Project Title: Crash Analytics and Injury Research (CAIR) – Holistic Approach to Vulnerable Road User Safety

Project Overview

The traveling public expects new and existing roadway systems to safely support all multimodal forms of transportation. An uncomfortable reality is that Vulnerable Road Users (VRUs) such as pedestrians, cyclists, and e-scooter riders comprise an increasing proportion of roadway fatalities, accounting for 21% of nationwide roadway fatalities in 2022 (NHTSA Traffic Safety Facts). Rates of VRU fatalities per 100,000 population have been steadily increasing, from a low of 1.6 in 2009 to 2.7 in 2022. If injured in a collision, a VRU is five times more likely to die from their injuries than a vehicle occupant (rate of 6.8 fatalities per 100 injury cases for VRUs, compared to 1.3 for vehicle occupants). Like most localities, the Charlottesville-Albemarle Metropolitan Planning Organization (CA-MPO) area has acutely felt the effects of VRU collisions, with 89 cases of VRU fatalities and serious injuries from 2018-2022 (out of 777 total roadway fatalities and serious injuries during that period).

Effectively addressing VRU safety requires a holistic approach including risk-based infrastructure planning, on-vehicle collision avoidance technology, an understanding of human perception and behavior in a mixed road user environment, and an understanding of the potential injury and fatality consequences if a VRU-vehicle collision occurs. Traditionally, each of these are studied in isolation, with limited consideration that they act in concert to contribute to safety, or fatality causation.

Recognizing the critical interplay between infrastructure, behavior, technology, and collision consequence, we've assembled a diverse team of experts to tackle VRU safety through a systems-based approach. Our partner VDOT will provide practical insight into roadway design, and the constraints that affect complete-street design and implementation. Our collaborators at Honda Research America (HRA), who will provide a 10% funding match, will provide insight into integrated vehicular onboard pedestrian detection and avoidance technologies, including their expected capabilities and the use cases for which those systems are typically designed and assessed. The University of Virginia Omni-Reality and Cognition Lab (UVA-ORCL) will conduct a multi-modal study of pedestrian, e-scooter, cyclist, and vehicle driver behavior in various scenarios representative of local mixed-use roadways. This will include both on-road data collection to observe real-world road user behavior, as well as controlled Virtual Reality (VR) simulation to mimic potential conflict scenarios. Emphasis will be placed on locations with a high potential for VRU-vehicle conflict, where VRU-vehicle interaction is driven by mixed mobility needs due to varied ambulatory capabilities and socioeconomic factors (e.g., VRU considerations close to senior care facilities, medical facilities, public transportation nodes, and in geographic transition between lower-income residential areas and commercial areas to which those residents travel). Finally, our partners at the UVA Center for Applied Biomechanics (UVA-CAB) and UVA Department of Emergency Medicine (UVA-EM) will assist in contextualizing the potential risk of injury and fatality if a VRU collision were to occur, and how that risk may be mitigated to reduce the severity of the collision. If a VRU injury case occurs within our area during the study period, our UVA-EM partners will gather case information on the specific injuries, the context and mechanisms of those injuries, and the prognosis for the patient (where allowed by the UVA Institutional Review Board and the permission of the patient).

This comprehensive investigation that considers and connects practical roadway design constraints, vehicle technology, road user behavior, and the end consequences of collisions represents a truly end-to-end, systems-level analysis of VRU safety within the CA-MPO area. The Team will create and calibrate a model that predicts VRU trajectories given VRU characteristics, environmental

conditions, vehicular traffic, and infrastructure realities. The Team will also create and calibrate an injury consequence model based upon parameters considered in the VRU projected path trajectory model, using injury prediction computer modeling. We will then combine probability distribution of projected path trajectories, based on behavioral choices, with the injury consequence model, that predicts severity of injuries, to create better holistic understanding of VRU safety factors and effective mitigation designs.

Approach

Effective and enduring safety initiatives require identifying the root causes of safety concerns, injuries, and fatalities. The CA-MPO area represents a unique environment with a variety of high-density residential areas (ranging from lower-income neighborhoods to student housing) in close proximity to commercial zones and large employers. This results in a mixed-mobility environment, with a consistent and widespread presence of VRUs (pedestrians, cyclists, and e-scooter riders). The roadways in the CA-MPO span development over the course of 200 years. This is evident in the wide variety of roadway designs, resulting from eras prioritizing dense neighborhoods and local foot traffic, to suburban sprawl aided by motored mobility, and finally a trend back towards new urban mixed land use development. This profound diversity of roadway environments and mobility needs creates a substantial challenge for VRU safety, requiring a comprehensive action plan considering the end-to-end sequence of events affecting VRU safety.

To develop a comprehensive action plan, we will: (i) Analyze historical crash data, locations, severity, contributing factors, and crash types by various VRUs across the CA-MPO area. (ii) Collect actionable data on local roadway design factors influencing VRU and vehicle interaction through the demonstration activities described below. This includes on-the-road and virtual VRU & driver behavioral studies, as well as risk modeling and medical investigation to predict the consequences of collisions and benefits of intervention. (iii) Consult roadway design collaborators at VDOT to contextualize the performance-based, practical considerations for the design and implementation of safety countermeasures targeting mixed-mobility environments. In addition, we will consult collaborators at HRA to review vehicle-based countermeasures to aid in VRU safety (such as pedestrian collision detection systems), including context for how those systems may perform in varied roadway and traffic environments. (iv) We will then work closely with our locality's leadership, engineers, and planners to set safety goals and create a roadmap for achieving Vision Zero for VRUs. This includes establishing a timeline for the development and implementation of the action plan.

Outcomes

Our primary goal with this grant is to develop a comprehensive, data-driven VRU safety action plan for the CA-MPO, to supplement the safety action plan currently under development by the Thomas Jefferson Planning District Commission under SS4A grant #693JJ32340220. This will include a detailed review of existing policies, plans, and standards to improve transportation safety, presented as actionable items prioritized with short-, mid-, and long-term timelines. The focus will be on safety, accessibility, and justice. CA-MPO aims to identify countermeasures and interventions in infrastructure, education, or operations, which will be outlined, and shared with the public through in-person and online resources. Results will be shared with, and used by, critical CA-MPO stakeholders, including VDOT, Albemarle County, and the City of Charlottesville. Additionally, this work will almost certainly benefit researchers, planners, designers, and road users well beyond CA-MPO by enabling better evaluation of safety when practicing risk-based, performance-based roadway design, improving design for VRU safety in high-risk situations such as urban work zones, and integration into automotive crash avoidance technologies to advance predictive safety features

which could reduce VRU accidents and fatalities. To aid in the development of the action plan, this proposal includes two demonstration & research activities:

Demonstration & Research Activity #1: VRU and Driver Interaction Behavior

The critical link between roadway design and VRU safety lies in how the design of the environment influences the behavior of drivers and VRUs as they interact. In this activity, researchers at the UVA-ORCL will conduct a dual-mode investigation on the influence of roadway design and environmental factors on VRU and driver interaction behavior, in the setting of high-priority areas of potential conflict within CA-MPO. These priority areas will be collaboratively identified, with consideration for the local density of mixed traffic, past data on collisions and injuries, equity of mobility modes and opportunities in the area, and unique safety challenges. On-the-road behavioral data will be collected by pedestrian, cyclist, and e-scooter volunteers who typically transit the selected areas (each equipped with dataloggers and on-board video recorders to capture their interaction with surrounding traffic). These data will be examined to identify potential conflict scenarios within the study location. The study areas will then be replicated in virtual reality at the UVA-ORCL, where volunteers representing both drivers and VRUs can interact together in various potential conflict scenarios in a safe simulation environment. With this capability we will trial various conflict scenarios in simulations representing the chosen high-priority locations and demonstrate the potential risk reducing effect of selected roadway, vehicle, and behavioral countermeasures (e.g., speed reduction, intersection signaling, lighting improvement, etc.).

Demonstration & Research Activity #2: VRU Collision Consequence Investigation & Modeling

In this activity, we will augment the collision causation activity above by carrying through to the end consequences, investigating and modeling the injuries and fatalities that happen when a VRU collision occurs. Using information on potential conflict scenarios gathered in the previous activity, researchers at the UVA-CAB will use physics-based simulation models to predict the risk of injury and fatality that would result in the event of a collision. This will allow us to demonstrate the potential consequences of a collision, and also to gauge the potential safety benefit that may be gained by reducing the severity of the collision (e.g. through reducing the impact speed or the potential for secondary impacts). These simulations will be performed using high-throughput, fast-running human body computer models, which can also account for differences in injury vulnerability associated with age, sex, and other aspects of person-to-person variability. Collaborators at the UVA-EM will provide clinical insight into the presentation and prognosis of cases of VRU injury. The UVA Health System is a Level 1 Trauma Center and has participated in roadway trauma case study research for over a decade through programs like NHTSA's Crash Injury Research and Engineering Network (CIREN). UVA-EM will screen for VRU-related injuries during the study period, and the research office of UVA-EM will track those cases and seek their permission to enroll for in-depth case study (collecting information such as emergency response information, patient radiology, medical notes, incidence reports, and follow-up surveys). In the event of a VRU fatality case, UVA-EM would coordinate with the Office of the Chief Medical Examiner to gather available information on the incident, including location information, incident reports, and cause of death (including a research study investigating the specific injury). We will utilize these clinical data to conduct thorough crash investigation and injury causation analysis which will further inform modeling and countermeasure development. Throughout all aspects of this work (including the volunteer studies described above), data collection will be reviewed and governed by the Institutional Review Board of the University of Virginia. In total, these activities will not only demonstrate the consequences of VRU safety and the tangible benefits that our action plan will achieve, but will also provide invaluable information that will benefit localities and road users across the country.