ENTERPRISE Transportation Pooled Fund Study TPF-5 (231)

ENTERPRISE

Evaluation for Transferring Full Motion Video from Rural Traffic Cameras

EVALUATION REPORT

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Acknowledgements

This document was prepared for the ENTERPRISE Transportation Pooled Fund TPF-5(231) program (enterprise.prog.org/). The main purpose of ENTERPRISE is to use the pooled resources of its members and the United States federal government from North America to develop, evaluate, and deploy Intelligent Transportation Systems (ITS).

Project Champion

Tim Simodynes, Iowa Department of Transportation, was the ENTERPRISE Project Champion for this effort. The Project Champion serves as the overall leads for the project.

ENTERPRISE Members

The ENTERPRISE Board consists of a representative from each of the following member entities of the program.

- Georgia Department of Transportation
- Illinois Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Oklahoma Department of Transportation
- Ontario Ministry of Transportation
- Pennsylvania Department of Transportation
- Texas Department of Transportation
- Transport Canada
- USDOT Federal Highway Administration

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1.0 Introduction

Significant progress has been made over the past decade in improving the breadth and quality of wireless communications services, yet challenges still remain with communications in rural areas to support Intelligent Transportation System (ITS) devices.

This ENTERPRISE project "Demonstrate and Evaluate Rural Communications to Support Rural ITS" outlined an initiative to identify, demonstrate, and evaluate one or more emerging communication support technologies that could be used by transportation agencies to communicate with ITS devices in rural areas. Per direction from the ENTERPRISE Board, the project was separated into two phases in order to properly assess issues and potential solutions before coordinating a deployment and evaluation. Phase 1 gathered information about issues and potential solutions and developed a scope of work for Phase 2.

This Phase 2 project includes an effort to evaluate commercially available products for supporting the transfer of full motion video over wireless communications (e.g. cellular) in a real-world setting by utilizing deployments coordinated by Iowa DOT and North Dakota DOT. This document presents an evaluation of test deployments being coordinated by Iowa DOT for one commercially available product for transferring full motion video over wireless communications, as well as a second, similar product tested by Iowa DOT and more broadly utilized by North Dakota DOT.

The intent of this evaluation was to understand the potential for these technologies and the performance levels that agencies might expect when deploying the current state of practice in transferring full motion video from rural traffic cameras. This project did not attempt to evaluate specific vendor products 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 these technologies to support communications with rural devices.

This document contains the following sections:

2.0 Summary of Findings and Recommendations

Operational systems were evaluated in both Iowa and North Dakota with the intent of helping ENTEPRISE member agencies understand the extent to which existing vendor products can help support communications with video cameras located in rural areas (without fiber or landline telephone communications). The evaluation was not intended to compare the performance of different vendors, but rather to help ENTERPRISE members understand the potential for these types of vendor products to support rural communication needs. This section summarizes the overall findings that are detailed in the following sections, then adds some context to the evaluation findings based on other observations from the Evaluation Team. A series of recommendation are included below to support member agencies who decide to competitively procure vendor systems. Finally, conclusions are presented based on the evaluation findings.

2.1 Key Findings

The findings of this evaluation are summarized as follows:

- **Enhanced capabilities**. Both products improved agency capabilities and provided benefits by enabling communication of real-time images from remote connections at a cost that was acceptable to the DOTs.
- **Increased user access without cost concerns**. Without the product there is no good way to manage or monitor usage, so user access would have to be greatly restricted in order to limit data usage and better prevent communication links from being left open accidentally to avert high cellular data modem costs.
- **User needs satisfied**. Despite some instances of limited functionality, both agencies were satisfied with the products and how they met their respective needs.
- **Ability to share motion video with many users.** Video from rural cameras was able to be integrated into the ATMS software used by the Traffic Management Center (TMC), and "near real-time" video was also made available to the general public through the DOT traveler information websites.
- **Some improvements identified**. The improvements most frequently cited by TMC operators that would enhance the product were a more reliable connection, less sensitive camera controls, and ability to have a longer video feed during incidents.
- **Ongoing product enhancement and evolution likely**. Given the continuing evolution of products and improvements in cellular communications, it is likely that commercially available product offerings will only continue to better meet the needs of DOTs to transfer full motion video from rural traffic cameras in the future, including but not limited to the ones tested in this project.
- **Technology worth considering for deployment**. Given these findings, it is recommended that agencies give further consideration to vendor products enabling video from rural traffic cameras, and a series of recommendation are included below to support any procurement processes and ultimately help members select the most appropriate vendor for their situation and needs.

2.2 Discussion

It is important to note that despite the limitations of the two products as described in the detailed evaluation summary below, the ITS engineers and TMC operators that use the technologies were very satisfied with the enhanced capabilities. That is, given the remote location with weaker cellular

communications, DOT staff were understanding that these products did not always operate at the same level as traditional cameras communicating using fiber communications. Instead, DOT staff enthusiastically emphasized the benefits of being able to view rural areas that would have previously been unavailable. Specifically, remote verification allows more timely decisions and saves the cost incurred by requiring staff verification from the field, while the technology also enables additional users to access and use the information without concerns of accruing unreasonable costs.

Further, this Evaluation was not intended and cannot provide a clear side-by-side comparison of these two products given their use by different state DOTs that operate different ATMS software and largely for two differing monitoring purposes: work zone management and winter maintenance. This project views participating vendors as a valuable resource for ENTERPRISE member agencies to better understand the current state and potential for these technologies. These and other similar products are continuously improving in various ways, and any product may perform differently for other agencies given different uses, ATMS software, or locations given varying levels of cellular communications. As such, the intent of this Evaluation was to understand the potential for these technologies and the performance levels that agencies might expect when deploying the current state of practice in transferring full motion video from rural traffic cameras.

Network security and modem management are also factors that should be considered. Subsequent to this evaluation, Iowa DOT converted all of their ITS cell modems to an internal-only facing virtual private network (VPN) to increase security and enable more management tools. Iowa DOT also decided to prohibit direct access to Iowa DOT modems by third party vendors—which is required by these bandwidth management services. This decision applied only to Iowa DOT-owned modems and did not prohibit the use of these services on modems and cameras that are owned by others and contracted for use by Iowa DOT.

2.3 Recommendations

Multiple products are commercially available that have the ability to transfer full motion video from rural traffic cameras. This project evaluated two such products used by two state DOTs, primarily for different purposes. Agencies will have to consider the trade-offs and potential limitations of the various commercially available products in order to ascertain which best meets their needs. Agencies may wish to insert requirements or specifications into any bid request to confirm that responding vendor products have the desired capabilities and functionality. Based on the evaluation findings, this may include the following:

- **Command reliability and latency** – specify the percentage of time cameras shall be able to respond to operator commands in less than a specified period of time.
- **Connection reliability and latency** – specify the percentage of time live video shall be made available in less than a specified period of time.
- **Inclement weather reliability and latency** – specify expectations, if different than those listed above, for the reliability and latency of camera command and connection availability during rain, snow, wind, and/or other inclement weather conditions.
- **Viewing capabilities** – specify the percentage of times that video must be able to be viewed by multiple users over multiple Internet access points.
- **Maintenance responsiveness** – specify the percentage of time camera functionality must be restored in less than a specified period of time.

- **Video quality** – specify the percentage of time live video shall be expected of high quality, e.g., no skipping.
- **Command sensitivity** – specify amount of pan/tilt/zoom motion and sensitivity given a single click on the controller interface.
- **Incident mode** – given that operators sometimes wish to pan/tilt/zoom to view a crash or other incident for an extended period of time, the provision of an over-riding "incident mode" might prevent disabling the connection or the return to a preset view for a longer, specified period of time.

3.0 System Description

The ENTERPRISE Pooled Fund Program evaluated two technology solutions for communicating full motion video from cameras deployed in rural areas to central locations. Typically, because rural areas often lack full communication coverage, such as fiber infrastructure, the cameras deployed in rural areas are often only connected through cellular phone communications or land-line telephone communications with bandwidths less than fiber connections typically seen in urban areas. The Evaluation Plan describes the background, a series of use cases, and requirements for how video communicated from cameras located in rural areas can be used, which is summarized below, and forms the basis for the evaluation activities presented in subsequent sections. The intent of this evaluation is to help ENTERPRISE member agencies understand the potential for vendor products to support communications with rural ITS devices, specifically rural video cameras, and meet the use case needs of DOT and contractor staff who use the video communicated.

3.1 Use Cases for Transferring Video from Traffic Cameras in Rural Areas

In order to effectively evaluate solutions for relaying full motion video to a central location, it is important to understand how video feeds from cameras deployed in rural areas are and may be used by both the transportation agencies and the traveling public. Once these use cases are understood, transportation agencies can better understand the critical performance aspects of full motion video communications, and therefore effectively evaluate their role within the agency. Overall, six use case scenarios were defined in the Evaluation Plan for how DOTs use full motion video feeds from cameras deployed in rural areas. These six use cases were:

- **Use Case #1: Traffic Monitoring in Rural Areas**: DOT personnel view video from cameras to assess traffic conditions for congestion or reduced speeds that are affecting travelers. This is often for work zones, but other permanent or temporary locations are also monitored such as rural event venues (e.g. seasonal events such as the fishing opener or start of hunting season, planned events such as concerts, races, etc.) or approaching regularly congested areas such as weigh stations or international border crossings.

- **Use Case #2: Disseminate Driving Condition Information to Travelers**: DOTs make full motion video from rural cameras available to travelers visiting traveler information websites or mobile applications.

- **Use Case #3: Monitor Work Zone Activities in Rural Areas**: DOT personnel may view full motion video captured from the rural cameras to assess work zone conditions. Specifically, DOT work zone supervisors and staff may view video to understand the progress and monitor construction activities and traffic movement occurring in and around the work zone. DOT traveler information staff may view the video to understand to lane closures and estimated congestion or delay resulting from the work zone.

- **Use Case #4: Monitor Operational Status of Field Devices (e.g. ICWS, DMS, or curve warning sign)**: Rural cameras are often strategically located in proximity to devices to enable DOT staff to monitor the condition of the device and the operational status. Typical uses include viewing a Dynamic Message Sign (DMS), Intersection Conflict Warning System (ICWS), curve warning sign, or a road closure gate arm to verify these devices are functioning as expected. Typically, this use case would monitor the performance or help with troubleshooting suspected issues to: minimize trips to the field to observe such conditions.

- **Use Case #5: Monitor Driving Conditions During Inclement Weather Events**: While the capture and communications of static images during inclement weather provides some insight on the extent to which precipitation or wind is impacting the roadway, full motion video provides additional information to help observers understand the speed that vehicles are traveling and the volume of traffic. DOT staff use video feeds to better understand the condition of the roadway system in rural areas in order to make decisions about maintenance/treatment of the roadway or determine traveler information messages to disseminate through various mechanisms.
- **Use Case #6: Monitor High Crash Locations**: In places identified as high crash locations, DOTs position cameras to capture video to later review the events leading up to and following a crash, and understand how to prevent future crashes at the locations. Thus, real-time access is not required, but video recordings are important.

3.2 Overview of Evaluated Products

This evaluation included two commercially available products connected to traffic cameras positioned to view highways in rural areas. The two products were examined in real-world conditions, both on permanent traffic cameras and on portable traffic cameras located in rural highways and work zones. Some cameras are DOT-owned; others are owned and operated by the product provider or the work zone contractor providing traffic control services for the DOT. The two products utilize different approaches for transferring full motion video from rural cameras.

The first product provides a still image and a recorded video clip for each preset (e.g. view position) as defined by the DOT, for each camera. Iowa DOT defined and uses video clips that are 10 seconds in length; each video clip is updated every 10 minutes. This product provides two live streams for every camera, a lower and a higher resolution stream. The live stream is automatically shut down after 5 minutes of inactivity. Iowa DOT currently allows the TMC operators to access the live video stream as needed when incidents occur. All other users, including those accessing the clips via Iowa DOT's 511 websites, have access only to the prerecorded clips. By transferring smaller (e.g. 10-seconds in length) video clips at periodic intervals (e.g. every 10 minutes rather than continuous live streaming), communications data usage is reduced versus usage associated with continuous live streaming.

The second product provides a live video stream to every single user, while still limiting communications data usage. In order to do this, the product closely monitors usage activity to ensure users are not streaming video when they are not watching, then subsequently implements an automatic shut-off to the live stream thereby limiting communications data usage. The product software relies on HTTP GET and POST commands for integration with DOT ATMS software.

3.3 Evaluated Rural Camera Deployments

This Evaluation examined deployments used by the Iowa DOT and North Dakota DOT to examine each of these products. The initial intent for this project, as described in the Evaluation Plan, was to analyze both deployments in Iowa. However, the software for one of the products relies on HTTP GET and POST commands that are not accommodated by Iowa DOT's ATMS software. As a result, the North Dakota DOT was identified as an alternative for the evaluation.

Both Iowa DOT and North Dakota DOT similarly use these products primarily for cellular communications to transfer data from rural cameras that cannot be joined to the existing ITS communications network to

the statewide Traffic Management Center (TMC). Cameras using the product in Iowa are primarily deployed for improving work zone management, particularly during incident conditions (Use Case #3), while cameras using the product in North Dakota were primarily intended to monitor winter weather driving conditions and inform winter maintenance activities at trouble locations (Use Case #5). Each state DOT has integrated these products with their ATMS software and use them to monitor traffic (Use Case #1) and also provide video to their 511 traveler information websites (Use Case #2). Table 1 provides an overview of the Iowa DOT and North Dakota DOT deployments, how they are used, number of cameras, and initial deployment dates.

That said, the deployment capabilities do not restrict the cameras for being utilized for other use cases, as needed. For example, camera usage by Iowa DOT also relates to the remaining three use cases given their use during inclement weather to monitor incidents and traffic mobility (Use Case #5), have archiving capabilities to examine video for post-crash analysis if needed (Use Case #6), and some are positioned in a manner that could facilitate monitoring of various work zone ITS devices (Use Case #4).

Table 1: Camera Deployments Evaluated

Agency	Use Case(s), primary purpose in bold	Cameras	Initial Deployment
Iowa DOT	#1 Traffic Monitoring in Rural Areas #2 Disseminate Driving Condition Information to Travelers **#3 Monitor Work Zone Activities in Rural Areas**	13 contractor-owned portable cameras	May 2015
North Dakota DOT	#1 Traffic Monitoring in Rural Areas #2 Disseminate Driving Condition Information to Travelers **#5 Monitor Driving Conditions during Inclement Weather Events**	11 contractor-owned permanent cameras 1 DOT-owned permanent camera	2013

Figure 1 shows a screenshot of a recorded video clip on Iowa DOT's 511 website, as provided via the product. When "Load Video" is selected, the pre-recorded video clip runs for 10 seconds. The video clip shows the actual time of the recording above the video image. Each pre-recorded video is updated every 10 minutes (as defined by Iowa DOT). The North Dakota DOT's 511 website allows users to stream a live video feed from the cameras using the product.

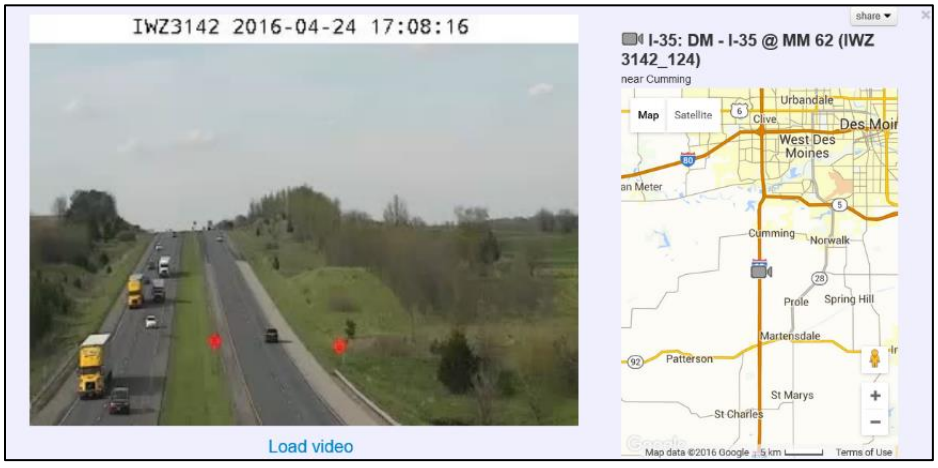

Figure 1: Recorded video clip on Iowa DOT 511 website

4.0 Evaluation Approach

4.1 Focus Areas for the Evaluation

Four important focus areas were identified for examination as a part of this effort. The Evaluation Plan written for this effort details requirements that are common for all uses of this technology, as well as requirements that were specific to individual use cases. These requirements were the basis for the development of hypotheses, which then link to one or more measures of effectiveness, as described in the Evaluation Plan. All hypotheses trace back to the following four focus areas:

- **Integration with ATMS**: DOT operators performing traffic management functions routinely use ATMS software or an "ATMS Lite Client" software for control of field equipment, event recording, and other key functions. The ability to control cameras and view video from within this ATMS software (without the need to open a separate software solution) is critical to their efficiency and effectiveness.

- **Public Access**: Other DOT staff and members of the general public who do not use the ATMS software may still require or prefer access to be able to view video communicated from the cameras. These may include traveler information staff, construction managers, Strategic Communications Staff, or travelers accessing traveler information websites who would benefit from access to video (without control of the cameras).

- **Connection Reliability**: The use of video from camera images supports multiple functions, including traffic management, work zone management, and traveler information. It is critical that video be accessible when needed, and that downtime be minimized. In addition, periods that include inclement weather or peak cellular phone use periods are often the times when DOT access to video is most critical. Thus, while connection reliability is important at all times, it may be even more imperative at these times when the connection is more likely to be less dependable.

- **Cost Controls**: DOTs need to minimize costs by minimizing data transferred and/or amount of time that video is transferred over cellular connections. When communications are established with cameras and the transmission not stopped in a timely manner, excessive communications costs can be incurred. Thus, DOTs would benefit from solutions that reduce the likelihood of high communications costs.

4.2 Data Sources

The Evaluation Plan identifies data sources to address each measure of effectiveness during analysis. The Evaluation utilized the following data sources:

- **DOT Staff Feedback**: Interviews were conducted with DOT staff who had knowledge and frequent interaction with the rural cameras. This included four TMC staff members and an ITS engineer from Iowa DOT and an ITS engineer from North Dakota DOT. These interviews provided the majority of input for the evaluation, given the many experiences regarding the reliability and functionality of these rural camera communications, as well as their knowledge of costs and integration with ATMS and 511.
- **Evaluation Team Validation**: The Evaluation Team used the North Dakota and Iowa 511 websites to assess functionality from the public standpoint. The Evaluation Team was also provided guest access to the Iowa DOT ATMS thin client and the North Dakota DOT product interface, which was used to

gain an understanding of functionality and reliability that was then verified by DOT staff during the interviews.

- **ITS Vendor Input**: The Evaluation Team interacted with representatives from both product suppliers and also the support contractor for the Iowa DOT ATMS software. These discussions provided understanding regarding cost, functionality, and integration.
- **Troubleshooting Logs and Usage Data**: This data was acquired from the Iowa DOT, and reviewed to assess if there were any patterns of repeated errors or problems encountered by the users. Usage data was also provided by Iowa DOT for examination by the Evaluation Team.

5.0 Evaluation Findings

The evaluation of the two product capabilities was conducted during October 2016. The evaluation team accessed the North Dakota and Iowa 511 websites and Iowa DOT ATMS "thin client" site for multiple consecutive days, scheduled and conducted interviews with DOT and ITS vendor staff, and examined other available data. Findings are presented below for the four focus areas, and then summarized in a table for each hypothesis.

5.1 Integration with ATMS

This focus area centers on the ability for DOT operators performing traffic management functions to control cameras and view video from within ATMS software or an "ATMS Lite Client" software (without the need to open a separate software solution). Table 2 presents the evaluation objectives and MOEs that were examined for this focus area.

Table 2: Objectives and Measures of Effectiveness Examined for the Integration with ATMS Focus Area

Evaluation Objective	Measures of Effectiveness
Evaluate the ability for video communicated from rural cameras to be integrated with the DOT operated ATMS software solution(s), enabling operators to view and control cameras using the ATMS software, without the need to open external systems.	Extent of configurations, modifications, or integration actions required to integrate the video communication system with the ATMS.
	Operator ability to pan/tilt/zoom cameras using the ATMS software.
	Operators using the ATMS software ability to select cameras and view video communicated by the communication software/system.

Iowa DOT successfully integrated one product with its ATMS software. North Dakota DOT successfully integrated the second product with its ATMS, however Iowa DOT indicated the second product was unable to be fully integrated with their ATMS.

5.1.1 Iowa Feedback and Results

One product successfully was integrated within the Iowa DOT ATMS software by the ATMS support contractor, which took some time to get all communications links to function properly. The Iowa DOT ITS engineer noted that the limitations and capabilities of the ATMS software are well known, making integration fairly straightforward. As such, the challenge was largely left to the product supplier staff to perform the integration. A positive experience that facilitated integration was the cooperative nature of the ITS vendor that owned the cameras to allow the ATMS support contractor and product supplier full access to make the systems operational, without being a middle man.

5.1.2 North Dakota Feedback and Results

The product was integrated within the North Dakota DOT ATMS by the ATMS support contractor, and no major issues were identified by the North Dakota DOT ITS engineer. Product cameras are fully operational within the ATMS, such that DOT operators have full access and control of the cameras, as expected.

The Iowa DOT ITS engineer noted that this second product is a solution that works, but required a certain command that the Iowa ATMS software was unable to perform or make a connection available as needed. A workaround was achieved to allow functionality, however full integration of this second product with the Iowa DOT ATMS software did not work as anticipated.

5.2 Public Access

This focus area centers on the ability of other DOT staff and members of the general public who do not use the ATMS software to access and view video communicated from the cameras. These may include traveler information staff, construction managers, Strategic Communications Staff, or travelers accessing traveler information websites who would benefit from access to video (without control of the cameras). Table 3 presents the evaluation objectives and MOEs that were examined for this focus area.

Table 3: Objectives and Measures of Effectiveness Examined for the Public Access Focus Area

Evaluation Objective	Measures of Effectiveness
Evaluate the ability for video communicated from rural cameras to be accessed and viewed by DOT staff who do not use the ATMS software.	Ability for other DOT staff members (without using ATMS) to select camera locations and view video without access to the ATMS system.
Evaluate the ability to communicate and make video available to traveler information systems within ***15 minutes*** from the time the video was captured by cameras in the field.	Given a limited period of testing, recorded number of times video is not available to the traveler information system within the time parameter when tested during typical conditions.
Evaluate the ability for video feeds from the cameras to enable still frame images in addition to full motion video captured by the cameras to be displayed on traveler information websites.	Functionality to deposit still images in a designated DOT server to be retrieved by the traveler information system.
	Capability of interfacing with the DOT ATMS software
	Functionality to deposit video files in a designated DOT server to be retrieved by the traveler information system.
Evaluate the ability for video communicated from rural cameras to enable travelers to recognize travel speeds and ambient precipitation when viewed using mobile devices and accessing mobile traveler information websites.	Evaluation Team opinion about the quality of video provided to travelers

The Evaluation Team examined the Iowa DOT product using two interfaces in their ATMS thin client and 511 website, and the North Dakota DOT product using their 511 website. The ability to access and view video and images was examined for five days for all 13 active cameras that use the product in Iowa and three days with 11 cameras that use the product in North Dakota.

5.2.1 Iowa Feedback and Results

For Iowa, the Evaluation Team was able to download live video streams via the ATMS thin client, and pre-recorded 10 second video clips via both the ATMS thin client and 511 website. The product functionality to view still images and video without accessing the ATMS software was successfully demonstrated. The quality of video was sufficient to recognize travel speeds and precipitation, even when viewed on a mobile device.

Table 4 shows the Evaluation Team findings for accessing and viewing video and images on five separate days. For each day, the camera status (green, red, blue as defined below the table) and availability (Y for Yes, N for No) are shown in the left column. The middle and right columns show the latency, in minutes, of the pre-recorded video clips available via the ATMS thin client and 511 website, respectively. Note in several instances where the timestamp inaccurately reflected a time in the future. Instances where no live stream was available indicate a need to contact the product supplier to reset the video feed, which can be done almost immediately to resume functionality.

Table 4: Availability and Latency of Live and Pre-Recorded Product Video on Iowa DOT ATMS and 511

Date:	October 10			October 11			October 12			October 13			October 14		
Time (CT):	1:30pm			5:00pm			9:30am			11:30am			11:00am		
Camera Number	ATMS Live Stream, Status	Latency on ATMS (min)	Latency on 511 (min)	ATMS Live Stream, Status	Latency on ATMS (min)	Latency on 511 (min)	ATMS Live Stream, Status	Latency on ATMS (min)	Latency on 511 (min)	ATMS Live Stream, Status	Latency on ATMS (min)	Latency on 511 (min)	ATMS Live Stream, Status	Latency on ATMS (min)	Latency on 511 (min)
3113	Y	2	10	Y	10	1	Y	5	9	Y	2	7	Y	3	<1
3147	N	6	1	N	<1	3	N	7	2	N	2	8	N	-	-
3154	N	3	<1	N	3	1	N	3	+	N	+	6	N	1	2
3155	Y	6	8	Y	9	9	Y	11	8	Y+	+	+	Y+	+	+
3158	N	3	<1	N	3	3	N	5	2	N	+	+	N	3	3
3162	Y	5	7	Y	7	8	Y	11	6	Y	9	7	N	7	8
3163	N	8	9	N	8	8	N	1	7	N	9	9	Y	8	8
3169	Y	4	5	Y	5	7	Y	8	1	Y	4	5	N	3	2
3171	N	9	8	N	5	8	N	<1	<1	N	5	8	Y	3	2
3172	Y	5	6	Y	5	7	Y	8	10	Y	4	9	N	3	3
3173	Y	5	8	Y	4	8	Y	8	<1	Y	3	9	Y	2	3
3174	Y	5	8	Y	2	8	Y	8	9	Y	3	8	Y	2	1
3175	Y	10	11	Y	7	13	Y	13	14	Y	8	13	Y*	8	6

Note: Green – online, with communications; cameras with green status that lack live video can be "reset" within minutes by contacting product supplier staff

Red – supposed to be online but no communications with camera

Blue – offline, camera no longer deployed

- No images available

+ Timestamp error, 1-20 minutes forward in time

*Timestamp for live video was 5 minutes back in time

Overall, video clips that were less than 15 minutes old were provided via both the ATMS thin client and 511 website, with a latency of 5 and 6 minutes, respectively, per Evaluation Team observations in Table 4. However, live video was consistently unavailable from five of the 13 cameras. The Iowa DOT ITS engineer noted that while the ATMS allows a camera tour of several preset views, the 511 website lacks this capability. As a result, a single camera is represented on the 511 website by multiple camera icons: one for each preset view. Given the already high number of icons on the 511 website, this could be an area of potential confusion for web visitors. Iowa DOT TMC staff noted that cameras using the product will sometimes only show a blue screen on the 511 website.

5.2.2 North Dakota Feedback and Results

The North Dakota 511 website was viewed on October 18-20 at 5:30 pm, 12:00pm, and 11:00am Central Time. Clicking on the camera loaded a view with multiple tabs in which the user could load live video or

view still images from several preset views. Timestamps were not shown on the images or video, so there was no ability to evaluate latency. Still images and live video was available from all 11 cameras that use the product on all three days, with the exception of one camera on October 20, which would not load. As of October 21, 2016, in an effort to reduce costs, the North Dakota DOT only provides still images instead of video feeds on the 511 website from these cameras.

The North Dakota DOT ITS engineer noted that the product cameras provide a live stream via the 511 website, while their other cameras only offer still images. It was noted that there are occasional broken links between the product cameras and 511 website, which may be due to routine Internet Explorer updates, for example.

5.3 Connection Reliability

This focus area centers on the accessibility of video when needed and minimization of downtime, including periods of inclement weather or peak cellular phone use when DOT access to video is most critical. Table 5 presents the evaluation objectives and MOEs that were examined for this focus area.

Table 5: Objectives and Measures of Effectiveness Examined for the Connection Reliability Focus Area

Evaluation Objective	Measures of Effectiveness
Evaluate the reliability of the wireless video communications from rural cameras.	Occurrences of unplanned down time when video communication is not available
	Occurrences when video quality (as communicated) is of degraded quality to the extent it prevents operators from observing roadway status.
Evaluate the ability to provide full pan/tilt/zoom control of cameras.	Operator satisfaction with camera control capabilities during busy periods in the TMC
	Operator satisfaction with camera control capabilities related to latency of camera image and ability to control the camera
Evaluate the ability of DOT operators to configure preset positions and zoom settings (e.g. to avoid glare, to capture one or both lanes of travel), and to step through presets.	Operator satisfaction with preset functionality
Evaluate camera ability to return to preset view after five minutes of DOT operator inactivity.	Percentage of camera panning sessions that return to preset view after roughly 5 minutes
Evaluate the ability to make video available to DOT staff with a latency that does not prohibit pan/tilt/zoom of the camera controls.	Average elapsed time from camera capture of video to display to operators.
	Maximum elapsed time from camera capture of video to display to operators.
	Minimum elapsed time from camera capture of video to display to operators.
Evaluate the ability to communicate and display video to operators within ***30 minutes*** from the time the video was captured by cameras in the field.	Number of times video is not available to the TMC operator within the time parameter when tested during inclement weather.
Evaluate splitting ability of video communicated from rural cameras to be viewed by multiple users over multiple Internet access points.	Multiple viewers at different locations can access video

Evaluation Objective	Measures of Effectiveness
Evaluate the ability for video communicated from rural cameras to enable viewers to identify a vehicle and estimate the approximate speed of travel to determine the status of the roadway traffic using typical Internet browsers during daylight hours.	Operator ability to understand status of roadway traffic (e.g. moving slow, free flow, congested)
	Operator feedback on confidence in speed estimates.
Evaluate the ability for video communicated from rural cameras during periods of darkness to enable operators to track headlights or tail lights to estimate speed of travel using known landmarks.	Operator feedback on confidence in speed estimates.
Evaluate the ability for video communicated from rural cameras to enable viewers to determine if ambient precipitation is falling when viewed using typical Internet browsers during daylight hours.	Viewer ability to understand when rain or snow is falling based on video viewed.
	Viewer ability, based on the video, to understand enough about the rate of precipitation to determine actions
Evaluate the ability for video communicated from rural cameras to enable DOT operators to view whether the road is covered in snow, partially covered, or if there is snow and tire tracks present during daylight hours.	Operator ability to determine snow coverage on the road, based on the video available.
	Operator ability to determine if tire tracks of clear pavement are visible while the rest of the road is covered in snow, when viewing video.
Evaluate the ability for video communicated from rural cameras during periods of darkness with roadway lights present to enable DOT operators to view whether the road is covered in snow, partially covered, or if there is snow and tire tracks present.	Operator ability to determine snow coverage on the road, based on the video available.
	Operator ability to determine if tire tracks of clear pavement are visible while the rest of the road is covered in snow, when viewing video.
Evaluate the quality of video for operators to clearly identify objects located within 100 feet of the camera during daylight hours or when viewing lighted objects (e.g. DMS signs).	Operator ability to consistently identify objects within 100 feet of the camera.
Evaluate the ability for video communicated from rural cameras to not fail or reduce in quality during snow or rain, or other weather conditions, as this is the critical time for DOT operators to view conditions.	Periods when video is not available during inclement weather conditions.
	Periods when video quality is degraded during inclement weather conditions.
Evaluate the ability for video communications tools to support the storage of video for at least 2 weeks, in order to support monitoring of high crash locations.	Storage allocations for video
	Ability to access (download as needed) stored video from the TMC (without visiting the field) when needed.

5.3.1 Iowa DOT Feedback and Results

In general, the Iowa DOT TMC operators appreciated the presence of product cameras to verify traffic conditions in the field where cameras are typically not present, enabling quicker notification to highway patrol. Day shift operators noted that they do not use product cameras as frequently as traditional cameras because they are less accessible given the cellular modem. However, the night shift operator noted daily use to double check the automated messages being posted on PDMS in work zones.

The Iowa DOT TMC operators expressed satisfaction with video quality being comparable to traditional cameras regardless of night-time or inclement weather conditions, but noted several issues regarding latency and availability. All operators stated that product video will load only 60 to 70 percent of the time,

with only day shift operators noting slightly decreased reliability and quality during rainy weather. TMC operators noted that using more than two product cameras simultaneously was generally not possible, and that two TMC operators were generally not able to view the same product camera stream on different work stations.

Iowa DOT TMC operators said that the controls for product cameras were harder to work with, being more sensitive than the traditional cameras by overreacting to a single click, for instance, requiring more time and patience to pan and zoom as needed. Day shift operators noted a 5-10 second latency to be common with up to a 20 second response and unwarranted disconnection at times, while the night shift operator only a 1-2 second latency that was comparable to the traditional cameras. One operator who had worked both day and night shifts confirmed this significant change in latency, noting that these cameras experience a lot more issues during the day. The nature of the product is such that it automatically disconnects after several minutes of inactivity, however when an incident occurs there is no ability for the operator to keep the camera active and trained on a specific view; reconnecting and resetting the camera view can take several minutes. The night shift operator specifically noted that the connection to the cameras is sometimes not fast enough to permit use to the fullest extent. These items constitute the most frequently cited improvements that TMC operators said would enhance the product: a more reliable connection, less sensitive camera controls, and ability to have a longer video feed during incidents.

Troubleshooting logs provided by the Iowa DOT for the Intelligent Work Zone deployments identify 44 times (out of 225 total logged incidents) for a 9-month period from mid-January to mid-October in 2016 where the product cameras required attention to restore functionality. These errors most often involved no video or the display of old video that could not be updated more than half of these logged times. It should be noted that a couple failures were due to vandalism and the power unit being submerged in standing water.

Regarding functionality, the Iowa DOT ITS engineer noted that preset tour video clips would sometimes only load the first video clip, and not load other views; this issue was also experienced by the Evaluation Team. TMC operators experienced challenges with focusing cameras at night, or on debris due to increased pixilation; however, PDMS and arrow boards can be clearly seen day or night, as well as a general view of traffic. It was also noted that having access to all the different options of pre-recorded video clips, live stream, and still images, as well as having multiple icons for a single camera on the 511 website, had the potential to be confusing. Finally, the cameras that use the product have a recording capability that stores video locally for three days, however this function is not a product feature.

5.3.2 North Dakota Feedback and Results

Overall, the North Dakota ITS engineer expressed satisfaction for connection reliability, noting that the control and full access to cameras has been better than expected for these remote areas with poor cellular coverage regardless of the current weather conditions. All measures of effectiveness listed above were said to be good, with additional clarifications noted here. Relatively few occurrences of unplanned downtime have been noted, except for some incidents where a cold battery at the onset of winter may require some maintenance, for instance. Product cameras generally have an acceptable latency for live video streams; a little delay has been observed for pan/tilt/zoom functions, however this has been improving over time. Finally, regarding video quality, it was noted that there were some instances where live video breaks up a bit for cameras in areas with particularly poor cellular coverage, although the still images are still available.

5.4 Cost Controls

This focus area centers on the DOT need to minimize costs by minimizing data transferred and/or amount of time that video is transferred over cellular connections. When communications are established with cameras and the transmission not stopped in a timely manner, excessive communications costs can be incurred. Thus, DOTs would benefit from solutions that reduce the likelihood of high communications costs. Table 6 presents the evaluation objectives and MOEs that were examined for this focus area.

Table 6: Objectives and Measures of Effectiveness Examined for the Cost Controls Focus Area

Evaluation Objective	Measures of Effectiveness
Evaluate the ability for video communications solutions to assist DOTs in minimizing costs related to bandwidth use of cellular phone communications by minimizing data transferred and/or amount of time that video is transferred over cellular connections.	DOT ITS Engineer input regarding agency satisfaction with costs.
	Average and maximum monthly per camera data usage for video communications.

Both the Iowa DOT and North Dakota DOT ITS engineers spoke favorably about the costs for the product systems, respectively. Note that the evaluation was unable to examine "before" costs given that the remote areas in which the product cameras are deployed would typically not have had camera coverage in the first place, and costs are incurred differently than indicated by the MOEs. It is worth noting however, this project originated out of concerns for cameras previously deployed in rural areas that had incurred incredibly high costs because the connection had remained active and continued to transfer video for hours after the operator had stopped using the feed.

5.4.1 Iowa Feedback and Results

The Iowa DOT product is available through a larger series of Intelligent Work Zone (IWZ) ITS contracts that have been in place for three years. In these contracts, the vendor charges Iowa DOT a flat daily rate for the portable cameras that are used in work zones and utilize the product to transfer camera data. The daily rate includes a given allowance of data, and then additional charges are incurred. However, the Iowa DOT ITS engineer notes that when overages occur, it is "money well spent" given that the product enables TMC operators to focus on a crash. The Iowa DOT ITS engineer notes that the product functionality of providing video clips prevents large data bills, allowing it to be shared with more DOT users and the public, which is huge. Specifically, because Iowa DOT had no good way to manage or monitor usage before using the product, user access would have been greatly restricted in order to limit data usage and better prevent communication links from being left open accidentally.

5.4.2 North Dakota Feedback and Results

The North Dakota DOT product supplier installs camera units at a flat rate, which the North Dakota ITS engineer indicated was comparable to installation costs for a traditional camera. The product supplier charges a monthly rate, which includes unlimited data transfers associated with camera usage and all maintenance costs. (Note that this product supplier offers portable camera units that do not include an installation fee, but have a higher monthly cost.) The services provided with this product are beneficial to North Dakota DOT due to the remote locations that lack power connections, requiring solar panels that create added maintenance and would take a full day for DOT staff to access. Additionally, given limited

availability of North Dakota DOT information technology (IT) staff, since the product supplier installs and maintains the equipment, including the added maintenance required for solar panels, the services are seen as cost effective.

5.5 Summary of Findings

Table 7 summarizes evaluation objectives, the extent to which these objectives were supported by the two products (i.e., fully supported [●], mostly supported [◐], partially supported [○], not supported, or not evaluated [-]), and an explanation of supporting evidence on the extent to which the rural communications solutions address the objective. This Evaluation does not provide a side-by-side comparison of the two products given their use by different state DOTs that operate different ATMS software and largely for two differing monitoring purposes: work zone management and winter maintenance. As such, this Evaluation did not attempt to compare one vendor's product against another. Rather, Table 7 is intended as a resource to show considerations and the potential for these technologies.

Table 7: Evaluation Objectives and Findings

Objective	Support	Explanation
Video communicated from rural cameras is **integrated** with the DOT operated ATMS software solution(s), enabling operators to view and control cameras using the ATMS software, without the need to open external systems.	◐	One product was unable to be integrated with Iowa DOT ATMS software.
Video communicated from rural cameras can be **accessed and viewed** by DOT staff who do not use the ATMS software.	●	Verified by the Evaluation Team.
Good **reliability** of the wireless video communications from rural cameras.	○	Iowa TMC operators estimate it works well 60-70% of the time; North Dakota noted times where cameras were unavailable or degraded quality, but this may be expected with poor cellular connections.
Video communications solutions assist DOTs in **minimizing costs** related to bandwidth use of cellular phone communications by minimizing data transferred and/or amount of time that video is transferred over cellular connections.	●	The North Dakota DOT product helps to minimize costs, but the DOT pays a flat monthly rate and is allowed unlimited usage.
Provision of full **pan/tilt/zoom control** of cameras.	◐	Iowa TMC operators note product cameras are harder to use than other cameras, particularly during the day: more touchy and returns to presets or disconnects during a crash that operator wants to watch.
DOT operators can **configure preset positions and zoom settings** (e.g. to avoid glare, to capture one or both lanes of travel), and to step through presets.	●	This functionality was verified by Iowa and North Dakota TMC operators.
Camera ability to **return to preset view** after five minutes of DOT operator inactivity.	●	This functionality was verified by Iowa and North Dakota TMC operators.

Objective	Support	Explanation
Video is available to DOT staff with a **latency** that does not prohibit pan/tilt/zoom of the camera controls.	◐	Day shift Iowa TMC operators note an average 5-10 second delay, and up to 20 seconds; only 1-2 second delay at night.
Ability to **communicate and make video available to traveler information systems** within 15 minutes from the time the video was captured by cameras in the field.	●	Timestamps of video on both Iowa and North Dakota 511 websites was within 15 minutes of viewing.
Ability to **communicate and display video to operators** within 30 minutes from the time the video was captured by cameras in the field.	●	This functionality was verified by Iowa and North Dakota TMC operators.
Video feeds from the cameras enable **still frame images** in addition to full motion video captured by the cameras to be displayed on traveler information websites.	●	This functionality was present on both Iowa and North Dakota 511 websites.
Video communicated from rural cameras can be split to be **viewed by multiple users** over multiple Internet access points.	◐	The Iowa DOT product at times would not allow more than one TMC user to view a camera.
Video communicated from rural cameras enables viewers to identify a vehicle and **estimate speed** of travel to determine the status of the roadway traffic using typical Internet browsers **during daylight hours**.	●	This functionality was verified by Iowa and North Dakota TMC operators.
Video communicated from rural cameras **during periods of darkness** enables operators to track headlights or tail lights to **estimate speed** of travel using known landmarks.	●	This functionality was verified by Iowa and North Dakota TMC operators.
Video communicated from rural cameras enables viewers to determine if ambient **precipitation is falling** when viewed using typical Internet browsers during daylight hours.	●	This functionality was verified by Iowa and North Dakota TMC operators.
Video communicated from rural cameras enables DOT operators to view whether the **road is covered in snow**, partially covered, or if there is snow and tire tracks present **during daylight hours**.	●	This functionality was confirmed by Iowa and North Dakota TMC operators.
Video communicated from rural cameras **during periods of darkness with roadway lights** present enables DOT operators to view whether the **road is covered in snow**, partially covered, or if there is snow and tire tracks present.	●	This functionality was verified by Iowa and North Dakota TMC operators.
Video communicated from rural cameras enables travelers to **recognize travel speeds and ambient precipitation** when viewed using mobile devices and accessing mobile traveler information websites.	●	This functionality was present on both Iowa and North Dakota 511 websites on a phone and laptop.
Video quality allows operators to clearly **identify objects located within 100 feet** of the camera during daylight hours or when viewing lighted objects (e.g. DMS signs).	●	Neither used for ITS device monitoring. One Iowa DOT operator noted that a touchy zoom made it difficult to pinpoint debris or location.
Video communicated from rural cameras does not fail or reduce in **quality during snow or rain**, or other weather conditions, as this is the critical time for DOT operators to view conditions.	◐	Some day shift Iowa DOT operators note the product was less reliable when raining.
Video communications tools support the **storage of video** for at least 2 weeks, in order to support monitoring of high crash locations.	●	North Dakota and Iowa cameras have video storage capabilities, but this use case is not used in either location.

6.0 Next Steps – How to Use this Document

This ENTERPRISE project evaluated two emerging, commercially available communication support technologies that could be used by transportation agencies to communicate with ITS devices in rural areas. Both of these products support the transfer of full motion video over wireless communications (e.g. cellular) in real-world deployments and provide benefits to the DOTs that were included in the evaluation. As such, DOTs are encouraged to consider the use of these types of products if they deploy rural cameras for any of the use cases presented.

Despite remaining challenges with communications in rural areas to support ITS, significant progress has been made over the past decade in improving the breadth and quality of wireless communications services. Given the continuing evolution of products and improvements in cellular communications, it is likely that commercially available product offerings will only continue to better meet the needs of DOTs to transfer full motion video from rural traffic cameras in the future.

The findings from this evaluation can serve as a resource to agency stakeholders who may be considering using one of the multiple commercially available products. Detailed evaluation findings presented in Section 5.0 may help agency stakeholders understand the potential applications, limitations, and performance levels that might be expected when deploying the current state of practice in transferring full motion video from rural traffic cameras.

Agency stakeholders have to consider the trade-offs of the various commercially available products in order to ascertain which best meets their needs. Inserting specific requirements or specifications into a bid request, such as the considerations presented in Section 2.3, may help to confirm that responding vendor products have the desired capabilities and functionality.