

Metro Dubuque Traffic Data Aggregation for Connected Vehicles Project

Stage 1 Implementation Report

2025 SMART Grants Program

East Central Intergovernmental Association (ECIA)



In coordination with

Harman Automotive; Parsons; City of Dubuque; City of East Dubuque; City of Asbury; City of Peosta; Iowa Department of Transportation; Illinois Department of Transportation; Wisconsin Department of Transportation.

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Executive Summary

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Project Title: Metro Dubuque Traffic Data Aggregation for Connected Vehicles Project

The Metro Dubuque Traffic Data Aggregation for Connected Vehicles Project is an innovative initiative designed to enhance transportation safety, resiliency, and integration in the Dubuque metropolitan area by communicating important and time-critical traffic events directly to motorists. Located at the intersection of Iowa, Illinois, and Wisconsin, the Dubuque region (Urban Area 24823, population 70,332) is an ideal testbed for this project. Major transportation routes, including U.S. Highways 20, 52, 61, and 151, converge at key Mississippi River crossings, providing wide coverage while enabling rapid development of a scalable solution. Also, Parsons Advanced Traffic Management System (ATMS) has been deployed and actively used for traffic management in the region.

Parsons in partnership with Harman Automotive collaborated with the ECIA Metropolitan Planning Organization (MPO) which partnered with the City of Dubuque, City of East Dubuque, City of Asbury, City of Peosta, Iowa Department of Transportation (DOT), Illinois DOT, and the Wisconsin DOT, to deliver the Stage 1 project focused on deploying an operational prototype system called Vehicle Data Aggregator (VDA) for distributing real-time traffic information to motorists of the Dubuque region using a cloud-based service.

This system ingests and disseminates incidents, events, scheduled road work, and real-time traffic signal timing information in the Dubuque metropolitan area and sends it to subscribed vehicle terminals via the cellular network in near real time. Harman Automotive used its Ready Aware service to validate the distribution of this traffic information and display the received messages to drivers on its in-vehicle application user interface (UI).

Stage 1 project focused on demonstrating the feasibility of aggregating and disseminating real-time traffic data to connected vehicles for specific event types. The operational prototype deployment confirmed that the system can pass a wide variety of events as well as real-time traffic signal timing updates through the VDA to vehicles via cellular networks in near real time.

The Stage 1 VDA proof-of-concept system demonstrated the ability to send a large and diverse set of transportation data, with negligible latency using cellular networks available in the region. It emphasized the importance of standardized data formats, robust cybersecurity measures, and modular system design for scalability. Plans for Stage 2 would include supporting additional traffic events and traffic data types to provide a comprehensive data set for the metro area.

This project represents a significant step toward integrating connected vehicles into regional transportation management systems, with the potential for nationwide adoption to improve safety and efficiency in transportation networks.

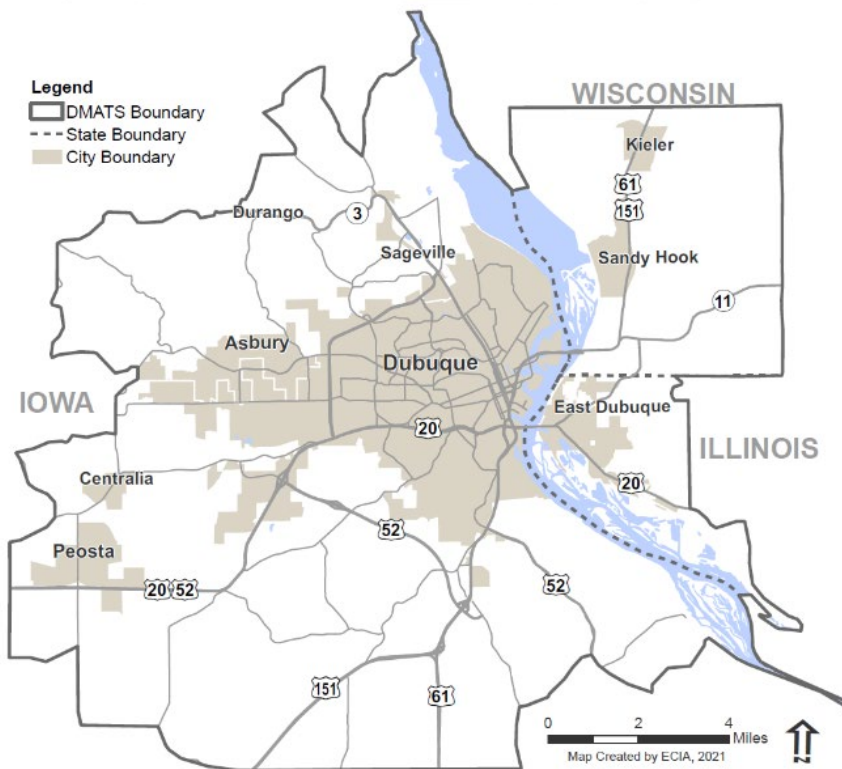
Introduction and Project Overview

While the world is connected in many ways, it remains challenging to provide motorists with complete, real-time travel information while driving. Existing solutions, such as Dynamic Message Signs (DMS), Advanced Traveler Information Systems (ATIS), travel apps, and roadside units (RSU)/onboard units (OBU), each have limitations that make them less than ideal for disseminating timely and actionable information to drivers. Leveraging existing cellular connections to vehicles offers a promising alternative, enabling the delivery of real-time information directly to motorists when and where they need it. Feedback from original equipment manufacturers (OEMs) emphasized the importance of

providing a full set of data for entire metropolitan areas, rather than isolated corridors, to maximize the value of integrating this information into their vehicle infotainment systems.

The SMART Grant Vehicle Data Aggregator system is an Azure-based platform designed to ingest, process, and disseminate near real-time transportation data from a variety of external sources. Built with Java for scalable and high-performance handling of continuous data streams, the system transforms raw data into standardized Traveler Information Messages (TIMs) with configurable International Traveler Information Systems (ITIS) code mappings and geo-hash-based localization. Raw traffic data is stored in Azure Data Lake, while transformed data is stored in a cloud-hosted MongoDB for fast retrieval. Real-time dissemination to infotainment providers, such as Harman Automotive, is achieved using Kafka streaming technology to the Harman's Ready Aware cloud. The system also includes a map-based web user interface (UI) built with ReactJS (open-source Javascript library), allowing operators to visualize live events, configure and edit event detection and TIM notification zones, customize ITIS codes in TIMs, and manage decision points. This comprehensive ready-to-use platform provides integration and delivery of transportation data to connected vehicles in the format of SAE J2735 messages.

The VDA system was designed for regional travelers to inform them well in advance of major incidents, such as the closure of a bridge over the Mississippi River, allowing them to avoid the metro area entirely and prevent contributing to regional gridlock. Similarly, emergency response personnel equipped with this information real-time can gain improved mobility and respond faster during critical situations. At-scale implementation of the VDA system would ensure that communities across the Dubuque metropolitan area and surrounding regions experience safer, more efficient, and more resilient transportation networks.



Dubuque metropolitan study area

The goals of this project align with the SMART Program priorities outlined in the Bipartisan Infrastructure Law (BIL). The project aims to improve transportation safety and reliability by enabling avoidance of road hazards, enhancing work zone safety, and supporting first responders to reduce

fatalities and injuries in support of the Vision Zero goal. It also enhances resiliency by providing critical alerts during major incidents or extreme weather events and improving emergency response efforts. Through public-private partnerships with entities such as the City of Dubuque, Iowa DOT, Illinois DOT, Wisconsin DOT, Parsons, and Harman Automotive, the project fostered collaboration among transportation agencies and smart transportation systems. Furthermore, the project considered scalability, cybersecurity, and measurement, ensuring that the solution could be scaled up and replicated nationwide to deliver deployable system for infrastructure improvements.

Overview of the proof-of-concept or prototype

For the Stage 1 project, the team developed a fully functional prototype. First, interfaces were developed between the City of Dubuque Advanced Traffic Management System (ATMS), Iowa DOT, Illinois DOT, and the Wisconsin DOT ATMS. This integration created a full regional picture of all the events in the entire metropolitan area. The VDA ingests events throughout the region from the Dubuque ATMS and generates TIM messages with corresponding notification zones and ITIS event codes, which are passed to the Harman Ready Aware cloud-based V2N service which presents it on the vehicle driver interface (e.g. using Harman reference application user interface in the vehicle). During the recent demonstration, the VDA passed real-time SPaT messages for 21 sample intersections via cellular connection to the Harman prototype application.

The VDA supports many kinds of traffic events relevant throughout the metro area. This includes accidents, planned lane closures, spot weather events (such as Road Weather Information System (RWIS)), Active School Zone notification, rail crossing notifications, and single spot special events.

The events are displayed in the vehicle using appropriate messages and graphical icons using Harman user interface. The start of notification corresponded when the vehicle entered the notification zone. The notifications disappeared once the vehicle exited the notification zone.

The interface also displayed the signal timing information changes as they occurred while the vehicle was approaching the intersection or stopped at the red light, with no distinguishable delay compared to the same signal status and signal changes displayed with the traditional traffic signal heads.

Anticipated scale of the Stage 2 deployment

The overall project key goal was to provide the most complete set of transportation related data for the entire metropolitan area to the automotive infotainment system providers. Each type of data presents unique considerations for integration and delivery. For a stage 2 project, the team anticipated integration of the remaining traffic signals in the entire Dubuque metro area. This would fill in any other gaps to provide a complete regional picture for the entire Dubuque metro area. This would also include emergency vehicle approach alerts, advances rail crossing closure predictions, enhanced regional weather forecasts, regional consolidated planned lane closure and special event notifications, and integration with school zone notification systems.

With the cancellation of the SMART Grant Program, the City is looking for alternative funding sources to support the deployment of this V2N solution.

Summary of project activities

The project adhered to the initial plan and timeline established at its inception. The Team coordinated with regional stakeholders to develop scenarios and story boards for a wide variety of transportation related events. Based on these story boards, the team planned an initial design and wrote an initial Design Document. Using the Design Document, the team developed an operational prototype that successfully demonstrated the ability to pass a wide variety of event types and real time signal timing

data to the demonstration vehicles as seen in Figure 1. New Center-to-Center (C2C) interfaces were developed between the regional ATMS including Iowa DOT, Illinois DOT, and the Wisconsin DOT. The VDA was implemented to receive events from all three DOTs and to create TIM events with ITIS phrases appropriate for each event type. Furthermore, using VDA UI, system operators can adjust templates for event notifications including notification zones, even severity to priority mapping and ITIS phrase dictionary.

An initial API was developed for end users such as automotive Original Equipment Manufacturers (OEMs) or other third-party data providers to access the data in real time. During two prototype demonstrations – summer 2025 and winter 2026, Harman successfully ingested the events and traffic signal timing and displayed them in the vehicle with no noticeable delays. See section below on latency.

To date, the project has met or exceeded the original goals for Stage 1 with no significant deviations from the originally planned functionality of the operational prototype. The project has drawn attention from other agencies, and in addition to Harman, Audi and Brandmotion have expressed interest in supporting the project if it were to proceed into Stage 2.

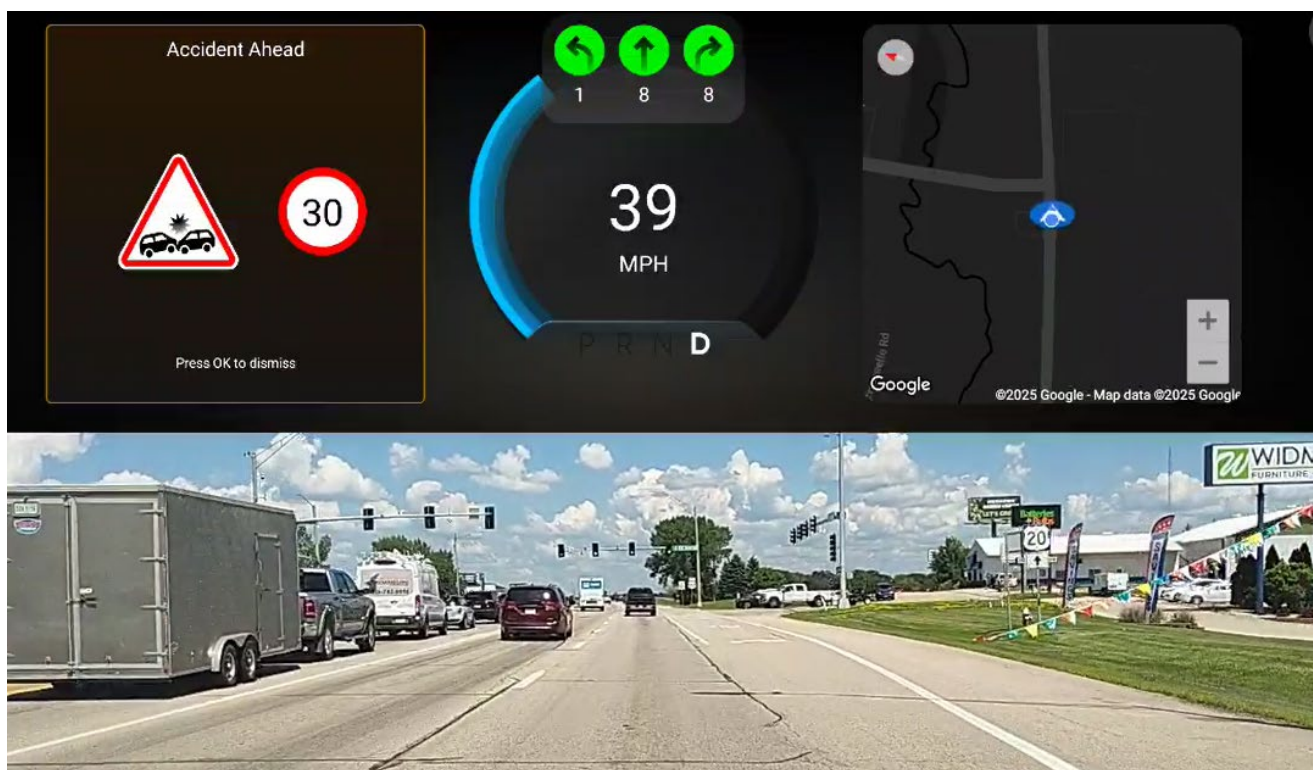
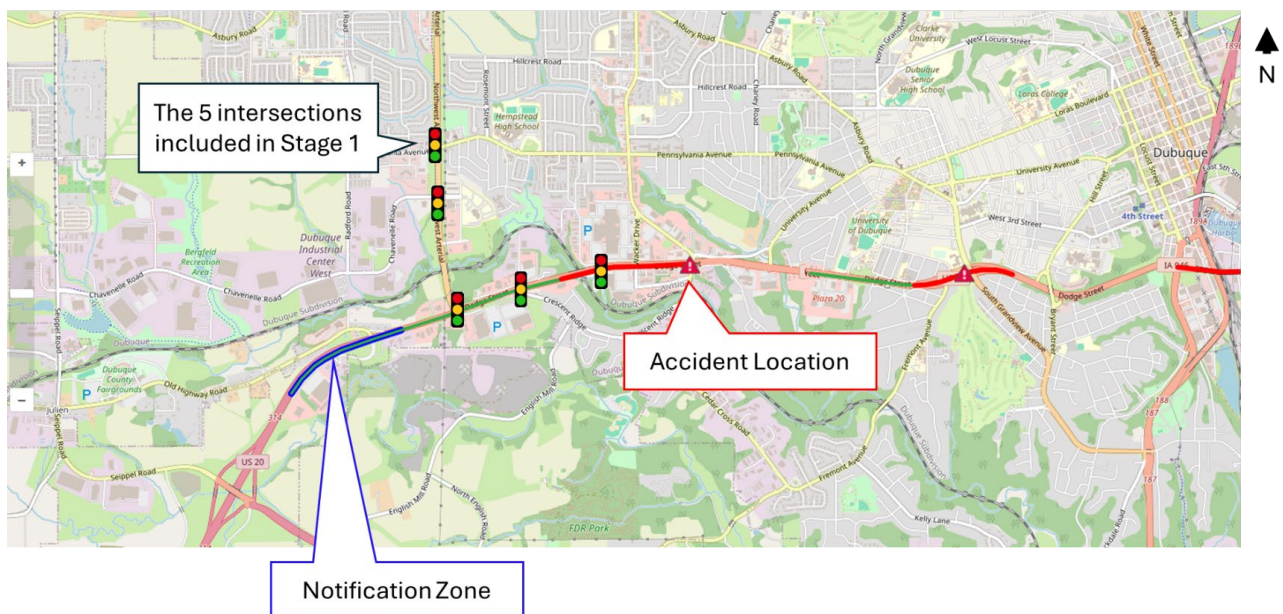


Figure 1 Prototype map of SPaT intersections event notification zones and corresponding in-vehicle messages

Figure description: The map links a roadway accident to an upstream notification zone and identifies five pilot signalized intersections. The corresponding vehicle display combines an Accident Ahead alert with separate directional signal indicators and countdowns. The example illustrates how a driver receives event warnings and signal phase and timing information while approaching the mapped locations.

Proof-of-Concept or Prototype Evaluation Findings

Prototype Performance

On July 10, the project team conducted VDA demonstration to the Dubuque project stakeholders. During the demo, multiple events in the Dubuque Testing instances of ATMS were created, including planned events like planned road closures and incidents. The VDA deployed in Azure cloud received these events and automatically set up notification zones and generated TIM messages with corresponding ITIS code messages for each notification zone based on rules set by the event type and severity. Within the VDA operators were able to view and modify notification zones and ITIS codes for the TIM messages as desired. System operators could then save modified notification zones and TIM message parameters for future use for events of the same type and severity.

For the demonstration, the team drove two vehicles equipped with the Harman user interface notification application. The vehicles looped through the established notification zones and the five pilot signalized intersections set up to forward SPaT information to the VDA. The system successfully passed incidents and planned event details from the Dubuque ATMS to the VDA, and then onto the Harman Ready Aware cloud to be displayed on the in-vehicle user interface. Harman application used cellular connection to retrieve TIM messages and to display driver alerts using notification zones included in the TIM messages. Also, ITIS codes in the TIM message were used to display corresponding icons and message on the application user interface.

The overall performance of the solution during the demonstration was better than expected. Traffic signal timing changes in the field were consistently indistinguishable from the time they appeared on the application user interface in the vehicle. Event notifications appeared in the test vehicles as they passed into the defined notification zones and disappeared as the vehicle exited from the notification zones.

Evaluation of Message Latency

To evaluate end-to-end message delivery performance, the project team estimated message propagation latency across the SPaT distribution path by measuring network response times between major system components. Measurements were collected for the following interfaces:

- Traffic signal controller to ATMS server
- ATMS server to the VDA cloud infrastructure
- The VDA cloud infrastructure to Harman cloud
- Harman cloud to the in-vehicle application

These measurements were used to estimate cumulative network transmission latency between SPaT message generation at the traffic signal controller and receipt by the in-vehicle application. Because the measurements were performed at the network-interface level, the results should be considered an estimate of message propagation latency and do not include detailed application processing delays within each subsystem.

The SPaT distribution process used during the prototype deployment consisted of the following steps:

1. Siemens traffic signal controllers transmitted signal status information using Battelle-formatted messages to the City of Dubuque ATMS server. The ATMS server is connected to the City's transportation network through a dedicated fiber-optic communications system.
2. The ATMS server received and aggregated messages from participating intersections and converted them into SAE J2735 SPaT messages.

3. The ATMS server forwarded SPaT messages to the VDA cloud infrastructure hosted in Microsoft Azure (Parsons' tenant located in Central region). The VDA maintained Kafka-based message distribution services for downstream subscribers (i.e., Harman backend system).
4. Harman's backend system subscribed to SPaT message streams from the VDA and distributed the information to a prototype in-vehicle application running on a tablet device. The application displayed signal phase and timing information as the test vehicle approached participating intersections.

Measured Network Latency

Network Segments	Estimated 1-Way Network Propagation Latency (ms)	Measurement Method
Traffic controller → ATMS server	<1	Measured using network response times between the ATMS server and field controllers connected through the City's fiber network.
ATMS server → VDA cloud infrastructure	66	Measured using a SPaT receiver on the ATMS server subscribed to the VDA Kafka stream. One-way latency is estimated as half of the observed 131 ms round-trip latency.
VDA cloud infrastructure → Harman backend	39	Estimated from an average 78 ms round-trip latency measured between cloud-hosted systems.
Harman backend → In-vehicle application	30	Estimated from an average 60 ms round-trip latency measured between the Harman backend and the tablet device connected through the cellular network in Dubuque.
Total Estimated Latency	136	Sum of estimated one-way latencies across all measured interfaces.

The measured interface latencies indicate an estimated end-to-end network propagation delay of approximately 136 milliseconds between the signal controller and the in-vehicle application. During field demonstrations, signal phase changes displayed in the vehicle appeared effectively in real time, with no noticeable delay observed by project participants.

The latency evaluation conducted during Stage 1 relied primarily on network-level measurements collected at key system interfaces. As part of the next phase, the project team plans to implement additional timestamp logging throughout the message processing chain, including SPaT generation, cloud ingestion, message distribution, and in-vehicle receipt. This enhanced instrumentation will enable direct measurement of end-to-end message delivery latency including application processing time over extended periods and under varying network conditions, providing a more comprehensive assessment rather than the point-in-time measurements collected during the prototype deployment.

Matching the evaluation criteria

Overall, the project followed its evaluation criteria defined in the project's Evaluation Plan document. The table below highlights how the project implementation fits within the performance targets.

Evaluation Criteria Match

Evaluation Question	Performance Measure	Performance Measure Target
1. How collaborative is the effort?	Number of endorsements.	Target Met: Harman, Audi, and Brandmotion support this project for Stage 2
2. What is the latency for traffic data to be available to travelers?	Time from data collection to the time it is packaged and ready to be sent to providers.	Target Met: Prototype network-level measurements across major system interfaces indicate cumulative propagation transmission latency of approximately 136 milliseconds from signal controller to in-vehicle device under test conditions. Delay times from the changing of signals in the field to the change in the vehicle were consistently indistinguishable from real time, which exceeded expectations. See the latency discussion above.
3. What additional enriched data sets will be valuable to travelers?	Identification of new data sets (e.g., signal timing, incident and road closure events, bridge crossings, railroad crossings).	Target Met: Stage 1 deployment already makes the most comprehensive regional data set available through cellular connection to vehicles using emerging CV standards e.g., SAE J2735, CTI4501, and etc.
4. How will the data specification be made available to integrators and other agencies?	Publication of data specification documents.	Target Met: An open and fully documented standards-based API is available. It was shared with Harman and Brandmotion for their own implementation of message receiver applications.
5. How will the project be advertised.	Presentations about the project and results.	Target Met: The project has been presented at regional ITE and ITS conferences as well as to the regional MPO board and Dubuque Multi-Disciplinary Safety Team. Results are scheduled to be presented at ITS Midwest.

Data collected

The system collects many types of data from the ATMS including traffic incidents and events as well as real-time signal timing from several intersections in Dubuque. The full deployment of the project for the City of Dubuque is expected to collect and integrate a comprehensive set of real-time transportation data from local, regional, and state sources, including traffic management systems, signal controllers, detection systems, and third-party feeds such as Waze, INRIX, and Acyclica, all of which will be channeled through the City's ATMS to ensure proper authentication and formatting is applied before passing it on to OEMs. This data—is standardized and processed into a cloud-based VDA platform. All collected data is non-sensitive and free from personally identifiable information. The data is structured into Traveler Event Notifications (TENs), transformed into J2735-compliant TIM messages, and distributed in near real-time to downstream consumers (e.g., Harman Ready Aware cloud and notification application) via Kafka or MQTT streams. The system supports long-term data retention using the Azure Data Lake for archival, and a cloud-based MongoDB NoSQL database instance for storing and retrieving application data with real-time access.

The project met all its evaluation goals. The functionality provided by distributing transportation data through the implemented VDA to OEMs already demonstrates significantly improved capabilities to

share notifications with motorists compared to traditional methods such as DMS, or ATIS web sites. The next step is to have close collaboration with OEMs to ensure that this information is fully integrated into vehicle infotainment systems. Feedback from Tier 1 supplier, aftermarket solution provider and informal conversations with OEMs reinforces that demonstrating a complete, standardized data set for an entire metropolitan area is essential to encourage widespread adoption.

Anticipated Costs and Benefits of At-Scale Implementation

Upon the completion of Stage 2 with a fully cloud-based, production-ready implementation, scaling the system to new regions will be cost-effective and straightforward. There will still be costs for integrating with additional ITS infrastructures and ATMS in each region, and ongoing operational expenses for hosted VDA solutions. Key cost drivers will include cloud hosting and storage for high-throughput ingestion of SPaT, incident, and roadway data across a growing number of intersections; increased network traffic and bandwidth charges for real-time data streaming; and provisioning of scalable APIs and Kafka topics to serve multiple data consumers i.e. partner vehicle OEMs. The table below provides approximate anticipated costs broken by size of the agency (i.e., number of intersections).

Estimated deployment and annual costs

Cost Driver	Small Metro (<500 intersections)	Medium Metro (500-2000 intersections)	Large Metro (>2000 intersections)
SPaT & Agency integration	\$20K – \$50K one-time	\$50K - \$75K one-time	\$100K - \$125K one-time
API Gateway & OEM Integration	\$15K - \$50K one-time	\$50K - \$60K one-time	\$60K - \$75K one-time
Agency Onboarding & Customization	\$10K - \$30K one-time	\$40K - \$50K one-time	\$50K - \$60K+ one-time
Cloud Hosting & Storage, Software licensing and Security	\$24K - \$96K / yr	\$36K - \$144K / yr	\$60K - \$240K+ / yr
Kafka Streaming Infrastructure	\$8K - \$10K / yr	\$12K - \$24K / yr	\$20K - \$36K+ / yr
System Monitoring & Service Level Agreement (SLA) Support	\$12K - \$36K / yr	\$30K - \$60K / yr	\$50K - \$150K+ / yr
Network Bandwidth / Data Transfer	\$10K - \$24K / yr	\$20K - \$50K / yr	\$50K - \$120K+ / yr
Agency Support & Coordination	\$16K – \$36K / yr	\$40K – \$60K / yr	\$60K – \$80K / yr

Cost driver descriptions

SPaT & Agency integration

Covers initial one-time onboarding of new government agencies, including configuration of SPaT feeds, agency-specific data formats, and coordination with local IT/ITS teams. This cost is largely fixed per agency and does not increase significantly after initial setup.

API Gateway & OEM Integration

Provides secure API endpoints, rate limiting, and partner-specific filtering logic; needed for OEM consumption.

Agency Onboarding & Customization

Covers technical onboarding of agencies/partners including mapping configurations, test support, and partner-specific tuning.

Cloud Hosting & Storage, Software licensing and Security

Covers cloud infrastructure (VMs, databases, object storage), software licensing (3rd-party licensing, managed services etc.), and security-related implementation efforts (IAM, encryption, network hardening etc.). These components are critical to support ingestion, transformation, and distribution at scale.

Kafka Streaming Infrastructure

Supports real-time message delivery with low latency; costs grow with volume, partitions, and consumer-specific streams.

System Monitoring & Service Level Agreement (SLA) Support

Enables system uptime guarantees, alerting, and performance monitoring for SLA compliance and diagnostics.

Network Bandwidth / Data Transfer

Reflects cloud data egress, external partner feeds, and increased traffic from sensor-rich or signal-heavy regions.

Agency Support & Coordination

Ongoing technical support and coordination with each integrated agency. Includes assistance with data feed maintenance, troubleshooting, policy alignment, reporting, and stakeholder communications. Costs scale with the number of partner agencies and level of support required.

Historically, agencies have relied on DMS and ATIS websites to provide traveler information. However, ATIS sites do not provide adequate vehicle information, and DMS signs are expensive to deploy and maintain. A typical full size DMS can cost \$150K to \$200K to deploy. We would expect that the cost to deploy the VDA to make information directly available to the vehicles would cost between \$200K and \$300K for a typical agency and be able to provide real time information throughout the region. This project demonstrates that critical traveler information can be delivered to vehicles in real-time at the exact point of need at a fraction of the cost of deploying an array of DMS throughout a metropolitan area.

Challenges and Lessons Learned

Overall, the project progressed as expected. Partially due to the previous ITS projects in the region, including Parsons delivery of the regional ATMS which included a collaboration effort between ECIA, the City of Dubuque and Parsons with the Iowa DOT, Wisconsin DOT, and Illinois DOT. The Metropolitan Planning Organization already includes all three DOTs as part of its board. This preexisting cooperation allowed for team formation, agency coordination, development of the VDA

and center-to-center integration to proceed smoothly. The project was completed on budget and on time, with an extension added to provide a demo to the USDOT

The project encountered some notable challenges, particularly in identifying the optimal architecture and system design. The team dedicated significant time early in the project evaluating operational scenarios and determining how vehicle infotainment systems would utilize the data. This process required more time than anticipated, because it was critical to ensure alignment with the most relevant and emerging industry standards. The team also needed to consider how to deploy a solution that supports the distribution of a full set of transportation-related data via cellular networks to vehicles, while ensuring it is readily scalable and replicable. Fortunately, with a well-sized team of highly experienced developers, the project team was able to recover some of the time during the development phase. The final solution leverages what we call the Vehicle Data Aggregator (VDA). The VDA is a standalone component that can sit on top of any ATMS or data provider and package TIM messages in standard format for distribution to OEM's and other third-party data providers. This approach supports easy replication of this solution throughout the country.

In contrast to other similar projects focusing on distributing a single data type (like SPaT) or a few traffic event notification types, this project aimed to provide a comprehensive set of relevant regional data and events available for OEMs. Considering a full set of events and data types and designing for a wide range of messages created additional complexity which needed to be addressed early in the project development cycle. The team needed a design that would allow a single event to be associated with multiple notification zones, which could provide advanced notifications for a configurable distance to vehicles upstream of the events. The system also needed to automatically generate a wide variety of messages with ITIS codes for different event types and severity levels while allowing operators to modify responses and save those adjustments for future use.

Although Stage 1 focused on demonstrating technical feasibility within a defined pilot area, scalability was considered during architectural design. The system was implemented using standardized message formats and a publish/subscribe messaging pattern, allowing additional data sources and consumers to be integrated without redesigning the core processing workflow.

Expanding from a limited number of pilot intersections to a larger regional deployment will primarily involve onboarding additional signal controllers into the existing ingestion workflow and increasing message volume within the messaging infrastructure. Because the prototype architecture separates data ingestion, transformation, and publishing functions, growth in the number of intersections would require operational scaling of infrastructure resources rather than fundamental architectural redesign. As deployment scales further, certain infrastructure optimizations—such as enhanced monitoring, redundancy configurations, and messaging partition strategies—may be implemented to support higher throughput and resiliency requirements typical of production-scale environments.

In practical terms, scaling to 500+ intersections would involve:

- Configuring additional signal data sources
- Validating SPaT mappings for each controller
- Expanding cloud processing and messaging capacity as needed

The data pipeline and messaging pattern developed in the prototype can accommodate such expansion conceptually. Full production-scale deployment in Stage 2 would incorporate additional operational hardening, performance monitoring, and resiliency enhancements appropriate for large-scale regional service.

While Stage 1 demonstrated integration with Harman's platform, the VDA publishes standardized SPaT and TIM messages to pre-defined Kafka topics using documented message schemas. This

publish/subscribe approach will allow additional OEMs, Tier 1 suppliers, aftermarket providers, or agency partners to subscribe to the same message streams without requiring changes to the roadway ingestion layer. Future consumers could be onboarded through a controlled process involving schema documentation review, secure topic access provisioning, and validation in a test environment.

This decoupled design ensures that adding new consumers does not require changes to the roadway ingestion layer, and adding new intersections does not require modifications by existing consumers.

Fortunately, this project had strong support from government agencies in the area. During project status meetings where local and regional agencies participated, including the MPO board, all the regional stakeholders were excited about sending the traffic information directly to vehicles displays instead of using DMS or other traditional methods of traveler information distribution. Similarly, Harman, being a Tier 1 supplier to automotive OEMs, strongly advocated for providing a full data set for entire metropolitan areas rather than fragmented corridor-based data sharing approaches.

As the system expands regionally, governance will become a critical parallel effort. Stage 1 focused on technical validation; Stage 2 will require formalized governance mechanisms to address:

- Agency participation criteria and data sharing agreements
- Data ownership and stewardship responsibilities
- Security, authentication, and access control policies
- Change management for schema updates and system modifications
- Operational roles between roadway agencies, cloud operators, and downstream consumers

Establishing a structured regional governance forum—potentially led by the Metropolitan Planning Organization (MPO) or participating agencies—will be essential to ensure consistent decision-making and responsible scaling beyond the pilot deployment.

Given the pilot nature of the current implementation, cybersecurity was incorporated into the architecture and design but was not fully implemented during this phase. Most implementation efforts went into developing core data ingestion from ATMS, data transformation, and distribution functionality. However, the team recognized the importance of incorporating security considerations early, particularly as the system interfaces with multiple external data sources and delivers information to third-party consumers. Basic safeguards were implemented, including secure API endpoints, controlled access to the development environment, and standard cloud security practices. A key lesson learned was the importance of planning for cybersecurity integration from the outset — particularly for production environments — including encryption of data in transit, network segmentation, secure key management, and audit logging. Additional cybersecurity measures will be prioritized in Stage 2 of the project as the team works towards creating a fully replicable production-ready solution.

Deployment Readiness

Stage 2 readiness for at-scale implementation

Requirements for Successful At-Scale Implementation

To move from prototype to a fully operational Software-as-a-Service (SaaS) offering that can serve multiple metro areas and OEMs, the following key elements are required:

- Containerized, scalable deployment in a production-grade cloud environment.
- Expanded ingestion pipelines to handle additional ATMS and SPaT sources
- Centralized partner authentication and secure API gateway management.

- SLA-backed monitoring and diagnostics for high availability and system reliability.
- Formalized data sharing agreements with new infrastructure owners.

Strategies and Demonstrated Progress

- The core ingestion, transformation, and publishing pipelines have been validated using real-world data.
- Kafka-based topic structures and consumer logic have been tested with Harman's Ready Aware system and in-vehicle application.
- A standardized data schema has already been developed for TIM and SPaT messages.
- The UI components are modular and reusable, ready to support broader visualization needs.

Key Considerations for Scaling

- Differences in traffic controller capabilities/brands across jurisdictions may require the addition of pluggable controller specific adapters or translation logic to generate uniform SPaT formats.
- OEM onboarding and API alignment timelines will vary, requiring a structured partner integration process.
- Network capacity planning will be important to handle growing volumes of real-time SPaT and event data.
- Legal and operational onboarding with new jurisdictions may introduce variability in deployment speed.

While the core system is production-aligned and designed for scale, a few remaining details would need to be addressed during Stage 2:

- Formalizing the long-term support model (e.g., 24/7 monitoring, DevOps ownership).
- Refining processes for managing jurisdiction-specific SPaT and incident feed configurations.
- Finalizing strategies for multi-tenant partner onboarding and tiered support SLAs.
- Cyber Security enhancements

With the SMART Grant program canceled the City is looking into other funding sources that could be utilized to deploy this V2N based solution.

Gaps in understanding the maintenance and operating requirements

The prototype deployment of the VDA has successfully demonstrated core system functionality in a controlled cloud environment, including near real-time distribution of SPaT and incident data from the Dubuque ATMS and dissemination to a downstream consumer (Harman) via Kafka. The system architecture was intentionally designed with scalability in mind, using modular, cloud-native technologies suitable for production-grade operations. However, as this phase of the project was focused on prototyping, the primary objective was to validate technical feasibility and data flow performance—not to establish a sustainable operational framework. As a result, operational issues such as ongoing system monitoring, performance assurance, uptime reliability, and client-facing service obligations were not deeply explored at this stage.

Looking ahead at future deployments, the emphasis will shift to operating the VDA as a fully managed service offering, with a focus on delivering consistent, reliable performance to multiple stakeholders and OEM clients. Current gaps in understanding center on the operational performance requirements, the definition of service-level agreements (SLAs), and the organizational and technical capabilities necessary to meet client expectations at-scale. Stage 2 will address these areas by developing clear service-level characteristics, formalizing operational support models, and refining the processes

needed to ensure that the VDA can function as a dependable, production-ready platform for long-term use.

Wrap-up

The Stage 1 deployment progressed as expected. The functional prototype met expectations, demonstrating that a cellular based connection with vehicles can provide most of the desired traveler information directly to end users without noticeable delays. The team was able to consolidate data from multiple agencies and make it available in a standards-based format (SAE J2735 compliant TIMs generated according to USDOT TIM Best Practices guide) through the VDA and the Harman Ready Aware to the in-vehicle prototype without any noticeable delay.

The project team and regional stakeholders agreed that getting the information directly to vehicles is far superior to traditional methods such as DMS and ATIS sites.

The core architecture and design principles of the VDA have proven effective during the prototype phase. A few strategic enhancements will be made in the future as funding is available to support broader, at-scale deployment. Most notably, the project team plans to transition from a development-grade environment to a production-grade, containerized cloud deployment with autoscaling capabilities and SLA-backed observability. In addition, the system will adopt a more modular approach for SPaT data ingestion by introducing pluggable adapters to accommodate varying signal controller protocols across jurisdictions. The team will also formalize partner onboarding workflows and access control mechanisms to support a growing number of OEMs and infotainment providers. However, no fundamental changes to the proposed solution's architecture or data flow will be required, which reinforces the system's scalability and readiness for multi-region expansion.

A key aspect for the next phase of this project will involve continued collaboration with OEM's and other third-party providers to apply TIM message format for traffic events and applicable data types. Stage 1 made strong progress on many data types, but numerous additional types and messaging details must still be refined.

What advice would you give to other communities embarking on the same path

ECIA and the regional stakeholders strongly believe that this project represents the future for the distribution of traveler information. The ability to provide the right information directly to vehicles at the right time can help balance traffic, smooth traffic flow, and enhance safety. The sooner OEMs can be encouraged to deploy this information into vehicles on a broad scale the better off all agencies will be.

It is significantly more cost effective than the use of DMS and allows for notifications to be delivered exactly when they are most appropriate throughout the region. It supports additional notifications that would be cost-prohibitive with other methods and moves agencies one step closer to full two-way communications with vehicles.

The project team encourages other agencies to move quickly to adopt this approach. The sooner full data sets from multiple agencies are demonstrated, the faster OEMs will move to adopt the display of this information in their vehicle infotainment systems. This will help all agencies to provide more effective and cost-efficient communications with motorists, improve traffic flows, and enhance roadway safety.