Safety Management Plan (SMP)

for the Smart Columbus Demonstration Program

FINAL REPORT | November 7, 2019

Produced by City of Columbus

Notice

Acknowledgement of Support

This material is based upon work supported by the U.S. Department of Transportation under Agreement No. DTFH6116H00013.

Disclaimer

Abstract

This document presents the Safety Management Plan for the Smart Columbus demonstration program. The Smart Columbus demonstration program goal is to advance and enable safe, interoperable, networked wireless communications among vehicles, the infrastructure, and travelers' personal communications devices and to make surface transportation safer, smarter, and greener. The purpose of this document is to identify the major safety risks associated with the Smart Columbus demonstration program and lay out a plan to promote the safety of the participants and surrounding road users including drivers, pedestrians, bicyclists, and transit riders. The plan describes the potential safety risk scenarios related to the program and project applications proposed, assesses the level of risk for each safety scenario using the Automotive Safety Integrity Level (ASIL) process defined by international standard ISO 26262, provides mitigation strategies and puts forth a safety operational concept for the Smart Columbus demonstration program. This document also discusses coordination with other Smart Columbus demonstration program tasks.

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

1.1. SAFETY MANAGEMENT PLAN INTRODUCTION

The Safety Management Plan (SMP) for the Smart Columbus Demonstration Program is a companion document to the program and project-level systems engineering documents, including various Smart Columbus projects' Concept of Operations (ConOps) and System Requirements and Specifications (SyRS), the program's Data Management Plan (DMP) and Data Privacy Plan (DPP), a Human Use Approval Summary, and the Performance Measurement Plan (PfMP). It is the key document which outlines how each project ensures the safety of travelers and users of the various systems contained in the demonstration, and how the program ensures the security of the system data and communications.

This document follows the principles of assigning an Automotive Safety Integrity Level (ASIL) to the identified safety scenarios for each project, as the International Organization for Standardization (ISO) standard 26262 outlines. The authors also sought input from the eight Smart Columbus Program project teams to identify and assess safety issues, their impacts, and strategies to mitigate them. The result is a reference document for the Smart Columbus Project Management Office (PMO) and eight Smart Columbus project teams that aids in designing their projects, mitigates potential safety risks from the deployments, and protects the safety of travelers. This plan identifies the major safety issues associated with each project and lays out a preliminary plan to promote the safety of participants, motorists, other road users such as pedestrians, bicyclists, and transit riders, and any resident that may interact or engage with a solution or technology deployed by the projects.

The plan accomplishes these goals by describing the underlying needs of the demonstration with respect to participant and traveler safety. It also documents the impacts of various scenarios at the program and project levels; for example, power outages, communication failures, unintended or malicious attacks, severe crashes, and adverse weather conditions. It assesses each risk and documents the guidance on designing a safety-critical system that is capable of either eliminating these risks from the design, reducing the risks by modifying the design to lower the probability of the occurrence of the hazard, or – at a minimum – mitigating the impact of the hazard if it does occur.

The Smart Columbus PMO and project teams recognize the importance of safety for users of the smart vehicles, applications, and infrastructure this program will deploy. Although the teams will design and implement the project systems to be as fail-safe as possible, they cannot eliminate all potential for hazard due to unforeseen and uncontrollable events.

As a Federal research project, an Institutional Review Board (IRB) must provide oversight for Smart Columbus projects. Formal informed consent documents, which the IRB will review and approve, will add a level of safety by informing participants of their responsibilities and risks, and by implementing adequate training in the use of the connected devices. To further ensure safety, the Smart Columbus PMO and project teams will continue to evaluate additional enablers to improve participants' interactions with the systems. For example, a help program (telephone line, email address) will be considered to assist connected vehicle (CV) drivers and multimodal travelers using smartphone-based applications. In addition, the project risks and the implementation of the mitigation strategies to reduce the severity or likelihood of occurrence will be evaluated at least annually (if not more frequently).

As a pilot for smart cities, the SMP has been built into the design of each project rather than tracked as an afterthought. The development of the smart vehicle deployments, applications and infrastructure follow fault-tolerant or fail-safe procedures to eliminate or minimize the risk of faults and failures. The success of this demonstration depends on the public's acceptance that the safety of both the users and non-users of these technologies is enhanced and, at the very least, not endangered.

1.2. DOCUMENT OVERVIEW

This document includes the following chapters, which detail the Smart Columbus program's safety-critical system that is designed to address various, potential risks from project demonstration:

- **Chapter 1. Introduction** introduces the SMP.
- **Chapter 2. Smart Columbus Program** describes the demonstration program, its goals and vision and introduces the program's eight projects.
- **Chapter 3. Safety Risk Process and Approach** explains the program's overall approach to safety risk management as ISO 26262 outlines.
- **Chapter 4. Safety Needs** provides analysis and assessment of the safety scenarios identified within the Smart Columbus projects.
- **Chapter 5. Safety Operational Concept** explains the program's safety operational concept including its functional requirements, SMP and systemwide fail-safe mode.
- **Chapter 6. Coordination with Other Tasks** describes how this SMP coordinates with related program tasks.
- **Chapter 7. Conclusions** summarizes this document's conclusions.

1.3. REFERENCES

Table 1 lists the documents and literature this document used to gather information.

Table 1: References

Doc. No.	Title	Rev.	Pub. Date
–	Integrating Intelligent Driver Warning Systems: Effects of Multiple Alarms and Distraction on Driver Performance http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=E7907EDF6BF9081A68F3D9C0813658AE?doi=10.1.1.353.9940&rep=rep1&type=pdf	–	Nov. 15, 2005
–	Ohio Manual of Uniform Traffic Control Devices. Ohio Department of Transportation http://www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/traffic/OhioMUTCD/Pages/OMUTCD2012_current_default.aspx	–	Jan. 13, 2012
	Preparing a Safety Management Plan for Connected Vehicle Deployments https://www.its.dot.gov/pilots/pdf/CVP-Tech-Assistance-Webinar-Safety-Management_Final.pdf	–	Dec. 7, 2015
–	Connected Vehicle Pilot Deployment Program Phase 1, Safety Management Plan – ICF/Wyoming https://rosap.ntl.bts.gov/view/dot/30734	–	March 14, 2016

Doc. No.	Title	Rev.	Pub. Date
–	Central Ohio Transit Authority (COTA) – Long Range Transit Plan https://www.cota.com/wp-content/uploads/2016/04/LRTP.pdf	–	April 2016
–	Connected vehicle pilot deployment program phase 1, Safety Management Plan – Tampa (THEA) https://rosap.ntl.bts.gov/view/dot/30733	–	April 6, 2016
–	NYC CV Pilot Deployment: Safety Management Plan: New York City https://rosap.ntl.bts.gov/view/dot/31726	–	April 22, 2016
–	USDOT Guidance Summary for Connected Vehicle Pilot Site Deployers: Safety Management. Contract No. DTFH61-11-D-00018 https://rosap.ntl.bts.gov/view/dot/31556	–	July 1, 2016
–	Opportunities and Challenges of Smart Mobile Applications in Transportation https://www.sciencedirect.com/science/article/pii/S2095756416302690	–	Nov. 9, 2016
–	City of Columbus Americans with Disabilities Act (ADA) Rules and Regulations https://www.columbus.gov/publicservice/Design-and-Construction/document-library/Curb-Ramp-Construction/	–	April 1, 2018
–	Low-Speed Automated Shuttles: State of the Practice Final Report https://rosap.ntl.bts.gov/view/dot/37060	–	Sept. 9, 2018
	ISO 26262, Road Vehicle Functional Safety Standards https://www.iso.org/standard/68383.html		Dec 2018
–	Traffic Signal Design Manual. City of Columbus, Department of Public Service https://www.columbus.gov/WorkArea/DownloadAsset.aspx?id=2147506380	–	Oct. 1, 2018

Source: City of Columbus

Chapter 2. Smart Columbus Program

2.1. INTRODUCTION

The United States Department of Transportation (USDOT) pledged $40 million to the City of Columbus (COC) as the winner of the Smart City Challenge (SCC). By challenging American cities to use emerging transportation technologies to address their most pressing problems, USDOT aimed to spread innovation through a mixture of competition, collaboration and experimentation. The SCC called on cities to do more than merely introduce new technologies onto city streets. It called on them to boldly envision new solutions that would change the face of transportation in our cities by closing the economic gap, capturing the needs of both young and old, and bridging the digital divide through smart design so that the future of transportation meets the needs of all city residents.

As the winner of the SCC, the Smart Columbus program will demonstrate how advanced technologies can be integrated into other operational areas within the COC, utilizing advancements in Intelligent Transportation Systems (ITS) and connected and automated vehicle technologies to meet these challenges, while integrating data from various sectors and sources to simultaneously power these technologies while leveraging the new information they provide. Community and customer engagement will be present throughout the program, driving the requirements and outcomes for each project. This end-user engagement reinforces the idea that, ultimately, the residents of Columbus are the owners and co-creators of the Smart Columbus program.

2.2. PROJECT DESCRIPTION AND GOALS

The COC established the following vision and mission for its strategic Smart Columbus program:

- **Smart Columbus Vision:** Empower residents to live their best lives through responsive, innovative, and safe mobility solutions.
- **Smart Columbus Mission:** Demonstrate how equitable access to transportation can have positive impacts of every day challenges faced by cities.

The Smart Columbus program includes the following outcomes:

- **Improve Safety:** Columbus wants to create safer streets where vehicles, cyclists and pedestrians are less likely to be involved in crashes.
- **Enhance Mobility:** Columbus wants to make traversing the city and parking as efficient and convenient as possible.
- **Enhance Access to Opportunities and Services:** Columbus wants to make multimodal transportation options and the ability to access them equitably available to all residents; especially those who need to access to opportunities related to health care, jobs, school, and training.
- **Reduce Environmental Impact:** Columbus wants to reduce the negative impact transportation has on the environment through becoming more efficient and embracing multimodal options.
- **Agency Efficiency:** Columbus wants to provide tools and access to the data generated by the projects to improve operations and efficiency of the city services.
- **Customer Satisfaction:** Columbus wants to provide resources and information to the citizens to increase their satisfaction with city services through the use and application of technology.

Figure 1 shows the Smart Columbus vision, mission, and outcomes.

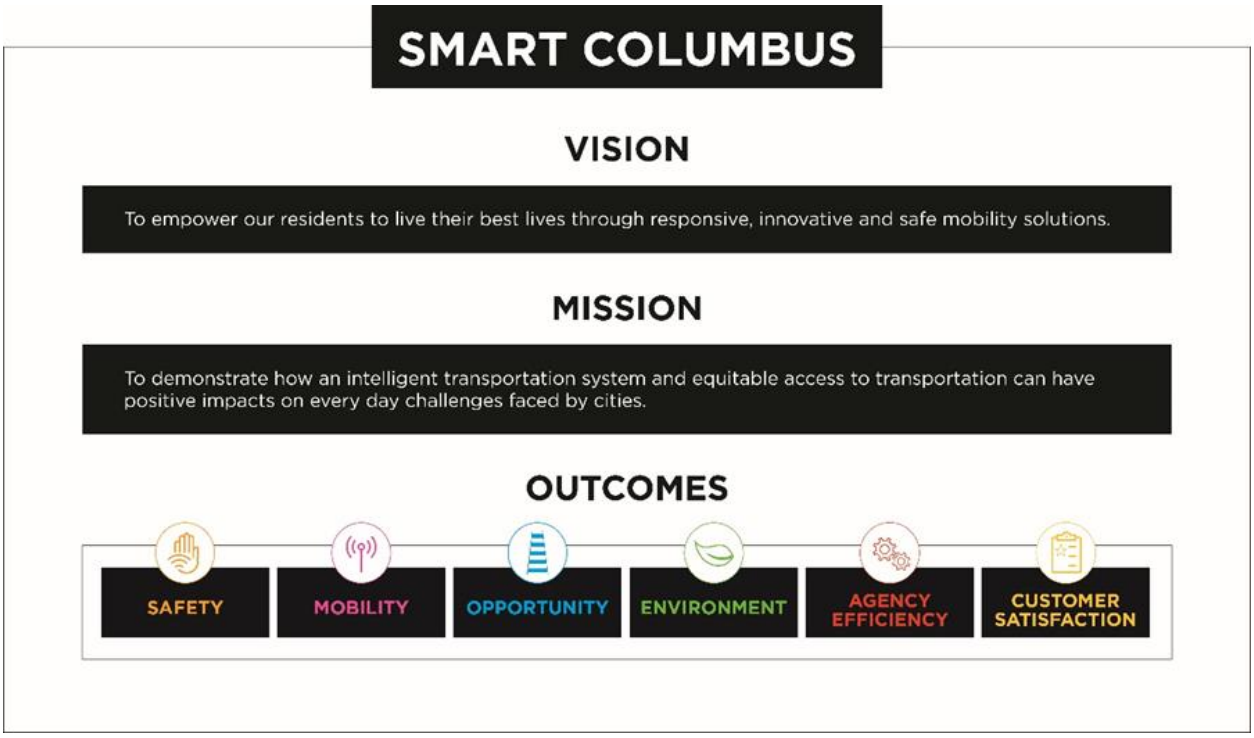

Figure 1: Smart Columbus Vision, Mission, and Outcomes

Source: City of Columbus

The Smart Columbus program organized these new capabilities into three focus areas addressing unique user needs: Enabling Technologies, Enhanced Human Services, and Emerging Technologies.

- **Enabling Technologies:** These advanced technologies use new and innovative ways to enhance safety and mobility of the transportation infrastructure. These technologies allow deployments that increase our capabilities with rich data streams and infrastructure that can respond on demand. The Connected Vehicle Environment (CVE) improves safety using cutting-edge technology that advances the sustainable movement of people and goods.
- **Enhanced Human Services:** These services encompass meeting human needs through technology applications that focus on preventing and remediating problems and improving users' overall quality of life with technology-based solutions. These projects create opportunity by improving access to jobs, health care, and events.
- **Emerging Technologies:** These are new and developing technologies that will substantially alter the business and social environments within the next five to 10 years. By focusing on key emerging technologies, the city can demonstrate potential future solutions to transportation and data-collection challenges.

2.3. PROJECT DESCRIPTIONS

Figure 2 summarizes the Smart Columbus Operating System (Operating System) and portfolio of USDOT projects. It depicts the criticality of the Operating System tying together these three themes, as well as the supporting projects under each theme.

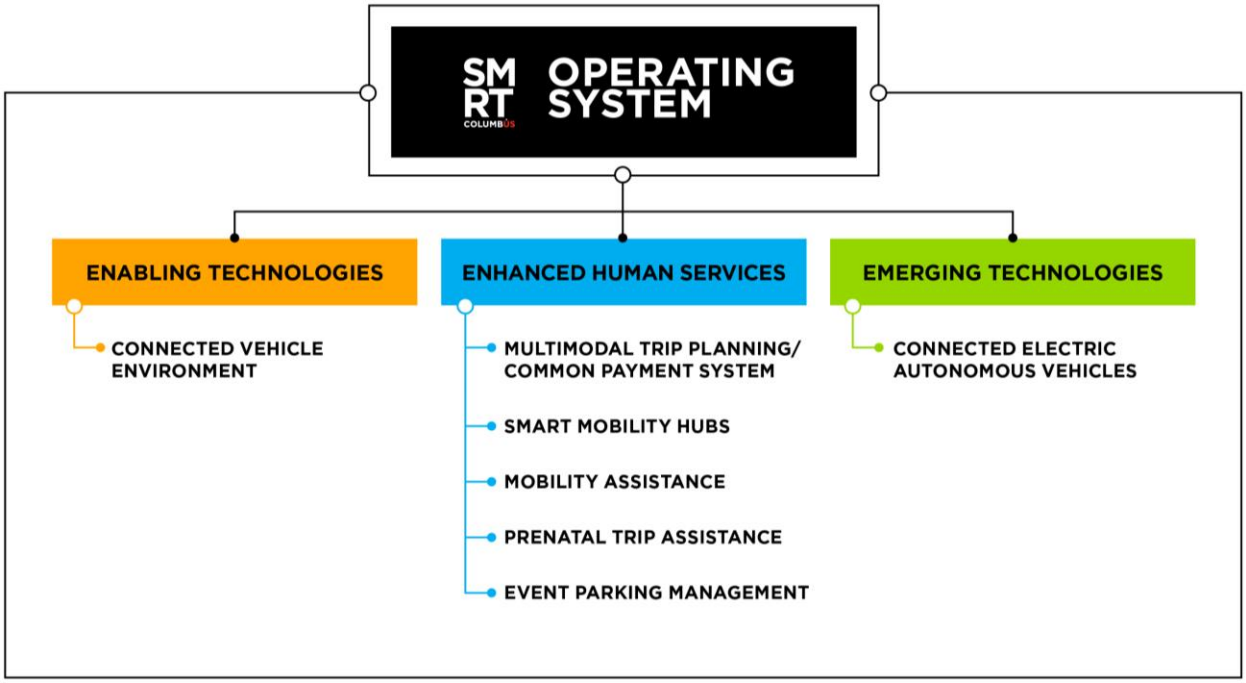

Figure 2: Smart Columbus Framework

Source: City of Columbus

2.3.1. Smart Columbus Operating System

The Operating System is envisioned as a web-based, dynamic, governed data delivery platform built on a federated architecture that is at the heart of the Smart Columbus system. It will ingest and disseminate data while providing access to data services from multiple sources and tenants, including the planned Smart Columbus technologies, traditional transportation data and data from other community partners, such as food pantries and medical services. The Operating System will embody open-data, best-of-breed technologies including open-source and commercial off-the-shelf concepts that enable better decision-making and problem solving for all users. It will support a replicable, extensible, sustainable data delivery platform. The Operating System will be the source for performance metrics for program monitoring and evaluation; serve the needs of public agencies, researchers and entrepreneurs; and assist health, human services organizations and other agencies in providing more effective services to their clients. The Operating System will be scalable and demonstrate the potential for serving COC and private sector needs well beyond the life of the SCC award period.

2.3.2. Enabling Technologies

2.3.2.1. CONNECTED VEHICLE ENVIRONMENT

Columbus has corridors and intersections with high numbers of crashes involving vehicles, bicyclists, and pedestrians, and several congested corridors have poor mobility for emergency vehicles, freight vehicles, and transit buses. The project team selected the CVE corridors based on regional crash data, enhanced transit services, recent infrastructure investments, and their relationships to other Smart Columbus projects.

The CVE will connect up to1,800 vehicles and 113 smart intersections across the region. The project team plans to install safety applications for multiple vehicle types including transit buses, first responder vehicles,

COC and partner fleet vehicles, and private vehicles. Application deployments will ensure that the Central Ohio Transit Agency (COTA) Bus Rapid Transit (BRT) fleet can utilize traffic signal prioritization as needed to maximize efficiency and emergency vehicles can utilize traffic signal pre-emption as needed to maximize safety. The data created by the system will be aggregated by the Operating System, anonymized, de-identified and stored for historical analysis and visualization.

The CVE project will utilize CV technologies and applications with an emphasis on addressing congested and high-crash intersections and corridors. The project team anticipates the CVE project outcomes will include enhanced safety and mobility throughout the COC's transportation system.

2.3.3. Enhanced Human Services

2.3.3.1. MULTIMODAL TRIP PLANNING APPLICATION/COMMON PAYMENT SYSTEM

Columbus residents and visitors do not have access to a system that allows for the seamless planning of or paying for a trip involving multiple transportation service providers and parking providers. Moreover, some Columbus residents are unbanked and therefore cannot access alternative modes of transportation including car and bike sharing systems.

The Multimodal Trip Planning Application (MMTPA) will make multimodal options easily accessible to all by providing a robust set of transit and alternative transportation options including routes, schedules, and dispatching possibilities. The application will allow travelers to request and view multiple trip itineraries and make reservations for shared-use transportation options such as bike-share, ride-hailing, and scooter-share. Using the MMTPA, users will be able to compare travel options across modes and pay for their travel based upon historic and current traffic conditions and availability of services.

A Common Payment System (CPS) will process payments for transportation service and parking providers. The city's goal for the CPS application, which may be the first of its kind in the United States, is that the public will use it to access Columbus' current and future transportation systems, maximizing these services to live their best lives.

This project is anticipated to provide an innovative solution to improve mobility and access to opportunity.

2.3.3.2. SMART MOBILITY HUBS

Currently, no enhanced mobility or multimodal features alleviate first-mile/last-mile (FMLM) challenges in the Linden area or along the Cleveland Avenue corridor. Columbus is working to make mobility the great equalizer in part by embracing multimodal transportation and making it as accessible and easy to use as possible. Our vision is to transform some COTA bus stops and transit centers along the BRT CMAX corridor into Smart Mobility Hubs (SMH), where someone getting on or off the bus can easily access the next leg of his or her trip. Public Wi-Fi will be a key enabler for the hub and its points of connection (Wi-Fi is also present in COTA's stations and entire fleet). The City plans to outfit the hubs with kiosks to assist in travel planning and expanded transportation options via other modes, such as bike and car-sharing. The SMH will be linked with COTA systems to provide transit information with real-time arrival and departure times to the passengers waiting at the hubs.

This project provides an opportunity for residents and visitors to access multiple modes of travel to solve FMLM challenges.

2.3.3.3. MOBILITY ASSISTANCE FOR PEOPLE WITH COGNITIVE DISABILITIES

People with cognitive disabilities who wish to independently use public transit services in Columbus must either qualify for special paratransit services in accordance with federal law, or they must be able to safely use fixed-route bus service without assistance. The City's goal for the Mobility Assistance for People with

Cognitive Disabilities (MAPCD) application is that it will allow people with cognitive disabilities to travel independently via COTA's fixed-route bus system. The mobile application will feature a highly accurate, turn-by-turn navigator designed to be sufficiently intuitive such that senior adults and people with cognitive disabilities and visual impairments can use it to travel independently.

This project provides an opportunity for users to empower themselves and gain mobility independence and not rely upon caregivers or the COTA paratransit system for transportation.

2.3.3.4. PRENATAL TRIP ASSISTANCE

The COC has one of the highest infant mortality rates in the country, which is partially attributable to pregnant women not getting necessary prenatal healthcare. The existing Non-Emergency Medical Transportation (NEMT) system does not always provide reliable round-trip transportation. Linden residents have challenges accessing healthcare services due to the current NEMT model and technologies. The goal of the Prenatal Trip Assistance (PTA) project is to work with Franklin County and CelebrateOne to develop a means for bridging the gap among healthcare providers, expectant mothers and NEMT services that are paid for through the Medicaid system. A driving force for deployment of this project is the need to provide a more streamlined and efficient NEMT system to improve mobility and satisfaction for users.

2.3.3.5. EVENT PARKING MANAGEMENT

The COC lacks an integrated system for residents and visitors to easily and efficiently view the available parking spaces at parking garages, surface lots, and parking meters, especially at large events. Indirect routing of travelers causes congestion and inefficiency in the transportation network.

This project will integrate parking information from multiple providers into a single availability and reservation services solution. This will allow travelers to plan and search for parking options at certain locations to reserve and book a parking space with the CPS. More direct routing of travelers during large events is expected to reduce congestion during those times.

2.3.4. Emerging Technologies

2.3.4.1. CONNECTED ELECTRIC AUTONOMOUS VEHICLES

The use of connected and automated shuttles has been widely proposed as a solution to the FMLM problem. Therefore, this project will address, investigate and develop solutions to the social and technical challenges associated with the use of Connected Electric Autonomous Vehicles (CEAV) technology for safer and more efficient access to jobs in a smart city.

This project will introduce and develop holistic modeling and simulation tools that will enable a priori determination and solution of connected and automated mobility technical challenges including the actual route and other vehicles and mobility improvements. This will be followed by proof-of-concept work and pilot deployments to demonstrate that connected and automated mobility can be used to improve the FMLM access to jobs in a smart city.

The team will conduct the CEAV project with partners from the Ohio Department of Transportation (ODOT), The Ohio State University (OSU) and The Columbus Partnership to plan, implement, and evaluate the deployment of automated vehicles in the COC. Working with these partners allows for the generation of various use cases, which will result in the deployment of CEAVs in various settings.

This project provides an opportunity for residents and visitors to access cutting edge mobility technologies to solve FMLM challenges.

2.3.5. Deployment Area

While the COC will deploy some projects within specific areas, it will deploy many projects citywide, integrating them with the Operating System, which is the backbone and heart of all current and future Smart Columbus projects.

Figure 3 shows an overview of the deployment area.

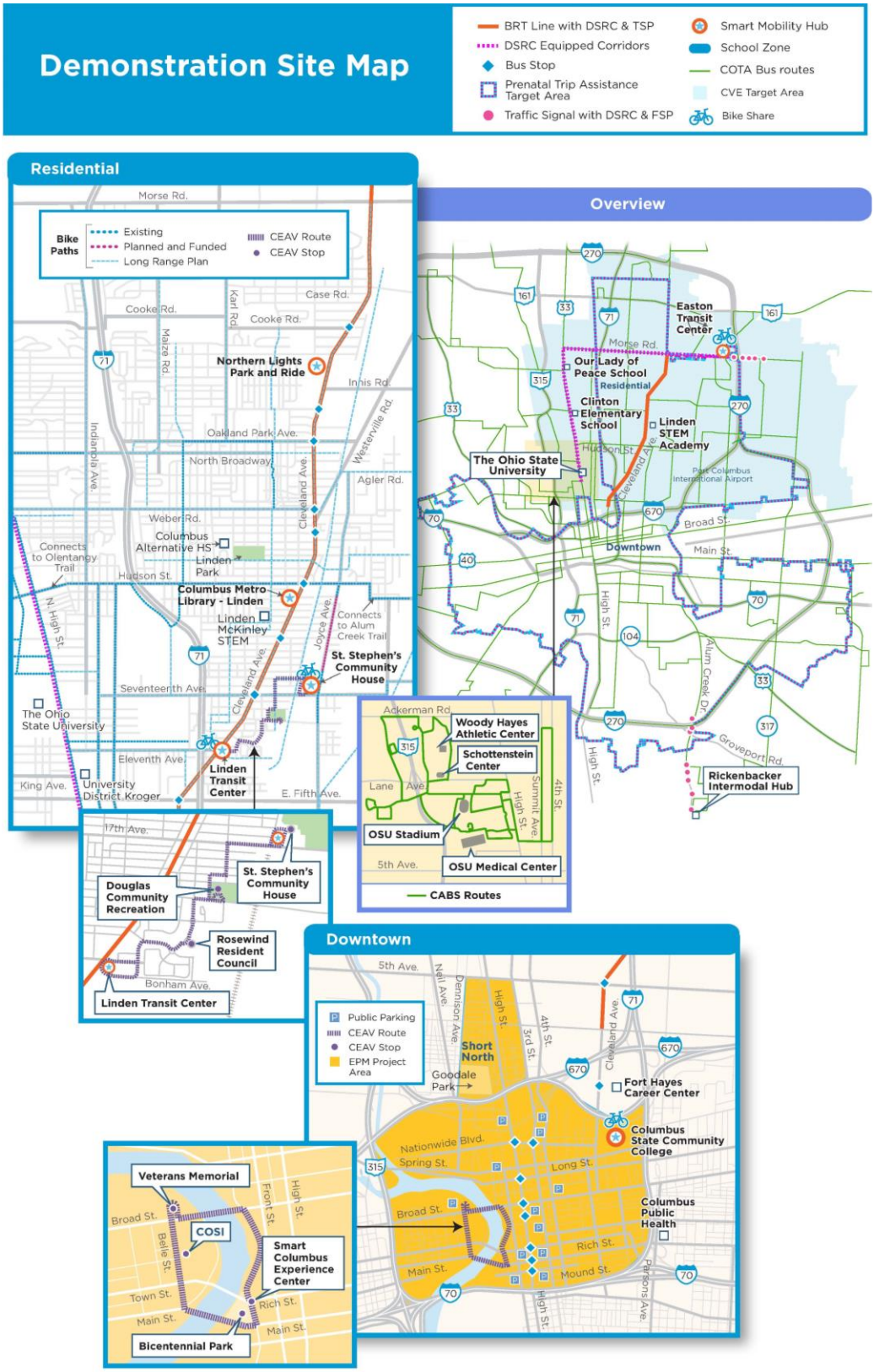

Figure 3: Smart Columbus Deployment Map

Source: City of Columbus

Table 2 identifies the relationships among the demonstration projects and their potential outcomes.

Table 2: Smart Columbus Project Outcomes

SMART COLUMBUS PROJECTS	SMART COLUMBUS OUTCOMES					
	Safety	Mobility	Opportunity	Environment	Agency Efficiency	Customer Satisfaction
1. The Smart Columbus Operating System					P	P
2. Connected Vehicle Environment	P	P, S		S		
3. Multimodal Trip Planning Application/Common Payment System		P, S	P, S	S		P
4. Mobility Assistance for Cognitive Disabilities		P	P		P	P
5. Prenatal Trip Assistance		P	P			P
6. Smart Mobility Hubs		P	S			P
7. Event Parking Management		S		S		P
8. Connected Electric Autonomous Vehicles		P, S	P, S			P

P – Indicates project level outcome; S – indicates program-level outcome the above table reflects the most recent decisions by the project teams.

Source: City of Columbus

Chapter 3. Safety Risk Process and Approach

3.1. INTRODUCTION

This section describes the safety risk process and approach for Smart Columbus project deployments and the procedures the Smart Columbus PMO and project teams will use to manage safety risks.

3.2. SAFETY RISK PROCESS AND APPROACH

Deployments will include a structured approach to identifying safety risks within the eight Smart Columbus projects, and the program will mitigate those risks to keep participants safe. As the program proceeds from planning to design and implementation, and then to operations and maintenance, the approach to managing safety risks will continue to evolve, identifying new risks, and either mitigating completely the currently identified risks or changing their statuses. The process that the team develops and utilizes will produce periodic updates to the risk assessment table (see **Table 12**) to reflect current and emerging mitigation efforts.

The approach adapts the steps in ISO 26262 for developing a safety plan in the concept phase. During the systems engineering phase, the Smart Columbus PMO and project teams worked to develop the safety-related requirements for each project. As the projects move into design and implementation, this plan will verify and implement these requirements. The development of this SMP followed the USDOT guidelines originally distributed to the CV Pilot Projects. The steps are outlined below:

- Identify safety scenarios for the eight Smart Columbus projects based on the proposed applications defined in the ConOps of each project.
- Assess the level of risk for each safety scenario.
- Develop a safety operational concept for each scenario if it is identified as high/medium risk.

Figure 4 illustrates the development process for the safety scenarios.

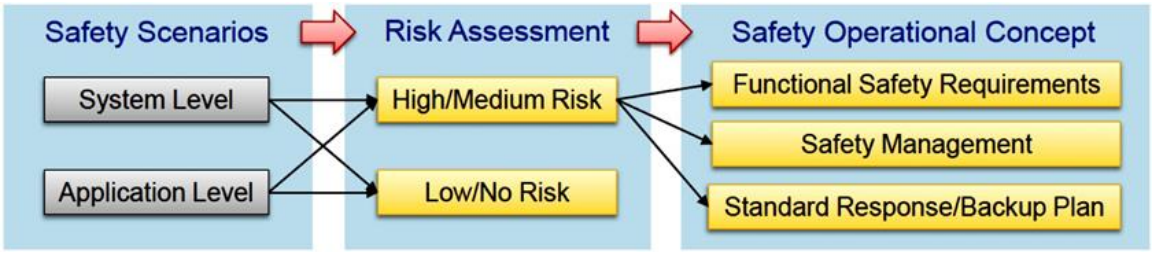

Figure 4: Safety Management Plan Development Process

Source: USDOT Guidance Summary for Connected Vehicle Deployments: Safety Management

3.3. SAFETY STAKEHOLDERS

Table 3 lists, in no certain order, the safety stakeholders for the eight Smart Columbus program projects. As travelers, participants fall into broad categories of drivers, pedestrians and transit users and are not treated here. Project participants will receive instruction through the individual projects according to the human use treatments, Informed Consent Documents, and participant training programs. The project stakeholders listed in **Table 3** are supporting participants in their travel and extending their services to meet participant needs. **Table 3** summarizes the safety stakeholders who are providing services to the project participants and to identify multiple-project involvement, responsibility and safety management.

Table 3: Smart Columbus Safety Stakeholders by Project

Stakeholder	Smart Columbus Operating System	Connected Vehicle Environment	Multimodal Trip Planning Application/ Common Payment System	Mobility Assistance for Cognitive Disabilities	Prenatal Trip Assistance	Smart Mobility Hubs	Event Parking Management	Connected Electric Autonomous Vehicles
COC Police		✓		✓	✓	✓	✓	✓
COC Fire, Emergency Medical Services		✓		✓	✓	✓	✓	✓
COC Dept. of Public Service Traffic Managers	✓	✓	✓				✓	✓
COC Department of Technology	✓	✓	✓	✓	✓	✓	✓	✓
COC Light-Duty Vehicle Operators		✓						
COC Ride-hail Vehicle Operators			✓		✓	✓		
Logistics Providers		✓						
COTA	✓	✓	✓	✓		✓		✓
Mobility Providers	✓		✓			✓		

Stakeholder	Smart Columbus Operating System	Connected Vehicle Environment	Multimodal Trip Planning Application/ Common Payment System	Mobility Assistance for Cognitive Disabilities	Prenatal Trip Assistance	Smart Mobility Hubs	Event Parking Management	Connected Electric Autonomous Vehicles
Third-Party Users	✓		✓					
Certification and Accreditation Provider	✓		✓					
Metro Library – Linden Branch						✓		
St. Stephens Community House						✓		
Columbus State Community College						✓		
Third Party Developer or Application	✓			✓	✓	✓	✓	
Prenatal Travelers/Application Users					✓			
NEMT Providers – Ride-hail and COTA, Taxis/Limo					✓			
Managed Care Organizations					✓			
The Ohio State University	✓			✓	✓			✓
Ohio Department of Medicaid					✓			
Medical Offices					✓			

Stakeholder	Smart Columbus Operating System	Connected Vehicle Environment	Multimodal Trip Planning Application/ Common Payment System	Mobility Assistance for Cognitive Disabilities	Prenatal Trip Assistance	Smart Mobility Hubs	Event Parking Management	Connected Electric Autonomous Vehicles
Parking Facilities and Parking Operators							✓	
Clinton Township Police and Fire		✓				✓		
Mifflin Township Police and Fire		✓				✓		
Franklin County Sheriff		✓		✓	✓	✓	✓	✓
Franklin County Fire Rescue, Emergency Medical Services (EMS)		✓		✓	✓	✓	✓	✓

Source: City of Columbus

3.4. EMERGENCY RESPONDER COORDINATION

Agencies within the State of Ohio, Franklin County, COC and other associated localities have their own emergency response plans for various events, such as severe incidents, natural disasters, or planned events. The Smart Columbus PMO and project teams will coordinate with emergency responders on what actions are expected from both the agencies and the deployment program (e.g., safety manager(s)) in response to the emergency situations identified in this SMP.

Should a vehicle or pedestrian in the deployment be involved in a crash due to any cause, the response will follow existing emergency response procedures. As with any emergency involving a vehicle, multimodal traveler or pedestrian, an available person will call 911, and COC responders will perform according to their standard training. **Table 4** lists the emergency response agencies along with their operation timings.

Table 4: Emergency Response Stakeholders

Agency	Response Hours
COC Police	24 hours x 7 days
COC Fire Rescue	24 hours x 7 days
COC EMS	24 hours x 7 days
Franklin County Sheriff	24 hours x 7 days
Franklin County Fire Rescue	24 hours x 7 days
Franklin County EMS	24 hours x 7 days
Ohio Highway Patrol	24 hours x 7 days
COC Traffic Operations and Maintenance	24 hours x 7 days
COC Traffic Management Center	Mon-Fri 6:30am-6:30pm
Smart Columbus Demonstration Program Operations and Maintenance	Mon-Fri 5am-6:30pm
Clinton Township Police	24 hours x 7 days
Clinton Township Fire	24 hours x 7 days
Mifflin Township Fire and Police	24 hours x 7 days

Source: City of Columbus

3.5. SAFETY RISK MONITORING

Each potential safety risk listed in **Table 12** will be closely monitored and controlled to eliminate or minimize its potential impact. The primary means to do so will be to conduct periodic safety reviews; these are also discussed in Section 5.2.3. At a minimum, these reviews will be conducted annually although certain events (for example, project launch, an incident or a major design change) may also necessitate a review. The safety review will help in identifying and mitigating any unforeseen shortfalls. The Smart Columbus PMO and project teams will ensure safety risk controls are effective and new safety risks are identified by considering the following items during a scheduled safety review:

- Verifying that periodic checks on the equipment, software, interfaces, and processes are being conducted

- Reviewing feedback and information received from demonstration participants via beta testing or surveys.
- Reviewing any incident reports
- Keeping up to date with best practices and lessons learned from related pilots and projects like US-33 Smart Mobility Corridor and Scioto Mile CEAV project in Columbus, Ohio and CV pilots in New York City, Tampa, and Wyoming.
- Coordinating with identified emergency response agencies as necessary for demonstration of the Smart Columbus projects.
- Conducting internal reviews of project documentation
- Providing regular safety communications and updates to the project teams in between reviews and accepting feedback as offered.

Safety risk monitoring will be tracked and documented throughout the program duration via the safety review process. The Safety Review Template included in **Appendix C**. Any incidents reported will be reviewed following the procedures discussed in Chapter 5 and will be document using the Incident Report Form attached in **Appendix D.**

3.6. MAPPING SAFETY RISK PROCESS TO PROJECT DELIVERABLE

The eight Smart Columbus projects have been developed using either the Vee or Agile systems engineering methodology. Regardless of the methodology used, it is important to identify and verify that safety requirements have been planned and accounted for in the system design. **Table 5** identifies the systems engineering methodology used to develop each project and provides traceability to the documentation containing safety related requirements and potential mitigation strategies for the risks identified in **Table 12**. The documentation and methodologies followed by the Smart Columbus projects ensure that the requirements and mitigation strategies are carried through the deployment phase of each project. Note that items that are still in development or that cannot be made publicly available are identified in *italics*.

Table 5: Systems Engineering Methodology for Smart Columbus Projects

Smart Columbus Project	System Engineering Methodology	Documentation/ Process
The Smart Columbus Operating System	Agile	DPP DMP De-Identification Policy Data Curation Process Privacy Impact Assessment

Smart Columbus Project	System Engineering Methodology	Documentation/ Process
Connected Vehicle Environment	Vee	ConOps SyRS Interface Control Document *System Design Document* On-board Unit (OBU) and Road-side Unit (RSU) Integration Request for Proposals (RFP) *IRB materials (research protocol, informed consent document, recruiting and training materials)* *Operations and Maintenance Plan* *Test Plan* *Test Results Report*
Multimodal Trip Planning Application/Common Payment System	Agile	ConOps CPS SyRS MMTPA RFP CPS RFP *User training materials* *Test plan* *Test Results Report*
Mobility Assistance for Cognitive Disabilities	Agile	Trade Study Interface Control Document Test Plan and Report Operations and Maintenance Plan IRB materials (research protocol, informed consent, training plan – for caregivers and participants)
Prenatal Trip Assistance	Agile	ConOps RFP IRB materials (research protocol, informed consent document, training materials) Participant User Guide Test Plan and Report
Smart Mobility Hubs	Vee	ConOps SyRS Interface Control Document System Design Document Request for Proposal Test Plan *Test Results Report* *Operations and Maintenance Plan*

Smart Columbus Project	System Engineering Methodology	Documentation/ Process
Event Parking Management	Vee	ConOps SyRS *Test Plan* *Test Results Report* *Operations and Maintenance Plan*
Connected Electric Autonomous Vehicles	Agile	CEAV Operational Concept Request for Proposal *EasyMile User Guide* *Standard Operating Procedures* Test Plan *Test Results Report*

Source: City of Columbus

Chapter 4. Safety Needs

The safety needs were considered from the perspective of the travelers (travelers for Smart Columbus includes CV and CEAV vehicle operators, multimodal travelers, prenatal travelers, and people with cognitive disabilities) using the solutions being developed and deployed as part of the Smart Columbus demonstration program. Each project will provide a system of hardware and/or software. Some projects, such as CVE and CEAV, contain applications that will have interfaces to other specialized equipment in the deployment, existing infrastructure, and people using the solutions (drivers or riders). Other projects will provide a strictly software solution which will have several types of traveler interfaces available (mobile, web, voice, etc.). Regarding the projects that contain both hardware and software elements, the solutions deployed for each of the projects could present a hazard due to an internal failure of one of its components, or because of failures in one of the external elements with which it interfaces. Software solutions can present a hazard with respect to protection of traveler data or availability of the application.

Each project's solutions must perform its functions in ways that do not introduce new risks to the traveler. They must do so regardless of whether their functions are operating as intended or malfunctioning due to internal failures, external failures, or foreseeable misuse. This SMP identifies and assesses user safety needs and safety problems that may arise and offers safety mitigations that need to be decomposed into functional requirements and then design solutions. System requirements are written in the project SyRS document. This SMP does not offer design solutions but lays out the overarching strategies intended to bring about requirements that lead to designs that work and, when they do fail, fail safely. While is not possible to design entirely safe systems or ones with complete backup, redundancy, and error-checking at every step, it is the intention of the SMP to make the use of the hardware and software systems it deploys helpful and safe for users.

Table 6 summarizes the software and hardware uses in the projects.

Table 6: Hardware and Software Uses

Project	Software	Hardware
Smart Columbus Operating System	Operating System	Data storage
Connected Vehicle Environment	CV Applications	OBU, RSU
Multimodal Trip Planning Application/Common Payment System	Smartphone Application	Smartphone
Mobility Assistance for Cognitive Disabilities	Smartphone Application	Smartphone
Prenatal Trip Assistance	Smartphone Application	Smartphone
Smart Mobility Hubs	SMH Software	Kiosk
Event Parking Management	Smartphone Application	Smartphone
Connected Electric Autonomous Vehicles	CEAV Software	CEAV Light Detection and Ranging (LiDAR), Radar, cameras, etc.

Source: City of Columbus

4.1. IDENTIFY SAFETY SCENARIOS

The intent of the safety scenarios is to identify and document potential safety risks associated with the Smart Columbus Demonstration Program and each project therein. This is accomplished through a systematic analysis process that includes system hardware, software, interfaces, human behavioral factors, intended applications, operational environment, weather events, external factors, data security, user abilities, and infrastructure. The scenarios consider the entire life of the program and the eight individual projects. The potential safety impacts of each scenario are then documented so mitigation measures may be developed.

4.1.1. Program Level

Safety scenarios identified at the program level apply to the entire Smart Columbus demonstration program. The Operating System, which is one of the eight projects of the program, serves as the heart and integral backbone of all the Smart Columbus projects. The risks identified under the Operating System are considered program-level risks. The program-level risks include power outage, communication failure, data storage, and external, malicious impacts on the system.

The Operating System will process and store data from all program projects. It will have operators, curators, and administrators, but it will not have human participants, per se. As the program proceeds and standards change, if required, the team will coordinate with an independent IRB. If the Operating System requires IRB oversight, it would be only for Personally Identifiable Information (PII) collected through surveys and data security, not for physical safety. Program-level Operating System issues are treated in depth in the DPP and the DMP, and companion policies and practices that have been developed by recommendation of the DMP and DPP development. Given that, a core principle of the Operating System is that no PII is or will be provided to the system. The tools that are in place to ensure this does not occur include the DPP, a de-identification policy which is provided to any entity that will provide data to the Operating System, the privacy impact assessment process (which is conducted with any entity that will provide data to the Operating System) and the data curation process.

Operating System-related safety issues to users are treated specifically in each project's ConOps and development documentation and in this SMP under each project.

4.1.2. Project Level

Safety scenarios identified at the project-level apply to the specific elements (hardware, software, applications) selected and deployed for each Smart Columbus project. In addition, human application of the project applications and hardware is an important factor. Smart Columbus does not expect to replace human judgement and responsibility in travel with electrical and electronic (E/E) devices. By aiding human judgement with the capabilities of machines and machine intelligence, the best of both human and computer systems will complement one another.

Table 7 lists the project-level IRB oversight and informed consent needs identified for each project. In those cases where an IRB will review the project's research protocol and associated participant materials, potential safety issues will be explained to participants and the Informed Consent Document will contain instructions about what to do in case of a safety problem. A separate Smart Columbus report on human use will give further details on IRB activities and results for each project.

The Informed Consent Document, where applicable, will state that the user (e.g., driver, pedestrian) is responsible for control of their vehicle or their movements crossing city streets or negotiating transit vehicles. The training will include user responsibilities and limitations of the equipment, as well as what to do in case of a difficulty with user applications, equipment, or a crash. Operator control and training is an important mitigation strategy and is the fallback to any system difficulties that are not circumvented by E/E failsafe, warning, and control systems.

Table 7: Institutional Review Board Oversight

Project	IRB Oversight and Informed Consent?
1. Smart Columbus Operating System	No – no participants associated directly with this project
2. Connected Vehicle Environment	Yes
3. Multimodal Trip Planning Application/Common Payment System	No – IRB will only be consulted as part of the performance measurement process. Informed consent will not be required for the project's demonstration.
4. Mobility Assistance for Cognitive Disabilities	Yes – users are from a protected class
5. Prenatal Trip Assistance	Yes – users are from a protected class
6. Smart Mobility Hubs	No – IRB will only be consulted as part of the performance measurement process. Informed consent will not be required for the project's demonstration.
7. Event Parking Management	No – IRB will only be consulted as part of the performance measurement process. Informed consent will not be required for the project's demonstration.
8. Connected Electric Autonomous Vehicles	No – IRB will only be consulted as part of the performance measurement process. Informed consent will not be required for the project's demonstration.

Source: City of Columbus

4.1.2.1. CONNECTED VEHICLE ENVIRONMENT

Cars, trucks, and buses will communicate with the infrastructure and to one another to reduce congestion and increase safety. The project team plans to install safety applications for multiple vehicle types including transit buses, first responder vehicles, city and partner fleet vehicles, and private vehicles.

Safety scenarios for the proposed applications stem from the use of these applications, the use or interpretation of the alerts they may provide, and the potential impact of communications failures and interruptions. The CVE deployment applications will include:

- Emergency electronic brake light warnings
- Forward collision warnings
- Lane change and blind spot warnings
- Transit and freight signal priority
- Emergency vehicle preemption
- Red-light violation
- School zone speed reduction

Safety scenarios for the proposed applications may be caused by the presence of a pedestrian or other Vulnerable Road User (VRU), driver distraction, incorrect or non-issuance of warnings, improper installation

and miscommunication of devices, road conditions, device tampering, inadequate training, and the breach of device data protection.

The IRB will oversee human use in this project. The research protocol and Informed Consent Document will explain potential safety issues to participants, the protection of their information and instructions for actions in response to problems or an emergency.

For CVE drivers, appointments to register, install or reinstall equipment, or fix operational problems will be included in the training and is also provided in the user manual.

Safety issues may range in seriousness from a loose connection in the OBU to an actual crash. In the event of a crash, the participant will be instructed to call 911. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

4.1.2.2. MULTIMODAL TRIP PLANNING APPLICATION/COMMON PAYMENT SYSTEM

Travelers interact with the MMTPA/CPS using smartphones, web portal, or kiosks at SMH.

The MMTPA is enabled by trip optimization services that connect with mobility providers such as transit agencies, ride-hailing companies, and car-, scooter- and bike-sharing companies to create customized trip itineraries for the Traveler. The CPS and COTA fare system are integrated, so travelers may fund a single account to pay for services, enabling them to simply “click to pay once” for multimodal trips.

Safety scenarios for the proposed application may be caused by impacts of maintenance modes, call failures, mobile device failure, mobility provider network failure, multimodal transportation availability, special events, trip planning during traffic incidents, and driver distraction. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

The oversight of an IRB would pertain primarily to PII and data security issues, not the physical safety of travelers. Therefore, IRB will only be consulted as part the performance measurement process. Informed Consent will not be required for the project’s demonstration.

4.1.2.3. MOBILITY ASSISTANCE FOR PEOPLE WITH COGNITIVE DISABILITIES

The MAPCD mobile application will include a highly accurate, turn-by-turn navigator designed to be sufficiently intuitive such that older adults and groups with disabilities including those with cognitive and visual disabilities can travel independently.

Safety scenarios for the proposed applications may be caused by connectivity issues, inaccurate route information, or issues with the pedestrian portion of the route (such as issues with Americans with Disabilities Act (ADA) compliance in a crosswalk). Safety scenarios include the potential impacts of maintenance modes, emergency call failures, mobile device failure, COTA network failure, traveler distraction, and inaccurate instructions or route information. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

The IRB will oversee human use in this project. Persons with cognitive disabilities comprise a vulnerable population and deserve fair treatment according to their needs. The research protocol and Informed Consent Document will explain potential safety issues, such as getting lost, to participants and their caregivers. The research protocol will also discuss protection of participant information. The Informed Consent Document specifically will communicate risks to the participants and their caregivers and provide information around tools available to helped eliminate the risk or mitigate its impact.

4.1.2.4. PRENATAL TRIP ASSISTANCE

Pregnant women will interact with the PTA system to schedule rides through three flexible options: a website, a smartphone app, or a call center.

The PTA System is integrated with Managed Care Organizations (MCOs) to verify Medicaid eligibility for each of the NEMT requests and to share usage data. Based on the eligibility of the prenatal traveler, the PTA system will be connected to the NEMT Mobility Providers who will be responsible for providing the NEMT service to the Prenatal Traveler.

Safety scenarios for the proposed applications may be caused by impacts of maintenance modes, emergency call failures, mobile device failure, mobility provider network failure, driver distraction, cancellations and late arrivals of the scheduled rides, vehicle crashes, and NEMT safety precautions. This unique project also considers the risks of increased stress on pre-term labor and related risks that can arise related to the installation of car seats to accommodate the traveler's children that may accompany her on a trip. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

The IRB will oversee human use in this project. Pregnant women comprise a population that is especially vulnerable to potential safety hazards and stresses in travel. The research protocol will explain potential safety issues with respect to the physical security of participants, the study protocol and protection of personal information. The Informed Consent Document will communicate risks to the participants and provide information around tools available to help eliminate the risk or mitigate its impact.

4.1.2.5. SMART MOBILITY HUBS

The purpose of the SMH project is to provide travelers with consolidated transportation amenities at physical facilities to solve FMLM challenges in the Linden area. Mobility hub services include interactive kiosks, Wi-Fi, and emergency call buttons. These services will enable access to real-time transportation information and comprehensive trip-planning tools, and they give residents and visitors the opportunity to access multiple travel modes to solve FMLM challenges.

Smart Mobility Hub facilities will feature designated bike-, car-, and scooter-sharing areas, pickup and drop-off zones for ride-hailing, park-and-ride lots, and access to COTA bus services.

Safety scenarios for the proposed applications may be caused by both software and connectivity issues such as cellular network failure, unavailability of the MMTPA, special events or incidents that impact traffic, kiosk Wi-Fi failures, and mobility provider network failures. Safety scenarios also consider the impact of infrastructure-related risks such as emergency call button failure, safety feature failures related to multimodal transportation options (e.g., not wearing helmets for bikes and scooters), obstruction of hub features due to weather hazards (snow not cleared), and potential accessibility issues. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

This project will not collect PII because it does not require formal participation. IRB will be consulted as part the performance measurement process. Informed consent will not be required for the project's demonstration.

4.1.2.6. EVENT PARKING MANAGEMENT

The Event Parking Management (EPM) project will be a one-stop shop for parking. Users will be able to identify available parking spaces from parking garages and surface lots to probability of availability of parking meters and loading zones. Through the EPM services users will be able to reserve and pay for the parking through the CPS application in advance.

Safety scenarios for the proposed applications may be caused by impacts of the application's maintenance modes, connectivity and data sharing for payment, and driver distraction from using the mobile application. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

IRB will be consulted as part the performance measurement process although informed consent will not be required for the project's demonstration.

4.1.2.7. CONNECTED ELECTRIC AUTONOMOUS VEHICLES

The project provides an accessible and easily expandable FMLM transportation solution to the region by deploying a fleet of multi-passenger CEAVs that will use the enhanced connectivity provided by the CVE and citywide travel-planning solution.

Safety scenarios for the proposed applications of the CEAV project include VRUs interaction with CEAVs, vehicle operations around detours, road construction areas and construction workers, stopped operation of vehicle due to unpredictable maintenance issues along the roadway, VRUs taking advantage of the vehicle, operational risks related to automated vehicle technology, including the impact of vehicle speed limits, road conditions, tampering with the device, mixed traffic environment, and inadequate training. Specific issues and mitigation strategies are detailed in the risk assessment matrix later in this document.

IRB will be consulted as part the performance measurement process although informed consent will not be required for the project's demonstration.

4.2. RISK ASSESSMENT

There is more to assessing risks than evaluating the statistical measures of risk; risk assessment includes the following three steps:

1. An analysis identifying the risks.
2. Making judgements on the tolerability of the risks.
3. Mitigation of the risks.

For this risk assessment, data sources for risk analysis are in short supply as the projects are innovations new to the cityscape, with little existing data collection and analysis. As these are new applications, informed engineering judgement is the tool of greatest efficacy. The analysis follows identification of risks, evaluation and mitigation, using the ISO 26262 ASIL Standards for software development and design. ASIL is a risk classification scheme that applies ratings for Severity, Exposure, and Controllability of the operating scenario to complete the risk analysis.

The ASIL analysis is extended from exclusively vehicular uses to include pedestrians and transit users who are travelers using E/E apps that interface especially with transit vehicle uses in the transportation network. This includes MMTPA/CPS, SMH, MAPCD, and PTA. EPM is a vehicular application like CVE and CEAV. This extension of ASIL to MMTPA, SMH, MAPCD and PTA is justified since Severity, Controllability, and Exposure are useful measures of E/E application capabilities in vehicular environments. The Operating System has ASIL application as well as it has E/E interfaces with all the projects and corresponds to Traffic Management Center (TMC) data collection.

The project teams examined all safety scenarios related to the installation of the devices for both the vehicle fleets, infrastructure and mobile applications that are deployed as part of the Smart Columbus program. The ConOps, SyRS, DPP, and DMP documents provide guidance regarding security and privacy, as well as mitigation plans for security breaches for confidentiality, integrity, and availability, along with the potential threats. There are four ASIL ratings identified which will necessitate additional planning around the safety operational concept: ASIL A, ASIL B, ASIL C, and ASIL D. Safety risks identified as QM, or "Quality Management," do not require specific mitigation measures as the risk is handled by normal quality management practices. For all risks, quality management practices to be performed are described in **Chapter 5** and includes provisions for equipment procurement, device installation, inclusion of a fail-safe system mode, quality training, safety manager responsibilities, safety reviews, and safety incident reporting.

Safety risks that are determined to be ASIL D have the highest safety risk and need the highest level of mitigation measures, while those that receive ratings of ASIL A have the lowest level of testing requirements per ISO 26262.

The following three classes of attributes determine an ASIL rating:

- **Classes of Severity**
  - S0: no injuries
  - S1: light and moderate injuries
  - S2: severe and life-threatening injuries (survival probable)
  - S3: life-threatening injuries (survival uncertain), fatal injuries
- **Classes of Probability**
  - E1: very low probability
  - E2: low probability
  - E3: medium probability
  - E4: high probability
- **Classes of Controllability**
  - C1: simply controllable
  - C2: normally controllable
  - C3: difficult to control or uncontrollable

In addition to these ASIL classes, the Smart Columbus team used classes of S0a and C0 for instances when the integrity level would be of inconsequential severity (S0a) or insignificant to control (C0). It is a combination of these attributes that results in the ASIL scores. Analysis of each of the identified safety scenarios and the level of severity, exposure and controllability was conducted using the ISO 26262 ASIL determination matrix shown in **Table 8,** which illustrates how the attributes are considered collectively to develop the integrity level.

Table 8: Automotive Safety Integrity Level Determinations

Severity	Probability of Exposure	C1 Controllability	C2 Controllability	C3 Controllability
S0	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	QM
	E4	QM	QM	QM
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A

Severity	Probability of Exposure	C1 Controllability	C2 Controllability	C3 Controllability
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

Source: ISO 26262

As mentioned above, the Smart Columbus risk assessment includes ratings of S0a and C0 that are not in the ASIL ratings table (**Table 8**). These scenarios can be excluded from further analysis. This applies if a scenario cannot happen, causes no harm, or can be unquestionably handled by any participant. In these cases, that assessment is documented, and no safety requirements are needed. These items are scored as "-" in **Table 12**.

The ASIL attributes are generally very broad. In their application of the ASIL methodology, the NYC CV Pilot developed more specific rating rules which they used to better classify their project risks according to the ASIL attributes. Likewise, Smart Columbus started with the rating rules developed by the NYC CV Pilot and updated them with input and feedback from the PMO, project teams and an independent reviewer from Battelle. These rules provide granular description of the various severity, exposure and controllability attributes that the Smart Columbus projects may encounter and rolls them up to the higher level ASIL ratings for better application to the Smart Columbus projects. These rating rules provide justification to the ASIL scoring of the safety risks and helps the project team to better interpret and apply the ASIL scoring methodology. The Severity, Exposure, and Controllability Rule Ratings shown in **Table 9**, **Table 10** and **Table 11** were applied to the safety risks identified in **Table 12** to help in the assessment of the values in the final score of each risk. Each safety risk is rated with a rating rule and ASIL Severity scoring.

Table 9: Automotive Safety Integrity Level Severity Rule Ratings

Rule	Description	Rating	Score
S-A	Any incident where a vehicle strikes a pedestrian is severe.	S3	3
S-B	A malfunction that cannot lead to a vehicle striking a vehicle, a pedestrian, or a fixed object is at most an inconvenience. Pedestrians are assumed to be able to avoid fixed objects and one another. Missed messages do not themselves cause a crash.	S0a	0
S-C	A low speed crash is assumed to cause minor injuries	S1	1
S-D	Vehicle-to-vehicle or vehicle-to-fixed-object crashes where the speed limit is 25 mph or below	S2	2
S-E	Vehicle-to-vehicle or vehicle-to-fixed-object crashes where the speed limit is above 25 mph	S3	3
S-F	Fires in vehicles are S2	S2	2
S-G	Existing policy or tested equipment prevents a scenario and it can be argued that the deployment will not disrupt the existing protections.	S0	0
S-H	The severity of a missed message depends on the application or unknown misuse of the vehicle. A preliminary severity will be resolved later.	S3	3
S-I	Release of personal data is a concern but not a safety hazard	S0a	0
S-J	Traveler unable to complete the trip (or have a long wait) but is in a safe location	S0a	0

Rule	Description	Rating	Score
S-JA	Traveler unable to complete the trip and is subject to elements.	S1	1
S-K	Traveler unable to complete the trip (or have a long wait) and in a risky location	S2	2
S-L	Pedestrian slip, trip, or fall. Bicycle or scooter fall or collision with a fixed object.	S1	1
S-M	Minor non-traffic injury or disease	S1	1
S-N	Missed or ignored messages do not themselves cause a crash	S0	0
S-O	False warnings or inappropriate warnings.	S1	1
S-P	Delayed emergency response to the CEAV emergency increase the severity of the situation and uninformed response presents hazards to responders.	S2	2
S-Q	Safety concern when encountered in an assault related situation.	S2	2

Source: City of Columbus

Table 10: Automotive Safety Integrity Level Exposure Rule Ratings

Rule	Description	Rating	Score
E-A	Existing policy or tested equipment prevents a scenario and it can be argued that the deployment will not disrupt the existing protections.	E0	0
E-B	Rare, extreme weather events, such as lightning strikes, hurricane landfall, and deep snow	E1	1
E-C	More common storms, such as rain or ice.	E1	1
E-D	Vandalism of protected equipment happens.	E1	1
E-E	All organizations will experience staff turnover which can lead to untrained employees.	E2	2
E-F	School begins and ends every year. Work zones are established, moved, and cleared.	E2	2
E-G	Periodic maintenance occurs occasionally.	E1	1
E-H	A designed-in fault that affects every trip or an application expected to activate on every or nearly every trip	E4	4
E-I	A designed-in fault that affects applications expected to activate only occasionally	E3	3
E-J	A designed-in fault that is manifested only when unusual circumstances occur is rated at the frequency of those circumstances.	E2	2
E-K	A designed-in fault that is manifested only when unusual circumstances occur is rated at the frequency of those circumstances.	E1	1
E-L	Difficulties in radio transmission, at least at a minor level, are expected daily, unless historical data shows a different frequency.	E2	2
E-M	Even with training, a few participants can be expected to misunderstand their role or forget a function used infrequently.	E1	1
E-N	Project equipment does not deliver permissive messages.	E0	0

Rule	Description	Rating	Score
E-O	Crashes involving fleet vehicles are expected a few times during the deployment.	E1	1
E-P	Delayed DSRC messages are rare but happen.	E0	0
E-Q	GPS vagaries occur regularly but not always.	E2	2
E-R	Automated vehicle encounters an unexpected situation.	E2	2
E-S	The general public is untrained and will occasionally act unexpectedly.	E2	2
E-T	Malicious activity is assumed to succeed occasionally.	E1	1
E-U	Random fault in one of the components of the system.	E2	2
E-V	A few participants can be expected to lose situational awareness and become distracted. Rate of occurrence is expected to be a few times a year.	E2	2
E-W	A designed-in fault that is manifested to occur rare or never.	E0	0

Source: City of Columbus

Table 11: Automotive Safety Integrity Level Controllability Rule Ratings

Rule	Description	Rating	Score
C-A	UMTRI showed in RDCW and IVBSS that drivers can ignore spurious warnings.	C1	1
C-B	Ignoring or missing a message that calls for action is an incorrect response.	C1	1
C-C	Failure to present an advisory message when a message is warranted will not degrade the performance of a normal driver with all ordinary information (sights and sounds) available. Missed alerts are rated C1 to account for the case of a driver who has become accustomed to them and expects to be alerted to developing situations.	C1	1
C-D	Distractions other than frequent unwarranted messages, such as displays that are difficult to interpret or loose equipment, can cause the driver to miss important external information.	C2	2
C-E	A message with incorrect information, even if it is advisory, is rated as less controllable than a missing message or a spurious message. The incorrect message will, at a minimum, require cognitive effort to discount, and may yield an incorrect response.	C2	2
C-F	A driver who misinterprets a signal or misunderstands the desired response and behaves inappropriately.	C3	3
C-G	Traffic signals will be obeyed by drivers and pedestrians, so any improper operation by traffic signals cannot be overcome by travelers.	C3	3

Rule	Description	Rating	Score
C-H	System-wide malfunctions that can be recognized by staff at the TMC can be controlled by those staff. It could take time to respond and travelers will be affected until response is complete.	C1	1
C-I	A driver confronted with a fire can stop and exit the vehicle but must do so promptly.	C2	2
C-J	A traveler that is stranded by a disabled vehicle, a vehicle is not dispatched, or other equipment malfunction causes the vehicle to be unusable to continue the trip.	C3	3
C-K	Equipment or wiring in the wrong place should not be moved by the driver while in motion and will slow emergency responders	C3	3
C-L	Any defect that exacerbates injury during a crash or impairs rescue following a crash is wholly uncontrollable by the driver	C3	3
C-M	Participant will notice nothing unusual and normal movement is the proper course.	C0	0
C-N	Harm that occurs regardless of driver or traveler response is not controllable.	C3	3
C-O	Any system feature (static equipment or inappropriate message) that leads a driver to take harm-causing action is not controllable.	C3	3
C-P	Avoiding a crash requires skills beyond what is expected in most drivers. Professional drivers would be challenged beyond their ordinary skill to avoid a crash.	C3	3
C-Q	The response may be a more sudden steering or a harder braking.	C2	2
C-R	Provider cancelling the trip or being late is not controllable by the traveler.	C3	3
C-S	A person has little control immediately after personal data is exposed.	C3	3
C-T	Drivers of surrounding vehicles can handle slightly erratic behavior of an AV.	C1	1
C-U	Drivers of surrounding vehicles cannot handle an AV with sudden or unexpected behavior.	C3	3
C-V	Professional driver can intervene in moderate malfunctions.	C1	1
C-W	Traveler has probably encountered a similar situation before and handled it.	C1	1
C-X	Travelers who ignore safety equipment (like bicycle helmets, seat belts) cannot be helped.	C3	3
C-Y	Vulnerable travelers are incapable of dealing with even minor mishaps.	C3	3
C-Z	System has no control over deliberate misuse by the participants.	C3	3
C-ZA	A trained operator on board will be capable of handling the situation.	C0	0
C-ZB	Any system failure caused by the weather is not controllable by the driver.	C3	3
C-ZC	Harm that occurs due to distracted driving	C3	3

Source: City of Columbus

A multidisciplinary team including the Smart Columbus PMO, project teams, independent staff (Battelle and Michael Baker), partners (COTA, OSU, CelebrateOne) and vendors (AbleLink, Mtech, Bytemark, Kaizen Health, Pillar Technologies, May Mobility, EasyMile, Kapsch, and Siemens) assembled to identify and assess each safety scenario and develop the corresponding safety risk response plans for all the eight Smart Columbus projects.

Table 12 shows the results of the safety risk assessment process, detailing each safety scenario identified, the associated safety impacts anticipated, the safety risk response plan developed, the ASIL dimensions assigned, and the resulting ASIL rating.

The Smart Columbus risk assessment includes ratings of S0a and C0 that are not in the ASIL ratings table (**Table 8**). These scenarios can be excluded from further analysis. This applies if a scenario cannot happen, causes no harm, or can be unquestionably handled by any participant. In these cases, that assessment is documented, and no safety requirements are needed. These items are scored as "**-**" in **Table 12**.

Table 12: Summary of Safety Risk Assessment

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
PROGRAM-LEVEL RISKS										
Smart Columbus Operating System										
1	Unauthorized person has access to restricted data.	An unauthorized person has access to the restricted data that can be used to commit a crime. Unauthorized person collects the restricted information from different applications in the Operating System combines them to reidentify.	Data will be anonymized prior to transmission to the Operating System. Diligent data security practices and regular patching and updates will take place. Avoid collecting unnecessary or sensitive information from participants. Ensure adherence to wireless message standards. Users will also be encouraged to use strong passwords for their mobile applications. Deidentification Policy and Data Curation process outlines how data ingested into the operating system is stored and protected.	S-I	S0a	E-T	E1	C-S	C3	-
2	Person has access to PII stored in the Operating System.	Person has access to the PII and can be used to commit a crime.	No PII is provided to the Operating System and this makes a rare/never risk of occurrence. Data received will be anonymized by the operating system team prior to transmission to the Operating System. Deidentification Policy and Data Curation process outlines how data ingested into the Operating System is stored and protected.	S-I	S0a	E-W	E0	C-S	C3	-
3	Vulnerabilities of data transmission and storage.	Unauthorized access to PII (could be employees or hackers). Could release sensitive information regarding health, transportation patterns, credit card information. Increased potential for identify theft because of storage of the data collected from the app users.	No PII, PHI, or PCI is provided to the Operating System and this makes a rare/never risk of occurrence. Project team to work with vendors to anonymize data prior to transmission to Operating System. Work with the developer to restrict the permissions requested by the application to only what is necessary for functionality. Smart Columbus DPP Chapter 5: Security Controls describes in detail how data collected will be stored and protected and the steps that will be taken when there is a data breach. Lessons learned and best practices will also be included in the security measures.	S-I	S0a	E-T	E1	C-S	C3	-
4	Authorized user combines datasets to reidentify a person and commit crime.	Authorized person collects and combines data stored in the Operating System for different applications of the project and has access to personal information. Using this personal information, unauthorized person can use it commit a crime, which may result in a safety issue to the user.	Contractual terms will be in place on how someone shall not reidentify data. Assessment of safety risks introduced from new data sets, de-identification, potential exclusion of new data set, ethics policy will take place. Diligent data security practices and regular patching and updates will also be carried out.	S-I	S0a	E-W	E0	C-S	C3	-
PROJECT-LEVEL RISKS										
Connected Vehicle Environment										
5	The CVE system is hacked into and unauthorized personnel have access to traffic control system.	Disruption to normal operations of the traffic control system and disconnecting the CV could result in issuing false warnings. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	The Security Credential Management System (SCMS) will protect RSUs, OBUs, CVE and CEAV data transfers. Diligent data security practices and regular patching and updates will be carried out per the DPP and DMP. Multiple firewalls will be installed as part of the network security. Strong passwords will be used to increase the safety of CVE connections. Signal controllers are physically secured with locks and accessible only to the TMC personnel. RSUs will also have access control. CVE network will reside outside of traffic signal system.	S-N	S0	E-T	E1	C-H	C1	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
6	The CVE system is hacked into and unauthorized personnel have access to the data.	Unauthorized person may have access to the user's personal and vehicle identification data that is collected and can be used to commit a crime, which may result in a safety issue to the user.	Diligent data security practices and regular patching and updates will be carried out. Strong passwords will be used to increase the safety of the participant registration and vehicle identification information that is collected. If data is exposed, users will be informed about the unauthorized access of the data. Smart Columbus DPP Chapter 5: Security Controls describes in detail how PII collected will be stored and protected and the steps that will be taken when there is a data breach.	S-I	S0a	E-T	E1	C-S	C3	-
7	OBU is hacked and provides false warnings to the driver.	Device gives a warning that is not valid or accurate. Safety of the passengers and the roadway users is at risk. This may cause vehicle operator distraction and may result in a crash. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	The SCMS will protect RSUs, OBUs, CVE and CEAV data transfers, Drivers will be instructed and will sign an Informed Consent Document that lays out OBU warnings are secondary to vehicle operator control. Operator will still be in control of the vehicle and must assess the situation and react appropriately.	S-N	S1	E-T	E1	C-D	C2	-
8	Vehicle operator gets distracted by the device information or gets confused with the warnings given by the CV.	Safety of the participant and nearby road users, including transit riders and pedestrians is a risk. This may cause driver distraction which could result in a crash. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	Drivers will be instructed and will sign an Informed Consent Document that lays out CV OBU warning systems are secondary to vehicle operator control. Operator is still to be in control of the vehicle and must assess the situation and react appropriately. Siemens and Brandmotiion will coordinate with the COC with the frequency and type of alerts that will be received by the driver. HMI for private vehicles is HUD which is designed to keep eyes on the road.	S-O	S1	E-M	E1	C-D	C2	QM
9	Miscommunication between the RSU and OBU because of radio interference issues, reduced power, capacity exceeded, or occlusion.	Safety issues because of the different warning systems that could be impacted by these issues. Primary concern is related to emergency signal preemptions. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	Emergency vehicles are responsible for observing the actual traffic signal phase. ConOps references applicability of normal rules of the road for intersection safety in lieu of notifications to vehicle operators of equipped vehicles. Emergency vehicle operators will be required to watch the training videos provided through the training gateway.	S-B	S0a	E-L	E2	C-E	C2	-
10	Vehicle position not as accurate as needed for the successful operation of the application.	The CV application may not accurately provide alerts regarding potential Vehicle-to-Vehicle (V2V)/ Vehicle-to-Infrastructure (V2I) interactions. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	Providing position correction capability is a system requirement and vendor will provide (Radio Technical Commission for Maritime Services (RTCM)) or Sirius XM propriety solution. Vehicle operator will be in full control of the vehicle and must assess the situation. Drivers should understand vehicle position can be imprecise because of radio interference, occlusion, or going out of system range.	S-N	S0	E-Q	E2	C-E	C2	-
11	Incorrect information (MAP not updated) provided to the equipped vehicles concerning lane assignment and function.	Safety of the participant and nearby road users, including pedestrians and bicyclists is a risk. Incorrect warning information related about lane usage or false alarms may be given to the equipped vehicle. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	The user training will emphasize that CVE is only a warning aid and is not at all intersections. Impact is not crash related. Vehicle operator will be in full control of the vehicle and must assess the situation. MAP update policies will be included in the O&M plan.	S-N	S0	E-H	E4	C-E	C2	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
12	Incorrect and/or misreported information provided to the equipped vehicle or RSU concerning vehicle position.	Safety of the participant and nearby road users, including pedestrians and bicyclists is a risk. Inaccurate vehicle position impacts operation/functionality of the CVE applications and presentation timing, potentially creating a safety risk to the travelers. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	Providing position correction capability (RTCM) improves accuracy and is a system requirement; also, alternate approaches can be considered to the extent feasible. Vehicle operator will be in full control of the vehicle and must assess the situation. Drivers should understand vehicle position can be imprecise because of radio interference, occlusion, or going out of system range.	S-N	S0	E-L	E2	C-E	C2	-
13	Miscommunication of the device due to improper installation (for example, antenna position) causes incorrect /inaccurate warnings to the vehicle operator.	This may result in the distraction of the vehicle operator, increasing the potential for a crash. The risk may create a higher than normal number of false positives, which may desensitize the vehicle operator to the information being relayed. Vehicle operators may also disable their in-vehicle device due to the perceived annoyance with the number of alerts received.	Installer training to include sufficient checking of OBU installation. Driver to return vehicle for reinstallation/adjustment/repair as needed. The user training will emphasize that CVE is only a warning aid and is not at all intersections. Impact is not crash related and the vehicle operator will be in full control of the vehicle and must assess the situation. Increased false alarms and missed warnings can reduce user reliance on the system but should not cause a safety concern. Device and installation check list will be completed before the vehicle is operated in real-time. Installation managers verifies the completion of checklist and completed checklist is archived.	S-N	S0	E-H	E4	C-E	C2	-
14	System power outage and RSU does not send or receive the necessary information to the operator.	Intersections equipped with this technology will not relay information as designed. CV will not be getting necessary messages. Not all intersections will have RSUs, but drivers may become accustomed to familiar CV signal operation.	Quick identification and repair of RSUs and power that is not working. Since these are warning systems and only available at some intersections, the vehicle operator is still in control of the vehicle and will need to assess the situation and determine how to react. Warnings are only intended as an additional way to draw attention to the situation. Kapsch health monitoring system will be available. RSUs will be communicating with one other and can identify if there is a disconnect with other RSUs.	S-N	S0	E-K	E1	C-C	C1	-
15	Device installed in the vehicle becomes in-operable (e.g. tampering, not installed properly).	Safety of the vehicle operator, passengers, and other roadway users is at risk. Vehicle would not be able to send or receive communications from other vehicles or RSUs when the device does not operate as per the manual.	Training and Informed Consent Document should refer user to customer care line/installation resources for reinstallation/adjustment/repair as needed. Driver to be advised during training not to tamper with OBU equipment and to be stated in Informed Consent Document. Vehicle operator will be in full control of the vehicle and must assess the situation. Device calibration and installation checklist will be completed before the vehicle is operated in real-time. Installation managers verifies the completion of checklist and completed checklist is archived.	S-N	S0	E-K	E1	C-C	C1	-
16	Vehicle operator lacks sufficient training to adequately understand and interpret alerts.	Driver is overconfident and ignores standard visual and auditory cues, causing a crash that compromises the safety of the vehicle operator, transit riders, and nearby road users and pedestrians.	CVE is only a warning aid and is not at all intersections. Impact is not crash related – vehicle operator still makes the final decision. Provide adequate training to the vehicle operators on how to react to different situations and understand that the CV system is a warning aid and vehicle operator will have full responsibility and control over the vehicle. Vehicle Operators will receive training both in person and through videos based on the vehicle types. Siemens and Brandmotion will coordinate with COC with the frequency and type of alerts that will be received by the drivers. Newsletters will be provided to the vehicle operator throughout the deployment period.	S-E	S3	E-I	E3	C-F	C3	C

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
17	Safety issue when the device is not operating how the user was trained or instructed when there is a malfunction.	This may result in the distraction and/or misinformation, which compromise the safety of the vehicle operator, transit riders, nearby road users and pedestrians.	Training and Informed Consent Document should refer user to customer care line/installation resources for reinstallation/adjustment/repair as needed. CV is only a warning aid and is not at all intersections. Impact is not crash related – vehicle operator still makes the final decision. Provide adequate training to the vehicle operators on how to react to different situations and understand that the CVE system is a warning aid and vehicle operator will have full responsibility and control over the vehicle.	S-E	S3	E-K	E1	C-C	C1	QM
18	Important safety/warning messages given by the system ignored by the operator (due to number of alerts, etc.)	Vehicle operator does not acknowledge the alert or adjust his or her driving behavior to account for it, thereby compromising the safety of the vehicle operator, other vehicles, and nearby road users and pedestrians.	Reference studies/surveys that identify the appropriate number of alerts. The CVE system will be configured based on the survey results for the warning messages. Siemens and Brandmotion will coordinate with COC with the frequency and type of alerts that will be received by the drivers. The project team will have training types (training videos and in person training) based on the driver type (LDV and preemption) and the videos will be provided to the fleet operators through the training gateway.	S-H	S3	E-H	E4	C-A	C1	B
19	The operator does not know how to react when the OBU disconnects.	The OBU disconnects when the vehicle is in operation and the vehicle operator reacts inappropriately, increasing the risk of collision. Vehicle would not be able to send/or receive communications from other vehicles or RSUs.	Training and Informed Consent Document should refer user to customer care line/installation resources; vehicle operator is still in control of the vehicle and must assess the situation as needed.	S-G	S0	E-E	E2	C-J	C3	-
20	Time of the school zone is wrong in the system and the device does not give accurate warnings.	Safety of the passengers, pedestrians, and the roadway users is at risk. The CVE system does not give the vehicle operator appropriate warnings at the school zone and operator doesn't slow down during the active school zone, which may result in a crash.	School Zone warning is a cloud hosted system. The roadside safety message to indicate school zone warning will be linked to the operation of the flashing school zone indicator signal. The data of the school zone timings will be live and will automatically provide current signal timings to the CVE system. However, these are warning systems only and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	S-G	S0	E-H	E4	C-H	C1	-
21	Driver trained for the CV is assigned to a non-CV and comes to expect warnings that are not sent. Applies to personal vehicles as well.	Safety of the vehicle operator, passengers, and the roadway users is a risk. Vehicle operators become accustomed to alerts and/or priority and are desensitized to potential hazards, reducing their reaction to these situations.	Participant training includes vehicle operators switching from CV vehicle to a non-CVE vehicle with safety precautions and how to react to different situations.	S-G	S0	E-E	E2	C-C	C1	-
22	A misconception by the participant results in the participant believing the system takes control of the vehicle in case of a hazard.	Safety of the participant and nearby road users, including transit riders and pedestrians is a risk. A participant's misconception may result in a crash when the vehicle operator is not in full understanding of the capabilities of the CVE system and does not react to the situation as needed. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	Incorporate into the Vehicle Operator Training and provide adequate training to all the participants to understand that the vehicle operator is in full control of the vehicle and ultimately responsible to obey the laws and CV is only a warning aid and is not at all intersections. Informed Consent Document covers that this is a CV warning and not automated vehicle functions. Marketing and recruiting materials will include this information and will be conveyed to the participant during the training process.	S-E	S3	E-M	E1	C-F	C3	A
23	A heavy snow storm or other weather-related issues result in the power outage and loss of communication to the CV system.	Safety of the participant and other road users, including transit riders and pedestrians is a risk. Loss of communication would result in the failure of warnings to be issued when appropriate. However, these are warning systems and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	Include lessons learned and best practices in the design. Perform design review of installation. Verify installation before deployment, including specific end-of-line testing and checklists. Provide adequate training to the vehicle operators on how to use the CVE equipment and react in inclement weather.	S-B	S0a	E-B	E1	C-ZB	C3	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
24	Signal changed to flash mode either manually or due to cabinet error and is not communicated to RSUs.	When the cabinet is flashing, the RSUs do not receive this information and still communicate the usual signal phase timings to the OBUs. Due to this situation the driver will be given alerts that are not applicable at that time and may cause driver confusion. This may result in a crash creating a safety issue to the driver, passengers and roadway users.	Vehicle operator training to include awareness to these unusual situations. However, these are warning systems only and the vehicle operator is still in control of the vehicle and must assess the situation and react appropriately.	S-O	S1	E-M	E1	C-D	C2	QM
Connected Electric Autonomous Vehicles										
25	AVs operating at low speed (slower than 15 mph) with vehicles at higher speeds (exceeding the posted speed limit).	The disparity in speed between an AV operating below 15 mph and other traffic exceeding the posted speed limit might cause a crash.	Traffic calming measures, speed enforcement, AV informational signage, and route design on the sections of roads that AVs will be operating will help with the speed control. Also work with the vendor to have CEAVs travel as close to the speed limit as the technology allows for safe operation.	S-D	S2	E-S	E2	C-U	C3	A
26	Sudden stop of the AV because it encounters an unanticipated obstacle.	Safety to the passengers and the road users is at risk due to sudden stop. AV not anticipating the obstacle stops unexpectedly. This sudden stop of the AV can cause a safety issue to the passengers and to the road users behind the vehicle. This may also cause rear-end crashes.	Operator will be present in the vehicle at all times when the vehicle is in operation and must take control and maneuver around the obstacle. To improve passenger safety, the operator will instruct the passengers remain seated and belted, as available. Passengers to hold onto rails. Signage installation on the routes about the AV operations will be installed.	S-D	S2	E-I	E3	C-U	C3	B
27	Pedestrians go into the path of an oncoming AV.	VRU goes in front of the moving vehicle and the CEAV makes a sudden stop. The sudden stop may cause safety risk to the passengers in the AV and a safety issue to the pedestrian crossing the street.	Testing for reaction to several types of VRUs will be thoroughly vetted. CEAV Test Plan to cover all the test cases related to testing for reaction to VRUs. Testing will also include objects that are below knee height. Operator should be aware of operating conditions. Ensuring pedestrian safety for interactions with AVs is accounted for in SOP. For example, increasing awareness of pedestrians and other road users will be included as part of operating training procedures and educating the public about the operation of AVs on roadways will be included as part of the outreach.	S-A	S3	E-S	E2	C-Q	C2	A
28	Passenger may not be fully boarded or alighted when AV begins to move.	Passengers may be trying to board the vehicle and the AV may depart not knowing that the passenger has not boarded the vehicle fully. The passenger then may try to catch the moving AV trying to board the vehicle.	EasyMile User Guide ensures that the vehicle does not move until the door is fully shut and vehicle operator training will also emphasize to make sure the door is fully closed before initiating the stop departure; door sensors should be aware of complete closure. Operator will always be present when the AV is in operation and permits the vehicle to leave the station when passengers are fulling boarded or alighted.	S-A	S3	E-S	E2	C-V	C1	QM
29	Passenger approaches the AV as it is departing a stop.	Passenger in a hurry to reach the destination and tries to board a moving AV. This may result in a safety issue to the passenger.	Operator training should include measures to handle operating the vehicle as potential passengers approach it (intervene and stop AV operation to manually open the door).	S-A	S3	E-S	E2	C-V	C1	QM
30	Passenger alighting may not accommodate an entire loading/unloading (for multi-passenger parties, ADA customers, etc.).	Passengers are trying to alight the vehicle and the AV may depart not knowing that all the passengers are not alighted yet, creating a safety risk to those passengers still boarding.	EasyMile User Guide ensures that the vehicle does not move until the door is fully shut and vehicle operator training will also emphasize to make sure the door is fully closed before initiating the stop departure; door sensors should be aware of complete closure. Operator will always be present when the AV is in operation and permits the vehicle to leave the station when passengers are fulling boarded or alighted.	S-A	S3	E-K	E1	C-ZA	C0	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
31	Slower speed and unpredictable operations of bike and scooter traffic, and any other shared mobility device along the AV route may cause dangerous interactions with the AV.	Safety risk to bicyclists, scooter operators and passengers is increased. When there is an unpredictable interaction with the other roadway users, there might be a delayed response from the AV to stop and this may result in an injury risk to the bike and scooter passengers.	Scooter is a new mode that may interact with an AV – testing for reaction to VRUs of all types will be thoroughly vetted. CEAV Test Plan to cover all the test cases related to testing for reaction to VRUs. Testing will also include objects that are below knee height. Operator will be present at all time when the AV is in operations and Operator training will include measures to handle operating the vehicle during these situations.	S-A	S3	E-S	E2	C-Q	C2	A
32	Stopped operation of an AV could create an impediment in the roadway.	While on the roadway, there might be maintenance issues to the AV causing it to stop on the side of the roadway. This might result in the impediment in the roadway to the roadway users, creating a safety risk to the passengers and other roadway users due to either a sudden stop, maneuver or collision.	SOP and EasyMile User Guide will cover training for first responders and CEAV operators on how to handle emergency situations. Operator will always be present when the AV is in operation. Operator training should include measures to handle operating the vehicle as it makes a sudden stop for any maintenance reasons. Testing for this risk will be performed under closed course to minimize interaction with public. Hazard lights initiated for programmed stops before stopping. Outreach will be conducted to communities with route information and vehicle operations.	S-D	S2	E-R	E2	C-U	C3	A
33	An AV operating in manual mode and the operator may not notice VRUs (bikes, scooters and pedestrians) taking advantage of the AV.	When there is an unpredictable interaction with the other roadway users, there might be a delayed response from the AV operator to stop in the assumption the AV will be able handle the situation. This may result in an injury risk to the bike and scooter operators, and possibly the passengers on the AV.	Operator training and operating procedures should account for potential vehicle operator distraction. AV is equipped with standard vehicle awareness equipment (sensors) for the vehicle operator to rely on when operating manually and the safety chain will be active even when the vehicle is in manual mode. This information is contained in the EasyMile User Guide.	S-A	S3	E-S	E2	C-U	C3	B
34	There is a danger of the public taking advantage of (or having a false sense of security around) AV safety protocols and slow down operations.	Safety of the passengers, pedestrians and the roadway users is increased. With the increased interaction of pedestrians and other road users with AVs, there is an increased potential for risk. The roadway users might take advantage of AVs and have a false sense of the security around them.	SOP, education and outreach will be implemented throughout the operational period of the AVs. The EasyMile User Guide will cover this aspect for the operators of the shuttles.	S-A	S3	E-S	E2	C-U	C3	B
35	Latency and high network traffic creating issues/problems in connectivity/communications with other road users and infrastructure.	Loss of connectivity impacts V2V and V2I communications, causing lack of alerts and interruption of data collection. This can cause a crash when the AV does not get signal phase and timing information.	CV OBU warning systems are secondary to vehicle operator control. Operator is still to be in control of the vehicle and must assess the situation and react appropriately. Onboard Operator is a backup to the onboard systems. Operator will be trained to intervene in vehicle operations as necessary. Shuttle route does not cross any signalized intersections so the vehicle will only be receiving SPaT messages, not using them for navigational purposes.	S-E	S3	E-L	E2	C-C	C1	QM
36	No certification, testing, and rating systems for safe pre-deployment evaluation methods for these shuttles currently exist.	Inconsistent approaches/solutions are available. No uniform/agreed upon process to ensure and measure public safety, so it is difficult to assess the 'safest' solution.	This project will be documenting lessons learned and the safety standards used for these specific deployments. System cannot to proceed from Level 4 to Level 5 until the standards are developed. The CEAV Test plan for the Scioto Mile deployed in Columbus, OH and MnDOT Autonomous Bus Pilot Project deployments will be referred to before deploying CEAVs in the Linden area.	S-H	S3	E-S	E2	C-N	C3	B
37	CEAV operator not trained to handle emergency or real-time situations.	In an emergency, operator not trained to handle the situation, which may result in delayed response and may increase severity of incident/impact.	Training and certification for AV operator included in the EasyMile User Guide. Training includes how to handle emergency situations. Training will be thorough and precise to handle the situations. Operators will be trained before they start operating CEAV.	S-A	S3	E-M	E1	C-F	C3	A

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
38	CEAV operator is distracted and unable to handle emergency or real-time situations.	Safety risk to passengers and other road users is increased. Operator is distracted and unable to handle the situation which may result in delayed response, increased severity of incident/impact. Distraction of the driver (may be checking phone) under assumption of not having to pay attention 100% of the time since vehicle is an AV and might take advantage of that fact.	Operator training and operating procedures will account for potential vehicle operator distraction. These guidelines will also be addressed in the SOP and EasyMile User Guide. Training includes proper operation of the vehicle which leaves no free handles to use a cell phone.	S-E	S3	E-J	E2	C-D	C2	A
39	Road conditions and construction projects (lane closures, lane assignment, detours) may affect the CEAV route impacting the AV's ability to understand current roadway assignment.	Safety risk to passengers, construction workers and other road users is increased. Reaction time of the AV will be impacted, increasing risk of unplanned or sudden stop, or potential interaction with obstacles.	Operator must take control and maneuver the route. Close coordination with construction projects to maintain current and accurate lane lines. EasyMile User Guide provides guidance on CEAV operations on route with road closures and detours. Operating procedures include coordination between City and AV operator to assess road conditions. Manual operating speed is much slower than programmed speed of roads.	S-E	S3	E-R	E2	C-V	C1	QM
40	Passengers tamper with the controls of the CEAV if and when the AV will operate without a vehicle operator.	Safety of passengers and the roadway users is a risk. Without an operator on the AV, there is a possibility of passengers tampering with the controls of the vehicle, which may result in unexpected behavior of the vehicle.	As per the contract of the Smart Columbus program, all CEAVs will have an operator on board who would reactivate the AV or prevent passenger tampering. Surveillance cameras could monitor as well.	S-D	S2	E-S	E2	C-ZA	C0	-
41	Law enforcement and emergency responders not trained to handle emergency situations with the AVs.	Safety risk to passengers, emergency responders and others involved in an emergency is increased. Delayed response to passengers/other roadway users increases the potential severity of the risk when the emergency responders at the site are not trained to handle the situation involving AVs. Safety of the responders when not knowing how to interact with the CEAV.	Outreach for emergency responders to train them on responding will also be part of the training agenda. Include tabletop exercise and SOP as part of the training. CEAV communications and outreach plan will include training of emergency responders before deploying CEAVs in the Linden area.	S-P	S2	E-E	E2	C-N	C3	A
42	Flat tire or some kind of AV maintenance failure that a non-AV can experience.	AV encounters a maintenance issue and delayed arrival to the stop. Passengers may end up waiting for the AV and get stranded for a long time, which may result in a safety issue for the user.	Operator should always be monitoring vehicle response to surroundings, and the training will include how to react to different situations. Operator will also be trained to intervene in vehicle operations as necessary. Daily maintenance checks will also occur.	S-JA	S1	E-J	E2	C-J	C3	-
43	ADA equipment could become dislodged during AV operations.	Safety of the traveler who needs access to the ADA equipment is a risk. The operator not familiar with the ADA equipment may not be able to safely board the passenger into the vehicle, which may encounter a safety situation to the passenger.	Operator should monitor vehicle response to surroundings at all times and assist passengers getting on and off the AV. Operators will be trained to use the ADA equipment and assist the passengers that need ADA access.	S-M	S1	E-K	E1	C-L	C3	QM
Smart Mobility Hubs										
44	Passenger does not realize where the emergency call button is located at the hub location.	Traveler could not locate the emergency call button located at the hub location and emergency situation intensifies, which may result in a safety issue for the user.	Outreach at the location of the SMH sites about all the features provided by the kiosks will be provided. Information about the kiosks will also be available on the Smart Columbus website. In any emergency, the travelers are requested to call 911.	S-JA	S1	E-S	E2	C-J	C3	-
45	Over activation of call button (false alarms).	Call button at the hub location is overactivated and is misused by the travelers. These false alarms can potentially result in longer response times, resulting in risk to the safety of the traveler.	Discussion with law enforcement will be held on how to handle these situations. Provide outreach at the SMH sites about all the features, including the use of the kiosk emergency button.	S-G	S0	E-S	E2	C-Z	C3	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
46	Responding late to the emergency calls from the hub location.	Safety issue arises when the officials do not respond fast enough to the users.	Voice over IP channel is opened with the emergency dispatch during the time the passenger is waiting for help to arrive. Capital Crossroads shares safety information with stakeholders affecting the area.	S-G	S0	E-M	E1	C-Z	C3	-
47	Emergency call button does not respond at the mobility hubs.	In a situation where the traveler needs support, the emergency call button does not work, and the delayed response to the emergency need might increase the safety risk to the passenger.	Automatic monitoring of kiosks to notify maintenance if electronic heartbeat is not received. Routine testing of emergency call button will be implemented as part of the deployment process. Timing and parameters to the test will be discussed in the O&M plan which will be drafted and posted on the Smart Columbus website. Passengers can also call 911 through their phone in an emergency situation.	S-H	S3	E-K	E1	C-N	C3	A
48	Transit delay at the hub locations.	Passengers get off the bus and wait for a long time to find another service. This may cause a safety issue to the traveler at the location.	Kiosk should be able to offer alternate transportation options including calling taxi or other transportation. Camera and emergency call button available for passengers to alert officials in an emergency situation when waiting for the ride. Passengers can also call 911 through their phone.	S-G	S0	E-K	E1	C-J	C3	-
49	Additional modes of transportation and increased passenger traffic may result in higher conflict interactions (motor vehicle to motor vehicle).	With various transportation modes available at one location, there might be vehicle to vehicle crash at low speeds while navigating through the parking lot or through car share locations. This may also cause an impediment in the roadway for other roadway users.	SMH will have a designated area for specific modes to park to reduce the congestion. The travelers will be encouraged to use the designated areas. Additional signage, and pavement markings will be posted showing the parking locations for different modes of transportation for drop-off and pickup. Outreach will be conducted when the SMH are open to the public to educate the public with all the services provided at the hub location. Communications, strategies, and content will be finalized before the hubs are open to public.	S-C	S1	E-I	E3	C-W	C1	QM
50	Additional modes of transportation and increased pedestrian traffic may result in higher conflict interactions (motor vehicle to VRU).	With various transportation modes available at one location, there might be vehicle to VRUs crash at low speeds while navigating through the parking lot, car share locations, and bike and scooter parking locations. This may also cause an impediment in the roadway for other roadway users.	SMH will have a designated area for specific modes to park to reduce the congestion. The travelers will be encouraged to use the designated areas. Additional signage and pavement markings will be constructed showing the parking locations for different modes of transportation for drop-off and pickup. Outreach will be conducted when the SMH are open to the public to educate the public with all the services provided at the hub location. Communications, strategies, and content will be finalized before the hubs are open to public.	S-A	S3	E-S	E2	C-W	C1	QM
51	Additional modes of transportation and increased pedestrian traffic may result in higher conflict interactions (VRU to VRU).	With various transportation modes available at one location, there might be crash at low speeds involving VRUs while navigating through the parking lot, car share locations, and bike and scooter parking locations. This may also cause an impediment in the roadway for other roadway users.	SMH will have a designated area for specific modes to park to reduce the congestion. The travelers will be encouraged to use the designated areas. Additional signage and pavement markings will be constructed showing the parking locations for different modes of transportation for drop-off and pickup. Outreach will be conducted when the SMH are open to the public to educate the public with all the services provided at the hub location. Communications, strategies and content will be finalized before the hubs are open to public.	S-C	S1	E-S	E2	C-W	C1	QM
52	Unattended devices (like scooters, bikes) left on site blocking ramp and can pose tripping hazard.	Additional modes and more travelers at the SMH locations might increase the possibility of having unattended devices which can increase the safety risks for the travelers at the locations.	Dockless device zones are designated at SMH to encourage these devices be left within areas that will not interfere with pedestrian traffic. There will also be signage and pavement markings designated for the dockless devices. Traditional bike racks and CoGo bike racks are also accessible at the hub sites. The agreements between the property owners and mobility providers will outline asset management responsibilities.	S-L	S1	E-S	E2	C-W	C1	QM

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
53	Planned maintenance mode occurs when the system is operating in Backup mode to restore, repair, or replace system components.	Travelers try to use the kiosk and not able to connect because of the maintenance mode and cannot plan their trip. Safety issues may arise when they wait long in an unsafe situation.	These are planned events. Architecture is a no-fail system and updates occur during off-peak hours to minimally impact users. Regular updates occur with minimal interruption.	S-JA	S1	E-G	E1	C-H	C1	QM
54	Failure mode of the kiosk resulting in the complete systemic disruption of the user's ability to plan or complete the trip.	The kiosk is not working, and the users cannot access to plan or continue their journey and might be stranded for a long time, which may result in a safety issue for the user.	MMTPA/ CPS and SMH should be able to offer alternate transportation options for calling taxi or other transportation when not able to reach the central system. Signage at the site could provide contact information to other transportation modes.	S-JA	S1	E-U	E1	C-J	C3	QM
55	Unable to access kiosks because of the heavy snow fall or icy conditions.	Imminent severe weather expected in area. Ice/snow affects ability of passengers to safely move around SMH.	Weather warnings posted on kiosk. Stakeholders will be responsible for clearing snow and ice at the installed designated zones for modes of transportation.	S-B	S0a	E-B	E1	C-J	C3	-
56	Passenger at St. Stephens cannot access kiosk (off hours – lobby locked).	St. Stephens is closed, and the travelers cannot access the trip, as the kiosk is in the lobby of the building. Travelers end up waiting longer than anticipated and encounter an unsafe situation.	When installing the kiosks, stakeholders, along with the city, will look at different operating scenarios including how to deal with the scenarios when travelers are waiting for their ride or need to access the kiosk in off hours. Outreach plan will include the lobby hours that can be posted by the building. When the need for trip assistance outside the business hours at the lobby, a customer care number could be posted on the SMH signage that will redirect to the pivot app.	S-JA	S1	E-I	E3	C-J	C3	A
57	Planned travel modes are not readily available to users within a reasonable amount of time as shown by the kiosks.	Travelers plan the trip and the travel modes are not available as booked to continue their journey and might be stranded for a long time which may result in a safety issue for the user.	Kiosk at the site will be able to offer alternate transportation options. Alert notifications sent out to site/social media/news media. Signage at the site may be able to provide contact information to other transportation modes.	S-JA	S1	E-C	E1	C-J	C3	QM
58	Passengers not utilizing safety features of bike shares or scooters when starting their ride from the mobility hubs.	Travelers using bikes and scooters at the mobility hubs do not follow the safety standards (like wearing helmet) required and potentially create a safety risk.	Notification of local laws covers the safety standards before the traveler starts the ride with any transportation modes. Scooters and bikes will require the user to wear a helmet while riding. Mobility Providers can encourage the users of the scooters by giving out free helmets.	S-L	S1	E-S	E2	C-X	C3	QM
Multimodal Trip Planning Application/Common Payment System										
59	A traveler cannot plan his or her entire trip origin-destination (including FM/LM options) due to system-unrelated event, such as a traffic incident or other emergency event.	Traveler unable to plan the trip as the travel modes are unavailable and traveler might be stranded at the location for a long time, which may result in a safety issue for the user.	App should be able to offer alternate transportation route and mode options. ConOps includes scenarios for changes in plans.	S-JA	S1	E-K	E1	C-N	C3	QM
60	Planned travel modes are not readily available to users within a reasonable amount of time.	Travelers plan the trip and travel modes shown for the route are not available to continue their journey and might be stranded at the location for a long time, which may result in a safety issue for the user.	App should be able to offer alternate transportation route and mode options. ConOps includes scenarios for changes in plans. App will also alert the traveler about service disruptions and modal unavailability. When scheduling the trip, traveler will not be able to select a mode of transportation when not readily available.	S-JA	S1	E-J	E2	C-J	C3	QM
61	Failure mode of the application results in the complete systemic disruption of the user's ability to access the transportation modes or complete the trip.	The MMTPA/CPS system is not working, and the users cannot access the system to continue their journey and might be stranded for a long time, which may result in a safety issue for the user.	App will offer a customer care number to COTA when not able to reach the central system.	S-JA	S1	E-K	E1	C-J	C3	QM
62	Maintenance mode occurs when the system is operating in Backup mode to restore, repair, or replace system components.	Travelers try to use the application and not able to connect because of the maintenance mode and wait to reserve other transportation modes. Safety issue when they wait for a long time in an unsafe situation.	These are planned events. Architecture is a no-fail system and updates occur during off-peak hours to minimally impact users. Proper notification will be given to potential users in advance of the event when traveler's phone is offline.	S-JA	S1	E-G	E1	C-M	C0	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
63	Traveler is focused on the phone, not his or her surroundings (distraction). If headphones are in use, may not hear traffic or roadway noise as needed.	Traveler pays attention to his or her phone trying to follow the instructions provided by the application and is distracted, not paying attention to the surroundings. The distraction of the traveler may result in a crash causing a safety issue to the traveler and the roadway users.	COC to work with the outreach team to include the road safety mitigation strategies before the launch of the application. Road safety education and awareness programs are vital for discouraging the use of applications that stimulate unsafe driving/walking behaviors. Educating the traveling public about the dangers of unsafe driving/walking behavior could have significant safety benefits to all road users. A one-time pop-up screen with warnings and instructions that includes driving behavior will be presented to the traveler.	S-A	S3	E-V	E2	C-ZC	C3	B
64	Malicious activity: active monitoring of the traveler causes hacking of traveler account/activity.	Creates the potential for unauthorized account activity (related to payments, trip planning, personal data, etc.) while user trying to book a multimodal trip. Also, app might store the user information when creating the user account.	Work with the developer to restrict the permissions requested by the app to only what is necessary for functionality. Development of the app along with the vendor will provide visibility and customization allowing for more exposure of code base and how it functions. Make only services available to the user (availability of transportation modes, maps) that are related to the MMTPA/ CPS project. Vendor security documents lists the security measures for the data collected through this application. Smart Columbus DPP Section 5.3: Security Controls describes the standards that will be taken to protect and secure the confidentiality of PII collected. Bytemark is a PCI Level 1 vendor and their card processing system are complaint with PCI Data Security Standards.	S-I	S0a	E-T	E1	C-S	C3	-
65	Vulnerabilities for data transmission and storage.	Increased potential for identify theft because of storage of the data collected from the app users including credit card information, billing information that is used while booking a ride.	Work with the developer to restrict the permissions requested by the application to only what is necessary for functionality. Lessons learned and best practices to be included in the security measures. Perform routine information security audits. Avoid collecting unnecessary or sensitive information from participants. Vendor security documents lists the security measures for the data collected through this application. Smart Columbus DPP Section 5.3: Security Controls describes the standards that will be taken to protect and secure the confidentiality of PII collected. Bytemark is a PCI Level 1 vendor and their card processing system is complaint with PCI Data Security Standards.	S-I	S0a	E-T	E1	C-S	C3	-
66	Traveler cannot access PayNearMe stores to load CPS account.	PayNearMe stores are closed, and traveler is not able to load his CPS account which may result in a safety issue for the traveler while waiting in an unsafe situation.	MMTPA/CPS will show a map with the PayNearMe stores near the location of the traveler with the store timings. Traveler will have information to the store hours to choose to load his or her CPS account.	S-JA	S1	E-M	E1	C-N	C3	QM
67	Traveler/driver assault when booked through the MMTPA.	Driver or traveler may encounter an assault and is a safety concern.	Traveler/ driver can call 911 when in a safety concern issue or location. Leave the location and shout for help.	S-Q	S2	E-T	E2	C-S	C3	A
Mobility Assistance for People with Cognitive Disabilities										
68	Application provides inaccurate, incomplete, or incorrect walking instructions to the traveler with cognitive disabilities.	The directions provided by the application are incorrect and traveler not realizing it, follows the instructions provided by the application and ends up at the wrong address, which might be an unsafe location.	Traveler can contact his/her caregiver using the 'contact' feature within the application when needing assistance. For travelers with severe disabilities, coach may accompany the traveler on the trip (decided by multiple stakeholders in advance of the trip being planned) until the traveler is able to travel independently. Safety training and COTA Transportation Training includes who and what to ask for help when lost getting to the destination (Store worker, manager, police officer, COTA bus driver). Goal of the training process is to have failures occur and be resolved prior to real-world use.	S-K	S2	E-Q	E2	C-Y	C3	A

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
69	Application is not updated with current traffic/pedestrian and traffic information that will impact route provided to the traveler.	The directions provided by the application are not up to date and no alert is provided for the road closures and the traveler may take a wrong route to reach the destination or might even end up in the wrong place.	Training recommends traveler to utilize "Contact" feature within the application that will contact the traveler's caregiver. Safety training includes who and what to ask for help when lost getting to the destination (Store worker, manager, police officer, COTA bus driver). Goal of the training process is to have failures occur and be resolved prior to real-world use.	S-K	S2	E-J	E2	C-Y	C3	A
70	Application freezes or shuts down and the traveler cannot access it.	MAPCD application malfunctions mid-trip, and the step-by-step navigation instructions are not provided to the traveler. The traveler may be stranded in an unsafe situation with no further directions provided.	Assuming traveler is not with a coach; training indicates for the traveler to re-start the program and contact his or her ICE (in case of emergency contact). Safety training includes who and what to ask for help when lost getting to the destination (Store worker, manager, police officer, COTA bus driver). Goal of the training process is to have failures occur and be resolved prior to real-world use.	S-K	S2	E-K	E1	C-Y	C3	QM
71	Traveler selects incorrect route when departing his or her location.	Traveler selects wrong destination/route in the MAPCD app. The app provides the directions for the destination selected, and traveler ends up in the wrong place.	Training recommends traveler to utilize "Contact" feature within the application that will contact the traveler's caregiver. Safety training provided to the traveler will include all safety risk scenarios and how to react to these scenarios. Goal of the training process is to have failures occur and be resolved prior to real-world use. Destinations in the app are preprogrammed and should be safe so while the traveler may be at the wrong one it should be familiar and friendly to the user.	S-K	S2	E-M	E1	C-Y	C3	QM
72	Application malfunctions midtrip, and no instructions can be created.	MAPCD application malfunctions mid-trip and the step-by-step navigation instructions are not provided to the traveler. The traveler may be stranded in an unsafe neighborhood with no further directions provided.	Assuming traveler is not with a coach; training indicates for the traveler to re-start the program and contact his or her ICE (in case of emergency contact through the smart phone). Safety training and smartphone training provided to the traveler will include all safety risk scenarios and how to react to these scenarios.	S-K	S2	E-K	E1	C-Y	C3	QM
73	Traveler is lost and caregiver is not updated with the latest information of the traveler location.	Missed communication between traveler and caregiver, and caregiver does not receive real-time feedback on traveler location, and in an emergency the caregiver is provided with inaccurate information about the location of the traveler. Traveler may be stranded in an unsafe situation.	Traveler will be able to call his/her caregiver using the "contact" feature within the application or using his or her smartphone and provide location information to the caregiver. City will be providing data/phone plan to all the participants to be able call the caregiver any time.	S-K	S2	E-K	E1	C-Y	C3	QM
74	Traveler is focused on the phone, not his or her surroundings (distraction). If headphones are in use, may not hear traffic or roadway noise as needed.	Traveler pays attention to the phone trying to follow the instructions provided by the application and is distracted, not paying attention to the surroundings. The distraction of the traveler may result in a crash causing a safety issue to the traveler and the roadway users.	Application includes visual and audio cues; Safety training, COTA transportation training, smartphone training and application training will be conducted with the participants before travelers can go out on the route. These trainings provided to the travelers discuss distraction due to their mobile phone. Travelers will also be required to take multiple quizzes through the training process until they have 80% proficiency.	S-A	S3	E-M	E1	C-Y	C3	A
75	Traveler leaves the phone in the transit vehicle when he or she departs.	Traveler forgets his or her phone in the transit vehicle and will not receive post-vehicle instructions. Traveler may be stranded in an unsafe situation.	Safety training and COTA transportation training includes who and what to ask for help when lost getting to the destination (store worker, manager, police officer, COTA bus driver). For travelers with severe disabilities, coach may accompany the traveler on his or her trip until the traveler is able to travel independently.	S-K	S2	E-M	E1	C-Y	C3	QM

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
76	Application cannot accommodate changes to route/vehicle (if a vehicle breaks down mid route, and a traveler must change buses).	Traveler's transit vehicle breaks down and the application cannot provide route information to carry the trip. Traveler may be stranded and may encounter an unsafe situation.	When traveler goes off route, a text or email is sent to the traveler's primary caregiver. These messages can continue at a prescribed time interval until the individual is back on route. Traveler can contact the caregiver with any unfamiliar situations using "contact" button within the app. Safety training and COTA transportation training includes what and who to ask for help when lost getting to the destination (store worker, manager, police officer, COTA bus driver). A travel coach may be accompanied with the traveler until the traveler is able to travel independently.	S-JA	S1	E-J	E2	C-Y	C3	QM
77	Traveler's phone does not have enough battery to provide instructions throughout the entire trip.	Traveler's phone switches off and will not have instructions to continue the route. Traveler may be stranded in an unsafe neighborhood.	Safety training provided to the traveler will include all the safety scenarios when leaving the house including checking the battery level and charging the phone overnight. Training also includes what and who to ask for help when lost getting to the destination (store worker, manager, police officer).	S-K	S2	E-M	E1	C-Y	C3	QM
78	Cell phone network goes down and the traveler cannot contact his or her caregiver if needed.	Traveler may not be able to communicate with his or her caregiver due to the network loss, which might result in the safety issue to the traveler waiting for instructions.	Application only requires GPS (does not need Wi-Fi). City will also provide data plan to participants in the plan. Also, the travelers will be trained to operate independently or depending on the disability level, a coach will accompany the traveler to guide throughout travel until the traveler is able to travel independently.	S-K	S2	E-K	E1	C-Y	C3	QM
79	Stop sign to cross the street instead of a walk sign.	When following the step-by-step instructions provided by the app, there is a situation when there is stop sign at an intersection where the traveler needs to cross the street.	Routes can be personalized based on the traveler's ability to complete the route. Participants will either be able to navigate independently or will have a travel coach with them to assist on these types of crossings until the traveler is able to travel independently. Safety training provided to the traveler will include all the safety scenarios and how to react to these scenarios.	S-A	S3	E-I	E3	C-Y	C3	C
80	Non-ADA-compliant crosswalks or no sidewalks in the step by step navigation.	Safety issue for the traveler when the sidewalk ramps are not ADA-compliant, and the traveler needs to cross the street when following the instructions provided by the app.	Routes and stops can be customized based on the traveler's ability to complete the route. Caregiver (family, coach) will also be trained along with the traveler when creating the route for the traveler. A travel coach will be accompanied with the traveler until the traveler is able to travel independently.	S-L	S1	E-H	E4	C-Y	C3	B
81	The ICE contact does not respond to the traveler's request.	If lost, traveler cannot connect with their ICE contact for additional guidance. Traveler may be stranded and may encounter an unsafe situation.	Training would also guide traveler to use phone capabilities on how and when to contact a secondary person when assistance is needed. Traveler can also call the coach to get assistance.	S-B	S0a	E-M	E1	C-Y	C3	-
Prenatal Trip Assistance										
82	Trip scheduled by the prenatal traveler is cancelled and the prenatal traveler is not informed about the cancellation of her ride.	While waiting for her ride, the prenatal traveler may encounter an unsafe situation.	The system will automatically request another ride for the traveler. The traveler will receive text or phone call about the new ride scheduled. The traveler can also schedule a ride through the call center or through the app and get a last-minute pickup.	S-JA	S1	E-J	E2	C-R	C3	QM
83	Trip scheduled by the prenatal traveler for her doctor visit is late for the pickup.	Prenatal Traveler may encounter safety issues while waiting for her ride.	Traveler can contact call center for alternative and check status of her ride through the app.	S-JA	S1	E-J	E2	C-R	C3	QM
84	App is under maintenance and prenatal traveler cannot schedule a ride or obtain any updates about delayed or cancelled trips.	While waiting for her ride, the prenatal traveler may encounter an unsafe situation.	Prenatal traveler can contact call center for alternative. Training for the app use and how to react to different situations.	S-JA	S1	E-G	E1	C-J	C3	QM

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
85	Malicious functionality: Active monitoring of the traveler causes hacking of traveler account/activity.	Creates the potential for unauthorized account activity. Also, app might store the user information when creating the user account.	Application design restricts the permissions requested to only what is necessary for functionality. Development of the app along with the vendor will provide visibility and customization allowing for more exposure of code base and how it functions. Make only services available to the user that are related to this project. Vendor security documents lists the security measures for the data collected through this application. Smart Columbus DPP Section 5.3: Security Controls describes the standards that will be taken to protect and secure the confidentiality of PII collected.	S-I	S0a	E-T	E1	C-S	C3	-
86	Vulnerabilities for data transmission and storage.	Increased potential for identity theft because of storage of the data collected from the app users.	Application design restricts the permissions requested to only what is necessary for functionality. Lessons learned and best practices to be included in the security measures. Perform routine information security audits. Collect only necessary information from the participants. All parties to collect, transmit and store PTA data have received the DMP and DPP. Data is also governed in the IRB research study and Informed Consent Document.	S-I	S0a	E-T	E1	C-S	C3	-
87	When the prenatal traveler doesn't have access to a mobile phone and won't be updated when her ride back from the doctor visit is late or cancelled.	Prenatal traveler does not have access to her phone and will miss updates about her ride being late or cancelled returning from her doctor's visit. Prenatal Traveler may encounter an unsafe situation while waiting for her ride.	Prenatal traveler will be able to call the call center from the doctor's office for alternative (ask for the status of her ride or schedule another ride).	S-JA	S1	E-K	E1	C-N	C3	-
88	Pregnant woman feels more stressed while trying to use the app.	Prenatal traveler trying to use the app for the first time feels more stressed.	Feedback from the focus groups about the application developed and design based on the feedback received. Pregnant woman can use web or call center to schedule trips. User guide and training are provided for each participant. User guide is provided in paper form and is also available in app and on the web. Retraining is available for travelers.	S-G	S0	E-S	E2	C-Y	C3	-
89	The ride arrived for the prenatal traveler pickup is less user friendly and doesn't follow safety standards while driving the prenatal traveler.	Ride provided to the prenatal traveler did not follow safety standards and results in the injury of the prenatal traveler.	Car choice will be given to the prenatal traveler when scheduling the appointment based on her requirements. Prenatal traveler will be able to cancel the ride at any point of time she feels unsafe and schedule a new ride. Prenatal traveler will be able to provide feedback for the ride. Mobility providers will also provide defensive driving course to the drivers.	S-E	S3	E-M	E1	C-X	C3	A
90	Car seats are provided by vendor upon request and the car seat is not installed properly and the child is injured.	Safety of the child traveling with the prenatal travel in her ride to the doctor office is a risk. The car seat provided by the vendor is not installed properly by the driver and the child may be injured due to the improper installation of the car seat.	Training will be provided to all the vendor drivers regarding all the safety features and driver will also be trained with different installation procedures for three different car seats that are provided as per the program. Car Seat User Guide, which includes installation procedure and troubleshooting, is also provided to the drivers as part of the training.	S-E	S3	E-E	E2	C-J	C3	B
91	The car seats provided to the vendor might have bed bugs and lice.	Safety of the prenatal traveler and her kids is at risk. Both the traveler and her kids might get infected by bed bugs and lice while traveling with the car seat provided.	Kaizen Interior Sanitation Policy is in place to ensure each stakeholder understands the service standards. Carriers (drivers) will ensure their vehicle(s), and any needed additional equipment, have been properly cleaned and sanitized prior to provided services. Appropriate cleaning solution and supplies will be provided to clean any unsanitary object(s), seat(s) or piece(s) of equipment.	S-M	S1	E-K	E1	C-N	C3	QM
92	Traveler enters incorrect destination when planning a trip.	Prenatal traveler is taken to the wrong location; misses her appointment; needs to contact provider to plan another trip.	Application design restricts destinations to preapproved locations for selection. Training materials will also cover proper planning of a trip and reviewing information before booking. If wrong trip is executed, passenger can contact call center for assistance in planning an alternative and get a last-minute pickup.	S-J	S0a	E-M	E1	C-W	C1	-

ID	Safety Risk	Safety Impact	Mitigation Strategy	S-Rule	S	E-Rule	E	C-Rule	C	ASIL
Event Parking Management										
93	Driver distraction from paying attention to the app while driving to find the parking location.	Driver not paying attention while trying to find the parking spot and encounters a safety issue.	The app should not cause a risk to the drivers. All interactions should only be for stopped vehicles.	S-E	S3	E-S	E2	C-ZC	C3	B
94	Driver distraction when navigating to the parking spot through the app.	Driver not paying attention while trying to find the parking spot reserved through the app and encounters a safety issue.	The app should not cause a risk to the drivers. The application developed shall have be able to send the destination to a driver's preferred navigation app. All interactions should only be for stopped vehicles.	S-E	S3	E-S	E2	C-ZC	C3	B
95	Malicious functionality: active monitoring of the traveler causes hacking of traveler account/activity.	Creates the potential for unauthorized account activity (related to payments, trip planning, personal data, etc.), while traveler is trying to reserve a parking space using the mobile application. Also, app might store the user information when creating the user account.	Application design restricts the permissions requested only what is necessary for functionality. Development of the app along with vendor will provide visibility and customization allowing for more exposure of code base and how it functions. Make only services available to the user that are related to this project. Vendor security documents lists the security measures for the data collected through this application. Smart Columbus DPP Section 5.3: Security Controls describes the standards that will be taken to protect and secure the confidentiality of PII collected. ParkMobile is also a PCI Level 1 vendor.	S-I	S0a	E-T	E1	C-S	C3	-
96	Vulnerabilities for data transmission and storage.	Increased potential for identify theft because of storage of the data collected from the app users.	Application design restricts the permissions requested to only what is necessary for functionality. Lessons learned and best practices will be included in the security measures. Perform routine information security audits. Avoid collecting unnecessary or sensitive information from participants. Smart Columbus DPP Section 5.3: Security Controls describes the standards that will be taken to protect and secure the confidentiality of PII collected. ParkMobile is also a PCI Level 1 vendor.	S-I	S0a	E-T	E1	C-S	C3	-
97	Driver not able to access his/her car when parked in a garage after garage operation hours.	Traveler not able to access the car parked in a garage reserved through the app. Traveler may be stranded in an unsafe situation.	Traveler will be presented with the terms of service before he or she starts using the app. Traveler will be responsible for any actions related to parking his or her car. Traveler will be responsible to check the hours and other information about the parking space. ParkMobile will have information about the parking operations in the app. Towing information will also posted at the parking facility.	S-JA	S1	E-M	E1	C-J	C3	QM

Source: City of Columbus

Chapter 5. Safety Operational Concept

5.1. FUNCTIONAL SAFETY REQUIREMENTS

This section defines the functional safety requirements for the projects within the Smart Columbus demonstration program. The program SMP has been developed following the principles of assigning an ASIL risk assessment of the identified safety scenarios for each project, as outlined in ISO 26262. The safety activities will be included and considered in future systems engineering and project documents along with the activities that will eliminate or mitigate them such as the hazard analysis, security analysis and risk assessment. The systems requirements (for Vee model projects) and development backlogs (for Agile projects) developed for the eight projects will include appropriate functional safety requirements to mitigate the safety scenarios that **Table 12** identifies. These are requirements to ensure safe operation of the hardware and/or software and the actions to be taken within each project's deployment to reduce the likelihood and potential impact of the safety scenarios. Some of the requirements will be combined because they overlap between scenarios. Other requirements will be split because they apply differently, based on different applications deployed under each of the eight projects. All requirements (including safety functional requirements) will be subject to verification, for which testing plans and procedures will substantiate that the requirement has been implemented. For this verification, post-design documentation such as test plans and results, operations and maintenance guides and training materials will validate that these requirements were tested and implemented.

5.1.1. Equipment Procurement

The following three Smart Columbus program projects will be installing equipment:

- **CVE:** OBUs will be installed in transit, private, emergency, fleet, and freight vehicles. In addition, a Human Machine Interface (HMI) will also be deployed in private vehicles that consists of a Head-Up Display (HUD).
- **CEAV:** Automated vehicles will be deployed along specific routes within the COC Linden neighborhood. The Operational Concept document lists the routes that the AVs would be operating along with connected infrastructure that will be installed as part of the project.
- **SMH:** Will install kiosks at six locations in Columbus to facilitate FMLM connections.

These projects will utilize quality equipment by requiring all the suppliers to submit and follow a quality management process, approved by Smart Columbus project management, for designing, constructing, producing, and testing their devices, subsystems and interfaces. This will help to ensure the equipment provided is properly assembled to assist with safe operations. The supplier's quality management will verify that system requirements, listed in the project SyRS, have been met with the oversight of Smart Columbus project management.

For the CVE project, device certification will be sought. If certification is not available by one of the three USDOT contracted certification bodies (Omni Air, DanLaw, or Layer7), manufacturer self-certification may be utilized. In this scenario, the acceptable QM plan for these devices will include the submission and approval of test plans, test procedures and test results. The system equipment shall be interoperable with other vendor equipment at any interfaces. Interfaces shall be compatible according to the system requirements and their standards as defined in the SyRS.

A safety review of the proposed operator interface will be performed. Lessons learned and best practices will be included in the design. Safety checks for all the installed equipment will comprise the equipment

reset functions, redundancy, security, and actions upon power loss and restoration which will be discussed in each project's documentation of the installed equipment.

5.1.2. Device Installation

Precautions and measures will be taken to make sure the equipment is properly installed to minimize the risks associated with equipment installation. Each project requires all the installers to provide and follow a quality management process in installing the equipment. Installer/maintainers will be comprised of manufacturer approved vendors or Smart Columbus demonstration program partner personnel who have been sufficiently trained by manufacturer approved vendors.

As **Table 5** shows, only the CVE, CEAV and SMH projects will require hardware installations by developers. The other projects require only participant smartphones.

- CVE RSUs and OBUs will be installed by trained and qualified manufacturer installers. The OBU installations will require the most planning as OBUs will need to be retrofitted to a variety of privately-owned vehicles and COTA buses. The OBU manufacturer will submit an installation plan that will meet the CVE user needs and system requirements. Installers will need to follow the installation safety requirements. Lessons learned in the USDOT CV Pilots will be applied as appropriate to the CVE installation process.
- CEAVs will come prepackaged and tested in the manufacturer's plant and any related equipment external to the vehicles will be installed according to the safety requirements of the CEAV quality management plan. They will also be tested in a closed course environment prior to deployment on the route.
- SMHs will be kiosks openly available to the public and installed according to the system design requirements. They will also be tested in a closed environment prior to being opened to the public.

A design review of the device installation will be performed, and safety checks will be completed for the installation that consider the condition of the vehicle or smart mobility hub site, bypasses, manual shutdown, security, possible overload conditions and a safety review of the proposed location of the OBU and of the SMH. Installation will be verified before deployment, including specific end-of-line testing and checklists. The draft installation plan will include details on the quality management activities described in this document for CVE, CEAV, and SMH. The draft site map and installation schedule will be developed following the system requirements phase for these three projects.

Final project documentation, lessons learned, and best practices used in the installation procedures will be shared with other cities interested in pursuing similar efforts.

5.1.3. Fail-Safe System Mode

All eight projects within the Smart Columbus program will have a fail-safe system mode. The system will revert to a fail-safe mode upon failure of the system to meet necessary and essential operational capabilities as defined in each project's system requirement documentation. Fail-safe mode intends to guarantee that, in the event of a system failure, the system, applications and devices will respond in a way that will not harm the system, devices, participants or other road users. It is a safeguard that prevents safety risks to people and property if failure occurs. The design mitigates unsafe consequences of the system's failure.

The system default position may be the fail-safe mode in which the user does not receive safety or mobility feedback from the unit and must drive unassisted. Therefore, in the event of a failure, the system and devices return to default mode, about which the participant will be familiarized during training program. Each project's SyRS document presents additional detail about its respective fail-safe modes. Safety management will include the periodic testing of these conditions and following established procedures.

5.1.4. Quality Training

All system operators, system maintainers, installers/maintainers and owners of a response plan included referenced herein will receive adequate, approved training based on their point of interface with the system. This training will be documented as it occurs as part of the Smart Columbus demonstration program.

While systems and installer trainings are essential, the most critical aspect of safety training concerns the project participants who will be using the project devices in the street environment. Development and implementation of participant training for the projects will be evaluated as the teams move into the design phase. In several projects, an IRB will oversee human use in the projects, which will be further strengthened by an Informed Consent Document that explains safety and data privacy risks to participants.

For projects that an IRB oversees, the IRB may require participant trainers to be certified in protecting human research participants to work with the participants. Training may be required for project staff involved with project management, person-to-person recruitment of participants, explanation of the informed-consent document, training of participants, the Safety Manager, caregivers and others who may work with participants.

Each Smart Columbus project has a training plan based on the infrastructure and device installation that will installed. A training plan which will be discussed in detail in the QM process of each project.

5.2. SAFETY MANAGEMENT

Safety management is the oversight of the activities necessary to ensure the safe execution of the project's deployment, which includes preparing this document and ensuring the project teams follow through with the plans. The Smart Columbus PMO has appointed a Safety Manager for the deployment phase of the program. At a high level, the safety manager's role will be to work with project leadership, suppliers, systems engineers and other stakeholders. Each project team will also identify certain staff to ensure that the elements of the risk response plan are implemented and documented. In addition, the annual safety reviews discussed in Section 5.2.3 in this SMP will be conducted annually and at critical project milestones to review project risks and mitigations.

Planning for risk began with the drafting of this SMP and identification of initial risks and potential mitigations. This assessment resulted in documentation of requirements related to safety management. As the deployment begins for each project, the project team will ensure that functional safety requirements in the project's SyRS are met. The systems engineering process provides a method to ensure that all the safety requirements that are identified in the SyRS or project backlog (for projects using the Agile software methodology) are carried out through design, implementation, verification and validation. Requirements are systemically designed to flow down to the design and acquisition activities. Suitable verification of safety requirements will be performed and documented as part of the SyRS check list of requirements.

Safety management also includes validating that plans and policies account for risks and their mitigations as the projects continue in deployment. For example, ensuring that equipment is calibrated and installed as per the safety requirements, speed limits are enforced strictly for the CVE and CEAV routes, end user agreements for applications are in place, and user training for applications like MAPCD and PTA are implemented, and TMC operator and Operating System training is conducted. The plans and policies for each project will be identified and developed as part of the engineering and IRB process for each project; the list presented in this paragraph is not intended to be exhaustive for all the projects.

All Smart Columbus projects will develop Operations and Maintenance (O&M) plans or a Standard Operating Procedures (SOP) guide. These documents will also include and address safety management procedures and practices to be followed during the demonstration period.

Finally, during the deployment phase the final element of safety management is to monitor any anomalies, near-misses, or crashes that occur and review these incident reports with project teams and relevant

stakeholders. Examination of reports of incidents may reveal shortcomings and adjustments that need to be made. Sources of information may be participant interviews, data downloads, police reports, and repair records as are appropriate for the incident.

5.2.1.1. SMART COLUMBUS OPERATING SYSTEM

Mitigation strategies listed for safety risks (Risk ID #1 through Risk ID #4) in **Table 12** will be reflected in the DPP and DMP, which outline processes for:

- De-Identification Policy – This document will incorporate mitigations for safety risks related to:
    1. Data re-identification
    2. Data collection and storage
    3. Data anonymization
    4. Authorized users access to restricted data
- Privacy Impact Assessment – This document will incorporate mitigation strategies for safety risks related to:
    1. Data breach
    2. Restricted data loss and notification of participants
- Data Curation process – The data curation process will mitigate safety risks related to:
    1. Data evaluation
    2. Data validation

During the development of the O&M manual, the safety risks will be taken into consideration and best practices will be used to mitigate anticipated risks and ensure that when problems occur the safety risks to participants is minimized. Items that will be covered in the O&M Manual include:

- Data patching and updates
- Security controls and measures
- Security logs
- System recovery

5.2.1.2. CONNECTED VEHICLE ENVIRONMENT

Mitigation strategies listed for safety risks (Risk ID #5 through Risk ID #24) for CVE applications in **Table 12** are reflected in the CVE SyRS and have been applied in the CVE RFP.

Hardware and software requirements are listed in the SyRS, ICD and SDD documents. The RFP provides more specific requirements around these items. Safety mitigations related to these requirements contained in the RFP include:

- Security protections with SCMS, firewalls, access controls, strong passwords and regular software patches
- Provision of GPS accuracy and correction with RTCM, or similar
- Use of a HUD to provide alert messages
- Standards for BSM and all SAE message accuracy, reduction of radio interference

- Requirements for checklists related to OBU installations
- Requirement for an RSUs health monitoring system to ensure connectivity and alert of disconnection. This also provides quick identification and repair of RSUs and power that is not working.
- Coordination between the City and its vendors on the frequency and type of alerts that will be received by the drivers and reviewing early deployer feedback to adjust accordingly. This includes:
    1. Reference studies/surveys that identify appropriate number and type of alerts
    2. Involvement from independent subject matter experts to review icons and alerts prior to implementation
- Use of a cloud-based system for automatic update of school speed zone timings in the CVE corridors
- Application of lessons learned and best practices from the CV pilots implemented in New York, Florida, Wyoming and US-33 Smart Corridor project in Columbus, Ohio

During the development of the training and driver materials, the safety risks will be taken into consideration and training will be provided to all the participants to mitigate anticipated risks and ensure that when problems occur the safety risks to participants is minimized.

Training materials for both the installers and participants will incorporate strategies to reduce the risks related to:

- Installation and repairs of RSUs and OBUs
- Driver understanding and sources of confusion with the CV alerts
- Alert accuracy and false alerts
- Weather related issues
- Power outages and equipment failure
- PII security

5.2.1.3. MULTIMODAL TRIP PLANNING APPLICATION/COMMON PAYMENT SYSTEM

Mitigation strategies listed for safety risks (Risk ID #59 through Risk ID #67) for MMTPA/ CPS project in **Table 12** are reflected in the MMTPA/ CPS SyRS and have been applied in the MMTPA/CPS RFP.

Software safety mitigations contained in the RFP include:

- Maintenance modes occur during off-peak hours.
- Application to offer multiple transportation modes available
- Provision of trip service disruption alerts to travelers
- Use of security and protections to safeguard PII
- Processes to inform travelers of any PII data breaches
- For PayNearMe stores, requiring accurate information on hours of the stores

During the development of the RFP and outreach materials, the safety risks will be taken into consideration and best practices and lessons learned will be incorporated to mitigate anticipated risks and ensure that when problems occur the safety risks to participants is minimized.

Outreach materials will incorporate strategies to reduce the risks related to:

- Road safety
- Unsafe driving
- Driver distraction

5.2.1.4. SMART MOBILITY HUBS

Mitigation strategies listed for safety risks (Risk ID #44 through Risk ID #58) for SMH project in **Table 12** are reflected in the SMH SyRS, construction as-built plans, and have been applied in the SMH RFP.

Kiosk software safety mitigations contained in the RFP include:

- Providing location specific content at the kiosks
- Requirement for accurate location of ECB when activated
- Maintenance modes occur during off-peak hours.
- Providing alerts for failure modes
- Presenting the application to plan a trip at the kiosk
- Provided Wi-Fi services at the SMH location
- Providing trip service disruption alerts to travelers
- Use of security and protections to safeguard PII
- Processes to inform travelers of any PII data breaches

During the development of the RFP, construction as-builts plans, and outreach materials, the safety risks will be taken into consideration and best practices and lessons learned will be incorporated to mitigate anticipated risks and ensure that when problems occur the safety risks to participants is minimized.

Safety mitigations contained in the construction as-builts plans include:

- Pavement markings and signage showing parking locations of transportation modes at SMH locations

Outreach materials will incorporate strategies to reduce the risks related to:

- Features provided at the SMH location
- Law enforcement outreach regarding emergency call button activation at the SMH locations
- Road safety features

5.2.1.5. MOBILITY ASSISTANCE FOR PEOPLE WITH COGNITIVE DISABILITIES

Mitigation strategies listed for safety risks (Risk ID #68 through Risk ID #81) for MAPCD project in **Table 12** are reflected and been applied in the MAPCD RFP and MAPCD O&M plan.

MAPCD application software safety mitigations contained in the RFP include:

- Providing correct route based on the options selected
- Maintenance modes occur during off-peak hours
- Alerts for failure modes of the application
- Use of security and protections to safeguard PII

- Processes to inform travelers of any PII data breaches

During the development of the training and outreach materials, the safety risks will be taken into consideration and training will be provided to all the participants to mitigate anticipated risks and ensure that when problems occur the safety risks to participants is minimized.

Training materials are provided to both the traveler and their caregiver and will incorporate strategies to reduce the risks related to:

- The traveler going off route
- Loss of mobile phone or mobile issues (no charging or no network coverage)
- Caregiver not responding
- MAPCD application not working

5.2.1.6. PRENATAL TRIP ASSISTANCE

Mitigation strategies listed for safety risks (Risk ID #82 through Risk ID #92) for PTA project in **Table 12** are reflected and been applied in the PTA RFP and PTA O&M plan.

PTA application software safety mitigations contained in the RFP include:

- Providing correct customer care number
- Maintenance modes occur during off-peak hours.
- Alerts for failure modes
- Use of security and protections to safeguard PII
- Processes to inform travelers of any PII data breaches

During the development of the training and outreach materials, the safety risks will be taken into consideration and training will be provided to all the participants to mitigate anticipated risks and ensure that when problems occur the safety risks to participants is minimized.

Training materials will incorporate strategies to reduce the risks related to:

- When a ride is late or cancelled
- A traveler not having access to mobile phone
- Unavailability of car seats or wheelchair accessibility
- PTA Application not working

5.2.1.7. EVENT PARKING MANAGEMENT

Mitigation strategies listed for safety risks (Risk ID #93 through Risk ID #97) for EPM project in **Table 12** are reflected in the SyRS and been applied in the EPM RFP and EPM O&M plan.

EPM application software safety mitigations contained in the RFP include:

- Maintenance modes occur during off-peak hours.
- Use of security and protections to safeguard PII
- Processes to inform travelers of any PII data breaches

During the development of the outreach materials, the safety risks and mitigation strategies will be taken into consideration and ensure that when problems occur the safety risks to participants is minimized.

5.2.1.8. CONNECTED ELECTRIC AUTONOMOUS VEHICLES

Mitigation strategies listed for safety risks (Risk ID #25 through Risk ID #43) for CEAV project in **Table 12** have been applied in the CEAV RFP and CEAV O&M plan.

CEAV safety mitigations contained in the RFP and SOP include:

- Traffic flow harmonization
- VRU identification and object avoidance
- Identification and avoidance of scooters
- Training of emergency responders
- Review of CEAV Test plan of Scioto Mile deployed in Columbus, OH and MnDOT Autonomous Bus Pilot Project deployments
- Liability insurance in the absence of proven systems

During the development of the training and SOP materials, the safety risks listed in **Table 12: Summary of Safety Risk Assessment** will be taken into consideration and ensure that when problems occur the safety risks to participants is minimized.

For the Linden deployment, the CEAV will not run without an operator on board. In addition, CEAV operator training materials will include strategies and training related to:

- Intervening to stop AV operation and manually open the door for passengers
- Assisting the passengers that need ADA access
- Not moving until the door is fully shut
- Manually maneuvering around any obstacle
- Taking control of the vehicle as backup to the onboard systems
- Reviewing EasyMile AV User Guide for emergency situations
- Reducing vehicle operator distraction
- Prohibiting hands-free devices during AV operation
- Providing operator instruction of passengers to remain seated and belted or holding onto rails
- Preventing passenger tampering

Other strategies will include:

- Signage installation on the AV routes.
- Installing signage on the back of the vehicle about making frequent stops.
- Coordinating with construction projects along AV routes

5.2.2. Safety Manager Responsibilities

The Smart Columbus Safety Manager's role will be to work with the COC, project teams, suppliers/vendors, systems engineers and other stakeholders. The following are some of the key safety coordination areas that the safety manager will be responsible for:

- Leadership and direction in safety procedures
- Ensuring compliance with applicable regulations and the SMP

- Ensuring Safety Management is represented in the informed-consent documents and participant training
- Incorporating safety into design, deployment, and operational phases
- Guidance for equipment procurement and acceptance
- Oversight for device certification, testing and installation
- Operational safety and monitoring
- Incident reporting, documentation, and investigation of the incident
- Maintaining and updating safety processes and the SMP
- Safety coordination with other entities and task leads

5.2.3. Safety Reviews

Safety reviews support the Smart Columbus PMO focus on safety, ensure compliance with the SMP, and identify opportunities to improve safety. Regular assessments help to identify any new safety risks and develop the appropriate control measures. The review panel will be identified/defined prior to the review and will likely include members of the PMO and project team (to include vendors and testers), although independent/third party staff may also be considered to offer an objective opinion on the review.

Safety review are conducted either annually, prior to project's launch, or when an incident occurs. When safety reviews are conducted, the reviewers will ensure that:

- Appropriate technical experts and team members are present.
- Improvement opportunities are discussed and/or identified.
- Review outcomes are communicated to the PMO and project team members.
- Follow up with project team regarding actions that arise from reviews.
- Ongoing operations are monitored for compliance with the SMP.

For the 2019 annual safety review, the projects were categorized into three different phases as listed below.

- Deployment phase
- Pre-installation phase
- Design phase

Separate agendas were developed for all three phases listed above, attached in **Appendix B**, for the annual safety review meetings.

Aside from the safety reviews outlined above, the safety manager and project team will work together to validate the development and implementation of safety related requirements through the projects' development and demonstration. The safety manager, along with project leads, will review the project materials and ensure that the safety requirements are carried through the design process. These materials include:

- Major project deliverables (such as system design or test plan)
- Operational and participant training materials such as:
    1. User Guides
    2. Informed Consent Documents
    3. Participant training materials
    4. Operating Procedures

- Equipment, software, and process checklists

Certain project milestones and events may also prompt an informal discussion between the safety manager and project team to determine if a safety review is warranted. These potential events may include:

- Periodic equipment, software, and process checks during operation.
- After a critical event or significant design or operational change that could affect safety
- After a participant, team member or other individual submits a safety-related complaint
- After a change to applicable standards and codes of practices

Figure 5 illustrates the Safety Incident process described above.

5.2.4. Safety Incident Reporting

Reporting an incident helps identify improvements that can prevent the incident from reoccurring. The policy will accomplish the following actions:

- Report and record all safety incidents
- Safety Manager will use Incident Report Form shown in **Appendix D** to document incidents occurred to the participants
- Participants will receive guidance about safety reporting during training and in the Informed Consent Document
- Safety incidents will be investigated, and the underlying causes identified
- Serious harm incidents will prompt a review of application performance
- A regular review of all safety incidents occurs to identify any trends
- System upgrades will be undertaken as needed for safety
- Participants will be notified, as needed, of systemic safety problems that occur and/or of system upgrades to their applications

Figure 5 illustrates the safety incident process.

5.2.4.1. PRIVACY INCIDENTS

While not causing physical harm to any one person, privacy incidents, such as breach of PII or Sensitive PII (SPII), may adversely affect persons whose employment, finances, healthcare or personal security could be compromised by data or identity theft.

Treatment of privacy incidents is described in the DPP. To summarize, data privacy has standard built-in protections that include filtering and de-identifying of PII before it would be stored for use. Per the Informed Consent Document that each participant signs, affected participants will be notified of a data breach and informed of what Smart Columbus data managers are doing about it. The IRB will be informed of the data breach and the IRB or the PMO will inform U.S. Department of Health and Human Services (HHS) of the breach, according to the provisions of HHS guidelines.

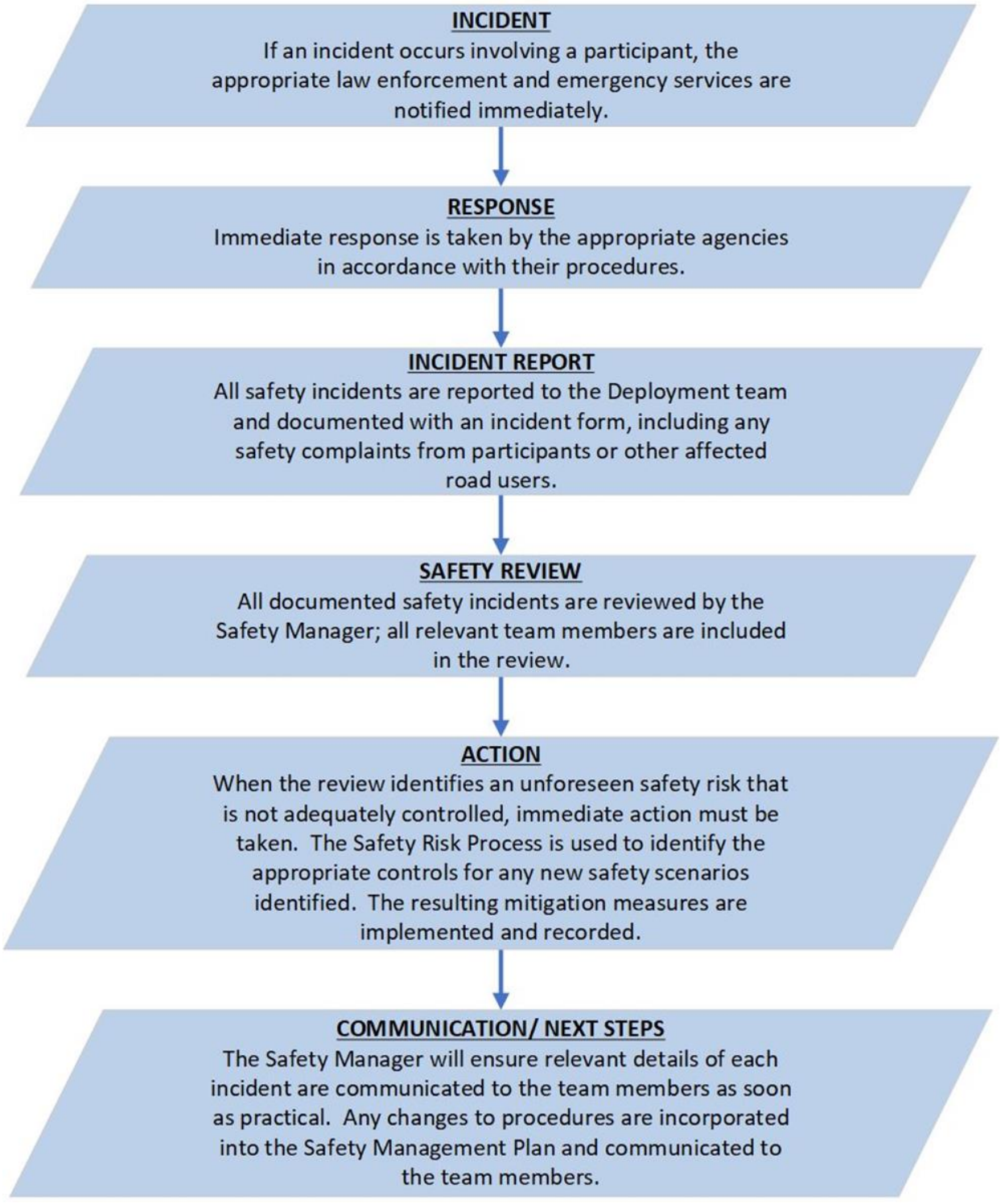

Figure 5: Safety Incident Process

Source: City of Columbus

Chapter 6. Coordination with Other Tasks

Part of safety management is coordinating tasks in the deployment of the Smart Columbus Program so that safety needs are addressed throughout it. The safety needs and operational concepts discussed in this plan will be incorporated into the program portfolio by the project leads and team members who coordinate tasks during their monthly progress meetings. It is the intention of the Smart Columbus team to avoid “stove piping” tasks and projects and reduce isolation of systems development among the projects, except as necessary for system integrity protection. Agreement between project systems across artificial boundaries is a goal of project coordination and is an essential feature of the Operating System. The following subsections explain how the systems engineering process advances safety in the Smart Columbus Program. With the exception of the Operating System, individual projects oversee participant physical safety. The Operating System does not address participant physical safety, per se, but rather secures data collection and overall system integrity. The following subsections explain how the systems engineering process advances safety in the Smart Columbus Program.

6.1. TASK B: CONCEPT OF OPERATIONS

Safety scenarios in this SMP follow the ConOps, operational concept or trade studies developed for the eight Smart Columbus projects based on the project type. These documents list the user needs, applications to be deployed and operational practices to be followed for each project. Chapter 5, Safety Operational Concept was developed in coordination with the proposed operational practices described in these conceptual documents for each project.

6.2. TASK B: SYSTEMS REQUIREMENTS AND SPECIFICATION

The SyRS Plans include functional requirements, interface requirements, data requirements, performance requirements, security requirements etc., for all the systems that will deployed as part of the Smart Columbus demonstration program. The SMP lists all the requirements and the safety risks associated with those requirements. This SMP will be incorporated into the respective SyRS documents developed for all the Smart Columbus projects. For projects following the Agile software development methodology (MMTPA/CPS, PTA, and CEAV), the development backlog will contain the traceability to requirements.

6.3. TASK B: SYSTEM ARCHITECTURE AND STANDARDS PLAN

The Systems Architecture and Standards Plan (SASP) documents the architecture for systems associated with the Smart Columbus program and associated standards that will be used. The architecture document captures enterprise, functional, physical and communications architecture of the system architecture. The SASP will follow this SMP's assessments of risks, impacts and mitigations to the extent that they apply to and influence the architecture.

6.4. TASK B: INTERFACE CONTROL, SYSTEM DESIGN , TEST PLAN AND RESULTS, AND OPERATIONS AND MAINTENANCE DOCUMENTS

The Interface Control, System Design and Test Plan documents should refer to the SMP to make sure all the safety risks listed in this plan in **Table 11** are addressed while designing and testing the system and

applications developed in the Smart Columbus demonstration program. The Test Results and Operations and Maintenance Plans validate that the safety requirements were tested and implemented.

6.5. TASK C: PERFORMANCE MANAGEMENT PLAN

The methods and processes detailed in the Performance Measurement and Independent Evaluation Support Plan need to be consistent with the safety operational concept discussed in Chapter 5 in this SMP. Performance measurement will be done electronically through surveys and data collection, and so will not endanger safety of persons. The data security issues discussed in the DPP, and briefly summarized in **Section 5.2.4.1**, apply to performance measurement data and metadata which might be used to identify persons and compromise PII.

6.6. TASK D: DATA PRIVACY PLAN

The SMP outlines the high-level mitigation for the risks identified for the privacy and security of the participants and the system. The Smart Columbus DPP provides detailed protections and mitigation for data risks identified to protect the privacy of the users and ensure secure operations. The DPP works with this SMP to ensure that PII is secure and that SPII, particularly that of vulnerable populations such as users of the MAPCD and PTA, are protected. Any breach in data security with PII loss will be reported to participants along with the measures taken by the Smart Columbus program team to ensure safety of the participants. Also, the IRB will be notified and the HHS, as needed, per HHS Guidelines.

6.7. TASK E: DATA MANAGEMENT PLAN

While the SMP outlines high-level mitigation strategies for the data storing risks identified, the Smart Columbus DMP describes how data will be collected, managed, integrated, and disseminated before, during, and after the Smart Columbus program. The DMP also provides detailed protections and mitigation for data risks identified to protect the privacy of the users and ensure secure operations. The DPP and DMP work to ensure that data privacy and operations are secure.

6.8. TASK E: HUMAN USE APPROVAL SUMMARY

The Smart Columbus Human Use Approval Summary aims to document the efforts made to ensure the protection of personal information, which is the purview of the DPP, and human safety, which includes the mitigation strategies discussed in this SMP. The SMP, with safety scenarios and associated safety operational concepts, is necessary to obtain IRB approval to proceed for any project requiring IRB oversight (see **Table 6** for IRB oversight of projects). An IRB-approved Informed Consent Document will instruct participants that, in the event of a data breach of PII or SPII, they will be notified of the breach and what the Smart Columbus PMO is doing about it. Participants will be instructed in proper device use, that the devices in the projects are only aids to travel and that they, as travelers, are responsible for their travel behavior while using the devices. The Informed Consent Document will inform participants where to call and what to do if help is needed.

6.9. TASK G: COMMUNICATIONS AND OUTREACH

Communications and Outreach includes Participant Training and Stakeholder Education. These activities identify the roles that program staff will take during the deployment, their actions, responsibilities, and training requirements. Communications and Outreach will be consistent with the actions described in the SMP to reduce the likelihood and potential impact of each safety scenario.

Chapter 7. Conclusions

The SMP provides guidance material about the identification of safety scenarios and risk mitigation for the Smart Columbus demonstration program. The plan identifies the safety scenarios at both program-level and project-level, assesses the level of risk for each scenario, and provides a safety operational concept for high/medium risk scenarios. Safety stakeholders for each project were identified and coordination with emergency responders was incorporated in the SMP.

At this time, the Smart Columbus PMO has determined that the risks to the demonstration program are manageable. For the CVE project, the conservative approach of delivering only alerts and not permissive messages means that many applications will naturally fail to a safe condition. Training of all participants, from mechanics to drivers will be necessary. For the projects deploying mobile applications, training will be provided to the users willing to use the application. Careful attention to details in design, software requirements, combined with diligent testing, will address many of the safety risks identified in **Table 11**. Ongoing safety management throughout the remainder of the project will ensure follow-through.

Additional conclusions and next steps regarding safety management for both the program and projects include:

- The safety manager will provide guidance to the project teams and continue to follow all the scenarios. The purpose will be to document verification of safety-related requirements and to coordinate safety-related activities of all stakeholders, under the direction of Smart Columbus PMO.
- For projects receiving IRB oversight, participant training and the Informed Consent Document will advise participants of the safety problems that might arise and how to get aid, if needed.
- While the ConOps and SyRS documents are finalized for the projects, refined analysis may lead to more safety scenarios being identified. They will be rated and tracked along with those already identified. Some of the safety scenarios will be addressed by writing safety requirements and verifying designs to those requirements. They will be tracked through design and development phases of the program. Other hazards will require ongoing safety management through the duration of the deployment phase.
- As the project proceeds to detailed design, safety requirements will be allocated to systems and subsystems, and to their interfaces. Evidence that requirements have been met will be collected, scrutinized, and documented. The level of documentation and independent review will be in accordance with the rating of each safety risk assigned.

Appendix A. Acronyms

Table 13 contains project specific acronyms used throughout this document.

Table 13: Acronym List

Abbreviation/Acronym	Definition
ADA	Americans with Disabilities Act
ASIL	Automotive Safety Integrity Level
AV	Automated Vehicle
BRT	Bus Rapid Transit
CMAX	COTA's Bus Rapid Transit (BRT) Service
COC	City of Columbus
ConOps	Concept of Operations
COTA	Central Ohio Transit Authority
CPS	Common Payment System
CV	Connected Vehicle
CVE	Connected Vehicle Environment
DMP	Data Management Plan for the Smart Columbus Demonstration Program
DPP	Data Privacy Plan for the Smart Columbus Demonstration Program
DSRC	Dedicated Short Range Communications
E/E	Electrical and Electronic
EHS	Enhanced Human Services
EMS	Emergency Medical Services
EPM	Event Parking Management
FHWA	Federal Highway Administration
FMLM	First Mile/Last Mile
GPS	Global Positioning System
HHS	U. S. Department of Health and Human Services
HMI	Human Machine Interface
HUD	Heads Up Display
IRB	Institutional Review Board
ISO	International Organization for Standardization
ITS	Intelligent Transportation System
MAPCD	Mobility Assistance for People with Cognitive Disabilities

Abbreviation/Acronym	Definition
MCO	Managed Care Organization
MMTPA	Multimodal Trip Planning Application
NEMT	Non-Emergency Medical Transportation
ODOT	Ohio Department of Transportation
OBU	On-board Unit
Operating System	Smart Columbus Operating System
OSU	The Ohio State University
O&M	Operations and Maintenance
PfMP	Performance Management Plan
PII	Personally Identifiable Information
PTA	Prenatal Trip Assistance
PMO	Program Management Office
QM	Quality Management
RCTM	Radio Technical Commission for Maritime Services
RFP	Request for Proposal
RSU	Roadside Unit
SASP	Systems Architecture and Standards Plan
SCC	Smart City Challenge
SCMS	Security Credential Management System
SMH	Smart Mobility Hub
SMP	Safety Management Plan
SOP	Standard Operating Procedures
SPII	Sensitive Personally Identifiable Information
SyRS	System Requirements and Specifications
TMC	Traffic Management Center
USDOT	U.S. Department of Transportation
V2V	Vehicle-to-Vehicle
V2I	Vehicle-to-Infrastructure
VRU	Vulnerable Road User

Source: City of Columbus

Appendix B. Safety Review Agendas

B.1 AGENDA FOR PROJECTS IN DEPLOYEMENT PHASE

For 2019 annual safety reviews, for the projects that are in the deployment phase, the agenda below was used for the safety review meeting. Four Smart Columbus projects (MAPCD, PTA, OS and MMTPA) were in deployment phase.

- Walkthrough of each risk and mitigation strategy listed in the SMP (prioritize the risks with higher ASIL scores)
    1. Identify risks and mitigation strategies that are obsolete (closed or resolved).
    2. Identify changes to the mitigation strategies (additional strategies planned/implemented, changes and/or additions to policies, procedures, training etc., strategies removed or classified as obsolete).
    3. Identify new risks and mitigation strategies.
    4. Identifying/referencing where policies are documented.
- Verification that safety requirements (mitigation strategies) are carried through as-built documents
    1. Design (engineering documentation: SyRS, ICD and SDD).
    2. Installation documents.
    3. Testing (including test plan/requirements test matrix, RTM).
    4. Policies/procedures such as end user agreements, recruiting materials, research protocol, user training materials
        - Including validation that user training (where specified) is planned or has been conducted and is listed under mitigation strategies
- Operations and Maintenance Plan
    1. Ensure all safety related practices are put into effect. This would include training and inspections.
    2. Monitor any anomalies, near-misses, or crashes that occur.
        - Each project team will also identify certain staff to ensure that the elements of the risk response plan are implemented and documented.
        - Periodic equipment, software, and process checks during operation.
        - Reporting and follow up procedures for near-misses or events
    3. Verification of safety requirements performed and documented as part of the SyRS check list of requirements.
    4. Establish processes/procedures and communicate to project teams and stakeholders.
- Update Risk Assessment spreadsheet
- Verify new requirements/ policies/procedures are carried through as-built documents.
- Complete safety review template for the reviewed project.

- Other action items identified during the review meeting

B.2 AGENDA FOR PROJECTS IN PRE-INSTALLATION PHASE

For 2019 annual safety reviews, for the projects that are in the deployment phase, the agenda below was used for the safety review meeting. Four Smart Columbus projects (MAPCD, PTA, OS and MMTPA) were in deployment phase.

- Walkthrough of each risk and mitigation strategy listed in the SMP (prioritize the risks with higher ASIL scores)
    1. Identify risks and mitigation strategies that are obsolete (closed or resolved).
    2. Identify new risks and mitigation strategies.
    3. Identify areas for improvement.
        - Identify changes to the mitigation strategies (additional strategies planned/implemented, changes and/or additions to policies, procedures, training etc., strategies removed or classified as obsolete).
- Verification that safety requirements (mitigation strategies) are carried through
    1. Procurement Specs (RFP and/or contracts)
    2. Device certification
    3. Design (engineering documentation: SyRS, ICD and SDD)
    4. Installation documents
    5. Testing (including test plan)
- Operations and Maintenance Plan
    1. Ensure all safety related practices are put into effect. This would include training and inspections.
    2. Monitor any anomalies, near-misses, or crashes that occur.
        - Each project team will also identify certain staff to ensure that the elements of the risk response plan are implemented and documented.
        - Periodic equipment, software, and process checks during operation.
        - Reporting and follow up procedures for near-misses or events
    3. Verification of safety requirements performed and documented as part of the SyRS check list of requirements.
    4. Establish processes/procedures and communicate to project teams and stakeholders.
- Update Risk Assessment spreadsheet
- Verify new requirements/ policies/procedures are carried through as-built documents.
- Complete safety review template for the reviewed project.
- Other action items identified during the review meeting

B.3 AGENDA FOR PROJECTS IN DESIGN PHASE

For 2019 annual safety reviews, for the projects that are in the deployment phase, the agenda below was used for the safety review meeting. Four Smart Columbus projects (MAPCD, PTA, OS and MMTPA) were in deployment phase.

- Review each risk and mitigation strategy listed in the SMP (prioritize the risks with higher ASIL scores
    1. Identify new risks and/or mitigation strategies
    2. Identify areas for improvement.
        - Identify changes to the mitigation strategies (additional strategies planned/implemented, changes and/or additions to policies, procedures, training etc., strategies removed or classified as obsolete).
- Verify that safety management requirements are carried through
    1. Design (engineering documentation: SyRS, ICD and SDD).
    2. Test Plan
    3. Procurement specs
- Update Risk Assessment spreadsheet
- Verify new requirements/policies/procedures are carried through engineering documents.
- Complete safety review template for the reviewed project.
- Other action items identified during the review meeting

Appendix C. Safety Review Template

Table 14 shows the safety review template that will be used during the safety reviews by the safety manager and the project team to document changes in the project's risks assessment.

Table 14: Safety Review Template

Safety Review Template	
Name of Reviewer: _____	**Date of Review:_____**
What type of review was it? (document, deliverable, deployment, etc.)	
Purpose of the review: (Annual Safety Review, Pre-Installation Review, Pre-Deployment Review, Design review, Periodic/Random Check, etc.)	
Version of the Risk Assessment that was used: **Revision:**	**Date:**
Review Notes:	
Were there any new safety issues identified? (please circle one) YES NO	
If **YES** – Describe the issue:	
If **YES** – Describe recommended mitigation action:	

Safety Review Template

Review Notes:

Were there any safety issues identified as obsolete? (please circle one) YES NO

If **YES** – Describe the issue:

If **YES** – Describe recommended mitigation action:

Review Notes:

Were there any mitigation strategies listed for identified safety issues modified?

(please circle one) YES NO

If **YES** – Describe the issue:

If **YES** – Describe recommended mitigation action:

Were any new safety issues identified that should be included on the risk register for future reviews?

(please circle one) YES NO

If **YES** – What was the issue identified?

If **YES** – Has the Safety Manager been contacted to include the risk?

(please circle one) YES NO

Name (please print) Signature Date

Source: City of Columbus

Appendix D. Incident Report Form

Table 15: Incident Report Form - Part A

Incident Report Form – Part A (To be filled by the participant)
Information about the person who had the incident:
Name: _____
Participant / Team Member / Visitor / Contractor *(please circle one)*
Participant's Mode of Travel *(Personal Vehicle/Bus/Trolley/Bicycle/Pedestrian)*: _____
Contact Telephone: Work:_____ Mobile:_____ Home:_____
What type of incident was it? *(please circle one)*
Near Miss Collision Property Damage Property Loss Application Failure Identity Theft
When did the incident happen?
Date: Time:
Where did the incident happen?
Location:
What happened?
Description: *(include details of any device involved, other vehicles involved, property lost or damaged)*
Was a known safety hazard involved? *(please circle one)* YES NO
If YES – what was the safety hazard?
Names and contact information of any witnesses:

Incident Report Form – Part A (To be filled by the participant)

What injury or injuries were sustained, and to whom?

Is this a serious harm injury? (*please circle one*) YES NO

Was first aid or emergency care provided? (*please describe*)

Was law enforcement notified?

Name of agency:

Declaration: The above report provides a true, accurate and complete account of the accident / incident / near miss / malfunction

Participant Name *(please print)*	Signature	Date

Source: City of Columbus

Table 16: Safety Incident Form - Part B

Part B: (To be filled by the Safety Manager)
Were there any contributing factors to this incident?

Safety Hazard Identification:

Is this a new safety hazard? YES NO

It is a significant safety hazard? YES NO

If YES identify the hazard management process to be done (eg: update risk register and put in recommended actions below)

Recommended Actions		Individual Responsible	By when	Date completed
Has the Risk Management Process been completed for this safety scenario? YES NO (please circle)	What has been done?			
Is a review of Safety Management Plan required? YES NO (please circle)	Which section?			
Other Recommended Actions		**Individual Responsible**	**By when**	**Date completed**
Specific actions to prevent recurrence				
Specific actions to prevent recurrence				
Communications		**Individual Responsible**	**By when**	**Date completed**
All relevant team members and participants have received information regarding the incident, changes of operation / procedures.				

Part B: (To be filled by the Safety Manager)		
Was the incident related to a malfunction of the device or system? *(please circle)*	YES	NO
If yes, describe the malfunction.		
Was the incident related to an issue with the installation of the device? *(please circle)*	YES	NO
If yes, describe the installation issue.		
Overall comments:		

Safety Manager's Name *(please print)*	Signature	Date

Source: City of Columbus

THE CITY OF
COLUMBUS
ANDREW J. GINTHER, MAYOR