Evaluation of Video Analytics for Incident Detection – Pilot Demonstration Houston, Texas

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Evaluation of Video Analytics for Incident Detection – Pilot Demonstration

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EXECUTIVE SUMMARY

To improve incident management while leveraging existing ITS resources, TxDOT was interested in evaluating technologies that might enable faster detection of incidents and increase the number of incidents being detected. TxDOT identified video analytics (using existing CCTV cameras) as one such technology to test and engaged in conversations with the video analytics vendor *TrafficVision* on a demonstration of their video analytics technology. *TrafficVision* agreed to provide TxDOT with their software and server for a no-cost, no-obligation pilot demonstration period of 12 weeks. The evaluation was conducted by integrating the video analytics software into a subset of existing CCTV cameras with pan, tilt and zoom (PTZ) function without adjusting the camera settings (gain, shutter speed, and white balance) to evaluate system viability with the existing CCTV monitored at Houston TranStar. The evaluation goals were to identify the accuracy of the software, its potential for detecting incidents faster and detecting additional incidents than being identified by operators. Another goal of the evaluation was to document TxDOT's on-floor staff operators experience and perceptions of the use of the software.

The results for the software accuracy show that the system sent a total of 974 stopped vehicle alerts, out of which 56% were for vehicles stopped in the freeway travel lanes, shoulders, HOV lanes and medians (helpful for incident detection), 20% were for vehicles stopped for traffic signals on the frontage road and cross street (events not of interest, but correctly identified by the software), and 24% alerts were false. Out of the 230 stopped vehicle false alerts, 21% alerts showed no vehicle present while the other 79% were for vehicles that stopped for less than 26 seconds (the threshold was set at 30 seconds). Results for incident detection time with *TrafficVision* when compared to incident detection time with currently used detection tools showed that average detection time for 34 incidents was approximately seven minutes less and for 32 incidents was 14 minutes more than that noted in Regional Incident Management System (RIMS).

Results for detecting additional incidents using video analytics software showed potential. During the 12-week evaluation period, *TrafficVision* detected an additional 462 stopped vehicle events that were not part of RIMS data. These 462 stopped vehicle alerts highlight the potential of the software in detecting additional incidents. These are *potential* incidents since this number includes stopped vehicle alert events for stop and go traffic (when vehicles stop for more than 30 seconds) and some repeat alerts. Note that while an alert for stop and go traffic might be a true incident from the software accuracy perspective; it is a false "incident" alert from the operator perspective since there is no collision or stalled vehicle.

A comparison of RIMS and TrafficVision data with recorded video data for a duration of 14 days showed a gap in incident detection by both currently used detection tools and *TrafficVision* process. RIMS had logged 32% while *TrafficVision* had logged 14% of all incidents that were manually logged from viewing the recoded video. Since TrafficVision detection zones are limited in length as compared to human eye watching the recorded video for incidents, it is possible that some of the 85% incidents not detected by *TrafficVision* were out of the software's detection zones or were part of the background image when the camera view focused on the incident. The average detection time of 14% incidents logged in

TrafficVision was 2.75 minutes whereas average detection time of 32% incidents logged in RIMS was 7.25 minutes, thus highlighting the potential for faster detection of incidents that are detected by the software. For the 10 incidents identified common in all three data sources, the average detection time in RIMS was approximately three minutes whereas the average detection time for TrafficVision was approximately five minutes.

Operator and supervisor feedback highlighted the fact that currently all of the TranStar CCTV cameras have a PTZ function and experience drift that affects the TrafficVision software performance and requires operators to continuously reset and move the camera views back on the preset views. The operator feedback suggested that the software is somewhat useful in detecting congestion issues and stalls on shoulders. However, with the current CCTV camera setup, it was perceived that the software does not reduce detection time nor does it assist in locating more incidents than the operators find using a variety of other tools. In addition, operators felt that keeping cameras on preset views was a time consuming process. Researchers note that if operators were not tasked with moving the cameras back to preset views continuously, their experience might have been somewhat different. As mentioned previously, alerts for stop and go traffic though true from software perspective yet were viewed as false alerts by operators.

A sample Before-After study (using only stalled vehicle incidents) to identify difference in incident duration based on use of TrafficVision alerts showed a reduction in clearance times when TrafficVision alerts were reported as the detection source. On average, clearance times in the after period for stall vehicles that were noted as detected by TrafficVision were 9.5 minutes less as compared to clearance times for stall vehicles in the before period. However, these reductions should be viewed with caution due to the small sample size and variation in the characteristics of each incident included in the before-after study.

This analysis suggests that video analytics is a viable incident detection tool that has the potential to increase the number of incidents detected (especially stalled vehicles) even when used with PTZ cameras. The software had mixed results in detection times; some incidents were detected earlier than that noted in RIMS while others were detected later than that noted in RIMS. The software was also found lacking in detecting incidents that were detected by moving the camera but then stayed as active incidents for over 15 minutes in the camera view. The unavailability of fixed camera views (background images) was provided as one reason for these incidents not being detected. As such, researchers recommend evaluating the software with a set number of fixed cameras such that fixed views will cover the entire length of study segment along a corridor. One such candidate segment could be on the IH 610 (West Loop) northbound on approach to US 59.

Operators mentioned keeping cameras on preset views as a time consuming process and alerts with no collision or stall in the view (alerts due to congestion, alerts for vehicles waiting on traffic signal, and false alerts) as negative outcomes. It is recommended that if TxDOT decides to integrate the video analytics software with fixed cameras, only a subset of the operators with proper training should be included in an analysis of that deployment (this would be a pilot study phase 2). During conversations with operators, it was clear that some operators did not have complete understanding of the alerts despite a formal training. It is recommended that operators be asked to volunteer for the use of this tool especially during the evaluation period. In addition, researchers recommend evaluating changes to the operator workload if video analytics were provided as an additional incident detection tool (clearing false alerts and alerts for stopped vehicles that are not incidents as well as keeping cameras on preset views).

Researchers also recommend that the software vendor should identify possible reasons for incidents not being detected in the camera's view even after being in the camera's view for over 15 minutes and develop suitable solutions for this issue. In addition, the software vendor should find solutions for alerts that were sent for vehicles stopping less than 30 seconds (threshold set in the software), which contributed to over 79% of all false alerts.

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT). The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of TxDOT.

This report does not constitute a standard, specification or regulation. This report is not intended for construction, bidding, or permits purposes. The engineer in charge of the project was Roma G. Stevens, Texas Registered Engineer #100354.

Reference herein to any specific commercial products, services by trade name, manufacturer, or otherwise, does not constitute or imply endorsement, recommendation, or favoring by the State of Texas or Texas A&M Transportation Institute.

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PROJECT BACKGROUND

The Texas Department of Transportation (TxDOT) has over 700 closed-circuit television (CCTV) cameras deployed along freeway corridors to monitor freeway operations in the Houston area. These cameras were installed with the need to and mainly used to verify incidents, largely after being reported through other means. These other means for incident detection include floor operators listening in to the motorists phone calls, Houston Police Department (HPD) scanner radio, Houston Fire Department (HFD) fire screen, input from private traffic services on the floor, manually moving the CCTV cameras to detect and verify a possible incident when a sudden speed drop occurs on the TranStar's Traffic Speed Map (automatic vehicle identification data), and use of Google Application 'Waze' (Waze was found to be used by a subset of operators and is not TxDOT endorsed official tool for incident detection).

Despite the use of existing, mostly manual methods of incident detection, there are delays and gaps in incident detection. Past studies have estimated an average delay of 10-15 minutes in incident detection (from actual incident time to time detected) and about 60% of the incidents not being detected at all (compared to the Crash Records Information System). These undetected incidents and delay in incident detection results in additional congestion on the freeway system. In general, it has been estimated that for every five to seven minutes of delay in verification and clearance of an incident, there can be one additional mile of queue in the system.

To improve incident management and leverage existing resources, TxDOT was interested in evaluating technologies that might enable faster detection of incidents and increase the number of incidents being detected. TxDOT identified video analytics (using existing CCTV cameras) as one such technology to test. TxDOT engaged in conversations with the video analytics vendor TrafficVision on a demonstration of their video analytics technology (more information on TrafficVision and the software in the Software Overview section). However, prior to making a commitment to purchase the software for implementation, the TxDOT Houston district conducted a test of the technology by integrating the video analytics software into a subset of existing CCTV cameras to evaluate system viability with the existing CCTV monitored at Houston TranStar.

The TxDOT Houston District tasked the Texas A&M Transportation Institute (TTI) to evaluate the software's accuracy and usability in detecting incidents for this pilot test. TrafficVision agreed to provide TxDOT with their software and server in a no-cost, no-obligation agreement for a pilot demonstration period of 12 weeks. In January 2016, TrafficVision's software was integrated with 24 existing TxDOT camera feeds for a pilot demonstration period of 12 weeks. Figure 1 shows locations of the 24 cameras integrated in the software.

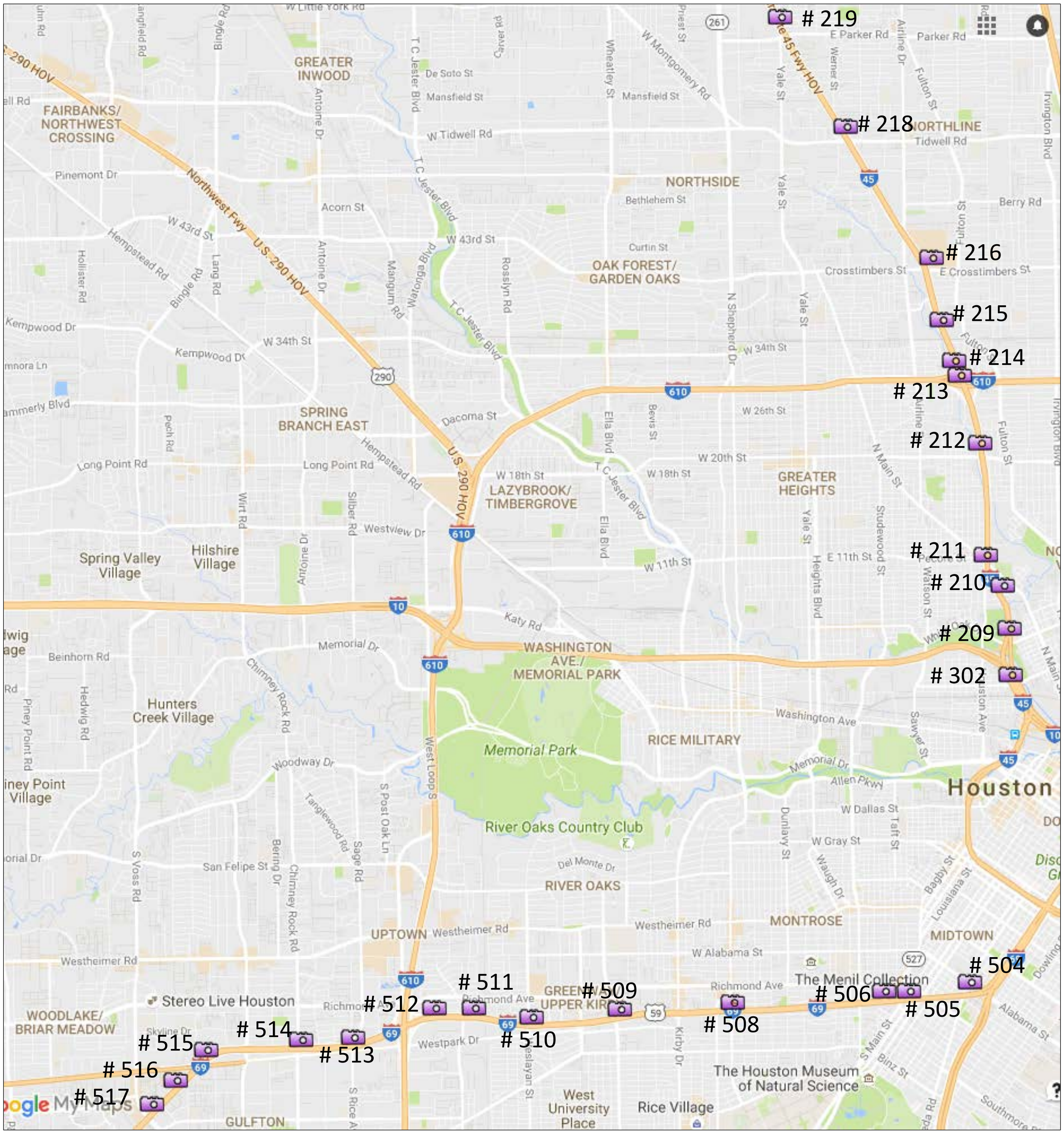


Figure 1. Locations of 24 Cameras Integrated in Software (Courtesy: Google Maps)

This evaluation report documents the findings from data collected and analyzed during the evaluation time period from February 2, 2016 to April 11, 2016. The report also presents an overview of video analytics and some factors that can affect the detection accuracy and consistency, as well as recommendations on the next steps in evaluating video analytics for further use.

PROJECT TEAM

Project team for this pilot demonstration included TxDOT Houston District Staff, City of Houston Police Department's Incident Management floor staff at TranStar, Harris County Sherriff's Office Incident Management Floor Staff at TranStar, TTI, and TrafficVision.

EVALUATION OBJECTIVES

The evaluation objectives for this study included the following.

1. Determine Software Accuracy in Detecting Incidents.
   This objective was selected to answer the question, what percent of alerts sent by the software are true based on the threshold criteria?
   The results will document the accuracy rate of the software in detecting stopped vehicles on freeway mainlanes when the camera field of view is:
   - In the calibrated preset position.
   - Not in the calibrated preset position.
2. Determine Differences in Incident Detection Time.
   Document any differences in incident detection time for events detected by software versus detected by floor operators and logged in Regional Incident Management Software (RIMS). This was completed for all 24 cameras integrated in the software where RIMS data could be matched with TrafficVision data for a reasonable time difference and incident location.
3. Documenting Gaps in Incident Detection Efficiency.
   Document any differences in number of events detected via software versus detected in RIMS versus noted on video for the incidents that occur.
   - While the CCTV cameras are in the pre-set mode.
   - While the CCTV cameras are not in the pre-set mode but the incident is in the viewing zone of the camera.
4. Document any changes in incident clearance times in the after period (when operators use the software for incident detection) as compared to the before period (when operators were not using software for incident detection).
5. Accuracy in Data Collection.
   Evaluate the software's ability to collect accurate data. For this pilot, software vendor had informed the project team that data collection is most accurate when software operation mode is Automatic Preset Select and camera field of view is on a calibrated preset view. The software's ability to collect accurate speed data were not evaluated since speed data from another independent source at the same location as the camera view was not available. However a sample of the volume data collected via the TrafficVision software were compared with the manual counts completed using 24x7 video data collected for one of the cameras.
6. Document the experience of TxDOT staff (traffic management center managers and floor personnel/operators) regarding the usefulness and usability of software.

OVERVIEW OF VIDEO ANALYTICS

TrafficVision's Traffic Management Center (TMC) software is a backend analytics software intended to detect incidents and collect volume and speed by processing CCTV camera images using computer vision as opposed to machine vision. Computer vision extracts information from images while accounting for changes in light conditions, field of view (pan, tilt and zoom), and other variables, whereas machine vision usually implies an industrial setting where light and motion are controlled and the camera is simply looking for change/defects in manufactured goods as they pass by on a conveyor belt (predictable events). Some key elements of computer vision and object tracking are discussed below.

Field of View

In video analytics, when using pan, tilt and zoom cameras, the software tracks objects by performing advanced calculations while taking into account a known background image. The background image can be a preset view calibrated by the user (for automatic preset select mode) or a different view of the camera to which the camera has been moved (in dynamic preset select mode). In order for the software to detect crashes or stalled vehicles, the vehicle/s involved in the crash has to be part of the background image prior to the crash. In other words if the objects were not in the camera's field of view, when the camera pans or tilts and then sees the crash or stalled vehicle, that is part of the background image to the software; it can only detect movement it sees, not detect what was there before and compare that with the current camera image. This is one reason why crashes are sometimes not *detected* by TrafficVision until many minutes after an operator moves the camera to view the crash; If a crash is already part of the background image, the software needs time to re-learn the scene and then wait for another vehicle to arrive on scene and stop in order to trigger a stopped vehicle/object alert.

Light Condition

There must be reliable and sufficient ambient light for an object to be differentiated from the background. In completely dark environments, sudden light appearance can be over-accentuated (causing bloom) and can make the object detection difficult.

Image Contrast

Image contrast is another key component of video analytics related to ambient light conditions. There must be proper contrast in order to differentiate objects from the background. For example, if a gray vehicle pulls over against a gray road at twilight, it will be harder to detect than a bright white or yellow car against the same background.

Object (Pixel) Size

Objects must meet an internal video analytics system threshold for them to be registered as objects of interest for the software instead of background *noise* introduced in the video encoding process, or other objects that are not worth tracking. TrafficVision software uses an internal threshold of 10x10 pixels that objects must meet in order to qualify for tracking and sometimes vehicles can be missed if they are too small in the background. This internal threshold is used so that the software would not unnecessarily track pixel groupings that were not actual objects of interest.

Quality of Video Stream

Quality of video stream by adjusting a camera's gain, shutter speed, and white balance will improve detection, specifically during nighttime. However, for the current pilot demonstration no optimization or changes were made to the existing TxDOT camera video streams. Without optimization and in the absence of ambient light, headlights from approaching vehicles magnify the glare on the camera thereby making it more difficult to detect. Camera resolution, frame/data packet loss, and low bit rate of the video stream have been identified as some factors that can cause missed detections by the software. Thus, a quality video stream with higher bit rates of 300-500 kilobits per second would be expected to result in increased number and accuracy of detections.

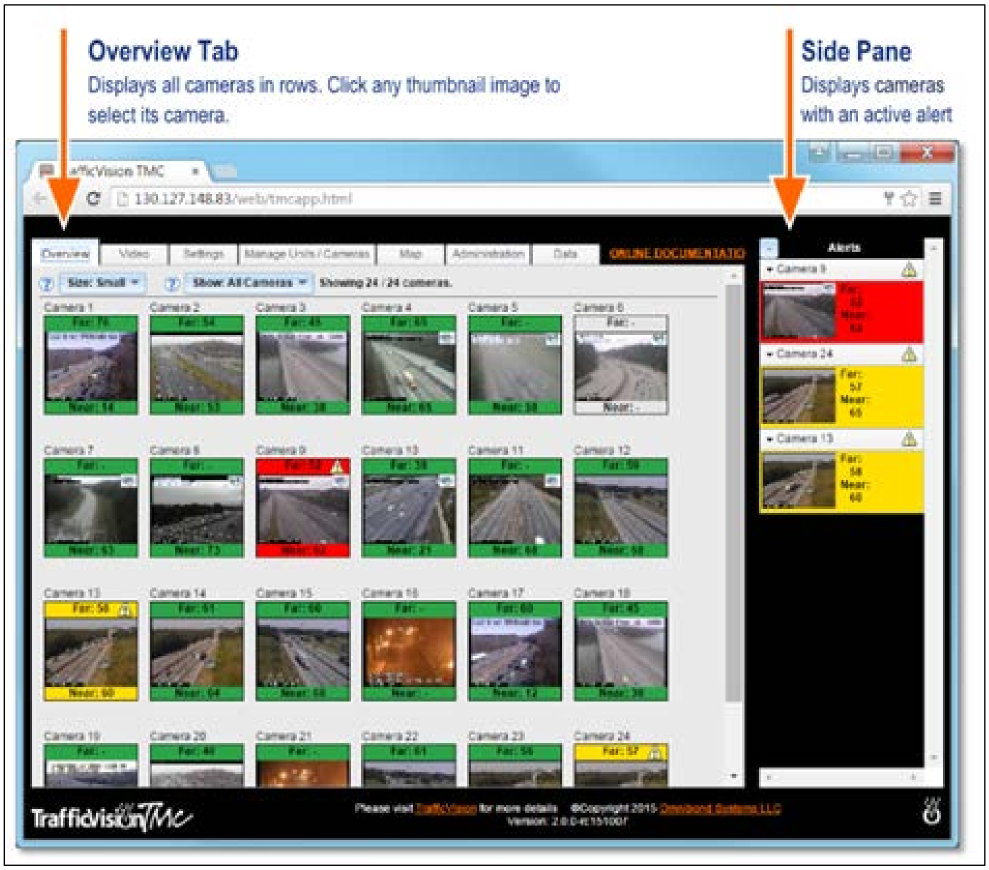
SOFTWARE OVERVIEW

TrafficVision is a video analytics company that develops software solutions to automatically process video from roadway cameras. TrafficVision's TMC software is a backend analytics software intended to detect incidents and collect volume and speed data using video images from CCTV cameras. The software algorithm builds a background model that adapts to changing light and weather conditions to track vehicles over time by comparing their appearance in successive frames. Some other transportation organizations that are using the TrafficVision software include Missouri Department of Transportation, South Carolina Department of Transportation, Ohio Department of Transportation, Colorado Department of Transportation, and Ministry of Transport in Ontario, Canada.

For this pilot project, in order for the software to detect incidents and collect data, detection zones were set up separately for incident detection and for data collection. For data collection, individual lanes were identified, whereas for incident detection a single zone was configured. At the beginning of the demonstration period, the software was configured by the vendor to send three types of alerts using following threshold parameters:

- *Stopped Vehicle Alert* – a vehicle that has been stationary for 30 seconds or more. Threshold of 30 seconds for stopped vehicle alerts is a default value in the software that can be adjusted for local needs and conditions. For the Pilot demonstration, the threshold for stopped vehicle alert was left at default value of 30 seconds, which in retrospect was found to be too short of a duration for the study corridors especially during peak periods. During this study, no sensitivity analysis was completed to identify an optimal threshold, however for future pilots or implementation, it is suggested that a sensitivity analysis be completed to identify the optimum threshold for each corridor/each camera location.
- *Congestion Alert* – when lane occupancy is 80% or higher in any lane.
- *Slow Speed Alert* – when average speeds of vehicles in the detection zone are 20 mph or lower.

Figure 2 shows TrafficVision software's thumbnail screen. Left side of the screen shows all cameras integrated in the software and right side pane of the screen shows alerts. The camera thumbnails change from green to yellow or red based on the alert type. The camera thumbnails stay green when there is no alert, change to yellow for a congestion or slow speed warning alert and to red for very slow speeds (10 mph or below—can be changed) and stopped vehicle alerts.



Source: TrafficVision

Figure 2. Screenshot of TrafficVision Software Camera Thumbnail Screen

The software is capable of using two different modes when analyzing the camera's field of view for detecting incidents and collecting data. These two modes are Automatic Preset Select mode and Dynamic Preset Adjust mode, both of which are described below.

Automatic Preset Select Mode

In this mode, the TrafficVision software will select the best previously configured calibration preset to match a camera field of view (FOV) automatically. This saves the user from the need to change software calibration presets themselves for different views of the cameras. However, this mode is most useful if the camera's FOVs primarily match a range of known (consistently predictable) camera positions where software calibrations have been made. There is a small degree of tolerance if a FOV does not line up perfectly with a previously saved position and the software can automatically make a minor adjustment. However, positioning the camera at a FOV that exceeds the threshold, or is significantly different from a previously saved calibration preset, will result in the software not applying any analytic overlays or calculation for data collection. The reason for this is that any data collected may be incorrect because the view's parameters are unknown to the software and may have a different number of lanes and different pixel to distance ratio as compared to saved presets.

Dynamic Preset Adjust Mode

This mode is similar to Automatic Preset Select mode in that it can automatically change calibration presets to different views but allows for more operational flexibility (primarily for incident detection but also for data collection) with the understanding that data collected (volumes and speeds) will likely not be as accurate compared to when the camera is at a known preset. This mode is useful when a camera's position is difficult to predict or the camera moves frequently, but the user would still like active incident detection capability and traffic speed. This mode operates exactly the same as Automatic Preset Select when the camera is at a known FOV. When the view is off or new, the software algorithm picks the closest saved calibration preset then makes calculated adjustments and extrapolates a new calibration to match that view automatically. The software will continue to collect traffic data and look for incidents as before. However, the data may be less accurate because the parameters such as number of lanes, or the zoom level of the camera may have been changed, which affect data collection.

If a user chooses this dynamic mode, they will receive more incident alerts and the software will still attempt to collect data on most views. However the data will likely not be as accurate compared to when a camera is at a known preset. A significant factor in data accuracy is the zoom level of a camera because the pixel to distance ratio will have been changed. Since the software is not embedded in the camera itself to use the camera's optics and zoom metadata for calculations, the software can only track vehicles over a length of pixels. If that previously established length of pixels translates to a different distance, then data accuracy will be affected.

DATA COLLECTION

Data collected for this analysis included the following:

1. TrafficVision generated alert data including time of alert, type of alert, and camera number.
2. TrafficVision generated video snippets accompanying each alert.
3. TrafficVision generated camera view information (on preset, off preset, near preset) for the study duration in 10-minute intervals.
    - *On Preset* is defined as when camera field of view exactly matches the calibrated preset view.
    - *Off Preset* is defined as when camera field of view does not match the calibrated preset view.
    - *Near Preset* is defined as when camera field of view matches the preset view but zoom/angle are not exact same as in the calibrated preset view.
4. Software operation mode periods provided by TrafficVision personnel.
5. Alert threshold data retrieved from TrafficVision software.

6. Incident data from Regional Incident Management System database.
   RIMS Data collection for US 59 included all incidents logged in RIMS from February 2, 2016 through April 11, 2016 along US 59 from Hillcroft Avenue to SH 288 and included incidents before, at, or after the following cross streets.
   - Hillcroft Avenue
   - Chimney Rock Road
   - Dunlavy Street
   - Edloe Street
   - Fannin Street
   - Main Street
   - Fondren Road
   - Fountain view
   - Greenbriar Drive
   - Hazard Drive
   - Shepherd Drive
   - IH 610 West Loop
   - Kirby Drive
   - Mandell Drive
   - Montrose Road
   - Newcastle Road
   - South Rice
   - Spur 527
   - Weslayan Street
   - Westpark Drive
   - SH 288

   RIMS Data collection for IH 45 included all incidents logged in RIMS from February 2, 2016 through April 11, 2016 along IH 45 from IH 10 to Parker Road and included incidents before, at, or after the following cross streets.
   - IH 10 Katy
   - Patton Street
   - Crosstimbers Street
   - Quitman Street
   - Cavalcade Street
   - Airline Drive
   - North Street
   - IH 610 – North Loop
   - Tidwell Rd
   - North Main Street
   - Northern Railroad
   - Parker Road

   Video Data recorded for eight TranStar cameras listed below.
   - US 59 @ Buffalo Speedway – #509*
   - US 59 @ SH 288 – #504
   - US 59 @ IH 610 West Loop – #514
   - US 59 @ Chimney Rock Road – #513
   - IH 45 @ North main – #211
   - IH 45 @ North Loop – #214
   - IH 45 @ Cavalcade – #216
   - IH 45 @ Tidwell Road – #218

   *Due to faulty port on the digital video recorder, video from Camera 509 was not recorded for the period from February 2, 2016 to March 2, 2016.
7. TranStar TMC operator and supervisor feedback interviews.

STUDY PERIOD AND ASSOCIATED SOFTWARE OPERATION MODE

The pilot demonstration period was divided into six sub-periods based on software operation mode and introduction of software to TranStar operators. Table 1 shows dates and software operation mode for each of the six study periods.

Table 1. Study Periods and Associated Software Operations Mode

Study Period	Software Mode	Description of Study Period
2/2/2016-2/15/2016	Automatic Preset Select	Before – TranStar Floor Operators not asked to use software alerts for incident detection.
2/16/2016-2/29/2016	Dynamic Preset Adjust	Before – TranStar Floor Operators not asked to use software alerts for incident detection.
3/1/2016-3/7/2016	Automatic Preset Select while some cameras were still on Dynamic mode	Transition 1 – TranStar Floor Operators were introduced to the software and were encouraged to get familiar with the software alerts
3/8/2016-3/21/2016	Automatic Preset Select	After – TranStar Floor Operators were asked and encouraged to use software alerts for incident detection.
3/22/2016-3/28/2016	Dynamic Preset Select	Transition 2 – TranStar Floor Operators were asked and encouraged to use software alerts for incident detection. Software configuration was changed where congestion and slow speed alerts were discontinued.
3/29/2016-4/11/2016	Dynamic Preset Adjust	After – TranStar Floor Operators were asked and encouraged to use software alerts for incident detection.

EVALUATION RESULTS AND FINDINGS

1. Software Accuracy

One of the primary goals of this evaluation was to determine the accuracy rate of software in detecting incidents (stopped vehicles on the freeway mainlanes, high occupancy vehicle lanes, medians and shoulders). This section documents the results of TrafficVision generated alerts analysis. The analysis was completed using TrafficVision provided alert data (pictures showing the vehicle that caused the alert, alert time, and camera number, and a video clip that recorded the camera view for 2.0 minutes with 30 second prior to the alert and two minutes after the alert).

An Overview of Alerts Received

During the pilot demonstration period from February 2, 2016 to April 11, 2016, TrafficVision software sent a total of 6,777 alerts of three types—congestion, slow speeds, and stopped vehicles. Figure 3 shows the number of alerts by type and by freeway segment.

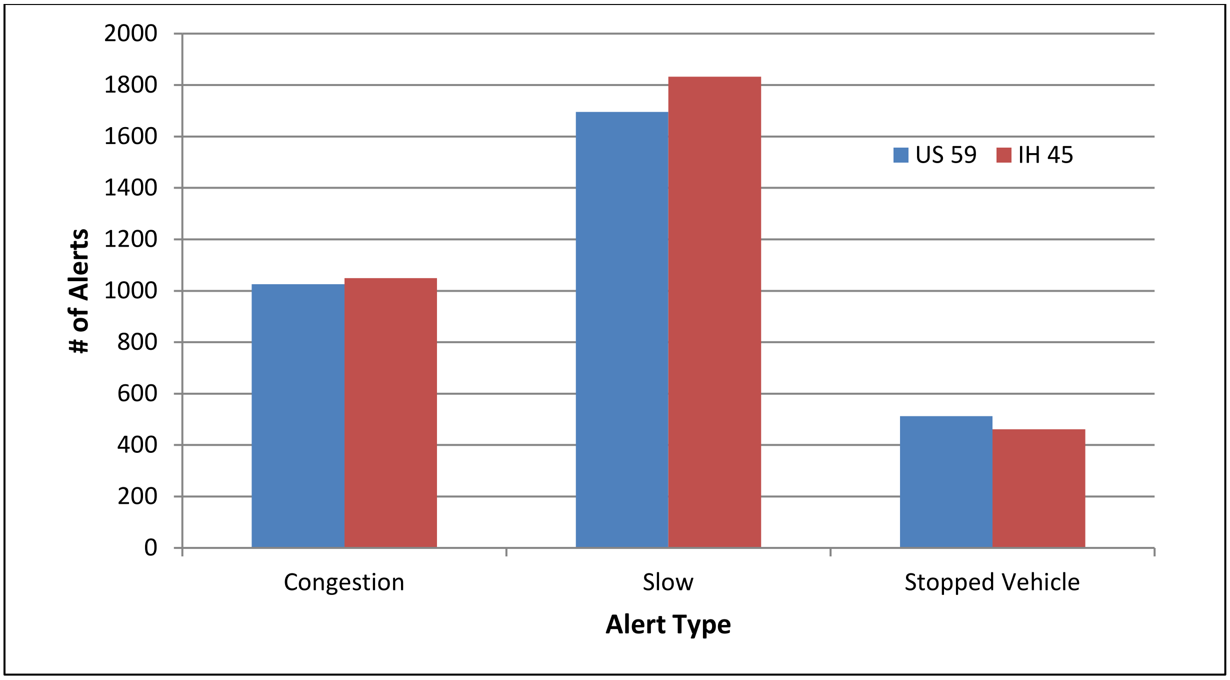


Figure 3. Number of Alerts Received from February 2–April 11, 2016 by Alert Type and Freeway

Despite setting the speed threshold for slow alerts to 20 mph, and congestion threshold to 80% occupancy, the number of congestion and slow alerts combined was about five times as high as number of stopped vehicle alerts. After seeing initial results, TrafficVision was concerned that a high number of congestion and slow vehicle alerts might cause some floor operators to disregard the software alerts even when the alert is for a stopped vehicle, as such the 'Congestion' and 'Slow' type alerts were discontinued on March 22, 2016.

Congestion and slow alerts were not analyzed in greater detail since speed data from an independent source is not available to verify if the speeds in the camera view were below 20 mph at the time of alert. The analysis of congestion alerts was based on the analyst's judgement of whether the camera view appeared at 80% or greater occupancy or not (this was a subjective review). Analysis of congestion alert data showed that approximately 95% of all congestion alerts were true for congestion at least in one lane of freeway. This analysis is not discussed in greater detail in the report as the analysis results will vary upon the viewer's judgement of the video that accompanied the alert—it was a secondary portion of the analysis for this reason. In addition, since congestion alerts were discontinued on March 22, 2016, operators did not use these alerts to detect downstream incidents. The remainder of this report focused on only stopped vehicle alerts.

Methodology for Documenting Software Accuracy

In order to evaluate the usefulness of TrafficVision software in detecting stopped vehicles (true incidents) in the camera view, researchers analyzed the stopped vehicle alert data and the accompanying recorded video (both provided by the TrafficVision system). The stopped alerts were categorized as 'True–For Incidents,' 'True–Not Incidents,' and 'False' by using the following criteria:

- A stopped vehicle alert was categorized as 'True-For Incidents' when the alert was sent for a vehicle stopped in the freeway travel lanes, shoulders, medians, and/or high occupancy vehicle lane for duration of 30 seconds or more;
- A stopped vehicle alert was categorized as 'True-Not Incidents' when the alert was sent for a vehicle stopped either on the cross street/frontage road intersection waiting for a signal or in a parking lot (not on the freeway travel lanes, shoulders, medians, and/or high occupancy vehicle lane).
- A stopped vehicle alert was categorized as 'False' if the alert was for a slow moving vehicle, a vehicle that stopped for less than 30 seconds, an object/light glare/structure etc. in the camera, but not for a vehicle.

At the start of the pilot study, the vendor had informed the project team that the software provides the most accurate alerts when cameras stay in their preset view. However, one constraint put on the test was to use existing TranStar CCTV cameras that would remain in normal use, subject to manipulation by dozens of operators at any one time. The TranStar cameras are often moved from their preset view, either to verify an incident that is out of focus in camera's preset view and then not reverted to the preset view, or because the cameras have developed an inherent drift that makes the camera view shift to a slightly different view over time. Therefore, in addition to calculating the software accuracy for all stopped alerts received, researchers analyzed the stopped alerts data by camera view setting—both on preset and off preset. TrafficVision software logs information about camera view setting in the archived data files for each camera and researchers used this software logged information to determine if camera was in preset view or not at the time a stopped alert was sent.

Accuracy Results

Table 2 shows the analysis results for stopped alerts by camera view and alert accuracy. Looking at Table 2, it can be seen that overall software sent 76% true stopped vehicle alerts and 24% false alerts, however from the TranStar floor operator's perspective, 20% of the stopped vehicle alerts (True – Not Incidents) sent for vehicles stopped on frontage road/cross street traffic signals were not useful and thus fall in the false category. Figure 4 shows the overall accuracy results by software operation mode for all 24 cameras integrated with the TrafficVision software for the complete study duration from February 2, 2016 to April 11, 2016.

Table 2. Stopped Alerts by Camera View and Alert Accuracy

Study Period (Software Mode)	Camera View	Stopped Alerts						Total
		True–For Incidents		True–Not Incidents		False		
		Count	%	Count	%	Count	%	
Feb 2–Feb 15 (Automatic)	On Preset	54	64%	9	11%	21	25%	84
	Off Preset	2	20%	1	10%	7	70%	10
Feb 16–Feb 29 (Dynamic)	On Preset	48	73%	6	9%	12	18%	66
	Off Preset	108	55%	42	21%	47	24%	197
Mar 1–Mar 7 (Automatic)	On Preset	27	71%	4	11%	7	18%	38
	Off Preset	17	55%	10	32%	4	13%	31
Mar 8–Mar 21 (Automatic)	On Preset	35	66%	4	8%	14	26%	53
	Off Preset	18	75%	0	0%	6	25%	24
Mar 22–Mar 28 (Dynamic)	On Preset	16	53%	3	10%	11	37%	30
	Off Preset	54	56%	27	28%	15	16%	96
Mar 29–Apr 11 (Dynamic)	On Preset	36	57%	6	10%	21	33%	63
	Off Preset	132	47%	84	30%	66	23%	282
Total	**On Preset**	216	65%	32	10%	86	26%	334
	Off Preset	331	52%	164	26%	145	23%	640
Grand Total		547	56%	196	20%	231	24%	974

*Because of the round off error, percentages may not add up to 100.

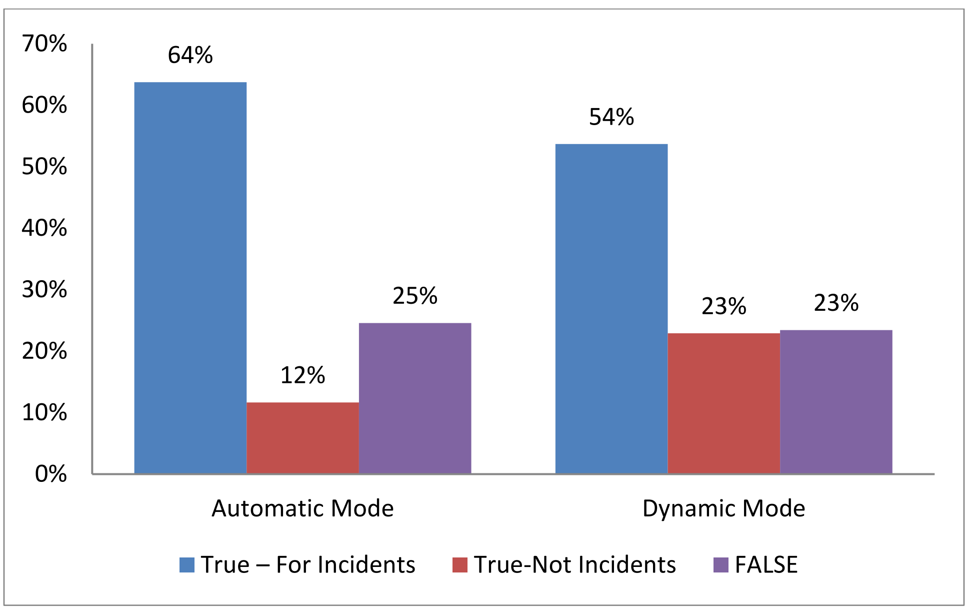


Figure 4. Stopped Alerts Accuracy Results by Software Operation Mode

Researchers examined false alerts to understand if false alerts were shadows created due to light conditions and structures on the roadway. Reasons for false alert were divided into two categories: 1) No vehicle was seen in the alert and 2) vehicle that triggered the alert was stopped for 29 seconds or less. Figure 5 shows the results for detailed analysis of stopped vehicle false alert data for the evaluation period.

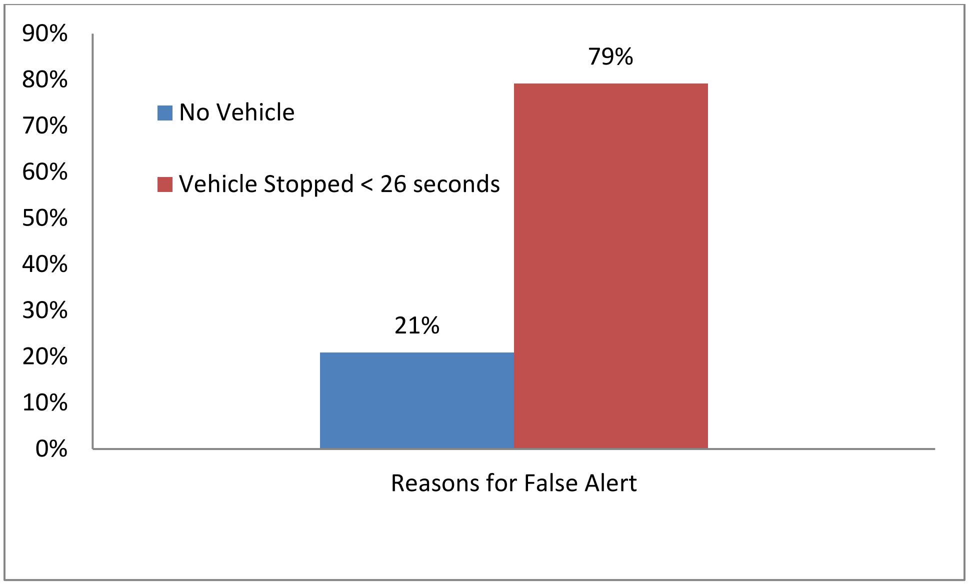


Figure 5. False Alert Analysis Results for Evaluation Period

Stopped alert data were also analyzed by time of day to identify if there were any significant differences in the number of alerts received and the number of true alerts received based on light conditions. Figure 6 and Figure 7 show bar charts showing number of alerts and number of true alerts by time of day for US 59 and IH 45 respectively.

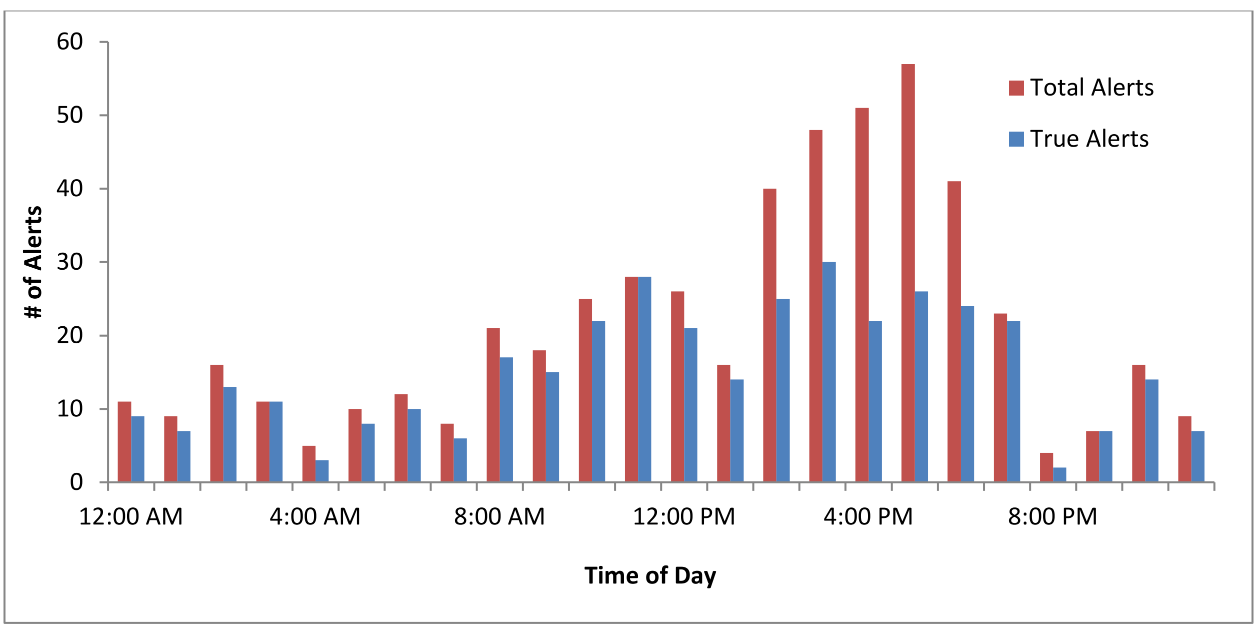


Figure 6. Stopped Vehicle Alert Distribution by Time of Day – US 59

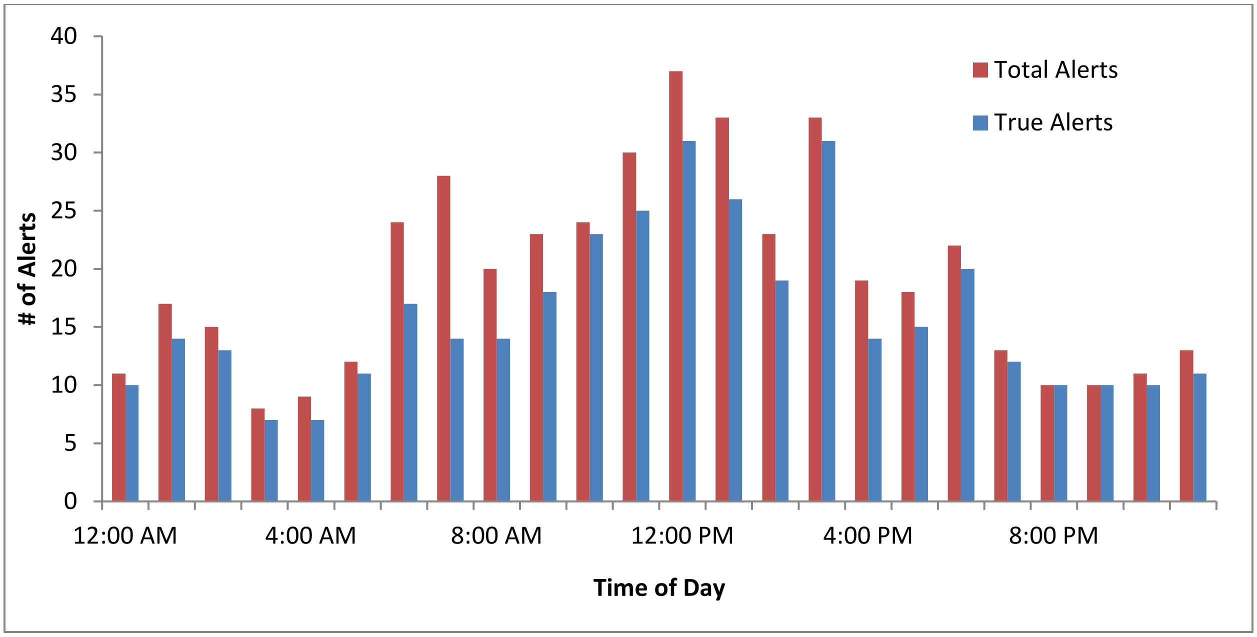


Figure 7. Stopped Vehicle Alert Distribution by Time of Day – IH 45

Looking at Figure 6 and Figure 7, it seems the number of total alerts is somewhat lower for the morning hours between 3:00 and 8:00 a.m. especially for US 59. This alert pattern is somewhat contradictory to a typical traffic pattern where volumes are higher during the 6:00 to 8:00 a.m. hours as compared to nighttime hours and daytime off-peak hours. The US 59 study segment alignment is northeast/southwest resulting in glare from the rising sun for the morning rush hour traffic traveling in the northeast direction. Though, the camera presets were not calibrated pointed towards the sun, yet drift and minor changes to camera view can cause a sun glare on the lens. Thus, it is possible that lighting conditions and sun glare may have contributed to this discrepancy.

Software Accuracy Findings

- The total number of congestion and slow alerts per camera received along IH 45 (262 alerts per camera) were higher than those received along US 59 (209 alerts per camera) whereas, the number of stopped vehicle alerts per camera received along IH 45 (42 alerts per camera) were about the same as those received along US 59 (40 alerts per camera).
- The total number of alerts received during the dynamic preset mode (five weeks) was approximately three times the total number of alerts received during the automatic preset mode (five weeks). The percent of false alerts during both modes was approximately the same whereas the percent of true alerts-not incidents was less during the automatic preset mode. This result is in line with the fact that the software in automatic preset mode does not adjust to the changes in the camera field of view and thus fewer alerts are generated when the camera field of view was looking at non-mainlane/high occupancy vehicle facilities (the frontage road and adjacent parking lots).
- Overall, the software sent a total of 974 stopped vehicle alerts, out of which 56% true alerts were sent for incidents, 20% true alerts were for vehicles stopped for traffic signals on the frontage road and cross street, and 24% alerts were false.

- Out of the 230 stopped vehicle false alerts, 21% alerts showed no vehicle present while the other 79% were sent for vehicles that stopped for less than 26 seconds while the threshold set for stopped vehicle alert was 30 seconds.
- Out of 334-stopped vehicle alerts sent during the times when the cameras were on preset calibrated view, 65% alerts were for incidents, 10% alerts were for vehicles stopped for traffic signals on the frontage road and cross street, and 26% alerts were false.
- The analysis did not show any significant differences in percent of true alerts based on camera field of view (camera on calibrated preset views versus camera off the calibrated preset view) but it did appear to lessen the number of alerts for vehicles stopped for traffic signals on the frontage road and cross street (off mainlanes, freeway shoulders, freeway medians, and high occupancy vehicle lanes).
- The analysis showed some effect of lighting conditions on number of alerts for the morning peak hours, especially for cameras on US 59 data.

2. Comparison of TrafficVision and RIMS Data

TTI researchers compared RIMS data with TrafficVision Alert data to identify potential incidents that might have been detected by TrafficVision whether noted as such or not in the RIMS database. When calculating this measure, researchers used time of incident/alert, location of incident/alert, engineering judgement, and recorded video when available (24 hour video for eight cameras and alert accompanied video) in determining if TrafficVision stopped vehicle alert sent was for an incident logged in RIMS database. The alerts/incidents that could be matched in both RIMS and TrafficVision data were used to:

- Identify any differences in incident detection time by TrafficVision software versus other means of incident detection.
- Document the differences in number of incidents detected by TrafficVision and total number of incidents detected in RIMS for the study segment. It should be noted here that incidents detected by TrafficVision would be limited to the incidents occurring in the camera view whereas RIMS database includes incidents detected via cameras, citizen calls, Harris County and City of Houston’s radio scanners, automatic vehicle identification (AVI) speed map, and Waze app based on crowdsourcing.

Differences in Number of Incidents Detected

The RIMS and TrafficVision stopped vehicle alerts data were analyzed in two groups: the first group included all incidents associated with sixteen of the camera locations for which no continuous video data were available; and the second group included all incidents associated with eight camera locations for which continuous 24 hour video data were available for most of the study period. Common incidents associated with the 16 camera locations were matched using time stamp of alert, detection and clearance times in RIMS, alert and incident location, video clip recorded by TrafficVision software with each alert, and engineering judgement. Common incidents associated with the eight camera locations for which recorded video was available, were matched using time stamp of alert, detection and clearance times in RIMS, alert and incident location, and recorded video. Figure 8 shows the relationship between RIMS detected and TrafficVision detected incidents graphically for the entire study period and 24 cameras integrated in the software.

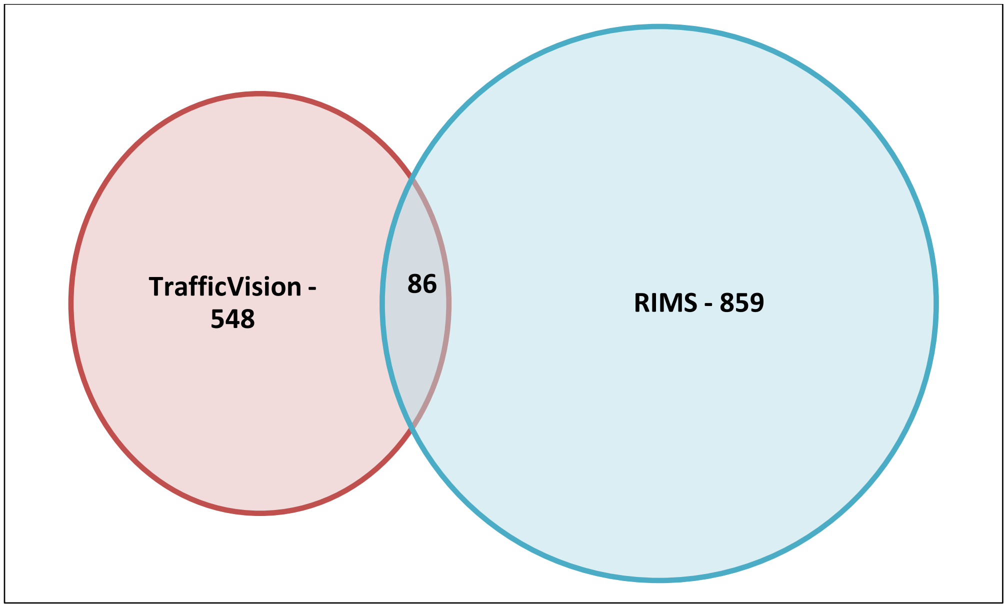


Figure 8. Venn diagram showing Incidents Detected in TrafficVision and RIMS

Difference in Detection Times

Out of the 86 incidents identified as common in both TrafficVision Alert and RIMS datasets, 20 were noted by operators in RIMS as having been detected using TrafficVision, thus the detection time for these 20 incidents was the same in both databases. The remaining 66 incidents were further analyzed to determine if TrafficVision detected the incident earlier, at the same time or later than the detection time noted in RIMS data. Table 3 summarizes the analysis results.

Table 3. Difference in Incident Detection Time for TrafficVision Alerts and RIMS Data

Data Description	Count	Average Difference in Detection Time (h:mm:ss)
Incidents detected earlier or at same time as RIMS by TrafficVision	34	0:07:18
Incidents detected later than RIMS by TrafficVision	32	0:14:58

Out of the 32 incidents that were detected later by TrafficVision, camera recordings were available for 21 incidents while the other 11 were matched using engineering judgement, incident detection and clearance time, and location information. For these 21 incidents, three incidents occurred in the camera view while for the other 18 incidents; the operators moved the camera to the incident location to verify the incident after receiving an incident report from another source. Two out of the three incidents that occurred in camera view occurred during daylight hours while one occurred during nighttime hours.

Distribution of TrafficVision Detected Incidents by Incident Type

The 'True Alerts' sent by TrafficVision were further analyzed to understand the distribution of incidents being detected by the software. For this purpose, TrafficVision alerts (548 true alerts) were categorized as one of following incident types:

1. Stall – A true alert was categorized a stall when a single vehicle was stopped on the shoulder, median, ramp shoulder, or in the mainlanes and did not appear to be hit by another vehicle or structure.
2. Accident – A true alert was categorized an accident when the alert vehicle appeared to be either hit or had hit another vehicle or structure. In addition, if emergency vehicles were present at the scene, the alert was categorized to be an accident.
3. Congestion – A true alert was categorized a congestion alert when software is detecting vehicles stopped for more than 30 seconds (threshold set for stopped vehicle alerts), however there is no accident or stalled vehicle in the camera view.
4. Police Enforcement – A true alert was categorized as police enforcement when a police officer was pulling vehicles from mainlanes of travel and stopping these vehicles on the shoulder thus triggering a true alert from software.
5. Maintenance Activity – A true alert was categorized as maintenance activity when a TxDOT vehicle with flashers was stopped thereby triggering a true alert from the software.

Table 4 shows the distribution of TrafficVision detected incidents for alerts that were associated with incidents found in RIMS database as well as alerts that could not be associated with any incidents in RIMS.

Table 4. Distribution of TrafficVision Detected Incidents by Incident Type

Description	Incident Category					Total
	Accident	Stall	Congestion	Police Enforcement	Maintenance Activity	
Alerts Matched in RIMS	28 (33%)	58 (67%)	-	-	-	86 (100%)
Alerts Not Matched in RIMS	40 (9%)	322 (70%)	56 (12%)	29 (6%)	15 (3%)	462 (100%)
All True Alerts	68 (12%)	380 (69%)	56 (10%)	29 (5%)	15 (3%)	548 (100%)

Findings

Based on the results of data analysis, if TrafficVision alerts were used as an incident detection source, on average 34 incidents would have been detected approximately seven minutes earlier during the evaluation period from February 2, 2016 through April 11, 2016. During this same time period, TrafficVision also detected an additional 462 stopped vehicle events that were not part of RIMS data. *These 462 stopped vehicle alerts highlight the potential to detect and manage additional incidents that are currently not being detected and logged in RIMS*. Out of the 462 alerts, 79% were stalled vehicles and incidents whereas the remaining 21% were alerts for vehicles stopped for longer than 30 seconds but not due to a stall or incident. When an alert is sent for stop and go traffic (vehicles stopped for more than 30 seconds), or a police/maintenance vehicle stopped on the shoulder or mainlanes, it is a true incident from the software accuracy perspective; however from the perspective of an operator, it is a false alert since there is no collision or stalled vehicle.

For the incidents noted in RIMS database and not detected by TrafficVision (773 incidents), it should be noted that camera views (especially the software detection zone) do not cover the entire length of the study segment and as such it is not feasible for the software to detect all incidents noted in the RIMS database. Detailed information for each of the incidents in Table 3 is included in Appendix A.

During the analysis of incident data, researchers found that once an incident gets reported to TranStar and logged into RIMS, in a majority of instances, operators will move the camera view to focus on the incident location and leave the camera view in that position till the incident is cleared. For these times when the camera is focused on the incident scene, TrafficVision software would occasionally send an alert while other times it did not. One of the explanations for this inconsistency is that when camera is moved, the new field of view (including the incident scene) is assumed to be the background image for the software and the software does not send an alert until another vehicle arrives at the scene and stops. As such if for an incident, no additional vehicle arrives after camera movement, the software does not recognize it as a stopped vehicle and no alert is sent.

3. Comparison of Incidents Recorded in RIMS, TrafficVision, and Video

Recorded video data was viewed for a representative 14 days (as shown in **Error! Reference source not found.**) to make an independent analysis of RIMS data and TrafficVision data for the following measures:

- Number of incidents detected and logged in RIMS versus actual incidents observed to occur in the camera view.
- Number of alerts detected and sent by TrafficVision versus actual incidents observed to occur in the camera view.
- Difference in detection times versus actual incident occurrence time.

Comparison of Number of Incidents Detected

This part of data analysis was completed using video from three cameras for six days in February and from four cameras for the remaining eight days for which video data were analyzed. Table 5 summarizes the results from this analysis.

Table 5. Number of Incidents Recorded in Video, RIMS, and TrafficVision for 14 Analysis Days

Date	Number of incidents associated with Eight Cameras (# 504, #509*, #513,and #514, # 211, #214, #216,and #218)			
	Recorded Video	RIMS Database	TrafficVision Stopped Vehicle Alerts	Common in RIMS and TrafficVision
Feb 10, 2016	6	1	0	0
Feb 12, 2016	22	2	4	0
Feb 13, 2016	15	3	1	0
Feb 18, 2016	19	5	4	1
Feb 22, 2016	19	9	4	1
Feb 23, 2016	21	6	5	0
Mar 10, 2016	19	11	1	1
Mar 11, 2016	15	4	0	0
Mar 16, 2016	17	7	1	0
Mar 30, 2016	17	4	2	1
Mar 31, 2016	12	5	4	3
Apr 1, 2016	23	6	3	2
Apr 4, 2016	23	10	4	1
Apr 10, 2016	17	5	2	0
Total	245	78	35	10

*Camera 509 feed was not viewable for 6 days of February.

Out of the 245 incidents detected from viewing the recorded video, 78 incidents were logged in the RIMS database and 35 incidents had TrafficVision alerts associated with them. Ten incidents were common in both RIMS database and TrafficVision Alert data, while 142 incidents (58%) found in video recordings were not detected either in RIMS or in video analytics alert data.

Differences in Incident Detection Time

Incidents detected via viewing recorded video, RIMS database, and TrafficVision alerts were further analyzed to identify any differences in detection times. Figure 9 below shows the difference in detection times for incidents detected in RIMS and for incidents detected by TrafficVision Alerts as compared to the actual incident time found via video analysis.

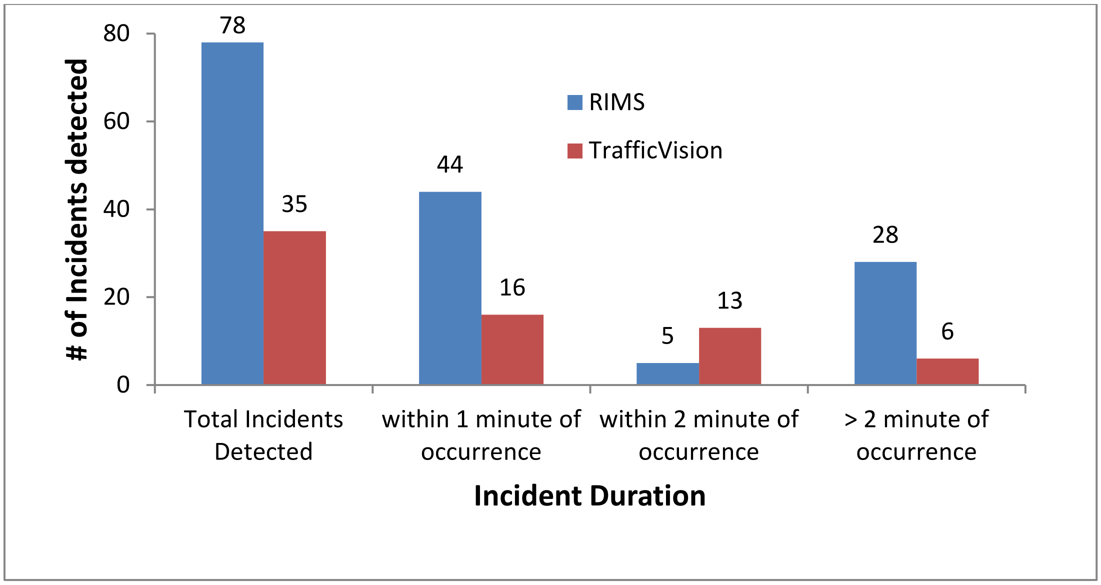


Figure 9. Detection Time for Incidents Detected in RIMS and TrafficVision

- Out of the 78 incidents noted in RIMS database, for 44 incidents (56%) the detection time was one minute or less, for five incidents (6%) the detection time was between one and two minutes, and for the remaining 28 incidents (36%) detection time on average was approximately 20 minutes. The average detection time for all of the 78 incidents was 7.25 minutes.
- For TrafficVision, 16 out 35 incidents (46%) were detected within a minute of actual occurrence, while 13 incidents (37%) were detected within two minutes of occurrence and the remaining six incidents (17%) were detected after an average of 14 minutes of incident occurrence. The average detection time for all of the 35 incidents was 2.75 minutes.
- For the 10 incidents identified common in all three data sources, the average detection time in RIMS was approximately three minutes whereas the average detection time for TrafficVision was approximately five minutes.

Incident Durations for Incidents not Detected in RIMS and TrafficVision

Incidents not found in RIMS database and TrafficVision Alert data were further analyzed to determine if short incident duration (less than one minute) might have been the reason for these incidents going unreported. The incident duration was categorized as incidents lasting less than one minute, lasting one to 10 minutes or lasting more than 10 minutes. Figure 10 shows the number of incidents not detected by both RIMS and TrafficVision for the three incident duration categories.

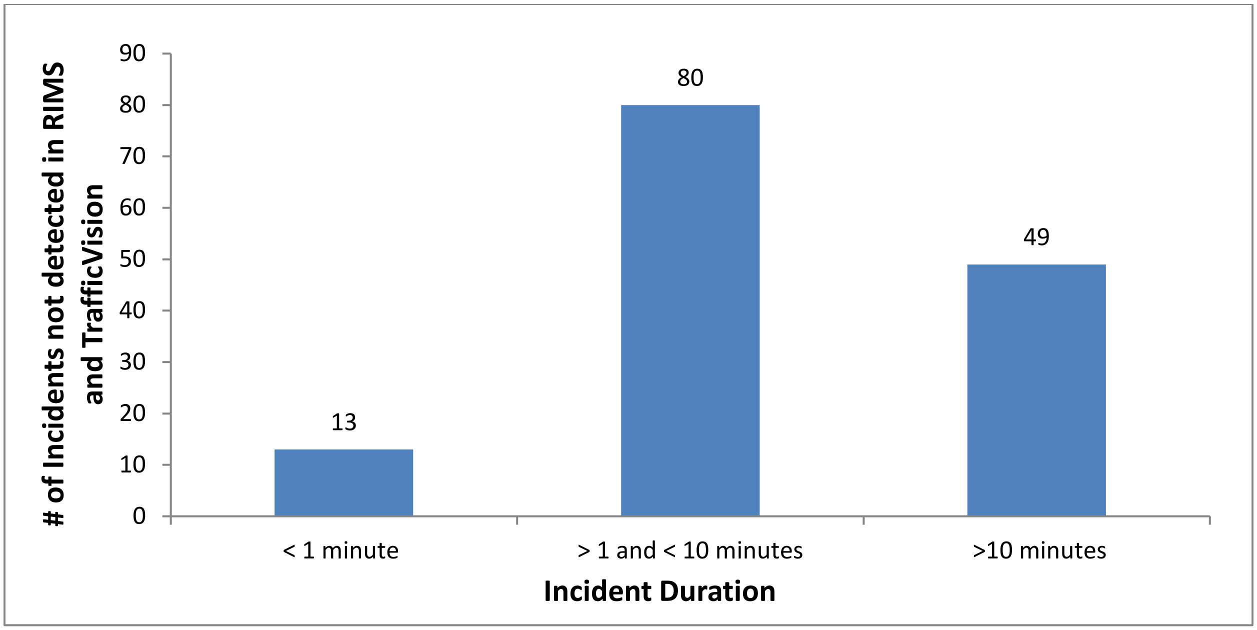


Figure 10. Incidents Not Detected in RIMS and TrafficVision versus Average Incident Duration

For the 142 incidents not reported in RIMS and found in video, 113 were stalled vehicles on the shoulders or ramp medians, 16 were accidents, and the remaining 13 were vehicles stopped by police, due to congestion, and for maintenance activities. The average incident duration for these 142 incidents was approximately 14 minutes. Table 6 shows a distribution of all incidents detected from 14 days of video data by incident type. Incident type used for Table 6 is the same as used previously for Table 4.

Table 6. Distribution of Incidents Detected in Recorded Video by Incident Type

Description	Incident Category					Total
	Accident	Stall	Congestion	Police Enforcement	Maintenance Activity	
Detected in Video Only	16 (11%)	113 (80%)	4 (3%)	7 (5%)	2(1%)	142 (100%)
Detected in Video and TrafficVision but not RIMS	3 (12%)	13 (52%)	7 (28%)	1(4%)	1 (4%)	25 (100%)
Detected in Video and TrafficVision and RIMS	4 (40%)	6 (60%)	-	-	-	10 (100%)
Detected in Video and RIMS but not TrafficVision	27 (40%)	41 (60%)	-	-	-	68 (100%)
Total	50 (20%)	173 (71%)	11 (4%)	8 (3%)	3 (1%)	245 (100%)

4. Before–After Comparison of Incident Clearance Times

Study Using 10 Incidents Common in RIMS, TrafficVision, and Video Data

The 10 incidents that were detected by both RIMS and TrafficVision were separated into a before period (February 2016) and after period (March 8 through April 11) to determine if operators' access to TrafficVision alerts allowed in early detection and faster clearance of incidents. Table 7 shows the detection and clearance times, as well as a brief description of these incidents.

Table 7. Incidents Detected in Video, RIMS Data and TrafficVision Data

Date	Incident Start Time	Incident End Time	Incident Duration	TrafficVision Detection Time	RIMS Detection Time	RIMS Clearance Time	Incident Description
02/18/16	12:00:18	12:37:34	0:37:16	12:00:27	12:12:00	12:39:00	Vehicle rear ended truck in front of it as traffic came to a stop.
02/22/16	11:07:35	11:29:03	0:21:28	11:08:56	11:12:00	11:29:00	Vehicles stopped on the shoulder because of an accident
03/10/16	20:15:25	20:35:07	0:19:42	20:26:21	20:16:00	23:52:00	Vehicle stopped on shoulder
03/30/16	13:40:36	13:53:09	0:12:33	13:41:12	13:50:00	13:53:00	Fire Trucks blocking lanes 2, 3,and 4
03/31/16	17:18:44	17:48:25	0:19:42	17:19:18	17:19:00	17:49:00	Stalled Vehicle on Shoulder
03/31/16	7:33:24	9:28:29	1:55:05	7:34:03	7:34:00	9:29:00	Stalled Vehicle on Shoulder
03/31/16	17:37:56	18:12:12	0:34:16	17:38:35	17:39:00	18:13:00	Two vehicle accident
04/01/16	6:16:03	6:46:06	0:30:03	6:32:02	6:20:00	6:47:00	Stalled Vehicle on Shoulder
04/01/16	12:16:58	12:48:31	0:31:33	12:38:26	12:17:00	12:50:00	Stalled vehicle in far left lane
04/04/16	13:22:56	13:24:16	0:01:20	13:23:30	13:23:00	13:24:00	Stalled truck on Shoulder

Before period (days from February) – Two incidents, both were detected by TrafficVision earlier than the RIMS detection time. Average incident duration is approximately 30 minutes.

After period (days from March/April) – A total of eight incidents were common in both RIMS and alert data; four were detected by TrafficVision at the same time as the detection time in RIMS, one was detected earlier and three were detected later. For the incidents that were detected at the same time by both RIMS and TrafficVision, incident duration varied from one minute to one hour and 55 minutes, thus it is difficult to draw any conclusions from this data. For the one incident that was detected earlier by TrafficVision, since fire trucks were already on the scene, the actual incident (not seen in the video) had already been responded to. Three incidents were detected later than the incident detection time in RIMS even though these incidents were in camera view. The average clearance time for the eight incidents was approximately 33 minutes. Due to the different nature of incidents, small sample size, and no information if TrafficVision alerts were used to detect these incidents, it is difficult to draw any conclusions.

Comparison of Incident Clearance Times for Incidents of Type Stall

In an effort to reduce the variables associated with clearing an incident, Researchers completed another before-after comparison of incident clearance times for incidents that were noted as stalls on the shoulder lane and were not taking up any other travel lanes. This comparison was made for incidents that were identified as common in RIMS and TrafficVision data either using engineering judgement or using the recorded video. Table 8 shows the before-after comparison for stall incidents that were noted in RIMS as detected by TrafficVision and Table 9 shows this comparison for stall incidents that were not noted as detected by TrafficVision.

Table 8. Before-After Clearance Times for Stall Incidents and TrafficVision Detected

Study period	Noted in RIMS as TrafficVision Detected	Date	TrafficVision Alert Time	RIMS Detection Time	Clearance Time	Incident Duration	Average Incident Duration Time
Before	No	2/18/2016	12:49:08	12:58:00	13:33:00	0:35:00	0:41:48
		2/19/2016	15:50:17	15:54:00	15:57:00	0:03:00	
		2/23/2016	18:33:29	18:33:00	19:19:00	0:46:00	
		2/27/2016	5:21:50	5:08:00	7:10:00	2:02:00	
		2/29/2016	2:28:35	2:27:00	2:30:00	0:03:00	
After	Yes	3/7/2016	13:45:09	13:45:00	13:48:00	0:03:00	0:17:30
		3/14/2016	14:11:17	14:11:00	14:15:00	0:04:00	
		3/17/2016	10:33:53	10:34:00	10:37:00	0:03:00	
		3/17/2016	16:11:26	16:12:00	16:25:00	0:13:00	
		3/21/2016	13:25:03	13:25:00	13:45:00	0:20:00	
		3/21/2016	13:44:26	13:45:00	15:11:00	1:26:00	
		3/24/2016	16:38:13	16:39:00	16:46:00	0:07:00	
		3/31/2016	14:04:33	14:05:00	14:55:00	0:50:00	
		4/1/2016	9:28:21	9:30:00	9:48:00	0:18:00	
		4/7/2016	16:51:58	16:51:00	17:05:00	0:14:00	
		4/8/2016	11:58:10	11:57:00	11:58:00	0:01:00	
		4/11/2016	10:55:39	10:56:00	11:14:00	0:18:00	
		4/11/2016	11:33:15	11:33:00	11:37:00	0:04:00	
		4/11/2016	15:51:29	15:51:00	15:55:00	0:04:00	

Table 9. Before-After Clearance Times for Stall Incidents with No TrafficVision Detection

Study period	Noted in RIMS as TrafficVision Detected	Date	TrafficVision Alert Time	RIMS Detection Time	Clearance Time	Incident Duration	Average Incident Duration Time
Before	No	2/18/2016	12:49:08	12:58:00	13:33:00	0:35:00	0:41:48
		2/19/2016	15:50:17	15:54:00	15:57:00	0:03:00	
		2/23/2016	18:33:29	18:33:00	19:19:00	0:46:00	
		2/27/2016	5:21:50	5:08:00	7:10:00	2:02:00	
		2/29/2016	2:28:35	2:27:00	2:30:00	0:03:00	
After	No	3/10/2016	20:26:21	20:16:00	23:52:00	3:36:00	0:40:43
		3/23/2016	15:09:16	15:09:00	15:14:00	0:05:00	
		3/25/2016	15:52:39	16:26:00	17:05:00	0:39:00	
		3/28/2016	9:26:15	9:31:00	9:53:00	0:22:00	
		3/30/2016	3:41:46	3:37:00	4:02:00	0:25:00	
		3/30/2016	2:39:50	2:44:00	2:51:00	0:07:00	
		3/31/2016	17:29:12	17:30:00	18:22:00	0:52:00	
		4/1/2016	6:32:02	6:20:00	6:47:00	0:27:00	
		4/1/2016	12:39:36	12:58:00	13:07:00	0:09:00	
		4/2/2016	2:17:54	1:57:00	2:43:00	0:46:00	
		4/4/2016	13:53:57	13:25:00	14:05:00	0:40:00	
		4/5/2016	18:44:38	18:33:00	19:34:00	1:01:00	
		4/7/2016	16:48:29	16:49:00	17:07:00	0:18:00	
		4/9/2016	1:41:28	1:39:00	1:42:00	0:03:00	

A look at average incident duration time suggests that for stalls that were noted as reported by TrafficVision, the incident duration was significantly lower than the duration for incidents that were not reported in RIMS as TrafficVision detected. However, a closer look at the data shows two stall incidents with very high duration (3:36:00 and 2:02:00) that is skewing the average incident duration time for incidents that were not noted in RIMS as detected by TrafficVision Alerts. Using engineering judgement, researchers decided to remove incidents with clearance times of more than one hour from the before and after data and the resulting average clearance times are shown in Table 10.

Table 10. Average Clearance Times for Stall Incidents After removing Outliers

Study Period	TrafficVision used as Detection Source	Number of Incidents	Average Clearance Time
Before	No	4	0:21:45
After	Yes	13	0:12:14
After	Unknown	12	0:24:25

The average clearance time is significantly less for stalled vehicles that were noted as TrafficVision detected in comparison to stall vehicle incidents that were not noted as TrafficVision detected. Even though due to the small number of stalls in the before period (4) as compared to in the after period (13), it is difficult to draw any definitive conclusions, but results suggest that the clearance times for stalled vehicles might be reduced with early detection using video analytics (TrafficVision in this case). In addition to small sample size, each incident is different and requires a different response. For example, six of the 13 incidents that were detected by TrafficVision lasted less than five minutes and required no tow, thus reducing the average clearance time.

5. Evaluation of TrafficVision Collected Data

The software's ability to collect accurate speed data was not evaluated since speed data from another independent source at the same location as the camera view was not available. However, a sample of the volume data collected via the TrafficVision software were compared with the manual counts completed using video data collected for one of the cameras. The sample volume data for comparison with manually counted video data were chosen for Camera 218 located at IH 45 North and Tidwell Road for February 14, 2016 when the camera operation mode was automatic preset mode. In addition, the TrafficVision software collects data only when the camera field of view is in the preset calibrated view, as such the volume comparison was made only for the selected 15-minute time periods when the camera field of view was in preset calibrated view and the camera was not moved during that 15-minute time period.

Table 11 and Table 12 show the volumes collected by TrafficVision software and volumes from manual counts using video data for the near side and far side of freeway mainlanes respectively. Looking at the two volume counts, it can be seen that for all 40 of the 15-minute time periods for which the video counts were completed , volumes provided by TrafficVision for travel direction 1 (near side) were on average 58% less than the volumes counted from the recorded video. The difference was even more pronounced for volume data in the other direction where the volumes provided by TrafficVision were 99% less than the volumes counted from the recorded video.

Table 11. Comparison of Volume Data from Software and Video Counts for February 14, 2016, Camera 218 – Near Side Only

Sample Interval Start	Near Side Volume from		Change	Percent Change	Sample Interval Start	Near Side Volume from		Change	Percent Change
	Software	Video				Software	Video		
5:30 am	161	481	320	67%	11:30 am	864	2597	1733	67%
6:30 am	281	622	341	55%	12:30 pm	950	1581	631	40%
6:45 am	257	610	353	58%	12:45 pm	1024	1628	604	37%
7:00 am	135	579	444	77%	1:00 pm	1097	1801	704	39%
7:15 am	142	669	527	79%	1:15 pm	1219	1819	600	33%
7:30 am	181	859	678	79%	1:30 pm	1204	1834	630	34%
7:45 am	179	993	814	82%	1:45 pm	1427	1813	386	21%
8:00 am	158	859	701	82%	5:15 pm	850	1829	979	54%
8:15 am	226	983	757	77%	6:00 pm	810	1659	849	51%
8:30 am	253	1127	874	78%	6:30 pm	1065	1678	613	37%
8:45 am	246	1166	920	79%	8:00 pm	582	1282	700	55%
9:00 am	270	1185	915	77%	8:15 pm	509	1304	795	61%
9:15 am	386	1309	923	71%	10:30 pm	302	805	503	62%
9:30 am	443	1396	953	68%	10:45 pm	323	713	390	55%
9:45 am	359	1241	882	71%	11:00 pm	268	659	391	59%
10:00 am	412	1410	998	71%	11:15 pm	309	621	312	50%
10:45 am	682	2041	1359	67%	11:30 pm	292	607	315	52%
11:00 am	546	1745	1199	69%	11:45 pm	294	525	231	44%
11:15 am	592	1994	1402	70%					
Total (9.25 hours)	19298	46024	26726	58%					

Table 12. Comparison of Volume Data from Software and Video Counts for February 14, 2016, Camera 218 – Far Side Only

Sample Interval Start	Near Side Volume from		Change	Percent Change	Sample Interval Start	Near Side Volume from		Change	Percent Change
	Software	Video				Software	Video		
5:30 am	7	316	309	98%	11:30 am	26	1807	1781	99%
6:30 am	4	472	468	99%	12:30 pm	17	1387	1370	99%
6:45 am	3	423	420	99%	12:45 pm	16	1295	1279	99%
7:00 am	5	502	497	99%	1:00 pm	22	1353	1331	98%
7:15 am	1	559	558	100%	1:15 pm	20	1311	1291	98%
7:30 am	6	626	620	99%	1:30 pm	6	1354	1348	100%
7:45 am	4	678	674	99%	1:45 pm	14	1436	1422	99%
8:00 am	11	642	631	98%	5:15 pm	22	1580	1558	99%
8:15 am	3	700	697	100%	6:00 pm	11	1657	1646	99%
8:30 am	4	739	735	99%	6:30 pm	42	1765	1723	98%
8:45 am	9	838	829	99%	8:00 pm	27	1549	1522	98%
9:00 am	4	829	825	100%	8:15 pm	24	1391	1367	98%
9:15 am	10	946	936	99%	10:30 pm	17	959	942	98%
9:30 am	5	970	965	99%	10:45 pm	15	861	846	98%
9:45 am	6	914	908	99%	11:00 pm	18	837	819	98%
10:00 am	25	954	929	97%	11:15 pm	10	813	803	99%
10:45 am	24	1573	1549	98%	11:30 pm	10	637	627	98%
11:00 am	20	1303	1283	98%	11:45 pm	20	612	592	97%
11:15 am	16	1697	1681	99%					
Total (9.25 hours)	504	38285	37781	99%					

Findings

The vehicle counts collected by the software (with camera on calibrated preset view and remaining in that view) for the sample time period were 58% less than the vehicle counts from recorded video data. It does not appear that lighting (day or night) conditions have any impact on the accuracy of vehicle counting. Unless adjustments are made in the video analytics process, this initial sampling and analysis suggests that count data collected by the software may not be useful for planning or operational analysis of the corridor.

6. Documentation of TranStar Freeway Incident Management and Operations Staff Experience in Use of TrafficVision Software

TranStar freeway incident management and operations staff works 24 hours per day, seven days per week, to monitor freeway operations and incidents in an effort to detect and manage all freeway incidents as quickly and efficiently as possible. TranStar's incident management program staff consists of multiple agencies, including TxDOT's freeway operations staff, Harris County's Motorist Assistance Program staff, City of Houston's SAFEClear Program staff, and Houston Metro Police Department staff, among others. Each agency has workstations on the TranStar floor where the real-time video feed from CCTV cameras deployed along freeway corridors in greater Houston area can be viewed on their personal workstation monitors as well as on the wall screens. Each staff member (usually known as an operator) has access to change (pan, tilt, and/or zoom) CCTV views in order to detect, verify, and monitor incidents. At the start of the TrafficVision pilot demonstration, 28 operators (16 from TxDOT, seven from SAFEClear, and 5 from Motorist Assistance Program) were selected to participate in the pilot demonstration.

TrafficVision Training to Operators

After a four-week before period (February 2 through February 29 – where the TrafficVision system was installed and running, but not available to operators), TrafficVision alert thumbnails were installed on operator's workstations on March 2 and a formal training was provided to a subset of operators and floor supervisors from each agency. Since floor operators' work schedule is shift based, it was logistically not feasible to provide formal training to all operators, however it was requested that floor supervisors and operators participating in the training impart this knowledge to other operators. For this purpose, a two-week period was set aside as operator training/software introduction period and all operators were requested that they make themselves familiar with the use of software during this two week time period.

Staff Usage and Experience Assessment

To assess staff experience in use of TrafficVision alerts for detecting incidents, researchers developed a questionnaire to ask the operators about system use. Researchers subsequently found that only 23 operators (15 from TxDOT, 5 from SAFEClear, 3 from Motorist Assistance Program) used the software during the pilot. The three supervisors (one for each agency) were also introduced to the software who are not responsible for detecting incidents and entering those into the RIMS, as such were not using the software on a routine basis.

In the last week of the pilot demonstration period, researchers used face-to-face, phone, and email communications with operators to get their feedback using the Operator Questionnaire as a guide. Researchers received 15 responses from TxDOT staff (one staff member was off duty for the entire time period), two complete questionnaires and two narrative email responses from SAFEClear staff (only five of them used the software), and one narrative email feedback from Motorist Assistance Program staff (three operators were identified as having the software on their workstations). Researchers contacted the three supervisors to get their feedback on the demo project and received a response only from the TxDOT Freeway Operations Supervisor. Below is a summary of responses to the questionnaire that was completed by 16 operators.

1. Question 1: Do you have the thumbnails on your desktop?
   Response Summary: All 17 operators had thumbnails on their desktop.
2. Question 2: Do you have to login every day to have the thumbnails on your computer screen?
   Response: Yes
3. Question 3: If yes to Question 2, have you been able to do that every day as soon as you start your shift or do you sometimes remember it later on in the day?
   Response: Fourteen out of the 17 operators responded yes, three operators said sometimes remember it later in the day.
4. Question 4: Were you informed about the purpose of this software?
   Response: Sixteen out of 17 operators knew the purpose of this software, one said training would have helped.

5. Question 5: Did you understand what the alerts mean?
   Response: Fifteen of the 17 operators who completed the questionnaire responded yes, two responded maybe.
6. Question 6: Do you zoom into the camera view when you receive an alert to see if there is a stall or an incident that requires you to dispatch an officer or take some other action?
   Response: Eight operators responded yes, while three operators had discontinued use after the first couple of weeks, one person needed more training, and remaining five operators were non-committal about whether they zoomed in the camera view to verify incidents based on alerts.
7. Question 7: Have you detected any incidents using the alerts?
   Response: Seven out of 17 operators responded yes.
8. Question 8: If yes, how many incidents have you detected using the software?
   Response: Seven operators who had detected incidents using TrafficVision Alerts reported to have detected a total of 36 incidents using alerts.
9. Question 9: Do you record in the RIMS if the incident was detected via TrafficVision alert?
   Response: Four operators had recorded incidents in RIMS as having detected by TrafficVision; however, there was no specific option in the database for recording TrafficVision as the source of detection as such operators used automated detection as the option, which is also used for AVI detected incidents.
10. Question 10: Does getting the alerts make it easier to detect incidents?
    Response: Eleven out of 17 operators said it does not make it any easier, three operators said it makes no difference, and other three said it makes it easier; however, accuracy of alert is the issue.
11. Question 11: Does getting the alerts make it faster to detect incidents?
    Response: None of the operators responded positive to this question and instead said that they have already identified the incident by the time an alert is received.

In addition to the formal survey feedback, following provides a summary of general operator feedback regarding the pilot integration of TrafficVision software:

- The software is more apt in detecting congestion issues and stalls on shoulders than actual incidents in the mainlanes of traffic.
- The current cameras have drift, which means the preset on the camera itself is not the same as when the preset was selected in the software. This requires resetting the presets every three days or so and this is a very time consuming process.
- TrafficVision has issues detecting incidents when cameras are not on the preset view. Since many people have permissions to move cameras, the TxDOT operators had to continuously monitor these camera views and move them back to presets every few hours to ensure that the cameras will stay on the same exact preset view at least 80% of the time. This was considered a negative experience by the operators that took away from other duties.
- Morning rush hour detection of incidents was found to be lacking and lighting may be affecting the software’s ability to detect incidents.

- The software helped operators find a few incidents by detecting congestion and operators tracking down the incident from that alert. The software also helped detect a few stalls. However, operators felt that with the current CCTV camera setup, the software does not reduce detection time nor does it assist in locating more incidents than the operators find using a variety of other tools. These tools are:
  - Real-Time Video Feed from CCTV Cameras.
  - TranStar's Speed Map.
  - Motorist Assistance Program Radio.
  - HPD Radio.
  - HFD Fire Screen.
  - Citizen's Calls.
  - Google's Waze Application (only two operators reported using this tool).

TxDOT Traffic Operations Supervisor's feedback highlighted the fact that since TranStar cameras do not maintain their preset views, the software is picking up vehicles parked in the parking lots and stopped on driveways and intersections (increasing what would be considered false positives), thus proving to be not very effective in detecting actual incidents. It was also mentioned that TranStar CCTV cameras are difficult to keep on calibrated preset view for two reasons: 1) cameras have an inherent drift that changes the preset view to a different view overtime, and 2) a large number of users (449) have suitable level of permissions to move the cameras that makes it difficult to keep the cameras in a preset view. The overall operator perspective, considering the camera view set up limitations at TranStar, was that this software could be useful (operators could recognize the utility), but was not found very useful in detecting incidents during the pilot test.

Findings from Operator and Supervisor Feedback

- The software is somewhat useful in detecting congestion issues and stalls on shoulders. However, with the current CCTV camera setup during the pilot test, the software does not reduce detection time nor does it assist in locating more incidents than the operators find using a variety of other tools that they already have. These tools include
  - Real-Time Video Feed from CCTV Cameras.
  - TranStar's AVI Speed Map.
  - Motorist Assistance Program Radio.
  - HPD Radio.
  - HFD Fire Screen.
  - Citizen's Calls.
  - Google's Waze Application (only two operators reported using this tool).
- Operators felt that keeping cameras on preset views was a time consuming process.
- Seven operators who used the tool identified 36 incidents using alerts (not all of these incidents were noted in RIMS as detected using TrafficVision), however none of the operators thought TrafficVision alerts helped with quicker incident detection.

7. Additional Observations from Analysis of Alerts

In addition to analyzing the 974-stopped vehicle alerts from the perspective of evaluation goals, researchers made some additional observations that may be useful. Following are two examples that highlight: 1) how a congestion alert can help track an actual incident thereby reducing the detection time when incident is not in the camera view, and 2) when an incident occurred in the camera view (on preset) is not detected while another camera detects the congestion for the same incident can lower user trust in the software.

Example 1. Figure 11 below shows view from camera 212 that sent a false alert for stopped vehicle when it is just stop and go traffic, however this stop and go traffic is due to an incident downstream (see Figure 12) that is detected by moving the camera in the next minute or so.

Figure 11. Camera 212 View at Time 8:47:20 – Stop and Go Traffic (Alert Sent)

Figure 12. Camera 212 View at Time 8:48:30 – Incident Detected That Caused the Previous Alert

Example 2. Figure 13 and Figure 14 (different time stamp, same camera) show an incident that is in the camera view and camera field of view is on preset as per the software log, but no alert. Figure 15 shows a camera view from Camera 213 that sent a stopped vehicle alert for vehicles stopped/slowed due to congestion. The congestion was the result of the incident downstream seen on Camera 214 for which Camera 214 never sent the alert.

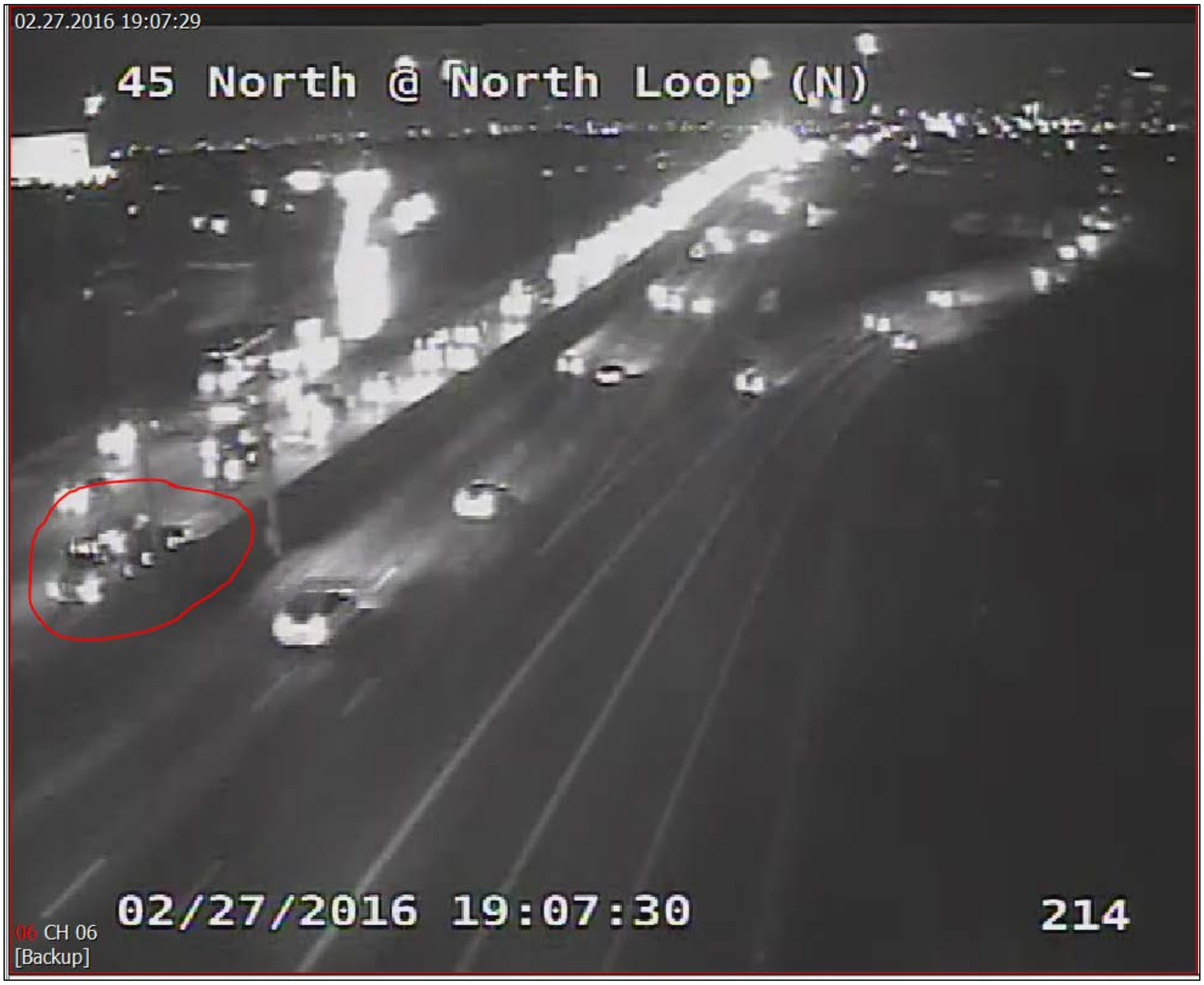


Figure 13. Camera 214 at 19:07:30 with Incident in Camera View (No Alert) – Preset View

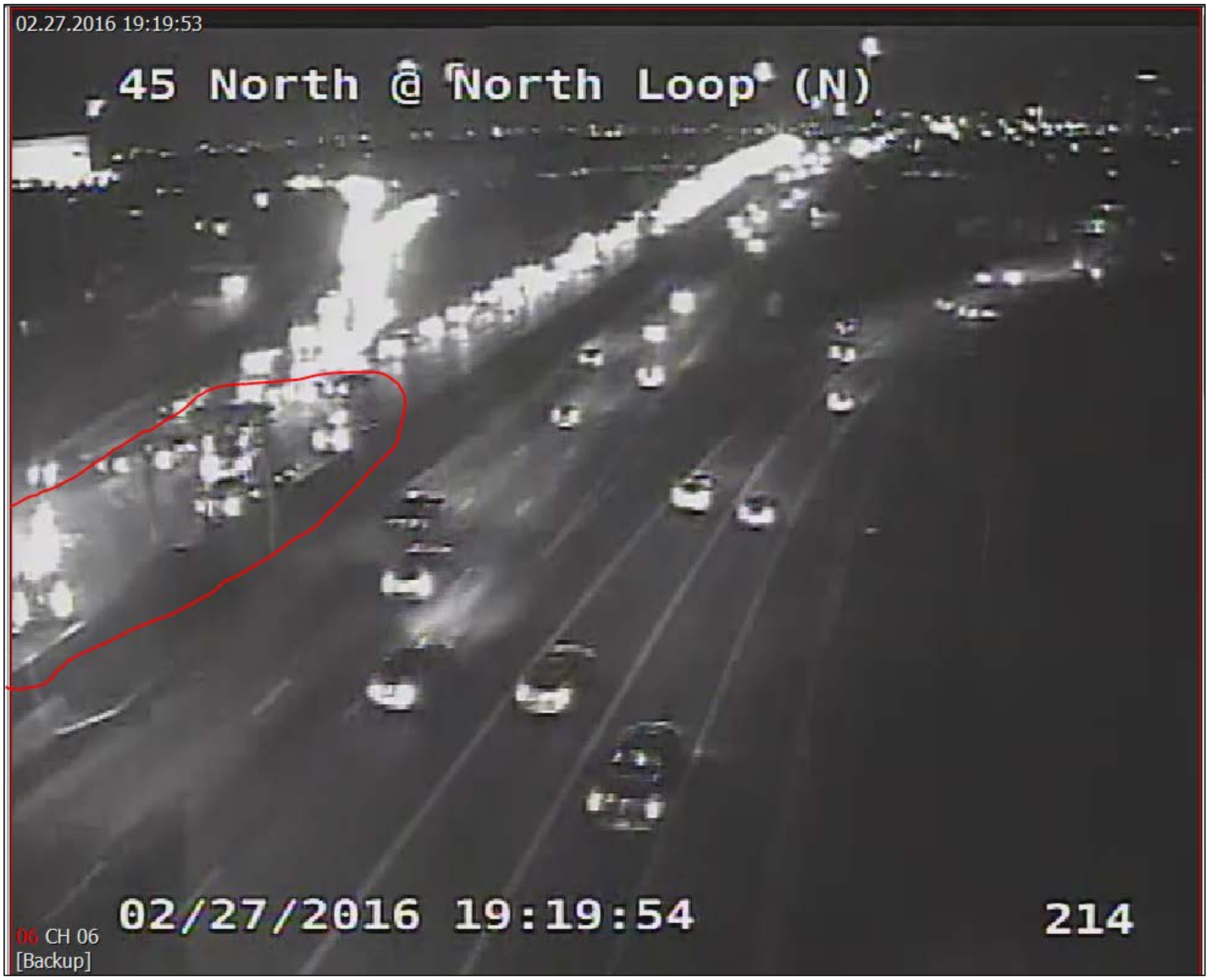


Figure 14. Camera 214 at 19:07:30 with Incident in Camera View with Police on Scene (Still No Alert)

Figure 15. Camera 213 view at 19:19:18 – Alert for Stopped Vehicle Due to Congestion (Result of Incident seen in Camera 214)

SUMMARY OF FINDINGS

This evaluation was completed using existing pan/tilt/zoom (PTZ) cameras that do not stay in their preset calibrated views. The camera settings such as shutter speed, frame bit rate, lens zoom were also not optimized for use with the software. As such, researchers suggest that findings from this evaluation should be viewed with some reservation since software was not being used under optimal conditions to provide best possible performance measures during the pilot test.

Software Accuracy

- Overall, the software sent a total of 974 stopped vehicle alerts, out of which 56% were for vehicles stopped in the freeway travel lanes, shoulders, HOV lanes and medians (helpful for incident detection), 20% were for vehicles stopped for traffic signals on the frontage road and cross street, and 24% alerts were false.
- Out of the 230 stopped vehicle false alerts, 21% alerts showed no vehicle present while the other 79% were for vehicles that stopped for less than 26 seconds (threshold was set at 30 seconds).

- Data analysis did not show any significant differences in percent of true alerts based on calibrated preset views but it did appear to lessen the number of alerts for vehicles stopped for traffic signals on the frontage road and cross street (this was expected).
- The total number of alerts received during the dynamic preset mode (five weeks) was approximately three times the total number of alerts received during the automatic preset mode (five weeks). The percent of false alerts during both modes was approximately the same (23%).
- Data analysis showed some effect of lighting conditions on number of alerts for the morning peak hours especially for cameras on US 59 data.

Comparison of TrafficVision and RIMS Data

- During the pilot period, the RIMS database logged 859 incidents. TrafficVision video analytics software sent alerts for 548 incidents that included 86 incidents logged in the RIMS database. As such it stands to reason that if TrafficVision video analytics alerts were used as an additional incident detection source, an additional 462 stopped vehicle events (all of the 462 alerts are not incidents as it includes alerts for stop and go traffic as well as repeat alerts for the same incident) would have been detected. Furthermore, data analysis showed that average detection time for 34 incidents would have been approximately seven minutes less and for 32 incidents 14 minutes more than that noted in RIMS.

Comparison of RIMS, TrafficVision, and Recorded Video Data

Fourteen days of recorded video data from selected cameras were viewed to identify and compare detection rates and detection times for RIMS data as well as TrafficVision alert data. The following are findings from this analysis:

- For the 14 days of data analysis period, out of the 245 incidents detected from viewing the recorded video, 78 incidents (32%) were logged in the RIMS database and 35 incidents (14%) had TrafficVision alerts associated with them. Ten incidents were common in both RIMS database and TrafficVision Alert data, while 142 incidents (58%) found in video recordings were not detected either in RIMS or in video analytics alert data. For the 142 incidents not reported in RIMS and found in video, 113 were stalled vehicles on the shoulders or ramp medians, 16 were accidents, and the remaining 13 were vehicles stopped by police, due to congestion, and for maintenance activities. The average incident duration for these 142 incidents was approximately 14 minutes.
- The incident duration for incidents not detected in RIMS and TrafficVision alerts varied from less than 1 minute to more than 10 minutes while the average duration for these incidents was approximately 14 minutes.
- The average detection time for the 78 incidents logged in RIMS was 7.25 minutes while for the 35 incidents detected by TrafficVision was 2.75 minutes. For the 10 incidents identified common in all three data sources, the average detection time in RIMS was approximately three minutes whereas the average detection time for TrafficVision was approximately five minutes.

Accuracy of Vehicle Counts Data Collected

- Vehicle counts collected by the software (camera on calibrated preset view and stayed in that view) for the sample time period were 58% less than the vehicle counts from recorded video data. This suggests that count data collected by the software as conducted in the pilot test will not be useful for planning or operational analysis of the corridor.

Operator and Supervisor Feedback

- Currently all of the TranStar CCTV cameras have a PTZ (pan, tilt, and zoom) function and experiences drift that affects the TrafficVision software's performance and requires operators to continuously reset and move the camera views back on the preset views.
- The software is somewhat useful in detecting congestion issues and stalls on shoulders. However with the current CCTV camera setup, the software does not reduce detection time nor does it assist in locating more incidents than the operators find using a variety of other tools including motorist calls, AVI speed map, HPD radio, real-time video feed from CCTV cameras, HPD fire screen, and Google's Waze application (not an official tool).
- Operators felt that keeping cameras on preset views was a time consuming process. It is possible that if operators were not tasked with moving the cameras back to preset views continuously, their experience might have been somewhat different.
- Some operators brought up the fact that software will send an alert due to congestion but miss an incident that is in camera view. The additional findings section of the report shows an example of this. These types of occurrence though not common have the tendency to lower operator confidence in the usefulness of the software.

Before-After Comparison of Clearance Times

- Researchers performed a sample Before-After study (using only stall vehicle incidents) to identify difference in incident duration based on use of TrafficVision alerts. Though due to the small sample size and variability in characteristics of each incident, the results are not definitive, yet these results show a reduction in clearance times when TrafficVision alerts were reported as the detection source for stall vehicles. On average clearance times in the after period for stall vehicles that were noted as detected by TrafficVision were 9.5 minutes less as compared to clearance times for stall vehicles in the before period.

Other Findings

- During analysis of data, researchers found that once an incident is reported to TranStar operators, staff would move the camera view to focus on the incident location and leave the camera view in that position until the incident is cleared. For these times when the camera is focused on the incident scene, TrafficVision software is inconsistent on whether an alert will be sent. As per vendor's explanation, software considers new field of view (with incident already in the view) as a background image and only sends the alert if another vehicle arrives and stops at the incident scene after the camera has been moved. Despite the logical explanation, floor operators see it as a flaw in the software's ability to detect incidents.

RECOMMENDATIONS

This evaluation was completed using existing PTZ cameras that do not stay in their preset calibrated views as a prerequisite for a video analytics pilot test. The optimal video analytics setup is with a dedicated camera with fixed view. One of the unique aspects of the TrafficVision system is the purported ability to detect incidents *actively* or with cameras without fixed views. Conversations with operators and supervisors highlighted the importance of keeping camera views on preset calibrated views and the difficulty associated with maintaining preset views for PTZ cameras due to inherent and unexplained *drift* in the cameras. Data analysis suggests that video analytics is an incident detection tool that has the potential to increase the number of incidents detected (especially stalled vehicles) even when used with PTZ cameras. The software had mixed results in detection times; some incidents were detected earlier than that noted in RIMS while others were detected later than that noted in RIMS. However, the software was also found lacking in detecting incidents that were detected by moving the camera but then stayed as active incidents for over 15 minutes in the camera view. As such, researchers recommend evaluating the software with a set number of fixed cameras such that fixed views will cover the entire length of study segment along a corridor. A candidate corridor could be on IH 610 (West Loop) northbound on approach to US 59.

It is also recommended that if TxDOT decides to integrate the video analytics software with fixed cameras, only a subset of the operators with proper training should be included in an analysis of that deployment (this would be a pilot study phase 2). During conversations with operators, it was clear that some operators did not have complete understanding of the alerts despite a formal training. It is recommended that operators be asked to volunteer for the use of this tool especially during the evaluation period. In addition, researchers recommend evaluating changes to the operator workload if video analytics were provided as an additional incident detection tool (clearing false alerts and alerts for stopped vehicles but not incidents as well as keeping cameras on preset views and entering).

Researchers also recommend that the software vendor should identify reasons for incidents not being detected in the camera's view even after being in the camera's view for over 15 minutes and develop suitable solutions for this issue. In addition, the software vendor should find solutions for alerts that were sent for vehicles stopping less than 30 seconds (threshold set in the software), which contributed to over 79% of all false alerts.

For the Pilot demonstration, the threshold for triggering stopped vehicle alert was left at default setting of 30 seconds, which in retrospect was found to be too short for the study corridors especially during peak periods. For future pilots or implementation, researchers recommend conducting a sensitivity analysis to select the optimum threshold value for stopped vehicle alerts based on local traffic conditions.

APPENDIX A

Table A1. TrafficVision Detected Incidents with Earlier or Same Detection Time as RIMS

Date	Detection Time		Difference in Detection Time	Noted in RIMS as TrafficVision Detected	Camera Preset
	RIMS	TrafficVision			
2/16/2016	15:03:00	14:58:11	0:04:49	No	On Preset
2/18/2016	12:58:00	12:49:08	0:08:52	No	Near Preset
2/18/2016	12:12:00	12:00:27	0:11:33	No	Near Preset
2/19/2016	14:29:00	14:27:33	0:01:27	No	Off Preset
2/19/2016	15:54:00	15:50:17	0:03:43	No	On Preset
2/22/2016	11:12:00	11:08:56	0:03:04	No	Off Preset
2/23/2016	13:51:00	13:50:08	0:00:52	No	Near Preset
2/26/2016	7:19:00	6:59:08	0:19:52	No	Near Preset
3/1/2016	17:06:00	16:56:12	0:09:48	No	On Preset
3/4/2016	8:34:00	8:28:48	0:05:12	No	On Preset
3/19/2016	22:42:00	22:30:05	0:11:55	No	Off Preset
3/25/2016	17:37:00	17:18:33	0:18:27	No	Near Preset
3/29/2016	10:26:00	10:10:15	0:15:45	No	Near Preset
3/31/2016	7:34:00	7:34:03	0:00:03*	No	Off Preset
3/31/2016	17:30:00	17:29:12	0:00:48	No	Near Preset
3/31/2016	17:39:00	17:38:35	0:00:25*	No	Near Preset
4/1/2016	12:58:00	12:39:36	0:18:24	No	Near Preset
4/4/2016	15:36:00	15:32:27	0:03:33	No	Near Preset
4/7/2016	16:49:00	16:48:29	0:00:31*	No	Near Preset
4/8/2016	15:40:00	15:33:09	0:06:51	No	On Preset
4/10/2016	16:38:00	16:37:39	0:00:21*	No	Near Preset
2/7/2016	15:50:00	15:40:50	0:09:10	No	On Preset
2/9/2016	23:17:00	23:09:54	0:07:06	No	On Preset
2/16/2016	5:57:00	5:52:52	0:04:08	No	Off Preset
2/23/2016	18:33:00	18:33:29	0:00:29*	No	Near Preset
2/29/2016	6:41:00	6:31:13	0:09:47	No	Off Preset
3/23/2016	8:49:00	8:47:34	0:01:26	No	Off Preset
3/23/2016	15:09:00	15:09:16	0:00:16*	No	Near Preset
3/25/2016	16:26:00	15:52:39	0:33:21	No	Near Preset
3/28/2016	9:31:00	9:26:15	0:04:45	No	On Preset
3/30/2016	2:44:00	2:39:50	0:04:10	No	Near Preset
3/30/2016	13:50:00	13:41:12	0:08:48	No	On Preset
4/7/2016	14:19:00	14:19:22	0:00:22*	No	Near Preset
4/9/2016	2:51:00	2:32:57	0:18:03	No	On Preset

*Difference in detection time likely due to different formats for recording data in RIMS and TrafficVision.

Table A2. TrafficVision Detected Incidents with Detection Time Later than RIMS

Date	Detection Time		Difference in Detection Time	Incident in Camera View when Occurred	Camera Preset
	RIMS	TrafficVision			
2/19/2016	13:44:00	14:18:38	0:34:38	Yes	Near Preset
2/21/2016	15:53:00	16:04:15	0:11:15	No Video	Near Preset
2/22/2016	6:03:00	6:21:10	0:18:10	No Video	Near Preset
2/23/2016	16:38:00	16:59:04	0:21:04	No Video	Near Preset
2/25/2016	19:40:00	19:44:39	0:04:39	No Video	Near Preset
2/27/2016	5:08:00	5:21:50	0:13:50	No Video	Near Preset
2/29/2016	2:27:00	2:28:35	0:01:35	No Video	On Preset
3/1/2016	0:19:00	0:22:28	0:03:28	No Video	Near Preset
3/24/2016	6:15:00	6:32:23	0:17:23	not until 6:31:50	Near Preset
3/30/2016	3:37:00	3:41:46	0:04:46	No Video	Near Preset
4/1/2016	6:20:00	6:32:02	0:12:02	not until 6:20:00	Near Preset
4/1/2016	12:17:00	12:38:26	0:21:26	not until 12:17:00	Near Preset
4/1/2016	18:28:00	18:32:27	0:04:27	No Video	Near Preset
4/2/2016	1:57:00	2:17:54	0:20:54	Yes	Near Preset
4/2/2016	14:11:00	14:40:58	0:29:58	No Video	Near Preset
4/6/2016	5:24:00	5:27:28	0:03:28	No Video	Off Preset
4/11/2016	2:42:00	3:08:07	0:26:07	not until 2:42:00	Off Preset
2/17/2016	14:05:00	14:08:57	0:03:57	No	Off Preset
2/22/2016	7:04:00	7:13:00	0:09:00	No	Off Preset
3/1/2016	13:54:00	14:38:58	0:44:58	No	Off Preset
3/1/2016	17:33:00	18:05:58	0:32:58	No	Off Preset
3/10/2016	20:16:00	20:26:21	0:10:21	No	Off Preset
3/14/2016	5:40:00	5:52:49	0:12:49	Yes	On Preset
3/25/2016	10:11:00	10:24:33	0:13:33	No	Near Preset
3/27/2016	14:14:00	14:21:19	0:07:19	No	Near Preset
3/29/2016	19:56:00	20:28:44	0:32:44	No	On Preset
4/3/2016	12:38:00	12:44:25	0:06:25	No	Near Preset
4/4/2016	2:50:00	2:51:38	0:01:38	No	Near Preset
4/4/2016	13:25:00	13:53:57	0:28:57	No	Near Preset
4/5/2016	18:33:00	18:44:38	0:11:38	No	Near Preset
4/8/2016	14:29:00	14:40:14	0:11:14	No	Near Preset
4/9/2016	1:39:00	1:41:28	0:02:28	No	On Preset

APPENDIX B

TrafficVision Software Catalog as was used for the pilot demonstration, some features might change in the future versions.

Technical Product Description: TrafficVisionTMC

Summary of technical functionality and support for the TrafficVisionTMC product

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Technical Product Description: TrafficVisionTMC

Table of Contents

1.0 Overview

This document provides technical details about the TrafficVisionTMC product.

1.1 Summary

The solution provides real-time and recorded-video analytic TrafficVision technology on a 1U rack-mounted platform. Each TrafficVisionTMC unit can be enabled to analyze 60 video streams from existing traffic cameras simultaneously in real-time for incident detection and data collection, and automatically-recalibrating software configurations based on a camera's field of view. Purchase includes delivery, installation, training, documentation and technical support.

1.2 Architecture Overview

The products in this order are designed to extend the functionality of an existing traffic monitoring network through flexible integration of the framework illustrated in Figure 1.

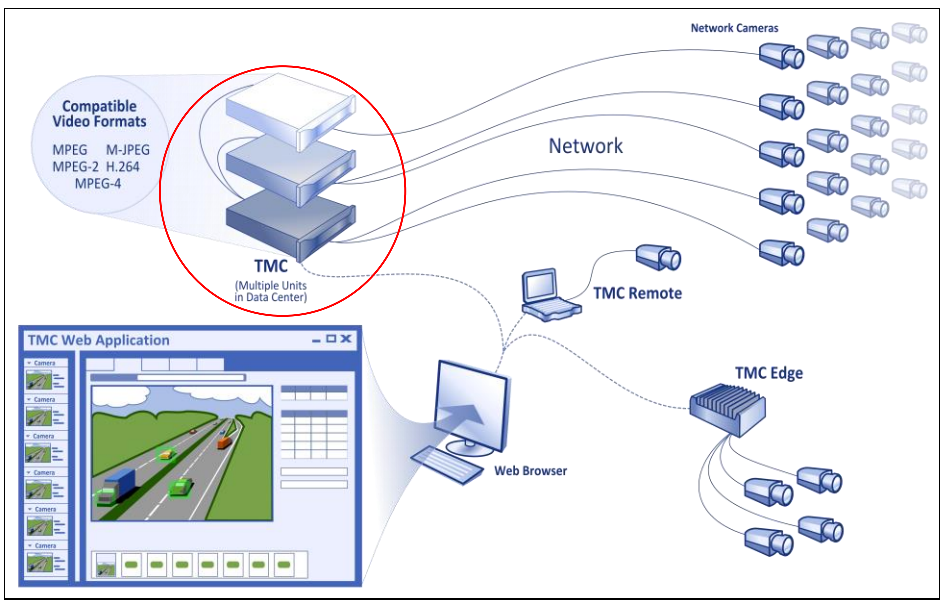

Figure 1 Basic network architecture for TrafficVisionTMC product line.

1.3 Scope of purchase

A purchase for this product order includes:

- Delivery, installation and training
- Network appliance(s)
- TrafficVision incident detection and data collection technology
- TMC Web Application (user interface)
- Documentation
- Technical support (1 Year)

Details on each of these items are provided in later sections of this document.

1.4 Scope of application

The solution will enable certain new and existing cameras designated by the customer to provide automated traffic video incident detection and data collection. Each TrafficVisionTMC unit can process up to 60 video streams simultaneously.

Detection specifications

Video detection is designed to the following standards, given a minimum frame rate of 15 frames/second:

- Compatible* with IP (M-JPEG, MPEG, MPEG-2, MPEG-4, and H.264) encoded video from color (SD/HD), grayscale, and thermal/IR cameras.
- Capable of clearly detecting incidents in both day and night
- Capable of clearly detecting incidents in extreme weather conditions
- Capable of remote setup through Ethernet communications

Note It is highly recommended that all video streams input into the TrafficVision Web Application not exceed 704x480 pixel resolution to ensure the highest level of data collection accuracy.

* Some restrictions may apply due to camera vendor proprietary encoding limitations

2.0 TrafficVisionTMC image processing technology

TrafficVision products encompass two major categories of functional technology across all TMC product lines:

- Incident detection
- Real-time data collection

TrafficVision uses patented computer-vision based algorithms for object tracking to minimize spillover and occlusion error, as opposed to traditional localized presence detection based algorithms. It implements computer-vision developments regarding edge detection, feature tracking, and vehicle-base fronts.

Pan-Tilt-Zoom cameras are supported by auto-recalibration. Movements in camera positions can be automatically detected and associated with multiple calibration presets (up to 8 presets). Users can define how they would like the recalibration ability to operate for each camera by selecting one of three modes.

2.1 Incident detection

The algorithm detects incidents within user-configurable regions of interest along the roadway. Up to eight regions can be set up and saved as individual presets.

When an incident is detected, it is identified on the camera image and an alarm is presented to the TMC product. The TMC product is configured to send the camera image to specified camera outputs (as determined by customer engineers during installation and configuration). Users can choose to automatically record a variable length of video before and after a detected incident occurs. These optional rolling buffer recordings are archived and can be retrieved for testing and analysis purposes.

Software Features:

- Immediate on-screen, audible, and E-mail alerts provided to users with a snapshot of the detected incident.
- Archived tables per day providing links to incident snapshots and video snippets of recorded footage prior to and after an incident occurred (optional feature).
- Capable of working with a wide variety of existing cameras (PTZ and fixed).

Incident types

Detected incidents, which are also configurable in the user interface, include:

- **Stopped Vehicle and Object Detection**
  The algorithm detects vehicles or objects, such as debris, stopped in the user-definable regions of interest along the roadway configured for that field of view while the camera is positioned for that direction. The minimum size of an object to be detected is 10x10 pixels in the particular field of view per camera.
- **Slowed Traffic**
  The algorithm detects drops in average speed along the roadway.
- **Pedestrians**
  The algorithm detects pedestrians within the regions of interest at a minimum of 10x10 pixels in the field of view of that camera.
- **Wrong-Way Drivers**
  The algorithm detects wrong-way drivers within the roadway. The user can specify the correct direction of travel per lane, per preset depending on different times of day. This is useful for reversible lanes or other scenarios where lane directions may correctly change. If using TrafficVision for wrong way-only detection in critical areas, the user is strongly cautioned to use a fixed camera and to not change the field of view and zoom level at the position that best matches ideal conditions advised by TrafficVision technical staff.
- **Congestion**
  The algorithm alerts users if lane occupancy rises above a user-defined threshold.

2.2 Real-time data collection

The algorithm collects real-time data continually, 24 hours per day. All data can be organized per-lane and per-bound. Specified amount of data can be accessed as an archived file and assigned a URL link for real-time dissemination. Archived CSV data tables are created for each video stream per day providing links to per-lane and per-bound data.

Collected Data

Data is collected according to the following categories and settings:

- **Traffic Speed**
  The algorithm detects the speed of traffic in real-time and displays an average speed, updatable in increments of 15, 30, or 60 seconds.
- **Vehicle Counts**
  The algorithm counts vehicles traveling in the field of view. In the absence of ambient light at night, the algorithm counts headlights to represent vehicles.
- **Vehicle Classification**
  The algorithm can make classifications of vehicles into a minimum of four distinct classes with sufficient ambient light:
  - Motorcycle
  - Passenger vehicle (2-door and 4-door cars, SUV’s, pickup trucks)
  - Small truck (UPS, FedEx-sized delivery trucks)
  - Tractor trailer
- **Lane Occupancy and Flow Rate**
  The algorithm can determine the level of lane occupancy and flow rate.
- **Data Writing Intervals**
  The user can select from the following time intervals for the algorithm to compute the real-time data information:

- 15 seconds
- 30 seconds
- 60 seconds

The user can select from the following time intervals for the algorithm to store archived data information:

- 5 minutes
- 10 minutes
- 15 minutes
- 20 minutes
- 30 minutes
- 60 minutes

- **Per Vehicle Log**

  The user can choose to enable per vehicle logging and have compiled information of every individual vehicle by the time they were detected by lane as well as the vehicle speed and class.

3.0 TMC Web Application (user interface)

The Web Application, based in the HTML coding language, can be accessed (with user ID and password credentials) from any networked computer that has an updated Google Chrome, Mozilla Firefox, or Internet Explorer 9 or higher Web browser.

Scope

The Web Application is a turnkey method of configuring the software settings and thresholds for all technology and software capabilities of each connected camera.

Following is a list of key features and functionality that has been designed into the Web Application:

- **Aggregation**
  The Web Application can aggregate the cameras of multiple TMC appliances and virtual machines into a single browser window; all of these cameras can then be configured and monitored from the same browser.
- **Integration into Advanced Traffic Management Software (ATMS)**
  Alerts and real-time roadway information can be integrated into existing ATMS systems. Contact TrafficVision for further details.
- **At-A-Glance Traffic Notification**
  The Web Application includes a separate tab from which operators can view small snapshots or thumbnail images of all of the video streams that they have input to the software. These thumbnails are color-coded to represent the status of traffic on the road:
  - Green for freely flowing, normal traffic conditions
  - Yellow for a possible incident or traffic speed slowed to below the user-definable threshold
  - Red for a serious incident or traffic speed slowed to below the user-definable threshold
- **Camera Configuration and Recalibration Modes**
  The Web Application includes a dedicated tab for configuring each camera in up to eight position presets. The user can select how the algorithm behaves in regard to these presets when the camera changes fields of view by panning, tilting or zooming. The user can verify alignment of camera to previously saved TrafficVision calibration presets. The user can add notes per video stream.
- **Adding and Deleting Video Streams**
  The Web Application includes a dedicated tab for adding or removing video streams of various widely used encodings for real-time analysis. The user can assign names to the video streams.
- **Incident Notification Settings**
  The Web Application includes a dedicated tab for adjusting a wide range of settings available for incident notifications for each camera or video stream, including:
  - Ability for users to create time-specific rules of differing thresholds regarding alert notifications for each camera per day of the week and time of day
  - Length of time a vehicle must be stopped before notification

  - Level of congestion the traffic must reach before notification
  - Level of average slowed traffic speed before notification
  - A minimum of eight rules (different times of the day and week) to define when any specific camera can generate notifications. These rules become active immediately until the user changes, deletes or edits them.
  - Types of incidents the algorithm will detect for certain times of day.
  - Whether to automatically switch to the view of any camera for which an incident notification is detected.
  - Length of time, up to 12 hours, before the algorithm will automatically clear an incident alert.
  - Length of time before receiving the same alert from a particular camera.
  - Whether users can automatically record a short segment, (user definable), of video for review and analysis prior to and after an incident occurs.
  - Whether users can search for and download archived images of recorded incidents for each camera or each day.
  - Options for real-time email alert about incident notifications. Email options include:
    - A snapshot of the incident with a time stamp
    - Type of incident
    - Name of the camera where the image was captured
    - The in-house or external SMTP server from which to send email notifications (using TLS or SSL encryption)
  - Ability for users to control which user(s) receive certain types of incidents at certain times of day

- **Advanced Controls**
  The Web Application enables users to change debugging and diagnostic options.
- **Mapping Interface**
  The Web Application includes a dedicated tab integrating with an Internet-based mapping application. Mapping capabilities include the following features:
  - Placement of markers to represent the location of existing cameras.
  - Markers link directly to video streams of existing cameras and change color to signify incident conditions.
- **Archived Data Access**
  The Web Application includes a dedicated tab for searching and accessing archived data files. Access options include:
  - Separate files written for each video stream every day
  - Ability to select and download files for specific days of data
  - Comma-separated value (CSV) format for importing to analysis tools and other software programs.
  - Snapshots and recorded video snippets of incidents which are stored per day

4.0 Network appliance

Each TMC unit includes the following features:

- 19-inch network appliance conforms to 1U rack-mount standards with aluminum housing and front bezel
- Enclosure dimensions conform to the following limits:
  - Height = 1.68 inches
  - Width = 18.98 inches
  - Depth = 27.57 inches
- All systems will have 64-bit Windows 7 and greater or Windows Server 2012 or greater.
- Runs 24 hours continuously with redundant power supplies in a climate-controlled data center environment
- Computer performance and reliability:
  - Central processor unit (CPU) has a minimum of two Intel based processors running at a minimum of 2.3 gigahertz (GHz) and is provided with a minimum of 45MB cache and a minimum of 36 total cores
  - At least two hard drives with a minimum of 1 terabyte (TB) in storage size, in a mirrored configuration. The hard drives can retain data without power, capacitor, or battery backup, and remain permanent until changed by user data entry
  - Dual, hot-plug, redundant (two) 750W power supplies with two 10 ft. NEMA approved power cords

- Housing
  - Supports a minimum of 8 hard drives
  - Can be fitted with rack-mountable rails and cable management arm
- Network interface
  - Two built-in 1GB Ethernet with RJ-45 connectors on the back of the unit
  - Network appliance can be assigned a unique and dedicated Internet protocol (IP) address.
  - At least two USB ports
  - At least one VGA port
  - Can be accessed over a KVM-standard interface screen or via the network from multiple user workstations over the Internet or Remote Desktop Protocol
  - Includes iDRAC, which allows remote access and diagnostics to the system.

As applicable, hardware installation includes rails, rail converter kits, rack-mountable shelves, all necessary cables and all materials required to ensure a complete installation.

5.0 Documentation

Documentation is provided in both online and printed (PDF) formats.

Note While documentation exists for the previous versions of TMC application software, it is constantly being updated and the customer is encouraged to always verify they are viewing the documentation that corresponds with the version of TMC application software they are using.

Documentation is organized as follows:

- **QuickStart**
  A reference sheet that comes packaged with some TMC models, provides enough setup information to start your TMC system. Once the system is running, you can use this online documentation for further instructions.
- **Setup Guide**
  Provides the information you need to set up, run and maintain the TMC system hardware, including:
  - How the TMC system works
  - Setting up the system for operation
  - Working with multiple users
  - Other system tasks
- **Application Guide**
  Provides the information you need to use the TMC Web Application, including:
  - How the TMC system works
  - Overview of the Web Application
  - Step-by-step procedures for Administrator tasks, such as:
    - Adding camera feeds and video input files
    - Calibrating cameras and adjusting their settings, warnings and alerts
    - Carrying out general account administration tasks
  - Daily tasks and functions for users with a standard user account type, such as Web Application to monitor and interpret traffic conditions
    - Monitoring and interpreting traffic camera activity
    - Responding to traffic incidents and conditions
    - Downloading data files

The online documentation also includes a **FAQ**, which lists frequently asked questions and answers about the TMC, including links to more information across all of the online documentation.

6.0 Technical support

Purchase price includes:

- Installation of each TMC unit, setup of cameras, calibration of software and training
- Technical support (phone, email, web) during EST weekdays (1 Year)
- Next-business day faulty hardware replacement and repair (1 Year)
- Ongoing software feature additions and updates (1 Year)

Note All aspects mentioned in the Technical support section of this document (section 6.0) can be purchased for additional years beyond the first year at a negotiated percentage of the purchase price.

7.0 Exceptions / limitations

Please note the following exceptions and limitations:

- Neither the network appliance nor the user interface software will control pan, tilt and zoom operations of traffic cameras.
- All elements of user interface, software and any custom programming will be in the English language only.
- Hardware and supporting accessories for the TMC network appliance do not include client equipment, such as workstations and display monitors.
- Each TrafficVisionTMC appliance can analyze up to 60 video streams per unit.

For more information contact:

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