I. OVERVIEW

The City of Madison, Wisconsin (herein known as the 'City') requests $1,980,500 in federal discretionary funding through the FY 2024 Strengthening Mobility and Revolutionizing Transportation (SMART) grants program. This funding will advance SMART goals by validating the **PeopleFirst** Vulnerable Road User (VRU) Safety System (herein known as 'PeopleFirst' or the 'Project').

PeopleFirst builds on the City's Vision Zero campaign, Stage 1: Planning and Prototyping. Grant funding will implement a strategy to eliminate traffic deaths and severe injuries by targeting road user distraction and situational awareness. The Project leverages existing local and state investments in Smart City Technologies on Madison's Park Street Connected Corridor (PSCC) as part of the 2015 USDOT Smart City Challenge Grant Application, and compliments pursuits such as Safe Streets and Roads for All (SS4A) and FTA Small Starts Bus Rapid Transit (BRT) to multimodal-focused improvements along the corridor.

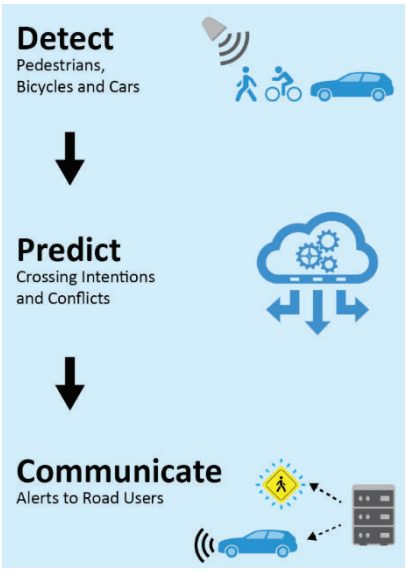
Real World Issues and Challenges

There have been 38 pedestrian and bicycle crashes along Park Street in Madison over the last five years. High roadway volumes (up to 37,100 vehicles per day) and heavy pedestrian traffic from the University of Wisconsin-Madison (approximately 49,000 students and faculty in Spring 2024), result in a high number of conflicts along the PSCC. Bicycle and pedestrian related crashes are increasing with **13 crashes occurring in 2022** alone. A lack of awareness of VRUs is a major contributing factor to these crashes. While many warning systems exist for VRU presence, these generally are manually activated or only display warnings once the VRU is already in a conflict zone. The upcoming introduction of BRT along the corridor in 2027 will introduce more VRUs, necessitating an innovative solution to holistically enhance safety for vulnerable users. PeopleFirst is unique in that it **predicts and alerts drivers of crossing intentions,** enabling a much wider window of time to increase awareness.

Proposed Technologies

PeopleFirst creates a safety net technology to improve VRU safety at signalized, unsignalized, and mid-block crossings. The three key elements of the Project are (1) detection, (2) prediction, and (3) communication:

- **Detection** of VRUs using LiDAR and cameras.
- **Prediction** of road users' crossing movements and conflicts with vehicles to provide more reaction time.
- **Communication** of warnings to road users via:
  - » Blank-out warning signs;
  - » Low-powered electrochromic signs, and;
  - » Rectangular Rapid Flashing Beacons (RRFBs);
  - » Vehicle-to-everything (V2X) connected technology.



The City will **deploy the PeopleFirst prototype on two signalized and four unsignalized intersections along the PSCC**, which had V2X equipment installed as part of the Smart City Challenge

Grant. Numerous partners, contributors, and interested stakeholders identified connected vehicle technologies and their benefits. In May 2016, the PSCC corridor team identified Park Street as the technology test area for a five-year plan of connected vehicle technology investments. A full timeline of the projects and investments can be found here. The partners have completed 16 milestones, deployments, or projects directly related to the PSCC.

This Stage 1 grant will conduct an **18-month** process to test the flexibility and scalability of the PeopleFirst concept under varying contexts and conditions. Based on Project results, the City intends to apply for Stage 2 Implementation grant funding to deploy PeopleFirst to other segments of the high injury network (HIN) across Madison including the East Washington and University Avenue corridors, two roadway segments with the highest concentration of serious pedestrian and bicyclist crashes. Stage 2 will demonstrate the ability to scale-up the concept at both intersections and mid-block segments. Further, a Safe System Approach enables PeopleFirst solutions based on **crash risk** and not just crash history.

The Project advances the City's priority of "implementing traffic safety measures in a fair and equitable manner to eliminate traffic deaths and serious injuries on City streets." Eligibility is demonstrated through three criteria: (1) Connected vehicles; (2) Intelligent, sensor-based infrastructure, and (3) Systems Integration.

II. PROJECT LOCATION

The Project is in Madison, Wisconsin, an urban area with a population of 269,840, per the 2020 Decennial Census. It is the capital city of Wisconsin and the Dane County seat. Madison is designated as a Large Community. As the regional center for employment, education, and health care, Madison streets serve nearly three quarter million residents and visitors daily. Park Street is one of seven north/south principal arterial roadways connecting users to downtown Madison to the north and the beltline (US 12/14/18/151 carrying 138,000 vehicles per day) to the south. PeopleFirst lies partially in disadvantaged communities as half of the Project intersections are within census tract 14.01 and next to tract 14.02. According to the Climate and Economic Justice Screening Tool (CEJST), both tracts are designated as disadvantaged in Transportation and/or Water and Wastewater categories (due to proximity to toxic concentrations of wastewater discharge and traffic – mostly coming from Park Street).

III. COMMUNITY IMPACT

PeopleFirst will provide direct and indirect safety improvements to the disadvantaged communities and approximately 12,600 residents in the tracts identified above. The southern third of the PSCC is identified as disadvantaged by the CEJST, the northern third of the PSCC is located on the University of Wisconsin-Madison campus (census tracts 11.01 and 12). Census tracts 11.01 and 16.06 have **zero-vehicle household rates of 59.5 percent and 43.7 percen**t (respectively), indicating that Madisonians in this area are dependent on walking, biking, or using transit to access everyday essentials (attending class, work, shopping etc.), and depend on reliable and safe infrastructure to cross Park Street. Moreover, according to the 2020 Biennial Transportation Survey Report, 69 percent of UW-Madison students indicate walking or bicycling as their travel mode to Campus. The workplan will deploy PeopleFirst directly along Park Street. The South Madison Neighborhood Plan indicates that 32.9 percent of residents in the southern third of the corridor identified as Latino or Hispanic (nearly 4.9

times higher than the City-wide average). Engagement activities will focus on involving these and other underrepresented populations at all phases of the Project. The Project will work to protect data privacy for all users to proactively address residents' potential concerns.

IV. TECHNICAL MERIT OVERVIEW

Identification and Understanding of Problem to be Solved

Pedestrian-involved crashes have become more deadly and frequent. Nationally, the pedestrian fatality rate has increased by nearly 64 percent from 2013 to 2022 with 7,522 pedestrian fatalities in 2022 alone. This represents a 1.8 percent increase from 2021. **Improving the safety of vulnerable roadway users is an urgent need for all cities in the US, including Madison.**

Park Street sees many crashes resulting from the high volumes of both vehicles and VRUs. In crash reports most drivers stated that they did not see the VRUs before making the turning movements while some VRUs indicated that they thought drivers were going to stop. Overall, drivers are unable to predict the movements of others, especially under complicated traffic conditions, which ultimately causes crashes.

Two major contributing factors can be summarized from these crashes:

- The lack of ability to detect road users, and
- The lack of ability to predict movements or intentions of road users.

Park Street Crashes (2019-2024)

- **21** Pedestrian
- **17** Bicycle
- **3** Incapacitating Injuries
- **18** Non-Incapacitating Injuries
- **15** Pedestrian Crashes During Turning Maneuvers

Appropriateness of Proposed Solution

The City and its partners propose "PeopleFirst" - a real-time, proactive traffic safety solution to improve VRU safety at intersections and mid-block segments. While systems to detect VRUs and provide presence indications exist in various forms, PeopleFirst is unique in that it incorporates layered technologies and sophisticated prediction models to provide much greater awareness for all road users.

PeopleFirst has three major components: detection, prediction, and communication. The combination of technologies will directly address the contributing factors in VRU crashes. **No system subcomponents need additional waivers or permits to be deployed as part of the Project.**

- The **detection** component integrates different sensor technologies including LiDAR and video to detect VRUs. The team identified multiple off-the-shelf sensors, minimizing technical risk. For example, an existing artificial intelligence (AI)-based solution using LiDAR technology includes the LiDAR, edge computing unit, and Power over Ethernet (PoE) box. Installation is simple, with sensors attached to traffic signal poles and powered from signal cabinets. The team will assess multiple, low-cost, open-sourced sensors to compare their performance under various conditions and determine the optimal configurations of sensors.
- The **prediction** component can dramatically improve the efficacy of VRU warnings. Using sensor fusion approaches on detector data, the prediction system will determine VRU "pose" – their orientation and posture relative to the roadway and their head orientation, which suggests their direction of movement. Fusing this data with calculated movement trajectories will allow

PeopleFirst to identify conflicts before the VRU enters the roadway and do so over a much larger area, such as a mid-block segment.

- The **communication** component connects sensors, roadside units (RSU), drivers, and VRUs in a flexible and adaptable way. For example, at a signalized intersection, the RSU can transmit the predicted warning information to connected vehicles through infrastructure-to-vehicle (I2V) communication. To warn other vehicles, it can transmit the information to a blackout sign through infrastructure-to-infrastructure (I2I) communication.

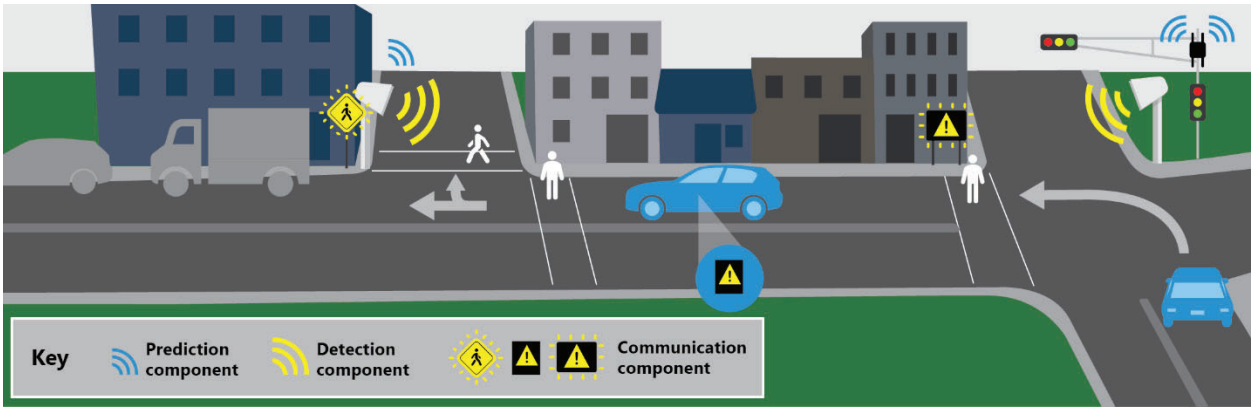


Figure 1 System Overview demonstrates the varying contexts to be studied in the Project.

PeopleFirst is based on existing studies that provide a strong foundation for algorithms that detect road users using cameras, LiDAR, and other sensors. Moreover, the proposed system and predictive models are **scalable and easily adaptable** to other locations. Roadside units already deployed on Park Street offer a perfect opportunity for field testing and comparing different technologies.

External Project Challenges and the Status Quo:

The Park Street corridor has several significant challenges that result in high crash frequency:

- High VRU/vehicle conflict frequency.
- Limited detection (especially for VRUs like pedestrians and bicyclists).
- Limited communication between VRUs, infrastructure, and vehicles.

Unfortunately, the current status quo fails to address these challenges in the following ways:

- Dynamic signs are difficult to scale to off-grid locations due to power needs.
- Infrastructure solutions are vendor specific and are not easily configured at other locations that lack compatible devices.
- Static traffic signs and markings do not communicate to VRUs or drivers when a conflict is likely.
- State-of-the-art advanced analytics are usually used as decision support systems that may improve traffic engineers' diagnosis of safety issues, but do not provide the means to address those issues.

The PeopleFirst combination of system technologies is novel; however, the individual subsystems are based on proven approaches. The system is expected to be highly reliable and provide warnings to the public that are otherwise impossible. The additional situational awareness by VRUs and drivers is expected to provide safety benefits to all roadway users along the corridor. The Project is appropriate for Park Street's population density and existing transportation system – especially considering the introduction of bus rapid transit (BRT) and continued development along the corridor – and will test varying intersection configurations and traffic patterns.

Expected Benefits

PeopleFirst showcases several distinct, innovative approaches that go beyond the capabilities of existing VRU detection and warning deployments and are in alignment with USDOT and SMART Grant Program priorities. The Project will establish the effectiveness of the approach, identify optimal combinations of technologies, and create a pathway to scalability, creating an avenue for deployment in a wide variety of urban and non-urban contexts.

Equity and Access

- The system is highly adaptable and applicable to numerous roadway contexts, providing benefits to all road users.
- Low-cost, readily available sensors provide system scalability. Low power requirements ensure that the system is deployable for all communities and minimizes energy and climate impacts.

Enhanced Safety through Layered Warnings

- Combining technologies such as on-board units and roadside signs increases the number of road users receiving warnings and the time remaining for users to avoid conflicts.
- Conditionally active warning signing reduces "exposure fatigue" and increases the attentiveness of roadway users.
- Other future applications such as winter weather advisories and real-time dynamic lane control could also be enabled through the low-cost conditional static signs.

Systems Integration

- Real-time conflict communication at both intersections and mid-block promotes connectivity infrastructure, ease of travel for drivers, and safety for VRUs.

Partnerships

- The partnership approach of the Project team reduces individual costs to public and private partners, which makes investments more economically competitive. Additionally, the Project creates a channel for workforce development through apprenticeships and internships offered by the Project team.

Performance Measurement

- At a broad level, the Project team will evaluate PeopleFirst for accuracy, efficiency, and scalability. **Accuracy** refers to both the accuracy of detecting road users and predicted conflicts. To measure accuracy, the workplan will conduct field measures of the accuracy of video and sensor detection of crashes and "near misses." A unique benefit of PeopleFirst is the combination of multiple vendors, which serve as quality control to one another, providing a "best of all worlds" approach. **Efficiency** is the robustness of communication between sensors, vehicles, infrastructure, and cloud. To measure efficiency, the workplan will evaluate the quality of data output between the components of PeopleFirst, to document troubleshooting prior to Stage Two. **Scalability** includes the requirements in terms of power, network bandwidth, and cost. To measure scalability, the Project team will assess overall installation and maintenance costs of PeopleFirst, and document power and bandwidth usage for deployment during Stage Two. Further specifics of Stage 1 performance measurement are described in Section V.

V. PROJECT READINESS OVERVIEW

Feasibility of Workplan

Work will begin on PeopleFirst as soon as the grant funds are obligated. The detection system will use commercially available sensors that do not require additional exemptions, waivers, permits, or special permissions. The Project team identified 11 candidate sensor vendors, including five based on video, three based on LiDAR, and two multi-modal sensors. The Project team also identified vendors that provide VRU tracking, traffic conflict prediction, and integration with warning systems within the target cost range. The Project team has already established the feasibility and affordability of PeopleFirst, meaning that prototype development can begin upon award.

The Project has an 18-month schedule, divided into four tasks. Each task provides the foundation for the next, resulting in a clearly defined, tested, and evaluated prototype system. Additionally, workforce development will occur concurrently using training and education programs to meet future workforce capacity needs. The Project tasks are as follows:

Planning and Design (3 months) – The Project team will engage with project partners and stakeholders for listening sessions and design consultations. During monthly stakeholder meetings, the team will make final site selections, complete a review of legal and regulatory impacts, and identify a "beta test" group for initial system evaluations.

Development (5 months) – Based on input from the first task, the Project team will procure system components, and configure predictive models. The team will then complete initial system integration (validated with a lab-based bench test) followed by "closed course" testing, and a test deployment at one site along the PSCC.

Field Testing (8 months) – Following a successful test, the team will deploy PeopleFirst at the identified field sites. The Project team will use different configurations of detection and communication components to characterize their interactions. This will identify different environmental factors and experimental setups that may affect PeopleFirst's performance. During the eight-month test period, the team will collect extensive data for evaluation purposes, including effects of different precipitation types.

Evaluation and Reporting (2 months) – Using the evaluation process created in the Planning and Design task, the Project team will use the data collected from field tests to determine the accuracy, efficiency, and scalability of PeopleFirst. The final report will describe the system's overall availability ("uptime"), significant component failures or maintenance practices, and activation records. The team will compare multiple accuracy measures to assess the system's overall impact on VRU conflicts and crashes. The team will conduct "ground truth" crossing data validation using human annotation of video data using equipment and processes used in previous studies. The team will also gather advanced metrics such as "near miss" counts for VRUs using advanced video processing techniques and temporarily installed recording equipment.

Workforce Development (concurrent) – The City, UW-Madison, and Madison College will provide opportunities to create a pipeline of future workforce opportunities through apprenticeship and internship programs. The educational partners will offer courses for students and existing staff to develop the skills required by Smart City technologies. Additionally, the City will hire interns and apprentices to assist City staff, providing the potential to absorb these trained workers into its

workforce. The workforce development program will also provide opportunities for historically underrepresented groups, in alignment with City of Madison's ongoing initiatives and priorities.

Community Engagement and Partnerships

Community-centered Approach – In 2013, the City launched the Racial Equity and Social Justice Initiative that focuses on eliminating racial and social inequities in municipal government by implementing equity strategies that influence City policies, budgets, operations, and the community. The City improved equitable investment in underserved communities in Madison to prevent pedestrian, bicycle, and vehicular fatalities and serious injuries. Moving forward, the City will implement (as part of the Project) enhanced community outreach and engagement activities with consultant support to better integrate equitable community feedback in the decision-making process. These engagement activities will do the following:

- Engage partners in listening sessions at multiple sites on the corridor.
- Hold monthly stakeholder meetings.
- Develop a beta testing stakeholder group.

Committed and Sustainable Partnerships – The Project partners include government agencies, industry, and academia. The partners have a proven history of efficient and effective collaborations that maximize the value of investments. The City, as the applicant, understands the legal and policy requirements of deploying equipment and reporting. Letters of Commitment are available here.

Leadership and Qualifications

Dr. Yang Tao will lead the City of Madison team, which **leads the project** and assist the project partners with system integration with existing City infrastructure. The Madison team has a long history of leading successful projects related to VRU safety with the University of Wisconsin Traffic Operations and Safety (TOPS) Laboratory and Wisconsin Department of Transportation (WisDOT), such as the recent development of the City's HIN. The City has also applied for the SS4A grant with a particular emphasis on VRU safety including on South Park Street, and for the Small Starts funding to implement bus rapid transit with pedestrian/bicycle improvements along the corridor.

Dr. David Noyce will lead the TOPS Lab team, which **will perform system development and prototyping.** The TOPS Lab, part of the College of Engineering at the University of Wisconsin-Madison, is a nationally recognized research organization with a mission to improve traffic operations and safety through research, partnership, service, and training. Researchers at the TOPS Lab have conducted various studies focused on detecting road users using different sensors and predicting road users' movements and conflicts, which will be utilized as a solid foundation for developing the proposed solutions.

Dr. Kevin Mirus will lead the Madison College team **focusing on a workforce development program** to prepare apprentices and interns who can be integrated into the project. As the community college, Madison College provides open access to quality higher education and prepares its diverse communities to earn an associate degree, technical diploma, or certificate in more than 180 programs.

Dr. Avni Argun will lead The Giner Inc. consultant team to **develop a dynamically switching, electrochromic traffic sign** prototype that provides high optical contrast between its transparent and opaque states. Giner has successfully developed novel prototypes using electrochromic technology, including SBIR funded projects by NASA and the Air Force (AFWERX).