ESTIMATING TRUCK FLOWS ON A FREEWAY NETWORK TO IMPROVE FREIGHT OPERATIONS AND PLANNING

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ABSTRACT
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, and improve long-range planning and forecasting. This paper explores techniques that use current ITS technologies such as video image processing 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 were created, and then compared using statistical analyses to produce results that that reveal some new information about the freight transportation system in the Portland metropolitan region.

KEYWORDS
freight, archived data, traffic management

INTRODUCTION

The growing volume of freight that is increasingly moved by trucks on the nation's transportation network makes 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 (LV) 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 the CCTV network, video image processing technologies, inductive loop detectors, the traffic data storage networks, and data processing algorithms.

This project had several objectives. First, the ability of researchers and public agencies to collect freight data using the existing Oregon Department of Transportation (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 DVDs could be processed with a video image processing system (Autoscope RackVision), and done such that a methodology was established that can be used for future data collection experiments. Third, the robustness of the Nihan-Wang algorithm [1] was established for data collected in the Portland metropolitan region. Other literature was also reviewed [2-6], and discussed more fully in a related research report. [7]

This research has shown that 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. 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 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.

Figure 1 - Site map

DATA

Four sites (see Figure 1) were selected to begin recording video and collecting data using manual counting techniques and the Autoscope video image processing system. These included I-5 and Marine Drive in North Portland, I-84 and Sandy Blvd in Northeast Portland, SW Lower Boones Ferry Rd. and Interstate 5 in southwest suburban Washington County and ORE-217 and Hall Blvd. in Washington County. The ODOT CCTV cameras were designed to maximize the amount of high volume or high crash freeway locations that can be monitored for incident verification and response. All cameras have pan, tilt and zoom (PTZ) functionality so dispatchers can see both travel directions. The camera network functions well for its purpose, but poses some difficulties when used for video image processing. For collecting data using the Autoscope

Rackvision, the cameras should be mounted at least 35 feet above the freeway and positioned directly over the center lane of traffic. This would allow between 200-250 feet of pavement to be seen, and the camera can be pointed downward to reduce sun glare and occlusion. Small deviations from the ideal camera position produce large errors in the processed speed and length data. Through coordination with ODOT Traffic Management Operations Center (TMOC) staff, cameras were placed in fixed positions during data collection periods, though occasionally cameras had to be moved as part of an incident verification and response effort.

ANALYSIS

The Wang-Nihan algorithm [1] was implemented in the PORTAL system which enabled this project to easily extract data in a convenient format. 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. 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-sec 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 Estimated Speed column reports the estimated speed for a 5-min 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-min period. 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.

RESULTS

Data from a total of 47 video segments (totaling 43 hours) were collected from the three study sites during October and December 2005 and February 2006. The length of the time periods for each data unit ranged between 30 min and one hour. A total of 65,256 vehicles were manually counted (3,986 trucks) as the “ground truth.” Autoscope count data included total and LV counts using the count and speed detectors. PORTAL also provided total and LV counts using the Wang-Nihan algorithm. Prevailing flow and speed data (including variability) were also available through PORTAL and are used below for additional analysis. For each of the 47 data periods, a number of comparisons were made among the following sources:

- Manual (ground truth) total and truck counts.
- Autoscope count detector.
- Autoscope speed detector total and truck counts.
- PORTAL-Wang total and truck counts.

The average absolute percent difference between the Autoscope count detector and the ground truth for all vehicles was 3.5%, with a standard deviation of 3.5%. 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%). For the data periods that had good freeway detector data, the average absolute difference between PORTAL-Wang 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%).

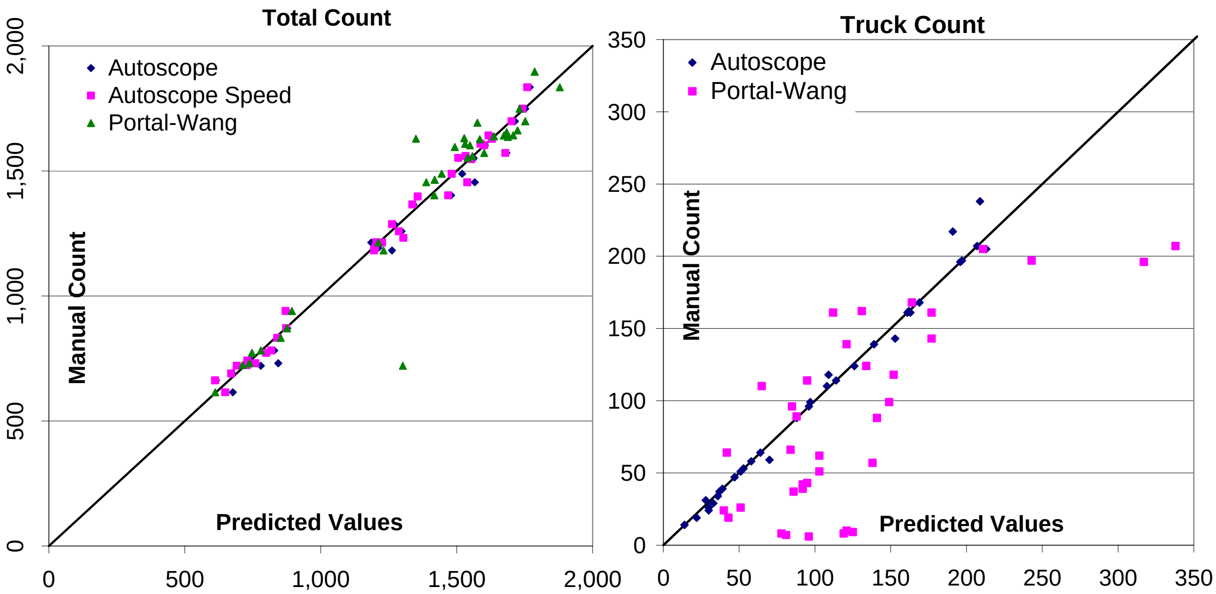

Figure 2 - Comparison of total and truck count mechanisms to ground truth

In order to illustrate some of the relationships between the differences found in this empirical analysis, a number of graphical illustrations have been prepared. Figure 2 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 2 also 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.

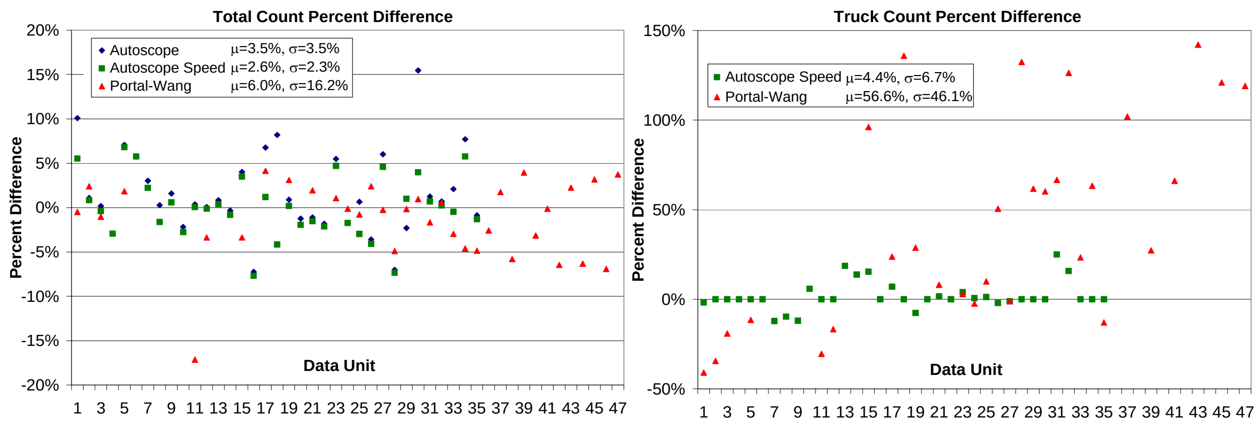

Figure 3 - Total and truck count percent difference

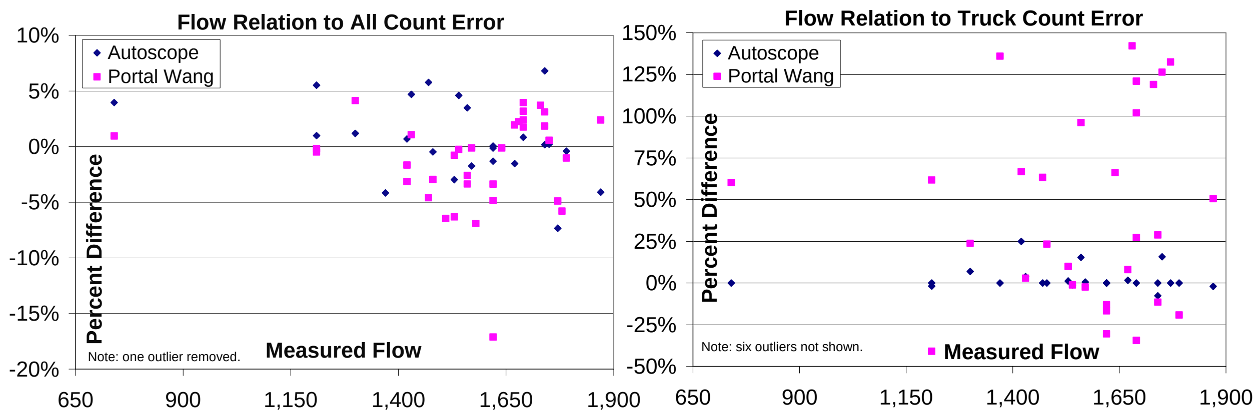

Figure 4 - Flow relation to all count and truck count error

In order to gain further insights into the level of vehicle and truck count capabilities from the considered methods, Figure 3 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.

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 3 also 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.

Most flow values measured were between 1,400 and 1,800 vehicles per hour per lane (average 1,560 vph), Figure 4 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.

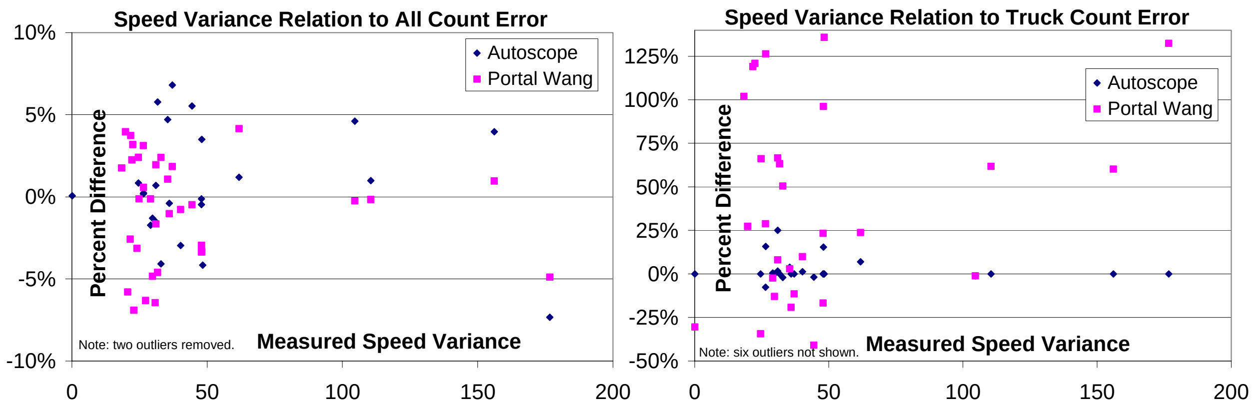

Figure 5 - Measured speed variance relation to all count and truck count error

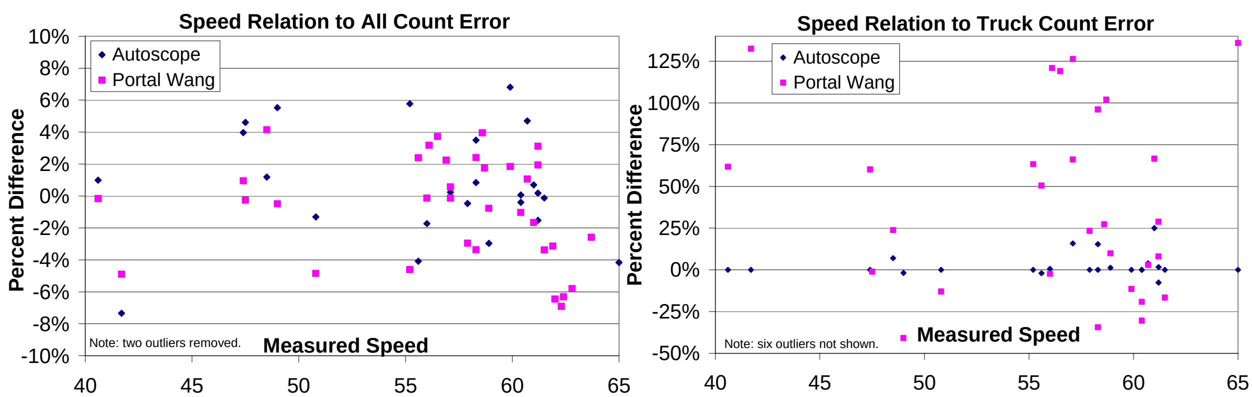

Figure 6 - Measured average speed relation to all count and truck count error

Similar to the previous graphic, Figure 4 also 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.

The Wang-Nihan algorithm requires constant speed during the 5-min calculation intervals in order to make accurate LV estimates. It was thought that if this assumption were not valid in this project, that the prediction accuracy would be negatively impacted. Therefore, the effect of the prevailing speed variance on count error was analyzed as shown in Figure 5. 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 5 also 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.

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 6 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 (average of 57 mph). The figure does not show a clear relation between the two. Figure 6 also 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.

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 10, 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.

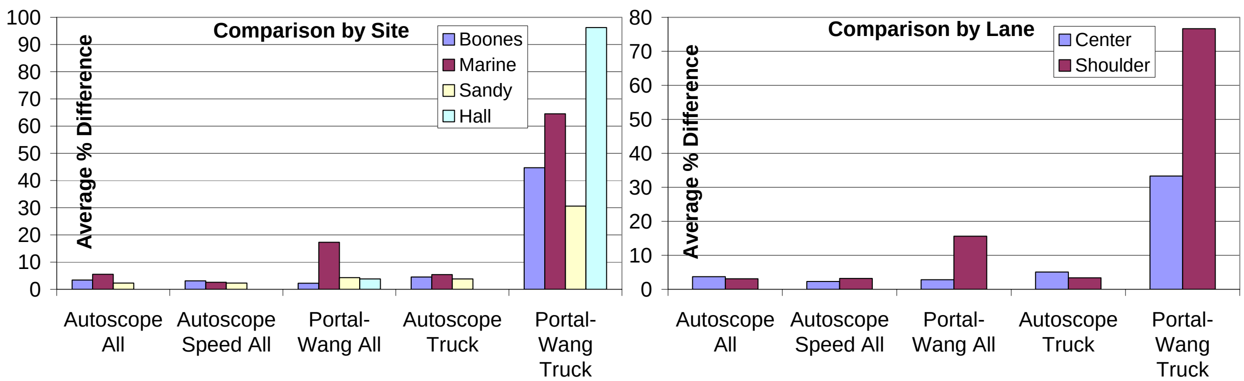

Figure 7 - Percent count differences by freeway site and by lane

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 7, 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.

CONCLUSIONS

This project has illustrated that video image processing can be 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 when used under the available CCTV camera conditions (the various positions, locations, and heights of highway cameras located in the Portland region) the image processor did not produce accurate vehicle length measurements.

While vehicle lengths were overall incorrect, in many circumstances the distribution of vehicle lengths measured during a time period conformed closely to a generalized distribution of manual observations.

There is no question 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 project show some promise in terms of their long-range abilities to produce freight data in an automated way.

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