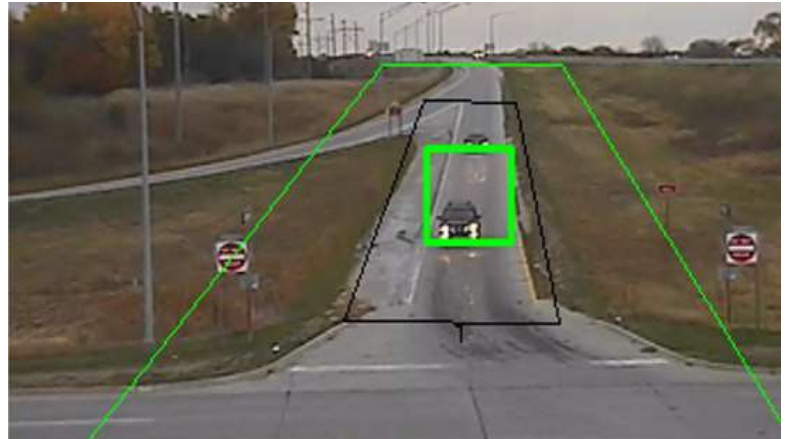


ENTERPRISE Transportation Pooled Fund Study TPF-5 (231)



Next Generation Traffic Data and Incident Detection from Video

FINAL REPORT

Prepared by



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16. Abstract The term Video Analytics refers to the capability of analyzing video feeds to determine events that are not based on a single image. A number of commercially available Video Analytics systems are available that are capable of processing video streams from fixed and pan-tilt-zoom traffic cameras and then automatically creating alerts for conditions such as traffic incidents, stopped/slow moving vehicles, wrong-way vehicle movements, wildlife, and debris in real-time. Additionally, data collected by these systems can include traffic volume by lane, speed, vehicle classification, and lane occupancy. The Ministry of Transportation of Ontario (MTO) partnered with the ENTERPRISE Transportation Pooled Fund Program to conduct a project to research and document the potential for Video Analytics as a tool for traffic operations centers (TOCs) and for traffic data collection. This report summarizes the testing results of several systems in the United States (Iowa, Missouri) and in Ontario, Canada, under real-world environments.			
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Project Champions and Project Participants

Dennis Tessarolo and Mike Barnet, Ministry of Transportation of Ontario (MTO), were the ENTERPRISE Project Champions for this effort.

Representatives from ENTERPRISE member agencies played an important role in the project by serving as host agencies for deploying video analytics systems, implementing field test sites, contributing to the evaluation design, and providing data for comparison analysis. Project participants were:

- Brian Carlson, Iowa DOT
- Gary Covey, Kansas DOT
- Kyle Halligan, Iowa DOT
- Phil Mescher, Iowa DOT
- Tim Simodynes, Iowa DOT
- Jason Sims, KC Scout/Missouri DOT
- Willy Sorenson, Iowa DOT

Vendors who participated by providing equipment and staff time with no cost to the project included:

- **DRS Technologies, Inc.** – DRS Technologies provided a thermal camera for use during the traffic data collection test. The thermal camera was in place for two weeks during this test.
- **Iteris, Inc.** – Iteris, Inc. participated in the traffic data collection test and the incident detection test. Iteris contributed the use of the Abacus Video Analytics system and servers for the Cedar Rapids/rural Iowa deployment, allowing for analysis of several video feeds for approximately eight months. Iteris also trained Iowa DOT personnel on the operation of the Abacus system and provided support time to the project at their cost.
- **Peek Traffic Corporation** – Peek Traffic Corporation participated in the wrong-way vehicle detection test by providing an on-site Video Analytics system at a camera located near a freeway ramp in Ames, Iowa. Peek trained Iowa DOT personnel on the operation of the system and provided support during the field test.
- **TrafficVision** – TrafficVision participated in the traffic data collection test, the incident detection test, and the wrong-way vehicle detection test. TrafficVision contributed the use of its Video Analytic systems and servers in Cedar Rapids/rural Iowa and in DesMoines, Iowa, allowing for analysis of several video feeds, for approximately eight months. In addition, TrafficVision provided a Video Analytics system at a rural freeway ramp in Ames, Iowa, for the wrong-way vehicle controlled test. TrafficVision trained Iowa DOT personnel on use of all systems and provided support time to the project at their cost. TrafficVision also provided support time for the traffic data collection at Kansas City Scout, for an in-place TrafficVision system in place at that location.

- **VideoIQ** – Video IQ participated in the wrong-way vehicle detection test by providing an on-site Video Analytics system at a camera located near a freeway ramp in Ames, Iowa. Video IQ trained Iowa DOT personnel on the operation of the system and provided support during the field test.

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Executive Summary

ENTERPRISE member agencies have the need to collect traffic data and detect incidents on the transportation network. New initiatives, such as connected vehicles, integrated corridors, and managed lanes, will require an increase in network monitoring. This increase could overburden existing Transportation Management Center (TMC)/Traffic Operations Center (TOC) staff, unless supporting technologies are deployed. The term Video Analytics refers to the capability of analyzing video feeds to determine events that are not based on a single image. A number of commercially available Video Analytics systems are capable of processing video streams from fixed and pan-tilt-zoom traffic cameras and automatically creating alerts for conditions such as traffic incidents, stopped/slow moving vehicles, wrong-way drivers, wildlife, and debris in real-time. Additionally, data collected by these systems can include traffic volume by lane, speed, vehicle classification, and lane occupancy.

The overall goal of this project was to assess and understand the potential of Video Analytics as a tool for gathering the data and information needed to support the long term vision of more efficient, safer travel.

A multi-state ‘test-bed’ included demonstrations of Video Analytics technologies from multiple vendors, utilizing multiple types of cameras. A formal evaluation compared traffic data (e.g. speed, volume, vehicle classifications) generated by Video Analytics systems against trusted loop detectors near the cameras capturing the images. In addition, detected incidents were evaluated against reported incidents, and a controlled test of wrong-way detections against actual wrong-way movements was conducted. Finally, operators in traffic management centers provided their feedback on the value and usefulness of the Video Analytics to assist them in performing their daily routines of managing the road network.

Based on the testing and analysis conducted in this project, the findings suggest:

- Video Analytics systems can meet the traffic data needs for a number of scenarios where TMC/TOC operators require real-time traffic data.
- Video Analytics can detect stopped vehicles and debris on the roadway in order to meet the needs of TMC/TOC operators for a number of defined scenarios.
- Video Analytics can detect wrong-way vehicle movements; however, agencies should decide whether redundant detection systems are required based on specific uses and needs.
- Video Analytics can support temporary data collection, detecting incidents or traffic and offering the related video to assist in assessing conditions.
- With both traffic data collection and incident detection, the accuracy rates, detection rates, and false alarm rates all vary depending upon multiple factors:
 - The best performances are achieved from video feeds from cameras at locations with good views to the road and under good lighting conditions.
 - The configuration of the Video Analytics systems, and extent to which the system is ‘tuned’ and ‘calibrated’ plays a tremendous role in the overall performance. Transportation agencies considering the use of Video Analytics should not underestimate the need for configuration and re-configuration during use of the systems.
 - Camera movement, either TMC/TOC operators panning and zooming the camera or unintended shifts in camera orientation can reduce Video Analytics performance or create periods when data is not available.

- Weather conditions that influence visibility (e.g. fog, precipitation) can impact Video Analytics performance as it reduces the quality of the video feed.
- Other ambient conditions such as glare from lights or obstructions can also impact performance.

Because there are so many influences that may impact Video Analytics performance, agencies considering Video Analytics are encouraged to define their Concept of Operations for how the Video Analytics will be used. This will help agencies understand the performance requirements and the extent to which Video Analytics is a viable option.

Based on the input from agencies participating in the project, a series of use case scenarios for Video Analytics were defined. Based on the findings in the evaluation phase (presented in Section 2), the overall ‘readiness’ of Video Analytics is estimated for each use case scenario. Table E-1 summarizes the use case scenarios and estimated readiness of Video Analytics to meet the needs as represented for this project. Additional clarifications for how the readiness of Video Analytics to each use case scenario was determined are included in Section 3 of this report.

Table E-1: Use Case Scenarios and Readiness of Video Analytics State of the Practice

#	Title of Use Case Scenario	Readiness of Video Analytics State of the Practice
1	Traffic data collection to support TMC/TOC operations with no long term data retainage or real-time device control <ul style="list-style-type: none"> • This scenario is primarily to use traffic data for real-time TMC/TOC operations support 	Based on the findings of this evaluation, Video Analytics is ready to support this scenario (with clarifications defined in Section 3).
2	Traffic data collection with 24/7 use and archiving <ul style="list-style-type: none"> • This scenario includes the real-time TMC/TOC operations support in Scenario #1, but also includes archiving and long-term uses of traffic data beyond the real-time operations and may involve data feeding systems such as ramp metering algorithms and traffic map displays 	Based on the findings of this evaluation, Video Analytics is not ready to support all aspects of this scenario (however Section 3 identifies partial aspects and defines the roles Video Analytics could play and anticipated benefits).
3	Traffic data collection to support long-term planning and FHWA reporting <ul style="list-style-type: none"> • This scenario includes a need to collect vehicle classification data, in addition to volumes and speeds at designated traffic recording stations 	Based on the findings of this evaluation, Video Analytics is not ready to support all aspects of this scenario (however, Section 3 defines the roles video analytics could play and anticipated benefits).
4	Incident detection or alerts to notify TMC/TOC operators	Based on the findings of this evaluation, Video Analytics is ready to support this scenario (with clarifications defined in Section 3)
5	Wrong way detection at entrance points to freeways or arterials	Based on the findings of this evaluation, Video Analytics is ready to support this scenario (with clarifications defined in Section 3).
6	Temporary deployments for targeted analysis of current conditions	Based on the findings of this evaluation, Video Analytics is ready to support this scenario (with clarifications defined in Section 3).

Two additional use case scenarios that could be addressed by Video Analytics, either as a stand-alone tool or as part of a redundant system, are described in this report. These two scenarios were not tested as a part of this project; therefore the 'readiness to meet needs' are not reported for these use cases.

- Scenario #7: Detection of wrong-way vehicles at roadway lanes that are signed or barricaded to restrict entrance
- Scenario #8: Detection of stopped vehicles in locations with dynamic lane control

The remainder of this report presents the background information supporting these project recommendations:

- Section 1 presents the project purpose and overview;
- Section 2 presents the evaluation approach and results; and
- Section 3 presents information to support transportation agencies considering Video Analytics (e.g. 'straw man' concepts of operation, requirements, and scenarios for use).

1.0 Project Purpose and Overview of Report Content

1.1 Background and Project Purpose

The term Video Analytics refers to the capability of analyzing video feeds to determine events that are not based on a single image. A number of commercially available Video Analytics systems are available that are capable of processing video streams from fixed and pan-tilt-zoom traffic cameras and then automatically creating alerts for conditions such as traffic incidents, stopped/slow moving vehicles, wrong-way drivers, wildlife, and debris in real-time. Additionally, data collected by these systems can include traffic volume by lane, speed, vehicle classification, and lane occupancy. The Ministry of Transportation of Ontario (MTO), as a member of the ENTERPRISE Transportation Pooled Fund Program, initiated this 'Next Generation Traffic Data and Incident Detection from Video' project to conduct a proof of concept assessment, involving multiple Video Analytics solutions, to understand the potential for Video Analytics technologies to support the transition towards increased data collection and management.

This report documents Phase 2 of a two phase initiative. In Phase 1, an initial systems engineering analysis was performed. A Concept of Operations (ConOps) was created to document the current situation, challenges, and needs for Video Analytics systems. In addition, functional requirements of technologies were developed. Finally, project partnerships were initiated with Video Analytics vendors and representatives from transportation agencies who would serve as host locations for short-term deployments of Video Analytics systems to be used during Phase 2. This project (Phase 2) performed a technology proof of concept evaluation in which multiple Video Analytics systems were connected to existing cameras at a limited number of sites to assess the appropriateness of Video Analytics systems to address the needs identified in the Concept of Operations.

The purpose of this technology proof of concept evaluation is to understand the performance levels that agencies can expect when deploying the current state of practice in Video Analytics for transportation planning and traffic management applications. This project did not attempt to evaluate specific technologies or to compare one vendor's product against another. Rather, the project treated participating vendors as a valuable resource that enabled ENTERPRISE member agencies to better understand the potential for Video Analytics technologies.

1.2 Evaluation Areas and Presentation of Results

The project evaluated Video Analytics capabilities in three distinct functional areas:

- Traffic Data Collection
- Incident Detection
- Wrong-Way Vehicle Detection

Note: the initial project intention was to also evaluate animal detection; however the deployment situations did not allow sufficient animal instances to enable this evaluation.

Because this is a proof of concept evaluation, findings are presented in a manner that defines, in current state of practice, a level of performance that can be achieved by Video Analytics technologies. As such, comprehensive data comparisons and analysis results will not be reported.

Although this project is reporting the highest overall average weekly performance levels that were achieved during testing of Video Analytics, it is also important to understand how likely traffic data collected are to be consistently within acceptable accuracy levels. Therefore, for the traffic data collection portion of the

evaluation, the report will also present trend analysis results to show how ‘repeatable’ the best result was, for the numerous weeks of Video Analytics output data that was compared to agency detectors.

This evaluation was structured to investigate the performance of Video Analytics systems when integrated into agencies’ existing infrastructure (e.g. existing camera locations/mounting heights) and TMC/TOC practices (e.g. continuing camera use for everyday traffic monitoring needs). Therefore, the conditions at each test site were not controlled to the level that ensured optimum performance. For instance, camera settings and system configurations were not always ideal for video processing, because doing this may have affected the TMC/TOC operators’ viewing ability (e.g. image quality for human viewing). In addition, workflow and daily TMC/TOC operations did not allow for constant monitoring, adjusting, and configuring the Video Analytics systems to ensure that they would perform optimally for the entire duration of the test. It was not practical to request that TMC/TOC operators consistently log changes in conditions/settings that may impact Video Analytics performance. Rather, a good faith attempt was made by deployment agencies to monitor and adjust conditions as much as practical. For these reasons, comprehensively reporting analysis results would not accurately convey system performance.

A specific example of this is the fact that TMC/TOC operators were not asked to avoid panning and zooming the cameras as they normally would. Therefore, the overall weekly performance levels reports include times when cameras were panned and zoomed from their resting position.

For each evaluation component, this report provides a summary of the evaluation approach and results from the analyses conducted. The evaluation approach will summarize field test locations and conditions, the analysis approach, and other relevant details to understand how the evaluation was conducted. Results will be displayed in a format that reports ‘Highest Level of Performance Achieved’ and ‘Factors that Impacted the Level of Performance.’

1.3 Development of Procurement Support Resources

Presenting results in a format that conveys ‘Highest Level of Performance Achieved’ (with trend analysis for traffic data collection) and ‘Factors that Impacted the Level of Performance’ provided a basis for establishing findings in terms of level of performance that can be achieved. It also guided the development of the agency procurement support resources detailed in Section 3 of this report. These procurement support resources provide deployment considerations, steps for deployment, and performance requirements that could be used as a starting point for procuring vendors.

2.0 Evaluation Approach and Results

2.1 Traffic Data Collection

This component of the evaluation collected and analyzed data in order to understand the potential for Video Analytics systems to be an effective tool for collecting traffic data, specifically volumes (vehicle counts), speeds, and vehicle classifications.

The traffic data collection evaluation included the following elements:

- A comparison of traffic data generated by Video Analytics systems to traffic data from in-place agency detectors at two deployment sites was conducted to determine accuracy levels and factors that impact performance.
- Observations were collected from agency staff regarding the potential for traffic data from Video Analytics in transportation planning and traffic management applications. Observations were also collected from agency staff who calibrated and monitored the systems during the deployment.

In addition, a separate evaluation of traffic data was conducted by the Ontario Ministry of Transportation (MTO) in Toronto. Results of this evaluation are summarized in this section.

2.1.1 Data Comparisons at Rural Iowa and Kansas City Deployments

Deployment Sites

The evaluation was conducted at two deployment sites where Video Analytics systems were connected to multiple in-place cameras. Table 2-1 lists the deployment sites, roadway types, number of cameras instrumented, number of participating vendors, and traffic data types evaluated at each site.

Table 2-1: Deployment Sites for Traffic Data Collection

Deployment Location	Roadway Type	Number of Cameras Instrumented	Number of Participating Vendors	Traffic Data Evaluated
Near Iowa City, IA	Rural Freeway	2 analog cameras & 1 thermal camera	2 vendors	Volumes (Vehicle Counts) Vehicle Speeds
Kansas City, MO	Metro & Suburban Freeways	4 analog cameras	1 vendor	Volumes (Vehicle Counts) Vehicle Speeds Vehicle Classifications

Selection of Camera Views and Duration of Evaluation

The cameras chosen for inclusion in this portion of the evaluation were selected in consultation with the Video Analytics vendors, to select camera positions and zoom levels that would be most favorable for traffic data collection. However, since existing camera infrastructure was utilized, it was not possible to position cameras at ideal positions for traffic data collection.

The chosen cameras varied in the direction they faced (North, South, West, East) and included traffic moving toward the camera and traffic moving away from the camera in the lane nearest to the camera. The camera views included various roadway geometrics such as 4-lane and 6-lane, median-separated and barrier-separated, and roadway curves and underpasses in the field of view. Figure 2-1 shows the 4 camera

views in the Kansas City deployment and Figure 2-2 shows the 3 view in Iowa included in the traffic data analysis portion of the evaluation.



Figure 2-1: Camera Views Included in Traffic Data Analysis – Kansas City Deployment



Figure 2-2: Camera Views Included in Traffic Data Analysis – Rural Iowa Deployment

At each analog camera, 3-4 weeks of traffic data (24 hours per day) was collected and compared to data from in-place detectors. The thermal camera was in place for 2 weeks. The data collection period included a number of changing conditions, including variable weather (dry, rain, and snow), day and night lighting conditions, metro and rural freeway settings, and peak/non-peak traffic periods.

The variability in camera placement, roadway geometrics, weather conditions, and traffic levels allowed the evaluation team to identify and assess factors that could potentially impact the performance of Video Analytics systems to accurately collect traffic data.

Approach

Traffic data outputs (traffic volumes, speeds, and vehicle classifications) produced by Video Analytics systems were compared to traffic data generated by in-place agency detectors (loop detectors or radar) near each camera. The in-place agency detectors used for comparison were considered “trusted” in the sense that agencies routinely validate functionality and accuracy of their detectors. However, loop detectors and radar detection devices, though used as “ground truth” in this evaluation, are not 100% accurate at all times.

Collected data were grouped into 15-minute increments for comparison. For each week of data compared, up to 672 separate 15-minute comparisons were available for comparison. Periodically, 15-minute data outputs from Video Analytics systems were reported as “0” readings, likely due to a temporary power loss or other interruption in the video feed. Because “0” readings would have skewed results significantly using an average percent difference calculation (as described in the following paragraph), the “0” readings were removed from weekly averages. During any given week, the total number of “0” readings was small in comparison to the 672 possible 15-minute increments that occurred during one week’s time.

Absolute percent difference was used for the error calculation during data analysis. For each 15-minute period, the difference between the Video Analytics generated data and the detector data was calculated; this result was converted to absolute error by removing any negative values; then the percent difference was calculated, resulting in absolute percent difference. An average percent difference was calculated for each week of the evaluation period. It is important to note that absolute percent difference results for low traffic volumes (mostly seen during nighttime) and low vehicle classification counts (such as motorcycles) were not always a meaningful indicator for level of performance; slight differences in volume comparisons often equated to large absolute percent differences when traffic volumes were low at night.

Below is a summary of the traffic data compared in this component of the evaluation:

- **Traffic volumes (vehicle counts)** included a count of the number of vehicles detected during the 15-minute period. The number of vehicles detected by Video Analytics systems was directly compared to the vehicle counts from in-place agency detectors.
- **Vehicle speeds** included the average speed of all vehicles detected during the 15-minute period. The average speed of vehicles detected by Video Analytics systems was directly compared to the average speeds from in-place agency detectors.
- **Vehicle classifications** included a count of the number of vehicles detected in each classification category during the 15-minute period. The for vehicle classification categories produced by the participating Video Analytics system’s output did not directly correlate to the vehicle classifications from in-place agency detectors. The in-place agency detectors reported vehicle counts in all 13 of FHWA’s classification categories. The Video Analytics system reported vehicle counts in four classification categories that combined the FHWA categories as shown in Table 2-2.

Table 2-2: Vehicle Classification Categories from Video Analytics

Classification Categories from Video Analytics	Corresponding FHWA Classifications
Motorcycles	Classifications 1
Cars	Classifications 2-3
Small Trucks	Classifications 4-7
Large Trucks	Classifications 8-13

Results

Results from Analog Cameras:

The highest level of performance for traffic data from analog camera feeds is reported in this section. Although this project is reporting the highest overall average weekly performance levels achieved during testing of Video Analytics, it is also important to understand how likely traffic data collected are to be consistently within acceptable accuracy levels. Therefore, a trend analysis was conducted and aggregate results will be reported. Aggregated results include all average weekly results from all participating vendors (i.e., aggregated results do not reflect the actual accuracy of any one vendor.) Aggregated results will report the range of results (most accurate result and least accurate result), mean, median, number of results within 10 percentage points of the best result, and number of results within 15% difference. The number of results within 15% difference is reported in order to show how many results meet the requirement set forth in SAFETEA-LU 23 CFR 511¹, which states: “For traffic and travel conditions made available by real-time information programs, information is required to be 85% accurate as a minimum, or have a maximum error (percent difference) of 15%.”

Traffic Volumes (Vehicle Counts):

The highest level of performance achieved for one week of traffic volumes (one direction of traffic) was an average percent difference of 9% during the day, 17% difference at night, 14% difference for the AM peak period, and 9% average difference for the PM peak period.

Seven weeks of Video Analytics volume outputs were compared to agency detector data, for a total of 42 results (24 ‘Near Side Lane’ results and 18 ‘Far Side Lane’ results.) Near Side Lane results are for traffic lanes nearest to the camera; Far Side Lane results are for traffic traveling in the other direction, further from the camera. Fewer Far Side Lane results were available because only one vendor’s system was configured to collect traffic data in the Far Side lanes. Tables 2-3 and 2-4 show aggregated results for volume comparison results, for daytime and nighttime lighting conditions.

Findings from the trend analysis indicate that the most accurate daytime volume result of 9% difference (daytime, Near Side Lanes) carries a reasonable expectation of repeatability, with 21 of 24 weekly comparison results within 10 percentage points of the most accurate result. The most accurate result for nighttime volume was less repeatable; only 4 of 18 results were within 10 percentage points of the most accurate result of 17% (Far Side Lanes). Nighttime trends also resulted in much higher median and mean percent differences than the daytime trends.

Table 2-3: Daytime Trends for Volumes – Aggregated Results*

Daytime Trends for Volumes Near Side Lanes	Daytime Trends for Volumes Far Side Lanes
Total Number of Results = 24	Total Number of Results = 18
Most Accurate Result = 9% difference Least Accurate Result = 35% difference	Most Accurate Result = 10% Least Accurate Result = 42%
Mean =14.0%, Median = 13.5%	Mean = 26.1%, Median = 26.5%
21 of 24 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 9% and 19% diff.)	5 of 18 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 10% and 20% diff.)
17 of 24 Results were within 15% difference (SAFETEA-LU ¹)	4 of 18 Results were within 15% difference (SAFETEA-LU ¹)

*Aggregated results include all average weekly results from all participating vendors; these results do not reflect the actual accuracy of any one vendor.

Table 2-4: Nighttime Trends for Volumes – Aggregated Results*

Nighttime Trends for Volumes Near Side Lanes	Nighttime Trends for Volumes Far Side Lanes
Total Number of Results = 24	Total Number of Results =18
Most Accurate Result = 20% difference Least Accurate Result = 255% difference	Most Accurate Result = 17% Least Accurate Result = 170%
Mean = 77.3%, Median = 55.0%	Mean = 68.7%, Median = 45.5%
6 of 24 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 20% and 30% diff.)	4 of 18 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 17% and 27% diff.)
0 of 24 Results were within 15% difference (SAFETEA-LU ¹)	0 of 18 Results were within 15% difference (SAFETEA-LU ¹)

*Aggregated results include all average weekly results from all participating vendors; these results do not reflect the actual accuracy of any one vendor.

Vehicle Speeds:

The highest level of performance achieved for vehicle speeds was an average percent difference of 2% during the day, 6% difference at night, 3 % average difference for the AM peak period, and 2% average difference for PM peak period.

Seven weeks of Video Analytics volume outputs were compared to agency detector data, for a total of 42 results (24 ‘Near Side Lane’ results and 18 ‘Far Side Lane’ results.) Tables 2-5 and 2-6 show trends for speed comparison results, for daytime and nighttime lighting conditions. Findings from the trend analysis indicate that the most accurate result of 2% difference (daytime, Near Side Lanes) carries a reasonable expectation of repeatability, with 15 of 24 results falling within 10 percentage points of the most accurate result. Nighttime results appear similarly repeatable, with 17 of 24 results falling within 10 percentage points of the most accurate result of 6% difference (Near Side Lanes).

Table 2-5: Daytime Trends for Speeds – Aggregated Results*

Daytime Trends for Speeds Near Side Lanes	Daytime Trends for Speeds Far Side Lanes
Total Number of Results = 24	Total Number of Results = 18
Most Accurate Result = 2% difference Least Accurate Result = 33% difference	Most Accurate Result = 2% Least Accurate Result = 21%
Mean = 11.2%, Median = 9.0%	Mean = 12.2%, Median = 12.5%
15 of 24 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 2% and 12% diff.)	9 of 18 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 2% and 12% diff.)
17 of 24 Results were within 15% difference (SAFETEA-LU ¹)	13 of 18 results were within 15% difference (SAFETEA-LU ¹)

*Aggregated results include all average weekly results from all participating vendors; these results do not reflect the actual accuracy of any one vendor.

Table 2-6: Nighttime Trends for Speeds – Aggregated Results*

Nighttime Trends for Speeds Near Side Lanes	Nighttime Trends for Speeds Far Side Lanes
Total Number of Results (Weeks) = 24	Total Number of Results (Weeks) = 18
Most Accurate Result = 6% difference Least Accurate Result = 29% difference	Most Accurate Result = 7% Least Accurate Result = 38%
Mean = 13.7%, Median = 10.5%	Mean = 21.4%, Median = 22.0%
17 of 24 Results were within 10 Percentage Points Of the Most Accurate Result (i.e., between 6% and 16% diff.)	7 of 18 Results were within 10 Percentage Points of the Most Accurate Result (i.e., between 7% and 17% diff)
16 of 24 Results were within 15% difference (SAFETEA-LU ¹)	6 of 18 Results were within 15% difference (SAFETEA-LU ¹)

*Aggregated results include all average weekly results from all participating vendors; these results do not reflect the actual accuracy of any one vendor.

Vehicle Classifications:

The highest level of performance achieved for vehicle classifications were the following average percent differences, compared to in-place agency detectors.

- ‘Motorcycles’ (FHWA Classification 1): Average percent difference of 24% at night
- ‘Cars’ (FHWA Classifications 2-3): Average percent difference of 13% during the day
- ‘Small Trucks’ (FHWA Classifications 4-7): Average percent difference of 44% during the day
- ‘Large Trucks’ (FHWA Classifications 8-13): Average percent difference of 23% during the day

Two weeks of Video Analytics outputs were compared to classification data from agency detectors. Because the data set was small, in terms of total weeks of comparisons, a trend analysis to report aggregated results was not completed for the vehicle classification comparisons. However, results for the two weeks of data compared were similar in terms of accuracy results.

Results from Thermal Camera:

The thermal camera, which was in place for 2 weeks, provided a very small sample size due to several factors which affected the quality of the video image. These factors included a significant snow event, a duration when the thermal camera was an error state with a blurred image, and a duration when the Video Analytics configuration was not matched accurately to the lanes of traffic. Therefore, a definitive conclusion about the level performance of thermal cameras could not be made from the analysis. However, a number of observations were made through the data analysis, when comparing the results from thermal camera to results from the analog camera mounted in the same location.

- During nighttime lighting conditions, traffic volume data processed by Video Analytics from the thermal camera was slightly more accurate than the analog camera for the same time period.
- Average vehicle speeds from the thermal camera were slightly less accurate than the analog cameras for both daytime and at night.
- Partway through the evaluation period, the thermal camera was zoomed in to improve data collection results. This adjustment improved accuracy volume and speed data, both during the day and at night.
- Significant reductions in accuracy were seen during the snow event, when the camera was in an error state, and when the camera was slightly out of position and the Video Analytics system was not accurately configured to the roadway lane markings.

The comparison analysis conducted during this portion of the evaluation was the first time the participating Video Analytics vendor had tested its product with a thermal camera feed. Given that this was the first time testing with a thermal camera, and because of various challenges encountered (e.g. zoom level not optimal, a significant weather event, camera being in an error state for a portion of the test), there is much more to be learned about the potential for the use of Video Analytics with thermal camera feeds.

Summary of Factors that Impacted the Level of Performance:

- Accurate calibration of the Video Analytics systems is critical to achieving accurate traffic data collection results. Since the Video Analytics processing is dependent upon ‘understanding’ the size of a vehicle relative to known distances in the environment, even slight changes in calibration can impact accuracy significantly.
- Performance was significantly affected during weather (rain/snow) events.
- Low lighting conditions resulted in lower accuracies, especially for volumes.
- Proximity of traffic to the camera was a factor in performance. Volumes in the lanes of traffic nearest to the camera were more accurately counted during the day. Camera position (e.g. zoom level, location of camera relative to the roadway) affected the accuracy of volumes to a much higher degree than it affected the accuracy of vehicle speeds. Vehicle speed measurements collected for traffic in far side lanes were slightly less accurate than the near side lanes, but the difference was not substantial.
- Camera settings (shutter speed and maximum gain), which were adjusted part-way through the evaluation period in an attempt to improve accuracies of volumes at night, did lead to a slight improvement in nighttime vehicle counts, but resulted in reduced accuracy during the day.
- A conclusion could not be made regarding whether traffic moving toward the camera in the lane nearest the camera (thereby counting headlights rather than taillights at night) was more accurate than positioning the camera so that traffic is moving away from the camera in the nearest lanes.

- The thermal camera feed appeared to be more sensitive to movements, adjustments (e.g. zoom level), and weather conditions, in terms of the Video Analytics system's ability to produce accurate data from the video feed. Increased zoom level improved traffic data results, and significant decreases in accuracy were seen during the snow event, when the camera was in an error state with a blurred image, and when the camera was moved slightly out of its original position.

2.1.2 Ministry of Transportation of Ontario - Pilot Study

The Ministry of Transportation of Ontario (MTO) conducted a pilot study to determine if camera and Video Analytics are feasible tools to automate traffic counts and vehicle classifications as an alternative to loop detectors. This section provides an overview of the approach and findings from the pilot study, as documented in a January 22, 2014 memo prepared by the MTO Central Region Traffic Office.

The pilot study, which took place from August 2013 to November 2013 in Ontario, Canada, instrumented 13 temporary cameras with Video Analytics at four locations. The temporary cameras were positioned as optimally as possible (within the existing infrastructure and any corresponding limitations) per vendor recommendations. Video was recorded for one week at each camera and sent to a Video Analytics vendor for processing. Vehicle counts (volumes) and vehicle classifications were collected by Video Analytics in 15-minute periods, 24 hours per day for the one week test period. Manual vehicle counts, conducted between 4:30 AM and 5:30 AM and between 4:30 PM and 5:30 PM, were completed and compared to Video Analytics data outputs.

Results:

- MTO's first pilot project to utilize temporary cameras and Video Analytics to collect volume data on freeway mainline sections provided traffic volumes with an absolute weighted accuracy of 91% (based on 139 15-minute comparisons). The vehicle classification results (based on large and small trucks) yielded an absolute weighted accuracy of 48%, indicating the results of this technology should not be used for vehicle classification.

Areas of Concern to Further Investigate:

- Counting Vehicles in Closed Lanes: Lane-by-Lane review revealed analytics software was counting vehicles in closed lanes during the night-time.
- Poor Weather Conditions: More analysis required to investigate whether accuracy degrades under poor weather condition (especially wet conditions at night.)
- Classification Counts: Accuracy of vehicle classification data was insufficient with truck volumes having an absolute weighted accuracy of only 48%. Truck volumes were especially poor at night, with the absolute weighted accuracy being 71% in the daytime and 17% at night.
- Frozen Images: Review of the camera footage revealed frozen images where vehicles were sometimes stuck on one area of the screen, resulting in the vehicle possibly being double-counted.

2.1.3 Observations from Agency Staff

Approach

A number of observations and lessons learned were shared by the Iowa DOT staff who were responsible for configuring the Video Analytics systems throughout the duration of the deployment in rural Iowa. In addition, an interview was conducted with Iowa DOT planning staff, regarding the potential uses and accuracy needs from data produced by Video Analytics.

Results

Importance of Consistent Calibration and Monitoring:

Iowa DOT staff tasked with configuring the Video Analytics systems to the roadway (e.g. drawing lane configurations, monitoring settings, and making adjustments if cameras were moved out of position) noted the importance of ensuring accurate configuration of the systems to optimize results. This required diligent monitoring and making adjustments as needed.

Potential for Video Analytics Outputs for Transportation Planning:

Transportation planning staff from Iowa DOT provided a number of observations about the potential for traffic data from video in transportation planning applications.

- Volume and speed data from Video Analytics could be useful, if it could provide accurate, reliable, consistent data; testing and validation would be required before Video Analytics could replace loop detectors. Agencies would still need to capture vehicle weights, which would not be possible with Video Analytics.
- Vehicle classification data from Video Analytics could be useful to supplement data from in-place sensors. Ideally, Iowa DOT would collect all 13 FHWA classifications, but detectors with this capability are expensive to implement on a large-scale basis. Iowa DOT does build some vehicle classification tables using a detector source that has three classification categories, so they see potential for the Video Analytics outputs that combine the 13 FHWA classification categories into four categories. Accurate data is needed on a 24-hour basis, especially because of high truck volumes at night, so a potential drawback to using Video Analytics data is the observed decrease in accuracy at night.
- An advantage to using video instead of current techniques (such as piezoelectric sensors) for data collection is that these tend to be dangerous to install in high traffic areas, while cameras are located off of the roadway.

2.1.4 Summary of Results - Traffic Data Collection

Table 2-7 provides a summary of results from the evaluation of Video Analytics for traffic data collection.

Table 2-7: Results Summary for Traffic Data Collection from Video Analytics

Results from Analog Cameras – Highest Level of Performance Achieved (All results shown include an average percent difference for one week, for one direction of traffic)	
<p style="text-align: center;">Traffic Volumes (Vehicle Counts):</p> <ul style="list-style-type: none"> • 9% average difference for daytime (Carries reasonable expectation of repeatability) • 17% average difference for nighttime (Does not carry reasonable expectation of repeatability) • 14 % average difference for AM peak period • 9% average difference for PM peak period 	<p style="text-align: center;">Vehicle Speeds:</p> <ul style="list-style-type: none"> • 2% average difference for daytime (Carries reasonable expectation of repeatability) • 6% average difference for nighttime (Carries reasonable expectation of repeatability) • 3% average difference for AM peak period • 2% average difference for PM peak period
<p>Vehicle Classifications:</p> <ul style="list-style-type: none"> • ‘Motorcycles’ (FHWA Classification 1): Average percent difference of 24% at night • ‘Cars’ (FHWA Classifications 2-3): Average percent difference of 13% during the day • ‘Small Trucks’ (FHWA Classifications 4-7): Average percent difference of 44% during the day • ‘Large Trucks’ (FHWA Classifications 8-13): Average percent difference of 23% during the day 	
<p style="text-align: center;"><u>Factors that Impacted Level of Performance</u></p> <ul style="list-style-type: none"> • Low light / dark conditions • Camera position (proximity to traffic, zoomed out, angled to roadway) • Weather events that reduce image quality • Inaccurate configuration of Video Analytics to roadway lanes • Camera settings (e.g. shutter speed, max gain) 	<p style="text-align: center;"><u>Factors that Did Not Appear to Impact Performance</u></p> <ul style="list-style-type: none"> • Position of camera relative to direction of traffic
Results from Thermal Camera	
<ul style="list-style-type: none"> • Volume data at night appeared to be slightly more accurate than the analog camera. Average speeds were slightly less accurate than the analog camera during the day and at night. Due to the small sample size of data from the thermal camera, a definitive conclusion could not be drawn regarding accuracy. • The thermal camera appeared to be more sensitive to movements, adjustments (e.g. zoom level), and weather conditions, than the analog cameras. 	
Observations from Agency Staff	
<ul style="list-style-type: none"> • Accurate calibration of Video Analytics to roadway lanes is critical for optimizing results; slight changes can significantly impact performance. • There is strong potential for Video Analytics to supplement data from in-place detector infrastructure for transportation planning purposes. The technology would need to be tested and proven to be accurate. Video has an advantage over in-pavement detection in high-traffic areas, due to safety concerns for agency workers who install these devices. Combining FHWA’s 13 categories into a smaller subset (e.g. four categories) would be adequate for building some types of classification tables for planning applications. 	

2.2 Incident Detection

This component of the evaluation collected and analyzed data in order to understand the potential for Video Analytics systems to be an effective tool for detecting incidents such as stopped vehicles, debris in the road, slow traffic/congestion, pedestrian in the roadway, and wrong-way vehicle movements.

The incident detection evaluation included three elements:

- A comparison of detection alerts generated by Video Analytics systems to video clips and still images at the time of each alert was conducted, to determine the percentage of validated incidents and those not validated (or ‘false alarms’) in both an urban and a rural deployment
- A comparison of detection alerts to agency-reported incidents was made, to gain insights about the effectiveness of video detection in an urban corridor instrumented with Video Analytics.
- Observations were collected from agency staff regarding the perceived value of Video Analytics to assist with Traffic Management Center (TMC)/Traffic Operations Center (TOC) operations.

2.2.1 Comparison of Detection Alerts to Video

Deployment Sites

The evaluation was conducted at two deployment locations where Video Analytics systems were connected to multiple in-place cameras. A total of 22 cameras were instrumented with Video Analytics for this portion of the evaluation. Figure 2-3 shows the deployment sites, including roadway type, number of cameras instrumented, and number of participating vendors.

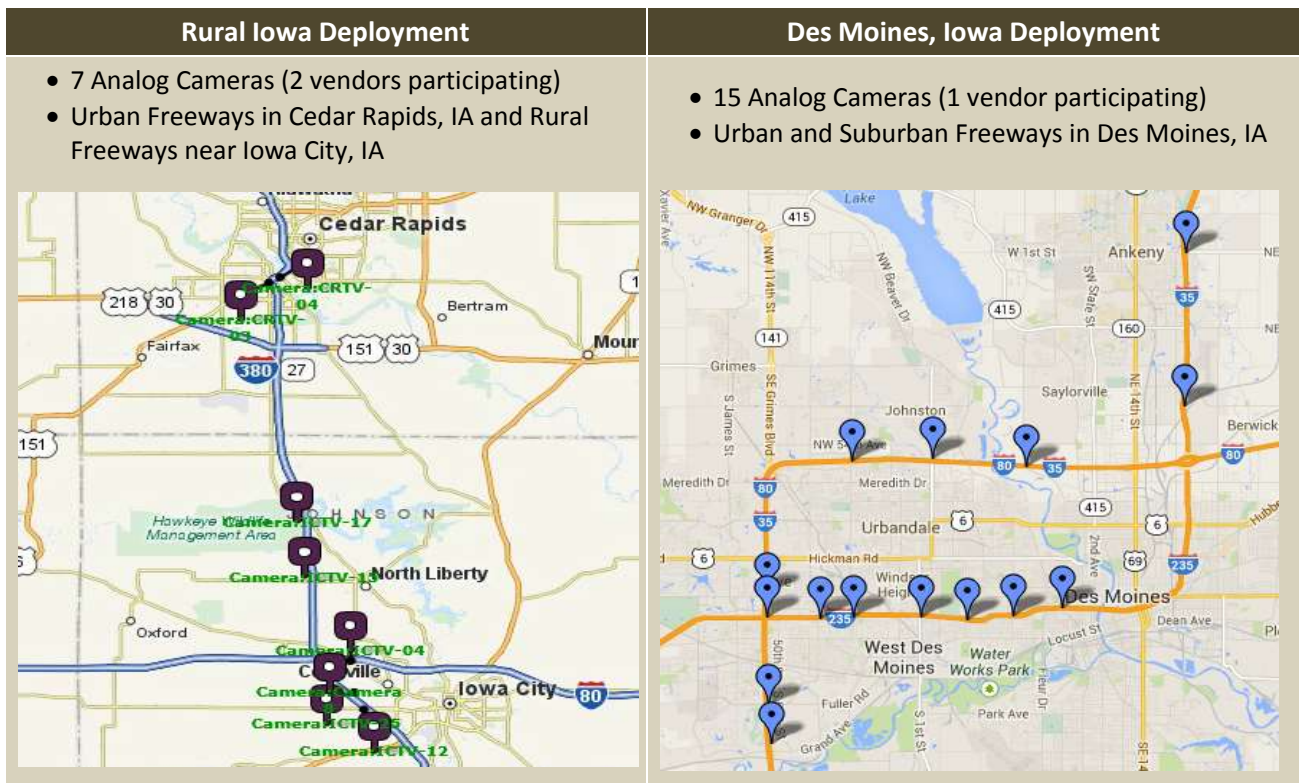


Figure 2-3: Deployment Sites for Incident Detection Evaluation

Selection of Camera Views and Duration of Evaluation

The cameras chosen for inclusion in this portion of the evaluation were selected by Iowa DOT staff and Video Analytics vendors. Care was taken to select in-place cameras that would be favorable for incident detection and positioned in locations that would be likely to capture video footage of incidents.

The chosen cameras varied in the direction they faced (North, South, West, East), included ‘head-on’ and side of road detection, and included positions that detected traffic moving toward the camera and traffic moving away from the camera in the lane nearest to the camera. The chosen views included various roadway geometrics such as 4-lane and 6-lane; median-separated and barrier-separated; and features such as entrance ramps, roadway curves, guardrails, overpass bridges, and other objects (poles, traffic signals, etc.) in the field of view. A variation in zoom levels was also apparent in the camera views. Cameras in Des Moines were programmed for 2-4 different preset positions throughout the day; therefore the variability of views processed by Video Analytics was substantially increased during the evaluation period. Figures 2-4 and 2-5 shows examples of camera views included in the incident detection portion of the evaluation.



Figure 2-4: Examples of RURAL Camera Views included in Incident Detection Evaluation



Figure 2-5: Examples of URBAN/SUBURBAN Camera Views included in Incident Detection Evaluation

The evaluation period for the incident detection test was 21 days (24 hours per day) for the Cedar Rapids/Rural Iowa deployment and 44 days (24 hours per day) for the Des Moines, IA urban area deployment. The data collection period included a number of changing conditions, including variable weather (dry, rain, and snow), day and night lighting conditions, metro and rural freeway settings, and peak/non-peak traffic periods.

The variability in camera placement, roadway geometrics, weather conditions, and traffic levels allowed the evaluation team to identify and assess factors that could potentially impact the performance of Video Analytics systems to detect incidents.

Approach

The following incident types were detected by Video Analytics systems and include in the incident detection component of the evaluation:

- Stopped Vehicle / Debris in Road
- Slow Traffic / Congestion
- Pedestrian
- Wrong-Way Vehicle

The evaluation approach included a visual comparison of detection alerts from Video Analytics systems to video clips and still images at the time when the alert was reported. The Video Analytics systems kept a log of incident alerts that were accessible to the evaluation team via web-based interfaces, for review and analysis after the incident alerts were reported. Upon review of each detection alert and comparison, each alert was classified into one of the following categories:

- Category #1: An actual incident likely occurred when/where detected (Validated)
- Category #2: It was not likely that an incident occurred when/where detected (Not Validated)
- Category #3: Based on video, the evaluation team was unable to conclusively determine if an incident did occur (Unable to Determine)

Figure 2-6, Figure 2-7, and Figure 2-8 show examples of still images for each category. It is important to note that the review of incidents was somewhat subjective, due to times when image quality was impacted by factors such as dark conditions at night, glare on the roadway at night, and/or weather events. However, care was taken to classify each incident as consistently as possible.



Figure 2-6: Examples of Category #1 (Validated) Incidents



Figure 2-7: Examples of Category #2 (Not Validated) Incidents

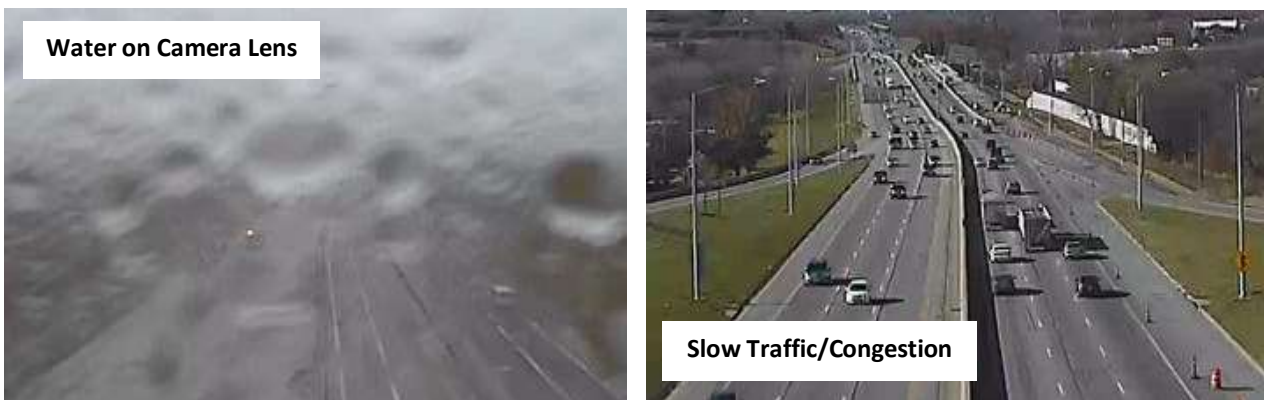


Figure 2-8: Examples of Category #3 (Unable to Determine) Incidents

For each incident type reviewed, the following was calculated:

- Percentage of incidents validated (Category #1), as a function of total number of alerts
- Percentage of incidents not validated (Category #2), as function of total number of alerts
- Percentage of incidents 'unable to determine' (Category #3), as a function of total number of alerts

For 'stopped vehicle/debris in road' incidents, adjusted results were calculated by removing repetitive alerts caused by objects in field of view. These repetitive 'false alarm' alerts prompted TMC/TOC operators to adjust the camera position to avoid multiple alerts, thereby improving overall performance.

Results

Highest Level of Performance Achieved:

- **Stopped Vehicle / Debris in Road Alerts:**
 - The highest level of performance occurred during the Des Moines (urban area) deployment. Of 81 'stopped vehicle/debris in road' alerts recorded during a 44-day period, 72% were validated; 23% were not validated; and 5% were classified as 'unable to determine.'
 - The highest level of performance when adjusted results were calculated by removing repetitive alerts caused by objects in the field of view occurred during the rural Iowa deployment. Of 26 'stopped vehicle/debris in road' alerts recorded during a 21-day period, 85% were validated; 0%

were not validated; and 15% were classified as 'unable to determine.' In this case, removing the repetitive alerts essentially eliminated 'false alarms,' significantly improving the results.

- **Slow Traffic / Congestion Alerts:** The highest level of performance occurred during the Des Moines (urban area) deployment. Of 1111 'slow vehicle/congestion' alerts recorded during a 44-day test period, 30% were validated; 33% were not validated; and 37% were classified as 'unable to determine.'
- **Pedestrian Alerts:** No pedestrians were detected in the roadway during the evaluation period. Therefore a performance level for pedestrian alerts was not determined.
- **Wrong-Way Vehicle Alerts:** No wrong-way vehicle movements were detected during the evaluation period. Therefore a performance level for wrong way vehicle alerts was not determined.

Factors that Impacted the Level of Performance:

Factors that affected the level of performance for incident detection included:

- Objects in the field of view often resulted in repetitive 'detections not validated' or 'false alarms.'
- Moisture on the camera lens, from rain or snow events, would sometimes cause 'false alarms.'
- An observation was made that headlight glare on the roadway (at night) were present at locations where multiple 'false alarms' were observed.

During this test, conditions were not controlled to the level that ensured optimum performance. For instance, workflow and daily TMC/TOC operations did not allow for constant monitoring, adjusting, and configuring the Video Analytics systems to ensure that they would perform optimally for the entire duration of the test. However, it is worth noting that system performance can vary significantly depending on the care taken to optimize conditions (e.g. selecting appropriate camera views, making presets that return cameras to optimal position, modifying calibrations/settings as needed) in order to enhance the system's ability to detect valid incidents and minimize 'false alarms'.

Factors that did not appear to impact performance included:

- Inaccurate configuration of Video Analytics to roadway lanes did not appear to adversely affect performance. The Video Analytics systems could often detect stopped vehicles or slow traffic when the camera was out of position and the lane configurations were not aligned with the roadway.
- Camera position (zoom level, angle to roadway) did not appear to impact performance. Camera views with a wide range of zoom levels and angles to the roadway produced alerts that resulted in validated detections during the test.

2.2.2 Comparison of Detection Alerts to Agency-Reported Incidents

Approach

An additional test was conducted for a two-week period during the Des Moines deployment, to compare Video Analytics detection alerts to IA DOT-reported incidents. For this test, the Iowa DOT TMC/TOC manager kept a log of incidents that occurred in the Des Moines area for two weeks. The log included the following information for each incident: Date, time, location (route and cross-road or exit number), and type of incident (stalled vehicle, accident, or debris.) At the end of the two week test, the dates, times, and locations were compared against video detection alerts recorded during that period.

Results

During the two week test period, the Iowa DOT recorded 215 incidents that were logged as a stalled vehicle, an accident, or debris. During the same period, the Video Analytics system recorded 58 'stopped vehicle/debris in road' alerts. Of the incidents reviewed, only three (3) validated incidents from Video Analytics were likely the same incident as the DOT-reported incident. These three incidents occurred within 60 minutes of the DOT-reported incident and were in the vicinity of the camera that detected the incident. Two conclusions can be drawn from this result: 1) It is likely that Video Analytics systems detected a number of incidents that were not recorded by the Iowa DOT; and 2) It is likely that Video Analytics systems did not detect a number of incidents that occurred within the test area corridors because either the incidents occurred out the field of view of the instrumented cameras or the incidents were within the view of the instrumented cameras but were not detected by Video Analytics. This finding indicates that Video Analytics can be an effective tool for alerting operators of incidents that they may not have been aware of using existing mechanisms. Strategic placement of instrumentation of cameras is needed to optimize overall usefulness of Video Analytics along a given freeway coverage area. It is also important to note that the vehicle lane miles visible through the cameras connected to Video Analytics systems represented only approximately 12% of the Des Moines metro freeway networkⁱ.

2.2.3 Observations from Agency Staff

Approach

A number of observations and lessons learned were shared by the Iowa DOT's TMC/TOC manager during an interview approximately mid-way through the deployment period. A focus of the interview was to assess perceived value of Video Analytics to TMC/TOC operators, especially in terms of alert mechanisms and usefulness of the Video Analytics systems for incident detection.

Results

The following observations were shared during the interview with the Iowa DOT's TMC/TOC manager:

- **Value of Alert Mechanisms:** Emails from Video Analytics system that have an attached still image of the incident are useful. These emails enable operators to quickly determine whether the alert is an actual incident or a false alarm.
- **Timeliness of Alerts:** The incident alerts (communicated through web-based interfaces and email) are timely. Sometimes the Video Analytics system detected incidents that hadn't yet been seen by operators; other times the operators already knew about the incident.
- **Appropriateness of Alerts:** The number of false alarms is still fairly high. Operators may turn off alerts if the false alarm rate is too high, especially when they have several other emails/alerts to monitor. However, this deployment was a significant improvement over a trial that the TMC/TOC manager participated in several years ago in another state.
- **General Comment:** Video detection would be useful to maximize coverage in rural areas, as these areas can be difficult to monitor.

ⁱ The percentage of vehicle lane miles visible through cameras connected to Video Analytics was estimated as follows: 1/3 mile visibility per camera x 15 cameras / 42 total miles in the Des Moines freeway network.

2.2.4 Summary of Results – Incident Detection

Table 2-8 provides a summary of results from the evaluation of Video Analytics for incident detection.

Table 2-8: Summary of Results for Incident Detection from Video Analytics

Comparison of Detection Alerts to Video	
<u>Highest Level of Performance Achieved:</u>	
Stopped Vehicle / Debris in Road	
81 total alerts reviewed during a 44-day period:	
<ul style="list-style-type: none"> • 72% alerts validated • 23% alerts not validated • 5% alerts unable to determine 	
Stopped Vehicle / Debris in Road (adjusted to remove repetitive alerts caused by object in field of view)	
26 total alerts reviewed during a 21-day period:	
<ul style="list-style-type: none"> • 85% alerts validated • 0% alerts not validated (i.e. 0 ‘false alarms’) • 15% alerts unable to determine 	
Slow Vehicle/Congestion	
1111 total alerts reviewed during a 44-day period:	
<ul style="list-style-type: none"> • 30% validated • 33% alerts not validated • 37% alerts unable to determine 	
<p><u>Factors that Impacted Level of Performance</u></p> <ul style="list-style-type: none"> • Objects in the field of view • Weather events / moisture on camera lens • Headlight glare on roadway during nighttime lighting conditions 	<p><u>Factors that Did Not Appear to Impact Performance</u></p> <ul style="list-style-type: none"> • Inaccurate configuration of Video Analytics to roadway lanes • Camera position (zoom level, angle to roadway)
Comparison of Detection Alerts to Agency-Reported Incidents	
<ul style="list-style-type: none"> • It is likely that Video Analytics detected incidents that were not observed by agency staff, indicating that Video Analytics can be an effective tool for supplementing existing mechanisms to alert operators. • Strategic selection of camera locations along a coverage area will optimize usefulness of Video Analytics. 	
Observations from Agency Staff	
<ul style="list-style-type: none"> • Emails alerts with attached still images of the incident are useful. • Email alerts are timely; sometimes the Video Analytics systems caught incidents that hadn’t yet been seen by operators; other times the operators already knew about the incident. • The number of false alarms is still fairly high, but this deployment was a significant improvement over a trial that the TMC/TOC manager participated in several years ago in another state. • Video detection would be useful to maximize coverage in rural areas that are currently difficult to monitor. 	

2.3 Wrong-Way Vehicle Detection

This portion of the of the evaluation collected and analyzed data in order to understand the potential for Video Analytics systems to be an effective tool for detecting wrong-way movements by vehicles.

The evaluation approach included three elements:

- A controlled field test of three system deployments at freeway ramps in Ames, Iowa, to test the detection rate of Video Analytics.
- A review of wrong-way vehicle detection alerts from the deployments in rural Iowa and in Des Moines, IA as part of the larger incident detection test.
- Observations from agency staff who were responsible for configuring and monitoring the Video Analytics systems for this portion of the evaluation.

2.3.1 Controlled Field Test

Deployment Sites

The controlled field test consisted of Video Analytics systems deployed by three vendors at three separate freeway ramps in Ames, Iowa. Cameras at each site were positioned as close as possible to vendor recommendations. Two cameras were positioned approximately perpendicular to the roadway (90 degree detection), while one camera was positioned 'head-on' to traffic movement. Figure 2-9, Figure 2-10, and Figure 2-11 show deployment sites.

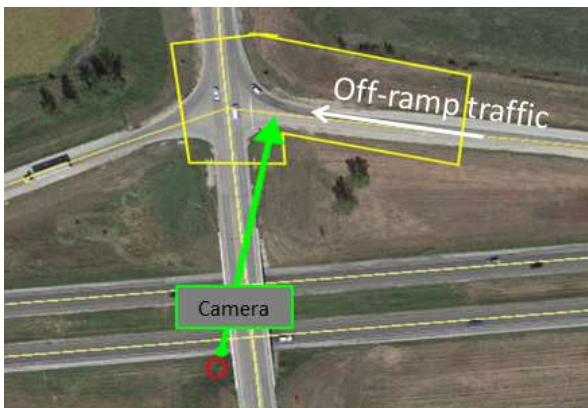


Figure 2-9: Deployment Site #1 (90 degree detection)



Figure 2-10: Deployment Site #2 (90 degree detection)



Figure 2-11: Deployment Site #3 ('head-on' detection)

Approach

The freeway ramps at each site were closed to traffic during the controlled test, while test vehicles were driven the in the opposite direction of traffic through a portion of the ramp within the field of view of the camera at each site. A detailed data collection plan was created prior to the controlled test, which outlined details for the 'test drives' conducted for each condition, the mechanism(s) for receiving alerts from the Video Analytics systems when a wrong-way movement was detected, and a method to document test conditions and results.

The following conditions were tested at each of the sites:

- Daytime/nighttime lighting conditions
- Three different vehicle sizes/types (small, mid-size, large);
- Three different vehicle colors (red, green, and blue);
- Different speeds (slow speed, typical speed);
- Vehicle positions within the test area (center of lane, edge of the lane, left shoulder, right shoulder);
- Vehicle changing directions within field of view (vehicle traveling the proper direction, then stopping and turning around within the test area)

At least 24 test drives were completed at each site – 12 test drives in daylight conditions and 12 test drives in nighttime lighting conditions. Each test condition was repeated at least two times. Some of the conditions were combined in one or more test drives (e.g. vehicle traveling slowly on the shoulder, vehicle traveling at typical speed in center of lane, etc.) If a particular condition resulted in a 'non-detection', additional tests were performed to focus on those conditions.

As each test drive was performed, detection alerts were provided to the evaluation team, either via automated emails, by viewing alerts at a web-based interface, or by viewing the vendor's detection alert interface in the field. For each test drive conducted, the evaluation team logged the result as 'detected' or 'not detected,' based upon the alert being received/observed or not received/observed.

Results

The highest level of performance achieved by Video Analytics systems evaluated during the controlled field test is as follows:

- **Daytime Test:** The highest level of performance achieved for the daytime test was 12 detections observed for 12 test drives (100% detection rate.)

- **Nighttime Test:** The highest level of performance achieved for the nighttime test was 10 detections and 2 non-detections observed for 12 test drives (83% detection rate.)

Factors that impacted the level of performance during the controlled field test included:

- **Slow Vehicle Speeds:** During both the daytime and nighttime tests, vehicles traveling slowly were detected less often than vehicles traveling at normal speeds by two of the three Video Analytics systems deployed.
- **Nighttime Lighting Conditions:** Each Video Analytics system that completed the nighttime test had better detection rates (more test drives resulting in detections) during the day than at night.

2.3.2 Wrong-Way Alerts from Incident Detection Deployments

Approach

This project's incident detection test, which deployed two Video Analytics systems in rural Iowa and one Video Analytics system in Des Moines, Iowa, included wrong-way vehicle detection capability. (See Section 2.2.1 for a full description of the evaluation approach for the incident detection component of the evaluation.) As such, when still images and video clips were reviewed and compared to alerts from the Video Analytics systems, an accuracy comparison was conducted for all incidents classified as wrong-way vehicle detections during the duration of the test. Wrong-way vehicle detection incidents were classified as 'likely detection (validated)', 'detection not likely (not validated)', or 'unable to conclusively determine.'

Because wrong-way vehicle movements are not common at these deployment locations, the analysis focused on determining the number of 'detections not likely (not validated)' or 'false alarms,' in addition to noting any actual wrong-way movements that may have been detected during the test period.

Results

Following are results from the review of detection alerts from the incident detection deployments:

- **Highest Level of Performance Achieved:**
 - The highest level of performance achieved was zero 'false alarms' for wrong-way vehicle movements during the 44-day Des Moines deployment test period.
 - During the test period, no actual wrong-way movements were observed or detected. Therefore, a conclusive determination of the accuracy of validated detections from Video Analytics could not be made.
- **Factors that Impacted the Level of Performance:** A factor that appeared to result in 'false alarms' was headlight glare was present during nighttime lighting conditions.

2.3.3 Observations from Agency Staff

Approach

A number of observations and lessons-learned were shared by Iowa DOT staff throughout the duration of the deployments at the test sites. Observations were noted by the evaluation team throughout the course of the project, with the intent of compiling information that would be of interest to other agencies who are considering wide-scale or small-scale (localized) deployments of Video Analytics for the purpose of detecting wrong-way vehicles.

Results

An important observation made by agency staff was that camera placement and accurate configuration of the Video Analytics system is critical to achieving accurate detections and minimizing ‘false alarms.’ For example, each vendor required specific camera placement (e.g. head-on to the direction of traffic or positioned at 90 degrees to the direction of traffic.) In addition, a significant amount of calibration and testing was done at each site by Iowa DOT staff, working with each respective vendor, to optimize system performance prior to performing the controlled test.

Other observations related to performance and usability of the systems were noted. Though the time of detection within the camera’s field of view varied from vendor to vendor, the systems generally detected wrong-way vehicle movements very quickly after the vehicle traveling the wrong direction entered the field of view. In addition, automated email alerts from vendors as detections occurred were timely and useful.

2.3.4 Summary of Results – Wrong Way Detection

Table 2-9 provides a summary of results from the evaluation of Video Analytics for detecting wrong-way vehicle movements. Results are displayed for the controlled field test, the review of detection alarms from system deployments in Iowa, and observations from agency staff.

Table 2-9: Results Summary for Wrong-Way Vehicle Detection from Video Analytics

Controlled Field Test	
<p>Highest Level of Performance Achieved: Daytime Test: 100% detection for 12 test drives Nighttime Test: 83% detection for 12 test drives</p>	
<p>Factors that Impacted Level of Performance:</p> <ul style="list-style-type: none"> • Slow vehicle speeds • Nighttime lighting conditions 	<p>Factors that Did Not Appear to Impact Performance:</p> <ul style="list-style-type: none"> • Vehicle size • Vehicle color • Vehicle position in the lane / vehicle changing directions within field of view
Review of Detection Alerts from Incident Detection Deployments	
<p>Highest Level of Performance Achieved: Zero ‘false alarms’ during a 44-day test period</p>	
<p>Factors that Impacted Level of Performance:</p> <ul style="list-style-type: none"> • Headlight glare on roadway during nighttime lighting conditions 	<p>Factors that Did Not Appear to Impact Performance:</p> <ul style="list-style-type: none"> • None observed (No actual wrong-way movements were observed)
Observations from Agency Staff	
<ul style="list-style-type: none"> • Camera placement and accurate configuration of the Video Analytics system is critical to achieving accurate detections and minimizing false alarms • Time of detection when the wrong-way vehicle entered the camera’s field of view varied from vendor to vendor, but the systems generally detected wrong-way vehicle movements very quickly • Automated email alerts provided by vendors as a detection occurs are timely and useful 	

3.0 Procurement Support Resources and Lessons Learned

3.1 Video Analytics Performance Requirements

Throughout the course of this project, discussions often led to the question “how accurate must Video Analytics be to be considered acceptable?” This section introduces a systems engineering approach that public agencies could follow (combined with the evaluation results presented in Section 2) to understand if the current Video Analytics state of the practice is appropriate for their situation, and to understand actions during the procurement process that might help them improve the likelihood that the Video Analytics systems deployed would match the needs.

The key to assessing the readiness of Video Analytics for deployment and real-time use is to understand the intended use(s) of the Video Analytics output. To this extent, the left side of the traditional systems engineering ‘Vee’ diagram is used as the background to this suggested approach, as illustrated in Figure 3-1, below.

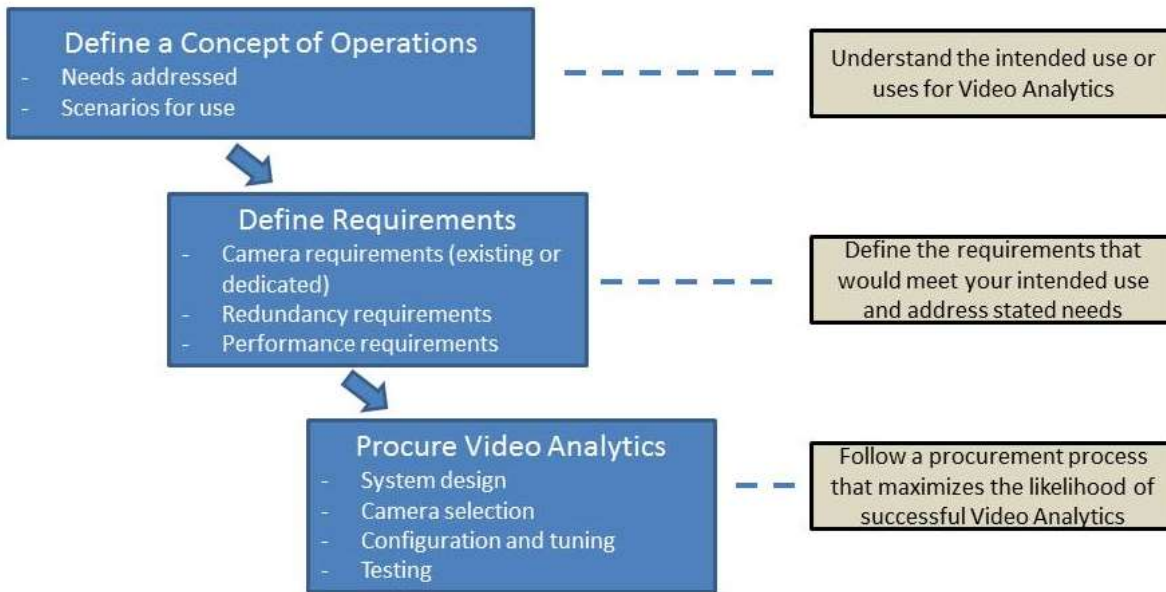


Figure 3-1: Approach to Determining Readiness of Video Analytics

3.2 Defining a Concept of Operations for Video Analytics

3.2.1 Understanding the Needs for Video Analytics

The extent to which any Video Analytics deployment will meet the end user needs depends upon the specifics of how the Video Analytics will be used. At the onset of this project, a series of challenges/issues with associated needs were identified for Video Analytics, summarized in Table 3-1. Each agency considering Video Analytics should consider these ‘straw man’ needs and determine if the needs are applicable for their agency, and modify as appropriate.

Table 3-1: Challenges/issues and Needs for Video Analytics

Challenges / Issues	Need for Video Analytics
Maintaining inductive loop detectors in a state that is adequate to deliver reliable data is expensive and inconvenient (e.g. creates lane closures when repairs are required, new loops are expensive, proper maintenance is expensive).	<p>Need #1: There is a need for real-time volume (per lane), occupancy (per lane), and speed data collection.</p> <p>Need #2: Traffic data collected using video analytics needs to be as reliable as or more reliable than data collected using loops, and as accessible (timeliness and accessibility to data) as loop detector data.</p> <p>Need #3: The overall costs (including deployment, operations and maintenance) of traffic data collection using video analytics needs to be equal to or less than the cost of data collection using inductive loops.</p>
Inductive loop detectors offer very little classification of heavy vehicles. Medium and heavy vehicle classification is needed to understand infrastructure use by commercial vehicles.	Need #4: There is a need to classify vehicles (FHWA 13 preferred, Med/Heavy vehicles required) – note this is not a real-time need, historical data processing is acceptable.
Current data collection methods offer no opportunities for automated Origin-Destination (O-D) generation, which is important for planning infrastructure additions and changes.	Need #5: There is a need to identify vehicles in order to generate O-D tables describing trip patterns. Note: This need will not be addressed by this Project.
Compass TMC operators cannot manually cycle through all video feeds especially if expanded coverage is added. Operators require a system to flag ‘events’ for them to examine.	Need #6: TMC operators need to receive real-time alerts when a crash/collision (or other traffic patterns typically identified as an incident) has occurred.
Current incident detection algorithms lack the ability to detect wrong way vehicles, debris on roadway, and other events, limited primarily by the data delivered by inductive loop detectors.	Need #7: TMC operators need to receive real-time alerts of other incidents/events, including wrong way vehicles, debris on roadway, vehicles on the shoulders.

Challenges / Issues	Need for Video Analytics
<p>In rural areas, animals, pedestrians, and recreational vehicles entering the highway pose a safety threat to travelers, and current technologies do not capture situations where animals are still in the median.</p>	<p>Need #8: There is a need for technologies with a sustainable business model to include operations in rural areas that will detect when an object is approaching or within the perimeter of the roadway.</p> <p>Need #9: Some detection (i.e. animal detections and wrong way vehicles) need to reach DMS/beacon displays locally immediately following detection, but need to reach central servers eventually for logging and analysis.</p>
<p>At locations (rural and urban) without fenced perimeters, pedestrians, snowmobiles, and other objects cross busy highways and/or freeways creating safety hazards.</p>	<p>Need #10: There is a need for an urban approach to detect animals or humans crossing a designated threshold outside the perimeter of the highway.</p>
<p>Regardless of how well video analytics perform, if the information is not delivered in a timely manner to those who need it, the effectiveness decreases substantially.</p>	<p>Need #11: There is a need to understand the options for communications and the performance levels possible with different communication mediums.</p>

3.2.2 Understanding the Use Case Scenarios for Video Analytics

During this project, a series of ‘Use Case Scenarios’ were identified by participating agencies, describing some intended uses for Video Analytics. This is not intended to represent a comprehensive list of uses for Video Analytics, but rather a series of scenarios that might match specific agencies’ needs.

Scenarios Tested in this Project

Scenario #1: Traffic data collection to support Traffic Management Center (TMC)/Traffic Operations Center (TOC) operators, with no long-term data retainage or real-time device control

In this scenario, traffic data (specifically volumes and speeds) are used by TMC/TOC operators to understand the status of the network and determine if real-time traffic management actions are required (e.g. posting messages to DMS or other information dissemination mediums, dispatching maintenance or field staff). Beyond the real-time use of the traffic data, there is not typically a need to store and maintain traffic data for long-term use. Traffic data from selected periods of time might be used for planning purposes, but in general, the goal is to support the real-time operations needs of TMC/TOC operators. Therefore, if a camera is panned and zoomed in on an incident and not able to record traffic data, this is not a concern because an operator in the TMC/TOC is observing the situation (by panning and zooming the camera) and therefore the TMC/TOC operator is knowledgeable of the situation. Also, the primary use of Video Analytics data would only be during hours when the TMC/TOC is in operation, and peak periods would be most critical. *(Related Video Analytics Needs: Need #1, Need #3, Need #4)*

Scenario #2: Traffic data collection with 24/7 use and archiving

This scenario includes all the activities of Scenario #1, and adds the use case that traffic data is used by TMCs/TOCs to support automated processes or systems (e.g. ramp metering, travel time calculations, real-time speed maps). In addition to real-time TMC/TOC operational support, the traffic data is also archived and used frequently by the DOT and partnering agencies (universities, planning organizations, consultants, etc.) when planning for future operational needs. In these cases, often traffic data is available for many

previous years and become a valuable asset for studying and understanding trends and current situations. Typically, these scenarios strive to have as close to complete data as possible. With traditional loop detectors, there are situations where data is missing for blocks of time, but in general the goal is high percentages of data availability, confidence in the data, and confidence that the data accuracy is consistent between day and night-time conditions. DOTs might consider this use for many or all of the cameras on their network, or for isolated cameras to supplement traffic data received from loop detectors or non-intrusive detectors. *(Related Video Analytics Needs: Need #2, Need #3)*

Scenario #3: Traffic data collection to support long-term planning and FHWA reporting

In this scenario, the use case is to collect traffic volume, speed, and vehicle classification data in regular increments (every 5 or 15 minutes). The traffic data is used to support long-term planning for infrastructure improvements and to report traffic information to the Federal Highway Administration (FHWA) or other federal/provincial government entities. Typically, these scenarios require high levels of accuracy for reported data, with very few gaps in data during the collection period (which may require a '24 hours per day/7 days per week' basis). In this scenario, vehicle classifications are an important data set to be collected, in addition to volume and speed data. For reporting to FHWA, vehicle classifications must be segmented into the 13 standard FHWA classification categories. However, this level of detail is not required for some planning purposes, and therefore Video Analytics could support a need to collect classification counts by grouping the 13 standard FHWA categories into 4 or 5 groups. DOTs may choose to use Video Analytics to supplement traditional data collection methods, especially those that collect all 13 FHWA categories, which can be expensive to implement on a large-scale basis. *(Related Video Analytics Needs: Need #4)*

Scenario #4: Incident detection or alerts to notify TMC/TOC operators

In this scenario, the use case is that Video Analytics would be used to process data from multiple cameras, flagging situations where incidents are detected (confirmed or likely) and alerting operators. Depending upon the specific DOT uses, incidents may include stopped vehicles or debris on the roadway or shoulder, slow or stopped traffic, and pedestrians or animals entering the roadway. Detection of these events would help operators monitor large numbers of cameras at one time without the need to visually observe each camera display. *(Related Video Analytics Needs: Need #6, Need #7)*

Scenario #5: Wrong way detection at entrance points to freeways or arterials

In this scenario, the use case is to equip cameras at the entrance points to freeways or arterials that are prone to vehicles entering the wrong way, and detect movement that would indicate a vehicle is entering the roadway traveling in the wrong direction. DOTs may use these detections to generate real-time alerts to be sent to the DOT or law enforcement agencies, as well as alerting travelers approaching the vehicle moving in the wrong direction. Information captured by these detections would also be helpful for DOTs to understand why drivers are entering the roadway in the wrong direction. *(Related Video Analytics Needs: Need #7)*

Scenario #6: Temporary deployments for targeted analysis of current conditions

In this scenario, Video Analytics is used for temporary deployments, to collect information that helps agencies conduct targeted analysis of existing conditions. One example would be deploying Video Analytics to detect incidents at locations thought to have high occurrences of wrong way drivers or crashes, possibly using a mobile system that is moved to multiple sites during a data collection period. The Video Analytics could detect the wrong way movements and also allow reviewers to watch the video of the vehicles to understand the lane of travel and direction they were traveling when they initiated the wrong way movement. Another example is the use of Video Analytics to collect traffic data on a temporary basis

during major events or when planning for situations that are likely to result in higher than normal traffic conditions. *(Related Video Analytics Needs: Need #3, Need #6, Need #7)*

Additional Scenarios Not Tested in this Project

Scenario #7: Detection of wrong-way vehicles at roadway lanes that are signed or barricaded to restrict entrance

In this scenario, the need is to detect wrong way vehicles in situations where full-time observation is required to closely monitor potential wrong-way vehicle movements. An example would include reversible lanes such as high occupancy volume (HOV) or toll lanes, where the geometry of the road allows wrong way vehicles to enter the lane and gates or signs are used to restrict entrance. Another example includes freeway entrance ramps that are closed to traffic during inclement weather conditions. These scenarios often require operator monitoring of the situation, and Video Analytics offers an alternative to this. *(Related Video Analytics Needs: Need #7)*

NOTE: *Scenario 7 was not tested as a part of this project.*

Scenario #8: Detection of stopped vehicles in locations with dynamic lane control

In this scenario, “dynamic lane control” refers to configurations that include one or more traffic lanes that are actively managed, often with overhead lane control signs operated by TMCs/TOCs. One such application is “hard shoulder running,” where a roadway shoulder is used as a travel lane during peak traffic periods. Another application is “managed lane control” which includes multi-lane configurations actively managed by operators in real-time, opening and closing lanes and/or posting variable speed limits using dynamic overhead signage, to manage traffic conditions. For this use case, Video Analytics needs to detect stopped vehicles and either automatically or via alerts, prevent operators from activating signs allowing vehicles to travel in one or more of the dynamic lanes. Typically, these scenarios would require Video Analytics to capture every stopped vehicle. However, this use case typically includes shorter stretches of roadway instrumented with overhead lane control signs, making Video Analytics a viable option in terms of feasibility to deploy dedicated cameras with complete coverage of the viewing area along the length of the corridor. *(Related Video Analytics Needs: Need #7)*

NOTE: *Scenario 8 was not tested as a part of this project.*

3.2.3 Sample Requirements and Procurement Considerations for Use Case Scenarios

In order to assist agencies procure and deploy Video Analytics systems for various uses, this section provides considerations such as sample requirements, recommended procurement actions, and readiness of the current state of practice for each of the scenarios tested during this project. As such, Tables 3-2 through 3-6 provide this information for Scenarios 1-6. Scenarios 7 and 8 were not tested during this project and therefore sample requirements and procurement considerations are not provided.

Table 3-2: Scenario #1 – Traffic data collection to support TMC/TOC operations with no long term data retainage or real-time device control

Operational Concept	
<p>In this scenario, traffic data (specifically volumes and speeds) are used by TMC/TOC operators to understand the status of the network and determine if real-time traffic management actions are required (e.g. posting messages to DMS or other information dissemination mediums, dispatching maintenance or field staff). Beyond the real-time use of the traffic data, there is typically not a need to store and maintain traffic data for long-term use. Traffic data from selected periods of time might be used for planning purposes, but in general the goal is not to save traffic data for long term retainage and later use.</p>	
Consideration	Description
Camera Requirements	<p>These scenarios would most likely not require dedicated cameras, but could use existing cameras, provided:</p> <ul style="list-style-type: none"> • The spacing between existing cameras is close enough to report an acceptable level of traffic data for the operational use (considering things such as intersections, on/off ramps, etc.) or there is an existing network of traffic data collection devices and Video Analytics is intended to fill gaps or supplement the data with existing cameras. • The lighting and viewing angle of existing cameras is suited to the use case.
Redundancy Requirements	<ul style="list-style-type: none"> • These scenarios would likely not require redundancy. Current traffic detection technologies have periods where readings are either not available (e.g. hardware failure or communications failure), or times when traffic situations prevent accurate readings (e.g. during extremely slow traffic, loop detectors report traffic with lower accuracies). • In situations where cameras are panned or zoomed, TMC/TOC operators would be involved in the response and relying less on the traffic data reported.
Performance Requirements	<p>Accuracy:</p> <ul style="list-style-type: none"> • For traffic and travel conditions made available by real-time information programs, information is required to be 85% accurate as a minimum, or have a maximum error (percent difference) of 15% (SAFETEA-LU 23 CFR 511¹). TMCs/TOCs may choose to require more or less accuracy, depending on the intended use of the data. • Performance requirements may vary based on the time of day and volume patterns of traffic. For example, overnight, when traffic volumes are very low, accuracy is likely to be less critical than during the daytime when volume is used to compute travel times and inform travelers. <p>Availability:</p> <ul style="list-style-type: none"> • 90% availability is required for real-time information for traffic and travel conditions (SAFETEA-LU 23 CFR 511¹), but not in a critical operational sense where operators would be needed to observe all situations where the system was taken off-line. <p>Timeliness of Delivery:</p> <ul style="list-style-type: none"> • TMC/TOC operations in this scenario would likely require delivery of data in 5-or 15-minute increments.
Recommended Procurement Actions	<ul style="list-style-type: none"> • Include a design phase to work with the Video Analytics provider to define the extent of conditions that Video Analytics is desired to support • Based on the design, include Video Analytics providers in the selection of camera

	<p>technologies (e.g. thermal / non-thermal, HD / non-HD), camera locations, communications, and processing center design.</p> <ul style="list-style-type: none"> • Include tasks in the scope of work to support a high degree of tuning and configuration, including tuning and configuration adjustments throughout the first annual cycle of deployment (seasonally). • Include testing at different lighting conditions, seasons, and weather events
Readiness of Current State of Practice	<p>Video Analytics demonstrated that it can collect traffic data with the following performance levels, for one direction of traffic:</p> <ul style="list-style-type: none"> • <u>Volumes</u>: 91% accuracy (9% difference) during the day, 86% accuracy (14% difference) for the AM peak period, 91% accuracy (9% difference) for the PM peak period, and 83% accuracy (17% difference) at night. • <u>Speeds</u>: 98% accuracy (2% difference) during the day and 94% accuracy (6% difference) at night, with even better accuracies in AM and PM peak periods. <p>Video Analytics is ready to support this scenario with the current state of practice, since it demonstrated that it exceeds performance requirements during the day, as well as during AM and PM peak periods when real-time traffic data (volumes and speeds) is most likely to be utilized to support TMC/TOC operations. If accurate nighttime data is needed, it may be possible to use Video Analytics as a supplementary tool near other detection devices and obtain acceptable accuracies by applying ‘correction factors’ to nighttime data outputs.</p> <p>Additional readiness considerations include:</p> <ul style="list-style-type: none"> • The ability of VA vendors to provide the traffic data through a delivery mechanism that is timely and readily accessible to TMC/TOC operators; and • That TMC/TOC operators accept that Video Analytics traffic data may not be available or may be inaccurate during periods when cameras are moved.

Table 3-3: Scenario #2 - Traffic data collection with 24/7 use and archiving

Operational Concept	
<p>This scenario includes all the activities of Scenario #1, and adds the use case that traffic data is used by TMCs/TOCs to support automated processes or systems (e.g. ramp metering, travel time calculations, real-time speed maps). In addition to real-time TMC/TOC operational support, the traffic data is also archived and used frequently by the DOT and partnering agencies (universities, planning organizations, consultants, etc.) when planning for future operational needs. In these cases, often traffic data is available for many previous years and become a valuable asset for studying and understanding trends and current situations. Typically, these scenarios strive to have as close to complete data as possible. With traditional loop detectors, there are situations where data is missing for blocks of time, but in general the goal is high percentages of data availability, confidence in the data, and confidence that the data accuracy is consistent between day and night-time conditions. DOTs might consider this use for many or all of the cameras on their network, or for isolated cameras to supplement traffic data received from loop detectors or non-intrusive detectors.</p>	
Consideration	Description
Camera Requirements	<p>These scenarios would most likely require dedicated cameras. Alternately, if multi-use cameras are used, DOTs would likely require Video Analytics to flag those periods when the camera was panned or zoomed and traffic detection was not complete for the period of interval, potentially including a smoothing algorithm to ‘fill’ in data based on the data during the period before and after the camera position changed.</p>

Redundancy Requirements	These scenarios would likely not require redundancy. Current traffic detection technologies have periods where readings are either not available (e.g. hardware failure or communications failure), or times when traffic situations prevent accurate readings (e.g. during extremely slow traffic, loop detectors report traffic with lower accuracies).
Performance Requirements	<p>Accuracy:</p> <ul style="list-style-type: none"> For traffic and travel conditions made available by real-time information programs, information is required to be 85% accurate as a minimum, or have a maximum error (percent difference) rate of 15% (SAFETEA-LU 23 CFR 511¹). TMCs/TOCs may choose to require more or less accuracy, depending on the intended use of the data. Traffic data accuracies should be consistent for 24-hour periods (e.g. accuracy levels that do not vary from day to night) due to the need for the data to feed real-time information systems as well as <p>Availability:</p> <ul style="list-style-type: none"> 90% availability is required for real-time information for traffic and travel conditions (SAFETEA-LU 23 CFR 511¹), but not in a critical operational sense where operators would be needed to observe all situations where the system was taken off-line. <p>Timeliness of Delivery :</p> <ul style="list-style-type: none"> Some TMC/TOC operations, such as ramp metering and real-time travel time reporting, may require very timely delivery of data, such as 1–minute reporting, as opposed to every 5 minutes.
Recommended Procurement Actions	<ul style="list-style-type: none"> Include a design phase to work with the Video Analytics provider to define the extent of conditions Video Analytics is desired to support Based on the design, include Video Analytics providers in the selection of camera technologies (e.g. thermal / non-thermal, HD / non-HD), camera locations, communications, and processing center design. Include tasks in the scope of work to support a high degree of tuning and configuration, including tuning and configuration adjustments throughout the first annual cycle of deployment (seasonally). Include testing at different lighting conditions, seasons, and weather events.
Readiness of Current State of Practice	<p>Video Analytics demonstrated the following performance levels for one direction of traffic:</p> <ul style="list-style-type: none"> <u>Volumes</u>: 91% accuracy (9% difference) during the day, and 83% accuracy (17% difference) at night. <u>Speeds</u>: 98% accuracy (2% difference) during the day, and 94% accuracy (6% difference) at night. <p>Video Analytics is not ready to support this scenario with the current state of practice because 24/7 data accuracy and consistency in accuracy is required, and the demonstrated volume accuracies at night do not meet the accuracy requirement. However, if Video Analytics is used as a supplementary tool near other detection devices, it may be possible to obtain acceptable accuracies at night by applying ‘correction factors’ to nighttime data outputs. In addition, TMC/TOCs could decide that Video Analytics provides enough reliability and accuracy to supplement a network of traffic detection systems by deploying Video Analytics at selected</p>

locations and by smoothing data from nearby detectors to achieve accuracy requirements during overnight hours.

Table 3-4: Scenario #3 - Traffic data collection to support long-term planning and FHWA reporting

Operational Concept	
<p>In this scenario, the use case is to collect traffic volume, speed, and vehicle classification data in regular increments (e.g. every 5 or 15 minutes.) The traffic data is used to support long-term planning for infrastructure improvements and to report traffic information to the Federal Highway Administration (FHWA) or other federal/provincial government entities. Vehicle classifications are an important data set to be collected. DOTs may choose to use Video Analytics to supplement traditional data collection methods, especially those that collect all 13 FHWA categories, which can be expensive to implement on a large-scale basis.</p>	
Consideration	Description
Camera Requirements	This scenario would most likely require dedicated cameras if data collection must be performed for 100% of the data collection period.
Redundancy Requirements	This scenario would either require reliable data collection capable of measuring data for 100% of the data collection period or redundant systems.
Performance Requirements	This use case requires very high accuracies during the entire data collection period, with limited gaps in available data. Vehicle classifications must be segmented into the 13 standard FHWA classification categories for reporting to FHWA, while other planning applications can utilize data collection mechanisms that combine the 13 FHWA classifications into 4 or 5 groups.
Recommended Procurement Actions	<ul style="list-style-type: none"> • Include a design phase to work with the Video Analytics provider to define the extent of conditions Video Analytics is desired to support • Based on the design, include Video Analytics providers in the selection of camera technologies (e.g. thermal / non-thermal, HD / non-HD), camera locations, communications, and processing center design. • Include tasks in the scope of work to support a high degree of tuning and configuration, including tuning and configuration adjustments throughout the first annual cycle of deployment (seasonally). • Include testing at different lighting conditions, seasons, and weather events.
Readiness of Current State of Practice	<p>Video Analytics demonstrated the following performance levels, for one direction of traffic:</p> <ul style="list-style-type: none"> • <u>Volumes</u>: 91% accuracy (9% difference) during the day and 83% accuracy (17% difference) at night. • <u>Speeds</u>: 98% accuracy (2% difference) during the day and 94% accuracy (6% difference) at night. • <u>Vehicle Classifications</u>: 76% accuracy (24% difference) for “motorcycles” at night, 87% accuracy (13% difference) for “cars” during the day, 56% accuracy (44% difference) for “small trucks” during the day, and 77% accuracy (23% difference) for “large trucks” during the day. Even less accurate results were seen at night. <p>Video Analytics is not ready to support this scenario with the current state of practice because this use case requires high levels of accuracy during the entire data collection period; in particular, vehicle classification results did not demonstrate high accuracies.</p>

Video Analytics cannot currently classify vehicles into FHWA’s 13 classification categories. However, agency representatives involved in the project indicated that the groupings provided by Video Analytics are acceptable for some planning purposes, and Video Analytics could be a valuable tool to supplement existing mechanisms for collecting traffic data if accuracies improve to acceptable levels. Therefore, while Video Analytics may not be suited to be the sole data collection mechanism for this purpose, the groups that execute this use case scenario agreed that the additional classification data from Video Analytics equipped cameras throughout the state/province would be a valuable asset and improve their overall understanding of vehicular movements.

Table 3-5: Scenario #4 - Incident detection or alerts to notify TMC/TOC operators

Operational Concept	
<p>In this scenario, the use case is that Video Analytics would be used to process data from multiple cameras, flagging situations where incidents are detected (confirmed or likely) and alerting operators. This would help operators monitor large numbers of cameras at one time without the need to visually track each camera.</p>	
Consideration	Description
<p>Camera Requirements</p>	<ul style="list-style-type: none"> • These scenarios would most likely not require dedicated cameras. Testing in this project suggests that incident detection can be effective during periods when the cameras are panned or zoomed. • Testing in this project suggests that the coverage of cameras is most critical to capturing the highest percentage of incidents. Depending upon the use case, cameras could be located at key spots where incidents are likely or located to cover the entire network. • Camera placement can also impact incident detection performance. Effects such as glare from headlights (on the roadway monitored or nearby roadways), reflections off of steel or glass structures, objects in the field of view, exhaust fumes, the rising or setting sun can all be factors that influence incident detection and should be considered during camera selection and placement.
<p>Redundancy Requirements</p>	<p>These scenarios would likely not require redundancy other than the other incident reporting activities that occur within a TOC/TMC. This use of Video Analytics would supplement operators monitoring the cameras and the 911 phone calls and radio reports from law enforcement and DOT personnel in the field that also report incidents.</p>
<p>Performance Requirements</p>	<p>Accuracy:</p> <ul style="list-style-type: none"> • The frequency of false positive reports of incidents (reporting an incident when it does not exist, or ‘false alarms’) is a critical factor that would determine use of Video Analytics for this purpose. A high percentage of false positive reports compared to alerts that are actual incidents could cause operators to turn off alerts or begin to ignore them. Each agency must identify its acceptance level for false positives, taking into account the size of the traffic network, environment and work flow in the TMC/TOC, and other alert mechanisms that may be in place. • The frequency of false negative occurrences (not detecting and incident that has occurred) is also a factor in defining performance, though it is likely that Video Analytics will be used as a tool to supplement other mechanisms used by TMC/TOC operators to learn of incidents. There were no specific parameters

	<p>defined or tested regarding minimal acceptable false negative rates.</p> <p>Timeliness:</p> <ul style="list-style-type: none"> • Timely detection of incidents is another important performance requirement. If reporting time from when the incident occurred until the time it is reported is too long, TOC operators will already know about the incident. Unfortunately, time to detection and false positive ('false alarm') rates can often be directly related. For example, systems that are set to detect stopped vehicles quickly may also trigger alerts for image elements that are not valid incidents, such as shadows or roadway glare. <p>Availability:</p> <ul style="list-style-type: none"> • Near 100% availability would also be a requirement, but not in a critical operational sense considering the additional incident reporting mechanisms.
<p>Recommended Procurement Actions</p>	<ul style="list-style-type: none"> • Include a design phase to work with the Video Analytics provider to define the extent of conditions Video Analytics is desired to support. • Based on the design, include Video Analytics providers in the selection of camera technologies (e.g. thermal / non-thermal, HD / non-HD), camera locations, communications, and processing center design. • Include tasks in the scope of work to support a high degree of tuning and configuration, including tuning and configuration adjustments throughout the first annual cycle of deployment (seasonally). • Include testing at different lighting conditions, seasons, and weather events. • Through camera placement, configurations, and sensitivity tuning, Video Analytics providers would need to work with DOT to ensure false positive ('false alarm') rates are minimized. • Consider a go / no-go decision for each camera to decide whether false positive ('false alarm') rates can be minimized enough to justify deployment. This requires recognition from all parties that some existing camera sites work well for incident detection and some do not.
<p>Readiness of Current State of Practice</p>	<p>Video Analytics demonstrated that with proper location and configuration, detection of stopped vehicles and/or debris in roadway can have minimal false positives or 'false alarms' (as few as 0% false alarms), however the camera site is critical to achieve this. Slow traffic detections were found to have higher 'false alarm' rates. In addition, Video Analytics demonstrated that it can be effective in supplementing existing mechanisms for incident detection (e.g. detecting/alerting operators of incidents they were not already aware of.)</p> <p>Based on the findings of this evaluation, Video Analytics is ready to perform incident detection for stopped vehicles/debris, in situations where:</p> <ul style="list-style-type: none"> • A well scoped design, implementation, configuration, and testing phase allows the Video Analytics provider to configure and test selected cameras before real-time use; • All parties agree to reach a 'go/no-go' decision on each camera after testing occurs and false alarms are found to be minimal; and • There are provisions for periodic re-configuration of Video Analytics settings to ensure detections are appropriate (e.g. false positives are minimized). <p>In addition, Video Analytics may be ready to perform incident detection for slow traffic / congestion, provided that:</p>

	<ul style="list-style-type: none"> • Slow speed detections are tested and reviewed with TOC/TMC operators to ensure that the operators have a common definition of ‘slow speeds’ with those who configured and tested the Video Analytics; • All parties agree to reach a ‘go/no-go’ decision on each camera after testing occurs and false alarms are found to be minimal; and • Agencies define a threshold for acceptable ‘false alarm’ rates.
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Table 3-6: Scenario #5 - Wrong way detection at entrance points to freeways or arterials

Operational Concept	
<p>In this scenario, the use case is to equip cameras at the entrance points to freeways or arterials that are prone to vehicles entering the wrong way, and detect movement that would indicate a vehicle is entering the roadway traveling in the wrong direction. DOTs may use these detections to generate real-time alerts to be sent to the DOT or law enforcement agencies, as well as alerting travelers approaching the vehicle moving in the wrong direction. Information captured by these detections would also be helpful to help DOTs understand why drivers are entering the entrance ramps in the wrong direction, with the ultimate goal of determining an approach to minimize or eliminate these wrong-way movements.</p>	
Consideration	Description
Camera Requirements	These scenarios would most likely require dedicated cameras, fixed at zoom levels that will ensure 100% coverage of the selected area 100% of the time.
Redundancy Requirements	The extent to which redundancy is needed would be a local decision based on the frequency of wrong way vehicle movements and the specific intended use. For example, if the specific intended use is to detect every wrong way moving vehicle and alert oncoming vehicles, the redundancy should be considered.
Performance Requirements	<p>If agencies are using Video Analytics to identify problem locations where drivers are entering entrance ramps in the wrong-way direction and determine potential geometric changes or safety treatments, 100% detection accuracy would not be required. If agencies utilize Video Analytics to warn traffic, they should decide upon an acceptable rate of detection and decide if redundancy is required (e.g. 100% detection of wrong way vehicles in these situations may be required).</p> <p>False positive detections (‘false alarms’) should also be minimized, but are preferred to false negatives (not detecting and incident that has occurred).</p> <p>Near 100% up-time would also be a requirement. During periods when down-time is needed (e.g. system upgrades or modifications), operators could be used to view video and detect vehicles.</p>
Recommended Procurement Actions	<ul style="list-style-type: none"> • Include a design phase to work with the Video Analytics provider to define the extent of conditions Video Analytics is desired to support. • Based on the design, include Video Analytics providers in the selection of camera technologies (e.g. thermal / non-thermal, HD / non-HD), camera locations, communications, and processing center design. • Include tasks in the scope of work to support a high degree of tuning and configuration, including tuning and configuration adjustments throughout the first annual cycle of deployment (seasonally). • Include testing at different lighting conditions, seasons, and weather events • Include testing at various vehicle speeds.

Readiness of Current State of Practice	<p>Video Analytics demonstrated that with proper location and configuration, they can perform vehicle detections 100% of the time during daylight hours and 83% accurate detections during night-time conditions.</p> <p>Testing in this project suggests that Video Analytics state of practice is suitable to play the role in this scenario if 83% detection is acceptable and/or if additional redundancy is deployed.</p>
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Table 3-7: Scenario #6 - Temporary deployments for targeted analysis of current conditions

Operational Concept	
<p>In this scenario, Video Analytics is used for temporary deployments, to collect data/information that helps agencies conduct targeted analysis of existing conditions, such as identifying areas high incidences of wrong way drivers or collecting traffic data to plan for major events.</p>	
Consideration	Description
Camera Requirements	<p>These scenarios would require dedicated cameras for temporary deployments. Some deployments may require highly “mobile” configurations that can be moved to multiple sites during the data collection period.</p>
Redundancy Requirements	<p>The extent to which redundancy is needed would be a local decision based on the specific application. If the application is primarily for research and analysis, such as detecting occurrences of wrong way drivers to understand where the movements originate, redundancy may not be needed.</p>
Performance Requirements	<p>If agencies are using Video Analytics to identify problem locations where drivers are entering entrance ramps in the wrong-way direction and determine potential geometric changes or safety treatments, 100% detection accuracy would not be required. If agencies are using Video Analytics to collect traffic data during a major event, high levels of accuracy would be required and near 100% up-time would be required during the temporary data collection period</p>
Recommended Procurement Actions	<ul style="list-style-type: none"> • Include a design phase to work with the Video Analytics provider to define the extent of conditions Video Analytics is desired to support. • Based on the design, include Video Analytics providers in the selection of camera technologies (e.g. thermal / non-thermal, HD / non-HD), camera locations, communications, and processing center design. • Include tasks in the scope of work to support a high degree of tuning and configuration for the specific application • Include testing and verification of performance thresholds, prior to the data collection period
Readiness of Current State of Practice	<p>Video Analytics is ready to support many applications of this scenario with the current state of practice. Because this scenario requires dedicated Video analytics system(s) for specific temporary deployments, near-optimal conditions (camera locations, settings, configurations, etc.) are more likely to be achieved, when compared to deployments that utilize existing camera infrastructure.</p>

Scenario #7: Detection of wrong-way vehicles at roadway lanes that are signed or barricaded to restrict entrance

This scenario was not tested as a part of this project.

Scenario #8: Detection of stopped vehicles in locations with dynamic lane control

This scenario was not tested as a part of this project. In order to test this scenario, a controlled test would need to be conducted, where a fixed number of vehicles would be driven along a section of roadway (e.g. closed test track) and stopped in the lane to determine whether Video Analytics accurately detects each stopped vehicle occurrence.

3.3 Lessons Learned

The following provides a summary of lessons learned, which may be useful for transportation agencies that are planning for, procuring, deploying, and evaluating video analytics systems.

3.3.1 Planning and Procurement

- **Determine Uses and Needs:** Determine your agency's specific needs and use case (or use cases) for which the video analytics is being sought and procure a system that will accommodate those needs most appropriately. It may not be optimal to deploy Video Analytics in an attempt to meet all applications; for example, an agency may need incident detection capabilities at in-place cameras first and foremost and can achieve this using existing infrastructure. This decision may mean that traffic data collection performance at these existing cameras will not be optimal and if both applications are needed, a separate solution (Video Analytics or other) may be warranted.
- **Understand Limitations of Multi-Purpose Capabilities:** It is important to understand that a single camera deployed with Video Analytics may only be well-suited to one application or use. Depending on the landscape, geometric layout, zoom level, and camera angle, a single camera may not support all uses and needs. For example, a camera set to an optimal zoom level for detecting animals (on the roadside) may not be able to detect traffic incidents and/or collect traffic data in the travel lanes.
- **Recognize Investment Tradeoffs:** Agencies considering Video Analytics should aim to understand the full costs of implementing it. Video Analytics may carry lower initial infrastructure costs by utilizing existing cameras and/or existing mounting structures. However, other initial costs and long-term costs should be considered. Initial investments will include staff resources to learn the software, troubleshoot issues, and conduct setup and configuration. In addition, agency staff time and expertise will be required throughout the life of the system, to operate the software and to conduct re-configurations as needed to maximize performance.
- **Utilize Fixed Cameras and/or Dedicated Cameras for Traffic Data Collection:** For more accurate traffic data collection results, consider deploying Video Analytics with fixed/stationary cameras rather than in-place Pan-Tilt-Zoom (PTZ) cameras that are being used for traffic operations. The cost of installing a dedicated camera in a location where infrastructure (e.g. mounting apparatus) is already in place is relatively inexpensive compared to the cost of implementing new infrastructure. Similarly, consider using dedicated cameras positioned at optimal locations/zoom levels, for the most accurate traffic data collection results. Consider installing temporary dedicated cameras in locations where existing infrastructure does not accommodate adequate camera positioning to optimize video analytics processing.
- **Optimize Video Feed Quality and Communications:** The quality of video feeds as they are processed by Video Analytics can greatly affect the level of performance that can be achieved. If a video feed is "choppy," it will not be processed by Video Analytics as accurately as a feed that is streamed with minimal interruption. Communications mechanisms (e.g. fiber optics, wireless data transfer, etc.) used to relay video streams from cameras in the field to centrally located Video Analytics servers should be reliable and stable. Communications mechanisms should not be under-

estimated in terms of Video Analytics performance impacts, if interruptions in video streams are present. Consider sharing video feeds with potential vendors during procurement process and request that potential responders provide feedback on the video quality, along with suggestions for improvement. Consider testing video streams, perhaps by recording video and making it available for testing by potential vendors, in advance of the procurement process.

- **Include Design and Testing Provisions in Procurement Documents:** Include provisions for a design phase, tuning and configuration, and testing of Video Analytics systems in the procurement documents, as described in the 'Recommended Procurement Actions' section of each Use Case Scenario outlined in Section 3.2.3. This includes including the Video Analytics vendor in camera selection and following vendor guidelines for camera position, angle, and zoom level. Consider including tasks for additional testing and tuning 6 months to a year after initial deployment, to benefit from the experiences of the vendor to help achieve additional accuracy or to resolve any issues that are occurring.
- **Make 'Go/No-Go' Decision When Selecting Cameras:** It is recommended that agencies work with Video Analytics providers to reach a 'go/no-go' decision for each camera, after testing occurs. This is especially important for incident detection, in order to minimize false positives (false alarms), but holds true for other uses as well.
- **Consider Potential for Video Analytics when Installing New Cameras:** Even if agencies are not planning immediate deployments of Video Analytics, they may wish to consider its future potential when placing and installing new cameras. Video Analytics providers are typically willing to share guidelines for optimal camera placement, so agencies may wish to begin creating infrastructure that is better suited to Video Analytics as new installations of cameras and/or mounting structures are being completed.

3.3.2 Deployment

- **Dedicate Agency Resources to Deployment Activities:** The selected Video Analytics vendor will be on-site to install equipment, perform testing, trouble-shoot issues, train agency staff on system operations, and assist with initial system settings and calibrations. In order to realize the highest benefit from interactions with the vendor's technical staff, agencies should allow plenty of time and engage the appropriate staff to assist with installation, trouble-shooting, and to participate in training. Time on-site will typically be a few days; however, it may be beneficial to plan one or more check-in visits with vendors as agency staff learn and increase their use of the system.
- **Commit to Learning and Understanding System Procedures:** Video Analytics systems will perform best when operators fully understand the opportunities and limitations of the system's functionality and the associated calibration/adjustment procedures. Spend time to learn and understand the Video Analytics system's calibration procedures, in order to obtain the most accurate and useful results. Video Analytics will require a level of staff expertise to be maintained, as compared to other detection technologies (e.g. loop detectors) that do not require regular monitoring and re-configuration.

3.3.3 System Operation

- **Use Camera Presets and Auto-Return to Preset Positions:** If PTZ cameras are used, employ preset camera position settings, so that if a camera is moved out of position for incident viewing, it will return to its "home" position that corresponds to its Video Analytics calibration position within a certain time period. This will minimize time periods when Video Analytics is reporting data/results

that are not accurate due zooming or camera movements out of the position that is configured for Video Analytics processing.

- **Monitor Calibrations and Adjust as Needed:** For the most accurate and reliable results, operators should monitor cameras and Video Analytics calibration settings on a regular basis to determine whether or not they are positioned appropriately. If cameras are moved out of a “home” position, the Video Analytics settings should be adjusted accordingly, especially if an automatic return to the camera preset positions is not available or utilized. Agency representatives involved in this project provided feedback that this can be a manageable task if the Video Analytics system auto-adjusts to calibration settings when the camera is returned to a position that is close to the original calibration.
- **Recognize the Strong Link between Human Interaction and System Performance:** There is a strong ‘human’ component involved with operating and maintaining Video Analytics systems. The success of Video Analytics is highly dependent upon the level of commitment an agency makes to ensure that operators are engaged to consistently optimize camera settings, views, and placements. TMC/TOC leaders should be aware of this interaction, managing operations, workflow, and staff accordingly to achieve the highest possible level of performance.

3.3.4 Evaluation

- **Establish Performance Parameters:** A future evaluation approach could establish ‘success’ parameters, for a number of applications/uses of Video Analytics. For example, this project did not aim to determine operators’ tolerance level for false alarms during incident detection (e.g. how many false alarms are too many?) This is especially important for subjective performance criteria. A future evaluation could establish performance parameters upfront, in order to evaluate actual performance levels against these parameters.
- **Compare Video Analytics to Other Detection Mechanisms:** There are a wide range of perceptions and opinions about the performance of various detection technologies (e.g. accuracy, ease of use, strengths/weaknesses.) A future evaluation could include a component to compare and contrast Video Analytics against other detection technologies by collecting and analyzing relevant data, engaging TMC/TOC operators in comparison activities, and comparing performance outcomes for various technologies and specific uses.
- **Test the Effectiveness of Video Analytics to Improve Operations:** A future evaluation could be conducted to determine how effective Video Analytics is in improving operational efficiency in a various TMC/TOC settings, including major metro areas and rural operational settings. The test could work closely with operators to understand how Video Analytics is received into current operational practices and to identify changes in practice that may be needed when adopting Video Analytics as a technology tool to ultimately improve overall operations.
- **Extend Incident Detection Testing to “Missed Incidents”:** This project did not include systematic testing for “missed incidents,” to determine the extent to which Video Analytics failed to detect actual incidents that occurred. This type of testing would involve driving/stopping vehicles in the roadway, either in real-world conditions (e.g. freeway) or in a controlled environment such as a test track. Any testing conducted in an actual freeway setting has safety implications, both for the individuals who are driving/stopping and for the traveling public. An alternate approach would be to conduct testing on a closed test track; this approach would likely require several vehicles/drivers, to simulate real-world conditions and would not completely eliminate safety concerns.

Works Cited

¹ Federal Highway Administration. (2010) *Real-Time System Management Information Program [1201] Fact Sheet*, Federal Highway Administration, <http://ops.fhwa.dot.gov/1201/factsheet/>.