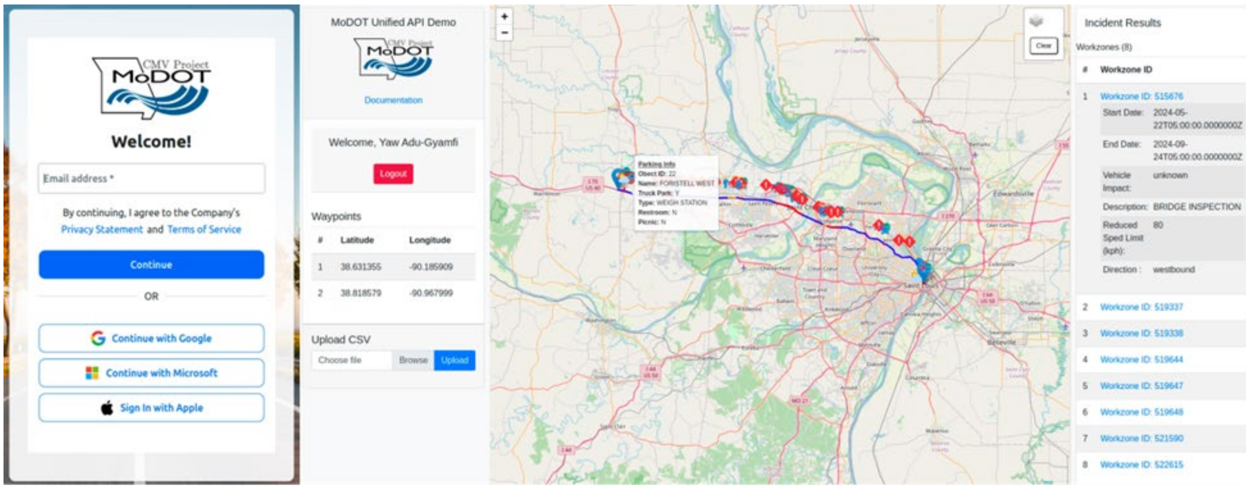
Effective Methods to Safely Communicate with Commercial Motor Vehicles



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16. Abstract
One critical aspect of a proactive approach to improving the safety of commercial motor vehicles (CMVs) involves how to communicate with CMV drivers safely and effectively through an electronic notification system (ENS). The objectives of this project are to: 1) conduct a review of existing ENS methods in use by CMV drivers, trucking companies, and the freight industry; 2) conduct a survey of selected state departments of transportation (DOTs) regarding their current practice in ENS for communicating with CMV drivers; 3) conduct a needs assessment brainstorming workshop with MoDOT and other stakeholders; and, 4) develop standards and specifications for data feeds consisting of traveler information critical for CMV operators. Results from the literature review indicate that several communication technologies have a wide range of applications for communication with CMV drivers. In their survey responses, all 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers. Based on the discussion at the stakeholder workshop, a matrix of various facets (e.g., what is available, what is important and urgent, challenges) of types of information and technology used to convey that information to CMV drivers was developed. To address the challenges of diverse data streams for CMV drivers, a unified application programming interface (API) was developed to consolidate all relevant data (e.g., work zones, weather, congestion, traffic incidents, parking availability, weight and height restrictions) into a single, cohesive platform, providing CMVs with seamless access to critical information. The API, which was demonstrated through a web interface, ensures that CMVs and their operators can make well-informed, safe, and timely routing decisions. The API's modular and scalable design offers flexibility to add additional features in the future.

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List of Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
API	Application Programming Interface
ATDM	Active Transportation and Demand Management
ATMS	Advanced Traffic Management Systems
CB	Citizens Band
CMS	Changeable Message Signs
CMV	Commercial Motor Vehicle
CVISN	Commercial Vehicle Information Systems and Networks
DMS	Dynamic Message Signs
DOT	Department of Transportation
EAS	Emergency Alert Systems
ELD	Electronic Logging Device
ENS	Electronic Notification System
FCC	Federal Communications Commission
FMCSA	Federal Motor Carrier Safety Administration
GPS	Global Positioning System
HAR	Highway Advisory Radio
ITS	Intelligent Transportation Systems
ITTS	Institute for Trade and Transportation Studies
MoDOT	Missouri Department of Transportation
RFID	Radio Frequency Identification
TDx	Transportation Data Exchange
TMDD	Traffic Management Data Dictionary
TPIMS	Truck Parking Information Management System
UHF	Ultra High Frequency
VHF	Very High Frequency
VMS	Variable Message Signs
WZDx	Work Zone Data Exchange

Abstract

One critical aspect of a proactive approach to improving the safety of commercial motor vehicles (CMVs) involves how to communicate with CMV drivers safely and effectively through an electronic notification system (ENS). The objectives of this project are to: 1) conduct a review of existing ENS methods in use by CMV drivers, trucking companies, and the freight industry; 2) conduct a survey of selected state departments of transportation (DOTs) regarding their current practice in ENS for communicating with CMV drivers; 3) conduct a needs assessment brainstorming workshop with MoDOT and other stakeholders; and, 4) develop standards and specifications for data feeds consisting of traveler information critical for CMV operators. Results from the literature review indicate that several communication technologies have a wide range of applications for communication with CMV drivers. In their survey responses, all 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers. Based on the discussion at the stakeholder workshop, a matrix of various facets (e.g., what is available, what is important and urgent, challenges) of types of information and technology used to convey that information to CMV drivers was developed. To address the challenges of diverse data streams for CMV drivers, a unified application programming interface (API) was developed to consolidate all relevant data (e.g., work zones, weather, congestion, traffic incidents, parking availability, weight and height restrictions) into a single, cohesive platform, providing CMVs with seamless access to critical information. The API, which was demonstrated through a web interface, ensures that CMVs and their operators can make well-informed, safe, and timely routing decisions. The API's modular and scalable design offers flexibility to add additional features in the future.

Executive Summary

The Missouri Department of Transportation (MoDOT) is taking a proactive approach to improve the safety of commercial motor vehicles (CMVs). One critical aspect of this approach involves how to communicate information to CMV drivers safely and effectively. An electronic notification system (ENS) can be used to communicate information pertaining to low bridge clearances, steep grades, work zone presence, incidents, and inclement weather. Since use of mobile phone by CMV drivers while driving is illegal, any ENS method must not be solely phone centric. The timeliness of information is also critical for drivers to revise their routes (i.e., detouring or parking), if necessary. The technology should be accessible by any driver to receive critical information regarding their route.

This project has the following objectives:

- Conduct a review of existing ENS methods in use by CMV drivers, trucking companies, and the freight industry
- Conduct a survey of selected state departments of transportation (DOTs) regarding their current practice in ENS for communicating with CMV drivers
- Conduct a needs assessment brainstorming workshop with MoDOT and other stakeholders
- Develop standards and specifications for data feeds consisting of traveler information critical for CMV operators

The research methodology to meet these objectives includes a literature review, survey of DOTs, stakeholder workshop, and development of an Application Programming Interface (API).

The literature review encompassed various technologies that can be used to communicate information to CMV drivers, such as Advanced Traffic Management Systems (ATMS), 511 travel information systems, Citizens Band (CB) radio, Commercial Vehicle Information Systems and Networks (CVISN), and variable message signs (VMS). These technologies have a wide range of applications for communication with CMV drivers.

- ATMS help to monitor and manage traffic flow and provide real-time information to motorists, including truck drivers. ATMS employ sensors, cameras, and other data collection methods to gather information on traffic conditions and relay it to central control centers, and the information is then disseminated to motorists. ATMS have become more widely used in urban areas.
- 511 systems provide various types of real-time information, such as road conditions, construction, and incidents. 511 systems offer the convenience of multiple platforms (e.g., phone, app, websites) and can help truck drivers make informed decisions about their routes and travel plans.
- CB radios have a long history of use as an integral communication tool in the trucking industry. CB radios allow drivers to exchange real-time information regarding road

conditions, traffic, and other pertinent areas. They have a limited range (typically a few miles).

- CVISN provide a platform for truck communication, offering safety inspection updates and regulatory information.
- Strategically placed along highways and major roadways, VMS provide truck drivers with critical information, such as lane closures, detours, and travel times. VMS are particularly useful for truck drivers, as they can alert them to restrictions on CMVs or available truck parking at rest areas.

An online survey questionnaire was distributed to 30 state DOTs, including members of the Mid-America Freight Coalition, the Institute for Trade and Transportation Studies (ITTS) and 12 other state DOTs selected for geographic diversity. Survey responses were received from 18 DOTs for a response rate of 60 percent. The survey included 12 questions and covered various topics related to communicating information electronically to CMV drivers, such as types of information communicated, communication methods, data sources, challenges, partnerships, and data standards or policies.

Survey results indicate that the types of information currently communicated to CMV drivers by the highest number of responding DOTs are extreme weather events, traffic incidents, and work zone lane closures, while no responding DOTs communicate information regarding tire checkup areas. Regarding future plans for types of information DOTs plan to communicate electronically to CMVs, the highest number of responding DOTs are working on communicating information on the availability of truck parking and traffic incidents.

The survey also sought information regarding data sources and partnerships for communicating information to CMVs. The data sources used by the highest number of responding DOTs to gather information for CMV drivers are traffic sensors, law enforcement and first responders or emergency services, feeds from data providers, and video cameras, while the data sources used by the lowest number of responding DOTs are trucking companies and radio frequency identification (RFID). Partnerships with law enforcement, technology vendors/app developers, and industry associations or trucking associations are pursued by the highest number of responding DOTs.

For communication methods, the methods used by the highest number of responding DOTs to communicate information to CMVs are dynamic message signs (DMS), 511 travel information systems, and changeable message signs (CMS). Responding DOTs perceive audible or visual alarms and in-cab alerts as the most effective methods for communicating information to CMV drivers and real-time Highway Advisory Radio (HAR) as the least effective method. In the future, the highest number of responding DOTs are planning to use in-cab alerts, connected vehicle technologies, and smartphone applications to communicate information to CMVs.

The survey found a need for data standardization for communicating information to CMVs. The perceived challenges to communicating information to CMV drivers noted by the highest number of responding DOTs are the need for data standardization, data availability, and funding constraints. All 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers.

A stakeholder workshop was conducted to discuss the desired characteristics of ENS. There were 42 attendees at the workshop representing 27 entities, including government agencies, law enforcement, trucking associations, vendors, and other organizations. The workshop included a presentation by the research team to give an overview of the project, followed by a series of question prompts to initiate a brainstorming exercise. A matrix of various facets (e.g., what is available, what is important and urgent, challenges) of types of information and technology used to convey that information to CMV drivers was developed based on the discussion at the workshop.

Topics discussed at the workshop include what information is available or would be beneficial to provide in the future and challenges of communicating information to CMVs. Several state DOTs, such as New York, New Jersey, Georgia, and North Carolina, have tried in-cab messaging. In addition, some states allow drivers to subscribe to alerts. Examples of information that could be helpful to CMV drivers include presence of active work zones (especially mobile work zones and worker presence), truck parking (number of miles ahead and number of spaces available), availability of parking and amenities at rest areas, end of queue alerts, sudden slowdown alerts, weather (e.g., extreme weather), low bridges, sharp curves, truck emergency escape ramps, brake check areas, and chain stations. Some of the challenges to efforts to communicate information to CMVs shared by workshop participants include providing accurate and useful information to drivers that is not overwhelming or distracting, disseminating information to drivers in different languages, differences between large and small carriers (e.g., response to winter events, technology capabilities, in-cab equipment), obtaining information on the availability of private truck parking (e.g., truck stops), and ensuring consistency between states.

The transportation industry is increasingly reliant on diverse, dynamic data streams—including traffic conditions, work zone information, parking availability, and weather data—that need to be communicated quickly and accurately to CMVs. Currently, these data streams are often accessed through separate APIs, creating a fragmented system. This fragmentation can lead to delays, data inconsistencies, and gaps in real-time communication, potentially compromising both safety and operational efficiency.

To address these challenges, a unified API was developed to consolidate all relevant data into a single, cohesive platform, providing CMVs with seamless access to critical information. By aggregating data from multiple sources into a standardized, consistent format, the unified API ensures that CMVs and their operators can make well-informed, timely decisions without the risk of delays or data conflicts.

A unified API for CMV communication was designed with clear objectives to improve the efficiency and reliability of incident reporting and data exchange. These objectives emphasize the seamless integration of multiple data sources, real-time communication capabilities, and the establishment of a standardized data format.

One of the main challenges of integrating data from multiple sources is the inconsistency in how the data is structured and reported. The unified schema addresses this issue by implementing a standardized data format that applies uniformly across various incident types, such as work zones, Waze jams, incidents, weather reports, and parking data.

The unified API incorporates the following datasets:

- **Work zones**: Delivers real-time updates on active work zones, including location, duration, and potential delays.
- **Weather**: Provides up-to-date weather information, highlighting conditions that could impact driving safety, such as rain, snow, or fog.
- **Waze Jam Data**: Offers real-time user-reported data on traffic congestion, indicating delays and slowdowns.
- **Waze Incident Data**: Reports accidents, hazards, and other incidents, allowing CMV operators to make better routing decisions.
- **TMS Incident Data**: Supplements user-reported incidents with verified data from Transcore's traffic management system (TMS).
- **Parking Information**: Provides information on available parking for CMVs, which is vital for long-haul drivers adhering to regulated driving hours.
- **Weight Restriction Data**: Supplies information on weight limits for roads and bridges, ensuring that CMVs avoid routes where their load exceeds legal or safe limits.
- **Vertical Clearance Data**: Provides data on bridge and overpass heights, helping CMVs avoid routes where vehicle height exceeds the clearance limits.

The unified API was designed with flexibility in mind, allowing users to efficiently query and filter incident data based on various criteria, such as location, time, and severity. This mechanism ensures that users can access the most relevant information for their specific needs, without being overwhelmed by unnecessary data. In addition to general filtering mechanisms, the schema supports route-based querying, which allows users to retrieve incidents and work zones that occur along a specific path.

The following design principles were incorporated into the API:

- Modularity: Each dataset is treated as a modular component that can be added or removed without disrupting the overall system. This allows for flexibility in incorporating new data sources and functionalities.
- Scalability: The system is designed to scale with increased data traffic as more CMVs or data sources are integrated.
- Real-Time Data Handling: The system processes data in real-time, ensuring that CMV operators receive the latest updates on road conditions, traffic jams, incidents, weather, and parking availability.
- Interoperability: The system supports multiple data formats (e.g., GeoJSON, JSON) and ensures that data from different sources can be combined and used seamlessly.

- Security: Secure communication protocols are employed to protect the data and maintain privacy across different API services.

As part of the API development, a web interface was developed (see screenshot in Figure ES-1) to demonstrate the API's functionality and how it interfaces with users. This interface allows users to interact with the API and retrieve real-time data relevant to CMV operations.

The web interface allows users to request data in two ways:

- **Start and End Destinations Waypoints**: Users can input start and end points, and the system will generate a detailed overview of incidents along the route. This includes work zones, traffic jams, crashes, weather hazards, and parking availability.
- **Route Submission**: Users also have the option to submit predefined routes, for which the system will pull relevant data regarding all incidents along the route. This ensures that even complex or customized routes receive comprehensive, real-time updates, enabling CMV drivers to plan accordingly.
- The interface is designed to streamline the process of querying and retrieving data.

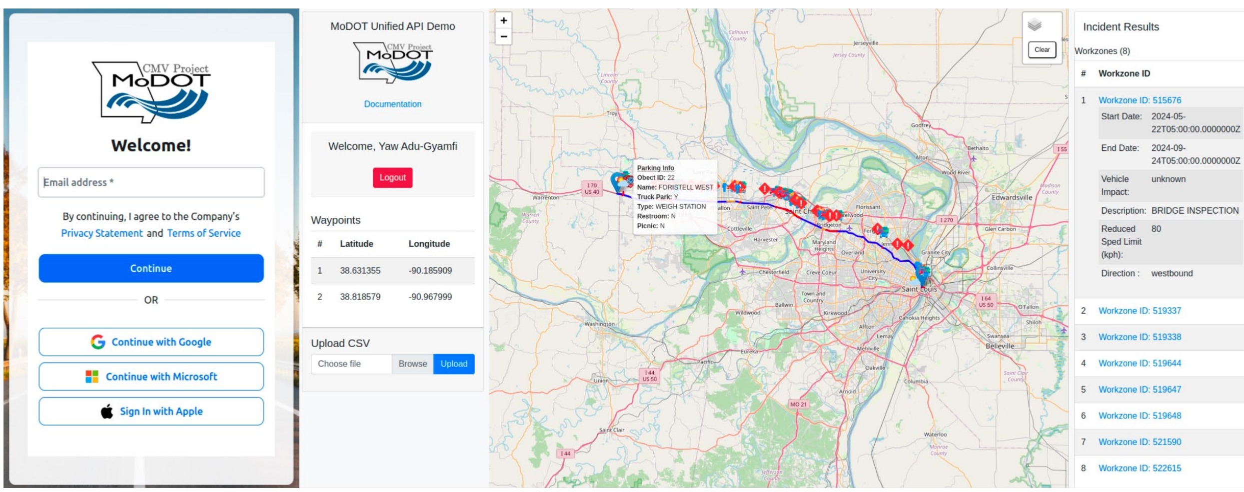

Figure ES-1. Schema for metadata and additional information.

1. Introduction

The Missouri Department of Transportation (MoDOT) is taking a proactive approach to improve the safety of commercial motor vehicles (CMVs). This project addresses one critical aspect of this approach i.e., how to communicate with CMV drivers safely and effectively. One such way to communicate with CMV drivers is an electronic notification system (ENS), which can be used to communicate information pertaining to low bridge clearances, steep grades, work zone presence, incidents, and inclement weather. Trucks colliding with low-clearance bridges in Missouri has become a recurring event and has been reported on recent news articles. For example, the Independence Avenue bridge in Kansas City with a clearance of 12 ft. is hit, on average, twice a month (Hardy 2020). Warning curtains installed at the bridge in early 2024 were damaged by a truck shortly after installation (Alcock 2024). Another bridge in Springfield, Missouri, with a clearance of 11.5 ft has also experienced its share of collisions (Garrity 2022). Both bridges are owned by railroad agencies and were built many decades ago when trucks were not as tall as they are today. Unfortunately, the high costs of raising the bridges means the problem continues to persist. Local agencies are working with the railroad agencies in identifying advance warning solutions. These efforts are well-aligned with the Missouri Supply Chain Task Force's recommendations on improving truck driver work environment including developing safe technologies to communicate with the CMV driver both inside the vehicle and outside (e.g., flashing lights, dynamic message signs (DMS)).

Since the use of mobile phones by CMV drivers while driving is illegal, any ENS method must not be solely phone centric. Another critical aspect is the timeliness in which information gets to drivers, allowing them to revise their routes (i.e., detouring or parking), if necessary. The technology should be accessible to any driver and allow them to receive critical information about their route. Although low-clearance bridge collisions are highlighted here, the developed ENS methods can be used to communicate critical information pertaining to work zones, incidents, and weather, that can help increase driver awareness and decision making.

1.1 Project Objectives

This project has the following objectives:

- Conduct a review of existing ENS methods in use by CMV drivers, trucking companies, and the freight industry
- Conduct a survey of selected state departments of transportation (DOTs) regarding their current practice of ENS for communicating with CMV drivers
- Conduct a needs assessment brainstorming workshop with MoDOT and other stakeholders
- Develop standards and specifications for data feeds consisting of traveler information critical for CMV operators

The research methodology to meet these objectives includes a literature review, survey of selected DOTs, stakeholder workshop, and development of data standards and an Application Programming Interface (API).

1.2 Report Overview

This report includes chapters on the following topics: literature review, DOT survey, stakeholder workshop, and development of the API. The final chapter of the report provides a summary of key research findings. Appendices include the survey questionnaire, survey responses, stakeholder workshop agenda and minutes, and API documentation.

2. Literature Review

This chapter presents the results of the literature review that was conducted on communicating information to CMVs.

2.1 Introduction

2.1.1 Background

The trucking industry in the United States constitutes a fundamental pillar of the economy, transporting goods and raw materials across extensive distances, and linking businesses and consumers nationwide. Given the crucial role trucking plays in the economy, ensuring the safety and efficiency of CMV operations is of the utmost importance. One essential aspect of this process is the establishment of effective communication practices for trucks. This review examines truck communication practices in the United States, focusing on various systems and methods that have been implemented to promote safe, secure, and efficient communication with CMVs.

2.1.2 Communication Practices

In the United States, communication practices within the trucking industry predominantly focus on employing technology to enhance safety, streamline efficiency, and facilitate coordination between drivers and dispatchers. Prevalent communication practices include:

- Citizens Band (CB) Radio: For many years, CB radios have been integral communication tools in the trucking industry. They enable drivers to exchange real-time information regarding road conditions, traffic, and other pertinent areas. CB radios generally function within a range of a few miles and utilize 40 channels (Obeidat et al. 2015, Worley 2011, Forge 2016, Zhao et al. 2019).
- Global Positioning System (GPS) and Fleet Management Systems: A considerable number of trucking companies harness GPS technology and fleet management systems for real-time vehicle tracking (Mintsis et al 2004, Sen and Kumar 2022). These systems empower dispatchers to monitor truck locations and relay voice or text messages to drivers, thereby enhancing efficiency and safety levels.
- Electronic Logging Devices (ELDs): To ensure adherence to federal regulations, trucking companies employ ELDs to electronically document drivers' hours of service (Gorman et al. 2023, Nkoro and Vershinin 2014, Sieber et al. 2022). Often incorporating built-in communication features, these devices facilitate the exchange of crucial information between drivers and dispatchers about scheduling, routing, and more.
- Mobile Phones and Smartphones: The trucking industry extensively relies on cell phones and smartphones for voice and text communication (Siuhi and Mwakalonge 2016, Ang et al. 2018, Mihelj et al. 2019). Applications such as WhatsApp and Skype offer supplementary communication alternatives, while specialized trucking apps furnish information on routing, weather, and truck stops.

- Satellite Communication: For remote areas with limited or no cell phone coverage, certain trucking companies utilize satellite communication systems (Nkoro and Vershinin 2014, Al-Hraishawi et al. 2022, Jacobs 1989, Kodheli et al. 2020). These systems depend on satellites to deliver voice and data services, guaranteeing uninterrupted communication.
- VHF/UHF Radios: In specific instances, trucking companies and drivers may employ Very High Frequency (VHF) or Ultra High Frequency (UHF) radios for communication purposes (Sieber et al. 2022, Sharma et al. 2020, Zhou and Shi 2009). These radios offer a more extensive range compared to CB radios and provide clearer signals in certain situations.

2.1.3 Truck Communication Standards and Systems

2.1.3.1 Advanced Traffic Management Systems (ATMS)

Advanced Traffic Management Systems (ATMS) form an integral component of contemporary intelligent transportation systems (ITS) devised to monitor and manage traffic flow, providing real-time information to motorists, including truck drivers (Bertini and Ahmed El-Geneidy 2004, Gilmore and Elibiary 1993, Shaon et al. 2021). ATMS have become increasingly prevalent in urban areas and along major highways, where traffic congestion and incidents can considerably impact transportation efficiency. These systems employ sensors, cameras, and other data collection methods to gather information on traffic conditions and relay it to central control centers. This information is then disseminated to motorists through various communication channels, such as variable message signs (VMS) (AlKheder et al. 2019, Erke et al. 2007, Miller et al. 1995), radio broadcasts (Forge 2016), and mobile applications (Siuhi and Mwakalonge 2016, Yigitcanlar et al. 2024, Abdelmagid et al. 2022, Luo and Hubaux 2006).

2.1.3.2 511 Travel Information Systems

The Federal Communications Commission (FCC) established the 511 Travel Information System as a nationwide telephone number for traveler information (Lindly and Hill 2003, Lanka and Jena 2016, Burgess and Pretorius 2007, Golob and Regan 2005). Numerous states have implemented localized 511 systems, offering information on road conditions, construction, and incidents (Burgess and Pretorius 2007). Truck drivers can access the 511 system through a simple phone call or by visiting dedicated websites and mobile applications in some states (Golob and Regan 2005). By providing timely and relevant information, the 511 system helps truck drivers make informed decisions about their routes and travel plans (Golob and Regan 2005). Figure 2-1 shows a map of states that have implemented 511 systems and a sample 511 travel web app of Ohio.

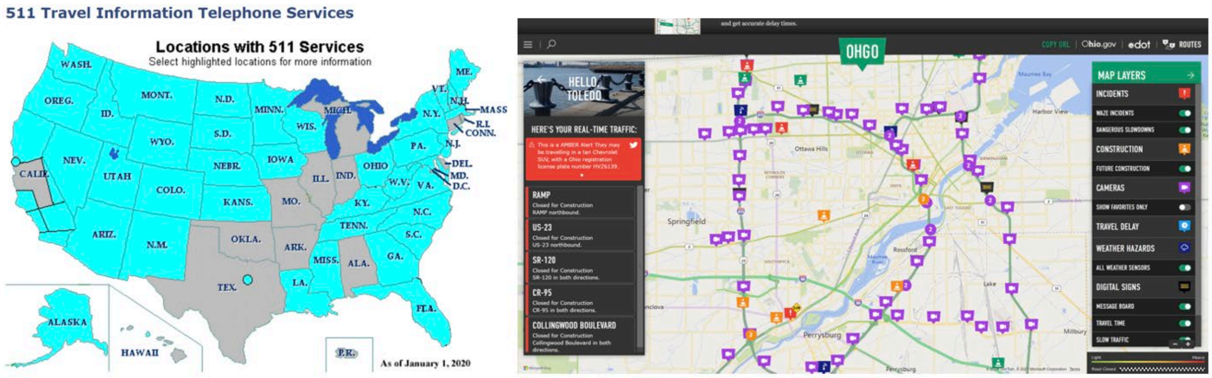

Figure 2-1. States implementing the 511 systems (left); Sample 511 travel web app of Ohio (right).

2.1.3.3 Variable Message Signs (VMS)

VMS are electronic traffic signs designed to display real-time information on road conditions, traffic, and other relevant updates (Erke et al. 2007, Miller 1995). Strategically placed along highways and major roadways, VMS provide truck drivers with critical information, such as lane closures, detours, and travel times. VMS are particularly useful for truck drivers, as they can alert them to restrictions on CMVs or available truck parking at rest areas (AlKheder et al. 2019, Erke et al. 2007). By delivering real-time information in a clear and concise manner, VMS contribute to enhancing road safety and efficiency for truck drivers (Zhao et al. 2019, AlKheder et al. 2019). Figure 2-2 shows a VMS sign example.

Figure 2-2. VMS example (Edara et al. 2011).

2.1.3.4 Emergency Alert Systems (EAS)

Emergency Alert Systems (EAS) constitute a critical component of truck communication practices in the United States (National Academies of Science, Engineering, and Medicine 2018; Martinez et al. 2010). The EAS is a national public warning system designed to disseminate emergency information and alerts through various communication channels, including radio, television, and wireless devices (Ali and Jacksi 2021, Sadiq et al. 2023). In the context of truck communication, EAS can provide truck drivers with timely warnings about severe weather conditions, natural disasters, and other emergency situations, enabling them to adjust their routes or take necessary precautions (Sen and Kumar 2022, Abusch-Magder et al. 2007, McBride et al. 2020).

2.1.3.5 Weather Information Systems

Weather Information Systems play a significant role in truck communication (Dey et al. 2014, Sukuvaara 2018), particularly in regions with extreme or rapidly changing weather conditions (Sukuvaara 2018, Mohammed et al. 2020, Dey et al. 2014). These systems provide real-time data on road and atmospheric conditions, helping truck drivers anticipate and respond to adverse weather situations (Kulmala 1997, National Research Council 2004). By integrating with other transportation management systems, such as ATMS and VMS, Weather Information Systems can provide truck drivers with comprehensive updates on weather-related road hazards, closures, and restrictions (Sukuvaara 2018).

2.1.3.6 Commercial Vehicle Information Systems and Networks (CVISN)

Commercial Vehicle Information Systems and Networks (CVISN) provide a platform for truck communication, offering safety inspection updates and regulatory information (Brand et al. 2004, Dingus et al. 1996, Silva et al. 2017, Dressler et al. 2008). This literature review introduces CVISN and compares its implementation and messaging practices among states, analyzing the types of messages transmitted through the system (Brand et al. 2004). Figure 2-3 shows an example of CVISN infrastructure.

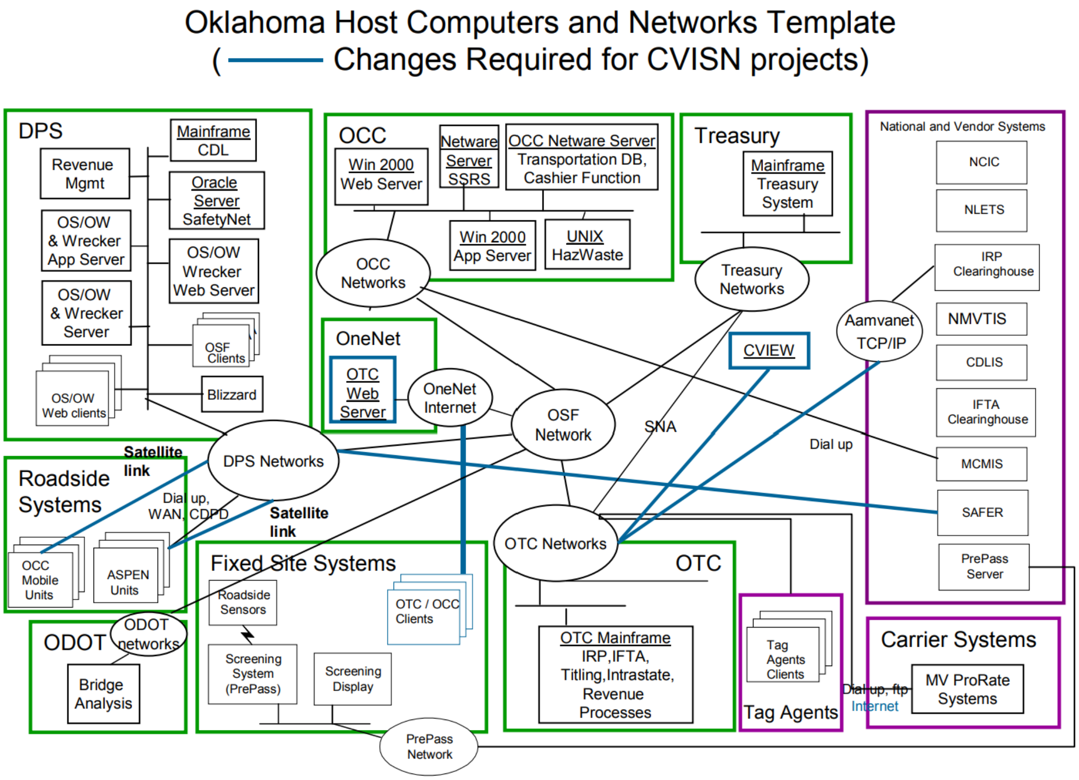

Figure 2-3. Example CVISN infrastructure.

3. DOT Survey

This chapter provides an overview of the methodology and results for the DOT survey.

3.1 Methodology for DOT Survey

A survey was developed and administered to gain greater understanding of the state of the practice for communicating information electronically to CMV drivers by state DOTs in the United States. The survey, which included 12 questions, was reviewed by the topic panel before being sent to 30 state DOTs via Qualtrics Survey Software (Qualtrics 2024). The state DOTs selected to participate in the survey included those in the Mid-America Freight Coalition (2024), the Institute for Trade and Transportation Studies (ITTS) (2024), and 12 additional states chosen for geographical diversity. The survey was sent to one respondent from each of the 30 state DOTs. An effort was made to identify the appropriate person at each DOT to complete the survey, and the list of DOT contacts for the survey was primarily developed based on the membership lists of the Mid-America Freight Coalition, ITTS, and the American Association of State Highway Transportation Officials (AASHTO) Special Committee on Freight. In addition, respondents were encouraged to collaborate with others at their DOT and to forward the survey to the staff who would be most capable of answering the questions and providing the most accurate information. Responses were received from 18 state DOTs for a response rate of 60 percent. A map showing the survey respondents is provided in Figure 3-1.

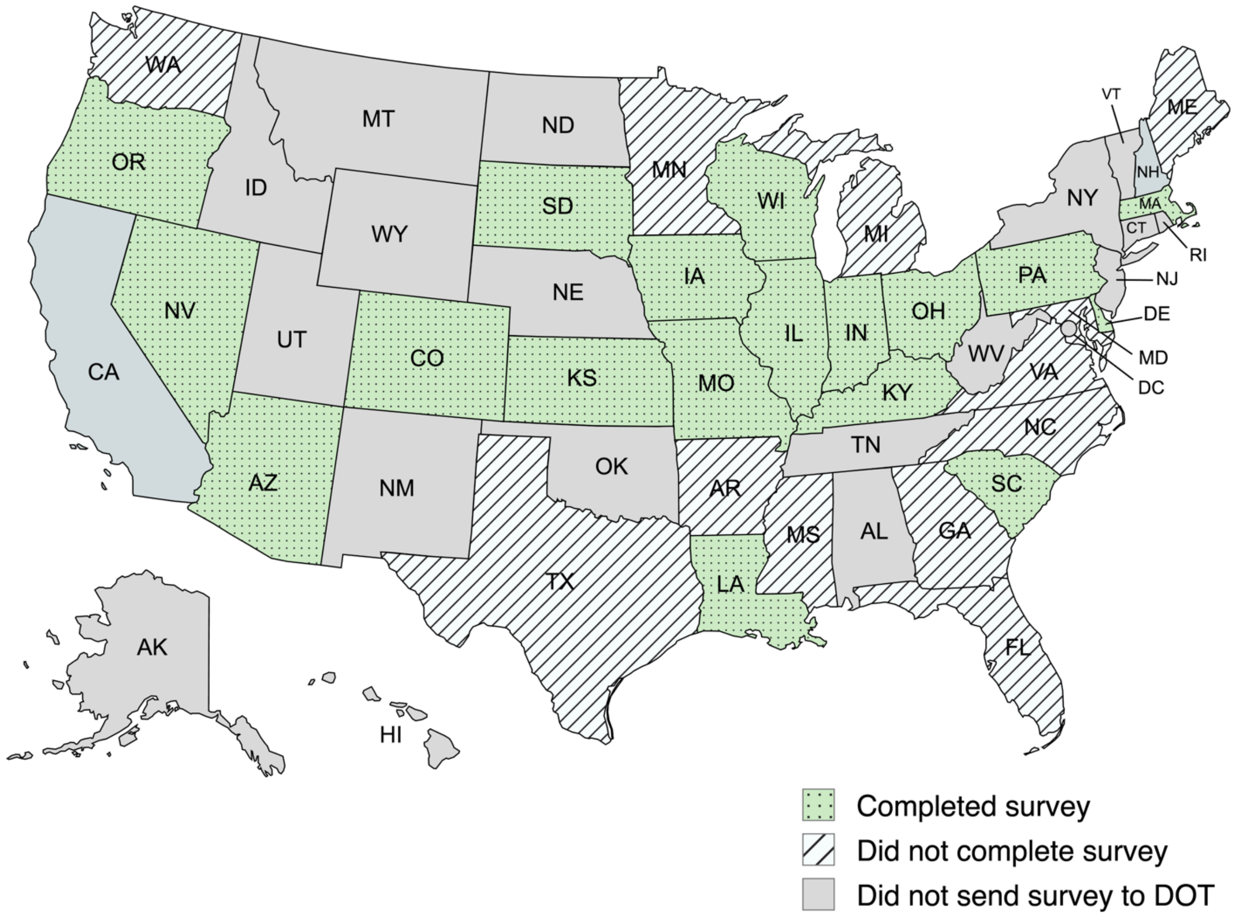

Figure 3-1. Respondents for DOT survey (map created with mapchart.net).

The survey covered various topics related to communicating information electronically to CMV drivers, such as types of information communicated, communication methods, data sources, challenges, partnerships, and data standards or policies. Several of the multiple-choice questions included an option for other with a text entry field and a field for comments. A copy of the full survey can be found in Appendix A. Individual survey responses, including comments and other text responses are provided in Appendix B.

3.2 Results for DOT Survey

This section presents the results of the DOT survey and is organized as follows: types of information communicated electronically to CMV drivers (survey questions 1,2), methods for communicating information electronically to CMV drivers (survey questions 3-5), implementation considerations (survey questions 6-9), and other survey feedback (survey questions 10-12).

3.2.1 Types of Information Communicated Electronically to CMV Drivers

The first and second survey questions sought information regarding types of information communicated electronically to CMV drivers now and in the future, respectively. The results for Question 1, shown in Table 3-1, indicate that the types of information currently communicated to CMV drivers by the highest number of DOTs are extreme weather events, traffic incidents, and work zone lane closures. Only one responding DOT communicates information regarding steep grades or truck emergency escape ramps electronically, while no responding DOTs communicate information regarding tire checkup areas. Other types of information noted in the text responses include winter road conditions, congestion, road closures, detours, commercial vehicle permit information, weight and dimension limits, travel advisories, and weigh station bypass/pull-in instructions.

Table 3-1. Survey results for types of information DOTs are currently communicating electronically to CMVs (Question 1).

Type of Information	Count
Extreme weather events	10
Traffic incidents	10
Work zone lane closures	10
Complete highway or bridge closure	8
Low bridge clearance	7
Rest area information	7
End of queue alerts	5
Truck restricted routes	5
Variable speed limits	5
Availability of truck parking	4
Weigh station information	4
Other	4
None of the above	4
Sharp curves	3
Truck restricted lanes	3
Worker presence in work zones	2
Steep grades	1
Truck emergency escape ramps	1
Tire checkup areas	0
Total Responses	**17**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

As shown in Table 3-2, the results for Question 2 indicate that the highest number of responding DOTs are working on communicating information electronically regarding availability of truck parking and traffic incidents in the future. One responding DOT is working on communicating information regarding truck emergency escape ramps, truck restricted routes, or truck restricted routes in the future, while no responding DOTs are working on communicating information regarding tire checkup areas. Other types of information mentioned in the text responses include applications solutions (e.g., Drivewyze, Trihydro), HAAS alerts (real-time alerts to let drivers know of the presence of law enforcement or roadway workers, HAAS, Inc. 2024), and in-cab turn-by-turn commercial vehicle permit directions.

Table 3-2. Survey results for types of information DOTs are working on communicating electronically to CMVs in the future (Question 2).

Type of Information	Response
Availability of truck parking	10
Traffic incidents	7
Extreme weather events	6
End of queue alerts	5
Low bridge clearance	5
Rest area information	5
Work zone lane closures	5
Worker presence in work zones	5
Long-term highway or bridge closure	4
Other	4
Sharp curves	3
Variable speed limits	3
Weigh station information	3
Steep grades	2
Truck emergency escape ramps	1
Truck restricted lanes	1
Truck restricted routes	1
Tire checkup areas	0
None of the above	0
Total Responses	**12**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

3.2.2 Methods for Communicating Information Electronically to CMV Drivers

Survey questions 3 and 4 sought information regarding methods for communicating information electronically to CMV drivers now and in the future, respectively. The results for Question 3, shown in Table 3-3, indicate that the methods used by the highest number of responding DOTs are DMS, 511 travel information systems, and changeable message signs (CMS), while none of the responding DOTs use fleet management systems, CB radio, satellite radio, or VHF/UHF radio. Other methods mentioned in the text responses include surveys, contracted preclearance vendors, travel information kiosks, and ports of entry.

Table 3-3. Survey results for methods used by DOTs to communicate information electronically to CMVs (Question 3).

Method	Count
Dynamic message signs (DMS) (permanent signs used for posting messages)	16
511 traffic information systems (accessed through phone number, online, and/or smartphone app)	14
Changeable message signs (CMS) (portable trailers used for posting messages)	12
Websites	11
Traveler information maps	10
Social media	10
Customer service centers	6
Smartphone applications	6
Static signs with dynamic features	6
Data providers	5
Print or broadcast media	5
Remotely activated traffic control devices	5
Email lists	5
Text messages	5
Real-time Highway Advisory Radio (HAR)	4
Audible or visual alarms	3
In-cab alerts	3
Other	3
Commercial radio	1
Flyers	1
Connected vehicle technologies	1
Fleet management systems	0
CB radio	0
Satellite radio	0
VHF/UHF radio	0
None of the above	0
Total Responses	**17**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

As shown in Table 3-4, the results for Question 4 indicate that the highest number of responding DOTs are planning to use in-cab alerts, connected vehicle technologies, and smartphone applications to communicate information electronically to CMVs in the future. No responding DOTs indicated that they are planning to use fleet management systems or VHF/UHF radio in the future. A Truck Parking Availability System was mentioned in the other text responses.

Table 3-4. Survey results for methods DOTs are planning to use in the future to communicate information electronically to CMVs (Question 4).

Method	Count
In-cab alerts	11
Connected vehicle technologies	9
Smartphone applications	8
Dynamic message signs (DMS) (permanent signs used for posting messages)	7
Data providers	6
511 traffic information systems (accessed through phone number, online, and/or smartphone app)	5
Changeable message signs (CMS) (portable trailers used for posting messages)	5
Static signs with dynamic features	5
Traveler information maps	5
Websites	5
Audible or visual alarms	4
Email lists	4
Remotely activated traffic control devices	4
Social media	4
Text messages	4
Customer service centers	3
None of the above	3
Print or broadcast media	3
Flyers	2
Other	2
Satellite radio	2
CB radio	1
Commercial radio	1
Real-time Highway Advisory Radio (HAR)	1
Fleet management systems	0
VHF/UHF radio	0
Total Responses	**17**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

For Question 5, respondents were asked to rate the effectiveness of communication methods they use on a scale of 1 (Highly Ineffective) to 5 (Highly Effective). As shown in Table 3-5, responding DOTs perceive audible or visual alarms and in-cab alerts as the most effective methods for communicating information to CMV drivers and real-time Highway Advisory Radio (HAR) as the least effective method. Notable comments in response to this question are summarized below:

- Effectiveness is hard to measure and judge.
- Many methods are successful.
- One DOT is switching from HAR to DMS.

Table 3-5. Survey results for perceived effectiveness (1 = Highly Ineffective, 5 = Highly Effective) for methods used to communicate information to CMV drivers.

Method	Average	Standard Deviation	Number of Ratings
Audible or visual alarms	4.3	0.6	3
In-cab alerts	4.3	0.6	3
Commercial radio	4.0	n/a	1
Changeable message signs (CMS) (portable trailers used for posting messages)	4.0	0.7	12
Flyers	4.0	n/a	1
Remotely activated traffic control devices	4.0	0.0	5
Dynamic message signs (DMS) (permanent signs used for posting messages)	3.9	1.1	16
Other	3.7	1.5	3
Websites	3.5	0.9	11
511 traffic information systems (accessed through phone number, online, and/or smartphone app)	3.4	1.2	14
Email lists	3.4	0.9	5
Traveler information maps	3.3	1.3	10
Data providers	3.2	1.3	5
Static signs with dynamic features	3.2	1.2	6
Social media	3.1	0.8	9
Customer service centers	3.0	0.6	6
Print or broadcast media	3.0	0.7	5
Smartphone applications	3.0	1.7	6
Connected vehicle technologies	3.0	n/a	1
Text messages	3.0	1.4	5
Real-time Highway Advisory Radio (HAR)	2.8	1.3	4
Fleet management systems	n/a	n/a	0
CB radio	n/a	n/a	0
Satellite radio	n/a	n/a	0
VHF/UHF radio	n/a	n/a	0

Note: Sort order = average (high to low).

3.2.3 Implementation Considerations for Communicating Information Electronically to CMVs

Questions 6-9 asked respondents about various implementation considerations for communicating information electronically to CMVs, including data sources, perceived challenges, partnerships, and development of data standards or policies. Question 6 sought information regarding data sources for information to share with CMV drivers, and the results are shown in Table 3-6. The results indicate that the data sources used by the highest number of responding DOTs are traffic sensors, law enforcement and first responders or emergency services, feeds from data providers, and video cameras, while the data sources used by the lowest number of responding DOTs are trucking companies and Radio Frequency Identification (RFID). Other data sources mentioned in the text responses include Drivewyze and INRIX.

Table 3-6. Survey results for data sources for information to share with CMV drivers (Question 6).

Data Source	Count
Traffic sensors	13
Law enforcement and first responders or emergency services	12
Feeds from data providers	11
Video cameras	11
Internal data sources at my agency	10
Crowdsourcing data	9
Work Zone Data Exchange (WZDx) Feeds	8
Environmental sensors	7
Truck Parking Information Management System (TPIMS)	7
Probe vehicles	5
Social media	5
Work Zone Activity Data (WZAD)	4
Transportation Data Exchange (TDx) feeds	2
Trucking companies	1
Other	1
Radio Frequency Identification (RFID)	0
Total Responses	**18**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

Question 7 asked DOTs about perceived challenges to their efforts to communicate information to CMV drivers, and the results are provided in Table 3-7. These results show that the challenges noted by the highest number of responding DOTs are the need for data standardization, data availability, and funding constraints, while the challenges noted by the lowest number of responding DOTs are stakeholder concerns and providing information in multiple languages. Other challenges noted in the text responses include getting data into the cabs of trucks, finding a technology with focused delivery of messages, and disseminating information to accommodate various outlets and formats.

Table 3-7. Survey results for perceived challenges to DOTs' efforts to communicate information to CMV drivers (Question 7).

Challenge	Count
Need for data standardization	13
Data availability	11
Funding constraints	10
Availability of agency staff	8
Concerns about CMV driver being distracted with information	8
Lack of available data standards	8
Obtaining accurate, reliable, and timely information	8
Technology issues	8
Need for information regarding effectiveness of methods used	7
Lack of buy-in from trucking companies	6
Stakeholder coordination	5
Other	3
Providing information in multiple languages	3
None of the above	0
Total Responses	**18**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

The results for Question 8, regarding partnerships as part of DOTs' efforts to communicate information to CMV drivers are provided in Table 3-8. These results show that partnerships with law enforcement, technology vendors/app developers, and industry associations or trucking associations are pursued by the highest number of responding DOTs, while partnerships with metropolitan planning organizations (MPOs) and Federal Motor Carrier Safety Administration (FMCSA) are pursued by the lowest number of responding DOTs. There were no other text responses for this question.

Table 3-8. Survey results for partnerships pursued by DOTs in efforts to communicate information to CMV drivers (Question 8).

Entity	Count
Law enforcement	12
Technology vendors/app developers	12
Industry associations or trucking associations	10
FHWA	7
Other state DOTs	6
Local agencies	5
Trucking companies	5
FMCSA	4
MPOs	2
None of the above	0
Other	0
Total Responses	**16**

Notes: Respondents could select multiple answers. Sort order = count (high to low).

In response to Question 9, all 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers.

3.2.4 Other Survey Feedback

Question 10 allowed respondents to provide any other general comments regarding communicating information to CMV drivers. Some of these comments are summarized below.

- Availability of many opportunities to provide information to CMV drivers
- Need for planning to ensure that information is not over communicated
- Concerns regarding data security when providing information to CMV drivers
- Exploration of funding opportunities and services such as Drivewyze
- Working with PrePass to provide a Work Zone Data Exchange (WZDx) feed
- Use of existing standards, such as WZDx and Traffic Management Data Dictionary (TMDD), for information

A full list of comments received is provided in Appendix B.

In response to Questions 11 and 12, all 18 responding DOTs indicated a willingness to be contacted if they have any follow-up questions and noted that they would like to receive a copy of the final report for the project once it is published.

3.3 Summary of DOT Survey Findings

A summary of key findings from the DOT survey is provided below.

- The types of information currently communicated to CMV drivers by the highest number of responding DOTs are extreme weather events, traffic incidents, and work zone lane closures. Only one responding DOT communicates information regarding steep grades or truck emergency escape ramps electronically, while no responding DOTs communicate information regarding tire checkup areas.
- Regarding future plans for types of information to communicate electronically to CMVs, the highest number of responding DOTs are working on communicating information electronically regarding availability of truck parking and traffic incidents in the future. One responding DOT is working on communicating information regarding truck emergency escape ramps, truck restricted routes, or truck restricted routes in the future, while no responding DOTs are working on communicating information regarding tire checkup areas.
- The methods used by the highest number of responding DOTs to communicate information to CMVs are DMS, 511 travel information systems, and CMS, while none of the responding DOTs use fleet management systems, CB radio, satellite radio, or VHF/UHF radio.
- For methods to communicate information electronically to CMVs in the future, the highest number of responding DOTs are planning to use in-cab alerts, connected vehicle technologies, and smartphone applications.
- Responding DOTs perceive audible or visual alarms and in-cab alerts as the most effective methods for communicating information to CMV drivers and real-time HAR as the least effective method.
- The data sources used by the highest number of responding DOTs to gather information for CMV drivers are traffic sensors, law enforcement and first responders or emergency services, feeds from data providers, and video cameras, while the data sources used by the lowest number of responding DOTs are trucking companies and RFID.
- The perceived challenges to communicating information to CMV drivers noted by the highest number of responding DOTs are the need for data standardization, data availability, and funding constraints.
- Partnerships with law enforcement, technology vendors/app developers, and industry associations or trucking associations are pursued by the highest number of responding DOTs, while partnerships with MPOs and FMCSA are pursued by the lowest number of responding DOTs.
- All 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers.
- Other concerns noted in survey comments include the need for planning to ensure that information is not overly communicated and data security.

4. Stakeholder Workshop

A stakeholder workshop was conducted on August 28, 2023 to discuss the desired characteristics of ENS. The workshop was held in Jefferson City, Missouri, with additional remote participation. There were 42 attendees at the workshop. The attendees represented 27 entities, including government agencies, law enforcement, trucking associations, vendors, and other organizations. A list of organizations represented at the workshop is provided in Table 4-1. The meeting agenda is provided in Appendix C.

The workshop included a presentation by the research team to give an overview of the project, followed by a series of question prompts to initiate a brainstorming exercise. A matrix of various facets (e.g., what is available, what is important and urgent, challenges) of types of information and technology used to convey that information to CMV drivers was developed based on the discussion at the workshop. The developed matrix is shown in Table 4-2, Table 4-3, and Table 4-4.

Some key points from the discussion at the stakeholder workshop are summarized as follows:

- Several state DOTs, such as New York, New Jersey, Georgia, and North Carolina, have tried in-cab messaging. In addition, some states allow drivers to subscribe to alerts.
- Examples of information that could be helpful to CMV drivers include presence of active work zones (especially mobile work zones and worker presence), truck parking (number of miles ahead and number of spaces available), end of queue alerts, sudden slowdown alerts, weather (e.g., extreme weather), low bridges, sharp curves, truck emergency escape ramps, brake check areas, and chain stations.
- Information provided needs to be accurate and provide true value to the driver while being conveyed in a useful format that does not overwhelm or distract the driver.
- Information provided to drivers can be both short-term or long-term.
- Information regarding the availability of parking at rest areas could help truckers plan. Static information regarding availability of amenities at rest areas would also be beneficial. Information on private truck parking (e.g., truck stops) is harder to obtain. MoDOT recently completed a research study on prioritizing truck parking investments.
- Some of the challenges to efforts to communicate information to CMVs include disseminating information to drivers in different languages, differences between large and small carriers (e.g., response to winter events, technology capabilities, in-cab equipment), and ensuring consistency between states.

A copy of the workshop minutes is provided in Appendix D.

Table 4-1. List of organizations represented at stakeholder workshop.

Organization
American Road and Transportation Builders Association
American Traffic Safety Services Association
CBB
CFI
Drivewyze
FHWA
FMCSA
HERE
Iowa DOT
Military Surface Deployment and Distribution Command
Missouri Dump Truckers Association
Missouri State Highway Patrol
Missouri Trucking Association
MoDOT (Highway Safety and Traffic)
MoDOT (Maintenance)
MoDOT (Motor Carrier Services)
MoDOT (Multimodal Operations)
MoDOT (Research)
MoDOT (Safety and Emergency Management)
MoDOT (St. Louis District)
PAR Electrical Contractors
PrePass
St. Louis Freightway
Twehous Excavating Company
Unigroup
University of Missouri
WSP

Table 4-2. Matrix for information and technology developed at stakeholder workshop (Part 1 of 3).

Factor	What is currently available? What is the frequency of the information? What is the availability of the technology? Who is providing the information/ technology?	What is most important? What is most urgent?
Information	• New York State DOT is providing bridge vertical clearance data to Google and HERE – updated within 24 hrs (HOOCS) • PrePass app combines information to drivers in cab – static and dynamic info • Work zone lane closures, end of queue alerts, extreme weather, low bridge clearance, sharp curves, runaway ramps, variable speed limits, Active Transportation and Demand Management (ATDM) • FHWA fact sheet on North Carolina DOT communicating work zone information to truckers • New York, New Jersey, North Carolina, Georgia in cab messaging, may not be permitted by all companies • Weather hot spots • Paper on existing analysis of truck parking in Missouri	• Accuracy and timeliness of information that is being shared, particularly for work zones • Not just collecting data but communicating it in the best way is critical • Offering truck-specific WZDx feeds (not just generic feeds that may not be applicable for trucks, e.g., car detour routes)
Technology	• Truckers can choose to enable or disable info – too many messages will lose effectiveness or distract • Some carriers lock down what messages come through enroute to limit them to necessary alerts only • Carriers can push important information to drivers themselves instead of directly through data providers to filter alerts • Alerts are audio and visual – option chosen by the driver • In cab alerts are short with a meaningful icon	• Not a new app, but open-source data feed that can be accessed by carriers and used through their own devices • How do carriers access the data? New York State DOT allows email subscriptions to receive alerts (e.g., traffic, work zone info) • Can information currently

Factor	What is currently available? What is the frequency of the information? What is the availability of the technology? Who is providing the information/ technology?	What is most important? What is most urgent?
	• Users choose to customize types of messages received, it is not auto filtered based on the vehicle type • Operator chooses language preferences • Preclearance: Drivewyze, PrePass, Elios, Ten Street Driver Pulse – if not set up with preferences, then it can be overwhelming and dismissed by operators • Truck Parking Information Management System (TPIMS), LIDAR, Inductive loop, other technologies for tracking available parking spaces • Kansas DOT will have DMS boards showing parking availability 90 mi, 60 mi, etc., in advance. Michigan may have something similar	communicated via DMS boards be provided as in-cab messages? • Technology that can quickly communicate with trucks regarding any downstream incidents is critical to avoid secondary incidents

Table 4-3. Matrix for information and technology developed at stakeholder workshop (Part 2 of 3).

Factor	What is not needed, an unnecessary distraction?	What is most needed that is not currently available?
Information	• Any messages that are not applicable to the driver's particular route • Safety campaigns (e.g., seat belt use)	• Data for active work zones – workers present, lane shift, closure, etc. • Especially important for mobile work zones • Number of truck parking spots available. Context-specific –only share messages for parking areas that the driver would need on their route. • Tire check-up areas • Inclement weather – high winds, snow • Truck restricted routes • Traffic incidents, ASAP, and ones that impact other states
Technology	• Some inconsistency about what should be considered a work zone	• Provide vehicle type in app so information is auto filtered (e.g., detour routes) • Predictive technology for parking based on historical usage data

Table 4-4. Matrix for information and technology developed at stakeholder workshop (Part 3 of 3).

Factor	What are problems and challenges to implementation?	Other information that is not urgent	Other ideas
Information	• Smaller fleets have more problems with accessing/pushing/filtering data to drivers • How to emphasize importance of not driving during severe weather? • Information varies by state – would be great if formatting is consistent between states i.e., data standardization across states (e.g., Transportation Data Exchange (TDx))	• Scheduled closures • Parking • Rest area amenities, (no facilities available at minimum, using icons might help with quick comprehension)Messaging for non-English speaking operators	• Effectiveness of in cab messaging needs to be studied • Use of heads up display to communicate urgent safety messages needs to be explored
Technology	• Available spaces at truck parking - Inventory is needed first • Timeliness of sharing available parking data as drivers are approaching the rest stop • Can a state share private truck stops information? • Predictive technology to know if rest stops are busy when the driver would arrive at the rest stop • State to State communication	-	-

5. CMV Data Feed Standards and API Development

The transportation industry is increasingly reliant on diverse, dynamic data streams—including traffic conditions, work zone information, parking availability, and weather data—that need to be communicated quickly and accurately to CMVs. Currently, these data streams are often accessed through a variety of separate APIs, creating a fragmented system. This fragmentation can lead to delays, data inconsistencies, and gaps in real-time communication, potentially compromising both safety and operational efficiency.

To address these challenges, a unified API was developed to generate a standardized dataset that can be shared with CMVs and other data users. This approach consolidates all relevant data into a single, cohesive platform, providing CMVs with seamless access to critical information. By aggregating data from multiple sources into a standardized, consistent format, the unified API ensures that CMVs and their operators can make well-informed, timely decisions without the risk of delays or data conflicts.

The primary objective of this unified API is to improve interoperability among data sources, minimize communication latency, and establish a secure infrastructure for real-time data exchange. By integrating these diverse data streams, the API significantly enhances situational awareness and responsiveness for CMVs, reducing risks on the road and improving overall operational performance.

This chapter explores the development of the standardized dataset and unified API, beginning with their design and architectural framework for bringing together multiple data sources. It covers the integration process, focusing on secure, efficient communication and performance optimization. Additionally, the chapter will address key challenges encountered during development, such as data standardization, security protocols, and real-time processing, and will conclude with a discussion on future improvements and enhancements.

5.1 Review of Current Data Schema in CMV Communication

In the current landscape, CMV operators and developers depend on multiple APIs to access essential information, such as traffic incidents, parking availability, weather conditions, and work zones. However, this fragmented system requires users to manually compile data from these disparate sources to gain a comprehensive view of road conditions and other critical information. This process involves additional operations, such as filtering, querying, and cross-referencing, which not only introduces inefficiencies but also hinders the widespread adoption of these systems by CMVs and developers.

The complexity of managing and integrating these individual sources creates significant barriers, underscoring the need for a unified solution. A unified API platform could offer streamlined, built-in services that deliver functional and actionable information, tailored specifically to the needs of CMV operators and their journeys.

Currently, the various APIs serving CMVs include:

- **Workzone API**: Delivers real-time updates on active work zones, including location, duration, and potential delays.
- **Weather API**: Provides up-to-date weather information, highlighting conditions that could impact driving safety, such as rain, snow, or fog.
- **Waze Jam Data API**: Offers real-time user-reported data on traffic congestion, indicating delays and slowdowns.
- **Waze Incident Data API**: Reports accidents, hazards, and other incidents, allowing CMV operators to make better routing decisions.
- **TMS Incident Data API**: Supplements user-reported incidents with verified data from traffic management systems.
- **Parking Information API**: Provides information on available parking for CMVs, which is vital for long-haul drivers adhering to regulated driving hours.
- **Weight Restriction Data API**: Supplies information on weight limits for roads and bridges, ensuring that CMVs avoid routes where their load exceeds legal or safe limits.
- **Vertical Clearance Data API**: Provides data on bridge and overpass heights, helping CMVs avoid routes where vehicle height exceeds the clearance limits.

While these individual APIs offer valuable data, using them in isolation requires additional processing—such as filtering, querying, and manual integration—to create a unified operational picture. This complexity makes it difficult for CMVs and developers to efficiently leverage the data.

The unified API addresses these challenges by consolidating data from multiple key sources into a single, cohesive platform. This system will provide CMV operators with seamless, real-time access to critical information, reducing the need for manual integration and enabling more efficient, data-driven decision-making on the road. Through this approach, CMV communication can be streamlined, improving both safety and operational efficiency.

5.1.1 Workzone API Schema

The following schema (Figure 5-1 and Table 5-1) represents the structure of the data provided by the Workzone API (adapted from WZDx). This schema is critical for understanding how the information is organized and how it can be integrated into a unified platform for CMV communication.

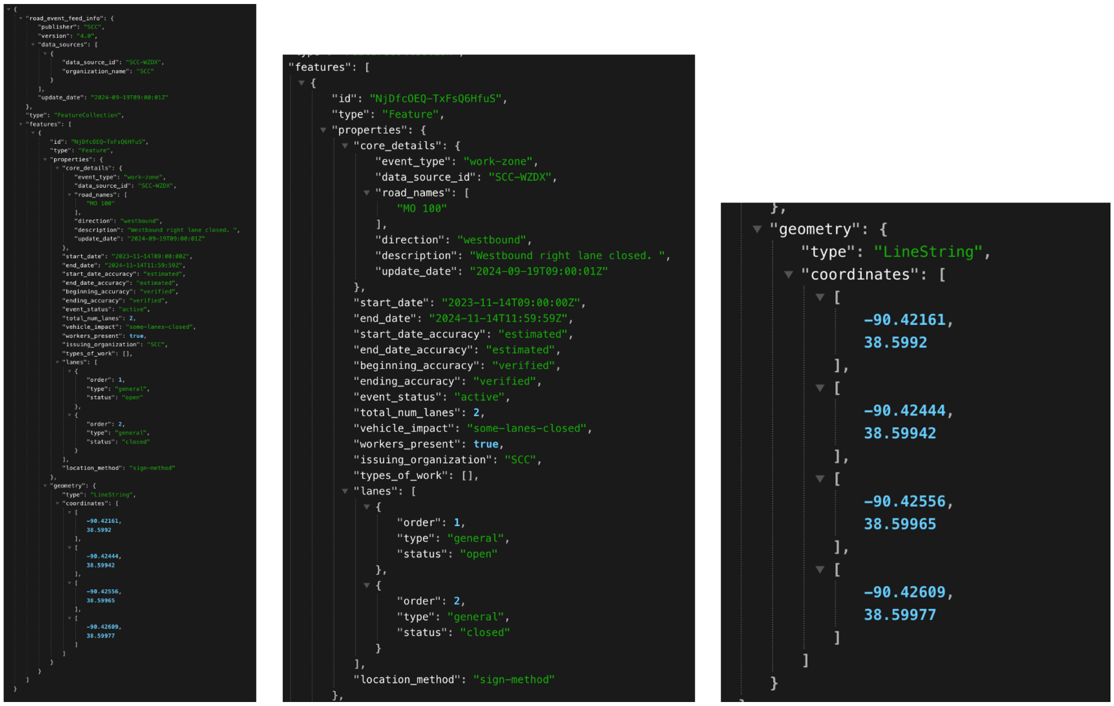

Figure 5-1. Workzone schema example.

Table 5-1. Schema breakdown for Workzone API.

Field	Description
Feed_info	Provides metadata about the data feed, including the publisher (e.g., Missouri Department of Transportation), version, licensing information, and data source details.

Field	Description
Data sources	Includes a list of sources contributing to the feed, with each source having a unique identifier, organization name, last update date, and data refresh frequency.
type	Indicates the type of GeoJSON object, such as a FeatureCollection.
Features	Contains a list of work zone features, each represented by a unique ID and type (feature). The details of each work zone are stored in the properties and geometry fields.
properties	Contains the core attributes of each work zone, including start/end dates, whether the dates and positions are verified, location determination method, and vehicle impact.

Field	Description
geometry	Specifies the type of geometric representation (e.g., LineString) and the coordinates of the work zone along the road network.
bbox	A bounding box containing the geographic extent of the work zone.

5.1.2 Weather API Schema

The Weather API (see Table 5-2 and Figure 5-2) delivers detailed weather information, including real-time temperature, wind speed, precipitation probability, cloud cover, and visibility for specific geographical locations. This data allows CMV operators to make informed decisions about routes and driving conditions. However, like other standalone APIs, the challenge is manually combining this data with other relevant information such as traffic incidents and work zones.

Table 5-2. Weather data schema breakdown.

Field	Description
active	Contains a list of active weather reports.
uuid	A unique identifier for each weather report, usually based on location and timestamp.
pub_millis	The timestamp of the weather report in ISO 8601 format.
temperature	The current temperature at the location (in degrees Fahrenheit).
temperatureApparent	The "feels like" temperature based on factors such as humidity and wind.
uvHealthConcern	A measure of UV radiation and its potential health impact.
uvIndex	The UV index at the location.
visibility	The visibility in miles.
cloudCover	The percentage of cloud cover.
cloudBase	The height of the cloud base in miles (may be empty if unknown).
cloudCeiling	The height of the cloud ceiling in miles (may be empty if unknown).
humidity	The humidity level in percentage.
freezingRainIntensity	The intensity of freezing rain (in inches/hour).
precipitationProbability	The probability of precipitation (as a percentage).
pressureSurfaceLevel	The surface level atmospheric pressure (in inches of mercury).
rainIntensity	The intensity of rain (in inches/hour).
sleetIntensity	The intensity of sleet (in inches/hour).
windDirection	The wind direction in degrees.
windGust	The wind gust speed (in miles/hour).
dewPoint	The dew point temperature (in degrees Fahrenheit).
windSpeed	The wind speed (in miles/hour).
weatherCode	A numeric code representing the weather condition (e.g., clear, cloudy, etc.).
county	The name of the county where the weather data applies.
latitude/longitude	The geographical coordinates of the weather report.

Weather


```
{
    "uuid": "ST. CLAIR_38.16562409,-93.72654999",
    "pub_millis": "2024-09-19 20:00:00",
    "temperature": 80.94,
    "temperatureApparent": 85.02,
    "uvHealthConcern": 0,
    "uvIndex": 0,
    "visibility": 9.94,
    "cloudCover": 96,
    "cloudBase": 0.42,
    "cloudCeiling": 0.42,
    "humidity": 73,
    "freezingRainIntensity": 0,
    "precipitationProbability": 5,
    "pressureSurfaceLevel": 28.84,
    "rainIntensity": 0.01,
    "sleetIntensity": 0,
    "windDirection": 153.69,
    "windGust": 10.07,
    "dewPoint": 71.6,
    "windSpeed": 5.59,
    "weatherCode": 4000,
    "county": "ST. CLAIR",
    "latitude": 38.16562409,
    "longitude": -93.72654999
},
```


TMS Incidents


```
{
    "at_cross_street": "Catalpa St",
    "event_description": "0\n",
    "event_lanes_blocked_closedcount": 1,
    "event_status": "Active",
    "event_time_line_estimated_duration": 433380,
    "event_type": "Scheduled",
    "lane_closed_list": "1",
    "lane_configuration_list": "1,2,3",
    "latitude": 37.201496,
    "longitude": -93.29878,
    "on_street_name": "GRANT AVE",
    "pub_millis": "2023-07-05 09:11:44",
    "uuid": 225120,
    "county": "GREENE",
    "event_class": "OTHER",
    "request_millis": "2024-09-19 21:25:12.102691"
},
```


Figure 5-2. Weather and Traffic Incidents Schema Example.

5.1.3 TMS Incidents API

The TransCore Incidents API (Table 5-3) provides data related to road incidents such as scheduled closures, lane blockages, and events that impact traffic flow. The API includes key details such as the number of lanes closed, the expected duration of the event, and the geographical location of the incident. Unlike crowd-sourced data from platforms like Waze, the TransCore Incidents API typically provides more formal, validated information, making it a reliable source for critical traffic disruptions.

Table 5-3. TMS incidents schema breakdown.

Field	Description
active	Contains a list of active incidents.
uuid	A unique identifier for each incident.
at_cross_street	The nearest cross street where the incident occurred.
event_description	A description of the event (may be brief or empty).
event_lanes_blocked_closedcount	The number of lanes blocked or closed due to the incident.
event_status	The current status of the event (e.g., "Active").
event_time_line_estimated_duration	The estimated duration of the event in seconds.
event_type	The type of event (e.g., "Scheduled").
lane_closed_list	A comma-separated list indicating which lanes are closed.
lane_configuration_list	A comma-separated list of lane configurations at the site.
latitude / longitude	The geographic coordinates of the incident.
on_street_name	The name of the street where the event occurred.
pub_millis	The timestamp when the event was published (ISO 8601 format).
county	The county where the incident took place.
event_class	A classification of the event (e.g., "OTHER").
request_millis	The timestamp when the data was requested (ISO 8601 format).

5.1.4 Waze Jams API Schema

The Waze Jams API (see Figure 5-3 and Table 5-4) offers information about road congestion, including road names, start and end points of the jam, and details about the severity and length of the traffic delay. The data includes speed in kilometers per hour (km/h), the total length of the traffic jam in meters, and geographic coordinates indicating the start and end points of the congestion. Like other standalone APIs, the challenge of integrating Waze Jams data into a holistic system involves piecing together traffic jams, incidents, and weather data for a complete picture of road conditions. By consolidating this information into a unified API platform, CMV operators can make more informed and efficient routing decisions.

Traffic Jams - Waze


```
{
View site information : -90.36052,
    "county": "ST LOUIS",
    "start_node": "",
    "street": "James S. McDonnell Blvd",
    "speed": 0,
    "start_lat_line": "38.758514,38.759272,38.760047,38.76018,38.760246,
    "request_millis": "2024-09-19 21:50:45.698447",
    "uuid": 744584288,
    "start_long": -90.351338,
    "delay": -1,
    "end_segment": "",
    "start_long_line": "-90.351338,-90.353286,-90.3553,-90.355789,-90.35
    "latitude": 38.758514,
    "type": "",
    "end_node": "James S. McDonnell Blvd",
    "blocking_alertuuid": "b589efa3-cc19-463b-9987-a1060e3b7447",
    "start_segment": "",
    "road_type": 6,
    "start_lat": 38.758514,
    "pub_millis": "2024-09-11 03:41:59.045000192",
    "speed_kmh": 0,
    "level": 5,
    "country": "US",
    "longitude": -90.351338,
    "turn_type": "NONE",
    "length": 844,
    "end_lat": 38.759961
},
```


Traffic Incidents - Waze


```
{
    "pub_millis": "2024-05-28 22:59:06",
    "city": "Eureka, MO",
    "confidence": 1,
    "report_description": "",
    "street": "City Hall Dr",
    "uuid": "be46bb69-b3b0-4d8c-89ee-e5dc6cda134f",
    "report_rating": 5,
    "country": "US",
    "request_millis": "2024-09-19 21:53:24.769268",
    "longitude": -90.628627,
    "road_type": 17,
    "subtype": "ROAD_CLOSED_EVENT",
    "reliability": 8,
    "county": "ST LOUIS",
    "latitude": 38.495684,
    "magvar": 222,
    "type": "ROAD_CLOSED",
    "n_thumbs_up": "",
    "event_class": "ROAD_CLOSED"
},
```


Figure 5-3. Waze traffic jams and incident schema example.

Table 5-4. Waze traffic jams data schema breakdown.

Field	Description
active	Contains a list of active traffic jams.
uuid	A unique identifier for each traffic jam report.
county	The name of the county where the traffic jam is occurring.
street	The name of the street affected by the traffic jam.
speed	The current speed of vehicles in the traffic jam (in miles/hour).
start_lat / start_long	Latitude and longitude of the starting point of the jam.
end_lat / end_long	Latitude and longitude of the ending point of the jam.
delay	The estimated delay caused by the traffic jam (in seconds).
length	The total length of the traffic jam (in meters).
road_type	A numeric value representing the type of road (e.g., freeway, arterial).
speed_kmh	The speed in kilometers per hour.
level	The severity level of the traffic jam.
latitude / longitude	Geographic coordinates of the traffic jam.
start_lat_line / start_long_line	A sequence of latitudes and longitudes that outline the traffic jam's path.
pub_millis	The timestamp when the data was published (ISO 8601 format).
request_millis	The timestamp when the data was requested.
blocking_alertuuid	A unique identifier for any blocking alert related to the traffic jam.
turn_type	The type of turn restriction or condition (e.g., "NONE").

5.1.5 Waze Incidents API Schema

The Waze Incidents API (Figure 5-4 and Table 5-5) delivers live updates on various types of road incidents, including road closures, accidents, and hazards. Each report contains critical details such as the location, reliability rating, road type, and incident subtype. This data is crowd-sourced from Waze users, ensuring a constant stream of up-to-date information that CMV operators can use to adjust their routes.

Waze Incidents


```json
{
    "pub_millis": "2024-05-28 22:59:06",
    "city": "Eureka, MO",
    "confidence": 1,
    "report_description": "",
    "street": "City Hall Dr",
    "uuid": "be46bb69-b3b0-4d8c-89ee-e5dc6cda134f",
    "report_rating": 5,
    "country": "US",
    "request_millis": "2024-09-20 12:22:59.609721",
    "longitude": -90.628627,
    "road_type": 17,
    "subtype": "ROAD_CLOSED_EVENT",
    "reliability": 8,
    "county": "ST LOUIS",
    "latitude": 38.495684,
    "magvar": 222,
    "type": "ROAD_CLOSED",
    "n_thumbs_up": "",
    "event_class": "ROAD_CLOSED"
},
```


Figure 5-4. Waze incidents schema example.

Table 5-5. Waze incidents schema breakdown.

Field	Description
active	Contains a list of active incidents.
uuid	A unique identifier for each incident report.
pub_millis	The timestamp when the incident was published (ISO 8601 format).
city	The city where the incident occurred.
confidence	The confidence level of the report (usually between 0 and 10).
report_description	A description of the incident (may be empty).
street	The street where the incident occurred.
report_rating	A rating based on user feedback, typically used to assess the reliability of the report.
country	The country where the incident occurred.
request_millis	The timestamp when the data was requested (ISO 8601 format).
longitude	Longitude coordinate of the incident location.
road_type	A numeric value representing the type of road affected (e.g., highway, city street).
subtype	The subtype of the incident (e.g., "ROAD_CLOSED_EVENT").
reliability	A reliability score based on user feedback.
county	The county where the incident occurred.
latitude	Latitude coordinate of the incident location.
magvar	The magnetic variation, indicating the difference between magnetic north and true north.
type	The type of incident (e.g., "ROAD_CLOSED").
n_thumbs_up	The number of "thumbs up" ratings from users (if applicable).
event_class	The class of the event (e.g., "ROAD_CLOSED").

5.1.6 Parking Information API Schema

The Parking Information API (Table 5-6 and Table 5-7) offers detailed data on parking facilities, including the availability of truck parking spaces, restrooms, picnic areas, and the type of parking area (e.g., truck stop, welcome center). The data is presented as geographic features, providing the exact coordinates of each parking facility.

Table 5-6. Parking information schema example.

<table>
<tr><th>Parking Information Schema</th><th>Example of Features</th></tr>
<tr><td>
{

  "type": "FeatureCollection",

  "name": "parking_info",

  "crs": {

    "type": "name",

    "properties": {

      "name":
"urn:ogc:def:crs:OGC:1.3:CRS84"

    }

  },

  "features": [

    {

      "type": "Feature",

      "properties": {

        "OBJECTID": "integer",

        "DES": "string",

        "NAME": "string",

        "RESTROOM": "string",

        "TYPE": "string",

        "TRUCKPARK": "string",

        "PICNIC": "string",

        "ORIG_FID": "integer"

      },
</td><td>
{

  "type": "FeatureCollection",

  "name": "parking_info",

  "features": [

    {

      "type": "Feature",

      "properties": {

        "OBJECTID": 1,

        "DES": "RA",

        "NAME": "MOUND CITY NORTH",

        "RESTROOM": "Y",

        "TYPE": "TRUCK PARKING",

        "TRUCKPARK": "Y",

        "PICNIC": "N",

        "ORIG_FID": 62

      },

      "geometry": {

        "type": "Point",

        "coordinates": [

          -95.21340785299998,

          40.10054028600007

        ]

      }
</td></tr>
</table>

Parking Information Schema	Example of Features

"geometry": {
 	
"type": "Point",
 	
"coordinates": ["float", "float"]
 	
}
 	
}
 	
]
 	
}
	}
	
	]
	
	}

Table 5-7. Parking Information schema breakdown.

Field	Description
type	Specifies that the object is a FeatureCollection, indicating that it contains multiple geographic features.
name	The name of the feature collection (in this case, "parking_info").
crs	The coordinate reference system used to define the geographic coordinates (CRS84 is commonly used for WGS84 coordinates).
features	A list of geographic features representing parking facilities.
properties	Contains details about each parking facility:
- OBJECTID	A unique identifier for the parking facility.
- DES	A code describing the type of facility (e.g., "RA" for rest area).
- NAME	The name of the parking facility.
- RESTROOM	Indicates if the facility has restrooms ("Y" for yes, "N" for no).
- TYPE	The type of facility (e.g., "TRUCK PARKING," "WELCOME CENTER").
- TRUCKPARK	Specifies if the facility offers truck parking.
- PICNIC	Indicates if the facility has picnic areas.
- ORIG_FID	Original feature identifier for reference purposes.
geometry	Contains the geographic location of the facility:
- type	Specifies that the location is a point.
- coordinates	The geographic coordinates (longitude, latitude) of the parking facility.

6. Objectives of the Unified Schema

The unified data schema for CMV communication was designed with clear objectives to improve the efficiency and reliability of incident reporting and data exchange. These objectives emphasize the seamless integration of multiple data sources, real-time communication capabilities, and the establishment of a standardized data format. Each objective is aimed at overcoming the key challenges in current CMV communication systems, such as fragmented data sources, delays in updates, and inconsistencies in data formats across different platforms.

6.1 Integration of Multiple Data Sources

A key objective of the unified schema is to consolidate diverse data sources into a single, cohesive framework. By bringing together data from work zones, Waze incidents, traffic jams, weather conditions, and parking availability, the schema provides CMV drivers and developers with a unified dataset. This eliminates the need to manually compile information from multiple APIs, streamlining access to critical data.

The integration of these various data sources within a standardized structure reduces fragmentation and simplifies querying. CMV operators can easily access essential information, such as work zones, accidents, hazardous conditions, weather updates, and parking options, from one interface. The schema is designed to be scalable, allowing the seamless incorporation of new data sources as they become available, ensuring it remains adaptable to future demands.

6.2 Real-Time Communication

Another key objective of the unified schema is to enable real-time communication, ensuring that CMV drivers have access to the most up-to-date information on road conditions, incidents, and potential hazards. The schema is built to support frequent updates from multiple data sources, allowing users to access real-time data for timely and informed decision-making.

With regular data updates, the system swiftly communicates new incidents or changes, such as the opening of a work zone or the onset of adverse weather. This real-time information is critical for CMV drivers, enabling them to quickly adjust their routes, minimize risks, and avoid delays.

6.3 Standardized Data Format

One of the main challenges of integrating data from multiple sources is the inconsistency in how the data is structured and reported. The unified schema addresses this issue by implementing a standardized data format that applies uniformly across various incident types, such as work zones, Waze jams, incidents, weather reports, and parking data.

This standardization ensures that all incident types are represented in a consistent manner, making it easier for developers and systems to process and interpret the data. Key fields such as time, location, incident severity, and type are uniformly defined throughout the schema, allowing for seamless querying and filtering of relevant information. This not only improves the efficiency of data communication but also enhances compatibility with existing infrastructure, simplifying adoption and implementation for CMV developers and service providers.

By consolidating multiple data sources, supporting real-time updates, and establishing a consistent data format, the unified schema significantly enhances the communication of critical information to CMV drivers, improving safety and operational efficiency on the road.

7. Design and Architecture of the Unified Schema

The design and architecture of the unified schema were developed to optimize data communication and integration for CMV safety. By consolidating multiple data sources into a standardized and adaptable format, the schema enables efficient querying and filtering of critical incident data. This section outlines the schema's structure, the integration of various data sources and incident types, and the querying mechanisms that make it a robust tool for enhancing CMV safety communication.

7.1 Overview of Schema Structure

The unified schema (Table 7-1, Table 7-2, and Table 7-3) consists of four main components: **schema_info**, **sources**, **incidents**, and **metadata**. These components work together to provide a comprehensive framework for managing, querying, and retrieving incident data from multiple sources.

Table 7-1. Unified API general schema summary table.

Field	Type	Description	Required
schema_info	object	Metadata about the schema (name, version, release date, mode).	Yes
data_sources	array	Array of data sources with publisher, version, and update details.	Yes
incidents	array	Array of incident data, including class, time, location, and details.	Yes
routes	array	Array of route objects with coordinates and drive route information.	Yes
metadata	object	Summary of the request, including request ID, status, and incident counts.	Yes

Table 7-2. Sub-objects for key fields.

Field	Type	Description	Required
class_info	object	Contains classification of incidents (class, subclass).	Yes
time_info	object	Start and end time of the incident, with optional duration.	Yes
location	object	City, county, direction, and geospatial information (coordinates).	Yes
incident_details	object	Details about the event, impact, and severity of the incident.	Yes
source_info	object	Information about the source of the incident, including the publisher.	Yes
verification_info	object	Contains the verified status of the incident.	No
additional_info	array	Array of additional info, such as extra notes or attributes.	No
routes	array	List of routes, including coordinates and drive coordinates.	Yes
metadata	object	Overall request metadata, such as status and summary of incidents.	Yes

1. **schema_info**: This section contains essential metadata about the schema itself, such as the version, update frequency, and any relevant descriptions. It ensures that users are aware of the schema's current state and updates, facilitating easier maintenance and adaptation of the system.
2. **sources**: The **sources** object stores information about the data providers, including the publisher, data source ID, update frequency, and other relevant details. By maintaining data sources in a separate object, the schema reduces redundancy and simplifies the integration of multiple data streams.
3. **incidents**: The core of the schema, the **incidents** array, contains data about individual incidents, such as work zones, Waze jams, weather conditions, and more. Each incident entry includes fields for time, location, event details, and impact. The standardized structure ensures consistency across different incident types, making it easier to analyze and interpret the data.
4. **metadata**: This section provides a summary of the incident data, including the total number of incidents, and breakdowns by type (e.g., work zones, jams, weather). Metadata also

includes pagination details for large datasets, ensuring that data can be efficiently managed and retrieved in smaller chunks.

Table 7-3. Full schema description and objectives.

Section	Subsection	Description	Purpose
schema_info		Contains metadata about the API schema, such as its name, version, and release date.	Provides essential details about the schema, including the version and operational mode.
	name	The name of the schema.	Identifies the schema in use (e.g., "Unified API Schema").
	version	The version of the schema.	Indicates which version of the schema is being used.
	release_date	The release date of the schema.	Tracks when the schema version was released.
	mode	Defines whether the data is presented as "raw" or "grouped".	Determines how the data is structured (e.g., all incidents in one array or grouped by type).
	notes	Optional additional information or notes about the schema.	Provides any necessary comments or details about the schema usage.
data_sources		Lists the data sources used to populate the incidents and other information.	Provides details on the data sources feeding the API, such as publisher, version, and update data.
	source_id	Unique identifier for each data source.	Used to reference the source of the data in incidents and other sections.
	publisher	The organization that published the data source.	Helps identify the origin of the data (e.g., DOT, Waze, etc.).
	version	The version of the data source being used.	Indicates the data source's version for tracking and verification purposes.
	update_frequency	The frequency with which the data source is updated (in seconds).	Specifies how often the data is refreshed.

Section	Subsection	Description	Purpose
	update_date	The last time the data was updated.	Tracks when the last update occurred for the data source.
	license	The licensing information for the data.	Provides legal information regarding the use of the data.
incidents		An array of incidents containing details such as classification, time, and location.	Stores individual incident records and their relevant information.
	id	Unique identifier for each incident.	Used to reference and differentiate incidents.
	class_info	Contains classification information about the incident.	Identifies the type and subclass of the incident.
	class_id	Unique identifier for the incident class.	Used to track the category of incident (e.g., workzone, jam).
	incident_class	The main class of the incident (e.g., workzone, jam).	*Classifies the incident into a broad category.*
	subclass	Sub-classification of the incident (e.g., lane_closure for workzones).	Provides finer granularity for incident classification.
	time_info	Contains time-related information, such as the start and end times of the incident.	Helps track when the incident starts and ends or its estimated duration.
	start_time	When the incident started.	Indicates the start time of the incident.
	end_time	When the incident is expected to end.	Provides the estimated end time for the incident (can be null for ongoing incidents).
	estimated_duration	How long the incident is expected to last.	Provides a rough estimate of the incident duration.
	location	Contains location-based information about the incident.	Specifies where the incident occurred or is affecting.
	city	The city where the incident occurred.	Provides city-level granularity for location.

Section	Subsection	Description	Purpose
	county	The county where the incident occurred.	Offers additional geographic granularity.
	direction	The direction of the affected area (e.g., northbound, southbound).	Specifies which direction is impacted by the incident.
	impacted_roadways	Array of roadways affected by the incident.	Lists all roadways impacted by the incident.
	geospatial_info	Contains geometric data for mapping the incident.	Provides geospatial information (coordinates) for the incident.
	geometry_type	The type of geometry (e.g., Point, LineString).	Identifies the format of the geospatial data.
	geometry	The coordinates representing the location of the incident.	Array of coordinates for the affected area.
	incident_details	Contains detailed information about the incident, such as event type and severity.	Stores specific attributes of the incident.
	event	Contains the event information, including type and description.	Tracks what the event is (e.g., road closure, work).
	impact	Details the type of impact the incident has (e.g., lane closure, roadblock).	Specifies the effect of the incident.
	severity	Contains severity information (e.g., minor, major).	Tracks how serious the incident is.
routes		Holds route data, including requested and generated route coordinates.	Tracks the path or route associated with the incidents.
	route_id	Unique identifier for the route.	Helps differentiate between different routes.
	coordinates	The requested coordinates for the route.	Provides the original points requested for the route.
	drive_coordinates	The generated full route path.	Provides the actual route, as calculated or provided by the system.

Section	Subsection	Description	Purpose
	routes	Array of route objects (defaults to empty if no route data is available).	Stores the route information, empty if no route is present.
metadata		Provides summary information about the API response, such as status and incident counts.	Tracks the overall status and summary of the request.
	request_id	Unique identifier for the request.	Helps track and log the specific request.
	status	The status of the API response (e.g., success, failure).	Indicates whether the request was successful.
	summary	Contains total counts of different incident types (e.g., total workzones, total weather).	Summarizes the results, including totals for various incident types.

7.1.1 Data Sources and Incident Types

The unified schema integrates multiple data sources, including work zones, Waze incidents, Waze jams, weather data, TMS incidents, and parking information. These data sources are harmonized into a single structure, allowing for consistent representation and interpretation of incident data.

- **Work Zones**: Information about active and upcoming roadwork, including the affected road names, the start and end times, and the impact on traffic. These details are crucial for CMV drivers to plan routes and avoid delays.
- **Waze Incidents and Jams**: Real-time crowdsourced data from Waze, providing information on road closures, hazards, traffic jams, and other incidents reported by users. The schema standardizes this data and integrates it with other sources for a complete view of road conditions.
- **Weather**: Weather conditions that could affect road safety, such as visibility, precipitation, temperature, and wind speed. This data helps CMV drivers prepare for hazardous conditions along their routes.
- **TransCore Incidents**: Data from TransCore systems, including scheduled events and lane closures. This information is important for understanding the long-term impacts on roadways.
- **Parking Information**: Real-time data about available parking spaces for CMV drivers, particularly useful for planning rest stops and complying with Hours-of-Service regulations.

Each of these data sources is integrated into the **incidents** array, with fields mapped to a consistent structure. This allows developers to access relevant data from multiple sources without needing to navigate different formats or API structures.

7.1.2 Flexible Querying and Filtering Mechanism

The unified schema is designed with flexibility in mind, allowing users to efficiently query and filter incident data based on various criteria, such as location, time, and severity. This mechanism ensures that CMV drivers and developers can access the most relevant information for their specific needs, without being overwhelmed by unnecessary data.

- **Location-based Filtering**: Users can query incidents based on geographical coordinates, retrieving information about incidents that occur within a certain radius of a location or along a specified route.
- **Time-based Filtering**: Incidents can be filtered based on their start and end times, allowing users to focus on current or upcoming events that may affect their journey.
- **Severity and Impact Filtering**: The schema enables filtering based on the severity or impact of an incident, such as lane closures or road blockages. This allows users to prioritize more critical incidents that may pose significant risks to safety or cause delays.

By providing these flexible querying options, the schema ensures that users can tailor their data requests to their specific needs, improving the efficiency and effectiveness of CMV safety communication.

7.1.3 Route-Based Querying

In addition to general filtering mechanisms, the schema supports **route-based querying**, which allows users to retrieve incidents that occur along a specific path. This feature is particularly useful for CMV drivers, who can query incidents based on their planned routes and adjust their journey accordingly.

The **route** section of the schema accepts geometry in the form of **LineString coordinates**, representing the path from a source to a destination. Users can query the system for incidents that impact their route, such as work zones, jams, or weather conditions. The schema also supports optional route-based information, meaning that it can provide data relevant to the entire path or specific points along the route, depending on the user's query.

This feature enhances CMV safety by ensuring that drivers have access to real-time information about hazards or incidents that may affect their specific journey. The ability to request route-specific data helps drivers avoid dangerous or congested areas, improving both safety and operational efficiency.

7.2 Key Components of the Unified Schema

The unified data schema for CMV safety communication is composed of several key components that allow for the effective aggregation, querying, and communication of data from various sources. These components—**schema information**, **sources**, **incidents**, and **metadata**—work together to create a robust and flexible system that delivers real-time, standardized data. This section provides a detailed description of each of these components and their role in ensuring seamless data integration and communication for CMVs.

7.2.1 Schema Information

The **schema information** component contains metadata about the schema itself, including versioning details, update frequency, and relevant descriptions. This section is essential for maintaining the integrity of the data schema, ensuring that developers and users have access to the most current version, and understanding when and how often data is updated.

- **Versioning**: The version number of the schema is included to help track updates and changes over time. As the schema evolves, this information ensures that systems using the API are aligned with the latest version.
- **Update Frequency**: This field indicates how often data is refreshed. For real-time communication, it is crucial that users understand the update intervals, ensuring that decisions are made based on the most recent information available.
- **Description**: Additional fields may provide context on the schema, outlining any significant changes or features added in newer versions.

The schema information (Table 7-4) acts as the foundation of the entire data structure, providing the necessary context for users and developers working with the system.

Table 7-4. Schema_Info schema.

Field	Type	Description	Required
name	string	The name of the schema	Yes
version	string	The version of the schema	Yes
release_date	string	The release date of the schema in ISO format	Yes
mode	string	Mode of data, either 'raw' or 'group'	Yes
notes	string	Optional additional notes	No

7.2.2 Sources

The **sources** component of the schema (Table 7-5) is designed to manage information about the various data providers, which significantly reduces redundancy in the incidents themselves. Each data source is represented with key details, such as the publisher, data source ID, update frequency, and version. By maintaining source information separately, the schema avoids the repetition of these details in individual incident entries.

- **Source ID**: A unique identifier for each data provider, which is referenced in the incident data. This allows for easy identification of the origin of the data.
- **Publisher**: The organization or agency that provides the data, such as the Missouri Department of Transportation (MoDOT), Waze, or TransCore.
- **Update Frequency**: The interval at which the data from each source is updated. This is critical for ensuring that data is timely and accurate.
- **Version**: The version number of the data from the source, ensuring compatibility with the unified schema and allowing users to track updates over time.

The **sources** component serves as a central repository for all data providers, enabling a clear separation between incident data and source details. This not only reduces redundancy but also simplifies the process of adding new data sources in the future.

Table 7-5. Sources schema.

Field	Type	Description	Required
source_id	string	Unique identifier for the data source	Yes
publisher	string	Publisher of the data source	Yes
version	string	Version of the data source	Yes
update_frequency	integer	Update frequency in seconds	Yes
update_date	string	Last update date in ISO format	Yes
license	string	License information for the data source	Yes
source_url	string	URL to access the data source	No

7.2.3 Incidents

The **incidents** component is the core of the unified schema, containing detailed information about individual incidents. Each incident is structured consistently across various data types (work zones, Waze jams, weather, etc.), making it easier to parse and interpret. The schema standardizes several key fields for each incident:

- **Time Information**:
  - **Start and End Times**: Each incident contains fields for the start and end times, which define when the incident begins and ends. These times help users understand the temporal relevance of the incident.
  - **Verification Status**: Indicates whether the start and end times are confirmed or estimated, providing additional clarity about the accuracy of the information.
- **Location Information**:
  - **Coordinates**: Each incident includes geospatial information, such as latitude and longitude, to pinpoint the exact location of the event. The **geometry_type** field indicates whether the incident location is represented as a point or a line (for longer stretches of road like work zones).
  - **Road Information**: The affected road names and directions are included to provide context for where the incident is occurring. This helps CMV drivers and dispatchers understand which segments of the route are impacted.
  - **City and County**: Administrative information such as the city and county are included to further localize the incident.
- **Event and Impact Details**:
  - **Event Type and Code**: Each incident is classified by an event type, such as a work zone or weather condition, with a corresponding event code. This allows users to filter and query data by specific incident types.
  - **Impact Type**: Describes the severity or impact of the event, such as lane closures or road blockages. This information is critical for CMV drivers to determine how much an incident will affect their route.
  - **Severity**: Severity levels are standardized across incident types, helping prioritize which incidents are most critical.

- **Additional Information**:
  - This section includes any incident-specific data that doesn't fit into the core fields. For example, lane closure information for work zones, reliability scores for Waze incidents, or weather-related conditions like precipitation and visibility. These fields ensure flexibility in handling a wide range of data while keeping the structure consistent.

The **incidents** component (Table 7-6 through Table 7-16) is designed to handle multiple incident types with a unified structure, ensuring that all relevant information is captured in a consistent and standardized format.

Table 7-6. Incidents schema.

Field	Type	Description	Required
id	string	Unique identifier for the incident.	Yes
class_info	object	Classification of the incident, including class and subclass.	Yes
time_info	object	Start time, end time, and duration of the incident.	Yes
location	object	Location information, including city, county, and geospatial data.	Yes
incident_details	object	Event, impact, and severity details about the incident.	Yes
source_info	object	Information about the source of the incident.	Yes
verification_info	object	Verification status of the incident.	No
additional_info	array	Array of additional information objects.	No

Table 7-7. Class_info object schema.

Field	Type	Description	Required
class_id	string	Unique identifier for the class or subclass	Yes
incident_class	string	Broad class of the incident (e.g., workzone)	Yes
subclass	string	More specific classification (e.g., lane_closure)	No

Table 7-8. Time_info object schema.

Field	Type	Description	Required
start_time	string	Start time of the incident in ISO format	Yes
end_time	string	End time of the incident in ISO format	No
estimated_duration	string	Estimated duration of the incident	No

Table 7-9. Location object schema.

Tab	Type	Description	Required
city	string	City where the incident occurred	Yes
county	string	County where the incident occurred	Yes
state	string	State where the incident occurred	No
country	string	Country where the incident occurred	No
street	string	Street where the incident occurred	No
direction	string	Direction of the incident	Yes
impacted_roadways	array of string	Affected road names in the incident	No

Table 7-10. Geospatial_info object schema.

Field	Type	Description	Required
geometry_type	string	Geometry type (e.g., Point, LineString, MultiLineString)	Yes
geometry	array of arrays (2 numbers)	Coordinates representing the incident location	Yes

Table 7-11. Incident_details object schema.

Field	Type	Description	Required
event	object	Event details (see table below)	Yes
impact	object	Impact details (see table below)	Yes
severity	object	Severity details (see table below)	Yes

Table 7-12. Event object schema.

Field	Type	Description	Required
code	string	Event code	Yes
type.main	string	Main event type	Yes
type.sub	string	Sub-event type	No
value	string	Event description	Yes
notes	string	Optional notes about the event	No

Table 7-13. Impact object schema.

Field	Type	Description	Required
code	string	Impact code	Yes
type.main	string	Main impact type	Yes
value	string	Impact description	Yes
notes	string	Optional notes about the impact	No

Table 7-14. Severity object schema.

Field	Type	Description	Required
code	string	Severity code	Yes
type.main	string	Main severity type	Yes
value	string	Severity description	Yes
notes	string	Optional notes about severity	No

Table 7-15. Additional Info schema.

Field Name	Type	Description	Required
code	string	A code that uniquely identifies the additional info item.	No
name	string	The name of the additional info item (e.g., "temperature", "restroom").	Yes
value	varied	The value associated with the additional info item (e.g., 75°F, "Y").	Yes
unit	string	The unit of measurement (e.g., "°F", "km/h", "percent").	No
notes	string	Optional notes providing extra context or details for the info item.	No

Table 7-16. Verification_info schema.

Field Name	Type	Description	Required
is_time_verified	boolean	Indicates if the event time (start and end) is verified.	No
is_position_verified	boolean	Indicates if the event location (coordinates) is verified.	No
is_event_verified	boolean	Indicates if the event details (type, description) are verified.	No
verification_source	string	Source of verification, specifying how or from where the data was confirmed.	No

7.2.4 Metadata

The **metadata** component provides a high-level summary of the incident data, offering insights into the total number of incidents and their breakdown by type. This is useful for quickly assessing the scope of incidents affecting CMV operations at any given time.

- **Total Incidents**: This field counts the total number of incidents across all types, providing a snapshot of the data available for querying.
- **Categorization by Incident Type**: The schema categorizes incidents by type (e.g., total work zones, total Waze incidents), allowing users to understand the distribution of different incident types in the dataset.
- **Pagination Information**: If the dataset is large, pagination details are included to help manage and navigate through the data efficiently, ensuring that users can load data incrementally.
- **Route Information:** This field contains the requested sources and destinations as coordinate pairs of longitudes and latitudes, and the generated

The **metadata** component (Table 7-17, Table 7-18, and Table 7-19) offers valuable insights into the overall state of CMV incidents, allowing users to quickly gauge how many incidents are active and which types are most prevalent.

Table 7-17. Metadata schema.

Field	Type	Description	Required
request_id	string	Unique identifier for the request	Yes
status	string	Response status (e.g., success, failure)	Yes
summary	object	Summary data for the incidents	Yes
routes	object	Summary data for requested routes, and generated route paths coordinates	No

Table 7-18. Summary object schema.

Field	Type	Description	Required
total_incidents	integer	Total number of incidents	Yes
total_workzones	integer	Total number of work zone incidents	Yes
total_waze_jams	integer	Total number of Waze jams	Yes
total_waze_incidents	integer	Total number of Waze incidents	Yes
total_transcore_incidents	integer	Total number of TransCore incidents	Yes
total_weather	integer	Total number of weather-related incidents	Yes

Table 7-19. Routes object schema.

Field	Type	Description	Required
route_id	string	Unique identifier for the route	Yes
coordinates	array of Point	The requested coordinates (can be multiple points)	Yes
drive_coordinates	array of LineString	The full route path generated by the server	Yes
routes	array	List of route objects (defaults to an empty array if no routes)	Yes

7.3 Methodology for Data Harmonization

The data harmonization process for the unified schema focuses on converting and standardizing information from different data sources (such as work zones, Waze incidents, jams, TransCore incidents, and weather data) into a common, consistent format. This allows developers and users to access data from various sources in a uniform structure, improving ease of use and real-time communication.

The harmonization process involves three main steps:

1. **Mapping Existing APIs to the Unified Schema**: Converting fields from each data source (e.g., weather, work zones) to the unified schema structure.
2. **Standardization of Incident Classifications**: Ensuring consistent classification of event types, impacts, and severity across all incident types.
3. **Handling Optional and Additional Data**: Managing optional or unique fields by placing them in dedicated sections like additional_info while ensuring they do not disrupt the core structure.

Table 7-20 through Table 7-24 show how fields from each data source are mapped to the unified schema.

Table 7-20. Work Zone API field mapping.

Original Field	Mapped Unified Field	Description
start_date	time_info.start_time	Start time of the work zone.
end_date	time_info.end_time	End time of the work zone.
road_names	location_info.road	Affected road(s).
coordinates	location_info.geometry	Geospatial location of the work zone.
vehicle_impact	incident_details.impact.type	Impact of the work zone on traffic.
description	incident_details.event_description	Description of the work zone activity.

Table 7-21. Waze jams API field mapping.

Original Field	Mapped Unified Field	Description
start_lat	location_info.latitude	Latitude of the start point.
start_long	location_info.longitude	Longitude of the start point.
end_lat	location_info.geometry	Endpoint coordinates (as a LineString).
speed	incident_details.impact.severity	Severity of the traffic jam.
length	additional_info.length	Length of the traffic jam in meters.
delay	incident_details.delay	Traffic delay caused by the jam.

Table 7-22. Waze incidents API field mapping.

Original Field	Mapped Unified Field	Description
type	incident_details.event_type	Type of incident (e.g., road closed).
latitude	location_info.latitude	Latitude of the incident.
longitude	location_info.longitude	Longitude of the incident.
road_type	additional_info.road_type	Type of road affected by the incident.
confidence	incident_details.reliability	Reliability score of the report.
subtype	incident_details.event_subtype	Subtype of the incident.

Table 7-23.TransCore Incidents API field mapping.

Original Field	Mapped Unified Field	Description
event_type	incident_details.event_type	Type of scheduled event (e.g., lane closure).
latitude	location_info.latitude	Latitude of the incident.
longitude	location_info.longitude	Longitude of the incident.
lane_closed_list	incident_details.impact.type	Information on lanes closed.
event_status	incident_details.status	Status of the event (e.g., active).

Table 7-24. Weather API field mapping.

Original Field	Mapped Unified Field	Description
temperature	additional_info.temperature	Temperature at the location.
windSpeed	additional_info.wind_speed	Wind speed at the location.
visibility	incident_details.visibility	Visibility at the location.
precipitationProbability	additional_info.precipitation_probability	Probability of rain or snow.
latitude	location_info.latitude	Latitude of the weather event.
longitude	location_info.longitude	Longitude of the weather event.

This simplified mapping approach (Table 7-25) converts diverse fields from multiple APIs into a common structure, ensuring consistency across different incident types while preserving the unique attributes of each data source.

Table 7-25. Unified schema description and requirements.

Field	Type	Description	Required
schema_info	object	Metadata about the schema (name, version, release date, mode).	Yes
data_sources	array	Array of data sources with publisher, version, and update details.	Yes
incidents	array	Array of incident data, including class, time, location, and details.	Yes
routes	array	Array of route objects with coordinates and drive route information.	Yes
metadata	object	Summary of the request, including request ID, status, and incident counts.	Yes

8. Design and Architecture of the Unified API System

The Unified API System for CMV communication integrates data from multiple sources, such as work zones, weather, Waze traffic jams, Waze incidents, TransCore incidents, and parking information. The goal is to provide CMV operators with real-time, reliable data in a single, cohesive platform, allowing for improved decision-making, safety, and efficiency on the road.

This section outlines the design principles, architecture, and key components of the Unified API System, focusing on the technologies and methodologies used to create a seamless integration of these diverse data sources.

8.1 Design Principles

- Modularity: Each API is treated as a modular component that can be added or removed without disrupting the overall system. This allows for flexibility in incorporating new data sources and functionalities.
- Scalability: The system is designed to scale with increased data traffic as more CMVs or data sources are integrated.
- Real-Time Data Handling: The system processes data in real-time, ensuring that CMV operators receive the latest updates on road conditions, traffic jams, incidents, weather, and parking availability.
- Interoperability: The system supports multiple data formats (e.g., GeoJSON, JSON) and ensures that data from different sources can be combined and used seamlessly.
- Security: Secure communication protocols are employed to protect the data and maintain privacy across different API services.

8.2 Architecture Overview

The Unified API System follows a microservices-based architecture (Figure 8-1), which enables independent management of each data source while providing a centralized platform for data retrieval and processing.

8.3 Key Components

8.3.1 API Gateway

- The API Gateway serves as the entry point for all external requests. It routes incoming queries to the appropriate service (e.g., work zone, weather, parking) based on the user's request.
- It also handles user authentication, rate limiting, and load balancing, ensuring that the system can handle multiple simultaneous requests efficiently.

8.3.2 Data Integration Layer

- This layer is responsible for fetching, transforming, and normalizing data from the various APIs.
- Each API (work zones, weather, Waze jams/incidents, TransCore incidents, parking) is treated as a microservice, which can be independently queried and maintained.
- The data integration layer ensures that all responses are returned in a unified format, making it easier for end-users to consume the data.

8.3.3 Database/Cache Layer

- A caching mechanism (i.e., Redis cache) is implemented to store frequently accessed data, reducing latency, and improving system performance.
- A central database stores historical data and logs for audit and analysis, allowing operators to track patterns and improve future operations.

8.3.4 Service Query Engine

- The service query engine allows users to create custom queries that pull information from multiple sources in real-time.
- For instance, CMV operators can query for incidents, work zones, and parking availability along a specific route, receiving all relevant information in one request.

8.3.5 Security and Authentication Layer

- The security layer ensures that only authenticated users can access the Unified API System. OAuth 2.0 or JWT (JSON Web Tokens) can be employed for user authentication and authorization.
- This layer also includes security protocols like HTTPS for secure communication and encryption of sensitive data.

8.3.6 Monitoring and Logging

- The system includes a monitoring service that tracks the health of each microservice, monitoring uptime, response times, and any potential errors.
- Logs are collected for each API request and response, which are then stored for auditing and performance optimization.

8.4 Technologies Used

- FastAPI/Flask: Used for building the individual API endpoints, these frameworks provide a fast, asynchronous API development environment, ideal for real-time applications.
- Microservices Architecture: Each data source is developed as a microservice, ensuring flexibility and scalability.

- Redis: For caching frequently accessed data to reduce API response times.
- Docker: For containerizing each microservice, ensuring consistent deployment across different environments.
- Kubernetes: Used for orchestrating and managing microservices, ensuring that they are deployed, scaled, and managed efficiently.
- OAuth2.0/JWT: For user authentication and secure access control to the API system.

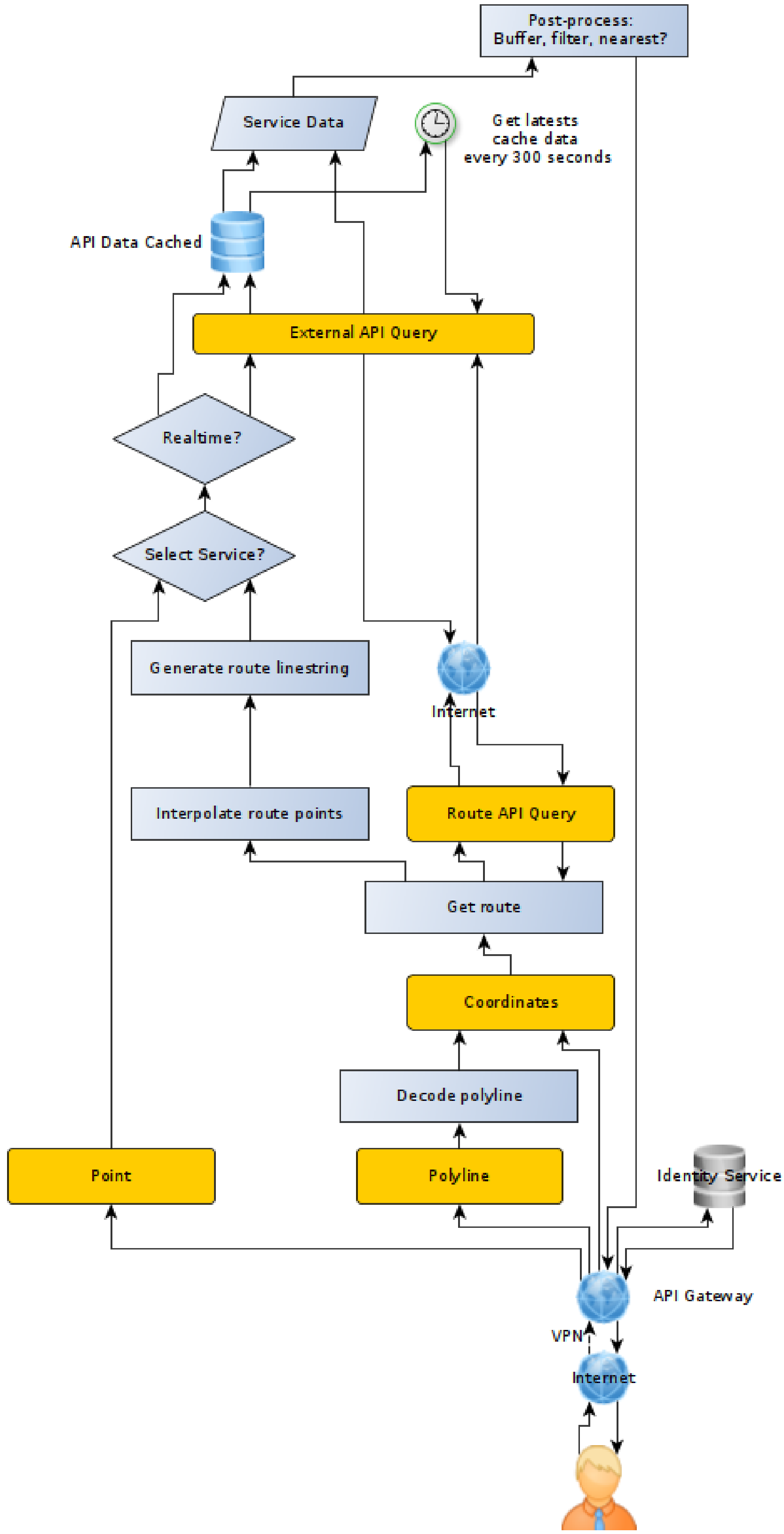

Figure 8-1. Unified API system architecture.

8.5 Key Functionalities of the Unified API

The Unified API System offers a robust set of functionalities designed to streamline communication between various data sources and provide real-time, actionable information to CMV operators. These functionalities are centered around route planning, data retrieval from different services, and detailed reporting of incidents and conditions affecting CMV routes. Table 8-1 shows the key functionalities of the system.

Table 8-1. Key functionalities and API endpoints.

Objective	METHOD Endpoint(s)	Function	Description
Route Generation and Coordinates	POST /route	The system allows users to generate a route between two or more geographic points. This functionality is essential for CMV operators who need to plan trips or reroute based on changing conditions.	This API takes in coordinates and calculates the best route, considering real-time data from all integrated APIs (e.g., work zones, jams, incidents, parking, weather). The generated route can be further interpolated to provide more granular insights into activities or incidents along the way.
Raw API Data Access	GET /raw_api/{raw_api} options: workzone, weather, waze_jams, waze_incidents, transcore_incidents, parking_info, bridge_info	Provides users with access to the raw data from each of the individual APIs (e.g., work zones, weather, Waze incidents)	This endpoint is designed for users who may want to see the unfiltered, unprocessed data from a particular service. This raw data can be useful for auditing, analysis, or integration into custom applications.
Service-Specific Incident and	GET /service/{service}/	Returns filtered or impacted incidents	Users can query for specific services

Objective	METHOD Endpoint(s)	Function	Description
Condition Reporting	point/{longitude},{latitude} GET /service/{service}/coordinates/{coordinates} GET /service/{service}/polyline/{polyline}	or activities related to a specific service (e.g., work zones, weather, traffic jams) along a route between two or more points.	such as work zones, Waze jams, or parking to get real-time data affecting their route. This API is especially useful when CMV operators are interested in focusing on a particular service or condition. The system interpolates route data to offer more detailed reports on incidents, providing fine-grain insights about how certain conditions (like weather or incidents) may impact the route.
Comprehensive Route Reporting	GET /services/point/{longitude},{latitude} GET /services/coordinates/{coordinates} GET /services/polyline/{polyline}	This functionality retrieves combined data from all integrated services (work zones, jams, incidents, weather, parking, etc.) for a given route.	Instead of querying individual services, this endpoint aggregates data from all APIs and returns comprehensive route information. This includes all relevant incidents, weather conditions, parking availability, and more, along a specified route or location. The system further interpolates the route, offering a

Objective	METHOD Endpoint(s)	Function	Description
			detailed breakdown of conditions and potential impacts, ensuring that CMV operators have all the information they need in one response.

8.6 Other functionalities of the Unified API

8.6.1 Real-Time and Fine-Grain Reporting

- Functionality: The Unified API System supports real-time data updates for all services, ensuring that CMV operators are always aware of the most current conditions.
- Description: As CMVs travel along their route, the system continuously updates the conditions, including work zones, incidents, and jams, that may affect their journey. The interpolation feature allows for the system to generate fine-grain reports, breaking down the route into smaller segments and providing highly detailed insights for each section.

8.6.2 Flexible Data Querying for Route Optimization

- Functionality: Users can query the Unified API System using points, coordinates, or polylines (a series of connected geographic points).
- Description: This flexibility allows users to optimize routes in a variety of ways. Whether it's for long-distance routes or specific segments of a journey, the system provides dynamic querying options that fit different use cases. CMV operators can adapt routes in response to real-time changes in conditions like traffic, weather, or parking availability.

8.6.3 Customizable API Responses

- Functionality: Users can retrieve data from specific services or request a comprehensive response that includes all relevant information for a particular route or point.
- Description: The system allows CMV operators and developers to tailor responses according to their needs. For example, if a user is only interested in weather data, they can query the weather service specifically. Alternatively, if they need an all-encompassing report, they can retrieve data for all available services, ensuring comprehensive decision support.

8.6.4 Interoperability and Scalability

- Functionality: The Unified API System is designed to be interoperable with other platforms and scalable as more services and users are added.
- Description: This system can grow with future needs, adding more services or supporting more users without compromising performance. It is designed to work seamlessly with external platforms and devices, making it easy to integrate into existing CMV fleet management systems.

The Unified API System provides a powerful, real-time data platform that helps CMV operators optimize their routes and manage their journeys more efficiently. Its ability to combine multiple data sources, provide real-time updates, and offer detailed reports for specific services or entire routes makes it a comprehensive solution for modern CMV operations. The flexibility in querying and customizable data output ensures that the system can adapt to the specific needs of operators, improving both safety and operational efficiency. Figure 8-2, Figure 8-3, and Figure 8-4 show snapshots of the unified schema used to integrate all the different data sources for communicating with CMVs.

```
"class_info": {
    "type": "object",
    "properties": {
        "class_id": {
            "type": "string"
        },
        "incident_class": {
            "type": "string"
        },
        "subclass": {
            "type": "string"
        }
    },
    "required": [
        "class_id",
        "incident_class"
    ]
},
"time_info": {
    "type": "object",
    "properties": {
        "start_time": {
            "type": "string",
            "format": "date-time"
        },
        "end_time": {
            "type": "string",
            "format": "date-time"
        },
        "estimated_duration": {
            "type": "string"
        }
    },
    "required": [
        "start_time"
    ]
},
```

```
"administrative_info": {
    "type": "object",
    "properties": {
        "city": {
            "type": "string"
        },
        "county": {
            "type": "string"
        },
        "state": {
            "type": "string"
        },
        "country": {
            "type": "string"
        },
        "street": {
            "type": "string"
        },
        "direction": {
            "type": "string"
        },
        "impacted_roadways": {
            "type": "array",
            "items": {
                "type": "string"
            }
        }
    },
    "required": [
        "city",
        "county",
        "direction"
    ]
},
```

```
"geospatial_info": {
    "type": "object",
    "properties": {
        "geometry_type": {
            "type": "string"
        },
        "geometry": {
            "type": "array",
            "items": {
                "type": "array",
                "items": {
                    "type": "number"
                },
                "minItems": 2,
                "maxItems": 2
            }
        }
    },
    "required": [
        "geometry_type",
        "geometry"
    ]
}
```

Figure 8-2. Incident type, time, and location details schema.

Figure 8-3. Event source, verification, impact, and severity schema.

Figure 8-4. Schema for metadata and additional information.

8.7 Web Interface for API Integration and Data Push to CMVs

As part of our API development for CMV communication, the research team has developed a web interface (Figure 8-5) that demonstrates the API's functionality and how it interfaces with users. This interface serves as a critical tool for users to interact with the API and retrieve real-time data relevant to CMV operations.

The web interface allows users to request data in two ways:

1. **Start and End Destinations Waypoints**: Users can input start and end points, and the system will generate a detailed overview of incidents along the route. This includes work zones, traffic jams, accidents, weather hazards, and parking availability, ensuring CMV operators are informed of potential risks before and during their journey.
2. **Route Submission**: Users also have the option to submit predefined routes, for which the system will pull relevant data regarding all incidents along the route. This ensures that even complex or customized routes receive comprehensive, real-time updates, enabling CMV drivers to plan accordingly.

The interface is designed to streamline the process of querying and retrieving data. It uses API endpoints to request the necessary information and pushes the data directly to CMV systems. By leveraging this web-based platform, users can quickly gain access to critical road information without the need for manual data gathering from multiple sources.

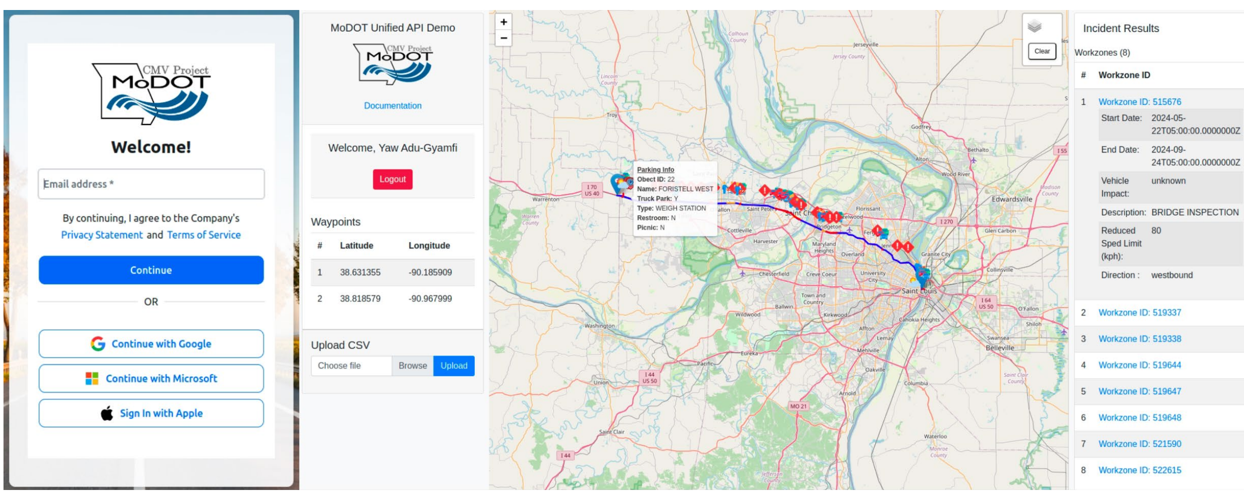

Figure 8-5. Web interface for demonstrating unified API data exchange with CMVs.

This integration ensures seamless communication between the API and CMVs, allowing operators to make informed, real-time decisions based on up-to-date incident reports, thereby improving safety and operational efficiency. The platform is scalable, allowing for future enhancements as new data sources and additional functionality are incorporated into the API.

9. Conclusions

This chapter presents the overall conclusions of the research, organized by topic.

9.1 Literature Review

The literature review encompassed various technologies that can be used to communicate information to CMV drivers, such as ATMS, 511 travel information systems, CB radio, CVISN, and VMS. These technologies have a wide range of applications for communication with CMV drivers.

- ATMS help to monitor and manage traffic flow and provide real-time information to motorists, including truck drivers. ATMS employ sensors, cameras, and other data collection methods to gather information on traffic conditions and relay it to central control centers, and the information is then disseminated to motorists. ATMS have become more widely used in urban areas.
- 511 systems provide various types of real-time information, such as road conditions, construction, and incidents. 511 systems offer the convenience of multiple platforms (e.g., phone, app, websites) and can help truck drivers make informed decisions about their routes and travel plans.
- CB radios have a long history of use as an integral communication tool in the trucking industry. CB radios allow drivers to exchange real-time information regarding road conditions, traffic, and other pertinent areas. They have a limited range (typically a few miles).
- CVISN provide a platform for truck communication, offering safety inspection updates and regulatory information.
- Strategically placed along highways and major roadways, VMS provide truck drivers with critical information, such as lane closures, detours, and travel times. VMS are particularly useful for truck drivers, as they can alert them to restrictions on CMVs or available truck parking at rest areas.

9.2 DOT Survey

- The types of information currently communicated to CMV drivers by the highest number of the DOTs that responded to the survey are extreme weather events, traffic incidents, and work zone lane closures. Only one responding DOT communicates information regarding steep grades or truck emergency escape ramps electronically, while no responding DOTs communicate information regarding tire checkup areas.
- Regarding future plans for types of information to communicate electronically to CMVs, the highest number of responding DOTs are working on communicating information electronically regarding availability of truck parking and traffic incidents in the future. One responding DOT is working on communicating information regarding truck emergency escape ramps, truck restricted routes, or truck restricted routes in the

future, while no responding DOTs are working on communicating information regarding tire checkup areas.

- The methods used by the highest number of responding DOTs to communicate information to CMVs are DMS, 511 travel information systems, and CMS, while none of the responding DOTs use fleet management systems, CB radio, satellite radio, or VHF/UHF radio.
- For future methods to communicate information electronically to CMVs in the future, the highest number of responding DOTs are planning to use in-cab alerts, connected vehicle technologies, and smartphone applications.
- Responding DOTs perceive audible or visual alarms and in-cab alerts as the most effective methods for communicating information to CMV drivers and real-time HAR as the least effective method.
- The data sources used by the highest number of responding DOTs to gather information for CMV drivers are traffic sensors, law enforcement and first responders or emergency services, feeds from data providers, and video cameras, while the data sources used by the lowest number of responding DOTs are trucking companies and RFID.
- The perceived challenges to communicating information to CMV drivers noted by the highest number of responding DOTs are the need for data standardization, data availability, and funding constraints.
- Partnerships with law enforcement, technology vendors/app developers, and industry associations or trucking associations are pursued by the highest number of responding DOTs, while partnerships with MPOs and FMCSA are pursued by the lowest number of responding DOTs.
- All 18 responding DOTs indicated that they have not developed any data standards or policies for communicating information electronically to CMV drivers.
- Other concerns noted in survey comments include the need for planning to ensure that information is not over communicated and data security.

9.3 Stakeholder Workshop

- A matrix of various facets (e.g., what is available, what is important and urgent, challenges) of types of information and technology used to convey that information to CMV drivers was developed based on the discussion at the workshop.
- Several state DOTs, such as New York, New Jersey, Georgia, and North Carolina, have tried in-cab messaging. In addition, some states allow drivers to subscribe to alerts.
- Examples of information that could be helpful to CMV drivers include presence of active work zones (especially mobile work zones and worker presence), truck parking (number of miles ahead and number of spaces available), end of queue alerts, sudden slowdown alerts, weather (e.g., extreme weather), low bridges, sharp curves, truck emergency escape ramps, brake check areas, and chain stations.
- Information provided needs to be accurate and provide true value to the driver while being conveyed in a useful format that does not overwhelm or distract the driver.
- Information provided to drivers can be both short-term or long-term.

- Information regarding the availability of parking at rest areas could help truckers plan. Static information regarding availability of amenities at rest areas would also be beneficial. Information on private truck parking (e.g., truck stops) is harder to obtain. MoDOT recently completed a research study on prioritizing truck parking investments.
- Some of the challenges to efforts to communicate information to CMVs include disseminating information to drivers in different languages, differences between large and small carriers (e.g., response to winter events, technology capabilities, in-cab equipment), and ensuring consistency between states.

9.4 Development of Unified API

- To address the challenge of diverse data streams for CMV drivers, a unified API was developed to consolidate all relevant data into a single, cohesive platform, providing CMVs with seamless access to critical information. By aggregating data from multiple sources into a standardized, consistent format, the unified API ensures that CMVs and their operators can make well-informed, timely decisions without the risk of delays or data conflicts.
- The unified API for CMV communication was designed with clear objectives to improve the efficiency and reliability of incident reporting and data exchange. These objectives emphasize the seamless integration of multiple data sources, real-time communication capabilities, and the establishment of a standardized data format.
- The unified API implements a standardized data format that applies uniformly across various incident types, such as work zones, Waze jams, incidents, weather reports, and parking data. The unified API incorporates the following datasets:
    - **Workzone API**: Delivers real-time updates on active work zones, including location, duration, and potential delays.
    - **Weather API**: Provides up-to-date weather information, highlighting conditions that could impact driving safety, such as rain, snow, or fog.
    - **Waze Jam Data API**: Offers real-time user-reported data on traffic congestion, indicating delays and slowdowns.
    - **Waze Incident Data API**: Reports accidents, hazards, and other incidents, allowing CMV operators to make better routing decisions.
    - **TMS Incident Data API**: Supplements user-reported incidents with verified data from traffic management systems.
    - **Parking Information API**: Provides information on available parking for CMVs, which is vital for long-haul drivers adhering to regulated driving hours.
    - **Weight Restriction Data API**: Supplies information on weight limits for roads and bridges, ensuring that CMVs avoid routes where their load exceeds legal or safe limits.
    - **Vertical Clearance Data API**: Provides data on bridge and overpass heights, helping CMVs avoid routes where vehicle height exceeds the clearance limits.
- The unified API was designed with flexibility in mind, allowing users to efficiently query and filter incident data based on various criteria, such as location, time, and severity. In

addition to general filtering mechanisms, the schema supports route-based querying, which allows users to retrieve incidents that occur along a specific path.

- The following design principles were incorporated into API:
    - Modularity: Each API is treated as a modular component that can be added or removed without disrupting the overall system. This allows for flexibility in incorporating new data sources and functionalities.
    - Scalability: The system is designed to scale with increased data traffic as more CMVs or data sources are integrated.
    - Real-Time Data Handling: The system processes data in real-time, ensuring that CMV operators receive the latest updates on road conditions, traffic jams, incidents, weather, and parking availability.
    - Interoperability: The system supports multiple data formats (e.g., GeoJSON, JSON) and ensures that data from different sources can be combined and used seamlessly.
    - Security: Secure communication protocols are employed to protect the data and maintain privacy across different API services.
- As part of the API development for CMV communication, a web interface was developed to demonstrate the API's functionality and how it interfaces with users. The web interface allows users to request data through start and end destinations waypoints or by submitting a predefined route.

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Appendix A: DOT Survey

Missouri Department of Transportation

Project Title

DOT Survey

Letter to the Respondent

Dear Participant,

The Missouri Department of Transportation is sponsoring a research study titled "Effective Methods to Safely Communicate with Commercial Motor Vehicles (CMVs)." The research is being performed by the University of Missouri and CBB Transportation Engineers + Planners. This project will achieve the following objectives:

1. Conduct a review of existing Electronic Notification System (ENS) methods in use by CMV drivers, trucking companies, and freight industry.
2. Conduct a survey of selected state DOTs regarding their current practice in ENS for communicating with CMV drivers.
3. Conduct a needs assessment brainstorming workshop with MoDOT and other stakeholders, and
4. Develop standards and specifications for data feeds consisting of traveler information critical for CMV operators.

Your cooperation in completing this survey will help to ensure the success of this research project. This survey is being sent to one person from several state DOTs. You have been identified as the appropriate person at your agency to complete this survey. The survey link that you received for completing the survey is unique for your agency. If it would be more appropriate for someone else at your agency to take this survey, please forward the email with the survey link to them or send their name and email address to Henry Brown (brownhen@missouri.edu). You may also collaborate with colleagues at your agency to complete the survey by sharing the survey link with them. However, the survey may only be open on one computer at a time, and partial responses are saved upon closing the browser window.

DOT survey responses will be shown in the published research report. However, the identity of survey respondents will remain anonymous. Additional instructions are provided at the beginning of the survey. If you would like to download a PDF version of the survey for informational purposes, please click here.

Please complete this survey by February 16, 2024. The survey includes 10 questions, and we estimate that the survey will take approximately 5 to 20 minutes to complete. If you have any questions, please contact Henry Brown at (573) 882-0832 or brownhen@missouri.edu. Any supporting materials may be sent by email to Henry or uploaded in lieu of providing URLs. Thank you for participating in this survey!

Survey Instructions

1. To begin the survey, click the forward arrow at the bottom of this page.
2. To view and print the entire survey for informational purposes, click on this survey link and download and print the document.
3. To save your partial answers and complete the survey later, close the survey. Answers are automatically saved upon closing the browser window. To return to the survey later, open the original email from Henry Brown and click on the survey link.
4. To pass a partially completed survey to a colleague, close the survey and forward the original email from Henry Brown to a colleague. Note that only one person may work on the survey at a time; the survey response should only be active on one computer at a time.
5. To view and print your answers after completing the survey, submit the survey by clicking "Submit" on the final page. Download and print the PDF on the following page which contains a summary of your responses.
6. To submit the survey, click on "Submit" on the last page.

Survey Tips

1. Survey navigation is conducted by selecting the forward and back arrows at the bottom of each page.
2. If you are unable to complete the survey in a single session, you can return to the survey at any time by reentering through the survey link.

Questions

Contact Information

Name ____________________
State ____________________
Job Title ____________________
Phone Number ______________________

Email Address ______________________

1. Which of the following types of information does your agency communicate to CMV drivers **electronically**? Please select all that apply.

   ☐ Availability of truck parking
   ☐ End of queue alerts
   ☐ Extreme weather events
   ☐ Complete highway or bridge closure
   ☐ Low bridge clearance
   ☐ Rest area information
   ☐ Sharp curves
   ☐ Steep grades
   ☐ Tire checkup areas
   ☐ Traffic incidents
   ☐ Truck emergency escape ramps
   ☐ Truck restricted lanes
   ☐ Truck restricted routes
   ☐ Variable speed limits
   ☐ Weigh station information
   ☐ Work zone lane closures
   ☐ Worker presence in work zones
   ☐ Other (please describe) ____________
   ☐ None of the above

Comments:

____

2. Which of the following types of information is your agency working on communicating to CMV drivers **electronically** in the future? Please select all that apply.

   ☐ Availability of truck parking
   ☐ End of queue alerts
   ☐ Extreme weather events
   ☐ Long-term highway or bridge closure
   ☐ Low bridge clearance
   ☐ Rest area information
   ☐ Sharp curves

☐ Steep grades
☐ Tire checkup areas
☐ Traffic incidents
☐ Truck emergency escape ramps
☐ Truck restricted lanes
☐ Truck restricted routes
☐ Variable speed limits
☐ Weigh station information
☐ Work zone lane closures
☐ Worker presence in work zones
☐ Other (please describe) _____________
☐ None of the above

Comments:

____

3. Which of the following methods does your agency <u>currently</u> use to communicate information to CMV drivers? Please select all that apply.

☐ 511 traffic information systems (accessed through phone number, online, and/or smartphone app)
☐ Audible or visual alarms
☐ Customer service centers
☐ Data providers
☐ In-cab alerts
☐ Fleet management systems
☐ CB radio
☐ Satellite radio
☐ VHF/UHF radio
☐ Commercial radio
☐ Changeable message signs (CMS) (portable trailers used for posting messages)
☐ Dynamic message signs (DMS) (permanent signs used for posting messages)
☐ Flyers
☐ Print or broadcast media
☐ Real-time Highway Advisory Radio (HAR)
☐ Remotely activated traffic control devices
☐ Smartphone applications
☐ Traveler information maps

☐ Connected vehicle technologies
☐ Social media
☐ Email lists
☐ Static signs with dynamic features
☐ Text messages
☐ Websites
☐ Other (please describe) _____________
☐ None of the above

Comments:

____

4. Which of the following methods is your agency planning to use in the future to communicate information to CMV drivers? Please select all that apply.

☐ 511 traffic information systems (accessed through phone number, online, and/or smartphone app)
☐ Audible or visual alarms
☐ Customer service centers
☐ Data providers
☐ In-cab alerts
☐ Fleet management systems
☐ CB radio
☐ Satellite radio
☐ VHF/UHF radio
☐ Commercial radio
☐ Changeable message signs (CMS) (portable trailers used for posting messages)
☐ Dynamic message signs (DMS) (permanent signs used for posting messages)
☐ Flyers
☐ Print or broadcast media
☐ Real-time Highway Advisory Radio (HAR)
☐ Remotely activated traffic control devices
☐ Smartphone applications
☐ Traveler information maps
☐ Connected vehicle technologies
☐ Social media
☐ Email lists
☐ Static signs with dynamic features

- ☐ Text messages
- ☐ Websites
- ☐ Other (please describe) ____________
- ☐ None of the above

Comments:

____

5. On a scale of 1 to 5 (1 = Highly Ineffective, 5 = Highly Effective), how would you rate the effectiveness of each of the following methods currently used by your agency to communicate information to CMV drivers? *(Only display answer choices currently used by agency based on response to Question 3 – carry forward answer responses from Question 3 that are selected. Do not display question if they answered "None of the above" in Question 3.)*

Method	**Effectiveness**
511 traffic information systems (accessed through phone number, online, and/or smartphone app)	
Audible or visual alarms	
Customer service centers	
Data providers	
In-cab alerts	
Fleet management systems	
CB radio	
Satellite radio	
VHF/UHF radio	
Commercial radio	
Changeable message signs (CMS) (portable trailers used for posting messages)	
Dynamic message signs (DMS) (permanent signs used for posting messages)	
Flyers	

Method	Effectiveness
Print or broadcast media	
Real-time Highway Advisory Radio (HAR)	
Remotely activated traffic control devices	
Smartphone applications	
Traveler information maps	
Connected vehicle technologies	
Social media	
Email lists	
Static signs with dynamic features	
Text messages	
Websites	
Other	

Comments:

____

6. Which of the following data sources does your agency use to obtain information to share with CMV drivers? Please select all that apply.

- ☐ Crowdsourcing data
- ☐ Environmental sensors
- ☐ Feeds from data providers
- ☐ Internal data sources at my agency
- ☐ Law enforcement and first responders or emergency services
- ☐ Probe vehicles
- ☐ Radio Frequency Identification (RFID)
- ☐ Social media
- ☐ Traffic sensors
- ☐ Transportation Data Exchange (TDx) feeds
- ☐ Truck Parking Information Management System (TPIMS)
- ☐ Trucking companies

- ☐ Video cameras
- ☐ Work Zone Activity Data (WZAD)
- ☐ Work Zone Data Exchange (WZDx) Feeds
- ☐ Other (please describe) _____________
- ☐ None of the above

Comments:

____

7. Which of the following factors is a challenge to your agency's efforts to communicate information with CMV drivers? Please select all that apply.

- ☐ Availability of agency staff
- ☐ Concerns about CMV driver being distracted with information
- ☐ Data availability
- ☐ Funding constraints
- ☐ Lack of available data standards
- ☐ Lack of buy-in from trucking companies
- ☐ Need for data standardization
- ☐ Need for information regarding effectiveness of methods used
- ☐ Obtaining accurate, reliable, and timely information
- ☐ Providing information in multiple languages
- ☐ Stakeholder coordination
- ☐ Technology issues
- ☐ Other (please describe) _____________
- ☐ None of the above

Comments:

____

8. Does your agency pursue partnerships with any of the following entities in your efforts to communicate information to CMV drivers? Please select all that apply.

- ☐ FHWA
- ☐ FMCSA
- ☐ Industry associations or trucking associations
- ☐ Law enforcement
- ☐ Local agencies

☐ MPOs
☐ Other state DOTs
☐ Technology vendors/app developers (please list) ____________
☐ Trucking companies
☐ Other (please describe) ____________
☐ None of the above

Comments:

____

9. Has your agency developed any data standards or policies for communicating information **electronically** to CMV drivers?

☐ Yes
☐ No

(Display question below if answer to above question = Yes.)

If you are willing to share these resources, please provide URL(s) for the relevant documents in the box below, upload files, or email files to brownhen@missouri.edu:

____

Comments:

____

10. Please provide any additional comments that you may have regarding communicating information to CMV drivers.

____
____
____
____
____

11. May we contact you if we have any follow-up questions?

☐ Yes
☐ No

12. Would like to receive a copy of the final report once it is published?

- ☐ Yes
- ☐ No

Submittal Instructions

To complete the survey and record your answers, please click the "Submit" button.

Please note that once you click the "Submit" button, you will not be able to modify your answers. To save your partial answers and complete the survey later, close the survey. Answers are automatically saved upon closing the browser window. To return to the survey later, open the original email from Henry Brown and click on the survey link. To pass a partially completed survey to a colleague, close the survey and forward the original email from Henry Brown to a colleague. Note that only one person may work on the survey at a time; the survey response should only be active on one computer at a time. To review your answers before submitting, please select the forward and back arrows at the bottom of each page.

End of Survey

Thank you for completing this survey. Your efforts are greatly appreciated. Your responses are very important, and your feedback is welcome. For your information, a copy of your responses is provided below. You may download your responses in pdf format using the "Download pdf" link shown below. If you have any questions or comments, please contact the principal investigator, Henry Brown:

Henry Brown, P.E.
E2509 Lafferre Hall
University of Missouri
Columbia, MO 65211
(573) 882-0832
brownhen@missouri.edu

Your responses have been recorded, and you may now close your browser.

Appendix B: Individual Responses for DOT Survey

Table B-1. Individual survey responses for Question 1 (types of information DOTs are currently communicating electronically to CMVs).

Respondent	Availability of truck parking	End of queue alerts	Extreme weather events	Complete highway or bridge closure	Low bridge clearance	Rest area information	Sharp curves	Steep grades	Tire checkup areas	Traffic incidents	Truck emergency escape ramps	Truck restricted lanes	Truck restricted routes	Variable speed limits	Weigh station information	Work zone lane closures	Worker presence in work zones	Other	None of the above
Arizona	-	X	X	X	X	-	-	-	-	X	-	X	X	X	X	X	X	-	-
Colorado	-	X	X	X	X	-	X	X	-	-	X	-	-	-	-	X	X	-	-
Delaware	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	X	-
Illinois	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Indiana	X	-	X	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-
Iowa	X	-	X	X	X	X	-	-	-	X	-	-	X	-	X	X	-	X	-
Kansas	X	X	X	X	X	X	-	-	-	X	-	-	-	-	-	X	-	-	-
Kentucky	X	-	-	-	-	X	-	-	-	X	-	-	-	-	X	X	-	-	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X

Respondent	Availability of truck parking	End of queue alerts	Extreme weather events	Complete highway or bridge closure	Low bridge clearance	Rest area information	Sharp curves	Steep grades	Tire checkup areas	Traffic incidents	Truck emergency escape ramps	Truck restricted lanes	Truck restricted routes	Variable speed limits	Weigh station information	Work zone lane closures	Worker presence in work zones	Other	None of the above
Massachusetts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Missouri	-	-	X	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-
Nevada	-	-	X	X	-	X	-	-	-	X	-	X	X	X	-	X	-	X	-
Ohio	-	X	-	-	X	-	X	-	-	-	-	-	-	X	-	X	-	-	-
Oregon	-	-	X	-	-	-	-	-	-	X	-	-	-	X	-	X	-	-	-
Pennsylvania	-	X	X	X	X	-	-	-	-	X	-	-	X	X	-	X	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
South Dakota	-	-	X	X	-	X	-	-	-	X	-	X	X	-	X	X	-	X	-
Wisconsin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Count	**4**	**5**	**10**	**8**	**7**	**7**	**3**	**1**	**0**	**10**	**1**	**3**	**5**	**5**	**4**	**10**	**2**	**4**	**4**

Table B-2. Other text responses for Question 1 (types of information DOTs are currently communicating electronically to CMVs).

Other - Text
Slowdowns, congestion, road closures if more than at least several hours
CV Permit Information; weight & dimension limits; detours; road conditions; travel advisories; weigh station bypass/pull-in instructions
Winter road conditions
DMS and mobile message signs

Table B-3. Comments for Question 1 (types of information DOTs are currently communicating electronically to CMVs).

Comment
We have signed an agreement for 1 year with Drivewyze/INRIX safety alert system in which they provide the information above through a CMV's ELD device.
We provide this through the 511 traveler information system.
By "communicate," it is available on various web-based programs/apps if the carrier is using them.
The above list is provided via DMS and ODOT's website TripCheck.com. Oregon DOT does not currently communicate anything via in-cab devices other than Weigh Station bypass or report messages associated with Weigh-In-Motion systems via Drivewyze.
We post information on our websites and those are electronic but we assumed you meant sent directly to the CMV users.
We are nearly completed in getting our work zone and queue warning project expanded. We currently are running safety warnings through our I-70 mountain corridor.
We have standard DMS Messaging and our 511 System but nothing specific to commercial vehicles.

Table B-4. Individual survey responses for Question 2 (types of information DOTs are working on communicating electronically to CMVs in the future).

Respondent	Availability of truck parking	End of queue alerts	Extreme weather events	Long-term highway or bridge closure	Low bridge clearance	Rest area information	Sharp curves	Steep grades	Tire checkup areas	Traffic incidents	Truck emergency escape ramps	Truck restricted lanes	Truck restricted routes	Variable speed limits	Weigh station information	Work zone lane closures	Worker presence in work zones	Other	None of the above
Arizona	X	X	X	X	X	-	-	-	-	X	-	X	X	-	X	X	-	-	-
Colorado	X	X	X	X	X	X	X	X	-	X	X	-	-	-	X	X	X	X	-
Delaware	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Illinois	X	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	X	-	-
Indiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kansas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kentucky	X	X	X	-	X	-	-	-	-	X	-	-	-	-	-	-	X	-	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Respondent	Availability of truck parking	End of queue alerts	Extreme weather events	Long-term highway or bridge closure	Low bridge clearance	Rest area information	Sharp curves	Steep grades	Tire checkup areas	Traffic incidents	Truck emergency escape ramps	Truck restricted lanes	Truck restricted routes	Variable speed limits	Weigh station information	Work zone lane closures	Worker presence in work zones	Other	None of the above
Missouri	X	-	X	X	-	X	-	-	-	X	-	-	-	-	-	X	X	-	-
Nevada	X	X	X	X	-	X	-	-	-	X	-	-	-	X	-	X	-	X	-
Ohio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Oregon	X	-	X	-	X	X	X	X	-	X	-	-	-	X	-	-	X	-	-
Pennsylvania	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
South Dakota	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-
Wisconsin	-	X	-	-	X	-	X	-	-	-	-	-	-	-	-	X	-	-	-
Count	**10**	**5**	**6**	**4**	**5**	**5**	**3**	**2**	**0**	**7**	**1**	**1**	**1**	**3**	**3**	**5**	**5**	**4**	**0**

Table B-5. Other text responses for Question 2 (types of information DOTs are working on communicating electronically to CMVs in the future).

Other - Text
Looking into applications solutions i.e. Drivewyze, Trihydro
In-cab turn by turn CV permit directions
HAAS alerts

Table B-6. Comments for Question 2 (types of information DOTs are working on communicating electronically to CMVs in the future).

Comment
Oregon DOT applied for an ATTAIN grant to work with Drivewyze and PrePass to provide the in-cab alerts checked above.
WisDOT engineering has an active WZDx feed, and we are willing to work with third party providers who can provide in-cab information.
I am in the early stages of working with our two class 1 railroads to do two-way comms at at-grade crossings to attempt to reduce truck/train incidents.
We have no specific plans yet, but we are investigating services specific to commercial vehicles that would include many of these items.
Nothing more in the works at this time, other than what is shown in the first category above. We are looking at integrating ProMiles turn-by-turn app being added to our automated OSOW system choices.

Table B-7. Individual survey responses for Question 3 (methods used by DOTs to communicate information electronically to CMVs) – Part 1 of 2.

Respondent	511 traffic information systems	Audible or visual alarms	Customer service centers	Data providers	In-cab alerts	Fleet management systems	CB radio	Satellite radio	VHF/UHF radio	Commercial radio	Changeable message signs (CMS)	Dynamic message signs (DMS)
Arizona	X	-	-	-	-	-	-	-	-	-	-	X
Colorado	X	X	X	X	X	-	-	-	-	-	X	X
Delaware	-	-	-	-	-	-	-	-	-	-	-	X
Illinois	X	-	X	-	-	-	-	-	-	-	-	X
Indiana	X	-	-	-	-	-	-	-	-	-	X	X
Iowa	X	-	-	X	-	-	-	-	-	-	X	X
Kansas	X	-	-	-	-	-	-	-	-	-	-	-
Kentucky	X	X	X	-	-	-	-	-	-	-	X	X
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	X	-	X	X	-	-	-	-	-	-	X	X
Missouri	-	X	X	X	X	-	-	-	-	-	X	X
Nevada	X	-	X	-	-	-	-	-	-	-	X	X
Ohio	X	-	-	-	X	-	-	-	-	-	X	X
Oregon	-	-	-	-	-	-	-	-	-	-	-	X
Pennsylvania	X	-	-	X	-	-	-	-	-	-	X	X
South Carolina	X	-	-	-	-	-	-	-	-	-	X	X
South Dakota	X	-	-	-	-	-	-	-	-	X	X	X
Wisconsin	X	-	-	-	-	-	-	-	-	-	X	X
Count	**14**	**3**	**6**	**5**	**3**	**0**	**0**	**0**	**0**	**1**	**12**	**16**

Table B-8. Individual survey responses for Question 3 (methods used by DOTs to communicate information electronically to CMVs) – Part 2 of 2.

Respondent	Flyers	Print or broadcast media	Real-time Highway Advisory	Remotely activated traffic	Smartphone applications	Traveler information maps	Connected vehicle technologies	Social media	Email lists	Static signs with dynamic	Text messages	Websites	Other	None of the above
Arizona	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Colorado	X	X	-	X	-	X	-	X	X	-	X	X	-	-
Delaware	-	-	X	-	-	X	-	-	-	X	-	X	-	-
Illinois	-	-	-	-	X	X	-	-	-	-	-	X	-	-
Indiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	X	X	-	X	-	-	X	X	-	-
Kansas	-	-	-	-	-	-	-	X	-	-	-	-	-	-
Kentucky	-	-	-	-	-	X	-	X	X	X	-	X	-	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	-	-	-	-	X	X	X	-	-	X	X	X	-	-
Missouri	-	X	-	-	-	X	-	X	X	-	-	X	X	-
Nevada	-	X	X	X	X	X	-	X	-	X	-	X	X	-
Ohio	-	-	-	-	-	-	-	X	-	-	-	X	-	-
Oregon	-	-	X	X	-	X	-	-	-	-	-	X	-	-
Pennsylvania	-	X	X	-	-	-	-	X	-	-	X	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-	-	-	-
South Dakota	-	X	-	X	X	X	-	X	X	X	X	X	X	-
Wisconsin	-	-	-	X	-	-	-	X	X	X	-	-	-	-
Count	**1**	**5**	**4**	**5**	**6**	**10**	**1**	**10**	**5**	**6**	**5**	**11**	**3**	**0**

Table B-9. Other text responses for Question 3 (methods used by DOTs to communicate information electronically to CMVs).

Other - Text
We send out surveys on both I-80 and I-15 as needed.
Travel information kiosks at rest areas and ports of entry
Contracted preclearance vendors

Table B-10. Comments for Question 3 (methods used by DOTs to communicate information electronically to CMVs).

Comment
freight.colorado.gov We also have nearly 10,000 subscribers for text or email notifications on construction restriction notifications and chain control notifications.
Nothing specific to commercial vehicles.
In addition to the list above, Oregon DOT posts information on an open-source platform called TripCheck API for third party data aggregators to distribute to CMV.

Table B-11. Individual survey responses for Question 4 (methods DOTs are planning to use in the future to communicate information electronically to CMVs) – Part 1 of 2.

Respondent	511 traffic information systems	Audible or visual alarms	Customer service centers	Data providers	In-cab alerts	Fleet management systems	CB radio	Satellite radio	VHF/UHF radio	Commercial radio	Changeable message signs (CMS)	Dynamic message signs (DMS)
Arizona	X	-	-	-	-	-	-	-	-	-	-	X
Colorado	X	X	X	X	X	-	X	-	-	X	X	X
Delaware	-	-	-	-	-	-	-	-	-	-	-	-
Illinois	-	-	-	-	X	-	-	-	-	-	-	-
Indiana	-	-	-	X	X	-	-	-	-	-	-	-
Iowa	-	-	-	-	X	-	-	-	-	-	-	-
Kansas	-	-	-	X	X	-	-	-	-	-	-	-
Kentucky	-	-	-	-	X	-	-	-	-	-	-	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	X	-	X	X	-	-	-	-	-	-	X	X
Missouri	-	X	X	X	X	-	-	-	-	-	X	X
Nevada	X	X	-	-	X	-	-	X	-	-	X	X
Ohio	-	-	-	-	-	-	-	-	-	-	-	-
Oregon	-	-	-	-	X	-	-	-	-	-	-	X
Pennsylvania	-	-	-	-	X	-	-	-	-	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-	-
South Dakota	-	X	-	-	X	-	-	X	-	-	-	-
Wisconsin	X	-	-	X	-	-	-	-	-	-	X	X
Count	**5**	**4**	**3**	**6**	**11**	**0**	**1**	**2**	**0**	**1**	**5**	**7**

Table B-12. Individual survey responses for Question 4 (methods DOTs are planning to use in the future to communicate information electronically to CMVs) – Part 2 of 2.

Respondent	Flyers	Print or broadcast media	Real-time Highway Advisory Radio (HAR)	Remotely activated traffic control devices	Smartphone applications	Traveler information maps	Connected vehicle technologies	Social media	Email lists	Static signs with dynamic features	Text messages	Websites	Other	None of the above
Arizona	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Colorado	X	X	-	X	X	X	X	X	X	X	X	X	-	-
Delaware	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Illinois	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Indiana	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kansas	-	-	-	-	X	-	X	-	-	-	-	-	-	-
Kentucky	-	-	-	-	-	-	X	-	-	-	-	-	-	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Massachusetts	-	-	-	-	X	X	X	X	-	X	X	X	-	-
Missouri	-	X	-	X	X	X	X	X	X	X	X	X	X	-
Nevada	X	X	X	X	X	X	X	X	X	X	X	X	X	-
Ohio	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oregon	-	-	-	-	-	X	X	-	-	-	-	X	-	-
Pennsylvania	-	-	-	-	-	-	X	-	-	-	-	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-	-	-	X
South Dakota	-	-	-	-	-	-	X	-	-	-	-	-	-	-
Wisconsin	-	-	-	X	-	-	-	-	X	X	-	-	-	-
Count	**2**	**3**	**1**	**4**	**8**	**5**	**9**	**4**	**4**	**5**	**4**	**5**	**2**	**3**

Table B-13. Other text responses for Question 4 (methods DOTs are planning to use in the future to communicate information electronically to CMVs).

Other - Text
Strategies for communication delivery is fluid, but best practices and emerging technology will be evaluated.
Truck Parking Availability System (TPAS)

Table B-14. Comments for Question 4 (methods DOTs are planning to use in the future to communicate information electronically to CMVs).

Comment
We use many of these services, but they are not targeted to commercial vehicles. These target all drivers. We are investigating services that would target commercial vehicles and would likely use many of these services.
These are many years out, but we have hopes of eventual integration.

Table B-15. Individual survey responses for Question 5 (perceived effectiveness (1 = Highly Ineffective, 5 = Highly Effective) for methods used to communicate information to CMV drivers) – Part 1 of 2.

Respondent	511 traffic information	Audible or visual alarms	Customer service centers	Data providers	In-cab alerts	Fleet management systems	CB radio	Satellite radio	VHF/UHF radio	Commercial radio	Changeable message signs (CMS)	Dynamic message signs (DMS)
Arizona	1	-	-	-	-	-	-	-	-	-	-	1
Colorado	3	4	4	3	4	-	-	-	-	-	4	4
Delaware	-	-	-	-	-	-	-	-	-	-	-	4
Illinois	3	-	3	-	-	-	-	-	-	-	-	5
Indiana	4	-	-	-	-	-	-	-	-	-	4	4
Iowa	5	-	-	5	-	-	-	-	-	-	5	5
Kansas	4	-	-	-	-	-	-	-	-	-	-	-
Kentucky	3	5	3	-	-	-	-	-	-	-	4	4
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	2	-	3	2	-	-	-	-	-	-	2	2
Missouri	-	4	2	4	4	-	-	-	-	-	4	4
Nevada	4	-	3	-	-	-	-	-	-	-	4	4
Ohio	3	-	-	-	5	-	-	-	-	-	4	4
Oregon	-	-	-	-	-	-	-	-	-	-	-	4
Pennsylvania	4	-	-	2	-	-	-	-	-	-	5	5
South Carolina	2	-	-	-	-	-	-	-	-	-	4	5
South Dakota	5	-	-	-	-	-	-	-	-	4	4	4
Wisconsin	5	-	-	-	-	-	-	-	-	-	4	4
Average	**3.4**	**4.3**	**3.0**	**3.2**	**4.3**	**n/a**	**n/a**	**n/a**	**n/a**	**4.0**	**4.0**	**3.9**
Standard Deviation	**1.2**	**0.6**	**0.6**	**1.3**	**0.6**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**0.7**	**1.1**
Number of Responses	**14**	**3**	**6**	**5**	**3**	**0**	**0**	**0**	**0**	**1**	**12**	**16**

Table B-16. Individual survey responses for Question 5 (perceived effectiveness (1 = Highly Ineffective, 5 = Highly Effective) for methods used to communicate information to CMV drivers) – Part 2 of 2.

Respondent	Flyers	Print or broadcast media	Real-time Highway Advisory Radio (HAR)	Remotely activated traffic control devices	Smartphone applications	Traveler information maps	Connected vehicle technologies	Social media	Email lists	Static signs with dynamic features	Text messages	Websites	Other
Arizona	-	-	-	-	1	-	-	-	-	-	-	-	-
Colorado	4	4	-	4	-	5	-	4	4	-	4	5	-
Delaware	-	-	4	-	-	3	-	-	-	4	-	4	-
Illinois	-	-	-	-	4	4	-	-	-	-	-	3	-
Indiana	-	-	-	-	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	4	5	-	4	-	-	4	5	-
Kansas	-	-	-	-	-	-	-	3	-	-	-	-	-
Kentucky	-	-	-	-	-	2	-	2	2	4	-	3	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	-	-	-	-	1	1	3	-	-	1	1	2	-
Missouri	-	2	-	-	-	3	-	3	3	-	-	3	5
Nevada	-	3	3	4	3	3	-	3	-	3	-	3	2
Ohio	-	-	-	-	-	-	-	4	-	-	-	4	-
Oregon	-	-	1	4	-	3	-	-	-	-	-	3	-
Pennsylvania	-	3	3	-	-	-	-	2	-	-	2	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-	-	-
South Dakota	-	3	-	4	5	4	-	3	4	3	4	4	4
Wisconsin	-	-	-	4	-	-	-	-	4	4	-	-	-

Respondent	Flyers	Print or broadcast media	Real-time Highway Advisory Radio (HAR)	Remotely activated traffic control devices	Smartphone applications	Traveler information maps	Connected vehicle technologies	Social media	Email lists	Static signs with dynamic features	Text messages	Websites	Other
Average	4.0	3.0	2.8	4.0	3.0	3.3	3.0	3.1	3.4	3.2	3.0	3.5	3.7
Standard Deviation	n/a	0.7	1.3	0.0	1.7	1.3	n/a	0.8	0.9	1.2	1.4	0.9	1.5
Number of Responses	1	5	4	5	6	10	1	9	5	6	5	11	3

Table B-17. Individual survey responses for Question 6 (data sources for information to share with CMV drivers).

Respondent	Crowdsourcing data	Environmental sensors	Feeds from data providers	Internal data sources at my agency	Law enforcement and first responders or emergency services	Probe vehicles	Radio Frequency Identification (RFID)	Social media	Traffic sensors	Transportation Data Exchange (TDx) feeds	Truck Parking Information Management	Trucking companies	Video cameras	Work Zone Activity Data (WZAD)	Work Zone Data Exchange (WZDx) Feeds	Other	None of the above
Arizona	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-
Colorado	-	-	X	X	-	-	-	-	X	-	-	-	X	-	X	-	-
Delaware	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-
Illinois	-	-	-	-	-	-	-	-	X	-	X	-	X	-	-	-	-
Indiana	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-
Iowa	X	-	X	-	X	X	-	X	X	-	X	-	X	-	X	-	-
Kansas	X	-	-	-	X	-	-	-	-	-	X	-	X	-	-	-	-
Kentucky	X	X	X	X	X	X	-	-	X	X	X	-	X	-	X	-	-
Louisiana	X	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	X	X	X	X	X	X	-	X	X	-	-	-	X	X	X	-	-

Respondent	Crowdsourcing data	Environmental sensors	Feeds from data providers	Internal data sources at my agency	Law enforcement and first responders or emergency services	Probe vehicles	Radio Frequency Identification (RFID)	Social media	Traffic sensors	Transportation Data Exchange (TDx) feeds	Truck Parking Information Management	Trucking companies	Video cameras	Work Zone Activity Data (WZAD)	Work Zone Data Exchange (WZDx) Feeds	Other	None of the above
Missouri	-	-	X	X	X	-	-	X	X	-	-	X	X	-	X	-	-
Nevada	X	X	X	X	X	X	-	X	X	X	-	-	X	X	X	-	-
Ohio	X	-	X	X	X	-	-	-	X	-	X	-	X	X	-	-	-
Oregon	-	X	-	X	-	X	-	-	X	-	-	-	-	-	X	-	-
Pennsylvania	X	-	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-
South Carolina	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
South Dakota	-	X	X	X	X	-	-	-	X	-	-	-	X	-	-	-	-
Wisconsin	-	X	-	X	X	-	-	X	X	-	X	-	X	X	X	-	-
Count	**9**	**7**	**11**	**10**	**12**	**5**	**0**	**5**	**13**	**2**	**7**	**1**	**11**	**4**	**8**	**1**	**0**

Table B-18. Other text responses for Question 6 (data sources for information to share with CMV drivers).

Other - Text
Drivewyze/INRIX

Table B-19. Comments for Question 6 (data sources for information to share with CMV drivers).

Comment
SDDOT maintenance and construction staff are responsible for providing information on winter road conditions and construction work zones, as a part of their job duties.
Truck GPS data through a vendor, HPMS data

Table B-20. Individual survey responses for Question 7 (perceived challenges to DOTs' efforts to communicate information to CMV drivers).

Respondent	Availability of agency staff	Concerns about CMV driver being distracted with information	Data availability	Funding constraints	Lack of available data standards	Lack of buy-in from trucking companies	Need for data standardization	Need for information regarding effectiveness of methods used	Obtaining accurate, reliable, and timely information	Providing information in multiple languages	Stakeholder coordination	Technology issues	Other	None of the above
Arizona	-	X	-	-	-	-	X	-	-	X	-	X	-	-
Colorado	-	X	X	X	X	X	X	X	X	X	X	X	-	-
Delaware	X	-	X	-	-	-	-	-	X	-	-	-	-	-
Illinois	-	X	X	-	-	-	-	-	-	-	-	X	-	-
Indiana	-	-	X	X	X	-	X	-	X	-	X	-	-	-
Iowa	-	X	-	-	X	-	X	-	-	-	-	-	X	-
Kansas	X	X	-	X	-	-	X	-	-	-	-	X	-	-
Kentucky	X	X	-	-	X	X	X	-	-	-	-	X	-	-
Louisiana	-	-	-	X	-	-	-	X	-	-	-	-	-	-

Respondent	Availability of agency staff	Concerns about CMV driver being distracted with information	Data availability	Funding constraints	Lack of available data standards	Lack of buy-in from trucking companies	Need for data standardization	Need for information regarding effectiveness of methods used	Obtaining accurate, reliable, and timely information	Providing information in multiple languages	Stakeholder coordination	Technology issues	Other	None of the above
Massachusetts	X	X	X	X	X	X	X	X	X	-	X	X	-	-
Missouri	-	-	X	X	X	-	-	X	X	-	-	X	X	-
Nevada	X	X	X	X	X	X	X	X	X	X	X	X	-	-
Ohio	X	-	X	X	-	X	X	-	X	-	-	-	-	-
Oregon	-	-	X	X	-	-	X	-	-	-	-	-	-	-
Pennsylvania	X	-	-	-	X	X	X	-	-	-	-	-	-	-
South Carolina	X	-	-	-	-	-	X	X	-	-	-	-	-	-
South Dakota	-	-	X	-	-	-	X	-	X	-	-	-	X	-
Wisconsin	-	-	X	X	-	-	-	X	-	-	X	-	-	-
Count	**8**	**8**	**11**	**10**	**8**	**6**	**13**	**7**	**8**	**3**	**5**	**8**	**3**	**0**

Table B-21. Other text responses for Question 7 (perceived challenges to DOTs' efforts to communicate information to CMV drivers).

Other - Text
Determining a technology that allows focused message delivery that does not opting-in by the customer
Providing information feeds to a multitude of disparate outlets in a multitude of formats
We have the data and use the WZDx standard, but to get our data into the cabs of trucks is the biggest challenge.

Table B-22. Comments for Question 7 (perceived challenges to DOTs' efforts to communicate information to CMV drivers).

Comment
The largest challenge for Oregon DOT presently is the operation cost that companies like Drivewyze and PrePass are requiring for their in-cab alerts. Via grants ODOT can fund development of integrating these in-cab notification systems, but ongoing operation budget is not available for ODOT to pursue in-cab alerts long term.

Table B-23. Individual survey responses for Question 8 (partnerships pursued by DOTs in efforts to communicate information to CMV drivers).

Respondent	FHWA	FMCSA	Industry associations or trucking associations	Law enforcement	Local agencies	MPOs	Other state DOTs	Technology vendors/app developers	Trucking companies	Other	None of the above
Arizona	X	X	X	X	X	X	-	X	X	-	-
Colorado	-	-	X	X	-	-	X	X	X	-	-
Delaware	-	X	-	X	-	-	-	X	-	-	-
Illinois	X	-	-	X	-	-	X	-	-	-	-
Indiana	-	-	-	-	-	-	-	X	-	-	-
Iowa	-	X	-	X	-	-	-	-	-	-	-
Kansas	X	-	X	X	-	-	-	X	-	-	-
Kentucky	X	-	X	-	-	-	X	-	X	-	-
Louisiana	-	-	-	-	-	-	-	-	-	-	-
Massachusetts	X	-	X	X	X	-	X	X	X	-	-
Missouri	-	-	X	X	-	-	-	X	X	-	-
Nevada	X	-	X	X	X	X	X	X	-	-	-
Ohio	-	-	X	X	-	-	-	X	-	-	-
Oregon	-	-	-	-	-	-	-	X	-	-	-
Pennsylvania	-	-	X	-	-	-	-	X	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-	-	-
South Dakota	-	-	-	X	X	-	-	X	-	-	-
Wisconsin	X	X	X	X	X	-	X	-	-	-	-
Count	**7**	**4**	**10**	**12**	**5**	**2**	**6**	**12**	**5**	**0**	**0**

Table B-24. Descriptions for technology vendors/app developers for Question 8 (partnerships pursued by DOTs in efforts to communicate information to CMV drivers).

Description
Drivewyze
Drivewyze and PrePass
Drivewyze and PrePass
Working with Google, Waze, Drivewyze, other third-party navigation providers
ProMiles but seems somewhat limited
Waze
PrePass Safety Alliance; Drivewyze
Drivewyze/INRIX

Table B-25. Comments for Question 8 (partnerships pursued by DOTs in efforts to communicate information to CMV drivers).

Comment
Not yet but we are exploring.

Table B-26. Individual survey responses for Question 9 (development of data standards or policies for communicating information electronically to CMV drivers).

Respondent	Response Text
Arizona	No
Colorado	No
Delaware	No
Illinois	No
Indiana	No
Iowa	No
Kansas	No
Kentucky	No
Louisiana	No
Massachusetts	No
Missouri	No
Nevada	No
Ohio	No
Oregon	No
Pennsylvania	No
South Carolina	No
South Dakota	No
Wisconsin	No

Table B-27. Comments for Question 10 (general comments).

Response
We are exploring services such as Drivewyze and other services. We are also exploring funding opportunities and Grants to target Commercial vehicles.
We attempt to use existing standards for information (WZDx, TMDD, etc.)
Oregon DOT would like to pursue in-cab alerts on a large scale, but operation budget limitations are restricting options working with existing providers. If solutions are available for in-cab alerts that do not require yearly subscription costs, then ODOT would like to participate as in-cab alerts are anticipated to have the largest impact to safety for CMV and surrounding vehicles.
We have a lot of data and provide our data feeds on our open data portal, but the only in-cab provider we've partnered with so far is PrePass. As they're working to use the WZDx data feed for their in-cab data.
There are so many untapped opportunities in this field. I spent years in the trucking industry and had in-cab cameras and so much more in our cabs over a decade ago. We have the opportunity to give professional truck drivers critical information before their eyes can see it. A true professional will do the right thing with the right information at the right time. We do not want to over communicate basic information though, and without proper planning and adjustments, these systems can become more of a distraction than help. One of my number one concerns is that the current ELD regulations and hardware on the market are so easy to hack into and cause havoc, that we need to put a major fix into that before we take too large of steps forward. With very little hacker knowledge, I could personally hack hundreds of trucks in a day and without new security standards, I find it risky to put too much into these programs.

Table B-28. Individual survey responses for Question 11 (willingness to be contacted for follow-up questions).

Respondent	Response Text
Arizona	Yes
Colorado	Yes
Delaware	Yes
Illinois	Yes
Indiana	Yes
Iowa	Yes
Kansas	Yes
Kentucky	Yes
Louisiana	Yes
Massachusetts	Yes
Missouri	Yes
Nevada	Yes
Ohio	Yes
Oregon	Yes
Pennsylvania	Yes
South Carolina	Yes
South Dakota	Yes
Wisconsin	Yes

Appendix C: Stakeholder Workshop Agenda

AGENDA
CMV Communication Stakeholder Workshop

Monday, August 28, 2023
1:00 PM – 3:00 PM Central

Missouri DOT Research Project TR 202410

University of Missouri and CBB

I. Meeting Preliminaries (Edara) *[10 minutes]*
   A. Call to Order
   B. Welcome, Introductions, and Housekeeping
II. Project Overview (Edara) *[10 minutes]*
III. Brainstorming Session (Leight/Martin) *[90 minutes]*
   A. What types of information have you seen being communicated to CMV drivers?
      1. How frequently is this information being communicated?
      2. What types of information is being communicated primarily through internal dispatch systems, 3rd party information providers, and public agencies?
      3. What technologies have you seen being used to communicate information to CMV drivers?
      4. What vendors are active in providing communication technologies and apps for CMV drivers?
      5. For information that is being provided, what is most important?
      6. For information that is being provided, what is most urgent?
      7. Is there information currently being provided that is of marginal value or a distraction?
      8. How easy is it for CMVs to select/filter the information being provided to them to prevent unnecessary distractions?
   B. What information is not currently being provided that should be?

C. What are some of the obstacles/challenges for trucking companies to adopt new driver communication options (e.g., apps, in-vehicle messages)?

D. Have you seen or heard of any international practices on using alternative methods to provide information to CMV drivers?

E. Have you heard of any ideas for new methods or technologies to provide information to CMV drivers?

F. Do you have any other thoughts or ideas that are relevant to this discussion?

G. Other Comments?

IV. Closing Remarks (Edara/Leight) *[10 minutes]*

V. Adjourn

Appendix D: Stakeholder Workshop Minutes

August 28, 2023

Minutes Prepared by: H. Brown and revised by P. Edara

1. There were 42 attendees.
2. Praveen Edara provided an overview of the project. The project seeks to proactively improve CMV safety. Project objectives include conducting a review of existing electronic notification system (ENS) methods in use by CMV drivers, trucking companies, and freight industry; conduct a survey of selected state DOTs regarding their current practice in ENS for communicating with CMV drivers; conducting a needs assessment brainstorming workshop with MoDOT and other stakeholders; and developing standards and specifications for data feeds consisting of traveler information critical for CMV operators.
3. Based on the discussion at the workshop, a matrix was completed for information and technology.
4. New York State DOT publishes information for bridge clearances from its HOOCS permitting system. This information is updated daily.
5. Several state DOTs, such as New York, New Jersey, Georgia, and North Carolina, have tried in-cab messaging.
6. Examples of information that could be helpful to CMV drivers include presence of active work zones (especially mobile work zones and worker presence), truck parking (number of miles ahead and number of spaces available), end of queue alerts, sudden slowdown alerts, weather (e.g., extreme weather), low bridges, sharp curves, truck emergency escape ramps, brake check areas, and chain stations.
7. Information provided needs to be accurate and provide true value to the driver while being conveyed in a useful format.
8. Too much information can overwhelm and distract the driver. A balance is needed to provide useful information without distracting the driver.
9. Allowing CMV drivers to set up profiles to customize and filter alerts based on vehicle parameters and driver preferences would help to make information useful for drivers.
10. Text for in-cab alerts should be brief to avoid driver distraction. Some technologies offer audio alerts.
11. Information on detour routes may need to be customized as some detour routes may not be appropriate for CMVs due to geometric design.
12. Information provided to drivers can be both short-term or long-term.
13. Information regarding the availability of parking at rest areas could help truckers plan. Static information regarding availability of amenities at rest areas would also be

beneficial.

14. Information on private truck parking (e.g., truck stops) is harder to obtain.
15. Some carriers push information to drivers through their own apps.
16. One challenge involves disseminating information to drivers in different languages. Some apps can send information in the language of the driver's choice.
17. There are some differences in how carriers handle major winter events. Large carriers tend to park while smaller carriers keep going. Communicating information to encourage drivers to get off the road to help plowing efforts is important.
18. There are also some differences in technology capabilities and in-cab equipment between larger and smaller fleets. Smaller fleets may not have capabilities to filter data.
19. Consistency between states is important to make it easier for data communicators to get information to drivers.
20. Some states allow drivers to subscribe to alerts.
21. MoDOT's efforts for truck parking have been focused on expanding truck parking inventory. MoDOT recently completed a research study on prioritizing truck parking investments.
22. Kansas DOT has DMS boards showing availability of truck parking 90 miles, 60 miles, etc. Michigan DOT may have something similar.
23. Since Missouri neighbors eight states, it would be useful to get information for incidents in other states.
24. A final report for the project will be submitted in December 2024 and posted on MoDOT's website.