OHIO TURNPIKE AND
INFRASTRUCTURE COMMISSION

ADDENDUM NO. 5
ISSUED JANUARY 21, 2026

to

RFP NO. 30-2025
TO SELECT A VENDOR TO DESIGN, IMPLEMENT, AND MAINTAIN AN ADVANCED TRAFFIC MANAGEMENT SYSTEM
PROJECT NO. 46-26-02

PROPOSAL DUE DATE: 5:00 P.M. (EASTERN TIME) JANUARY ~~12~~ 26, 2026

ATTENTION OF RESPONDENTS IS DIRECTED TO:

ANSWERS TO QUESTIONS RECEIVED THROUGH 5:00 P.M. ON JANUARY 9, 2026:

MODIFICATIONS TO THE CONTRACT DOCUMENTS

OTIC DMS VSL ConOps FINAL v1.0 1-9-26, For Reference Only

Issued by the Ohio Turnpike and Infrastructure Commission through Aimee W. Lane, Esq, Director of Contracts Administration.

Aimee W. Lane

______________________________ January 21, 2026
Aimee W. Lane, Esq., Date
Director of Contracts Administration

ANSWERS TO QUESTIONS RECEIVED THROUGH 5:00 P.M. ON JANUARY 9, 2026:

Q#5 At Part VI(B) of the RFP, under the heading "Executive Order 2022-02D – State of Ohio's Response to Russia's Unjust War on the Country of Ukraine," item C, should the reference to "Appendix F" actually be a reference to "Appendix E"? It appears to be a minor typographical error and we just seek confirmation.

A#5 That is correct. Appendix E should read "Ethics Policy" and Appendix F should read "Combination Affirmation and Disclosure Form (Executive Order No. 2019-12D and Executive Order No. 2022-02D)"

Q#6 Regarding the Public Records Act at Part VI(B) of the RFP, if an offeror has information exempt from disclosure in its proposal, is it sufficient for that offeror to mark pages containing such information "confidential" and provide a redacted version if the pertinent document is responsive to a Public Records Act request? Or should proposals be submitted with redacted versions the offeror pre-approves for release?

A#6 If a Respondent has information exempt from disclosure in its proposal, it will be sufficient for that Respondent to mark the pages containing such information "confidential" and to provide a redacted version to the Commission with justifications if the pertinent document is responsive to a Public Records Act request.

Q#7 A requirement at Exhibit A, Section I, "Data Ownership & Residency," states that "All data . . . are owned by the Commission with perpetual rights to export in open formats." Can the Commission confirm that this requirement does not mean that the contractor must maintain data in perpetuity so it is available for export indefinitely and the contractor shall only be required to maintain data for the period covered by a contract for the contractor's services?

A#7 The ability to export data should exist throughout the life of the system, but the contractor is only required to maintain the data for the period covered by the contract.

Q#8 Regarding Exhibit C, section 7.1, "Performance Bonds," what is the performance bond form that will be satisfactory to the Commission?

A#8 The Commission does not have a required performance bond form. The awarded respondent can submit the performance bond form used by its surety or use the applicable AIA form.

Q#9 Regarding Exhibit C, section 7.1, "Performance Bonds," may an offeror propose that costs for the required performance bond(s) will be handled as pass-through expenses that the Commission will reimburse rather than incorporating them into the proposed pricing and be found responsive to the RFP?

A#9 Performance bond costs should be included in the proposed pricing.

Q#10 Regarding Exhibit C, section 7.1, "Performance Bonds," can the Commission please confirm that the performance bond requirement applies only to the Initial Term of the contract (i.e., the implementation phase) and not to the Maintenance Term?

A#10 That is correct. The performance bond requirement only applies to the Initial Term of the contract and will not apply to the Maintenance Term.

Q#11 Are all of the 1250 existing cameras that are currently in the Milestone system integral to the functionality intended for the ATMS or does the ATMS only need to incorporate the streams of the cameras deployed for the OTIC Overhead DMS and Variable Speed Limit Sign, Project No. 46-25-01?

A#11 All camera streams will need to be integrated into the ATMS System for ease of use by the Communications Center staff.

Q#12 How many WIM devices do you have? What type of Communication does it use? Outside of event management, what WIM reporting would the ATMS be expected to provide? Who is the device Manufacture and what is the Model/Firmware version?

A#12 The Commission has five current locations for WIM, with potential to expand the system with 7 additional locations. Each current site has the following: 12- INTERCOMP STRAINGAUGE SENSOR 1.75M , 4- INEX IZA800GDOT Cameras, and 8-INEX IZA800G-L-DR Cameras. The communication used is IRD Open Protocol via IRD's iSINC – intelligent System and Interface Network Controller. ATMS should provide a report of each event by date, time, and location. The WIM device manufacture is IRD/Quarterhill and the model/firmware number is WCU Model W4, WCU-OS 2.2.0, WCU-Core 3.0.0.

Q#13 Section B (Phase I) of the RFP Draft Scope of Services references the ConOps Refinement & Requirements Baseline for item 2. Can Ohio Turnpike please provide the existing ConOps to bidders for review ahead of proposal submission?

A#13 The ConOps Document has been included with Addendum No. 5, for reference only.

END OF ADDENDUM NO. 5

Ohio Turnpike and Infrastructure Commission

Variable Speed Limit and Dynamic Message Signs

Concept of Operations

Ver 1.0

December 2024

Prepared By:

Michael Baker INTERNATIONAL

OHIO TURNPIKE

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1.0 Introduction

1.1 Document Overview

This Concept of Operations (ConOps) outlines the foundational vision for the Ohio Turnpike and Infrastructure Commission (OTIC) Variable Speed Limit (VSL) and overhead Dynamic Message Sign (DMS) project. The document aims to provide a comprehensive overview from the perspective of stakeholders, detailing the system's goals, user needs, and expectations. This ConOps has been developed in collaboration with OTIC and other key partners, ensuring that it accurately reflects the needs and expectations of all relevant stakeholders.

The primary purpose of this ConOps is to:

1. Establish a clear, high-level vision for the VSL and DMS system.
2. Define the goals and objectives of the project.
3. Identify key stakeholders and their roles.
4. Outline user needs and system capabilities.
5. Describe operational scenarios and use cases.
6. Set the stage for subsequent phases of the systems engineering process.

This document has been developed in close collaboration with OTIC and other key partners.

Serving as a cornerstone document, this ConOps establishes the framework for the VSL and DMS system. It offers a high-level perspective on the intended uses and operations of the proposed system. As an initial step in the Systems Engineering Analysis (SEA), this document does not delve into specific, testable system requirements or technical design details. Instead, it sets the stage for subsequent phases, including the development of technical requirements, design, and testing and verification processes.

The systems engineering process for the VSL and DMS project follows the V Diagram model, which is a standard approach in ITS projects. This model emphasizes the importance of defining user needs and system requirements early in the project lifecycle and ensures that these requirements are met through rigorous testing and validation.

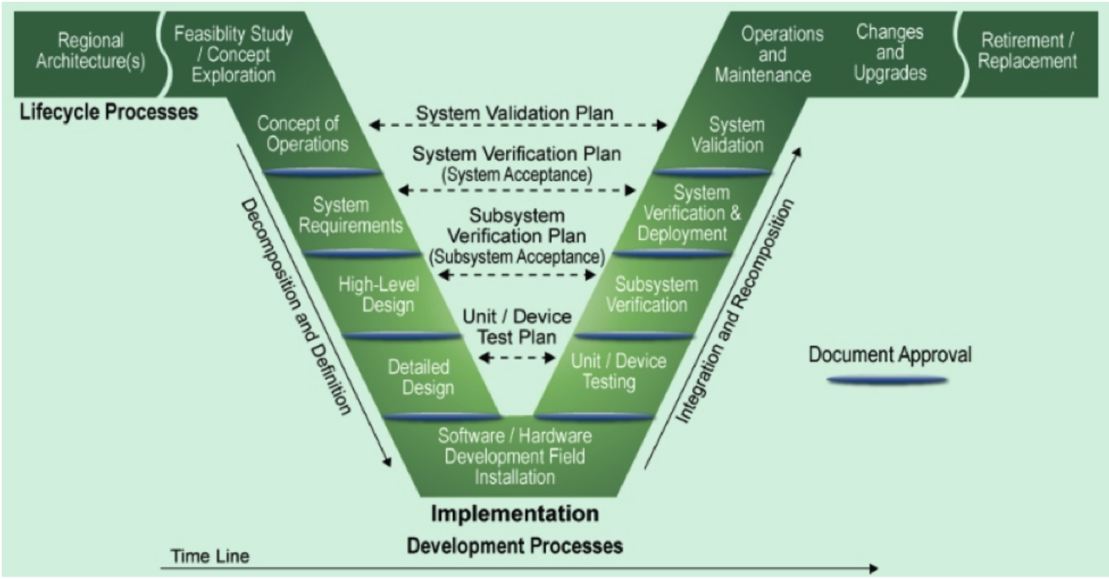

Figure 1. FHWA V-Model Project Life Cycle[1]

1. **Concept of Operations (ConOps):** This initial phase involves understanding the needs and expectations of stakeholders and defining the high-level vision for the system. The ConOps document serves as a foundation for all subsequent phases.
2. **System Requirements:** Based on the ConOps, detailed system requirements are developed. These requirements specify what the system must do to meet the needs identified in the ConOps.
3. **High-Level Design:** This phase involves creating a high-level design that outlines the system architecture and major components. It ensures that all system requirements are addressed.
4. **Detailed Design:** The high-level design is further refined into detailed specifications that guide the development and implementation of the system.
5. **Implementation:** During this phase, the system is built according to the detailed design specifications. This includes hardware installation, software development, and system integration.
6. **Integration and Testing:** The implemented system components are integrated and tested to ensure they work together as intended. This phase includes unit testing, integration testing, and system testing.
7. **Verification and Validation:** Verification ensures that the system meets all specified requirements, while validation ensures that the system fulfills its intended purpose and meets stakeholder needs.
8. **Operations and Maintenance:** Once the system is deployed, it enters the operations and maintenance phase. This involves monitoring system performance, performing regular maintenance, and making necessary updates or improvements.

[1] Source: https://ops.fhwa.dot.gov/plan4ops/sys_engineering.htm

9. **Retirement/Replacement:** Eventually, the system will reach the end of its lifecycle and will need to be retired or replaced. This phase involves planning for and executing the transition to a new system.

By following the V Diagram model, the OTIC VSL and DMS project ensures a structured and systematic approach to systems engineering, promoting the successful delivery of a reliable and effective ITS solution.

This document is structured to provide a comprehensive overview of the proposed VSL and DMS system. It begins with an Introduction that sets the context for the project, followed by a detailed Scope section that outlines the boundaries of the system. The Users and Stakeholders section identifies all parties involved in or affected by the system, while the User Needs section delves into the specific requirements of these stakeholders. The System Overview provides a high-level description of the proposed solution, which is then elaborated upon in the Operational Scenarios / Use Cases section, illustrating how the system will function in various situations. System Design Considerations are then discussed, outlining key factors that will influence the system's development. The document concludes with Systems Engineering Next Steps, outlining the path forward, and an Acronyms List for easy reference. Each of these sections contributes critical information to build a comprehensive understanding of the proposed VSL and DMS system, its intended use, and the context in which it will operate.

This ConOps document is designed to serve a diverse audience involved in various aspects of the VSL and DMS project. It caters to OTIC decision-makers and project managers who require a comprehensive understanding of the system's vision and objectives to guide strategic planning and resource allocation. Traffic management authorities will find valuable insights into how the system will enhance their operational capabilities. System designers and developers will use this document as a foundation for creating detailed technical specifications and implementations. Operations and maintenance personnel will gain an understanding of the system's functionality and operational requirements, preparing them for future system management. Additionally, other relevant stakeholders, such as law enforcement agencies and emergency services, will benefit from understanding how the system will impact their roles and responsibilities in maintaining road safety and responding to incidents. By addressing the needs and perspectives of this wide-ranging audience, the ConOps ensures that all parties have a shared understanding of the project's goals, scope, and operational context, fostering better collaboration and alignment throughout the system's lifecycle.

1.2 Background

The Ohio Turnpike, spanning 241 miles across northern Ohio, has long been a critical transportation artery for both commercial and private vehicles. However, like many major highways, it faces significant challenges related to adverse weather conditions, which can dramatically impact road safety and traffic flow. These road weather challenges have emerged as a major concern for the OTIC, prompting a comprehensive review of existing safety measures and the exploration of innovative solutions.

In recent years, the turnpike has experienced several severe weather-related incidents that have underscored the urgent need for enhanced traffic management and safety systems. Two particularly notable events occurred in 2014 and 2022, both in a specific section of the turnpike prone to sudden changes in visibility and road conditions.

The 2014 incident involved a multi-vehicle collision during a severe snowstorm. This event resulted in several fatalities, significant injuries, extensive property damage, and a prolonged closure of the turnpike, causing substantial disruption to traffic and commerce. The sudden onset of the snowstorm, combined with rapidly deteriorating visibility, created hazardous conditions that overwhelmed existing safety measures.

Similarly, in 2022, a chain-reaction crash occurred during a period of whiteout conditions. This incident led to multiple fatalities and necessitated extensive road closures, once again highlighting the vulnerability of the turnpike to extreme weather conditions. The freezing temperatures, blowing snow, and strong winds and their severe impact on visibility caught many drivers off guard, demonstrating the limitations of traditional static warning systems.

These events served as stark reminders of the turnpike's susceptibility to weather-related hazards and emphasized the critical need for a more robust, responsive system to manage such situations effectively. In response to these challenges, OTIC conducted a thorough analysis of weather-related incidents and their impacts on turnpike operations. This analysis culminated in the creation of a comprehensive recommendation report focusing on zero visibility events, with particular emphasis on the section of the turnpike where the 2014 and 2022 incidents occurred.

The report's findings highlighted several key areas for improvement:

- Real-time monitoring of weather and road conditions
- Dynamic adjustment of speed limits in response to changing conditions
- Timely and effective communication of hazards to drivers
- Enhanced coordination between traffic management authorities and emergency services

In light of these findings and the urgent need to enhance driver safety, OTIC has prioritized the implementation of a Variable Speed Limit (VSL) system and Dynamic Message Signs (DMS). These technologies represent a significant leap forward in traffic management capabilities, offering the potential to dramatically improve safety and operational efficiency on the turnpike.

The VSL system will enable real-time adjustments to speed limits based on current road and weather conditions. This dynamic approach to speed management will allow for more appropriate speed limits during adverse conditions, potentially reducing the risk of crashes and improving traffic flow. The system will utilize a network of sensors and advanced algorithms to continuously monitor conditions and determine optimal speed limits.

Complementing the VSL system, the DMS will provide timely and relevant information to drivers. These signs will be capable of displaying a wide range of messages, including warnings about upcoming hazards, changes in road conditions, and updated speed limits. By providing drivers with real-time information, the DMS system aims to enhance situational awareness and enable better decision-making behind the wheel.

Together, the VSL and DMS systems represent a comprehensive approach to addressing the weather-related challenges faced by the Ohio Turnpike. By leveraging advanced technologies and data analytics, this initiative aims to:

- Reduce the risk of weather-related crashes.
- Improve overall traffic flow, even during adverse conditions.
- Enhance the responsiveness of traffic management to rapidly changing weather patterns.
- Provide drivers with the information they need to make safer travel decisions.

This project is part of OTIC's broader commitment to enhancing infrastructure resilience and operational efficiency. As weather patterns become increasingly unpredictable due to climate change, the need for adaptive, responsive traffic management systems becomes ever more critical. The VSL and DMS project represents a proactive step towards creating a safer, more efficient turnpike that can better withstand the challenges posed by adverse weather conditions.

By implementing these advanced systems, OTIC aims to set a new standard for highway safety and operational excellence, not just for the Ohio Turnpike, but potentially serving as a model for other major highways facing similar challenges across the United States.

1.3 System Overview

The VSL and DMS systems represent cutting-edge information systems designed to enhance roadway safety and efficiency on the Ohio Turnpike. These systems leverage advanced technologies to collect, process, and disseminate real-time data on weather, traffic, and road conditions, enabling dynamic responses to changing environmental factors and traffic situations.

At their core, the VSL and DMS systems are designed to provide drivers with timely, relevant information and to implement adaptive traffic management strategies. By doing so, they aim to mitigate the risks associated with adverse weather conditions, reduce the likelihood of crashes, and optimize traffic flow along the turnpike.

Variable Speed Limit (VSL) System

The VSL system is a sophisticated traffic management tool that dynamically adjusts speed limits based on real-time data. This system comprises several key components and subsystems:

- **Data Collection:** A network of sensors and monitoring devices deployed along the turnpike continuously gathers data on:
  - Weather conditions (precipitation, temperature, visibility)
  - Traffic flow (vehicle speed, volume, density)
  - Road surface conditions (wetness, ice formation)

- **Data Processing:** In the Comm Center, the central control application uses advanced algorithms consistent with traffic engineering principles analyze the collected data in real-time, assessing current conditions and predicting short-term changes.

- **Speed Limit Determination:** Based on the processed data, the system calculates optimal speed limits for different sections of the turnpike.

- **VSL Signs:** Electronic regulatory speed limit signs update to show the new speed limits, ensuring drivers are always aware of the current regulatory speeds.

- **Road Weather Information Systems (RWIS):** These systems include a network of weather stations that monitor various atmospheric conditions such as temperature, humidity, wind speed, and precipitation. The RWIS can also determine road surface conditions like pavement temperature, presence of ice and estimated friction coefficients. The data collected by RWIS is essential for predicting and responding to adverse weather conditions, allowing the VSL and DMS systems to adjust speed limits and display relevant warnings in real-time.

- **Closed-Circuit Television (CCTV) Cameras:** CCTV cameras are strategically placed along the turnpike to provide visual monitoring of traffic and weather conditions. These cameras feed live video to the central traffic management system, enabling operators to visually confirm incidents, assess traffic flow, and monitor weather impacts. The real-time footage from CCTV cameras enhances the accuracy of data analysis and decision-making processes. The cameras also confirm proper operation of VSL sign and DMS to ensure legibility and consistency with the management system.

- **Vehicle Detection System (VDS):** A VDS device provide detailed, accurate real-time feedback on vehicle speeds, volumes, and occupancies across all lanes of traffic. VDS data is used to determine system effectiveness and driver compliance with displayed speed limits. The data is also used to provide traveler information to the Ohio Department of Transportation (ODOT) Real Time Traveler information system (OHGO) and third-party data providers along with use for future planning and engineering studies. A VDS equipment can also be used to detect and alert for wrong way drivers.

The VSL system's primary function is to lower speed limits during adverse conditions such as heavy rain, snow, fog, or high traffic volumes. By encouraging slower, more cautious driving during hazardous conditions, the system aims to reduce the risk of crashes and maintain smoother traffic flow.

Dynamic Message Sign (DMS) System

The DMS system serves as a critical communication channel between traffic management authorities and drivers. It consists of a network of electronic signs strategically placed along the turnpike. Key features of the DMS system include:

- Versatile Display: The signs are capable of showing a wide range of messages, including text and high-resolution color graphics to emulate standard MUTCD signs for easier understanding by drivers.
- Real-time Updates: Messages are updated in real-time based on current conditions and emerging situations.
- Strategic Placement: Signs are evenly distributed across the turnpike and where possible positioned to provide timely information before key decision points (e.g., toll plaza, freeway to freeway interchanges) and in areas prone to rapidly changing conditions.

The DMS system displays various types of information, including:

- Warnings about upcoming hazards (e.g., crashes, road work, severe weather)
- Changes in speed limits and approaches to VSL segments.
- Alternative route suggestions during major incidents

- General safety reminders, Amber and Blue alerts, and public service announcements

By providing this timely information, the DMS system enhances drivers' situational awareness, enabling them to make informed decisions about their travel plans and driving behavior.

Integration and Coordination

A key strength of the proposed system is the seamless integration between the VSL and DMS components and their coordination with OTIC's central traffic management system. This integration ensures:

- Consistent Information: Speed limits displayed on VSL signs are reflected in messages on DMS, providing drivers with coherent, non-contradictory information.
- Coordinated Responses: The system can implement comprehensive strategies in response to incidents or severe weather, combining speed limit adjustments with informative messages.
- Efficient Data Sharing: All components of the system share a common data pool, ensuring that decisions are based on the most up-to-date and comprehensive information available.
- Centralized Control: Traffic management operators have a unified interface to monitor and control both VSL and DMS systems, streamlining operations and decision-making processes.

Moreover, the system is designed with scalability and adaptability in mind. This forward-thinking approach allows for a range of future enhancements and expansions. The system can be easily extended to cover additional sections of the turnpike as needs arise or resources become available. It's also capable of integrating new data sources as they emerge, ensuring that the system can always leverage the most comprehensive and up-to-date information. The design accommodates the incorporation of emerging technologies and traffic management strategies, keeping the system at the forefront of innovation in highway management. Furthermore, it's built to adapt to evolving traffic patterns and user needs, ensuring that the system remains effective and relevant even as the demands on the turnpike change over time. This flexibility and futureproofing are crucial aspects of the system's design, ensuring that it can continue to meet OTIC's needs for years to come.

Benefits

The implementation of VSL and DMS systems offers several key benefits:

- **Improved Safety:** By providing real-time information and dynamically adjusting speed limits, these systems help reduce the likelihood and severity of crashes, especially during adverse weather conditions. The ability to quickly warn drivers of upcoming hazards and encourage appropriate speeds for current conditions can significantly mitigate risks associated with sudden changes in weather or traffic.

- **Enhanced Traffic Flow:** Dynamic adjustments to speed limits, coupled with timely information about road conditions and incidents, help maintain smooth traffic flow. This can lead to reduced congestion, shorter travel times, and a more consistent, predictable driving experience for turnpike users.

- **Increased Driver Awareness:** Real-time messages and warnings keep drivers informed about current road conditions and potential hazards. This enhanced situational awareness enables drivers to make safer, more informed decisions about their travel plans and driving behavior.

- **Operational Efficiency:** The integration of VSL and DMS systems with OTIC's traffic management infrastructure enhances the overall efficiency of roadway operations and incident management. Traffic managers can respond more quickly and effectively to changing conditions, implementing comprehensive strategies that combine speed management with informative messaging.

- **Data-Driven Decision Making:** The wealth of data collected by the system provides valuable insights into traffic patterns, recurring problem areas, and the effectiveness of different management strategies. This information can guide future infrastructure investments and policy decisions.

- **Environmental Benefits:** By optimizing traffic flow and reducing stop-and-go traffic, the system can contribute to reduced fuel consumption and lower vehicle emissions.

- **Flexibility and Futureproofing:** The scalable and adaptable nature of the system ensures that it can evolve to meet changing needs and incorporate new technologies, protecting OTIC's investment in the long term.

The proposed VSL and DMS systems represent a comprehensive, technologically advanced solution to the challenges faced by the Ohio Turnpike. By providing real-time information, dynamically managing traffic, and enhancing overall situational awareness, these systems promise to significantly improve safety, efficiency, and the overall driving experience on the turnpike.

1.4 References

The development of this Concept of Operations document for the VSL and DMS systems drew upon a wide range of authoritative sources and industry best practices. These references not only informed the content and structure of this document but also provided valuable insights into the latest advancements in intelligent transportation systems and traffic management strategies.

Key references consulted during the preparation of this document include:

1. International Council on Systems Engineering (INCOSE). (2015). Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities, 4th Edition. Hoboken, NJ: John Wiley & Sons, Inc. This comprehensive guide provided the foundational framework for our systems engineering approach, ensuring that our ConOps aligns with industry-standard practices and methodologies.

2. Federal Highway Administration (FHWA). (2007). Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals. Washington, D.C.: U.S. Department of Transportation. The FHWA's guidance on systems engineering for ITS projects was instrumental in shaping our approach to the VSL and DMS systems, particularly in terms of lifecycle considerations and stakeholder engagement.

3. Michigan Department of Transportation. (2019). Concept of Operations for Active Traffic Management. Lansing, MI: MDOT. This document served as a valuable reference point, offering insights into how another state transportation agency approached the development of a ConOps for a similar system.

4. Ohio Turnpike and Infrastructure Commission. (2023). Solutions for Zero Visibility Events Report. Berea, OH: OTIC. This internal report provided critical context specific to the Ohio Turnpike, including detailed information on past incidents and current challenges that informed the need for the VSL and DMS systems.

5. Transportation Management Center Pooled-Fund Study. (2024). Traffic Management Systems (TMSs) Managing the Use of Variable Speed Limits (VSLs) During Adverse Weather Conditions, Listening Session. Washington, D.C.: U.S. Department of Transportation. This recent study offered valuable insights into the latest practices and challenges in implementing VSL systems, particularly in the context of adverse weather conditions.

2.0 Scope

The Ohio Turnpike and Infrastructure Commission (OTIC) Variable Speed Limit (VSL) and Dynamic Message Sign (DMS) project represents a comprehensive initiative to revolutionize traffic management on one of Ohio's most critical transportation arteries. This ambitious undertaking encompasses the design, development, implementation, and ongoing maintenance of an advanced, integrated traffic management system. The primary goal of this project is to significantly enhance road safety and operational efficiency along the Ohio Turnpike, addressing longstanding challenges related to adverse weather conditions and variable traffic patterns.

The scope of this project is multifaceted, reflecting the complex nature of modern intelligent transportation systems. It extends beyond mere hardware installation to include sophisticated software development, intricate system integration, and the establishment of new operational protocols. The following key components and activities define the breadth and depth of this initiative:

- **Variable Speed Limit (VSL) System**:

  At the heart of this project is the implementation of a state-of-the-art Variable Speed Limit system. This component involves:

  - Installation of a network of advanced sensors along strategic sections of the turnpike, capable of detecting a wide range of environmental and traffic conditions.
  - Deployment of electronically variable speed limit signs that can be updated in real-time.
  - Development and implementation of sophisticated algorithms to analyze sensor data and determine optimal speed limits.
  - Creation of a user-friendly interface for traffic management personnel to monitor and, when necessary, override the system.
  - Installation of the following subsystems:
    - RWIS to collect detailed weather data (temperature, humidity, wind speed, precipitation) to inform dynamic speed limit recommendations and driver warnings.

  - CCTV Cameras to provide visual monitoring of traffic conditions and road surfaces, enhancing data accuracy and decision-making.
  - VDS to collect real-time vehicle speed, volumes, and occupancies.

The VSL system will provide dynamic recommendations for speed limits based on real-time road and weather conditions. This approach promotes safer driving behaviors during adverse conditions while maintaining efficient traffic flow during optimal conditions. Operators will use these recommendations to make informed decisions and implement appropriate speed limits.

- **Dynamic Message Sign (DMS) System:**

Complementing the VSL system, the DMS component will provide drivers with critical, real-time information. This aspect of the project includes:

  - Strategic placement of large, high-visibility, high resolution, color electronic signs along the turnpike.
  - Development of a content management system to create, schedule, and display messages.
  - Integration with various data sources to ensure timely and relevant information dissemination.
  - Implementation of protocols for message prioritization during multiple concurrent events or hazards.

The DMS system will deliver warnings, travel time estimates, and other pertinent information to drivers, enhancing situational awareness and enabling informed decision-making.

- **Integration with Existing Infrastructure**:

A critical aspect of this project is ensuring seamless integration with OTIC's existing systems and infrastructure. This integration encompasses:

  - Interfacing the new VSL and DMS systems with OTIC's central communications center.
  - Ensuring compatibility with existing communication networks and protocols.
  - Upgrading or modifying current infrastructure as necessary to support the new systems.
  - Developing APIs and data exchange protocols to facilitate smooth information flow between systems and external applications such as OHGO and third-party data providers such as Waze and Google Maps

This integration will create a cohesive, unified traffic management ecosystem, maximizing the effectiveness of both new and existing systems.

- **Stakeholder Collaboration**:

Recognizing the diverse group of individuals and organizations impacted by this project, extensive stakeholder collaboration is a key component of the scope. This includes:

  - Engaging with traffic management authorities to understand operational needs and constraints.
  - Collaborating with local law enforcement and emergency services to ensure the system supports their critical functions.
  - Coordinating with other relevant agencies, such as the Ohio Department of Transportation and local municipalities.

This collaborative approach ensures that the final system meets the needs and expectations of all stakeholders, promoting widespread acceptance and effective utilization.

- **Testing and Validation:**

To ensure the reliability and effectiveness of the VSL and DMS systems, comprehensive testing and validation processes are included within the project scope:

  - Development of detailed test plans covering all aspects of system functionality.
  - Implementing a phased rollout with extensive field testing under real-world conditions.
  - Validation of system performance against predetermined metrics and stakeholder requirements.

These thorough testing and validation procedures will ensure that the system meets all specified requirements and performs reliably under various conditions before full deployment.

- **Operations and Maintenance:**

The scope extends beyond initial implementation to include the establishment of robust operations and maintenance procedures:

  - Development of comprehensive operational guidelines and protocols.
  - Creation of training programs for traffic management personnel, maintenance staff, and other relevant stakeholders.
  - Establishment of regular maintenance schedules and procedures.
  - Implementation of performance monitoring systems to track system effectiveness over time.
  - Development of update and upgrade protocols to ensure the system remains current with evolving technologies and needs.

These measures will ensure the long-term effectiveness and reliability of the VSL and DMS systems, maximizing the return on OTIC's investment.

- **Project Boundaries:**

While the scope of this project is extensive, it's important to delineate its boundaries:

  - Geographic Limitations: The initial implementation will focus on specific, high-priority sections of the Ohio Turnpike, with the potential for future expansion.
  - System Limitations: While the VSL and DMS systems will significantly enhance traffic management capabilities, they are not designed to replace human decision-making entirely. OTIC operations personnel will retain ultimate control and oversight.
  - Regulatory Compliance: All aspects of the project will be designed and implemented in compliance with relevant federal, state, and local regulations.

By clearly defining these boundaries, we ensure a focused and achievable project scope while laying the groundwork for potential future enhancements.

In conclusion, the scope of the OTIC VSL and DMS project represents a comprehensive approach to modernizing traffic management on the Ohio Turnpike. By addressing all aspects from initial design through long-term maintenance, this project aims to create a robust, adaptable system that will significantly enhance safety and efficiency for years to come. The successful implementation of this project will not only benefit the millions of drivers who use the Ohio Turnpike annually but could also serve as a model for similar initiatives across the nation.

2.1 Project Description

The OTIC VSL and DMS project is a strategic initiative aimed at improving traffic safety and efficiency on the Ohio Turnpike. The project involves the deployment of advanced technologies to monitor and manage traffic conditions in real-time. By dynamically adjusting speed limits and providing timely information to drivers, the system aims to reduce the risk of crashes, enhance traffic flow, and improve overall driver awareness.

The VSL system will utilize data from weather sensors, traffic cameras, and road condition monitoring devices to adjust speed limits based on current conditions. The DMS system will display important messages to drivers, such as warnings about upcoming hazards or changes in road conditions, through electronic signs placed at strategic locations along the turnpike.

This project is part of OTIC's broader commitment to leveraging technology to enhance infrastructure resilience and operational efficiency, particularly in response to the challenges posed by adverse weather conditions.

2.2 Vision

The vision of the OTIC VSL and DMS project is to enhance roadway safety and operational efficiency on the Ohio Turnpike by leveraging advanced technologies and real-time data. This project aims to create a safer driving environment, reduce the risk and severity of crashes, and improve traffic flow under various conditions, ultimately contributing to a more resilient and efficient transportation infrastructure.

2.3 Mission

The mission of the OTIC VSL and DMS project is to successfully implement a VSL and DMS management system through a comprehensive systems engineering process. This involves engaging with key stakeholders, including public and private partners, to secure the necessary financial and technical resources. The project will focus on the design, development, deployment, and maintenance of the VSL and DMS systems, ensuring they meet the needs of all users and enhance the overall safety and efficiency of the Ohio Turnpike.

2.4 Goals

The primary goals of the OTIC VSL and DMS project are:

1. **Enhance Road Safety**: Reduce the likelihood and severity of crashes by providing real-time information and dynamically adjusting speed limits based on current road and weather conditions.
2. **Improve Traffic Flow**: Maintain smooth traffic flow and reduce congestion by adjusting speed limits and providing timely information to drivers.
3. **Increase Driver Awareness**: Keep drivers informed about current road conditions and potential hazards, enabling them to make safer driving decisions.
4. **Ensure Operational Efficiency**: Streamline traffic management processes and improve incident response through system integration. Success indicators will include reduced operational costs and improved incident clearance times.

5. **Promote Infrastructure Resilience**: Develop a robust system capable of responding to and managing the challenges posed by adverse weather conditions, ensuring the turnpike remains safe and operational under various conditions.
6. **Foster Innovation and Knowledge Sharing:** Position OTIC as a leader in intelligent transportation systems and contribute to the advancement of the field. This goal will be measured through research collaborations, publications, and adoption of OTIC's strategies by other agencies.

By pursuing these goals, the OTIC VSL and DMS project aims to create a transformative impact on the Ohio Turnpike, enhancing safety, efficiency, and resilience while contributing to the broader advancement of intelligent transportation systems.

3.0 Users and Stakeholders

The successful implementation and operation of the VSL and DMS systems on the Ohio Turnpike rely on the coordinated efforts of various stakeholders. Each group plays a crucial role in ensuring the system's effectiveness, from initial design through daily operations and ongoing maintenance. This section outlines the key stakeholders, their roles, and their responsibilities within the context of this project.

Lead Designer (Michael Baker International (MBI))

- **Role**: Civil and Systems Engineering
- **Responsibilities**:
  - Oversee the comprehensive design and development process of both the VSL and DMS systems.
  - Ensure that the design meets all specified requirements and integrates seamlessly with existing infrastructure.
  - Coordinate with other stakeholders to incorporate feedback and make necessary adjustments.
  - Conduct system analyses and optimize the design for OTIC's specific needs.

As the Lead Designer, MBI plays a pivotal role in shaping the VSL and DMS systems. Its expertise ensures that each component meets the highest standards of functionality and reliability while promoting system cohesion and operational efficiency. Through ongoing coordination with other stakeholders, MBI fosters a collaborative approach that results in a system that is both comprehensive and user-centric.

Traffic Management Authority (OTIC)

- **Role**: System Operators and Managers
- **Responsibilities**:
  - Monitor and manage the VSL and DMS and supporting ITS systems on a daily basis.
  - Ensure that the systems are functioning correctly and efficiently.
  - Respond to real-time data and review and approve speed limits adjustments and messages as needed.
  - Coordinate with local law enforcement and emergency services during incidents.
  - Oversee system maintenance and upgrades.

As the primary System Operators and Managers, traffic management authorities, including OTIC, are central to the day-to-day operation of the VSL and DMS systems. Their continuous monitoring and informed decision-making ensure real-time responsiveness to changing road and weather conditions, balancing safety considerations with traffic flow optimization.

Local Law Enforcement (OSHP)

- **Role**: Enforcement and Safety
- **Responsibilities**:
  - Enforce the variable speed limits and ensure compliance by drivers.
  - Respond to incidents and emergencies on the turnpike.
  - Collaborate with traffic management authorities to enhance road safety.
  - Provide feedback on the system's effectiveness from a law enforcement perspective.

Local law enforcement agencies play a crucial role in the Enforcement and Safety aspects of the system. Their on-the-ground presence and swift response capabilities are essential for maintaining the integrity of the variable speed limits and ensuring overall road safety.

Emergency Services (OSHP, Local Fire Department)

- **Role**: Incident Response
- **Responsibilities**:
  - Provide rapid response to collisions and emergencies.
  - Coordinate with traffic management authorities and local law enforcement during incidents.
  - Ensure that emergency vehicles can navigate the turnpike safely and efficiently.
  - Offer insights on how the system impacts emergency operations.

Emergency Services personnel are vital for Incident Response. Their ability to leverage the enhanced situational awareness provided by the VSL and DMS systems contributes to more effective and efficient emergency responses on the turnpike.

General Public (Travelers)

- **Role**: System Users
- **Responsibilities**:
  - Adhere to the variable speed limits and follow the messages displayed on the DMS.
  - Provide feedback on the system's effectiveness and report any issues.
  - Stay informed about current road conditions and adjust driving behavior accordingly.

As the primary System Users, the general public plays a crucial role in the success of the VSL and DMS systems. Their adherence to the system's guidance and active participation in providing feedback contribute significantly to the overall safety and efficiency of the turnpike.

By clearly delineating the roles and responsibilities of each stakeholder group, this project aims to create a collaborative ecosystem that ensures the VSL and DMS systems operate at peak effectiveness. The success of this initiative relies on the active engagement and cooperation of all these stakeholders, working together to enhance safety, improve traffic flow, and optimize the overall experience for all users of the Ohio Turnpike.

4.0 User Needs

This section outlines the specific needs of various stakeholders that OTIC's VSL and DMS system aims to address. Understanding these user needs is crucial for designing a system that meets the expectations and requirements of all users, ensuring enhanced safety, efficiency, and overall satisfaction. The user needs are categorized into general needs, as well as specific needs related to the VSL, DMS, Road Weather Information Systems (RWIS) and wrong-way driving detection (WWDD) systems.

User Needs – General (UN)

These are the overarching needs that apply to all users of the system. They include requirements for system reliability, ease of use, and overall effectiveness in improving traffic management and safety. Each need will be identified with an ID starting with "UN" followed by a number (e.g., UN1, UN2).

User Needs – VSL (UNVSL)

These needs are specific to the VSL system. They focus on the ability to dynamically adjust speed limits based on real-time traffic conditions, weather, and other factors to enhance road safety and traffic flow. Each need will be identified with an ID starting with "UNVSL" followed by a number (e.g., UNVSL1, UNVSL2).

User Needs – DMS (UNDMS)

These needs pertain to the DMS system. They emphasize the importance of clear, timely, and accurate information dissemination to drivers, such as traffic updates, road conditions, and emergency alerts. Each need will be identified with an ID starting with "UNDMS" followed by a number (e.g., UNDMS1, UNDMS2).

User Needs – Vehicle Detection (UNVD)

These needs are related to the vehicle detection system. Each need will be identified with an ID starting with "UNVD" followed by a number (e.g., UNVD1, UNVD2).

User Needs – Wrong Way Driving Detection (UNWWDD)

These needs are related to the wrong-way detection system. They highlight the necessity for early detection and warning of vehicles traveling in the wrong direction to prevent crashes and ensure driver safety. Each need will be identified with an ID starting with "UNWWDD" followed by a number (e.g., UNWWDD1, UNWWDD2).

User Needs – Road Weather Information Systems (UNRWIS)

These needs are related to the Road Weather Information Systems (RWIS). They emphasize the importance of monitoring real-time weather conditions, predicting short-term weather changes, and integrating data from multiple sources to ensure road safety. Each need will be identified with an ID starting with "UNRWIS" followed by a number (e.g., UNRWIS1, UNRWIS2).

User Needs – Closed-Circuit Television (CCTV) (UNCCTV)

These needs are related to the CCTV system. They focus on the requirements for effective visual monitoring and data collection to support traffic management and safety. Each need will be identified with an ID starting with "UNCCTV" followed by a number (e.g., UNCCTV1, UNCCTV2).

User Needs – Priorities

In order to effectively address the diverse needs of stakeholders, the user needs for OTIC's VSL and DMS systems have been prioritized based on their criticality and impact on system performance and user satisfaction. High-priority needs are those that are essential for ensuring system reliability, safety, and seamless integration with emergency and dispatch systems. These needs must be addressed immediately to guarantee the system's core functionality and effectiveness. Medium-priority needs, while important, focus on enhancing operational efficiency, user experience, and feedback mechanisms, and should be addressed after the high-priority needs. Low-priority needs are those that can be considered for long-term implementation or as resources allow, often involving future scalability and adaptability to new technologies. This prioritization ensures a structured approach to system development, addressing the most critical aspects first while planning for continuous improvement and future enhancements.

TABLE 1. GENERAL USER NEEDS

ID	User Need	Priority
UN-1	Need to provide motorists reliable, accurate, and timely real-time warnings of inclement meteorological conditions that limit visibility.	High
UN-2	Need to provide motorists reliable and timely advanced notification of inclement pavement conditions.	High
UN-3	Need to provide motorists reliable and timely advanced notification of inclement meteorological condition that are hazardous to vehicle operation.	High
UN-4	Need for the system to detect and respond to stopped or slow-moving vehicles that may indicate incidents or congestion.	Low
UN-5	Need to improve safety in areas that are prone to crashes and incidents due to road weather events.	High
UN-6	Need to operate a proposed notification system in a manner that provides reliable messaging while reducing operator workload, such as through use of decision-tree recommendations or automation.	High
UN-7	Need to ensure the system is user-friendly and intuitive for both operators and motorists.	High
UN-8	Need to ensure the system is resilient to cyber threats and unauthorized access.	High
UN-9	Need to integrate with emergency response systems to provide coordinated incident management.	High
UN-10	Need to ensure the system can operate effectively under various environmental conditions, including extreme weather.	High
UN-11	Need to integrate with Computer Aided Dispatch systems operated by OHSP to provide notification roadway conditions and DMS and VSL activations.	High
UN-12	The system needs to provide recommended speed limit changes that can be approved by the Comm Center operator. Once approved, all variable speed limit signs should be updated simultaneously to reflect the new speed limits.	High
UN-13	The operator will have the ability to cancel actions taken by the system.	High
UN-14	Need to have dedicated display(s) for Comm Center operators to easily monitor the conditions on the roadway and sign messaging status along the entire corridor and specifically for the VSL section.	High
UN-15	Need to ensure speed limit signs are highly visible and legible under all conditions.	High
UN-16	Need to provide feedback mechanisms for drivers to report issues or provide input on the VSL system.	Medium
UN-17	System needs to be capable of sharing real-time data on road conditions, traffic incidents, and speed limit changes with navigation applications like Waze and Google and OHGO website managed by ODOT.	High
UN-18	System needs to have a mechanism for drivers to provide feedback on road conditions and incidents through navigation apps, enhancing the accuracy and timeliness of the information.	Low

UN-19	System needs to be scalable, allowing for the integration of additional ITS elements and new technologies like those for connected and automated vehicles as they become available.	Medium
UN-20	System needs to have a robust data backup and recovery system to ensure continuity of operations in case of system failures.	High
UN-21	System needs to have the ability adapt to future technological advancements and changing traffic management strategies.	Medium
UN-22	Need for a comprehensive training program for all system operators and maintenance personnel.	High
UN-23	Need to integrate new video sources with existing video management system (Milestone Xprotect)	High
UN-24	Need to collect performance measures to demonstrate value and return-on-investment of technological systems.	High
UN-25	Ability to provide visual confirmation of DMS and VSL operational status.	High
UN-26	Ability to provide visual confirmation of weather conditions.	High
UN-27	The system needs to actively monitor the health and status of all ITS elements and provide reports for assisting maintenance staff on any immediate repairs or scheduled maintenance activities.	High
UN-28	The system needs to collect, store, and disseminate operations data generated by the ITS elements for future reporting, engineering analysis and legal discovery. This will include VSL sign and DMS activations/deactivations along with video information provided through the existing video management system.	High

TABLE 2. DYNAMIC MESSAGE SIGNS USER NEEDS

ID	User Need	Priority
UNDMS-1	Need to support other traffic operations information, such as informing motorists of work zones, traffic incidents, and slow speed advisories.	High
UNDMS-2	Need to provide specific speed-related operational messages to help encourage motorists to collectively reduce speed when necessary for inclement travel conditions.	High
UNDMS-3	Need to strategically place DMS signs to maximize visibility and impact.	High
UNDMS-4	Need for the system to prioritize messages based on urgency and relevance when multiple messages need to be displayed.	High
UNDMS-5	Need for the ability to display graphical information (e.g., simple icons or symbols) alongside text messages for improved comprehension.	Medium
UNDMS-6	Need to ensure DMS messages are clear, concise, and easily understandable to all motorists.	High
UNDMS-7	Need to integrate DMS with other traffic management systems for coordinated information dissemination.	High
UNDMS-8	Need to provide real-time updates on traffic conditions and incidents to help motorists make informed decisions.	High
UNDMS-9	Need to ensure DMS systems are resilient to environmental conditions and vandalism.	High
UNDMS-10	Need to provide training for operators on effective DMS message creation and management.	Medium
UNDMS-11	Need to ensure DMS systems comply with regulatory standards and guidelines.	High

TABLE 3 VARIABLE SPEED LIMITS USER NEEDS

ID	User Need	Priority
UNVSL-1	Need capability to dynamically adjust speed limits based on real-time traffic conditions to enhance road safety and traffic flow.	High

UNVSL-2	Need to integrate weather data to adjust speed limits during adverse weather conditions.	High
UNVSL-3	Need to provide clear and timely communication of speed limit changes to motorists.	High
UNVSL-4	Need to ensure speed limit signs are visible and legible under all lighting and weather conditions.	High
UNVSL-5	Need to minimize the frequency of speed limit changes to avoid driver confusion.	Medium
UNVSL-6	Need to collect and analyze data on the effectiveness of speed limit changes in improving traffic safety and flow.	Medium
UNVSL-7	Need to coordinate speed limit changes with other traffic management systems to ensure consistency.	High
UNVSL-8	Need to provide feedback mechanisms for drivers to report issues or provide input on the VSL system.	Medium
UNVSL-9	Need to ensure the system can adapt to future technological advancements and changing traffic management strategies.	Medium
UNVSL-10	Need to integrate with navigation applications to provide real-time speed limit updates to drivers.	Medium
UNVSL-11	Need to ensure the system is resilient to cyber threats and unauthorized access.	High
UNVSL-12	Need to provide training for operators on managing and monitoring the VSL system.	Medium
UNVSL-13	Need to ensure compliance with regulatory standards and guidelines for speed limit changes.	High
UNVSL-14	Need to log when the system detects the necessary conditions when a reduced speed limit is required and when conditions return to a normal state.	Medium
UNVSL-15	Need to ensure continuous operation of VSL signs, cameras, and communication equipment during power outages.	Medium
UNVSL-16	Need to develop and implement an algorithm to determine appropriate speed limits.	High
UNVSL-17	Need for VSL systems to operate automatically or semi-automatically	High
UNVSL-18	Need to provide real-time VSL sign speed limit information to law enforcement	High
UNVSL-19	Need to log each instance of a VSL sign speed limit change.	Medium

TABLE 4. VEHICLE DETECTION USER NEEDS

ID	User Need	Priority
UNVD-1	Ability to collect volume, speed, and occupancy of vehicles at key locations along the turnpike.	High
UNVD-2	Ability to collect vehicle classification information at key locations along the turnpike.	High
UNVD-3	Ability to quickly assess traffic conditions promptly through real-time feeds.	High
UNVD-4	Ability to support Wrong Way Driving Detection User Needs on the same platform.	High
UNVD-5	Need to comply with cybersecurity industry standards and regulations.	High

TABLE 5. WRONG WAY DRIVERS DETECTION USER NEEDS

ID	User Need	Priority
UNWWDD-1	Need to detect Wrong way drivers and notify the Comm Center to notify OSHP.	High
UNWWDD-2	Need to detect Wrong way drivers and notify other drivers in the impacted area through DMS	High
UNWWDD-3	Need to accurately detect vehicles traveling in the wrong direction on the turnpike.	High
UNWWDD-4	Need to provide immediate alerts to both the wrong-way driver and other drivers in the vicinity of wrong way driving events to prevent crashes.	High
UNWWDD-5	Need to automatically notify local law enforcement of wrong-way incidents for rapid response.	High

UNWWDD-6	Need to maintain a log of wrong-way incidents for analysis and assessment of potential causes and remediation.	Medium
UNWWDD-7	Need for the system to integrate with in-vehicle navigation systems to provide direct alerts to wrong-way drivers.	Low

TABLE 6. ROAD WEATHER INFORMATION SYSTEMS USER NEEDS

ID	User Need	Priority
UNRWIS-1	Need to monitor real-time weather conditions such as ambient and pavement temperature, visibility, and wind speeds impacting the roadway.	High
UNRWIS-2	Ability to send data to Comm Center in real time.	High
UNRWIS-3	Need for the system to predict short-term weather changes that could affect road conditions.	High
UNRWIS-4	Need for the system to integrate data from multiple weather sources, including nearby weather stations and national weather services, for more accurate and comprehensive weather information.	High
UNRWIS-5	The system needs to provide a user-friendly interface for operators to easily monitor weather conditions and system status.	Medium
UNRWIS-6	The system needs to store historical weather data and provide tools for analyzing trends and patterns to improve future weather predictions and traffic management strategies.	Low
UNRWIS-7	The system needs to be scalable and flexible to accommodate future expansions, additional sensors, and new technologies as they become available.	Medium
UNRWIS-8	The system needs to ensure that all collected and transmitted data is secure and complies with privacy regulations to protect sensitive information.	High

TABLE 7. CCTV SYSTEMS USER NEEDS

ID	User Need	Priority
UNCCTV-1	Ability to provide valuable visual information to law enforcement and emergency services to assist in managing incidents.	Medium
UNCCTV-2	Need to enhance the situational awareness of comm center operators by providing comprehensive visual coverage of key areas.	High
UNCCTV-3	Ability to utilize existing video management system to maintain a record of video footage for post-incident analysis, training, improving future traffic management strategies and legal purposes	Medium
UNCCTV-4	Need to ensure seamless integration of CCTV cameras with existing video management system	High
UNCCTV-5	Ability to share relevant CCTV footage with the public to enhance transparency and provide real-time traffic updates, helping motorists make informed travel decisions.	Medium
UNCCTV-6	Need to implement measures to protect the privacy of individuals and secure the data collected by CCTV systems, ensuring compliance with relevant regulations and standards.	High
UNCCTV-7	The system should include a mechanism to lower cameras for maintenance and cleaning, ensuring they remain operational and provide clear images.	High
UNCCTV-8	Adequate coverage requires a sufficient number of cameras strategically placed along the turnpike to monitor key areas, including high-traffic zones and locations prone to adverse weather conditions.	High
UNCCTV-9	Cameras should capture clear and detailed images, even in low-light or adverse weather conditions.	High
UNCCTV-10	Cameras should have PTZ capabilities to allow operators to remotely adjust the field of view, zoom in on specific areas, and track moving objects or incidents.	High

UNCCTV-11	Cameras need to be robust and weather-resistant to withstand harsh environmental conditions, ensuring continuous operation.	High
UNCCTV-12	The CCTV system should seamlessly integrate with the central traffic management system and existing video management system, providing real-time video feeds and allowing operators to make informed decisions based on visual data.	High
UNCCTV-13	The interface for controlling and monitoring the CCTV system should be intuitive and easy to use, enabling operators to quickly access and manipulate camera views.	High
UNCCTV-14	The CCTV system should have the capability to record and store video footage for a specified period, allowing for review and analysis of past events.	High
UNCCTV-15	Operators should be able to access and control the CCTV system remotely, ensuring continuous monitoring even when not physically present at the traffic management center.	Medium
UNCCTV-16	The system should be scalable to allow for the addition of more cameras and other components as needed, without significant reconfiguration.	High
UNCCTV-17	The system should include redundancy and backup features to ensure continuous operation in case of equipment failure or power outages.	Medium
UNCCTV-18	The CCTV system should have robust cybersecurity measures in place to protect against unauthorized access and ensure the integrity of the video data.	High
UNCCTV-19	The system should provide alerts for maintenance needs, such as cleaning or technical issues, to ensure cameras are always functioning optimally.	High
UNCCTV-20	Comprehensive training and support should be provided to operators to ensure they can effectively use and manage the CCTV system.	Medium

5.0 System Overview

The system will operate in environments characterized by varying visibility conditions, including fog, rain, and snow. This adaptive system seamlessly integrates with existing OTIC infrastructure, leveraging real-time data to respond dynamically to changing road and weather conditions. The system's architecture is comprised of three primary components: Field Information Collection, Information Processing, and Information Distribution.

5.1 Field Information Collection

The foundation of the system's effectiveness lies in its robust network of ITS sensors and monitoring devices strategically positioned along the entire length of the Ohio Turnpike. The VSL component of the project will be focused on a subsection of the turnpike between MP 91 and MP 118. This network incorporates advanced weather sensors capable of detecting temperature fluctuations, pavement conditions, precipitation levels, and visibility ranges. High-definition traffic cameras provide real-time visual monitoring.

This comprehensive array of devices collects real-time data on weather conditions, road surface conditions, and traffic flow. This wealth of information enables the system to swiftly detect and respond to adverse conditions, forming the foundation for informed decision-making and timely interventions.

CCTV cameras will be positioned to provide visual confirmation of DMS messaging and VSL sign status. The video images provided will also confirm current roadway and weather conditions. The cameras will be capable of pan, tilt and zoom and in some cases, there will be multiple cameras included in one housing to capture multiple video feeds focused on different zones.

5.2 Information Processing

Once collected, the data is efficiently transmitted to the Communications Center in Berea via a robust communication network. Here, the raw data undergoes sophisticated processing and analysis. Advanced algorithms, specifically designed for this system, assess the incoming data to determine the current state of the roadway and predict potential hazards. Based on this analysis, the system calculates optimal speed limits and generates appropriate messages for drivers. This process involves complex decision-making algorithms that consider multiple factors simultaneously to ensure the most appropriate response to current conditions. A crucial feature of this system is the involvement of the Communications Center operator. The system will provide notifications with recommended changes to speed limits and DMS messages. Operators will have the opportunity to review these recommendations and, with a single button press, implement the changes across the focus area/system. This ensures that operators can make informed decisions while maintaining control over the system, even when engaged in other critical tasks. This human oversight adds an additional layer of verification, ensuring that all system outputs are appropriate and contextually relevant. Initially the system will rely on the operator for approval and as the system becomes more finely tunes and the operators comfort level goes up, the system may be switched a fully automatic mode.

5.3 Information Distribution

The processed information will be distributed to drivers and external stakeholders through various means. The DMS will display real-time messages, such as warnings about upcoming hazards, changes in speed limits, and other critical information. The VSL signs will update to reflect the new speed limits calculated by the system. This real-time distribution ensures that drivers receive timely and relevant information, allowing them to adjust their driving behavior accordingly.

Data will be made through available through APIs to feed third party data providers such as Waze and Google Maps so those users can see the latest information on the turnpike conditions. Information will also be provided to the ODOT OHGO traveler information website and app.

5.4 Conceptual Architecture

The system's conceptual architecture is designed for robustness, scalability, and seamless integration. It comprises several key components:

1. Field Devices:
   - Sensors and Monitoring Devices:
     - Weather sensors (temperature, precipitation, visibility, winds speed)
     - Traffic flow sensors
     - CCTV cameras
   - Variable Speed Limit (VSL) Signs: Update speed limits based on the processed data
   - Dynamic Message Signs (DMS): Display real-time messages to drivers

2. Communication Network:
   - Fiber optic backbone access at OTIC facilities

- 5G/4G LTE cellular
- Dedicated unlicensed Wireless links

3. Central Management System:
   - Operator interfaces to monitor and manage field devices
   - Data processing and analytics engine
   - Automated decision-making algorithms
   - User interface for communications center operators
   - Data storage and management system
   - Video display

4. Integration Interfaces:
   - Emergency services
   - Law enforcement CAD system
   - Public information systems (OHGO website, 3rd party mobile app)

Data Flow

Communication network ensures seamless data transmission between sensors, the central system, and the distribution components.

1. Field devices continuously collect and transmit data to the central system.
2. The central system processes the data in real-time, using predefined algorithms to determine appropriate speed limits and messages.
3. Video can be viewed by operators to confirm conditions and messaging.
4. Operators can review and override system recommendations if necessary.
5. Operators can post ad hoc messages on DMS as needed.
6. Updated speed limits and messages are transmitted back to the field devices for display.
7. Relevant information is pushed to integrated systems for law enforcement and emergency services.
8. Information is pushed to ODOT OHGO and 3rd party data providers through API.

Conceptual Architecture Diagram

The conceptual architecture diagram provides a high-level overview of the system's structure and components. It illustrates how the various subsystems, including VSL, DMS, CCTV, and RWIS, interact with each other and with external systems. This visual representation helps stakeholders understand the system's design, data flow, and integration points, ensuring a cohesive and efficient implementation.

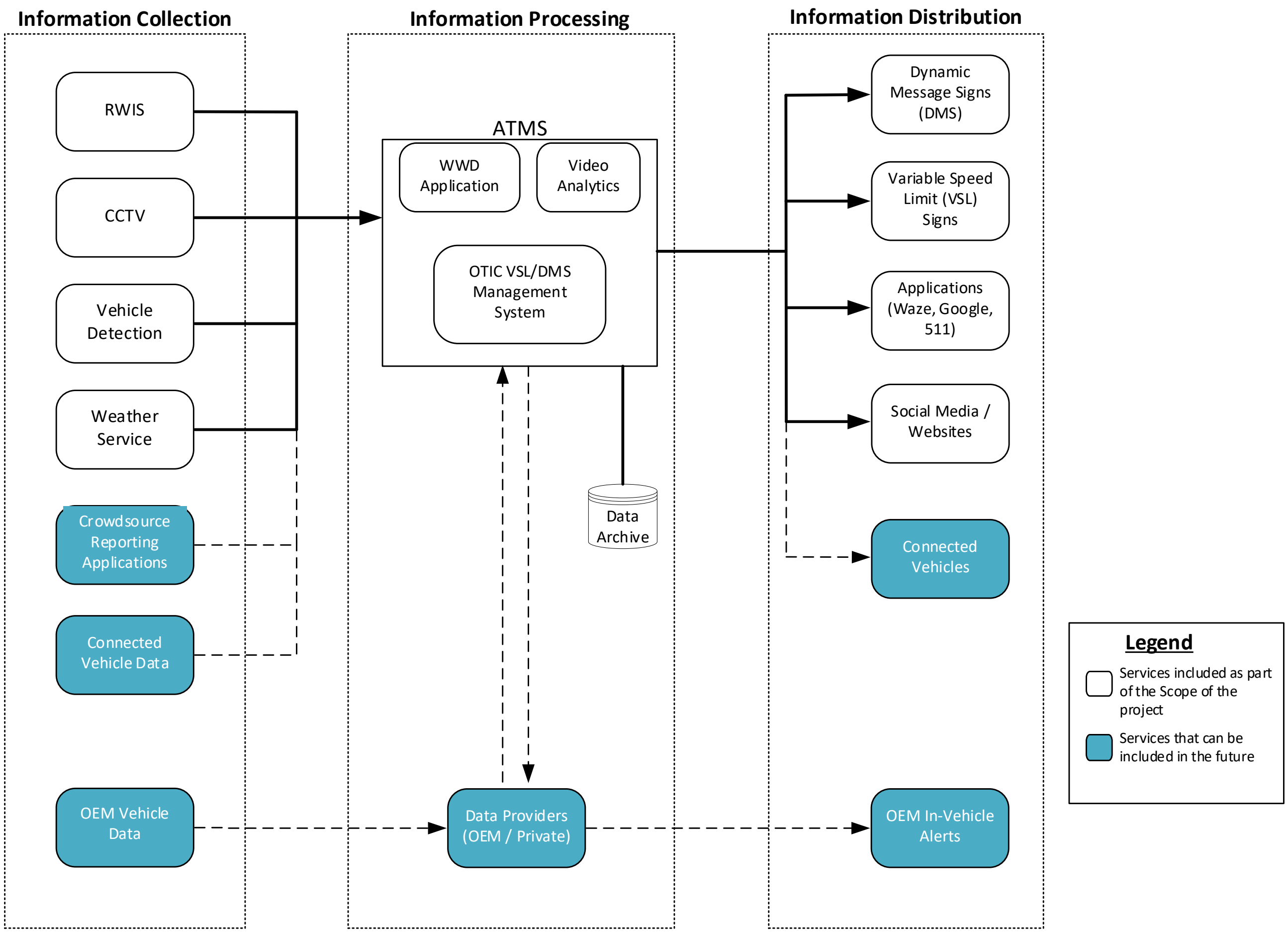

FIGURE 2. CONCEPTUAL ARCHITECTURE DIAGRAM

5.1 Operational Policies and Constraints

The operation of the VSL and DMS systems will be governed by a set of policies and constraints to ensure safety, efficiency, and compliance with regulatory standards. Key policies include:

- **Safety First**: The primary objective is to enhance road safety by providing accurate and timely information to drivers.
- **Data Privacy**: Ensure that all collected data is handled in compliance with privacy regulations and used solely for traffic management purposes.
- **System Reliability**: Maintain high system reliability through regular maintenance, updates, and testing.
- **Coordination with Authorities**: Collaborate with local law enforcement and emergency services to manage incidents and ensure compliance with speed limits.
- **Continuous Improvement:** Regular system performance reviews and stakeholder feedback sessions are conducted to identify areas for improvement and implement necessary enhancements.

These policies and constraints form the operational framework for the VSL and DMS systems, ensuring that the technology serves its intended purpose while maintaining the highest standards of safety, efficiency, and legal compliance.

6.0 Operational Scenarios / Use Cases

This section discusses operational scenarios that are relevant to OTIC's proposed VSL and DMS system. Each operational scenario focuses on a specific type of road weather event or traffic condition, illustrating how the VSL and DMS systems will function to enhance safety and traffic management on the Ohio Turnpike. These scenarios provide detailed examples of how the system responds dynamically to real-time data, ensuring that drivers receive timely and accurate information to navigate various conditions safely.

1. Limited Visibility
2. Inclement Weather
3. Traffic Incident
4. Road Work Zones
5. Wrong Way Driver Detection

Each scenario will detail the steps involved in detecting the condition, processing the information, and distributing relevant messages and speed adjustments to drivers. By examining these scenarios, stakeholders can gain a comprehensive understanding of the VSL and DMS systems' capabilities and their impact on road safety and traffic efficiency.

6.1 Limited Visibility

A driver is traveling on the Ohio Turnpike near MP 91, where OTIC has implemented a weather-responsive advisory system due to high-profile incidents occurring in the past during adverse weather conditions. This system includes Road Weather Information Systems (RWIS), traffic speed detectors, variable speed limit (VSL) dynamic signs, and CCTV cameras positioned between mileposts 91 and 118. Additionally, the turnpike is equipped with overhead DMS in both directions.

On this particular day, several roadside RWIS units detect meteorological conditions indicative of whiteout snow conditions. These RWIS units transmit the data to OTIC's operations center. Along with data from other reliable meteorological sources, the operations center uses a pre-programmed decision tree to determine an appropriate response. The algorithm automatically suggests displaying a message on the DMS to alert drivers of low visibility along with a recommend reduced speed limit based on the severity of conditions. The Operator, in conjunction with the Chief Engineer or designee, reviews the recommended speed limit and once approved, the VSLs automatically adjust.

The DMS located both before and within the affected area immediately activate, displaying a message that reads "LOW VISIBILITY AHEAD" along with a graphical regulatory speed limit. The driver, who has not yet encountered the weather conditions, sees the sign and decides to proceed with caution, anticipating reduced visibility. Operators at the OTIC operations center are notified of the automated message activation and use the cameras to visually confirm the presence of whiteout snow along the corridor. Local law enforcement may also be alerted to monitor for potential incidents in the snow-affected area.

6.2 Inclement Weather

The Ohio Turnpike is experiencing a severe thunderstorm with heavy rainfall. The VSL and DMS systems work in tandem to manage traffic safety during these challenging conditions.

Multiple weather sensors along the turnpike detect the intensity of the rainfall and reduced visibility. This data is transmitted to the central traffic management system, which processes the information and determines the appropriate response. The system recommends a lower the speed limit to the Comm Center Operator in tandem with issuing warnings to drivers. The Operator, in conjunction with the Chief Engineer or designee, reviews the recommended speed limit and, once approved, VSL signs along the affected stretch of the turnpike display reduced speed limits, depending on the severity of the conditions. Simultaneously, DMS activate with messages such as "SEVERE WEATHER AHEAD - REDUCE SPEED" and "HEAVY RAIN - USE CAUTION".

As drivers enter the affected area, they are met with both the lowered speed limits and warning messages, allowing them to adjust their driving behavior accordingly. The system continues to monitor the storm's progress, adjusting speed limits and messages as the weather system moves along the turnpike.

6.5 Traffic Incident

A driver traveling along the Ohio Turnpike encounters a crash ahead. As the vehicle approaches the crash scene, the VSL and DMS systems activate to ensure the safety of all drivers in the vicinity.

Traffic cameras and road condition sensors detect the resulting traffic congestion. This data is immediately relayed to the central traffic management system. The traffic management system analyzes the data and determines that the crash poses a significant risk to drivers and requires immediate action to manage traffic flow and ensure safety. The system provides recommended messages, and the Operator confirms resulting in the DMS system displaying a warning message on electronic signs positioned before the crash scene. The message reads: "CRASH AHEAD / REDUCE SPEED / PREPARE TO STOP." In areas where there are VLSs, the VSL system adjusts the speed limit for the affected section of the turnpike. Electronic speed limit signs update to reflect the new, lower speed limit, ensuring that drivers are aware of the necessary speed reduction.

The driver sees the warning message and the updated speed limit. They reduce their speed accordingly and prepare to stop if necessary. The traffic management system continues to monitor the situation, providing real-time updates and additional warnings if the traffic conditions change or if further incidents occur. Local law enforcement and emergency services are alerted to the crash and dispatched to the scene. They work to manage the traffic, assist any injured parties, and clear the crash scene as quickly and safely as possible. Once the crash is cleared and traffic flow returns to normal, the system recommends the VSL and DMS systems revert to their standard operations, the operator confirms, and the system removes the warning messages and restoring the regular speed limits. By providing real-time information and dynamically adjusting speed limits, the VSL and DMS systems help ensure that drivers can safely navigate around crash scenes, reducing the risk of secondary collisions and improving overall road safety.

6.6 Road Work Zone

A major road maintenance project is underway on a 5-mile stretch of the Ohio Turnpike between mileposts 100 and 105. The VSL and DMS systems play a crucial role in managing traffic flow and ensuring worker and driver safety throughout the duration of this project.

Well in advance of the work zone, the system begins to alert approaching drivers. DMS located 10 miles before the construction area display messages such as "ROAD WORK AHEAD - PREPARE TO REDUCE SPEED" and "CONSTRUCTION ZONE - FINES DOUBLED". These early warnings allow drivers to mentally prepare for changed conditions and potentially consider alternative routes if appropriate.

As vehicles approach closer to the work zone, the VSL sign displays a lowered speed limit for the safety of the workers on foot and drivers.

The DMS system works in tandem with the VSL, providing more specific information as drivers get closer. Messages might include "RIGHT LANE CLOSED AHEAD" or "MERGE LEFT - 1000 FT", helping to manage traffic flow and reduce last-minute lane changes.

The DMS within the work zone provide real-time updates on conditions, with messages like "SLOW TRAFFIC AHEAD - BE PREPARED TO STOP" or "WORKERS PRESENT - STRICT SPEED ENFORCEMENT".

As vehicles exit the work zone, VSL signs step the speed back up to normal limits, while DMS thank drivers for their caution with messages like "END WORK ZONE - DRIVE SAFELY".

Throughout the project, the system continuously monitors traffic flow, worker presence, and any incidents within the work zone. It adjusts speed limits and messages in real-time to optimize safety and traffic flow based on current conditions. Operators at the Comm Center can remotely monitor the work zone and lane closures in real time and the system can send data and video to OHGO notifying drivers of what they can expect.
This dynamic management of the work zone not only enhances safety for both workers and drivers but also helps to minimize congestion and delays associated with the construction project. By providing clear, timely, and relevant information, the VSL and DMS systems help drivers navigate the changed road conditions safely and efficiently.

Although this scenario relies on work occurring in the VSL section, work outside if the VSL section can benefit from the DMS and CCTV in those areas.

6.7 Wrong Way Driver Detection

A vehicle has managed to enter the turnpike through an exit ramp or has somehow been turnaround while on the mainline. This vehicle is now traveling the wrong direction on the mainline of the turnpike in the vicinity of the VSL segment. Infrared video or radar-based vehicle detection applying AI analytics detects the vehicle. The field detection device immediately alerts the Comm Center and the OSHP through the CAD system of a possible wrong way driving event.

Through a prepared notification strategy approved by the Chief Engineer, DMSs downstream of the wrong way driver (upstream for normal traffic) are automatically posted with a message “WRONG WAY DRIVER AHEAD - USE CAUTION” or “WRONG WAY DRIVER REPORTED - STAY ALERT” as examples.

Nearby CCTV cameras images are immediately displayed at the Comm Center for visual confirmation and tracking by the Comm Center. Post analysis can be conducted through recorded video to determine the preceding events that led to the wrong way driving event. An after-action report will be developed to see what improvements, if any, need to be made improve response.

7.0 Operational Needs and Procedures

The effective implementation and operation of the VSL and DMS systems on the Ohio Turnpike requires a comprehensive understanding of key operational needs. These needs form the foundation upon which the system's functionality is built, ensuring that it can respond dynamically to changing road conditions, communicate effectively with all stakeholders, and maintain high levels of performance and reliability. By addressing these operational needs, OTIC can maximize the system's potential to enhance road safety, improve traffic flow, and provide a superior driving experience for all turnpike users. The following subsections outline the critical operational needs that underpin the VSL and DMS systems:

7.1 Operational Needs

To support the complex operations of the VSL and DMS systems, several key operational needs must be addressed:

1. Real-Time Data Processing
The system requires the ability to analyze and respond to traffic conditions instantly. This involves processing large volumes of data from various sensors and sources in real-time, enabling rapid decision-making and system responses.

2. User-Friendly Interface
The system must provide accessible information for all user groups, including traffic management operators, emergency services personnel, and the general public through websites and social media platforms. Intuitive interfaces are crucial for efficient system operation and effective information dissemination.

3. Robust Communication Channels
Reliable information flow among stakeholders is essential. This includes seamless data transmission from field devices to the central system, as well as effective communication channels between traffic management authorities, emergency services, and the public.

4. Scalability and Flexibility
The system should be designed to accommodate future expansions and technological advancements, allowing for the integration of new features and capabilities as needs evolve.

5. Redundancy and Reliability
Given the critical nature of the system, redundant components and backup systems are necessary to ensure continuous operation even in the event of partial system failures.

6. Data Security and Privacy
Robust measures must be in place to protect the integrity and confidentiality of the data collected and processed by the system, complying with all relevant data protection regulations.

7.2 Operational Procedures

The operational procedures for the OTIC VSL and DMS project are carefully designed to ensure the effective and efficient functioning of the system. These procedures incorporate daily operations, monitoring, and maintenance activities necessary to maintain optimal performance and safety. By adhering to these procedures, OTIC aims to maximize the benefits of the VSL and DMS systems, enhancing road safety and improving traffic management along the Ohio Turnpike.

1. System Monitoring and Data Collection

- **Continuous Monitoring**: The central management system a continuously monitors real-time data from road weather sensors, CCTV cameras and vehicle detection sensors.
- **Data Analysis**: Collected data is analyzed real-time to assess current road and weather conditions, traffic flow, and potential hazards.

2. Dynamic Speed Limit Adjustment

- **Real-Time Adjustments**: The VSL system dynamically suggests speed limits based on real-time data. These suggestions are provided to operators for confirmation. Once confirmed, speed limits are lowered during adverse conditions (e.g., heavy rain, snow, fog) and increased when conditions improve.
- **Speed Limit Display**: Updated speed limits are displayed on variable speed limit signs along the turnpike.

3. Message Dissemination

- **Warning Messages**: The DMS system displays real-time messages to drivers, providing warnings about upcoming hazards, changes in speed limits, and other critical information.
- **Message Updates**: Messages are updated based on the latest data from traffic management centers, weather stations, and other relevant sources.

4. Incident Management

- **Crash Response**: In the event of a crash or other roadway incident, the VSL and DMS systems are activated to manage traffic flow and ensure safety. Speed limits are adjusted, and warning messages are displayed to alert drivers.
- **Coordination with Emergency Services**: Traffic management authorities coordinate with local law enforcement and emergency services to manage the incident and clear the scene as quickly and safely as possible.

5. System Maintenance

- **Regular Inspections**: Routine inspections and maintenance of the VSL and DMS and supporting ITS elements and supporting communications infrastructure are conducted to ensure all components are functioning correctly.
- **System Updates**: Software and hardware updates are applied as needed to maintain system performance and security and incorporate new technologies as they appropriate.

6. Stakeholder Communication

- **Public Information**: Information about the VSL and DMS systems, including any changes or updates, is communicated to the general public through various channels (e.g., websites, social media, press releases).
- **Feedback Mechanism**: A feedback mechanism is established to allow drivers and other stakeholders to report issues and provide input on the system's effectiveness.

7. Performance Monitoring and Reporting

- **Performance Metrics**: Key performance metrics (e.g., crash rates, traffic flow, system reliability) are monitored to evaluate the effectiveness of the VSL and DMS systems.
- **Regular Reporting**: Regular reports are generated to provide insights into system performance and identify areas for improvement.

By implementing these detailed operational procedures, OTIC ensures that the VSL and DMS systems function at peak efficiency, maximizing their potential to enhance safety and improve traffic flow along the Ohio Turnpike. These procedures also provide a framework for continuous improvement, allowing the system to evolve and adapt to changing needs and technological advancements.

8.0 System Design Considerations

The design of the VSL and DMS systems for OTIC requires careful consideration of various factors to ensure the systems are effective, reliable, and user-friendly. This section outlines the key design considerations that must be addressed during the development and implementation phases.

8.1 System Integration

- **Compatibility**: Ensure that the VSL and DMS systems are compatible with existing traffic management infrastructure and other Intelligent Transportation Systems (ITS).
- **Interoperability**: Design the systems to work seamlessly with various data sources, including weather sensors, traffic cameras, and road condition monitoring devices. Implement standard communications protocols such as IEEE, NTCIP and NEMA for interfacing with different ITS field devices and central systems.
- **Scalability**: The systems should be scalable to accommodate future expansions, additional sensors, and new technologies.

8.2 Reliability and Redundancy

- **System Reliability**: Design the systems to operate reliably under all conditions, including adverse weather and high traffic volumes.
- **Redundancy**: Implement redundant components and failover mechanisms where feasible to ensure continuous operation in case of hardware or software failures.
- **Maintenance**: Establish regular maintenance schedules and procedures to keep the systems in optimal working condition.
- **Central Management:** Implement failover mechanisms for the central management system, including real-time data mirroring to a backup site.

- **Health Monitoring:** Conduct regular automated system health checks with alert mechanisms for any component failures.

8.3 Real-Time Data Processing

- **Data Collection**: Utilize a network of sensors and monitoring devices to collect real-time data on weather, road conditions, and traffic flow.
- **Data Analysis**: Implement advanced algorithms to analyze the collected data and make real-time recommendations regarding speed limit adjustments and message displays.
- **Latency**: Minimize data processing latency to ensure timely updates and responses to changing conditions.

8.4 User Interface and Experience

- **Visibility**: Ensure that VSL signs and DMS displays are highly visible and legible under all conditions, including low visibility scenarios.
- **Clarity**: Design messages to be clear, concise, and easily understandable by all drivers.
- **Feedback Mechanism**: Incorporate a mechanism for collecting driver feedback on the effectiveness of the VSL and DMS systems.

8.5 Environmental Considerations

- **Weather Resistance**: Design all hardware components to withstand broad temperature ranges and extreme weather conditions, such as heavy rain, snow, and high winds.
- **Energy Efficiency**: Implement energy-efficient technologies to reduce the environmental impact and operational costs of the systems.
- **Sustainability**: Use sustainable materials and practices in the design and deployment of the systems.

8.6 Safety and Compliance

- **Safety Standards**: Ensure that the systems comply with all relevant safety standards and regulations.
- **Driver Safety**: Design the systems to enhance driver safety by providing timely and accurate information and dynamically adjusting speed limits.
- **Enforcement Support**: Provide support for local law enforcement to ensure compliance with speed limits and other traffic regulations.

8.7 Cost and Budget Considerations

- **Cost-Effectiveness**: Design the systems to be cost-effective, balancing initial investment with long-term operational and maintenance costs.
- **Budget Adherence**: Ensure that the project stays within budget by carefully planning and managing resources.
- **Funding Sources**: Identify and secure funding sources for the development, implementation, and maintenance of the systems.

8.8 Stakeholder Engagement

- **Collaboration**: Engage with various stakeholders, including traffic management authorities, local law enforcement, emergency services, and the general public throughout the design and implementation process.
- **Training**: Provide training for traffic management authorities and other relevant stakeholders on the operation and maintenance of the systems.
- **Communication**: Maintain open lines of communication with stakeholders to address concerns and incorporate feedback into the system design.

8.9 Scalability

- **Future Expansion**: Design the systems with the capability to expand and incorporate additional sensors, monitoring devices, and new technologies as they become available.
- **Modular Design**: Utilize a modular design approach to allow for easy upgrades and enhancements without significant disruptions to existing operations.
- **Adaptability**: Ensure that the systems can adapt to changing traffic patterns, technological advancements, and evolving user needs over time.

8.10 Data Management and Privacy

- **Data Anonymization:** Implement data anonymization techniques for all collected traffic data to protect individual privacy.
- **Access Controls:** Establish strict access controls and encryption for all stored data to prevent unauthorized access.
- **Security Audits:** Conduct regular security audits and penetration testing of the entire system to identify and address potential vulnerabilities.
- **Data Retention:** Develop clear data retention policies, including automated deletion of non-essential data after a defined period.

By addressing these design considerations, OTIC can ensure the development of a robust, efficient, and user-friendly VSL and DMS system that meets the current needs of the Ohio Turnpike while also being prepared for future advancements and challenges.

9.0 Systems Engineering Next Steps

The following steps outline the subsequent phases in the systems engineering process for the OTIC VSL and DMS project. These steps ensure a systematic approach to system development, implementation, and ongoing improvement.

9.1 Development of Detailed System Requirements

- **Requirement Specification**: Based on the ConOps, develop detailed system requirements that specify what the VSL and DMS systems must achieve to meet the identified needs.
- **Stakeholder Review**: Engage stakeholders to review and validate the system requirements, ensuring they align with user needs and expectations.
- **Requirements Traceability:** Establish a requirements traceability matrix to link each requirement back to specific user needs and forward to design elements and test cases.

9.2 High-Level System Design

- **System Architecture**: Create a high-level design that outlines the overall system architecture, including major components and their interactions.
- **Design Review**: Conduct design reviews with stakeholders to ensure the high-level design addresses all system requirements.
- **Technology Selection:** Evaluate and select appropriate technologies for implementation, considering factors such as performance, reliability, and long-term supportability.

9.3 Detailed System Design

- **Component Specifications**: Refine the high-level design into detailed specifications for each system component, including hardware, software, and communication interfaces.
- **Integration Planning**: Develop plans for integrating the VSL and DMS and supporting ITS elements with existing infrastructure and other relevant systems.
- **Security Design**: Incorporate robust security measures into the design to protect against cyber threats and ensure data integrity.

9.4 Implementation Planning

- **Development Plan**: Create a detailed plan for the development and implementation of the VSL and DMS systems, including timelines, resource allocation, and risk management strategies.
- **Procurement**: Initiate the procurement process for necessary hardware, software, and services.
- **Risk Management**: Develop a comprehensive risk management plan to identify, assess, and mitigate potential risks throughout the development and implementation process.

9.5 System Development and Integration

- **System Development**: Develop the VSL and DMS systems according to the detailed design specifications.
- **Integration**: Integrate the developed systems with existing infrastructure and ensure seamless operation.
- **Configuration Management**: Implement robust configuration management practices to track changes and maintain system integrity throughout the development process.

9.6 Testing and Validation

- **Test Planning**: Develop comprehensive test plans covering all aspects of system functionality and performance.
- **Unit Testing**: Conduct unit testing to verify that individual components function correctly.
- **Integration Testing**: Perform integration testing to ensure that all system components work together as intended.
- **System Testing**: Conduct comprehensive system testing to validate that the VSL and DMS systems meet all specified requirements.
- **User Acceptance Testing**: Engage stakeholders in user acceptance testing to confirm that the systems fulfill their intended purpose and meet user needs.

- **Performance Testing**: Conduct stress tests and performance evaluations to ensure the system can handle peak loads and maintain responsiveness.

9.7 Deployment and Operations

- **Deployment Planning**: Develop a detailed deployment plan, including strategies for minimizing disruption to existing traffic operations during installation.
- **System Deployment**: Deploy the VSL and DMS systems on the Ohio Turnpike.
- **Operational Training**: Provide comprehensive training for traffic management authorities, local law enforcement, and other relevant stakeholders on the operation and maintenance of the systems.
- **Documentation**: Develop and distribute user manuals, operational procedures, and maintenance guides.
- **Monitoring and Maintenance**: Establish procedures for ongoing monitoring and maintenance to ensure the systems remain effective and reliable, including regular software updates and hardware maintenance schedules.

9.8 Performance Evaluation and Feedback

- **Performance Monitoring**: Continuously monitor the performance of the VSL and DMS systems using key metrics such as crash rates, traffic flow efficiency, system reliability, and user compliance with variable speed limits.
- **Compliance Monitoring**: Monitor and record vehicle speeds before, during, and after events to determine level of compliance to posted variable speed limits.
- **Feedback Collection**: Implement mechanisms to collect feedback from users and stakeholders to identify areas for improvement. This may include surveys, focus groups, and analysis of system usage patterns.
- **Data Analysis**: Regularly analyze collected data to identify trends, assess system effectiveness, and inform decision-making.
- **System Updates**: Based on performance data and stakeholder feedback, implement updates and enhancements to ensure the systems continue to meet evolving needs and leverage new technologies as they become available.
- **Continuous Improvement:** Establish a process for continuous improvement, regularly reviewing and updating the systems to maintain their effectiveness and relevance over time.

By following these detailed next steps, OTIC can ensure a systematic and comprehensive approach to the development, implementation, and ongoing improvement of the VSL and DMS systems, maximizing their effectiveness in enhancing safety and traffic management on the Ohio Turnpike.

10.0 Verification and Validation

The Verification and Validation (V&V) process is a critical component of the systems engineering lifecycle for the OTIC VSL and DMS project. This chapter outlines the strategies and activities that will be employed to ensure that the VSL and DMS systems meet all specified requirements and fulfill their intended purpose.

10.1 Objectives

The primary objectives of the V&V process are:

- **Verification**: Ensure that the VSL and DMS systems meet all specified requirements as outlined in the system requirements document.
- **Validation**: Confirm that the VSL and DMS systems fulfill their intended purpose and meet the needs of all stakeholders, including traffic management authorities, local law enforcement, emergency services, and the general public.

10.2 Verification Activities

Verification activities are designed to confirm that the system components and overall system meet the specified requirements. These activities include:

Unit Testing

- **Objective**: Verify that individual components (e.g., sensors, VSL signs, DMS displays, CCTV Cameras) function correctly.
- **Method**: Conduct tests on each component in isolation to ensure they meet their design specifications.
- **Documentation**: Record test results and any issues identified during testing.

Integration Testing

- **Objective**: Ensure that all system components work together as intended.
- **Method**: Perform tests on integrated subsystems to verify that they interact correctly and meet system requirements.
- **Documentation**: Document the integration test results and any issues that arise.

System Testing

- **Objective**: Validate that the complete VSL and DMS systems meet all specified requirements.
- **Method**: Conduct comprehensive tests on the fully integrated system, simulating various operational scenarios.
- **Documentation**: Record system test results, including any discrepancies and corrective actions taken.

10.3 Validation Activities

Validation activities are designed to confirm that the VSL and DMS systems fulfill their intended purpose and meet stakeholder needs. These activities include:

User Acceptance Testing (UAT)

- **Objective**: Ensure that the systems meet the needs and expectations of end-users.
- **Method**: Engage stakeholders in testing the systems under real-world conditions. Collect feedback on system performance and usability.

- **Documentation**: Document user feedback and any issues identified during UAT. Implement necessary adjustments based on this feedback.

Operational Validation

- **Objective**: Confirm that the systems operate effectively under various conditions and scenarios.
- **Method**: Continuously monitor system performance during normal operations. Validate that the systems respond correctly to real-time data and changing conditions.
- **Documentation**: Maintain logs of operational performance and any incidents. Use this data to make ongoing improvements to the systems.

10.4 Performance Metrics

To evaluate the effectiveness of the VSL and DMS systems, the following performance metrics will be monitored:

- **Accuracy of Speed Limit Adjustments**: Measure the accuracy and timeliness of speed limit changes in response to real-time data.
- **Message Clarity and Timeliness**: Assess the clarity and timeliness of messages displayed on DMS signs.
- **System Reliability**: Monitor system uptime and the frequency of any failures or malfunctions.
- **User Satisfaction**: Collect feedback from drivers and other stakeholders on the effectiveness and usability of the systems.
- **Safety Improvements**: Track changes in crash rates, severity, and traffic incidents in areas covered by the VSL and DMS systems.
- **Compliance**: Collect traffic speed data to determine drive compliance to VSL signs.

The Advanced Traffic Management System (ATMS) will monitor and report on these KPIs. This process will be automated, utilizing real-time data collection and analysis tools to ensure accurate and timely reporting. The system will generate automated reports, which will be reviewed by traffic management operators and relevant stakeholders to ensure the KPIs are being met and to identify any areas for improvement.

10.5 Continuous Improvement

The V&V process is iterative and ongoing. Based on the results of verification and validation activities, continuous improvements will be made to the VSL and DMS systems. This includes:

- **Addressing Identified Issues**: Implementing corrective actions for any issues identified during testing and validation.
- **Updating System Components**: Making necessary updates to hardware and software components to enhance performance and reliability.
- **Incorporating User Feedback**: Using feedback from stakeholders to make improvements to system usability and effectiveness.
- **Adapting to New Technologies**: Regularly assess emerging technologies and industry best practices for potential integration into the VSL and DMS systems.

- **Refining Algorithms**: Continuously refine the decision-making algorithms based on collected data and observed system performance to improve the accuracy and effectiveness of speed limit adjustments and message displays.

11.0 Acronyms List

API: Application Programming Interface
ATMS: Advanced Traffic Management System
CAD: Computer-Aided Dispatch
CCTV: Closed-Circuit Television
CFR: Code of Federal Regulations
ConOps: Concept of Operations
DMS: Dynamic Message Sign
FHWA: Federal Highway Administration
ITS: Intelligent Transportation Systems
KPI: Key Performance Indicator
ODOT: Ohio Department of Transportation
OSHP: Ohio State Highway Patrol
OTIC: Ohio Turnpike and Infrastructure Commission
RWIS: Road Weather Information Systems
SEA: Systems Engineering Analysis
TMC: Traffic Management Center
UAT: User Acceptance Testing
UN: User Needs
UNDMS: User Needs – Dynamic Message Sign
UNVSL: User Needs – Variable Speed Limit
UNVD: User Needs – Vehicle Detection
UNRWIS: User Needs - Road Weather Information Systems
UNWWDD: User Needs – Wrong Way Driver Detection
V&V: Verification and Validation
VDS: Vehicle Detection Systems
VSL: Variable Speed Limit
WWD: Wrong Way Driving

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