Invitation No.: 555-20
Location: District 6, US 33 Smart Corridor
Commodity: Dedicated Short-Range Communication

REQUEST FOR PROPOSAL (RFP)

State of Ohio, Department of Transportation
Office of Contract Sales, Purchasing Services
Jack Marchbanks, Ph. D., Director

Bid Submission Deadline (Bid Opening Date):
July 8, 2019 at 2:00 p.m. eastern time

Submitted by:

Company Name: __________________________________

Federal Tax ID No.: __________________________________

<table>
<thead>
<tr>
<th>Physical/Mailing Address:</th>
<th>Remit to Payment Address:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street Address:</td>
<td></td>
</tr>
<tr>
<td>P.O. Box:</td>
<td></td>
</tr>
<tr>
<td>City:</td>
<td></td>
</tr>
<tr>
<td>St:</td>
<td></td>
</tr>
<tr>
<td>Zip:</td>
<td></td>
</tr>
</tbody>
</table>

Contact Person and Phone Number:
(authorized to answer questions about your company’s bid)

E-Mail Address (required):
(person who filled out bid)

E-Mail Address (required):
(for notification of future bid opportunities)

Telephone Number | 800 Number | Fax Number |
|-----------------|------------|-----------|

Return Properly Marked, Complete Bid Packages To:
contracts.purchasing@dot.ohio.gov

BIDDERS MUST SUBMIT ANY QUESTIONS, CLARIFICATIONS, OR INQUIRIES REGARDING THIS RFP VIA THE FOLLOWING WEBSITE:
[http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/Pages/PurchasePBQ.aspx](http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/Pages/PurchasePBQ.aspx)
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1. PROPOSAL INTRODUCTION

1.1 Project Background

In 2016, the U.S. Department of Transportation (USDOT) awarded to the NW 33 Innovation Corridor Council of Governments (COG) an Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) grant for the 33 Smart Mobility Corridor (33 SMC or “Project”). The COG was formed by the City of Marysville, the City of Dublin, Union County, and the Marysville – Union County Port Authority to coordinate multi-agency needs and efforts.

The 33 SMC will demonstrate how smaller cities can leverage innovative technologies, such as connected vehicle (CV) applications with Dedicated Short-Range Communication (DSRC), to improve operations, safety, and mobility. The technology and communications elements of project involve building out the physical CV environment, which includes the construction and/or installation of roadside infrastructure (e.g. roadside units, or RSUs), on-board units (OBUs) in vehicle fleets, and supporting connected vehicle environment network systems, including backhaul communications and data, infrastructure and security credential management systems. Building on the foundation of these CV components, the project will deploy a series of CV applications that will leverage the data generated by the infrastructure to deliver real-time safety and mobility services to equipped vehicles.

Just outside the 33 SMC, the City of Columbus is developing a cutting-edge, region-wide connected and autonomous (CAV) transportation network after receiving a federal grant through its successful bid for the Smart City challenge. The 33 SMC deployment will bolster this region’s commitment to smart transportation and provide a unique opportunity for coordinating adjacent CV systems.

DriveOhio has also expressed interest in deploying CV applications and supporting infrastructure within the 33 SMC environment. DriveOhio, which operates under the auspices of the ODOT, brings together various public and private entities involved in smart mobility research, development and implementation. While efforts by DriveOhio within the corridor are considered outside the scope of the ATCMTD grant and this project, the 33 SMC environment will establish a working connected vehicle system where additional infrastructure and CV applications can be developed and easily deployed. The 33 SMC project will be leveraging future investments by DriveOhio in the corridor as part of the overall connected vehicle environment. 33 SMC is also an opportunity to develop partnerships for research, testing, and development of CV applications. Designing this system to be scalable will be necessary to allow for additional functionality or extension of the system limits in the future.

The CV Environment deployment will occur along US-33 and within the cities of Dublin and Marysville. Contained within Appendix A is the approximate location of roadside infrastructure and associated suite of applications to be deployed as part of the CV Environment. The deployment of in-vehicle devices includes agency/fleet vehicles from government entities that target populations and vehicles that are located, travel near or are frequently used within the infrastructure deployment corridors. Collectively, the applications, deployed on vehicles traveling in and near these infrastructure equipped corridors is the heart of the CV Environment. When complete, the entire scope envisioned from the CV Environment include:

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Vehicles</th>
<th>Applications and Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>90+ RSUs</td>
<td>400-600 OBU</td>
<td>CV Applications</td>
</tr>
<tr>
<td>The project will install new RSUs and necessary communications equipment at ~34 signalized intersections in the project area and at ~61 freeway locations</td>
<td>The project will install onboard units (OBUs) on participating fleet, emergency, and public works vehicles.</td>
<td>The project will deploy four (4) vehicle-to-infrastructure (V2I) safety, and mobility applications.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data Capture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The project will capture, relate, store, and respond to data generated by the infrastructure and vehicles, used by the applications</td>
</tr>
</tbody>
</table>
The **33 Smart Mobility Corridor Concept of Operations**, included as Appendix B, dated February 2019, provides greater detail on the background, needs, goals, and vision for the project. NOTE: The ConOps has been provided for information only purposes. Refinements to the specific deployment locations, vehicle quantities by agency, number of CV applications and the functionality of the applications have occurred since the ConOps was developed. **Information provided in this RFP supersedes the Concept of Operations.**

The **33 Smart Mobility Corridor System Requirements Specification**, included as Appendix C, dated May 2019, details the functional, physical, performance, and other requirements associated with the project. The latest set of detailed requirements, organized by functional groups, is included for reference as Appendix D as a Microsoft Excel file download at the following location: ftp://ftp.dot.state.oh.us/pub/Districts/D06/Downloads/US-33_Smart_Mobility_Corridor/RSU-RFP/Appendix_D/

The Proposer will be expected to download, complete the Proposer response field for each requirement in the provided Excel file and include the file as part of their proposal.

With the initial systems engineering phase now complete, the 33 SMC has embarked upon the next phase of the project, to prepare the detailed design and deploy the CV Environment. The first step in this process will be the selection of systems integrators who will help lead the procurement and installation of the in-vehicle and roadside equipment, and associated applications. A CV Environment network integrator will also be procured.

The 33 SMC deployments will continue to be managed by the COG and their program management consultant, Michael Baker International, known as the Program Manager. The COG and Program Manager understand that the success of this project phase requires the coordination and cooperation of additional parties, both public and private including the in-vehicle equipment integrator, the infrastructure integrator and the CVE network integration team. Together, these parties will be instrumental in equipping, operating and maintaining the vehicles, infrastructure and network elements associated with this project during the operational test period. Design and development activities are also expected to be a part of the upcoming phase.

**Figure 1. CV Environment Project Relationships** articulates the various parties that the offeror will work with to collaboratively deliver a functional CV environment. Details of the requirements and scope of the offeror follow.

---

**Figure 1. CV Environment Project Relationships**
1.2 Proposal Purpose

The Ohio Department of Transportation (ODOT) (in cooperation with the COG), is seeking a systems integrator/integrator team, known as the RSU Integrator, that will be responsible for the development, procurement, installation, testing and verification of nearly 100 DSRC-based RSUs, as described herein. ODOT will award and enter into contract with the RSU Integrator and will provide for the payment for all services. Michael Baker International, the COG’s Program Manager, will manage the contract, provide all direction, and serve as the RSU Integrator’s primary point of contact for the duration of the contract. The RSU Integrator will be responsible for completing the detailed system engineering analysis process, furnishing, configuring, installing, testing, and verifying the roadside units for the project. The scope of work for the integrator will include development of any software components necessary to fulfill the RSU functions identified by the 33 Smart Mobility Corridor System Requirements Specification shown in Appendix C. The RSU Integrator will also be required to work closely with the RSU vendors, On-Board Unit (OBU) integrator and CV Environment network integrator to troubleshoot issues during the entire operational testing period.

The intent of this Request for Proposal is to select the most qualified and highest scoring Proposer. The RSUs must be installed and operational by December 31, 2019. The Proposer is to provide all services listed in the RFP until the end of the operation testing period, ending on December 31, 2021 in accordance with the schedule contained in Section 1.3.

1.3 Project Location

The project encompasses US-33 from the City of Dublin, OH to East Liberty, OH as shown in Figure 2.

![Figure 2. Project Location](image_url)

All work on this project will be within the limits of ODOT District 6 (Delaware and Union Counties), except for the western project limit near East Liberty, Ohio, which will require physical work within Logan County.

The roadside units include deployments at 19 traffic signals and three (3) pedestrian actuated beacons within the City of Marysville, eight (8) traffic signals and two (2) pedestrian actuated beacons within the City of Dublin, and 61 freeway locations along US 33 between the City of Dublin and East Liberty, OH. There are
eight (8) RSUs in the City of Marysville and two (2) RSUs in the City of Dublin that have been installed either under this project's pilot phase or by the cities. The Proposer will need to reconfigure these RSUs as required to meet the requirements of this RFP. Final locations and number of RSUs is subject to change.

The project described in this document primarily occurs at the location of the proposed field devices. However, some development and integration work may be required offsite. Project work involving implementation and support activities may take place at the following locations:

- **ODOT Central Office**
  Ohio Department of Transportation
  1980 West Broad Street
  Columbus, Ohio 43223

- **City of Marysville**
  209 S. Main Street
  Marysville, OH 43040

- **City of Dublin**
  6555 Shier-Rings Rd
  Dublin, OH 43016

This additional work may occur at the above agency offices where PC’s and users are located. Training activities may take place at any of the above locations or at another location near the above locations.

### 1.4 Project Schedule

Following is a high-level project schedule commencing with the notice to proceed (NTP) expected to occur on or before July 22, 2019. A detailed US-33 SMC schedule will be developed with the successful Proposer upon award.

<table>
<thead>
<tr>
<th>Task</th>
<th>Timeline</th>
<th>Contract Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Vehicle Infrastructure Integrator Procurement (NTP Issued by) *</td>
<td>July 22, 2019</td>
<td>This Contract</td>
</tr>
<tr>
<td>Connected Vehicle In-Vehicle System Integrator Procurement (NTP Issued by) *</td>
<td>September 1, 2019</td>
<td>Separate Contract</td>
</tr>
<tr>
<td>Systems Engineering and Design Development for RSUs</td>
<td>July 2019 – September 2019</td>
<td>This Contract</td>
</tr>
<tr>
<td>OBU Application Development, Configuration and Installation</td>
<td>Complete by April 2020</td>
<td>Separate Contract</td>
</tr>
<tr>
<td>RSU Configuration and Installation – Signalized Intersections and Pedestrian Actuated Beacons</td>
<td>September 2019 – November 2019</td>
<td>This Contract</td>
</tr>
<tr>
<td>RSU Configuration and Installation – US 33</td>
<td>October 2019 – December 2019</td>
<td>This Contract</td>
</tr>
<tr>
<td>Connected Vehicle Environment Network Design and Integration</td>
<td>Complete December 31, 2021</td>
<td>Separate Contract</td>
</tr>
<tr>
<td>Operational Test Period</td>
<td>Complete December 31, 2021</td>
<td>This Contract</td>
</tr>
</tbody>
</table>

*Approximate Date for NTP. Integrator to begin work immediately upon NTP.

### 2 PROPOSAL GUIDELINES

#### 2.1 Proposal Process

The overall Proposal Process for this Connected Vehicle Infrastructure Integration RFP has been broken down into the following 11 steps:
Step 1. Verify all materials listed in the RFP Structure are received
Step 2. Utilize the Proposal Inquiry process as necessary
Step 3. Notify the Department of Intention to attend Pre-Proposal Conference by electronic mail to contracts.purchasing@dot.ohio.gov and todd.vankirk@dot.ohio.gov.
Step 4. Attend the optional Pre-Proposal Conference
Step 5. Submit Final Questions by Inquiry Deadline
Step 6. Prepare the Proposal Content in accordance with the Structure outlined herein
Step 7. Deliver the Proposal Content by Deadline
Step 8. Respond to ODOT during Proposal Evaluation as necessary including but not limited to; responding to questions from the Review Panel, providing pricing clarifications or adjustments as requested, and conducting a Solution Presentation, if invited.
Step 9. COG/ODOT Evaluates and Scores the Proposals
Step 10. ODOT notifies all Proposers of Award Results
Step 11. ODOT begins Contract Negotiations with Awarded Proposer

2.2 Proposal Inquiries

Proposers should submit questions/inquiries regarding this proposal via the ODOT Office of Contract Sales at the following URL:

http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/Pages/Purchase.aspx

Pre-bid questions must be received no later than the close of business the Thursday prior to the scheduled opening date. An addendum being issued is dependent upon the information received and the impact on the competitive bidding process.

All pre-bid inquiries must have the following: Name of the Sender, Contractor or Company Name, Phone Number, RFP No., a detailed description of the question.

Proposers are NOT to contact any other ODOT office, including District offices, for responses to pre-bid questions.

2.3 Optional Pre-Proposal Conference

The COG/ODOT will hold an optional Pre-Proposal Conference on May 22, 2019 at 10:00 AM at:

Ohio Department of Transportation
1980 West Broad Street
Columbus, OH 43223
Conference Room 2A

Pre-proposal conference will also be available via teleconference. To connect via teleconference use the information below:

Call-in Number: 571-209-6390 (Cisco WebEx)

Access Code: 992 207 774 (Meeting does not require a password)

At this meeting, proposers will be able to hear a brief overview of the project and will have the chance to ask questions.

Please use best efforts to email (contracts.purchasing@dot.ohio.gov and todd.vankirk@dot.ohio.gov) if intending to attend or call-into pre-proposal meeting.
The pre-proposal conference meeting presentation, sign-in sheet and the answers to questions from the meeting will be available at:

ftp://ftp.dot.state.oh.us/pub/Districts/D06/Downloads/US-33_Smart_Mobility_Corridor/RSU-RFP/Pre-Proposal_Meeting/

2.4 Proposal Format

Only the following format will be accepted:

- Proposals may not exceed 20 letter-size (8.5” x 11”) pages and shall include the information listed within this section. The required cover letter, forms, and addenda listed below in 2.5 Proposal Content do not count towards the 20-page limit.
- Page numbers shall be included and centered at the bottom of each page.
- Font shall be 12 point, minimum.

2.5 Proposal Content

Proposals, in addition to complying with the 2.4 Proposal Format and 2.6 Proposal Delivery Requirements, must include at a minimum:

- A signed, Proposal Cover Letter must be included with the Proposal submittal. The cover letter should state the purpose of the submittal and be an original signature by a representative of the offering organization authorized to bind the Proposer, including the representative’s title, address, and telephone number.
- The following signed and completed forms; Signature Page with an original signature (blue ink) by a representative of the offering organization authorized to bind the Proposer.
- A copy of all issued addenda.
- The proposal shall be limited to no more than 20 total pages of information (e.g. text, graphics, etc.) A ‘page’ is one side of a sheet of paper with text, graphics, etc. If only one side of the sheet of paper has text, graphic, etc., then that is one page. If both sides of a sheet of paper have text, graphics, etc., that is two pages. The proposal shall include the required documents listed above (Cover letter, Signature page, and issued addenda), which will not count in the 20-page limit. The required response to the Requirements Verification Matrix (Appendix D) is not counted in the 20-page limit. Any manufacturer specifications for products, staff resumes, and the mandatory requirements, are not counted in the 20-page limit. No appendices, other than for product specifications and staff resumes, will be acceptable.
- The Mandatory Requirements must be addressed in the Proposer’s written proposal in sufficient detail to determine that the mandatory requirements will be met. The proposal shall contain information requested below in the order outlined or the proposal may be rejected. The proposal shall address each of the following subjects in the order specified below, using the header provided. These headers correspond to the evaluation criteria noted in Section 2.7, and are further detailed in the sections below.

<table>
<thead>
<tr>
<th>Mandatory Content</th>
<th>Content Provided?</th>
<th>Counted in page limit?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Letter</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Signature Page</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Issued Addenda</td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>
### Appendix D

**Requirements Verification Matrix**

The Bidder shall fully complete and provide the Requirements Verification Matrix located at ftp://ftp.dot.state.oh.us/pub/Districts/D06/Downloads/US-33_Smart_Mobility_Corridor/RSU-RFP/Appendix_D/

The Bidder must identify the specific RSU equipment (manufacturer/model/version) being provided, ensure that it meets the specifications provided in Appendix E and note whether the device is OmniAir certified.

| Part 1 | Project Team | Yes |
| Part 2 | Past Performance | Yes |
| Part 3 | Solution, Understanding or the Project & Approach | Yes |
| Appendix F | Pricing Proposal | No |

**Part 1 – Project Team**

- A list of the key individuals from the Proposer’s organization, including subcontractors or vendors, who will be involved in delivering the Proposer’s service solution. Provide the percentage of work to be performed by each firm. For each individual, include his/her role and responsibilities on in this proposal, education, training, overall qualifications, and a brief résumé of experience within the body of the proposal response. Provide availability for the project manager and key staff for this project. More detailed resumes may be provided as an appendix, however, they may or may not be considered as part of the evaluation.

- Provide an overview of the resources the 33 SMC Project Team should consider as part of the implementation plan.

**Part 2 – Past Performance**

- A description of the Proposer’s organization, including a summary of previous experience which qualifies the Proposer to successfully deliver the system described in this document. Include specific details of related experience: project name, project characteristics (including any unique conditions), team members and contact information, contract amount, dates of work or assignment, names and addresses of client organizations, or other details that appropriately support the Proposer’s ability and experience to deliver the proposed system. Projects with greater relevancy to this project will be given greater considerations. The proposal shall demonstrate the financial stability and experience of the organization.

**Part 3 – Solution, Understanding of the Project & Approach**

- A Proposal shall detail the Proposer’s understanding of the topics and provide technical capabilities related to the areas discussed herein (See 1. Proposal Introduction, 4. Connected Vehicle Infrastructure Integration Requirements Overview and Appendix D for further details) Present a proposal that demonstrates the Proposers understanding of the scope, challenges, and limits within the context of the project. Provide an explanation of innovative approaches and cost containment measures for project execution. Proposer shall submit the completed requirements table in Appendix D (Mandatory requirement) identifying which requirements they currently meet, will meet at deployment or will not meet.
Provide details how the Proposer's Service Solution Proposal will meet the Project Management Requirements (See Section 4.4 Scope of Services for further details).

2.6 Pricing Requirements

Departments Pricing Requirements

The Proposal must include pricing for all required items in the bid sheet, Appendix E, (in $US) to ODOT for the proposed Connected Vehicle Infrastructure Integration services meeting all requirements outlined in this Request for Proposal. These prices shall be effective for a period ending December 31, 2021, assuming continued service.

Note: ODOT will not allow an upfront charge for any implementation activities.

2.7 Proposal Delivery Requirements

The proposal must be prepared and submitted in accordance with instructions found in this section. The proposal submission must include:

- A pdf file including the complete proposal submission.
- A pdf file including complete pricing.
- A completed Appendix D-Requirements Verification Matrix in Excel format.

Any pages or documents omitted negatively affect the vendor’s score and possibly result in disqualification.

The Proposer’s total complete proposal submission (both the technical and cost proposals) must be received by Contract Sales no later than 10:00 a.m. on June 17, 2019 to the following web address:

contracts.purchasing@dot.ohio.gov

All proposals must be received by the posted submission deadline, date and time. No exceptions will be made.

2.8 Proposal Evaluation

Proposal Evaluation begins when proposals are delivered, and the Office of Contract Sales has verified compliance with the Proposal Delivery Requirements, Proposal Format and Proposal Content sections. The Office of Contract Sales provides the Review Panel with all responsive Proposals. The Review Panel consists of members of the COG, the Program Manager, ODOT and DriveOhio.

Below are the steps for evaluating proposals received by the Office of Contract Sales:

Step 1. Verify that the proposals satisfy the Proposal Format and Proposal Content requirement and qualify to be evaluated by the Review Panel.

Step 2. Issue Evaluator Instructions to the Review Panel in conjunction with all Proposals that have cleared the first step of verification.

Step 3. Review and Accept the Proposals Mandatory Requirements in order for the Proposal to advance to Scoring Evaluation (see Table of Mandatory Proposal Requirements for Acceptance).

Step 4. Exercise the option to invite Selected Proposers or a subset of Selected Proposers for a Solution Presentation. The Review Panel has sole discretion to determine which Proposers are qualified to invite for Solution Presentation, if required.
Step 5. Initiate Scoring Evaluation for all proposals that have not been eliminated from scoring in Steps 1 through 4 listed above. Scoring is conducted by the Review Panel evaluating each proposal according to the criteria in Scoring Evaluation Table.

Step 6. Notify all Proposers of Award Results
Step 7. Begin Negotiations with Awarded Proposer

Mandatory Requirements.
The first table lists this RFP’s mandatory requirements. If the offeror’s Proposal meets all the mandatory requirements, the offeror’s Proposal may be included in the next part of the technical evaluation phase described in the next table.

<table>
<thead>
<tr>
<th>Mandatory Requirements</th>
<th>Reject</th>
<th>Accept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offeror Mandatory Requirement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Bidder shall fully complete and provide the Requirements Verification Matrix...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Bidder must identify the specific RSU equipment (manufacturer/model/version) being provided, ensure it meets or exceeds the specifications included as Appendix E and indicate whether the device is OmniAir certified.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplier provided a separate Sealed Cost Proposal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scored Criteria</th>
<th>Weight</th>
<th>Does Not Meet</th>
<th>Meets</th>
<th>Exceeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Team: the proposer should provide an overview of the staff it will provide, and the resources the COG should consider as part of the implementation plan.</td>
<td>20</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Past Performance: Proposer will identify a maximum of three specific projects in its portfolio that best encapsulate the breadth of capabilities as it directly relates to this project.</td>
<td>25</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Solution, Understanding of Project &amp; Approach: This score will be based on the completeness of the response, understanding of the project, support for the goals of the program, and alignment with COG’s expectations.</td>
<td>55</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Note that the rankings are not limited to the whole integers indicated above, but that various values between 0-5 may be used in the scoring evaluation.

Price Performance Formula. The evaluation team will rate the Proposals that meet the Mandatory Requirements based on the following criteria and respective weights.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Proposal</td>
<td>80%</td>
</tr>
<tr>
<td>Cost Summary</td>
<td>20%</td>
</tr>
</tbody>
</table>
To ensure the scoring ratio is maintained, the State will use the following formulas to adjust the points awarded to each offeror. The offeror with the highest point total for the Technical Proposal will receive 400 points. The remaining offerors will receive a percentage of the maximum points available based upon the following formula:

**Technical Proposal Points** =  
(Offeror's Technical Proposal Points/Highest Number of Technical Proposal Points Obtained) x 400

There are a maximum of 400 Technical Proposal Points available.

**Cost Proposal Points** = (Lowest Price Received/Offeror’s Price) X 100

There is a maximum of 100 Cost Points available.

### 2.8.1 Total Score

The total score used for selection will include both the technical score and the Proposer’s price. Price will be a weighted portion of the scoring evaluation. Price proposals will only be opened once the technical proposals have been evaluated and scored. The scoring formula will be applied as follows and will be used to determine top scoring proposer:

**Total Score Formula**

\[
Total \ Score = \left[ 400 \times \frac{\text{technical score}}{\text{highest score}} \right] + \left[ 100 \times \frac{\text{lowest price}}{\text{offeror price}} \right]
\]

### 2.8.2 Selection of Qualified Proposer

The Review Panel will select the Proposer whom ODOT considers qualified to deliver a service which meets the requirements defined in this document. In the event the Review Panel does not identify a qualified Proposer, ODOT reserves the right to cancel this request for proposal without further notice.

The selected qualified Proposer will be notified of its selection by the Review Panel Coordinator. ODOT reserves the right to request from the qualified Proposer:

- Answers to questions from the Review Panel.
- Pricing clarification or adjustments.
- An audited financial statement of the Proposer, prepared by a certified public accountant, substantiating the Proposer’s financial capacity to administer the Connected Vehicle Infrastructure Integration Services.

### 2.8.3 Solution Presentations

ODOT reserves the right to ask the qualified Proposers to give a Solution Presentation to the Review Panel for the purposes of explaining, elaborating, or otherwise clarifying the major elements or features of its proposal. The Solution Presentation would be held within two or three weeks after the opening date of this Request for Proposal. Chosen Proposers will be notified of date(s) and times available for their oral presentation. The presentation is restricted to representatives of the Proposer, staff members of ODOT, and Review Panel members. Oral presentations may be held online. Guidelines of the presentation will be provided when and if required.

### 2.8.4 Scoring Evaluation

The technical proposal score will represent 80% of the total score overall. In the Proposal Scoring Evaluation phase, the Review Panel will rate the solution merits of the Proposal based on the following points assigned to each requirement:
▪ **Project Team – Weight = 20% of technical score**

To support the Proposer’s solution, the Proposer should provide an overview of the staff it will provide, and the resources the COG should consider as part of the implementation plan. The COG will guide the design, data collection, research, and evaluation efforts. The Program Manager will support the COG and the overall deployment of the 33 SMC and be the point of contact for the Integrator. The organizational support plan should include the following items:

- A draft table of the Proposer’s organization of staff and qualifications needed to deliver the proposed solution. Availability of project manager and key staff should also be included.
- A job description for each position within the draft table that identifies the roles and responsibilities in supporting the Proposer’s solution.
- The education, training, experience, overall qualifications, and availability for the Proposer’s project manager.
- A brief discussion of the approach the project manager and team will take to effectively manage the project. Since the integrator will need to work closely with other manufactures or vendors to obtain multiple RSUs for interoperability, this section should include a discussion of the approach to manage the potentially diverse team.

▪ **Past performance – Weight = 25% of technical score**

The responding Proposers will identify a maximum of three specific projects in its portfolio that best encapsulate the breadth of capabilities as it directly relates to this project’s requirements, its ability to deliver the solution on time and its ability to send data to the Infrastructure Management Suite. These highlighted projects will include a point of contact that can be contacted by the selection team as a reference. It should be made clear as to how many implementations have been delivered to date, in both the United States and internationally. Preference will be given to teams that can demonstrate experience with integrating RSUs on a USDOT connected vehicle pilot or similar deployment.

▪ **Solution, Understanding of Project & Approach – Weight = 55% of technical score**

This score will be based on the completeness of the response, understanding of the project, support for the goals of the program, and alignment with COG’s expectations. When submitting the details of the solution, respond to the items and address the individual functional requirements defined in Proposal Introduction, Connected Vehicle Infrastructure Integration Requirements Overview and Appendix D.

The Proposer should identify adherence to the schedule and how it intends to meet the required deliverables and dates to fully deploy the project.

The Proposer should describe its ability to meet the COG’s goals, the challenges and solutions with the technology, the varying maturity levels of CV applications and the plan to develop and test those needing further development, and data capture to the connected vehicle environment network. The Proposer should describe the ability to meet the needs of the 33 SMC project goals, as well as those of the COG.

The Proposer’s proposal shall contain a narrative description tailored to the project. The Proposer should demonstrate a thorough understanding of the project and how the Proposer’s entire team will successfully execute the project. The Proposer should make a clear presentation of how the project team is organized, how they will coordinate with multiple related parties including the in-vehicle integrator, the Management Team, the Roadside Infrastructure Contractor, the Connected Vehicle Environment Network Integrator, and those that will manage the infrastructure, and their
understanding of the project requirements, including the challenges and areas of risk and a detailed plan for execution.

The Proposer’s proposal should give the selection team a clear understanding of the Proposer’s:

- **Process** – The Proposer’s process/approach to planning, executing, and evaluating deployments such as this.
- **Capabilities** – Demonstration that the Proposer’s capabilities fulfill the requirements of the RFP, and additional needs that may arise.
- **Initial Thinking** – Proposer’s initial ideas for achieving the project’s objectives. This may include preliminary thoughts for operating in suboptimal conditions and initial recommendations for testing procedures.
- **Collaboration** – How the Proposer will collaborate with the 33 SMC team and within the Proposer’s team to successfully deliver on the project’s objectives. This includes a commitment to flexibility in operating parameters, particularly installation scheduling, in response to possible changes in real-world conditions.
- **Creativity** – This may include proven innovations in the approach to meet and/or exceed this RFP’s requirements, not explicitly outlined within this RFP.

As part of their proposal, the Proposer shall include a list of applications and interfaces that the offeror believes will need developed. The specific methodology used to develop any software component or interface is at the discretion of the Proposer, but the methodology should be discussed in the response to this RFP. Any claims to proprietary software must be identified as part of the proposal.

Due to the phasing of the infrastructure installation, the work related to installation of the traffic signal RSUs and perform integration, verification, and testing is expected to begin on notice to proceed. The roadside installation along US-33 will be dependent on installation of the power and poles by the infrastructure contractor. The intention is to have all of the RSUs installed and broadcasting by 12/31/2019. Schedule is a critical driving factor on this project. The Proposer should include a discussion of their approach to meeting the schedule.

### 3 Award of Contract

It is ODOT’s intention to award this Connected Vehicle Infrastructure Integration RFP for a period beginning from the date of award until December 31, 2021 upon ODOT’s completion of Service Solution Presentation (if applicable), the evaluation period, and/or any additional negotiations or follow ups ODOT deems necessary. ODOT reserves the right to cancel this request for proposal without further notice. In the event that establishing contractual terms with the top scoring Proposer is unsuccessful, ODOT reserves the right to begin negotiations with the next highest scoring Proposers until an agreement can be reached.

### 4 Connected Vehicle Infrastructure Integration Requirements Overview

**Section 4.1 - General Integrator Information**

This section provides additional details about the project scope of the integrator’s role and requirements.

**Section 4.2 - Equipment Specifications**
This section will detail out the requirements for the Roadside Unit Specifications and RSU and CV application requirements.

**Section 4.3 - System Integration and Testing Requirements**

System integration and testing includes network integration of the RSU into the communication network and testing to prove functionality and operation for local device assembly, local subsystem and final system. The integration services include all necessary configuration and programming work at communication aggregations points, subsystem locations and the traffic management center (TMC), if necessary.

**Section 4.4 - Scope of Services**

The 33 SMC has identified a high-level work plan they believe will allow for successful completion of the integration activities associated with the CV Environment project and meeting the goals of the overall 33 SMC project. Deviations from this plan will be considered but must be identified and documented by the Proposer in their proposal.

### 4.1 General Integrator Information

As previously indicated, the COG, in cooperation with ODOT, is seeking a systems integrator/integrator team, known as the RSU Integrator, that will be responsible for the development, procurement, testing, verification, and the uploading of security certificates of nearly 100 DSRC-based RSUs.

The scope of work for the RSU Integrator will include development of any software components necessary to fulfill the RSU functions identified in the 33 SMC Systems Requirements, including but not limited to, integration with the connected vehicle environment network for real-time data exchange, development activities necessary to provide the safety and mobility applications identified, connecting to and implementing the statewide SCMS, enabling over-the-air updates for OBUs, and connection to additional outside resources such as a GPS position correction service, mobile app, network time source or similar.

Further, the RSU Integrator will be responsible for creating the Verification Plan, upon approval by the Program Manager, and will be responsible to support the necessary test activities and to demonstrate that the infrastructure components meet all mandatory requirements, found within the 33 Smart Mobility Corridor Systems Requirements documents.

#### 4.1.1 RSU Sourcing

The 33 SMC recognizes that not all roadside equipment may be suitable for all installation configurations that the project has identified. The importance of testing interoperability between vendors of this technology must be recognized. As such, 33 SMC requires the offerors to supply a minimum of 2 different RSU manufacturers for this project. The number of devices should be reasonably balanced and deployed in various settings (signals, US-33 roadside). The devices must meet or exceed the specifications included as an attachment. With this provision the offeror shall ensure that the approach to channel allocation, over-the-air updates, certificate management, or any other similar interaction with a DSRC OBU, necessitate a common, single approach to these interactions across all platforms/vendors and in coordination with the OBU provider(s). The proposed RSUs also shall meet the requirements of ODOTs SCMS provider. The response should identify whether or not the device is Omni Air Certified.

In order to manage this new infrastructure efficiently, the RSU Integrator shall provide an infrastructure management system, similar to how traffic signal controllers are managed, that allow for health and status monitoring, software/firmware updates and other operational features. The management system shall support all RSU configurations deployed in the CV environment, including existing RSUs identified within this RFP, and can support solutions from multiple manufacturers, both current and future, including OmniAir certified devices. The system is preferred to be web based.
The 33 SMC seeks to demonstrate interoperability among all CV equipment deployed as part of this project, and is following DriveOhio’s policy for this testing, which is as follows:

**Interoperability Testing** - All connected vehicle equipment, i.e. RSUs, OBUs, etc., shall pass any interoperability tests that DriveOhio may have developed to ensure that any hardware follows the SAE published standards. Initially, it is expected that initial testing will only include validation that SAE J2735, J2945/0, and J2945/1, including RF signal quality, are being followed. In the future, as further SAE J2945 standards are published, it is expected that any equipment manufacturers operating within the state validate against those published standards to ensure interoperability throughout the state. This testing will eventually be utilized for individual application use cases. The RSU Integrator will assist the DriveOhio partners by providing all documentation for deployed applications, including, but not limited to, message format, Frequency and channel, notification methods (haptic, visual symbols, audible sounds, etc.), and all data fields needed for the correct implementation/operation of the application.

### 4.1.2 Security Credential Management System (SCMS)

All connected vehicle equipment, i.e. RSUs, OBUs, etc., shall be integrated into the DriveOhio Statewide SCMS hosted by Integrity Security Services (ISS). ODOT/DriveOhio has contracted with ISS to be the statewide SCMS provider for 1 year with provisions to extend for another 2 years. The offeror shall coordinate with ISS to have any equipment provisioned with the correct security certificates prior to shipment or as it aligns with the project goals. The SCMS will provide the following configuration for security operations:

- OBU pseudonym certificate use of 20 per week
- RSU application certificate use of 1 per week (per service offered by the RSU)
- Equipment to be provisioned at a coordinated site
- Security Certificates should be provided by the Integrator at the DriveOhio contracted pricing. DriveOhio can assist with coordination between the parties.

The RSU Integrator will be responsible for procuring the RSU certificates for the operational test period. RSU pricing is $60/year per application. The integrator will be responsible for the upfront costs and can coordinate with Integrity Security Services for any additional information regarding the terms of the ODOT DriveOhio agreement.

### 4.1.3 RSU Installation Support

Third parties, as listed in the table below, will be responsible for hanging the device and running power and communications back to the controller cabinet. The RSU Integrator will be required to provide necessary training and guidance to the Agency(s) maintenance staff and the roadside infrastructure contractor to support the installation of RSUs and any other necessary roadside equipment. The Proposer is not expected to perform installation activities, at signalized intersections, once the device has been configured and submitted to the City(s) for installation, however, Offeror will be expected to participate in the installation to ensure the device is functioning properly.

<table>
<thead>
<tr>
<th>Location</th>
<th>Installer</th>
<th>RSU Integrator Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>US-33</td>
<td>Roadside Infrastructure Contractor</td>
<td>Provide all RSU components, mounting hardware, cables, power injectors and installation guidance. Reimburse the contractor for any additional adjustments or remounting required after the initial installation. Additional equipment required inside the control cabinet (standard ODOT ITS cabinet) to meet the RSU Integrator’s engineered solution is the responsibility of the RSU Integrator to install. The RSU integrator will make final terminations and connections in the cabinet.</td>
</tr>
</tbody>
</table>
The 33 SMC team is currently finalizing the CV Environment Network requirements. The RSU Integrator will be responsible for connecting, integrating and configuring devices to work on the network using the physical connection (routers/switches) available at each site. See table under Section 4.1.3 for a list of RSU installation responsibilities.

The CV Environment network will be comprised of dedicated fiber pairs, connected to dedicated local (in-pole or cabinet) layer 3 switches, which are interconnected, in aggregate, to dedicated layer 3 switches (located in separate communications cabinets) with a location to be determined and ultimately to an IP network.
This CV Environment network will also provide limited access to public services as necessary to connect to an infrastructure management system, the SCMS, the GPS correction provider, and any other public resources as determined to be necessary.

As previously indicated, the ODOT/COG is procuring a Roadside Infrastructure Contractor to complete the construction of the roadside infrastructure located along US-33 (e.g. poles, foundations, etc.). The RSU Integrator will be responsible for supplying and supporting the installation of any roadside infrastructure components (DSRC RSUs, power-over-Ethernet modules, GPS antennas, cabling, etc.) required to create a fully functional RSU system. The RSU Integrator will be required to reimburse the Roadside Infrastructure Contractor for any additional installations or adjustments to the mounting. A complete set of detailed US-33 infrastructure plans will be provided to the selected offeror upon contract award. The infrastructure contractor will be responsible for mounting the RSU devices that will be provided by the RSU Integrator. The RSU Integrator will not be installing RSUs.

It is intended under this Contract to have the installation of the roadside infrastructure components (DSRC RSUs, middleware, additional controller modules, power-over-Ethernet modules, GPS antennas, cabling, etc.) at the signalized intersections, as provided by the RSU Integrator, completed by the respective city staff. The offeror will provide guidance for the placement of the RSUs at each signalized intersection based on a site survey evaluation. There are existing RSUs that have already been installed under this project or by the cities. The RSU Integrator will be required to reconfigure these devices so that they work seamlessly with the RSU Integrator’s solution. Removal, relocation, remounting, or replacement of the devices should be coordinated with the respective city maintenance staff.

The RSU Integrator will be responsible for providing the roadside infrastructure components (RSUs, power-over-Ethernet modules, GPS antennas, equipment cabinet, micro-processors, message handlers, cabling, etc.) intended to be located at the pedestrian actuated beacon crossings.

4.1.5 Inventory and Installation Management

The RSU Integrator will be responsible for managing the inventory of RSUs including their storage prior to installation as well as maintain records for device installation and device configuration. As part of the response to this RFP, the RSU Integrator shall provide product sheets for the major components of the system proposed to be installed. This shall include the RSU, PoE, antenna(s) and other major components of the installed system necessary to be placed in the signal cabinet, pole cabinet or installed on the mast/bracket arm/pole. These elements will not be counted against the offeror’s page count limit. The RSU Integrator shall also develop a database and inventory of each device and where it is installed. An identifying number should be placed on each device corresponding to the database.

4.2 Equipment Specifications

4.2.1 General Description

The RSU Integrator shall be responsible for furnishing, integrating, operating and maintaining the network of DSRC Roadside Units (RSU) through the operational test period. The Integrator shall supply 98 DSRC RSUs to be deployed at the traffic signal equipped intersections, pedestrian actuated beacon crossings, and locations along the 35-mile US-33 corridor as identified in Appendix A. It is expected roughly 95 are expected for deployment and 3 for spares. The Integrator shall supply all necessary radios, mounting hardware, cables, power supplies, electrical connectors, and other equipment (microprocessors, message handlers) necessary to achieve the full functionality/ connectivity expected from the RSU.

The Proposer will be required to purchase RSUs that meet or exceed the functionality described in Appendix W. Whether the device is OmniAir Certified should be identified in the proposal. It will be the offeror’s responsibility to work with the SCMS provider, ISS, to ensure that any proposed and existing devices are functional with the SCMS system.
4.2.2 RSU and CV Application Requirements

System functional, performance, interface, etc. requirements for the various configuration of RSUs and corresponding CV applications are detailed in Appendix D. As part of the RFP response, the RSU Integrator shall review each requirement and provide an assessment of their ability to meet each using the following response (this is not counted toward the maximum page requirements). It is understood that the vehicle on-board application development is part of the in-vehicle system integrator however, it is important to know that the RSU Integrator’s solution will work seamlessly with the properly equipped and configured vehicles.

- **Fully Compliant** – The proposed solution can meet the requirement exactly as indicated using an off-the-shelf product.

- **Comply with minor modification** – The proposed solution can meet the requirement with minimal changes to the product and without impacting the ability to deliver on schedule. Offeror should indicate the proposed change or reason need for change.

- **Comply with major modification** – The propose solution can meet the requirement with changes to the product that would likely impact the ability to deliver per the current schedule. Offeror should indicate what an expected revised delivery might be and the reason for not meeting the requirement.

- **Non-Compliant** – The proposed solution cannot meet the requirement without significant change that will have major impact to budget and schedule.

4.2.3 DSRC Messages

This section identifies the primary over-the-air messages that will be necessary to implement the CV Environment. Most of these messages will originate from the infrastructure and be broadcast on recurring intervals by the RSU. RSU broadcast messages, as defined by SAE, include, SPAT, MAP, RTCM, RSM, and BSM. DriveOhio has deployed connected vehicle technology along the US-33 Smart Mobility Corridor. DriveOhio will work with the RSU Integrator to ensure that all current applications will continue to function, as the RSUs are updated and configured to meet the needs of this project. All OBUs are expected to broadcast BSM messages at 10Hz. With the exception of RSM, which is currently in draft form within the SAE J2945/5 standard, all messages shall be compliant with SAE J2735:201603. A brief summary of the messages, source and purpose of each message are in the table below.

<table>
<thead>
<tr>
<th>Message</th>
<th>Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSM</td>
<td>OBU devices deployed by 33 SMC project</td>
<td>Enables future Vehicle Data for Traffic Operations (VDTO)</td>
</tr>
<tr>
<td>SPAT</td>
<td>Traffic Signal Controller via RSU</td>
<td>Each signal controller that is equipped with CV technology shall produce the SPAT message.</td>
</tr>
<tr>
<td>MAP</td>
<td>Roadside Computing Platform/ RSU</td>
<td>Each RSU shall broadcast the MAP message for the related intersection, curve warning, reduced speed and lane closure applications.</td>
</tr>
<tr>
<td>RTCM</td>
<td>Proposer should identify solutions for real-time GPS position correction information; alternate methods other than RTCM may be proposed.</td>
<td>GPS Position Correction information relayed by the RSU to the vehicle.</td>
</tr>
<tr>
<td>RSM</td>
<td>Roadside Computing Platform/ RSU</td>
<td>Part of SAE J2945 and used to support the curve warning, pedestrian crossing at beacon locations and the reduced speed/lane closure applications.</td>
</tr>
</tbody>
</table>

The RSU Integrator will be required to prepare an interface control document (ICD) for the message contents prior to configuring the equipment. The ICD will be reviewed and approved by the Program Manager.
Each message will need to be based on channel allocation requirements set forth by SAE and DriveOhio as part of the statewide System Engineering Analysis for Connected Vehicles. The channel allocation table will be provided to the awarded Proposer.

4.2.4 CV Application Descriptions

CV Vehicle-to-Infrastructure applications are expected to be developed for the 33 SMC as part of the in-vehicle OBU integrator. The RSU Integrator will work with and support the OBU Integrator and application developer to configure the RSUs appropriately to support the application. These applications are expected to be developed after the projected 12/31/19 installation date of the RSUs. The applications are expected to be:

Intersection Warning and Collision Avoidance (Red Light Violation Warning)

Reduced Speed Zone / Lane Closure Warning

Curve Speed Warning

Pedestrian Actuated Beacon Crossing Warning

4.3 System Integration and Testing Requirements

4.3.1 Integration Requirements

This section contains requirements for system integration and testing to include network integration of the RSUs into the communication network and testing to prove functionality and operation for local device assembly, local subsystem and final system. These integration services shall include all necessary configuration and programming work at communication aggregations points, subsystem locations and traffic management centers (TMC), if necessary. The RSU Integrator shall integrate to the Security and Credentials Management System (SCMS) from DriveOhio to ensure that it is working with data from trusted sources. The RSU Integrator operational data will be transmitted in real-time (<0.5 second latency) back to the data and infrastructure management systems. The RSU will transmit DSRC messages based on raw, un-encoded, data receive from a network host. Each data stream that is forwarded to the data and infrastructure management systems will include raw data elements for one DSRC message. Below are the following transmission instructions that should be applied to each message:

- Message Type/Description
- Message PSID
- Message Priority
- Transmission Channel
- Transmission Channel Mode
- Transmission Interval (set to Null)
- Message Delivery (transmission) start time (set to Null)
- Message Delivery (transmission) stop time (Set to Null)
- Signature
- Encryption

The RSU may:

1. Accept raw data over a non-DSRC Interface for encoding into messages to be transmitted over a DSRC interface
2. Encode raw data received on a non-DSRC interface into messages to be transmitted over a DSRC interface

4.3.2 Health Status and Monitoring
The RSU shall perform the management, status and health check reports over SNMPv3.

1. Status of its memory (OID ucdavis.4)
2. Status of its CPU load
3. Status of its non-volatile storage
4. Standard system load average values
5. Time elapsed since entering the “Operate” state
6. Time elapsed since first powered on
7. Last user to log in
8. Time of last user log in
9. Source IP address of last user log in
10. Number of messages transmitted and received over DSRC, Sorted by Alternating or Continuous, SCH or CCH, and Sent of Received
11. Number of messages transmitted over DSRC, sorted by PSID
12. Internal temperature

4.3.3 Interface Log Files

The RSU will provide the infrastructure management entity the ability to capture packets transmitted and received on any enabled communication interface for troubleshooting purposes. Interface logs are not intended for long term data capturing. The RSU shall:

1. Have the ability to log all transmitted and received packets across all enabled communication interfaces, while in the “Operate” State. All Interface Log File configurations contained in SNMPv3 MIB OID 1.0.15628.4.1.9 shall have the following default values:
   
   • Generate=off
   • Max file size=20MB
   • Max collection time=24 hr

2. Generate an Interface Log File for an RSU communication interface upon setting the “generate” flag in SNMPv3 MIB OID 1.0.15628.4.1.9 for that interface to “on”. A separate and independent Interface log file shall be generated for each direction (transmit and receive) of an RSU communication interface when the SNMPv3 MIB OIB 1.0.15628.4.1.9 for that interface is set to "on".

3. Generate Interface Log Files. Each file shall be generated in the industry standard packet capture (pcap) format and contain the following data:
   
   • Date and Time (in UTC, when the packet was logged)
   • RSSI (for Packets Received over DSRC)
   • TxPower (for Packets Transmitted over DSRC)
   • Packet (complete transmitted or received packet)

4. Close an active Interface Log File upon reaching the configured “Max file size” in SNMPv3 MIB OID 1.0.15628.4.1.9.

5. Close all active Interface Log Files when transitioning to "standby" state.

6. Close an active Interface Log File upon reaching the configured "Max collection time" in SNMPv3 MIB OID 1.0.15628.4.1.9.

7. Generate a new Interface Log File upon closing a previously active Interface Log File when the configured "Max file size" in SNMPv3 MIB OID 1.0.15628.4.1.9 is reached.

8. Be named according to the following convention:
   
   • RSU ID (see MIB OID 1.0.15628.4.1.17)
   • Interface ID
Transmit, receive, or both
- Date and time (UTC date and time when the file was created)

9. Allow authorized users to view Interface Log Files stored in the Interface Log File directory on the device through an Ethernet interface

4.3.4 Backhaul Network Security Requirements

The system will use fiber-optic backhaul to provide connectivity between the respective city management systems, the infrastructure management system, data management system and field devices. The cities currently use the network to remotely manage their traffic signals. The Cities and ODOT are currently defining network security protocols and how connectivity will be preserved or restored when outages are experienced. The RSU Integrator is required to coordinate with the final network architecture and requirements before implementing security configurations to communication devices include edge Ethernet switches and core switches. The RSU Integrator is required to work with the Connected Vehicle Environment Network Integrator to develop a network configuration plan identifying the IP addresses for all network components including but not limited to the RSU, and ethernet switches.

The roadside infrastructure and a fiber maintenance contractor will be responsible for configuring the components of the backhaul communication network including but not limited to the Layer 3 ethernet switches at the locations along US-33. The RSU integrator is responsible for configuring the RSU. It is reasonable to anticipate that the fiber network backhaul communications along US-33 will not be available to the RSU Integrator prior to the 12/31/2019 deadline for installation and broadcast of the RSUs along US-33.

4.3.5 MAP File Development

The RSU Integrator shall create all MAP files required for creating the DSRC broadcast to support the use cases. The RSU Integrator may use available tools, such as the USDOT MAP Creator Tool or utilize other sources, software or tools to develop MAP files. The Proposer will be required to document the project for developing the MAP files and should verify the accuracy of the MAP file development process. The RSU Integrator is responsible for creating the MAP files, and for loading the MAP files on the RSUs.

The RSU Integrator shall identify, in writing, the process used to create the MAP file, noting typical distances between node points on straight and curved roadway segments.

4.3.6 Real-Time GPS Correction

The Proposer should recommend and develop a method to handling Real-Time GPS Correction.

4.3.7 Data and Interface Requirements

Details of message and interface requirements will need to be developed by the RSU Integrator in the form of an Interface Control Document (ICD).

4.4 Scope of Services

The 33 SMC has identified a high-level work plan they believe will allow for successful completion of the integration activities associated with the CV Environment project and meet the goals of the overall 33 SMC project. Deviations from this plan will be considered but must be identified and documented by the Proposer in their proposal.

Task 1 – Project Management and Reporting
Upon notice to proceed, the selected Proposer will be provided with the most current 33 SMC schedule identifying the key milestones and deliverables of the overall connected vehicle environment project. The RSU Integrator shall prepare and submit a detailed work plan and schedule that meets the 33 SMC schedule. A draft of this work plan shall be submitted within two (2) weeks of NTP. The RSU Integrator shall update and submit a revised work plan and schedule within 1 week of receipt of comments. The 33 SMC project team shall have 5 business days to review, as will be typical for all deliverable / approval items provided for all tasks delineated in this scope.

The RSU Integrator shall participate in a Weekly Status Meeting with the 33 SMC Program Management team. The project manager shall attend the first meeting of each month in person. The remaining meetings will be via conference call.

The RSU Integrator shall provide Bi-weekly Status Reports that identify accomplishments, upcoming activities, risks/concerns, status of percent complete for each of the major installation phases/groups and updated schedule.

**Task Deliverables**
- Work Plan (draft/final)
- Bi-weekly Status Report

**Task 2 – Roadside Devices and Related Services Procurement**

Upon approval of work plan, the RSU Integrator shall initiate procurement of the hardware and software components in accordance with the approved schedule and work plan. Further, if it is necessary to secure facilities, tools and other services related to the storage and testing, this work may proceed upon approval of the work plan. It is the responsibility of the RSU Integrator to produce any specifications necessary to complete these activities.

The RSU Integrator will be responsible for receipt, inspection, and storage of all purchased items and shall maintain an accurate accounting of this equipment. Any major equipment items not already identified by a vendor serial number shall be tagged for inventory and installation tracking purposes by the RSU Integrator. Any damage or discrepancy items shall be reported to the Program Manager along with remedy plan. These will be tracked as part of the weekly status.

A representative example of each RSU, including antenna, PoE, and any other major component shall be made available to the Program Manager within 30 days of NTP in order to support installation planning activities. The procurement should expect to secure all 98 RSUs. All equipment for which the RSU Integrator has been reimbursed becomes the property of the COG with the offeror serving in the role of custodian.

**Task Deliverables**
- Inventory/Discrepancy Reports
- Device Tracking Database
- RSU Deployment location plan
- RSU and supporting hardware

**Task 3 – Systems Engineering Design and Documentation**

The project has developed the hi-level system requirements for the project, as noted in Appendix C. The system requirements define what is required for the project but does not describe in detail how it will be accomplished. The RSU Integrator must document the detailed design elements. Additional details may need to be provided to satisfy both FHWA and ODOT systems engineering requirements. As part of the project development, the RSU Integrator may be required to produce some or all the following documents:

- System Design Document (SDD)
- System Integration Plan
The system design should define the system level architecture, which should be further refined to the sub-systems of hardware, software, databases, and people. At the component level, the design should define how the system will be built. Components should be broken into hardware, software, database elements, firmware, and/or processes. For these components, provide the details on how each will be built, procured or developed and what hardware fabrication or software development may be required. Identify any commercial off-the-shelf [COTS] hardware and software products that will be used.

The RSU Integrator shall also prepare a verification plan that identifies the testing procedures to verify compliance with the system requirements for the project and that the system is broadcasting the messages such that they can be received properly by an equipped vehicle. The plan must detail the process used to verify the correct broadcast of the SPaT, MAP and GPS correction messaging, in addition to previously passing DriveOhio interoperability tests in a lab environment.

SPaT and MAP verification should be identified to be performed in accordance with System-Level Verification and Message-Level Verification as documented in the The SPaT Challenge Verification Document Revised - October 30, 2017 Version 1.2 available for download at https://transportationops.org/content/spat-challenge-verification-document.

**Task Deliverables**
- System Design Document (SDD)
- System Integration Plan
- Interface Control Document (ICD)
- Verification Plan

**Task 4 – Software Development**

The RSU Integrator will be required to interface the roadside infrastructure to the connected vehicle environment network via a management system. The management system shall allow for the RSU health monitoring, coordinate firmware or other upgrades for RSUs, certificate updates for the security credential management system and any GPS correction function that may require interface through the network to the individual RSUs.

The RSU Integrator will work in coordination with the Connected Vehicle Environment Network Integrator and other COG/ODOT partners to ensure project data is also made available to and stored by data management system.

Any software developed under contract to ODOT shall be considered open-source and may ultimately be published to the USDOT Open Source Application Data Portal (OSADP) upon successful testing and release.

The infrastructure management system under this contract is to provide the COG with the necessary oversight/management of the RSUs along US-33 and at the signals within each city and perform minimal data logging. All devices installed under this contract will eventually be connected via a fiber network within the operational test period. The infrastructure owners (COG, ODOT, Cities) and the Connected Vehicle Environment Network Integrator will be available to the RSU Integrator to coordinate interfaces between the roadside infrastructure and the data and infrastructure management systems. There will also be coordination necessary to implement the interfaces to public resources such as the SCMS, and GPS correction services, etc. As it is not expected for 33 SMC OBU’s to interface directly with the infrastructure management system, all data exchange will be enabled thru the RSU.

**Task Deliverables**
- Source-code and related documentation published to OSADP
Task 5 – Unit Preparation

The RSU Integrator will be expected to perform any/all activities necessary to prepare devices for installation. This includes changing default passwords, reviewing default device security settings, performing firmware updates, loading of application software, completing network configuration, installing and configuring certificate management, configuring firewall settings, configuring logging capability, etc.

In addition to the roadside units provided as part of the project, the RSU Integrator will be required to reconfigure the existing RSUs that have already been deployed at traffic signals in the City of Marysville and City of Dublin and by ODOT along US 33. The existing units shall be configured to make them consistent with those that are being provided for the project. The following is a list of the locations and device make and models of each existing RSU:

<table>
<thead>
<tr>
<th>Location</th>
<th>RSU Make and Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marysville</td>
<td></td>
</tr>
<tr>
<td>5th Street and Walnut Street</td>
<td>Kapsch RIS-9160</td>
</tr>
<tr>
<td>5th Street and Main Street</td>
<td>Kapsch RIS-9160</td>
</tr>
<tr>
<td>5th Street and Maple Street</td>
<td>Kapsch RIS-9160</td>
</tr>
<tr>
<td>Amrine Mill Road and Maple Street</td>
<td>Kapsch RIS-9160</td>
</tr>
<tr>
<td>5th Street and Plum Street</td>
<td>Siemens ESCoS</td>
</tr>
<tr>
<td>5th Street and Court Street</td>
<td>Siemens ESCoS</td>
</tr>
<tr>
<td>4th Street and Main Street</td>
<td>Siemens ESCoS</td>
</tr>
<tr>
<td>4th Street and Main Street</td>
<td>Siemens ESCoS</td>
</tr>
<tr>
<td>Dublin</td>
<td></td>
</tr>
<tr>
<td>Avery-Muirfield Road and Hospital Drive/Perimeter Loop Road</td>
<td>Siemens ESCoS</td>
</tr>
<tr>
<td>Avery-Muirfield Road and Perimeter Drive</td>
<td>Siemens ESCoS</td>
</tr>
<tr>
<td>US 33</td>
<td></td>
</tr>
<tr>
<td>US 33 at I-270</td>
<td>Cohda MK5</td>
</tr>
<tr>
<td>US 33 at Post Road Interchange</td>
<td>Cohda MK5</td>
</tr>
</tbody>
</table>

This step also includes preparation of the MAP files that need to be loaded for each intersection. The RSU Integrator will be responsible for converting this point data into the corresponding MAP message.

The RSU Integrator shall also be responsible for creating the necessary interfaces with the traffic signal controller in order to obtain signal phase and timing (SPAT). All signal controllers will be capable of outputting NTCIP 1202 signal phasing and timing information. The RSU Integrator will be responsible for any software or hardware modules that would need to be developed/deployed as necessary to support the stated CV applications. Conversion to SAE J2735 messages will not be permitted within the RSU. The SPaT message development/conversion should not occur in the RSU. The RSU should simply be forwarding the SPaT SAE J2735 message.

The RSU Integrator shall, in advance of commencing unit preparation, prepare detailed procedures and a high-level checklist, for each unit type/configuration that will be deployed. These procedures and the resulting checklist shall require the approval of the Program Manager before unit preparation activities commence in full. A copy of the approved checklist shall be completed for each unit provisioned and maintained along with installation records related to each unit. A copy of the completed checklists shall be made available to the Management Team upon request. All records for all units shall be transferred to the COG upon completion of the operational testing period.

Task Deliverables
- Unit Preparation Procedures and Checklist
- Completed Unit Preparation Checklists

Task 6 – First-Article Installation Planning
One (1) month prior to any planned infrastructure deployment activities, the RSU Integrator should prepare and submit installation plans for the following three deployment groups: Signalized locations in the City of Marysville; Signalized locations within the City of Dublin; and roadside locations along US-33. The plan shall follow the procedures and requirements described in this RFP, and the project schedule provided after award. The plan should cover all the different RSU vendors, including those that are already in the field and including specific requirements per vendor if applicable. Any deviations from these specifications shall be noted in the plan and shall not be executed in the field without the approval of the 33 SMC project team.

Further, the RSU Integrator should prepare Installation Training Plans to accompany the Installation Plans to ensure installers are adequately prepared to install the devices.

Upon plan approval, the RSU Integrator shall, working in coordination with the Program Manager and installing entity identified in Section 3.8.2, configure, and furnish for installation one example of each of the three deployment groups for each RSU manufacturer provided. Necessary modifications to the installation plans should be captured during this activity. These plans are intended to be used to support installation training for subsequent installation activities as identified in Task 8, since remaining RSUs will be installed by others.

**Task Deliverables**
- Device Installation Plans and Checklist
- Installation Training Plans
- Completed Installations of First-Article sites

**Task 7 – Testing**

The RSU Integrator shall create and provide a verification test plan (VTP) for review and approval by the COG. The offeror shall conduct the approved verification test plan in accordance with the agreed-to work plan and schedule. The verification test plan shall include but not limited to the following tests:

- **On-site Stand-alone Test (Stand-alone):** Before the sub-system acceptance testing (SST), conduct on-site stand-alone tests of the equipment installed at each field site as approved by the Program Manager. The test shall, at a minimum, exercise all stand-alone (non-network) functional operations of the field equipment with the equipment installed per the plans or as directed by the Program Manager.
- **Sub-System Acceptance Test (SSAT):** Conduct SSAT to verify a section of the overall CV Environment system is functioning properly. Sub-system acceptance testing shall be conducted at logical nodes, aggregation points, or the TMC to verify both communications and device functionality.
- **Final System Test (FST):** FST is the last step in the VTP and serves as the basis for system acceptance. After the successful completion of the FST, the 30-day burn-in period begins.
- **Burn-in Test:** The offeror shall provide the Program Manager with a test plan to be carried out by the 33 SMC project team during the 30-day test. This includes the final version of all applicable manuals, printed guides and procedures.

The COG will have five (5) business days to review and provide comments on the testing procedures. The offeror will not be permitted to conduct any tests without an approved test procedure.

Testing Requirements: The RSU Integrator will provide test case(s) with pass/fail criteria for each requirement to be verified. All functional requirements in the test case shall pass during the witness testing to grant final acceptance. During the review of the VTP report, both the COG and the RSU Integrator has the ability to recommend the addition, revision, or removal of test case requirements as agreed to by all parties. These changes shall be documented.

Test reports, documenting all pass/fail results for all phases of testing, corrective actions, re-test results, and any data sheets and calibration records developed as a part of the testing activities shall be submitted to the COG for approval.
Task Deliverables

- Verification Test Plan
- Test Cases
- Test Reports

Task 8 – First-Article Equipment Burn-In Testing

After initial acceptance testing has been completed and all test cases have passed, the RSU Integrator shall subject the first-article equipment to a 30-day burn-in test per the following requirements.

- Maintain a failure log that records the date, time, and location of major and minor failures that occurs, and the corrective actions taken. Record the details of the failure and corrective action in this log. Make documentation available for inspection by the COG and provide a copy to the COG at the end of the burn-in period.
- Equipment failure reports with proposed corrective action plans shall be generated and provided to the Program Manager for review and concurrence.
- There may be no major failures during the 30-day burn-in period. If one occurs the 30-day period will restart after the major failure has been corrected to the Program Manager’s satisfaction. The following are considered major failures:
  - Less than 95 percent of devices under test are operational at any moment.
  - Any failure that requires more than 48 hours to correct after providing notice to the Integrator.
  - Frequent occurrence of minor failures indicating a major system flaw, as determined by the COG.
- A minor failure includes a physical equipment failure that does not affect the operation of the entire system of an entire corridor. The 30-day burn-in period shall be stopped when a minor failure occurs and restarted without resetting to zero after the minor failure is corrected to the satisfaction of the Program Manager.

During this 30-day burn-in monitor the system as specified in the Verification Test Plan. During the test, field elements must be continuously monitored with daily reports generated to confirm proper integration with the software. The RSU Integrator shall make available a systems technician who is fully knowledgeable and capable of operating all functions of the specified subsystem on an on-call basis for technical support during the 30-day test period.

During this period, it is expected that interfaces to the SCMS, GPS correction services and the infrastructure management system will all be operational. Further, the RSU health and status monitoring tools/application shall also be operational.

Task Deliverables

- Equipment manuals, printed guides and procedures
- Failure Log and Remedies Report

Task 9 – Equipment Installation

Upon successful completion of burn-in testing (Task 8) and approval of the Program Manager, and in coordination with the Management Team and Roadside Infrastructure Contractor, the RSU Integrator shall proceed with the preparation and coordination of infrastructure installation.

The RSU Integrator is responsible for providing all elements related to the installation, including unique tools, microprocessors, message handlers to provide a function system for the prescribed use case. The deliverable should include installation plans and check lists. Installation is expected to be performed in phases along the
various corridors and based on CV application and the availability of the roadside infrastructure. The RSU Integrator is also responsible for demonstrating that the testing criteria (Task 7) continues to be met at both the device and system level as the installation proceeds.

Device installation should be accompanied by completion of an installation checklist and confirmation that the device is fully operational. These results will be managed along with the device configuration checklist.

**Task Deliverables**
- Provisioned RSUs along with PoE injector, antenna, coprocessors, wiring, mounting hardware etc.
- Completed installation checklist and test results
- Plan sheets detailing out wiring schematic and mounting requirements for the RSU equipment

**Task 10 – System Verification**

In accordance with the approved verification plan developed in Task 3, the RSU Integrator shall initiate the system verification for each roadside installation. The verification will be completed in coordination with the Program Manager. Partial system acceptance will be based on completion and acceptance of the system verification process. Any defects or issues that are found during the verification will be the responsibility of the RSU Integrator to resolve prior to acceptance.

**Task Deliverables**
- System verification results

**Task 11 – Application Development Support**

CV Vehicle-to-Infrastructure application development will fall under the responsibility of the 33 SMC OBU Integrator and application developer. The Project Team recognizes that not all the proposed application use cases are fully developed and will likely require additional development to be deployment ready.

The RSU Integrator shall be responsible for coordinating with the OBU Integrator and Application developer to configure the RSU message sets appropriately to support the identified applications, including the message building, message handling, and development of the appropriate Roadside Safety Message.

As all V2I CV applications require software modules on both the OBU and RSU, the Proposer will also be expected to work with the in-vehicle integrator in an open, collaborative environment. In the case of any disagreements between parties, the US-33 Program Manager will confer with the project partnering agencies to determine the paths and responsible parties moving forward.

**Task Deliverables**
- Application development support
- RSU message development

**Task 12 – Operations and Maintenance**

Starting with the installation of the first RSU, through the end of the operational testing period, the RSU Integrator will be responsible for monitoring the health and status of the RSU network, ensuring that it is producing the necessary over-the-air messages and collecting BSM messages from vehicles, and subsequently forwarding these to the data management and infrastructure management systems. Furthermore, monitoring the SCMS, including revocation lists, and verifying connection and operations of any external, dependent system shall also be performed. The approach to this monitoring will be at the discretion of the integrator, however the COG expects the following level of services associated with this task at a minimum. The RSU Integrators shall notify DriveOhio within 12 hours of any identified missing equipment, once the equipment has been provisioned with security certificates.
• The RSU Integrator shall notify the COG within 4 hours of any identified or suspected RSU failures which affect its operation in supporting driver safety applications.
• The RSU Integrator shall notify the COG within 24 hours of any identified or suspected failures which affect the ability of the system to forward data to the data and infrastructure management systems.

Notification shall include location(s) affected, suspected error, proposed remedy, and timeline for remedy. If the detected failure necessitates the replacement of the RSU or any other roadside equipment, the RSU Integrator shall make said equipment available within 48 hours.

The COG will provide the RSU Integrator with remote access to network and infrastructure management system (as necessary) to enable this activity.

As there presently is no way to guarantee RSU broadcast is functioning properly from the remote console, the RSU integrator shall also be responsible to perform weekly checks of the RSU components using a packet sniffer or other suitable tool.

Weekly reporting during this O&M phase shall include a summary of system health and the status of any open or recently close actions.

The RSU Integrator shall also produce metrics reported on weekly basis that include:

- System Uptime Percentage (Weekly, Year-to-Date)
- Mean-time-between-failures (MTBF)
- Mean-time-to-repair (MTTR)
- Transmit/Receipt Statistics including:
  - Number of messages
  - Data use

The procedures use by the RSU Integrator to perform the activities documented in this task shall be documented in the form of Standard Operating Procedures, which shall be submitted within 30 days of the initial deployment, and within two (2) weeks of any changes to the procedure.

During the operational testing period, the RSU Integrator will be responsible for providing and installing all firmware upgrades for the RSU’s installed in the field. The RSU Integrator will also be responsible for the reconfiguration of any RSU’s due to any applicable SAE message standard changes or USDOT RSU specification changes.

**Task Deliverables**
- Weekly Reporting as indicated
- Standard Operating Procedures (initial, updates)

**Task 13 – Project Hand Off Planning**

No later than December 31, 2020, the RSU Integrator shall prepare and submit the final Standard Operating Procedures along with a user training guide that shall be prepared for purposes of training the COG staff to assume operation of the connected vehicle environment at the completion of the operational testing period. Both the procedures and training plan will be reviewed by the COG and Program Manager and the RSU Integrator is then expected to submit a final version.

The RSU Integrator will be expected to provide on-site training to the COG staff in a minimum of 2 locations, an activity that will be coordinated as the end of the operational testing period approaches.

**Task Deliverables**
• Equipment Technical Data Sheets
• Final Standard Operating Procedure
• Operations Manuals
• Training Material
1. DOWNLOADING THE EXCEL PRICING FILE: Bidders can access and download the most current Excel Pricing File for this invitation to bid by following the hyperlink provided below:


2. SUBMISSION OF EXCEL PRICING FILE: Bidders should submit both a media device with the completed electronic Excel pricing file (.xls) and a hard copy print out of the completed Excel file in their submitted bid package. The media device should be marked with the bidder’s name and the Invitation to Bid number.

   “Media Device”- Compact Disc (CD), DVD (Digital Versatile Disc), or Flash Drive

   Failure to submit this media device with a completed Excel price sheet from the Department’s Microsoft Excel file and the hard copy print out of the completed Excel price sheet may result in a bid being deemed non-responsive by the Department.

3. DISCREPANCIES IN SUBMITTED INFORMATION: In the event there is a discrepancy between the information submitted on the media device and the hard copy Excel price sheet, the information submitted on the media device will take precedence.

4. NON-FUNCTIONAL MEDIA DEVICE: The Department shall not be held liable in the event a bidder’s media device is not functional, is broken, or is unable to be accessed/downloaded by the Department for any reason. Bidders should take care to ensure all submitted media devices are properly protected during transport.

5. UNAPPROVED ALTERATIONS TO EXCEL PRICING FILE: Bidders who materially alter the original content of the Excel pricing file (e.g. specifications, formulas, etc.) issued by the Department may be found non-responsive and ineligible for award of this invitation to bid.

6. CHANGES TO EXCEL PRICING FILE: The Department will only make modifications to the Excel pricing file by written addendum only. Where changes are necessary to the Excel pricing page, the Department will issue a new Excel pricing page indicating the revisions made and a revision date for the changes.

   It is the sole responsibility of the bidder to check for issued addenda prior to submitting a bid package to ensure the most updated Excel pricing file is being utilized.

7. DESCRIPTIVE LITERATURE: Bidders may electronically, on their submitted media device, provide any descriptive literature (e.g. brochures, spec/cut sheets, drawings, MSDS, etc.) regarding the products and/or services offered by the bidder. As this literature may be publicly posted for viewing by purchasers, bidders must not submit any literature electronically in which they consider to be a trade secret, proprietary, or confidential in any way.

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State of Ohio, Department of Transportation (ODOT)  
Office of Contract Sales, Purchasing Services  
INSTRUCTIONS, TERMS AND CONDITIONS FOR BIDDING  
(Last revised 02/2019)  

1. **BIDDER REGISTRATION**: The Department requires awarded bidder(s) to successfully register as a State of Ohio Supplier with the Department of Ohio Shared Services and successfully obtain an OAKS vendor identification number (OAKS ID) within fourteen (14) calendar days from the date of contract award and execution. The Department cannot utilize awarded Contracts to purchase from a bidder who cannot obtain an OAKS ID from Ohio Shared Services. In the event an awarded bidder is unable to obtain an OAKS ID, the Department shall reserve the right to revoke its award to the bidder and immediately cancel any resulting Contract.

A Supplier Information Form and W-9 must be completed and sent back directly to Ohio Shared Services in order to register and apply for an OAKS ID. The following website can be accessed by bidders to obtain both the forms and specific instructions for obtaining an OAKS ID:

http://ohiosharedservices.ohio.gov/SupplierOperations/Forms.aspx

It is strongly recommended that all interested bidders not already registered with Ohio Shared Services submit the above paperwork prior to the bid submission deadline.

2. **HOW BIDS MUST BE PACKAGED**: All submitted bids in response to this Invitation to Bid (ITB) must be submitted in a sealed envelope or box (envelope means any type of sealed, opaque container) marked with the ITB number, the title of the ITB, bid submission deadline (bid opening date), and bidder (company) name clearly marked on the outside of the envelope/box. If a bidder is using an “Express Mail” or similar type of service, the bid response must be contained in a sealed envelope within the “Express” mailer (the bid number must be listed on the exterior of the sealed envelope contained within the “Express” mailer). A bid that is not properly and clearly marked and is inadvertently opened, before the scheduled bid opening time, may be disqualified, at the Department’s discretion, without additional consideration for award of the contract.

Below is an example to illustrate how the outer surface of the bid package should be labeled:

- **Invitation to Bid #**: (insert bid number)
- **Commodity/Service**: (insert title of bid)
- **Bid Submission Deadline**: (insert due date)
- **Company Name**: (insert company name)

3. **WHAT NEEDS INCLUDED IN BID PACKAGE**: Submitted bid packages should include, at a minimum, a completed Signature Page, a hard copy print out of this entire invitation to bid document, media device with a completed Excel pricing page, hard copy of the completed Excel pricing page, and all necessary supportive documentation, forms, and any other information required herein. The Department may deem a bid non-responsive for failure to submit any of the documents requested above.

4. **PREBID QUESTIONS, DISCREPANCIES, AND CLARIFICATIONS**: Any discrepancies, omissions, ambiguities, or conflicts in or among the bidding documents or doubts as to the meaning shall be brought to the Department’s attention by the bidder no less than three (3) business days prior to the bid submission deadline. All questions, discrepancies, clarifications, etc. must be submitted electronically (hyperlink below). During the competitive bidding process, bidders (and their agents) are prohibited from contacting any ODOT office, including District offices, other than the Office of Contract Sales, Purchasing Services section to obtain responses to any questions. The Department may find a bidder non-responsive for failing to adhere to any of the above requirements.

Pre-bid questions/inquiries must be submitted electronically through the following website:

http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/Pages/PurchasePBQ.aspx
Answers to Pre-Bid Questions/Inquiries will be posted on the following document available for download at the following website:
http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/Purchase/PBQ-Answers.doc

It is each bidder's sole responsibility to check the website for updates to pre-bid questions and answers before submitting its bid package to the Department.

5. MODIFICATIONS TO THE BIDDING DOCUMENTS: When it is deemed necessary to modify these bidding documents, the Department will only do so by written addendum. The issuance of an addendum is dependent upon the information received and the impact on the competitive bid process. All issued addenda will be posted to the Department’s Upcoming ITB’s website and shall be automatically incorporated into the bidding/contract documents:

http://www.dot.state.oh.us/Divisions/ContractAdmin/Contracts/Lists/PurchaseUpcomingITBs/UpITBs.aspx

In addition to posting on the above website, the Department also may email addenda information out to all known bidders for convenience purposes only. The Department shall not be held responsible for a bidder's failure to receive the email with the addenda information. It is the sole responsibility of all interested bidders to diligently visit the above-listed website to see if any addenda have been issued prior to submitting their bid to the Department. Those interested in obtaining addenda information via email for a particular invitation to bid must send the Department its request in writing to the following email address: Contracts.Purchasing@dot.ohio.gov

6. PRE-BID CONFERENCES: The Department reserves the right to hold mandatory or optional pre-bid conferences at its discretion. Conferences may be held either in-person or via webinar/phone conference formats. Bidders will be required to sign-in at all pre-bid conferences. The sign-in sheet for all pre-bid conferences is considered a public record, will be kept in the bid file, and will be shared with any requesting party. Additionally, any business cards collected during any pre-bid conference shall be considered public records and may be distributed out to all conference attendees. Any changes to the requirements or specifications of an invitation to bid, as a result of the pre-bid conference content, will be made by written addendum and publicly posted.

For mandatory pre-bid conferences, the Department requires that those companies intending on submitting a bid be in attendance for the entire duration of the pre-bid conference. Mandatory pre-bid conferences will officially begin five (5) minutes after the scheduled date and start time at the location specified in the Special Terms and Conditions. Those bidders not in attendance at that time will be considered ineligible to submit a bid. The conference will be considered adjourned and complete when a representative of the Office of Contract Sales, Purchasing Services section indicates so. To be considered in attendance and eligible to bid, a bidder must have at least one representative of the company in attendance. A single representative cannot be present on behalf of two or more companies (bidders). Each company (bidder) must send its own representative on behalf of their organization. It is the sole responsibility of the bidder to ensure that the representative follows the sign-in procedures to properly document the bidder’s attendance. The Department shall not be held responsible for a bidder’s failure to arrive at the meeting on time, properly sign-in, or failure to stay for the entire duration of the meeting.

7. WHERE BIDS MUST BE DELIVERED TO: The Department only accepts hand delivered and mailed bid packages. Bids submitted via email, telephone, electronic facsimile (fax), or any other mode of electronic transmission will not be considered a responsive bid submission. Bids must be in possession of the ODOT Office of Contract Sales, Purchasing Services section, on or prior to 2:00 p.m. eastern time, on the scheduled date of the bid submission deadline (public bid opening) as listed on the cover of this Invitation to Bid (ITB). Properly labeled bid packages must be either hand delivered by the bidder to the Office of Contract Sales, Purchasing Services section or mailed to the following EXACT address:
For hand delivery of bids, the Office of Contract Sales, Purchasing Services section is located on the 1st floor of ODOT Central Office (same address as where bids will be received). Bidders will be required to sign-in at the front desk of the building and then must be escorted back to the Office of Contract Sales, Purchasing Services section in order to drop off their bid. It is the responsibility of the bidder to ensure enough time is allotted to allow for all sign in and security procedures prior to the 2:00 p.m. bid submission deadline. Delivery of bids to any other location (including the ODOT mailroom), does not constitute receipt by the Purchasing Services section. Bids delivered to the ODOT mail room by a courier service must be delivered so as to leave a reasonable amount of time for the transfer of the bid to the Purchasing Services section. The ODOT mail room delivers received mail to Purchasing Services at scheduled times during normal office hours.

8. LATE BIDS: A bid received after 2:00 p.m. eastern time, on the bid submission deadline (bid opening date) established, shall be deemed “late” and will not be considered for award of this invitation to bid. The late bid package will be marked as late, remain sealed, and will be kept in the Department’s bid file to serve as official record of a late bid having been received.

Note: The Office of Contract Sales, Purchasing Services timeclock takes precedence over any other timekeeping device (e.g. cell phones, other ODOT clocks, wrist watches, etc.) and will be utilized by the Department to determine whether or not a bid was received by the 2:00 p.m. deadline.

9. PUBLIC BID OPENING PROCEDURE: All bids in possession of the Purchasing Services section shall be publicly opened, at ODOT Central Office, Office of Contract Sales, Purchasing Services section, 1st floor, starting at 2:01 p.m. on the scheduled date of public bid opening (bid submission deadline). All bids will be opened and read to any interested parties in attendance. At the conclusion of the public bid opening, bids may no longer be shared with interested parties until after a contract award has been made.

10. BIDS FIRM: Once publicly opened, all bids are firm and cannot be altered by the bidder. Once a Contract is awarded and executed, the Vendor shall deliver all products and/or services at the bid prices and terms contained in the Contract. All submitted bids shall remain valid for a period of sixty (60) calendar days after the date of the public bid opening. Beyond sixty (60) calendar days, bidders will have the option to either honor their submitted bid or make a written request to withdraw their bid from consideration. The Ohio Department of Transportation shall receive the benefit of any decrease in price during the sixty (60) day period.

11. WITHDRAWAL OF BIDS: A bidder may, by way of written notice to the Purchasing Services section, request to withdraw their bid response prior to the bid submission deadline. The request must be received by the Purchasing Services Section PRIOR to the start of the public bid opening (beginning at 2:01 p.m.) on the date of the bid submission deadline. Such written notice must set forth the specific reasons for the bid withdrawal.

For requests to withdrawal a bid after the public bid opening has begun, the bidder may request to withdraw their bid response from consideration if the unit bid price(s) submitted are unreasonably lower than the other bids received, provided the bid was submitted in good faith, and the reason for the unit bid price(s) being substantially lower was due to an unintentional and substantial arithmetical error or unintentional omission of a substantial quantity of material or labor in the compilation of the bid. Written notice of any such request to withdraw after the bid opening must be received by the Purchasing Services section within no later than forty-eight (48) hours of the scheduled public bid opening.
The decision to allow a bid to be withdrawn is at the sole discretion of the Purchasing Services section. If the bid is to be awarded by category, lot, or group the withdrawal request will apply to all items within the category, lot, or group. All documents and conversations relating to any withdrawal request will become a part of the permanent bid file.

12. MODIFICATION OF SUBMITTED BIDS PRIOR TO PUBLIC BID OPENING: A bidder may request to modify their bid response prior to the scheduled date and time set for the public bid opening (i.e. bid submission deadline). To modify a bid response, the bidder must provide an alternate, complete bid package containing all required forms and necessary documents. The alternate bid package must be marked somewhere on the outer packaging as “REVISED”. Purchasing Services will not return the original bid package to the bidder. The original bid package will be kept in the contract file.

In order to protect the integrity of the bidding process, bids shall not be prepared on the premises of ODOT. Any bid which is prepared on the premises of ODOT may be immediately disqualified and receive no further consideration for award.

13. UNIT BID PRICES: The unit bid price(s) submitted shall govern the award of this invitation to bid unless otherwise specified in the bid evaluation criteria. The unit bid price should be entered for each required bid item on the Department’s pricing page. Use of ditto marks, arrows, or other markings in lieu of the actual unit price may result in a non-responsive bid determination. Lot or group prices listed in the unit bid price area shall be considered as the unit price unless clearly identified as the lot price. Unless specifically allowed in the contract’s terms and conditions, requests to change or alter unit bid prices after the public bid opening are prohibited.

The following requirements also apply to unit bid prices:

a. DECIMAL POINT: Bidders should not insert a unit cost of more than two (2) digits to the right of the decimal point. Digit(s) beyond two (2) will be dropped and not recognized by the Department for the purposes of bid evaluation or contract award.

b. CREDIT CARD FEES: Bidders must incorporate into their unit bid price(s) submitted all costs and fees associated with the State’s use of a payment (credit) card.

c. DISCOUNTS: While bidders may offer to the Department discounts for prompt payment and other similar incentives, discounts and incentives these will not be used to alter the submitted unit bid price(s) for purposes of bid evaluation and contract award. This section only applies to bids awarded to the lowest responsive and responsible bidder either by individual bid item or group of bid items and does not include bids which are awarded to all responsive and responsible bidders (i.e. Multiple Award Contracts).

d. MULTIPLE AWARD CONTRACTS: Pursuant to Ohio Revised Code 5513.02, the Department may award Contracts to all responsive and responsible bidders for articles (i.e. bid items) meeting the general specifications provided. These are referenced by the Department as ‘Multiple Award Contracts’. Unit bid prices submitted for Multiple Award Contracts shall be considered by the Department as an amount not-to-exceed unit bid price for the entire duration of the Contract. These awarded, amount-not-to-exceed bid prices often do not reflect potential quantity discounts, freight discounts, nor other similar discounts/incentives offered periodically by a distributor, manufacturer, or supplier. Where like or similar bid items are being offered by two or more awarded Vendors (bidders) on the awarded Contract, the Department reserves the right to obtain quotes from all awarded bidders on the Contract in order to achieve the best and most up-to-date pricing available to the Department at the time of ordering.

e. UNBALANCED BIDS: The Department will not accept unit bid prices that are deemed to be either materially or mathematically unbalanced. The final determination of an unbalanced unit bid price shall be at the Department’s sole discretion.
f. **Tie Bid Process**: If two or more responsive bids offer the same unit bid price, ODOT may break the tie as follows: during the bid evaluation process, the bidders that submitted tie bids will be contacted and given up to three (3) business days to submit a written revised unit price for the affected item or items. Bidders are not required to submit a revised unit price. In the event a tie still exists after the above-prescribed deadline has passed, ODOT will schedule a coin flip to be conducted in the presence of both bidders. The winner of the coin flip will be deemed awarded the affected bid item(s).

14. **Preference for Ohio/Border State Products**: The bid award for this invitation to bid may be subject to the domestic preference provisions of the Buy America Act, 41 U.S.C.A., 10a-10d, as amended, and to the preference for Ohio products under O.R.C. Sections 125.09 and 125.11 and Ohio Administrative Code Rule 123:5-1-06. A bidder must complete the enclosed *Buy Ohio/Buy America Certification Statement* form to be eligible to receive any applicable bid preferences.

15. **Responsive Bidder**: A bidder is responsive if its bid responds to the bid specifications in all material respects and contains no irregularities or deviations from the specifications that would affect the amount of the bid or otherwise give the bidder an unfair competitive advantage.

16. **Minor Informalities or Irregularities in Bids**: A minor informality or irregularity is one that is merely a matter of form and not of substance. It also pertains to some immaterial defect in a bid or variation of a bid from the exact requirements of the invitation that can be corrected or waived without being prejudicial to other bidders. The defect or variation is immaterial when the effect on price, quantity, quality, or delivery is negligible when contrasted with the total cost or scope of the supplies or services being acquired. The Department either shall give the bidder an opportunity to cure any deficiency resulting from a minor informality or irregularity in a bid or waive the deficiency, whichever is to the advantage of the Department.

17. **Bidder Responsibility**: The Department will only award this invitation to bid to what it deems to be a responsible bidder. The Department’s determination of a bidder’s responsibility includes, but is not limited to, the following factors:

   a) experience of the bidder;
   b) bidder’s financial condition;
   c) bidder’s conduct and performance on previous contracts;
   d) the bidder’s facilities;
   e) the bidder’s management skills;
   f) the bidder’s employees;
   g) past experience and/or quality of bidder’s proposed subcontractors;
   h) the bidder’s ability to execute the contract;
   i) review of Federal and Department debarment lists;
   j) bidder has history of successful performance on contracts of similar size and scope; and
   k) current or impending legal actions against a bidder.

18. **Apparent Clerical Mistakes**: Clerical mistakes apparent on the face of the bid may be corrected, at the Department’s discretion, before contract award. The Department first shall obtain from the bidder a verification of the information intended and will attach written verification of the mistake by the bidder in the contract file and award documents. Example of apparent clerical mistakes are:

   (1) Obvious misplacement of a decimal point or comma;
   (2) Obvious incorrect discount factor; or
   (3) Transcription error in Part Number.

19. **Additional Information**: The Department reserves the right to request additional information to evaluate a bidder’s responsiveness to the Invitation to Bid’s requirements and/or to evaluate a bidder’s overall responsibility. These requests may require the bidder’s submission of confidential materials (e.g. financial statements). If a bidder does not provide all of the requested information within the prescribed timeframe, the Department may find the bid non-responsive and ineligible for award.

20. **Product Samples**: The Department may require bidders, by Invitation to Bid or by request during bid evaluation, to provide sample supplies or equipment or examples of work, at the Bidder’s expense. Samples
must clearly identify the Bidder, the bid number, and the item the sample represents in the bid. The Department will return samples that are not destroyed by testing, at the Bidder's expense, upon the Bidder's timely request. The Department may keep the samples of the Bidder awarded the contract until the completion of the contract. Unsolicited samples submitted in response to this Invitation to Bid will not be evaluated and the Department may dispose of them in any way it chooses.

21. **SPECIFICATIONS:** The Department is authorized by Sections 5513 and/or 125.02(B) of the Ohio Revised Code to prepare specifications and establish contracts to obtain the supplies, equipment, and/or services referenced within this invitation to bid. The purpose of the provided specifications is to describe the supplies, equipment, and/or services to be purchased and will serve as a fair and equitable basis for comparison of submitted bids. The Department may use any form of specification it determines to be in the best interest of the Department and that best describes the supplies or services to be purchased. Specifications may be in the form of a design specification or a combination thereof. If the department determines that a design, performance or a combination specification is not in the best interest of the Department, it may use brand name or equal specifications.

Unless otherwise specified in this Invitation to Bid, all products, equipment, supplies, etc. offered by bidders must be in a new condition. A ‘new’ product is one that will be first used by the Department after it has been manufactured or produced. Used, reconditioned, or previously titled products, supplies, or equipment will not be considered for award of this Invitation to Bid.

The Department uses qualified products list (QPL) and/or approved products lists (APL) developed by either itself or other qualified institutions to specify acceptable products and supplies that have been through proper application and testing procedures to verify conformance with technical and/or performance specifications. Where the Department requires products and supplies to be included on a specific QPL/APL listing, the Department will not accept bids for products/supplies that are not included on a specified QPL/APL at the time of public bid opening.

A bidder may not be compensated for damages arising from inaccurate or incomplete information in the Invitation to Bid specifications or from inaccurate assumptions based upon the specifications.

22. **USE OF BRAND NAMES:** Unless otherwise provided in this solicitation, the name of a certain brand, make, or manufacturer does not restrict bidders to the specific brand, make, or manufacturer named, but conveys the general style, type, character, and quality of the article desired. Any article which the Department, in its sole discretion, determines to be the equivalent of that specified, considering quality, workmanship, economy of operation, or suitability for the purpose intended, may be accepted. The bidder is responsible to clearly and specifically identify the product being offered and to provide sufficient descriptive literature, catalog cuts and technical detail to enable the Department to determine if the product offered meets the requirements of the solicitation. Failure to furnish adequate data for evaluation purposes may result in declaring a bid nonresponsive. Unless the bidder clearly indicates in its bid that the product being offered is an equivalent product, such bid will be considered to offer the exact brand, make, or manufacturer name referenced in the bid solicitation.

23. **DEVIATIONS:** Statements or modifications made by a bidder in their submitted bid package that deviate from this Invitation to Bid’s terms, conditions, specifications and requirements may render a bid non-responsive and ineligible for award.

Acceptance of any deviations or modifications will be confirmed by the Department in writing, if accepted. If the Department does not specifically approve submitted deviations or modifications in writing, an award of this invitation to bid shall not constitute acceptance of the bidder’s submitted modifications.

24. **ESTIMATED QUANTITIES:** Any purchase estimates indicated for bid item(s) are to be considered as estimates only. The Department makes no representation or guarantee as to the actual amount of item(s) to be purchased by the Department or Political Subdivisions.

25. **OVERLAPPING CONTRACT ITEMS:** The products and/or services included in this solicitation may be available from other State of Ohio contracts and/or other contracts made available for the Department’s use. The existence of these contracts containing like or similar products and/or services could be either known or
unknown to the Department at the time this Invitation to bid has been published. Unless otherwise stated in this contract, the Department may acquire these products and/or services from any available source. The Department will make purchases from sources that are deemed to be in the best interest of the Agency.

26. **REJECTION/PARTIAL AWARD OF BIDS:** The Department reserves the right to reject any or all bid responses, award partial contracts, or choose to rebid when:

   (1) Product, supplies and/or services are not in compliance with the requirements, specifications, and terms and conditions set forth in this Invitation to Bid; or

   (2) Pricing offered is determined to be excessive in comparison with existing market conditions, or exceeds the available funds of the Department; or

   (3) Only one bid is received, and the Department cannot determine the reasonableness of the bid prices submitted; or

   (4) It is determined that the award of any or all items would not be in the best interest of the Department; or

   (5) The Department, in its opinion, did not achieve the desired amount of competition amongst qualified bidders for the products, supplies, and/or services being offered in the bid solicitation; or

   (6) Inadequate or ambiguous specifications were cited in the bidding documents; or

   (7) The Department determines that specifications and/or requirements were missing from the bidding documents; or

   (8) A bidder imposes additional terms and conditions against the Department.

27. **NOTICE TO BIDDERS OF REJECTED BIDS:** When the Department deems it necessary to reject a bid, the Department will notify each affected bidder and the reasons for such actions.

28. **BID PROTESTS:** Any bidder either deemed not responsible or whose bid has been deemed non-responsive shall be notified by the Department of that determination and the reasons for it. The notification will be provided by the Department in writing and sent by certified U.S. mail and at the email address provided on the front cover of this bid. The bidder will have five (5) calendar days after receipt (by mail or email confirmation) of this notification to file a written, valid protest of the Department’s determination. A valid written protest must contain substantive information and evidence so as to refute the Department’s asserted claims against either the bid’s responsiveness or bidder’s responsibility, whichever apply. The Department will only review and respond to valid written protests containing substantive information and evidence. After review of the valid written protest, the Department will either affirm or reverse its original determination.

   If a valid written protest is not received by the Department within five (5) calendar days of receipt, the Director of ODOT will move forward awarding the Contract and the affected bidder will have effectively waived its right to protest the Department’s decision. For the purposes of this paragraph, “receipt” shall be defined as verification (via either certified mail return receipt or electronic read or delivery receipt) that the apparent low bidder has received the Department’s written determination against the affected bidder. Upon the bidder’s receipt, the five (5) calendar day response deadline shall commence.

29. **DELAYS IN CONTRACT AWARD:** Delays in the award of this Invitation to Bid beyond the anticipated Contract start date may result in a change in the contract period as indicated in the Special terms and conditions of this bid solicitation. In these instances, ODOT shall reserve the right to award a contract covering a period equal to or less than the initial contract term than originally specified in this bid solicitation.

30. **CONTRACT AWARD AND FORMATION:** Successful bidder(s) will receive via U.S. regular mail and/or email a Notice of Contract Award letter as well as a photocopy version of the Signature Page executed by both
Parties. These documents shall serve to form the Contract between the Parties. The Signature Page must be executed by both the bidder and the Director of ODOT for the Contract to be deemed valid and enforceable. The Department will maintain in the Contract file the Signature Page document containing each parties’ original signature(s).

Upon award of an Invitation to Bid, the bid invitation number (e.g. Invitation No. 999-16) will subsequently become the number assigned to the resulting Contract (e.g. ODOT Contract number 999-16) and will be referenced by the Department in all matters and documents related to said Contract.

Upon award of an invitation to bid, successful bidders will thereafter be referenced as “Vendor” or “Contractor” by the Department in all matters and documents related to the resulting Contract.

31. **PUBLIC POSTING OF AWARDED CONTRACTS**: All Contracts awarded by the Office of Contract Sales, Purchasing Services section are posted to the Department’s website. Successful bidders and awarded Contract pricing can be found by viewing the Contract’s award tab (Excel file). Award tabs can be accessed via the following website:


32. **PUBLIC RECORD**: All opened bids and their contents are subject to the Public Records Law, Section 149.43 of the Ohio Revised Code. Copies of bid responses must be requested and will be provided within a reasonable period of time and at a fee established by the Director of ODOT. To expedite and properly respond to such public records requests, a written request must be submitted to the Department. To prevent delays in evaluating bids and awarding contracts, such requests for recently opened bids, will be honored after a Contract has been executed.

Bidders may request that specific information, such as trade secrets or proprietary data, be designated as confidential and not considered as public record. Material so designated shall accompany the bid and be in a sealed container duly marked, and shall be readily separable from the bid in order to facilitate public inspection of non-confidential portion. Prices, makes, models, catalog numbers of items offered, deliveries and terms of payment cannot be considered as confidential. The decision as to whether or not such trade secrets or proprietary data shall be disclosed at the bid opening rests solely with the Department.

Requests to view previously submitted bids must be submitted in writing to either of the following addresses:

Contracts.Purchasing@dot.ohio.gov
Ohio Department of Transportation
Office of Contract Sales, Purchasing Services
1980 West Broad St. Mail Stop 4110
Columbus, OH 43223

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State of Ohio, Department of Transportation (ODOT)  
Office of Contract Sales, Purchasing Services

GENERAL DEFINITIONS

When used in this Invitation to Bid or any ensuing contract, the following definitions shall apply. If a conflict exists between these definitions and any definition listed in the bid specifications, the bid specifications shall prevail.

1. AGENCY: Ohio Department of Transportation.

2. AUTHORIZED DISTRIBUTOR: The bidder/vendor who maintains written legal agreements with manufacturers/producers to act as their agent and provide supplies, materials, equipment or services listed in the bid/contract. The authorized distributor must maintain active and sufficient facilities necessary to perform the awarded contract, own title to the goods inventoried within these facilities and maintain a true stock of these goods on a continuing basis and in sufficient quantity to provide uninterrupted service to ordering agencies.

3. BIDDER: The company and/or authorized representative of the company who has signed and is submitting a bid response and who will be responsible to ensure proper performance of the contract awarded pursuant to the bid.

4. DEPARTMENT: Ohio Department of Transportation

5. EQUIPMENT: Items, implements and machinery with a predetermined and considerable usage life.

6. F.O.B. PLACE OF DESTINATION: meaning the Vendor pays, and includes the cost of such in their bid, and bears the risk for the transportation/delivery of goods delivered to the specified locations provided by the Purchaser.

7. INVITATION TO BID/CONTRACT: All documents, whether attached or incorporated by reference, utilized for soliciting bids. Upon completion of the evaluation and award of the bidder’s response, the Invitation to Bid then becomes the contract between ODOT and the successful bidder, both governed by the laws of the State of Ohio.

8. INVOICE: An itemized listing showing delivery of the commodity or performance of the service described in the order, and the date of the purchase or rendering of the service, or an itemization of the things done, material supplied, or labor furnished, and the sum due pursuant to the contract or obligation.

9. LOWEST RESPONSIVE/RESPONSIBLE BIDDER: A bidder who offers the lowest cost for the goods or services listed in the bid; and whose proposal responds to bid specifications in all material respects and contains no irregularities or deviations from the specifications which would affect the amount of the bid or otherwise give him a competitive advantage; and whose experience, financial condition, conduct and performance on previous contracts, facilities, management skills evidences their ability to execute the contract properly.

10. MINORITY BUSINESS ENTERPRISE (MBE): means an individual, partnership, corporation or joint venture of any kind that is owned and controlled by U. S. Citizens and residents of Ohio, who are and have held themselves out as members of the following socially and economically disadvantaged groups: Blacks, American Indians, Hispanics and Asians. Only businesses certified by the State of Ohio Equal Opportunity Division in accordance with Section 123.151 of the Ohio Revised Code shall be recognized as being MBE certified within the purpose of this invitation.

11. MATERIALS: Items or substance of an expendable or non-expendable nature from which something can be made, improved or repaired.
13. **PURCHASE:** To buy, purchase, installment purchase, rent, lease, lease purchase or otherwise acquire equipment, materials, supplies or services. "Purchase" also includes all functions that pertain to obtaining of equipment, materials, supplies or services, including description of requirements, selection and solicitation of sources, preparation and award of contracts, and all phases of contract administration.

14. **SERVICES:** The furnishing of labor, time or effort by a person, not involving the delivery of a specific end product other than a report which, if provided, is merely incidental to the required performance. "Services" does not include services furnished pursuant to employment agreements or collective bargaining agreements.

15. **SPECIFICATION:** Any description of the physical or functional characteristics or of the nature of supplies, equipment, service, or insurance. It may include a description of any requirements for inspecting, testing, or preparing supplies, equipment, services, or insurance.

16. **SUPPLIES:** Provisions and items normally considered expendable or consumable.

17. **UNBALANCED:** Any unit price contained in the bid schedule which is obviously unbalanced either above or below reasonable cost analysis and or unreasonably disproportionate to current market prices as determined by the Director of ODOT, or if such unbalanced prices are contrary to the interest of the department.

18. **VENDOR:** The bidder who, upon awarding of a contract, then becomes a Vendor who is considered to be a primary source for providing the goods and/or services included in the awarded contract and the party to whom payment will be made upon delivery of the goods and/or completion of the contract.

19. **SUBVENDOR/SUBCONTRACTOR:** An individual, firm or corporation to whom the Vendor sublets part of the contract to be performed.

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State of Ohio, Department of Transportation (ODOT)  
Office of Contract Sales, Purchasing Services  

STANDARD CONTRACT TERMS AND CONDITIONS  
(Last Revised 02/2019)

1. **HEADINGS**: The headings used in this Contract are for convenience only and shall not be used to affect the interpretation of any of the Contract terms and conditions.

2. **ENTIRE CONTRACT**: This Contract consists of the complete Invitation to Bid, including the Instructions, Terms and Conditions for Bidding, these Standard Contract Terms and Conditions, the Special Contract Terms and Conditions, ODOT Cooperative Purchasing Program Requirements, mutually executed Signature Page, Specifications and Requirements, awarded unit bid pricing, and any written addenda to the Invitation to Bid; the completed competitive sealed bid, including proper modifications, clarifications and samples; and applicable, valid State of Ohio purchase orders or other ordering documents ("Contract").

3. **APPROPRIATION OF FUNDS**: Pursuant to the Constitution of the State of Ohio, Article II Section 22, ODOT’s funds are contingent upon the availability of lawful appropriations by the Ohio General Assembly. If the Ohio General Assembly fails at any time to continue funding for the payments or obligations due hereunder, the Work under this Contract that is affected by the lack of funding will terminate and ODOT will have no further obligation to make any payments and will be released from its obligations on the date funding expires.

The current Ohio General Assembly cannot commit a future Ohio General Assembly to a future expenditure. If the term of this Contract extends beyond a biennium, the Contract will expire at the end of a current biennium and the State may renew this Contract in the next biennium by issuing written notice to the Vendor no later than July 1 of the new biennium. The operating biennium expires June 30th of each odd-numbered calendar year.

4. **OBM CERTIFICATION**: None of the rights, duties, or obligations in this Contract will be binding on the Department, and the Vendor will not begin its performance, until all of the following conditions have been met:

1. All statutory provisions under the O.R.C., including Section 126.07, have been met; and
2. All necessary funds are made available by the Ohio Office of Budget and Management; or
3. If ODOT is relying on Federal or third-party funds for this Contract the ODOT gives the Vendor written notice that such funds have been made available.

5. **CONTRACT MODIFICATIONS**: Amendments or modifications to this Contract must be executed in writing between the parties and signed by the Director of ODOT. Amendments or modifications to this Contract made between the Vendor and other Department personnel shall be void and unenforceable.

6. **CONTRACT CONSTRUCTION**: Any general rule of construction to the contrary notwithstanding this Contract shall be liberally construed in favor of the effect the purpose of this Contract and the policy and purposes of the Department. If any provisions in this Contract are found to be ambiguous, an interpretation consistent with the purpose of this Contract that would render the provision valid shall be favored over any interpretation that would render it invalid.

7. **GOVERNING LAW / SEVERABILITY**: This Contract shall be governed by the laws of the State of Ohio, and the venue for any disputes will be exclusively with the appropriate court in Franklin County, Ohio. If any provision of the Contract or the application of any provision is held by that court to be contrary to law, the remaining provisions of the Contract will remain in full force and effect.

8. **ASSIGNMENT / DELEGATION**: The Vendor will not assign any of its rights nor delegate any of its duties under this Contract without the written consent of the Director of ODOT. Any assignment or delegation not consented to may be deemed void by the Department.
9. **PLACEMENT OF ORDERS/METHODS OF PAYMENT**: The Department shall use either State of Ohio Purchase Order or State of Ohio Payment Card (i.e. credit card) to authorize performance under this Contract and to issue payments for supplies, products, and/or services acquired. Vendors are required to accept both forms of payment. For Department purchases over $2,500.00, an official State of Ohio purchase order must be generated and obtain approvals from the Office of Budget and Management, the Department of Administrative Services, and the Director of Transportation prior to its effectiveness. An approved State of Ohio purchase order will be sent to the Vendor and the Vendor will provide the goods and/or services listed on the ordering documents and in accordance with the Contract’s terms and conditions. Any order placed not using an approved ODOT purchase order or against a State payment card, shall not be considered a valid order and may result in denial of payment and/or return of goods at the Vendor’s expense.

10. **ACCEPTANCE OF ORDERS**: The Vendor must accept orders placed by the Department pursuant to this Contract up through the last day of the Contract’s effectiveness, inclusive of any contract extensions exercised or agreed-upon between the Parties.

11. **BLANKET PURCHASE ORDERS**: The Department utilizes blanket purchase orders to pre-authorize funding for use on Contracts containing bid items that, due to the urgent nature of maintaining the Department’s highways and facilities, are critical to the Department executing its mission and objectives. The generation of blanket purchase orders are not used by the Department to place a specific order, rather as a means to make funding more readily available for use when Contract items are needed. The Vendor shall keep all blanket purchase orders on file and make them readily available for use by Department personnel to place orders against. When placing orders against a blanket purchase order, the Department will telephone or email orders referencing the blanket purchase order and its associated ODOT purchase order number. All of the Contract’s terms and conditions shall apply to the Department’s orders referencing a blanket purchase order.

For all blanket purchase orders, quantities and amounts to be purchased from these purchase orders is unknown by the Department and Vendors must not construe these purchase orders as a commitment to purchase a specific amount of goods and/or services. Accordingly, the Department reserves the right to increase or decrease the available funding on these blanket purchase orders at its discretion.

12. **DELIVERY INSPECTION AND ACCEPTANCE**: Upon pick-up or delivery of any supplies, products, and/or services, ODOT retains the right to inspect the product/service prior to final acceptance and/or payment for the product/service. ODOT shall have sufficient and reasonable time to fully inspect supplies and/or services for compliance. The purpose of the inspection process is to ensure that the product/service is in compliance with the specifications set forth in the awarded contract. In the event that the product/service does not meet the specifications, ODOT shall notify the Vendor for removal/replacement of the product and/or service at the Vendor’s expense. ODOT shall retain all rights and remedies as described herein. Wherein products ordered by ODOT are delivered to a facility, which is not owned by ODOT and where ODOT has contracted with this facility to take delivery of products ordered by ODOT, acceptance will occur when the products have been inspected and accepted by ODOT within a reasonable amount of time after delivery to the facility. ODOT shall not be responsible for any storage costs incurred prior to the inspection and acceptance.

13. **RETURN GOODS POLICY**: The Department will apply the following Return Goods Policy on all purchases made under the Contract:

(A) Return goods, when due to Vendor debar (i.e. over-shipment, defective merchandise, unapproved substitution, etc.) shall be returned to the Vendor, at the Vendor’s expense. The Vendor shall make arrangements to remove the return goods from the Department’s premises within five (5) calendar days after notification. The Vendor shall not apply any restocking or other charges to the Department. At the option of the Department, replacement items may be accepted and will be shipped within five (5) calendar days of notification. Failure of the Vendor to arrange for return of the items within the specified time will result in the items being deemed as abandoned property and the Department will dispose of accordingly.
(B) For orders of custom manufactured items, the Vendor will provide a production sample of the item to the Department for acceptance. The production sample will be identical to the item to be provided. The Department will provide written acceptance of the item prior to the Vendor continuing with production. Once delivery and acceptance has been completed and the Department determines for any reason that any remaining quantities will not be used, the agency may request the return of the custom manufactured items. Acceptance of the return of custom manufactured items will be at the option of the Vendor. If the Vendor agrees to the return of these items, the Department will be responsible for all costs associated with packaging, shipment and transportation, to include the original shipment to the Department and subsequent return of goods to the location designated by the Vendor. The Vendor may assess restocking fees that are equivalent to restocking fees that are normally assessed to other customers or as published by the Vendor. Failure of the Vendor to provide a production sample and obtain written approval from the Department will result in the Vendor bearing all responsibility and costs associated with the return of these goods.

(C) Return goods of regular catalog stock merchandise, when due to Department error (i.e. over purchase, discontinued use, inventory reduction, etc.) will be accepted by the Vendor if notice is given by the Department within six (6) months of delivery and acceptance. All items to be returned must be unused and in their original containers and in suitable condition for resale. The Department will be responsible for all transportation costs associated with both the original shipment of items to the agency and the subsequent return of the items to the location designated by the Vendor. The Vendor may assess a restocking fee (not to exceed 10%) associated with the return of the items to the location designated by the Vendor. Return of regular stock catalog merchandise, when delivery and acceptance exceed six (6) months will be at the option of the Vendor.

14. **PRODUCT RECALLS**: In the event product delivered has been recalled, seized, or embargoed and/or has been determined to be misbranded, adulterated, or found to be unfit for human consumption by the packer, processor, manufacturer or by any Department or Federal regulatory agency, the Vendor shall be responsible to notify the ODOT Office of Contract Sales, Purchasing Services section and all other ordering agencies/entities within two business days after notice has been given. Vendor shall, at the option of the Department, either reimburse the purchase price or provide an equivalent replacement product at no additional cost. Vendor shall be responsible for removal and/or replacement of the affected product within a reasonable time as determined by the ordering agency. At the option of the ordering agency, Vendor may be required to reimburse storage and/or handling fees to be calculated from time of delivery and acceptance to actual removal. Vendor will bear all costs associated with the removal and proper disposal of the affected product. Failure to reimburse the purchase price or provide equivalent replacement product will be considered a default.

15. **PRODUCT SUBSTITUTION**: In the event a specified product listed in the Contract becomes unavailable or cannot be supplied by the Vendor for any reason (except as provided for in the Force Majeure clause), a product deemed in writing by the Department to be equal to or better than the specified product must be substituted by the Vendor at no additional cost or expense to the Department. Unless otherwise specified, any substitution of product prior to the Department’s written approval may be cause for termination of Contract.

The Department reserves the right to deny any substitution request that it is deemed to not be in the best interest of the Department. In these instances, the Department may seek substitute products from another supplier and assess the difference in cost, if any, as damages against the Vendor for their material breach.

16. **INVOICE REQUIREMENTS**: The Vendor must submit an original, proper invoice to the office designated on the purchase order as the “bill to” address. To be a proper invoice, the invoice must include the following information: 1. The ODOT purchase order number authorizing the delivery of products or services. 2. A description of what the Vendor delivered, including, as applicable, the time period, serial number, unit price, quantity, and total price of the products and services. 3. The Contract number pursuant to the deliverable.
17. **DEFECTIVE INVOICES**: In the event the Department is in receipt of defective or improper invoices, the Department shall postpone payment pursuant to Section 126.30 of the Ohio Revised Code. Invoices shall be returned to the Vendor noting areas for correction. If such notification of defect is sent, the required payment date shall be thirty (30) calendar days after receipt of the corrected invoice.

18. **PAYMENT DUE DATE**: Payments under this Contract will be due on the 30th calendar day after the date of actual receipt of a proper invoice in the office designated to receive the invoice, or the date the service is delivered and accepted in accordance with the terms of this Contract. The date of the warrant issued in payment will be considered the date payment is made. Interest on late payments will be paid in accordance with O.R.C. Section 126.30.

19. **INSURANCE POLICIES**: By way of provision in this Contract to maintain specific minimum levels of insurance coverage(s) (e.g. Commercial General liability, Auto liability, Public liability, Property Damage, etc.), the Vendor shall provide to Department upon request evidence of such insurance required to be carried by these provisions, including any endorsement affecting the additional insured status, is in full force and effect and that premiums therefore have been paid. Such evidence shall be furnished by the Vendor within two (2) business days and on the insurance industry's standard ACORD Form (Certificate of Insurance) or a certified copy of the original policy. The Certificate of Insurance or certified copy of the policy must contain an endorsement naming the State of Ohio, Department of Transportation, its officers, agents, employees, and servants as additionally insured, but only with respect to Work performed for the Department under this Contract, at no cost to Department. Vendor shall notify the Department within ten (10) calendar days of receipt of a notice of cancellation, expiration, or any reduction in coverage, or if the insurer commences proceedings or has proceedings commenced against it, indicating the insurer is insolvent. Vendor shall provide to the Department evidence of a replacement policy at least five (5) calendar days prior to the effective date of such cancellation, expiration, or reduction in coverage.

All required insurance policies shall be maintained at Vendor’s sole expense and in full force for the complete term of the Contract, including any warranty periods. Reference 107.12 the Construction & Materials Specification handbook.

20. **TAXATION**: ODOT is exempt from federal excise taxes and all Department and local taxes, unless otherwise provided herein. ODOT does not agree to pay any taxes on commodities, goods, or services acquired from any Vendor.

21. **CONTRACT TERMINATION**: If a Vendor fails to perform any one of its obligations under this Contract, it will be in breach of contract and the Department may terminate this Contract in accordance with this section. Notices of contract termination shall be made in writing. The termination will be effective on the date delineated by the Department.

   a. **Termination for Breach**. If Vendor’s breach is unable to be cured in a reasonable time, the Department may terminate the Contract by written notice to the Vendor.

   b. **Termination for Un-remedied Breach**. If Vendor’s breach may be cured within a reasonable time, the Department will provide written notice to Vendor specifying the breach and the time within which Vendor must correct the breach. If Vendor fails to cure the specified breach within the time required, the Department may terminate the Contract. If the Department does not give timely notice of breach to Vendor, the Department has not waived any of the Department’s rights or remedies concerning the breach.

   c. **Termination for Persistent Breach**. The Department may terminate this Contract by written notice to Vendor for defaults that are cured, but persistent. “Persistent” means three or more breaches. After the Department has notified Vendor of its third breach, the Department may terminate this Contract without providing Vendor with an opportunity to cure. The three or more breaches are not required to be related to each other in any way.

   d. **Termination for Endangered Performance**. The Department may terminate this Contract by written notice to the Vendor if the Department determines that the performance of the Contract is endangered through no fault of the Department.
e. **Termination for Financial Instability.** The Department may terminate this Contract by written notice to the Vendor if a petition in bankruptcy or a Federal or State tax lien has been filed by or against the Vendor.

f. **Termination for Delinquency, Violation of Law.** The Department may terminate this Contract by written notice, if it determines that Vendor is delinquent in its payment of federal, Department or local taxes, workers’ compensation, insurance premiums, unemployment compensation contributions, child support, court costs or any other obligation owed to a Department agency or political subdivision. The Department also may cancel this Contract, if it determines that Vendor has violated any law during the performance of this Contract. However, the Department may not terminate this Contract if the Vendor has entered into a repayment agreement with which the Vendor is current.

g. **Termination for Subcontractor Breach.** The Department may terminate this Contract for the breach of the Vendor or any of its subcontractors. The Vendor will be solely responsible for satisfying any claims of its subcontractors for any suspension or termination and will indemnify the Department for any liability to them. Subcontractors will hold the Department harmless for any damage caused to them from a suspension or termination. The subcontractors will look solely to the Vendor for any compensation to which they may be entitled.

h. **Termination for Vendor’s Failure to Pay Material Suppliers.** Pursuant to Section 4113.61 of the Ohio Revised Code, Vendors shall promptly pay material suppliers, within ten (10) calendar days of receipt of payment from the State of Ohio, for materials ordered and delivered as a result of this contract. A Vendor unable to furnish bid items because of non-payment issues related to a material supplier shall constitute grounds for the Director of ODOT to terminate this contract immediately. A Vendor may, at the discretion of the Department, be given an amount of time, amount shall be specified by the Department in writing, to furnish past due payment to the material supplier before termination shall occur.

j. **Failure to Maintain MBE Certification.** Pursuant to O.R.C. Section 125.081, the State may set aside a bid for supplies or services for participation only by minority business enterprises (MBE’s) certified by the State of Ohio, Equal Opportunity Coordinator. After award of the Contract, it is the responsibility of the MBE Vendor to maintain certification as a MBE. If the Vendor fails to renew its certification and/or is decertified by the State of Ohio, Equal Opportunity Coordinator, the State may immediately cancel the Contract.

k. **Failure to Maintain Licensure.** The Vendor’s failure to maintain the proper license(s) to perform the services or provide the goods prescribed by this Contract shall be grounds to terminate this Contract without prior notice.

l. **Qualified Products Listing and Approved Products Listing.** Any products or supplies removed from a specific qualified products listing/approved product listing, by either the Department, government, or governing body throughout the duration of the Contract shall be removed from the Contract effective on the date of removal from the respective listing.

22. **NOTICE OF BREACH:** Each party of this Contract has an obligation to provide written notice when it is determined by one party that the other party is in default of this Contract. A notice of ODOT’s default of this Contract must be sent to the Procurement Manager of the ODOT Office of Contract Sales.

23. **CONTRACT SUSPENSION:** A Vendor who fails to perform any one of its obligations under this Contract will be in breach. In these instances, ODOT may choose to suspend the Vendor from the contract rather than terminate the Contract.

In the case of a suspension for ODOT’s convenience, the amount of compensation due the Vendor for work performed before the suspension will be determined in the same manner as provided in this section for termination for ODOT’s convenience or the Vendor may be entitled to compensation for work performed
before the suspension, less any damage to ODOT resulting from the Vendor’s breach of this Contract or other fault.

The notice of suspension, whether with or without cause, will be effective immediately on the Vendor’s receipt of the notice. The Vendor will immediately prepare a report and deliver it to ODOT which will include a detailed description of work completed, percentage of project completion, estimated time for delivery of all orders received to date, and costs incurred by the Vendor.

24. CANCELLATION FOR CONVENIENCE: The Department reserves the right to cancel and terminate this Contract, in whole or in part, without penalty, upon thirty (30) days written notice to an awarded vendor. In the event the initial contract period is for more than 12 months, the resulting contract may be terminated by either party, without penalty, after the initial 12 months of the contract period and upon a minimum of sixty (60) days written notice to the other party. Cancellations exercised in accordance with this section shall not relieve the Vendor of the obligation to deliver and/or perform on all outstanding orders issued prior to the effective date of cancellation.

25. CONTRACT DAMAGES: The Department may assess, at a minimum but not limited to, the following damages against a Vendor:

A. ACTUAL DAMAGES: Vendor is liable to the State of Ohio for all actual and direct damages caused by Vendor’s breach. The Department may substitute supplies or services, from a third party, for those that were to be provided by Vendor. In accordance with Ohio Revised Code §5513.05(c), the Department may recover the costs associated with acquiring substitute supplies or services, less any expenses or costs saved by Vendor’s breach, from Vendor.

B. LIQUIDATED DAMAGES: If actual and direct damages are uncertain or difficult to determine, the Department may recover liquidated damages in the amount of 1% of the value of the order, deliverable or milestone that is the subject of the breach for every day that the breach is not cured by the Vendor. If Delay of the cure is caused by ODOT, the delivery date shall be extended accordingly to offset such delays. Approval to extend any scheduled delivery date(s) shall be at the sole discretion of ODOT.

C. DEDUCTION OF DAMAGES FROM CONTRACT PRICE: The Department may deduct all or any part of the damages resulting from Vendor’s breach from any part of the price still due on the contract, upon prior written notice issued to the Vendor by the Department.

D. INCIDENTAL/CONSEQUENTIAL DAMAGES: Pursuant to Section 5513.05 of the Ohio Revised Code, the Department may recover from a Vendor who fails to promptly provide conforming articles, any incidental or consequential damages as defined in Section 1302.89 of the Ohio Revised Code, incurred by the Department in promptly obtaining the conforming articles.

26. CONTRACT TERM EXTENSIONS: ODOT reserves the right to unilaterally extend this Contract up to one (1) calendar month beyond the original contract expiration date at the original unit bid prices awarded. Contract extensions beyond one (1) calendar month shall be executed by means of written, mutual agreement with the Contract Vendor.

27. FIRM, FIXED PRICE CONTRACT: Unless otherwise specified in the bidding documents, this Contract is a Firm, Fixed-Price Contract. The Vendor will be required to provide to the Department with the materials, supplies, equipment and/or services at the awarded bid price(s) for the entire duration of the contract, and any extensions thereto.

28. FORCE MAJEURE: If the Department or Vendor is unable to perform any part of its obligations under this Contract by reason of force majeure, the party will be excused from its obligations, to the extent that its performance is prevented by force majeure, for the duration of the event. The party must remedy with all reasonable dispatch the cause preventing it from carrying out its obligations under this Contract. The term “force majeure” means without limitation: acts of God; such as epidemics; lightning; earthquakes; fires; storms; hurricanes; tornadoes; floods; washouts; droughts; any other severe weather; explosions; restraint of government and people; war; labor strikes; and other like events.
29. **EQUAL EMPLOYMENT OPPORTUNITY**: The Vendor will comply with all Department and federal laws regarding equal employment opportunity, including O.R.C. Section 125.111 and all related Executive Orders.

30. **ANTITRUST ASSIGNMENT TO THE DEPARTMENT**: Vendor assigns to the State of Ohio, through the Department of Transportation, all of its rights to any claims and causes of action the Vendor now has or may acquire under Department or federal antitrust laws if the claims or causes of action relate to the supplies or services provided under this Contract. Additionally, the State of Ohio will not pay excess charges resulting from antitrust violations by Vendor’s suppliers and subcontractors.

31. **CONFIDENTIALITY**: The Vendor may learn of information, documents, data, records, or other material that is confidential in the performance of this Contract. The Vendor may not disclose any information obtained by it as a result of this Contract, without the written permission of the Department. The Vendor must assume that all Department information, documents, data, records or other material is confidential.

The Vendor’s obligation to maintain the confidentiality of the information will not apply where it: (1) was already in the Vendor’s possession before disclosure by the Department, and it was received by the Vendor without the obligation of confidence; (2) is independently developed by the Vendor; (3) is or becomes publicly available without breach of this Contract; (4) is rightfully received by the Vendor from a third party without an obligation of confidence; (5) is disclosed by the Vendor with the written consent of the Department; or (6) is released in accordance with a valid order of a court or governmental agency, provided that the Vendor (a) notifies the Department of such order immediately upon receipt of the order and (b) makes a reasonable effort to obtain a protective order from the issuing court or agency limiting disclosure and use of the confidential information solely for the purposes intended to be serviced by the original order of production. The Vendor will return all originals of any information and destroy any copies it has made on termination or expiration of this Contract.

The Vendor will be liable for the disclosure of any confidential information. The parties agree that the disclosure of confidential information of the Department’s may cause the Department irreparable damage for which remedies other than injunctive relief may be inadequate, and the Vendor agrees that in the event of a breach of the obligations hereunder, the Department shall be entitled to temporary and permanent injunctive relief to enforce this provision without the necessity of providing actual damages. This provision shall not, however, diminish or alter any right to claim and recover.

32. **DRUG-FREE WORKPLACE**: The Vendor agrees to comply with all applicable Department and federal laws regarding drug-free workplace and shall make a good faith effort to ensure that all its employees, while working on Department property, will not purchase, transfer, use or possess illegal drugs or alcohol or abuse prescription drugs in any way.

33. **WORKERS’ COMPENSATION**: Workers’ compensation insurance, as required by Ohio law or the laws of any other Department where work under this Contract will be done. The Vendor will also maintain employer’s liability insurance with at least a $1,000,000.00 limit.

34. **OHIO ETHICS LAW**: Vendor agrees that it is currently in compliance and will continue to adhere to the requirements of Ohio Ethics law as provided by Section 102.03 and 102.04 of the Ohio Revised Code.

35. **PUBLICITY**: The Vendor will not advertise that it is doing business with the Department or use this Contract as a marketing or sales tool without prior, written consent of the Department. This provision includes marketing or sales tools related to the ODOT Cooperative Purchasing Program.

36. **STRICT PERFORMANCE**: The failure of either party, at any time to demand strict performance by the other party of any of the terms of this Contract, will not be construed as a waiver of any such term and either party may at any time demand strict and complete performance by the other party.

37. **SUBCONTRACTING**: The Department recognizes that it may be necessary for the Vendor to use subcontractors to perform portions of the work under the Contract. In those circumstances, the Vendor shall submit a list identifying its subcontractors or joint venture partners performing portions of the work under the Contract. If any changes occur during the term of the Contract, the Vendor shall supplement its list of
subcontractors or joint venture business partners. In addition, all subcontractors or joint venture business partners agree to be bound by all of the Terms and Conditions and specifications of the Contract. The Department reserves the right to reject any subcontractor submitted by the Vendor. All subcontracts will be at the sole expense of the Vendor and the Vendor will be solely responsible for payment of its subcontractors. The Vendor assumes responsibility for all sub-contracting and third party manufacturer work performed under the Contract. In addition, Vendor will cause all subcontractors to be bound by all of the Terms and Conditions and specifications of the Contract. The Vendor will be the sole point of contact with regard to all contractual matters.

38. **SURVIVORSHIP:** All sections herein relating to payment, confidentiality, license and ownership, indemnification, publicity, construction warranties, limitations of warranties and limitations on damages shall survive the termination of this Contract.

39. **GENERAL REPRESENTATIONS AND WARRANTIES:** The Vendor warrants that the recommendations, guidance, and performance of the Vendor under this Contract will:

   1. Be in accordance with the sound professional standards and the requirements of this Contract and without any material defect.
   2. No services, products or supplies will infringe on the intellectual property rights of any third party.
   3. All warranties are in accordance with Vendor’s standard business practices attached.
   4. That the products or supplies hereunder are merchantable and fit for the particular purpose described in this contract. Additionally, with respect to the Vendor’s activities under this Contract, the Vendor warrants that:
   5. The Vendor has the right to enter into this Contract.
   6. The Vendor has not entered into any other contracts or employment relationships that restrict the Vendor’s ability to perform under this Contract.
   7. The Vendor will observe and abide by all applicable laws and regulations, including those of the Department regarding conduct on any premises under the Department’s control.
   8. The Vendor has good and marketable title to any products or supplies delivered under this Contract and which title passes to the Department.
   9. The Vendor has the right and ability to grant the license granted in products or supplies in which title does not pass to the Department. If any services of the Vendor or any products or supplies fails to comply with these warranties, and the Vendor is so notified in writing, the Vendor will correct such failure with all due speed or will refund the amount of the compensation paid for the services, products or supplies. The Vendor will also indemnify the Department for any direct damages and claims by third parties based on breach of these warranties.

40. **VENDOR’S WARRANTY AGAINST AN UNRESOLVED FINDING FOR RECOVERY:** Vendor warrants that it is not subject to an unresolved finding for recovery under O.R.C. Section 9.24. If the warranty was false on the date the parties signed this Contract, the Contract is void ab initio.

41. **LIMITATION OF LIABILITY:** Notwithstanding any limitation provisions contained in the documents and materials incorporated by reference into this contract, the Vendor agrees that the Vendor shall be liable for all direct damages due to the fault or negligence of the Vendor.

42. **INDEMNITY:** The Vendor will indemnify the Department for any and all claims, damages, lawsuits, costs, judgments, expenses, and any other liabilities resulting from bodily injury to any person (including injury resulting in death) or damage to property that may arise out of or are related to Vendor’s performance under this Contract, providing such bodily injury or property damage is due to the negligence of the Vendor, its

The Vendor will also indemnify the Department against any claim of infringement of a copyright, patent, trade secret, or similar intellectual property rights based on the Department’s proper use of any products or supplies under this Contract. This obligation of indemnification will not apply where the Department has modified or misused the products or supplies and the claim of infringement is based on the modification or misuse. The Department agrees to give the Vendor notice of any such claim as soon as reasonably practicable and to give the Vendor the authority to settle or otherwise defend any such claim upon consultation with and approval by the Office of the Department Attorney General. If a successful claim of infringement is made, or if the Vendor reasonably believes that an infringement claim that is pending may actually succeed, the Vendor will take one (1) of the following four (4) actions:

1. Modify the products or supplies so that is no longer infringing;
2. Replace products or supplies with an equivalent or better item;
3. Acquire the right for the Department to use the infringing products or supplies as it was intended for the Department to use under this Contract; or
4. Remove the products or supplies and refund the fee the Department paid for the products or supplies and the fee for any other products or supplies that required the availability of the infringing products or supplies for it to be useful to the Department.

43. **AUDITS:** The Vendor must keep all financial records in a manner consistent with generally accepted accounting principles. Additionally, the Vendor must keep separate business records for this Contract, including records of disbursements and obligations incurred that must be supported by contracts, invoices, vouchers and other data as appropriate. During the period covered by this Contract and until the expiration of three (3) years after final payment under this Contract, the Vendor agrees to provide the Department, its duly authorized representatives or any person, agency or instrumentality providing financial support to the work undertaken hereunder, with access to and the right to examine any books, documents, papers and records of the Vendor involving transactions related to this Contract. The Vendor shall, for each subcontract in excess of two thousand five hundred ($2,500), require its subcontractor to agree to the same provisions of this Article. The Vendor may not artificially divide contracts with its subcontractors to avoid requiring subcontractors to agree to this provision. The Vendor must provide access to the requested records no later than (5) five business days after the request by the Department or any party with audit rights. If an audit reveals any material deviation from the Contract requirements, and misrepresentations or any overcharge to the Department or any other provider of funds for the Contract, the Department or other party will be entitled to recover damages, as well as the cost of the audit.

44. **INDEPENDENT CONTRACTOR ACKNOWLEDGEMENT:** It is fully understood and agreed that Vendor is an independent contractor and is not an agent, servant, or employee of the State of Ohio or the Ohio Department of Transportation. Vendor declares that it is engaged as an independent business and has complied with all applicable federal, state, and local laws regarding business permits and licenses of any kind, including but not limited to any insurance coverage, workers’ compensation, or unemployment compensation that is required in the normal course of business and will assume all responsibility for any federal, state, municipal or other tax liabilities. Additionally, Vendor understands that as an independent contractor, it is not a public employee and is not entitled to contributions from the State to any public employee retirement system.

**TRADE:** Pursuant to R.C. 9.76(B), Vendor warrants that Vendor is not boycotting any jurisdiction with whom the State of Ohio can enjoy open trade, including Israel, and will not do so during the term of this Contract.

45. **NON-DISCRIMINATION/COMPLIANCE WITH APPLICABLE LAWS:**

Vendor agrees that Vendor, any subcontractor, and any person acting on behalf of Vendor or a subcontractor, shall not discriminate, by reason of race, color, religion, sex (including pregnancy, gender identification and sexual orientation), age (40 years or older), disability, military status, national origin, or ancestry against any citizen of this state in the employment of any person qualified and available to perform the Work. Vendor further agrees that Vendor, any subcontractor, and any person acting on behalf of Vendor or a subcontractor shall not, in any manner, discriminate against, intimidate, or retaliate against any employee hired for the
performance of the Work on account of race, color, religion, sex (including pregnancy, gender identification and sexual orientation), age, disability, military status, national origin, or ancestry.

During the performance of this Contract, the Vendor, for itself, its assignees, and successors in interest agrees to comply with the Federal Requirements as follows:

1. Vendor will ensure that applicants are hired and that employees are treated during employment without regard to their race, religion, color, sex (including pregnancy, gender identification and sexual orientation), national origin (ancestry), disability, genetic information, age (40 years or older), or military status (past, present, or future). Such action shall include, but not be limited to, the following: Employment, Upgrading, Demotion, or Transfer; Recruitment or Recruitment Advertising; Layoff or Termination; Rates of Pay or other forms of Compensation; and Selection for Training including Apprenticeship.

2. Vendor agrees to post in conspicuous places, available to employees and applicants for employment, notices setting forth the provisions of this nondiscrimination clause. Vendor will, in all solicitations or advertisements for employees placed by or on behalf of Vendor, state that all qualified applicants will receive consideration for employment without regard to race, religion, color, sex (including pregnancy, gender identification and sexual orientation), national origin (ancestry), disability, genetic information, age (40 years or older), or military status (past, present, or future).

3. Vendor agrees to fully comply with Title VI of the Civil Rights Act of 1964, 42 USC Sec. 2000. Vendor shall not discriminate on the basis of race, color, national origin, sex (including pregnancy, gender identification and sexual orientation), age, disability, low-income status, or limited English proficiency in its programs or activities. The Director of Transportation may monitor the Vendor’s compliance with Title VI.

4. Compliance with Regulations: The Vendor (hereinafter includes consultants) will comply with the Acts and Regulations relative to Non-discrimination in Federally-assisted programs of the U.S. Department of Transportation, Federal Highway Administration (FHWA), as they may be amended from time to time, which are herein incorporated by reference and made a part of this contract.

5. Nondiscrimination: The Vendor, with regard to the work performed by it during the contract, will not discriminate on the grounds of race, color, national origin (ancestry), sex (including pregnancy, gender identification and sexual orientation), age (40 years or older), disability, low-income status, or limited English proficiency in the selection and retention of subcontractors, including procurements of materials and leases of equipment. The Vendor will not participate directly or indirectly in the discrimination prohibited by the Acts and the Regulations as set forth in section 10. below, including employment practices when the contract covers any activity, project, or program set forth in Appendix B of 49 CFR Part 21.

6. Solicitations for Subcontractors, including Procurements of Materials and Equipment: In all solicitations, either by competitive bidding, or negotiation made by the Vendor for work to be performed under a subcontract, including procurements of materials, or leases of equipment, each potential subcontractor or supplier will be notified by the Vendor of the Vendor’s obligations under this contract and the Acts and the Regulations relative to nondiscrimination on the grounds of race, color, national origin (ancestry), sex (including pregnancy, gender identification and sexual orientation), age (40 years or older), disability, low-income status, or limited English proficiency.

7. Information and Reports: The Vendor will provide all information and reports required by the Acts, the Regulations, and directives issued pursuant thereto, and will permit access to its books, records, accounts, other sources of information, and its facilities as may be determined by the Ohio Department of Transportation (hereinafter “ODOT”) or FHWA to be pertinent to ascertain compliance with such Acts, Regulations, and instructions. Where any information required of a Vendor is in the exclusive possession of another who fails or refuses to furnish this information, the Vendor will so certify to ODOT or FHWA, as appropriate, and will set forth what efforts it has made to obtain the information.
8. Sanctions for Noncompliance: In the event of the Vendor’s noncompliance with the nondiscrimination provisions of this contract, ODOT will impose such contract sanctions as it or FHWA may determine to be appropriate, including, but not limited to:

a. Withholding of payments to the Vendor under the contract until the Vendor complies, and/or
b. Cancellation, termination or suspension of the contract, in whole or in part.

9. Incorporation of Provisions: The Vendor will include the provisions of sections 1. through 9. in every subcontract, including procurements of materials and leases of equipment, unless exempt by the Acts, the Regulations, and directives issued pursuant thereto. The Vendor will take action with respect to any subcontract or procurement as ODOT or FHWA may direct as a means of enforcing such provisions including sanctions for noncompliance. Provided, that if the Vendor becomes involved in, or is threatened with litigation by a subcontractor, or supplier because of such direction, the Vendor may request ODOT to enter into any litigation to protect the interests of ODOT. In addition, the Vendor may request the United States to enter into the litigation to protect the interests of the United States.

10. During the performance of this contract, the Vendor, for itself, its assignees, and successors in interest, consultants and sub-contractors, agrees to comply with the following non-discrimination statutes and authorities; including but not limited to:

Pertinent Non-Discrimination Authorities:

- Title VI of the Civil Rights Act of 1964 (42 U.S.C. § 2000d et seq., 78 stat. 252) (prohibits discrimination on the basis of race, color, national origin); and 49 CFR Part 21
- The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (42 U.S.C. § 4601) (prohibits unfair treatment of persons displaced or whose property has been acquired because of Federal or Federal-Aid programs and projects)
- Section 504 of the Rehabilitation Act of 1973 (29 U.S.C. § 794 et seq.), as amended (prohibits discrimination on the basis of disability) and 49 CFR Part 27
- The Age Discrimination Act of 1975, as amended (42 U.S.C. § 6101 et seq.) (prohibits discrimination on the basis of age)
- Airport and Airway Improvement Act of 1982 (49 U.S.C. § 471, Section 47123), as amended (prohibits discrimination based on race, creed, color, national origin, or sex)
- The Civil Rights Restoration Act of 1987 (PL 100-209) (broadened the scope, coverage, and applicability of Title VI of the Civil Rights Act of 1964, the Age Discrimination Act of 1975, and Section 504 of the Rehabilitation Act of 1973, by expanding the definition of the terms “programs or activities” to include all of the programs or activities of Federal-Aid recipients, sub-recipients, and contractors, whether such programs or activities are Federally funded or not)
- Titles II and III of the Americans with Disabilities Act (42 U.S.C. §§ 12131-12189), as implemented by Department of Transportation regulations at 49 CFR parts 37 and 38 (prohibits discrimination on the basis of disability in the operation of public entities, public and private transportation systems, places of public accommodation, and certain testing entities)
- The Federal Aviation Administration’s Non-Discrimination Statute (49 U.S.C. § 47123) (prohibits discrimination on the basis of race, color, national origin, and sex)
- Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (ensures non-discrimination against minority populations by discouraging programs, policies, and activities with disproportionately high and adverse human health or environmental effects on minority and low-income populations)
- Executive Order 13166, Improving Access to Services for People with Limited English Proficiency, and resulting agency guidance, national origin discrimination includes discrimination because of limited English proficiency (LEP). To ensure compliance with Title VI, you must take reasonable steps to ensure that LEP persons have meaningful access to your programs (70 Fed. Reg. at 74087 to 74100)
- Title VIII of the Civil Rights Act of 1968 (Fair Housing Act), as amended (prohibits discrimination in the sale, rental, and financing of dwellings on the basis of race, color, religion, sex, national origin, disability, or familial status (presence of child under the age of 18 and pregnant women)
• Title IX of the Education Amendments Act of 1972, as amended (20 U.S.C. 1681 et seq.) (prohibits discrimination on the basis of sex in education programs or activities)
• Uniformed Services Employment and Reemployment Rights Act of 1994 (USERRA 38 U.S.C. 4301-4335) (prohibits discrimination on the basis of present, past or future military service)
State of Ohio, Department of Transportation (ODOT)
Office of Contract Sales, Purchasing Services

SIGNATURE PAGE
Invitation to Bid #
Commodity/Service:

This Signature Page must be completed and submitted with a Bidder’s sealed bid package to serve as acknowledgement to the Department that the Bidder understands and will comply with all terms, conditions, and requirements in submitting a bid (offer) for the above-referenced Invitation to Bid.

Furthermore, the execution and submission of this Signature Page shall serve as acknowledgment that the Bidder will enter into a Contract with the State of Ohio, Department of Transportation if selected for award of the above-referenced Invitation to Bid, and understands, upon Contract award, it shall be bound by all terms and conditions included in this invitation to bid.

The person signing and executing this Signature Page below acknowledges that he/she is signing on behalf of their Company in a representative capacity and hereby warrants that he/she has been duly authorized by his/her Company to submit this formal bid (offer) and is authorized to execute Contracts on such Company’s behalf.

(Please execute below using blue ink)

Company (Bidder) Name: _______________________________________________

Original Signature: _______________________________________________________

Print Name of Officer: _____________________________________________________

Title of Signing Officer: ___________________________________________________

Date: ________________________________

FOR USE BY THE OHIO DEPARTMENT OF TRANSPORTATION ONLY:

Pursuant to Section 30 of the Instructions, Terms and Conditions for Bidding, a signature below by the Director of ODOT shall serve as the Department’s formal acceptance of the bidder’s offer and will effectively form ODOT Contract between the State of Ohio, Department of Transportation and the above successful bidder (company):

__________________________________________
Thomas Pannett,
Administrator, Office of Contract Sales
State of Ohio, Department of Transportation

__________________________________________
Date

__________________________________________
Jack Marchbanks, Ph. D.
Director
State of Ohio, Department of Transportation

__________________________________________
Date
APPENDIX A – DEPLOYMENT AND APPLICATION MAP
Legend
Connected Vehicle Applications
Proposed Applications
- Reduced Speed Zone Warning/Lane Closure
- Curve Speed Warning
- Pedestrian in Crosswalk Warning
- Intersection Safety Warning and Collision Avoidance

Drive Ohio Applications
- Queue Warning
- Wrong Way Warning

Future Applications
- Railroad Crossing Warning
- Spot Weather Warning

06/19/2019 2:14:39 PM
Project Location

Map Index
Legend
Connected Vehicle Application
- Proposed Applications
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- Drive Ohio Applications
  - Curve Speed Warning
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  - Intersection Safety Warning and Collision Avoidance
- Future Applications
  - Queue Warning
  - Wrong Way Warning
  - Freeway Roadside Unit
  - Queue Warning
  - Railroad Crossing Warning
  - Spot Weather Warning

Sheet 2 of 13
Legend

Connected Vehicle Application

Proposed Applications

- Reduced Speed Zone
- Pedestrian in Crosswalk Warning
- Intersection Safety Warning and Collision Avoidance

Drive Ohio Applications

- Queue Warning
- Wrong Way Warning

Future Applications

- Queue Warning
- Railroad Crossing Warning
- Spot Weather Warning

Freeway Roadside Unit

Sheets of 13
Legend

Connected Vehicle Application
Proposed Applications
- Reduced Speed Zone Warning/Lane Closure
- Pedestrian in Crosswalk Warning
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- Railroad Crossing Warning
- Spot Weather Warning

Freeway Roadside Unit
APPENDIX B – 33 SMART MOBILITY CORRIDOR CONCEPT OF OPERATIONS
Systems Engineering Analysis
Concept of Operations

Prepared For:
NW 33 Innovation Council of Governments

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<tr>
<td>33 SMC</td>
<td>33 Smart Mobility Corridor</td>
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<tr>
<td>AADT</td>
<td>Annual Average Daily Traffic</td>
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<td>ABS</td>
<td>Anti-lock Braking System</td>
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<td>ANSI/AIAA</td>
<td>American National Standards Institute/American Institute of Aeronautics and Astronautics</td>
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<td>ARC-IT</td>
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<td>ATCMTD</td>
<td>Advanced Transportation and Congestion Management Technologies Deployment</td>
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<td>BSM</td>
<td>Basic Safety Message</td>
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<td>CA</td>
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<td>System Management Software</td>
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<td>Signal Phasing and Timing</td>
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1 DOCUMENT OVERVIEW

This Concept of Operations (ConOps) serves as the initial, high-level baseline for the connected vehicle (CV) environment of the 33 Smart Mobility Corridor (33 SMC). The purpose of this ConOps is to present a vision for the proposed system from the perspective of the stakeholders. The overall system goals, user needs, and expectations are also established within this document. This document has been prepared for the NW 33 Innovation Corridor Council of Governments (COG) which includes the City of Dublin, City of Marysville, the Marysville-Union County Port Authority and Union County.

This ConOps also serves as a foundation document that sets the framework for the overall environment. It describes a high-level view of the proposed system’s operation and management. The ConOps is the first documented description of the system as an early stage of the systems engineering analysis (SEA), as shown in Figure 1-1. It does not describe detailed, testable system requirements, nor does it specify the technical design of the system. However, it does frame the overall system, which guides the development of later processes such as technical requirements, design, and testing and verification. Systems Engineering is a required component for all ITS projects as per Code of Federal Regulations (CFR) 940.11. This ConOps is part of the Systems Engineering.

This ConOps defines:

- System goals
- Stakeholders involved with the system
- System elements and capabilities

![Figure 1-1. FHWA V-Model Project Life Cycle](https://www.fhwa.dot.gov/cadiv/segb/files/segbversion3.pdf)
- Physical extent and scope of the system
- Operation of the system
- Process of system development, operation, and maintenance

For this project, the ConOps process will be to first define the project goals and objectives which will be used to evaluate the applications to be deployed. The final step will determine where the application will be done and what level of complexity will be required. Figure 1-2 illustrates the process being used to develop this document.

![Figure 1-2. ConOps Process](Image)

The 33 SMC ConOps is intended to be a living document with opportunity for stakeholder input as to how the system should function. As the program evolves and elements of the system are developed, acting on the described activities and process, some elements may require refinement to reflect changes in actual system operation. This ConOps will be updated as needed to accommodate these changes, refinements, or stakeholder requests. This document will be revised as needed by the project management team to maintain alignment and reflect the decisions made during major milestones in the SEA.

This document is organized according to the American National Standards Institute/American Institute of Aeronautics and Astronautics (ANSI/AIAA-G-043) ConOps structure. Since this system is being developed, the ANSI/AIAA-G-043 standard is chosen since it lends itself more to new systems. As such, this document includes the following sections:

- **Section 1. Document Overview**: Purpose of document and goals of the ConOps
- **Section 2. Scope**: High level overview of the project and system
- **Section 3. References**: Identifies referenced documents
- **Section 4. Project Background**: Background on the project and existing conditions
- **Section 5. User-Oriented Operational Description**: System description from a user vantage point
- **Section 6. Operational Needs**: Goals and objectives that will drive system requirements
- **Section 7. System Overview**: Discussion on how the system will function.
- **Section 8. Operational Scenarios**: Description of anticipated events and procedures during normal and stressed conditions
- **Section 9. Operational and Support Environment**: Description of the system infrastructure & procedures
- **Section 10. Final System Recommendations**: Final Recommendations on the Deployment
2

Scope

2.1 Project Scope

In 2016, the U.S. Department of Transportation (USDOT) awarded approximately $6 million to the NW 33 Innovation Corridor Council of Governments (COG) as an Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) program grant. With matching funds, the overall project includes over $13m of funds. With this funding, the COG intends to address transportation needs for rapid residential and business growth along US-33. This ConOps is intended to cover the entire project, including the local match portion.

The vision of the COG is to coordinate planning for transportation, infrastructure, land use, and economic development along the corridor. The 33 SMC will demonstrate how smaller cities can leverage innovative technologies, such as connected vehicle (CV) applications with Dedicated Short-Range Communication (DSRC), to improve operations, safety, and mobility.

The scope of work for the project includes the construction and/or installation of CV components, which includes roadside infrastructure, on-board units in vehicle fleets and supporting systems; which includes a smart network, the development of software/applications, and system integration.

The 33 SMC will deploy CV applications and supporting infrastructure along US-33, spanning from the Transportation Research Center (TRC) near East Liberty, OH to Dublin, OH including within the cities of Marysville and Dublin. The applications deployed for the 33 SMC will draw on deployment-ready or nearly ready CV applications with vehicle-to-infrastructure (V2I) communications and interface with a fiber-optic (F/O) line that spans US-33 in the project area as a communication channel to other systems. DriveOhio has expressed interest in deploying CV applications and supporting infrastructure within the 33 SMC environment. While efforts by the DriveOhio are considered outside the scope of the ATCMTD Grant, the 33 SMC environment will establish a working connected vehicle system where additional infrastructure and CV applications can be developed and easily deployed.

The 33 SMC project and the COG will be leveraging investments by DriveOhio in the corridor as part of the overall connected vehicle environment. 33 SMC is also an opportunity to develop partnerships for research, testing, and development of CV applications. Designing this system to be scalable will be necessary to allow for additional functionality or extension of the system limits in the future.

The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) and the Connected Vehicle Reference Implementation Architecture (CVRIA) are USDOT references that provide descriptions of CV applications in the context of the National ITS architecture. CV applications as provided by CVRIA and ARC-IT. Modifications and customizations of the architecture is anticipated for most of the applications to meet project requirements.
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| Code of Federal Regulations, Title 23, Chapter 1, Subchapter K – Intelligent Transportation Systems, Part 940 – Intelligent Transportation System Architecture and Standards |
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4 PROJECT BACKGROUND

4.1 PROJECT INTRODUCTION
The ATCMTD program provides grant opportunities to eligible entities to develop model deployment sites for large scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment. On October 13, 2016, the US Department of Transportation announced a $5.9 million ATCMTD grant to the City of Marysville, OH to implement a variety of intelligent transportation system technologies in the US-33 corridor, in state-owned right-of-way from east of I-270, northwest through Marysville, and ending at the Transportation Research Center (TRC) near East Liberty; within the cities of Dublin and Marysville; and unincorporated areas. The NW 33 Innovation Corridor Council of Governments (COG) was formed by the City of Marysville, the City of Dublin, Union County, and the Marysville – Union County Port Authority to coordinate multi-agency needs and efforts. The project encompasses US-33 from the City of Dublin, OH to the City of Marysville, OH as shown in Figure 4-1.

The US-33 corridor is experiencing some of the fastest residential and business growth in the State of Ohio. The 33 SMC seeks to optimize the existing transportation network with the knowledge that building capacity is not a feasible means to an end. The project will be one of the first full-scale deployments of Connected Vehicle (CV) technologies in the State of Ohio. CV technology is a broad term encompassing the applications and systems that utilize vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications to improve mobility and productivity of the transportation system and to improve safety.
Just outside the 33 SMC, the City of Columbus is developing a cutting-edge, region-wide connected and autonomous (CAV) transportation network after receiving a federal grant through its successful bid for the Smart City challenge. While various multi-modal programs are developed under the Smart City Challenge, CV applications and DSRC will be deployed in Columbus. The 33 SMC deployment will bolster this region’s commitment to smart transportation and provide a unique opportunity for coordinating adjacent CV systems. The COG has partnered with the Ohio Department of Transportation (ODOT) to utilize existing and planned fiber optic installations along US-33 to support V2I applications along US-33.

The 33 SMC spans various community types and land uses, with the purpose of demonstrating how these technologies can improve transportation across these spectrums in a way that is cost-effective, scalable, and replicable as a blueprint for other communities.

4.2 CURRENT SITUATION

Data on the existing conditions within the corridor was used to help inform some of the decisions on technology deployments under the project. The ODOT Transportation Information Mapping System (TIMS) was used to obtain the following data sets:

- 2017 Traffic Count Data
  - Annual Average Daily Traffic (AADT) Volumes
  - Truck Percentages
- 2017 Congestion Data
- 2015-2017 Crash Data

These data sets cover only those roads that are on the State’s transportation system and were summarized in the following geographical areas:

1. US-33 from Riverside Drive to SR-347
2. The City of Dublin
3. The City of Marysville

4.2.1 Traffic Count Data

The traffic count data, including AADT and truck percentages/volumes, are provided by the ODOT Office of Technical Services, Traffic Monitoring Section. Permanent or long-term count stations are located on select Interstate and freeway road segments. Data at these stations is continuously collected and provides not only traffic volumes but also vehicle classifications and speed ranges for each hour of the day. There are three long-term stations located along US-33 within the project area. The locations are:

- Permanent count station between Avery Road and Post Road (Location ID 120025)
- Permanent count station south/east of US-42; no longer active as of 07/15/18 (Location ID 2980)
- Long-term count station between Scottslawn Road and US-42; 10/09/2017 – 06/30/2018 (Location ID 16380)

Additionally, short-term (24-48 hour) count data is collected on lower classification roads using manual, portable counters. Roads within each county are on a different count rotation, but short-term counts are typically collected every three years. The combination of long-term and short-term data is used to create uniform set of traffic count data throughout the state.
The AADT data and truck percentages for the study area are presented graphically on a color-coded scale in Appendix A. Traffic Count and Truck Percentage Diagrams.

### 4.2.2 US-33 Corridor

On US-33, AADT volumes range from about 25,000 vehicles per day (vpd) to nearly 65,000 vpd. The highest traffic volumes occur just west of I-270. Volumes decrease to about 50,000 vpd at Post Road and to 40,000 vpd west of US-42. The AADT stays within the 30,000-40,000 vpd range until Honda Parkway.

Truck percentages range from 5-14%. Truck volumes are lowest in the City of Dublin, east of I-270. From Post Road through the City of Marysville, daily truck volumes are about 4,000 – 5,000 (10-11% trucks) trucks per day (tpd). Further west, the truck volumes are about 3,000 – 3,500 tpd (10-14% trucks).

#### 4.2.2.1 City of Dublin

AADT in the City of Dublin ranges from less than 5,000 vpd to nearly 40,000 vpd. Several high-use corridors are located on the eastern side of the City of Dublin including Dublin Road, Riverside Drive, and Emerald Parkway, which experience AADT between 15,000 to 30,000 vpd. The highest AADT occurs at Frantz Road from Blazer Parkway to US-33 with 30,000-40,000 vpd. Daily truck percentages range from over 14% to about 1%. The highest truck percentages occur on ramps to and from US-33. Other roads that experience high truck volumes include Post Road west of US-33, Cosgray Road, and Rings Road.

#### 4.2.2.2 City of Marysville

The highest volumes within the City of Marysville are along roads with direct access to US-33, including US-36, N. Maple Street, W. 5th Street and N. Main Street, all near their US-33 interchanges. These road segments have AADTs in the range of 25,000 – 13,000 vpd. All other roads within the City of Marysville and further west have AADTs of 10,000 vpd or less. All roads have daily truck volumes of under 1,500 tpd. North of US-33, both N. Maple Street and N. Main Street experience high truck traffic. Further west of Marysville, high truck volumes are prevalent at Honda Parkway and SR-347 near US-33.

### 4.2.3 Congestion Data

The ODOT Office of Statewide Planning & Research maintains a traffic congestion model which provides estimates of measures of effectiveness including delay, level of service, and volume-to-capacity ratios. These measures are developed using peak hour traffic volumes, the number of lanes, and travel speeds.

Color-coded maps were created to show the congestion index ranges for each geographical context and are provided in Appendix B. Congestion Index Diagrams. The congestion index represents the severity of road congestion by comparing actual travel speeds to free flow travel speeds.

The congestion index values along US-33 follow a similar trend as the AADT volumes. Congestion is highest in Dublin, particularly west of the I-270 interchange. Congestion remains relatively high through Post Road and to US-42. After the US-42 interchange, congestion drops to a moderate level through the west side of Marysville, where it becomes negligible.

Congestion data within the City of Dublin and City of Marysville is limited. In Dublin, congestion is highest on Dublin Road north of US-33 and Riverside Drive south of US-33. Additionally, congestion is present on Post Road just west of US-33. In Marysville, many of the roads with data have low congestion index values (i.e. little to no congestion). The most notable congestion areas are US-35 west of US-33 and N. Maple Street north of US-33.
4.2.4 Crash Data

Crashes along US-33 and ramps associated with US-33 were obtained from ODOT’s GIS Crash Analysis Tool (GCAT) on the TIMS website for the years 2015-2017. Crash diagrams of the study area are provided in Appendix C. Crash Data Diagrams. Approximately 1,550 crashes occur within this period; 544 (35%) of which are rear end crashes. Review of these crashes show that 404 (26%) rear end crashes can be attributed to interchange ramp locations. This indicates that congestion is the leading cause of rear end crashes. The US-33 interchanges with the highest number of crashes are I-270, US-42, Post Road, and Avery-Muirfield Drive respectively.

Nearly 50% of ramp crashes can be attributed to vehicles not allowing enough assured clear distance ahead for stopping, and just over 20% of ramp crashes have contributing factors linked to speed. The interchanges with the most speed related ramp crashes are I-270, the western US-36 interchange, SR-4, and SR-31 respectively. These four interchanges contribute 67 of the 91 speed related crashes on ramps. Of the 91 speed related ramp crashes, 40% occurred with roadway conditions of wet, snow, or ice. Suggested speeds on ramps vary directly with the weather conditions.

There were 12 pedestrian crashes on US-33, the City of Dublin, or the City of Marysville between the years 2015-2017. Table 4-1 shows pedestrian crash locations primary roadways that are most applicable to the project. Two crashes occurred on US-33 west of Marysville but were not included. These crashes were not included because the driver was struck by a vehicle after they exited their vehicle due to an initial incident. Five other pedestrian crashes were recorded in Dublin but occurred on side streets or in neighborhoods.

<table>
<thead>
<tr>
<th>Location</th>
<th>Signalized</th>
<th>Frequency (No of crashes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin</td>
<td>US-33 (W Bridge St) &amp; Darby St</td>
<td>No</td>
</tr>
<tr>
<td>Dublin</td>
<td>Post Road &amp; OCLC Driveway</td>
<td>Yes</td>
</tr>
<tr>
<td>Marysville</td>
<td>US-33 off ramp &amp; US-36 (East)</td>
<td>Yes</td>
</tr>
<tr>
<td>Marysville</td>
<td>N Main St &amp; W 4th St</td>
<td>Yes</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Between 2015 and 2017 there were 126 crashes caused by a motorist that entered an intersection when the signal was red. Ninety-eight of these crashes were in the City of Dublin and 28 in the City of Marysville. The majority (21) of crashes in Marysville took place on 5th Avenue and Delaware Avenue. Exactly half of the Dublin crashes took place on either US-33, SR 161, Franz Rd, or Avery Road.

Fixed object crashes for US-33 and associated ramps were analyzed because these types of crashes typically indicate a vehicle that has left the roadway. The greatest concentration of fixed object crashes occurred near Marysville. This area has a high concentration of ramps and is nearly all curved.

Weather and roadway conditions were investigated to determine if there were any related crash trends. Marysville had a slightly increased crash concentration due to the curvature of the roadway. US-33 between Post Road and I-270 was the only other location with increased crashes. All other locations had no discernable increase in crashes due to weather conditions.
5 USER-ORIENTED OPERATIONAL DESCRIPTION

Users of the 33 SMC will include anyone who will travel along the limited access portion of US-33 or will interface with pedestrians, bicyclists or signalized intersections in the cities of Marysville and Dublin. Although users can include the public, most interactions with the system will come from public service vehicles equipped with on-board units (OBUs). The typical users include public school buses, law enforcement, public works, emergency services, and researchers and developers. While this system will be initially utilized by public service agencies and researchers and developers, it will be accessible to the public. This technology is still emerging and is not readily equipped in private motor vehicles but is anticipated to be utilized by the public as this technology penetrates the market. User needs are summarized at the end of this chapter in Table 5-1.

5.1 PEDESTRIANS/CYCLISTS
Pedestrians already in the crosswalk have the right-of-way over vehicles. However, crossing the roadway at any time can be hazardous, especially at unsignalized crossings or at other uncontrolled locations. Pedestrians using a crosswalk expect vehicles to yield to them. For a pedestrian to cross the road, they typically need assurance that vehicles in the roadway have stopped or will see them and stop. This interaction becomes increasingly difficult with older individuals, as their eyesight decreases and crossing time increases. Pedestrians expect that as innovative technologies are deployed in the field, vehicles will be able to either detect or respond to pedestrians in the roadway in a manner that prevents or helps to prevent pedestrian crashes. The walking or cycling public also want recognition in areas of higher pedestrian and cyclist traffic, such as urban settings with more frequent crossings.

5.2 PRIVATE MOTORISTS
As technology advances, drivers are exposed to new safety features in the form of driver assistance, traveler information from public sources and GPS navigation, along with traditional information from television and radio. More recently, cellular phone navigation applications, such as Waze and Google Maps, have begun to integrate roadway information such as traffic congestion, construction zones, traffic incidents, estimated time arrival (ETA), and route alternatives. As more safety features are integrated into vehicles, the public expects vehicles to be more integrated with their environment. The driving public wants information about the roadway that can prepare them for atypical scenarios, such as sudden lane closures, and potentially dangerous roadway conditions. Information regarding roadway characteristics, traffic signals, changes in operation, and other vehicles on the road should be made available to drivers.

The driving public desire signal systems that are more efficient and interactive with drivers, improving the operation and reliability of the overall transportation network. Poorly operating traffic signals create congestion and delays, both of which can cause frustration to the driving public. Generally, the public wants to travel from point A to B as quickly and safely as possible and desire a traffic signal network that can maintain a reasonable level of network performance. To maximum the benefits of connection, traffic signals should provide information to drivers and vice versa.

Drivers are becoming more and more reliant on information technology such as computer-aided navigation with cellphones and navigation integrated into their vehicles to guide their decision making.
Since road users often cannot avoid driving, as this is their means to go to work, to the store, etc. road condition information in a real time manner would be valuable information for drivers.

5.3 **Freight Operators**

Like the driving public, commercial freight companies desire a reliable transportation network, as their business and ability to provide goods in a timely fashion is essential to our economy. Commercial vehicle operators want information about the roadway and how it will impact their ability to safely and reliably do their job.

5.4 **First Responders**

Benefits of CV applications can also be applied to first responders such as law enforcement agencies, emergency medical services, and firefighting services. While this system may include first responder-specific applications, these agencies still value the benefits of informed and safer travel during non-emergency and emergency conditions. However, these agencies do interact with other vehicles and infrastructure in a different manner than the public. It is imperative that they constantly innovate to perform their services in the most efficient and safe manner possible.

5.5 **Railroads**

Road operators and railroad companies are continuously challenged with at-grade railroad crossing safety. While there are existing mechanisms to improve crossing safety and assign right-of-way, it is anticipated that further efforts to improve safety would be desired. Collisions at at-grade crossings can be catastrophic. Although these crashes can be severe, rail crossings are often traversed with little or no concern of trains, as these interactions are typically not as common as normal traffic conditions. This creates a comfort level with railroad crossings that is undesirable for transportation agencies. The prevalence of railroad infrastructure such as gates and warning beacons has garnered trust in those systems, however these safety systems can still fail. Additional warning will help to serve as a reminder of the dangers of at-grade railroad crossings.

5.6 **Transportation and Governmental Agencies**

It is the underlying vision of many agencies to provide transportation that is inclusive, multi-faceted, provides for mobility and safety, and meets the needs of their constituents. In an ever-evolving environment, it is evident that modernizing infrastructure is needed to keep pace with market advances and for sustainable transportation. This technology will also be implemented in instances where government forces and contractors are working in the roadway, informing drivers of their presence and changes in the roadway due to construction traffic patterns.
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrians/Cyclists</td>
<td>Improved pedestrian safety at crossings</td>
</tr>
<tr>
<td></td>
<td>Confidence in mid-block crossings</td>
</tr>
<tr>
<td></td>
<td>Responsive transportation network</td>
</tr>
<tr>
<td>Private Motorists</td>
<td>Informed and safe travel</td>
</tr>
<tr>
<td></td>
<td>Enhanced interaction with infrastructure and other modes</td>
</tr>
<tr>
<td></td>
<td>Warning/Alerts of potential hazards</td>
</tr>
<tr>
<td>Freight Operators</td>
<td>Informed and safe travel</td>
</tr>
<tr>
<td></td>
<td>Enhanced interaction with infrastructure and other modes</td>
</tr>
<tr>
<td></td>
<td>Advanced warning of potential hazards</td>
</tr>
<tr>
<td>First Responders</td>
<td>Enhanced interaction with infrastructure</td>
</tr>
<tr>
<td></td>
<td>Enhanced interaction with other vehicles on the road</td>
</tr>
<tr>
<td>Railroads</td>
<td>Improved safety at crossings</td>
</tr>
<tr>
<td>Government Agencies</td>
<td>Modernize transportation</td>
</tr>
<tr>
<td></td>
<td>Informed and safe travel</td>
</tr>
<tr>
<td></td>
<td>Planning for future needs</td>
</tr>
<tr>
<td></td>
<td>Sustainability and scalability</td>
</tr>
<tr>
<td></td>
<td>Keep pace with market technological advancements</td>
</tr>
<tr>
<td></td>
<td>Opportunities for economic development</td>
</tr>
</tbody>
</table>
6 OPERATIONAL NEEDS

Central Ohio is facing many challenges from recent population growth and the resulting strain on aging infrastructure to meet growing demands for safety, mobility, health, security, prosperity, environmental sustainability, and access to opportunity. The US-33 corridor has seen rapid growth in population and employment. US-33 and the local street network is congested near both ends of the project area and within the cities of Marysville and Dublin. Queueing traffic on US-33 and increasing pedestrian and vehicular traffic on the local street networks have created concerns with mobility and safety. This corridor also experiences large traffic volume influxes from shift changes of major manufacturing plants.

The vision of the 33 SMC is to demonstrate how smaller cities can leverage intelligent transportation technology to improve safety, congestion and mobility, and modernize infrastructure. In support of this vision, the COG established the following project goals as stated in the ATCMTD grant application:

1. Improve roadway congestion along US-33 by deploying roadside dedicated short-range communications (DSRC) and on-board units (OBUs).
2. Enhance intersection safety and mobility by upgrading municipal traffic signals to include dynamic signal phase and timing and pedestrian in crosswalk warning technology where warranted.
3. Increase job access by providing dynamic ridesharing opportunities to employees at existing employers.
4. Serve as a technology “leap-ahead” to provide future employment opportunities created by the deployment of connected and autonomous vehicle testbed components.

At the onset of the project, two partnering workshops were held on February 1, 2018 and February 6, 2018. During the workshop, a refined list of goals was developed based on input from the stakeholders. Subsequently, the program management team aligned each of the goals to the objectives within the grant application. The summary of these goals and associated objectives is documented in Table 6-1.

As the 33 SMC is also intended to be an opportunity to develop partnerships for research, testing, and development of new technology, the system should be easily accessed for data and have the capacity for augmentation or reconfiguration of system software.

The system should also be flexible and scalable to accommodate more users of CV technology. This scalability should also include expanding the system in terms of geographic area by adding RSUs, possibly including fiber optic communication lines, and supporting ITS roadway equipment. The backend systems for data management and system interfacing will need the capacity to handle additional future traffic and loadings on the proposed 33 SMC data network.
Table 6-1. 33 Smart Mobility Corridor Goals and Grant Objectives

<table>
<thead>
<tr>
<th>33 Smart Mobility Corridor Goals</th>
<th>Corresponding Objective from Grant Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance Intersection Safety and Mobility</td>
<td>Improve pedestrian safety at transit stops and crosswalks. Provide next generation signal prioritization and dynamic timing based on DSRC.</td>
</tr>
<tr>
<td>Improve Roadway Congestion</td>
<td>Improvement in travel time reliability. Reduction in average commute time to work. Reduce traffic queues and congestion for critical arterials.</td>
</tr>
<tr>
<td>Serve as a Technology “Leap-Ahead”</td>
<td>Increase the number of Connected Vehicles. Double the number of deployed Connected Infrastructure Components (RSUs) in the country. Serve as the &quot;go-to&quot; location for on-road tests of autonomous vehicle technologies. Provide the country’s largest open research repository of J2735 message sets collected within an actual deployment.</td>
</tr>
<tr>
<td>Increase access to employment</td>
<td>Increase ridesharing in the NW 33 Innovation Corridor. Reduce reoccurring congestion due to shift changes at manufacturing facilities in Marysville and Union County.</td>
</tr>
</tbody>
</table>

The 33 SMC connected vehicle system is envisioned to utilize pre-defined connected vehicle applications developed by the Connected Vehicle Reference Implementation Architecture team. These applications will be deployed for specific use cases to meet the project goals.

The following operational, informational, and institutional gaps currently affect the ability to manage and operate the US-33 corridor and surrounding urban transportation networks to their full potential.

- **Transportation system**
  - No existing ability to monitor real-time traffic conditions consistently through the corridor
  - Deployed signal controllers have advanced capabilities, but are not fully utilized
  - No existing V2I communications system
  - No existing data collection/analysis system

- **Information**
  - No direct communication links currently exist for multi-jurisdictional municipal programs
  - No existing network for transportation systems, servers, data management, etc.
  - No existing data sharing program

- **Institutional**
  - No existing system maintenance personnel identified
  - Fiscal responsibility of system operation and maintenance not defined

### 6.1 INFRASTRUCTURE NEEDS

V2I applications require supporting roadside infrastructure, in the form of DSRC roadside units. These devices will need coverage of US-33 from east of the I-270/US-33 Interchange in suburban Dublin to the TRC near East Liberty. Additional use cases in the urban environments of the City of Marysville and City of Dublin require devices to be potentially deployed, as needed, at signalized intersections, mid-block pedestrian crosswalks, and railroad crossings.
Transportation systems are most efficient when monitored and actively managed from a centralized management center. Centralizing these systems allows for better traffic management since this provides a more holistic view of the transportation network, instead of isolated pockets. If this project were to include an infrastructure management component, the project would need to include communication terminations, servers, data management and processing capabilities, and user interface necessary to properly manage this system.

6.2 NETWORK NEEDS
A backend network is envisioned to fully support connectivity, data storage, data processing, data analytics, performance metrics, and system management. As part of the project, a 432-strand fiber optic cable has been installed along US-33 in anticipation of future communication needs. To support further research, development, and testing, the system may need to support remote software updates of devices deployed in the field. Additionally, data from OBUs could be utilized to support automated performance metrics through backend data processing.

6.3 PHYSICAL CONSTRUCTION NEEDS
A fiber optic backbone has been constructed along US-33, with a redundant fiber optic backbone currently under construction along what is considered the local route, including Industrial Parkway. The installation of each of the backbones will allow for the 33 SMC system to tie into a network for communication. RSUs will need to be installed along US-33 and within local municipal transportation networks. RSUs that provide continue coverage on US-33 will help accommodate the future testing needs of additional connected vehicle applications and for the autonomous vehicle providers. RSUs installed within the cities of Marysville and Dublin would most likely be deployed at signalized intersections and other locations specific to the selected applications intended use. These devices will utilize the fiber optic backbone and redundant loop for network wide communications.

RSUs will need to be installed at the appropriate locations for the selected applications. Future applications to be deployed should also be considered and the potential infrastructure needed. These devices should leverage existing infrastructure for mounting as much as possible.

6.4 MAINTENANCE NEEDS
To ensure full system functionality, a diagnostic system should have the ability to verify if all elements of the system are functional. The diagnostics should identify equipment that has malfunctioned or lost connection. The system also needs to have the ability to be sure that firmware and other software or security certificates are up to date.

6.5 TRAINING AND SUPPORT
Personnel managing and maintaining the system will need to be trained on the system. This includes installation, system configuration, operation of the system, system software, administration of the system, preventative maintenance and repair, software development, and troubleshooting. System operational personnel should have a thorough understanding of the system, performance metrics, CV applications, and messages used.
The deployed project will include many different systems, subsystems, and components, which will require a training plan of agency staff. The system will also require software updates as necessary to keep the software up to date and functioning as intended. The agency will also require ongoing system support for unforeseeable events.

6.6 **Agency Needs**

Agencies overseeing transportation networks need to understand how the system is operating and have feedback that it’s meeting the project goals. This could include performance reporting that gives insight into corridor operations and safety improvements. It is important that agencies understand if the project is meeting the performance goals set forth at the project onset.

Secondly, agencies want to understand project lifecycle costs beyond the initial design and construction. Yearly budgets for operation, maintenance, and support of the system will need to be agreed to between agencies of the COG. Budgeting for the system shall include all relevant resources such as personnel, equipment, training, support, and administration.
7 SYSTEM OVERVIEW

The vision for the 33 SMC is to demonstrate how smaller cities can leverage innovative technologies, such as connected vehicle (CV) applications, to improve operations, safety, and mobility. Key concepts for this system are to deploy supporting V2I infrastructure, equip fleets of vehicles with OBUs, and deploy V2I applications to address operational and safety issues on the US-33 corridor and adjacent cities.

7.1 APPLICATION READINESS ASSESSMENT

The COG has documented a series of applications and technologies for the project. The program management team conducted an application readiness assessment to evaluate potential applications that can be deployed on the project. Criteria was developed to evaluate the readiness of each application so that impacts on project timeline and budget can be considered. Applications which are not considered ready for deployment will take additional time and cost to develop.

All appropriate applications listed on the CVRIA (https://local.iteris.com/cvria/); those included in the COG ATCMTD grant application developed to support this project; and additional applications identified by the stakeholders were considered in the assessment. Each application was assigned a “readiness” based on the following criteria:

1. Has the application been previously deployed elsewhere?
2. Has a proof of concept test/pilot been done?
3. Has a system architecture been developed?
4. Has the application been documented as considered?

Once each application was evaluated for “readiness,” the applications were broken down into recommendations from the program management team, with stakeholder input, which include a justification for each. Applications were also selected to get a cross-section of near ready applications and those that will require more development time. Important input provided by the stakeholders was that the project be innovative and not do things solely that “have been done before.” Table 7-1 on the next page includes the recommended applications and associated justifications. The applications are broken down into Tier 1 and Tier 2. Tier 1 includes applications that were determined to be strong candidates for this project. Tier 2 includes applications that will be considered if a Tier 1 application does not get deployed or additional project budget becomes available. The complete readiness assessment is provided in Appendix D. Application Readiness Assessment.
### Table 7-1. Recommended Applications Based on Readiness Assessment

<table>
<thead>
<tr>
<th>Applications</th>
<th>Identified in ATCMTD Grant</th>
<th>Application Readiness Assessment</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve speed warning at interchange ramps</td>
<td>X</td>
<td><strong>Proof of Concept</strong> – Deployment planning underway in Tampa CV Pilot</td>
<td>X</td>
</tr>
<tr>
<td>Ramp wrong-way warning</td>
<td>X</td>
<td><strong>System Architecture Determined</strong> - Application is being developed for a specific situation/use for the CV Pilot in Tampa</td>
<td>X</td>
</tr>
<tr>
<td>Spot Weather Impact Warning</td>
<td>X</td>
<td><strong>Deployed</strong> - Pilots in Michigan and Wyoming</td>
<td>X</td>
</tr>
<tr>
<td>SPaT - Signal Phasing and Timing</td>
<td>X</td>
<td><strong>Deployed</strong> - National deployments</td>
<td>X</td>
</tr>
<tr>
<td>PCW - Pedestrians in crosswalk warning</td>
<td>X</td>
<td><strong>Deployed</strong> - Deployment in Cleveland in a transit application</td>
<td>X</td>
</tr>
<tr>
<td>Q-WARN - Queue warning at interchanges</td>
<td>X</td>
<td><strong>Proof of Concept</strong></td>
<td>X</td>
</tr>
<tr>
<td>Camera analytics - crash avoidance at intersections and freeway incident detection</td>
<td>No Architecture Developed - No known applications or concepts</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Reduced Speed Zone Warning / Lane Closure</td>
<td>X</td>
<td><strong>Deployed</strong> – MDOT in Macomb County</td>
<td>X</td>
</tr>
<tr>
<td>Midblock Pedestrian Crossing Warning (using camera analytics)</td>
<td>No Architecture Developed - No known applications or concepts</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Roundabout application</td>
<td>X</td>
<td>No Architecture Developed - No known applications or concepts</td>
<td>X</td>
</tr>
<tr>
<td>Red Light Violation Warning (RLVW)</td>
<td>X</td>
<td><strong>Deployed</strong> - Being done on CV Pilot - NYC</td>
<td>X</td>
</tr>
<tr>
<td>Railroad Crossing Warning</td>
<td>X</td>
<td><strong>System Architecture Determined</strong> - May be difficult to obtain railroad coordination</td>
<td>X</td>
</tr>
</tbody>
</table>

#### 7.2 Alignment with USDOT/FHWA Strategic Goals

An evaluation to ensure that each application meets stated goals and objectives was conducted. All the recommended applications were evaluated against strategic goals from the Fixing America's Surface Transportation Act or "FAST Act." The applications that have been selected to be advanced in the project were specifically chosen to support FHWA/USDOT Strategic Goals and the objectives identified in the grant application. **Table 7-2** on the following page identifies the Strategic Goals that this project is supporting and the corresponding applications that are aligned with those goals.
Table 7-2. Alignment to USDOT/FHWA Strategic Goals

<table>
<thead>
<tr>
<th>FHWA/USDOT Strategic Goals</th>
<th>Project Objectives</th>
<th>Applications aligned with Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduction in the number and severity of traffic crashes and an increase in driver, passenger, and pedestrian safety;</strong></td>
<td>Enhance intersection safety and mobility. Improve pedestrian safety at transit stops and crosswalks. Provide next generation signal prioritization and dynamic timing.</td>
<td>Pedestrian in Crosswalk Warning Spot Weather Impact Warning Curve Speed Warning Queue Warning Reduced Speed Zone / Lane Closure Warning Red Light Violation Warning Ramp Wrong-Way Warning Railroad Crossing Warning</td>
</tr>
<tr>
<td><strong>Collection, dissemination, and use of real time transportation related information to improve mobility, reduce congestion, and provide for more efficient and accessible transportation, including access to safe, reliable, and affordable connections to employment, education, healthcare, freight facilities, and other services;</strong></td>
<td>Improvement in travel time reliability. Reduction in average commute time. Reduce traffic queues and congestion for critical arterials. Provide next generation signal prioritization and dynamic timing.</td>
<td>Spot Weather Impact Warning Queue Warning Red Light Violation Warning Pedestrian in Crosswalk Warning</td>
</tr>
<tr>
<td><strong>Accelerated deployment of vehicle-to-vehicle, vehicle-to-infrastructure, and automated vehicle applications, and autonomous vehicles and other advanced technologies;</strong></td>
<td>Increase the number of Connected Vehicles. Double the number of deployed Connected Infrastructure. Serve as the “go to” location for on-road tests of autonomous vehicle technologies. Provide the country’s largest open research repository of J2735 message sets collected with an actual deployment.</td>
<td>All Applications</td>
</tr>
</tbody>
</table>

Furthermore, the deployment of the project will also support the following two USDOT/FHWA Strategic Goals:

- *Demonstration, quantification, and evaluation of the impact of these advanced technologies, strategies, and applications towards improved safety, efficiency, and sustainable movement of people and goods.*
- *Reproducibility of successful systems and services for technology and knowledge transfer to other locations facing similar challenges.*
The metrics that will be identified and measured as part of deployment of the applications noted above will quantify and evaluate the impact of this advanced technology based on safety and mobility. All the lessons learned and best practices from this project will be documented and shared so that the successes are reproducible.

### 7.3 Final Application List

Based on alignment of the project goals and objectives and the application assessment, Table 7-3 includes the proposed applications to be part of the connected vehicle environment for the 33-SMC. The table includes the CVRIA description of each application, where applicable.

#### Table 7-3. Final Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve speed warning at interchange ramps</td>
<td>The curve speed warning application allows connected vehicles to receive information that it is approaching a curve along with the recommended speed for the curve. This capability allows the vehicle to provide a warning to the driver regarding the curve and its recommended speed. In addition, the vehicle can perform additional warning actions if the actual speed through the curve exceeds the recommended speed.</td>
</tr>
<tr>
<td>Intersection Safety Warning and Collision Avoidance (Red Light Violation Warning)</td>
<td>The Red Light Violation Warning (RLVW) application enables a connected vehicle approaching an instrumented signalized intersection to receive information from the infrastructure regarding the signal timing and the geometry of the intersection. The application in the vehicle uses its speed and acceleration profile, along with the signal timing and geometry information to determine if it appears likely that the vehicle will enter the intersection in violation of a traffic signal.</td>
</tr>
<tr>
<td>PCW (Pedestrian in Signalized Crosswalk Warning)</td>
<td>The Pedestrian in Signalized Crosswalk Warning application provides to the connected vehicle information from the infrastructure that indicates the possible presence of pedestrians in a crosswalk at a signalized intersection.</td>
</tr>
<tr>
<td>Q-WARN</td>
<td>The Queue Warning (Q-WARN) application utilizes vehicle-to-infrastructure (V2I) communications to enable vehicles to receive warnings requiring emergency maneuvers (e.g., rapid deceleration, lane location). The infrastructure will broadcast queue warnings to vehicles to minimize or prevent rear-end or other secondary collisions.</td>
</tr>
<tr>
<td>Railroad Crossing Warning</td>
<td>The Rail Road Crossing Warning enables a connected vehicle approaching an instrumented railroad crossing to receive information from the infrastructure regarding an approaching train. The application in the vehicle uses its speed and acceleration profile, along with the crossing information to determine if it appears likely that the vehicle will violate the crossing warning.</td>
</tr>
<tr>
<td>Ramp Wrong-Way</td>
<td>This application would use a wrong-way driver detection system to develop messaging that would be broadcast by the infrastructure to provide an alert to a wrong-way driver and warning messages to other drivers via roadside signs and in-vehicle messages.</td>
</tr>
<tr>
<td>Reduced Speed Zone Warning / Lane Closure</td>
<td>The Reduced Speed Zone Warning / Lane Closure (RSZW/LC) application provides connected vehicles which are approaching a reduced speed zone with information on the zone's posted speed limit and/or if the configuration of the roadway is altered (e.g., lane closures, lane shifts). The RSZW/LC application inside the connected vehicle uses the revised speed limit along with any applicable changed roadside configuration information to determine whether to provide an alert or warning to the driver.</td>
</tr>
<tr>
<td>Spot Weather Impact Warning</td>
<td>The Spot Weather Impact Warning (SWIW) application will alert drivers to unsafe conditions or road closure at specific points on the downstream roadway because of weather-related impacts, which include, but are not limited to high winds, flood conditions, ice, or fog. Application designed to use standalone weather systems to warn drivers about inclement weather conditions that may impact travel conditions. Real time weather information is collected via RWIS or via vehicle-based probe data. The information is processed to determine the nature of the alert or warning to be delivered and then communicated to connected vehicles.</td>
</tr>
</tbody>
</table>
7.4 Stakeholder Engagement

At the onset of the project, several coordinated efforts were outlined and defined to facilitate the decisions required for key elements of the system.

7.4.1 Partnering Workshop

A two-day Partnering Workshop was held on February 1 and 6, 2018. The purpose of the Partnering Workshop was to establish the internal project protocols and project goals. Participants in the workshops included the City of Marysville, City of Dublin, Union County, Marysville-Union County Port Authority, ODOT, DriveOhio, FHWA, TRC, Battelle, and Honda.

- Partnering Workshop #1 (2/1/2018) identified goals and priorities for the individual parties as well as identified opportunities and risks.
- Partnering Workshop #2 (2/6/2018) was a smaller group (COG members/staff and ODOT). This workshop established project protocols, such as, recurring project meetings, executive group and working groups, decision matrix, vendor requests, and communication plan.

7.4.2 Working Groups

An organizational structure shown in Figure 7-1 below was developed to aid in delivery of the project. The structure builds upon an Executive Committee, which will report directly to the COG Board. The Executive Committee has decision authority based on recommendations made by the working groups. Representation from the Executive Committee are included in each of the working groups.

The working group structure allows for nimble decision-making as the project moves forward. Given the aggressive schedule that is intended, the working group structure helps with decisions regarding items such as approval of system requirements, procurement methods, and implementation activities. Each working group includes appropriate subject matter experts both from within the partner agencies as well as from neighboring projects and stakeholders to provide input and recommendations. Table 7-4 on the following page indicates each working group purpose and the invited members of each group.
<table>
<thead>
<tr>
<th>Working Group</th>
<th>Purpose/Role</th>
<th>Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Committee</td>
<td>The Executive Committee will have a direct line of communication to the COG Board. The Executive Committee will make decisions based on recommendations provided by the Working Groups and will have final approval.</td>
<td>Donna Goss, Doug McCollough, Megan O’Callaghan, Justin Nahvi, Aaron Story, Andrew Bremer, Alana Haberman, Kevin Fiant, Thom Slack, Eric Phillips, City of Dublin, City of Dublin, City of Dublin, City of Marysville, DriveOhio, ODOT Central Office, ODOT District 6, ODOT District 6, Union Co/Marysville</td>
</tr>
<tr>
<td>Infrastructure Working Group</td>
<td>The purpose of the Infrastructure Working group is to coordinate and set the standards for the planning, design, construction, integration and use of the infrastructure elements of the US-33 Smart Mobility Corridor deployment. The infrastructure elements will include the Dedicated Short-Range Communications (DSRC) equipment used for vehicle-to-infrastructure communication, the fiber-optic line along US-33, traffic signal equipment, and other supporting communication and Intelligent Transportation Systems infrastructure.</td>
<td>Doug McCollough, Megan O’Callaghan, Mike Andrako, Aaron Story, Nick Hegemier, Nick Gill, Thea Walsh, Jason Yeray, Kevin Fiant, Joshua Every, Jeff Stauch, City of Dublin, City of Dublin, City of Marysville, City of Marysville, DriveOhio, MORPC, MORPC, ODOT Central Office, ODOT District 6, ODOT District 6, Union Co/Marysville</td>
</tr>
<tr>
<td>Vehicle Working Group</td>
<td>The purpose of the Vehicle Working group is to coordinate and set the standards for the onboard unit (OBU) procurement and installation. This group will work closely with the Infrastructure group to make sure that protocols, testing and validation processes are in place for the communications between the roadside devices and vehicle OBU. This working group could be involved in workforce development and vehicle recruitment in coordination with the Engagement Working Group.</td>
<td>Dominie Garcia, Megan O’Callaghan, Darryl Syler, Mike Andrako, Mike Wiseman, Cynthia Jones, Tom Corey, Joshua Every, Jeff Stauch, Battelle, City of Dublin, City of Dublin, City of Marysville, Honda, ODOT, ODOT Central Office, TRC, Union County</td>
</tr>
<tr>
<td>Smart Network Working Group</td>
<td>The “intelligence” behind the Smart US-33 Corridor will lie in the ability to turn the data generated by vehicles using the network into usable applications to benefit stakeholders and motorists. The development of this network, and how this network ties into other regional initiatives such as Smart Columbus, will be the focus area of the working group. The working group will focus on completing the systems engineering process for the network, developing the framework for the network, procure the needed products and service to implement the network, and coordinate with local partners and other initiatives in integrating data sharing processes.</td>
<td>Dominie Garcia, Doug McCollough, Aaron Story, Spencer Wood, Andrew Bremer, Nick Hegemier, Simon Herring, Jodie Bare, Joshua Every, Battelle, City of Dublin, City of Marysville, DriveOhio, Honda, Jobs Ohio, Logan County, MORPC, ODOT, Smart Columbus, TRC</td>
</tr>
<tr>
<td>Engagement Working Group</td>
<td>The engagement working group will collaboratively work to determine public engagement and industry engagement opportunities and strategies. Project branding and public facing project decisions will also be within their scope. As the project progresses, the potential for data monetization and workforce development will be discussed within this group.</td>
<td>Sue Burness, Donna Goss, Anna Krutowskis, Irene Alvarez, Andrew Bremer, Don Hensley, Kristi Tanner, Paul Benedetti, Terri Flora, Erica Hawkins, Joanna Pinkerton, Eric Phillips, City of Dublin, City of Dublin, City of Marysville, Columbus2020, DriveOhio, Honda, Jobs Ohio, Logan County, MORPC, ODOT, TRC, Union Co/Marysville</td>
</tr>
</tbody>
</table>
Working Groups have normally been held on a monthly or bimonthly basis, or as needed, throughout the project development process. Table 7-4 represents the initial invited attendees, but attendee lists have been refined as the project has progressed.

7.4.3 ConOps Workshop
A two-day ConOps Workshop was held on October 15 and 16, 2018. The purpose of the ConOps Workshop was to gather stakeholder interests in the project and finalize some of the remaining issues for the project that are needed to support the development of the Concept of Operations and high-level system requirements.

The outline of the workshop was as follows:

1. **ConOps Overview** – Why it’s done and why it’s required for this project
2. **Goals and Objectives** - Review of the previously defined project goals and objectives
3. **The Scope of the System** – the series of subsystems that make up the connected vehicle environment, including local, regional and statewide systems
4. **Introduction to the Applications** – Defining the basic functionality of each application
5. **Traffic Hot Spots** – Discussion on crash and congestion hot spots within the project limits
6. **Application Use Cases** – Defining what the stakeholders want out of each application, including brainstorming scenarios for each application and where
7. **Operational Needs** – Need with respect to data, data storage, backend processing and analytics, security, and operation of the system
8. **Ownership and O&M** – For the systems and subsystems, who will own them, who will operate and maintain them
9. **Agreement** – Additional agreements that may be required between various agencies

The outcomes of the ConOps Workshop have supported the development of this document.

7.5 **System Components**
Based on the final list of applications and elements contained within the project scope of services, the system components have been defined as follows:

1. Continuous RSU coverage along US-33, spanning multiple jurisdictions in three counties
2. Signal phasing and timing (SPaT) and MAP messages throughout RSU equipped signals within the Cities of Dublin and Marysville
3. CV applications
   1. Curve Speed Warning
   2. Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning)
   3. Pedestrian in Crosswalk Warning (PCW)
   4. Queue Warning (Q-WARN)
   5. Railroad Crossing Warning
   6. Ramp Wrong Way Warning
   7. Reduced Speed Zone Warning / Lane Closure
   8. Spot Weather Impact Warning
4. An OBU equipped vehicle fleet comprising multiple jurisdictions and vehicle types
5. The connected vehicle environment will include necessary back end systems for infrastructure management, data warehousing, and security credential management
6. ITS infrastructure to support the applications where necessary
7. Connection to the Dublin Metro Data Center

7.5.1 Continuous DSRC on US-33
The US-33 corridor will be equipped with RSUs that provide continuous DSRC communications coverage along US-33 from east of the US-33/I-270 Interchange to the TRC near East Liberty. The RSUs will serve as the primary interface between equipped vehicles and connected infrastructure and provide opportunity for data transmission between the RSU and OBU.

7.5.2 SPaT and MAP Messaging
DSRC infrastructure will be installed at signalized intersections at 27 locations in the City of Marysville and at a minimum of five locations within the City of Dublin. Message broadcasts from the traffic signal RSUs will include Signal Phasing and Timing (SPaT), MAP data, and Radio Technical Commission for Maritime Services (RTCM) GPS correction data as defined in the SAE J2735 standard.

All RSUs deployed at signalized intersections will support SPaT and MAP configured applications such as Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning). Additional applications will be supported, where specified, such as Pedestrian in Crosswalk Warning using the Travel Information Message (TIM) channel.

Intersection RSUs will be integrated into the existing Marysville and Dublin fiber optic networks for data transmission, and ultimately to the infrastructure management system for management and system monitoring.

7.5.3 Connected Vehicle V2I Applications
The initial applications utilized for the 33 SMC have been vetted to include available or nearly available applications as well as some more complex applications. The purpose of implementing some ready CV applications is to accelerate design and implementation of the system. The 33 SMC will be easily scalable to include additional CV applications as they are developed.
7.5.3.1 Curve Speed Warning
Curve Speed Warning is a V2I application that allows equipped vehicles to generate a warning to the driver if the vehicle is approaching a curve at higher than its recommended speed. This application is a connected vehicle implementation of what is traditionally handled with advance curve warning signing and warning beacons in some instances. This application could be applied anywhere there are higher speed curves or for a horizontal curve is less than the posted speed limit. Figure 7-2 illustrates the basic functionality system architecture for Curve Speed Warning could include.
7.5.3.2 Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning)

The Intersection Safety Warning and Collision Avoidance application enables equipped vehicles approaching a signalized intersection to receive information from the signal RSU regarding signal timing and geometry (SPaT & MAP) of the intersection. The vehicle can then use its speed and acceleration profile, along with SPaT and MAP messages, to process this information and determine if the vehicle will pass safely through the intersection. The vehicle’s OBU will process the information to determine if it will violate the signal red-light. If the OBU determines that proceeding through the intersection is unsafe, a warning is provided to the driver. Figure 7-3 illustrates the basic functionality system architecture for Intersection Safety Warning and Collision Avoidance could include.

![Figure 7-3. Intersection Safety Warning and Collision Avoidance Architecture](image-url)
7.5.3.3 Pedestrian in Crosswalk Warning

The Pedestrian in Crosswalk Warning application presented by the Architecture for Cooperative and Intelligent Transportation (ARC-IT) provides for sensing and warning systems used to interact with pedestrians, cyclists, and other non-motorized roadway users. The application provides equipped vehicles information that indicates the possible presence of a pedestrian or cyclist in the roadway or crossing.

The initial use case, based on the ARC-IT architecture, can be applied at signalized intersections. Upon actuation of the pedestrian push button and servicing of that pedestrian phase, the traffic controller will route information to the RSU to be broadcasted to equipped vehicles. The warning to the vehicle driver will indicate the possible presence of a pedestrian in the crosswalk.

A second use case, which is a modification of the ARC-IT architecture, is being considered at existing signalized mid-block pedestrian crossings. The infrastructure-based indication is triggered by actuation of the pedestrian push button. Once actuated, the RSU will broadcast a message to equipped vehicles indicating the possible presence of a pedestrian in the mid-block crosswalk.

A third use case, which will be discussed further in the document, uses a combination of infrastructure detection devices and data and system analytics to determine the presence of uncontrolled pedestrian or bicycle activity near RSU equipped signalized intersections. An equipped vehicle would receive information from the RSU and then use its location, speed, and acceleration profile to determine if the vehicle driver needs to be warned about an impending conflict.

Figure 7-4 illustrates what the basic functionality system architecture for Pedestrian in Crosswalk Warning could include.
7.5.3.4 **Queue Warning**

The queue warning application (Q-WARN) utilizes V2I communications to enable equipped vehicles to receive information regarding a queued condition. An infrastructure-based detection system detects a vehicle queue and provides the information to the adjacent RSU. The RSU then broadcast queue information to equipped vehicles. The application on-board the equipped vehicle determines, based on location, speed and heading, whether to provide a warning to the driver of an immediate queue event. **Figure 7-5** illustrates what the basic functionality system architecture for Queue Warning could include.

![Figure 7-5. Queue Warning (Q-WARN) Architecture](image-url)
7.5.3.5 **Railroad Crossing Warning**

The Railroad Crossing Warning application is suited for at grade railroad crossings. Both passive and active railroad warning systems are supported by this application. Railroad wayside equipment notifies a nearby RSU of an approaching train or additional detection equipment is used to determine an approaching train. The RSU then broadcasts a traveler information message indicating the presence of a train at the nearby crossing. The equipped vehicle determines, based on location, heading and speed, whether a warning message is sent to the driver. **Figure 7-6** illustrates the basic functionality system architecture for Railroad Crossing Warning.

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**Figure 7-6: Railroad Crossing Warning Architecture**
7.5.3.6 **Ramp Wrong Way Warning**
For the Ramp Wrong Way Application, an RSU near the interchange, through secondary sensing equipment, will broadcast MAP and TIM information to an equipped vehicle when a wrong way vehicle is detected entering the highway. The equipped vehicle will then use its location and direction of travel to determine if a warning message to the driver is required, warning of a wrong-way vehicle. Figure 7-7 illustrates the basic functionality system architecture for Ramp Wrong Way Warning.

![Figure 7-7. Ramp Wrong Way Warning Architecture](image-url)
7.5.3.7 **Reduced Speed Zone Warning / Lane Closure**

The Reduced Speed Zone Warning / Lane Closure application provides equipped vehicles information about approaching zones with speed limits less than the posted speed limit and/or if the roadway configuration is altered, or if there are maintenance vehicles and personnel located at the roadside. Reduced speed zones encompass construction zones, maintenance work, or other low speed zones. Lane closures encompass lane shifts and lane closures due to construction or incidents. Information regarding the revised speed limit along and/or changed roadway configuration information is generated on the infrastructure side, and then communicated to equipped vehicles. The equipped vehicles will determine whether to provide an alert or warning to the driver. **Figure 7-8** illustrates the basic functionality system architecture for Reduced Speed Zone Warning / Lane Closure could include.

![Figure 7-8. Reduced Speed Zone Warning / Lane Closure Architecture](image-url)
7.5.3.8 **Spot Weather Impact Warning**

The Spot Weather Impact Warning alerts drivers of unsafe weather conditions at specific points on the roadway, which include, but are not limited to, high winds, flood conditions, ice, precipitation, or fog. Standalone weather systems are used to warn drivers about inclement weather. Real-time weather information is collected from fixed environmental sensors and vehicle-based probe data. The information is processed at the roadside to determine the nature of the alert or warning to be delivered and then communicated to equipped vehicles. In addition, the RSU may calculate the appropriate speed for the current weather condition and provide this information. **Figure 7-9** illustrates the basic functionality system architecture for Spot Weather Impact Warning.

The National Weather Service (NWS) is an organization under the National Oceanic and Atmospheric Administration (NOAA). The mission of the NWS is to provide weather-related data, forecasts, and warning for the protection of life and property. Each NWS Weather Forecast Office (WFO) is responsible for issuing 10-day weather forecasts for their assigned County Warning Area (CWA) as well as issuing watches, warnings, and advisories for hazardous weather, along with many other tasks related to their mission. This system is located wholly within the Wilmington, OH WFO. Warnings and other data feeds generated by the NWS will be tied to the US-33 SMC system and reported through this application.

**Figure 7-9. Spot Weather Impact Warning Architecture**
7.6 OBU Equipped Vehicle Fleet
As part of the project deployment and key element of the connected vehicle environment, as many as 600 vehicles will be outfitted with DSRC-based OBUs. Candidate vehicles are public agency vehicles from various COG members and agency partners, including the City of Marysville, the City of Dublin, ODOT, Union County, Union County Sheriff’s Office (SO), and Honda. This vehicle fleet represents various vehicle types, consisting of passenger cars, first responder, public service, and other heavy vehicles to be fitted with aftermarket OBUs. Honda has committed to providing up to 200 equipped vehicles. The OBUs will include the necessary applications identified for this project and will provide warning messages to drivers. The number of candidate and types of vehicles that have been made available for this deployment are shown in Table 7-5. The candidate vehicles will be further evaluated and refined to determine their appropriateness and eligibility as part of the deployment.

Table 7-5. OBU Equipped Vehicle Fleet

<table>
<thead>
<tr>
<th>Owner</th>
<th>Passenger Car</th>
<th>Heavy Vehicle</th>
<th>First Responder</th>
<th>Transit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Dublin</td>
<td>125</td>
<td>30</td>
<td>73</td>
<td>4</td>
<td>232</td>
</tr>
<tr>
<td>City of Marysville</td>
<td>72</td>
<td>10</td>
<td>41</td>
<td>52</td>
<td>175</td>
</tr>
<tr>
<td>ODOT</td>
<td>18</td>
<td>21</td>
<td>--</td>
<td>--</td>
<td>39</td>
</tr>
<tr>
<td>Union County</td>
<td>37</td>
<td>29</td>
<td>--</td>
<td>--</td>
<td>66</td>
</tr>
<tr>
<td>Union County SO</td>
<td>--</td>
<td>--</td>
<td>23</td>
<td>--</td>
<td>23</td>
</tr>
<tr>
<td>Honda</td>
<td>200</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>256</strong></td>
<td><strong>61</strong></td>
<td><strong>118</strong></td>
<td><strong>54</strong></td>
<td><strong>735</strong></td>
</tr>
</tbody>
</table>

In addition to the fleet identified in Table 7-5, the project can benefit from other equipped vehicles that will be deployed as part of Central Ohio’s connected vehicle ecosystem. Smart Columbus will be deploying nearly 1,800 vehicles and ODOT has plans for as many as 400 private vehicles in and around Marysville as part of a research project relating to connected vehicles. Inclusion of multiple vehicle types will allow for more participation by other interested parties and will provide the USDOT with performance data across the vehicle spectrum.

Additional equipped vehicles offer the benefit of providing additional data in the form of Basic Safety Messages which would include data elements such as vehicle size, speed, location, heading, and transmission condition. OBUs should include event logging capabilities so that information can be gathered about when driver warning events occur, which will help identify safety issues in the transportation network.

7.7 Connected Vehicle Environment (SMART) Network
The project will include a network that has capabilities for data management, data warehousing, and data analytics. There are three key subsystems that are part of the network: (1) Infrastructure Management System, (2) Data Warehousing System, and (3) Security Credential Management System. The location of these systems, whether virtual or housed at locations such as the Dublin Metro Data Center or the Smart Columbus Data Exchange, has yet to be determined. The system should consider how to handle diagnostics. The network should also accommodate the ability to provide updates to software, firmware
and security credentials. It has been noted that the stakeholders desire the ability to store data to use the data for future needs, purposes or applications. There is also a desire to share data with other agencies, universities, research centers, auto manufacturers and technology companies should be considered. To this end, system management such as network modifications should be configured such that specialized access is required.

The basic architecture elements of the connected vehicle environment network are illustrated in the following figures.
Figure 7-11. Data Warehousing

Figure 7-12. Security Credential Management System
7.8 ITS INFRASTRUCTURE

The supporting ITS infrastructure, including CCTV cameras with analytics, vehicle and pedestrian detection systems, road weather information systems and other ITS devices will be required to supplement the connected vehicle environment. Some of the applications (notably spot weather impact warning, queue warning, and ramp wrong-way warning) require additional roadside infrastructure to support the development of messages to be broadcast via RSUs to equipped vehicles. The specific technology to deploy will be determined through the detailed design of the systems engineering process.

7.9 FIBER CONNECTION TO THE DUBLIN METRO DATA CENTER AND TRC

A fiber optic backbone has been constructed along US-33 and will connect from the Dublin Metro Data Center to the TRC near East Liberty. The termination point is at the ODOT Telecom Building located at TRC. The fiber optic installation along US-33 provides the opportunity to connect the RSU infrastructure to the points such as the Dublin Metro Data Center, Honda Data Center, the Smart Columbus Data Exchange and various traffic management centers. All RSUs deployed as part of this project are intended to have the capability of transmitting and receiving communications via the fiber network.

The implementation of fiber optic communications will provide low latency network communications to support safety applications, data transmission, and remote system management. The fiber installation also provides for the ability to scale the system to include additional applications.

7.10 APPLICATION DEPLOYMENT LOCATIONS

As part of the ConOps Workshop, stakeholder input was gathered to determine the specific locations for each application to be deployed. Locations were identified based on stakeholder experience, traffic congestion hot spots and crash cluster locations.

Appendix E. Recommended Application Deployment Locations illustrates the entire project limits and the proposed specific applications by location identified during the workshop and further developed by the program management team. Specific details of each application and the locations for the deployments are documented in the following sections. The entity that will be deploying the application is also noted.

7.10.1 Curve Speed Warning

The crash investigation in Section 4.2.4 Crash Data revealed that a significant portion of crashes are ramp-related. Of the 1,550 total crashes in the study area, 404 (26%) rear-end crashes were attributed to the presence of a ramp, reduced headway between vehicles, and speeding. The major interchanges of concern with US-33 are located at:

- I-270
- US-36 (western interchange)
- SR 4 (eastern interchange)
- SR 31

The project will deploy the Curve Speed application to reduce speed-related crashes on loop ramps at the following locations:

- SR 347 East Liberty
The geographic location of the Curve Speed Warning deployment, along with associated RSUs, are shown in the following figures.
Systems Engineering Analysis

Concept of Operations

US-33 & US-36 (Western Interchange)

US-33 & SR 31

RSU #21

RSU #22

RSU #27

Curve Speed Warning (w/weather)
7.10.2 Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning)

The Cities of Marysville and Dublin are both urbanized areas with sizeable traffic signal networks. Both areas experience crashes near and within the signalized intersections. The City of Dublin has higher traffic AADT volumes through the local transportation network. Marysville has a tight, signalized grid network in the downtown area, with closely spaced signals. Intersection safety is a major concern of both areas and V2I applications offer solutions to help improve safety.

The Intersection Safety Warning and Collision Avoidance application will specifically utilize the Red-Light Violation Warning feature to warn drivers that they are at risk of driving through an intersection on red signal indication. The Intersection Safety Warning and Collision Avoidance application will be deployed at all signalized intersections in Marysville and at 10 signalized intersections in Dublin. While not all signals in Dublin will have this application initially, this application can be deployed at more signals during future expansions. Also, the grant application specified 5 signalized intersections in Dublin. After evaluating the goals and the identified use cases, the 5 additional intersections are needed to provide the potential for more saturation of Dublin vehicles within the system and provide a logical terminus for the RSU network along US-33. The deployment intersections are listed as follows:

- **City of Dublin**
  - Avery Rd & Shier-Rings Rd
  - Avery-Muirfield Dr & Perimeter Dr
  - Avery-Muirfield Dr & Perimeter Loop Rd / Hospital Dr
  - Avery-Muirfield Dr & US 33 EB Ramp

- **Avery-Muirfield Dr & US 33 WB Ramp**
- **US-33/SR 161 & I-270 NB Off Ramp**
- **US 33/SR 161 & Post Rd/Frantz Rd**
- **Bridge St (US-33/SR 161) & Corbins Mill Dr/Shawan Falls Dr**
- Bridge St (US-33/SR 161) & High School Rd
- Bridge St (US-33/SR 161) & High St

City of Marysville
- Maple St & Amrine Mill Rd
c- SR 31 & Mill Rd / Echo Dr
c- SR 31 & Mill Wood Blvd
c- SR 31 & Creekview Dr
c- SR 4 & County Home Rd
c- US 36 & Watkins Rd / Square Dr
c- US 36 & US 33 WB Ramps C/D
c- US 36 & US 33 EB Ramps A/B
c- Delaware Ave & Coleman’s Crossing
c- Delaware Ave & Frontage / Charles
c- Delaware Ave / 5th St & Columbus Ave / N Cherry St
c- 5th St & Walnut St
c- 5th St & Plum St

These signals are also shown in the following figures.

Dublin (Avery-Muirfield Dr)
Marysville (North of US-33)

Marysville (South of US-33)
7.10.3 Pedestrian in Crosswalk Warning

The Cities of Dublin and Marysville both experienced pedestrian crashes from 2015-2017, 12 in total. Both cities use crosswalks with pedestrian actuated beacons and typical signalized intersection pedestrian crossings where there are many walking destinations for pedestrians. Since both cities have the capacity to generate many pedestrian trips and have experienced pedestrian crashes, stakeholders are seeking ways to improve safety and mobility for pedestrians.

The Pedestrian in Crosswalk application will alert drivers approaching the crosswalks of pedestrians using the crosswalk and reduce pedestrian crashes, particularly benefiting pedestrian crashes that occur with turning vehicles. The application will be deployed at the following intersections:

- City of Marysville
  - Collins Avenue & Hickory Drive (pedestrian actuated beacon)
  - Pedestrian crossing 100-ft south of S Main Street & 6th Street (pedestrian actuated beacon)
  - E 5th Street & Vine Street (pedestrian actuated beacon)
- City of Dublin
  - US-33 Bridge Street & High Street
  - US-33 & Post Road/Frantz Road
  - US-33 Bridge Street & High School Road
  - US-33 Bridge Street & Corbins Mill Drive/Shawan Falls Drive
  - US-33 Bridge Street & Darby Street (pedestrian actuated beacon)
  - High Street & North Street (pedestrian actuated beacon)

Pedestrian in Crosswalk application deployments are also shown in the following figures. DriveOhio is also deploying pedestrian warning applications within the corridor, at seven intersections within the City of Marysville.
Systems Engineering Analysis
Concept of Operations

City of Marysville (North)

Pedestrian Warning with Analytics

Google Earth

City of Marysville (West)

Pedestrian Warning (Midblock Xing)

Google Earth
7.10.4 Queue Warning

Heavy congestion is present on US-33 at various locations between Marysville and Dublin. This congestion has created safety concerns both near ramps that have backed up and on mainline US-33. The Queue Warning application offers a substantial benefit to drivers by warning them of slow or stopped traffic in advance of the queue or slowed traffic. This application is intended to be deployed at congested ramps on US-33 near Marysville and Dublin that experience heavy peak hour congestion.

The anticipated Queue Warning application deployment locations are shown in the following figures.
US-33 & SR 165 Honda Parkway

US-33 & SR 36
Systems Engineering Analysis
Concept of Operations
7.10.5 Railroad Crossing Warning

While there have not been documented crashes located at railroad crossings in the project area, stakeholders have expressed interest in adding this functionality as a proactive safety measure as railroad crashes can be catastrophic. Any additional safety measures are beneficial to drivers and railroad companies. This application is intended to supplement existing warning devices and be deployed at all crossings (four locations) in Marysville and (two locations) in Dublin.

Anticipated Railroad Crossing Warning application deployment locations are shown in the following figures. These deployments will include RSU placements at each location.
7.10.6 Ramp Wrong Way Warning

Wrong way entries to ramps can lead to crashes of high severity. Although there does not appear to be many documented crashes involving wrong way entries onto US-33, stakeholders have expressed interest in adding this functionality to the 33 SMC as a proactive safety measure. The concentration of partial cloverleaf interchanges throughout the corridor have the potential to create a wrong-way driver situation. This application is intended to be deployed at various locations for US-33 where crossroad ramp access is adjacent to ramp egress (i.e. the off ramp and on ramp are at the same intersection with the crossroad).

The anticipated Ramp Wrong Way Warning application deployment locations are shown in the following figures.
7.10.7 Reduced Speed Zone Warning / Lane Closure

The Reduced Speed Zone Warning / Lane Closure application can be used to warn drivers of reduced speed location, lane closure as it relates to work zones, or maintenance personnel/vehicles on the roadside. The primary benefit of applying this application is to provide warning to drivers of changes in lane configuration or resulting slowed traffic. This warning of hazards is beneficial to both drivers and road workers. While there does not appear to be a documented crash history with respect to construction work zones, it has real safety benefits and is highly desired by stakeholders, ultimately being beneficial to improve road worker safety.

It will help to reduce crashes by providing a timely warning to the driver about the impending reduced speed zone, lane closure, or roadside workers. Identifying an incident as a reduced speed zone or lane closure will also help to make the drivers in the crash and first responders safer by reducing speed through the zone. The Reduced Speed Zone Warning / Lane Closure application will be deployed throughout the entire US-33 project corridor since continuous RSU coverage can provide the flexibility for many different maintenance or work zone scenarios.

The Reduced Speed Zone Warning / Lane Closure application is programmed for each construction work zone; therefore, this application is not necessarily tied to one geographic location. The application does have use cases for static locations, such as school zones or other areas that consistently utilize reduced speed zones. Therefore, the application should have flexibility to be programmed for varying speeds, lane configuration, and geographic limits.
7.10.8  Spot Weather Impact Warning

Weather-related information is very beneficial to drivers. There are a few locations, such as US-33 near Marysville and US-33 between Post Road and I-270 near Dublin, that experience a higher density of weather-related crashes that would benefit from this application. Weather-related information in general is beneficial to all drivers. Leveraging both existing RWIS infrastructure and installing new infrastructure, this application can be implemented to provide precise information on weather hazards. Hazardous weather or road conditions are broadcasted to equipped vehicles within the immediate adjacent location where the weather information is gathered, and the hazard is identified, so that the driver can take immediate action to avoid the hazardous condition.

Real-time weather information is collected from RWIS weather stations, processed, and warnings broadcasted to connected vehicles as needed. Weather stations where RWIS sensors will collect weather data, both existing and proposed, are shown in the following figures.
8 OPERATIONAL SCENARIOS

This section is intended to provide an overview of the major operational uses for the proposed system. The system is described under various operating conditions relative to the core users and stakeholders. These scenarios are arranged by use-case and described from the perspective of each user class in varying degrees of system conditions; from normal, to stress, and failure. This section describes the application use-cases, functionality and operational scenarios as identified during stakeholder engagement as part of the ConOps Workshops.

While many scenarios are anticipated, typical and critical scenarios that will be encountered are documented. The following use-cases have been addressed:

- Vehicle Approaching Sharp Horizontal Curve
  - Curve Speed Warning
- Collision Avoidance at Signalized Intersections
  - Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning)
- Pedestrians Crossings
  - Pedestrian in Crosswalk Warning
- Peak Hour Queue Backups
  - Queue Warning
- Train Approaching Railroad Crossings
  - Railroad Crossing Warning
- Wrong Way Entry
  - Ramp Wrong Way Warning
- Road Construction and Lane Closures
  - Reduced Speed Zone Warning / Lane Closure
- Inclement and Hazardous Weather
  - Spot Weather Impact Warning

For each of the use cases identified, the basic functionality of each application as per the functionality documented in Section 7 was assumed to be part of each application. Each use-case will include multiple scenarios, each with a unique number and name for consistency and presentation, definition of the use-case goal, actors (users), and operation under typical, stress, and failure conditions. These use cases and scenarios only apply to connected vehicles which have an OBU.

8.1 USE CASE 1: CURVE SPEED WARNING ON RAMPS

The Curve Speed Warning application will be used in one case at several locations on US-33 throughout the length of the system boundaries. This application will warn drivers of equipped vehicles of approaching horizontal curves and provide a recommended speed for the curve. The application will use planned RSU installations near US-33 off ramps with sharp horizontal curves and low recommended speeds. The anticipated location of this application is predominately loop off ramps on US-33. The RSU adjacent to each curve will broadcast the traveler information message continuously.
8.1.1 Scenario 1: Vehicle Approaching Sharp Horizontal Ramp Curve
1. RSU near designated ramp continuously broadcasts location of horizontal curve and recommended speed
2. Vehicle equipped with OBU travelling on ramp receives RSU broadcast of curve location and recommended speed
3. Equipped vehicle uses positional, speed, directional, and vehicle dynamics data and curve data broadcast by the RSU to determine if warning is applicable
4. Equipped vehicle displays warning if vehicle is travelling over recommended curve speed
5. Warning is continuously displayed while the equipped vehicle traverses the horizontal curve at a speed higher than the recommended curve speed.
6. Warning is terminated as vehicle exits the horizontal curve, or if the vehicle slows to a speed less than the recommended curve speed.

8.1.2 Potential Additional Functionality – Curve Speed Warning
Through the ConOps process, alternative and additional functionality requirements were identified for the Curve Speed Warning application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-1 shows potential additional functionality of the Curve Speed Warning application.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add weather component – possibly at certain locations</td>
<td>This functionality adds in local RWIS information, such as fog, rain, snow, ice,</td>
<td>Implement at Critical</td>
</tr>
<tr>
<td>where weather is a concern</td>
<td>and additional data input to an edge or backend processor which will modified the</td>
<td>Locations</td>
</tr>
<tr>
<td></td>
<td>recommended speed information being broadcast by the RSU based on the prevailing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>conditions.</td>
<td></td>
</tr>
<tr>
<td>Lane by lane for speed assignment</td>
<td>This functionality would require multilane curves/ramps. There is not a significant</td>
<td>Do Not implement</td>
</tr>
<tr>
<td></td>
<td>amount of these sites/use cases.</td>
<td></td>
</tr>
<tr>
<td>OBU has the required application to make it work</td>
<td>All OBUs deployed on the project will include the appropriate applications.</td>
<td>Implement</td>
</tr>
</tbody>
</table>

8.2 Use Case 2: Collision Avoidance at Signalized Intersections
The Intersection Safety Warning and Collision Avoidance application will be used at signalized intersections equipped with RSUs. RSUs at signalized intersections will continuously broadcast Signal Phasing and Timing (SPaT), MAP, and GPS Correction data following the SAE J2735 standard. Equipped vehicles will use the SPaT message, along with their location, speed, and direction to determine if they will pass through the intersection without violating the red signal.

While the vehicle is approaching the intersection, the OBU will determine if it will likely pass through the intersection safely or not and provide a warning message to the driver if not. The warning will terminate
after the driver has safely come to a stop or has proceeded through the intersection. Where the equipped vehicle will pass through the intersection safely, no warning is displayed to the driver.

8.2.1 Scenario 1: Vehicle Will Not Pass Through Signalized Intersection Safely
1. Signal RSU continuously broadcasts SPaT, MAP, and GPS Correction
2. Equipped vehicle approaching intersection receives broadcast from RSU
3. OBU uses SPaT, MAP, and GPS Correction, along with speed, acceleration profile, location, and direction to determine if it will enter the intersection during a red signal indication
4. If the equipped vehicle determines it will enter the intersection, a warning is generated in the vehicle.
5. The driver of the equipped vehicle should immediately initiatives braking.
6. After the vehicle has fully stopped, the warning message is terminated

8.2.2 Potential Additional Functionality – Intersection Safety Warning and Collision Avoidance

Through the ConOps process, alternative and additional functionality requirements were identified for the Intersection Safety Warning and Collision Avoidance application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-4 shows additional functionality for the Intersection Safety Warning and Collision Avoidance application.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning to other vehicles that there is a potential red-light violation warning</td>
<td>The base application is an alert that is to be provided for a pending red light violation or collision. The timeliness of this message is important to the offending driver is important. The requirement to warn other drivers would make it significantly more complex and possibly create liability challenges for unsuspecting drivers.</td>
<td>Do Not Implement</td>
</tr>
<tr>
<td>Make sure all OBUs include RLVW capability/application</td>
<td>This is a basic functionality of most OBU manufacturers and will be a requirement of the selected vendor/product.</td>
<td>Implement</td>
</tr>
<tr>
<td>Dynamic signal phasing and timing</td>
<td>This is a form of multimodal intelligent traffic signal system (MMITS) that have been piloted/implemented in Anthem, AZ and Salt Lake City, UT. These systems require a significant amount of software development and have been very costly to implement.</td>
<td>Do Not Implement</td>
</tr>
<tr>
<td>Audible warning to pedestrians of a red-light violator.</td>
<td>The base application is an alert that is to be provided for a pending red light violation or collision. The timeliness of this message is important to the offending driver is important. The requirement to warn other, such as pedestrians could have implications, such as determined direction of travel, location of the pedestrian in relation to the violator and how they would be warned. This functionality likely requires a significant amount of detailed systems engineering.</td>
<td>Do Not Implement</td>
</tr>
</tbody>
</table>
8.3 Use Case 3: Pedestrian Crossings

The Pedestrian in Crosswalk Warning will be deployed in three distinct scenarios: 1) at signalized mid-block pedestrian crosswalks, 2) unsignalized intersections, and 3) at signalized intersections. In the basic functionality, the application uses pedestrian actuation to determine the presence of pedestrians at the crossings.

At signalized pedestrian crossings, when actuated by a pedestrian pushbutton, a traveler information message will be broadcasted to equipped vehicles immediately after actuation. At signalized intersections, the pedestrian actuation will be broadcast through the SPaT messaging during the appropriate signal phase, as this is when pedestrians will be crossing. The OBU application at signalized intersections must also consider the direction of location and heading.

8.3.1 Scenario 1: Pedestrian Enters a Pedestrian Actuated Beacon Crossing
1. Pedestrian approaches the crosswalk and actuates the pedestrian signal
2. RSU receives the pedestrian actuation information
3. RSU broadcasts presence of pedestrian in crosswalk during the crossing interval
4. OBU receives pedestrian in crosswalk broadcast
5. OBU uses location and direction to determine if broadcast message is applicable
6. OBU displays pedestrian in crosswalk warning to driver
7. Driver reduces speed and stops to allow safe passage for pedestrian
8. Driver continues after pedestrian(s) have cleared the roadway
9. Pedestrian in crosswalk broadcast terminated after pedestrian signal interval terminates

8.3.2 Scenario 2: Pedestrian Enters Crosswalk at Signalized Intersection
1. Pedestrian approaches the signalized intersection and actuates the pedestrian push button for the desired direction of travel
2. The signal controller receives the actuation
3. The signal controller converts NTCIP 1202 protocol to SAE J2735, sends updated SPaT message to RSU
4. RSU receives SPaT and MAP information
5. RSU broadcasts SPaT message which contains status of pedestrian in crosswalk for duration of pedestrian interval
6. OBU on equipped vehicle near intersection receives broadcast from RSU of pedestrian in crosswalk
7. OBU uses location and direction to determine if broadcast applies to equipped vehicle (i.e. crosswalk is downstream of equipped vehicle)
8. OBU displays pedestrian in crosswalk warning to driver
9. Driver is alert for pedestrians in the roadway when turning right or left
10. Driver continues after pedestrian(s) have cleared the roadway
11. Pedestrian in crosswalk warning terminates after driver has cleared intersection or signal phase terminates

8.3.3 Potential Additional Functionality – Pedestrian in Crosswalk Warning
Through the ConOps process, alternative and additional functionality requirements were identified for the Pedestrian in Crosswalk Warning application. The functionality requirements have been reviewed and
evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-3 shows potential additional functionality of the Pedestrian in Crosswalk application.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection zone could be about half a block</td>
<td>This functionality will require implementing camera detection and analytics along the curblines and providing backend or edge processing to determine and predict pedestrian trajectories along the entire curbline. See alternative solution BELOW.</td>
<td>Do Not Implement</td>
</tr>
<tr>
<td>Implement V2X Smart Intersection solution</td>
<td>This is the Honda Smart Intersection solution that has been piloted at the intersection of Main Street and 5th Street in Marysville. The essence of this functionality is to use cameras/analytics to detect pedestrians, bicycles, other vehicles within its wide-angle field of view. The RSU system then emulates an OBU and broadcasts a BSM similar to an OBU, detailing location, speed, and trajectory. The receiving equipped vehicle then determines the position of the threat and reacts accordingly.</td>
<td>Implement in Limited Key Locations and combine with detection zones</td>
</tr>
<tr>
<td>Want the processing to occur within the cabinet</td>
<td>This functionality can occur as long as the controllers are upgrade to specific makes, models and firmware versions that allow for SPaT output.</td>
<td>Implement</td>
</tr>
<tr>
<td>Non-signalized crossings</td>
<td>This functionality could be implemented similar to the V2X Smart Intersection but requires specifically identified locations for consideration.</td>
<td>Do Not Implement</td>
</tr>
</tbody>
</table>

8.4 USE CASE 4: PEAK HOUR QUEUE BACKUPS
The 33 SMC system will use the Queue Warning application in one scenario during traffic backups at designated locations in the system boundaries. This application will use vehicle detection to determine the location of a traffic queue. The infrastructure will determine if traffic is queued and where it is located through backend or edge processing. A traveler information message will then be broadcast by the adjacent RSU to equipped vehicles. The queue warning is intended to alert drivers to an immediate need to brake for a queue event.

The queue warning is anticipated to be deployed at several locations near US-33 off ramps. The vehicle detection will be located on the off ramp near the diverge area. As traffic begins to queue near the diverge area and is detected by the detection equipment, the infrastructure will determine the message to be provided. The RSU will broadcast information about the situation developing. The application within the OBU will determine if a warning is provided to the driver.

While this application is anticipated to be activated mostly during peak hour periods, it will run continuously in the event that a significant queue develops during off peak periods. While off peak queues may develop for various reasons (traffic incidents, events, etc.), the general operation of this application remains the same.
8.4.1 Scenario 1: Queue Forming on a Ramp
1. Queue on US-33 ramp begins to develop during peak hour periods
2. Queue length increases until vehicles are within the diverge area and are detected by vehicle detection equipment
3. The Infrastructure processes the information, generating the appropriate warning and indicates to the nearby RSU that sustained vehicle queue has developed
4. RSU continuously broadcasts queued vehicle status to upstream equipped vehicles
5. Approaching equipped vehicles receive broadcast from RSU
6. OBU uses location, speed, and direction to confirm intended message
7. OBU continuously displays Queue Warning message to driver
8. As the equipped vehicle progresses past the queue or slows to a speed below 10 MPH, the Queue Warning is terminated
9. RSU terminates broadcast once queue dissipates below queue threshold

8.4.2 Scenario 2: Queued Traffic on US 33 Mainline
This application use case is not being considered as part of the current project but is a future enhancement opportunity. This application will function differently since it does not rely on specific location detection of traffic queues. The application will either function as a V2V application or V2I application in which queued equipped vehicles broadcast information on position and direction when stopped or slowed below a certain threshold. This application’s reliance on significant connected vehicle penetration to ensure V2V communications is the primary reason that it is not included in this initial deployment.

8.4.3 Potential Additional Functionality for Queue Warning
Through the ConOps process, alternative and additional functionality requirements were identified for the Queue Warning application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-4 shows potential additional functionality for Queue Warning.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast to DMS signs for other locations (possibly test with portable DMS)</td>
<td>Can be implemented to accommodate messaging to non-equipped vehicles via ODOT TMC using backhaul fiber. Would require manual deployment of messages by ODOT TMC personnel. However, existing DMS locations are not in strategic locations, limiting effectiveness of this functionality.</td>
<td>Implement under a test case using portable DMS signs strategically placed for proper messaging – under a Phase 2 deployment</td>
</tr>
<tr>
<td>Queue by lane</td>
<td>Could help provide immediate warnings of queues to unsuspecting drivers at multilane off ramps. Likely difficult to implement and provide timely messaging by lane if the ramp widens from a single lane to multiple lanes. This could be best to implement on a mainline situation.</td>
<td>Do Not Implement</td>
</tr>
<tr>
<td>Provide queue information prior to alternative route</td>
<td>This requires that RSU messages are broadcast along appropriate locations. This would require programing of the messaging to be sent to a preselected range of RSUs.</td>
<td>Investigate implementation during detailed engineering</td>
</tr>
</tbody>
</table>
V2V communication/data flow | This application will function differently since it does not rely on specific location detection of traffic queues. The application will either function as a V2V application or V2I application in which queued equipped vehicles broadcast information on position, direction when stopped or slowed below a certain threshold. This application’s reliance on significant CV penetration to ensure V2V communications is the primary reason that it is not included in this initial deployment. | Do Not Implement – Consider as part of a future enhancement

8.5 USE CASE 5: AT GRADE RAILROAD CROSSINGS

Rail crossings will be equipped with RSUs and be integrated with railroad communications equipment. Where a train is approaching the grade crossing, a warning message will be provided to drivers of the approaching train, in supplement to existing infrastructure warning systems. Marysville features both passive and active railroad warning systems. Generally, active systems are deployed in more urbanized areas with passive systems utilized in less dense, lower traffic volume applications. Both passive and active railroad warning systems are supported by this application. Warning systems are activated on notification of an approaching train through interfaced railroad wayside equipment.

8.5.1 Scenario 1: Train Approaching At-Grade Crossing

1. A train approaching the grade crossing will activate the warning device (at some predetermined time interval)
2. Once activated, the railroad wayside equipment will activate the railroad grade crossing signal
3. The signal will be received by a processing unit, which will generate an information message
4. The information message will be transmitted to the RSU
5. The RSU will continuously broadcast the presence of the train for the duration of the crossing
6. Approaching vehicles equipped with OBUs will use positional and direction information along with the message generated by the RSU to determine if the equipped vehicle is approaching the grade crossing with a warning system activated.
7. A railroad crossing warning message will be displayed to the driver
8. Once the train has cleared and the infrastructure warning system terminates its warning, the RSU will terminate the message.

8.5.2 Potential Additional Functionality – Railroad Crossing Warning

Through the ConOps process, alternative and additional functionality requirements were identified for the Railroad Crossing Warning application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-5 shows potential additional functionality of the Railroad Crossing Warning application.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use detection – TrainFo</td>
<td>This functionality would use a third part cloud-based solution to help understand when and how long railroad crossings are</td>
<td>Consider Implementation as</td>
</tr>
</tbody>
</table>
8.6 USE CASE 6: WRONG WAY VEHICLE ENTRY ON FREEWAY

Ramp Wrong Way Warning will be deployed for wrong way ramp entries on US-33 at identified locations. Detection equipment will be used to monitor for wrong-way vehicles entering exit ramps. When there is a wrong way entry, a message will be transmitted to equipped vehicles upstream of the ramp, to alert other drivers of a potential wrong way vehicle. Upon receiving a notification of the activation of a wrong way entry, the TMC operator will deploy local authorities to the scene.

8.6.1 Scenario 1: Vehicle Enters Freeway in the Wrong Direction
1. Vehicle enters exit only ramp
2. Detectors (loops, cameras...etc.) identify vehicle traveling in the wrong direction
3. Back-end or edge processors determine there is a wrong way vehicle
4. Infrastructure transmits message to RSU
5. Detectors transmit identification to RSU (failsafe step)
6. RSU broadcasts traveler information message on location of the hazard
7. Various equipped vehicles receive broadcast
8. OBU confirms location and direction of travel in relation to wrong way vehicle
9. OBU displays a warning regarding a wrong way driver hazard
10. OBU terminates wrong way warning once past the hazard

8.6.2 Potential Additional Functionality – Ramp Wrong Way Warning

Through the ConOps process, alternative and additional functionality requirements were identified for the Ramp Wrong Way Warning application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-6 shows potential additional functionality of the Ramp Wrong Way application.

Table 8-6. Potential Additional Ramp Wrong Way Warning Functionality

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Table 8-6. Potential Additional Ramp Wrong Way Warning Functionality
8.7 Use Case 7: Road Work and Planned Lane Closures

This application will alert drivers approaching construction work zones of changes in roadway configuration, work zone speed limits, lane shifts, or maintenance personnel/vehicles on the roadside. This application can have two different scenarios. The first scenario includes a stationary work zone that has a predetermined location, work zone length, lane configuration, and work zone speed. Stationary RSUs along US 33 will be required for Scenario 1. The second scenario includes a mobile operation, such as pavement marking painting, where the work zone is generally constantly moving along the roadway and applies to most maintenance work.

8.7.1 Stationary Work Zone/Lane Closure

This scenario is intended for typical work zones that are fixed in length, location, lane configuration, and work zone speed. Although construction phases may change, work zone configuration does not change day-to-day typically. The location of this work zone can be predetermined each time its implemented, by assigning the work zone information to be broadcast by the nearest RSU. This use case relies on continuous RSU coverage, so that the nearest available RSU can be programmed for the lane closure or speed reductions. Programming the RSU will be performed by a qualified technician at the beginning of work and at any phase changes. The RSU programming will also be field tested and verified before full deployment.

1. Nearest RSU is programmed for work zone, including work zone speed and lane configuration/lane shifts
2. RSU is tested and verified
3. RSU continuously broadcasts Reduced Speed Zone / Lane Closure equipped vehicles immediately upstream
4. OBU receives broadcast and uses location, speed, and direction to confirm work zone, lane shift or reduced speed hazard is ahead
5. OBU continuously displays Reduced Speed Zone / Lane Closure warning message to driver
6. Equipped vehicle driver reduces speed and progresses through the work zone

8.7.2 Mobile Work Zone/Closure
This application use case is not being considered as part of the current project but is a future enhancement opportunity. This application will function differently since it does not rely on roadside RSUs. Due to the mobile nature, this application works best as a V2V application with an OBU deployed on a construction vehicle and communicating to other equipped vehicles. The OBU must be programmed to continuously broadcast the location of the roadside maintenance/mobile work zone as work is being performed and not during general travel. The OBU will continuously broadcast to upstream equipped vehicles. Since this project is trying to best leverage infrastructure to improve safety and mobility, the application does not meet the goals of the project.

8.7.3 Potential Additional Functionality – Reduced Speed Zone / Lane Closure
Through the ConOps process, alternative and additional functionality requirements were identified for the Spot Weather Impact Warning application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-7 shows additional functionality for the Reduced Speed Zone / Lane Closure Warning application.

Table 8-7. Potential Additional Reduced Speed Zone / Lane Closure Warning Functionality

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers ahead/mowing ahead notifications</td>
<td>This functionality would be a mobile work zone application, which is not part of the goals of the grant.</td>
<td>Implement in a future phase</td>
</tr>
<tr>
<td>Planned work/closures – use the RSUs</td>
<td>This is considered basic functionality of Scenario 1.</td>
<td>Implement</td>
</tr>
<tr>
<td>Reduced speed zones on 33</td>
<td>This functionality could be included as a fixed roadside unit at each location of speed reduction. The RSU would transmit out the speed reduction and equipped vehicles would determine the relevance of the message via travel speed, location and direction. While this functionality is like Scenario 1, the application would need to be programmed differently.</td>
<td>Consider Implementation as Project Budget and Schedule Allow</td>
</tr>
<tr>
<td>Incident management</td>
<td>Implementation will require integration with ODOT’s OHGO system or manually entered location and lane information by traffic management operators</td>
<td>Consider implementation and feasible methods</td>
</tr>
</tbody>
</table>
8.8 Use Case 8: Inclement and Hazardous Weather

Real time weather information is collected via RWIS or via vehicle-based probe data. The information is processed to determine the nature of the alert or warning to be delivered and then communicated to connected vehicles. This application will alert drivers of unsafe road conditions of hazardous weather at specific points on the roadway. Road weather information systems (RWIS) along US-33 will collect real-time weather and road information and process this information to determine the nature of the alert to be provided to equipped vehicles. Road weather information warning information will be broadcasted when a hazardous condition is present. These warnings will include the following weather conditions:

- High winds
- Flooding
- Ice
- Fog
- Severe weather
- Precipitation (snow/rain/sleet/freezing rain)

8.8.1 Scenario 1: Inclement Weather or Poor Road Conditions

This scenario is intended to display a warning to drivers about inclement weather or unsafe road conditions within the immediate area.

1. RWIS monitors weather sensors and road conditions and processes information
2. RWIS determines that weather conditions are hazardous
3. Back-end or edge processor generates the alert message/location and send the message to the adjacent RSU
4. RSU continuously broadcasts weather hazard message to equipped vehicles
5. OBU receives recommended weather information broadcast
6. Based on vehicle heading and direction, equipped vehicle displays warning message of weather or road conditions for duration of warning range
7. Spot Weather Impact Warning is terminated when weather conditions improve

8.8.2 Potential Additional Functionality – Spot Weather Impact Warning

Through the ConOps process, alternative and additional functionality requirements were identified for the Spot Weather Impact Warning application. The functionality requirements have been reviewed and evaluated to determine their applicability to the project, along with a recommendation on which functionalities to include as part of the project. Implementation of additional functionality will require revisions to the architecture presented in Section 7. The architecture will be detailed out in the system requirements and system engineering analysis. Table 8-8 shows potential additional functionality for the Spot Weather Impact Warning application.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Notes/Justification</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast out to appropriate audience/driver in advance</td>
<td>This application is limited to spot locations and contingent on providing timely alerts of near-term conditions at critical locations.</td>
<td>Do Not Implement</td>
</tr>
</tbody>
</table>
9 OPERATIONAL AND SUPPORT ENVIRONMENT

This section serves to describe the environment that system will operate in. This section will identify the personnel and operational procedures required to operate, maintain, and update the system and individual components.

9.1 EQUIPMENT AND PERSONNEL

9.1.1 Facilities and Civil Infrastructure
It is not anticipated that new buildings will need constructed to support this system. While the details of the connected vehicle environment network requirements are ongoing, the final location of the system hub will require space to housing all servers, computers, work stations, and monitors necessary to remotely manage and monitor the 33 SMC system. Modification of existing facilities may be required to meet these criteria.

Roadside Units and edge computing locations will require mounting poles, foundations, power and communication infrastructure to tie into the fiber optic backbone. RWIS, detection systems and other ITS infrastructure will also be needed to support the application deployments.

9.1.2 Equipment & Computing Hardware
Roadside units will be needed along US-33 and at signalized intersections, railroad crossings, and pedestrian crossings in Marysville and Dublin. The RSUs will have the capability to transmit and receive communication to/from the data exchange using the planned fiber optic installation along US-33. RSUs deployed at signalized intersections may require additional equipment or different communication methods as they will not be connected directly to the fiber optic cable on US-33. The RSUs will report status information for system monitoring. The RSUs will support CV applications identified in this ConOps.

OBUs will be installed in as many as 600 vehicles, as identified in Table 7-5. Honda of America has partnered with the COG to provide 200 OBU equipped vehicles. These OBUs will support the applications identified above and adhere to applicable standards for DSRC communications.

Network servers (actual or cloud-based) are anticipated for data processing, storage, and analysis. Servers for this system will have the capacity to store data for all system equipment for a predetermined amount of time. Existing computer work stations will be used for system management and monitoring personnel to oversee the system.

Maintenance personnel will require access to a hydraulic crane (bucket truck) to perform maintenance on RSUs installed overhead.

9.1.3 Software
Software may be procured or developed for the 33 SMC for system management and monitoring. General functions of the software package, herein referred to as the 33 SMC System Management Software (SMS) include:

- System status output
- Individual component status output
• Event logging for equipment failure or malfunction
• Weather alert and advisory message generator
• System overview display map with RSU locations
• Vehicle speed and queue status display on mapping (by direction)
• Automated reporting on system usage and network performance metrics

Additional software may be required for data sharing with external stakeholders. The COG is currently having ongoing discussions about ownership and how data will be shared. If data is provided to external stakeholders, access to a central data sharing site will provide for a more efficient workflow. This data sharing site will need to be managed with security credentials to restrict access to trusted third parties.

The COG desires a testing environment where others can test and develop applications. This will likely require a software development kit that allows for the development and testing of new or improved V2I applications. This could provide the ability to be programmed and remotely uploaded to specific or all RSUs as needed to test the application.

9.1.4 Personnel
Monitoring and control of the system has yet to be defined and is currently part of ongoing discussion with the COG. Personnel will need to be assigned for system management and monitoring. Maintenance personnel will need to be identified to support the 33 SMC system. Several technicians will be needed for redundancy and availability. These personnel will be trained on the 33 SMC system, the software, hardware, troubleshooting, and installation. The RSU manufacturer will provide training on all applicable tasks to the designated maintenance personnel, as well as documentation.

9.1.5 Security Credential Management System
Any system which utilizes the internet and wireless communications is susceptible to malicious attacks, unauthorized access, damage, or disruptions that may interfere with system operation. While these are significant issues, proper planning and design will mitigate cybersecurity concerns. It is important to note that cybersecurity requires continual attention as threats tend to evolve.

In response the Intelligent Transportation Systems Join Program Office and National Highway Traffic Safety Administration has partnered with the automotive industry to develop a solution for the connected vehicle environment utilizing a Security Credential Management System (SCMS).

SCMS handles the communications or “handshake” between a vehicle OBU and an RSU. SCMS is a Public Key Infrastructure (PKI) system that employs encryption and certificate management to enable devices unknown to each other to each to trust communications received. Certificate Authorities (CAs) issue certificates to authorized devices when testing by the CA confirms that the device meets authorization and certification criteria. After these criteria are met, the CA issues a certificate for the device. Devices are also continually monitored for misbehavior, such that, if enough misbehavior reports are received by the SCMS, it will revoke a device from the environment. Once removed that device is no longer considered trusted for sending or receiving messages and authorized devices will not communicate with unauthorized devices.

The project will use the SCMS provided by DriveOhio for securing and security management of the 33 SMC system. Devices deployed will need certificates issued by the CAs to be considered for this system.
9.2 OPERATIONS AND SUPPORT

9.2.1 Operations
Ongoing discussions regarding the connected vehicle environment network and system ownership and maintenance responsibility have yet to determine how the system will be managed. Activities performed by operators include monitoring the 33 SMC system alerts, devices statuses, and device event logs. They will ensure the system is always fully functional and will direct maintenance personnel when devices malfunction or otherwise are working improperly to resolve any issues and bring the system back to working condition.

Operators are responsible for identifying and resolving issues with the 33 SMC management software or supporting network. Operators will be responsible for ensuring all device software is up-to-date by installing and downloading software updates.

9.2.2 Ownership
At the time of this initial publication, the ownership responsibilities of the system have not been completely defined. This section will be updated once determination is made.

9.2.3 Maintenance
The owner of the different component of the system will also be responsible for maintenance of the system. The owner will need to identify several maintenance team members to perform the maintenance work to provide for redundancy. Maintenance personnel will need trained on the system, communications, safety, troubleshooting, and how to properly replace malfunctioning equipment. This training will be provided by the equipment manufacturer. The maintenance personnel will also be provided training documentation and manuals provided in both paper and electronic versions.

Due to the mounting height of RSUs, maintenance personnel will need to be able to use a hydraulic crane (bucket truck) to access the RSUs. If not already trained, the maintenance personnel will need training, and qualification if necessary, to operate the hydraulic crane.

9.2.4 Administration
An informed and responsive administration is critical to the success of the 33 SMC system. The COG will be responsible for general oversight of the system and its performance. Monthly system status and performance metrics will be reviewed through an automated report generated monthly.

The 33 SMC will need to be integrated into yearly budgets of all members of the COG. Budgeting should include:

- Infrastructure upgrades and maintenance
- Staffing for the system management and maintenance
- Training maintenance personnel for components that are the COGs responsibility
- System network upgrade and maintenance
- IT support (both internal and from the manufacturer)

Since coordination with external partners for research, development, and testing is a goal of the 33 SMC, the COG will need to coordinate access to data sharing and access to the system. Access to the software development program will need to be provided to allow external partners the ability to develop and test
new CV applications. The appropriate processes need to be in place to ensure that applications are not utilized by the public until proven to operate according to USDOT and SAE standards.
10 Final System Recommendations

Since objectives of this system include the ability to scale and expand functionality, V2I applications were identified that can be implemented now and in the future. As such, V2I applications were prioritized based on stakeholder needs, with the most pressing issues being addressed first. While it is desirable to deploy as many applications as possible, this system must adhere to budgetary and schedule constraints to be feasible and practical. This also allows for funding to be spread over multiple fiscal years and reduce budgetary impacts to stakeholders. This section will detail CV applications for this current deployment and their justification, as well as identify applications for future deployments.

10.1 Overall System Estimate

An initial cost estimate was developed for the project applications and deployments based on the locations and desires of the stakeholders. The estimated cost of the remaining components of the system is indicated in Table 10-1. The total cost of the project and the budget for the project is indicated in Table 10-2. Details of the estimate are contained in Appendix F. Estimate of Probable Cost.

| Table 10-1. Overall System Estimate of Probably Cost |
|----------------------------------|------|
| Element                          | Subtotal |       |
| Roadside Unit Pilot              |       |       |
| On-Board Unit Deployment         |       |       |
| Roadside Unit Procurement - Traffic Signals |       |       |
| Roadside Unit Procurement - Highway |       |       |
| Infrastructure Procurement (RSU and RWIS) |       |       |
| Advanced Application Deployment  |       |       |
| Connected Vehicle Environment Network |       |       |
| TOTAL                            |       |       |

| Table 10-2. Total Project Cost Estimate vs Budget |
|----------------------------------|------|
| Element                          | Subtotal | Encumbered | Budget |
| Fiber                            |       |           |       |
| Infrastructure                   |       |           |       |
| Vehicle                          |       |           |       |
| Program Management               |       |           |       |
| TOTAL                            |       |           |       |
10.2 Refined Recommendations

The initial list of applications and system deployments require funding beyond the available funds. An analysis and prioritization exercise were conducted to economize the project deployment while still meeting the goals of the project. It was determined that the best route forward is to reduce the number of applications to be deployed under the grant funding.

The following is the list of applications to be deployed under the grant funds:

1. Curve Speed Warning
2. Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning)
3. Pedestrian in Crosswalk Warning (PCW), including a Smart Intersection Application deployment
4. Reduced Speed Zone Warning / Lane Closure

In partnership with DriveOhio, the following applications will be deployed by DriveOhio using separate funds, outside the grant:

1. Queue Warning (Q-WARN) at select locations
2. Ramp Wrong Way Warning at select locations

The following applications will be deployed when additional funding becomes available.

1. Queue Warning (Q-WARN) at select locations
2. Ramp Wrong Way Warning at select locations
3. Railroad Crossing Warning
4. Spot Weather Impact Warning

Any applications that are not deployed under the project funds will be considered for the planning and execution of the project to ensure that when they are deployed at a future date, they will be able to be seamlessly integrated into the 33 SMC system with little or no additional effort.

10.3 Refined System Estimate

A refined cost estimate was developed for the reduced list of project applications and deployments based on the prioritization exercise. The estimated cost of the remaining components of the system is indicated in Table 10-3. The total cost of the project and the budget for the project is indicated in Table 10-4. Details of the estimate are contained in Appendix F. Estimate of Probable Cost.
### Table 10-3. Refined System Estimate of Probably Cost

<table>
<thead>
<tr>
<th>Element</th>
<th>Subtotal</th>
</tr>
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<tbody>
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<tr>
<td>On-Board Unit Deployment</td>
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<tr>
<td>Roadside Unit Procurement - Traffic Signals</td>
<td></td>
</tr>
<tr>
<td>Roadside Unit Procurement - Highway</td>
<td></td>
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<tr>
<td>Infrastructure Procurement (RSU and RWIS)</td>
<td></td>
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<tr>
<td>Advanced Application Deployment</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
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### Table 10-4. Refined Project Cost Estimate vs Budget

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<th>Element</th>
<th>Subtotal</th>
<th>Encumbered</th>
<th>Budget</th>
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<tr>
<td>Fiber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Program Management</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
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TO BE UPDATED
APPENDIX C – 33 SMART MOBILITY CORRIDOR SYSTEM REQUIREMENTS SPECIFICATION
## Document Control Panel

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<td>5/2019</td>
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<tr>
<td>Jim Katsafanas</td>
<td>Michael Baker International</td>
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<td>Amber Reimnitz</td>
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<tr>
<td>Nick Hegemier</td>
<td>DriveOhio</td>
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<td>Mike Andrako</td>
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APPENDICES

APPENDIX A. DETAILED SYSTEM REQUIREMENTS
1 INTRODUCTION

This Systems Requirements Specification (SyRS) is intended to provide the requirements that drive the specification, design, development, implementation, integration and testing of the 33 Smart Mobility Corridor (33 SMC). The SyRS is a “black-box” description of what the 33 SMC must do, but not how it will do it. The document contains descriptions of inputs, outputs, and required relationships between inputs and outputs.

1.1 DOCUMENT PURPOSE

This System Requirement Specification (SyRS) serves as the second in a series of engineering documents intended to describe the 33 SMC, building upon the Concept of Operations (ConOps) Document. The SyRS describes a set of requirements that, when realized, will satisfy the expressed needs of the 33 SMC. This document includes the identification, organization and presentation of the requirements for the 33 SMC project, which is a system made up of Connected Vehicle (CV) infrastructure and applications. These requirements are derived from the user needs, constraints and interfaces that the 33 SMC is expected to implement, and the work within leverages prior system requirements efforts for related projects and applications. This SyRS addresses conditions for incorporating operational concepts, design constraints, and design configuration requirements as well as the necessary characteristics and qualities of individual requirements and the set of all requirements.

The SyRS is the second documented description of the system as an early stage of the systems engineering analysis (SEA), as shown in Figure 1-1. Systems Engineering is a required component for all ITS projects as per Code of Federal Regulations (CFR) 940.11. This SyRS is part of the Systems Engineering.
This document was developed based on IEEE 1233-1998 IEEE Guidance for Developing System Requirements Specifications and contains the following chapters:

1. Chapter 1. Introduction provides an overview of the 33 SMC project and key elements that guide the development of this SyRS document, including an overview of the project, the stakeholders, requirements development process, and referenced materials.

2. Chapter 2. System Description focuses on describing and extending the 33 SMC system concepts established in the Concept of Operations (ConOps), including system capabilities, conditions, constraints, and decomposing the system into its functional groups for establishing requirements.

3. Chapter 3. System Requirements contains the requirements for each functional group that make up the system.

4. Chapter 4. Engineering Principles provides a description of engineering principles applied to the system and requirements definition process

1.2 PROJECT SCOPE
In 2016, the U.S. Department of Transportation (USDOT) awarded approximately $6 Million to the NW 33 Innovation Corridor Council of Governments (COG) as an Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) program grant. With matching funds, the overall project includes over $13 Million of funds. With its funding the, COG intends to use innovative strategies to deploy, demonstrate, and evaluate advanced transportation technologies through the deployment of corridor-focused connected vehicle applications in a mixture of rural and suburban environments across

---

Source: [https://rosap.ntl.bts.gov/view/dot/34725](https://rosap.ntl.bts.gov/view/dot/34725)
multiple communities to improve access to large employment sites and economic development. The project owner is the NW 33 Innovation Corridor Council of Governments (COG), which includes the City of Dublin, City of Marysville, the Marysville-Union County Port Authority and Union County. . . . The project also includes a partnership with ODOT and DriveOhio.

The US-33 corridor is experiencing some of the fastest residential and business growth in the State of Ohio. The COG seeks to optimize the existing transportation network with the knowledge that building capacity is not a feasible means to an end. The project will be one of the first full-scale deployments of Connected Vehicle (CV) technologies in the State of Ohio.

With the award, the COG established a strategic 33 SMC vision and mission:

- **33 SMC Vision**: Coordinate planning for transportation, infrastructure, land use, and economic development along the corridor.
- **33 SMC Mission**: Demonstrate how smaller cities can leverage innovative technologies, such as connected vehicle (CV) applications with Dedicated Short-Range Communication (DSRC), to improve operations, safety, and mobility.

To enable these new capabilities, the 33 SMC addresses needs as it relates to enabling technologies. The 33 SMC will integrate smart traveler applications, connected vehicles, and smart sensors into its transportation network by focusing on deploying CV infrastructure, CV Applications and a Connected Vehicle Environment Network (Smart Network).

- **CV Infrastructure** – The project will focus on building out the physical and logical CV infrastructure, which will consist of CV hardware and software (e.g. Roadside units (RSUs), On-board units (OBU), front and backhaul communications, equipment interface, etc.) The 33 SMC will generate the needed transportation-related data that will be used by applications.

- **CV Applications** – The project scope consists of deploying CV-specific applications that are deployment-ready or nearly ready for vehicle-to-infrastructure (V2I) communications. These applications will leverage the data generated by the infrastructure to deliver real-time safety and mobility services. These applications will be implemented across various locations and environments including both rural and urban uses-cases, highway and intersection use-cases, as well as work zone and pedestrian use-cases.

- **Connected Vehicle Environment (CVE) Network (Smart Network) and Data** – The project scope consists of deploying a CVE Network which includes the system integration of the CV applications with the existing fiber optic backbone. Data will be collected, processed, stored, and made available for use in other 33 SMC project applications. The network will include an infrastructure management element.
In support of this vision, and with the support of the program management team, the following goals and objectives were developed as shown in Table 1-1.

Table 1-1. 33 Smart Mobility Corridor Goals and Grant Objectives

<table>
<thead>
<tr>
<th>33 Smart Mobility Goals</th>
<th>Corresponding Objective from Grant Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance Intersection Safety and Mobility</td>
<td>Improve pedestrian safety at transit stops and crosswalks.</td>
</tr>
<tr>
<td></td>
<td>Provide next generation signal prioritization and dynamic timing based on DSRC.</td>
</tr>
<tr>
<td>Improve Roadway Congestion</td>
<td>Improvement in travel time reliability.</td>
</tr>
<tr>
<td></td>
<td>Reduction in average commute time to work.</td>
</tr>
<tr>
<td></td>
<td>Reduce traffic queues and congestion for critical arterials.</td>
</tr>
<tr>
<td>Serve as a Technology &quot;Leap-Ahead&quot;</td>
<td>Increase the number of Connected Vehicles.</td>
</tr>
<tr>
<td></td>
<td>Double the number of deployed Connected Infrastructure Components (RSUs) in the country.</td>
</tr>
<tr>
<td></td>
<td>Serve as the &quot;go-to&quot; location for on-road tests of autonomous vehicle technologies.</td>
</tr>
<tr>
<td></td>
<td>Provide the country's largest open research repository of J2735 message sets collected within an actual deployment.</td>
</tr>
<tr>
<td>Increase access to employment</td>
<td>Support future ridesharing in the NW 33 Innovation Corridor.</td>
</tr>
<tr>
<td></td>
<td>Reduce reoccurring congestion due to shift changes at manufacturing facilities in Marysville and Union County.</td>
</tr>
</tbody>
</table>

In line with 33 SMC’s vision and mission DriveOhio has expressed interest in deploying CV applications and supporting infrastructure within the project limits. While efforts by DriveOhio are considered outside the scope of the ATCMTD Grant, the 33 SMC environment will establish a working connected vehicle system where additional infrastructure and CV applications can be developed and easily deployed. The 33 SMC project and the COG will be leveraging investments by DriveOhio in the corridor as part of the overall connected vehicle environment. The 33 SMC is also an opportunity to develop partnerships for research, testing, and development of CV applications. Designing this system to be scalable will be necessary to allow for additional functionality or extension of the system limits in the future.

In anticipation of the 33 SMC project the COG partnered with the Ohio Department of Transportation (ODOT) to utilize existing and planned fiber optic installations along US-33 between the Transportation Research Center (TRC) near East Liberty, Ohio to Dublin, Ohio to support Vehicle-to-Infrastructure (V2I) applications. A Local fiber line “local loop” is being installed to create a fiber ring for redundancy and security. This redundancy will allow for access to all devices in the event of a fiber break along either the main corridor or the local loop.

The 33 SMC project will not only equip 35 miles of US-33 with the infrastructure and communication necessary for CV applications, CV equipment and applications will be installed within the cities of Marysville and Dublin. The CV infrastructure deployments will include in-vehicle devices that will target populations within the urban and rural environments. Table 1-2: 33 Smart Mobility Corridor Deployment Scope lists the associated planned improvements.
Table 1-2. 33 Smart Mobility Corridor Deployment Scope

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Vehicles</th>
<th>Applications and Data</th>
<th>Data Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td>90+ RSUs</td>
<td>400-600 OBUs</td>
<td>CV Applications</td>
<td>The project will capture, relate, store, and respond to data generated by the infrastructure and vehicles, used by the applications</td>
</tr>
<tr>
<td>The project will install new RSUs and necessary communications equipment at ~34 signalized intersections in the project area and at ~61 freeway locations</td>
<td>The project will install onboard units (OBUs) on participating fleet, emergency, and public works vehicles.</td>
<td>The project will deploy four (4) vehicle-to-infrastructure (V2I) safety, and mobility applications.</td>
<td></td>
</tr>
</tbody>
</table>

Just outside the 33 SMC, the City of Columbus is developing a cutting-edge, region-wide connected and autonomous (CAV) transportation network after receiving a federal grant through its successful bid for the Smart City challenge. While various multi-modal programs are developed under the Smart City Challenge, CV applications and Dedicated Shortrange Communications (DSRC) will be deployed in Columbus. The 33 SMC deployment will bolster this region’s commitment to smart transportation and provide a unique opportunity for coordinating adjacent CV systems.

The 33 SMC will span various community types and land uses, with the purpose of demonstrating how these technologies can improve transportation across these spectrums in a way that is cost-effective, scalable, and replicable as a blueprint for other communities.

1.3 ACRONYMS AND DEFINITIONS

The following table defines selected project-specific acronyms used throughout this System Requirements document.

Table 1-3. List of Acronyms/Abbreviations

<table>
<thead>
<tr>
<th>Acronym/Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>33 SMC</td>
<td>33 Smart Mobility Corridor</td>
</tr>
<tr>
<td>ATCMTD</td>
<td>Advanced Transportation and Congestion Management Technologies Deployment</td>
</tr>
<tr>
<td>BSM</td>
<td>Basic Safety Message</td>
</tr>
<tr>
<td>CAV</td>
<td>Connected and Automated Vehicles</td>
</tr>
<tr>
<td>COG</td>
<td>Council of Governments</td>
</tr>
<tr>
<td>ConOps</td>
<td>Concept of Operations</td>
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<tr>
<td>CV</td>
<td>Connected Vehicle</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communications</td>
</tr>
<tr>
<td>FCC</td>
<td>Federal Communications Commission</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
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<td>ISS</td>
<td>Integrity Security Solutions</td>
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<td>Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals, January 2007, United States Department of Transportation, Federal Highway Administration</td>
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<td>Systems Engineering Guidebook for ITS, FHWA CA Division/ Caltrans, version 3.0, November 2009</td>
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<td>Traffic Engineering Manual, Office of Roadway Engineering, Ohio Department of Transportation, January 19, 2018</td>
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<td>6</td>
<td>Code of Federal Regulations, Title 23, Chapter 1, Subchapter K – Intelligent Transportation Systems, Part 940 – Intelligent Transportation System Architecture and Standards</td>
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<td>12</td>
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1.5 DOCUMENT OVERVIEW
This document follows the sequential logic illustrated in Figure 1-1. It identifies how User Needs drove the development of the requirements at the System, interface and Sub-System level.

The project specific System Overview can be found in the 33 Smart Mobility Corridor Concept of Operations, dated February 2019, Chapter 7.
2 GENERAL SYSTEM DESCRIPTION

The 33 SMC project will develop a combination of subsystems that will make relevant information directly available to equipped vehicles within the project limits. The project is contained within the geographic area from the City of Dublin to the Transportation Research Center near East Liberty.

Figure 2-1 on the following page provides a detail context of the 33 SMC system. It defines technical subsystems, elements and interfaces that cross the system boundaries and the high-level interactions among the various components.

The left side of the diagram represents the vehicles equipped with OBUs using DSRC communication. The right side represents the traffic signal controllers, roadside sensors, future interfaces (such as road weather information system (RWIS), railroad wayside equipment, ramp queue detection) and pedestrian crossing signals that will feed external data to the 33 SMC system. The top portion of the diagram represents the Global Navigation Satellite System (GNSS) for synchronizing time and position (latitude, longitude, and elevation) and localized GPS corrections that will be provided as part of infrastructure system. The bottom portion of the diagram represents the Security and Credentials Management System (SCMS) that is being provided by ODOT, the integrated data exchanges that is currently under development and the infrastructure management platform to monitor RSU health, connections and activity. The locations of the integrated data exchange and the infrastructure management platform is still being evaluated as of initial publication of this document.
Figure 2-1
33 SMC Context Diagram

DESCRIPTION

33 Smart Mobility Corridor

PROJECT

33 Smart Mobility Corridor

DATE

5/24/2019

LEGEND

Existing System/Element
Proposed System/Element Implemented by 33 SMC Project
Future System/Element

Figure 2-1 CONTEXT DIAGRAM REVISED VISIO

LEGEND

Existing System/Element
Proposed System/Element Implemented by 33 SMC Project
Future System/Element
2.1 SYSTEM CONTEXT
Supporting the applications and the CV environment will include a system of RSU equipment, a system of OBU equipment and a system of backhaul networks for agency infrastructure and data management. The 33 SMC will interact with various external entities and subsystems to accomplish the stated objectives.

- Deploy RSUs with DSRC connectivity on US33 that can broadcast pertinent reduced speed/lane closure and curve speed information to vehicles in the vicinity. The RSUs located at the signalized intersections will broadcast SPaT and MAP messages to equipped vehicles in the vicinity.

- Deploy and operate a set of vehicles that will be equipped with OBUs with DSRC connectivity. Depending on their applications, may include a Human Machine Interface (HMI) and/or connect to vehicle data systems. These vehicles will broadcast Basic Safety Messages to other equipped vehicles and the RSUs. The OBU will utilize status information from the vehicle, other vehicles, the roadside, and location and time data (obtained from a location and time source), such as Global Navigation Satellite System (GNSS) to support safety and mobility applications. These vehicles will also receive in-vehicle alerts and information through the infrastructure from various applications developed and deployed as part of this project.

- Develop a connected vehicle environment network back-end system and backhaul network that will be capable of receiving and transmitting information to equipped vehicles. The system will include data management, data storage, data analytics, system management, and interface with outside systems, such as a security credential management system (SCMS) and GPS correction systems. The back-end systems will be centralized or cloud-based systems. The integrated data exchange (storage, management, analytics) will support research, development, and testing programs in the future.

Figure 2-2 presents a detailed view of the OBU system architecture and its connections to subsystems, external systems via DSRC, and other OBUs for future V2V applications. The host vehicle’s OBU will transmit Basic Safety Messages (BSMs) to RSUs and receive SPaT, MAP, RTCM, and Basic Infrastructure Message (BIM) messages through DSRC. The SPaT message is only received from RSUs interfaced with traffic signal controllers.

As part of the 33 SMC project several applications were identified by the stakeholders through the ConOps process. However, based on budgetary constraints, the total number of applications to deploy was reduced. The following applications are going to be deployed under the project:

- Curve Speed Warning
- Intersection Safety Warning and Collision Avoidance (Red-Light Violation Warning)
- Actuated Beacon Crossing Warning (PabCW)
- Reduced Speed Zone Warning /Lane Closure

The OBU will manage, process, and prioritize DSRC messages to determine applicable warning messages to display to the driver via the visual display. Information needed for the BSM Part 1 message can be derived from the Vehicle Data Bus connection, or by utilizing the GPS antenna on the 5.9 GHz DSRC antenna harness.
2.2 SYSTEM MODES AND STATES

Because 33 SMC is composed of multiple devices and potentially hosting several applications, the system mode is viewed at a micro level. With devices deployed across the deployment area and outside the deployment area (i.e., vehicles), viewing the deployment as a single system is not considered for defining modes. The mode will be composed of the status of a device, its ability to communicate, and the operational status of the installed applications.

Devices have three modes:

- Normal Mode: A device and its application are operating as intended and required
- Degradation Mode: Something unexpected occurred and part of the device or application may not be functioning as expected
- Error Mode: a complete failure of the device including communication failure

Each RSU or OBU (simply referred to as a device when considered generically as a DSRC-based unit) is considered to be in normal mode when the device is operating as designed and the applications are functioning as designed. A device will enter Degradation Mode when there is a failure of one or more of the applications or a part of the hardware fails. When an application fails, data is not being received, processed or transmitted for those application(s). Other applications may continue to function as designed. When portions of the device hardware fails, the applications may or may not be able to perform as designed. When a device completely fails or loses connectivity to the network, it enters Error Mode.

OBU’s modes cannot be determined in real time. Mode changes by these devices will be identified only when the vehicle’s data is downloaded and only for those OBUs that will capture data. If there is a complete failure of the device, then it will be apparent that the device is nonoperational. If the device is operating with an application that has failed, this will be determined after the data has been downloaded and analyzed. OBU failures may be determined more efficiently as drivers may notice the OBU not functioning properly.

When determining the system state, the focus will be on the RSUs. These devices will provide constant communication to the infrastructure management system that can be monitored. The OBUs are not considered when modeling and determining the system state, as there is no reliable means to know if these devices are functioning as required, except when RSUs are within range of neighboring RSUs.

The RSU device states are: Operational, Partial Failure and Failed.

When the RSU is fully operational it is known to be up and operating and in communication with the infrastructure management system via the appropriate network. Partial failure of an RSU indicates that the RSU is not functioning as designed. An RSU is to be considered nonoperational when the communications with the RSU is interrupted (down), there has been a power or network connectivity failure, or the RSU itself has some failure preventing it from operating properly. The RSU is considered to be in a failed state when it is inoperative.
2.3 **MAJOR SYSTEM CHARACTERISTICS**

This section provides an overview of the major capability groupings for the 33 SMC system requirements. Based on Figure 2-1, it describes the contextual components of the 33 SMC system.

### 2.3.1 System Capabilities

The primary outcome of the 33 SMC is deployment of technology both roadside and in-vehicles to enable communication between vehicles and the roadside equipment. The CV technology will provide information that will help reduce crashes along the target corridor, improve safety in work zones, and increase safety and awareness for light-duty vehicle operators, passengers, and public safety personnel.

The 33 SMC will also provide the mechanisms to improve traffic management throughout the US-33 corridor, Cities of Marysville and Dublin. This project will enable state and local agencies to collect low-cost, comprehensive and high-quality data that can be used in addition to data collected for other third-party sources to enhance traffic management. Archiving data from 33 SMC will further enhance the integration of transportation data into network management and long-term transportation planning. This data will be available to external third-parties for CV research, deployment and testing.

### 2.3.2 System Conditions

The 33 SMC is expected to perform under most conditions, securely and timely delivering data to and from vehicles, allowing for the project objectives to be met. Situations that might result in degraded or no performance include:

- **Loss of Power** – A power outage that impacts the infrastructure elements of the environment will prohibit the V2I applications from performing as expected.

- **Device Failure** – Device failures could be either the RSU, OBU or both.

- **Loss of Communications** – The infrastructure elements are connected on a fiber optic loop, allowing a single break in the fiber to not adversely affect the interaction between the vehicles and infrastructure or infrastructure and network. However, in the event of two breaks in the fiber the affected devices may not be able to forward information back to the back-end systems. The affected RSUs would still allow for localized communications which will be employed to ensure that information is being transmitted to the vehicles.

Management provisions will be made to monitor the operation of the system’s infrastructure devices to identify any failures and resolve them. When RSUs fail, vehicle operators will not be notified and will operate their vehicles normally without alerts or alarms from the OBUs for V2I applications. These type of failure conditions in the CV devices may result in safety-related implications such as inability to issue alerts. Furthermore, this may lead to insufficient or inaccurate data and safety benefit analysis of the system.

### 2.3.3 System Constraints

System constraints are those items that limit or restrict the system. System constraints of the 33 SMC can be grouped in several distinct categories which include equipment selection and deployment, network security and operations, user privacy and data collection, and impact to traffic operations.

- Equipment reliability and range
• Obtaining Power and reliability - Many important highway locations lack reliable, cost effective commercial power
• Vehicle penetration %
• GPS accuracy
• MAP accuracy
• Drivers adhering to the RSU/OBU warnings
• Policies regarding maintenance of the system components
• New agreements or modifications to existing SLAs to support CV technology and prioritize maintenance and support of the CV environment during the demonstration phase.
• COG and Fleet operators who are participants in the proposed system need to develop clear memorandums of understanding on roles and responsibilities for each of the parties
• Minimizing distraction to drivers is critical to any advisories and alerts issued by the system. Any in-vehicle advisory needs to be balanced with the demands of the driving tasks required of the driver during stressful conditions
• Certificate availability
• Privacy of Data
• Funding for Tier 1 applications only; tier 2 to be deployed later

2.4 User Characteristics
This section defines the user classes, stakeholders, and their roles and responsibilities within the 33 SMC system. Stakeholders refers to an individual or organization affected by the activities, inputs and outputs of the system being developed. They may have a direct or indirect interest in the system and their level of participation may vary. This includes public agencies, private organizations or the traveling public (end users) with a vested interest or "stake" in one or more aspects of the 33 SMC as identified in Table 2-1: 33 SMC Stakeholders and User Classes. User Classes are classified based on their perception of the system and the needs identified. Note that some key personnel may serve in multiple roles based on the user needs and functions. For each user type, their role, where they participate, and devices they use or interact with are discussed.
Table 2-1. 33 SMC Stakeholders and User Classes

<table>
<thead>
<tr>
<th>Project Stakeholders</th>
<th>User Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Light-Duty Vehicle Operator</td>
</tr>
<tr>
<td>City of Dublin fleet vehicle operators</td>
<td>X</td>
</tr>
<tr>
<td>City of Dublin maintenance vehicle Operators; fleet managers, police</td>
<td></td>
</tr>
<tr>
<td>City of Dublin/Washington Township Fire, Emergency Medical Services (First Responders)</td>
<td></td>
</tr>
<tr>
<td>City of Marysville Fleet Vehicle Operators</td>
<td>X</td>
</tr>
<tr>
<td>City of Marysville Fire, Emergency Services, Police (First Responders)</td>
<td></td>
</tr>
<tr>
<td>Union County Fleet Vehicle Operators</td>
<td>X</td>
</tr>
<tr>
<td>Union County Maintenance vehicle operators; fleet managers</td>
<td></td>
</tr>
<tr>
<td>Honda</td>
<td>X</td>
</tr>
<tr>
<td>City of Dublin Traffic Manager</td>
<td></td>
</tr>
<tr>
<td>City of Marysville Traffic Manager</td>
<td></td>
</tr>
<tr>
<td>Union County Sheriff’s Office</td>
<td>X</td>
</tr>
<tr>
<td>Infrastructure Management Entity</td>
<td></td>
</tr>
<tr>
<td>TMC Operator (Future)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Table based on current information regarding OBU deployment and may not reflect actual deployment.

2.5 **ASSUMPTIONS AND DEPENDENCIES**

The tables below list the known assumptions and dependencies that represent a risk to the 33 SMC project or system and can affect the ability to meet the desired functionality, maintain the project schedule or meet performance goals. Key assumptions are made in defining the features for the proposed system. Table 2-2 lists the known assumptions for the 33 SMC system.

<table>
<thead>
<tr>
<th>No.</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RSUs will be compliant with SAE J2735 &amp; USDOT v4.1 (October 2016) specifications</td>
</tr>
<tr>
<td>2</td>
<td>The SCMS will be coordinated by ODOT through their provider, Integrity Security Solutions (ISS), and available when needed by the project</td>
</tr>
<tr>
<td>3</td>
<td>Connected vehicle equipment deployed as part of this project will have the capabilities necessary to utilize the SCMS</td>
</tr>
<tr>
<td>4</td>
<td>Connected vehicle applications will be available from the Open Source Application Development Portal or can be custom built as required for the project.</td>
</tr>
<tr>
<td>No.</td>
<td>Assumption</td>
</tr>
<tr>
<td>-----</td>
<td>------------</td>
</tr>
<tr>
<td>5</td>
<td>Traffic signal controllers will interface to RSUs using NTCIP 1202</td>
</tr>
<tr>
<td>6</td>
<td>Traffic signal controllers will output SPaT in SAE J2735 format or other middleware or co-processors can directly translate to the SAE J2735 format</td>
</tr>
<tr>
<td>7</td>
<td>Traffic signal controllers output pedestrian actuations in SAE J2735 format or other middleware or co-processors can directly translate to the SAE J2735 format</td>
</tr>
<tr>
<td>8</td>
<td>RSUs will communicate with backend systems using planned fiber optic communications</td>
</tr>
<tr>
<td>9</td>
<td>RSUs will have capability to be updated remotely with firmware updates and applications</td>
</tr>
<tr>
<td>10</td>
<td>There will be a redundant fiber loop in place prior to the project go live</td>
</tr>
<tr>
<td>11</td>
<td>DSRC will be the medium for over-the-air message transmission</td>
</tr>
<tr>
<td>12</td>
<td>Data from OBUs will be collected and stored in the integrated data exchange (with no personally identifying information collected)</td>
</tr>
<tr>
<td>13</td>
<td>Position correction will be facilitated using RTCM v3.0 Type 1001/1005 messages</td>
</tr>
<tr>
<td>14</td>
<td>The number of connected vehicles is expected to be a fraction of the total traffic. As the rate of connectivity grows, the system needs to have the capacity and capability to integrate with new OBUs</td>
</tr>
<tr>
<td>15</td>
<td>Applications and software will support various manufacturers of OBU and RSU equipment</td>
</tr>
<tr>
<td>16</td>
<td>RSUs and OBUs will support over-the-air (OTA) firmware updates</td>
</tr>
</tbody>
</table>

**Table 2-3 lists the known risks to the 33 SMC system that will affect the ability to meet schedule or performance goals.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CAN bus information is difficult to acquire due to vehicle manufacturers using different and proprietary code sets, however this data is optional for BSM Part 1 messages.</td>
</tr>
<tr>
<td>2</td>
<td>The schedule may not be met by selected vendors. New technologies often experience technical difficulties which can lead to schedule overruns.</td>
</tr>
<tr>
<td>3</td>
<td>Contracting or installation delays will delay work on system components, which strains timelines for hardware design, construction, certification, and testing.</td>
</tr>
<tr>
<td>4</td>
<td>Differing manufacturer’s CV devices may not be interoperable and do not meet the standards required for 33 SMC</td>
</tr>
<tr>
<td>5</td>
<td>Unknown system/device compatibility issues</td>
</tr>
<tr>
<td>6</td>
<td>Loss of key staff</td>
</tr>
<tr>
<td>7</td>
<td>The SCMS may not be available</td>
</tr>
<tr>
<td>8</td>
<td>OBU/RSU cannot support encryption of messages</td>
</tr>
<tr>
<td>9</td>
<td>RTCM may be insufficient to meet 33 SMC needs due to quality of OBU GNSS hardware and use of RTCM</td>
</tr>
<tr>
<td>10</td>
<td>Lack of utilization of the different applications by the users; education/big brother complex</td>
</tr>
<tr>
<td>11</td>
<td>Funding constraints could reduce the project scope for deployment</td>
</tr>
<tr>
<td>12</td>
<td>Power availability in remote locations along US33 may be cost prohibitive</td>
</tr>
<tr>
<td>13</td>
<td>Product availability for both RSUs and OBUs may cause delays</td>
</tr>
</tbody>
</table>

### 2.6 Operational Scenarios

The Operational Scenarios can be found in the 33 Smart Mobility Corridor, Concept of Operations, dated February 2019, Chapter 8.
3 SYSTEM REQUIREMENTS

This section of the document lists the identified requirements for the 33 SMC. It provides the high-level requirements for the system of interest (i.e. what the system will do). The requirements are organized first by requirement type, then by system and services. The detailed system requirements for the project can be found in Appendix A and is broken down by the requirement types listed herein.

3.1 FUNCTIONAL REQUIREMENTS

The Functional requirements specify actionable and qualitative behaviors (e.g. functions, tasks) of the core system of interest, which in this case includes the roadside infrastructure, including RSUs; as well as OBU

Roadside Unit

- The RSU shall communicate through appropriate channels and protocols as established by SAE, NTCIP, and IEEE
- The RSU shall send, receive, and log messages
- The RSU shall function as intended to be able to perform the application functional requirements listed below
- The RSU shall communicate status, report errors, and send data back to the infrastructure management software system
- The RSU shall have the ability to store and forward messages, originating from both OBU and the messages and status generated at the RSU
- The RSU shall be configurable
- An RSU supplier shall provide the enrollment certificate for each RSU
- The RSU shall be compatible with a variety of OBU manufacturers
- The RSU shall support sending OTA firmware updates to an OBU

Infrastructure Management System

- The system shall communicate to the RSU, sending messages via an IP network.
- The software/web application provided by the RSU integrator shall be configurable by the infrastructure management entity for functions on the software and RSU equipment
- The system shall report status of the RSUs to the infrastructure management entity and provide alerts when the RSU is not properly functioning
- The system shall support logging of BSM, RSM and SPaT data
- The system shall maintain a log of all alerts issued to the system
- The system shall be capable of forwarding data (BSM, RSM, SPaT, MAP) to an integrated data exchange
- The system shall support a variety of RSU manufacturers

On Board Unit

- The OBU shall comply with IEEE, SAE
- The OBU shall not continue to start up and will log an error if the host processor determines it is not in a known good software state on boot up.
- The OBU shall notify the vehicle operator of the power status of the device (e.g. off, powering up and online)
• The OBU shall be configurable
• The OBU shall present alerts to drivers (via the HMI) using an HMI device that drivers are familiar with and limits driver interaction
• The OBU shall operate in a manner that will meet the application functional requirements listed below
• The OBU shall be able to send, receive and log BSM, RSM, and SPaT messages
• The OBU shall be compatible with a variety of RSU manufacturers
• The OBU shall support OTA firmware updates

Mobile Configuration Interface
• The mobile configuration interface shall provide configuration of an RSU along US 33 for the Reduced Speed Zone Warning/Lane Closure Application by generating a RSM message and MAP configuration
• The mobile configuration interface shall allow for the configuration of multiple RSU devices at one time

Applications
A. Intersection Warning and Collision Avoidance (Red Light Violation Warning) Application – The application shall identify when a vehicle is expected to cross the stop bar during a red signal by using the following data items:
   1. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus)
   2. Normal deceleration rate
   3. Perception/reaction time
   4. Expected DSRC Transmission Latency
   5. Expected processing time (time from receipt of SPaT to the time the alert is issued)
   6. SPaT data (received from the RSU)
   7. MAP data (received from the RSU)
   8. RTCM data (received from the RSU)

B. Reduced Speed Zone Warning /Lane Closure Application

The Reduced Speed Zone Warning Application shall identify when a host vehicle is expected to enter the reduced speed zone but not travelling below the reduced zone speed limit (given its current location, motion and expected deceleration rate) during an active work zone or reduced speed zone by using the following data items:
   1. Reduced speed zone area (manually entered via the mobile configuration interface)
   2. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus)
   3. RSM data (Received from the RSU)
   4. MAP data (Received from the RSU)
   5. RTCM data (Received from the RSU)
The Lane Closure Application shall identify when a host vehicle is expected to enter the lane closure zone but has not yet departed the drop lane (given its current location, motion and expected deceleration rate) during an active work zone by using the following data items:

1. Lane closure area (manually entered via the mobile configuration interface)
2. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus)
3. RSM data (Received from the RSU)
4. MAP data (Received from the RSU)
5. RTCM data (Received from the RSU)

C. Pedestrian Actuated Beacon Crossing Warning Application – The application shall identify when a host vehicle is expected to enter the crosswalk warning zone that has been actuated by a pedestrian (given its current location and motion) by using the following data items:

1. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus)
2. RSM data (Received from the RSU)
3. MAP data (Received from the RSU)
4. RTCM data (Received from the RSU)

D. Curve Speed Warning Application – The application shall identify when a host vehicle is expected to enter the curve speed zone but not below the posted speed limit (given its vehicle type, current location, motion and expected deceleration rate) by using the following data items:

1. Location, vehicle type and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus)
2. MAP data (Received from the RSU)
3. RSM data (Received from the RSU)
4. RTCM data (Received from the RSU)

3.2 PERFORMANCE REQUIREMENTS

The Performance requirements specify quantifiable characteristics of operations that define the extent, or how well, and under what conditions a function or task is to be performed (e.g. rates, velocities).

DSRC Messages
- The BSM shall be broadcast at a frequency of 10 Hz when congestion control algorithms (SAE J2945/1) do not prescribe a reduced rate
- The BSM shall always include Part I data (SAE J2735, Section 6.8)
- The MAP message shall be expressed with an accuracy of 0.5m (1.64-ft) or less
- The MAP messages shall be transmitted with a frequency of at least 1 Hz
- The SPaT messages shall be provided to the RSU in SAE J2735 format
- The SPaT messages shall be transmitted by the RSU with a minimum frequency of 10 Hz
- The RSM messages shall be transmitted with a frequency of at least 1 Hz

Roadside Unit
- The clock system shall be accurate to within 10 ms of the UTC reference
• All absolute times in any message shall be determined based on the RSU’s system clock

Infrastructure Management System
• The system shall notify the infrastructure management entity within five minutes of a noticed error or reported failure
• The system shall compile/aggregate CV data into configurable/user defined intervals
• The system shall be able to store at a minimum of 10 TB of archived CV data
• The system shall be able to store at a minimum of 10 TB of backup archived CV data
• The system shall copy all archived CV data into the backup archived CV data at a minimum once per day
• The system shall have the ability to forward all/filtered archived CV data to an integrated data exchange

On Board Units
• The OBU shall have a minimum reserve capacity of 50% upon deployment for the install and run of future firmware image updates

Mobile Configuration Interface
• The mobile configuration interface shall provide the ability to configure MAP and/or RSM messages for RSUs along US 33 in support of the Reduced Speed Zone Warning/Lane Closure Application

3.3 INTERFACE REQUIREMENTS
The Interface requirements define how the system will interact, communicate, or exchange data with external systems (external interface) and how core system elements interact with other parts of the system (internal interface).

Roadside Unit
• The RSU shall receive security certificates from the ODOT SCMS
• The RSU shall store security certificates
• The RSU shall receive data or messages from the Traffic Signal Controller, other roadside computing devices, GPS correction system, and the infrastructure management system
• The RSU shall be powered via power over Ethernet, the cable shall be outdoor rated
• The RSU shall send messages to the OBU
• The RSU shall receive over the air messages via DSRC, including BSMs from an OBU
• The RSU shall be IP addressable and connected via Ethernet to the fiber optic network

On Board Unit
• The OBU shall receive security certificates from the ODOT SCMS via the RSU
• The OBU shall receive and send messages to/from an RSU
• The OBU shall send BSMs consistent with SAE J2735 to other OBUs
• The OBU shall receive position data from GNSS satellites

Mobile Configuration Interface
• The mobile configuration interface shall communicate with the targeted RSUs along US for the updating of MAP and/or RSM messages in support of the Reduced Speed Zone Warning/Lane Closure Application

3.4 DATA REQUIREMENTS
The Data requirements define the data collected, transformed, and stored from various sources as well as identifies new data that is expected to be generated.

DSRC Messages
• The BSM Part I shall include all data elements contained in the BSMcoreData data frame (SAE J2735, Section 6.8)
• The MAP message shall contain all the appropriate provisions for the intersection per SAE J2735
• The management software shall generate messages consistent with SAE J2945/4
• The SPaT Message shall contain all the appropriate provisions per SAE J2735

Infrastructure Management System
• The system shall remove PII from data prior to sending it to the integrated data exchange or other third-party entities.

3.5 SECURITY REQUIREMENTS
The security requirements specify what is necessary to protect the integrity and operability of the system, its microservices, connections, and data. This includes physical security as well as cyber prevention, detection, identification, response and recovery requirements.

Roadside Unit
• The RSU shall verify received messages per IEEE 1609.2, Standard for WAVE – Security Services for Applications and Management Messages, before using them for operation in an application
• The RSU shall provide tamper evidence to detect tampering of the device (e.g. opening of the case)
• The RSU shall implement a firewall blocking all IP access from devices to any IP address other than those approved for a specific application
• The RSU shall delete old certificates if it is moved to another location

Infrastructure Management System
• The system shall detect abnormal unauthorized activity on an IP connection
• The system shall monitor the DSRC communications performance to detect any DoS attacks.
• The system shall monitor data traffic usage to detect unapproved use of an IP connection

On Board Unit
• The OBU shall cease transmission of BSM if it has determined that is has been blacklisted.
• The OBU shall prevent incoming messages with invalid conditions criteria per IEEE 1609.2 from being acted on
• The OBU shall obtain certificates via IPv6 connectivity through the RSU
• The OBU shall verify received messages per IEEE 1609.2 and relevant security profiles before using them for operations in any application
• The OBU shall only accept or provide data that complies with IEEE 1609.2
3.6 **POLICY AND REGULATION REQUIREMENTS**

The Policy and Regulation requirements specify relevant and applicable organizational policies or regulations that affect the development, operation or performance of the system (e.g. IT and labor policies, reports to regulatory agencies, health or safety criteria, etc.). This section also includes new policy and regulation imposed to realize the system.

- The RSU shall be licensed by the FCC (Subpart M of Part 90 of FCC Rules)
- The RSU shall be registered by site and segment with the FCC before operations
- The OBU shall meet the license requirements as indicated in subpart I of Part 95 of FCC rules

3.7 **NON-FUNCTIONAL REQUIREMENTS**

The non-functional requirements define the characteristics of the overall operation of the system such as availability, maintainability, reliability, safety, environmental, human factors and ergonomics.

3.7.1 **Physical Requirements**

The physical requirements specify the construction, durability, adaptability and environmental characteristics of the system.

**Roadside Unit**

- The RSU shall be mounted at the appropriate height, based on national standard of practice or manufacturer’s recommendation
- The RSU DSRC antennas shall be located to maximize the DSRC range along the corridor
- The RSU GPS antennas shall be located to maximize GPS reception
- The RSU Ethernet cable spans shall not exceed 100 meters
- The controller cabinet that contains roadside equipment shall be outfitted with tamper alert devices
- RSUs shall be connected to backhaul fiber optic communications
- Devices for outdoor use shall have NEMA rated enclosures and protection from power surges

**Infrastructure Management System**

- The system shall store archived CV data and backup archived data on separate physical storage devices or the cloud

**On Board Unit**

- The OBU HMI shall be mounted in such a manner that it does not obstruct the line of sight of the driver
- The OBU HMI shall be positioned in a location that can provide visual and audible output to the driver

3.7.2 **Availability and Recovery Requirements**

The availability and recovery requirements define the times of day, days of year, and overall percentage the system can be used and when it will not be available for use as well as recovery point and time objectives. It also specifies how well the system is expected to restore services in the event of a failure.

**Roadside Unit**

- The RSU shall have an uptime of 99% when power is available to the network
- The RSU shall return to an operational state within 5 min of regaining power
3.7.3 Maintainability Requirement
The maintainability requirement specifies the level of effort required to locate and correct an error during operation.

- The infrastructure management entity shall identify and maintain staff to troubleshoot and diagnose RSU and OBU issues
- A set of procedures for diagnostic, support and troubleshooting shall be developed
- An asset management list shall be maintained for all equipment included within the 33 SMC
- All support staff should be trained on how to install RSU and OBU devices by the vendor
- The COG and/or city shall maintain the RSUs installed within Marysville and Dublin
- The COG shall maintain the RSUs installed along US-33
- ODOT shall maintain the infrastructure installed along the roadside of US-33, including the support poles, network equipment and fiber optic communications
- ODOT appointed contractors shall maintain the fiber optic network utilized for communication to the RSU
- The RSU shall support physical access for maintenance activities
- The OBU shall support physical access for maintenance activities

3.7.4 Storage and Transport Requirements
The storage and transport requirements specify the physical location and environment for the system, including designated storage facility, installation site, repair facility, requirements for transporting equipment, etc.

These requirements have not yet been established for the 33 SMC.

3.7.5 Disposal Requirements
The disposal requirements specify the items related to the disposal of project/system components, due to either failure replacements, removal, end-of-life upgrade, or retirement.

- The 33 SMC shall remain operational beyond the completion of the deployment period

3.7.6 Relocation Requirements
For any RSU that is to be relocated, for any reason, the device shall be relocated and configured to a comparable new location as approved by the COG.

For equipped vehicles that are retired, the OBU, antennas and other associated hardware shall be returned to the COG. The COG will determine if and where the device will be reinstalled and configured. Each COG member shall be trained in installing on-board equipment.

3.8 Enabling Requirements
The Enabling requirements specify details concerning the management of information as well as the production of the system and its life cycle sustainment, including development, integration, verification, validation and training.
3.8.1 Information Management Requirements
The data management requirements specify the acquisition, management, and ownership of information from one or more sources, the custodianship and the distribution of that information to those who need it.

3.8.2 Life Cycle Sustainability Requirements
The life cycle sustainability requirements define what items the project or system will review, measure, and analyze as part of its commitment to quality during the life cycle of the system, including development, integration, verification, validation, and training.

The initial stages of the System Engineering process produce documents such as the System Engineering Management Plan, the Concept of Operations, and System Requirements Specification. These documents are reviewed by stakeholders, partners, and other interested parties to ensure a system based on quality concepts. As the project progresses, the review of System Engineering documentation promotes successful implementation and adherence to requirements, which trace back to user needs. In the testing phase of System Engineering, pieces of the system are tested on various levels defined as unit testing, module/subsystem testing, integration testing, and acceptance testing. These tests ensure components work individually, as well as together to form the system. It is anticipated that testing procedures will be developed for the following:

- RSUs
- OBUs & communication with vehicle data bus
- Encrypted communications (SCMS)
- Communication with traffic controllers
- System management interface, communication with RSUs, and data sharing
- Scrubbing PII & system data storage
- Automated performance metrics
- Connected vehicle applications

Once the system is deployed and CV data begins to be archived, the performance measurement evaluation process begins. The performance measures provide information on roadway operations to determine if and how much the system is improving the issues that exist. Utilizing this same data, the system quality and reliability can be assessed. If the data is showing that the appropriate information is being sent and received by devices, and the appropriate alerts are being broadcast, the system in general is functioning properly within its parameters. Error logs are monitored to determine if specific functions or components of the system may be experiencing problems.

As data is analyzed and experience is gained in using the system, new ideas, functionality, and better business practices will be realized. These lessons learned will be valuable in expanding this system and deploying connected vehicle technologies across the State of Ohio by feeding this information into the development of design and deployment standards.
APPENDIX A. DETAILED SYSTEM REQUIREMENTS
<table>
<thead>
<tr>
<th>ReqID</th>
<th>Functional Group</th>
<th>Sub-Component</th>
<th>Description</th>
<th>Verification Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The RSU shall obtain position correction information from a Continuously Operating Reference Station (CORS) for packaging and broadcasting as the Radio Technical Commission for Maritime Services (RTCM) messages.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The 33 SMC system shall acquire time from the Time and Location Source (TLS) interface in accordance with J2945/1 section 6.2.4.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The 33 SMC system shall acquire location from the Time and Location Source (TLS) interface in accordance with J2945/1 section 6.2.1.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall broadcast (reduced speed zone; curve warning; lane closure; Pedestrian Actuated Beacon Crossing Warnings) RSMs to an OBU when configured to perform this function</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The 33 SMC system shall use Coordinated Universal Time (UTC) time for all logged data (e.g., probe vehicle data, events logs) based on the format defined in J2375 section 6.19 and epoch of January 1st, 1970.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall have access to a function that generates SPaT messages from SPaT data inputs.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall have access to a function that generates RTCM messages from RTCM data inputs.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>RSU functionality failure shall not affect the safe operations of the signal controller.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>RSU functionality failure shall not affect the safe operations of the Pedestrian signal actuation.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>All roadside equipment (including RSUs) shall support remote authenticated access.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall broadcast the Wave Service Announcement (WSA) for certificate download on control channel 178 and indicate IPv6 connectivity and the IP address on a service channel other than channel 172 or 178.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall support IPv6 tunneling over IPv4.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall report the channel busy ratio to the Infrastructure Management System if the channel busy ratio rises above a configurable threshold.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>It shall be possible for the infrastructure management entity, with the appropriate permissions, to configure the RSU to request application certificates with only designated geographic locations.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The 33 SMC shall provide an interface to allow the infrastructure management entity to request new certificates bound to the new location if it moves from one location to another. (Note: its interface will allow requesting a new RSU application certificate with a site.)</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall communicate using SNMPv3 with SNMP messages protected by being sent over TLS.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall not create or transmit messages if the 1609.2 certificates do not contain the permissions for the corresponding PSID.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU supplier shall provide the enrollment certificate for each RSU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall broadcast MAP messages loaded on the RSU to an OBU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall send RTCM messages received from the CORS or another source to an OBU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall send SPaT messages generated from traffic signal controller output or other applicable source (coprocessor/microcontroller) to an OBU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>ReqID</td>
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<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall receive BSMs from an OBU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>An RSU shall send OBU operating system updates to an OBU over-the-air via DSRC.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The RSU shall support OBU operating system updates that need to occur over the range of more than one RSU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The RSU shall be compatible with a variety of OBU manufacturers.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>The RSU shall support over the air firmware updates to an OBU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Units</td>
<td>RSU shall immediately forward BSM, SPaT, MAP, and RSM to the infrastructure management system.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Mobile Configuration Interface</td>
<td>The mobile configuration interface shall provide configuration of an RSU along US 33 for the Reduced Speed Zone Warning/Lane Closure Application</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Mobile Configuration Interface</td>
<td>The mobile configuration interface shall allow for the configuration of multiple RSU devices at one time</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall be capable of sending SPaT messages to an integrated data exchange</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall enable uploading or sending for immediate forwarding by the RSU of RSMs to the RSU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall enable uploading or sending for immediate forwarding by the RSU of MAP messages to the RSU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall accept input for RSM from Traffic Management and Traffic Operations staff</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall accept input for MAP messages by infrastructure management entity staff</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall accept input for configurable parameters for functions on the infrastructure management system and on the RSU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall make the status of the RSUs available to the infrastructure management entity</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall provide the VISA’ Functions of Validation, Integrations, Sanitization (De-identification), and Aggregation of CV Data as defined in the U.S. DOT Semi ODE requirements.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall be capable of generating RSM messages</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall be capable of generating MAP messages</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall monitor uptime status of the RSUs.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system should automate the generation of performance metrics as defined in the performance management plan (TBD)</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system should use CV data made available through the 33 SMC to generate performance metrics as defined in the performance management plan (TBD)</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
This section provides the high-level requirements for the system of interest (i.e. what the system will do).

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<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall receive BSMs from the RSU</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall remove PII from BSMs that are received before further processing</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall monitor tamper alert devices</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall be capable of generating performance metrics (TBD) from archived CV data</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall accept inputs for all required elements of an RSM message via a user interface</td>
<td>Demonstration</td>
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<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall accept inputs for all required elements of an MAP message via a user interface</td>
<td>Demonstration</td>
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</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall provide means to download archived CV data.</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall provide a map-based user interface and display the locations of real-time messages being received. (SPaT, MAP, BSM, RSM)</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall copy all archived CV data into the archived CV data back up storage</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall provide an alert via an email to the location of an RSU that is offline</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall provide an alert via an email to the location of an RSU where unauthorized use has been detected and information regarding the unauthorized device.</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall display different colored icons on the UI to indicate the real-time status of each RSU.</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall support a variety of RSU manufacturers.</td>
<td>Demonstration</td>
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<td>Traffic Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall support a variety of RSU manufacturers.</td>
<td>Demonstration</td>
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</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The RSU shall forward BSM received from a given RSU to the Infrastructure Management System at a configurable frequency</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The RSU shall forward SPaT messages to the Infrastructure Management System at a configurable frequency</td>
<td>Demonstration</td>
<td></td>
</tr>
</tbody>
</table>
# FUNCTIONAL REQUIREMENTS

This section provides the high-level requirements for the system of interest (i.e. what the system will do).

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<tbody>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The RSU shall not forward a SPaT message unless there is a change in configurable select data elements (e.g. minEndTime, maxEndTime, etc.) from the previously forwarded message</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The RSU shall forward MAP messages to the infrastructure management system at a configurable frequency</td>
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<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The RSU should not forward duplicate MAP messages during a configurable time interval</td>
<td>Demonstration</td>
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<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The RSU shall forward RSMs to the Infrastructure Management System at a configurable time interval</td>
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<td>Vehicle Data for Traffic Operations</td>
<td>The RSU should not forward duplicate RSMs during a configurable time interval</td>
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<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall receive all BSMs sent by the RSU</td>
<td>Demonstration</td>
<td></td>
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<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall receive all RSMs messages sent by the RSU</td>
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<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall receive all SPaT messages sent by the RSU</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall store all logged BSMs sent by the RSU</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall store all SPaT messages sent by the RSU</td>
<td>Demonstration</td>
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<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure management system shall store all RSM messages sent by the RSU</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall store all MAP messages that are input at each RSU</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The Infrastructure Management System shall make all stored data available to the COG</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Red Light Violation Warning</td>
<td>The Red Light Violation Warning Application shall identify when a vehicle is expected to cross the stop bar during a red signal by using the following data items: 1. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus) 2. Normal deceleration rate 3. Perception/reaction time 4. Expected DSRC Transmission Latency 5. Expected processing time (time from receipt of SPaT to the time the alert is issued) 6. SPaT data (received from the RSU) 7. MAP data (received from the RSU) 8. RTCM data (received from the RSU)</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
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<tr>
<td>V2I Safety</td>
<td>Reduced Speed Zone Warning</td>
<td></td>
<td>The Reduced Speed Zone Application shall identify when a host vehicle is expected to enter the reduced speed zone but not traveling below the reduced zone speed limit (given its current location, motion and expected deceleration rate) during an active work zone by using the following data items: 1. Reduced speed zone area (manually entered) 2. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus) 3. RSM data (Received from the RSU) 4. MAP data (Received from the RSU) 5. RTCM data (Received from the RSU)</td>
<td>Demonstration</td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Lane Closure Warning</td>
<td></td>
<td>The Lane Closure Warning Application shall identify when a host vehicle is expected to enter the a lane closure zone but has not yet departed the drop lane (given its current location, motion and expected deceleration rate) during an active work zone by using the following data items: 1. Lane closure area (manually entered) 2. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus) 3. RSM data (Received from the RSU) 4. MAP data (Received from the RSU) 5. RTCM data (Received from the RSU)</td>
<td>Demonstration</td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Pedestrian Actuated Beacon Crossing Warning (PabCW)</td>
<td></td>
<td>The Pedestrian Actuated Beacon Crossing Warning Application shall identify when a host vehicle is expected to enter the crosswalk warning zone that has been actuated by a pedestrian (given its current location and motion) by using the following data items: 1. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus) 2. RSM data (Received from the RSU) 3. MAP data (Received from the RSU) 4. RTCM data (Received from the RSU)</td>
<td>Demonstration</td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Pedestrian Actuated Beacon Crossing Warning (PabCW)</td>
<td></td>
<td>The OBU (host) shall parse received RSMs to identify the crosswalk warning has been activated.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Curve Speed Warning</td>
<td></td>
<td>The Curve Speed Warning Application shall identify when a host vehicle is expected to enter the Curve Speed zone but not below the posted speed limit (given its current location, motion and expected braking rate) by using the following data items: 1. Location and motion data for the host vehicle (from GPS, OBU Onboard sensors, and/or the host vehicle CANBus) 2. RSM data (Received from the RSU) 3. RTCM data (Received from the RSU)</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td></td>
<td>An OBU host processor shall perform integrity checks on boot to ensure that it is in a known good software state.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td></td>
<td>An OBU shall not continue to start up and will log an error if the host processor determines it is not in a known good</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td></td>
<td>The OBU should notify the vehicle operators of the power status of device (e.g., off, powering up and online).</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td></td>
<td>An OBU shall acquire time from the Location and Time Service (LTS) interface in accordance with J2945/1 section 6.2.4.</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
This section provides the high-level requirements for the system of interest (i.e. what the system will do).

<table>
<thead>
<tr>
<th>ReqID</th>
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<tbody>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall acquire location from the LTS interface in accordance with J2945/1 section 6.2.1</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU may capture vehicle brake status over the OBU-OBD-II interface to the host vehicle</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU device shall comply with IEEE 1609.2: Standard for WAVE Security Services for Applications and Management Messages</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall implement a download protocol that permits resumption of incomplete downloads instead of requiring an incomplete download to be restarted.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall receive position data from GNSS satellites</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall not allow the driver to adjust settings while the vehicle is in motion.</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall present alerts to drivers (via the HMI) using an HMI device that drivers are familiar with and limits driver interaction.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall communicate with a vehicle operator via an HMI</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall have two levels of alert</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall have a low-level alert</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The low-level alert shall consist of a configurable audio/visual warning</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall have a high-level alert</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The high-level alert shall consist of a configurable audio/visual warning</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The high-level alert shall be louder and more visible compared to the low-level alert</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall not display more than one alert to the Vehicle Operator at a time</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall contain a configurable priority order for notifying with alerts</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The order of alerts shall be configurable so that the order of alerts can be modified once priority has been established.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU should provide system status information to vehicle operators. Information included in the system status includes power status, system settings, status of applications availability, and pending update status</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall provide messages that can be seen and/or heard by the vehicle vehicle operator via the HMI from the vehicle operator’s normal seating position</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall provide only the highest priority alert to the vehicle operator when more than one alert is currently active</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU should provide a visual output (via the HMI) that is similar in look and feel (i.e. similar in size, consistent use of color in icons or graphics, similar styles of icons or graphics) from various applications, if presenting visual information to vehicle operators</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall issue an alert to the vehicle operator via the HMI when a red-light violation will occur at an RSU-equipped intersection</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall determine if the OBU-equipped (host) vehicle will run a red light for each SPaT message it receives, provided it has also received a MAP message for the intersection that corresponds to the SPaT message.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>ReqID</td>
<td>Functional Group</td>
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<td>Description</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall determine when to issue a Red Light Violation Warning alert</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall issue an alert to the vehicle operator via the HMI when the OBU-equipped (host) vehicle will enter an RSU-equipped reduced speed zone over the reduced speed limit</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall issue an alert when the OBU-equipped (host) vehicle is inside of an RSU-equipped reduced speed zone over the reduced speed limit</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall determine when to issue a Reduced Speed Zone alert</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall issue an alert to the vehicle operator via the HMI when the OBU-equipped (host) vehicle will enter an RSU-equipped curve speed warning zone over the curve speed limit</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall determine when to issue a Curve Speed warning alert</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall issue an alert to the vehicle operator via the HMI when the OBU-equipped (host) vehicle will enter an RSU-equipped work zone lane closure warning zone</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall determine when to issue a Work Zone Lane Closure Warning alert</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU (host) shall issue an alert to the vehicle operator via the HMI when a OBU-equipped (host) approaches a RSU-equipped Pedestrian in crosswalk zone that has been activated</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU should provide system status to drivers (via the HMI) (e.g. off, powering up, online, powering down)</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall support over-the-air updates.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>ReqID</td>
<td>Functional Group</td>
<td>Sub-Component</td>
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</tr>
<tr>
<td>DSRC</td>
<td>Basic Safety</td>
<td>Message</td>
<td>The BSM shall be broadcast at a frequency of 10 Hz when congestion control algorithms (SAE J2945/1) do not prescribe a reduced rate</td>
<td>Test</td>
</tr>
<tr>
<td>DSRC</td>
<td>Basic Safety</td>
<td>Message</td>
<td>The BSM shall always include Part I data (SAE J2735, Section 6.8)</td>
<td>Demonstration</td>
</tr>
<tr>
<td>DSRC</td>
<td>Basic Safety</td>
<td>Message</td>
<td>The BSM shall be broadcast at the frequency specified by congestion control algorithms (SAE J2945/1) when congestion control algorithms (SAE J2945/1) prescribe a reduced frequency</td>
<td>Demonstration</td>
</tr>
<tr>
<td>DSRC</td>
<td>MapData</td>
<td>Message</td>
<td>The MAP message shall be expressed with an accuracy of 0.5 m or less.</td>
<td>Inspection</td>
</tr>
<tr>
<td>DSRC</td>
<td>MapData</td>
<td>Message</td>
<td>The MAP message shall be transmitted with a frequency of at least 1 Hz</td>
<td>Demonstration</td>
</tr>
<tr>
<td>DSRC</td>
<td>Signal Phase</td>
<td>and Timing Message</td>
<td>The SPaT messages shall be transmitted by the RSU with a minimum frequency of 10 Hz</td>
<td>Test</td>
</tr>
<tr>
<td>DSRC</td>
<td>Signal Phase</td>
<td>and Timing Message</td>
<td>The RSM messages shall be transmitted by the RSU with a minimum frequency of 1 Hz</td>
<td>Test</td>
</tr>
<tr>
<td>DSRC</td>
<td>Signal Phase</td>
<td>and Timing Message</td>
<td>The SPaT MsgCount data field shall be incremented with every update that is made to the corresponding IntersectionState data frame</td>
<td>Test</td>
</tr>
<tr>
<td>DSRC</td>
<td>Signal Phase</td>
<td>and Timing Message</td>
<td>The SPaT MovementStates shall be updated with at least the computation frequency of the traffic signal controller. If the controller is operating at 1 Hz, it is permissible to repeat the same MovementState information in 10 SPaT messages. However, if the controller is operating at 10 Hz or greater, the MovementStates needs to be updated for every message.</td>
<td>Test</td>
</tr>
<tr>
<td>Roadside</td>
<td>Roadside Unit</td>
<td></td>
<td>The system clock of the RSU shall be accurate to within 10 ms of the UTC reference</td>
<td>Inspection</td>
</tr>
<tr>
<td>Roadside</td>
<td>Roadside Unit</td>
<td></td>
<td>All absolute times in any message shall be determined based on the RSU’s system clock</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Roadside</td>
<td>Roadside Unit</td>
<td></td>
<td>The time difference between minEndTime (in the UTC reference system) and the earliest possible physical phase change shall be no larger than 100 ms</td>
<td>Test</td>
</tr>
<tr>
<td>Roadside</td>
<td>Roadside Unit</td>
<td></td>
<td>The time difference between maxEndTime (in the UTC reference system) and the earliest possible physical phase change shall be no larger than 100 ms</td>
<td>Test</td>
</tr>
<tr>
<td>Roadside</td>
<td>Roadside Unit</td>
<td></td>
<td>The data elements MinuteOfTheYear and DSecond shall be present in each transmitted message and accurate within 100 ms of UTC time</td>
<td>Test</td>
</tr>
<tr>
<td>Traffic</td>
<td>Infrastructure</td>
<td>Management System</td>
<td>The infrastructure management system shall notify designated personnel within five minutes of limited connectivity. Note: Limited connectivity refers to a state when the system is not able to communicate with the RSU</td>
<td>Test</td>
</tr>
<tr>
<td>Traffic</td>
<td>Infrastructure</td>
<td>Management System</td>
<td>The infrastructure management system shall notify designated personnel within five minutes of a monitored function becoming unavailable</td>
<td>Test</td>
</tr>
<tr>
<td>Traffic</td>
<td>Infrastructure</td>
<td>Management System</td>
<td>The infrastructure management system shall be able to store at a minimum of 10 TB of archived CV data</td>
<td>Inspection</td>
</tr>
<tr>
<td>Traffic</td>
<td>Infrastructure</td>
<td>Management System</td>
<td>The infrastructure management system shall be able to store at a minimum of 10 TB of backup archived CV data</td>
<td>Inspection</td>
</tr>
<tr>
<td>Traffic</td>
<td>Infrastructure</td>
<td>Management System</td>
<td>The infrastructure management system shall copy all archived CV data into the backup archived CV data once per day.</td>
<td>Demonstration</td>
</tr>
<tr>
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<tr>
<td>V2I Safety</td>
<td>Red Light Violation Warning (RLVW)</td>
<td>The RLVW application should employ algorithms that are used in applications verified by CAMP to issue an RLVW warning</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Red Light Violation Warning (RLVW)</td>
<td>The RLVW application shall meet TRL 6 criteria (has been tested in a realistic environment outside of a laboratory and satisfies operational requirements when confronted with realistic problems)</td>
<td>Analyze</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Red Light Violation Warning (RLVW)</td>
<td>The RLVW application shall issue alerts with a false discovery rate (number of false positive alerts divided by total number of alerts) no greater than 2%.</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Reduced Speed Zone (RSZ)</td>
<td>The RSZ application should employ algorithms that are used in applications verified by CAMP to issue an RSZ warning</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Reduced Speed Zone (RSZ)</td>
<td>The RSZ application shall meet TRL 6 criteria (has been tested in a realistic environment outside of a laboratory and satisfies operational requirements when confronted with realistic problems)</td>
<td>Analyze</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Reduced Speed Zone (RSZ)</td>
<td>The RSZ application shall issue alerts with a false discovery rate (number of false positive alerts divided by total number of alerts) no greater than 2%.</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Curve Speed (CS) Warning</td>
<td>The CS Warning application should employ algorithms that are used in applications verified by CAMP to issue an CS warning</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Curve Speed (CS) Warning</td>
<td>The CS Warning application shall meet TRL 6 criteria (has been tested in a realistic environment outside of a laboratory and satisfies operational requirements when confronted with realistic problems)</td>
<td>Analyze</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Curve Speed (CS) Warning</td>
<td>The CS Warning application shall issue alerts with a false discovery rate (number of false positive alerts divided by total number of alerts) no greater than 2%.</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Work Zone Lane Closure (WZLC) Warning</td>
<td>The WZLC Warning application should employ algorithms that are used in applications verified by CAMP to issue an WZLC warning</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Work Zone Lane Closure (WZLC) Warning</td>
<td>The WZLC Warning application shall meet TRL 6 criteria (has been tested in a realistic environment outside of a laboratory and satisfies operational requirements when confronted with realistic problems)</td>
<td>Analyze</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Work Zone Lane Closure (WZLC) Warning</td>
<td>The WZLC Warning application shall issue alerts with a false discovery rate (number of false positive alerts divided by total number of alerts) no greater than 2%.</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Pedestrian Actuated Beacon Crossing Warning (PabCW)</td>
<td>The PED Warning application should employ algorithms that are used in applications verified by CAMP to issue an PED warning</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>V2I Safety</td>
<td>Pedestrian Actuated Beacon Crossing Warning (PabCW)</td>
<td>The PED Warning application shall meet TRL 6 criteria (has been tested in a realistic environment outside of a laboratory and satisfies operational requirements when confronted with realistic problems)</td>
<td>Analyze</td>
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</tr>
<tr>
<td>V2I Safety</td>
<td>Pedestrian Actuated Beacon Crossing Warning (PabCW)</td>
<td>The PED Warning application shall issue alerts with a false discovery rate (number of false positive alerts divided by total number of alerts) no greater than 2%.</td>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>Vehicle onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall have a minimum reserve (processor, dynamic storage, persistent storage) capacity of 50% upon deployment to have the capacity to install and run future firmware image updates</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Vehicle onboard Equipment</td>
<td>OBU</td>
<td>The OBU HMI shall present an alert to the vehicle operator in a succinct manner while the vehicle operator is engaged in the driving task to minimize the 'eyes off the road' time.</td>
<td>Demonstration</td>
<td></td>
</tr>
</tbody>
</table>
### PERFORMANCE REQUIREMENTS

This section provides the performance requirements (PR) for the system of interest (i.e. what the system will do).

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>Vehicle onboard Equipment</td>
<td>OBU</td>
<td>The OBU Auditory signals (via the HMI) shall be loud enough to overcome masking sounds from road noise, the cab environment, and other equipment.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Mobile Configuration Interface</td>
<td>The mobile configuration interface shall provide the ability to configure MAP and/or RSM messages for RSUs along US 33 in support of the Reduced Speed Zone Warning/Lane Closure Application</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
### INTERFACE REQUIREMENTS

The 33 SMC interfaces allow dynamic and configurable functionality between internal components of the US33 System of Systems (SoS) and external systems that provide data or some other stated functionality as per the user needs.

<table>
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<tr>
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<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall receive security certificates from the ODOT statewide SCMS</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall be able to store security certificates</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall have the ability to receive RSM from the infrastructure management system</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall have the ability to receive MAP message from the 33 SMC Management Software system</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall receive position data</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall receive SpaT messages from the Traffic Signal Controller</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall be powered via power over Ethernet (cat6a)</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable that connects to equipment located outside of the traffic signal controller cabinet shall be outfitted with an in-line grounding mechanism</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable that connects to equipment located outside of the site controller cabinet shall be outfitted with an in-line grounding mechanism</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable that connects to equipment located outside of the site controller cabinet shall be outfitted with an in-line grounding mechanism (outdoor rated)</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable that connects to equipment located outside of the traffic signal controller cabinet shall be weatherproof (outdoor rated)</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable that connects to equipment located outside of the traffic signal controller cabinet shall be double shielded</td>
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<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable that connects to equipment located outside of the site controller cabinet shall be double shielded</td>
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<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>The RSU-SCMS interface shall allow a RSU to request application certificates with different contents from the current ones during the lifetime of the current ones.</td>
<td>Demonstration</td>
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<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Communication between the RSU and an SCMS shall operate in an encrypted, end-to-end connection in accordance with the ODOT SCMS interface. (Note: An SCMS interface should not need any further security.)</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Roadside Equipment</td>
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<td>An RSU shall send SpaT messages generated from traffic signal controller output to an OBU</td>
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<td></td>
<td>Roadside Equipment</td>
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<td>Roadside Equipment</td>
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<td></td>
<td>Roadside Equipment</td>
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<td></td>
<td>Traffic Management</td>
<td>Management</td>
<td>The infrastructure management system shall use a user interface to geographically display the location of each RSU and RSU information</td>
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</table>
The 33 SMC interfaces allow dynamic and configurable functionality between internal components of the US33 System of Systems (SoS) and external systems that provide data or some other stated functionality as per the user needs.

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<td>Vehicle Onboard Equipment</td>
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<td></td>
<td>Vehicle Onboard Equipment</td>
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<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall receive BSMs from an OBU</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall receive SPaT messages from an RSU</td>
<td>Demonstration</td>
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<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall receive MAP messages from an RSU</td>
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<td></td>
<td>Vehicle Onboard Equipment</td>
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<td></td>
<td>Vehicle Onboard Equipment</td>
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<td></td>
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<tr>
<td>ReqID</td>
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<tr>
<td>DSRC Messages</td>
<td>Basic Safety Message</td>
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<td>The BSM Part I shall include all data elements contained in the (coreData) BSMoreData data frame (SAE J2735, Section 6.8)</td>
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<td>DSRC Messages</td>
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<td>The MAP Message shall contain the (msgIssueRevision) MsgCount data element (SAE J2735, Section 7.104)</td>
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<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (intersections) IntersectionGeometryList data frame (a sequence of IntersectionGeometry; SAE J2735, Section 6.35)</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
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<td>The MAP Message shall contain the IntersectionGeometry data frame under the (intersections) IntersectionGeometryList data frame</td>
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<td>DSRC Messages</td>
<td>MapData Message</td>
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<td>The MAP Message shall contain the (id) IntersectionReferenceID data frame (SAE J2735, Section 6.36) under the IntersectionGeometry data frame</td>
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<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (id) IntersectionID data element (SAE J2735, Section 7.56) under the (id) IntersectionReferenceID data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
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<td>The MAP Message shall contain the (revision) MsgCount data element (SAE J2735, Section 7.104) under the IntersectionGeometry data frame</td>
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<td>DSRC Messages</td>
<td>MapData Message</td>
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<td>The MAP Message shall contain the (refPoint) Position3D data frame (SAE J2735, Section 6.87) under the IntersectionGeometry data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (lat) Latitude data element (SAE J2735, Section 7.91) under the (refPoint) Position3D data frame</td>
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<tr>
<td>DSRC Messages</td>
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<td>The MAP Message shall contain the (long) Longitude data element (SAE J2735, Section 7.95) under the (refPoint) Position3D data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (laneWidth) LaneWidth data element (SAE J2735, Section 7.90) under the IntersectionGeometry data frame</td>
<td>Demonstration</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (lanes) List of lanes data frame (sequence of GenericLane; SAE J2735, Section 6.47) under the IntersectionGeometry data frame</td>
<td>Demonstration</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the GenericLane data (SAE J2735, Section 6.29) under the LaneList data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (laneID) LaneID data element (SAE J2735, Section 7.88) under the GenericLane data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (maneuvers) AllowedManeuvers data element (SAE J2735, Section 7.4) under the GenericLane data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the NodeListXY data frame (SAE J2735, Section 6.72) under the GenericLane data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
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<td>The MAP Message shall contain the (nodes) NodeSetXY data frame (SAE J2735, Section 6.77) under the NodeListXY data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
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<td>The MAP Message shall contain the NodeXY data frame (SAE J2735, Section 6.78) under the NodeSetXY data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td></td>
<td>The MAP Message shall contain the (delta) NodeOffsetPointXY data element (Any representation Node-XY-20b through Node-XY-32b; SAE J2735, Section 6.61, 6.62, 6.63, 6.64, 6.65, 6.66)</td>
<td>Demonstration</td>
</tr>
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The data requirements (DR) for the core system of interest defines the data collected, transformed, and stored from various sources as well as identifies new data that is expected to be generated.

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<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message shall contain the (connectsTo) ConnectsToList data frame (a sequence of Connection; SAE J2735, Section 6.16) under the GenericLane data frame</td>
<td>Demonstration</td>
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</tr>
<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message shall contain the Connection data frame (SAE J2735, Section 6.14) under the (connectsTo) ConnectsToList data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message shall contain the (connectingLane) ConnectingLane data frame (SAE J2735, Section 6.13) under the Connection data frame</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message shall contain the (lane) LaneID data element (SAE J2735, Section 7.88) under the (connectingLane) ConnectingLane data frame</td>
<td>Demonstration</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message shall contain the (maneuver) AllowedManeuvers data element (SAE J2735, Section 7.4) under the (connectingLane) ConnectingLane data frame</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message should describe all egress lanes. This makes it possible to connect each ingress lane to the corresponding egress lane and also to describe the allowed maneuvers on all ingress lanes.</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message egress lanes (if included) may optionally contain a maneuvers field or a connectsTo field</td>
<td>Demonstration</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message egress lanes (if included) may optionally contain the nodes in the NodeSet sequenced such that the first node is the stop bar</td>
<td>Demonstration</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message Node points shall correspond to the center of the lane</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message Node points should extend to a recommended minimum of 300 m from the stop bar</td>
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<tr>
<td>DSRC Messages</td>
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<td>The MAP Message shall include a minimum of two node points to define the lane</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP Message shall define node points such that the perpendicular distance between two node points and the center of the lane shall be less than 0.5 m</td>
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<tr>
<td>DSRC Messages</td>
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<tr>
<td>DSRC Messages</td>
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<tr>
<td>DSRC Messages</td>
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<td>The MAP Message shall contain a maneuvers field and a connectsTo field for each ingress lane. The connectsTo field describes one or more Connections to egress lanes.</td>
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<tr>
<td>DSRC Messages</td>
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<td>The MAP Message Connection field shall contain the lane, maneuver, and signalGroup associated with the Connection. The signalGroup identifies which signal group in the SPaT controls the flow of traffic from the ingress lane to the egress lane.</td>
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<tr>
<td>DSRC Messages</td>
<td>MapData Message</td>
<td>The MAP message containing a single physical lane which has multiple different signals assigned (e.g., for straight and for right-turn movement), shall be represented by a single ingress lane and multiple connections that specify the relevant movements and the associated signal groups</td>
<td>Demonstration</td>
<td></td>
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<td>DSRC Messages</td>
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<tr>
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<tr>
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<tr>
<td>DSRC Messages</td>
<td>Signal Phase and Timing Message</td>
<td>The SPaT Message shall contain the (status) IntersectionStatusObject data element (SAE J2735, Section 7.57) under the IntersectionState data frame</td>
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<td>DSRC Messages</td>
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<td>The SPaT Message shall contain the (eventState) MovementPhaseState data element (SAE J2735, Section 7.103) under the MovementEvent data frame</td>
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<td>DSRC Messages</td>
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<td>The SPaT Message shall contain the (timing) TimeChangeDetails data frame (SAE J2735, Section 6.134) under the MovementEvent data frame</td>
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<td>The SPaT Message shall contain the (maxEndTime) TimeMark data element (SAE J2735, Section 7.194) under the TimeChangeDetails data frame</td>
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<td>Signal Phase and Timing Message</td>
<td>The SPaT Message shall contain the (likelyTime) TimeMark data element (SAE J2735, Section 7.194) under the TimeChangeDetails data frame</td>
<td>Demonstration</td>
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<td></td>
<td>DSRC Messages</td>
<td>Signal Phase and Timing Message</td>
<td>The SPaT Message shall contain a 'states' field, which is a list of one or more MovementStates. The number of MovementStates shall correspond to the number of movements defined in the MAP messages which should be based on controller traffic phases that are currently active.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>DSRC Messages</td>
<td>Signal Phase and Timing Message</td>
<td>The SPaT Message signalGroup shall be assigned number and is not necessarily based on the controller phase number</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>DSRC Messages</td>
<td>Signal Phase and Timing Message</td>
<td>The SPaT Message should provide maxEndTime or likelyTime</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall remove PII from data prior to sending it to the 33 SMC OS where it is made publicly available.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>V2I Mobility</td>
<td>Vehicle Data for Traffic Operations</td>
<td>The infrastructure management system shall capture data from all messages transmitted or received by an RSU</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
### SECURITY REQUIREMENTS

The security requirements (SR) for the core system of interest specifies what is necessary to protect the integrity and operability of the system, its microservices, connections, and data. This includes physical security as well as cyber prevention, detection, identification, response and recovery requirements.

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<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSUs shall support role-based authentication to enable physical access</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall verify received messages per IEEE 1609.2 and per the relevant security profiles before using them for operations in any application.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall verify a DSRC message if a device identifies the message as containing a new DE_TemporaryID value.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall support setting the certificate geographic region to be requested for application certificates.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall support establishment of a standard TLS-based VPN with client authentication for communication to the infrastructure management system, with a long-term client cert and a single CA cert trusted to authorize connections from the infrastructure management system.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall require that 1609.2 signed messages are signed by a certificate that is protected from modification by, or chains back to a certificate that is protected from modification by, the secure boot process.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall provide tamper evidence to detect tampering of the device (e.g. opening of the case).</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall implement a firewall blocking all IP access from devices to any IP address other than those approved for specific applications.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall comply with IEEE 1609.2: Standard for WAVE Security Services for Applications and Management Messages.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall delete old certificates if it has been moved to another intersection.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSU shall be FIPS 140-2 compliant.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall detect abnormal unauthorized activity on an IP connection.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall monitor the DSRC communications performance to detect DoS attacks.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Traffic Management Center</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall monitor the data traffic usage to detect unapproved use of the IP connection.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall cease transmission of BSMs if the OBU determines that it has been blacklisted. Note: Blacklists detail devices that should not be trusted in the system or network</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall prevent incoming messages with invalid conditions per criteria in the IEEE 1609.2 from being acted on.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU Vehicle Communications link shall have communications security to ensure the authenticity of all its messages in accordance to the standards prescribed by wireless messaging security standards.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall carry out plausibility checking on the remote vehicle BSM data.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall indicate successful receipt of the pseudonym certificates.</td>
<td>Demonstration</td>
</tr>
</tbody>
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The security requirements (SR) for the core system of interest specify what is necessary to protect the integrity and operability of the system, its microservices, connections, and data. This includes physical security as well as cyber prevention, detection, identification, response and recovery requirements.

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<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>When the OBU has no valid BSM signing certificates, it shall store the log file entries as IEEE 1609.2 data of type unsecured.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>The OBU shall obtain certificates via IPv6 connectivity through the RSU.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall communicate using SNMPv3 with SNMP messages protected by being sent over TLS.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall verify received messages per IEEE 1609.2 and per the relevant security profiles before using them for operations in any application.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall provide real-time tamper data which indicates that the device has been tampered with (e.g. opening of the case).</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall require that 1609.2 signed messages are signed by a certificate that is protected from modification by, or chains back to a certificate that is protected from modification by, the secure boot process.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall only transmit messages for any usage scenario if the usage scenario requires it to use 1609.2 certificates and it currently has valid certificates for that usage scenario.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall verify a DSRC message when a device identifies the message as containing a new DE_TemporaryID value.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall verify a DSRC message when the message results in the issuance of an advisory, warning, or alert.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall verify a DSRC message when the remote vehicle constitutes a potential threat (define potential threat as a vehicle that may collide with the host vehicle based on the both vehicle’s speeds and trajectories.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall verify a DSRC message when other potential threat situations such as red-light violations, and other safety applications are active.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>RSU shall be FIPS 140-2 compliant.</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
The policy and regulation requirements (RG) for the system of interest specifies relevant and applicable organizational policies and regulations that affect the development, operation or performance of the system (e.g. IT and labor policies, reports to regulatory agencies, health or safety criteria, etc.). This section also includes new policy and regulation imposed to realize the system.

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<tbody>
<tr>
<td>Common</td>
<td>Common</td>
<td>An RSU shall be licensed (subpart M of Part 90 of FCC Rules) by the FCC</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>An RSU shall be registered (RSU sites, channels, and other relevant data) by site and segment with the FCC before operation</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>An OBU shall meet the license requirements as specified in subpart I of part 95 of FCC rules</td>
<td>Inspection</td>
<td></td>
</tr>
<tr>
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<td>-----------------------------------------------------------------------------</td>
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</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>RSU</td>
<td>DSRC antennas shall be located to maximize the DSRC range along the corridors of interest.</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSU DSRC antennas shall be located no higher than 25' above the ground</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSU GPS antennas shall be located to maximize the GPS reception</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>Ethernet cable spans shall not exceed 100 meters (328 feet)</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>A traffic signal controller cabinet that contains Roadside Equipment shall be outfitted with tamper alert devices to prevent unauthorized physical access to networking components.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>A RSU site controller cabinet that contains Roadside Equipment shall be outfitted with tamper alert devices to prevent unauthorized physical access to networking components.</td>
<td>Demonstration</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSUs shall be located on a network that is physically isolated from the existing respective City Traffic Signal System network.</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSUs shall be located on a network that is physically isolated from the existing respective ITS (state or local) System network.</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Traffic Management</td>
<td>Infrastructure Management System</td>
<td>The infrastructure management system shall store archived CV data and backup archived CV data on separate physical storage devices.</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard</td>
<td>OBU</td>
<td>The OBU HMI shall be mounted or installed in a location where it does not obstruct the line of sight of the Operator nor distract the Operator from the primary task of driving.</td>
<td>Inspection</td>
</tr>
<tr>
<td></td>
<td>Vehicle Onboard</td>
<td>OBU</td>
<td>The OBU shall be positioned in a location such that it can provide a visual and audible output to the driver (via the HMI) that can be read from the driver’s normal seated position, if visual alerts are used.</td>
<td>Inspection</td>
</tr>
</tbody>
</table>

**PHYSICAL REQUIREMENTS**

The physical requirements specify the construction, durability, adaptability and environmental characteristics of the system, such as installation location, device weight limits, dimension and volume limitations, temperature regulations, layout, access for maintenance, growth and expansion characteristics, etc.
### AVAILABILITY & RECOVERABILITY REQUIREMENTS

The availability requirements define the times of day, days of year, and overall percentage the system can be used and when it will not be available for use. It also specifies the recovery time objective (RTO) of the system, which describes the time frame permitted for a system to become operational, the recovery point objective (RPO), which specifies up to what point in time shall the data be restored, as well as how the system is expected to restore services (e.g. failover, backups, etc.) in an event of a failure. The ability to recover quickly from a system failure or disaster depends on a blend of technologies and having a predefined plan for recovering the data on new hardware, when appropriate.

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<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>An RSU shall be available 99% of the time when power is available to the network.</td>
<td>Analyze</td>
</tr>
<tr>
<td></td>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSU shall return to an operational state within 5 min of regaining power</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
### MAINTAINABILITY REQUIREMENTS

The maintainability requirements for the system specify the level of effort required to locate and correct an error during operation, establishing a quantitative requirement for planned and unplanned support (e.g., mean and maximum times to repair or resolve issues, number of people and skill levels required, support equipment necessary, maintenance staff hours, time and frequency of preventative maintenance, etc.).

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<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>The COG shall retain Support Staff to troubleshoot and diagnose RSU and OBU issues</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>A set of support, diagnostic and troubleshooting procedures shall be developed to guide the support staff.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>The COG shall maintain a list of the OBU equipment and contact information for vehicle owners that have OBUs installed</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>The COG shall maintain an asset management list of the RSU equipment that includes (Vendor contact information, installation date, application use, model number, IP address, etc.)</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>Support Staff shall be trained by the RSU Integrator to install RSU Devices</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>Support Staff shall be trained by the OBU Integrator to install OBU Devices</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>The COG and/or city shall maintain the RSUs installed within Marysville and Dublin</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>The COG shall maintain the RSUs installed along US-33</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>ODOT shall maintain the RSU infrastructure installed along US-33</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>Appointed agency contractors shall maintain the Fiber optic network for 33 SMC</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Roadside Equipment</td>
<td>Roadside Unit</td>
<td>RSUs shall support physical access to support maintenance activities</td>
<td>Demonstration</td>
<td></td>
</tr>
<tr>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall support physical access to support maintenance activities</td>
<td>Demonstration</td>
<td></td>
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<tr>
<td>Vehicle Onboard Equipment</td>
<td>OBU</td>
<td>An OBU shall support role-based authentication to enable physical access.</td>
<td>Demonstration</td>
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<td>------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td></td>
<td>Removed RSUs shall be returned to the COG or relocated and configured to a comparable location.</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Common</td>
<td>Common</td>
<td></td>
<td>A participant shall be able to return the OBU to the COG for any reason (OBU malfunction, remove/uninstall OBU, etc.)</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>

The relocation requirements are for devices that are removed from physical roadside locations or from equipped vehicles.
### DISPOSAL REQUIREMENTS

The disposal requirements (DR) specify the items related to the disposal of project/system components, due to either failure replacements, removal, end-of-life upgrade, or retirement.

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<tr>
<td>Common</td>
<td>Common</td>
<td>Common</td>
<td>The 33 SMC should remain operational after the completion of the operational test period</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
APPENDIX D – REQUIREMENTS VERIFICATION MATRIX

Appendix D is a separate stand-alone Excel File. See following FTP Site:
**Roadside Unit (RSU) Specification**

The RSU shall have the following requirements:

1. RSU’s must be fully compliant with IEEE 1609.1-1609.4, IEEE 802.11p.
2. RSU’s must conform to the Federal Highway Administration DSRC Roadside Unit (RSU) Specification v4.1 dated October 31, 2016, or most current. The vendor must specifically identify any requirements contained in this document that are not fully met.
3. The vendor shall provide documentation verifying compliance with the Federal Highway Administration DSRC RSU Specification v4.1 specification.
4. RSU supports latest published version of SAE J2735 compliant message sets, including but not limited to: basic safety message (BSM), Personal Safety Message (PSM), Signal Phase and Timing (SPaT), MAP, Roadside Alert Message (RAM), Roadside Safety Message (RSM) and Traveler Information Message (TIM). This includes ability to support the full range of Provider Service Identifiers (PSID) as specified in IEEE 1609.12-2012.
5. Be compatible with the following controllers, but not limited to, Econolite Cobalt, Econolite ATC 2070C, Intelight 2070LDX, Intelight NEMA X2, Intelight NEMA X3 and Siemens M60.
6. The RSU’s shall be capable of hosting customized software (developed by 3rd parties) that can process, decode, forward, and/or initiate a customizable Traveler Information Message or Roadside Alert. The RSU’s shall include the appropriate Software Development Kit (SDK), Application Programming Interface (API), and documentation to allow for third party applications.
7. The RSU shall include a GPS antenna (integrated or externally mounted and environmentally hardened)
8. The RSU shall include two Omni-Directional Antenna’s integrated or externally mounted and environmentally hardened. The RSU shall have a minimum of two external antenna mounting ports for DSRC broadcast with at least one additional mounting port for GPS antenna if external antenna is required for GPS support.
9. The Base/Management unit enclosure complies with NEMA TS2 Surge protection providing protection to RSU. More over grounding is included to protect against lighting spikes.
10. RSU is 802.3af Power over Ethernet (PoE) and IEC60950 compliant. The vendor shall provide a NEMA TS2 AC/DC power supply for powering PoE unit.
11. RSU must be compliant with applicable sections of Title 47 of the Code of Federal Regulations Part 15, Subpart C.
12. RSU must operate on a 5.9 GHz radio frequency.
13. RSU must support both transmitting and receiving data using DSRC radios.
14. RSU must be capable of supporting both 10 and 20 megahertz (MHz) channel widths.
15. RSU has at least one Ethernet RJ-45 port for network connection and supports IPv4 and IPv6 address configuration dual stacked. Ensure all management of the RSU may be performed through via the RJ-45 port.
16. Minimum 64 Megabyte (MB) Static Dynamic Radom Access Memory (SDRAM).
17. Minimum 500MHz Central Processing Unit (CPU) speed.
18. Performance Requirements for SPaT, MAP and RTCM to support applications include the following; SPaT broadcast at 10 Hz; MAP broadcast at 1 Hz. RTCM version 3.0 correction message type 1001 (GPS L1 Observations) at 5 Hz, and the message type 1005 (Antenna Reference Point (ARP) coordinates) at 2 Hz.
Item Details:
A Complete Kit shall include PoE Power Supply, Cabinet Surge Protection, Omni Antenna, Mounting Hardware, Wiring (100 ft) and all the necessary cables, connectors and any other hardware necessary to provide a fully functional unit to be deployed in the field. Kit shall include all necessary end connectors.

Mounting Hardware shall be provided for installation on either an ODOT Standard Drawing TC-81.10 Strain Pole, TC-81.21 Mast Arm, HL-10.11 or equivalent round pole.

Equipment (Other) covers any items that are necessary and not listed in order to have a fully functional field deployed unit.

Manufacturer Warranty shall include repair or replacement by the vendor without costs to the purchasing agency for any defect in design, materials, or workmanship that may occur during proper and normal use through final system acceptance during a two-year period following delivery of the unit. This warranty shall include the RSU, provided antennas, and the PoE injector.