Identification and Correction of Dual-Loop Sensitivity Problems

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ABSTRACT

Freeway traffic speed and bin volumes for different vehicle categories are typically collected by dual-loop detectors. Good quality dual-loop detector data are crucial for effective real-time traffic management systems and traveler information systems. However, loop detectors are subject to various malfunctions that can result in erroneous measurements. Previous studies indicate that loop sensitivity-level discrepancies between two single loops forming a dual-loop detector and unsuitable sensitivity levels of the single loops are two major causes of quality degradation in dual-loop data.

This paper presents an algorithm and its implementation for the identification and correction of such loop sensitivity problems. The algorithm identifies dual-loop sensitivity problems using individual vehicle data extracted from loop event data and corrects dual-loop sensitivities through a two-step procedure: 1) remove the sensitivity discrepancy between the two single loops and 2) adjust their sensitivities to the appropriate level. Elimination of dual-loop sensitivity problems significantly enhances the reliability of dual-loop detectors and improves the quality of traffic speed and bin-volume data.

Keywords: dual-loop detectors, loop sensitivity level, traffic data, freeway application

INTRODUCTION

The Washington State Department of Transportation (WSDOT) has made a substantial investment in the installation of inductive loop detectors on its freeway network. There are about 620 loop stations with 4,800 single-loop detectors and 1,020 dual-loop detectors installed on the current Washington State freeways. A dual-loop detector is formed by two single loops placed several meters apart on a same traffic lane. In addition to volumes and loop occupancies, which can be collected by a single-loop detector, a dual-loop detector measures vehicle speeds and vehicle lengths. Based on the measured vehicle lengths, vehicles are classified into four bins in the WSDOT dual-loop detection system: Bin 1 represents vehicles shorter than 26 ft (7.92 m); Bin 2 includes vehicles from 26 ft (7.92 m) to 39 ft (11.89 m) long; Bin 3 vehicle lengths range from 40 ft (12.19 m) to 65 ft (19.81m); and Bin 4 contains vehicles longer than 65 ft (19.81 m) (*1*). These loop detectors currently serve as a major data source for the Advanced Traffic Management Systems (ATMS) and the Advanced Traveler Information Systems (ATIS). For example, loop data have been used by transportation professionals to measure and enhance freeway performance (*2, 3, 4*), detect incidents in real-time (*5*), alleviate delays from freeway accidents (*3, 6*), provide necessary information to develop and monitor ramp meter timing plans (*7*), and measure freight movements (*8*). Therefore, loop data accuracy is one of the key requirements for successful ATMS and ATIS.

In 2001, the WSDOT initiated a research project entitled “Evaluation of Dual-Loop Data Accuracy Using Video Ground Truth Data” (*9*). Its objectives were a) to evaluate the accuracy of dual-loop performance in measuring vehicle speed and bin volumes, b) to identify types and causes of dual-loop data errors, and c) to recommend suitable methods for improving the quality of real-time dual-loop measurements. Serious errors of vehicle classification were identified in some studied dual-loop detectors. For instance, the study of the ES-137R dual-loop station found that 41 percent of Bin 3 vehicles were incorrectly assigned to Bin 4 and 24 percent of Bin 2 vehicles were mistakenly assigned to Bin 1 while 6 percent of vehicles in that same category were assigned incorrectly to Bin 3. The causes for these dual-loop errors cannot be pinpointed by simply examining the differences between the dual-loop data and video ground truth data. Therefore, an in-depth analysis of dual-loop error causes, through careful scrutinizing of the WSDOT dual-loop algorithm and its implementation code, became necessary.

Although dual-loop measurements are available from the Transportation Data Acquisition and Distribution (TDAD) Website (http://www.its.washington.edu/tdad/), these aggregated data of 20-second intervals are too coarse to examine dual-loop error causes. In order to collect high-resolution loop data, the Detector Event DAta Collection (DEDAC) system was developed at the University of Washington (UW). The DEDAC system is capable of collecting high frequency loop event data from the Input File of a control cabinet without interrupting the controller’s normal operation (*10*). The event data contain specific information on individual vehicles. By analyzing the event data collected by the DEDAC system, the major cause of inaccurate dual-loop data was attributed to the inappropriate sensitivity levels of the component single loops.

Consequently, the detection and correction of loop sensitivity problems proved to be necessary for the collection of accurate dual-loop data. This paper describes the algorithm developed for identification and correction of dual-loop sensitivity problems. To facilitate onsite applications, the algorithm was implemented in a computer system called Advanced Loop Event Data Analyzer (ALEDA) (*11*). The following sections review previous research, and describe the details of the proposed algorithm and the processes of identification and correction of dual-loop sensitivity problems.

PREVIOUS STUDIES

Detection and correction of loop detector errors has become increasingly important because of the higher data accuracy needs from ATMS and ATIS. Several methodologies have been proposed to identify loop malfunctions using aggregated loop data (20- or 30-second interval data). Some of these methodologies rely on thresholds of several traffic parameters to filter out unreasonable or potentially bad data (*12, 13, 14, 15,* and *16*). For others, the mathematical relationships among flow, speed, occupancy, and average vehicle lengths were used to flag bad loop data (*17* and *18*). Chen et al. (*19*) used the time series of loop data samples to fix missing or invalid data. Vanajakshi and Rilett (*20*) concluded that a check for conservation of vehicles over a series of detectors could identify discrepancies that were unidentified by the basic error checking procedures at individual locations. The main disadvantage of using aggregated loop data is that some errors cannot be identified because valuable information (e.g., the arrival time on a loop) associated with individual vehicles is lost after loop data are integrated.

Recently employed transportation technologies led to the development of modern methods to flag and correct loop data errors. The availability of high-resolution loop data (event data) makes detailed investigations on loop data errors feasible because event data contain complete information on individual vehicles (*10, 21*). Video recorded ground-truth data have also been applied to identify dual-loop data errors. The validation tests of loop data using ground truth video showed that dual-loop detectors undercounted vehicle volumes and misclassified vehicle types (*9, 22*).

The distinction of the current study is its sensitivity correction method and use of event data for sensitivity-discrepancy identification and tune up. Features of vehicle length distribution are utilized to find the appropriate sensitivity levels.

THE ALGORITHM

The event data used for this research were collected at 60 Hz (i.e. 60 loop status readings per second). Based on the analysis of previously collected loop event data, loop sensitivity problems were divided into two categories: 1) sensitivity discrepancies between the upstream loop (called the M loop in the WSDOT dual loop detection system) and downstream loop (referred to as the S loop by the WSDOT); and 2) unsuitable sensitivity levels of both the M and S loops. The first category is easily identified by observation. For this case, if the basic measurements for the two loops do not agree (within an accepted margin of error), it is obvious that at least one of the loops is inaccurate. The second category, which is harder to identify through direct observation, occurs when no observed discrepancies between the M and S loops occur, yet both loops are giving inaccurate measurements.

Vehicle data collected by loop detectors are based on loop detector actuations. If a loop detector is over-sensitive, it detects a vehicle before the vehicle arrives to the loop. This results in lengthened on-times for the vehicle. Similarly, an under-sensitive loop produces a shortened on-time for a vehicle. The loop on-time refers to the period of time in which a vehicle occupies a loop detector. Since the on-times are used to calculate traffic speed, lane occupancy, and vehicle length, erroneous on-times can result in incorrect measurements of these important traffic variables.

For the case where the M loop is over-sensitive (FIGURE 1(a)) and the S loop is at the appropriate sensitivity level, the M loop gives a too-early arriving time stamp of a vehicle (*StartM*) that leads to a higher than realistic traverse time from the leading edge of the M loop to that of the S loop (*StartS* - *StartM*). As a result, the calculated speed using Equation (1) is lower than the actual speed. In contrast, if the S loop is over sensitive (FIGURE 1(b)) and the M loop is at the right sensitivity level, the measured speed is higher than the actual speed because of the shortened traverse time from the leading edge of the M loop to that of the S loop. Similarly, when the M loop is under-sensitive and the S loop is at the correct sensitivity level, vehicle speed will be over estimated; but when the M loop is at the right sensitivity level and the S loop is under-sensitive, vehicle speed will be under estimated.

The formula for speed is

$$Speed = \frac{DistMS}{(StartS - StartM)} \tag{1}$$

where:

StartM = time at which a vehicle starts occupying the M loop.
StartS = time at which a vehicle starts occupying the S loop.
DistMS = distance from the leading edge of the M loop to the leading edge of the S loop

Equation (1) indicates that it is the traverse time from the leading edge of the M loop to that of the S loop (*StartS* - *StartM*) that directly affects the speed calculation accuracy. As long as the sensitivity levels of the M and S loops are in agreement, the speed calculated using Equation (1) will be correct. However, a consistency in sensitivity between the M and S loops does not necessarily mean that there is no sensitivity problem. For example, even if both the M and S loops are overly sensitive, if there is no sensitivity discrepancy between them, the measured traverse time from the leading edge of the M loop to that of the S loop will be correct. The correct traverse time will result in an accurate speed calculation. However, the vehicle length measurement will be inaccurate because vehicle length is calculated using vehicle speed and on-times of the M and S loops (*OntimeM* and *OntimeS*, respectively), and the on-times cannot be correctly measured when sensitivity is off the right level. The equation for calculating vehicle length in the WSDOT dual-loop algorithm is as follows:

$$Length = \left[Speed * \left(\frac{OntimeM + OntimeS}{2} \right) \right] - loop\ length \tag{2}$$

where *loop length* is a constant value determined by the physical size of single loops.

An unsuitably high sensitivity on both the M and S loops will result in increased on-time measurements for both loops and, consequently, vehicle length estimates will be over estimated. Similarly, a lower than suitable sensitivity level on both the M and S loops will give shorter on-times and, consequently, shorter vehicle lengths. Accordingly, vehicle classifications based on measured vehicle lengths become misleading when the sensitivity levels of the M and S loops are unsuitably high or low even if there is no sensitivity discrepancy between them.

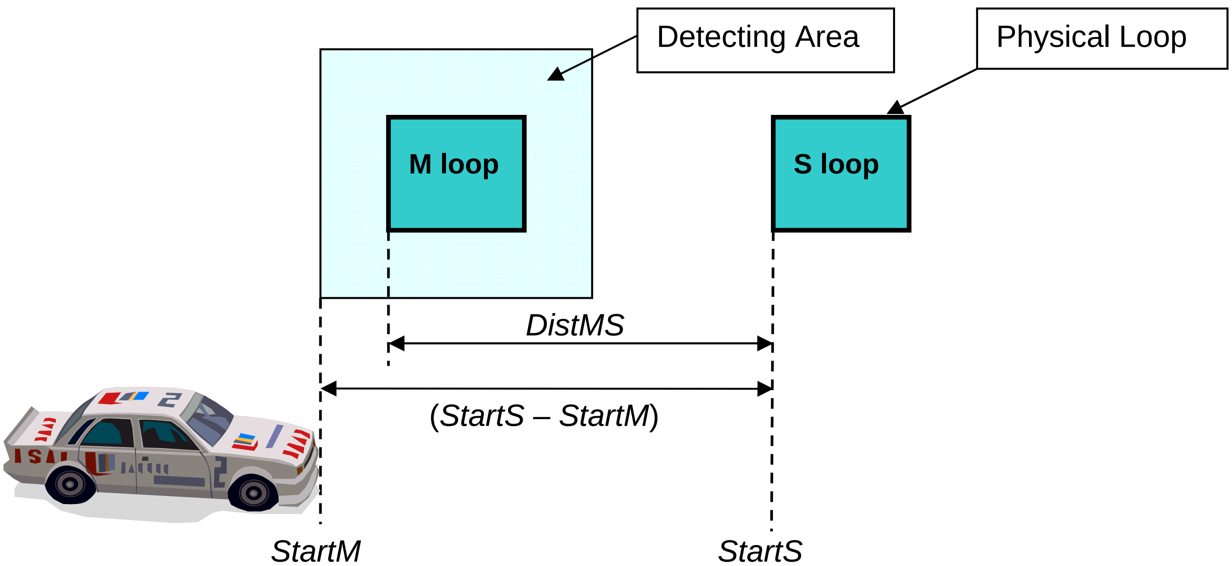


FIGURE 1(a) The M loop is over sensitive and the S loop is at the correct sensitivity level.

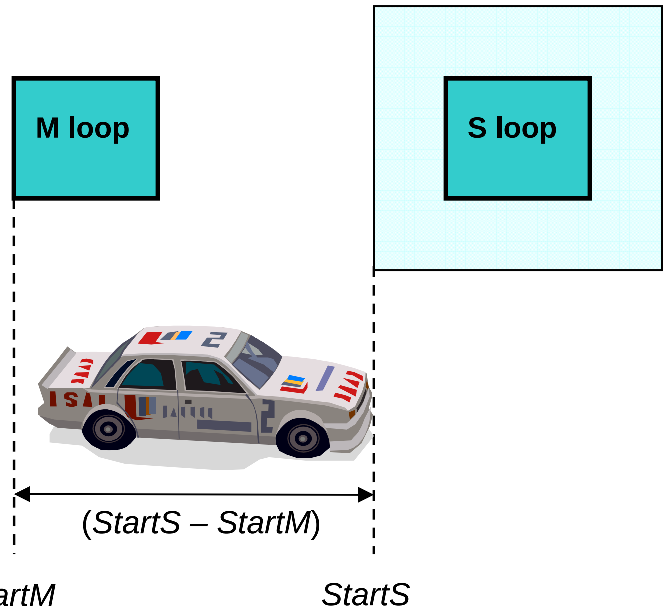


FIGURE 1(b) The M loop is at the right sensitivity level and the S loop is over sensitive.

Sensitivity Discrepancies

Since the distance between the M and S loops is small (about 16 ft or 4.88 m), vehicle speed is considered to be constant when a vehicle crosses over the M and S loops. With constant speed, the M and S loops should have identical on-times, i.e., the on-time differences should be zero if their sensitivities agree. The formula for the on-time difference calculation is

$$\textit{On-Time Difference}\,(\%) = \frac{(OntimeM - OntimeS)}{OntimeM} * 100 \tag{3}$$

The on-time differences calculated by Equation (3) indicate whether a sensitivity discrepancy problem exists with a dual-loop detector.

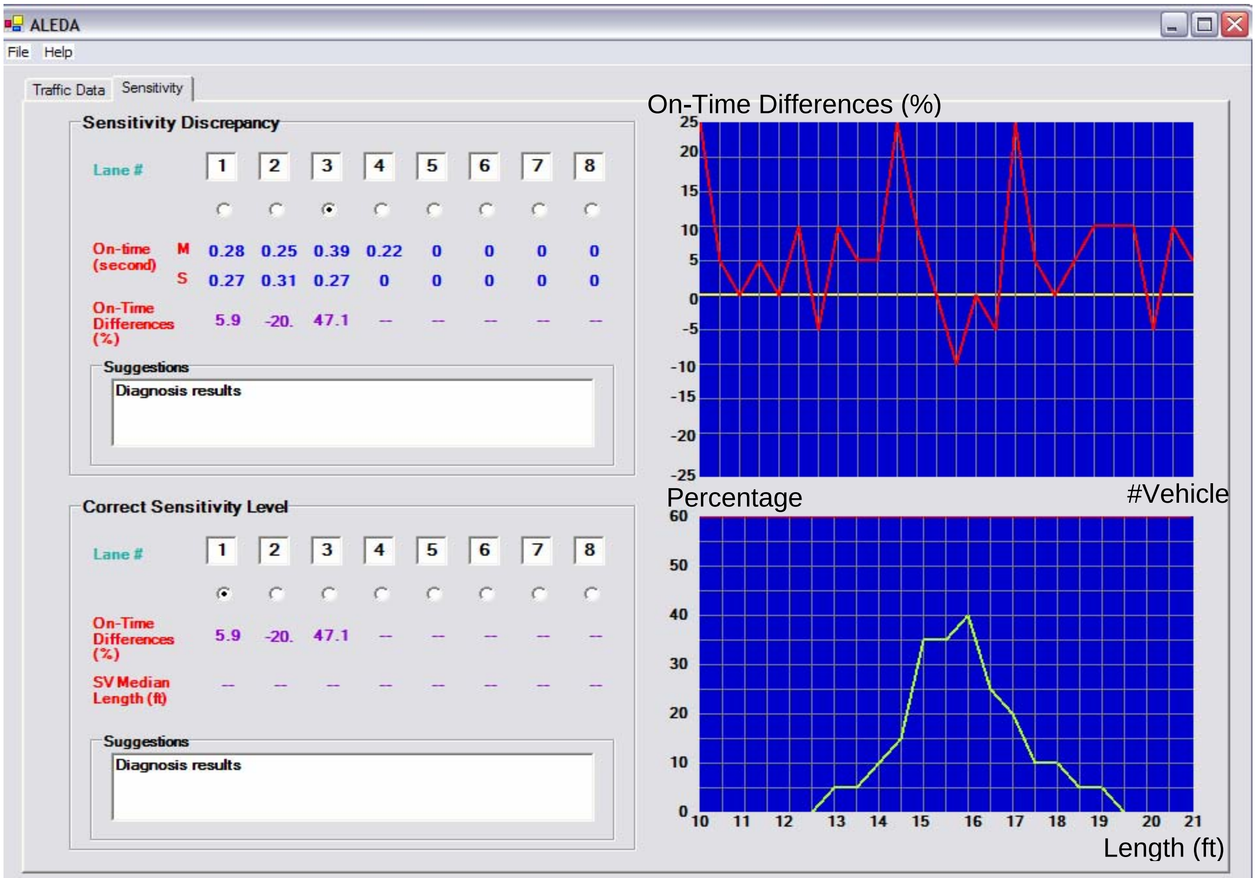


FIGURE 2 ALEDA user interface for the sensitivity problems.

The sensitivity discrepancy problem can be solved by adjusting the sensitivity levels at the loop amplifiers until the on-times for the M and S loops are the same or the on-time differences are zero. This adjustment can be accomplished through application of the ALEDA system (please refer to (*11*) for details). After the connection between ALEDA and the Input File of the control cabinet is established, ALEDA can show individual-vehicle on-time differences in real-time as well as the curve of on-time difference changes for each traffic lane. FIGURE 2 illustrates ALEDA's user interface, which displays the dual-loop on-time differences. This function makes onsite identification and correction of the sensitivity discrepancy problem feasible. For instance, if the on-time differences are positive, then the M loop is more sensitive than the S loop. We can remove the sensitivity discrepancy through one or both of the following actions: increase the sensitivity of the S loop and decrease the sensitivity of the M loop. Similarly, if the on-time differences are negative, then the M loop is less sensitive than the S loop. To merge the sensitivity gap, we can raise the sensitivity of the M loop and/or lower the sensitivity of the S loop. ALEDA can show the on-time differences for up to eight dual-loop detectors (or eight traffic lanes) at the same time.

According to the WSDOT dual-loop algorithm, if a vehicle's on-time difference is beyond ±10 percent, its length will not be calculated and the vehicle will be dropped from the classification process because of the suspicion of lane changing. However, on-time differences larger than 10 percent may result from sensitivity discrepancies instead of lane changing. Therefore, potentially good data may be discarded by the WSDOT dual-loop algorithm due to discrepancies in the M and S loop sensitivities. To eliminate the sensitivity discrepancies, the sensitivity settings on the loop amplifiers are adjusted until the mean on-time differences shown by ALEDA are close to zero.

Suitable Sensitivity Level

The measurement of vehicle speed from dual-loop detectors will be accurate once the sensitivity discrepancy problem is corrected. However, even if the sensitivities of both the M and S loops are in agreement, it is possible that the sensitivity of both loops are not at the right level, resulting in inaccurate measurement of loop on-times. As shown in Equation (3), the measurement of vehicle lengths is based on these on-times, thus incorrect on-times lead to erroneous calculation of vehicle lengths.

To achieve a correct sensitivity level, information on individual vehicle lengths is needed. However, it is very difficult to obtain ground-truth length data for vehicles traveling on freeways at a specific time period. Therefore, a statistical approach was applied using Short Vehicle (SV) length distribution observed by Wang and Nihan (*23*).

According to (*23*), SV (corresponds to Bin-1 vehicle) lengths follow a normal distribution with a mean = 15.21 ft (4.64 m) and a standard deviation = 2.20 ft (0.67 m). The small standard deviation implies that SV lengths change narrowly around the mean. Therefore, the length information for SVs can be employed to trace a correct sensitivity level without significant errors. In this study, we use the SV-length distribution reported by (*23*) as the ground-truth vehicle length distribution for SVs.

The calculated SV length from a dual-loop detector is precise only when a dual-loop detector is at a suitable sensitivity level. To achieve a suitable sensitivity level for the M and S loops, the calculated lengths of SVs were compared with the ground-truth SV-length distribution. However, a direct comparison between SV lengths gave insufficient accuracy in this study because lengths could sometimes vary significantly. Therefore, a comparison between the histogram of calculated SV lengths and the histogram generated from the ground-truth SV-lengths distribution was employed instead. Thus, when the distribution of SV lengths measured by dual-loop detectors is very similar to the ground-truth SV-length distribution, we can conclude that the M and S loops are at a suitable sensitivity level.

The efficiency and accuracy for obtaining a suitable sensitivity level were balanced through selecting an appropriate SV sample size for comparison with the ground-truth data. The bigger number of a sample size may smooth the distribution of SV lengths measured by dual-loop detectors and make the distribution look similar to that of the normal distribution. However, this may not guarantee that the distribution becomes more similar to the ground-truth SV-length distribution. Additionally, the time spent for collecting large SV samples may be too long. Therefore, upon statistical sampling analysis and time period for collecting SV lengths, a sample of one hundred SV-length measurements was deemed appropriate. The histogram of calculated lengths of these SVs was then compared to the histogram generated from the ground-truth SV-length distribution. At suitable sensitivity levels, the two histograms should match each other well.

The goodness of fit between the measured SV length distribution and the ground-truth SV length distribution is determined by the calculated sum of square errors. Since SV lengths range from 9 ft (2.74 m) to 25 ft (7.62 m), the measured SV-lengths are placed into seventeen categories with an increment of 1 ft (0.305 m) between consecutive categories. The error for each length category is defined as the observed number of vehicles subtracted from the expected number of vehicles. If the sum of square errors over all the 17 categories is smaller than a specified threshold, ALEDA will conclude that a dual-loop system is at a suitable sensitivity level. (Our experience showed that 400 is a reasonable threshold value.) Otherwise, ALEDA recommends adjustments to the sensitivity levels of the two single loops. After the adjustments are made, another one-hundred SV lengths are accumulated for a new test. The comparison of both histograms for every one hundred SVs is displayed by ALEDA as illustrated in the lower half of FIGURE 2. Vehicles that have calculated lengths shorter than 26 ft (7.92 m) are considered as SVs in ALEDA.

There are two extreme cases for the problem of unsuitable dual-loop sensitivity levels. In the first case, dual-loop detectors have a sensitivity level that is too high. The histogram of measured SV lengths shifts to the right side of the ground-truth histogram as shown in FIGURE 3(a) because of unrealistically large on-times on both the M and S loops. In this case, the sensitivity of the M and S loops should be reduced by adjusting the loop amplifiers. In FIGURE 3, the green bars denote the ground truth SV length histogram, and the blue lines represent the histogram of measured SV’s lengths. In contrast, if the sensitivity level of both loops is too low, the histogram of measured SV lengths shifts to the left side of the ground-truth histogram of manufacturers’ SV lengths as shown in FIGURE 3(b), because of unrealistically low on-times. Therefore, the sensitivity of the M and S loops should be adjusted to a higher level.

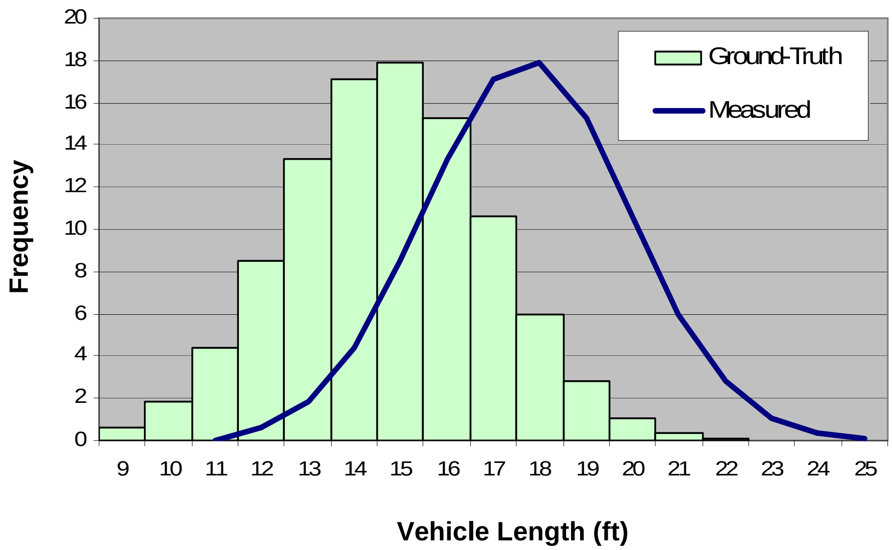


FIGURE 3(a) SV length histogram: too-high dual-loop sensitivity.

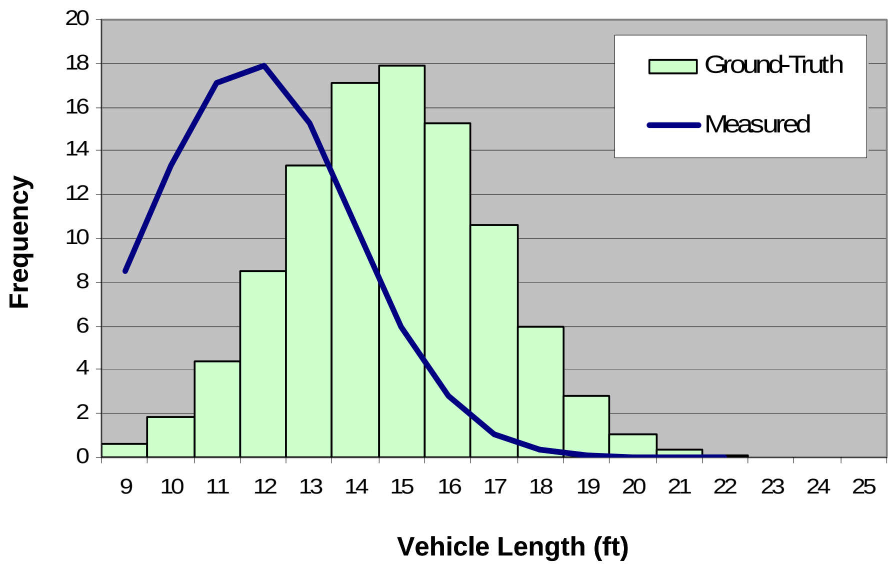


FIGURE 3(b) SV length histogram: too-low dual-loop sensitivity.
(*Note: 1 feet = 0.305 meter*)

The dual-loop sensitivity problems may be corrected by iterating the steps of identification and correction for both sensitivity discrepancies and unsuitable sensitivity levels until both problems are eliminated. The steps for identifying and correcting such sensitivity problems are summarized in FIGURE 4.

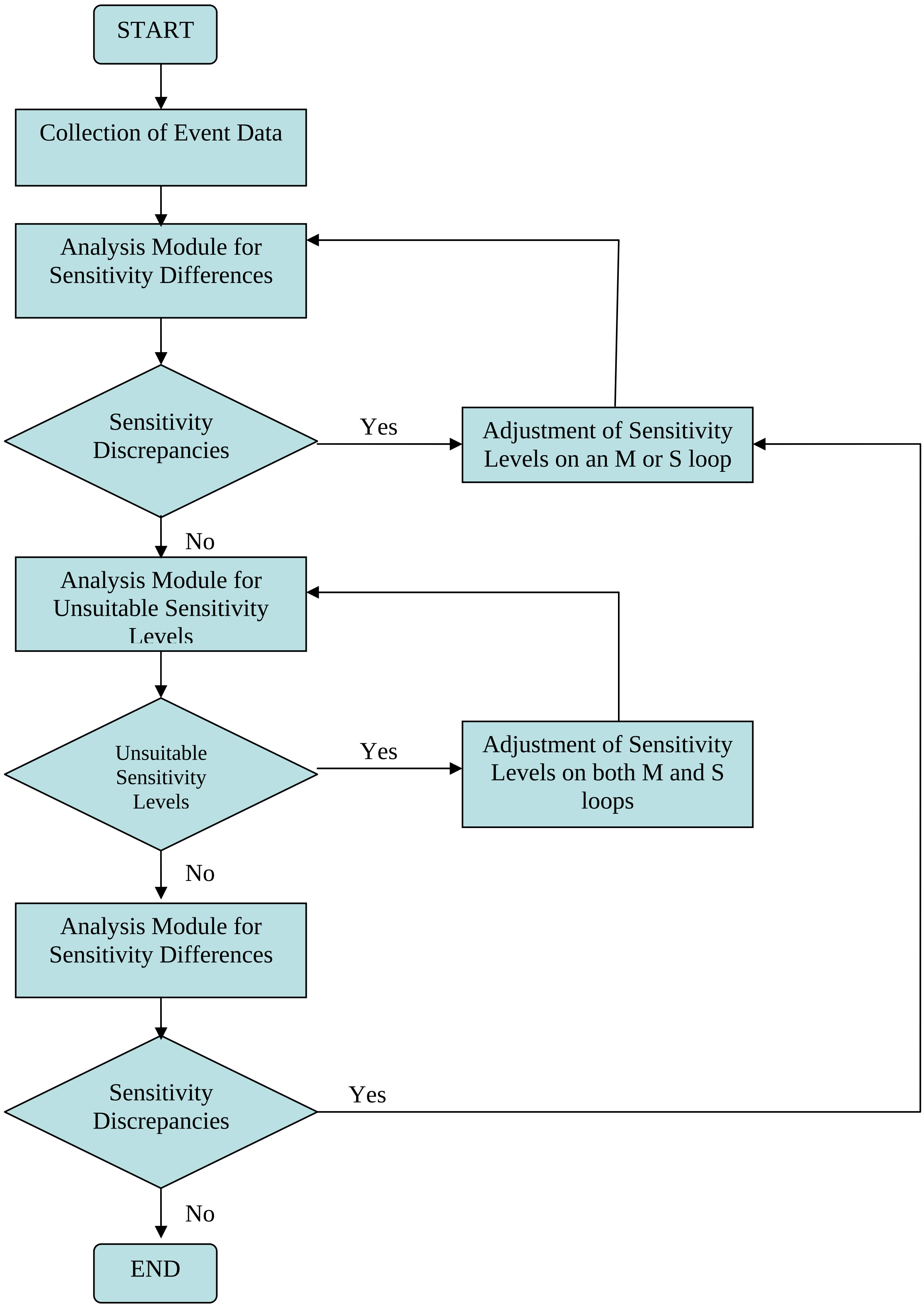


FIGURE 4 The algorithm for fixing the dual-loop sensitivity problems.

STUDY SITES

Data from the dual-loop stations with the sensitivity problems were needed to verify the proposed algorithm. Based on a preliminary analysis using the archived loop data and consultation with WSDOT technical supervisors, three dual-loop stations were selected for this study: 1) ES-167D (located at I-5 southbound & NE 145th St.); 2) ES-168R (located at I-5 northbound & NE 145th St.); and 3) ES-172R (located at I-5 northbound & Metro Base). The traffic counts for these sites obtained from the Traffic Data Acquisition and Distribution (TDAD) Website are shown in TABLE 1 (a)-(c). Each station has three General Purpose (GP) lanes and one High Occupancy Vehicle (HOV) lane. Because of the unique characteristics and low traffic volumes of the HOV lane, only the GP lanes were included in this study. The lanes were numbered from right to left, with the far right being lane 1 and far left being lane 3. Traffic volumes from the M loop, the S loop, and the dual-loop detector (ST – Speed Traps) are shown in the second, third, and fourth columns, respectively. The last column displays the percent difference (DIFF%) between the volume counted on the M loop and on the dual-loop system. The DIFF% column shows the severity of the bin-volume undercount problem.

TABLE 1(a) TDAD Data at ES-167D Station (SB I-5 & NE 145th St.)

Volume	M loop	S loop	ST	DIFF%
Lane 1	10592	10510	9576	9.59
Lane 2	15909	15933	14902	6.33
Lane 3	16097	15975	13027	**19.07**

TABLE 1(b) TDAD Data ES-168R Station (NB I-5 & NE 145th St.)

Volume	M loop	S loop	ST	DIFF%
Lane 1	7108	7206	5697	**19.85**
Lane 2	12523	12361	4306	**65.62**
Lane 3	12460	12334	8796	**29.41**

TABLE 1(c) TDAD Data ES-172R Station (NB I-5 & Metro Base)

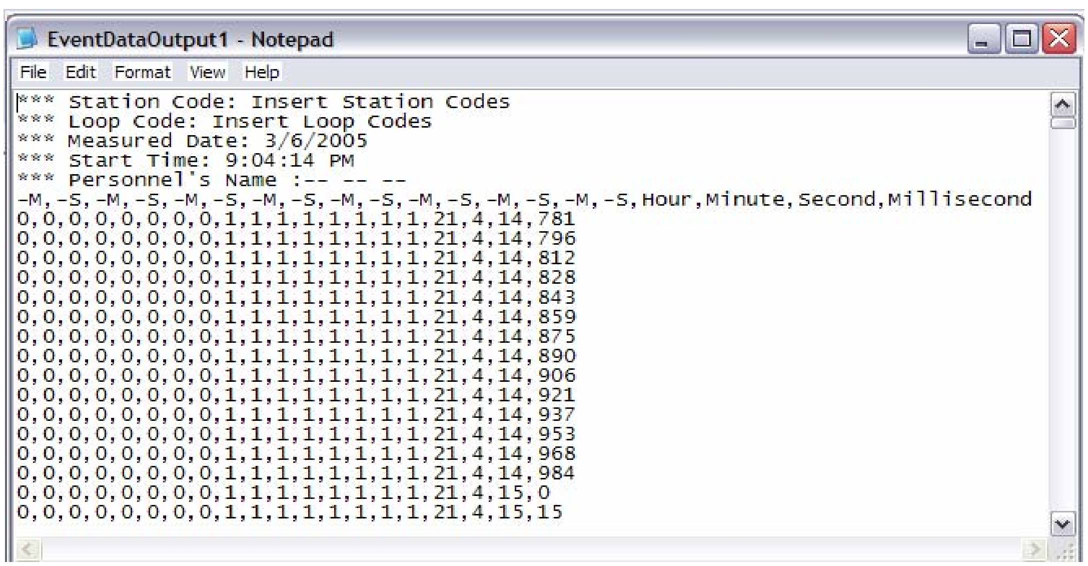
Volume	M loop	S loop	ST	DIFF%
Lane 1	15778	15872	14954	5.22
Lane 2	14082	14686	12845	8.78
Lane 3	10025	11186	567	**94.34**

As mentioned earlier, the current WSDOT dual-loop algorithm only calculates lengths for vehicles with on-time differences between the M and S loops within 10 percent. Since loop on-times are strongly dependent on loop sensitivities, lanes that had DIFF% of more than 10 percent were considered to have serious sensitivity problems. In the current study, such lanes included lane 3 at ES-167D, all the lanes at ES-168R, and lane 3 at ES-172R. The loop stations with good lanes (DIFF% less than 10 percent) and bad lanes (DIFF% more than 10 percent) were chosen for comparison purposes in this study.

The loop amplifiers at the test loop stations were EDI's and Sarasota's that had eight levels of sensitivity (from level zero to seven). The sensitivity levels of all single loop detectors in the dual-loop systems were set at level two except for one single loop on lane 3 at ES-172R (NB I-5 & Metro Base) that was set at level five. As shown in TABLE 1(c), the DIFF% on lane 3 at ES-172R was almost 95 percent. The WSDOT dual-loop algorithm allowed the dual-loop detector on this lane to calculate vehicle length for only 5 percent of the total lane traffic. The sensitivity settings were level two and level five for the M loop and the S loop, respectively. This result emphasized the importance of sensitivity setting in the dual-loop detector system. Furthermore, the same sensitivity level adjustments on both the M and S loop amplifiers may not guarantee that the M and S loops will have the same on-times because the loop inductance changes with its environmental factors including temperature, humidity, road structure, etc. This implies that the on-time differences may exceed 10 percent even when the loop sensitivity settings on both the M and S loop amplifiers are at the same level. Therefore, a computer system like ALEDA is desired to identify the dual-loop sensitivity problems at individual loop stations.

DATA COLLECTION

Event data were collected for about 24 hours from each station to check the impacts of different traffic conditions on the severity of sensitivity problems. The data collection at the ES-167D dual-loop station was conducted from 9:44:32am on October 25th until 9:42:03am on October 26th, 2004. At the ES-168R dual-loop station, the data were collected from 10:04:56am on December 8th until 9:30:35am on December 9th, 2004. Finally, at the ES-172R loop station, the data collection occurred from 10:25:42am on December 8th until 9:41:17am on December 9th, 2004. The sample file of the collected event data is shown in FIGURE 5. There are sixteen columns of event data for sixteen single-loop detectors comprising eight dual-loop detectors. For instance, the first and second columns are for the M and S loops, respectively, of a dual-loop detector in the first traffic lane (the rightmost lane).


EventDataOutput1 - Notepad

File Edit Format View Help

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*** Loop Code: Insert Loop Codes
*** Measured Date: 3/6/2005
*** Start Time: 9:04:14 PM
*** Personnel's Name :-- -- --
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FIGURE 5 Sample file of event data.

DISCUSSION OF TEST RESULTS

As mentioned earlier, loop sensitivity problems are the primary causes of the undercounting of the WSDOT dual-loops' classified vehicle volumes, because vehicles with sufficiently large on-time inconsistencies are dropped from the vehicle classification process by the WSDOT algorithm. The dual-loop on-time differences represent the sensitivity discrepancies between the M and S loops.

The on-time differences of all individual vehicles detected in a 15-minute interval at the ES-167D station are plotted in FIGURE 6(a)-6(c) for an in-depth investigation of the sensitivity level problems at the studied dual-loop stations.

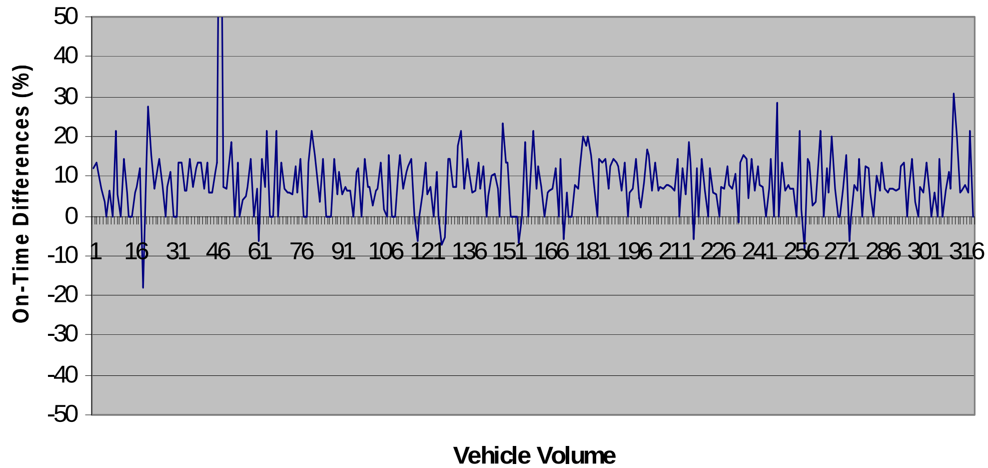

FIGURE 6(a) Dual-loop on-time differences for lane 1 at ES-167D.

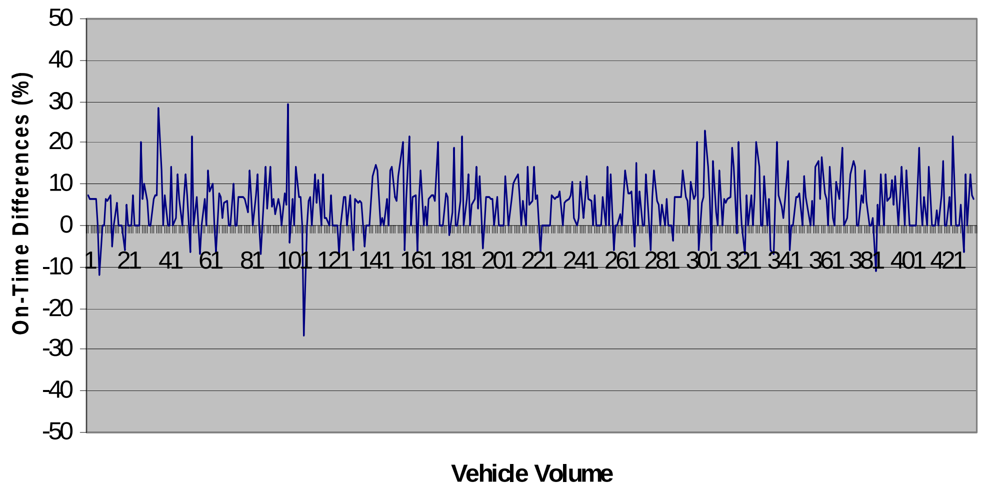

FIGURE 6(b) Dual-loop on-time differences for lane 2 at ES-167D.

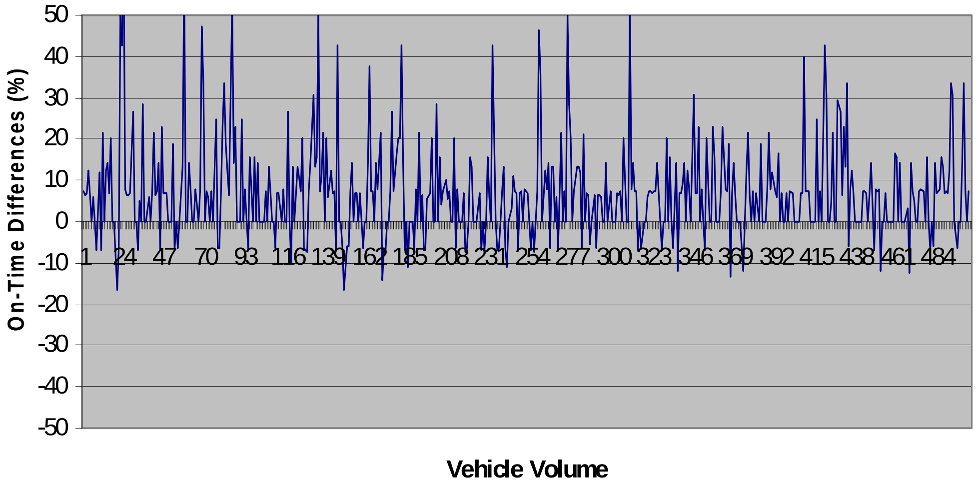

FIGURE 6(c) Dual-loop on-time differences for lane 3 at ES-167D.

In FIGURE 6(b), the plotted on-time differences on lane 2 at the ES-167D station are within ±10 percent for most time periods. This conforms to the small value of DIFF% (6.33 percent) in TABLE 1. The DIFF% for lane 1 (9.59 percent), however, is higher than that for lane 2 (6.33 percent). This is due to a higher severity of the sensitivity discrepancy problems. Most of the on-time differences on lane 1 are greater than zero (about +10 percent in average) as shown in FIGURE 6(a). The lane that has the worst sensitivity discrepancy problem at the ES-167D station is Lane 3. The on-time differences were greater than ±10 percent in most cases (FIGURE 6(c)). This is obviously reflected in the high DIFF% value (19.07 percent).

The sensitivity discrepancy problem can be solved by adjusting the sensitivity levels at loop amplifiers following a review of the results of the analysis function in ALEDA. Speed estimates should be reasonably accurate when no sensitivity discrepancy is present in a dual-loop detector system.

After a sensitivity discrepancy is eliminated, the next task is to determine a suitable sensitivity level for both single-loop detectors of a dual-loop system so that the measurement of vehicle lengths is accurate. Since vehicle lengths follow a certain statistical distribution, we can use the features of vehicle length distribution extracted from manufacturers' vehicle length data to identify the correct sensitivity level.

To illustrate the impact of incorrect sensitivity levels, the median lengths of every one hundred SVs on each lane of ES-167D were plotted in FIGURE 7. It is obvious that the calculated median vehicle lengths of Lane 1 are dissimilar to those of the other two lanes. The unrealistically short median lengths (the median length of SVs for the ground truth data is about 15.5 ft. or 4.65 meters) resulted from the low sensitivity settings in the dual-loop system.

By comparing the histogram of ground truth SV lengths and that of one-hundred measured SV lengths and follow the ALEDA recommended sensitivity adjustments, the sensitivity levels of the M and S loops can be adjusted to the correct level.

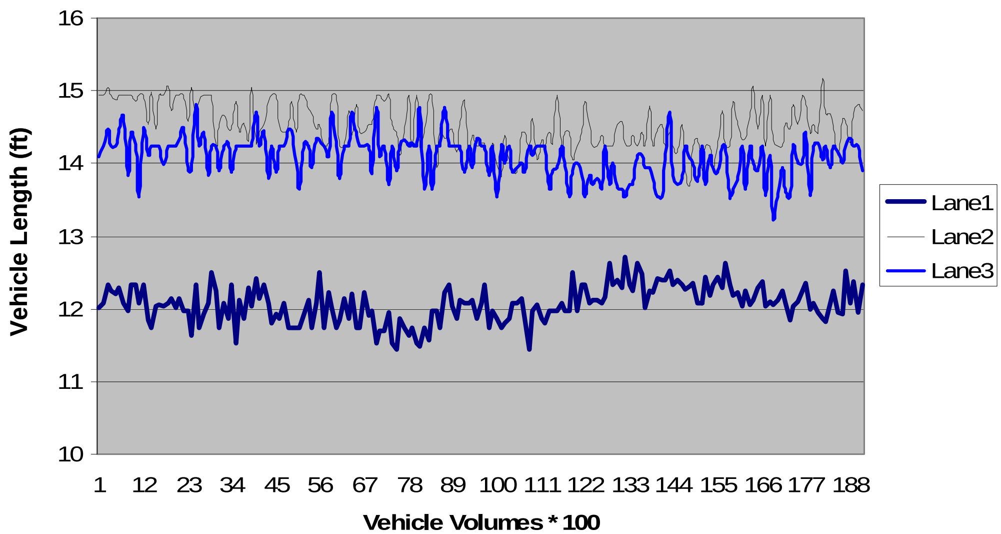

FIGURE 7 Estimated short vehicle median length at ES-167D (SB I-5 & NE 145th St.).

CONCLUSIONS

This paper describes a study on dual-loop sensitivity problems and proposes a new algorithm to detect and fix such sensitivity problem using loop event data and the statistical features of SV-length distribution. Event data that contain specific individual vehicle information make the detailed investigation of the dual-loop sensitivity problems feasible. The analysis results showed that the dual-loop sensitivity problem consists of a sensitivity discrepancy between the two single loops forming a dual-loop detector, and an unsuitable sensitivity level on both single loops. Dual-loop sensitivity inconsistencies result in erroneous calculation of loop occupancy, speed, and vehicle length. Unsuitable sensitivity levels cause imprecise measurements of vehicle lengths and hence misclassification. The combination of both dual-loop sensitivity problems can cause severely inaccurate measurements of traffic variables.

A new algorithm for solving dual-loop sensitivity discrepancies and finding suitable loop sensitivity levels has been developed based on loop event data and the characteristics of SV-lengths distribution. This algorithm has been implemented in a computer application, named ALEDA, for convenient usage. The dual-loop sensitivity problems are corrected by iterating the steps of identification and correction for both sensitivity discrepancies and unsuitable sensitivity levels until both sensitivity problems are eliminated. The system tests showed that by using the proposed algorithm the sensitivity problems of dual-loop detectors can be effectively corrected. Sensitivity discrepancies can be eliminated by adjusting sensitivity levels at loop amplifiers until the on-time differences of both loops are close to zero. Similarly, suitable sensitivity levels can be identified and corrected by comparing the distribution of ground-truth vehicle length data and the distribution of every one hundred SV lengths.

Dual-loop detectors are a major source of traffic data that are vital for effective ATMS and ATIS. The dual-loop sensitivity problems must be solved to increase the dual-loop reliability. In practice, these sensitivity problems are currently detected and corrected manually by traffic technicians based on their empirical experience. The process is time consuming and the result is often inaccurate. The proposed methodology and the implemented ALEDA are expected to help solve the dual-loop sensitivity problems effectively and accurately.

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