ITS AMERICA

November 15, 2022

Dr. Robert Hampshire
Deputy Assistant Secretary, Research and Technology
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Re: Docket No. DOT–OST–2022–0096

Dear Dr. Hampshire,

As the nation's leading advocate for the technological modernization of our transportation system by focusing on advancing research and deployment of intelligent transportation technology, the Intelligent Transportation Society of America (ITS America) is grateful for the opportunity to comment on the U.S. Department of Transportation's (USDOT) Request for Information on enhancing the safety of vulnerable road users (VRUs) at intersections.

ITS America was founded in 1991 as an advisory council to USDOT on technology innovation and emerging transportation technologies. It is the only organization in the country that represents all sectors – public, private, academic, and nonprofit – to advance transportation technology. Our membership includes state and city departments of transportation, transit agencies, metropolitan planning organizations, automotive manufacturers, technology companies, engineering firms, automotive suppliers, insurance companies, and research and academic universities. Our vision is a better future transformed by intelligent mobility: one that is safer, greener, and smarter. We work toward a world in which we achieve the nation's Vision Zero goals to eliminate fatalities and serious injuries on our roadways; a world that is more sustainable, resilient, and adaptable to climate change; and a world in which communities have equitable and affordable access to transportation and critical services. Our vision aligns directly with USDOT's goals to advance safety, climate, and equity.

ITS America applauds USDOT's efforts to study approaches to improving safety in intersections by deploying technology. We firmly believe that safety innovations are our best tool in achieving USDOT's vision of zero fatalities on U.S. roadways, and equally believe that such a goal cannot be accomplished without technology investment. As transportation fatalities continue to rise year after year, including extremely concerning trends around VRU fatalities and fatalities in underserved communities, ITS America maintains that new approaches must be utilized to improve road safety in and outside of the vehicle.

This effort by USDOT to improve safety in intersections through technology solutions represents a significant opportunity to realize that vision. We believe this effort to be consistent with both USDOT's National Roadway Safety Strategy and Innovation Principles, which both represent clear-sighted strategies to enhance safety while achieving additional important goals such as mobility, equity, and resiliency.

USDOT's leadership in supporting the deployment of technology and leading the discussion of incorporating technology into transportation infrastructure remains critical. The lessons learned from this RFI should be considered in all of the Department's funding programs, particularly those stemming from the once-in-a-generation Infrastructure Investment and Jobs Act (IIJA), including discretionary grant programs such as Safe Streets and Roads for All. Safety technologies are poised to provide significant benefit across the entire scope of USDOT's efforts in deploying IIJA resources, and ITS America looks forward to working with the Department to identify specific opportunities where technology can be utilized to provide benefits for road users.

VRU and Vehicle Roadway Warning System

Introduction

The need for action to improve safety for VRUs is clearer than ever. Pedestrian fatality numbers continue to rise: drivers struck and killed an estimated 7,485 people on foot in 2021 – the most pedestrian deaths in a single year in four decades, a 12 percent increase from 2020, and an average of 20 deaths every day, according to the Governors Highway Safety Association (GHSA).[1] These numbers demonstrate the scale of the problem, but we know that this is not just a number, each of these fatalities cause a tragic impact on the lives of tens of thousands of family members and friends who knew the victims.

ITS America believes it is the responsibility of transportation industry stakeholders to fully utilize all of the tools and strategies available to reduce this trend. Street redesign and changes to the physical infrastructure are certainly important components of a VRU safety strategy, but cannot be the entire strategy. Transportation technology solutions represent another important pillar of this effort: these include advanced cameras, sensors, radar, LiDAR, connected infrastructure (such as those utilizing C-V2X), artificial intelligence, and many others. They can provide critical warnings to drivers about pedestrians out of the line-of-sight or about to enter the roadway, and can allow infrastructure to act, such as by extending a red light, to avoid crashes. Transportation technologies can also provide much-needed insights to transportation planners about how and where to best utilize and deploy infrastructure solutions, both digital and physical. Through the use of technology and data collected, problematic intersections and corridors can be more readily identified and addressed.

Technology often provides a cost-effective way to accomplish policy objectives, such as enhancing VRU safety, when compared to other, more costly infrastructure interventions. ITS America believes in the value of street redesign – but redesign alone is insufficient – technology is a necessary addition to the

[1] Governors Highway Safety Association: "New Projection: U.S. Pedestrian Fatalities Reach Highest Level in 40 Years," May 19, 2022. Available at: https://www.ghsa.org/resources/news-releases/GHSA/Ped-Spotlight-Full-Report22#:~:text=WASHINGTON%2C%20D.C.%20%E2%80%93%20Drivers%20struck%20and,Highway%20Safety%20Association%20(GHSA).

transportation system. Combining these two complementary approaches will best enhance safety for the VRU community.

To best leverage technology in this way, USDOT should encourage a system of systems approach – one that utilizes contributions from different parties and technologies in a modular fashion. This approach should fit into a broader system of managing traffic flow and mobility in a way that prioritizes the safety of road users of all modes of travel; one that is made possible by connectivity and interoperability among various technology solutions – both those that will be deployed through this effort and those which have already been deployed and can be leveraged in new ways to advance the Department's goals (such as utilizing existing video technology or focusing on connecting unconnected intersections to take advantage of already-deployed technology).

USDOT must not miss the opportunity to utilize the once-in-a-generation influx of transportation funding through the Infrastructure Investment and Jobs Act (IIJA) to incorporate technology into intersections in order to reduce fatalities of VRUs and drivers alike.

Vehicle Roadway Warning System

Vehicle Roadway Warning Systems should incorporate a combination of audio, visual, and haptic warnings in order to alert drivers of potential VRU collisions. However, USDOT should consider the amount of information that is provided to the driver through these mediums and the frequency of alerts. Warnings must be delivered in a way that reinforces safe behavior and optimizes driver attention, rather than risking alert fatigue through too high a quantity or complexity of warnings and alerts.

Drivers should be warned about potential pre-crash scenarios that pose a risk to a VRU outside of their vehicle. This includes instances of lane incursion, pedestrian incursion into the flow of moving traffic, or pedestrians in a driver's blind spot. USDOT should consider ways to increase warning capabilities for visually impaired pedestrians through the use of personal devices or other similar means.

Modular and Interoperable

Modularity and interoperability are key factors to the success of technology deployments at the scale that this effort envisions. ITS America believes that USDOT must seek to advance a system that is modular, allowing for significant variability to meet the needs of very different intersection designs and requirements, and interoperable, allowing for a range of solutions that can be deployed throughout the system. It is also crucial that technology deployed through this effort is capable of being enhanced and expanded upon when advancements in transportation technology occur, which a modular and interoperable system will allow. This approach will make the best use of limited resources available for deployments, as it will extend the longevity of any investments being made today.

Interoperability should be prioritized so that the system can utilize technologies and solutions coming from a wide range of providers and with technologies demonstrating various capabilities. This is best accomplished by emphasizing standardized interfaces, data standards, and architecture that are designed to enable such interoperability. This cooperative environment will help reduce costs for transportation agencies in the future, as it will encourage competition in the market and reduce the costs associated with upgrading technology in the future. This should be a key priority of the Department in administering resources around this effort.

Costs and Variability

Transportation technology solutions of numerous types and features are ready to be deployed to solve transportation safety challenges – but which technology is needed in a given intersection will be determined by the unique challenges that specific intersection faces. While the overarching goal of this effort should be developing a deployable Vehicle Roadway Warning System, USDOT should refrain from adopting a one-size-fits-all approach when it comes to requirements surrounding which technologies, including sensors and applications, are to be deployed. There is simply too much variation between a complex, connected urban intersection and a rural unconnected intersection for the same solution to achieve the intended safety benefits in both cases in a cost-effective manner. Instead, local communities should deploy the technology solutions that are best-suited to resolve the specific crash scenarios most likely to occur in the type of intersections they manage. It is important to ensure that partial solutions are not considered end-points when considering intersection safety, but a modular approach allows partial, specific solutions to continue to be built upon.

The $10,000 figure suggested in this RFI as a target cost for the Vehicle Roadway Warning System will likely be insufficient to dramatically improve safety at most intersections, whether through road design or technology deployment. However, as the transportation technology market matures, and competition increases, we would expect costs for a Vehicle Roadway Warning System to be reduced dramatically. Notably, a modular and interoperable approach to the system will also reduce long-term costs.

Additionally, the costs associated with technology deployments of this sort are much different than those associated with hard infrastructure projects – while they include similar categories such as capital, installation, and maintenance, the similarities essentially end there. Maintenance costs for technology deployments include expenses related to the communication needs of connected assets, worker training, software updates, and cybersecurity considerations, while installation costs also have unique considerations in terms of vendor overlap and interoperability. Technology solutions often are capable of being updated though software patches and without physical changes, however, reducing one cost element typical of physical infrastructure. Public-private partnerships should be considered a viable tool for transportation planners to access and manage ongoing costs surrounding these deployments.

When considering these costs, however, USDOT should also consider the related benefits associated with technology investment. Those benefits can most clearly be defined as community safety benefits, with prevented fatalities representing the primary priority. However, reduced crashes have strong economic benefits for communities as well, including as it relates to the reduced costs associated with post-crash care, reduced community expenditure on collisions, reduced congestion, emissions, and many others. Each life saved would more than pay for the deployed technology from a cost-benefit perspective.[2] Additionally, data insights should be considered when calculating the cost and value of technology investment. These insights provide cost-effective ways to identify, locate and prioritize intersections that need to be addressed before deployment. Data insights are a concrete tool to measure the impact of projects and improvements after they have been implemented. Therefore, data insights should be considered as a complementary solution to hardware solutions supporting DOTs in their daily activities. Data insights, based on location-based service data, ensure an equitable approach across the country, demographics, rural/urban especially when those insights are fed by connected devices.

In conclusion, USDOT should include eligibility of technology operations and maintenance for both formula and discretionary grant funding opportunities, when possible. Innovative technology investments require sustainable funding for maintenance, operations, and stewardship. Technology has unique needs, such as technical support, data retention, software upgrades, and cybersecurity, which are distinct from hard infrastructure. Ongoing maintenance, investment, and support of transportation technologies is necessary – it provides the public meaningful return on investment and shows responsible stewardship of public funds. USDOT should also seek to provide technology programs with formula funding to ensure every public agency can benefit from technology deployment. Any formula or discretionary technology programs stemming from this RFI should be developed in a cohort model, so that USDOT can collaboratively organize the work similar to the Work Zone Data Exchange to ensure that different projects are learning from different use cases that can eventually be integrated into a larger system integration plan.

<u>Opportunities</u>

A combination of radar, lidar, cameras, along with edge computing, including mobile edge computing (MEC) with AI capabilities, and connectivity can provide broad opportunities for transportation systems while greatly improving safety for VRUs. Historical road data can be collected over time from the various sensors, which can be processed at the roadside to provide predictive analysis for faster response times to further protect VRUs. Infrastructure sensors at intersections can provide environment sensing data to analyze safety situation and identify the presence of a VRU and its attributes. Intersection environment sensing can be enhanced by collective perception where other road users' on-board sensing is augmented with infrastructure sensing. Safety metrics-based (for e.g., Minimum safe distance (MSD)-based) assessments for collision risk analysis may be introduced whereby measured kinematics between a VRU and approaching vehicle is used for the assessment. These technologies have numerous solutions within intersections, but they also have applications to work zones, school zones, and other areas as well. By building out these technologies in intersections, USDOT can both improve VRU safety in those intersections and take the next step in improving the functionality and safety of the nation's transportation system across the board.

[2] Crash Costs for Highway Safety Analysis, FHWA. January 2018. Available at: https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf

Limitations

Data use and privacy concerns are relevant considerations for any technology solutions to transportation challenges, and ITS America believes that USDOT's continued leadership in this space can help resolve any concerns. USDOT is a crucial partner in standards-setting and the development of a common understanding of how technology can be implemented and utilized, including in critical components such as privacy and security. USDOT's Intelligent Transportation System Joint Programs Office has been provided much-needed leadership on these issues for over 30 years, and continues to be an essential conduit of innovative research, project support, and collaboration between sectors. USDOT's efforts coupled with those of the wider transportation stakeholder community will typically be sufficient to resolve technical challenges around technology deployment. However, flexibility will be necessary to allow individual communities to deploy Vehicle Roadway Warning Systems that consider state and local requirements related to data and privacy, while also considering the perspectives of the communities in which these systems will be deployed.

Conclusion

ITS America believes that USDOT has a crucial opportunity to begin to unleash the potential of transportation technology solutions through a robust, Federally-managed deployment of safety innovations. Given the availability of IIJA funding, USDOT is in a unique position to steward the deployment of the next generation of safety technologies that are ready today to be deployed at intersections and save lives. ITS America and its members stand ready to assist USDOT in this deployment, and look forward to a continued dialogue on the best practices and approaches to such an investment. ITS America's answers to USDOT's specific technical questions in this RFI can be found below, but we would welcome the opportunity to discuss these or any additional questions that the Department might have. Additionally, ITS America's IIJA Implementation Recommendations, Equity Policy, and Principles for Inclusive Future Mobility are referenced in the responses below and are attached. If you have any questions regarding our response, please contact ITS America's Vice President of Public Policy and Regulatory Affairs, Timothy Drake, at tdrake@itsa.org.

Sincerely,

Laura Chace
President & CEO
ITS America

Specific Questions from the RFI

(A) General Technical Considerations

1. What is the overall feasibility of developing an effective intersection safety system for vulnerable road users (VRUs) based on existing and emerging mobile (vehicle) automation technologies (including other complementary technologies) as described in this RFI? Technologies are available now, ready to deploy, that can improve safety for VRUs.

Technology is ready for deployment in vehicles and on infrastructure today that can effectively improve intersection safety for VRUs, so the development of an effective intersection safety system for VRUs is very feasible. Many car models are already equipped with ADAS and ADS technologies capable of detecting VRUs and either alerting the driver or mitigating crash scenarios that are at risk of occurring. For example, using LiDAR it is possible to detect all moving objects in and around the intersection and classify them accordingly – including VRUs. The system can then send notifications and warnings as appropriate to mitigate the risk of VRUs.

Connected Vehicle technologies are poised to deliver safety benefits to all road users, given a regulatory environment with sufficient spectrum and certainty. Given limited spectrum, certain pedestrian/cyclist safety applications can be accomplished through cellular communications, edge computing (including MEC), and virtual RSUs. These technologies are capable of providing benefits both within the vehicle and as part of a larger infrastructure solution.

2. What perception, machine vision, and sensor fusion technologies (and other sensing modalities or combinations) are best suited to an effective intersection safety and VRU and vehicle warning system?

An effective intersection safety system would include combination of artificial intelligence (AI), machine learning (ML), sensors like LiDAR, radar, cameras, and integrated/interoperable traffic signal systems including RSUs, signal boxes, and the cable/fiber that integrates these systems or cloud computing IT functions that would connect back to a central system. Such a combination over an interoperable, standardized interface draws upon the strengths of each technology, allowing for the greatest likelihood of crash prevention. For example – while LiDAR provides stable operation and very accurate in day/night & low-light environments, it can be paired with cameras for additional object detection. Connected vehicle technologies, which are low-latency and do not rely on line-of-sight, can help augment the infrastructure safety strategy to account for more time-critical crash scenarios that other solutions might have missed.

3. What real-time image and data analysis techniques are best suited to provide the required machine vision and perception for an effective intersection safety system?

Techniques should include AI, ML, and deep learning tools that leverage both historical and real-time connected vehicle data to develop predictive analytics that are analyzed through AI algorithms to provide traffic management centers real-time insights into intersection safety, pedestrian detection, and near-misses. The techniques should include real-time 3D object detection and tracking modules, object classification, real-time multi-view, and multi-modal sensor fusion modules. Light-weight deep learning-based image and data analysis techniques are preferable. Given the nature of connected vehicle technologies, machine vision is less of a factor than is OBU adoption.

Additionally, USDOT should consider ways to further utilize technology that has already been deployed to make progress towards VRU safety goals. Many intersections are already equipped with advanced cameras and sensors, and likely would be good candidates for approaches that connect these through a system of systems that allows for a coordinated VRU safety strategy.

4. What techniques are most effective in providing real-time vehicle and VRU path planning and prediction capabilities at fixed roadway intersections?

Techniques should include AI, ML, and deep learning tools that leverage both historical and real-time connected vehicle data to develop predictive analytics that are analyzed through AI algorithms to provide traffic management centers real-time insights into intersection safety, pedestrian detection, and near-misses.

5. What new and emerging technologies can enhance machine-based decision making at intersections—including determining potential vehicle-VRU conflicts, incidents, dilemma zones, and encroachment in real-time?

Sensor fusion and hardware (cameras, lidars) data analytics (AI/ML), cloud or edge solution to transmit it back to a transportation operating system.

6. What is the potential role of AI and/or ML in perception, image analysis, data analysis and decision-making at intersections, both in real-time and asynchronously? What is the potential for real-time learning and group learning across a number of similarly-equipped intersections?

The potential role of AI and/or ML is the capacity to ingest and generate insights from a variety of data and different data sources. Moreover, it allows Public Authorities to anticipate safety concerns, instead of reacting afterward. Video allows us to validate and reconcile near misses that have been identified through other data models and sources. It enables data driven decisions and builds a strong use case for which measures should be implemented. By fusing data from multiple sources, including equipment installed at an intersection, the AI will generate insights that more accurately identify risky intersections for VRUs.

7. How could such a system work effectively with all types of VRUs (pedestrians, bicyclists, wheel-chair users, users of electric scooters, etc.) and all types of vehicles (cars, trucks, vans, transit buses, commercial vehicles, etc.)?

A combined approach to intersection safety solutions will allow sufficient sources of data to appropriately accomplish sensor fusion, which would help to account for the unique characteristics of various VRU types. A multi-faceted, technology-diverse approach allows the strengths of each solution to combine to best reduce the likelihood of crash scenarios. A successful system that supports multi-modal VRU safety includes fusing a variety of sensors from lidar, cameras, data from roadside units, signal phasing and timing data, collecting connected vehicle data, and using AI and ML systems to combine and integrate that data and perform real-time insights to detect safety incidents. Integrating the above-named technologies is user-neutral as lidar, cameras and the computing systems that analyze that data are able to detect all manner of users in various multi-modal environments.

(B) System Installation and Deployment

1. How can the required installation, setup and calibration requirements for a perception and decision-making based intersection safety system be minimized?

A modular approach would allow for incremental safety benefits while allowing a transportation agency to invest and deploy at a pace within their means. It is important to ensure that USDOT supports ongoing maintenance, support, and operations because these infrastructure technologies do not have similar lifespan to other infrastructure like concrete and steel; thus the USDOT needs to ensure that installation includes ongoing IT support and the ability to repair and replace in real-time to ensure systems remain operational.

2. What pedestrian and VRU alerting and warning methodologies and systems would be most useful, including for example, visual (or projected), audible, haptic, connected, other?

Until deeper market penetration of connected vehicle technologies takes place, audible and visual should remain the two primary VRU alerting mechanisms. Once that penetration has taken place, connectivity through personal devices can be added. USDOT should encourage human factors, user experience and human machine interface researchers to focus on developing research around the unintended consequences of integrating these systems into vehicles to ensure that drivers are not further distracted and that audible or visual cues are integrated into the vehicle system using a human-centered design approach that does not further distract operators.

3. What vehicle driver alerting and warning systems would be most useful, to alert drivers in real-time of impending conflicts at intersections?

In-vehicle alerts and visual infrastructure cues (such as LED warnings). Audible cues would be effective in certain scenarios.

4. What potential modes of connectivity, such as V2X (V2N, V2P, V2V, V2I . . .), cellular or Wi-Fi, for connecting vehicles, infrastructure, signals, and VRUs, would be most useful and effective to assure the greatest degree of accessibility for all intersection users?

Connectivity in general as an additional avenue of communication between vehicles, infrastructure, and VRUs should be considered a positive, even as a supplemental component to other infrastructure solutions while connected vehicle technologies are more widely deployed. To that end, cellular forms of connected vehicle technologies show significant promise in allowing VRU safety applications. Some of these applications, particularly those that interface between the infrastructure and a driver, would rely on cameras or LiDAR rather than direct communication with a device held by the VRU. For those that require the VRU to have a device, they should be considered additional layers of safety protection rather than the ultimate solution to intersection risks for that VRU, since we cannot assume that the VRU will have such a device.

The issuance of this RFI is particularly timely considering the growing ecosystem of ITS America members currently seeking to deploy Cellular Vehicle-to-Everything (C-V2X) technology to improve roadway and VRU safety. C-V2X uses dedicated spectrum to allow vehicles to communicate directly with each other (V2V), roadside infrastructure (V2I), and pedestrians (V2P), enabling a myriad of use cases that facilitate safe behaviors among drivers and other road users. Because direct mode C-V2X is not reliant on wide area networks, it can support low-latency, real-time information sharing at urban intersections and other congested environments. Importantly, C-V2X builds on the longstanding efforts by USDOT and the ITS community to develop V2X services along with recent advancements in cellular technologies. By combining cellular technology with the established foundational work on V2X, C-V2X enables new applications that can specifically address the unique safety needs of pedestrians and other VRUs. For example, C-V2X technology can enable "smart intersections" where roadside units equipped with C-V2X and sensors such as cameras and radar can use 5G network connectivity to send warnings to road users equipped with C-V2X. A "smart intersection" could similarly use a camera to detect a pedestrian intending to step into an intersection before signaled and broadcast an alert to all vehicles in the area to make drivers aware. This real-time awareness of pedestrian locations allows proactive anticipation and assistance to drivers who would otherwise be late to respond to VRUs.

The broad industry interest in deploying C-V2X is demonstrated by the large number of public and private stakeholders, including many ITS America members, currently seeking permission from the Federal Communications Commission (FCC) to deploy. At the time of this filing there are nearly 30 public and private entities seeking waivers to deploy C-V2X.3 In addition to three automakers and nearly a dozen equipment manufacturers, this list includes the Utah, Virginia, Georgia, Florida, Maryland, Colorado, Ohio, Texas, Oregon, and Hawaii state departments of transportation.

5. What industry standards, best practices, processes, protocols, and interoperability requirements and capabilities are needed or best suited for the development of an effective intersection safety system?

Cybersecurity, interoperability, and privacy standards are key requirements of an effective intersection safety system, and USDOT should clearly establish such standards as a condition of this deployment. USDOT should work with standards-setting organizations such as SAE to utilize the work that has already been done in this field, such as with J3224, a sensor data sharing standard that would apply to V2X sensor sharing for connected and autonomous vehicles. Public confidence in safety and privacy standards are critical, and USDOT's leadership in enforcing those standards is a key component of that.

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[3] *See* FCC Docket 19-138, Use of the 5.850-5.925 GHz Band, https://www.fcc.gov/ecfs/search/search-filings/results?q=(proceedings.name:(%2219-138%22))&limit=100&sort=date_disseminated,DESC.

6. How can interfaces with traffic signal controllers and traffic management systems be best implemented? What data storage and curation of the system performance history (on-board, at the edge or in the cloud) are required?

NTCIP interfaces with traffic controllers and other infrastructure devices were not designed for multiple/concurrent system interfaces and present both operational and cybersecurity challenges. There is a need to modernize these interfaces in both greater publication of localized datasets as well as manageable control over external systems' desired inputs to traffic control. SAE J2735 standardization offers a more consumable pathway of status data and means of signal priority request, however, does not yet serve the breadth of capabilities offered by infrastructure equipment. There is recommendation for greater synergy between NTCIP and SAE standardization. The CTI 4501 is a great step in this direction, has established a strong cross-community forum, and is suggested to be given additional funding/empowerment to drive closure to this standardization gap to include adaptive control interfaces, cooperative perception, and other more progressive application support.

There is likely to be a tiered architecture where lowest latency and highest reliability safety solutions must reside in the traffic cabinet and remain under tight control of IOOs. These systems then will publish data to and support ecosystems of ITS solutions that are resident in the mobile edge, C2F backhauled locales, as well as cloud. An idealized outcome is a set of data interface standards that serve the breadth of solutions providers, while preserving the stewardship and control that must be maintained by IOOs. An suggested outcome will offer a referential architecture where multiple applications can share sensors, storage, data, and processing under hardware-agnostic platform, allowing the IOO to scale hardware platforms consistent to expected need. The Advanced Transportation Control standard for traffic control may offer an interface for multiple application hosting but that platform is insufficient for this level of application. It is expected that a separate cabinet edge platform be put forth in referential design if not eventual ITS standardization.

Open-source software has proven to balance the needs of collaborative advancement and prepare a pathway for the respective standardization to follow. OSS4ITS and VOICES are excellent platforms that can be expanded to support these additional use cases.

Finally, USDOT must develop a comprehensive, multi-modal digital infrastructure framework, based off the ITS architecture, to ensure that existing and future systems are being designed, built, and operated to run off the same platform and to be interoperable with other systems. This supports a digital transformation leveraging legacy infrastructure, while helping to inspire private investment in public infrastructure that supports VRU safety without picking winners or losers in innovation.

7. How can issues related to reduced visibility (e.g., night-time, low light, bad weather) be addressed and mitigated during both the development and deployment of an effective intersection safety system?

Numerous technologies function well in reduced visibility, such as connected vehicle technologies and radar. Additionally, ITS America's research members are developing nonproprietary solutions to address these types of issues in other technologies, such as sensors that can clean themselves to remove obfuscation. That's why sensor fusion of lidar, cameras, radars and other additional sensors is critical for system redundancy.

8. Are there any existing research and development efforts, deployments, or pilot demonstrations underway that aim to provide some or all of the capabilities described in this RFI?

- The City of Peachtree Corners is demonstrating the benefits of C-V2X communications at their Curiosity Lab in Georgia, a real-world setting that serves as a model for other municipalities as they look to deploy smart solutions and programs.
- Audi of America is working with Spoke, a mobility platform for safety, connectivity, and rich rider experiences; Qualcomm Technologies, Inc.; and Commsignia to bring the benefits of C-V2X technology to VRUs and enhance safety on roadways.
- The city of Austin, Texas is deploying Velodyne's Intelligent Infrastructure Solution (IIS) to help achieve its Vision Zero goal of eliminating traffic deaths and serious injuries on Austin streets. The IIS installation began with a pilot at the 7th and Springdale intersection. This intersection has been identified as needing improvement due to accident history, fatality risks, speeding prevalence and congestion. The City of Austin is testing IIS at this intersection to demonstrate data accuracy and scalability to maximize taxpayers' dollars.
- Cisco and Verizon collaborated on a successful proof of concept demo in Las Vegas, showing that cellular and mobile edge compute (MEC) technology can enable autonomous driving solutions without the use of costly physical Roadside Units to extend radio signals. The result paves a simpler and more efficient route to powering applications such as autonomous/unmanned last-mile delivery bots and robotaxis in cities like Las Vegas, where public MEC technologies exist. Additionally, cities and roadway operators could create safer roads with C-V2X applications including pedestrian protection, emergency and transit vehicle pre-emption, on and off-ramp protection (e.g., when a loaded truck needs autonomous guidance to merge or brake safely), and potentially others that involve vehicles approaching intersections with traffic signals.
- Intel Corp. and its partners are working with the Arizona Institute of Automated Mobility to showcase a proof of concept called Smart RSU.[4] It is capable of taking multiple camera inputs from an intersection, performing AI analytics and decision making, and disseminating standardized safety messages to vehicles and other road users about the presence of VRUs in the roadway vicinity.
- Tome, a connected bicycle industry leader for VRU crash prevention, is working with HAAS Alert, a C-V2X Digital Alerting provider, on communications that enable identifying bicyclist hazards and send connected vehicles and infrastructure alerts to avoid vehicle on bicycle collisions.
- Iteris is equipping more than 20 signalized intersections in Ann Arbor, Michigan with its V2X-enabled detection technology as part of the University of Michigan's Transportation Research Institute's connected vehicle and smart intersections program.

[4] Kathiravetpillai Sivanesan, Varsha Ramamurthy, Vibhu Bithar, "Smart Roadside Unit (RSU)," Paper ID # 1228606, 28th ITS World Congress, Los Angeles, September 18 - 22, 2022

(C) Human Factors and Performance Measurement

1. What human behavioral considerations are most important in the implementation of an intersection safety system to ensure maximum VRU and driver compliance with the warnings and alerts provided?

These considerations vary depending on the technology being used. For some intelligent infrastructure solutions, VRUs are not required to interact with the technology in any capacity – their presence is detected by the infrastructure, and the infrastructure reacts. In that case, drivers would then comply with the infrastructure commands like they would in a typical driving scenario. For other technologies, pedestrians might need a personal information device such as a cell phone to benefit from the full-range of VRU protections.

ITS America recognizes that not all pedestrians and VRUs want, need, or should be required to carry a personal connected device like a cell phone and thus solutions need to be scaled that address situations where VRUs are not carrying personal smartphones. VRUs should not be expected to carry devices to protect their safety, but solutions that leverage the use of cell phones should be included in the system.

2. What are the most relevant human factors, cognition and human-machine interface (HMI) considerations for both VRUs and drivers to ensure the maximum efficacy of an intersection safety system?

From an infrastructure perspective, flashing LEDs are an effective warning for both drivers and VRUs, while sound-based alerts are particularly effective for VRUs – particularly those who are visually impaired. These components are essential to communicate the safety warnings that the VRUs would be relying on. Within the vehicle, there must be a balance between the quick and clear communications of VRU alerts while ensuring that these alerts do not become unnecessarily distracting to the driver, or come with such frequency that the driver begins to ignore them.

3. What metrics, key performance indicators, and measures of success are important for determining the performance and efficacy of an intersection safety system?

Generally, pedestrian/driver recognition and participation with the technologies is the most important factor. Specifically, count data, speed, near misses, and conflict analytics are all relevant indicators – however, these metrics must be both balanced with usability and responsive to the continued evolution of these technologies. It is essential that these performance indicators continue to be updated. Highway Safety Improvement Programs (HSIPs) already document fatalities and crashes, so existing data may be used to start identifying the intersections with the highest crashes, thus driving KPIs around safety such as decreasing the number of crashes, near-misses, and fatalities to advance our Vision Zero goals.

One universal requirement should be to require a level of demonstrated stewardship prior to increasing investment beyond stabilizing fundamentals. establish an existing infrastructure "State of Good Repair (Preservation)" and demonstrated "Maintenance and Operations" funding sustainability floor level of investment prior to releasing funds to a public agency to implement and expand the use of these technologies.

4. How would testing and validation of an intersection safety system best be accomplished before full system deployment at active intersections?

Many of these solutions are already being deployed in intersections within the United States. Analysis of the data and results from those deployments would begin to indicate their likelihood of success in similar intersections. Barring such similarities, a modular approach to the installation of these solutions would allow the demonstration of value for each component in phases – limiting the risk of an all-at-once deployment. USDOT should rely on pilots, best practices, and information sharing from these successful deployments to guide further deployments.

USDOT will know these deployments have been successful when lives are saved, crashes are avoided, and VRUs feel safer and more comfortable using the system.

5. How can a testing and validation plan be devised that would balance testing and development safety with the ultimate real-world performance of an intersection safety system?

A human-centered design approach would ensure that the program and project requirements are tested during key milestones of the VRU intersection safety project and ongoing testing and validation could be required to ensure ongoing system maintenance. USDOT must fund ongoing maintenance and testing to ensure these newer technologies can be repaired, replaced, and remain operational throughout the hardware and software life-cycles, which will require additional support for IT professionals.

6. What performance data would be required to validate the testing and efficacy of an intersection safety system, and how could that performance data be generated?

(Answered above with question 3)

7. What measurement and statistical approaches are applicable to real-time decision-making at intersections? How can decision or warning errors be minimized (e.g., through reducing false positives and/or false negatives)?

ITS America recommends USDOT continue to utilize robust pilot programs as needed to provide testing and technical information about real-time decision-making with newer technologies. These pilots would not be required in all cases, but could be informed by current knowledge and deployments. Lessons and best practices learned in these pilots would be easily transferable to similar intersections across the U.S., limiting the replication of learning curves.

(D) Development Costs and Time to Deployment

1. What is the potential schedule and cost to develop an effective intersection safety system? What are the potential future hardware and software "stack" costs for a system that can be deployed at the scale of (for example) 100,000 commercial installations after 3-5 years of development?

3-5 years may be an accurate estimate if the states get immediate funding through formula programs, have technical assistance in project development, and also receive funding for operations and maintenance to keep systems operational.

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Costs include sensor, CPU, application software, cabling, installation, setup, calibration, and ongoing operations and maintenance. It is difficult to define costs specifically for each installation, as successful implementation would require a system of systems in various types of intersections, but it is unlikely that a figure such as $10,000 would be sufficient for an intersection. It is important to note, however, that the current market is still fairly nascent, and that costs will reduce dramatically as the market for these technologies more fully develops and matures. Additionally, there ways that costs can be reduced, such as by using existing commercial wireless networks and virtual RSUs to decrease deployment and maintenance costs and time.

2. What equity considerations factor into the potential testing, implementation, and deployment of an effective intersection safety system?

Mobility/accessibility for disabled road users, deployment of these solutions in underserved communities where pedestrian fatalities are highest. Community engagement (particularly following USDOT's engagement principles) are an important component of this effort. An equity lens framework must be used throughout project development, which includes coordinating with the community, engaging them throughout the project lifecycle, and ensuring the community has the ability to proffer feedback and ideas throughout the process to ensure resources are invested where the communities see a need. Additional feedback related to this question can be found in ITS America's Equity Policy and Guiding Principles for Future Mobility, which are attached to this submission.

3. What team composition of development, commercialization and deployment partners would be required to achieve the successful commercialization and deployment of such a system?

Public-private partnerships should be considered as potential partners in the deployment of these solutions – USDOT should not assume that this will be an IOO implemented system. Hardware/software vendors must be part of the conversation.

Project teams should not rely on engineering expertise alone, but should include a multi-disciplinary team of engineers, IT professionals, planners, and ITS professionals and include private sector innovators to collaboratively develop project and program requirements, alongside public engagement and communications professionals, using a traditional project management plan and PMI project management principles.

4. For what proportion of intersections (signalized and/or unsignalized) would such a system be well-suited? What characteristics or measures are important in determining whether a specific intersection is well-suited for the implementation of an effective intersection safety system? How could such a system be further developed or adapted for use in rural areas?

The number of sensors/technologies needed for a given intersection is determined by its unique circumstances – not every intersection needs the full package. Determine investment by crash data, prioritizing investment starting with the intersections with the highest rate of crashes and fatalities.

5. What are the installation, calibration, training, maintenance, and operating considerations for deployment of such a system across its full life-cycle by a range of potential end-users, including State, local, Tribal and territorial DOTs, cities and towns?

The costs associated with technology deployments of this sort are much different than those associated with hard infrastructure projects – while they include some similar categories of costs such as installation and maintenance, the similarities essentially end there. Maintenance costs include expenses related to the communication between connected assets, software updates, and cybersecurity considerations, while installation costs have unique considerations in terms of vendor overlap and interoperability. Public-private partnerships should be considered a viable tool for transportation planners to access and manage ongoing costs surrounding these deployments. Additionally, using existing mobile wireless networks allows existing technology to be leveraged; which reduces cost and deployment timelines. This approach should be considered when applicable.