF3031500D;0703FFFF3031500D --   --   -- 1 -- None -- 41 -- 0 -- RackVision -- 192.216.2.1;102;shoulder speed;12/21/2005;3:04:02 PM;00:0
```

Figure 19: Raw Data produced by Autoscope

3.6 Formatting Data for Use in Analysis

The raw data produced by both the manual count and the Rackvision is stored in text files. These files need to be imported into Excel to begin the following series of steps to put the data into a format that can be used to create summary statistics and the plots. These steps are:

3.6.1 Explode Data into Columns

Using the text to column function in Excel, explode the data into its components by selecting the appropriate delimiter (a semicolon for video image processing data, and a double hyphen for the manual count data).

3.6.2 Clock Synchronization

When the data for both the manual and Autoscope counts is created, the timestamps on each piece of data is based upon the internal clock on the PC. These timestamps need to be synchronized with the PORTAL-Reported data. First, the data needs to synched to the actual time that the data was recorded. ODOT loop detectors clocks should be coordinated with the official United States time. This time can be found at any moment by visiting the federal government's official clock at http://www.time.gov. The time periods of each hour or 30 minutes of data is known. Using the time mathematical functions built into Excel, time is added or subtracted to the text file data in order to change the first record's time from internal PC clock to the actual time that the data occurred. This using the copy and paste functions, this adjustment is applied to all data records in the file. The result is that the timestamps on the collected data directly corresponds to the actual real-time occurrence of the event. This method is straightforward and produces highly accurate data.

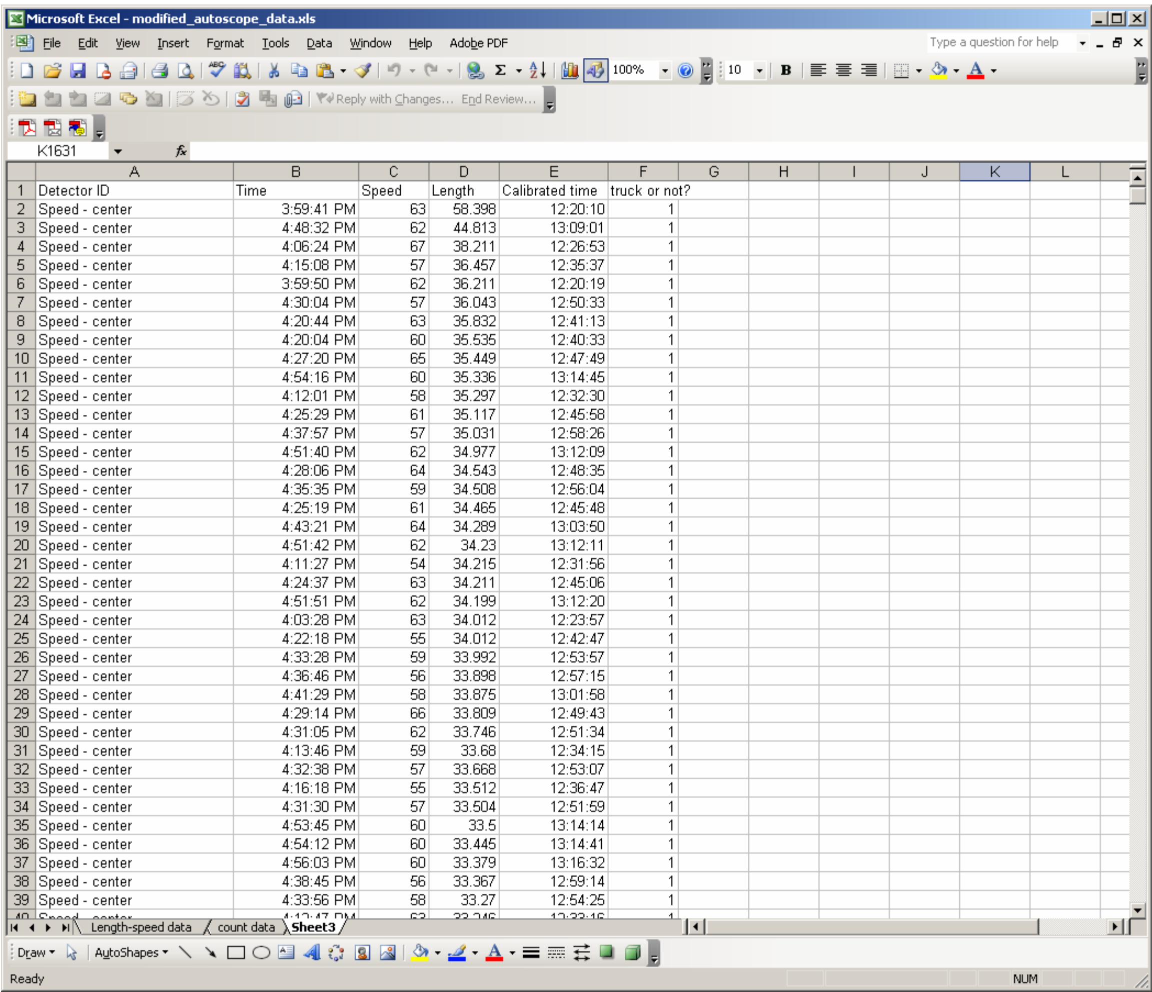
The next step in the synchronization process is to align the data produced above to the PORTAL-Reported data. Working on the assumption that the manual count data (total vehicles) is the most accurate of the four different counts, the PORTAL-Reported data should equal the manual count data, or at least be as close as possible. Since the PORTAL-Reported is aggregated in 20-second intervals, several groups of 180 observations (representing one hour of data) or 90 observations (30-minute segments) are summed together. This produces several different counts. The PORTAL-Reported count that is closest to the manual count, within a two-minute time period on each side of the PORTAL-Reported time that exactly corresponds to the manual count time is determined to be the correct time for all sets of data. Using the time math functions, the manual and Autoscope data is altered to match the correct PORTAL-Reported times. This method can be checked in several ways. It is usually fairly obvious which group of PORTAL-Reported observations correspond to the data (Table 2). In this example, knowing that the time.gov timestamp for the video was exactly 12:19:00 and the total manual count produced a result of 1629 vehicles, it be said with assurance that the corresponding PORTAL-Reported time fell between 12:18:20 and 12:18:40. After the data is plotted using either cumulative or oblique plots, similar patterns in the arrival times become apparent. If they are off, the manual or Autoscope count data can be adjusted.

Timestamp	Count
12:16:00 volume	1622
12:16:20 volume	1623
12:16:40 volume	1619
12:17:00 volume	1619
12:17:20 volume	1623
12:17:40 volume	1627
12:18:00 volume	1626
12:18:20 volume	1633
12:18:40 volume	1626
12:19:00 volume	1637
12:19:20 volume	1641
12:19:40 volume	1639
12:20:00 volume	1638
12:20:20 volume	1642
12:20:40 volume	1645

Table 2: PORTAL-reported Data Summed into Groups of 180 Observations

3.6.3 Sorting Data

Once all data timestamps have been synchronized, the data is sorted. The manual count is sorted based on the keystroke classification. The result is four sets of data: short vehicle in the center lane, short vehicles in the shoulder lane, long vehicles in the center lane and long vehicles in the shoulder lane. For the Autoscope data, the four categories are: speed data for the center lane, speed data for the shoulder lane, count data for the center lane and count data for the shoulder lane. For the Autoscope data, is it necessary to select the rows where the status is set to 'on' for the count data, since this is when the vehicle presence is detected, and 'off' for the speed data, the corresponding point where speed and length is calculated.



	Detector ID	Time	Speed	Length	Calibrated time	truck or not?
2	Speed - center	3:59:41 PM	63	58.398	12:20:10	1
3	Speed - center	4:48:32 PM	62	44.813	13:09:01	1
4	Speed - center	4:06:24 PM	67	38.211	12:26:53	1
5	Speed - center	4:15:08 PM	57	36.457	12:35:37	1
6	Speed - center	3:59:50 PM	62	36.211	12:20:19	1
7	Speed - center	4:30:04 PM	57	36.043	12:50:33	1
8	Speed - center	4:20:44 PM	63	35.832	12:41:13	1
9	Speed - center	4:20:04 PM	60	35.535	12:40:33	1
10	Speed - center	4:27:20 PM	65	35.449	12:47:49	1
11	Speed - center	4:54:16 PM	60	35.336	13:14:45	1
12	Speed - center	4:12:01 PM	58	35.297	12:32:30	1
13	Speed - center	4:25:29 PM	61	35.117	12:45:58	1
14	Speed - center	4:37:57 PM	57	35.031	12:58:26	1
15	Speed - center	4:51:40 PM	62	34.977	13:12:09	1
16	Speed - center	4:28:06 PM	64	34.543	12:48:35	1
17	Speed - center	4:35:35 PM	59	34.508	12:56:04	1
18	Speed - center	4:25:19 PM	61	34.465	12:45:48	1
19	Speed - center	4:43:21 PM	64	34.289	13:03:50	1
20	Speed - center	4:51:42 PM	62	34.23	13:12:11	1
21	Speed - center	4:11:27 PM	54	34.215	12:31:56	1
22	Speed - center	4:24:37 PM	63	34.211	12:45:06	1
23	Speed - center	4:51:51 PM	62	34.199	13:12:20	1
24	Speed - center	4:03:28 PM	63	34.012	12:23:57	1
25	Speed - center	4:22:18 PM	55	34.012	12:42:47	1
26	Speed - center	4:33:28 PM	59	33.992	12:53:57	1
27	Speed - center	4:36:46 PM	56	33.898	12:57:15	1
28	Speed - center	4:41:29 PM	58	33.875	13:01:58	1
29	Speed - center	4:29:14 PM	66	33.809	12:49:43	1
30	Speed - center	4:31:05 PM	62	33.746	12:51:34	1
31	Speed - center	4:13:46 PM	59	33.68	12:34:15	1
32	Speed - center	4:32:38 PM	57	33.668	12:53:07	1
33	Speed - center	4:16:18 PM	55	33.512	12:36:47	1
34	Speed - center	4:31:30 PM	57	33.504	12:51:59	1
35	Speed - center	4:53:45 PM	60	33.5	13:14:14	1
36	Speed - center	4:54:12 PM	60	33.445	13:14:41	1
37	Speed - center	4:56:03 PM	60	33.379	13:16:32	1
38	Speed - center	4:38:45 PM	56	33.367	12:59:14	1
39	Speed - center	4:33:56 PM	58	33.27	12:54:25	1

Figure 20: Working with Raw Data in Excel

3.6.4 Creating Data Summary Statistics

Once the Autoscope data has been sorted by lane and detector type, and the manual count data sorted by lane and vehicle type, it is a simple process to collect summary statistics for each category of data: merely add up the total rows for each data group. Two methods were used to determine the number of long vehicles as measured by the Autoscope speed detectors. The first way was to sort the individual vehicle length data, round them to the nearest foot and to create an Excel Pivot Table based on vehicle length. The values returned by this calculation were used to create a histogram of the data (Figure 21).

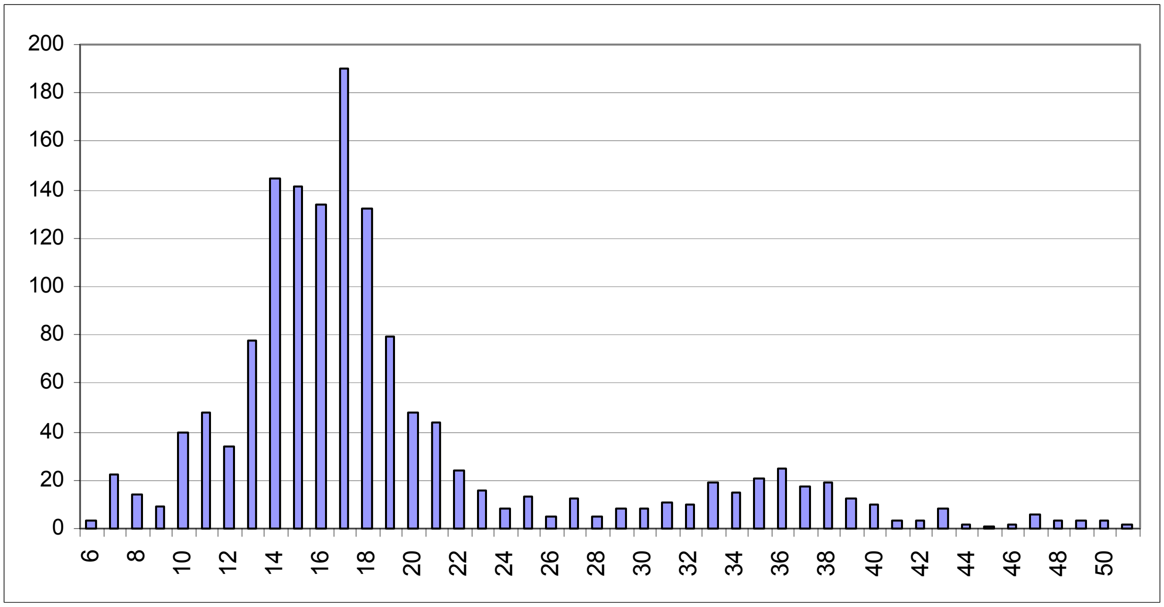


Figure 21: Autoscope Speed Detector Vehicle Length Histogram for Hour 14, Center Lane

Even though the vehicle lengths as reported by the Autoscope are incorrect, it was thought that their distribution would mimic the general vehicle length distribution. Using the manual data and a generalized vehicle histogram as guides, it was a straightforward process to make a 'cut' in the Autoscope vehicle length histogram and assign each side of the plot a designation as 'short vehicles' and 'long vehicles'. In the graph below, the cut was made at 30 feet. This resulted in a long vehicle count of 213, which compares favorable to the number of determined by the manual count, 205. For each hour of data, a histogram was made for both the shoulder and center travel lanes, and it was a requirement that the cut for each lane be made at the same place. For several hours of data, using the histogram method did not result in accurate data. For these segments of data, the second method of determining the number of long vehicle was used. This method simply looked at the number of long vehicles counted manually, and assigned the long vehicle designation to the same number of vehicles in the Autoscope speed detector counts, sorted by length. For example, Hour 18 produced a count of 196 long vehicles. The Autoscope data was then sorted by length, and the 196th longest vehicles were assigned the long vehicle designation. This produced oblique long vehicle plots that had similar increases in long vehicle flow (Figure 22).

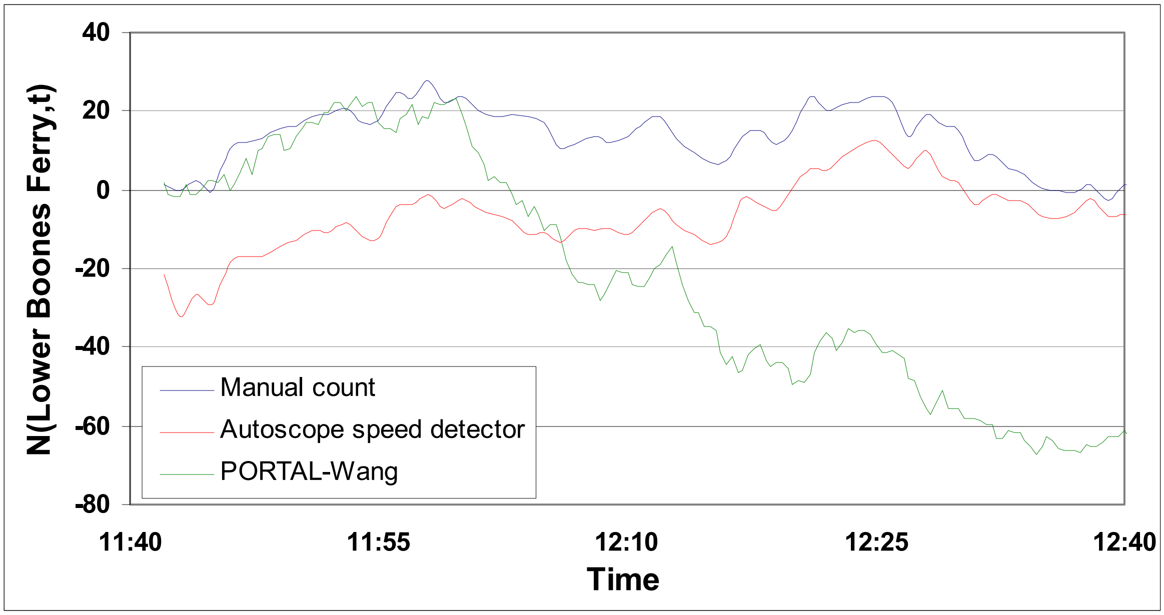


Figure 22: Cumulative Long Vehicle Count – Oblique Plot, Hour 21, Center Lane

3.6.5 Plotting Data

After the manual, Autoscope speed and count detector, PORTAL-Reported and PORTAL-Wang count data was processed, cumulative count plots were created. A scaling factor for each curve equal to the count values from the manual data was assigned for each curve in order to make a series of oblique plots. This scaling factor was divided by the number of 20-sec aggregation periods and then subtracted from the cumulative counts after each period to make the series of oblique curves. The resulting figures were then plotted against a time axis. Nine full sets of curves were produced, three for each of the three locations. These are located in Appendix A. Details on how each graph was produced is explained in more detailed in Section 4.2.

4.0 ANALYSIS

4.1 Calculating Truck Counts in PORTAL

Freeways all over the U.S. have inductive loop detectors installed in the roadway infrastructure. Archived loop detector data from the PORTAL project can be used as yet another tool for analyzing vehicle classification. Currently, the inductive loop detectors in the Portland freeway system are configured as dual-loop speed traps; however it is our understanding that they are currently functioning essentially as single-loop detectors by virtue of the way that speed is calculated. Dual-loop detectors have the technology to directly measure parameters such as speed and vehicle length, while single-loop detectors can only perform estimates based on an assumed average vehicle length. Currently in Portland, the measured count and occupancy values over 20-second periods are apparently used to calculate an average vehicle speed for the interval. With so many roadways already having single-loop detectors installed, or using dual-loop detectors as single-loop detectors, determining vehicle-classification can be rather challenging. Therefore, it is important for researchers to develop algorithms to estimate vehicle lengths and speeds from single-loop detector data. Such algorithms can be used for vehicle-classification and can replace or add to manual counting techniques.

Until the Portland freeway detectors can be reconfigured to take advantage of the dual loop speed traps for direct speed and vehicle length measurement, the algorithm developed by Wang and Nihan has been implemented within the PORTAL framework for counting truck volumes based on the effectively single-loop detector data [5] in PORTAL's data archiving system. With this algorithm integrated into PORTAL it is possible to use archived data to stress test the algorithm, and compare it with other data collection techniques, such as manual count, and video Autoscope counts.

4.1.1 Wang-Nihan Algorithm Description

The Wang-Nihan algorithm [5] was developed in 2003 and was based on earlier research by Wang and Nihan in 2001 and 2002 [1][8]. This section provides a summary of the Wang-Nihan algorithm. The Wang-Nihan study was conducted at the University of Washington and used the Washington State Department of Transportation's (WSDOT) loop detector data for experiments. The Wang-Nihan algorithm uses several steps to generate speed and vehicle-classification from single-loop data. The algorithm makes the assumption that speeds are constant within a 5-minute period and based on that assumption, an estimated speed is calculated for the period, and then the long vehicle volume for the 5-minute period is calculated.

The Wang-Nihan algorithm uses the concept of intervals and periods. An interval is a block of time within a period. Commonly, periods are 5-minutes long and intervals are 20-seconds. Along with WSDOT, the data set that the Wang-Nihan algorithm uses, the PORTAL-Wang calculations also use 20-second intervals and 5-minute periods.

Figuring out the estimated speed for a period is one of the first steps in the Wang-Nihan algorithm, since the vehicle-speed calculation is an input for the vehicle-classification algorithm. The speed calculation is based on Athol's speed calculation, [9], as shown in Equation (1) below.

In Equation (1), $\bar{s}(i)$ is estimated average speed, $N(i)$ is volume or count, and $O(i)$ is occupancy – all for time period i, T is the length of an interval, and g is the speed estimation parameter (or g-factor). The speed estimation parameter, g, is based on effective vehicle length or EVL.

The speed estimation parameter is so dynamic between time intervals that long vehicles tend to skew the mean EVL. With this problem in mind, the Wang-Nihan algorithm employs a method of sorting out intervals with long vehicles from intervals that do not have long vehicles in an effort to create a more accurate speed estimation for a given 5-minute period. Recall that the algorithm makes the assumption that speed remains constant throughout a period.

For every 5-minute period, the 20-second intervals are sorted into two different categories, intervals with short vehicles (SVs) and intervals with long vehicles (LVs). For the sake of the Wang-Nihan study a short vehicle is considered to be any vehicle 11.89 meters or less, and a long vehicle is anything greater. This SV-LV distinction was drawn based on Wang and Nihan's study of data from a WSDOT dual-loop detector on I-5 southbound (ES-163:MMD_T3) [5]. With a manual vehicle count techniques; there is always a "gray" area where the question is whether a vehicle is a SV or a LV. Therefore, when the Wang-Nihan algorithm is compared to other data collection techniques, such as manual counts or Autoscope counts, the line between SV and LV is not so clear. For the purposes of this study the data collection was matched with the lengths used in the PORTAL-Wang calculations.

$$\bar{s}(i) = \frac{N(i)}{T \cdot O(i) \cdot g} \qquad (1)$$

$$g(i)\frac{1}{\bar{l}(i)} \qquad (2)$$

The next step in calculating estimated 5-minute period speed is to separate intervals with LVs from intervals without LVs. The Wang-Nihan algorithm assumes that for every 5-minute period, there are at least two 20-second intervals with only SVs. This assumption is based on observations from WSDOT's dual-loop data. With this assumption, occupancy must be proportional to the EVL within each period. Using the two known SV-only intervals and the occupancy proportion, the EVL for an interval can be calculated, the EVL is used in turn to calculate an estimated speed for the 5-minute period (recall speed is assumed to be constant within 5-minute periods). This estimation is done by taking the summed SV volume and occupancy and using Athol's speed estimation equation, Equation (3). In this equation, $\bar{s}(j)$ is average speed for a period, $N_{sv}(j)$ and $O_{sv}(j)$ are, respectively, total volume and occupancy for (the two) intervals with short-vehicles only.

$$\bar{s}(j) = \frac{N_{SV}(j)}{O_{SV}(j) \cdot g} \qquad (3)$$

Since different single-loop detectors vary in their physical parameters, each must have a different speed estimation parameter, g. Wang and Nihan suggest calculating a correction coefficient for each detector, called Beta and defining the *g*-factor as shown in Equation (4). For the PORTAL-Wang study Beta is assumed to be 1. This study has verified that setting Beta equal to 1 is a reasonable assumption based on volume-occupancy graphs from PORTAL. An example of such a graph is shown below, Figure 23. In future research, further tests for Beta values will be conducted. For single loop stations where speed is unknown, one can choose a time period when traffic is free flowing. Free flow speed can be easily estimated based on local drivers' experience. Then Beta can be calculated with the estimated free flow speed. Also, if a PORTAL reported speed is measured by a dual loop, it can be used as ground truth speed to calculate Beta.

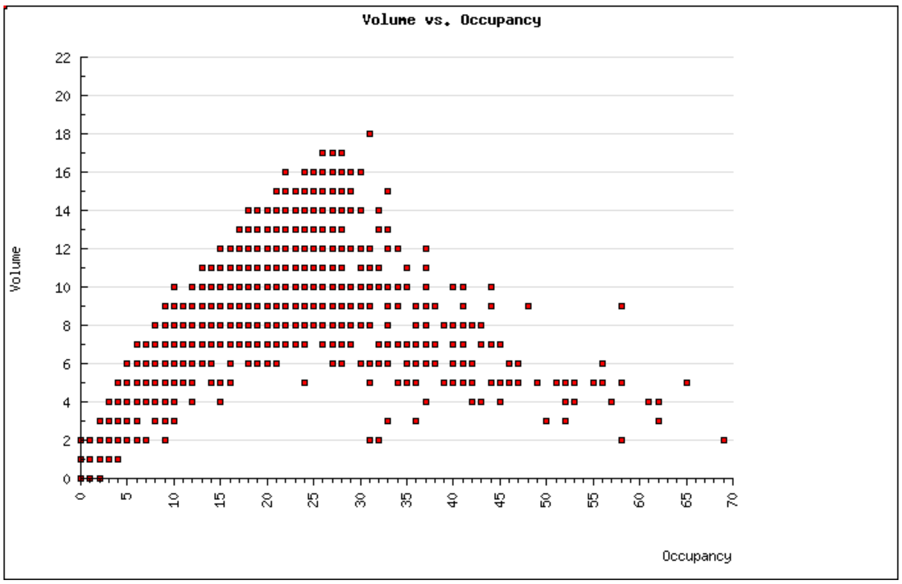


Figure 23: Dec 16, 2005, between 0:00-24:00, for WB I-84 Milepost 2.4, Sandy Blvd, Lane 1.

$$g = \frac{1}{\beta \bar{l}_{SV}} \quad (4)$$

With a known period speed calculation we the total interval counts can be divided into SV and LV counts in order to determine how many SVs and LVs are in each interval. From Equation (5) one is able to calculate an estimated EVL for any interval in a period. In Equation (5) $\bar{l}_k(j)$ is estimated EVL for the interval, $O_k(j)$, $N_k(j)$ are, respectively, measured occupancy and count for the interval and s(j) is estimated speed for the interval.

From the estimated EVL for an interval for each vehicle counted in the interval the determination must be made whether it is a short vehicle or a long vehicle. From the observations made by Wang-Nihan, it has been determined that for any one interval, (assuming 20-second intervals), there can be no more than 7 LVs. If the volume is over 7 it is assumed that there was no presence of LVs. It is known from the volume how many possible SV-LV categorizations there can be for one interval, if volume is less than or equal to 7. Volume plus one represents the number of categories. From an example in Wang and Nihan [5] if there was a count of 3 vehicles, the known possible categorizations are as shown in Table 3 below.

Short Vehicles	Long Vehicles	Total
3	0	3
2	1	3
1	2	3
0	3	3

Table 3: Possible Distributions of Short and Long Vehicles with 3 Total Vehicles

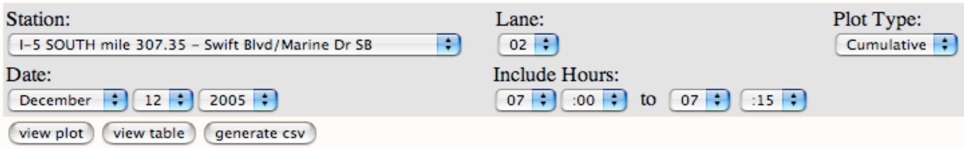
$$\bar{l}_k(j) = \frac{O_k(j) \cdot \bar{s}(j)}{N_k(j) \cdot \beta} \quad (5)$$

From Equation (5) the estimated EVL of the current interval is known and from the estimated EVL a statistical process is used to determine the most likely distribution of vehicles (short vs. long) in each interval. Thus the estimated truck volume can be determined for each interval.

$$d_{kx}(j) = \left| \frac{\bar{l}_k(j) - l_{loop} - \mu_{kx}(j)}{\sigma_{kx}(j)} \right| \text{for } x = 0, 1, \ldots\ldots, \min(N_k(j), 7) \quad (6)$$

4.1.2 Implementation in PORTAL

Using the Wang-Nihan algorithm described above and the Portland State University PORTAL project's data archive, studies of vehicle classification are possible with only a few interactions with the PORTAL website. The PORTAL-Wang algorithm implementation is found on the PORTAL website under the vehicle classification tab. A user can log in and choose a day, a time, and a duration and the website will query the archived data and produce a graph, a Table or a comma separated value (CSV) file.



Start Time	Volume	Occupancy	Truck Count	Car Count	Odot Speed	Estimated Speed
2005-12-12 07:00:00-08	5	38	2	3	24	26
2005-12-12 07:00:20-08	7	40	2	5	24	26
2005-12-12 07:00:40-08	6	42	3	3	24	26
2005-12-12 07:01:00-08	9	39	2	7	24	26
2005-12-12 07:01:20-08	7	35	1	6	24	26
2005-12-12 07:01:40-08	8	28	0	8	24	26
2005-12-12 07:02:00-08	6	14	0	6	24	26
2005-12-12 07:02:20-08	7	17	0	7	24	26
2005-12-12 07:02:40-08	8	27	0	8	24	26
2005-12-12 07:03:00-08	10	30	0	10	24	26
2005-12-12 07:03:20-08	5	35	2	3	24	26
2005-12-12 07:03:40-08	6	35	2	4	24	26
2005-12-12 07:04:00-08	5	30	1	4	24	26
2005-12-12 07:04:20-08	5	37	2	3	24	26
2005-12-12 07:04:40-08	8	28	0	8	24	26
2005-12-12 07:05:20-08	7	45	0	7	21	16
2005-12-12 07:05:40-08	8	33	1	7	21	16

Figure 24: Dec 12, 2005, Between 7:00-7:15, for Southbound I-5 Milepost 307.35 (Marine Drive), Lane 2, an Example of a Tabular Output from PORTAL's Comparison Section.

Should the user query the database and request table output they would receive such a table as shown in Figure 24. Currently, PORTAL displays seven columns in its table output including start time, volume, occupancy, truck count, car count, ODOT speed, and estimated speed. The data displayed in the table output is at a 20-second resolution; no aggregation is implemented for the table output. The Volume and Occupancy columns display the measured volume and occupancy reported by the ODOT loop detector systems. Note that Volume is the total measured volume for an interval. The Truck Count and Car Count columns provide the estimated number of LVs and SVs in the interval, respectively. Truck Count and Car Count are based on the Wang-Nihan algorithm calculations. The sum of the Car Count and Truck Count columns should equal the Volume column. The Estimated Speed column reports the estimated speed for an entire 5-minute period based on the Wang-Nihan algorithm. This estimated speed is used as input to the truck count algorithm. The ODOT Speed column reports the average of the speeds reported from the ODOT system over the 5-minute period. As expected, it is shown that the current ODOT speeds tend to be underestimated due to the added occupancy contributed by the LVs in each period. This has been a problem that is exacerbated during low traffic flow periods (for example, over night) when a single truck in an interval can result in a very low speed being reported.

In the future, PORTAL plans to study the differences between the estimated speed calculation using the Wang algorithm and the speed calculation provided by ODOT. Such a study between ODOT's speed estimation and the Wang-Nihan algorithm would help detect faulty detectors on the road, and give better insight on calculating the detector correction coefficient.

If a user chooses his or her output to be a CSV file they will receive the same output as if they choose to view a table. The idea behind a CSV file is that a user can take the data and input it into another analysis tool such as Microsoft Excel or Matlab.

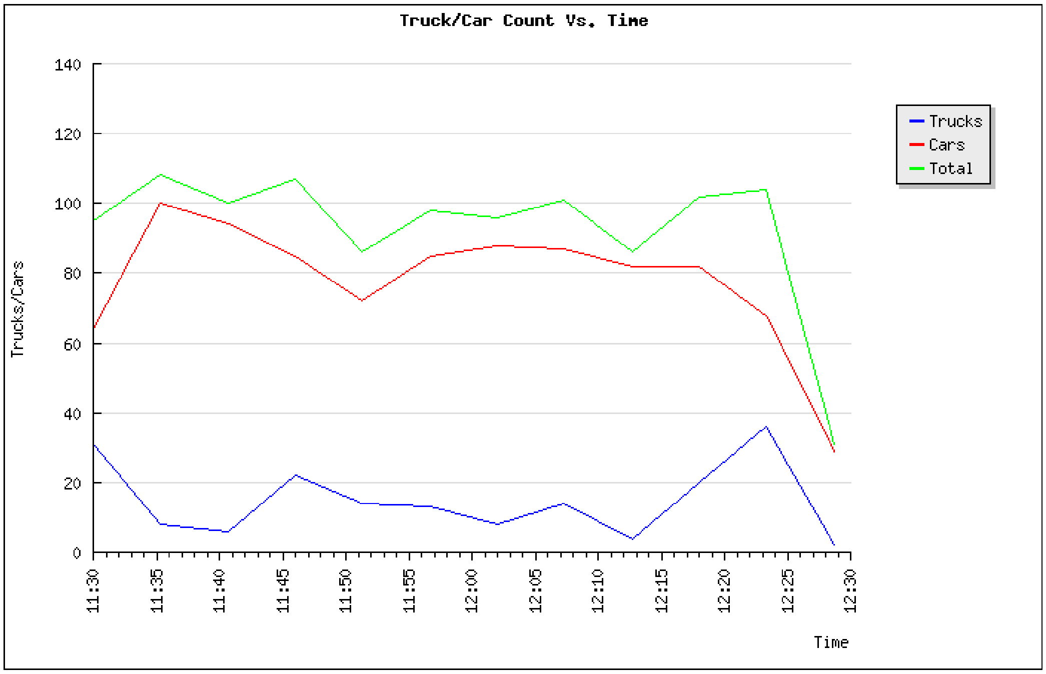


Figure 25: August 26, 2005, Between 11:30-12:30, Southbound I-5 Milepost 307.35 (Marine Drive), Lane 2, an Example of a Line Plot Output from PORTAL's Comparison Section

With any of the PORTAL-Wang output types a user also has the choice to choose a particular lane they want to study or all lanes at once. With the display table option and the CSV file option if the user chooses to have all lanes displayed for each time interval there will be a row for each lane. Should the user specify a particular lane the table will only include rows pertaining to the selected lane.

The plotting functionality, shown in Figure 25, is the most useful for viewing trends and looking at an overview of the data over a course of a time period. The PORTAL-Wang plots, shown in Figure 25, are plots of the count totals for each 5-minute period. For example, in the period 11:30-11:35 there were approximately 30 trucks, 65 cars, and 95 total vehicles. In addition, the user has the option of choosing the type of plot he or she wants to produce. Currently, the user can choose from a line plot or a cumulative plot, as shown in Figure 25 and Figure 26 respectively. Depending on the user's interest one plot maybe more powerful than the other. Also, much like the other two forms of output types the user may chose between all lanes or one lane in particular for a selected detector station.

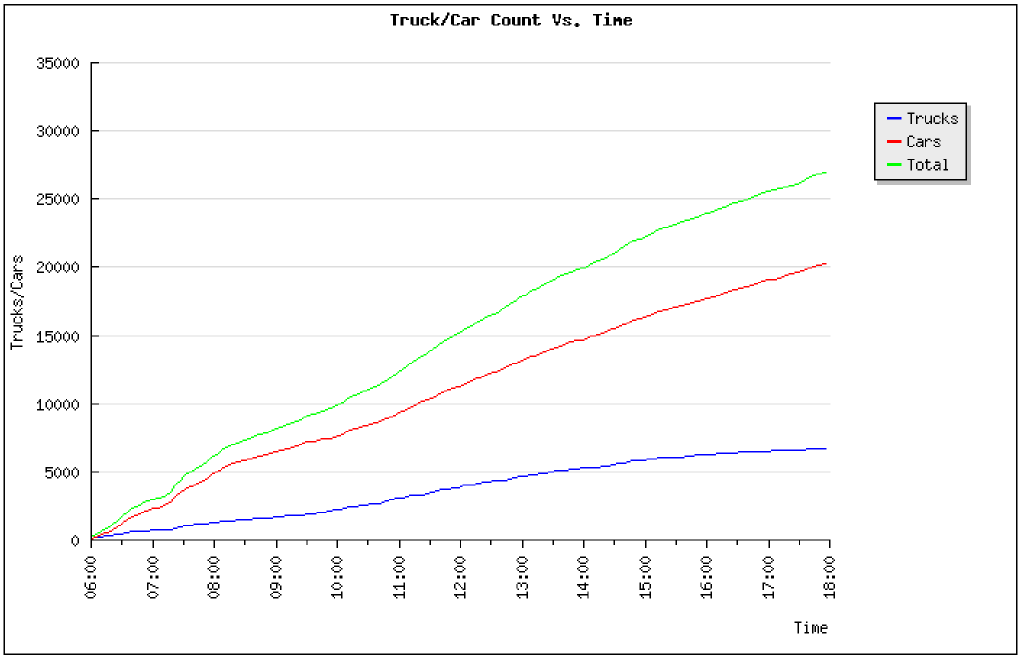


Figure 26: December 5, 2005, Between 6:00-18:00, Northbound I-5, Milepost 296.6 (Multnomah Blvd), All Lanes, an Example of a Cumulative Plot Output from PORTAL's Comparison Section

It is hoped that PORTAL will provide traffic researchers the ability to quickly glance at traffic or study deeply the affects of LVs and SVs on traffic flow. With the newness of vehicle classification PORTAL intends to use its online system to help validate algorithms and vehicle detection tools. Future additions to the PORTAL vehicle classification features includes but not limited to; adding other truck count algorithms, adding percent truck graphs and tables, and possible data fidelity studies. Figure 27 is an example plot showing truck percentages for a day at one of the study locations. Figure 28 provides a contour plot of truck volume percentage for the I-5 Northbound corridor on Dec 15, 2005; the graph shows data at a 5-minute aggregation level. For I-5 Northbound on Dec 15, 2005, the average percent trucks in a 5-minute period was 14.35%, with a standard deviation of 12.57%. The volume-weighted average truck percentage for 5-minute periods for the entire day was 18%, with a standard deviation of 13.09%. Figure 29 shows the same contour plot as Figure 28 (truck percentage for I-5 Northbound Dec 15, 2005), but the data are interpolated instead of faceted.

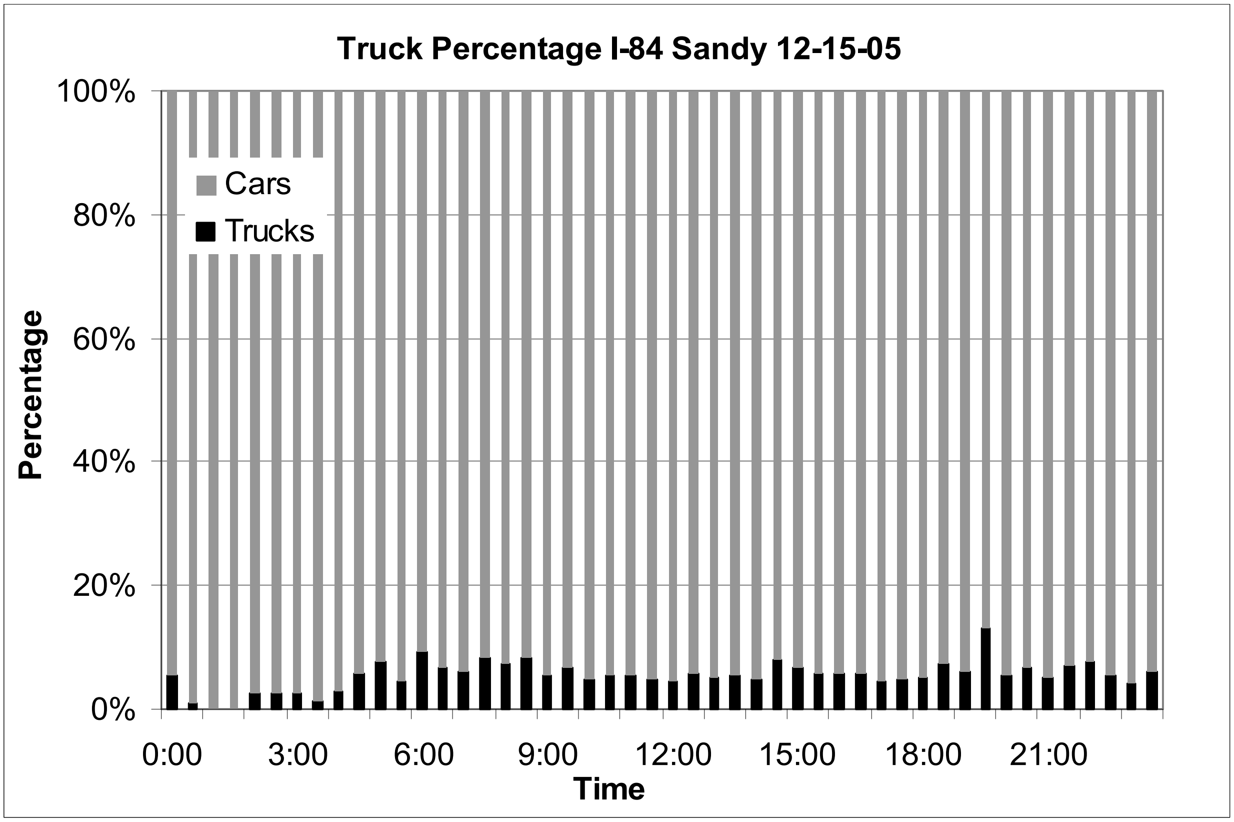


Figure 27: Hourly Truck (Long Vehicle) Percent I-84 Westbound at Sandy Blvd, Dec 15, 2005

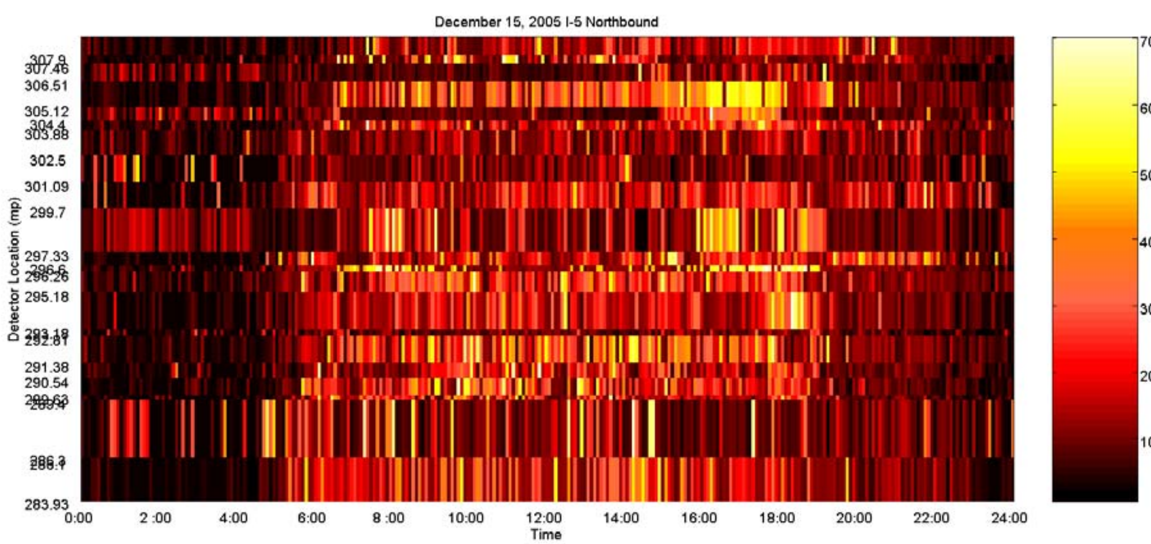


Figure 28: Truck Percent Contour Plot: I-5 Northbound, Dec 15, 2005

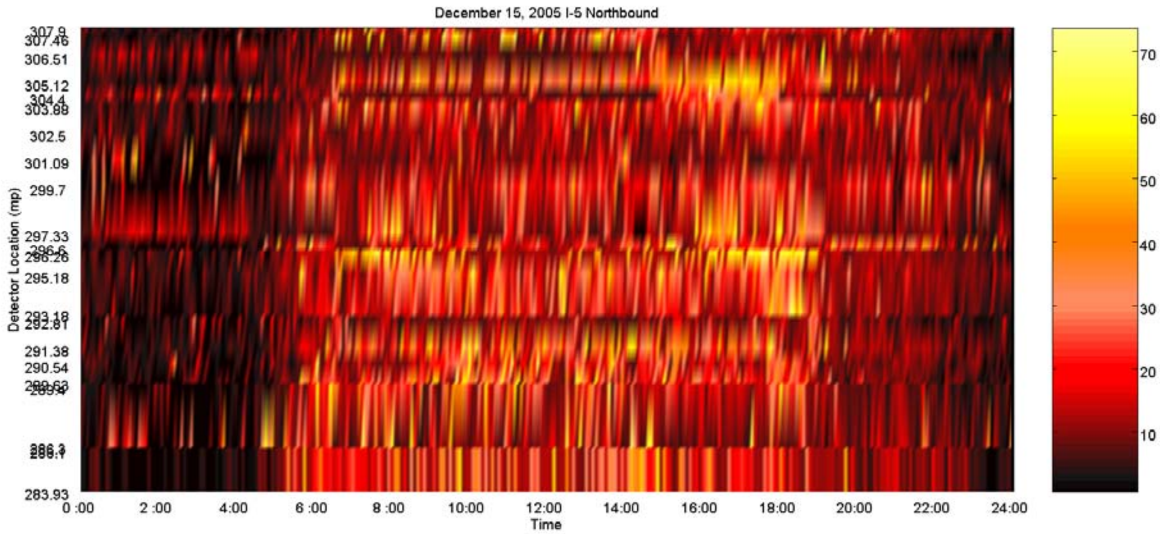


Figure 29: Truck Percent Contour Plot (interpolated): I-5 Northbound, Dec 15, 2005

4.2 Summary of Collected Data

Table 3 contains a summary of all of the data collected for this research project. As shown a total of 47 units of data were collected from the three study sites during October and February 2006. The length of the time periods for each data unit ranged between 30 minutes and one hour. The original intent was to collect one hour of data for each unit, but due to various external constraints, some were shortened. The Manual column contains the “ground truth” data for each data unit, including separate total counts for all vehicles and for long vehicles (henceforth for this research referred to as trucks). The difference between the values for all vehicles and for trucks is the number of cars observed.

The next several columns in Table 3 list the Autoscope count data—the first column includes the total vehicle counts measured by the count detector, and the following two columns include the total vehicle and truck counts using the Autoscope speed detector. The next eight columns contain data extracted from PORTAL with its implementation of the Wang-Nihan algorithm for estimating long vehicle counts and improving loop detector speeds. The first two columns (only for data units where PORTAL data were available) list the total vehicular count measured by the loop detectors (in 20-second intervals) as well as the total truck count extracted from PORTAL. The next two columns contain the prevailing vehicular flow measured over the particular loop detector for the time period of interest, and the measured loop detector speed. The following column contains the variance of the speed measurements reported by the loop detector, which is followed by a tabulation of the variance to mean ratio of the speeds. These values will be used below in some additional analysis. The next column contains the improved vehicular speed as a result of the implementation of the Wang-Nihan algorithm followed by a column containing the variance of that speed over each data unit’s time period. The last column is the mean speed measured by Autoscope for all vehicles. As shown in Table 3, more than 62,000 vehicles were counted during this empirical experiment, including more than 3,900 trucks.

No.	Length	Route	Site	Lane	Date	Time	Manual		Autoscope	Autoscope V		Portal-Wang		Portal	ODOT	Var	Var to	Speed	Variance	Speed
							All	Trucks	All	All	Trucks	All	Trucks	Flow	Speed	ODOT	Mean	Wang	Wang	Autoscope
1	30m	I-5S	Marine	Center	10/25/20	14:18:00-14:48:00	615	110	677	649	108	612	65	1210	49.0	44.4	0.9	56.3	27.8	54.7
2	30m	I-84W	Sandy	Center	10/28/05	12:10:00-12:40:00	833	64	842	840	64	853	42	1690	58.3	24.6	0.4	162.7	247.7	51.1
3	1h	I-84W	Sandy	Center	10/28/05	13:00:08-14:00:08	1749	162	1752	1742	162	1731	131	1790	60.4	36.0	0.6	160.7	434.7	55.2
4	1h	I-84W	Sandy	Shoulder	10/28/05	13:00:08-14:00:08	1398	58	1357	1357	58	--	--	--	--	--	--	--	--	56.7
5	55m	I-84W	Sandy	Center	10/28/05	14:00:08-14:55:08	1572	96	1683	1679	96	1601	85	1740	59.9	37.1	0.6	161.8	209.8	55.3
6	55m	I-84W	Sandy	Shoulder	10/28/05	14:00:08-14:55:08	1233	47	1304	1304	47	--	--	--	--	--	--	--	--	57.6
7	1h	I-5S	Marine	Center	12/6/05	12:33:30-13:33:30	1259	238	1297	1287	209	--	--	--	--	--	--	--	--	62.3
8	1h	I-5S	Marine	Shoulder	12/6/05	12:33:30-13:33:30	742	31	744	730	28	--	--	--	--	--	--	--	--	60.8
9	1h	I-5S	Marine	Center	12/6/05	13:33:30-14:33:30	1193	217	1212	1200	191	--	--	--	--	--	--	--	--	61.8
10	1h	I-5S	Marine	Shoulder	12/6/05	13:33:30-14:33:30	690	34	675	671	36	--	--	--	--	--	--	--	--	60.1
11	1h	I-84W	Sandy	Center	12/7/05	12:19:00-13:19:00	1629	161	1635	1630	161	1350	112	1620	60.4	0.1	0.0	184.0	2463.0	59.1
12	1h	I-84W	Sandy	Center	12/7/05	13:19:00-14:19:00	1603	114	1604	1601	114	1549	95	1620	61.5	47.9	0.8	169.7	327.0	59.7
13	1h	I-84W	Sandy	Center	12/7/05	15:30:00-16:30:00	1547	59	1560	1553	70	--	--	--	--	--	--	--	--	55.8
14	1h	I-84W	Sandy	Shoulder	12/7/05	15:30:00-16:30:00	1215	29	1211	1205	33	--	--	--	--	--	--	--	--	57.5
15	30m	I-84W	Sandy	Center	12/7/05	16:31:40-17:00:00	773	26	804	800	30	747	51	1560	58.3	48.0	0.8	185.0	858.0	56.3
16	30m	I-84W	Sandy	Shoulder	12/7/05	16:30:00-17:00:00	663	14	615	612	14	--	--	--	--	--	--	--	--	58.4
17	55m	I-5S	Marine	Center	12/9/05	13:43:00-14:40:00	1182	143	1262	1196	153	1231	177	1300	48.5	61.8	1.3	71.3	246.7	56.2
18	55m	I-5S	Marine	Shoulder	12/9/05	13:43:00-14:40:00	721	39	780	691	39	1302	92	1370	65.0	48.3	0.7	69.2	109.5	53.3
19	1h	I-84W	Sandy	Center	12/12/05	13:06:00-14:06:00	1699	118	1714	1702	109	1752	152	1740	61.2	26.4	0.4	171.5	728.4	57.4
20	1h	I-84W	Sandy	Shoulder	12/12/05	13:06:00-14:06:00	1287	51	1271	1262	51	--	--	--	--	--	--	--	--	58.9
21	1h	I-84W	Sandy	Center	12/12/05	14:06:00:15:06:00	1642	124	1624	1617	126	1674	134	1670	61.2	31.0	0.5	184.2	1002.1	54.5
22	1h	I-84W	Sandy	Shoulder	12/12/05	14:06:00:15:06:00	1366	53	1341	1337	53	--	--	--	--	--	--	--	--	56.1
23	1h	I-5N	Boones	Center	12/14/05	13:25:00-14:25:00	1403	205	1480	1469	213	1418	211	1430	60.7	35.4	0.6	71.5	445.0	63.1
24	1h	I-5N	Boones	Shoulder	12/14/05	13:25:00-14:25:00	1560	168	1533	1533	169	1558	164	1570	56.0	29.1	0.5	63.7	355.5	59.9
25	1h	I-5N	Boones	Center	12/14/05	15:26:00-16:26:00	1552	161	1562	1506	163	1540	177	1530	58.9	40.2	0.7	67.5	74.7	69.3
26	1h	I-5N	Boones	Shoulder	12/14/05	15:26:00-16:26:00	1835	99	1769	1760	97	1879	149	1870	55.6	32.9	0.6	63.8	27.9	65
27	30m	I-5N	Boones	Center	12/14/05	16:56:00-17:26:00	782	89	829	818	88	780	88	1540	47.5	104.6	2.2	50.5	7.5	50.7
28	30m	I-5N	Boones	Shoulder	12/14/05	16:56:00-17:26:00	940	37	874	871	37	894	86	1770	41.7	176.7	4.2	46.6	137.8	45.7
29	1h	I-5S	Marine	Center	12/15/05	12:14:00-13:14:00	1214	196	1186	1226	196	1212	317	1210	40.6	110.5	2.7	86.5	1801.9	49.4
30	1h	I-5S	Marine	Center	12/15/05	13:14:00-14:14:00	731	88	844	760	88	738	141	740	47.4	156.1	3.3	96.6	895.0	41.7
31	30m	I-5N	Boones	Center	12/18/05	12:50:00-13:20:00	724	24	733	729	30	712	40	1420	61.0	31.0	0.5	65.7	22.3	58.6
32	30m	I-5N	Boones	Shoulder	12/18/05	12:50:00-13:20:00	871	19	877	873	22	876	43	1750	57.1	26.5	0.5	61.3	12.0	57.4
33	1h	I-5N	Boones	Center	12/20/05	11:42:00-12:42:00	1489	197	1520	1482	197	1445	243	1480	57.9	47.9	0.8	97.4	739.3	63.1
34	1h	I-5N	Boones	Center	12/20/05	12:42:00-13:42:00	1455	207	1567	1539	207	1388	338	1470	55.2	31.7	0.6	101.2	850.0	57
35	1h	I-5N	Boones	Shoulder	12/20/05	12:42:00-13:42:00	1609	139	1595	1588	139	1531	121	1620	50.8	29.8	0.6	54.0	82.3	54.8

36	1h	OR-217S	Hall	Median	2/13/06	13:56:00-14:56:00	1627	7	--	--	--	1585	81	1560	63.7	21.6	0.3	86.4	179.6	--
37	1h	OR-217S	Hall	Center	2/13/06	13:56:00-14:56:00	1655	51	--	--	--	1684	103	1690	58.7	18.4	0.3	67.8	104.3	--
38	1h	OR-217S	Hall	Median	2/13/06	14:56:00-15:56:00	1897	8	--	--	--	1787	78	1780	62.8	20.6	0.3	78.3	27.8	--
39	1h	OR-217S	Hall	Center	2/13/06	14:56:00-15:56:00	1643	66	--	--	--	1708	84	1690	58.6	19.8	0.3	62.7	32.4	--
40	1h	OR-217S	Hall	Median	2/15/06	11:30:00-12:30:00	1465	10	--	--	--	1419	121	1420	61.9	24.0	0.4	109.2	435.4	--
41	1h	OR-217S	Hall	Center	2/15/06	11:30:00-12:30:00	1639	62	--	--	--	1637	103	1640	57.1	24.8	0.4	67.3	61.6	--
42	1h	OR-217S	Hall	Median	2/15/06	12:30:00-13:30:00	1596	9	--	--	--	1493	125	1510	62	30.8	0.5	112.7	537.6	--
43	1h	OR-217S	Hall	Center	2/15/06	12:30:00-13:30:00	1647	57	--	--	--	1684	138	1680	56.9	22.2	0.4	72.7	182.7	--
44	1h	OR-217S	Hall	Median	2/17/06	11:00:00-12:00:00	1631	8	--	--	--	1528	119	1530	62.4	27.2	0.4	104.6	469.1	--
45	1h	OR-217S	Hall	Center	2/17/06	11:00:00-12:00:00	1636	43	--	--	--	1688	95	1690	56.1	22.5	0.4	62.3	54.0	--
46	1h	OR-217S	Hall	Median	2/17/06	12:00:00-13:00:00	1693	6	--	--	--	1576	96	1580	62.3	22.9	0.4	95.9	197.5	--
47	1h	OR-217S	Hall	Center	2/17/06	12:00:00-13:00:00	1662	42	--	--	--	1724	92	1730	56.5	21.8	0.4	59.2	13.8	--
TOTALS							**62567**	**3986**	**43333**	**42819**	**3598**									

Table 3: Summary of Collected Data

Also in Table 3, it should be noted that there were no detector data available for the days analyzed for the Sandy shoulder lane, and several other time periods were marred by lack of PORTAL data due to malfunctions and loss of communications.

4.3 Prototypes of Graphical Analysis

For each video segment (1 hour or 30 minutes in length), for each lane of traffic, one set of 8 separate graphs was made. The eight plots can be placed into four groups of 2. Each group consists of a cumulative plot of either volume or speed, and a corresponding oblique plot using the same variable. The cumulative plots, for a specific location, show the passage of vehicles past the loops detectors graphed against a time axis. The oblique plots show the difference between the cumulative data and a scaling factor. Oblique plots of data other than the PORTAL-Reported data are aggregated into 1-minute chunks. PORTAL-Reported data remain in their 20-second aggregations. Oblique plots are useful in determining and describing trends between different sets of data and can illustrate traffic patterns that are not otherwise seen on a standard cumulative plot.

4.3.1 Cumulative Vehicle Count

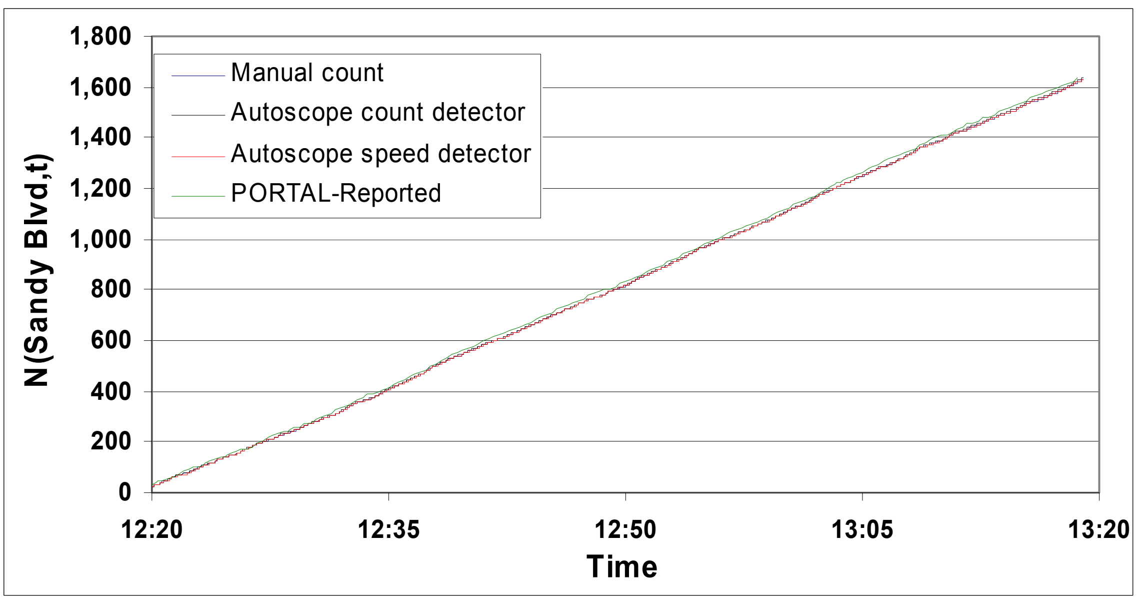


Figure 30a: Cumulative Vehicle Count

Figure 30a displays four sets of volume data: manual counts, Autoscope count and speed detectors counts and PORTAL-Reported counts. The cumulative count of all vehicles passing a point is shown against a time axis. All counts except for the PORTAL-Reported data are instantaneous recordings of the passage of a vehicle. The PORTAL-Reported counts are aggregated to 20-second periods.

4.3.2 Cumulative Vehicle Count - Oblique Plot

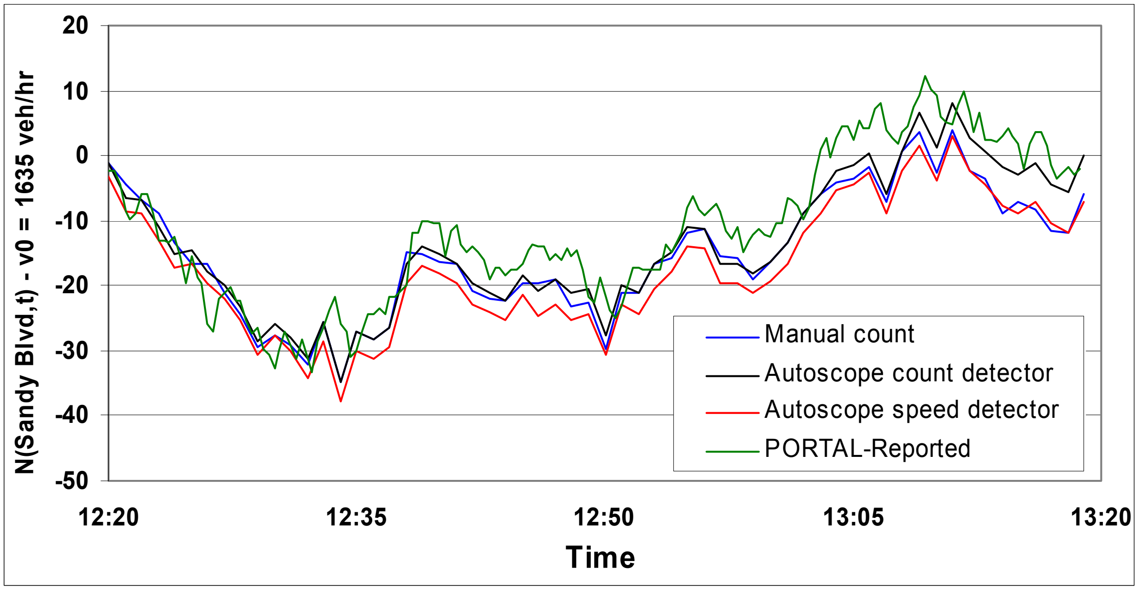


Figure 30b: Cumulative Vehicle Count – Oblique Plot

Figure 30b is made by subtracting a scaling factor from the cumulative counts. The scaling factor for this plot is determined by using the largest total number of vehicles from one of the four count methods. In the plot above, the scaling factor, referred to as v_0, is 1635 vehicles/hour. For each data point, either at the 1-minute or 20-second aggregation level, the cumulative number of vehicles is subtracted from the scaling factor divided by the time unit. The resultant plot above reveals that over the one-hour period, similar deviations from the average cumulative count of vehicles over that hour is relatively similar for each of the four data sets.

4.3.3 Cumulative Long Vehicle Count

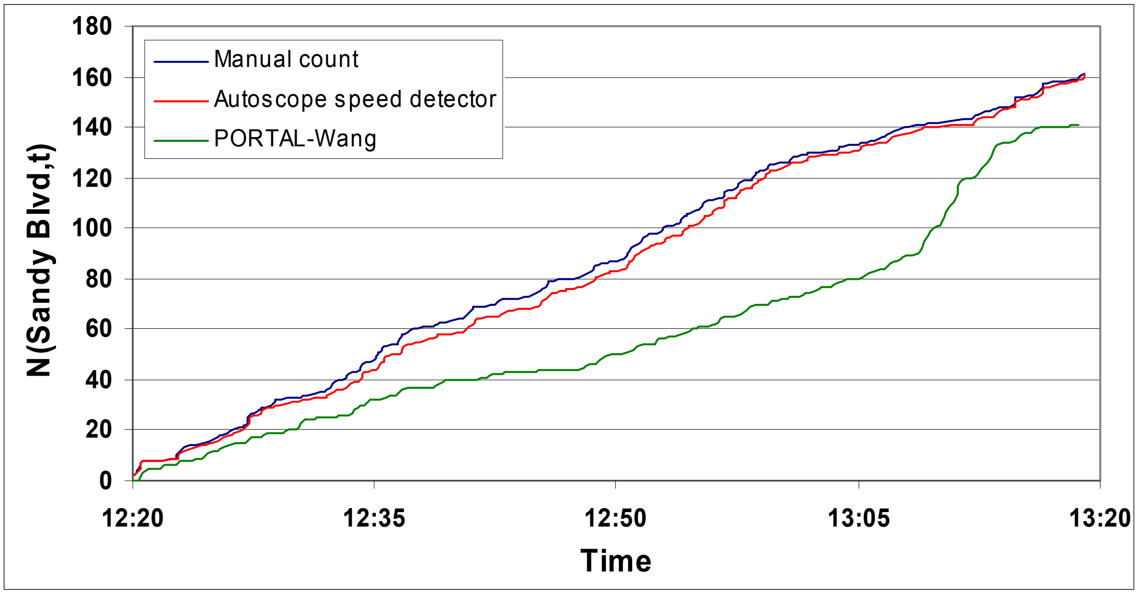


Figure 30c: Cumulative Long Vehicle Count

Figure 30c is similar to plot a, except that only long vehicles are considered. Manual count data is derived from the long and short vehicles that were identified during the manual count process. The previously mentioned difficulties with the camera position at all locations resulted in vehicle length figures that are well short of the true lengths of long vehicles. For example, during this hour, 161 trucks were counted manually. Clearly this figure is incorrect. Using the manual count as the best estimate for the presence of long or short vehicles, the vehicles were sorted in descending order of length, and the top 161 vehicles were considered 'long' and the rest of the vehicles were considered 'short.' The 161 vehicles were sorted by arrival time, and plotted cumulatively in one-minute aggregations, similar to the manual count data. The PORTAL-Wang data were then plotted as a third data series for comparison.

4.3.4 Cumulative Long Vehicle Count – Oblique Plot

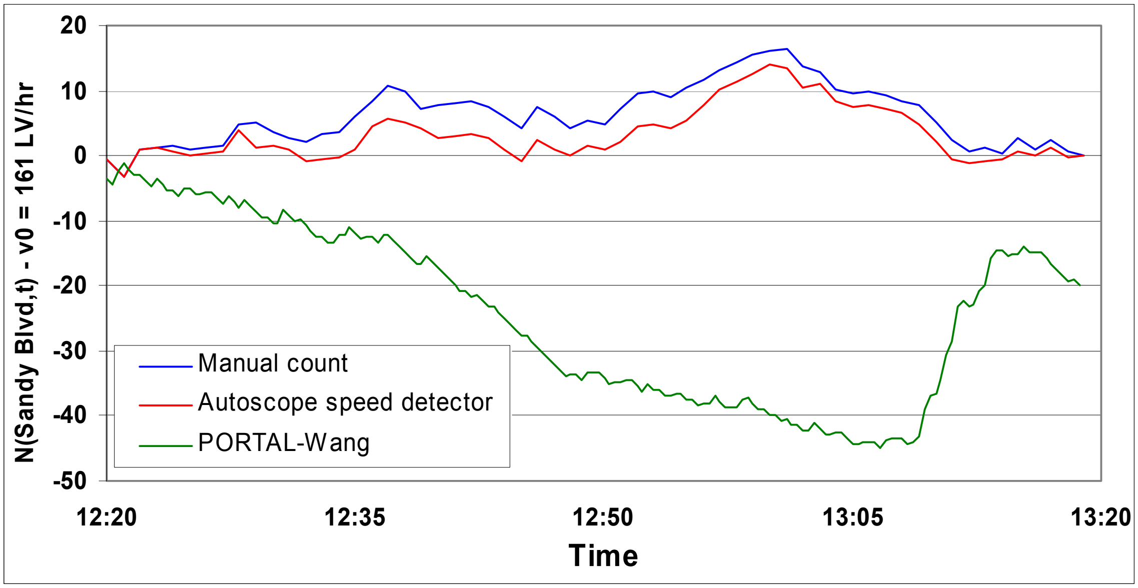


Figure 30d: Cumulative Long Vehicle Count – Oblique Plot

Figure 30d uses the number of long vehicles in the manual count as the scaling factor. The cumulative count of long vehicles is subtracted from the scaling factor to produce the oblique plot above. This is done for all three estimates of long vehicles: the manual count, the Autoscope speed detector and the PORTAL-Wang data.

4.3.5 Cumulative Short Vehicle Count

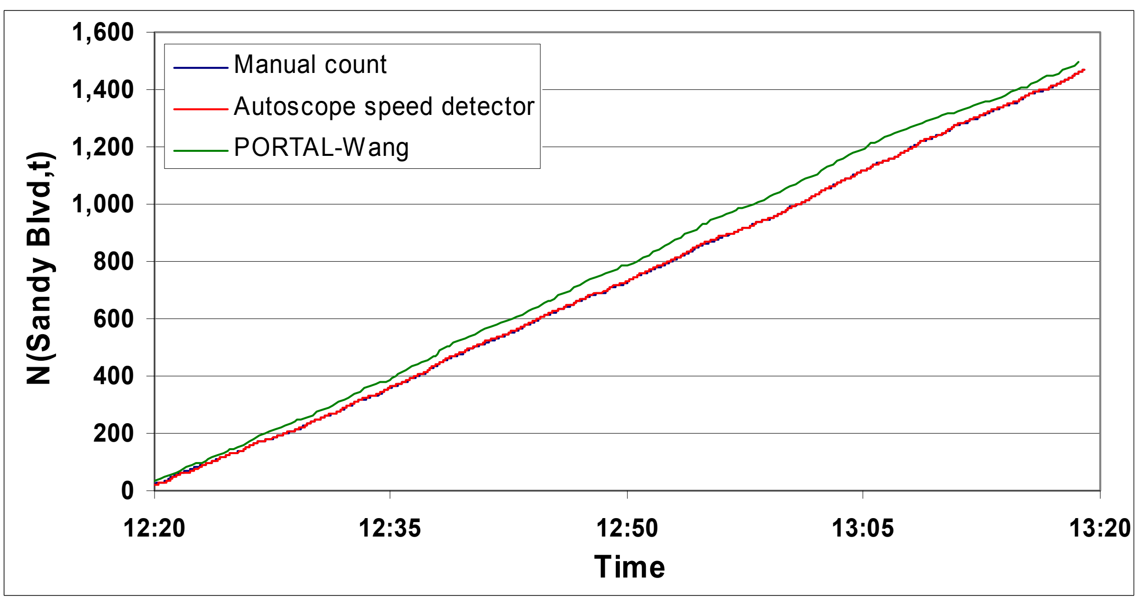


Figure 30e: Cumulative Short Vehicle Count

Similar to Figure 30c, the cumulative count of short vehicles uses the data derived during the manual count to plots all vehicles shorter than 35 feet. The Autoscope data was derived by removing the longest set of vehicles according to the number found in the manual long vehicle count. The remaining vehicles were considered short. (After several iterations, it might be possible to use a cutoff point for each of the three sites in terms of what the Autoscope considered long or short). The PORTAL-Wang algorithm, in addition to producing estimates of long vehicles, also produces a complementary set of data for short vehicles. These two sets of data always equal to the total volume recorded by the inductive loop detectors. Similar to the overall vehicle count, it is not surprising to see substantial overlap of all counts in the above graph due to the large number of vehicles counted during the hour. Small differences in flow changes are best seen by the next plot.

4.3.6 Cumulative Short Vehicle Count – Oblique Plot

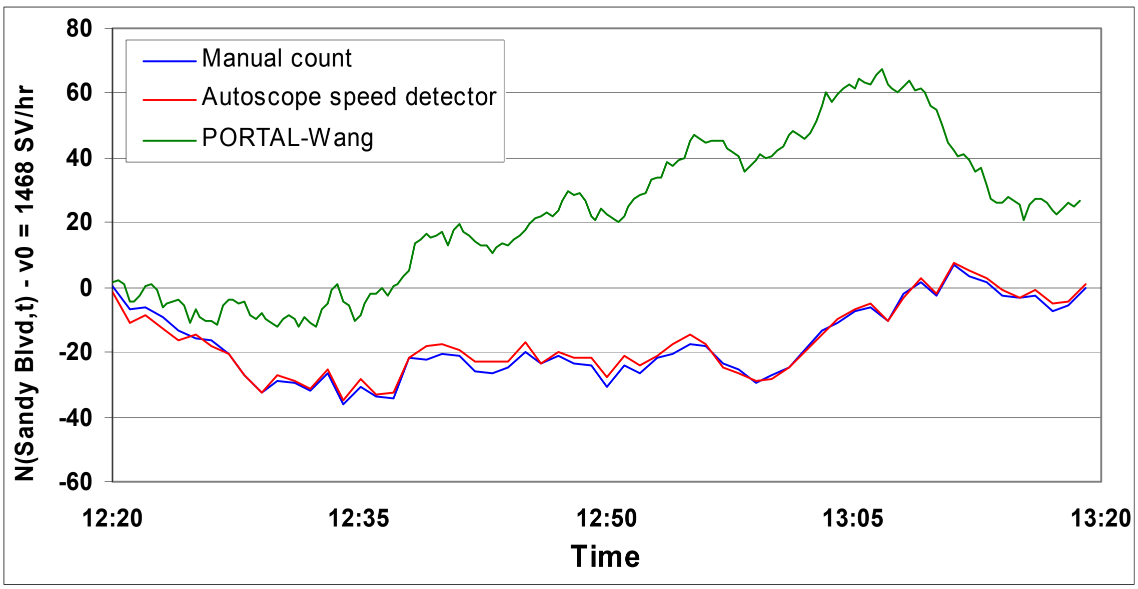


Figure 30f: Cumulative Short Vehicle Count – Oblique Plot

Figure 30f is an oblique plot that was created in the same manner as the cumulative long vehicle oblique plot. A scaling factor is used, in this case 1468 vehicles/hour, to show small deviations from an average number of vehicles passing the detector over an hour.

4.3.7 Cumulative Vehicle Speeds

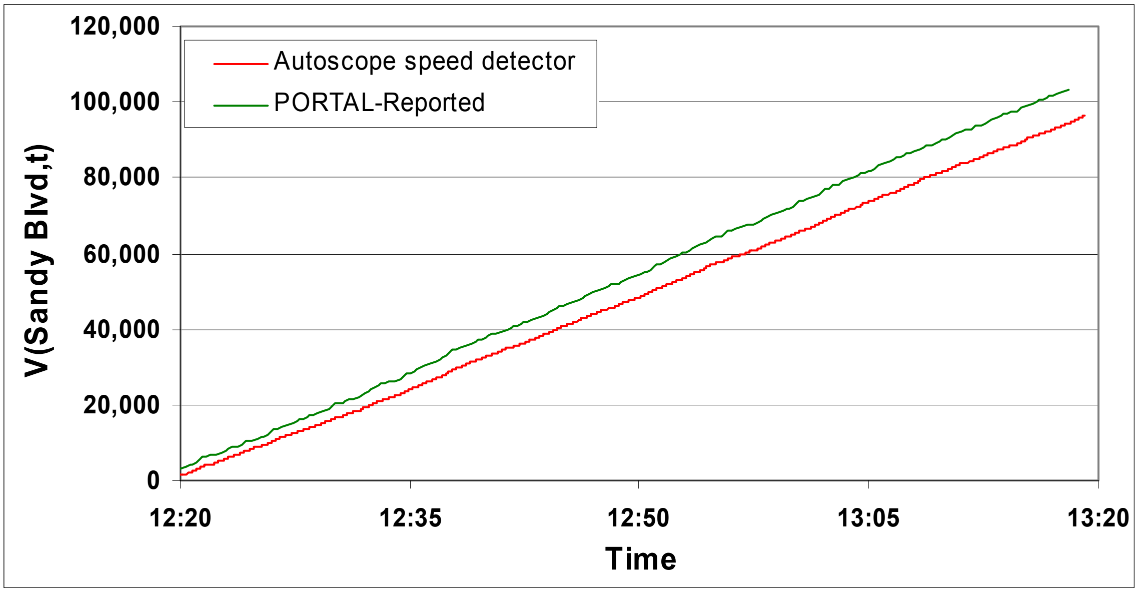


Figure 30g: Cumulative Vehicle Speeds

Figure 30g is a cumulative plot of all vehicle speeds over a time period. There is no manual count component to this plot, as there is not an accurate way available to measure vehicle speeds by hand. The Autoscope speed detectors readings for each passing vehicle are summed together over time and plotted. PORTAL reports speeds as a 5-minute aggregation average: speeds are the same for each vehicle that travels during the 5 minutes. This speed is then multiplied by the volume for each 20-second period and plotted as above. An oblique plot will show the variations in speed over time.

4.3.8 Cumulative Vehicle Speeds – Oblique Plot

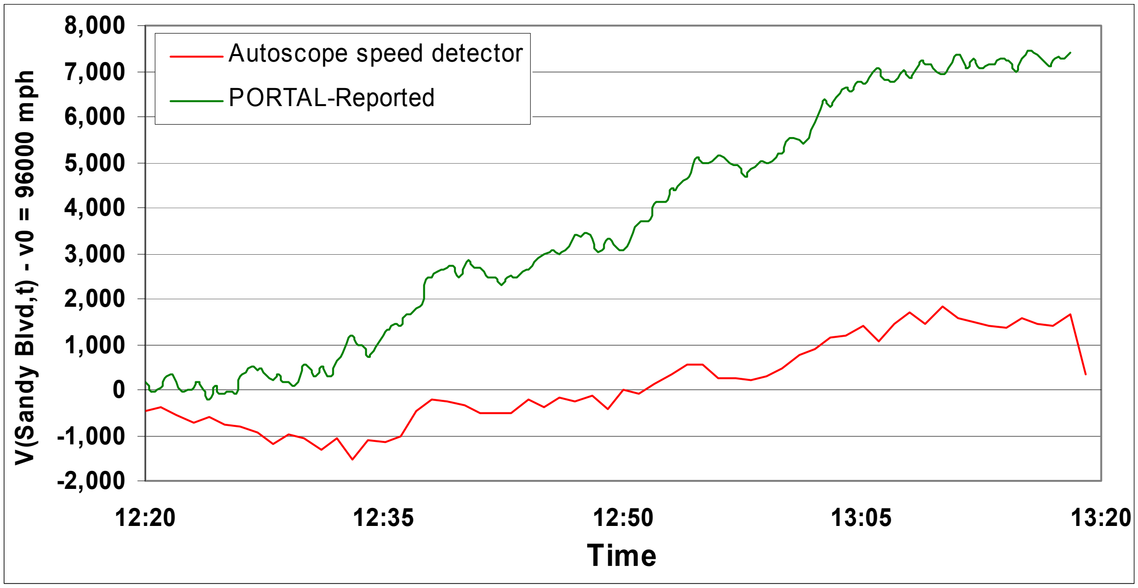


Figure 30h: Cumulative Vehicle Speeds – Oblique Plot

Figure 30h is an oblique plot of speed, using a scaling factor of 90,000 miles/hr. This figure represents the cumulative velocities of all vehicles as measured by the Autoscope speed detectors. The plot shows both data sets as the difference between an average cumulative speed and the measured cumulative speed.

4.5 Summary of Results

Table 4 contains the results of the data analysis conducted in this research. For each of the 47 data periods, several comparisons were made. The second and third columns of Table 4 contain the manual (ground truth) total and truck counts.

No.	Manual		Autoscope		Autoscope V		Autoscope V		Portal-Wang		Portal-Wang		Portal	ODOT	Variance	Var to	Speed	Variance
	All	Trucks	All	Diff	All	Trucks	All Diff	Truck Diff	All	Trucks	All Diff	Tr. Diff.	Flow	Speed	ODOT	Mean	Wang	Wang
1	615	110	677	10.1%	649	108	5.5%	-1.8%	612	65	-0.5%	-40.9%	1210	49.0	44.4	0.9	56.3	27.8
2	833	64	842	1.1%	840	64	0.8%	0.0%	853	42	2.4%	-34.4%	1690	58.3	24.6	0.4	162.7	247.7
3	1749	162	1752	0.2%	1742	162	-0.4%	0.0%	1731	131	-1.0%	-19.1%	1790	60.4	36.0	0.6	160.7	434.7
4	1398	58	1357	-2.9%	1357	58	-2.9%	0.0%	--	--	--	--	--	--	--	--	--	--
5	1572	96	1683	7.1%	1679	96	6.8%	0.0%	1601	85	1.8%	-11.5%	1740	59.9	37.1	0.6	161.8	209.8
6	1233	47	1304	5.8%	1304	47	5.8%	0.0%	--	--	--	--	--	--	--	--	--	--
7	1259	238	1297	3.0%	1287	209	2.2%	-12.2%	--	--	--	--	--	--	--	--	--	--
8	742	31	744	0.3%	730	28	-1.6%	-9.7%	--	--	--	--	--	--	--	--	--	--
9	1193	217	1212	1.6%	1200	191	0.6%	-12.0%	--	--	--	--	--	--	--	--	--	--
10	690	34	675	-2.2%	671	36	-2.8%	5.9%	--	--	--	--	--	--	--	--	--	--
11	1629	161	1635	0.4%	1630	161	0.1%	0.0%	1350	112	-17.1%	-30.4%	1620	60.4	0.1	0.0	184.0	2463.0
12	1603	114	1604	0.1%	1601	114	-0.1%	0.0%	1549	95	-3.4%	-16.7%	1620	61.5	47.9	0.8	169.7	327.0
13	1547	59	1560	0.8%	1553	70	0.4%	18.6%	--	--	--	--	--	--	--	--	--	--
14	1215	29	1211	-0.3%	1205	33	-0.8%	13.8%	--	--	--	--	--	--	--	--	--	--
15	773	26	804	4.0%	800	30	3.5%	15.4%	747	51	-3.4%	96.2%	1560	58.3	48.0	0.8	185.0	858.0
16	663	14	615	-7.2%	612	14	-7.7%	0.0%	--	--	--	--	--	--	--	--	--	--
17	1182	143	1262	6.8%	1196	153	1.2%	7.0%	1231	177	4.1%	23.8%	1300	48.5	61.8	1.3	71.3	246.7
18	721	39	780	8.2%	691	39	-4.2%	0.0%	1302	92	80.6%	135.9%	1370	65.0	48.3	0.7	69.2	109.5
19	1699	118	1714	0.9%	1702	109	0.2%	-7.6%	1752	152	3.1%	28.8%	1740	61.2	26.4	0.4	171.5	728.4
20	1287	51	1271	-1.2%	1262	51	-1.9%	0.0%	--	--	--	--	--	--	--	--	--	--
21	1642	124	1624	-1.1%	1617	126	-1.5%	1.6%	1674	134	1.9%	8.1%	1670	61.2	31.0	0.5	184.2	1002.1
22	1366	53	1341	-1.8%	1337	53	-2.1%	0.0%	--	--	--	--	--	--	--	--	--	--
23	1403	205	1480	5.5%	1469	213	4.7%	3.9%	1418	211	1.1%	2.9%	1430	60.7	35.4	0.6	71.5	445.0
24	1560	168	1533	-1.7%	1533	169	-1.7%	0.6%	1558	164	-0.1%	-2.4%	1570	56.0	29.1	0.5	63.7	355.5
25	1552	161	1562	0.6%	1506	163	-3.0%	1.2%	1540	177	-0.8%	9.9%	1530	58.9	40.2	0.7	67.5	74.7
26	1835	99	1769	-3.6%	1760	97	-4.1%	-2.0%	1879	149	2.4%	50.5%	1870	55.6	32.9	0.6	63.8	27.9
27	782	89	829	6.0%	818	88	4.6%	-1.1%	780	88	-0.3%	-1.1%	1540	47.5	104.6	2.2	50.5	7.5
28	940	37	874	-7.0%	871	37	-7.3%	0.0%	894	86	-4.9%	132.4%	1770	41.7	176.7	4.2	46.6	137.8
29	1214	196	1186	-2.3%	1226	196	1.0%	0.0%	1212	317	-0.2%	61.7%	1210	40.6	110.5	2.7	86.5	1801.9
30	731	88	844	15.5%	760	88	4.0%	0.0%	738	141	1.0%	60.2%	740	47.4	156.1	3.3	96.6	895.0
31	724	24	733	1.2%	729	30	0.7%	25.0%	712	40	-1.7%	66.7%	1420	61.0	31.0	0.5	65.7	22.3
32	871	19	877	0.7%	873	22	0.2%	15.8%	876	43	0.6%	126.3%	1750	57.1	26.5	0.5	61.3	12.0

33	1489	197	1520	2.1%	1482	197	-0.5%	0.0%	1445	243	-3.0%	23.4%	1480	57.9	47.9	0.8	97.4	739.3
34	1455	207	1567	7.7%	1539	207	5.8%	0.0%	1388	338	-4.6%	63.3%	1470	55.2	31.7	0.6	101.2	850.0
35	1609	139	1595	-0.9%	1588	139	-1.3%	0.0%	1531	121	-4.8%	-12.9%	1620	50.8	29.8	0.6	54.0	82.3
36	1627	7	--	--	--	--	--	--	1585	81	-2.6%	1057.1%	1560	63.7	21.6	0.3	86.4	179.6
37	1655	51	--	--	--	--	--	--	1684	103	1.8%	102.0%	1690	58.7	18.4	0.3	67.8	104.3
38	1897	8	--	--	--	--	--	--	1787	78	-5.8%	875.0%	1780	62.8	20.6	0.3	78.3	27.8
39	1643	66	--	--	--	--	--	--	1708	84	4.0%	27.3%	1690	58.6	19.8	0.3	62.7	32.4
40	1465	10	--	--	--	--	--	--	1419	121	-3.1%	1110.0%	1420	61.9	24.0	0.4	109.2	435.4
41	1639	62	--	--	--	--	--	--	1637	103	-0.1%	66.1%	1640	57.1	24.8	0.4	67.3	61.6
42	1596	9	--	--	--	--	--	--	1493	125	-6.5%	1288.9%	1510	62	30.8	0.5	112.7	537.6
43	1647	57	--	--	--	--	--	--	1684	138	2.2%	142.1%	1680	56.9	22.2	0.4	72.7	182.7
44	1631	8	--	--	--	--	--	--	1528	119	-6.3%	1387.5%	1530	62.4	27.2	0.4	104.6	469.1
45	1636	43	--	--	--	--	--	--	1688	95	3.2%	120.9%	1690	56.1	22.5	0.4	62.3	54.0
46	1693	6	--	--	--	--	--	--	1576	96	-6.9%	1500.0%	1580	62.3	22.9	0.4	95.9	197.5
47	1662	42	--	--	--	--	--	--	1724	92	3.7%	119.0%	1730	56.5	21.8	0.4	59.2	13.8
				3.5%			**2.6%**	**4.4%**			**2.74%**	**54.57%**	**1561.39**	**57.03**				
				3.5%			**2.3%**	**6.7%**			**13.26%**	**46.12%**						

Table 4: Summary of Data Analysis

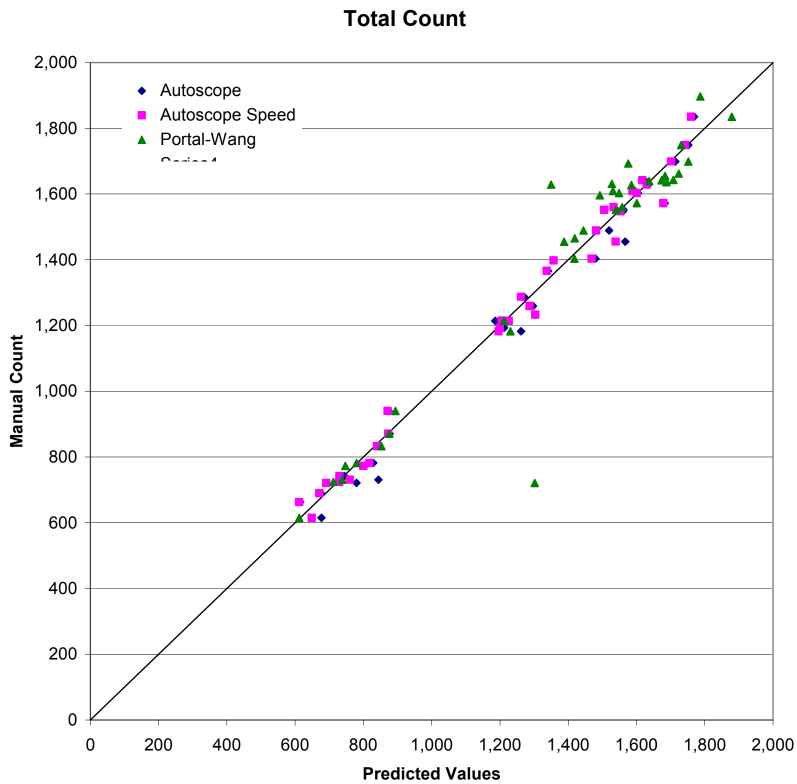


Figure 31: Comparison of Total Count Mechanisms to Ground Truth

Table 4 shows the total vehicle count collected from the Autoscope count detector. On average the absolute percent difference between this total count and the ground truth for all vehicles was 3.5%, with a standard deviation of 3.5%. The table also shows the total and truck counts using the Autoscope speed detector, along with the percent difference between them and the ground truth measurements. As shown in the table, the absolute percent difference between the Autoscope speed detector counts for all vehicles and ground truth was 2.6% (standard deviation 2.3%). The absolute percent difference between the Autoscope truck counts and ground truth was 4.4% (standard deviation of 6.7%).

Table 4 also shows the count estimates from the PORTAL implementation of the Wang-Nihan algorithm. For the data periods that had good freeway detector data, the average absolute difference between PORTAL and ground truth for all vehicles was 2.7% (standard deviation of 13.3%). In the area of truck counting, the average absolute difference between the PORTAL-Wang count and ground truth for trucks was 54.6% (standard deviation 64.1%).

In order to illustrate some of the relationships between the differences found in this empirical analysis, a number of graphical illustrations have been prepared to accompany Table 4. Figure 31 shows the three total count mechanisms (Autoscope, Autoscope Speed and PORTAL-Wang) on the *x*-axis versus the manual count ground truth on the *y*-axis. As shown, except for two outliers, the counts obtained from the three sources do not deviate dramatically from the diagonal line, indicating that most of the total count predictions were within a few percentage points of the ground truth.

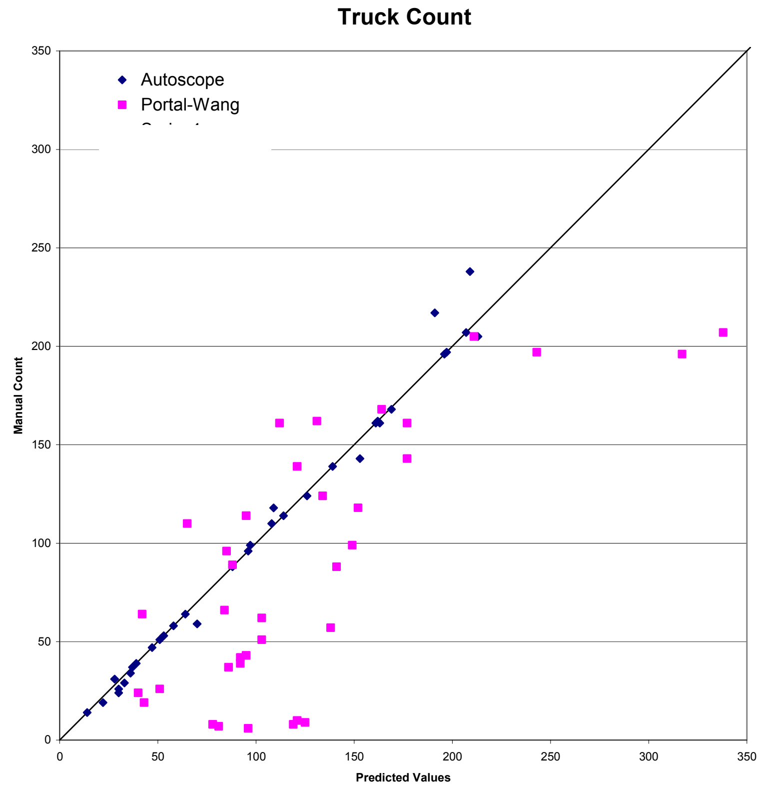


Figure 32: Comparison of Truck Count Mechanisms to Ground Truth

Similarly, Figure 32 shows the predicted truck count values using Autoscope and PORTAL-Wang on the *x*-axis against the manual counts on the *y*-axis. As shown on the figure, it appears that the Autoscope truck counts hover closer to the diagonal line than do the counts predicted by PORTAL-Wang.

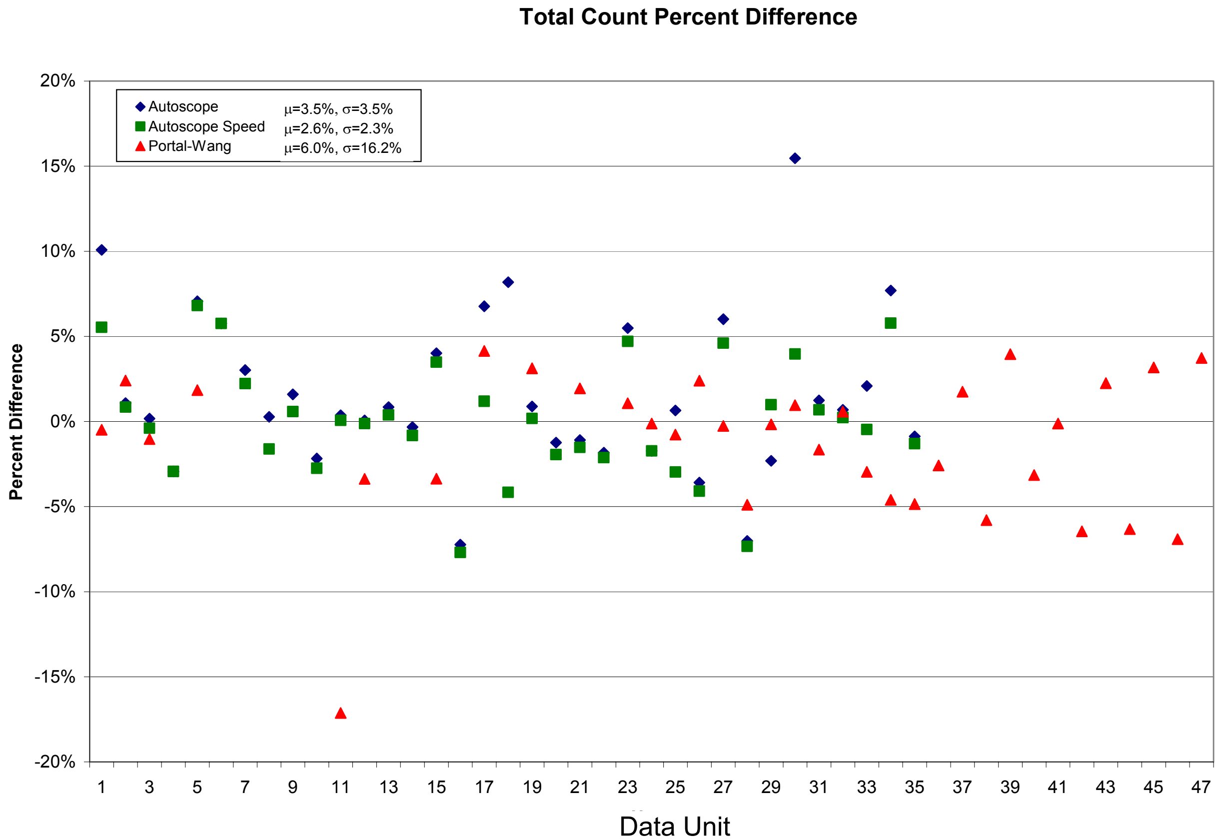


Figure 33: Total Count Percent Difference

In order to gain further insights into the level of vehicle and truck count capabilities from the considered methods, Figure 33 shows the percent difference for the three methods across all 47 data units (the *x*-axis in the figure refers to the 47 data units). As shown in the figure, there is a tight band of points within the +/- 5% range, with a few outliers above and below these values. The Autoscope Speed method appears to perform the best with an average error of 2.6%. The Autoscope method exhibits a 3.5% error on average while the PORTAL-Wang method had an average of 2.7% error.

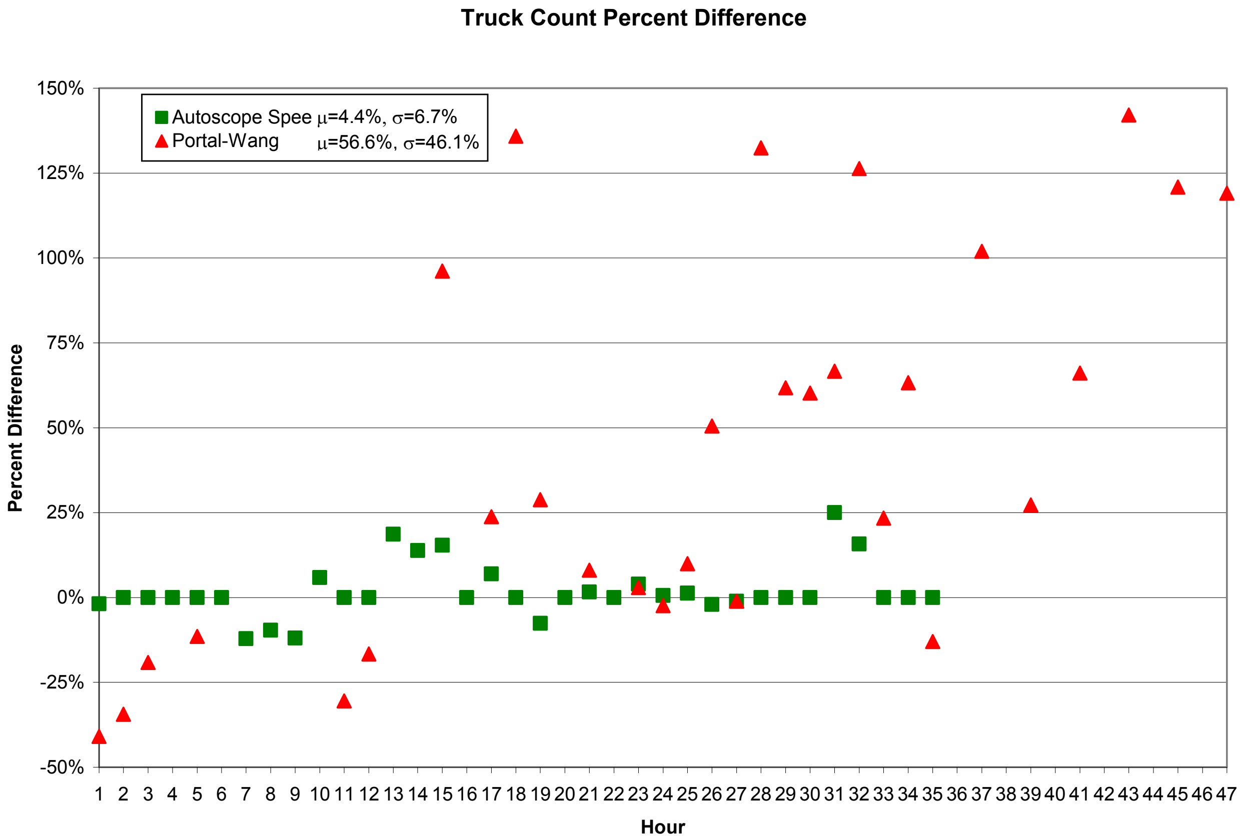


Figure 34: Truck Count Percent Difference

The primary interest in this research was to determine whether there are potential systematic means for estimating truck traffic flows on the freeway network of the Portland metropolitan region. Toward this end, Figure 34 shows the percent difference for the two truck counting mechanisms as compared to ground truth for all 47 data periods (where data were available). As shown, the Autoscope Speed method displayed an average of 4.4% error with most points near the zero *x*-axis. The PORTAL-Wang method exhibited truck counts that were more scattered.

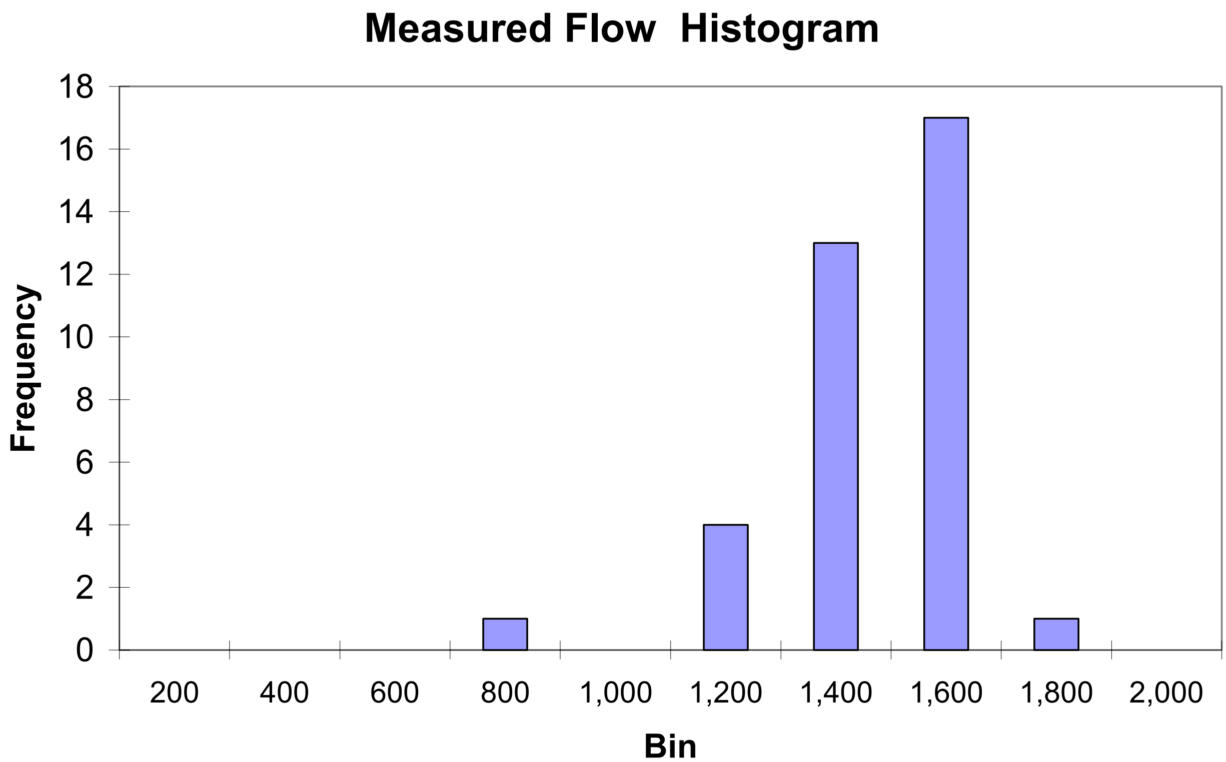


Figure 35: Measured Flow Histogram

Further insights were desired regarding potential systematic reasons for the errors discovered in the truck counting efforts. A question arose whether the prevailing average flow was a factor in the reliability of either the Autoscope or PORTAL-Wang methods. Figure 35 shows a histogram displaying the measured flows for all 47 data periods. The median value was 1,600 vph per lane.

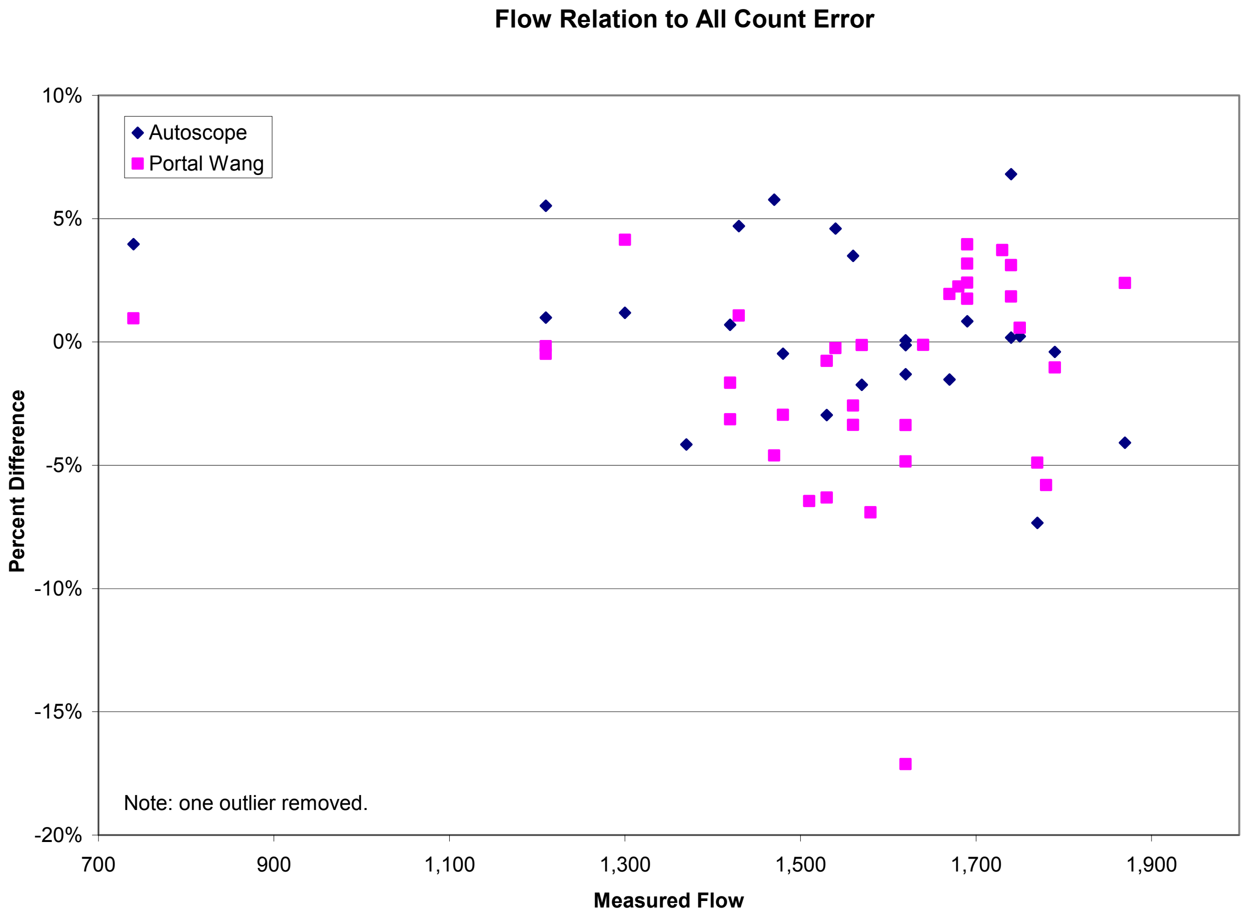


Figure 36: Flow Relation to All Count Error

Knowing from Figure 35 that most flow values measured were between 1,400 and 1,800 vehicles per hour per lane, Figure 36 now makes it possible to determine whether there is a relationship between the prevailing flow during a particular measurement period and the level of error for the total counts using the Autoscope and PORTAL-Wang methods (when data were available). From the figure, without need for any statistical tests at this point, it appears possible that there is a slight spreading of the percent difference as the flow exceeded about 1,600 vehicles per hour. This should be the topic of further research before firm conclusions can be drawn. The quantitative relationship would be important for data collection and usability issues.

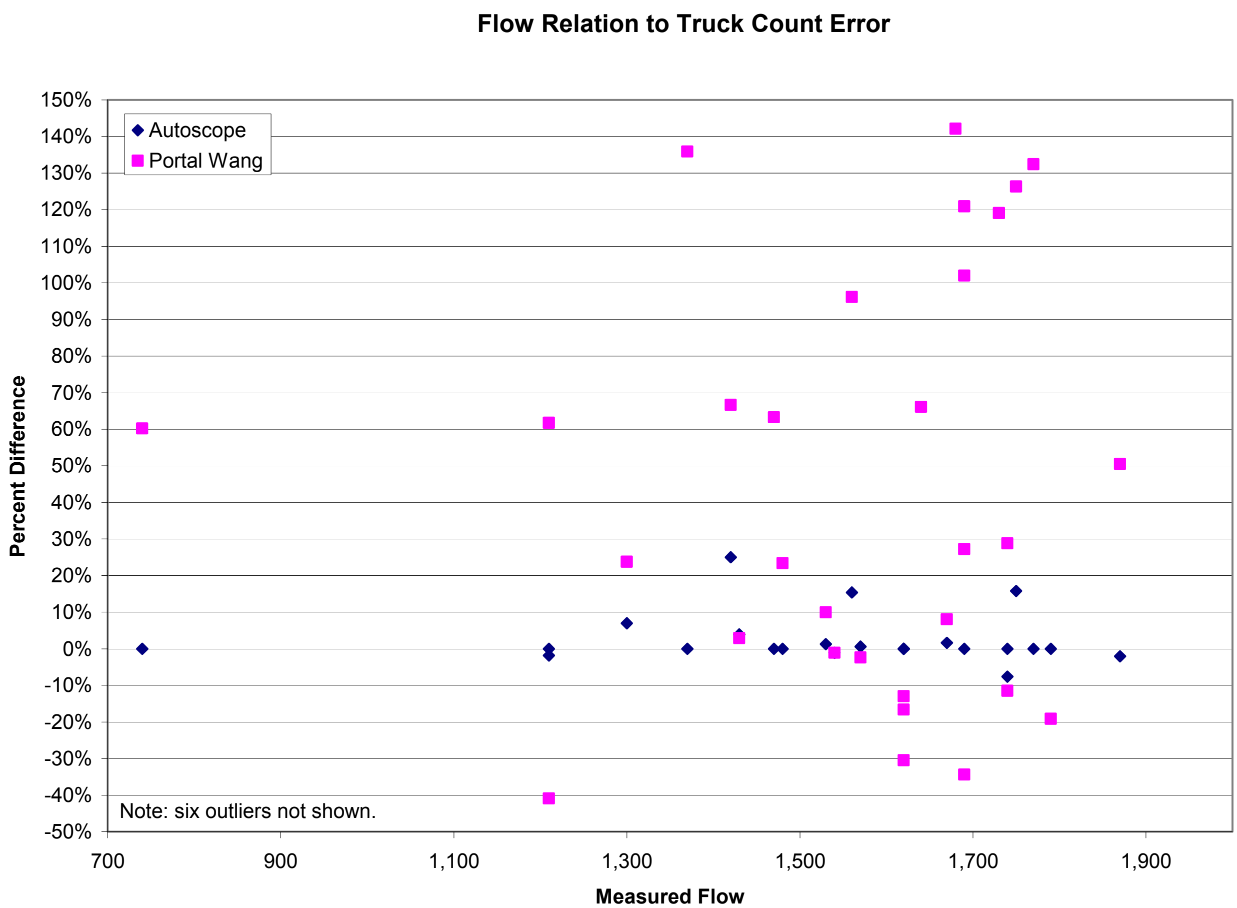


Figure 37: Flow Relation to Truck Count Error

Similar to the previous graphic, Figure 37 shows the relation between measured prevailing flow and the truck count accuracy. Here it is more difficult to draw any conclusions due to the wide range of errors in the PORTAL-Wang implementation using the Portland data.

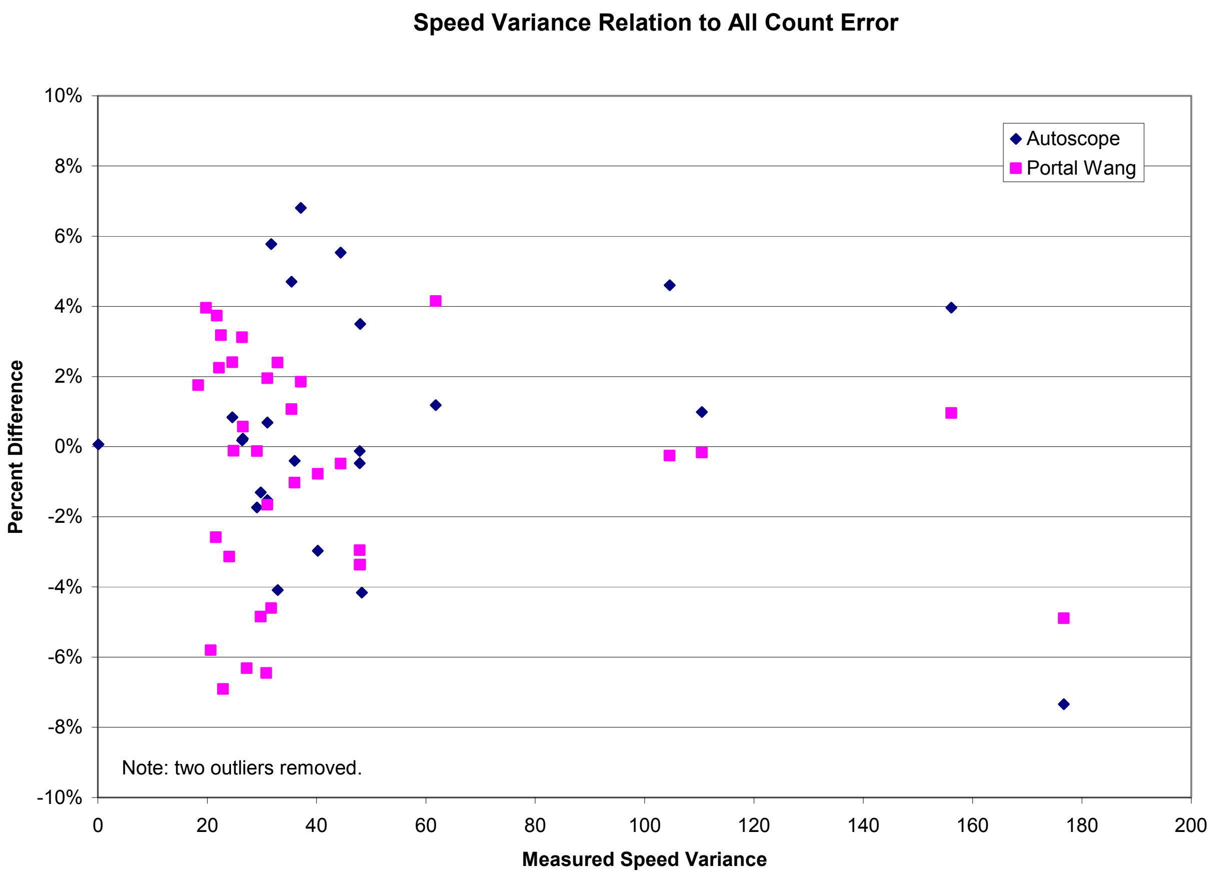


Figure 38: Measured Speed Variance Relation to All Count Error

As noted earlier, the Wang-Nihan algorithm requires constant speed during the 5-minute calculation intervals in order to make accurate long vehicle estimates. It was thought that if this assumption were not valid in this project, that the accuracy of the prediction for Portland data would be negatively impacted. Therefore, the effect of the prevailing speed variance on count error was analyzed as shown in Figure 38. Here the measured speed variance is shown on the *x*-axis while the percent difference for total vehicle count using the Autoscope and PORTAL-Wang methods is shown on the *y*-axis. There were several measurements with high variance (and five measurements with variance to mean ratios greater than one) which could indicate that the violation of the constant speed assumption contributed to the wide ranging errors found in this research.

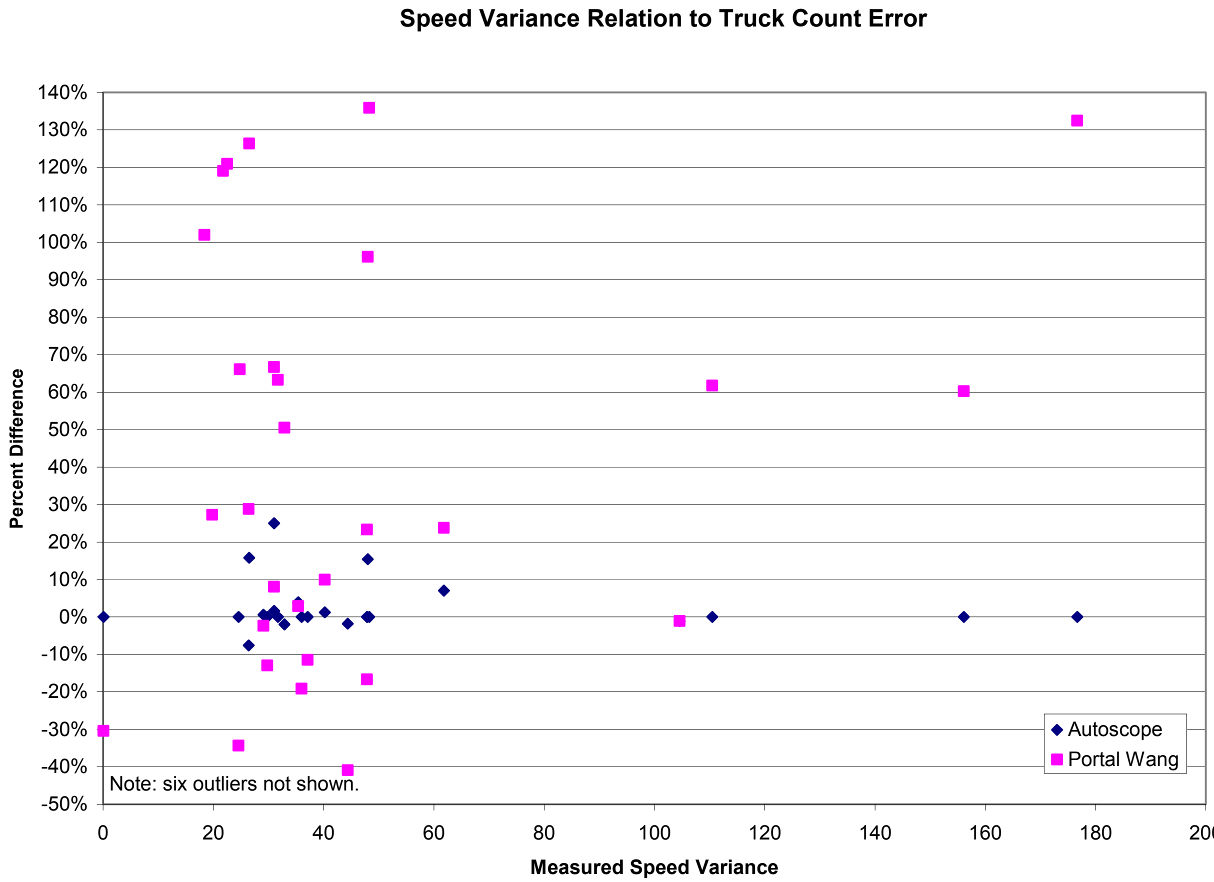


Figure 39: Measured Speed Variance Relation to Truck Count Error

Figure 39 shows a similar image, with the measured speed variance (when data were available from PORTAL) against the percent truck count difference for both Autoscope and PORTAL-Wang methods. Due to the many outliers, the picture here is less clear.

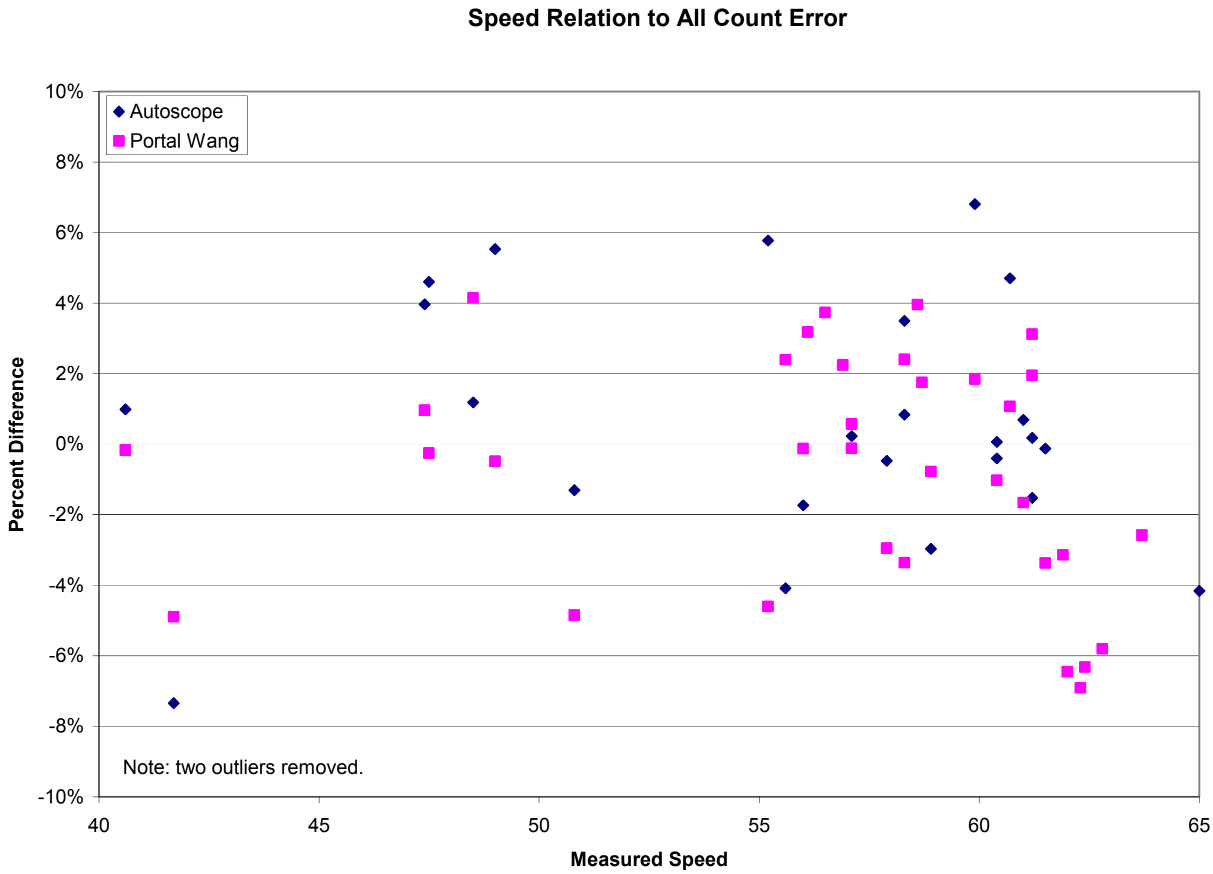


Figure 40: Measured Average Speed Relation to All Count Error

The question also arose whether the speeds of traffic during the data collection were appropriate for the use of Autoscope and the Wang-Nihan algorithm. Thus, Figure 40 was constructed to examine the measured average speed during each of the 47 data periods where data were available against the percent error in total count. Most of the observations were during periods with traffic flowing between 55 and 65 mph as measured by ODOT. The figure does not show a clear relation between the two.

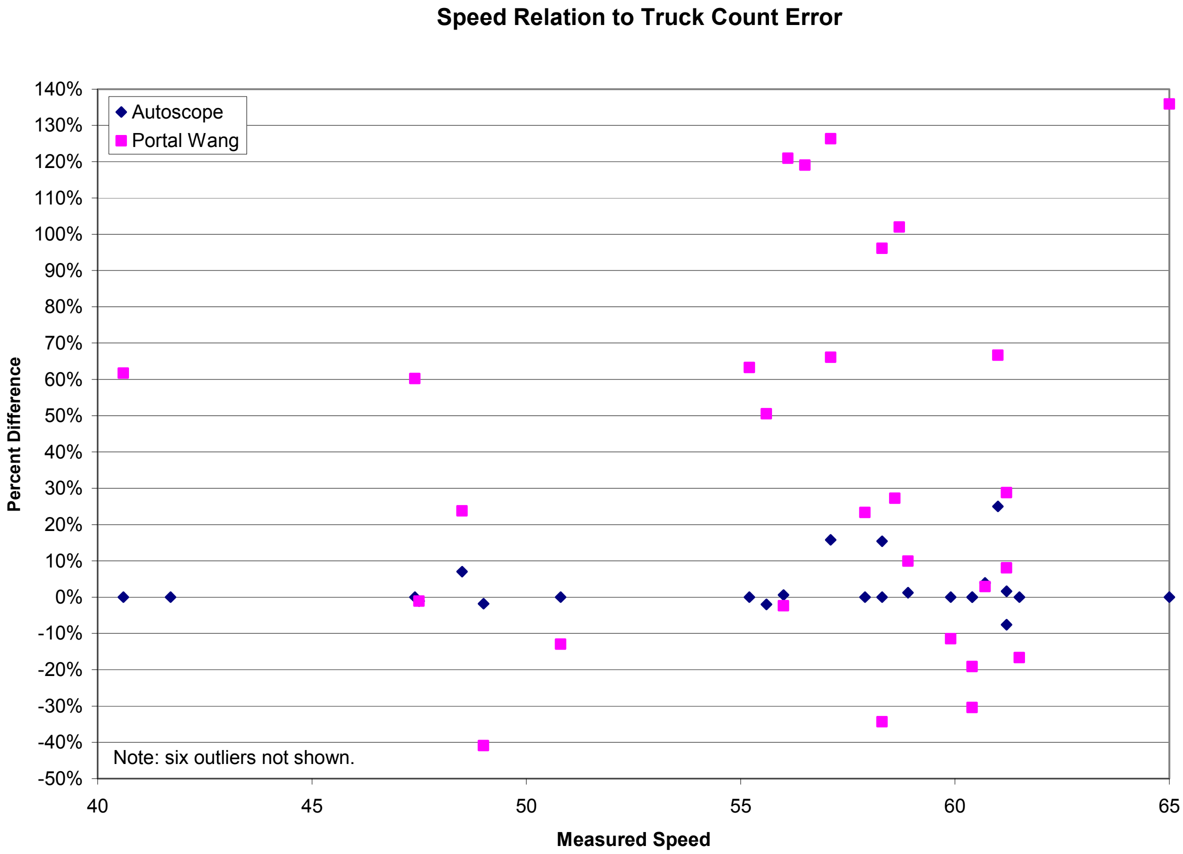


Figure 41: Measured Average Speed Relation to Truck Count Error

Figure 41 illustrates a similar relation between measured speed and percent error in truck counts for both the Autoscope and PORTAL-Wang methods. Here it appears that the scatter widens with increasing speed, particularly for the PORTAL-Wang method.

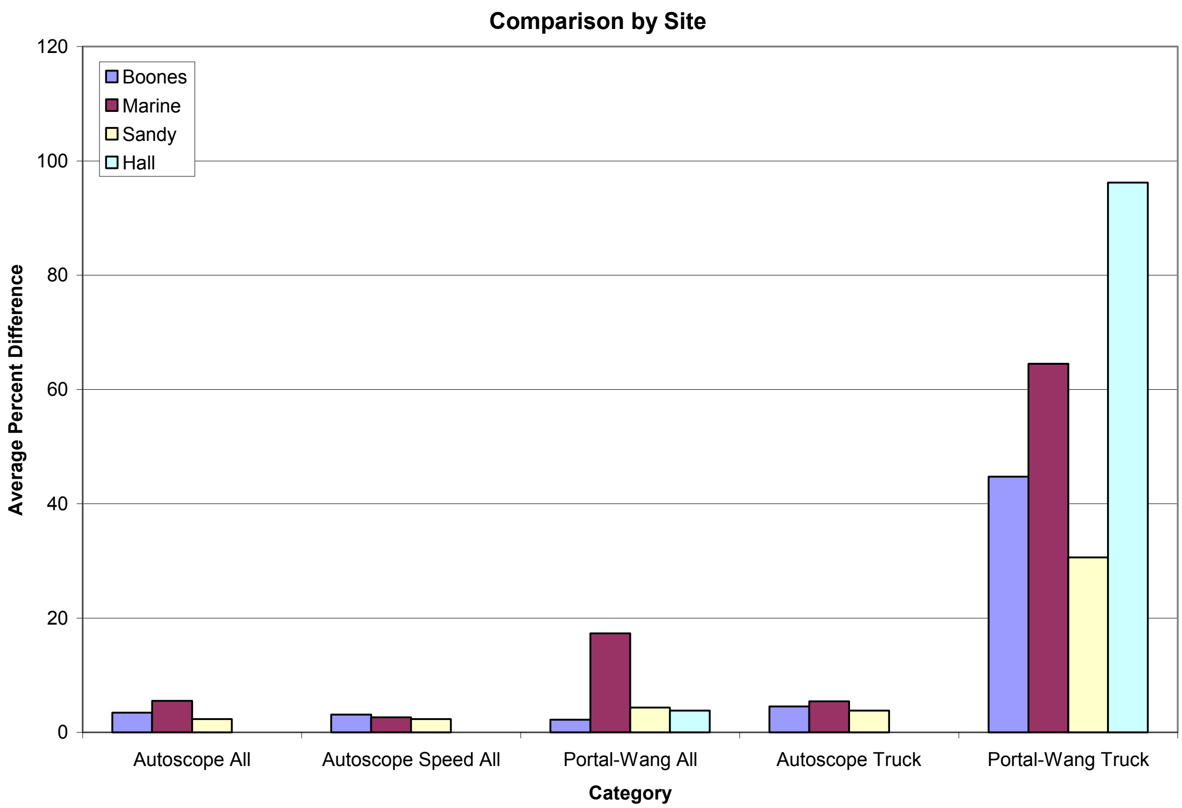


Figure 42: Percent Count Differences by Freeway Site

The three sites presented different opportunities for obtaining good Autoscope readings as well as varying in other ways. This analysis considers the four sites (Boones, Marine, Sandy, and Hall) separately across the five classifications. The total count using Autoscope, Autoscope Speed and PORTAL-Wang is compared against ground truth in absolute percent difference. As shown in Figure 42, the Marine Drive site appeared to perform worse than the other three sites. For the PORTAL-Wang method, the Hall site is the worst of the four. Turning to the truck counts the Marine site also performs less well than the Boones, Sandy and Hall locations.

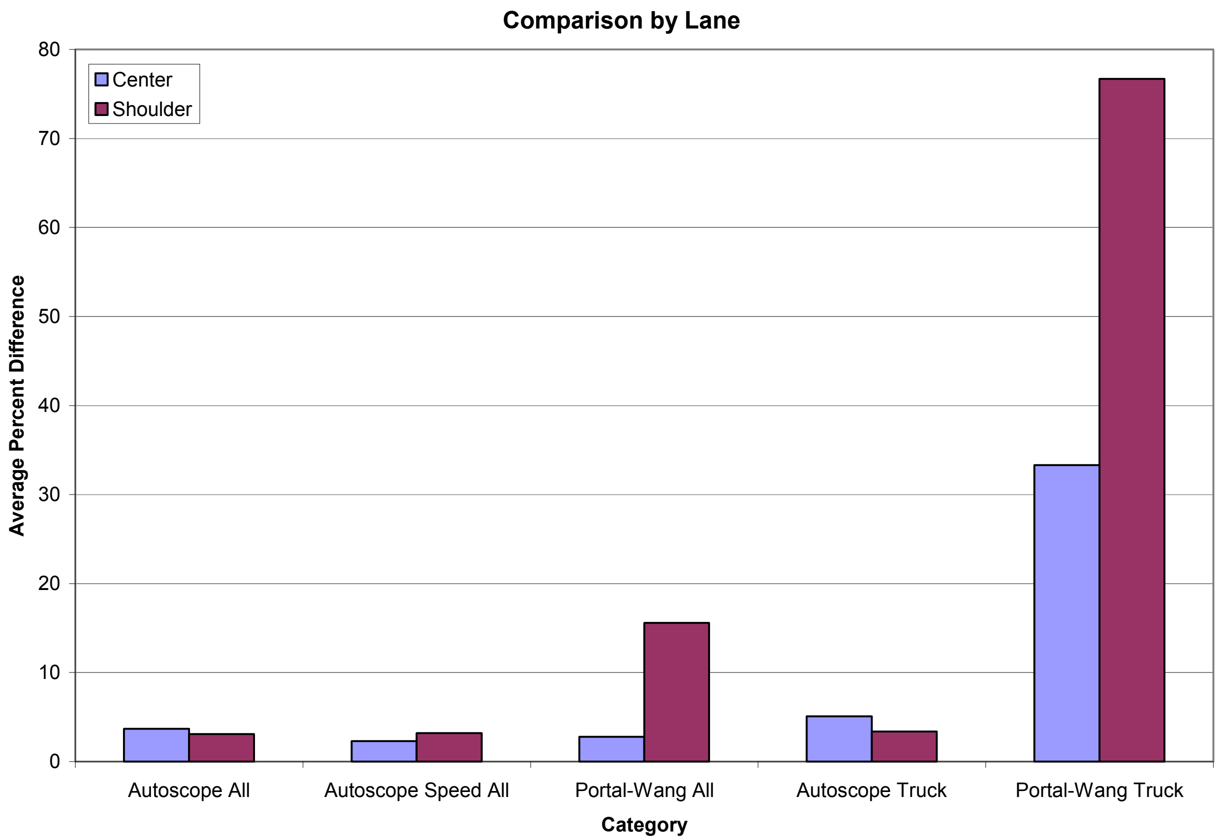


Figure 43: Percent Count Differences by Lane

The final consideration in this analysis was whether the lane used mattered in terms of the accuracy of the total or truck count. From Figure 43, it appears that the counts taken in the shoulder lane worked less well in the PORTAL-Wang method. This does not necessarily imply that there is anything wrong with using video or detector counts from the shoulder lane, but it could imply a need for detector tuning at the particular locations studies.

4.4 Overview of Results

In general, this experiment exhibited mixed results. There were some unforeseen loop detector malfunctions that resulted in limited data availability. Reliability of loop detectors is a known problem—in this case some of the preferred CCTV camera locations seemed to be associated with particularly poor loop detector performance. This is an area being examined more closely as part of the PORTAL project at this time. The PORTAL-Wang algorithm as implemented within the PORTAL database did not perform as well as was hoped, presumably due to loop detector tuning, loop sensitivity and low occupancy data resolution issues that need to be resolved. The Autoscope methods performed surprisingly well in total count and truck count, but were labor intensive and depended upon the surveillance cameras remaining in stationary positions for extended periods. In the case of these particular datasets, it appears that the Wang-Nihan algorithm was over-estimating truck counts more so than under-estimating. There are under-estimates, but the most notable misses are all over-estimates. Performing further sensitivity analysis using different/improved values of Beta may help in this area.

4.5 Sources of Errors

As noted throughout this report, there were numerous opportunities for error to enter into this research, despite the care taken in the experimental design, implementation and analysis. The camera position/height may have contributed to some of the errors found with the Autoscope methods. Generally, Autoscope is known to work better with high camera positions, since bad camera angles lead to incorrect vehicle lengths, speeds and vehicle counts due to occlusion. Also, as expected, the research was at the mercy of the ODOT TMOC staff—several times the cameras had to be moved as part of an incident verification and response effort. This issue would logically be extrapolated to any real implementation of a system using surveillance video for extraction of truck counts or other parameters.

4.6 Specific Issues with the Wang-Nihan Algorithm

It is clear from the original paper [5] that the Wang-Nihan algorithm is not expected to work properly in truly congested conditions. In the case of this research, none of the traffic conditions were truly congested since measured speeds were almost all above 40 mph and most were above 50 mph.

The two primary assumptions in [5] are that 1) speed should be constant over a 5-min period and 2) there are at least two 20-second intervals in a 5-minute period without long vehicles. If either is violated there is an accuracy problem. Clearly both can be violated in very congested conditions, but it is not clear that the conditions in this research violated those assumptions. If condition 1) is violated then both speed and long-vehicle volume will be over-estimated (large occupancies from low speeds are incorrectly attributed to long vehicles). If condition 2) is violated then speed and long-vehicle volume will be under-estimated.

One issue that might have clouded the results is related to the loop sensitivity correction factor—beta. Wang and Nihan state that an accurate beta is necessary to make the algorithm work; but we assumed beta = 1. An improvement may be necessary by actually measuring the speed in the field using a radar speed measurement device. In future research it may be possible to improve our estimates with an improved value of beta.

One further issue involved artificially high speeds on I-84 at Sandy that may have been caused by the artificially low occupancies reported by those detectors. High speeds were a likely result of low occupancies. It is interesting that the truck counts for I-84 at Sandy are reasonable even though the speeds are not.

As noted in the earlier summaries, the PORTAL-Wang speed estimates are highly variable and unreasonably high in some cases. For example, there can be a 40 mph reading for one 5-min period then 55 for the next, then 50, then 60, etc. One would guess that speeds aren't really that variable. It is possible that detector problems have led to these unusual readings. Also it is interesting to note that in some cases, such as I-84 at Sandy, where the detector is reporting artificially low occupancies, the ODOT reported speeds appear reasonable. The PORTAL implementation of the Wang-Nihan algorithm does not take into account detector calibration—it assumes the detectors are properly calibrated. It has turned out that this was a bad assumption that will need to be corrected in future research.

5.0 CONCLUSIONS & RECOMMENDATIONS

The objective of this project was to build upon past and ongoing research in the area of identifying techniques for collecting freight transportation data by designing data collection experiments using an existing ITS infrastructure and equipment. Despite mixed results, the objective was be met by carefully reviewing the literature, developing unique and comprehensive data sampling strategies, working with regional transportation agency partners to clearly define their data needs, and implementing a data collection experiment to demonstrate the capabilities of two existing ITS surveillance system for freight data collection. For the first time, a systematic experiment was conducted to examine the possibilities for automating the extraction of truck count data for the Portland metropolitan region. This is consistent with regional priorities that have increasingly focused on the mobility needs of the freight community.

In the context of PORTAL, future activities will include development of meta-data schema, consistent with the national ITS Architecture, particularly with regard to the aggregation methods used. Meta-data are critical components of any data archive and as PORTAL from research to deployment; this will be the primary means to assure future scalability. Further, PORTAL will add data sources, integrate GIS mapping techniques, and implement improved vehicle length and travel time calculation algorithms.

At the industry level, the PORTAL project has provided professionals from all over the world with the wealth of archived data that can be used to better our roadways. This project has provided an opportunity to test the National ITS Architecture in a real-world application, and development of this system will continue to meet the Architecture requirements.

There is a well-known freight data gap across the country. This project has taken a step toward completing a critical gap in the freight data collection program now being implemented by the Port of Portland and reflects an investment that will lead toward providing a permanent truck counting capability for the region’s freeways and beyond. This has represented an approach that will be unique in the nation, and will provide key inputs to the travel forecasting efforts now underway at the Port, Metro and ODOT. A new coordinated and at least partially automated data collection system will also allow us to track seasonal and long run changes in truck flows and to report levels of congestion to the freight industry that are reflective of when their vehicles are actually on the freeways. Travel times for key freight corridors will be able to be linked to those locations and times experiencing the heaviest freight traffic, which will aid in local, regional and statewide planning efforts.

Given the mixed results of this project, much additional work is needed. First, the PORTAL implementation of the Wang-Nihan algorithm is undergoing further testing and ODOT will be provided with the results of this experiment toward further tuning of the detectors used in this report.

Toward the development of permanent truck counting capabilities, a regional grant of $200,000 has been secured from the Metropolitan Transportation Improvement Program (MTIP) for the development of a permanent regional freight data collection system. This system will be installed in the freeway loop detector controller cabinets along the Portland freeway system, including I-5, I-205, ORE217, US26, I-84, all within the Portland metropolitan area.

This project will consist of new hardware to be installed in ramp meter controllers throughout the Portland metropolitan area, plus communications upgrades, software modifications and data archiving improvements to allow for permanent truck counts (at 20-second intervals, 24 hours per day, 365 days per year) at more than 50 locations on the freeway mainline in the metro area.

Freight transportation makes up a substantial portion of the daily vehicle miles traveled (VMT) in the Portland metropolitan area and is vital for the region's economic vitality. Further, truck movements on the Portland area freeway system are impacted heavily by congestion and in turn have a major safety impact. While it is possible to monitor and manage the movement of vehicles on the freeway system via an extensive traffic management operations system, it is currently not possible to determine how many trucks are traveling on the freeway system on an ongoing basis. In order to effectively manage our freeway transportation system today and plan for tomorrow, the region desperately needs a system for monitoring truck flows on the freeways. Fortunately, this can be achieved at a very low cost and will allow cities, counties, the Port of Portland, Metro, and ODOT to reap benefits immediately. Typically truck counts are obtained via labor intensive measurement techniques at a small number of locations on one or two days. This new system will enable permanent count/classification stations to be established at more than 50 locations, on a permanent basis. These data will be archived at Portland State University as part of the region's transportation data archiving program and will be available to all regional agencies via an Internet website.

REFERENCES

[1] Y. Wang and N. Nihan. Dynamic estimation of freeway large truck volume based on single-loop measurements. CD-Rom for the 80th Annual Meeting of TRB, paper 01-2853, TRB, National Research Council, Washington D.C., 2001.

[2] Kwon, Jaimyoung. Joint Estimation of the Traffic Speed and Mean Vehicle Length From Single-Loop Detector Data. CD-Rom for the 82nd Annual Meeting of TRB, National Research Council, Washington, D.C. 2003.

[3] Kwon, Jaimyoung; Varaiya, P. P.; Skabardonis, Alexander. ESTIMATION OF TRUCK TRAFFIC VOLUME FROM SINGLE LOOP DETECTOR USING LANE-TO-LANE SPEED CORRELATION. CD-Rom for the 82nd Annual Meeting of TRB, National Research Council, Washington, D.C. 2003.

[4] Nihan, NL; Wang, Y; Zhang, XP. EVALUATION OF DUAL-LOOP DATA ACCURACY USING VIDEO GROUND TRUTH DATA. TransNow, Transportation Northwest, Washington Univ, Civil Engineering Dept, 2002.

[5] Y. Wang and N. Nihan. Can Single-Loop Detectors Do the Work of Dual-Loop Detectors? ASCE Journal of Transportation Engineering, 129(2), 169-176, 2003

[6] National ITS ADUS Addendum

[7] S. Turner. Guidelines for Developing ITS Data Archiving Systems. Report 2127-3. FHWA, U.S. Department of Transportation, Texas Department of Transportation and Texas Transportation Institute, 2001.

[8] Y. Wang and N. Nihan. A Robust Method of Filtering Single-Loop Data for Improved Speed Estimation. CD-Rom for the 81st Annual Meeting of TRB, paper 02-3843, TRB, National Research Council, Washington, D.C. 2002.

[9] P. Athol. Interdependence of Certain Operation Characteristics within a Moving Traffic Stream. Highway Research Record 72, 58-87.

APPENDIX B – GRAPHICAL ANALYSIS

Hour 1

Location: I-5 SB @ Marine Drive
Date: October 25, 2005
Time: 14:18 to 14:48
Lane: Center

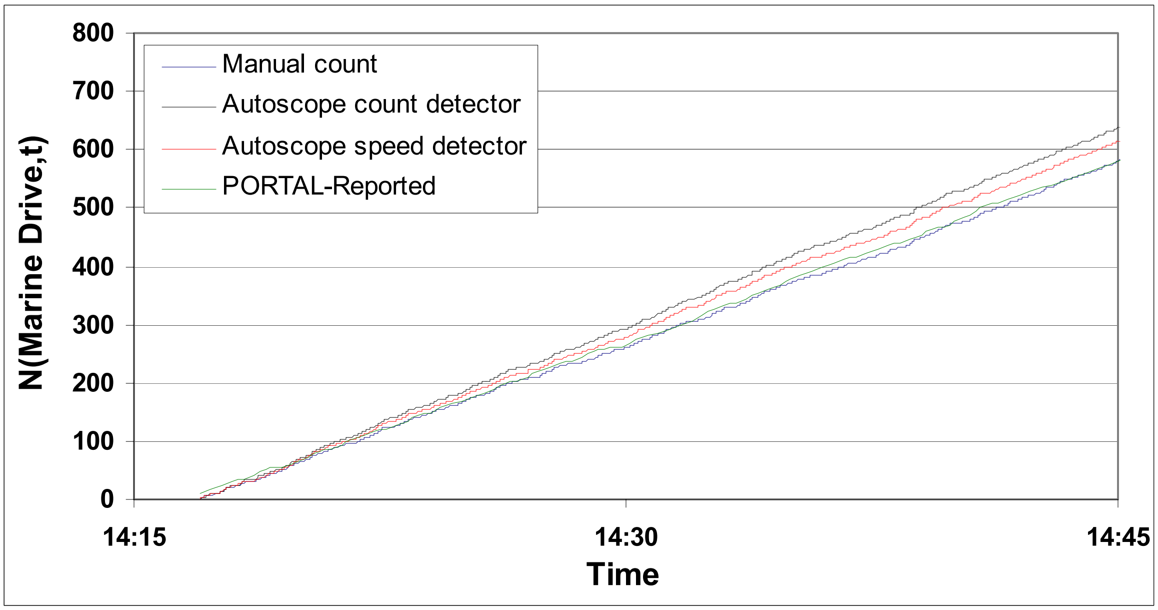


Figure H1a: Cumulative Vehicle Count

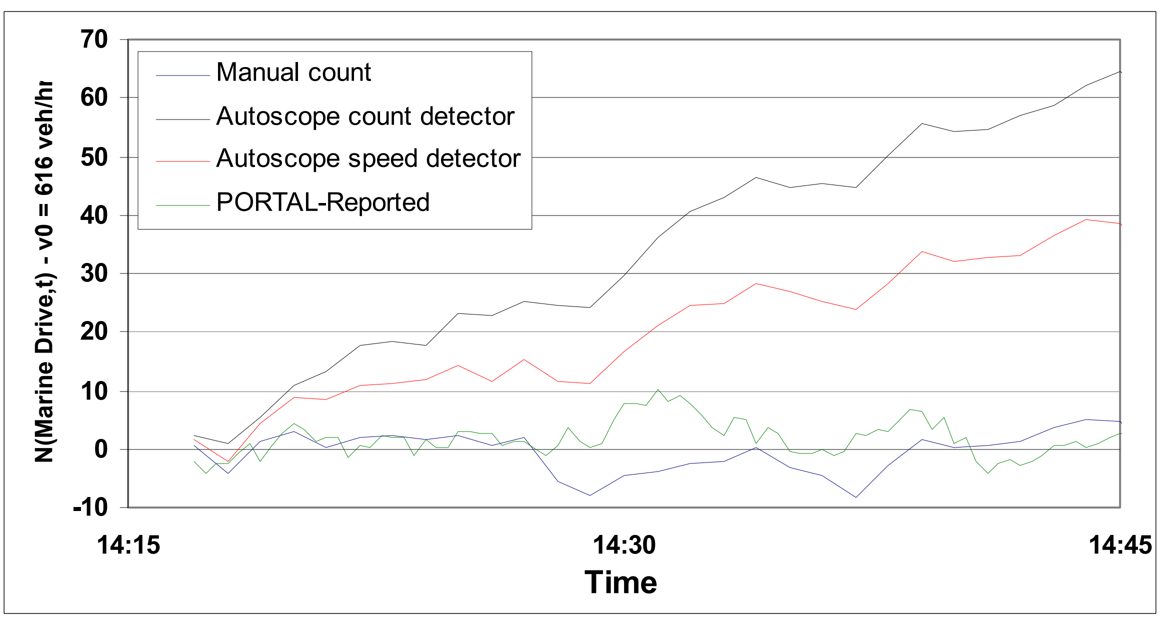


Figure H1b: Cumulative Vehicle Count - Oblique Plot

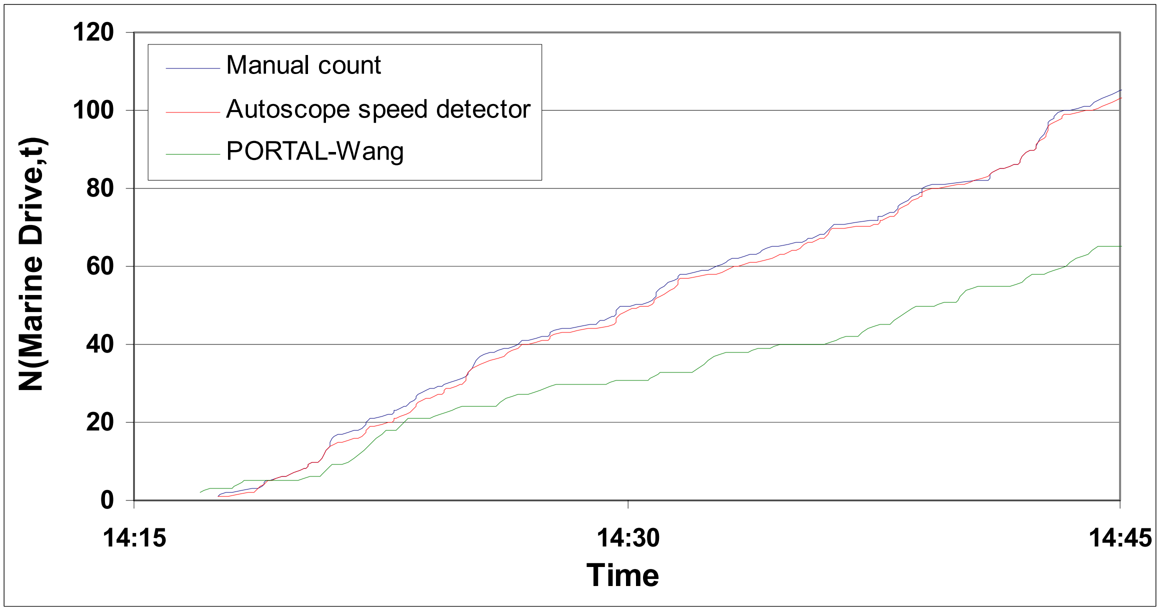


Figure H1c: Cumulative Long Vehicle Count

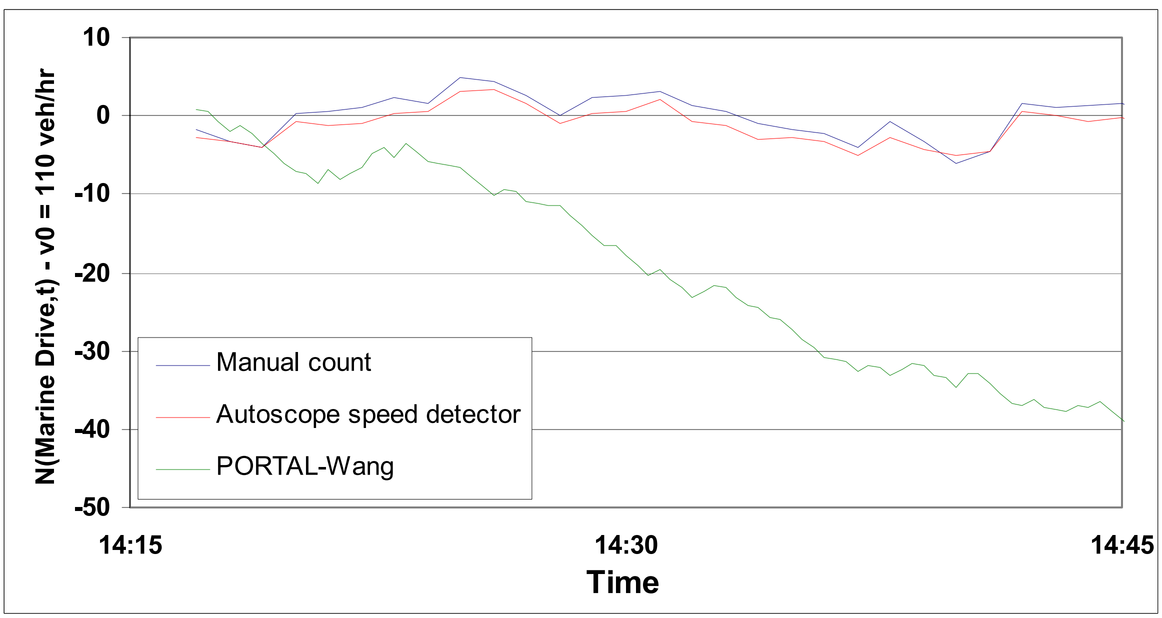


Figure H1d: Cumulative Long Vehicle Count – Oblique Plot

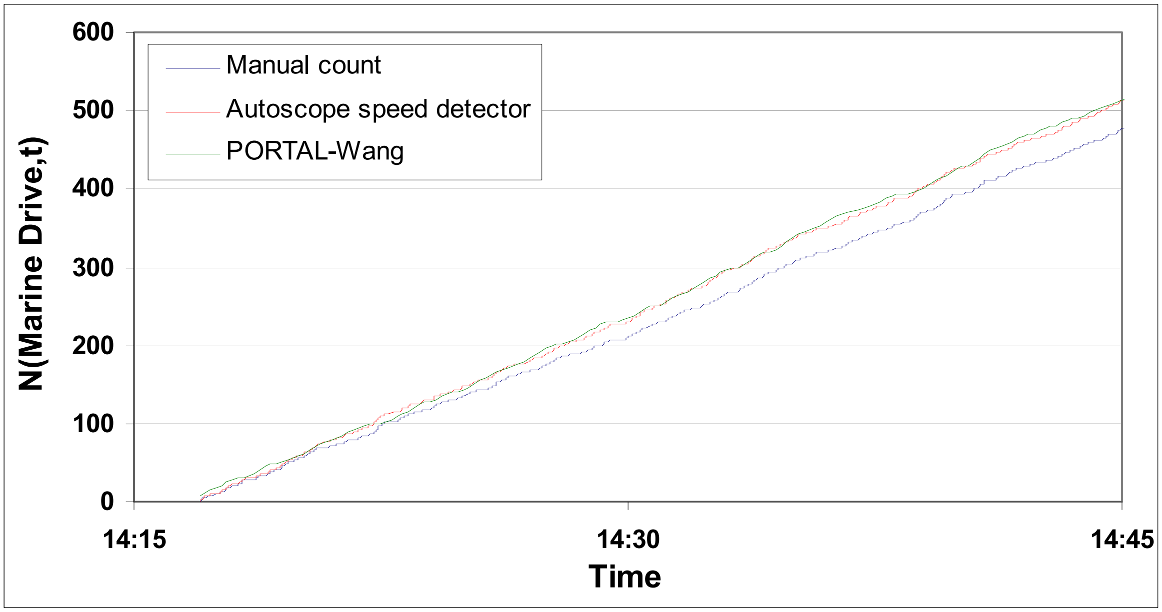


Figure H1e: Cumulative Short Vehicle Count

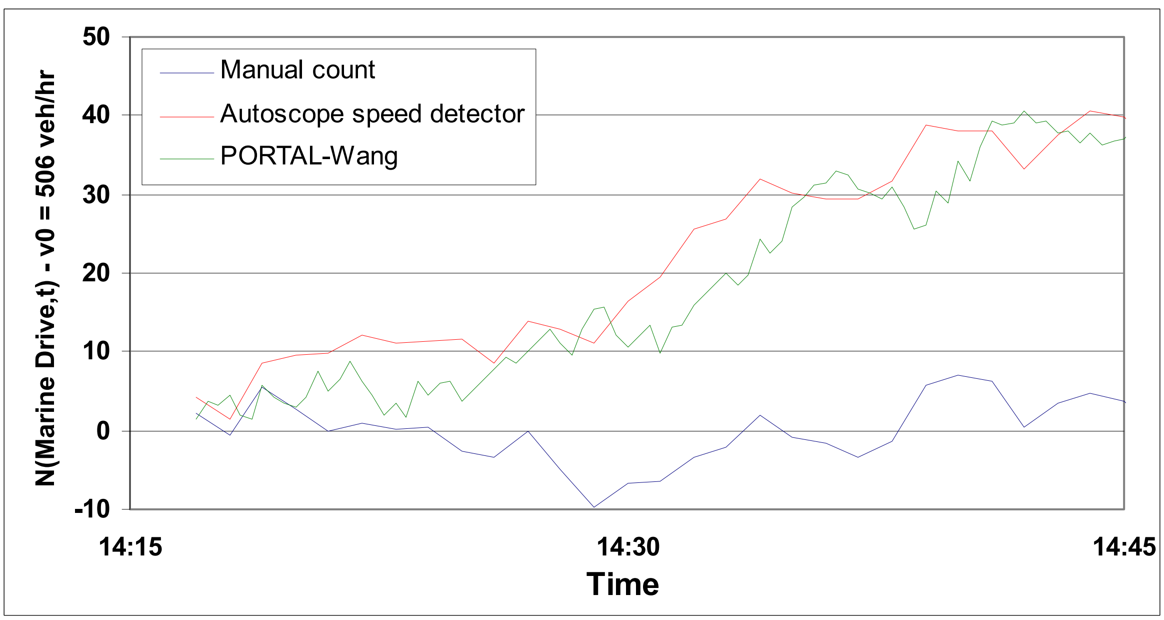


Figure H1f: Cumulative Short Vehicle Count – Oblique Plot

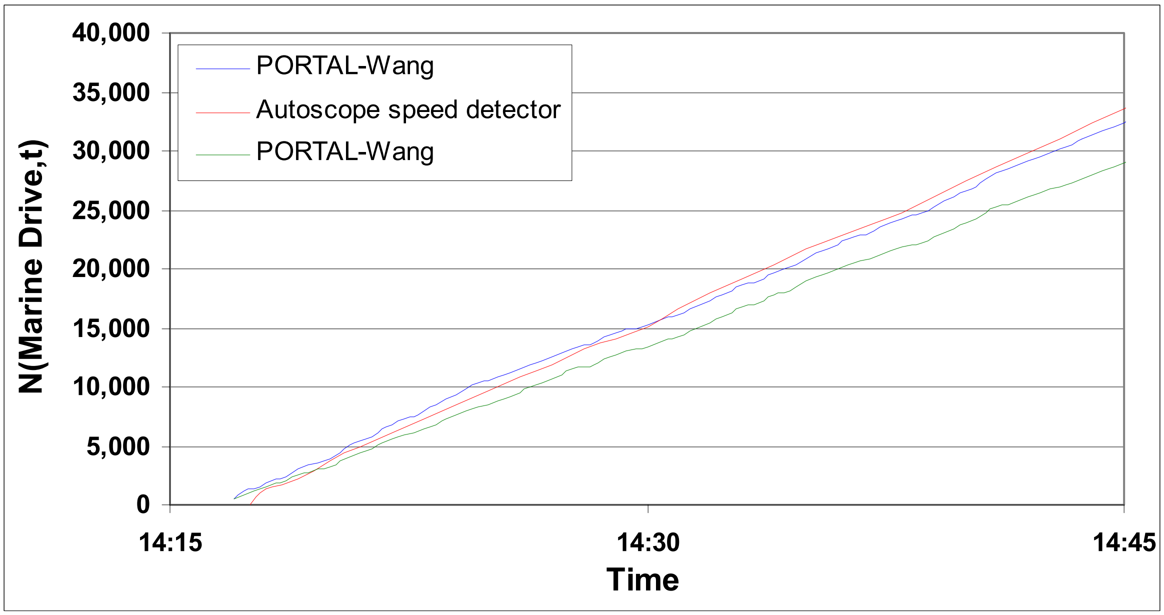


Figure H1g: Cumulative Vehicle Speeds

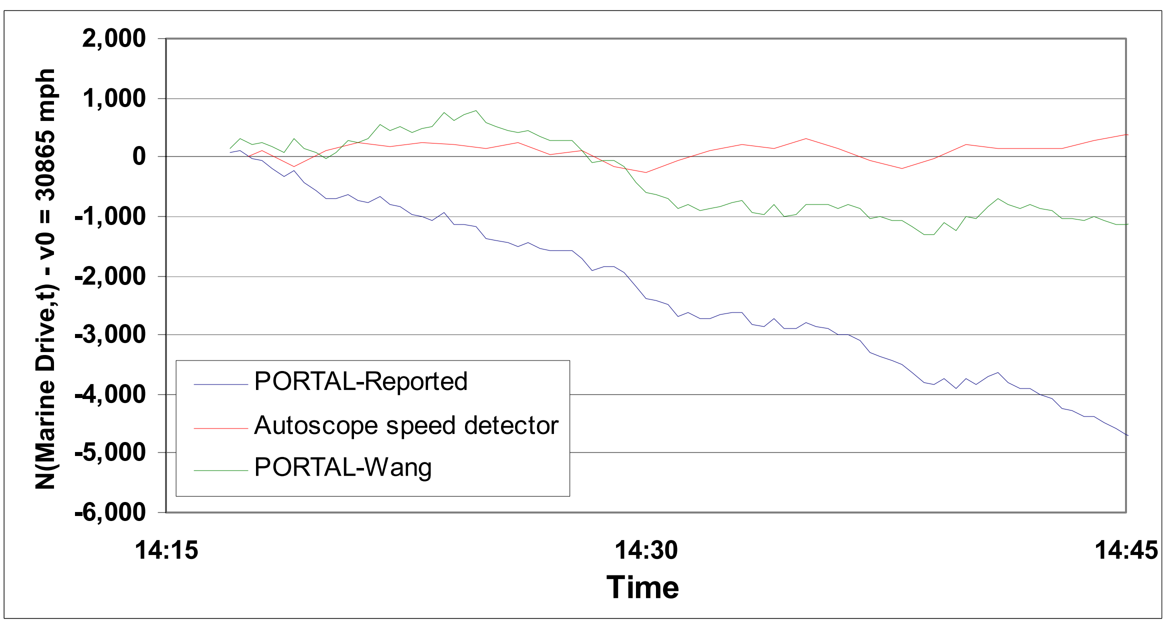


Figure H1h: Cumulative Vehicle Speeds – Oblique Plot

Hour 2
Location: I-84 WB @ Sandy Blvd
Date: October 28, 2005
Time: 12:10 to 12:40
Lane: Center

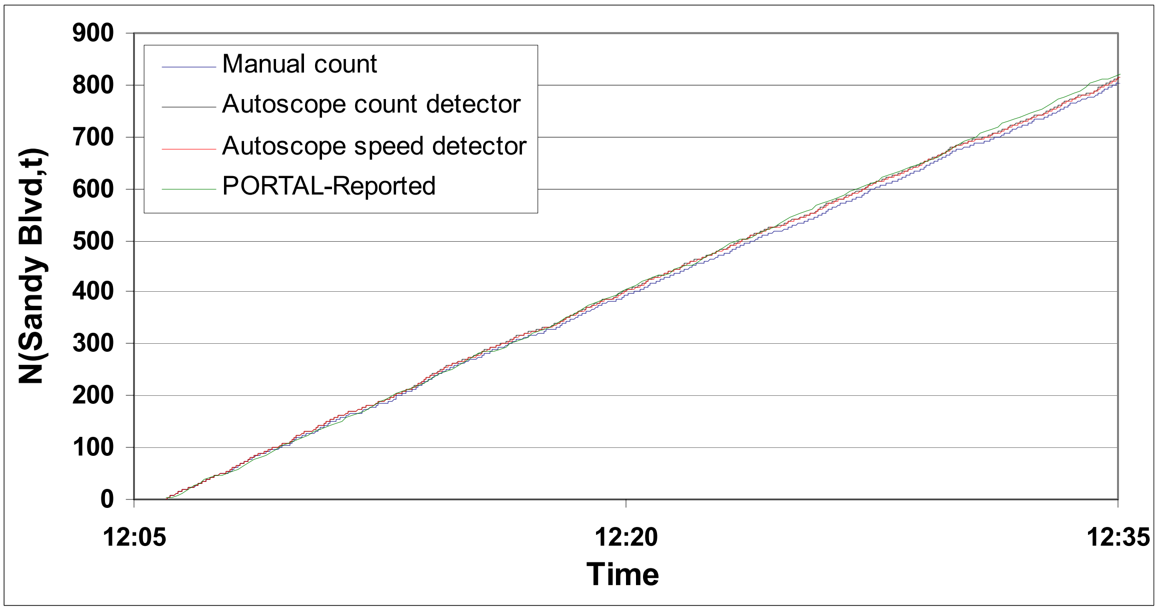


Figure H2a: Cumulative Vehicle Count

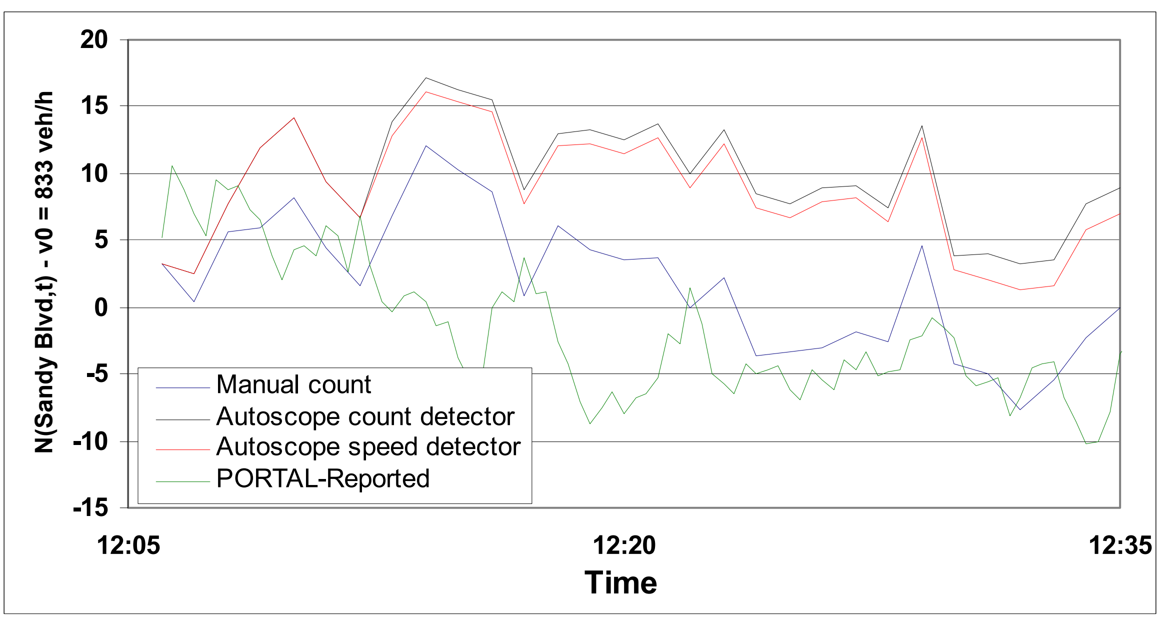


Figure H2b: Cumulative Vehicle Count - Oblique Plot

Figure H2c: Cumulative Long Vehicle Count

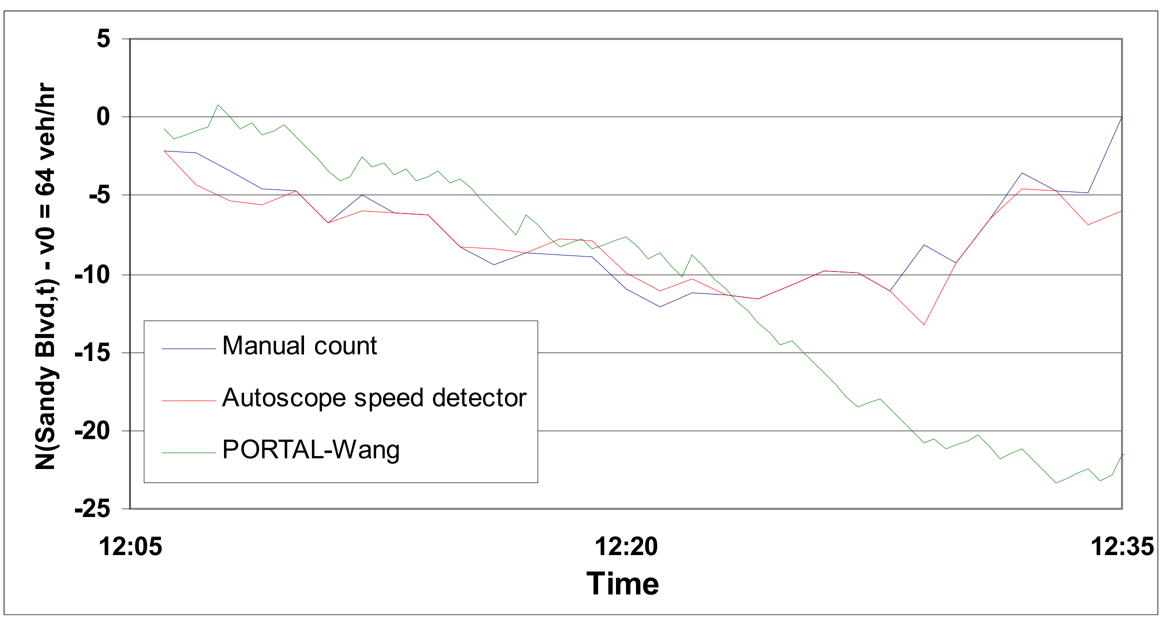


Figure H2d: Cumulative Long Vehicle Count – Oblique Plot

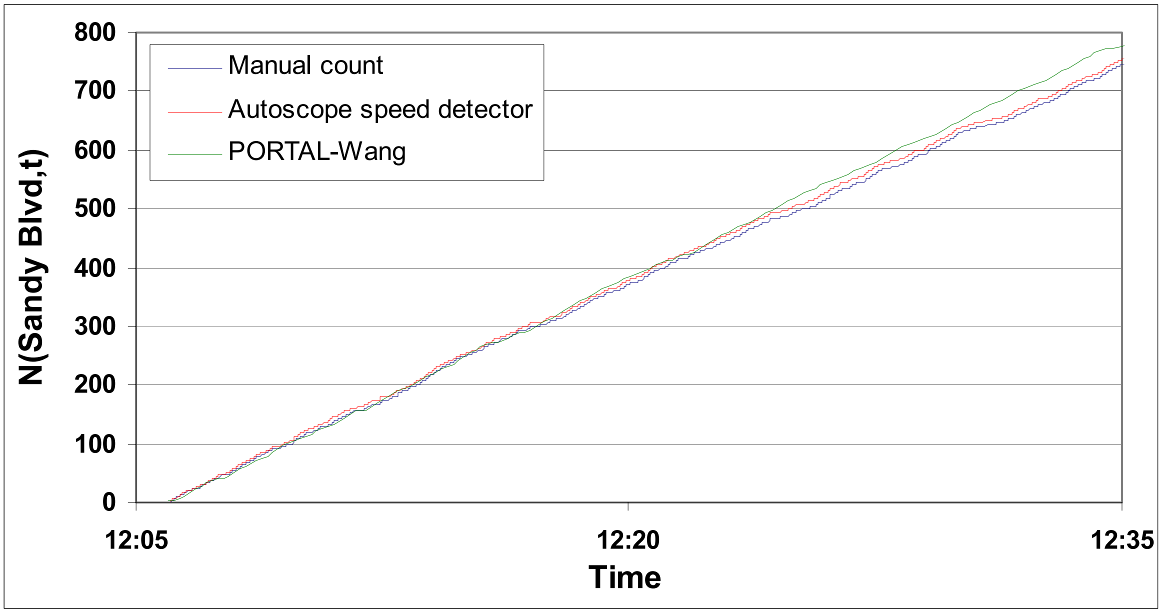


Figure H2e: Cumulative Short Vehicle Count

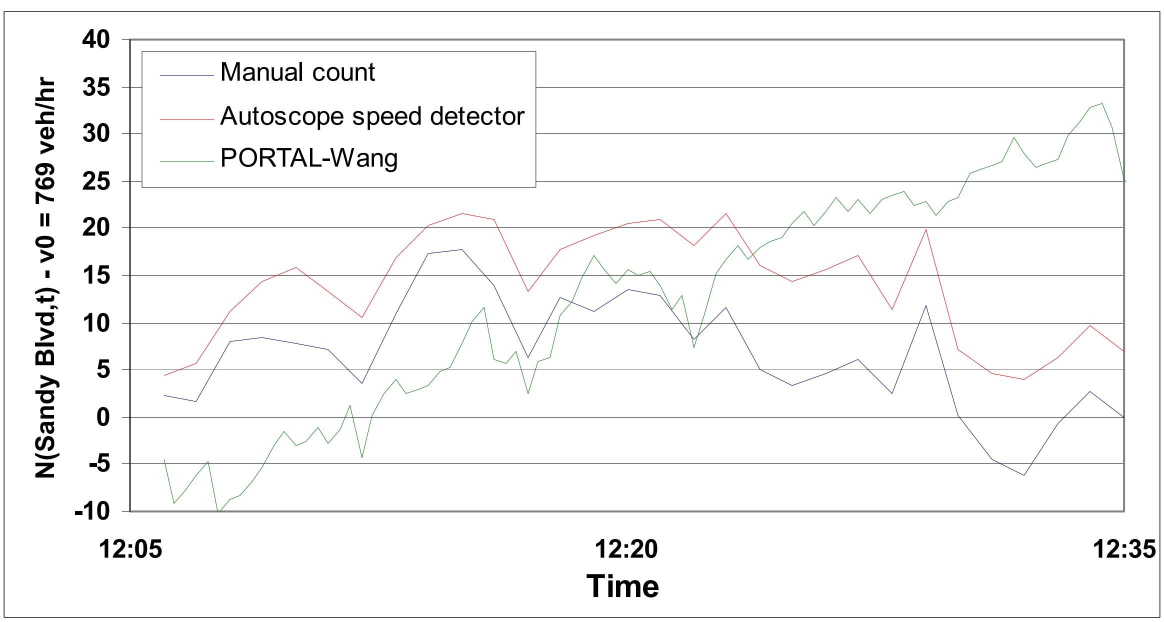


Figure H2f: Cumulative Short Vehicle Count – Oblique Plot

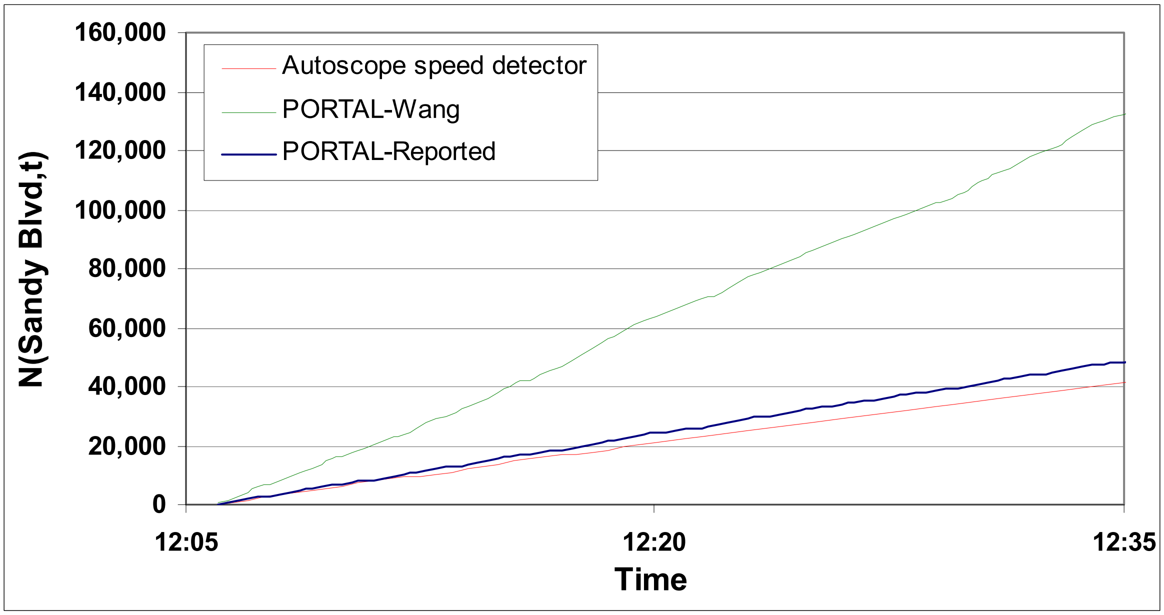


Figure H2g: Cumulative Vehicle Speeds

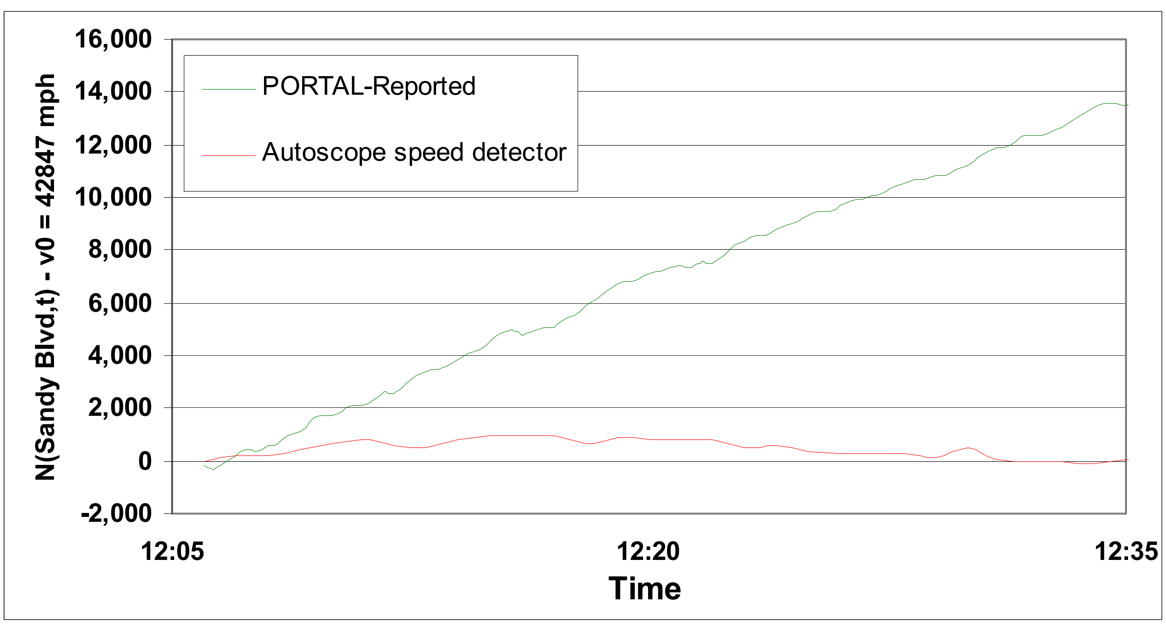


Figure H2h: Cumulative Vehicle Speeds – Oblique Plot

Hour 11
Location: I-84 WB @ Sandy Blvd
Date: December 7, 2005
Time: 12:19 pm to 13:19 pm
Lane: Center

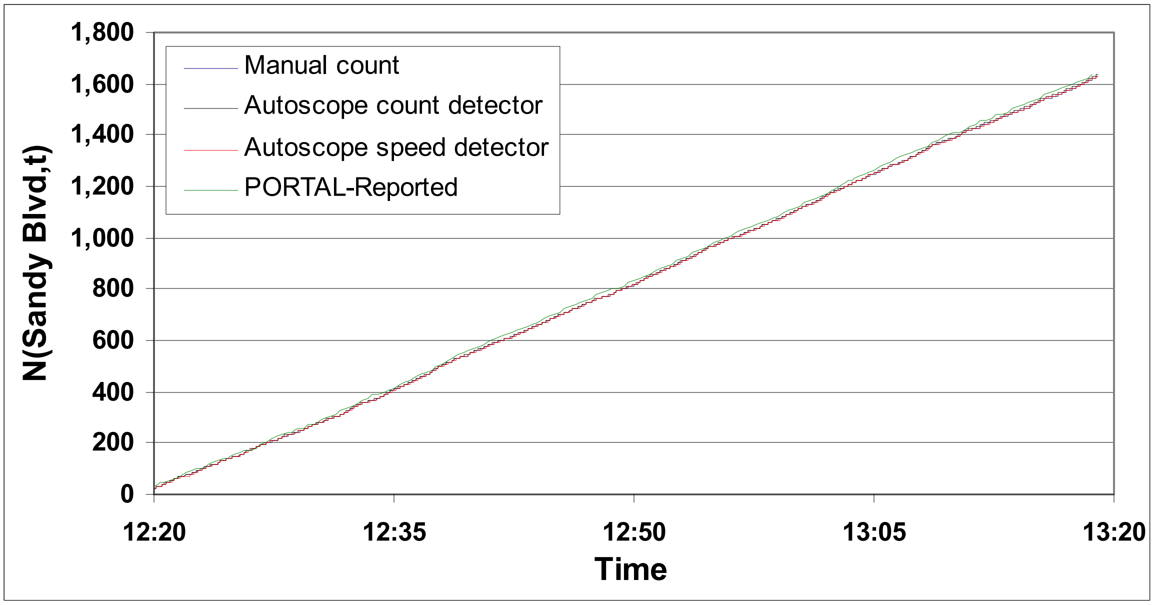


Figure H11a: Cumulative Vehicle Count

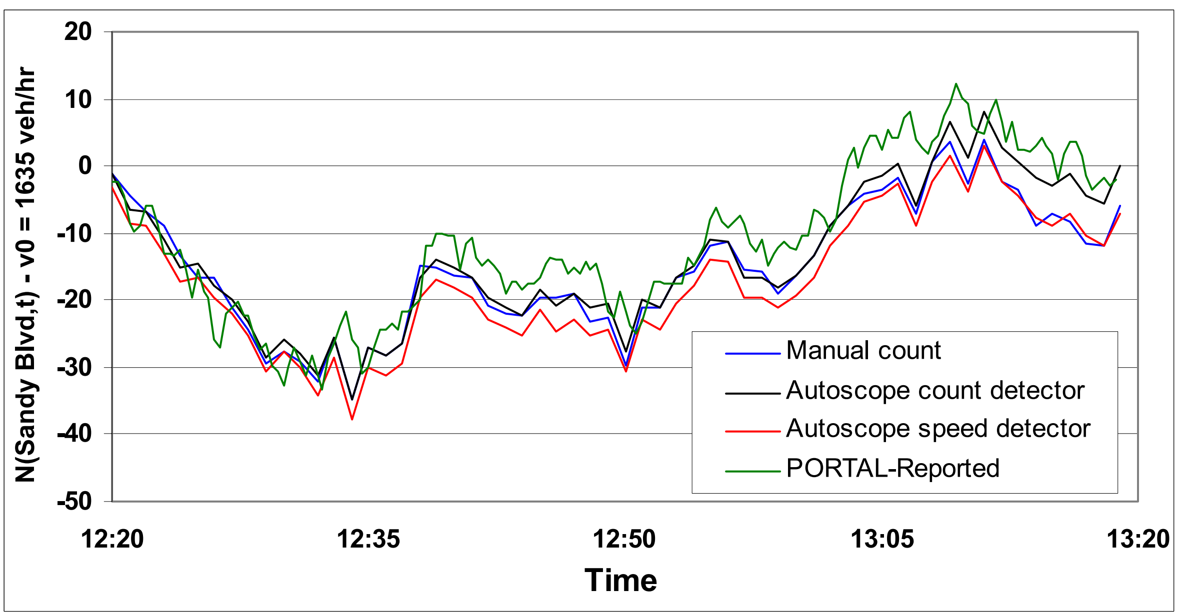


Figure H11b: Cumulative Vehicle Count - Oblique Plot

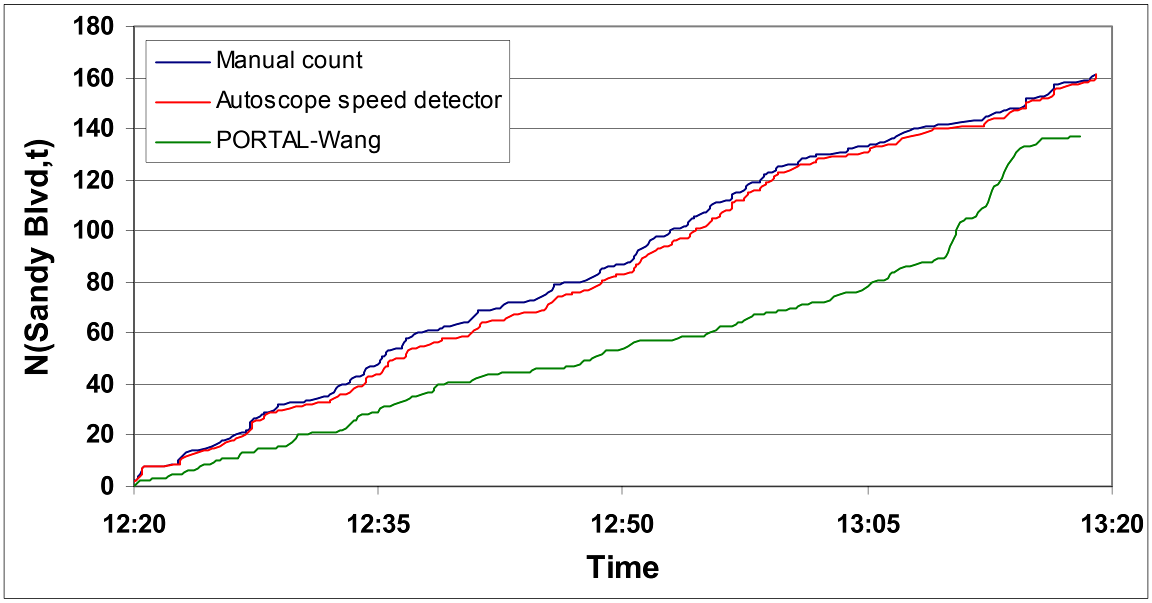


Figure H11c: Cumulative Long Vehicle Count

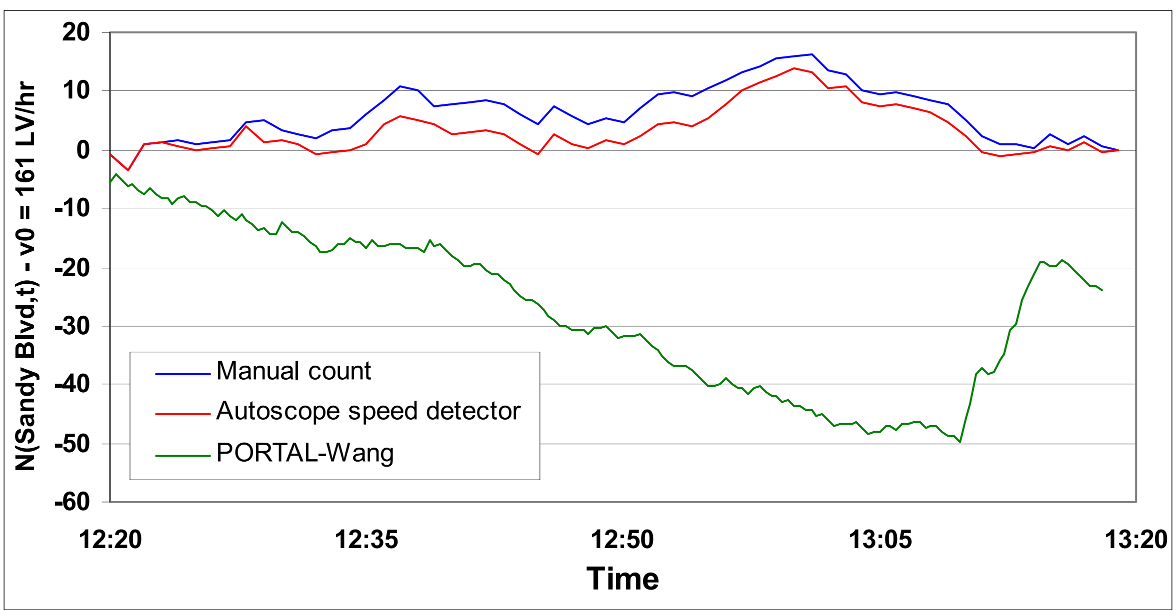


Figure H11d: Cumulative Long Vehicle Count – Oblique Plot

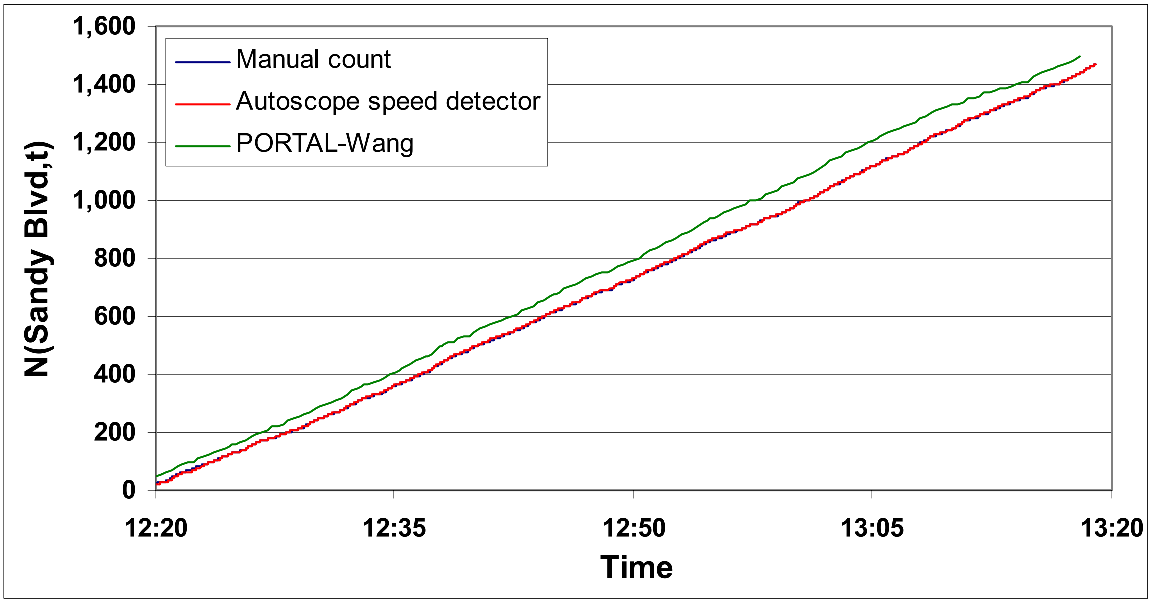


Figure H11e: Cumulative Short Vehicle Count

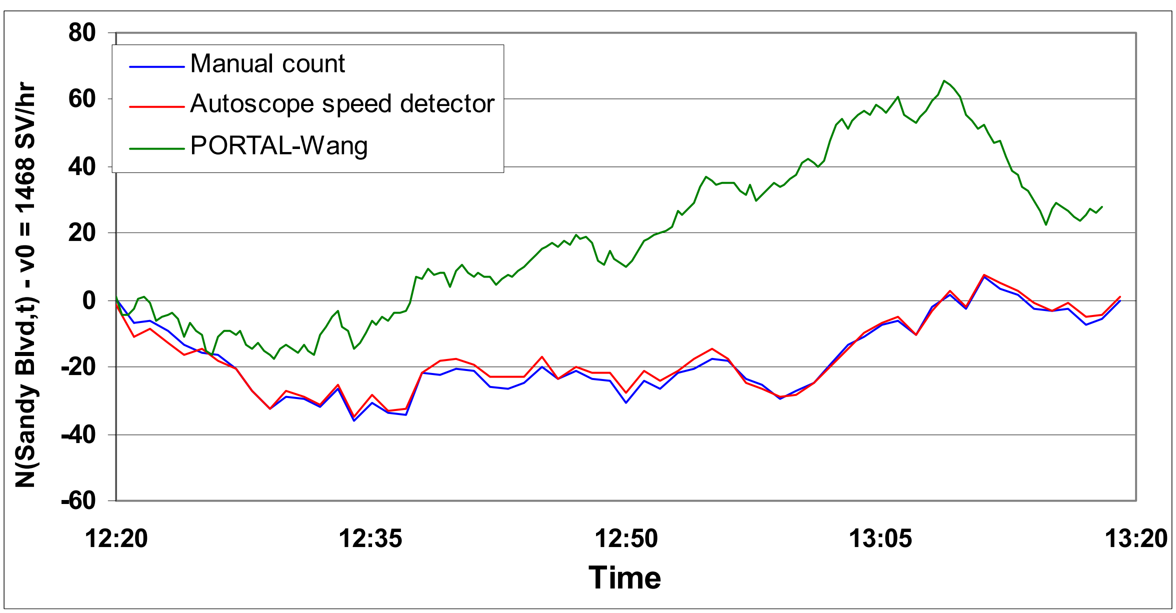


Figure H11f: Cumulative Short Vehicle Count – Oblique Plot

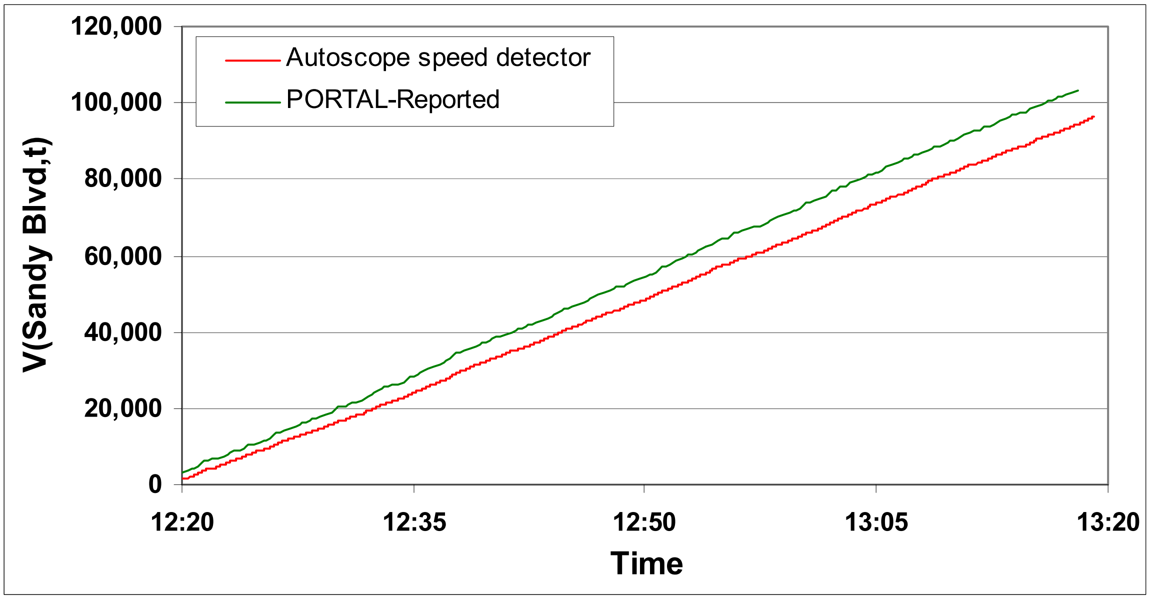


Figure H11g: Cumulative Vehicle Speeds

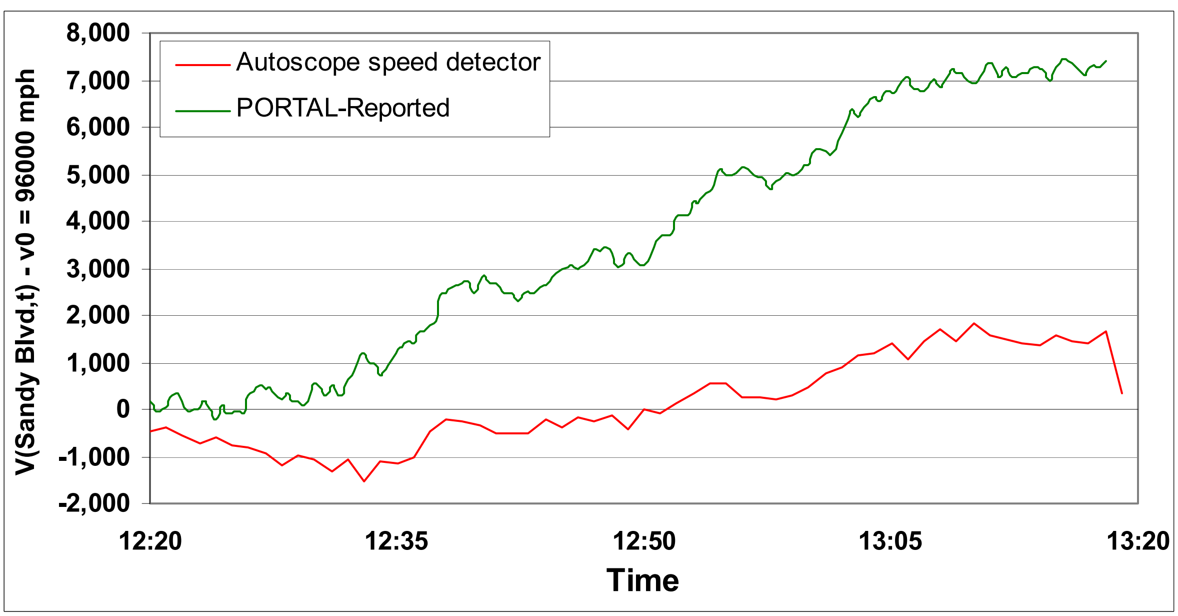


Figure H11h: Cumulative Vehicle Speeds – Oblique Plot

Hour 12
Location: I-84 WB @ Sandy Blvd
Date: December 7, 2005
Time: 13:19 pm to 14:19 pm
Lane: Center

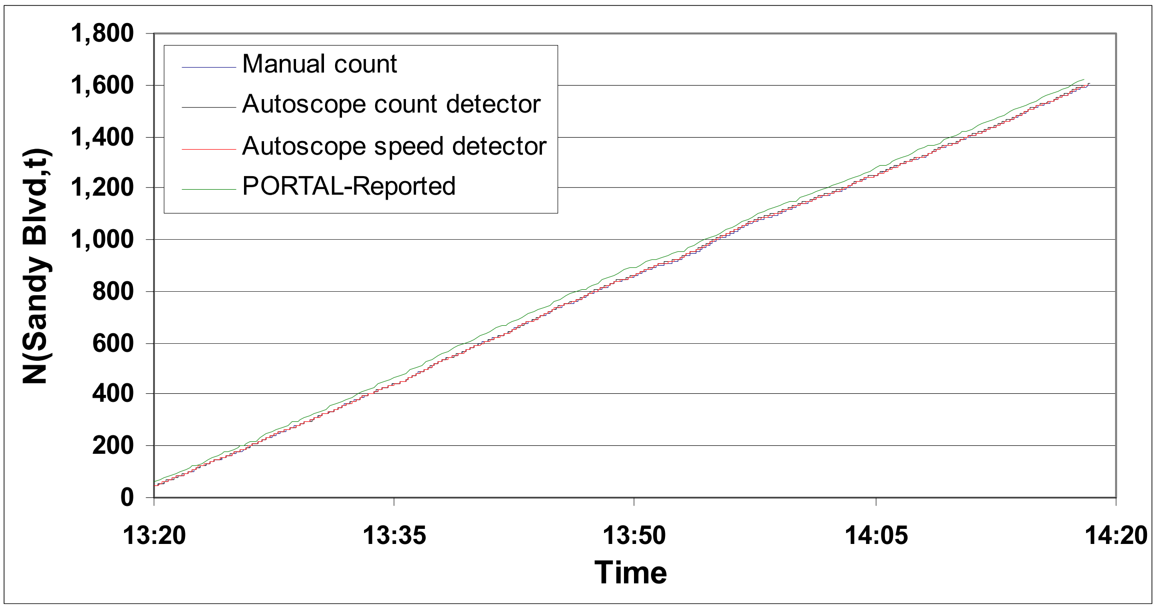


Figure H12a: Cumulative Vehicle Count

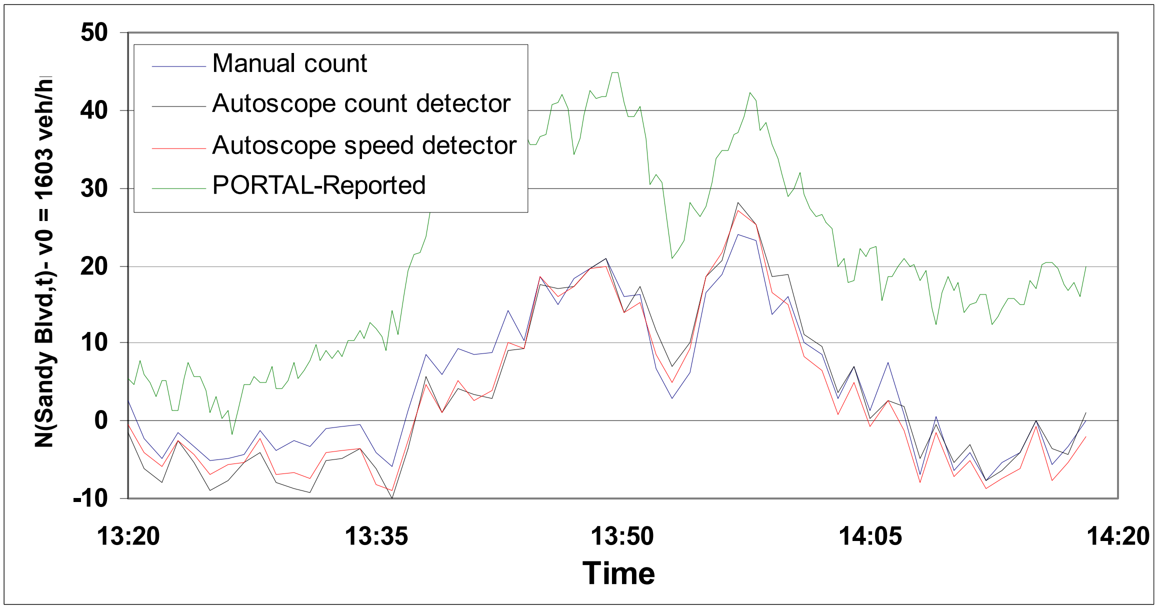


Figure H12b: Cumulative Vehicle Count - Oblique Plot

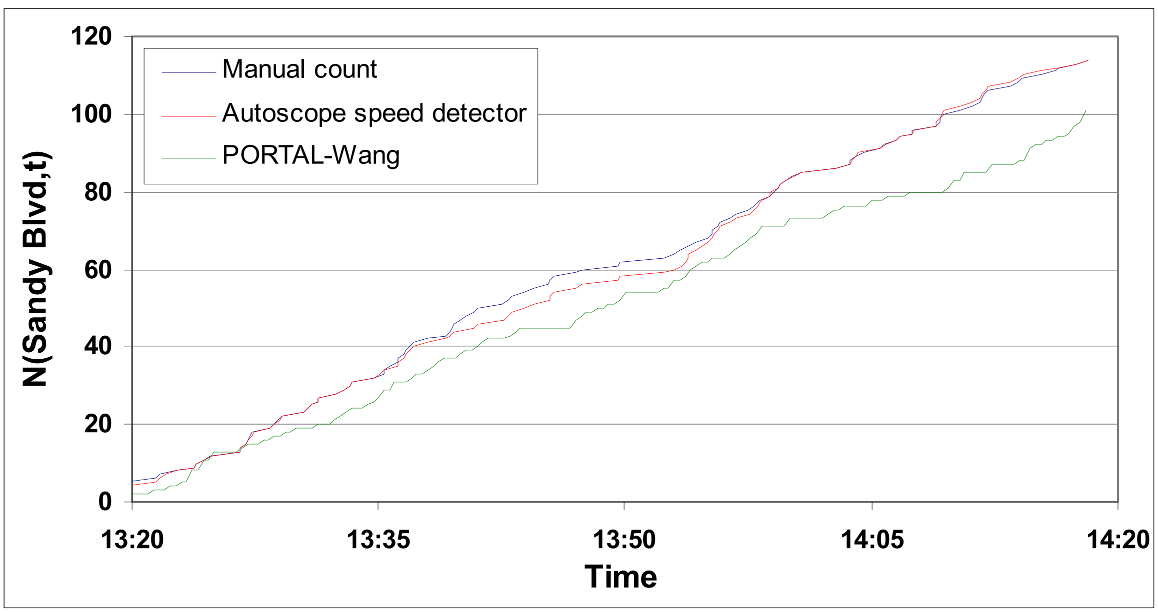


Figure H12c: Cumulative Long Vehicle Count

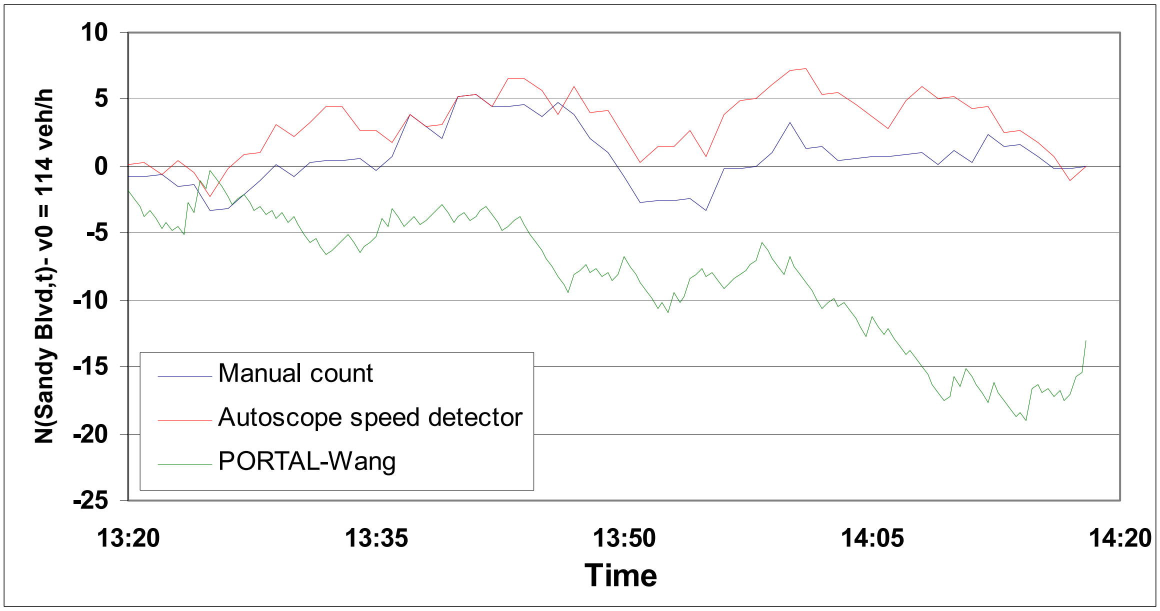


Figure H12d: Cumulative Long Vehicle Count – Oblique Plot

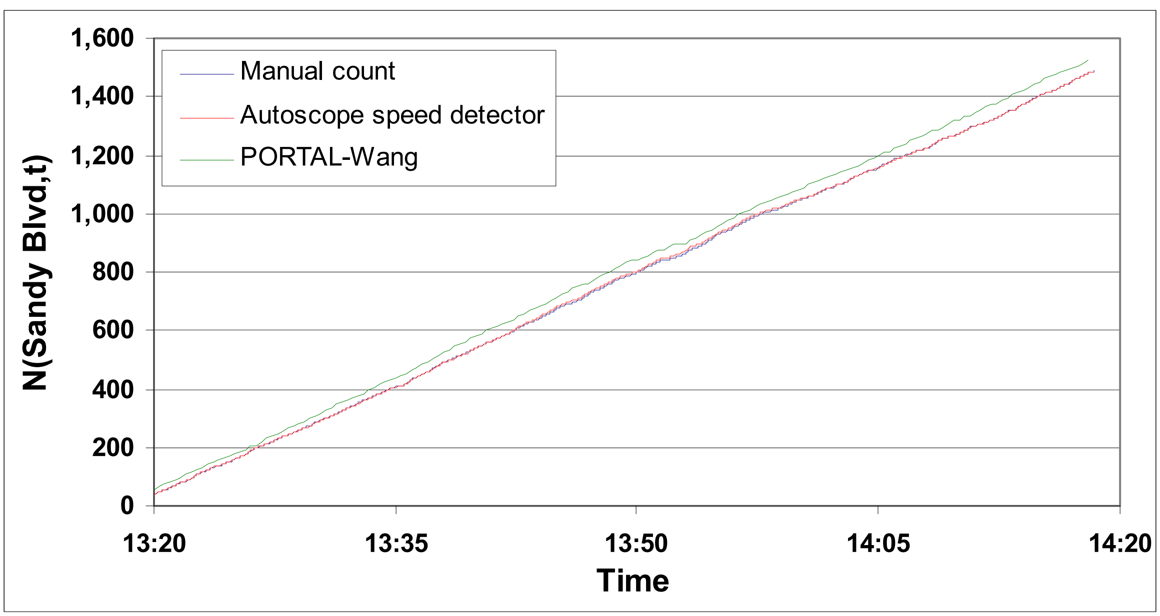


Figure H12e: Cumulative Short Vehicle Count

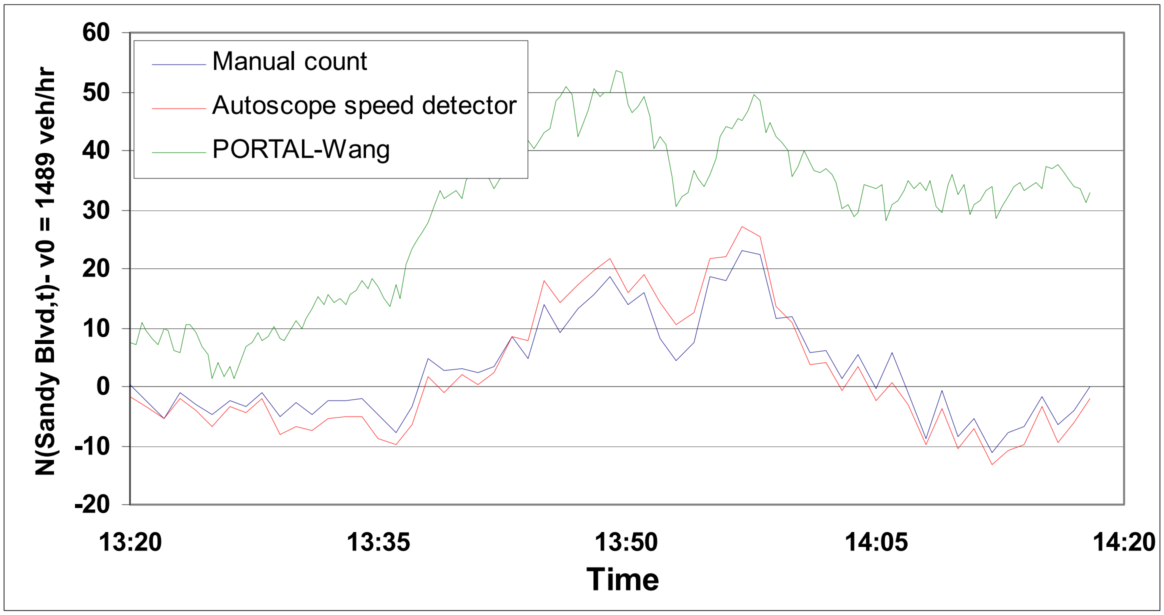


Figure H12f: Cumulative Short Vehicle Count – Oblique Plot

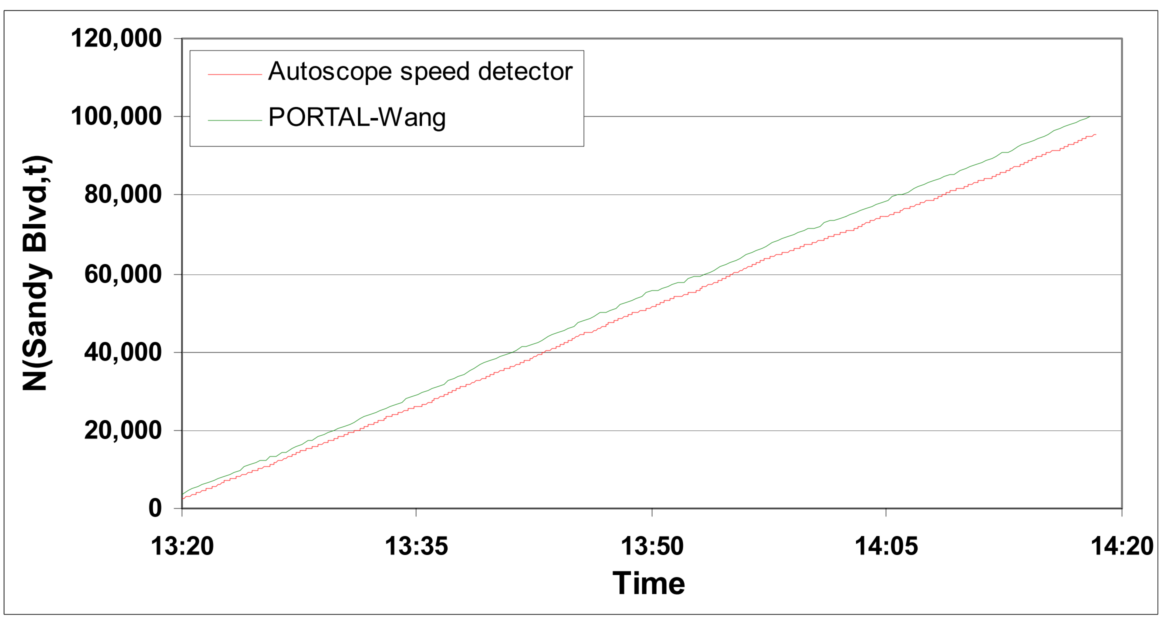


Figure H12g: Cumulative Vehicle Speeds

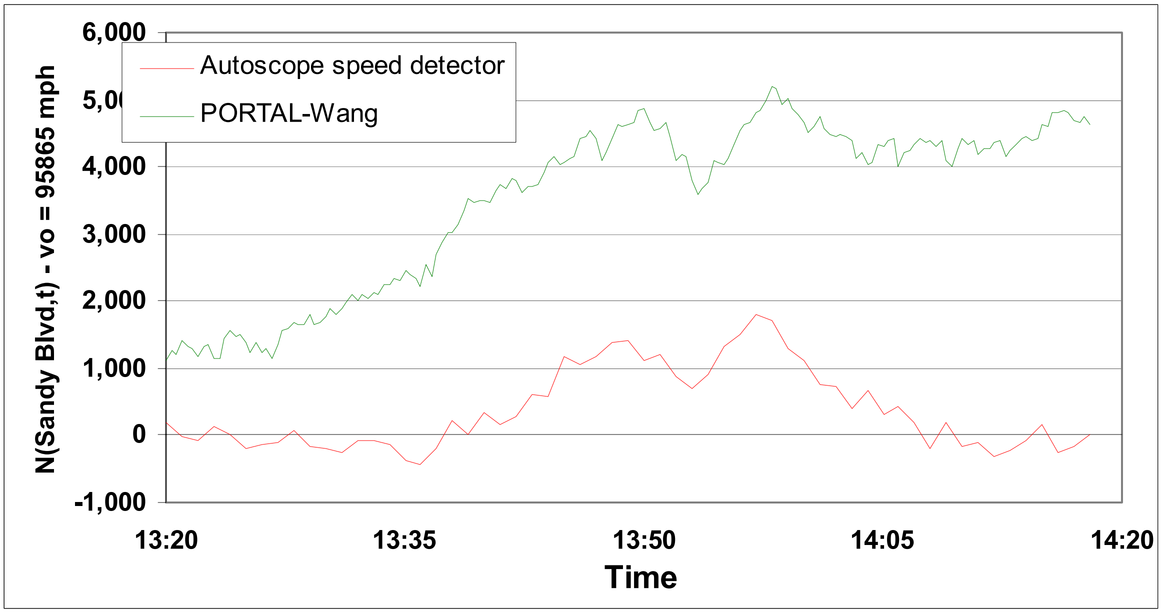


Figure H12h: Cumulative Vehicle Speeds – Oblique Plot

Hour 23
Location: I-5 NB @ Lower Boones Ferry Rd
Date: December 14, 2005
Time: 13:25:00 to 14:25
Lane: Center

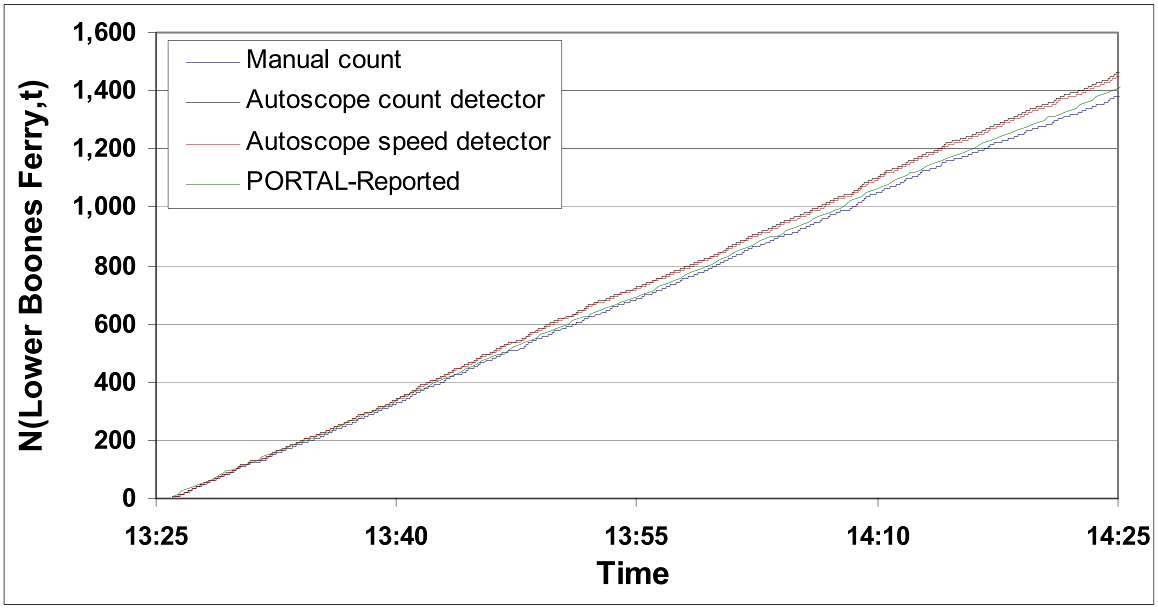


Figure H23a: Cumulative Vehicle Count

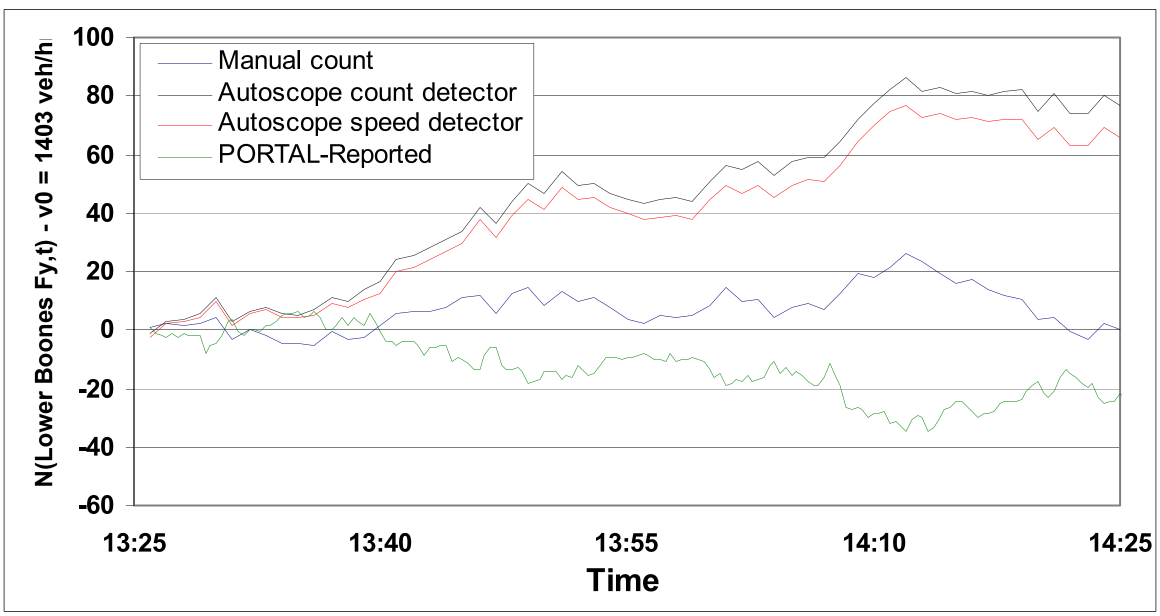


Figure H23b: Cumulative Vehicle Count - Oblique Plot

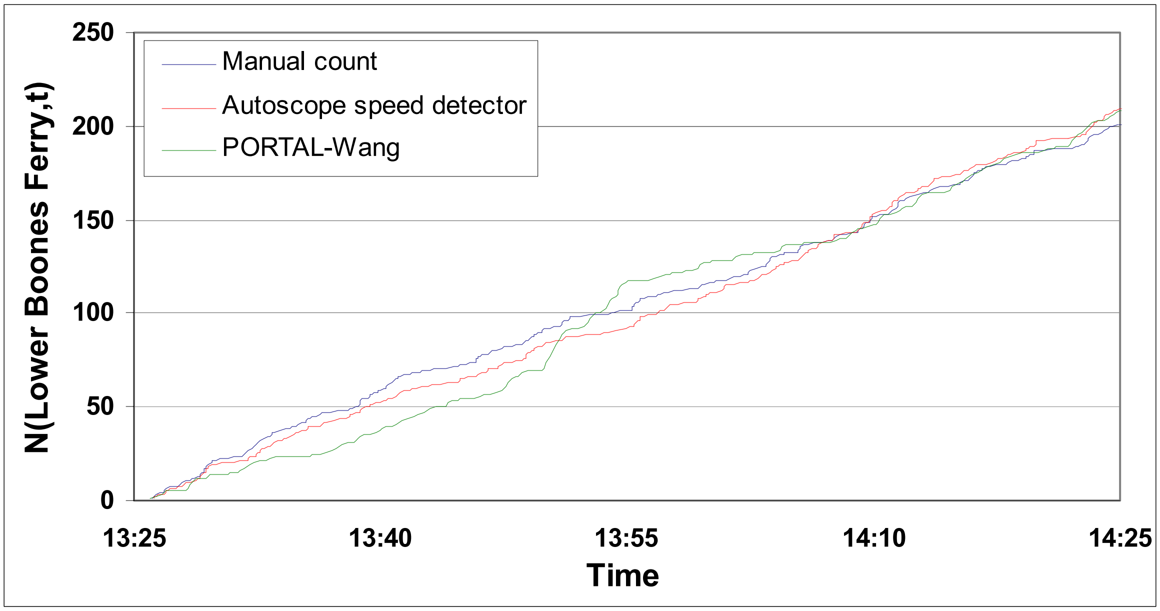


Figure H23c: Cumulative Long Vehicle Count

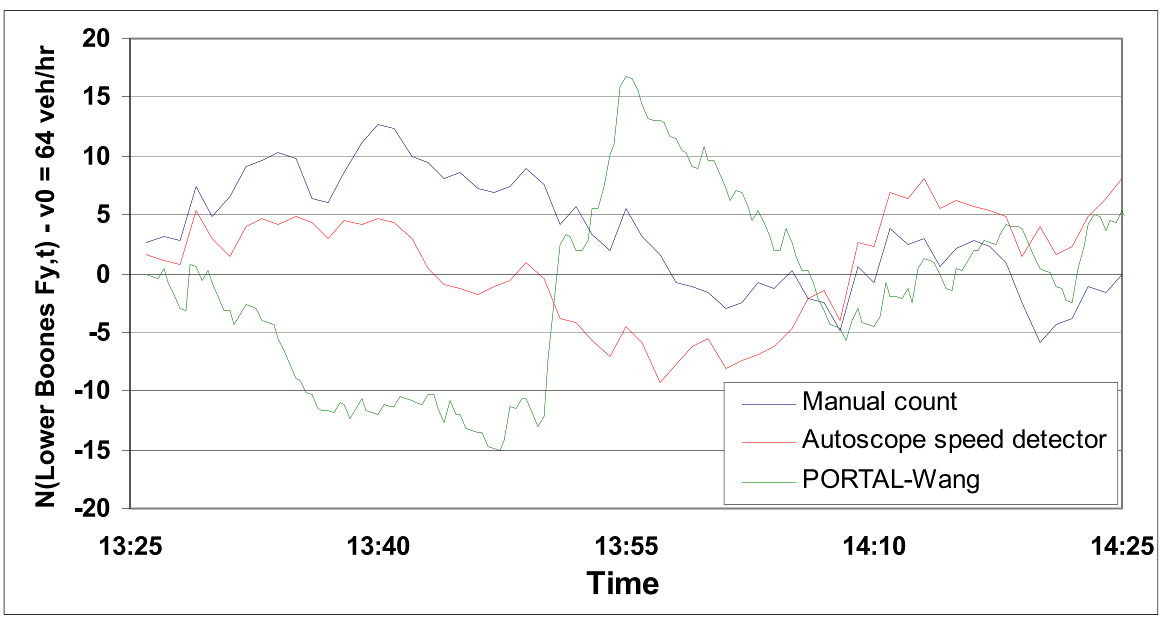


Figure H23d: Cumulative Long Vehicle Count – Oblique Plot

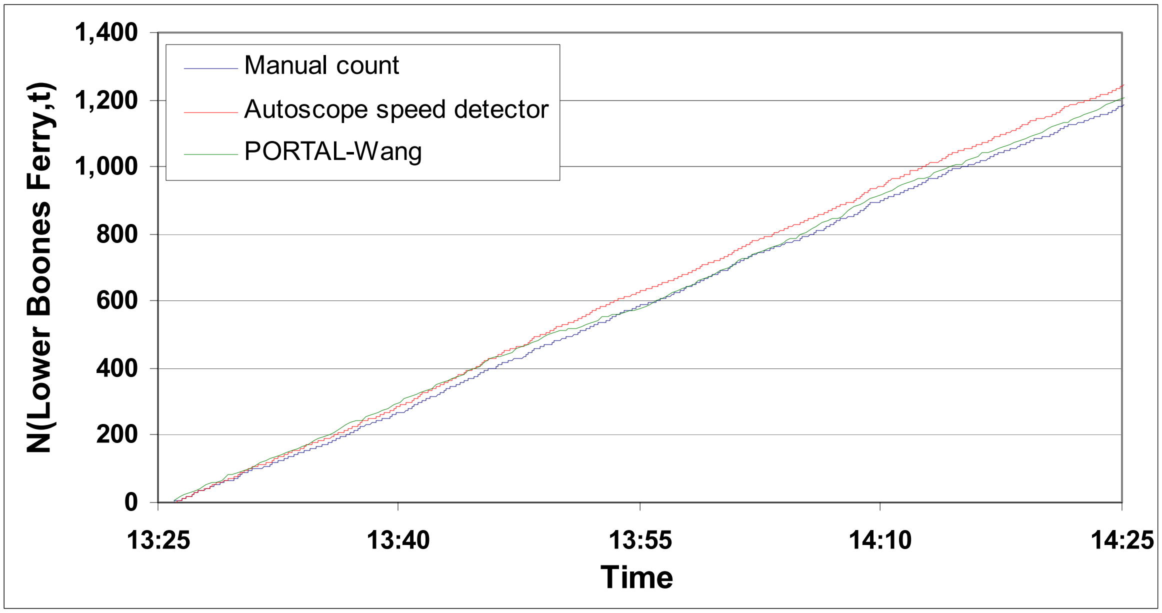


Figure H23 e: Cumulative Short Vehicle Count

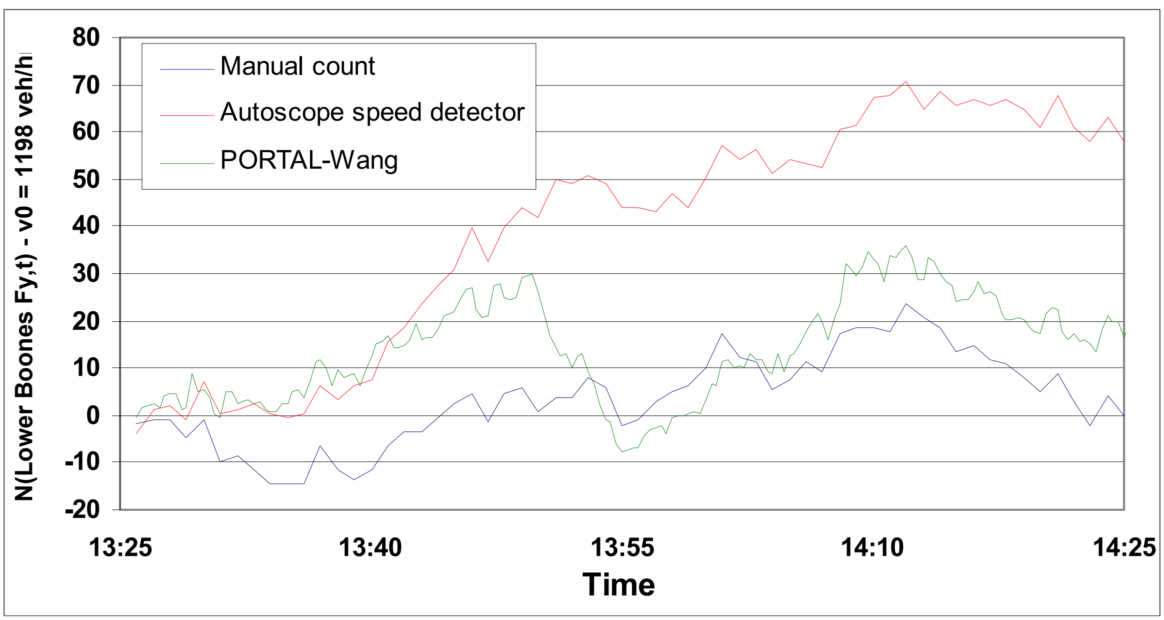


Figure H23f: Cumulative Short Vehicle Count – Oblique Plot

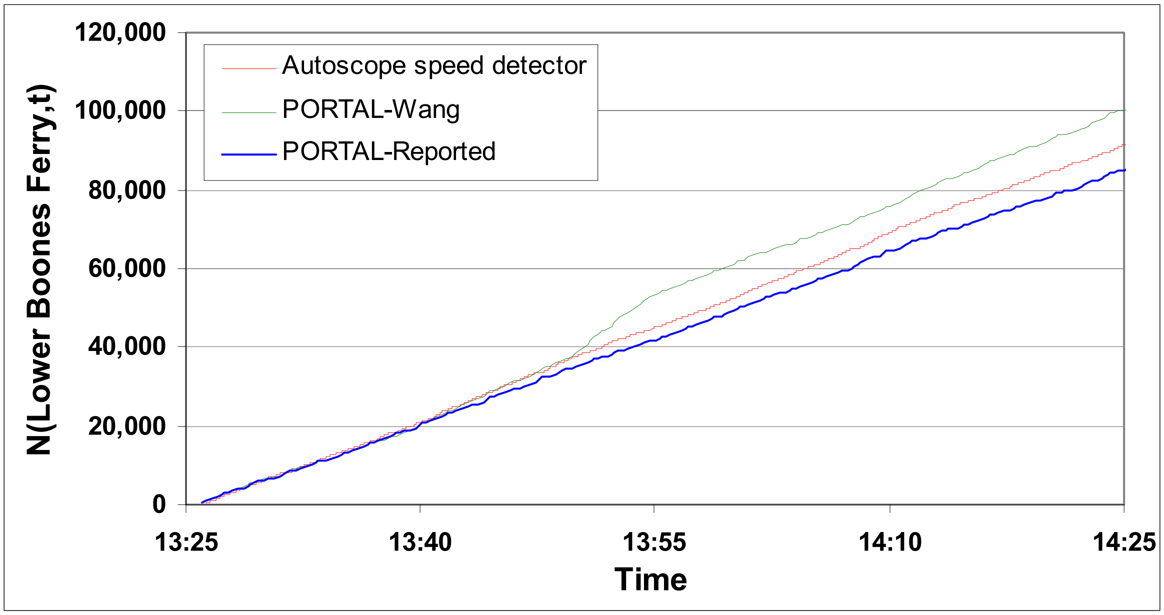


Figure H23g: Cumulative Vehicle Speeds

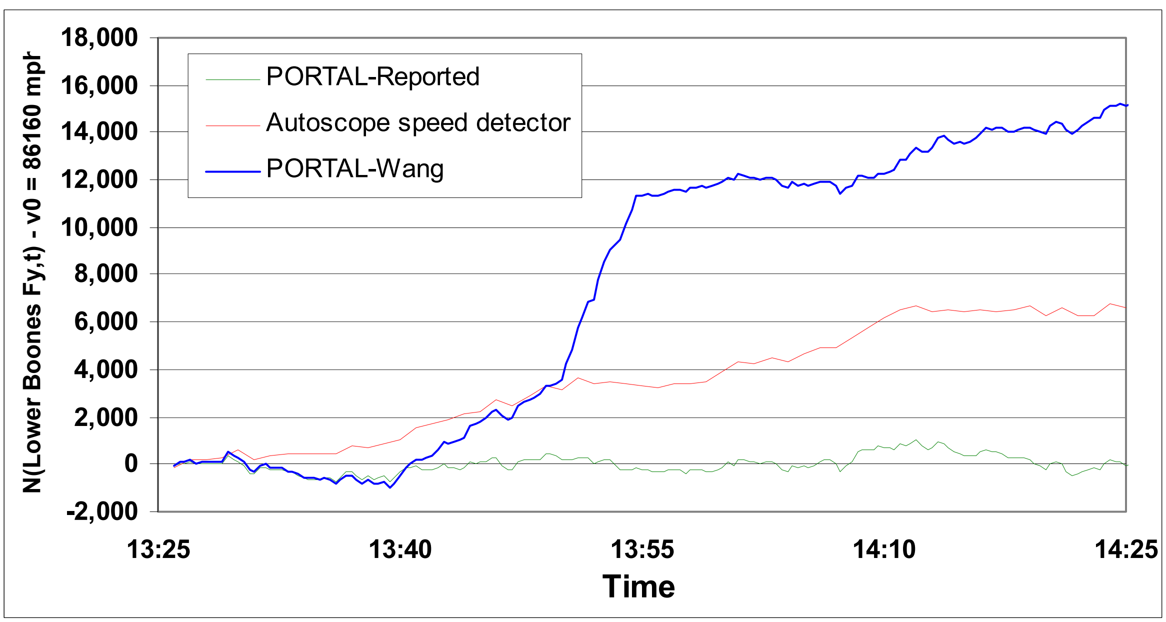


Figure H23h: Cumulative Vehicle Speeds – Oblique Plot

Hour 24

Location: I-5 NB @ Lower Boones Ferry Rd
Date: December 14, 2005
Time: 13:25:00 to 14:25
Lane: Shoulder

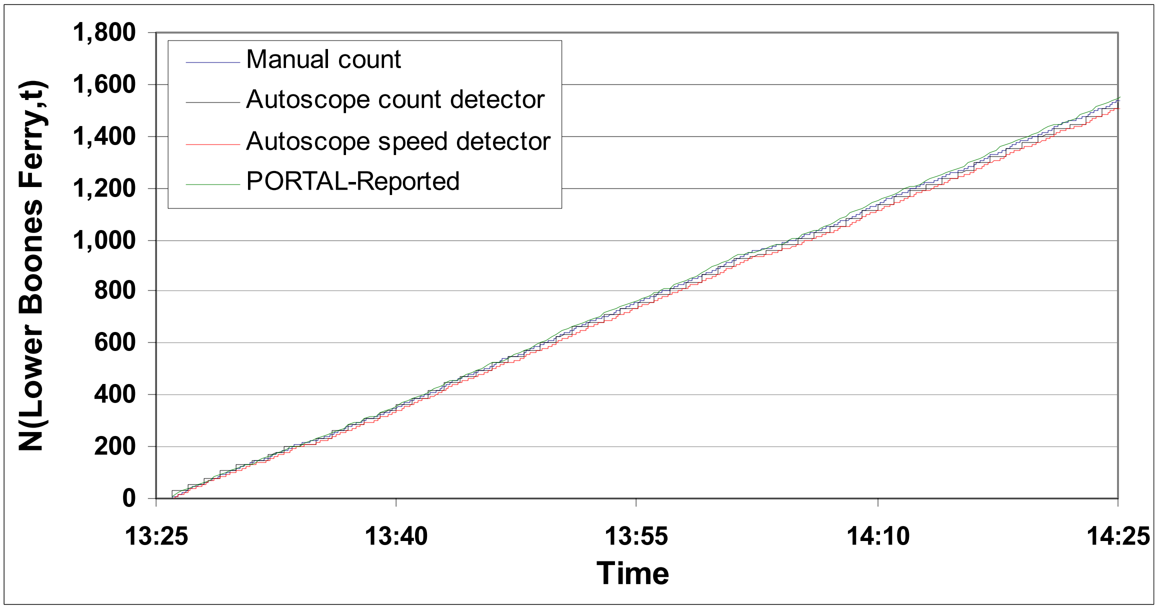


Figure H24a: Cumulative Vehicle Count

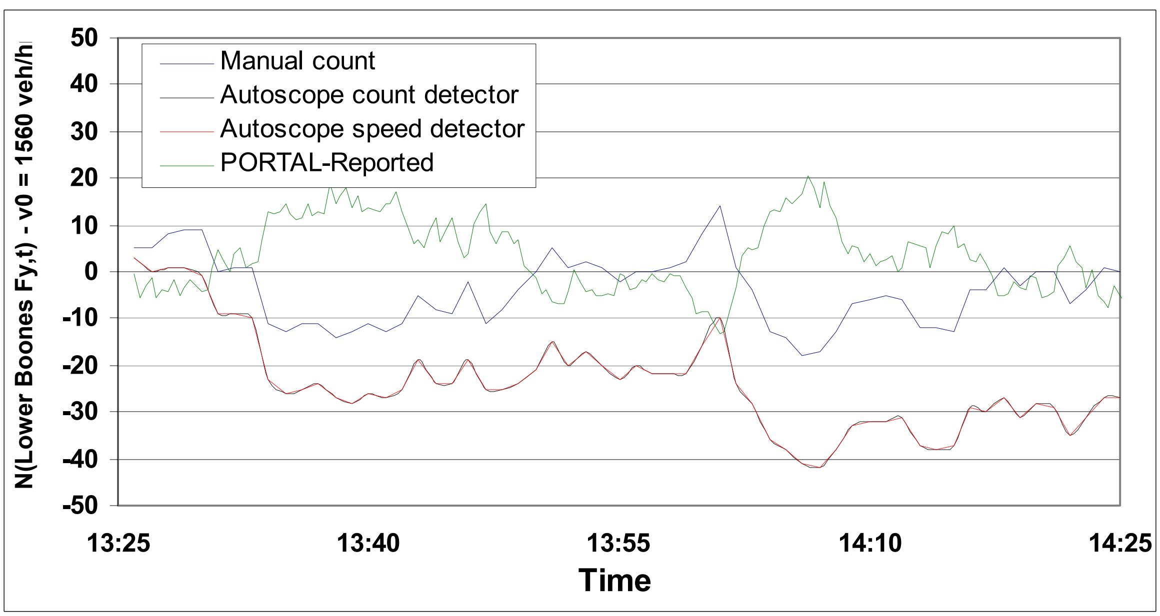


Figure H24b: Cumulative Vehicle Count - Oblique Plot

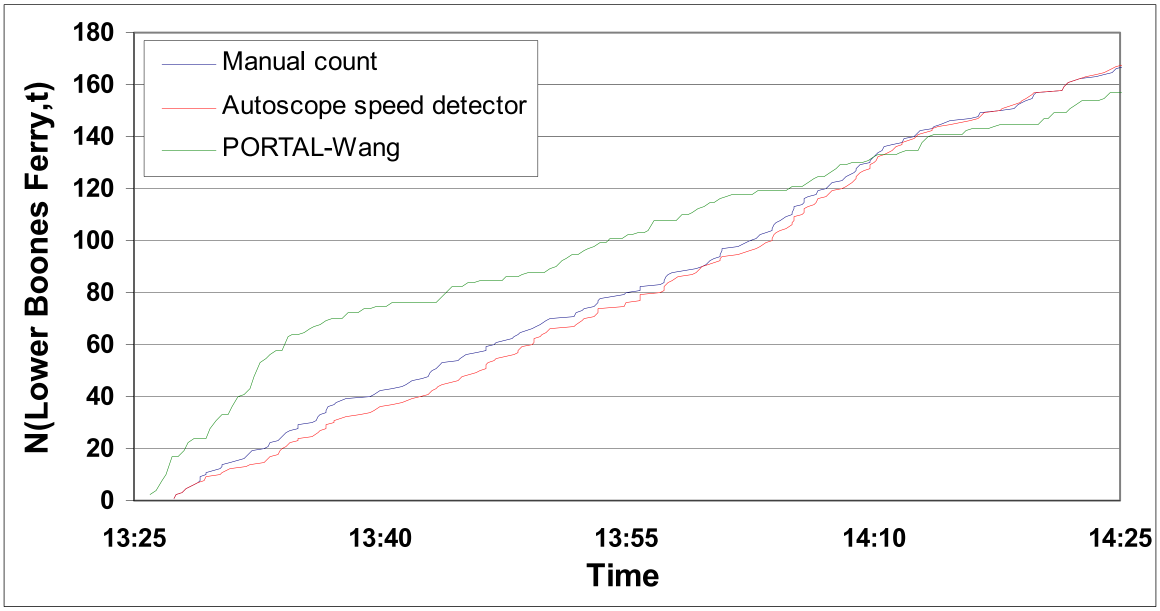


Figure H24c: Cumulative Long Vehicle Count

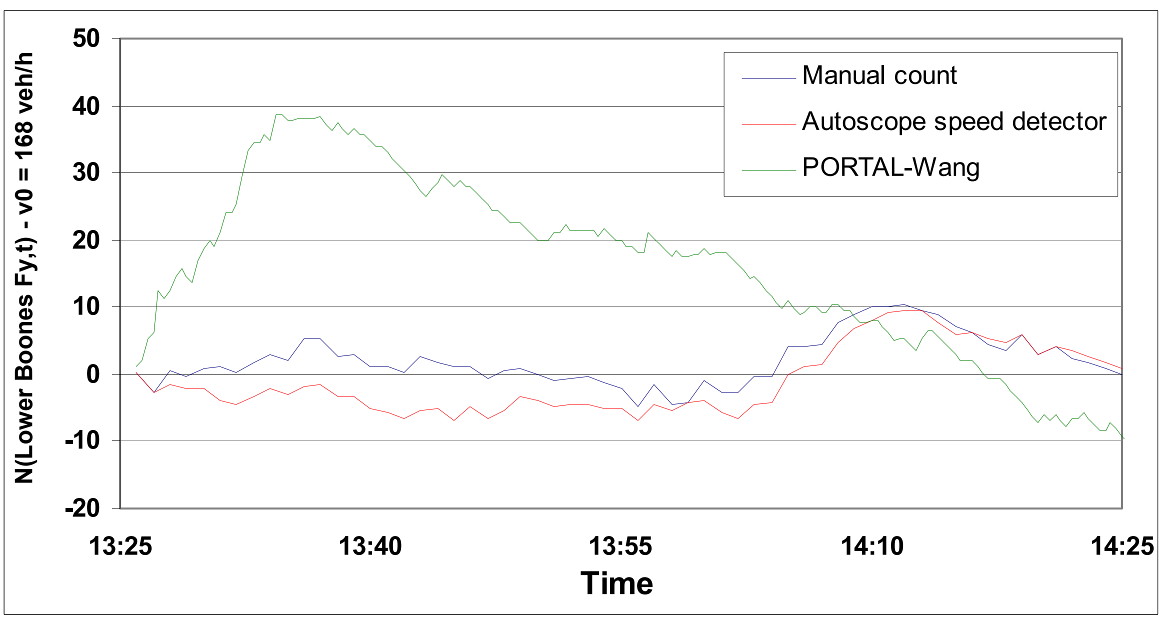


Figure H24d: Cumulative Long Vehicle Count – Oblique Plot

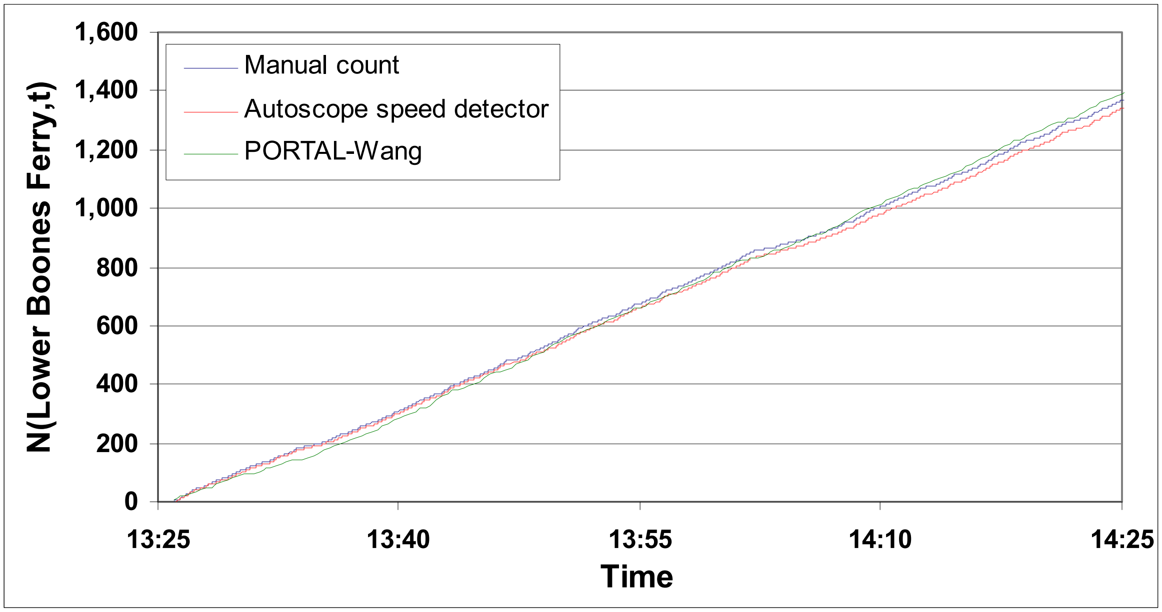


Figure H24e: Cumulative Short Vehicle Count

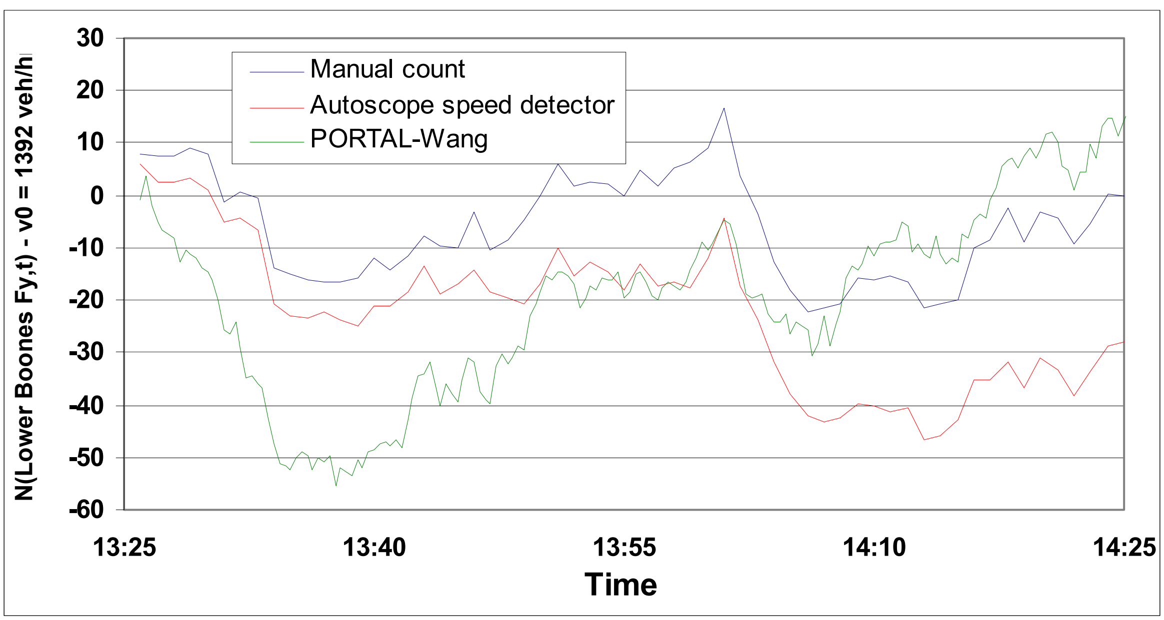


Figure H24f: Cumulative Short Vehicle Count – Oblique Plot

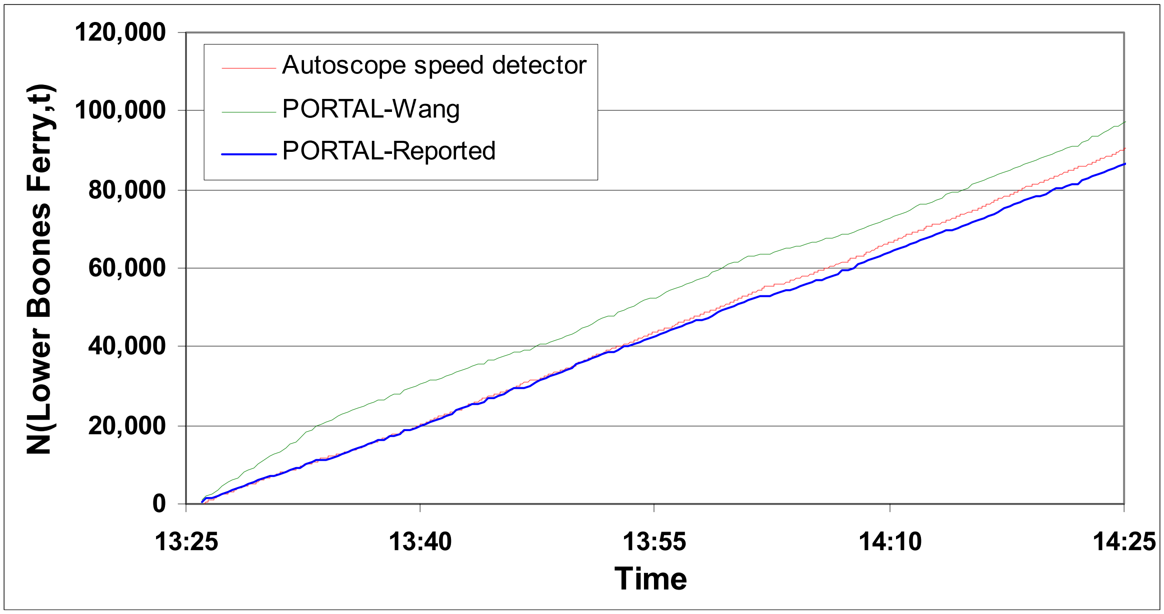


Figure H24g: Cumulative Vehicle Speeds

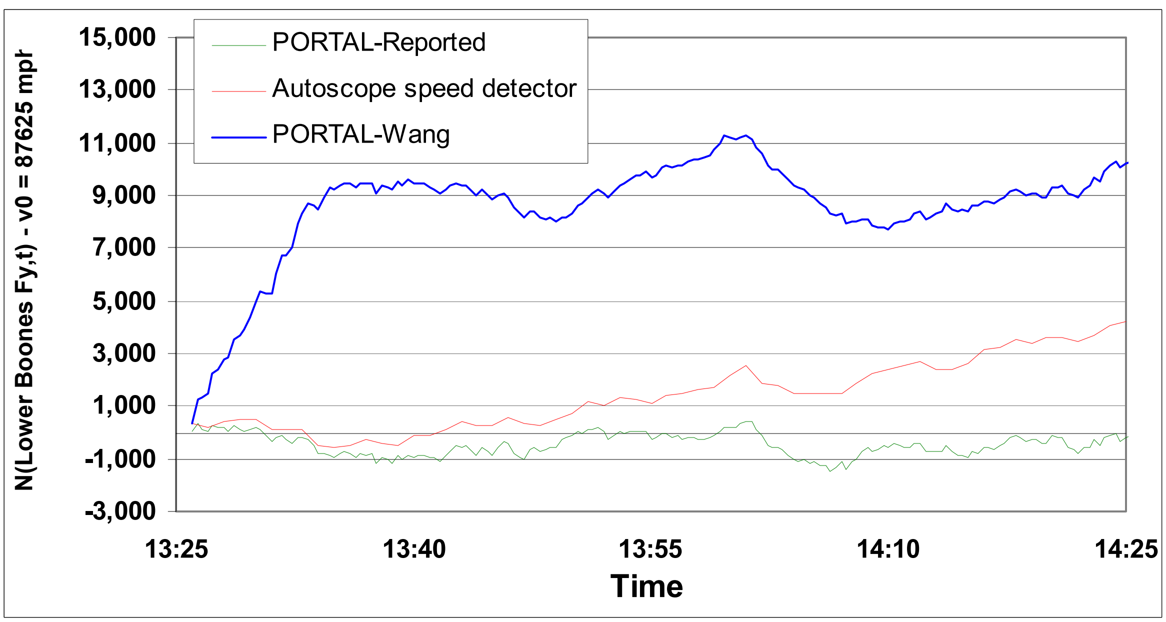


Figure H24h: Cumulative Vehicle Speeds – Oblique Plot

Hour 29

Location: I-5 SB @ Marine Drive
Date: December 15, 2005
Time: 12:14 to 13:14
Lane: Center

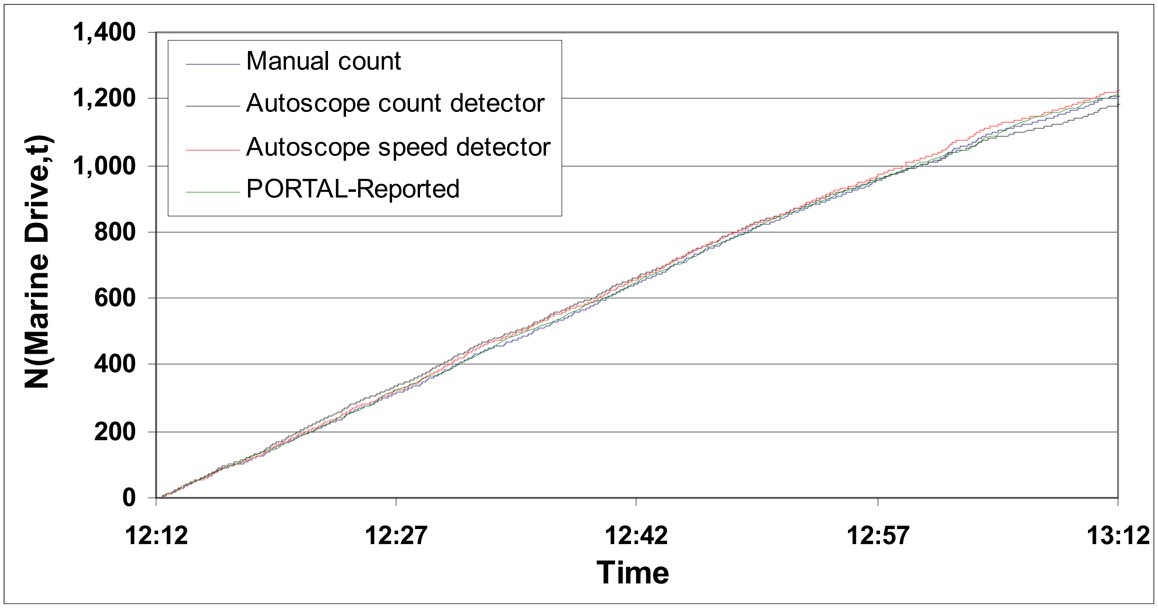


Figure H29a: Cumulative Vehicle Count

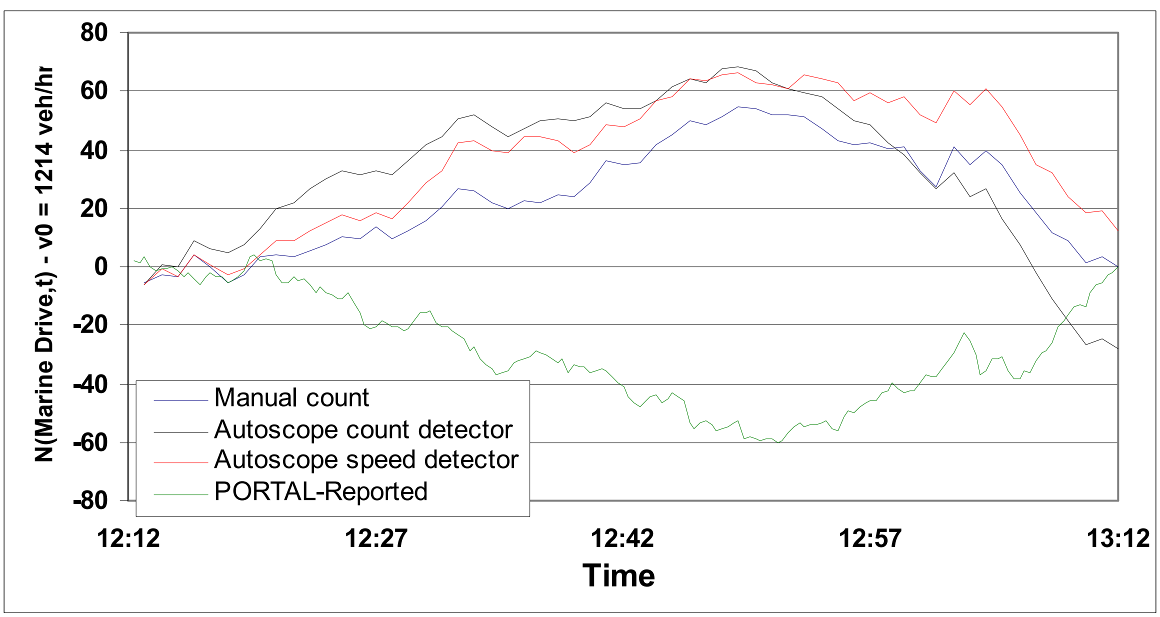


Figure H29b: Cumulative Vehicle Count - Oblique Plot

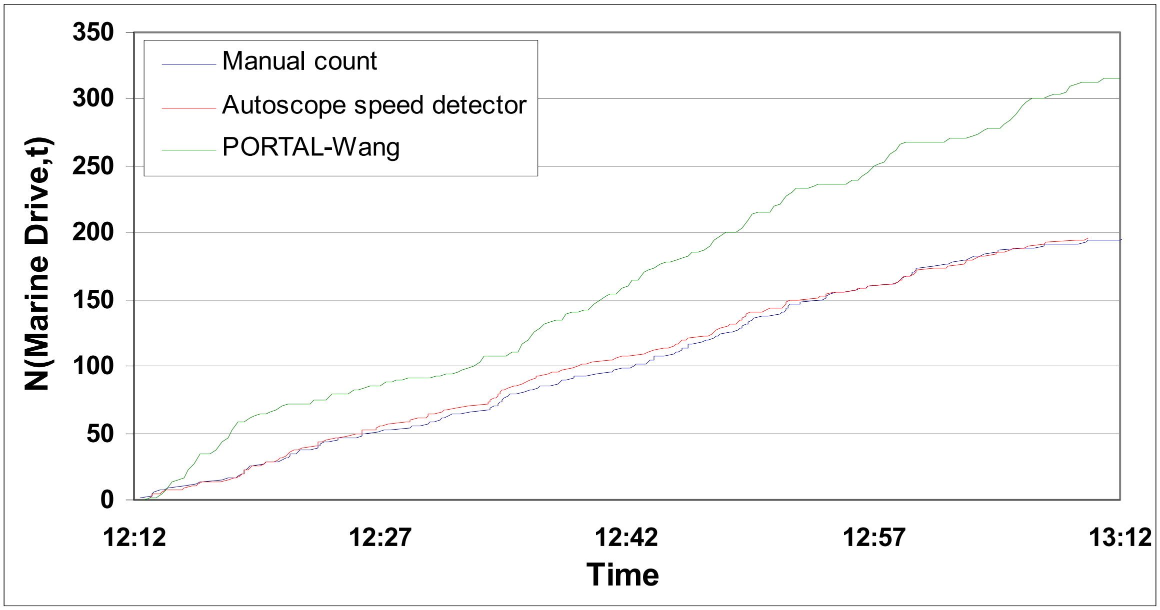


Figure H29c: Cumulative Long Vehicle Count

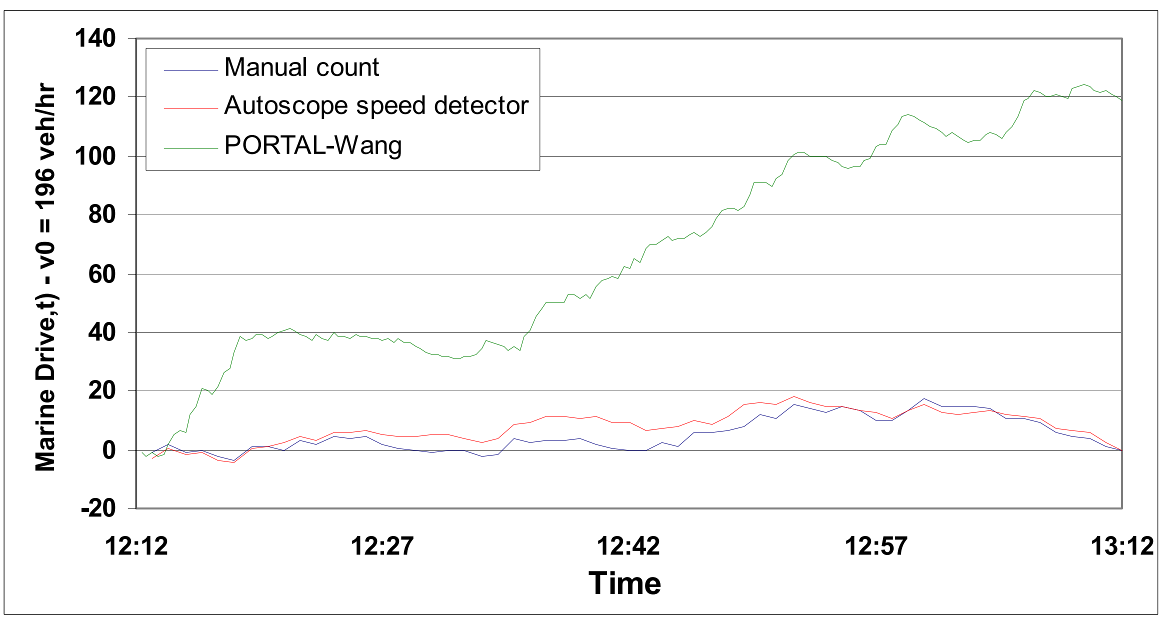


Figure H29d: Cumulative Long Vehicle Count – Oblique Plot

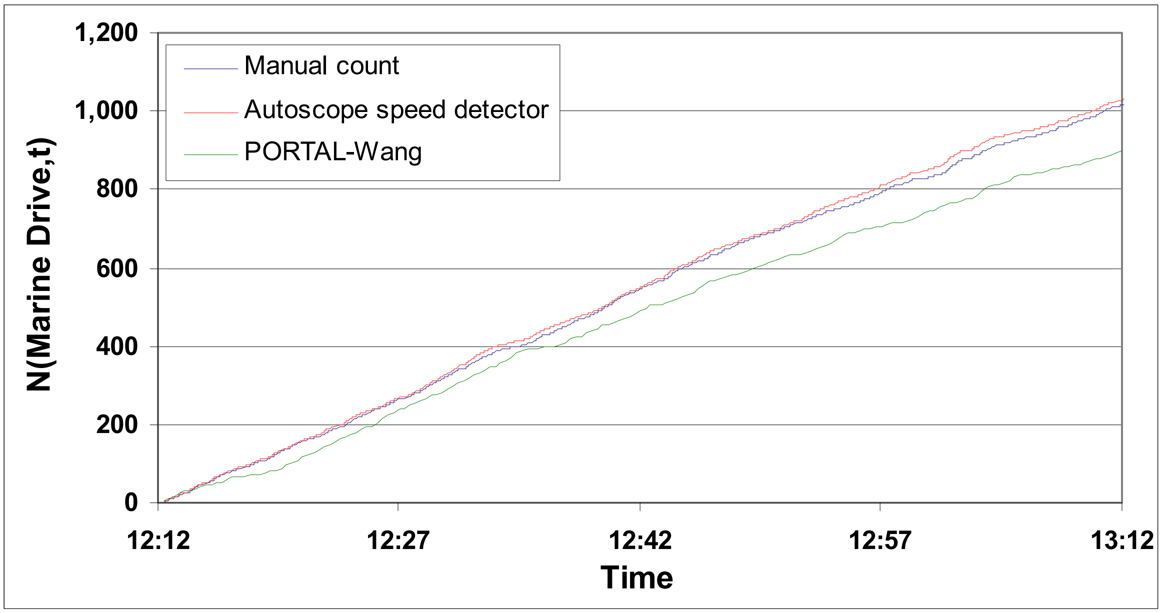


Figure H29e: Cumulative Short Vehicle Count

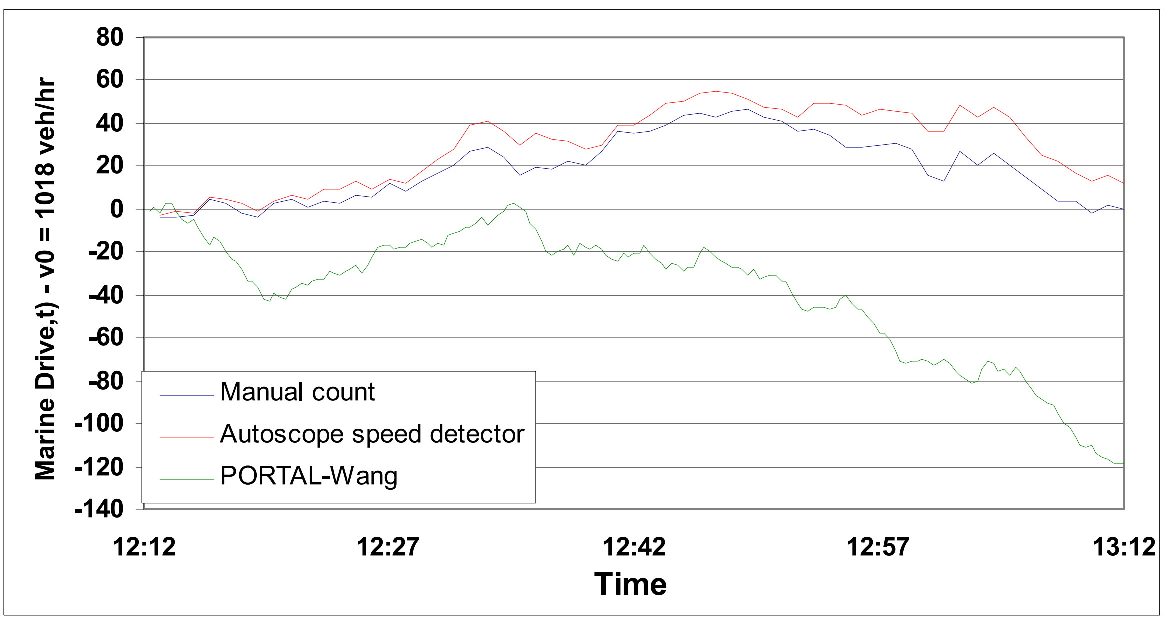


Figure H29f: Cumulative Short Vehicle Count – Oblique Plot

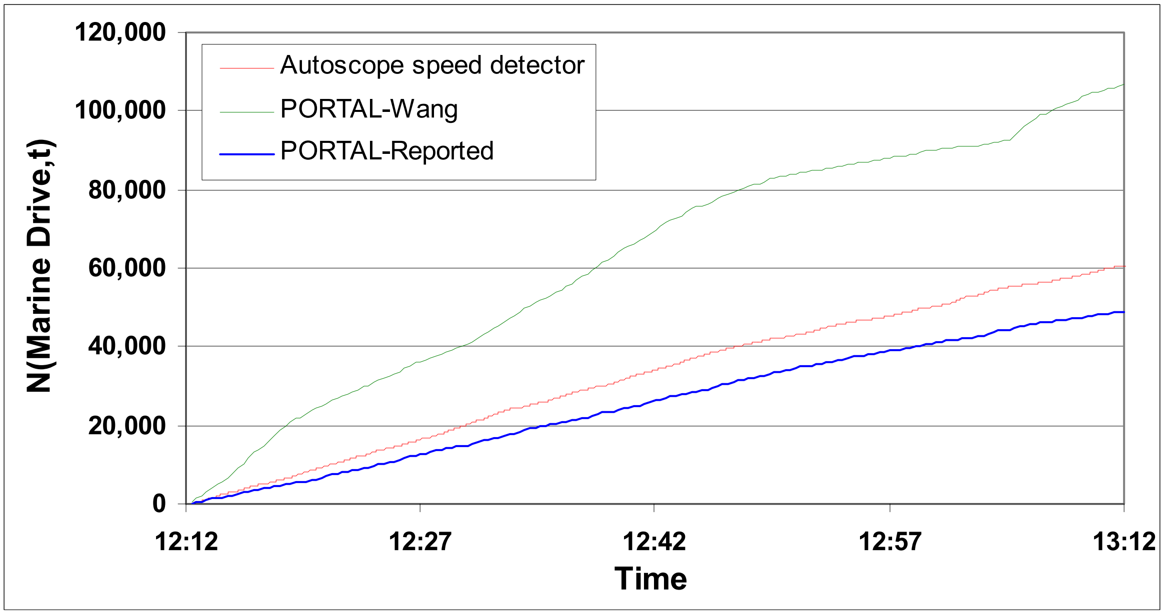


Figure H29g: Cumulative Vehicle Speeds

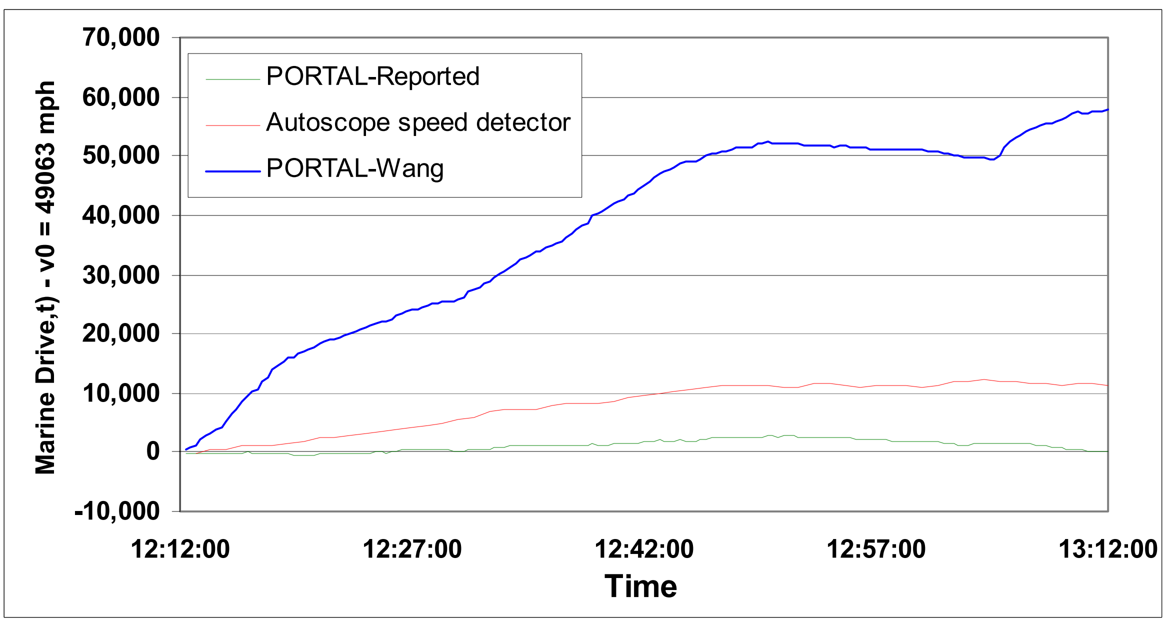


Figure H29h: Cumulative Vehicle Speeds – Oblique Plot

Hour 30

Location: I-5 SB @ Marine Drive
Date: December 15, 2005
Time: 13:14 to 14:14
Lane: Center

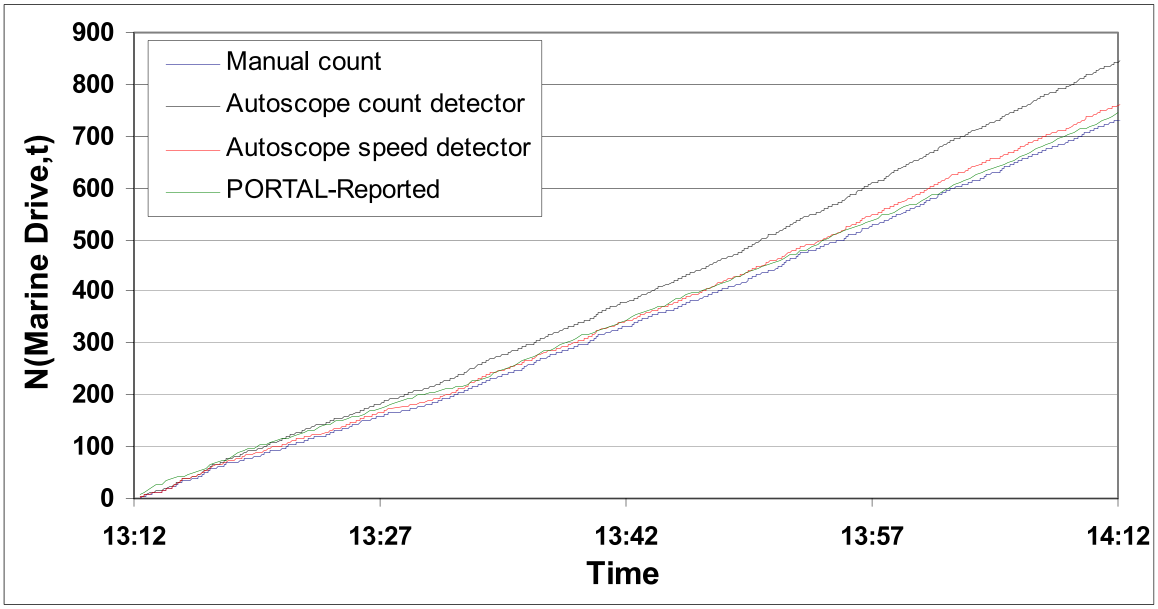


Figure H30a: Cumulative Vehicle Count

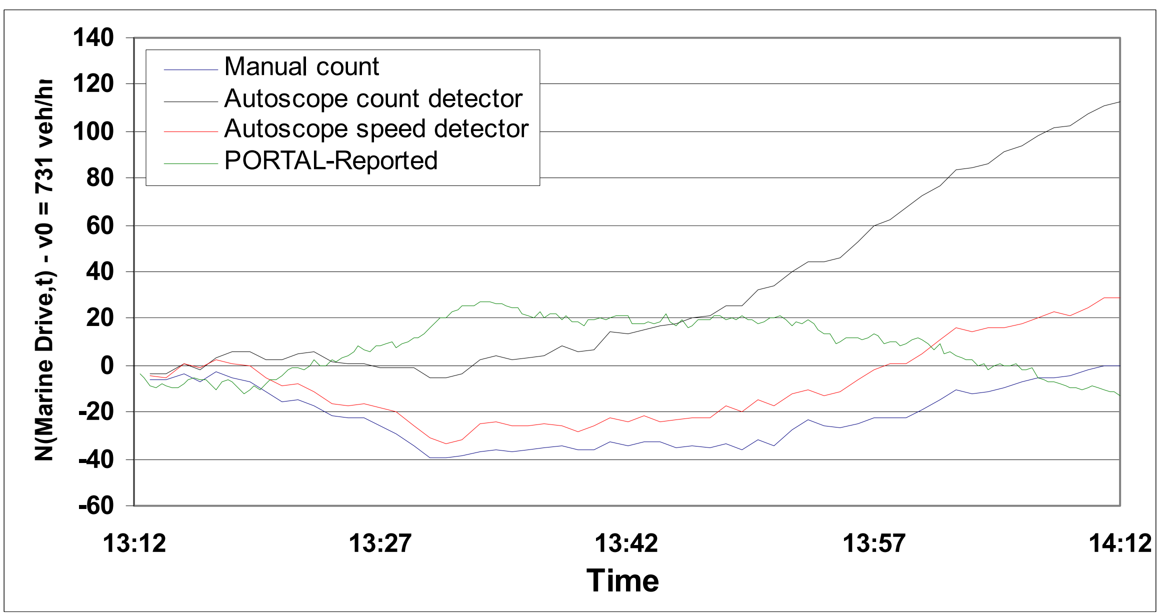


Figure H30b: Cumulative Vehicle Count - Oblique Plot

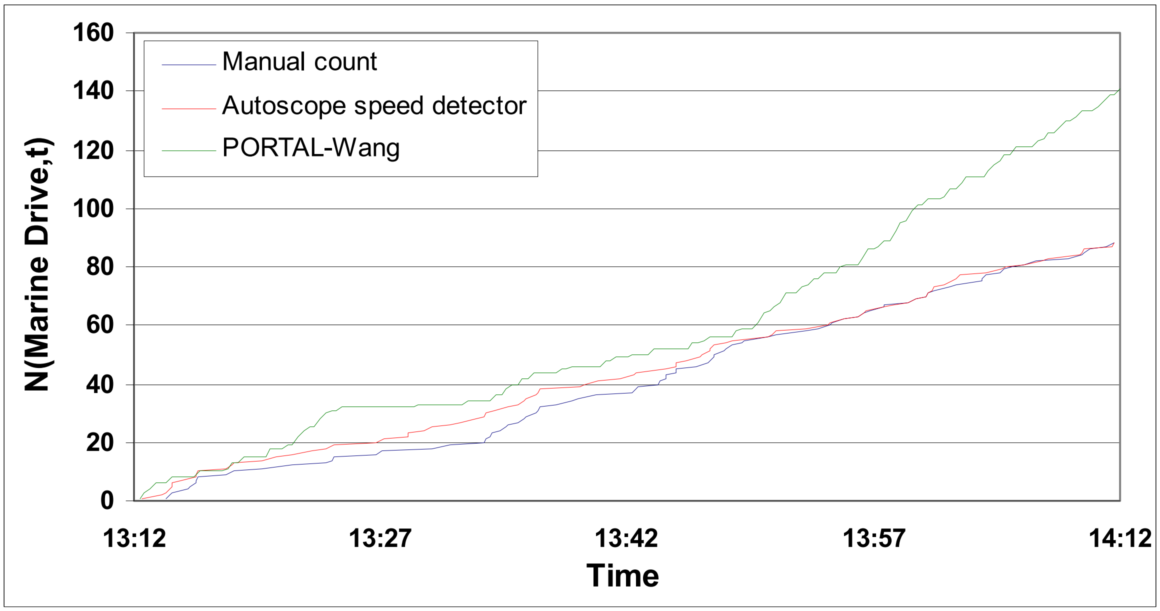


Figure H30c: Cumulative Long Vehicle Count

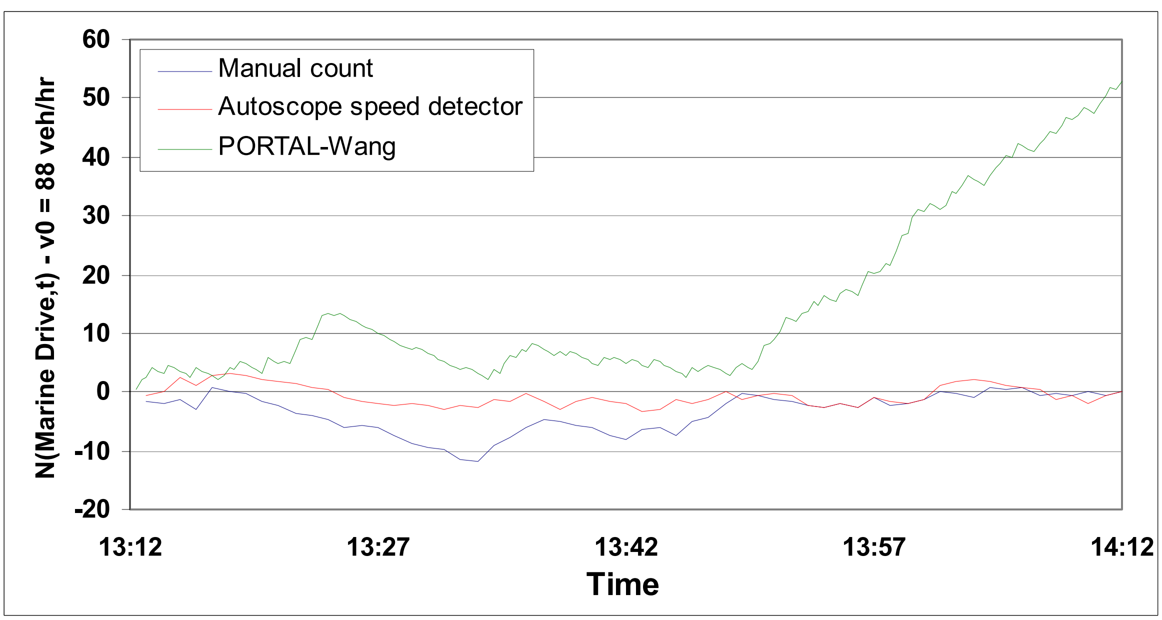


Figure H30d: Cumulative Long Vehicle Count – Oblique Plot

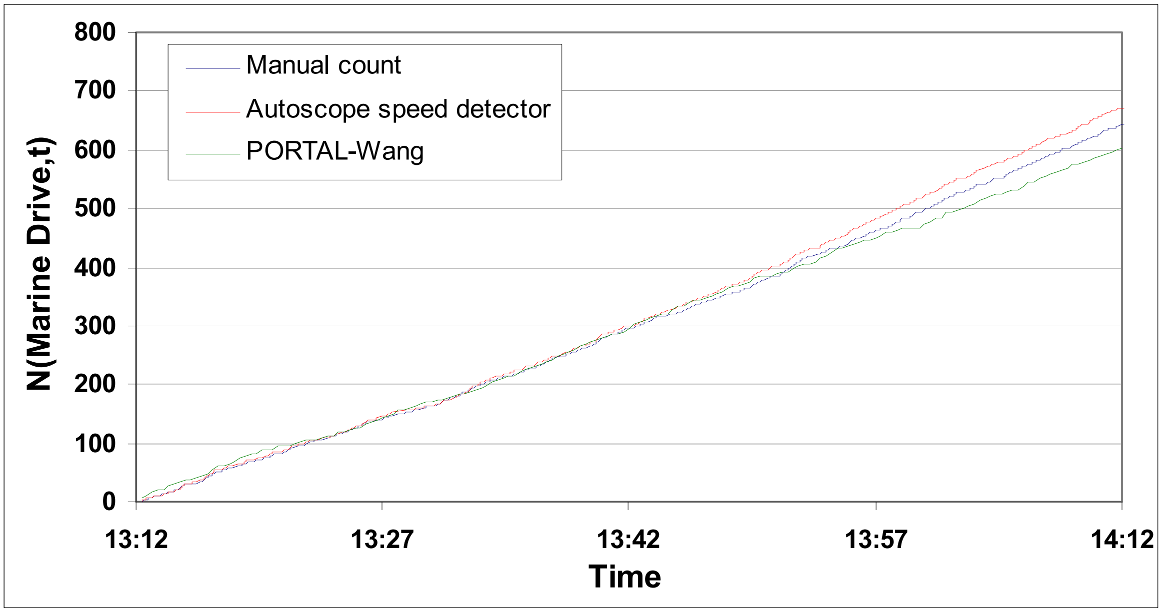


Figure H30e: Cumulative Short Vehicle Count

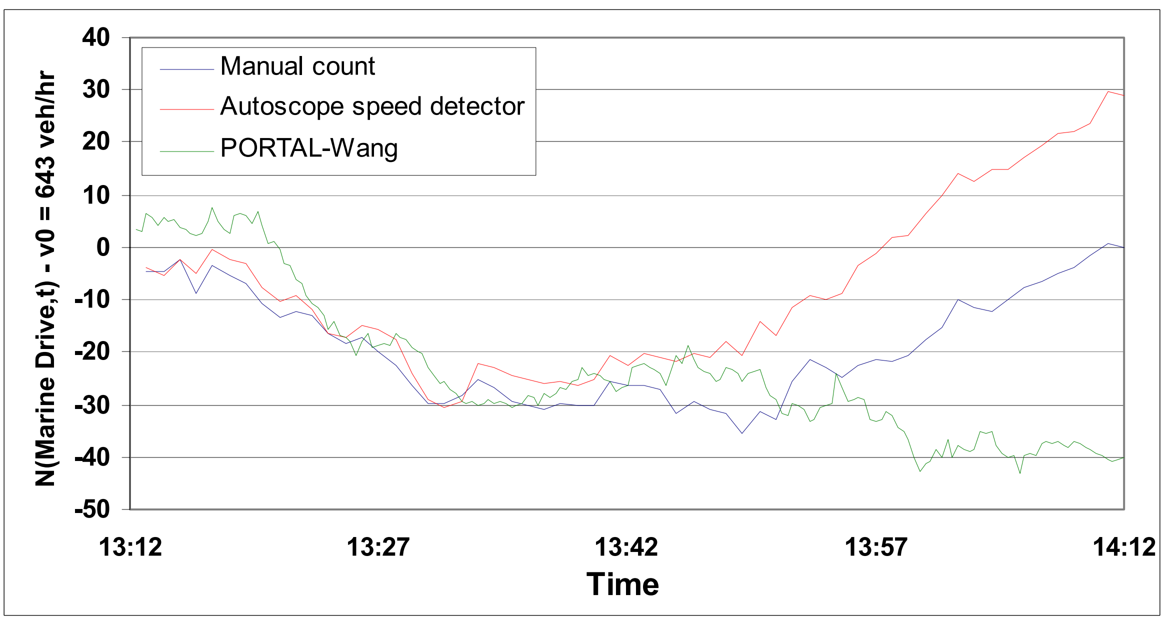


Figure H30f: Cumulative Short Vehicle Count – Oblique Plot

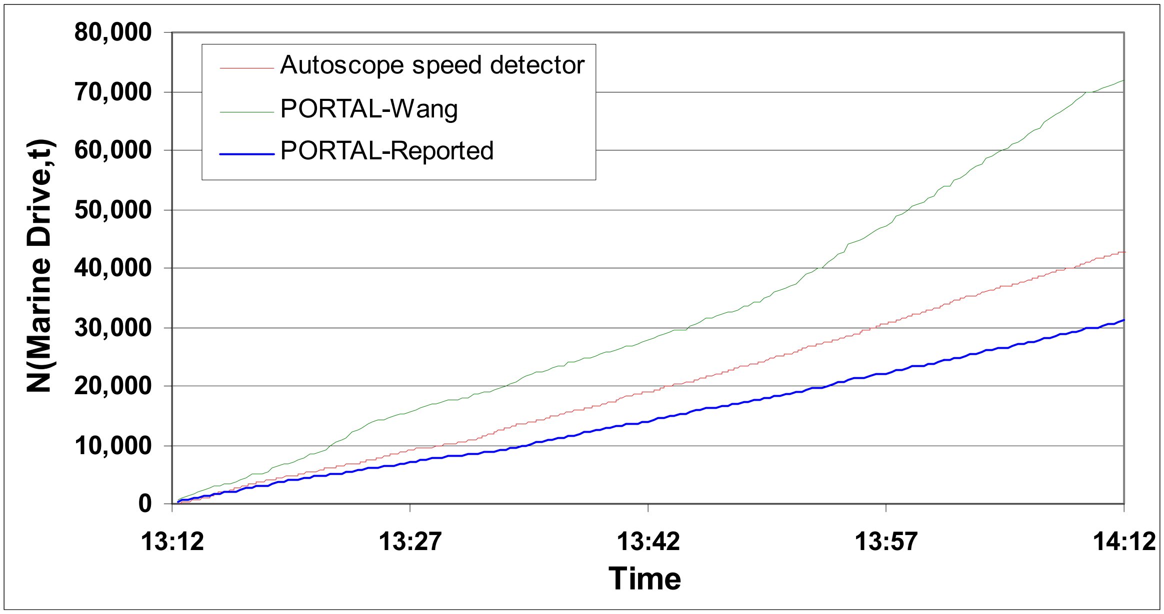


Figure H30g: Cumulative Vehicle Speeds

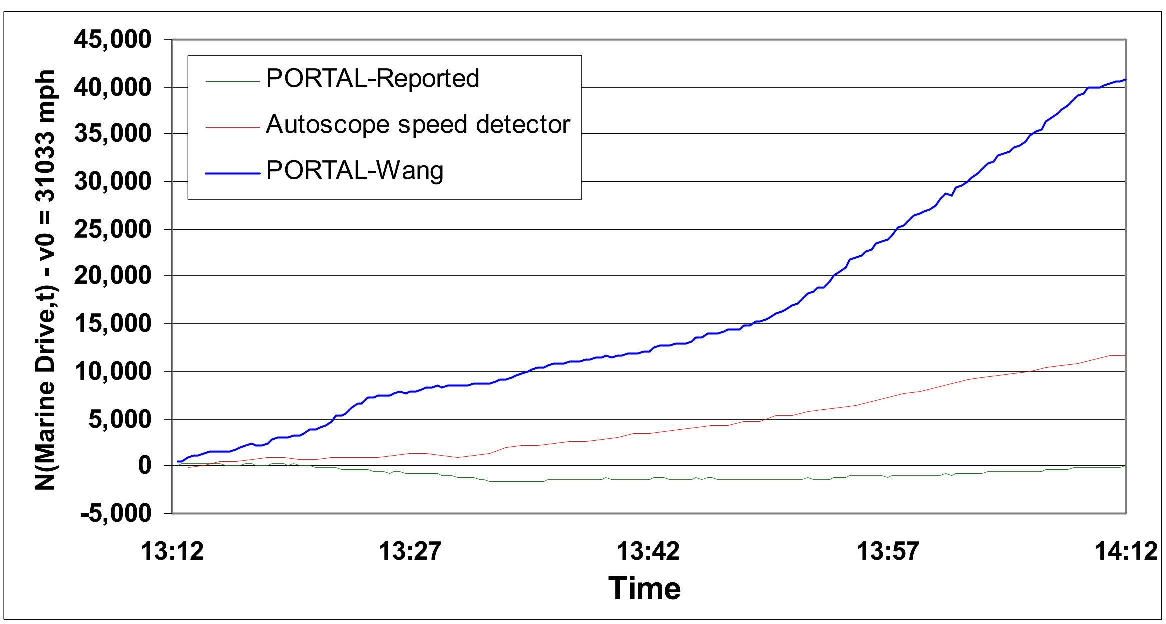


Figure H30h: Cumulative Vehicle Speeds – Oblique Plot

Hour 33
Location: I-5 NB @ Lower Boones Ferry Rd
Date: December 20, 2005
Time: 11:42 to 12:42
Lane: Center

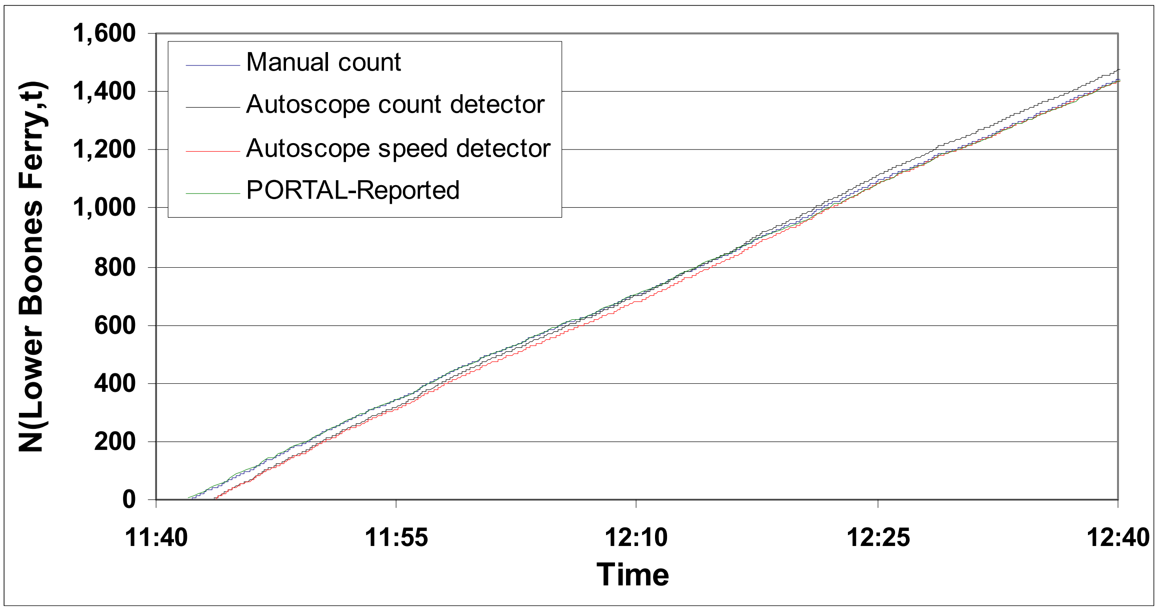


Figure H33a: Cumulative Vehicle Count

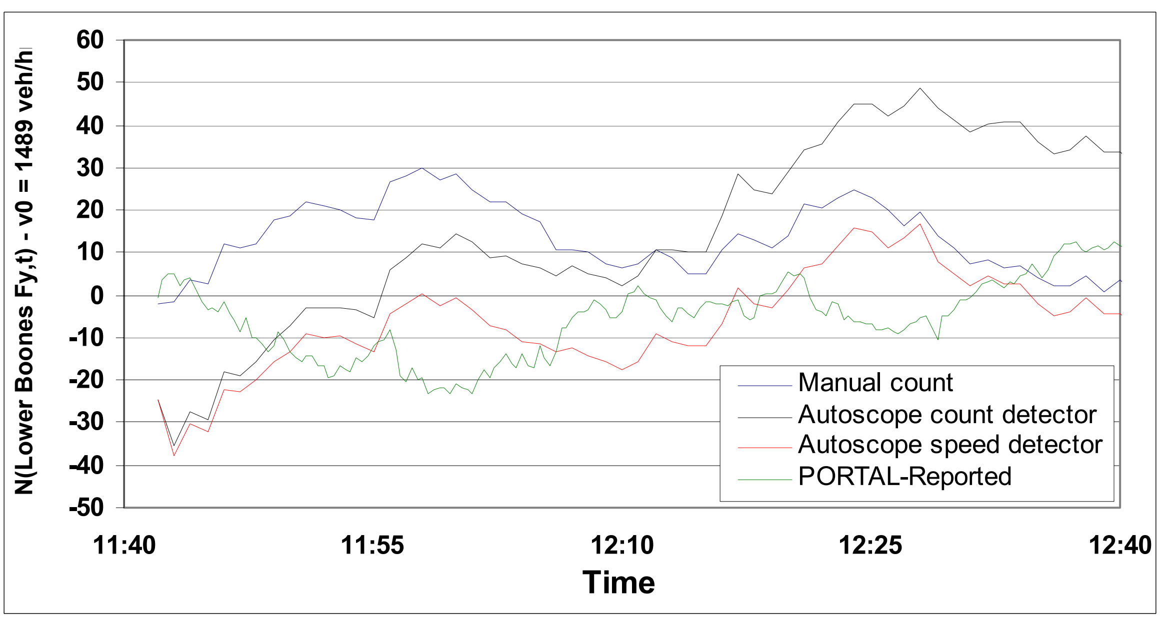


Figure H33b: Cumulative Vehicle Count - Oblique Plot

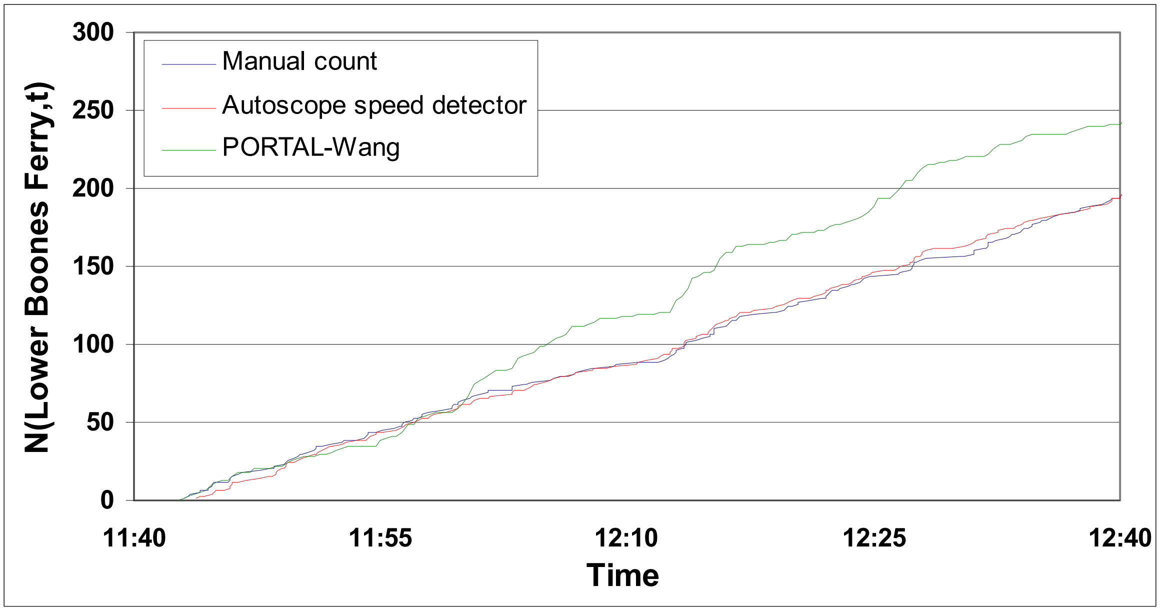


Figure H33c: Cumulative Long Vehicle Count

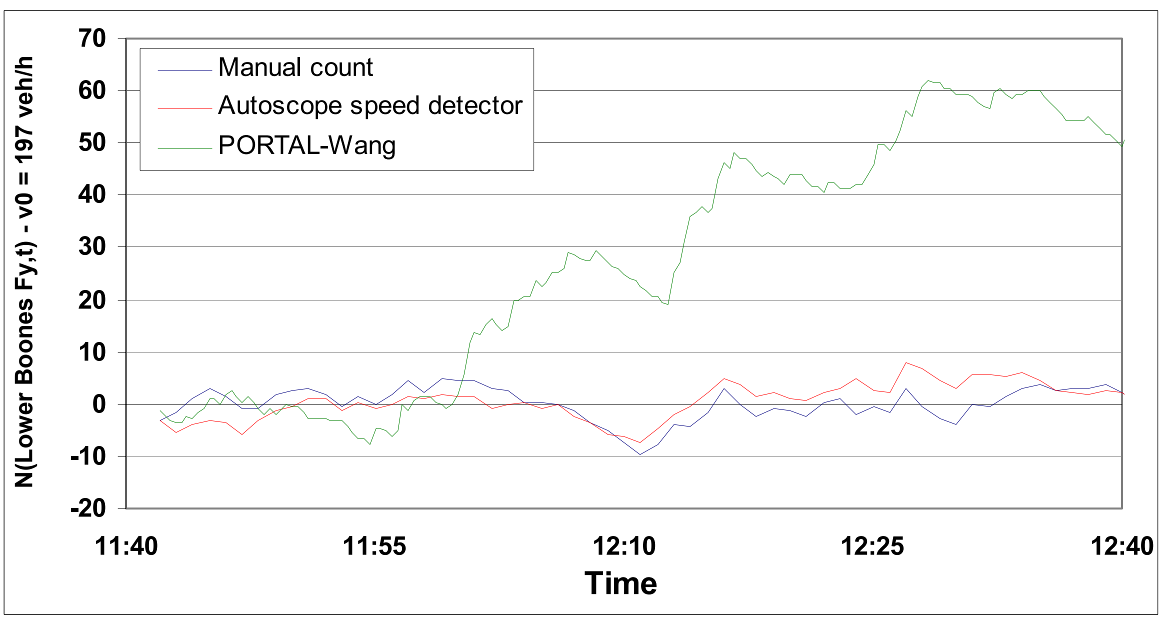


Figure H33d: Cumulative Long Vehicle Count – Oblique Plot

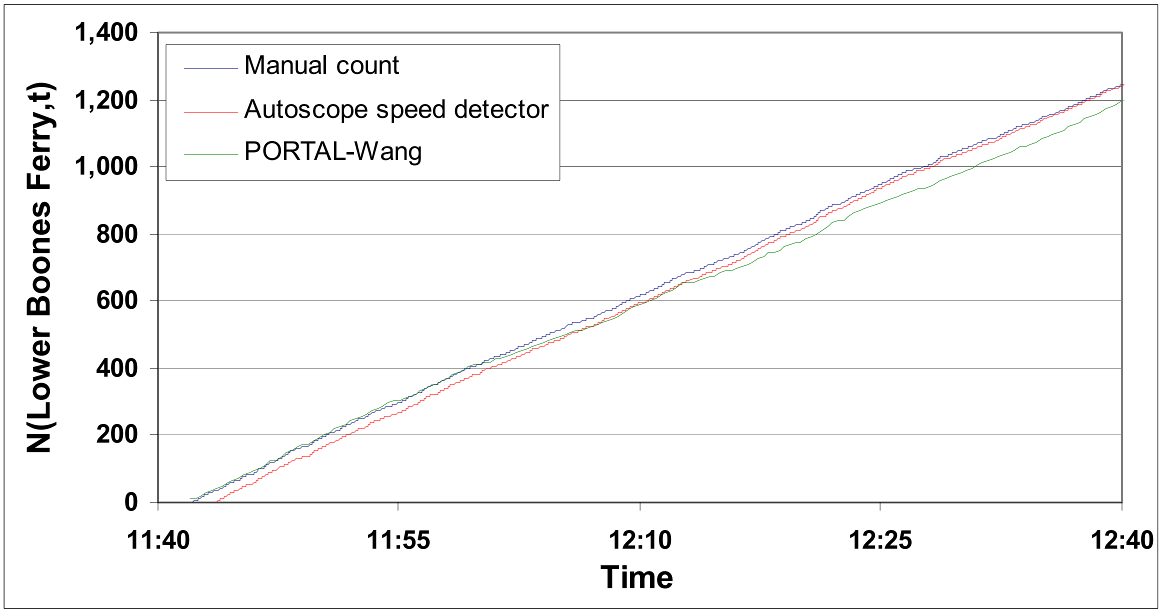


Figure H33e: Cumulative Short Vehicle Count

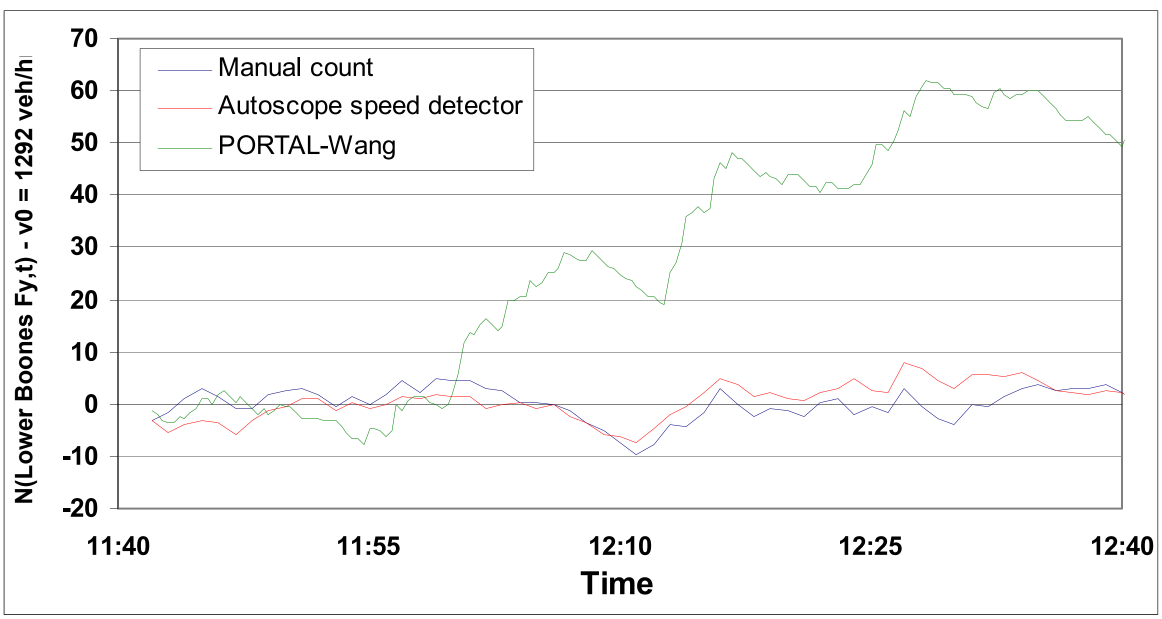


Figure H33f: Cumulative Short Vehicle Count – Oblique Plot

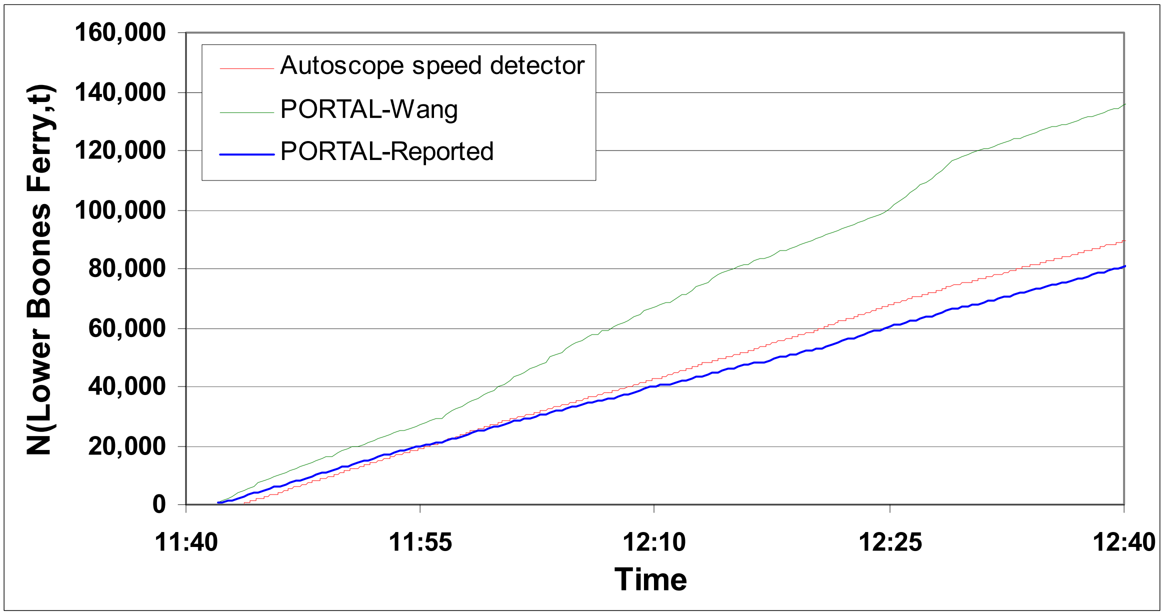


Figure H33g: Cumulative Vehicle Speeds

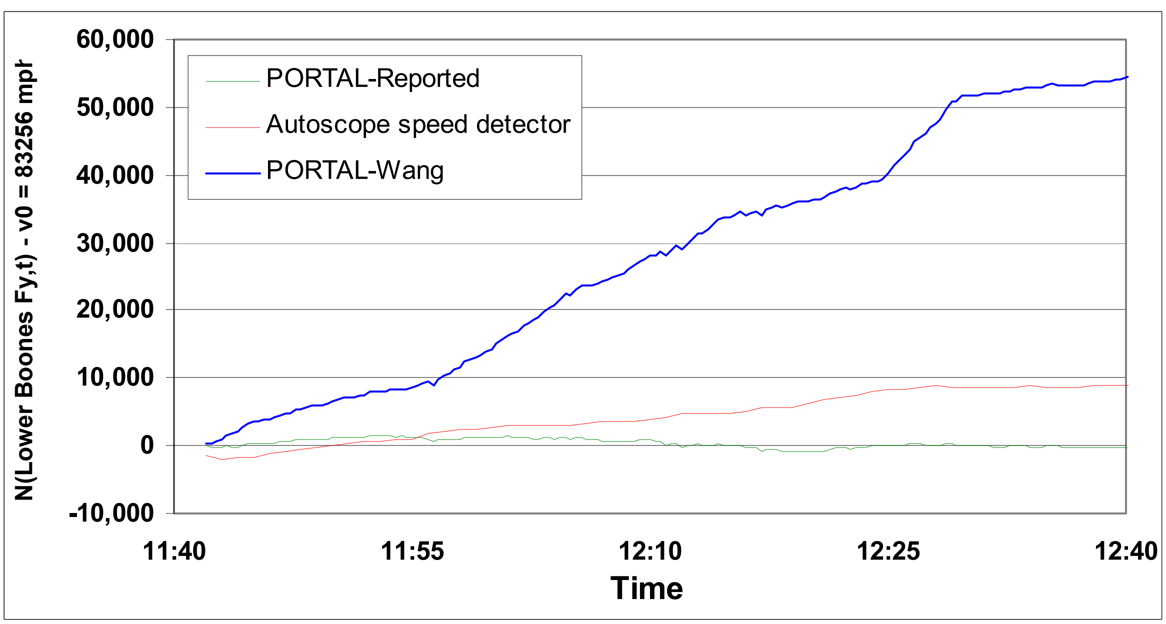


Figure H33h: Cumulative Vehicle Speeds – Oblique Plot