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EVALUATION OF VIDEO DETECTION SYSTEMS VOLUME 4 - EFFECTS OF ADVERSE WEATHER CONDITIONS IN THE PERFORMANCE OF VIDEO DETECTION SYSTEMS

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16. Abstract

The performance of three video detection systems (VDS): Iteris, Autoscope, and Peek, was evaluated using a side-by-side installation at a signalized intersection under various adverse weather conditions including rain and snow in both day and nighttime, and light fog and dense fog in daytime. Four types of detection errors (false, missed, stuck-on, and dropped calls) were quantified at stop bar and advance detection zones, and all errors were visually verified using video images from the intersection. Results indicate that VDS performance was not greatly impacted under daytime light fog or rain conditions without wind, but significant changes were observed under dense fog and snow in daytime, and snow and rain in nighttime. During dense fog conditions Iteris and Autoscope changed their operating mode and placed constant calls due to image contrast loss, with potential for significant effects on traffic operation, while Peek significantly increased its missed calls. Snow in daytime and nighttime greatly increased false calls for the three systems (more than 50% of the VDS calls were false), but it had limited effects on missed, stuck-on, and dropped calls. False calls during rainy conditions without wind also increased, during both daytime (around 10%) and nighttime (between 10% and 50%), mostly due to the reflection of headlights of vehicles in the adjacent lanes. Detailed performance of the three VDS in each of the three stop bars and the three advance zones, as well as potential causes and effects of the most prominent error types are presented.

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EXECUTIVE SUMMARY

The performance of a video detection system (VDS) can be degraded due to adverse weather conditions, and this may affect safety and operational efficiency of signalized intersections. The performance of three VDSs — Iteris, Autoscope, and Peek— was evaluated under various adverse weather conditions, including rain and snow in both day- and nighttimes, and light fog and dense fog in daytime. The three systems were installed side by side at a signalized intersection in Rantoul, Illinois. Four types of detection errors (false, missed, stuck-on, and dropped calls) were determined using activation and de-activation times at stop bar and advance detection zones, and all errors were visually verified using video images from the intersection. Results indicate that VDS performance was not greatly affected under daytime light fog or rain condition without wind, but significant changes were observed under dense fog and snow in daytime, and snow and rain in nighttime. During dense fog conditions, Iteris and Autoscope changed their operating mode and placed constant calls due to image contrast loss, while Peek significantly increased its missed calls. Snow in daytime and nighttime greatly increased false calls for the three systems (to more than 50%), but it had limited effects in terms of missed, stuck-on, and dropped calls. False calls during rainy conditions also increased during both daytime (around 10%) and nighttime (between 10% and 50%), mostly due to the reflection of headlights of vehicles in the adjacent lanes. Detailed performance for each detection zone, as well as the potential causes and effects of the most prominent error types, are also presented.

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INTRODUCTION

It is known that the performance of a video detection system (VDS) is susceptible to changes in weather conditions such as periods of snow, fog, wind, and rain, among others, in both day- and nighttime. Since these weather conditions are very common and represent periods when vehicle detection is critical in terms of safety and efficiency of signalized intersections, they can pose a serious challenge to VDSs. However, no comprehensive studies have been conducted to evaluate VDS performance under such conditions, creating a critical need in this respect, given the increasing number of VDS installations all over the United States.

Currently available literature is limited to studies of sunny, cloudy, night, and rain conditions using small datasets and practically no replications of the adverse conditions. Early evaluations of VDSs include a study by MacCarley (1998) using the Vantage Video Traffic Detection System (VTDS) at three intersections under twelve conditions. Different combinations of weather, time of day, traffic volume and electromagnetic interference were observed. Results were based on 15-minute datasets and demonstrated performance degradation due to shadows and low lighting conditions, among others. In a later study, Minnesota DOT and SRF Consulting Group (MnDOT 2001) evaluated the performance of VDSs at intersections using different mounting locations and heights. This study found degraded performance in scenarios with shadows (both stationary and moving) and wind. Also in 2001, Grenard, Bullock, and Tarko evaluated three days of data to determine the performance of Econolite, Autoscope, and Peek at an intersection under overcast, night rain, and partly sunny conditions. Results generated some concerns in nighttime detection and their use for dilemma zone protection. More recently, a study by Rhodes et al. (2006, 2007b) that followed the 2001 study by Grenard, Bullock, and Tarko indicated significantly more false and missed detections using VDSs than inductive loop detectors. The study installed three systems next to each other: Autoscope (version 8.10), Peek UniTrak (version 2), and Iteris Vantage (Camera CAM-RZ3). Results from two full days of data were analyzed. It was found that all the three VDSs had a moderate-to-high degree of missed and false calls and that none was superior to the others. In a later study, Rhodes et al. (2007a) evaluated the stochastic variation of activation and deactivation times between day and night conditions, using data from one day, and found earlier detections at night due to headlight reflection in the pavement.

This report presents the results of an evaluation of three widely used VDSs (Autoscope, Iteris, and Peek) at a signalized intersection under various adverse weather conditions, including rain and snow in both day- and nighttimes, and light fog and dense fog in daytime.

Datasets for this study were collected exclusively for the purpose of analyzing these conditions, allowing an analysis with data from multiple days (replications) with very similar characteristics. The three VDSs were evaluated using a side-by-side installation which is an ideal setting for comparing different systems under the same conditions. Their performance was evaluated based on four types of errors: false calls, missed calls, stuck-on calls, and dropped calls. The evaluation included an initial automatic data processing using a computer algorithm, followed by a manual verification of the errors using video images as the ground truth. This procedure assures accurate results that are verifiable and provide a complete overview of the potential strengths and weaknesses of the VDSs at signalized intersections.

This report focuses on the evaluation of the VDS performance under adverse weather conditions. It also briefly describes, in Chapters 2 and 3, the test setup, the data

collection process, and the methodology to estimate the detection errors. A more comprehensive description of the characteristics of this study is presented in Volume I of this series: “Effects of Configuration Changes in the Performance of Video Detection Systems.” In addition, the effects of different illumination conditions and the effects of wind on the VDS performance are presented in Volumes 2 and 3 of this series. Copies of all reports generated from this study can be found at the Illinois Center for Transportation of the University of Illinois via its website: http://www.ict.uiuc.edu/Publications.asp.

CHAPTER 1 TEST SETUP

The eastbound approach of the intersection of Veteran's Parkway (U.S. Route 45) and S. Century Blvd, located in the urban area of Rantoul, Illinois, was selected for this study. This approach has two left-turn lanes and a shared right-through lane (see Figure 1.1), and a speed limit of 35 mph. Cameras from the three manufacturers were installed on a luminaire arm located past the intersection at a height of approximately 40 ft. The cameras were placed above the projection of the center of the through lane, and not above the projection of the center of the approach lane, because the luminaire "arm" did not extend out that far. The field of vision from the camera location to both stop bar and advance detection zones was clear of obstacles.

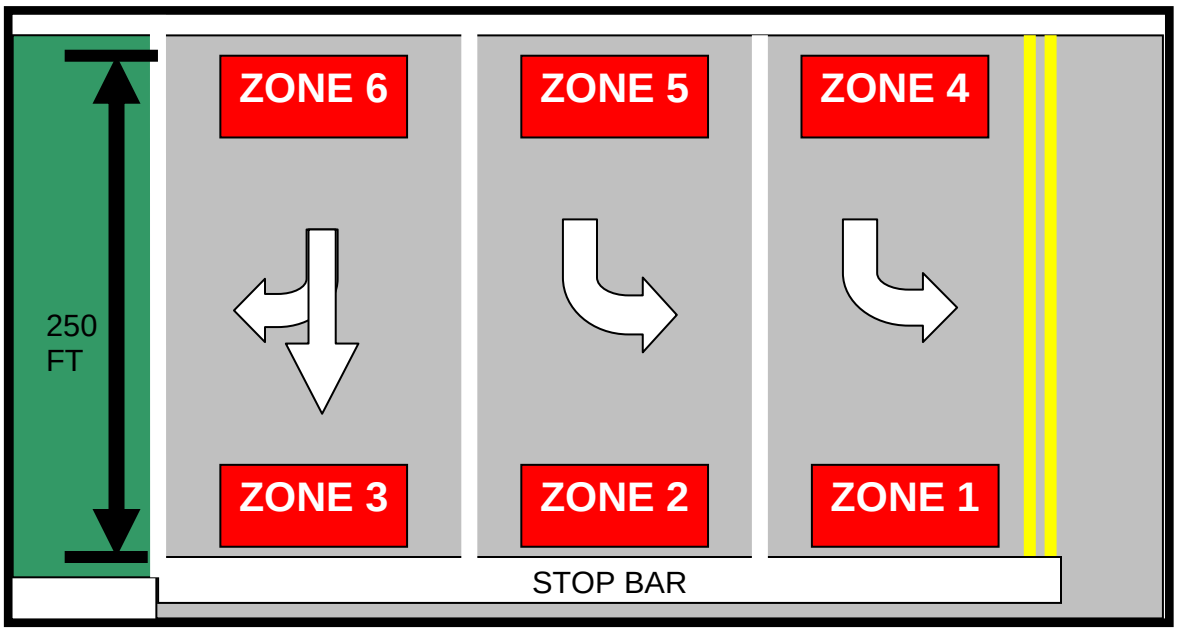


Figure 1.1. Intersection layout.

In addition to the VDSs, six inductive loops (each 6 ft × 6 ft) were also installed at the stop bar and advance locations. The purpose of inductive loops is to serve as a pointer to potential errors in detection.

Video detection systems were configured by the manufacturers and/or the distributors, to detect vehicles at locations where the loop detectors are installed. Thus, each camera had three advance and three stop bar detection zones. A representative from one of the manufacturers was present at the evaluation site during the setup; and for the other two systems, the distributors were present and received technical support from the manufacturers via telephone. The following product versions were installed: Autoscope (SoloPro with v 8.13), Peek (Unitrak with v 2.2), and Iteris (Edge 2 with v 1.08).

Manufacturers and/or distributors were given a chance to improve their configuration after receiving the results of a preliminary analysis conducted by the research team for daytime and nighttime conditions. Some of the manufacturers and/or distributors made some changes to their detection zone configurations using the preliminary results. Then, the research team provided the manufacturers and/or distributors a one-hour video of the how

their systems were performing after the configuration changes and they were given a second chance to modify their configurations if they wished. Some took this opportunity and made additional fine-tuning to their configurations.

Thus, the analysis presented in this report reflects the performance of VDSs after two rounds of modifications from the manufacturers and/or distributors. The authors believe that allowing for fine-tuning of the VDS setup before the collection of final datasets was a fair and important practice, because this evaluation was intended to provide insights into the capabilities of each system, only achievable when they are performing at their best. In addition, based on information provided by the staff of the Illinois Department of Transportation, it is not unusual to fine-tune the initial VDS configuration, and the authors are aware of situations that required changing the VDS settings more than once to obtain an adequate performance from the video detection systems.

CHAPTER 2 DATA COLLECTION AND METHODOLOGY

Two types of data were collected for the evaluation of the VDSs: timestamps and processed video images. Timestamps refer to the times at which a VDS zone or an inductive loop was activated or deactivated. The idea behind collecting timestamps was that a part of the data analysis procedure could be automated using computer algorithms. This would allow processing large datasets and overcoming one of the limitations of the previous studies. Timestamps were collected using an input/output (I/O) device to monitor vehicle presence (the changes in voltage) as identified by each loop detector and detection zone from the three VDSs. The I/O device verifies the state of these 24 detectors (six from each of the three VDSs and six from the loops) once every 50 milliseconds, resulting in 20 checks per second.

On the other hand, the processed video images from the three VDS cards were fed as inputs to a quad processor, generating a single image showing the three video feeds, plus a real-time graphical depiction of the detector states generated by an I/O device (lower right-hand corner of Figure 2.1). This graph shows the status—vehicle present or not—of the loop and the three VDSs at the six detection locations, providing an additional tool to visually confirm if a call took place in any detection system or zone. A sample of the quad image is shown in Figure 2.1. The recorded video images were used to calibrate and validate the computer algorithm, and to provide visual verification of the potential errors that were automatically identified. The video images also served as a ground truth to verify that there were no errors by the loops. Furthermore, the video images were used to ascertain the lighting/weather/traffic condition at the study location.

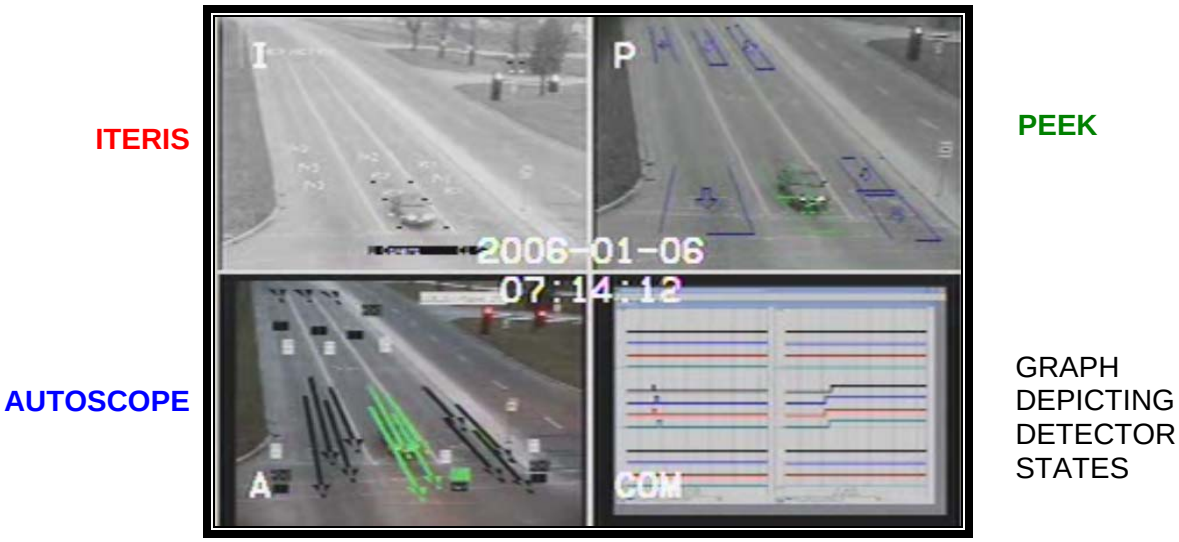


Figure 2.1. Quad image.

It should be noted that all hardware required to run the VDSs and store the data collection was housed in a cabinet independent of the cabinet that contains the traffic controller used to operate the intersection. The cameras used for data collection and the loop detectors did not affect the operation of the intersection. The intersection was operated by a totally different set of detectors, which happened to be a video detection system. Thus, the data collection devices did not have any interference with real traffic operations.

Four measures of performance (MOEs) were used to quantify the detection errors from the VDS and to evaluate their performance: false calls, missed calls, dropped calls, and stuck-on calls. These MOEs were estimated for each detection zone by automatically detecting potential errors using the computer algorithms, and then by manually verifying every potential error before labeling it as an actual detection error. Without the automated preliminary data analysis, the use of large datasets would not be practical, limiting the scope of the study to the analysis of small datasets.

2.1 COMPUTER ALGORITHM

A computer code was developed to read the timestamps from VDSs and loops and to determine if there was a discrepancy between the loop indication and the VDS indication. The loop calls were used as pointers to potential errors and the actual errors were determined based on a manual verification that took place after the identification of potential errors. It should also be noted that the exact times of activation and deactivation of loops and VDSs were not used as the criteria to identify errors. In this study, it was important to evaluate the VDS' ability to correctly detect the presence of vehicles within a reasonable time from the arrival or departure of the vehicle. The manufacturers/distributors were not restricted by a set of conditions (e.g., field of view or exact extent and location of detection zone), but were given the freedom to choose the field of view and zoom level that would yield their best performance. The freedom to choose their best camera setup provided a fair condition for all three VDSs, and avoided possible bias towards a system that could have advantages over the others under specified conditions. Thus, the activation and deactivation times from VDSs and loops are not expected to match exactly, but should be within time-windows within which detections are considered acceptable.

The concepts used to define MOEs, as well as the logic used in the computer code, including acceptable time windows, are briefly discussed as follows:

- Missed calls. Missed calls occur when the VDS fails to detect vehicles in the detection zone. In practice, missed calls may have adverse safety effects due to potential red-light runners in cases where the corresponding phase is not called by the controller. In terms of the timestamps, for every loop call, if there is no corresponding VDS call, it is considered a potential missed call. The algorithm identifies loop calls and searches for VDS calls in a window that starts *X* seconds before the start of the loop call and ends *Y* seconds after the end of the loop call. If no VDS call is found in this window, this is counted as a potential missed call.
- False calls. These are defined as calls placed by the VDS when there was no vehicle in the detection zone. In practice, false calls may have negative effects on the operational efficiency of the intersection. In the algorithm, for every call by a VDS, if there is no corresponding call from the loop detector, it is considered a potential false call. The algorithm identifies VDS calls and then searches for a loop call placed in a window that starts *X* seconds before the beginning of the VDS call and ends *Y* seconds after the VDS call is terminated.
- Dropped calls. These occur when a call by the VDS is dropped while the vehicle is still present in the detection zone. If the VDS prematurely terminates the call placed to the controller, this may prevent the corresponding phase from being called, generating potential safety issues due to red-light runners. In terms of timestamps, if the VDS call is terminated more than *X* seconds before the end of the loop call, it is considered a potential dropped call.

- Stuck-on calls. These are defined as calls held by the VDS once a vehicle has been correctly detected, even after the vehicle has departed from the detection zone. Stuck-on calls may affect operational efficiency of the signalized intersection. In the algorithm, if a VDS call continues to be active more than *X* seconds after the end of the loop call, it is counted as a potential stuck-on call.

Values assigned for the acceptable windows (*X, Y*) were not necessarily the same for all types of errors, and could change from one VDS to the other, depending on the location and size of their detection zones. Different thresholds were used to avoid unfair classification of calls as errors (false, missed, stuck-on, or dropped calls) when they actually are not errors. For example, from Figure 2.1, it is clearly seen that in the Peek system, the stop bar zones are shorter and the advance zones are longer and closer to the stop bar compared to Iteris and Autoscope. These differences translate into vehicle detections from Peek starting at slightly different times, and in calls not having the exact same duration as those from the other two systems. Considering these facts, different *X* and *Y* values were used so that the detection systems are judged fairly.

The selected time windows (*X* and *Y* values) were obtained to work for day and night conditions based on calibration and validation efforts that used day and night data. Calibration was performed by matching the errors from the computer code with the errors from manual verification from watching the videos; and for validation, results were compared from the calibrated computer code with manually verified errors from datasets not used in the calibration. An exact match between results from manual verification and the computer code was found after calibration and validation. Final *X* and *Y* values after validation are presented in Table 2.1.

Table 2.1. *X* and *Y* Values for Acceptable Time Windows

Location	**MOE**					
	Missed Calls		False Calls		Dropped Call	Stuck-on Call
	X	Y	X	Y	X	X
Stop Bar	2 (3*)	1 (0*)	1 (1*)	2 (3*)	5	10
Advance	1 (0*)	2 (4*)	3 (5*)	1 (0*)	5	10

* Peek Values; ** All values in seconds

It should be noted that no errors were observed in the loop detection. If any error had occurred, it would have been identified, since it would have indicated a discrepancy with the VDS. Furthermore, given that the loop information is only used for initially screening the data and for pointing to the time period during which a discrepancy occurred, the manual verification that took place in a later analysis stage would have prevented it from affecting the evaluation of the VDS performance.

Additional detailed information about the time window selection, calibration, and validation, as well as the details of the algorithm logic for detecting potential errors, can be found in Volume I of this study: “Effects of Configuration Changes in the Performance of Video Detection Systems.”

2.1.1 Manual Verification of Potential VDS Errors

The final step in the data analysis procedure was the manual verification of the results from the computer algorithms. After the automated detection of potential errors, there might still be some situations that cannot be handled by the computer program and that can only be resolved by manual verification. Video images from the intersection served as the ground truth for determining whether potential errors identified by the computer code are actual errors.

Each false, missed, stuck-on, and dropped call was verified using the videos recorded from the three systems using the quad image. This not only ensured the reliability of the numbers reported, but also provided the research team with an understanding of the possible causes and solutions that can potentially improve the performance of the VDS.

It should be noted that this manual verification does not require the entire datasets to be watched, but only the times at which the computer program reports a potential error. This procedure reduced the manual verification time to just a fraction of the time required to manually check the entire datasets for each of the VDSs and the loops calls.

CHAPTER 3 RESULTS

The results for three different weather factors (fog, rain, and snow) covering six conditions are presented in this section:

- Light fog in daytime
- Dense fog in daytime
- Rain in daytime
- Snow in daytime
- Rain in nighttime
- Snow in nighttime

Errors during adverse weather were compared against a base condition to establish the effects of each weather factor on VDS performance. Datasets from different days with similar conditions were aggregated into one single dataset and analyzed and reported in this chapter. The performance for each day is also presented in Appendix I of this report, for the reader to observe how much variation was measured from one day to another.

The base condition was selected as the scenario with the most favorable weather conditions. For the adverse weather effects during the daytime, the base condition was the VDS performance in a cloudy day (no shadows) around noon time; and for nighttime, the base was calm night conditions. In both of the base conditions (day and night), there was no wind or any other adverse weather-related factors. Statistical comparisons were made between the evaluated condition and the base condition using *Z* tests for proportions. A confidence level of 95% was used to interpret the test result. Also, *Z* values were included for all comparisons, so the interpretation of the test can easily be adjusted based on a different confidence level.

3.1 DROPPED CALLS FOR ALL CONDITIONS

Very few dropped calls were found in the base datasets and all the adverse weather conditions presented in this report, so they are briefly summarized in this section. Dropped calls were observed only at stop bar zones and mostly in nighttime conditions. Also, the effect of inclement weather on dropped calls was most prominent during rainy conditions, when headlight reflection on the pavement was more evident.

In summary, in the night base case, three dropped calls were found for all zones and systems together (two in Iteris and one in Peek); in snow at night, a total of six dropped calls were found (four in Iteris, one in Peek, and one in Autoscope); and in rain at night, for all three systems, three dropped calls occurred in Zone 1, five in Zone 2, and 17 in Zone 3. It is noted that out of the 25 dropped calls in rain at night, 20 occurred in Iteris zones, four in Peek zones, and one in Autoscope.

On the other hand, during daytime conditions, only three dropped calls were found: one in the base case (in Autoscope), and two in the dense fog conditions (both in Peek).

3.2 FOG IN DAYTIME

The analysis of the fog condition was divided into two subsections: effects of light fog and effects of dense fog. Datasets were selected based on visual inspection of the videos, such that only clear cases of light or dense fog were used for analysis. Selected datasets were not affected by additional weather factors such as wind or rain.

A total of over 4 hours of light fog condition from 6 different days were identified for the analysis, and a similar amount of time from 4 days was identified for the dense fog condition. All selected datasets were collected in the morning time (around 7 a.m.), except for one day in dense fog condition that was collected in the afternoon (around 4 p.m.).

3.2.1 Light Fog - 260 minutes (6 days)

For illustration purposes, a sample image of the base condition is presented in Figure 3.1 in contrast with an image during light fog condition.

(a) (b)

Figure 3.1. Sample images of (a) base and (b) light fog conditions.

3.2.1.1. Stop Bar Zones

- <u>False calls.</u> Significant increases in false calls were observed in Autoscope and Iteris, with no changes in Peek (See Table 3.1). For all stop bar zones combined, false calls increased from 3.5% in Base condition to 9.2% for Autoscope, and from 5.7% to 10% for Iteris. However, these errors were not necessarily caused by effects of the light fog condition itself. In Zone 1, false calls increased for Autoscope (from 9.5% to 18.5%) and Iteris (from 15.1% to 23%) due to the increase in heavy traffic in the center lane (adjacent to Zone 1). Recall that light fog data was collected during very early morning hours, when it is more likely for heavy traffic to use urban roads. As mentioned before, heavy vehicles making a left turn from the middle lane are very likely to cause false calls on Zone 1 because their image occupies a portion of this zone. In addition, multiple false calls can be generated by a single turning vehicle, since the false call can “flicker” on and off during the turning movement or while waiting for the green light.

False calls in Zone 2 increased significantly for Iteris due to the reflection of headlights from vehicles approaching Zone 1 (on the left-most lane), and to a lower degree due to higher heavy traffic volume on the right-through lane (Zone 3). Given the light fog condition, most drivers had turned on their headlights, creating some pavement reflection that affected the performance of adjacent lanes. The “flicker” effect mentioned for Zone 1 also affected Zone 2.

Table 3.1. False calls in light Fog and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Light Fog	444	9.2%	-3.93	Increased	509	7.5%	-0.40	Not Significant	470	10.0%	-2.86	Increased
	Base	1584	3.5%			1928	7.0%			1730	5.7%		
Zone 1	Light Fog	119	18.5%	-2.35	Increased	151	22.5%	-0.54	Not Significant	139	23.0%	-2.03	Increased
	Base	484	9.5%			615	20.5%			549	15.1%		
Zone 2	Light Fog	167	3.0%	-1.55	Not Significant	198	2.0%	-0.95	Not Significant	183	7.7%	-2.57	Increased
	Base	585	0.9%			698	1.0%			637	2.4%		
Zone 3	Light Fog	158	8.9%	-3.42	Increased	160	0.0%	1.00	Not Significant	148	0.7%	-0.70	Not Significant
	Base	515	1.0%			615	0.2%			544	0.2%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

In Zone 3, only Autoscope was affected by the headlight reflection of vehicles on the center lane, increasing its false calls by about 8% (from 1% in the base condition). Other systems did not show any change in false calls in Zone 3.

- Missed calls. No significant changes were observed in the missed calls during light fog conditions, with no missed vehicles on Autoscope and Iteris, and four vehicles missed by Peek, all of them in Zone 3. Note that in the base condition, Autoscope missed one vehicle, also in Zone 3.

Table 3.2. Missed Calls in Light Fog and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Light Fog	529	0.0%	0.00	Not Significant	529	0.8%	-1.86	Not Significant	529	0.0%	0.00	Not Significant
	Base	2070	0.0%			2070	0.0%			2070	0.0%		
Zone 1	Light Fog	125	0.0%	0.00	Not Significant	125	0.0%	0.00	Not Significant	125	0.0%	0.00	Not Significant
	Base	553	0.0%			553	0.0%			553	0.0%		
Zone 2	Light Fog	224	0.0%	0.00	Not Significant	224	0.0%	0.00	Not Significant	224	0.0%	0.00	Not Significant
	Base	849	0.0%			849	0.0%			849	0.0%		
Zone 3	Light Fog	180	0.0%	0.00	Not Significant	180	2.2%	-1.86	Not Significant	180	0.0%	0.00	Not Significant
	Base	668	0.0%			668	0.1%			668	0.0%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. Similar to missed calls, no major effects were observed in terms of stuck-on calls at the stop bar zones, resulting in a performance comparable to the base condition. Only two stuck-on calls were observed in the light fog condition, both in Zone 1 in Autoscope, compared to two false calls in the base condition—one in Zone 1 and one in Zone 3, also in Autoscope.

Table 3.3. Stuck-on Calls in Light Fog and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Light Fog	444	0.5%	-0.98	Not Significant	509	0.0%	0.00	Not Significant	470	0.0%	0.00	Not Significant
	Base	1584	0.1%			1928	0.0%			1730	0.0%		
Zone 1	Light Fog	119	1.7%	-1.23	Not Significant	151	0.0%	0.00	Not Significant	139	0.0%	0.00	Not Significant
	Base	484	0.2%			615	0.0%			549	0.0%		
Zone 2	Light Fog	167	0.0%	0.00	Not Significant	198	0.0%	0.00	Not Significant	183	0.0%	0.00	Not Significant
	Base	585	0.0%			698	0.0%			637	0.0%		
Zone 3	Light Fog	158	0.0%	1.00	Not Significant	160	0.0%	0.00	Not Significant	148	0.0%	0.00	Not Significant
	Base	515	0.2%			615	0.0%			544	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

4.2.1.2. Advance Zones

- False calls. False calls during light fog condition for all advance zones combined increased significantly in Autoscope (from 1.6% to 4%) and Iteris (from 5.0% to 7.5%), with no significant changes for Peek. These increases were caused by false calls in Zone 4 (for both systems) when the image of heavy vehicles traveling on the adjacent lane occupied small portions of this zone, similar to that described for Zone 1.

Table 3.4. False Calls in Light Fog and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Light Fog	550	4.0%	-2.67	Increased	537	5.6%	0.46	Not Significant	561	7.5%	-2.06	Increased
	Base	2011	1.6%			2033	6.1%			2065	5.0%		
Zone 4	Light Fog	118	15.3%	-3.00	Increased	143	20.3%	-0.68	Not Significant	146	24.0%	-3.15	Increased
	Base	474	4.9%			581	17.7%			575	12.0%		
Zone 5	Light Fog	256	1.2%	-0.37	Not Significant	224	0.4%	2.85	Decreased	241	2.5%	0.70	Not Significant
	Base	895	0.9%			818	2.4%			845	3.3%		
Zone 6	Light Fog	176	0.6%	-0.42	Not Significant	170	0.0%	1.00	Not Significant	174	0.6%	0.52	Not Significant
	Base	642	0.3%			634	0.2%			645	0.9%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

For the advance zones, there was no effect of headlight reflection on the pavement when vehicles approached, which could be attributed to the reduced visibility and contrast far back from the camera location compared to the stop bar zones.

- Missed calls. Missed calls in light fog condition, on average, decreased for Autoscope and Iteris for all advance zones combined. These changes were in the order of less than 2%, but are statistically and practically significant. For Iteris, missed calls completely disappeared in light fog, from about 36 vehicles missed (1.65%) in the base condition, and for Autoscope, they changed from 20 missed vehicles to only one. Vehicle headlights are believed to have reduced these missed calls, since they can increase contrast with the pale background color of the pavement during periods of fog.

Table 3.5. Missed Calls in Light Fog and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Light Fog	551	0.2%	2.69	Decreased	551	0.4%	0.91	Not Significant	551	0.0%	6.05	Decreased
	Base	2180	0.9%			2180	0.6%			2180	1.7%		
Zone 4	Light Fog	112	0.9%	0.63	Not Significant	112	0.0%	0.00	Not Significant	112	0.0%	2.46	Decreased
	Base	514	1.6%			514	0.0%			514	1.2%		
Zone 5	Light Fog	255	0.0%	2.65	Decreased	255	0.4%	1.23	Not Significant	255	0.0%	5.37	Decreased
	Base	985	0.7%			985	1.0%			985	2.8%		
Zone 6	Light Fog	184	0.0%	2.24	Decreased	184	0.5%	0.07	Not Significant	184	0.0%	1.42	Decreased
	Base	681	0.7%			681	0.6%			681	0.3%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. No significant changes were observed in terms of stuck-on calls, with only one stuck-on call observed in Zone 5 of Autoscope. In the base condition, only one stuck-on call was observed, also in Zone 6 of Autoscope.

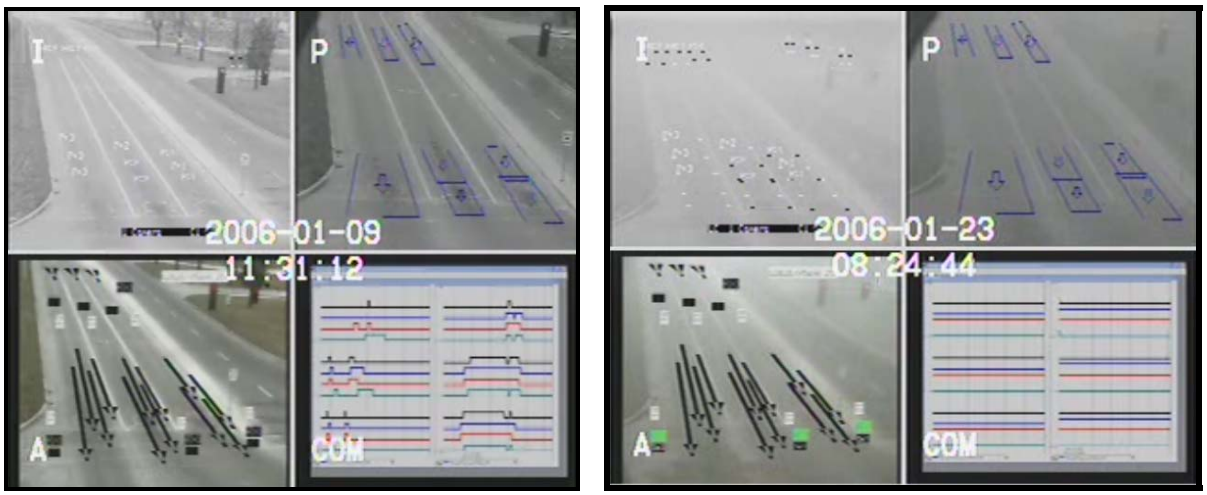
Table 3.6. Stuck-on Calls in Light Fog and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Light Fog	550	0.2%	-0.70	Not Significant	537	0.0%	0.00	Not Significant	561	0.0%	0.00	Not Significant
	Base	2011	0.0%			2033	0.0%			2065	0.0%		
Zone 4	Light Fog	118	0.0%	0.00	Not Significant	143	0.0%	0.00	Not Significant	146	0.0%	0.00	Not Significant
	Base	474	0.0%			581	0.0%			575	0.0%		
Zone 5	Light Fog	256	0.4%	-1.00	Not Significant	224	0.0%	0.00	Not Significant	241	0.0%	0.00	Not Significant
	Base	895	0.0%			818	0.0%			845	0.0%		
Zone 6	Light Fog	176	0.0%	1.00	Not Significant	170	0.0%	0.00	Not Significant	174	0.0%	0.00	Not Significant
	Base	642	0.2%			634	0.0%			645	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.2.2 Dense Fog - 250 minutes (4 days)

A sample image of the base and dense fog conditions is shown in Figure 3.2. Significant performance changes were observed during dense fog conditions.



(a) (b)

Figure 3.2. Sample images of (a) base and (b) dense fog conditions.

Two of the three VDSs, Iteris and Autoscope, modified their operation mode and placed constant calls during some time periods (fail-safe mode) due to the reduced visibility caused by the fog (see Table 3. 7). While Iteris placed constant calls in all zones during more than 75% of the total time period, Autoscope placed constant calls in the front zones for over 13% of the time. No change in Peek's operation mode was observed.

Table 3.7. Periods of Operating Mode Change (Fail-Safe) due to Dense Fog Condition

Date	Starting	Ending	TIME		
			Total	Placed Continuous Calls ("Fogged out") *	
				ITERIS	AUTOSCOPE
11/15/2005	7:00	7:30	0:30:00	0:30:00	0:00:00
1/23/2006	7:00	9:00	2:00:00	1:48:52	0:10:14
1/21/2007	16:00	16:40	0:40:00	0:18:16	0:00:00
12/17/2006	7:10	8:10	1:00:00	0:35:22	0:24:30
		Total	**4:10:00**	**3:12:30**	**0:34:44**

* Iteris "fogged out" in all zones at the same time, while Autoscope did it only in the stop bar zones.

Thus, given the changes in the operation mode during dense fog conditions, the number of false, missed, and stuck-on calls also changed significantly compared to the base condition. Operating in a "fail-safe" mode is expected to prevent the occurrence of missed calls, but at the expense of very long constant false calls or stuck-on calls. This favors errors that can make signal operation inefficient, but reduces errors that can potentially generate unsafe situations.

The description of false and missed calls for stop bar and advance locations are presented below. Stuck-on calls were mostly represented by times in which the systems placed constant calls (see Table 3. 7) and they are not described in further detail.

3.2.2.1. Stop Bar Zones

- False calls. In dense fog, false calls of the three zones together significantly increased for Autoscope only, from 3.5% in Base condition to 8.4%. At the individual zone level, increases were only observed in Zone 3 for Autoscope (from 1.0% in Base condition

to 13%) and Iteris (from 0.2% to 8%). These false calls were mostly generated by the reflection of headlights from vehicles approaching in the middle lane, similar to false calls observed in light fog condition but in lower proportion.

Table 3.8. False Calls in Dense Fog and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Dense Fog	392	8.4%	-3.30	Increased	460	5.7%	1.06	Not Significant	163	6.7%	-0.50	Not Significant
	Base	1584	3.5%			1928	7.0%			1730	5.7%		
Zone 1	Dense Fog	100	9.0%	0.16	Not Significant	129	16.3%	1.15	Not Significant	52	9.6%	1.25	Not Significant
	Base	484	9.5%			615	20.5%			549	15.1%		
Zone 2	Dense Fog	146	3.4%	-1.65	Not Significant	199	2.5%	-1.29	Not Significant	61	3.3%	-0.39	Not Significant
	Base	585	0.9%			698	1.0%			637	2.4%		
Zone 3	Dense Fog	146	13.0%	-4.26	Increased	132	0.0%	1.00	Not Significant	50	8.0%	-2.01	Increased
	Base	515	1.0%			615	0.2%			544	0.2%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

Missed calls. Missed calls only occurred in Peek in Zone 3, where about 13.8% of the vehicles (24 vehicles) were missed. Recall that Peek did not switch its operation mode to fail-safe in the dense fog condition, but Autoscope and Iteris did. Vehicles missed by Peek traveled directly over Zone 3 with no obvious reason for being missed other than reduced visibility due to the fog.

Table 3.9. Missed Calls in Dense Fog and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Dense Fog	494	0.0%	0.00	Not Significant	494	4.9%	-4.96	Increased	494	0.0%	0.00	Not Significant
	Base	2070	0.0%			2070	0.0%			2070	0.0%		
Zone 1	Dense Fog	108	0.0%	0.00	Not Significant	108	0.0%	0.00	Not Significant	108	0.0%	0.00	Not Significant
	Base	553	0.0%			553	0.0%			553	0.0%		
Zone 2	Dense Fog	212	0.0%	0.00	Not Significant	212	0.0%	0.00	Not Significant	212	0.0%	0.00	Not Significant
	Base	849	0.0%			849	0.0%			849	0.0%		
Zone 3	Dense Fog	174	0.0%	0.00	Not Significant	174	13.8%	-5.20	Increased	174	0.0%	0.00	Not Significant
	Base	668	0.0%			668	0.1%			668	0.0%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

3.2.2.2. Advance Zones

- False calls. For all advance zones combined, false calls only changed significantly for Peek, with a decrease from 6.1% in Base condition to 3.2%. However, at the individual zone level, there was no unique trend in Peek zones, with Zone 4 decreasing from 17.7% to 6.5%, Zone 6 increasing from 0.2% to 4.5%, and no significant changes in Zone 5.

False calls on Peek were affected by two factors: reduced visibility which decreased the occurrence of false calls in Zone 4 due to heavy vehicles in the center lane; and the reflection of headlights on the pavement which increased the false calls in Zone 6.

Table 3.10. False Calls in Dense Fog and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Dense Fog	398	1.5%	0.20	Not Significant	284	3.2%	2.51	Decreased	104	8.7%	-1.30	Not Significant
	Base	2011	1.6%			2033	6.1%			2065	5.0%		
Zone 4	Dense Fog	66	1.5%	1.84	Not Significant	46	6.5%	2.80	Decreased	23	8.7%	0.54	Not Significant
	Base	474	4.9%			581	17.7%			575	12.0%		
Zone 5	Dense Fog	185	2.7%	-1.46	Not Significant	128	6.5%	1.75	Not Significant	32	9.4%	-1.15	Not Significant
	Base	895	0.9%			818	2.4%			845	3.3%		
Zone 6	Dense Fog	147	0.0%	1.42	Not Significant	110	4.5%	-2.19	Increased	49	8.2%	-1.82	Not Significant
	Base	642	0.3%			634	0.2%			645	0.9%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

- Missed calls. Missed calls increased significantly in dense fog conditions for all systems in the three advanced zones. The average missed calls of all advance zones combined were 13.7% for Iteris, 17.8% for Autoscope, and 40.2% for Peek. Missed calls ranged between 6.1% and 20% for Iteris (which implemented the fail-safe mode in the advance mode), between 14% and 22.6% for Autocope, and between 33% and 57% for the Iteris. At the individual zone level, increases were also observed for all systems and all zones. These changes can be directly attributed to the reduced visibility generated due to the fog condition, which seemed to greatly affect the video detection's ability to determine if a vehicle was occupying the detection zone.

Table 3.11. Missed Calls in Dense Fog and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Dense Fog	517	17.8%	-9.95	Increased	517	40.2%	-18.28	Increased	517	13.7%	-7.85	Increased
	Base	2180	0.9%			2180	0.6%			2180	1.7%		
Zone 4	Dense Fog	93	22.6%	-4.79	Increased	93	57.0%	-11.04	Increased	93	11.8%	-3.14	Increased
	Base	514	1.6%			514	0.0%			514	1.2%		
Zone 5	Dense Fog	245	18.8%	-7.18	Increased	245	39.2%	-12.15	Increased	245	20.0%	-6.56	Increased
	Base	985	0.7%			985	1.0%			985	2.8%		
Zone 6	Dense Fog	179	14.0%	-5.05	Increased	179	33.0%	-9.16	Increased	179	6.1%	-3.23	Increased
	Base	681	0.7%			681	0.6%			681	0.3%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

3.3 RAIN IN DAYTIME

A total of 10 hours of daytime data with rain (and cloudy conditions) were collected from 5 different days with no significant wind. Most vehicles had their headlights on, causing their headlights to be reflected on the pavement.

(a) (b)

Figure 3.3. Sample images of (a) base and (b) rain conditions in daytime.

3.3.1 Stop Bar Zones

- False calls. Overall, there was an increasing trend in the occurrence of false calls for all zones combined during rainy conditions. Increases were on the order of 8.2% in Autoscope, 5.6% in Iteris, and 2.5% in Peek. At the individual zone level, however, not all changes were significant, especially for Peek, which did not have significant changes in any of the three stop bar zones (even though the false calls combined were significant).

Table 3.12. False Calls in Daytime Rain and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Rain	1002	11.7%	-7.29	Increased	1084	9.5%	-2.40	Increased	1036	11.3%	-4.92	Increased
	Base	1584	3.5%			1928	7.0%			1730	5.7%		
Zone 1	Rain	287	9.1%	0.21	Not Significant	374	25.1%	-1.67	Not Significant	349	24.4%	-3.34	Increased
	Base	484	9.5%			615	20.5%			549	15.1%		
Zone 2	Rain	387	8.3%	-5.10	Increased	409	2.2%	-1.46	Not Significant	402	6.7%	-3.14	Increased
	Base	585	0.9%			698	1.0%			637	2.4%		
Zone 3	Rain	328	18.0%	-7.85	Increased	301	0.0%	1.00	Not Significant	285	1.8%	-1.96	Not Significant
	Base	515	1.0%			615	0.2%			544	0.2%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

In Zone 1, significant changes were only observed for Iteris (9.3% increase), with no changes for Peek and Autoscope. The increases in false calls were caused by vehicles placing calls on the zone while turning left from the center lane.

Autoscope and Iteris showed significant increases in Zone 2, with 7.4% and 4.3% more false calls, respectively, during rain.. These changes were mostly due to the reflection of headlights on the pavement from vehicles approaching on the left-most lane.

Similarly, headlights also affected Zone 3 by increasing false calls, mostly in Autoscope (from 1% to 18%). In addition, camera movement due to occasional wind also caused some of the false calls to go on and off repeated times, further increasing false calls.

- Missed calls. Rain did not affect the missed calls at the stop bar locations (no missed calls in any system in rainy condition or the base condition).

Table 3.13. Missed Calls in Daytime Rain and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Rain	1180	0.0%	0.00	Not Significant	1180	0.0%	1.00	Not Significant	1180	0.0%	0.00	Not Significant
	Base	2070	0.0%			2070	0.0%			2070	0.0%		
Zone 1	Rain	327	0.0%	0.00	Not Significant	327	0.0%	0.00	Not Significant	327	0.0%	0.00	Not Significant
	Base	553	0.0%			553	0.0%			553	0.0%		
Zone 2	Rain	507	0.0%	0.00	Not Significant	507	0.0%	0.00	Not Significant	507	0.0%	0.00	Not Significant
	Base	849	0.0%			849	0.0%			849	0.0%		
Zone 3	Rain	346	0.0%	0.00	Not Significant	346	0.0%	1.00	Not Significant	346	0.0%	0.00	Not Significant
	Base	668	0.0%			668	0.1%			668	0.0%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. Stuck-on calls were not significantly affected by rain, and only Autoscope showed an increase of less than 1% when all three zones were combined. At the individual zone level, no significant changes were observed, with no stuck-on calls for Iteris and Peek, and a total of six stuck-on calls for Autoscope (0.6%).

Table 3.14. Stuck-on Calls in Daytime Rain and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Rain	1002	0.6%	-1.82	Increased	1084	0.0%	0.00	Not Significant	1036	0.0%	0.00	Not Significant
	Base	1584	0.1%			1928	0.0%			1730	0.0%		
Zone 1	Rain	287	0.7%	-0.92	Not Significant	374	0.0%	0.00	Not Significant	349	0.0%	0.00	Not Significant
	Base	484	0.2%			615	0.0%			549	0.0%		
Zone 2	Rain	387	0.8%	-1.74	Not Significant	409	0.0%	0.00	Not Significant	402	0.0%	0.00	Not Significant
	Base	585	0.0%			698	0.0%			637	0.0%		
Zone 3	Rain	328	0.3%	-0.31	Not Significant	301	0.0%	0.00	Not Significant	285	0.0%	0.00	Not Significant
	Base	515	0.2%			615	0.0%			544	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.3.2 Advance Zones

- False calls. False calls in the advanced zones increased in the rain condition to different degrees, depending on the zone and the VDS. For all zones combined, significant increases were observed in all three systems, but at the zone level, not all showed changes. In Zone 4, false calls did not change in Autoscope, but they increased in Peek by 6.9%, and in Iteris by 7.8%. These increases were mostly due to more vehicles placing calls while they occupied the median lane. In Zones 5 and 6, false calls increased for Autoscope and Peek, ranging from 3.0 to 8.8%, compared to false calls below 2.5% in the base condition.

Table 3.15. False Calls in Daytime Rain and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Rain	1214	6.3%	-6.23	Increased	1196	12.2%	-5.63	Increased	1231	8.0%	-3.27	Increased
	Base	2011	1.6%			2033	6.1%			2065	5.0%		
Zone 4	Rain	263	4.9%	-0.05	Not Significant	359	24.8%	-2.54	Increased	358	19.8%	-3.12	Increased
	Base	474	4.9%			581	17.7%			575	12.0%		
Zone 5	Rain	613	8.8%	-6.66	Increased	506	8.7%	-4.58	Increased	532	4.1%	-0.77	Not Significant
	Base	895	0.9%			818	2.4%			845	3.3%		
Zone 6	Rain	338	3.0%	-2.79	Increased	331	3.9%	-3.49	Increased	341	1.5%	-0.71	Not Significant
	Base	642	0.3%			634	0.2%			645	0.9%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

- Missed calls. Missed calls did not show a unique trend for all three VDSs. For the three advance zones together, missed calls decreased for Peek, and Iteris, and no change was observed for Autoscope. For Peek, a total of two missed calls (0.2%) were observed in the rain condition compared to 14 missed calls (0.6%) in the base condition. For Iteris, a very significant decrease occurred from 36 vehicles missed in the base condition, compared to none in the rain condition. From a manual inspection of the videos, it is apparent that the vehicles' headlights helped the VDS in detecting vehicles because they reflected on the pavement.

Table 3.16. Missed Calls in Daytime Rain and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Rain	1254	1.0%	-0.12	Not Significant	1254	0.2%	2.36	Decreased	1254	0.0%	6.05	Decreased
	Base	2180	0.9%			2180	0.6%			2180	1.7%		
Zone 4	Rain	289	0.3%	1.87	Not Significant	289	0.0%	0.00	Not Significant	289	0.0%	2.46	Decreased
	Base	514	1.6%			514	0.0%			514	1.2%		
Zone 5	Rain	614	0.7%	0.14	Not Significant	614	0.0%	3.18	Decreased	614	0.0%	5.37	Decreased
	Base	985	0.7%			985	1.0%			985	2.8%		
Zone 6	Rain	351	2.0%	-1.54	Not Significant	351	0.6%	0.04	Not Significant	351	0.0%	1.42	Not Significant
	Base	681	0.7%			681	0.6%			681	0.3%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. The occurrences of missed and stuck-on calls were very rare and comparable to the percentages for the base condition, with only one stuck-on call lasting 12 seconds in the rain condition and one in the base condition, both in Autoscope.

Table 3.17. Stuck-on Calls in Daytime Rain and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Rain	1214	0.1%	-0.34	Not Significant	1196	0.0%	0.00	Not Significant	1231	0.0%	0.00	Not Significant
	Base	2011	0.0%			2033	0.0%			2065	0.0%		
Zone 4	Rain	263	0.0%	0.00	Not Significant	359	0.0%	0.00	Not Significant	358	0.0%	0.00	Not Significant
	Base	474	0.0%			581	0.0%			575	0.0%		
Zone 5	Rain	613	0.2%	-1.00	Not Significant	506	0.0%	0.00	Not Significant	532	0.0%	0.00	Not Significant
	Base	895	0.0%			818	0.0%			845	0.0%		
Zone 6	Rain	338	0.0%	1.00	Not Significant	331	0.0%	0.00	Not Significant	341	0.0%	0.00	Not Significant
	Base	642	0.2%			634	0.0%			645	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.4 SNOW IN DAYTIME

Data from 4 days with snow conditions were collected for a total of 9 hours (all during daytime). Traveled lanes were mostly covered by snow, with tire marks visible along the traveled lanes. Tire marks generate image contrast between the portion of the roadway completely covered by snow and the exposed paved areas. Camera movement due to wind was occasionally observed, but wind was not prevalent during the entire analysis period. A sample image of the snow condition compared to the base condition is shown in Figure 3.4.

3.4.1 Stop Bar Zones

- False calls. There were drastic increases in the average false calls for all systems during snow condition compared to the base condition (See Table 3. 18). The percentages of false calls were 64% for Iteris, 88% for Autoscope, and 91% for Peek. For Autoscope and Peek, the average increase compared to the base case was 84%, and for Iteris it was 58%. The false calls at individual zones ranged from 48 to 68% for Iteris, 86 to 90% for Autoscope, and 88 to 94% for Peek in snow conditions. In contrast, the false calls in base condition (cloudy noon) ranged from 0 to 20%.

(a) (b)

Figure 3.4. Sample images of (a) base and (b) snow conditions in daytime.

Table 3.18. False Calls in Snow and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Snow	4150	88.4%	-124.72	Increased	7998	91.1%	-127.18	Increased	2030	64.2%	-48.69	Increased
	Base	1584	3.5%			1928	7.0%			1730	5.7%		
Zone 1	Snow	1856	90.2%	-53.70	Increased	3444	90.8%	-41.34	Increased	992	67.5%	-24.57	Increased
	Base	484	9.5%			615	20.5%			549	15.1%		
Zone 2	Snow	1339	85.6%	-82.02	Increased	2082	88.4%	-109.55	Increased	766	65.5%	-34.71	Increased
	Base	585	0.9%			698	1.0%			637	2.4%		
Zone 3	Snow	955	88.8%	-79.19	Increased	2472	93.6%	-180.87	Increased	272	48.5%	-15.90	Increased
	Base	515	1.0%			615	0.2%			544	0.2%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

Most of the false calls in snow condition occurred for two reasons: (MacCarley 1998) slight camera movement that caused a valid call to be dropped and picked up repeated times (going on and off), generating multiple false calls; and (MnDOT 2001) contrast between partially and fully snow-covered areas (over the zones), also generating multiple false calls when the wind moved the cameras.

- Missed calls. Missed calls at stop bar zones for Iteris were non-existent; for Autoscope, were negligible; and for Peek, it was 1.6% on average (see Table 3.19). In general, the snow condition did not have a significant impact in the VDS' ability to detect vehicles at the stop bar, except for an increase in Zone 3 of Peek. In Zone 3 of Peek, about 5.9% of the vehicles were missed, for a total of eight vehicles, showing a significant increase from the 0.1% in the base condition (only one vehicle was missed). It should be noted that the vehicular volume was greatly reduced on the right-through lane in the snow condition (only 136 vehicles), yet 6% of them were missed by Peek.

Table 3.19. Missed Calls in Snow and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Snow	553	0.2%	-1.00	Not Significant	553	1.6%	-2.92	Increased	553	0.0%	0.00	Not Significant
	Base	2070	0.0%			2070	0.0%			2070	0.0%		
Zone 1	Snow	202	0.5%	-1.00	Not Significant	202	0.5%	-1.00	Not Significant	202	0.0%	0.00	Not Significant
	Base	553	0.0%			553	0.0%			553	0.0%		
Zone 2	Snow	215	0.0%	0.00	Not Significant	215	0.0%	0.00	Not Significant	215	0.0%	0.00	Not Significant
	Base	849	0.0%			849	0.0%			849	0.0%		
Zone 3	Snow	136	0.0%	0.00	Not Significant	136	5.9%	-2.82	Increased	136	0.0%	0.00	Not Significant
	Base	668	0.0%			668	0.1%			668	0.0%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. Stuck-on calls for stop bar zones increased in the snow condition, but remained below 3% for all systems. In the base condition, stuck-on calls at stop bar locations were very rare (two stuck-on calls in total) and represented less than 1.8% of the calls of all three stop bar zones combined for each system. In snow conditions, stuck-on calls were mostly caused by clearly visible pavement patches due to tire marks that created high contrast with the snow-covered road. A total of 115 stuck-on calls were observed for all three systems, of which Autoscope had about 51% of them (59 stuck-on calls in total).

Table 3.20. Stuck-on Calls in Snow and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Snow	4150	1.4%	-6.34	Increased	7998	0.3%	-4.70	Increased	2030	1.7%	-5.88	Increased
	Base	1584	0.1%			1928	0.0%			1730	0.0%		
Zone 1	Snow	1856	1.1%	-2.75	Increased	3444	0.4%	-3.61	Increased	992	1.7%	-4.16	Increased
	Base	484	0.2%			615	0.0%			549	0.0%		
Zone 2	Snow	1339	1.1%	-3.89	Increased	2082	0.0%	-1.00	Not Significant	766	1.8%	-3.77	Increased
	Base	585	0.0%			698	0.0%			637	0.0%		
Zone 3	Snow	955	2.5%	-4.27	Increased	2472	0.3%	-2.83	Increased	272	1.1%	-1.74	Not Significant
	Base	515	0.2%			615	0.0%			544	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.4.2 Advance Zones

- False calls. Similar to stop bar zones, the false calls in advance zones were very high. For all three advance zones combined, false calls increased to 43%, 69%, and 79%, respectively, for Iteris, Autoscope, and Peek,. In addition, great variation was observed from zone to zone depending on the VDS, with false calls between 4% and 84% for Autoscope, between 9% and 90% for Peek, and between 33% and 57% for Iteris (see Table 3.21). From all advance zones, there were fewer false calls in Zone 6 in Autoscope (4%) and Peek (9%), but not in Iteris (43%), even though less traffic was observed in this zone (113 vehicles compared to 173 for Zones 4 and 368 for Zone 5).

Table 3.21. False Calls in Snow and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Snow	1598	69.0%	-56.56	Increased	1538	79.3%	-63.05	Increased	660	43.3%	-19.28	Increased
	Base	2011	1.6%			2033	6.1%			2065	5.0%		
Zone 4	Snow	979	83.6%	-51.00	Increased	1300	90.2%	-40.57	Increased	249	56.6%	-13.02	Increased
	Base	474	4.9%			581	17.7%			575	12.0%		
Zone 5	Snow	533	52.9%	-23.78	Increased	193	22.3%	-6.50	Increased	320	33.1%	-11.02	Increased
	Base	895	0.9%			818	2.4%			845	3.3%		
Zone 6	Snow	86	3.5%	-1.59	Not Significant	45	8.9%	-2.03	Increased	91	42.9%	-8.02	Increased
	Base	642	0.3%			634	0.2%			645	0.9%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

False calls for Zones 4 and 5 were very high and ranged from 22 to 90%, compared to the base condition where false calls were below 19%. Similar to stop bar zones, most of the false calls in the advance locations were caused by the contrast change of the tire marks on the snow-covered roadway. In addition to the tire marks, the corner of Zones 4 and 6 hitting the edge of the median or the curb also caused false calls when the wind moved the camera.

- Missed calls. Missed calls in the advance zones significantly increased for all systems. For all advance zones combined, 7.4% of the vehicles were missed by Autoscope, 12.4% by Iteris, and 23.4% by Peek. This contrasts with the stop bar zones, where there was no significant increase in the missed calls in the snow condition. At the individual zone level, the percentage of missed calls varied from 4 to 16% for Autoscope, 4 to 14% for Iteris,

and 21 to 35% for Peek, compared to missed calls below 3% in the base condition (see Table 3.22).

From a visual inspection of the videos, it could be observed that there was less contrast between approaching vehicles and the roadway, mainly caused by poor visibility conditions and the non-uniform pavement background (a mix of snow and pavement patches). No particular pattern related to color or type of car was identified to have increased missed calls in the snow condition.

Table 3.22. Missed Calls in Snow and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Snow	672	7.4%	-6.31	Increased	672	23.4%	-13.83	Increased	672	12.4%	-8.24	Increased
	Base	2180	0.9%			2180	0.6%			2180	1.7%		
Zone 4	Snow	173	3.5%	-1.28	Not Significant	173	21.4%	-6.84	Increased	173	13.3%	-4.61	Increased
	Base	514	1.6%			514	0.0%			514	1.2%		
Zone 5	Snow	386	6.7%	-4.62	Increased	386	21.0%	-9.51	Increased	386	14.2%	-6.14	Increased
	Base	985	0.7%			985	1.0%			985	2.8%		
Zone 6	Snow	113	15.9%	-4.37	Increased	113	34.5%	-7.54	Increased	113	4.4%	-2.11	Increased
	Base	681	0.7%			681	0.6%			681	0.3%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. No stuck-on calls were observed in the snow condition. This is similar to the base condition, in which only one stuck-on call was observed.

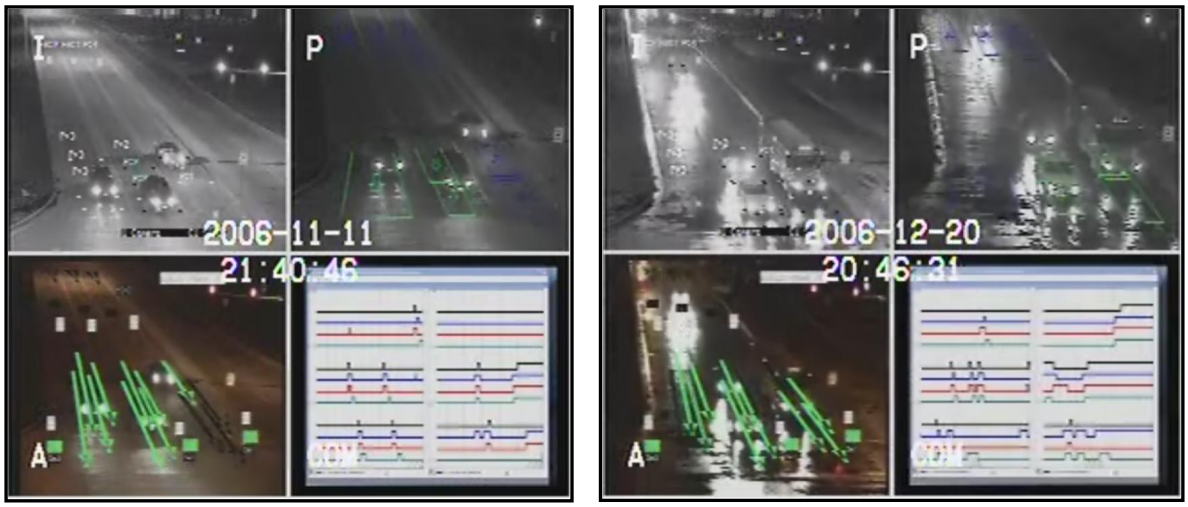
Table 3.23. Stuck-on Calls in Snow and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Snow	1598	0.0%	1.00	Not Significant	1538	0.0%	0.00	Not Significant	660	0.0%	0.00	Not Significant
	Base	2011	0.0%			2033	0.0%			2065	0.0%		
Zone 4	Snow	979	0.0%	0.00	Not Significant	1300	0.0%	0.00	Not Significant	249	0.0%	0.00	Not Significant
	Base	474	0.0%			581	0.0%			575	0.0%		
Zone 5	Snow	533	0.0%	0.00	Not Significant	193	0.0%	0.00	Not Significant	320	0.0%	0.00	Not Significant
	Base	895	0.0%			818	0.0%			845	0.0%		
Zone 6	Snow	86	0.0%	1.00	Not Significant	45	0.0%	0.00	Not Significant	91	0.0%	0.00	Not Significant
	Base	642	0.2%			634	0.0%			645	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.5 RAIN IN NIGHTTIME

A total of 10 hours of rain in nighttime from 5 different days were selected for the analysis. Selected datasets had no visible camera movement due to wind and no other weather factors. The most distinctive characteristic of this scenario is the increase in glare generated by the reflection of headlights in the pavement. Recall that for rainy night condition, the base scenario is night, not cloudy day, as in previous conditions. Sample images from nighttime with and without rain are shown in Figure 3.5 for illustrative purposes.



(a) (b)

Figure 3.5. Sample images of (a) base and (b) rain conditions in nighttime.

3.5.1 Stop Bar Zones

- False calls. False calls increased for all three stop bar zones during rainy night conditions compared to the night condition. For all stop bar zones combined, Autoscope increased from 29.5 to 39.9%, Iteris from 6.2 to 47.1%, and Peek from 8.5 to 24%.

Table 3.24. False Calls in Nighttime Rain and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Rainy Night	2043	39.9%	-6.82	Increased	1633	24.0%	-12.22	Increased	2443	47.1%	-34.20	Increased
	Base	1801	29.5%			1616	8.5%			1411	6.2%		
Zone 1	Rainy Night	571	37.1%	-11.00	Increased	406	2.2%	3.74	Decreased	478	25.1%	-5.55	Increased
	Base	366	9.3%			502	7.4%			383	11.0%		
Zone 2	Rainy Night	678	34.4%	0.11	Not Significant	759	33.7%	-9.32	Increased	633	27.0%	-10.61	Increased
	Base	707	34.7%			720	13.8%			513	5.5%		
Zone 3	Rainy Night	794	46.6%	-4.79	Increased	468	27.1%	-12.75	Increased	1332	64.5%	-39.99	Increased
	Base	728	34.6%			394	0.5%			515	3.3%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

In Zone 1, a clear increase in false calls was observed for Autoscope and Iteris, while Peek showed a decrease. The reason behind the increase of false calls in Autoscope and Iteris is the reflection of the traffic lights from the signal head facing the opposite direction of traffic. This signal head was located on a mast arm above the receiving lanes on the other direction of traffic. Thus, during the signal switching phases and the light changed from, for example, red to green, the green light was reflected on the pavement and caused a false call. This situation was not observed in night condition without rain. Figure 3.6 shows two examples of false calls generated by the reflection of the traffic light.

Figure 3.6. Sample images of false calls in stop bar zones due to reflection of traffic lights.

False calls in Zone 2 increased significantly for Iteris (from 5.5% in Base condition to 27% in rainy night condition) and Peek (from 13.8% to 33.7%), and remained high for Autoscope (34.4%). Most of these false calls were caused by headlight reflection from vehicles approaching on the left-most lane, similar to false calls in night condition, but in a higher scale, given the increased glare over the wet pavement. In addition, Autoscope and Iteris also had some false calls due to the reflection of the opposing traffic light, similar to Zone 1 (see Figure 3. 6).

False calls in Zone 3 showed an increase for all systems (ranging from 27 to 65%), also due to headlight reflection, but from vehicles approaching on the center lane.

- Missed calls. Missed calls at the stop bar zones did not change in rainy night conditions for any of the three systems. It is noted, however, that for Peek, the percentage of missed calls remained high for rainy night, with 15.9% (87 vehicles) in Zone 3, while the other two systems had no missed calls in any of these two conditions.

Table 3.25. Missed Calls in Nighttime Rain and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Rainy Night	1593	0.0%	0.00	Not Significant	1593	5.6%	1.93	Not Significant	1593	0.0%	0.00	Not Significant
	Base	1538	0.0%			1538	7.3%			1538	0.0%		
Zone 1	Rainy Night	449	0.0%	0.00	Not Significant	449	0.0%	0.00	Not Significant	449	0.0%	0.00	Not Significant
	Base	391	0.0%			391	0.0%			391	0.0%		
Zone 2	Rainy Night	597	0.0%	0.00	Not Significant	597	0.3%	-1.42	Not Significant	597	0.0%	0.00	Not Significant
	Base	561	0.0%			561	0.0%			561	0.0%		
Zone 3	Rainy Night	547	0.0%	0.00	Not Significant	547	15.9%	1.42	Not Significant	547	0.0%	0.00	Not Significant
	Base	586	0.0%			586	19.1%			586	0.0%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. Stuck-on calls increased for Autoscope and Iteris, while none was observed for Peek. For all zones combined, stuck-on calls in Autoscope changed from 0.2% in Base condition to 1.2% in rainy night condition, while in Iteris they changed from 2.5% to 4.4%. The highest percentage of stuck-on calls for Autoscope and Iteris were observed in Zone 1, with, respectively, 2.8% and 9.8%. From the manual verification of the videos, no pattern was clearly identified to have generated the stuck-on calls.

Table 3.26. Stuck-on Calls in Nighttime Rain and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Rainy Night	2043	1.2%	-4.04	Increased	1633	0.0%	0.00	Not Significant	2443	4.4%	-3.31	Increased
	Base	1801	0.2%			1616	0.0%			1411	2.5%		
Zone 1	Rainy Night	571	2.8%	-4.05	Increased	406	0.0%	0.00	Not Significant	478	9.8%	-7.21	Increased
	Base	366	0.0%			502	0.0%			383	0.0%		
Zone 2	Rainy Night	678	0.4%	-0.49	Not Significant	759	0.0%	0.00	Not Significant	633	6.6%	-0.55	Not Significant
	Base	707	0.3%			720	0.0%			513	5.8%		
Zone 3	Rainy Night	794	0.8%	-1.84	Not Significant	468	0.0%	0.00	Not Significant	1332	1.4%	-0.84	Not Significant
	Base	728	0.1%			394	0.0%			515	1.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.5.2 Advance Zones

- False calls. For all zones combined, false calls increased for all systems, with Autoscope increasing from 25.8% in Base condition to 30.7% in the rainy night condition, Iteris from 5.3% to 38.1%, and Peek from 3.3% to 19.8%. At the individual zone level, it is noted that no significant changes were observed in Zone 4, as expected, since headlight reflection from vehicles on other lanes do not fall on this zone. However, Zones 5 and 6 were clearly affected by the headlight reflection. Increases in false calls in Zone 6 were greater than in Zone 5 given the higher traffic volume on the center lane, compared to the volume in the left-most lane. Furthermore, the headlight reflection being so prominent in the wet pavement condition, some vehicles approaching two lanes apart affected the performance of advance zones, also affecting Zone 6 if they traveled in the left-most lane. An example of this situation is presented in Figure 3.7.

Table 3.27. False Calls in Nighttime Rain and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Rainy Night	2218	30.7%	-3.61	Increased	1804	19.8%	-15.72	Increased	3365	38.1%	-32.80	Increased
	Base	2066	25.8%			1432	3.3%			1708	5.3%		
Zone 4	Rainy Night	382	1.6%	-0.81	Not Significant	419	9.1%	1.52	Not Significant	517	20.1%	-1.53	Not Significant
	Base	332	0.9%			370	12.4%			424	16.3%		
Zone 5	Rainy Night	907	29.1%	-5.38	Increased	770	9.1%	-13.75	Increased	1221	29.7%	-18.87	Increased
	Base	764	18.1%			519	0.0%			751	2.7%		
Zone 6	Rainy Night	929	44.2%	-1.73	Not Significant	615	27.2%	-14.95	Increased	1627	50.0%	-39.16	Increased
	Base	970	40.3%			543	0.2%			533	0.4%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

Figure 3.7. Sample image of false call in Zone 6 due to vehicles in left-most lane.

- Missed calls. Missed calls increased only for Autoscope and Peek, and no changes were observed in Iteris, which remained with a relatively low missing rate (0.5%, for a total of 8 vehicles missed in all advance zones combined). Increases occurred mainly in Zone 6, where missed calls changed from 0.2% in Base condition to 1.6% in the rainy night condition in Autoscope, and from 1.5% to 11.9% in Peek.

Table 3.28. Missed Calls in Nighttime Rain and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Rainy Night	1684	0.7%	-2.65	Increased	1684	5.5%	-5.54	Increased	1684	0.5%	-1.86	Not Significant
	Base	1623	0.1%			1623	1.9%			1623	0.1%		
Zone 4	Rainy Night	413	0.0%	0.00	Not Significant	413	0.2%	0.70	Not Significant	413	0.0%	0.00	Not Significant
	Base	348	0.0%			348	0.6%			348	0.0%		
Zone 5	Rainy Night	707	0.4%	-0.98	Not Significant	707	3.5%	-0.66	Not Significant	707	0.7%	-1.62	Not Significant
	Base	686	0.1%			686	2.9%			686	0.1%		
Zone 6	Rainy Night	564	1.6%	-2.57	Increased	564	11.9%	-7.12	Increased	564	0.5%	-1.03	Not Significant
	Base	589	0.2%			589	1.5%			589	0.2%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

The cause for most of the missed calls was not clear from the manual verification of the videos and happened when vehicles travelled directly over the detection zone with no apparent reason for being missed. Only a few of these missed calls were generated when vehicles were not centered on the traveled lane, but were closer to the curb edge instead, or when headlights created a great amount of glare that covered a significant portion of the video image, missing the vehicle. An example of a missed vehicle due to excessive glare is shown in Figure 3.8.

Figure 3.8. Sample image of missed call in Zone 6 due to reflection of headlights.

- Stuck-on calls. Stuck-on calls at advance zones in rainy night condition increased for Peek and Iteris, and did not change for Autoscope. For all zones combined, the increase in Iteris corresponded to a change of only 0.8%, but given the high number of VDS calls, the stuck-on calls represented a total of 27 stuck-on calls from which 23 occurred in Zone 6. For Peek, the 0.3% increase in stuck-on calls represented 5 stuck-on calls, all of them in Zone 6.

Table 3.29. Stuck-on Calls in Nighttime Rain and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Rainy Night	2218	0.1%	0.07	Not Significant	1804	0.3%	-2.24	Increased	3365	0.8%	-5.22	Increased
	Base	2066	0.1%			1432	0.0%			1708	0.0%		
Zone 4	Rainy Night	382	0.0%	0.00	Not Significant	419	0.0%	0.00	Not Significant	517	0.2%	-1.00	Not Significant
	Base	332	0.0%			370	0.0%			424	0.0%		
Zone 5	Rainy Night	907	0.1%	-1.00	Not Significant	770	0.0%	0.00	Not Significant	1221	0.2%	-1.73	Not Significant
	Base	764	0.0%			519	0.0%			751	0.0%		
Zone 6	Rainy Night	929	0.1%	0.54	Not Significant	615	0.8%	-2.24	Increased	1627	1.4%	-4.83	Increased
	Base	970	0.2%			543	0.0%			533	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.6 SNOW IN NIGHTTIME

Datasets from both early morning time (before dawn) and evening (after sunset) were used for the analysis of snow in nighttime. A total of 530 minutes of data (from 4 days) were selected from early morning, and 200 minutes (from 2 days) from evening. Snow covered most of the roadway in the early morning time, but it was more exposed during the late evening time, as illustrated in Figure 3.8. Traffic volumes were very low and only accounted for a total of 186 vehicles during all the early morning time and 77 vehicles in the evening data. As mentioned before, the errors during nighttime snow condition are compared to the errors during calm nights (with no wind, rain, fog, or snow).

(a) (b)

Figure 3.8. Sample images of snow in night time during (a) early morning and (b) evening.

3.6.1 Stop Bar Zones

- False calls. During periods of snow in nighttime, false calls increased significantly for all three stop bar zones. Combining the effect of all three stop bar zones, there was an increase from 29.5% in Base condition to 65% in the snow night condition in Autoscope, from 8.5% to 83.2% in Peek, and from 6.2% to 67.8% in Iteris. At the individual zone level, all but Zone 2 in Autoscope increased significantly, but a generalized effect can be observed compared to the base data (calm night).

Table 3.30. False Calls in Nighttime Snow and Base Conditions at Stop Bar Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Night with Snow	663	65.0%	-16.58	Increased	3052	83.2%	-76.92	Increased	447	67.6%	-26.61	Increased
	Base	1801	29.5%			1616	8.5%			1411	6.2%		
Zone 1	Night with Snow	343	81.3%	-27.74	Increased	2747	87.9%	-60.85	Increased	127	67.7%	-12.72	Increased
	Base	366	9.3%			502	7.4%			383	11.0%		
Zone 2	Night with Snow	176	42.6%	-1.92	Not Significant	199	44.2%	-8.11	Increased	198	65.2%	-16.86	Increased
	Base	707	34.7%			720	13.8%			513	5.5%		
Zone 3	Night with Snow	144	53.5%	-4.16	Increased	106	34.9%	-7.37	Increased	122	71.3%	-16.24	Increased
	Base	728	34.6%			394	0.5%			515	3.3%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

Given that conditions in terms of wind speeds were not approximately constant throughout the whole nighttime snow period, false calls were further subdivided based on the wind conditions in order to understand the possible sources of error. A graphical presentation of the false calls in windy and calm conditions is shown in Figure 3.9.

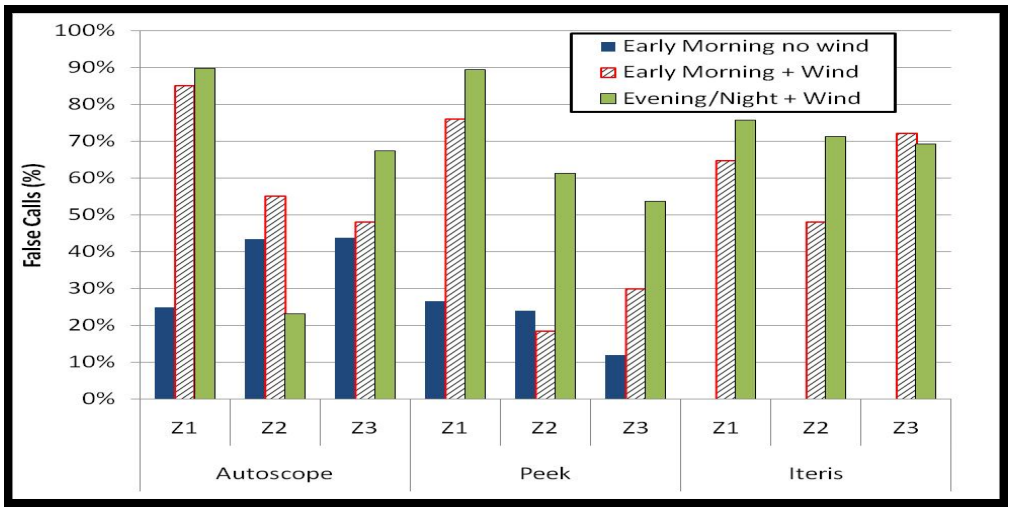


Figure 3.9. False calls in nighttime snow with and without wind at stop bar zones.

From Figure 3.9, a clear general increase in false calls is observed from periods with no wind to windy periods. Also, in general, more false calls tended to occur during the evening periods compared to morning periods, given the increase in contrast changes between areas covered with snow, and areas in which the pavement was exposed. It is also noted that, from a manual inspection of the videos, it was observed that most false calls in Zone 3 were caused by the reflection of headlights from vehicles approaching on the adjacent lane, while false calls in Zones 1 and 2 were mostly due to the combination of wind and snow-and-exposed paved areas.

- Missed calls. No significant changes were observed in terms of missed calls in any detection zone during nighttime snow, except for a decrease in Peek in Zone 3 from 19.1% in the base condition to 2.9% in the nighttime snow. No clear reason for this change in missed calls was observed from the manual verification for the videos.

Table 3.31. Missed Calls in Nighttime Snow and Base Conditions at Stop Bar Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Night with Snow	263	0.0%	0.00	Not Significant	263	2.3%	4.40	Decreased	263	0.0%	0.00	Not Significant
	Base	1538	0.0%			1538	7.3%			1538	0.0%		
Zone 1	Night with Snow	80	0.0%	0.00	Not Significant	80	2.5%	-1.42	Not Significant	80	0.0%	0.00	Not Significant
	Base	391	0.0%			391	0.0%			391	0.0%		
Zone 2	Night with Snow	114	0.0%	0.00	Not Significant	114	1.8%	-1.42	Not Significant	114	0.0%	0.00	Not Significant
	Base	561	0.0%			561	0.0%			561	0.0%		
Zone 3	Night with Snow	69	0.0%	0.00	Not Significant	69	2.9%	6.23	Decreased	69	0.0%	0.00	Not Significant
	Base	586	0.0%			586	19.1%			586	0.0%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. Stuck-on calls were affected differently for the three VDSs. While stuck-on calls increased to 2% in Zone 2 for Peek, they decreased from 5.8% in Base condition to 0.5% in the snow night condition in Zone 2, and from 1% to 0% in Zone 3 for Iteris. On the other hand, smaller changes were observed in Autoscope. Stuck-on calls remained lower than 1% for all stop bar zones.

Table 3.32. Stuck-on Calls in Nighttime Snow and Base Conditions at Stop Bar Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Stop Bar Zones	Night with Snow	663	0.3%	-0.58	Not Significant	3052	0.2%	-2.45	Increased	447	0.2%	4.79	Decreased
	Base	1801	0.2%			1616	0.0%			1411	2.5%		
Zone 1	Night with Snow	343	0.0%	0.00	Not Significant	2747	0.0%	-1.00	Not Significant	127	0.0%	0.00	Not Significant
	Base	366	0.0%			502	0.0%			383	0.0%		
Zone 2	Night with Snow	176	0.6%	-0.47	Not Significant	199	2.0%	-2.02	Increased	198	0.5%	4.63	Decreased
	Base	707	0.3%			720	0.0%			513	5.8%		
Zone 3	Night with Snow	144	0.7%	-0.79	Not Significant	106	0.9%	-1.00	Not Significant	122	0.0%	2.24	Decreased
	Base	728	0.1%			394	0.0%			515	1.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.6.2 Advance Zones

- False calls. A significant increase in false calls in all VDSs and all three advance zones was found during the nighttime snow. Overall, for the three advance zones combined, Autoscope increased from 25.8% in Base condition to 57.1% in the snow night condition, Peek increased from 2.8% to 87%, and Iteris from 5.3% to 67.5%. Similar to the description of false calls provided for the stop bar zones, false calls were also subdivided for the advance zones into those that occurred during the early morning periods (roadway almost fully covered with snow) with wind, separated from those during periods without wind; and those from the evening time (roadway partially covered with snow) when wind was constantly present. Figure 3.10 shows the subdivided false calls by zone and VDS.

Table 3.33. False Calls in Nighttime Snow and Base Conditions at Advance Zones

False Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Night with Snow	494	57.1%	-12.91	Increased	1713	87.0%	-91.25	Increased	357	67.5%	-24.47	Increased
	Base	2066	25.8%			1432	2.8%			1708	5.3%		
Zone 4	Night with Snow	134	61.2%	-14.16	Increased	123	39.8%	-6.22	Increased	114	76.3%	-13.70	Increased
	Base	332	0.9%			370	10.5%			424	16.3%		
Zone 5	Night with Snow	190	42.1%	-6.24	Increased	1523	93.4%	-146.38	Increased	102	34.3%	-6.65	Increased
	Base	764	18.1%			519	0.0%			751	2.7%		
Zone 6	Night with Snow	170	70.6%	-7.88	Increased	67	28.4%	-5.08	Increased	141	84.4%	-27.29	Increased
	Base	970	40.3%			543	0.2%			533	0.4%		

*** The percentage of false calls is computed based on the total number of calls placed by the VD system**

From Figure 3.10, a clear increase in false calls is observed during periods of wind and an even higher increase also occurred when the roadway was partially (i.e., not completely) covered by snow. Thus, the combination of partially snow-covered road and wind yielded the highest rate of false calls.

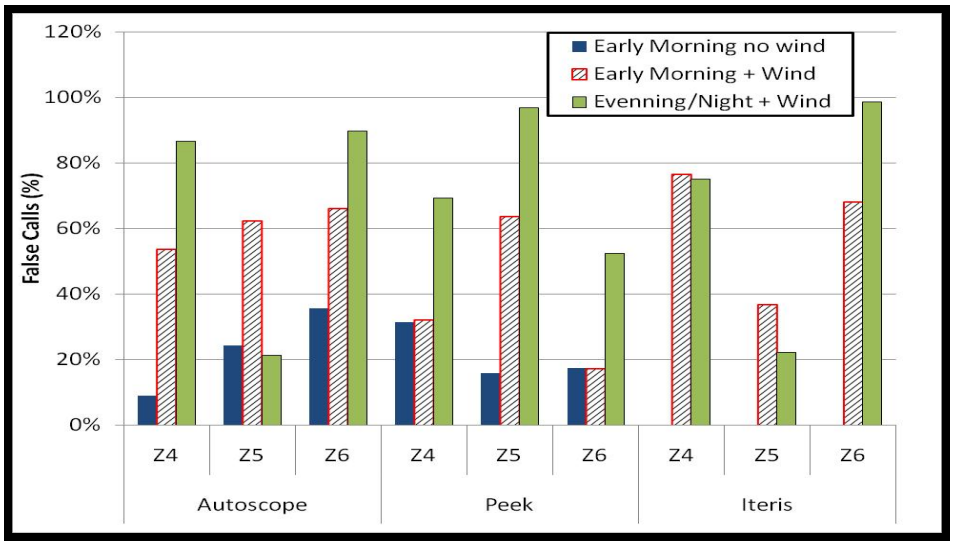


Figure 3.10. False calls in nighttime snow with and without wind at advance zones.

- Missed calls. No significant increases were observed during nighttime snow except in Zone 5 in Autoscope, where missed calls increased from 0.1% in Base condition to 6.2% in the snow night condition. This increase was caused to due to nine missed vehicles, seven of which traveled straight over the zone without being detected, and two of which were traveling between Zone 5 and an adjacent zone.

Table 3.34. Missed in Nighttime Snow and Base Conditions at Advance Zones

Missed Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Night with Snow	257	4.3%	-3.28	Increased	257	3.1%	-1.06	Not Significant	257	0.0%	1.41	Not Significant
	Base	1623	0.1%			1623	1.9%			1623	0.1%		
Zone 4	Night with Snow	56	1.8%	-1.00	Not Significant	56	1.8%	-0.66	Not Significant	56	0.0%	0.00	Not Significant
	Base	348	0.0%			348	0.6%			348	0.0%		
Zone 5	Night with Snow	146	6.2%	-3.01	Increased	146	2.1%	0.64	Not Significant	146	0.0%	1.00	Not Significant
	Base	686	0.1%			686	2.9%			686	0.1%		
Zone 6	Night with Snow	55	1.8%	-0.90	Not Significant	55	7.3%	-1.61	Not Significant	55	0.0%	1.00	Not Significant
	Base	589	0.2%			589	1.5%			589	0.2%		

*** The percentage of missed calls is computed based on the total number of calls placed by the loops**

- Stuck-on calls. No significant changes were observed in terms of stuck-on calls in any VDS or any of the advance zones. Stuck-on calls remained nonexistent in Peek and Iteris advance zones, and less or equal to 1.1% in Autoscope advance zones.

Table 3.35. Stuck-on in Nighttime Snow and Base Conditions at Advance Zones

Stuck-on Calls													
Zone	Condition	Autoscope				Peek				Iteris			
		Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result	Number of Calls	Error	Z value	Result
Average of Advance Zones	Night with Snow	494	0.6%	-1.43	Not Significant	1713	0.0%	0.00	Not Significant	357	0.0%	0.00	Not Significant
	Base	2066	0.1%			1432	0.0%			1708	0.0%		
Zone 4	Night with Snow	134	0.0%	0.00	Not Significant	123	0.0%	0.00	Not Significant	114	0.0%	0.00	Not Significant
	Base	332	0.0%			370	0.0%			424	0.0%		
Zone 5	Night with Snow	190	1.1%	-1.42	Not Significant	1523	0.0%	0.00	Not Significant	102	0.0%	0.00	Not Significant
	Base	764	0.0%			519	0.0%			751	0.0%		
Zone 6	Night with Snow	170	0.6%	-0.63	Not Significant	67	0.0%	0.00	Not Significant	141	0.0%	0.00	Not Significant
	Base	970	0.2%			543	0.0%			533	0.0%		

*** The percentage of stuck-on calls is computed based on the total number of calls placed by the VD system**

3.7 SUMMARY VDS PERFORMANCE IN ADVERSE WEATHER CONDITIONS

A summary of the VDS performance in the six conditions presented in this report—light and dense fog in daytime, rain in daytime and in nighttime, and snow in daytime and in nighttime—is included in this section. Results are shown in both graphical and table form in the sections below, indicating the general performance of the three VDSs at the stop bar zones and advance zones separated.

The reader will observe a general picture of the VDS performance in each condition from the graphical representation of the errors, where the maximum and minimum values are shown to illustrate the range of errors in the three systems.

The information provided in the figures is also presented numerically in the corresponding table below each figure. Tables provide the exact average percentage of error for all three systems (not only the upper and lower averages) in each zone and condition.

These summaries can be found useful by VDS users, who can observe in general terms the potential strengths and critical errors on the three systems, all together at a glance.

3.7.1 False Calls

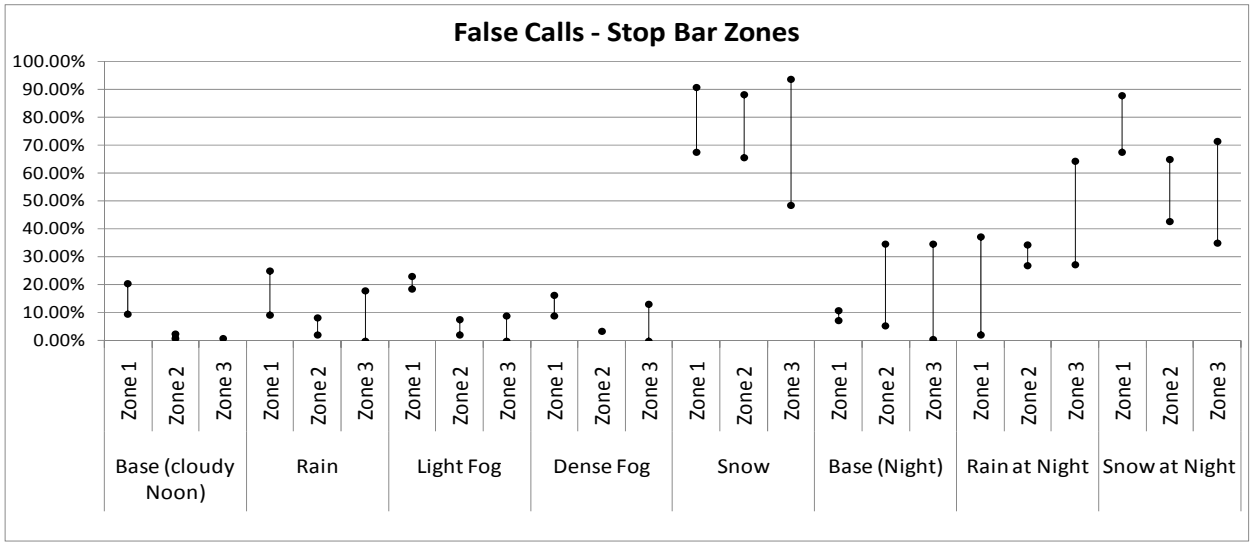


Figure 3.11. Summary false calls at stop bar zones.

Table 3.36. Summary False Calls at Stop Bar Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
False Calls	Base (cloudy Noon)	Zone 1	9.50%	20.49%	15.12%
		Zone 2	0.85%	1.00%	2.35%
		Zone 3	0.97%	0.16%	0.18%
	Rain	Zone 1	9.06%	25.13%	24.36%
		Zone 2	8.27%	2.20%	6.72%
		Zone 3	17.99%	0.00%	1.75%
	Light Fog	Zone 1	18.49%	22.52%	23.02%
		Zone 2	2.99%	2.02%	7.65%
		Zone 3	8.86%	0.00%	0.68%
	Dense Fog	Zone 1	9.00%	16.28%	9.62%
		Zone 2	3.42%	2.51%	3.28%
		Zone 3	13.01%	0.00%	8.00%
	Snow	Zone 1	90.19%	90.82%	67.54%
		Zone 2	85.59%	88.38%	65.54%
		Zone 3	88.80%	93.65%	48.53%
	Base (Night)	Zone 1	9.29%	7.37%	10.97%
		Zone 2	34.65%	13.75%	5.46%
		Zone 3	34.62%	0.51%	3.30%
	Rain at Night	Zone 1	37.13%	2.22%	25.10%
		Zone 2	34.37%	33.73%	27.01%
		Zone 3	46.60%	27.14%	64.49%
	Snow at Night	Zone 1	81.34%	87.88%	67.72%
		Zone 2	42.61%	44.22%	65.15%
		Zone 3	53.47%	34.91%	71.31%

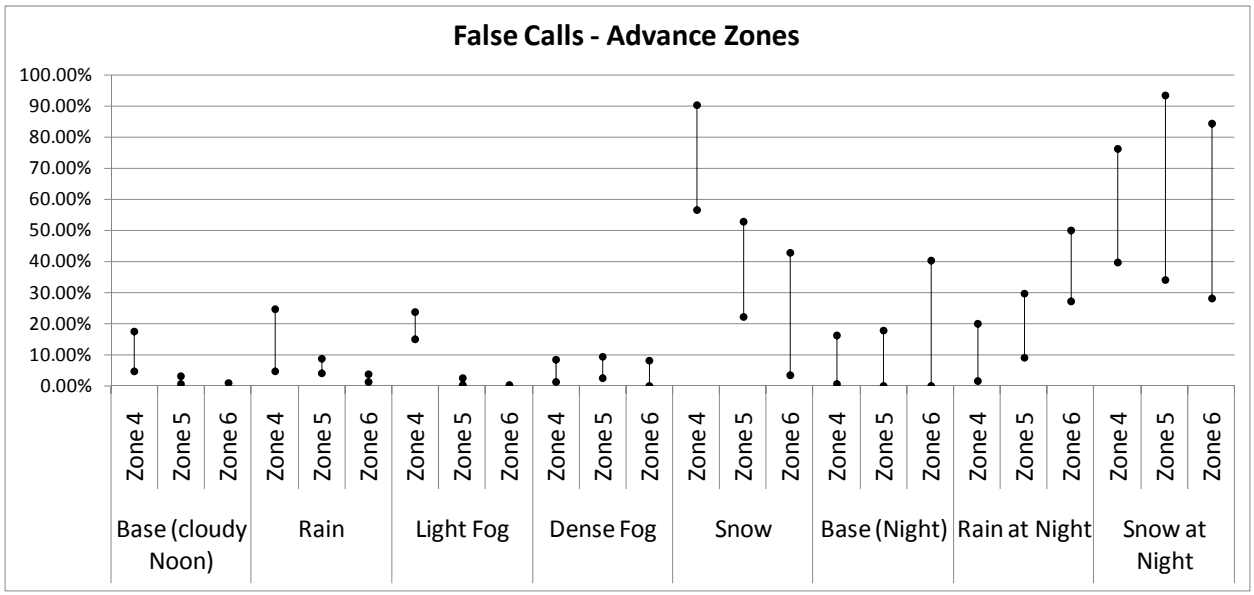


Figure 3.12. Summary false calls at advance zones.

Table 3.37. Summary False Calls at Advance Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
False Calls	Base (cloudy Noon)	Zone 4	4.85%	17.73%	12.00%
		Zone 5	0.89%	2.44%	3.31%
		Zone 6	0.31%	0.16%	0.93%
	Rain	Zone 4	4.94%	24.79%	19.83%
		Zone 5	8.81%	8.70%	4.14%
		Zone 6	2.96%	3.93%	1.47%
	Light Fog	Zone 4	15.25%	20.28%	23.97%
		Zone 5	1.17%	0.45%	2.49%
		Zone 6	0.57%	0.00%	0.57%
	Dense Fog	Zone 4	1.52%	6.52%	8.70%
		Zone 5	2.70%	6.52%	9.38%
		Zone 6	0.00%	4.55%	8.16%
	Snow	Zone 4	83.55%	90.23%	56.63%
		Zone 5	52.91%	22.28%	33.13%
		Zone 6	3.49%	8.89%	42.86%
	Base (Night)	Zone 4	0.90%	12.43%	16.27%
		Zone 5	18.06%	0.00%	2.66%
		Zone 6	40.31%	0.18%	0.38%
	Rain at Night	Zone 4	1.57%	9.07%	20.12%
		Zone 5	29.11%	9.07%	29.73%
		Zone 6	44.24%	27.15%	50.03%
	Snow at Night	Zone 4	61.19%	39.84%	76.32%
		Zone 5	42.11%	93.37%	34.31%
		Zone 6	70.59%	28.36%	84.40%

3.7.2 Missed Calls

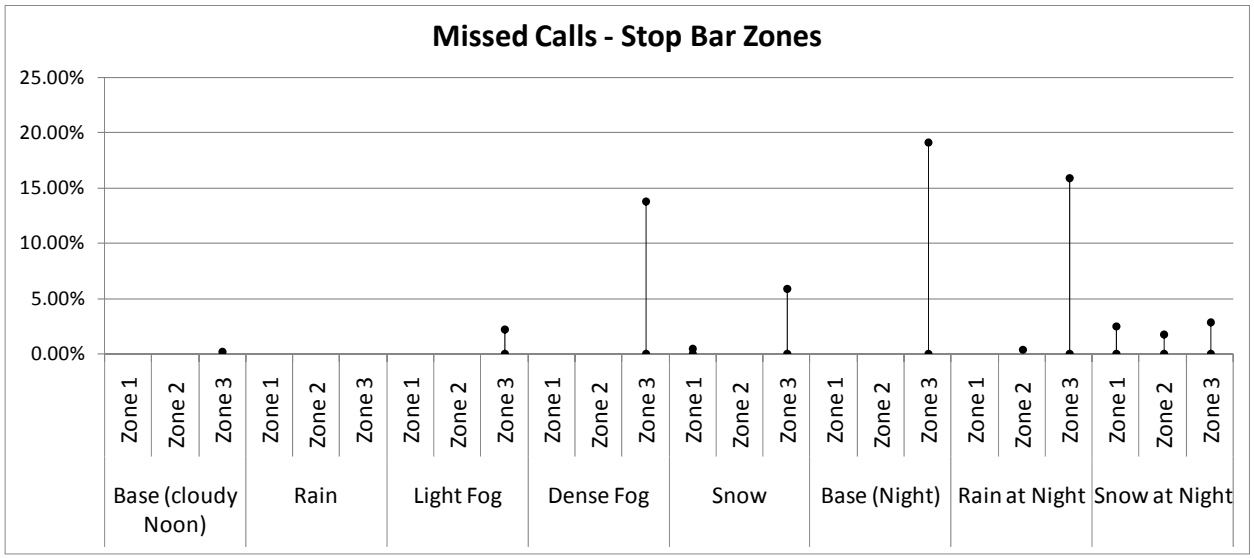


Figure 3.13. Summary missed calls at stop bar zones.

Table 3.38. Summary Missed Calls at Stop Bar Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Missed Calls	Base (cloudy Noon)	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	0.15%	0.00%
	Rain	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	0.00%	0.00%
	Light Fog	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	2.22%	0.00%
	Dense Fog	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	13.79%	0.00%
	Snow	Zone 1	0.50%	0.50%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	5.88%	0.00%
	Base (Night)	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	19.11%	0.00%
	Rain at Night	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.00%	0.34%	0.00%
		Zone 3	0.00%	15.90%	0.00%
	Snow at Night	Zone 1	0.00%	2.50%	0.00%
		Zone 2	0.00%	1.75%	0.00%
		Zone 3	0.00%	2.90%	0.00%

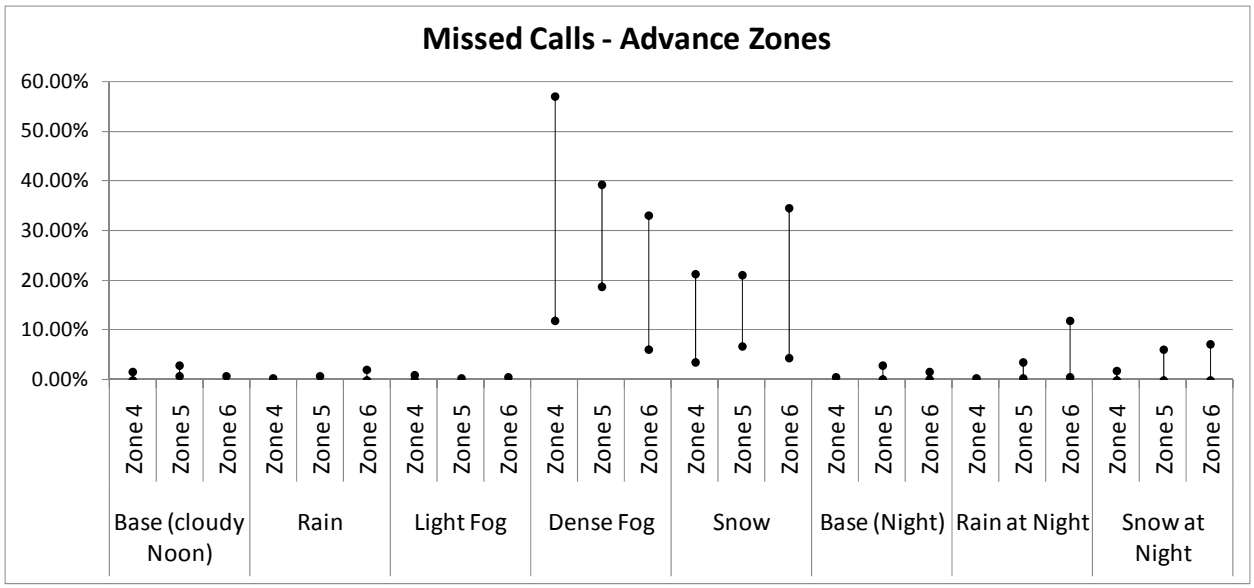


Figure 3.14. Summary missed calls at advance zones.

Table 3.39. Summary Missed Calls at Advance Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Missed Calls	Base (cloudy Noon)	Zone 4	1.56%	0.00%	1.17%
		Zone 5	0.71%	1.02%	2.84%
		Zone 6	0.73%	0.59%	0.29%
	Rain	Zone 4	0.35%	0.00%	0.00%
		Zone 5	0.65%	0.00%	0.00%
		Zone 6	1.99%	0.57%	0.00%
	Light Fog	Zone 4	0.89%	0.00%	0.00%
		Zone 5	0.00%	0.39%	0.00%
		Zone 6	0.00%	0.54%	0.00%
	Dense Fog	Zone 4	22.58%	56.99%	11.83%
		Zone 5	18.78%	39.18%	20.00%
		Zone 6	13.97%	32.96%	6.15%
	Snow	Zone 4	3.47%	21.39%	13.29%
		Zone 5	6.74%	20.98%	14.25%
		Zone 6	15.93%	34.51%	4.42%
	Base (Night)	Zone 4	0.00%	0.57%	0.00%
		Zone 5	0.15%	2.92%	0.15%
		Zone 6	0.17%	1.53%	0.17%
	Rain at Night	Zone 4	0.00%	0.24%	0.00%
		Zone 5	0.42%	3.54%	0.71%
		Zone 6	1.60%	11.88%	0.53%
	Snow at Night	Zone 4	1.79%	1.79%	0.00%
		Zone 5	6.16%	2.05%	0.00%
		Zone 6	1.82%	7.27%	0.00%

3.7.3 Stuck-on Calls

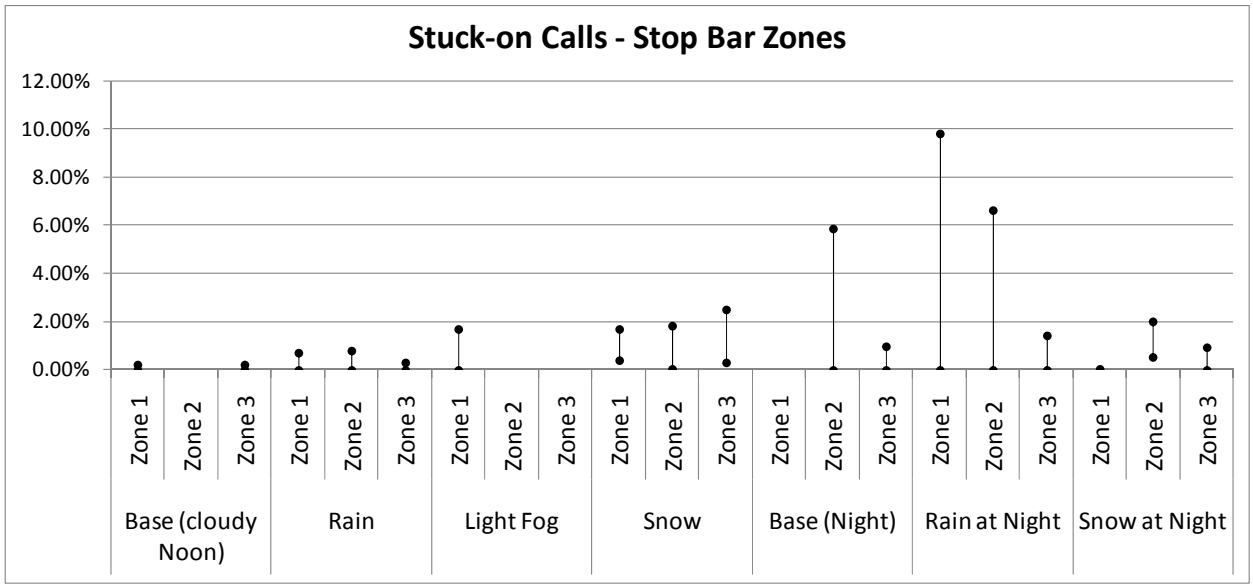


Figure 3.15. Summary stuck-on calls at stop bar zones.

Table 3.40. Summary Stuck-on Calls at Stop Bar Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Stuck-on Calls	Base (cloudy Noon)	Zone 1	0.21%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.19%	0.00%	0.00%
	Rain	Zone 1	0.70%	0.00%	0.00%
		Zone 2	0.78%	0.00%	0.00%
		Zone 3	0.30%	0.00%	0.00%
	Light Fog	Zone 1	1.68%	0.00%	0.00%
		Zone 2	0.00%	0.00%	0.00%
		Zone 3	0.00%	0.00%	0.00%
	Snow	Zone 1	1.08%	0.38%	1.71%
		Zone 2	1.12%	0.05%	1.83%
		Zone 3	2.51%	0.32%	1.10%
	Base (Night)	Zone 1	0.00%	0.00%	0.00%
		Zone 2	0.28%	0.00%	5.85%
		Zone 3	0.14%	0.00%	0.97%
	Rain at Night	Zone 1	2.80%	0.00%	9.83%
		Zone 2	0.44%	0.00%	6.64%
		Zone 3	0.76%	0.00%	1.43%
	Snow at Night	Zone 1	0.00%	0.04%	0.00%
		Zone 2	0.57%	2.01%	0.51%
		Zone 3	0.69%	0.94%	0.00%

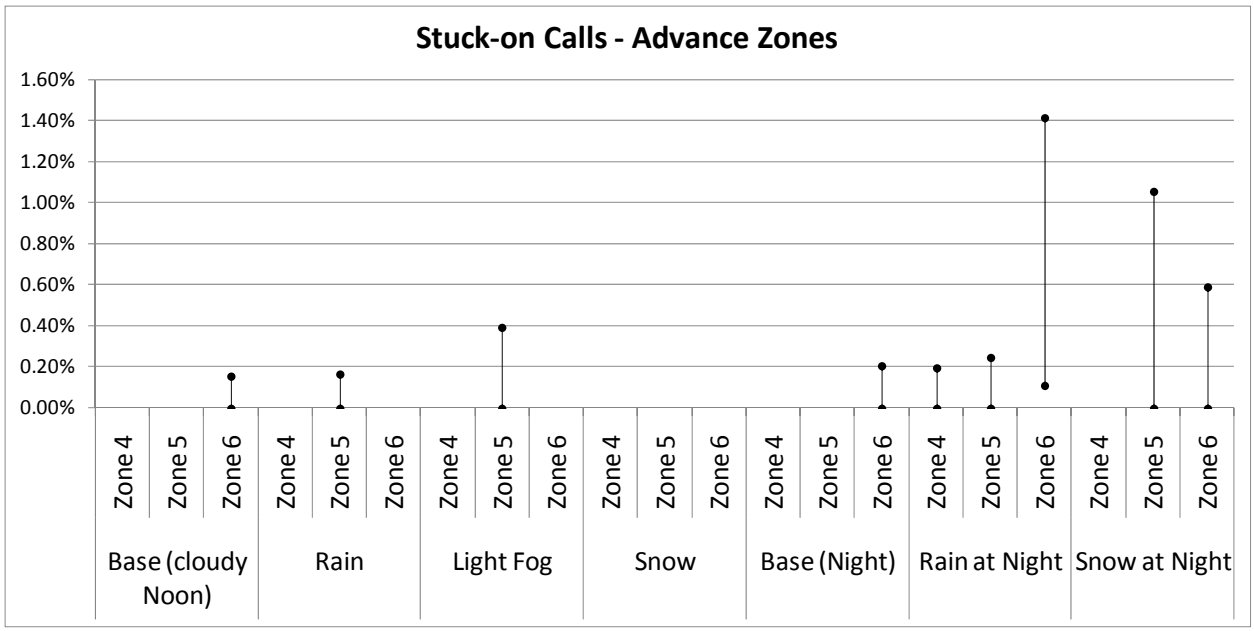


Figure 3.16. Summary stuck-on calls at advance zones.

Table 3.41. Summary Stuck-on Calls at Advance Zones

Error Type	Condition	Zone	Autoscope	Peek	Iteris
Stuck-on Calls	Base (cloudy Noon)	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.16%	0.00%	0.00%
	Rain	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.16%	0.00%	0.00%
		Zone 6	0.00%	0.00%	0.00%
	Light Fog	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.39%	0.00%	0.00%
		Zone 6	0.00%	0.00%	0.00%
	Snow	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.00%	0.00%	0.00%
	Base (Night)	Zone 4	0.00%	0.00%	0.00%
		Zone 5	0.00%	0.00%	0.00%
		Zone 6	0.21%	0.00%	0.00%
	Rain at Night	Zone 4	0.00%	0.00%	0.19%
		Zone 5	0.11%	0.00%	0.25%
		Zone 6	0.11%	0.81%	1.41%
	Snow at Night	Zone 4	0.00%	0.00%	0.00%
		Zone 5	1.05%	0.00%	0.00%
		Zone 6	0.59%	0.00%	0.00%

CHAPTER 4 FINDINGS AND CONCLUSIONS

Light Fog in Daytime

At the stop bar zones, light fog conditions generated a moderate increase in the false calls (less than 10%) for Autoscope and Iteris, especially due to the effect of headlights from vehicles on the adjacent lanes. However, no major changes were observed in terms of missed or stuck-on calls in any system or zone, thus making the effects of light fog on the VDS performance at stop bar zones very limited.

At the advance zones, false calls increased by a few percent points for Autoscope and Iteris, and that was mainly due to moderate increases in false calls for Zone 4. The effects related to headlight reflection from vehicles on the adjacent lanes, were not observed in the advance zones. Moreover, headlight reflection seemed to have contributed to a decrease in missed calls at the advance zones during light fog periods, when missed vehicles remained on the order of less than 1%. Stuck-on calls were not affected by the light fog and were lower than 1% for all VDSs in the three advance zones.

Dense Fog in Daytime

Two of the three VDSs (Iteris and Autoscope) changed their operating mode and placed constant calls due to contrast loss in periods of heavy fog. Iteris placed constant calls in all its zones during over 75% of the analyzed time period, while Autoscope placed constant calls in the front zones for about 13% of the time. Peek continued its operating mode without any apparent change.

Given these changes in the operating mode of the VDSs, the measures of performance during dense fog conditions were highly altered compared to the base condition. If a VDS places constant calls, it is obvious that the traffic operation of the intersection would tend to be inefficient but would avoid any missed calls. On the other hand, and in the particular case of Peek (no fail-safe mode), false calls did not increase at the stop bar zones, but missed calls did it so in Zone 3, from 0.1% in Base condition to 13.8% in dense fog condition. Thus, it is likely that having a fail-safe routine would promote the safe operation of the intersection at the cost of inefficiency in processing the vehicles; the opposite being true if no special VDS routines are used, such as in Peek.

At the advance zones, whenever the VDS did not place constant calls they increased the number of missed vehicles, given the low contrast in the video image. Missed calls were as high as 50% or more, indicating that most of the vehicles were not detected. It is also noted that false calls and stuck-on calls were not negatively affected by the dense fog conditions during periods of normal operating mode.

Rain in Daytime

At the stop bar locations, false calls increased because of the effect of the headlight reflection from approaching vehicles on the adjacent lanes, with averages between 9.5% and 11.7%. This was mainly due to the wet pavement, and was not observed in the base condition, when most vehicles had their headlights off. Rain conditions did not affect missed or stuck-on calls at the stop bar zones.

At the advance locations, false calls also increased due to the reflection of headlights of vehicles on the adjacent lanes (with averages between 6.3% and 12.2%), which at the same time generated a better contrast to detect vehicles and reduced the missed calls in

two of the three systems (<1%). No additional effects were found in stuck-on calls, which remained almost nonexistent at the advance locations.

Snow in Daytime

At the stop bar zones, false calls in snow periods were very high for all three VDS and constituted 64%, 88%, and 91% of the calls, respectively, for Iteris, Autoscope, Peek. For Autoscope and Peek, the average increase in false calls compared to Base condition was 84%, and for Iteris the increase was 58%. No generalized effect was observed in missed calls, except for a particular zone (Zone 3) in Peek that increased missed vehicles by close to 6%. Stuck-on calls significantly increased in snow conditions, but to levels lower than 2.5%.

At the advance zones, the false calls were very high for all three systems and constituted 43%, 69%, and 79% of the calls, respectively, for Iteris, Autoscope, and Peek. The average increase in the false calls compared to Base condition was 38% for Iteris, 67% for Autoscope, and 72% for Peek. Missed calls also increased in all three zones and with all systems except Zone 4 in Autoscope, ranging from 3.5 to 34.5%. On the other hand, stuck-on calls were not affected at the advance zones and were completely nonexistent during periods of snow in daytime.

Rain in Nighttime

During nighttime, rain significantly increased false calls to a range between 24% and 47% for the three stop bar zones combined. The reflection of headlights from vehicles approaching in the adjacent lane was the main cause of this increase in false calls. Similarly, stuck-on calls increased for Autoscope to 1.2%, and for Iteris, to 4.4%; while on Peek, they remained at zero. Missed calls were not affected during rain condition in nighttime at the stop bar zones.

At the advance locations, false calls were at a high level mainly in Zones 5 and 6, ranging from 9 to 50%, and mostly due to the reflection of headlights from vehicles approaching on the adjacent lane. Missed calls were slightly affected and remained lower than 1% for all three advance zones combined, similar to stuck-on calls, which had averages also lower than 1%.

Snow in Nighttime

At stop bar zones, false calls increased mostly when pavement was partially (not fully) covered with snow and when wind was present. False calls constituted 65%, 68%, and 83% of the calls, respectively, for Autoscope, Iteris, and Peek. The average increase in false calls compared to Base condition was 35% for Autoscope, 61% for Iteris, and 76% for Peek. Missed calls and stuck-on calls did not show great variation in snow conditions at nighttime, limiting the snow effects to false calls only.

Similarly, at advance zones, the increases in false calls mostly occurred in periods of partially snow-covered pavement and wind. False calls constituted 57%, 68%, and 87% of the calls, respectively, for Autoscope, Iteris, and Peek. The average increase in false calls compared to Base condition was 31% for Autoscope, 64% for Iteris, and 84% for Peek. No significant increase was observed in missed calls, except in Zone 5 of Autoscope, where 6.2% of the calls were missed. No changes were found for stuck-on calls at any advance zone in any system.

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APPENDIX I - Daily Variation of Video Detection Performance

As explained in Chapter 4, performance of the VDSs was evaluated under different severe adverse weather conditions (light and dense fog in daytime, rain in daytime and in nighttime, and snow in daytime and in nighttime). The duration and number of datasets from each condition could vary from one condition to the other, but the specific condition evaluated remained very similar throughout all the selected data. Thus, the VDS performance was analyzed when all datasets from a given condition were aggregated into one single dataset. In this Appendix, the VDS performance is presented on a day-by-day basis, so it is possible to observe the daily variation of the performance measures for each of three the VDS systems. To do this, tables with the actual percentage of the four types of error from each day, and in each detection zone are provided. Also, a graphical representation indicating the variation range (maximum and minimum) and the average percentage for all types of errors in all detection zones are included for an easier interpretation of the data.

Cloudy Noon Condition (Base Data for Daytime)

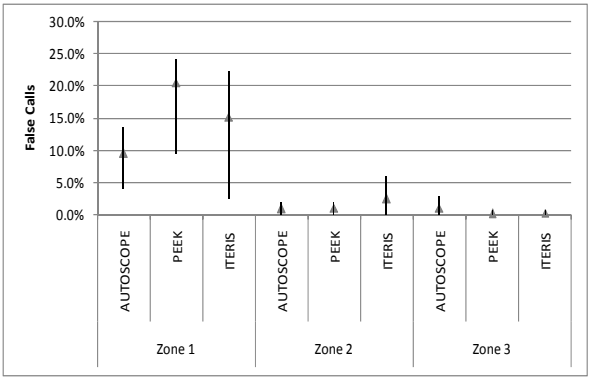
False Calls

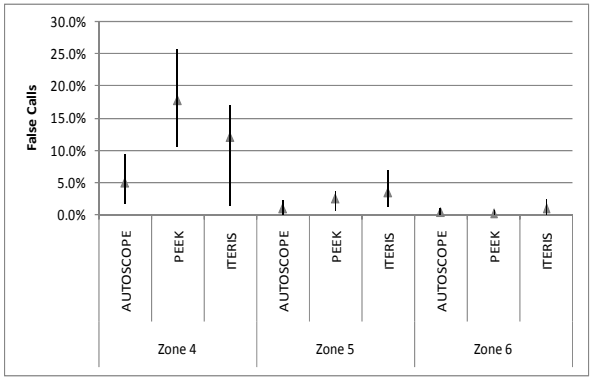
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	13.5%	23.9%	21.4%
	DAY 2	6.4%	23.7%	13.1%
	DAY 3	3.9%	9.4%	2.5%
	DAY 4	9.5%	17.7%	11.4%
	DAY 5	12.4%	23.6%	22.2%
ZONE 2	DAY 1	0.8%	0.6%	2.9%
	DAY 2	1.8%	1.6%	5.8%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.8%	2.0%	0.8%
	DAY 5	0.8%	0.7%	2.3%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	2.8%	0.8%	0.0%
	DAY 5	1.6%	0.0%	0.8%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	4.7%	25.5%	16.9%
	DAY 2	5.9%	14.4%	11.2%
	DAY 3	1.7%	10.4%	1.4%
	DAY 4	1.8%	16.2%	9.9%
	DAY 5	9.3%	18.5%	16.0%
ZONE 5	DAY 1	2.3%	3.6%	1.5%
	DAY 2	1.3%	2.7%	6.9%
	DAY 3	0.0%	1.4%	2.7%
	DAY 4	0.0%	3.6%	4.8%
	DAY 5	0.6%	0.6%	1.1%
ZONE 6	DAY 1	0.0%	0.0%	0.7%
	DAY 2	0.8%	0.0%	0.0%
	DAY 3	0.7%	0.8%	0.7%
	DAY 4	0.0%	0.0%	2.4%
	DAY 5	0.0%	0.0%	0.6%





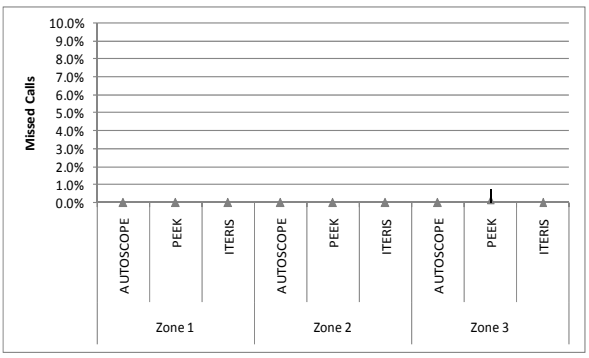
Missed Calls

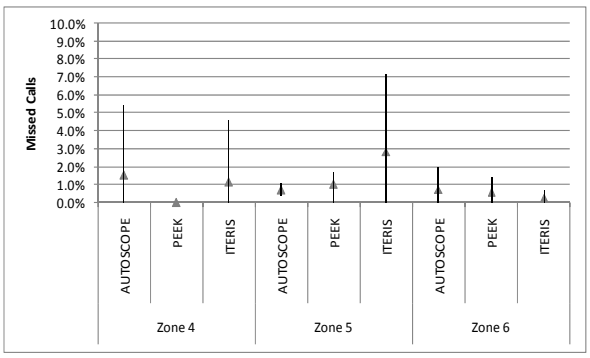
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.8%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.9%	0.0%	0.0%
	DAY 2	0.9%	0.0%	4.6%
	DAY 3	5.4%	0.0%	1.4%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	2.0%	0.0%	0.0%
ZONE 5	DAY 1	0.4%	0.4%	1.3%
	DAY 2	1.1%	0.0%	3.4%
	DAY 3	0.6%	1.7%	2.9%
	DAY 4	0.5%	1.5%	7.2%
	DAY 5	1.0%	1.5%	0.0%
ZONE 6	DAY 1	2.0%	0.0%	0.0%
	DAY 2	1.5%	0.8%	0.0%
	DAY 3	0.0%	1.4%	0.7%
	DAY 4	0.0%	0.0%	0.7%
	DAY 5	0.0%	0.6%	0.0%

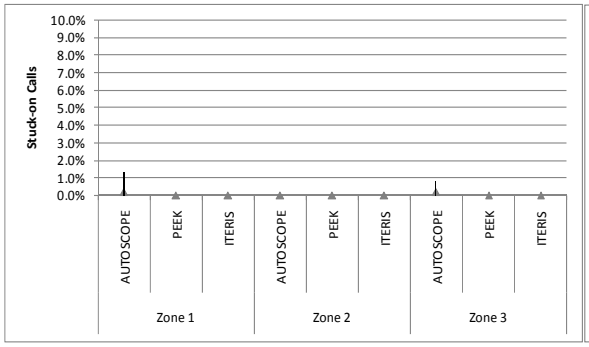


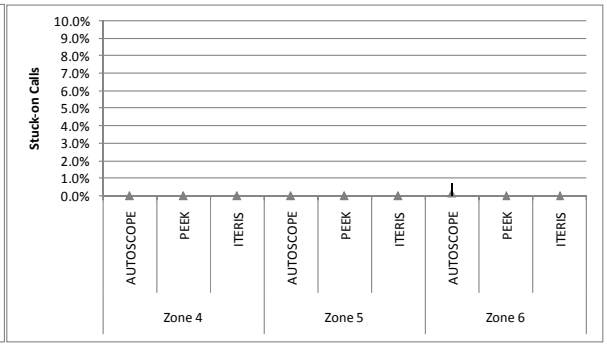


Stuck-on Calls

Stop Bar Zones		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	1.3%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.8%	0.0%	0.0%

Advance Zones		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 6	DAY 1	0.7%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%





Rain Condition

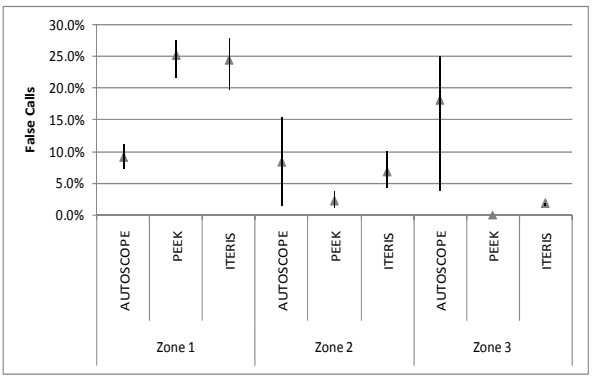
False Calls

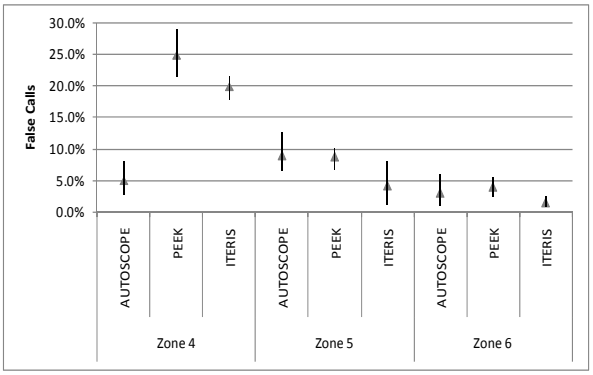
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	11.0%	26.2%	27.9%
	DAY 2	7.1%	21.6%	19.8%
	DAY 3	9.3%	27.5%	25.6%
ZONE 2	DAY 1	15.3%	1.0%	4.9%
	DAY 2	9.5%	1.4%	4.3%
	DAY 3	1.4%	3.7%	10.1%
ZONE 3	DAY 1	24.5%	0.0%	1.4%
	DAY 2	25.0%	0.0%	1.9%
	DAY 3	3.8%	0.0%	1.9%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	2.5%	21.5%	21.4%
	DAY 2	3.6%	23.1%	17.6%
	DAY 3	7.9%	29.0%	20.5%
ZONE 5	DAY 1	12.5%	9.7%	8.0%
	DAY 2	8.5%	6.5%	1.0%
	DAY 3	6.5%	10.1%	4.5%
ZONE 6	DAY 1	5.7%	2.4%	2.3%
	DAY 2	2.9%	5.4%	0.8%
	DAY 3	0.9%	3.3%	1.6%





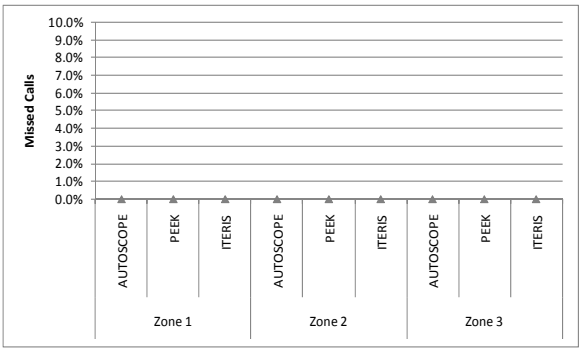
Missed Calls

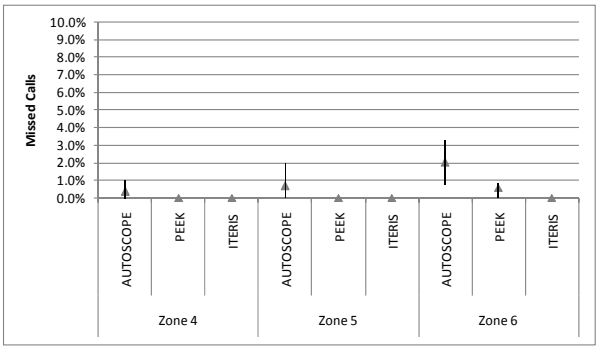
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%

Advance Zones

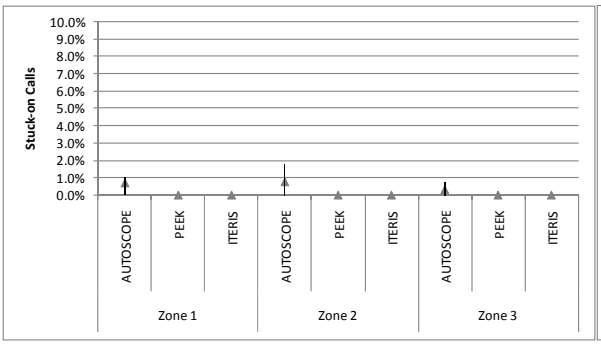
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	1.0%	0.0%	0.0%
ZONE 5	DAY 1	1.9%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.4%	0.0%	0.0%
ZONE 6	DAY 1	2.2%	0.0%	0.0%
	DAY 2	0.7%	0.7%	0.0%
	DAY 3	3.3%	0.8%	0.0%

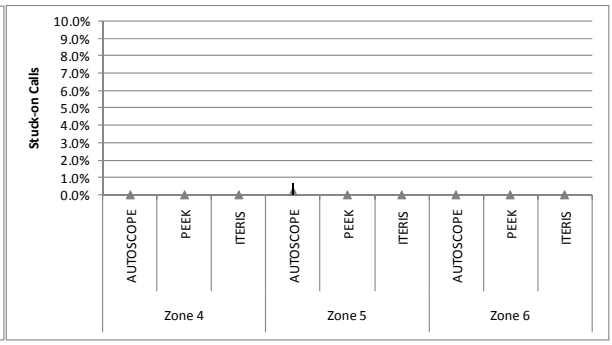




Stuck-on Calls

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	1.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.9%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
ZONE 2	DAY 1	1.8%	0.0%	0.0%	ZONE 5	DAY 1	0.6%	0.0%	0.0%
	DAY 2	0.7%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.8%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%





Light Fog Condition

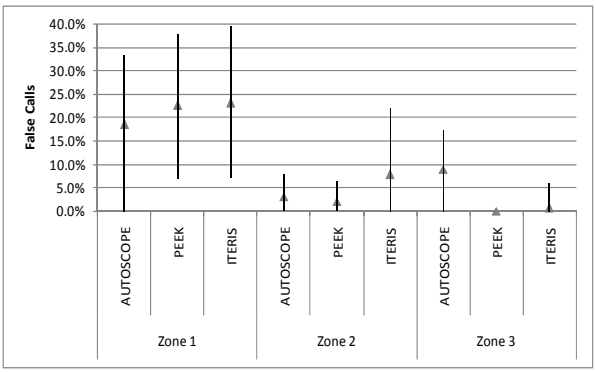
False Calls

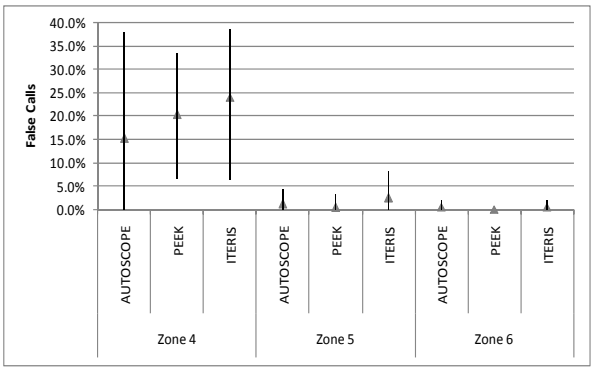
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	7.4%	9.7%	15.6%
	DAY 2	4.5%	13.8%	6.9%
	DAY 3	33.3%	32.3%	39.3%
	DAY 4	31.3%	37.5%	34.3%
	DAY 5	0.0%	6.7%	8.3%
	DAY 6	33.3%	20.0%	33.3%
ZONE 2	DAY 1	3.4%	6.3%	22.0%
	DAY 2	6.9%	0.0%	0.0%
	DAY 3	0.0%	0.0%	6.9%
	DAY 4	1.7%	2.7%	4.8%
	DAY 5	7.7%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%
ZONE 3	DAY 1	3.3%	0.0%	0.0%
	DAY 2	6.7%	0.0%	0.0%
	DAY 3	11.1%	0.0%	5.9%
	DAY 4	17.3%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	7.7%	6.7%	15.6%
	DAY 2	0.0%	11.1%	15.4%
	DAY 3	37.9%	32.1%	34.5%
	DAY 4	8.0%	33.3%	38.5%
	DAY 5	12.5%	6.7%	6.3%
	DAY 6	25.0%	25.0%	0.0%
ZONE 5	DAY 1	2.6%	3.2%	8.1%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	4.3%	0.0%	0.0%
	DAY 4	0.0%	0.0%	3.1%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%
ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	1.9%	0.0%	2.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%





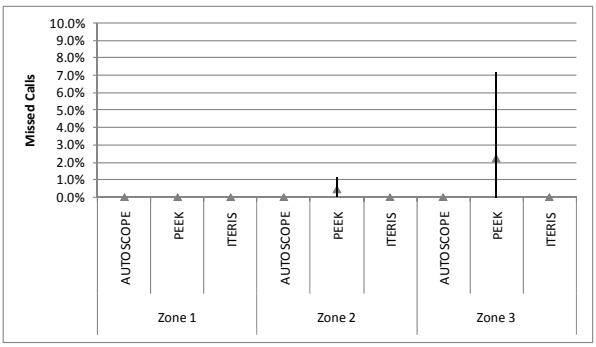
Missed Calls

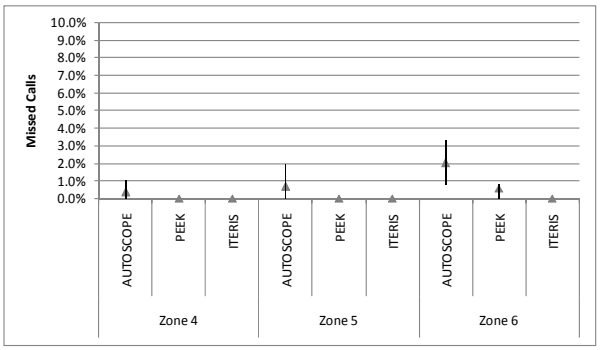
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	1.1%	0.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	2.5%	0.0%
	DAY 3	0.0%	4.5%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	7.1%	0.0%
	DAY 6	0.0%	0.0%	0.0%

Advance Zones

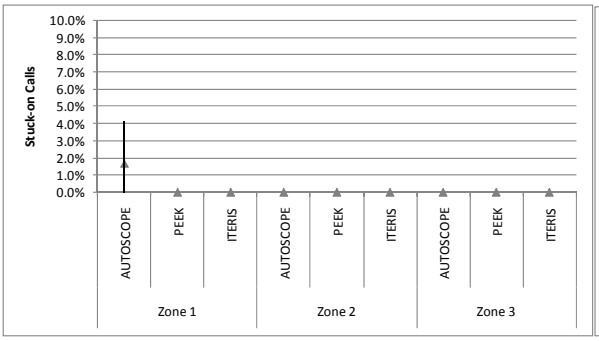
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	4.5%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%
ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	1.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%
ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	2.4%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%

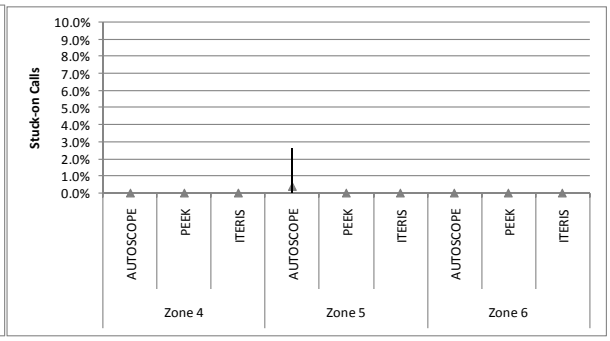




Stuck-on Calls

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	4.2%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	3.1%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%		DAY 6	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%	ZONE 5	DAY 1	2.6%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%		DAY 6	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
	DAY 6	0.0%	0.0%	0.0%		DAY 6	0.0%	0.0%	0.0%





Dense Fog Condition

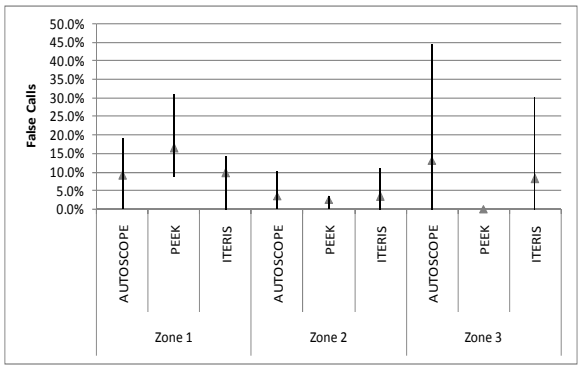
False Calls

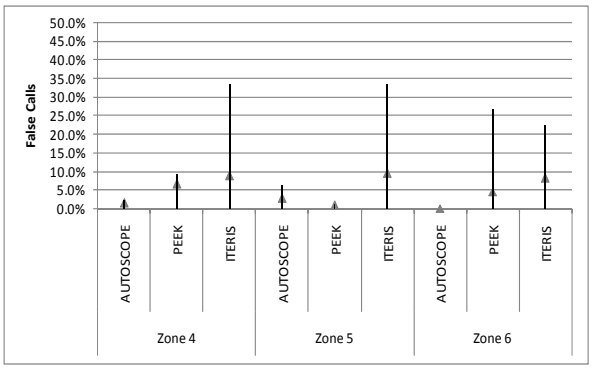
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	10.0%	8.3%	0.0%
	DAY 2	6.6%	11.9%	14.3%
	DAY 3	19.0%	30.8%	13.3%
	DAY 4	0.0%	28.6%	7.1%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	2.5%	3.5%	0.0%
	DAY 3	3.0%	0.0%	4.0%
	DAY 4	10.0%	3.1%	11.1%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	1.2%	0.0%	0.0%
	DAY 3	23.1%	0.0%	6.3%
	DAY 4	44.4%	0.0%	30.0%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	2.1%	9.1%	0.0%
	DAY 3	0.0%	0.0%	33.3%
	DAY 4	0.0%	0.0%	14.3%
ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	2.8%	1.3%	0.0%
	DAY 3	0.0%	0.0%	33.3%
	DAY 4	6.5%	0.0%	22.2%
ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	1.4%	6.3%
	DAY 3	0.0%	26.7%	7.1%
	DAY 4	0.0%	0.0%	22.2%





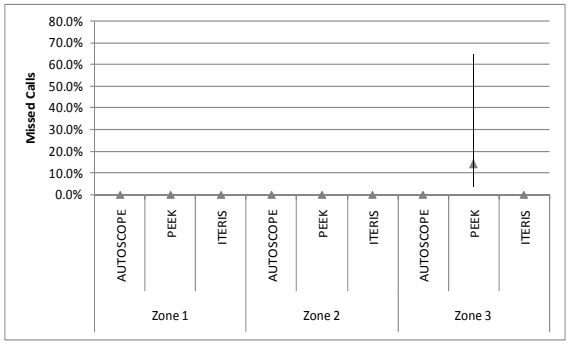
Missed Calls

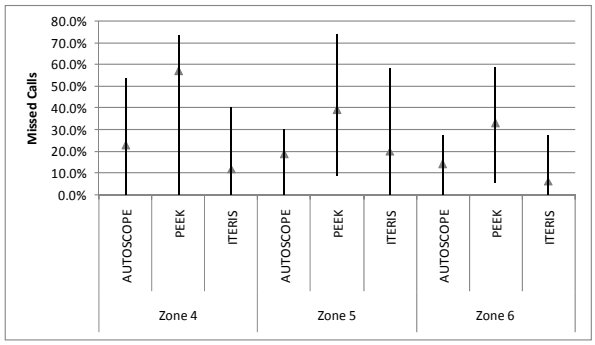
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	20.0%	0.0%
	DAY 2	0.0%	8.2%	0.0%
	DAY 3	0.0%	3.1%	0.0%
	DAY 4	0.0%	64.7%	0.0%

Advance Zones

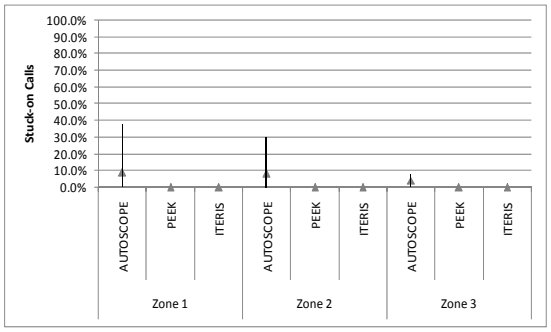
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	19.0%	61.9%	7.9%
	DAY 3	53.3%	73.3%	40.0%
	DAY 4	14.3%	42.9%	0.0%
ZONE 5	DAY 1	0.0%	8.3%	0.0%
	DAY 2	18.3%	35.2%	11.3%
	DAY 3	29.8%	73.7%	57.9%
	DAY 4	8.8%	8.8%	0.0%
ZONE 6	DAY 1	0.0%	5.3%	0.0%
	DAY 2	14.0%	33.3%	1.8%
	DAY 3	27.6%	58.6%	27.6%
	DAY 4	5.9%	17.6%	5.9%

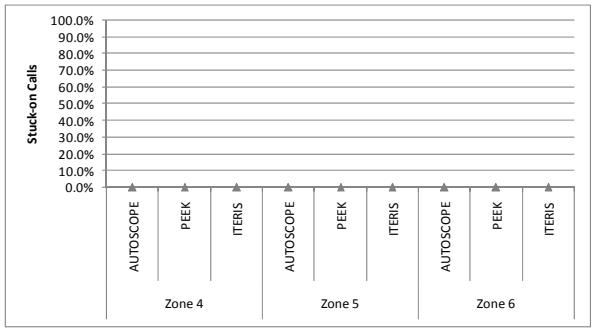




Stuck-on Calls

Stop Bar Zones				Advance Zones			
		AUTOSCOPE	PEEK			AUTOSCOPE	PEEK
ZONE 1	DAY 1	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%
	DAY 2	9.8%	0.0%		DAY 2	0.0%	0.0%
	DAY 3	0.0%	0.0%		DAY 3	0.0%	0.0%
	DAY 4	37.5%	0.0%		DAY 4	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	ZONE 5	DAY 1	0.0%	0.0%
	DAY 2	7.6%	0.0%		DAY 2	0.0%	0.0%
	DAY 3	0.0%	0.0%		DAY 3	0.0%	0.0%
	DAY 4	30.0%	0.0%		DAY 4	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	ZONE 6	DAY 1	0.0%	0.0%
	DAY 2	4.9%	0.0%		DAY 2	0.0%	0.0%
	DAY 3	0.0%	0.0%		DAY 3	0.0%	0.0%
	DAY 4	7.4%	0.0%		DAY 4	0.0%	0.0%





Snow Condition

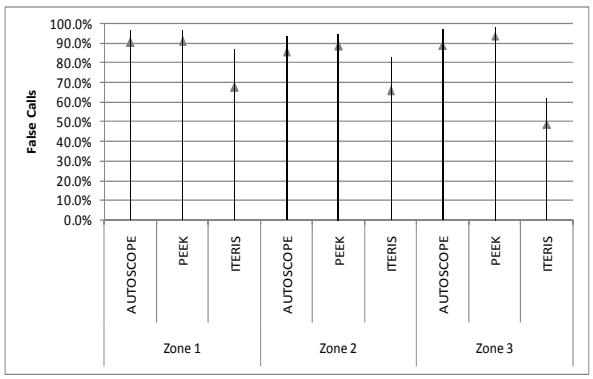
False Calls

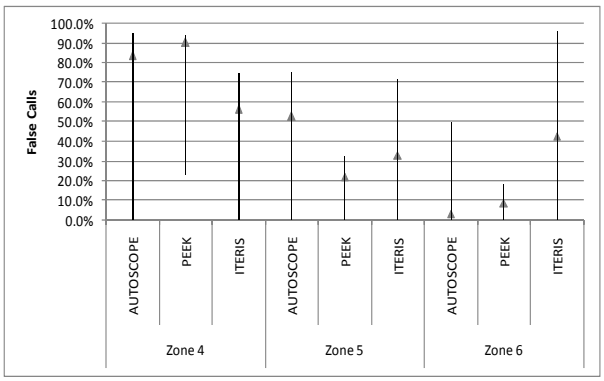
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	2.9%	91.7%	67.9%
	DAY 2	96.3%	92.9%	62.4%
	DAY 3	95.5%	96.3%	86.8%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	16.7%	83.1%	0.0%
ZONE 2	DAY 1	3.8%	0.0%	5.4%
	DAY 2	93.5%	92.5%	51.2%
	DAY 3	92.8%	94.7%	82.8%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	20.8%	58.4%	0.0%
ZONE 3	DAY 1	3.0%	32.1%	61.3%
	DAY 2	96.9%	98.1%	16.7%
	DAY 3	95.3%	93.5%	46.5%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	13.9%	81.2%	0.0%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	18.5%	94.0%	64.0%
	DAY 2	94.5%	73.3%	59.6%
	DAY 3	89.7%	87.4%	75.0%
	DAY 4	0.0%	23.1%	49.3%
	DAY 5	31.1%	94.4%	0.0%
ZONE 5	DAY 1	4.2%	8.8%	13.9%
	DAY 2	75.6%	31.0%	61.1%
	DAY 3	68.0%	32.0%	71.4%
	DAY 4	0.0%	0.0%	64.4%
	DAY 5	20.0%	27.9%	0.0%
ZONE 6	DAY 1	0.0%	4.8%	6.9%
	DAY 2	11.1%	18.2%	35.3%
	DAY 3	50.0%		95.7%
	DAY 4	0.0%	0.0%	69.2%
	DAY 5	0.0%	16.7%	0.0%





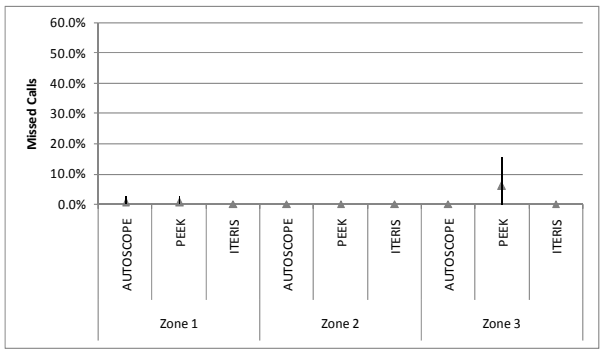
Missed Calls

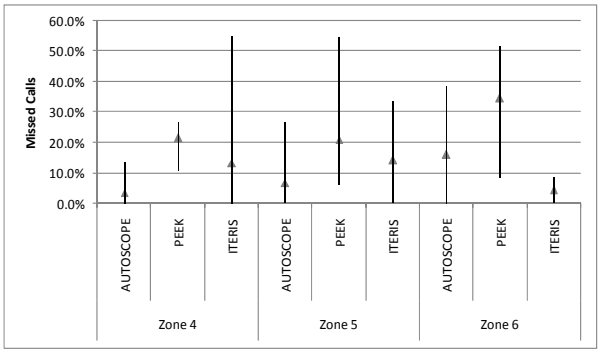
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	2.3%	2.3%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	4.4%	0.0%
	DAY 2	0.0%	9.1%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	15.4%	0.0%
	DAY 5	0.0%	4.8%	0.0%

Advance Zones

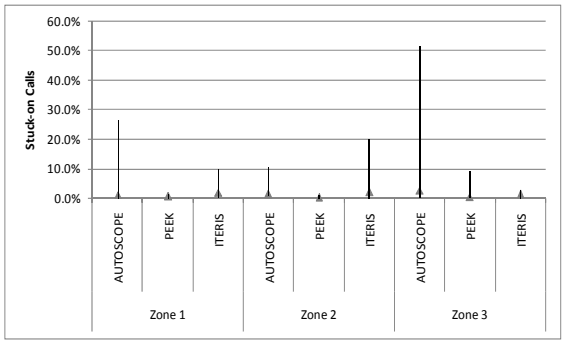
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	3.3%	26.7%	0.0%
	DAY 2	0.0%	24.0%	28.0%
	DAY 3	0.0%	20.7%	55.2%
	DAY 4	13.5%	10.8%	0.0%
	DAY 5	0.0%	25.0%	0.0%
ZONE 5	DAY 1	1.1%	7.9%	0.0%
	DAY 2	0.0%	11.1%	25.9%
	DAY 3	3.1%	6.1%	33.7%
	DAY 4	4.7%	41.9%	2.3%
	DAY 5	26.7%	54.7%	0.0%
ZONE 6	DAY 1	0.0%	32.4%	5.4%
	DAY 2	15.0%	25.0%	5.0%
	DAY 3	16.7%	8.3%	8.3%
	DAY 4	7.7%	38.5%	7.7%
	DAY 5	38.7%	51.6%	0.0%

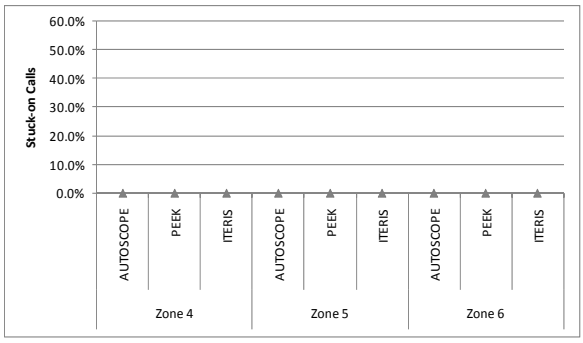




Stuck-on Calls

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	26.5%	1.2%	0.9%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.4%	0.4%	1.1%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	16.7%	0.0%	9.6%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	6.7%	0.1%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	3.8%	0.0%	5.4%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.4%	0.0%	0.5%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.5%	0.0%	0.2%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	10.0%	0.0%	20.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	10.4%	0.8%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	51.5%	8.9%	2.8%	ZONE 6	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.5%	0.1%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.3%	0.1%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	16.7%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	2.8%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%





Night Condition (Base Data for Nighttime)

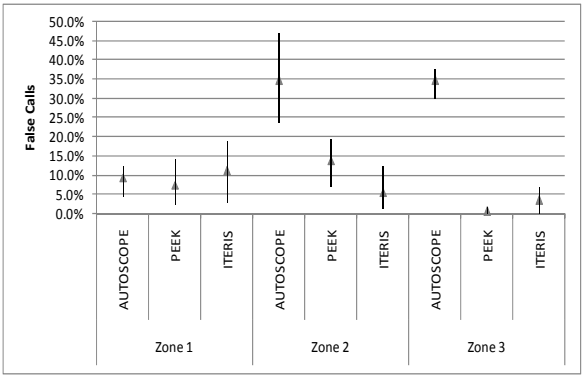
False Calls

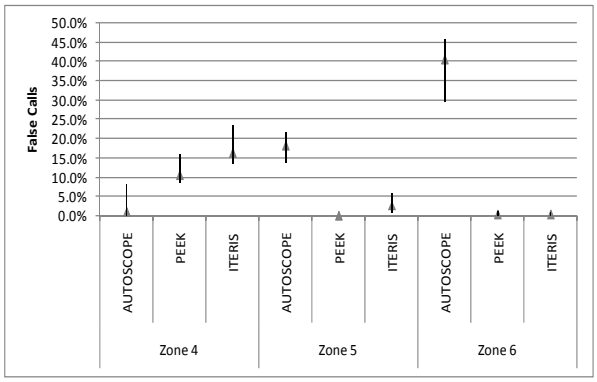
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	4.5%	14.1%	15.7%
	DAY 2	4.3%	2.1%	2.9%
	DAY 3	11.9%	10.0%	11.9%
	DAY 4	12.5%	12.5%	18.7%
	DAY 5	10.9%	4.0%	8.5%
ZONE 2	DAY 1	23.5%	8.7%	1.2%
	DAY 2	35.3%	19.4%	4.1%
	DAY 3	31.1%	12.7%	3.3%
	DAY 4	28.6%	7.0%	3.5%
	DAY 5	46.7%	18.4%	12.5%
ZONE 3	DAY 1	33.0%	0.0%	0.0%
	DAY 2	29.9%	0.0%	1.9%
	DAY 3	34.4%	1.4%	3.4%
	DAY 4	37.4%	0.0%	2.6%
	DAY 5	36.8%	1.1%	7.1%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	13.6%	23.2%
	DAY 2	0.0%	8.9%	17.2%
	DAY 3	8.3%	14.3%	17.7%
	DAY 4	1.8%	8.6%	15.5%
	DAY 5	1.7%	15.8%	13.4%
ZONE 5	DAY 1	14.3%	0.0%	0.8%
	DAY 2	21.6%	0.0%	5.8%
	DAY 3	17.9%	0.0%	1.7%
	DAY 4	13.6%	0.0%	2.5%
	DAY 5	20.7%	0.0%	2.1%
ZONE 6	DAY 1	43.1%	1.3%	0.0%
	DAY 2	46.0%	0.0%	0.9%
	DAY 3	43.0%	0.0%	1.0%
	DAY 4	42.7%	0.0%	0.0%
	DAY 5	29.5%	0.0%	0.0%





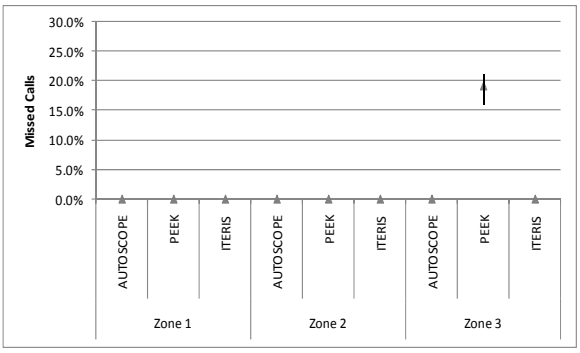
Missed Calls

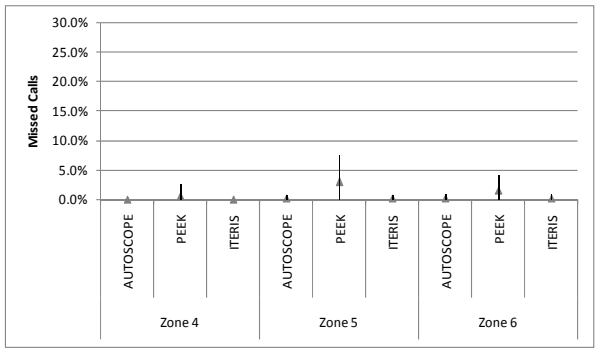
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	15.9%	0.0%
	DAY 2	0.0%	20.7%	0.0%
	DAY 3	0.0%	16.7%	0.0%
	DAY 4	0.0%	21.1%	0.0%
	DAY 5	0.0%	19.5%	0.0%

Advance Zones

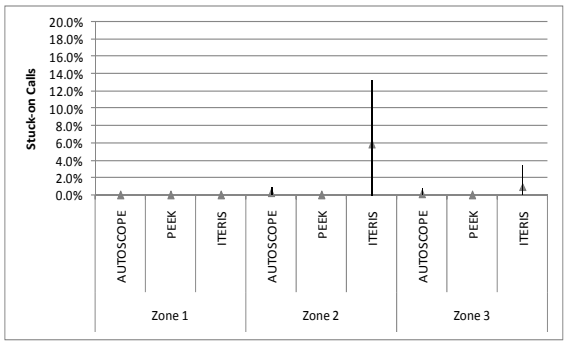
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	2.5%	0.0%
	DAY 2	0.0%	1.3%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 5	DAY 1	0.0%	7.5%	0.0%
	DAY 2	0.0%	6.7%	0.7%
	DAY 3	0.0%	0.9%	0.0%
	DAY 4	0.7%	1.4%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 6	DAY 1	0.0%	2.3%	0.0%
	DAY 2	0.0%	4.1%	0.8%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.8%	0.0%	0.0%
	DAY 5	0.0%	1.4%	0.0%

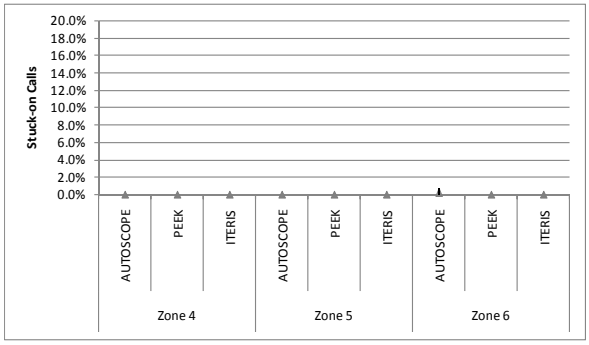




Stuck-on Calls

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%	ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%		DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	1.0%	0.0%	0.0%	ZONE 5	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.8%	0.0%	6.6%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	6.1%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	13.3%		DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%	ZONE 6	DAY 1	0.7%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%		DAY 2	0.5%	0.0%	0.0%
	DAY 3	0.8%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	3.4%		DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.8%		DAY 5	0.0%	0.0%	0.0%





Night Rain Condition

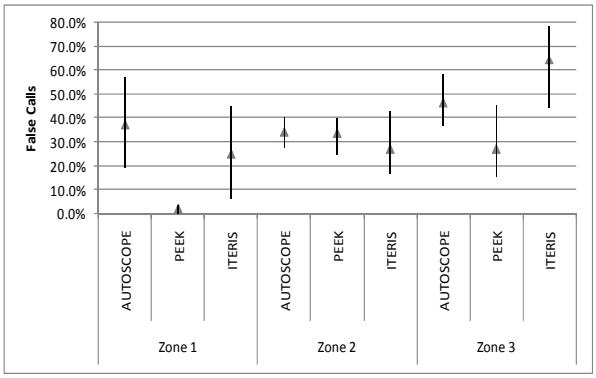
False Calls

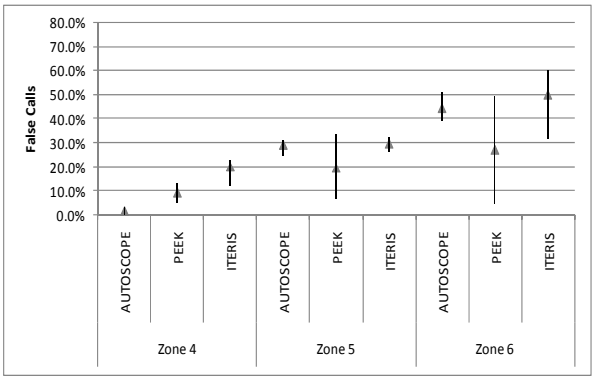
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	22.0%	2.5%	6.1%
	DAY 2	19.4%	3.9%	14.7%
	DAY 3	40.0%	1.9%	45.2%
	DAY 4	51.2%	0.0%	12.2%
	DAY 5	57.0%	0.0%	43.5%
ZONE 2	DAY 1	35.6%	38.6%	23.2%
	DAY 2	34.8%	30.4%	18.8%
	DAY 3	30.8%	33.1%	30.0%
	DAY 4	27.7%	24.8%	17.2%
	DAY 5	40.5%	39.7%	43.1%
ZONE 3	DAY 1	50.5%	30.6%	50.5%
	DAY 2	41.8%	17.0%	44.6%
	DAY 3	36.9%	15.4%	62.5%
	DAY 4	43.5%	23.6%	78.5%
	DAY 5	58.2%	45.6%	67.4%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	2.2%	13.3%	23.0%
	DAY 2	1.4%	8.5%	21.2%
	DAY 3	0.0%	5.1%	12.1%
	DAY 4	0.0%	7.0%	21.1%
	DAY 5	3.3%	8.6%	19.1%
ZONE 5	DAY 1	28.5%	21.7%	30.3%
	DAY 2	31.2%	7.0%	29.5%
	DAY 3	29.5%	24.4%	31.6%
	DAY 4	24.6%	15.0%	32.1%
	DAY 5	29.6%	33.6%	25.9%
ZONE 6	DAY 1	44.4%	26.7%	42.5%
	DAY 2	45.5%	4.6%	50.6%
	DAY 3	39.3%	22.0%	31.7%
	DAY 4	40.0%	30.4%	60.1%
	DAY 5	50.9%	49.6%	59.9%





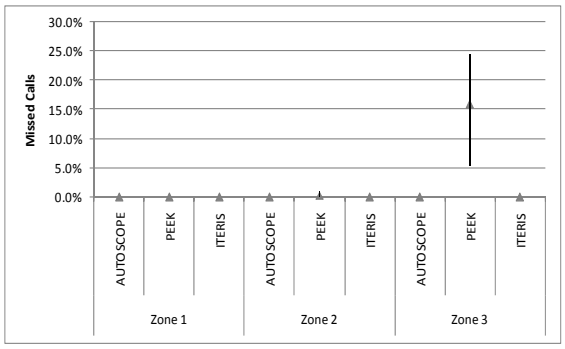
Missed Calls

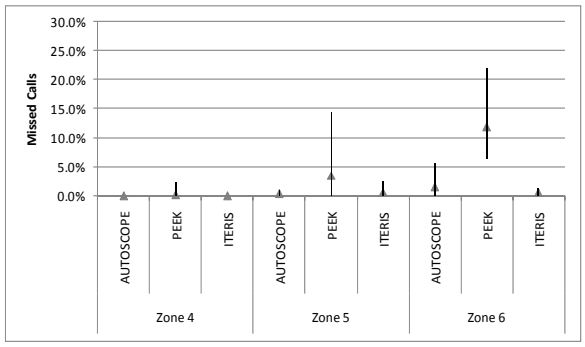
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	1.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 3	DAY 1	0.0%	24.6%	0.0%
	DAY 2	0.0%	20.4%	0.0%
	DAY 3	0.0%	12.6%	0.0%
	DAY 4	0.0%	5.4%	0.0%
	DAY 5	0.0%	11.6%	0.0%

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	2.3%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 5	DAY 1	0.0%	1.8%	0.0%
	DAY 2	0.5%	0.9%	0.0%
	DAY 3	0.9%	0.0%	0.9%
	DAY 4	1.0%	3.0%	1.0%
	DAY 5	0.0%	14.4%	2.5%
ZONE 6	DAY 1	0.0%	10.5%	0.0%
	DAY 2	1.3%	6.6%	1.3%
	DAY 3	5.5%	22.0%	0.0%
	DAY 4	0.0%	7.6%	1.1%
	DAY 5	1.1%	14.8%	0.0%

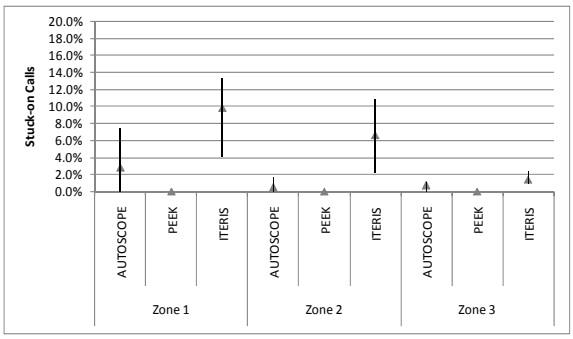


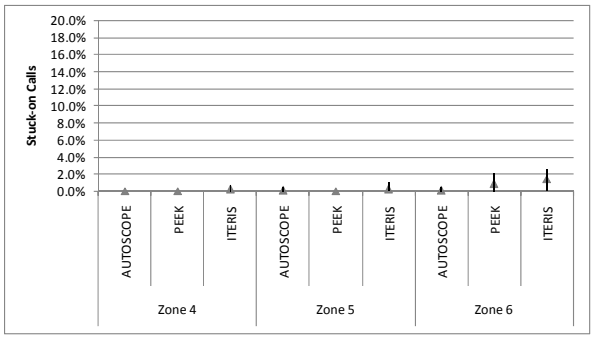


Stuck-on Calls

Stop Bar Zones		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.8%	0.0%	4.0%
	DAY 2	0.7%	0.0%	13.2%
	DAY 3	0.0%	0.0%	12.9%
	DAY 4	7.3%	0.0%	8.2%
	DAY 5	5.6%	0.0%	9.3%
ZONE 2	DAY 1	0.0%	0.0%	2.1%
	DAY 2	0.0%	0.0%	6.9%
	DAY 3	0.9%	0.0%	9.1%
	DAY 4	0.0%	0.0%	10.8%
	DAY 5	1.6%	0.0%	6.3%
ZONE 3	DAY 1	1.1%	0.0%	1.6%
	DAY 2	1.0%	0.0%	1.0%
	DAY 3	0.0%	0.0%	2.4%
	DAY 4	0.7%	0.0%	0.9%
	DAY 5	0.6%	0.0%	1.7%

Advance Zones		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.8%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 5	DAY 1	0.5%	0.0%	0.4%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.9%
ZONE 6	DAY 1	0.5%	1.5%	0.0%
	DAY 2	0.0%	0.0%	2.5%
	DAY 3	0.0%	0.0%	1.7%
	DAY 4	0.0%	0.0%	0.6%
	DAY 5	0.0%	2.2%	2.3%





Night Snow Condition

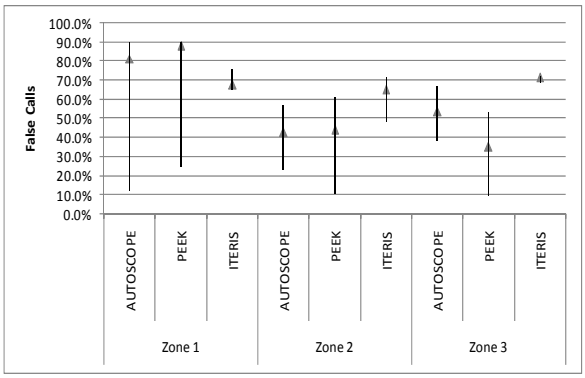
False Calls

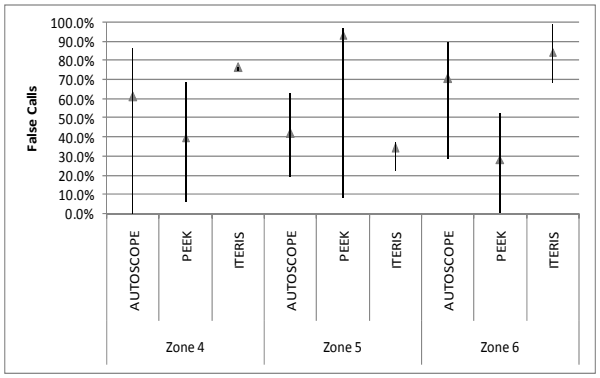
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	41.7%	30.0%	
	DAY 2	88.5%	44.2%	64.9%
	DAY 3	89.7%	89.4%	75.8%
	DAY 4	71.1%	89.9%	
	DAY 5	12.5%	25.0%	
ZONE 2	DAY 1	33.3%	30.0%	
	DAY 2	56.9%	11.1%	48.1%
	DAY 3	23.1%	61.2%	71.2%
	DAY 4	50.0%	33.3%	
	DAY 5	52.0%	11.1%	
ZONE 3	DAY 1	38.1%	13.3%	
	DAY 2	47.4%	28.6%	72.3%
	DAY 3	67.3%	53.7%	69.2%
	DAY 4	50.0%	33.3%	
	DAY 5	50.0%	10.0%	

Advance Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	50.0%	
	DAY 2	56.8%	28.6%	76.6%
	DAY 3	86.7%	69.2%	75.0%
	DAY 4	46.7%	41.2%	
	DAY 5	14.3%	6.3%	
ZONE 5	DAY 1	33.3%	23.1%	
	DAY 2	62.5%	15.2%	36.9%
	DAY 3	21.4%	97.0%	22.2%
	DAY 4	61.9%	86.1%	
	DAY 5	19.2%	8.3%	
ZONE 6	DAY 1	28.6%	0.0%	
	DAY 2	65.4%	21.7%	68.2%
	DAY 3	89.7%	52.4%	98.7%
	DAY 4	68.2%	0.0%	
	DAY 5	42.9%	27.3%	





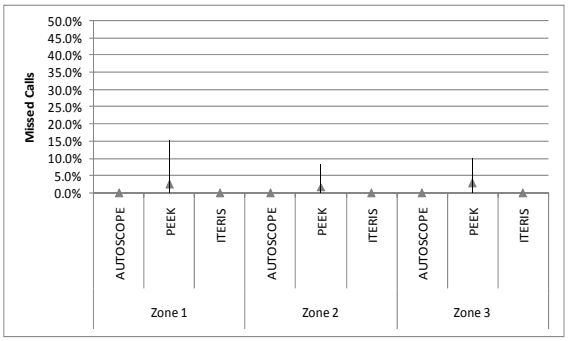
Missed Calls

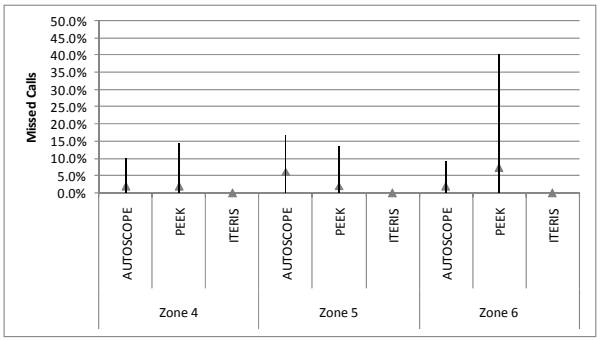
Stop Bar Zones

		AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	15.4%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 2	DAY 1	0.0%	6.7%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	8.3%	0.0%
ZONE 3	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	4.8%	0.0%
	DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	10.0%	0.0%

Advance Zones

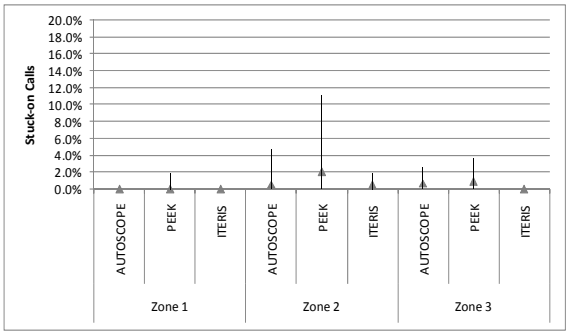
		AUTOSCOPE	PEEK	ITERIS
ZONE 4	DAY 1	0.0%	0.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	14.3%	0.0%
	DAY 4	10.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%
ZONE 5	DAY 1	0.0%	13.3%	0.0%
	DAY 2	16.7%	0.0%	0.0%
	DAY 3	2.1%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	4.5%	0.0%
ZONE 6	DAY 1	0.0%	40.0%	0.0%
	DAY 2	0.0%	0.0%	0.0%
	DAY 3	9.1%	0.0%	0.0%
	DAY 4	0.0%	0.0%	0.0%
	DAY 5	0.0%	0.0%	0.0%

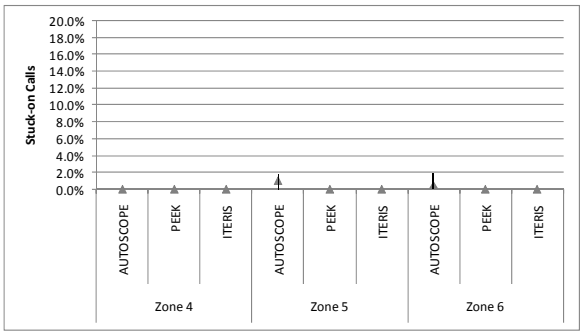




Stuck-on Calls

Stop Bar Zones					Advance Zones				
		AUTOSCOPE	PEEK	ITERIS			AUTOSCOPE	PEEK	ITERIS
ZONE 1	DAY 1	0.0%	0.0%		ZONE 4	DAY 1	0.0%	0.0%	
	DAY 2	0.0%	1.9%	0.0%		DAY 2	0.0%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%			DAY 4	0.0%	0.0%	
	DAY 5	0.0%	0.0%			DAY 5	0.0%	0.0%	
ZONE 2	DAY 1	4.8%	10.0%		ZONE 5	DAY 1	0.0%	0.0%	
	DAY 2	0.0%	2.8%	1.9%		DAY 2	1.4%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	1.8%	0.0%	0.0%
	DAY 4	0.0%	0.0%			DAY 4	0.0%	0.0%	
	DAY 5	0.0%	11.1%			DAY 5	0.0%	0.0%	
ZONE 3	DAY 1	0.0%	0.0%		ZONE 6	DAY 1	0.0%	0.0%	
	DAY 2	2.6%	3.6%	0.0%		DAY 2	1.9%	0.0%	0.0%
	DAY 3	0.0%	0.0%	0.0%		DAY 3	0.0%	0.0%	0.0%
	DAY 4	0.0%	0.0%			DAY 4	0.0%	0.0%	
	DAY 5	0.0%	0.0%			DAY 5	0.0%	0.0%	





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