Request for Research Funding for FY 2023-2024			
SPR Subpart B Project: (Research Center use only) OET-25-08			
Requesting Office	Office of Emerging Technologies	**Priority**	8 of 8 (projects may not have the same ranking – no ties)
Proposed Title	A Digital Twin for Quantitative Evaluation and Improvement of Vulnerable User Safety at Signalized Intersections		

Justification

The National Highway Transportation Safety Administration (NHTSA) estimates that in 2021, vulnerable users accounted for about 19% of U.S. traffic fatalities with 7388 pedestrians and 966 cyclists killed and more than a large fraction of these deaths occurring at intersections. Current approaches for evaluating traffic safety are based on analyzing crashes by severity, location, and causal factors. Safety impacts of countermeasures are evaluated using multiple years of before-and-after crash data. Such an approach may not be ideal in determining the marginal impact of one countermeasure when multiple changes have happened at the intersection over these years. Crash data are also not ideal to evaluate the benefits of operational changes (such as signal timing changes) that may be limited to specific times of the day as there may not be several crashes during the corresponding period. On the other hand, surrogate measures called severe events (broadly defined as near misses that could have led to crashes and unsafe behaviors such as hard braking, red-light running, and jaywalking) derived from video and lidar provide the required finer granularity to assess safety impacts of operational changes. In this case, before and after studies can be done over weeks or months (instead of years when using crash data) to determine the short-term benefits of the countermeasures.

In the light of the discussions thus far, a data-driven, machine-learning based digital twin for signalized intersections is needed for quantitative assessment of countermeasures aimed at improving safety. Within this broad framework, this proposed study will focus on signal timing countermeasures aimed at enhancing pedestrian safety. The framework itself will be flexible to accommodate all road users and consider all countermeasures (including traditional roadway geometry changes and emerging connected vehicle technologies) based on future efforts.

The digital twin will generate spatio-temporal pedestrian and vehicle trajectories based on video and lidar data that are consistent with the statistics of actual trajectories seen at intersections. The trajectories will be analyzed to determine severe events. Machine learning models will be developed to describe the trajectories of vehicles and pedestrians (and consequently severe events) as a function of intersection geometry, signal timing patterns, traffic and pedestrian demand, time of day, lighting, and other factors. It is important to note our ML models can be expected to produce more realistic (sensitive to demand levels and signal plans) trajectories of vehicles and pedestrians than those from popular traffic simulators that use empirically calibrated rule-based models (car following, lane changing, etc) to simulate vehicle movements. Surrogate measures of safety (severe events) will be derived from these trajectories. The ML-driven twin will be incorporated into present day traffic simulators, such as SUMO, so that the operational performance measures (delays, queue-lengths, etc.) at the intersection can be generated. The product can be used to evaluate the impacts of signal timing changes on pedestrian safety by conducting what-if analyses. As the vehicle and pedestrian behaviors (trajectories) have been determined based on real-world observations, the operational and safety performance of the digital twin of the intersection can be expected to mimic what would happen in the real world. Overall, the term digital twin used here is not meant to convey just the concept of a graphical representation of multi-sensor data. Rather, it is meant to evoke the image of a machine learning-driven simulator, fully capable of modeling the behavior of vehicles and pedestrians at intersections under alternate “what-if’ scenarios of interest.

Our digital twin for signalized intersections will leverage the prior work and support the following novel characteristics:

1. Develop models for both pedestrians and vehicle behavior at a signalized intersection that are sensitive to the amount of pedestrian and vehicular traffic, lighting conditions and signal timing plans. The simulator will provide information on various severe events. Some special use cases that could be explored include:
    1. Special events such as game days.
    2. Variable lighting and low visibility circumstances,
    3. Contextual variability in pedestrian behavior (behavior during normal business and school days, versus crossing behavior on nights and weekends)
2. Incorporate these behavior models in a traffic simulator such as SUMO or VISSIM which will allow agencies to quantify pedestrian safety (measured using severe events) under a variety of signal timing scenarios, lighting conditions and traffic volumes.
3. Demonstrate the applicability of these models for selected traffic intersections by changing signal timing plans for different times of the day and days of the week. Field observations can be compared to model predictions to serve as validations. (Note that we focus on countermeasures that can be implemented quickly in the field and evaluated within the project duration; therefore, we do not consider changes to roadway in this project). We will work closely with traffic engineers in the City of Gainesville and District 5 for this purpose.

	Although, simulators such as SUMO and VISSIM have been successfully used to study operational performance at an intersection, they are limited for safety applications for the following reasons: 1. The interactions between vulnerable users and vehicles is not fully captured, and is usually accounted for only from the vehicle perspective (delays to yielding, ped signal time etc.). The behavior of a vehicle driver depends on the number of vulnerable users and their locations at the intersections. Similarly, the behavior of vulnerable users depends on the number of cars approaching the intersection. Although illegal, the probability of a J-crossing depends on whether the pedestrian believes he/she will be hit by a car coming into the intersection. 2. The underlying models in these simulators are not data driven and generally follow a rule based approach (e.g. car following models). These rule-based models and algorithms can be calibrated for operations but not for safety analysis. This makes them brittle and does not capture a variety of interrelated parameters. 3. There is no easy way to calibrate simulation parameters based on data that is available for different signal timing and lighting conditions. This limits their use in practical scenarios where these conditions constantly change as the day evolves.		
Impact	Vulnerable Users (pedestrians, bicycle, and other personal mobility devices) are very difficult to understand and harder to predict and anticipate. We believe that reducing these events (near misses and severe events between vehicles and vulnerable users has the potential to improve the overall safety at both the intersection and city level. The result is envisaged to be a one-of-a-kind safety summarization and improvement focused broadly on Vulnerable Users safety at numerous intersections in Gainesville that can be easily scaled to other cities in the state of Florida and the rest of the nation. We will disseminate our traffic simulation software widely so that other communities with similar situations can use it. Follow up projects can look at other types of pedestrian environments..		
Affected Offices	Safety Office and Traffic Operations		
Existing Work	Through support from NSF and FDOT, UF has developed a video-based system for quantifying pedestrian (and other vulnerable users) safety at traffic intersections. In particular, we have refined the definition of near-misses by carefully processing 6 months of video data over six intersections. By incorporating phase information (from ground sensor data streams) and other trajectory-based information (e.g. deceleration etc.), we have defined severe events as a small subset of all "near misses" that indeed represent potentially serious encounters between vulnerable users and vehicles. Additionally, our heuristic approach has an automated way of deriving these severe events with a high level of precision and coverage.The severe events along with corresponding phase and deceleration information can then be used to derive potential countermeasures (like signal phasing and timing changes) that can reduce the frequency of such events.		
Keywords Used In Existing Work Search			
Related Contracts	None		
Funding Request	$400,000	**Anticipated Duration**	18 months
Project Manager	John Krause	**Contracting Method**	Direct contract with University of Florida
Equipment	N/A		
Urgency	Score 1-5 1= highest, most immediate need		
Implementability	Score 1-5 1=greatest likelihood of and proximity to implementing results	We will focus on use case on signal timing impacts of vehicle - pedestrian conflicts and resulting safety, so that the implementability is high	

Project Benefits (Succinct, complete explanation)

1. A quantitative understanding and modeling of signalized interactions between vulnerable users and vehicles obtained from data collected under different lighting conditions and signal timing phases along with traffic volumes.
2. A tool that allows qualitative and quantitative comparison of interventions for improving vulnerable user safety based on signal policy during normal and anomalous lighting conditions.
3. Clear feedback to city, county, and state officials on the benefits of digital intersection infrastructure improvements obtained from a fusion of

video, and ATSPM.		
Project Benefits **(Select all that apply and explain)**	**Quantifiable Benefits (units, dollars, etc…if applicable)**	**Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits**
o Materials Enhancement		
o Materials Savings		
o Time Savings		
o Lives Saved/Injuries Prevented	This research will lead to improved pedestrian safety. If successful, it should lead to fewer near misses and crashes in which pedestrians are involved	The methodology is described above. The research will use Video and Signal Timing Data to derive pedestrian and vehicle models that are based on traffic conditions, signal phasing and lighting conditions.
o Other (Explain)		

*Comments should explain and support urgency, financial benefit, and implementability scores