Request for Research Funding for FY 2022-2023			
SPR Subpart B Project: TEO-23-05			
Requesting Office	State Traffic Engineering and Operations Office	**Priority**	5 of 22
Proposed Title	**Developing and Evaluating Smart Work Zone (SWZ) Applications**		
Justification	Work zones are areas along the highway where roadwork such as maintenance or construction occurs. These areas are commonly characterized by closed lanes, detours, moving equipment, workers, work zone signs, barrels, and large trucks. Work zone areas are associated with unexpected congestion due to various factors, including day-to-day changes in traffic patterns, narrowed rights-of-way, and complex arrangements of traffic control devices and signs. Statistics show that work zones account for nearly 10% of non-recurring congestion.[1] Work zones not only adversely affect traffic operations, but they also have a detrimental effect on safety. Data shows that motor vehicle crashes and fatalities are more likely to occur in highway construction and maintenance work areas than on any other section of the road. For example, between 2016 and 2017, fatal freeway crashes in work zones increased by 8%, while fatal crashes outside work zones decreased by 1.5%. Moreover, 36,124 work zone crashes (of which 353 were fatal) were found to have occurred on the Florida state highway system from 2015-2020. During recent years, increased funding for road construction has led to a significant surge in highway construction projects across Florida. With the recent advances in technology, Smart Work Zone (SWZ) applications can improve traffic operations and safety at work zones. The SWZ technologies are a collection of portable computers, communication channels, and sensor technologies that collect real-time data in work zones, make a logical decision locally or with coordination to a central system, and disseminate information to road users and workers. The SWZ technologies primarily focus on improving safety and enhancing mobility. These benefits are achieved by alerting motorists on the work zone conditions, reducing the frequency and severity of work zone crashes, decreasing the likelihood of secondary crashes, and minimizing congestion in the vicinity of work zones[2]. Several FDOT districts have deployed (or are considering deploying) a variety of SWZ technologies at work zones to improve the traffic flow and the safety of both road users and workers. For example, Florida's Turnpike Enterprise (FTE) is considering SWZ technologies such as traveler information systems and work zone location technologies. D5 has implemented queue warning systems and has been leveraging the existing Dynamic Message Signs (DMSs) to communicate with road users. D5 has also developed a portable solar work zone alert trailer equipped with cameras, CV2X radios, and public announcement speakers. D6 is piloting an Incident Response Vehicle (IRV) fleet equipped with connected smart arrow boards that inform drivers of potential hazards ahead. D7 is using Dynamic Late/Zipper Merge to improve safety and reduce lane-closure-induced delays, and automated portable changeable message signs (PCMSs) to communicate real-time messages to the motorists. D4 is planning and designing SWZ technologies, including traveler information systems and queue warnings. This research effort aims to develop strategies to improve traffic operations and safety at work zones on freeways. The specific objectives include: • Understand and document the safety and mobility issues associated with work zones. • Enhance and test the FDOT D5 SWZ Proactive Safety System. • Evaluate the safety and mobility performance of SWZ technologies. **Objective 1: Safety and Mobility at Work Zones** The first step in devising strategies to improve the safety and operational performance of work zones is to identify and understand the safety issues at work zones. Below are some of the factors specific to work zones that impact safety: • type of work zones (shoulder/median, lane closure, or crossover), • the length and extent of the work zone, • the area where a crash occurred (advance warning area, transition area, activity area, or termination area), and • presence of any SWZ technologies.		

[1] Federal Highway Administration (2021). *Reducing Non-Recurring Congestion*. Accessed December 10, 2021. https://ops.fhwa.dot.gov/program_areas/reduce-non-cong.htm

[2] Florida Department of Transportation (FDOT). (2021). FDOT's Smart Work Zone Initiative. Florida Department of Transportation. Tallahassee, FL.

A detailed review of crash data along with the analysis of work zone data obtained from the Work Program will assist in identifying and understanding the safety problems in the vicinity of work zones on freeways. Besides analyzing safety, it is equally important to understand how the type of work zone affects traffic speeds and lane changing behavior. This analysis using real-time traffic data from the Regional Integrated Transportation Information System (RITIS) detectors could provide insights into the changes in the traffic flow characteristics in the vicinity of work zones. This information could help quantify the safety and operational performance of work zones. Additionally, a human factors study in a focus group setting will be conducted to determine the most effective signing and pavement markings that assist drivers in navigating through work zones. This will help analyze and understand driver behavior (based on age groups, gender, and other demographics) in and around work zones.

Objective 2: SWZ Proactive Safety System at D5

FDOT District-5 (D5) has been testing and deploying various SWZ technologies. In particular, D5 has developed a mobile Solar Alert Trailer to improve work zone safety. This mobile trailer features IR-PTZ camera technology (AUTODOME IP starlight 7000i) from Bosch Security. The camera technology has built-in intelligent video analytics, which provides object detection and counting (cars, pedestrians, cyclists, etc.), motion histories, and activity monitoring (such as a vehicle entering or exiting a predefined virtual zone). Apart from cameras, the trailer features radios (CV2X & others), lights, communication systems (i.e., public announcement speakers). Although this system has provided some initial encouraging results, there is still some room for improvement. For example, the inbuilt video analytics technology by Bosch has limitations. The performance of the system is degraded in low lighting conditions, which is usually the case at the work zones. The current system needs to be enhanced to identify near misses and predict a robust trajectory prediction of workers and vehicles to issue a real-time early conflict warning. Further incorporation of V2X data such as Basic Safety Message (BSM) and vehicle trajectory information will boost the capabilities of the system many folds.

This objective focuses on investigating the use of Light Detection and Ranging (LiDAR) technology and exploring the V2X technology to enhance the capabilities of the existing smart work zone trailer and evaluating the safety performance of the system. In an effort to improve the system, the functional and technical specifications will be first identified. The most suitable hardware components that can satisfy the technical requirements will be selected. For example, the selection of LiDAR equipment depends on the impact of parameters such as detection range, Field-of-View (FoV), and scan pattern on the real-time object detection and classification. The next step will involve building complementing capabilities based on LiDAR and V2X technologies and integrating them with the existing video-based alert system. The prototype will then be optimized for real-time operation in real-world scenarios. Finally, the developed system will be tested based on its effectiveness in identifying near misses. The end-product from this effort will be a compact design of the prototype deployable in a plug-and-play fashion.

Objective 3: Safety and Operational Performance of SWZ Technologies

Since several SWZ technologies are new and emerging, their impact on safety and mobility at the work zones is unknown. For the existing SWZ technologies that are already deployed, there is a need to estimate the acceptable ranges of expected safety and mobility outcomes. Safety Measures of Effectiveness (MOEs) could include crash frequency, crash severity, crash type, and several surrogate safety measures, including speed differentials and variation in speed. Similarly, mobility MOEs could consist of average travel time, travel time reliability, and diversion rates.

This objective focuses on quantifying the potential of SWZ technologies ((including the one developed in Objective 2) to meet operational and/or safety performance enhancement goals. This information could also be considered to support the Action Plan that the Department is finalizing to provide guidance for implementing SWZ technologies. Understanding that this objective is data-intensive, efforts will be undertaken to collect information about the SWZ deployments in Florida. Once the crash data, work zone data, roadway characteristics data, and real-time high-resolution traffic data associated with SWZ technologies are retrieved and processed, their safety performance could be quantified. Depending on data availability, crash modification factors (CMFs) will be developed to estimate the safety performance of SWZ deployments. The developed CMFs will assist the Department in estimating the safety B/C ratios for deploying SWZ technologies in terms of reduction in crashes. Similarly, mobility performance measures, once developed, could be used to estimate the mobility B/C ratios of SWZ technologies.

<table>
<tr><td>Impact</td><td colspan="3">The study will develop strategies to improve traffic operations and safety at freeway work zones, with a special focus on SWZ applications. The research results, especially from Objective 1 and 3, will assist FTE and other FDOT districts in determining the effectiveness of using the SWZ system and the regular Motorist Awareness System (MAS). The Department will have a clear understanding of when and where the SWZ applications could be deployed, along with the safety and operational benefits of deploying these SWZ technologies. Objective 2 focuses on developing data fusion methods to fully utilize and complement the D5's camera-based solar trailer system with LiDAR and CV2X technologies. The proposed plug-and-play system will provide a base for developing even more advanced safety systems for different on-road and off-road applications.</td></tr>
<tr><td>Affected Offices</td><td colspan="3">State Traffic Engineering and Operations Office; District Traffic Operations Offices; Safety Office; Traffic Incident Management (TIM); Transportation Technology</td></tr>
<tr><td>Existing Work</td><td colspan="3">The research team at FIU developed hotspots of work zone locations and work zone crashes across the state. As a preliminary analysis, the team also looked to see if any specific factors (such as type of construction activity, the extent of the work zone, etc.) affected the frequency and severity of work zone crashes. As part of another related effort, the team also explored several SWZ technologies. The team is currently working with the State Safety Office to review the crash reports of work zone crashes on the state highway system from 2015 through 2020.

Besides the work conducted by the research team at FIU, below are some examples of related research on SWZ system.

Radwan, E., Harb, R., & Ramasamy, S. (2009). Evaluation of safety and operational effectiveness of dynamic lane merge system in Florida: final report, April 2009.
Fontaine, M. D., & Edara, P. K. (2007). Assessing the benefits of smart work zone systems (No. 07-0371).
Li, Y., Martínez Mori, J. C., & Work, D. B. (2018). Estimating traffic conditions from smart work zone systems. Journal of Intelligent Transportation Systems, 22(6), 490-502.
Sun, C., Edara, P., Brown, H., Zhu, Z., & Rahmani, R. (2014). Calibration of Highway Safety Manual Work Zone Crash Modification Factors.
Sakhare, R. S., Desai, J. C., Mathew, J. K., McGregor, J. D., & Bullock, D. M. (2021). Evaluation of the impact of presence lighting and digital speed limit trailers on interstate speeds in Indiana work zones. Journal of transportation technologies, 11(2), 157-167.

The research team at UCF has been exploring various LiDARs for their suitability in pedestrian detection and tracking. Most of the existing LiDAR work relates to the autonomous vehicle applications. Below are some examples of technological solutions to make smart work zones.

Chukwuma Nnaji, John Gambatese, Hyun Woo Lee, Fan Zhang, "Improving construction work zone safety using technology: A systematic review of applicable technologies", Journal of Traffic and Transportation Engineering (English Edition), 2020.
Optimize the Work Zone Safety with Spatial Information Technology and Eye Tracker (https://trid.trb.org/View/1854735)
A Smart IoT Proximity Alert System for Highway Work Zone Safety (https://trid.trb.org/View/1749084)
Development of a Connected Smart Vest for Improved Roadside Work Zone Safety (https://trid.trb.org/View/1597716)
Using IoT Technology to Create "Smart Work Zones" (https://trid.trb.org/View/1723543)
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<tr><td>Keywords Used In Existing Work Search

(Cannot leave blank)</td><td colspan="3">Smart Work Zone (28 studies): Three are relevant to this project – but none focused on evaluating the performance of SWZ applications using real-time traffic data. One active study in Texas focuses on identifying best practices and lessons learned in implementing SWZ technologies. The research team will make sure not to duplicate the efforts from this study but review this study as part of this project.</td></tr>
<tr><td>Related Contracts</td><td colspan="3">BDV29-977-64 (Just Task 4): Performance Evaluation of CV and TSM&O Projects in Florida</td></tr>
<tr><td>Funding Request</td><td>$299,000</td><td>Anticipated Duration</td><td>24 months</td></tr>
<tr><td>Project Manager</td><td>Jeremy Dilmore (PM)
Eric Gordin (Co-PM)
Edith Wong (Co-PM)</td><td>Contracting Method</td><td>Florida International University (Lead)
University of Central Florida (Sub)</td></tr>
<tr><td>Equipment</td><td>Estimated equipment cost (or N/A)</td><td colspan="2">No equipment is needed for Objectives 1 and 3.
For Objective 2, the equipment cost is not included in the funding request – D5 will loan components such as LiDARs and Bosch cameras to the UCF team.</td></tr>
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Urgency	1	This research provides the Central Office with data-based intelligence on strategies to improve safety and mobility in the vicinity of work zones on freeways. This project will support the Department's Action Plan on providing guidance for implementing SWZ technologies. With the growing nationwide use of SWZ applications, this research is needed immediately to justify the use of ITS-based technology and the standard maintenance of traffic (MOT) devices. This research, particularly objectives 1 and 3, could assist the Department in making the work zones safer for both the road users and construction workers. Objective 2 of this research aims to support the ongoing smart work zone initiative at D5 by developing sensor fusion techniques that require extensive research before developing the actual product. The developed system will also have to be widely tested in different situations to ensure the accuracy and performance of real-world inference. The project ensures the success of the system that can be deployed rapidly and covers a wide area of applications not limited to on-site workers but extends alerts to connected vehicles as well. Hence, this effort needs to be conducted immediately.
Implementability	1	The research results will be readily implementable. The results will be disseminated to the DTOEs, DSEs, District TSM&O Engineers, Traffic Incident Management (TIM) teams, and other stakeholders for immediate adoption. Several FDOT districts including FTE and D5 have deployed (or, are considering deploying) a variety of SWZ technologies at work zones to improve the traffic flow and the safety of both road users and workers. The research results from Objectives 1 and 3 will directly support and benefit all FDOT districts in (a) understanding the factors affecting safety and mobility at work zones; (b) evaluating the feasibility and effectiveness of deploying SWZ applications; and (c) measuring the safety and operational benefits of deploying SWZ technologies. Objective 2 focuses on enhancing the existing D5 SWZ Proactive Safety System. It proposes a highly realizable plug-and-play end-product that is quick and easy to deploy.

Project Benefits (Succinct, complete explanation)

Overall, this project will provide a clear understanding of how safety and traffic flow can be improved in the vicinity of work zones on freeways. The more specific benefits include:

- Understand the safety and mobility issues associated with work zones
- Quantifiable safety performance of SWZ technologies (i.e., CMFs and surrogate safety measures)
- Quantifiable mobility performance of SWZ technologies (i.e., average trave time, queue length, etc.)
- B/C ratios of SWZ technologies
- The plug-and-play system (developed as part of Objective 2) will provide:
  - Real-Time classification (identification) of work zone and on-road objects
  - Real-Time tracking (localization) of work zone and on-road objects
  - Real-Time trajectory prediction (predicting future locations) of work zone and on-road objects
  - Near miss detection
  - Pro-active and active safety alerts broadcasting to connected entities
  - A 3D map of the work zone and detect any disorientation/falling of safety barrels/cones

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**
○ Materials Enhancement		One of the objectives of this research project (Objective # 2) aims to enhance the capabilities of the work zone safety trailer alert system.
○ Materials Savings	All-in-One Unit	Objective 2 focuses on enhancing the existing D5 SWZ Proactive Safety System. All the required sensors, microprocessors, communication modules, and storage will be deployed on the mobile TCS trailer unit to save materials such as unnecessary cables, unsupported communication modules, etc.

○ Time Savings	○ Reduction on traffic delay ○ Quick and easy deployment of the prototype	As part of Objectives 1 and 3, data-driven methodologies will be adopted to quantify the mobility benefits of the SWZ strategies. The developed mobility performance measures will be used to calculate the mobility B/C ratios of SWZ deployments. As part of Objective 2, the developed prototype will be pre-configured to allow plug-and-play for quick and easy deployment. In cases where customizations are necessary, such as in highly uneven terrain, the device will provide an easy-to-use interface for easy modifications.
○ Lives Saved/Injuries Prevented	Reduction in Crashes and Associated Fatalities/Injuries	As part of Objectives 1 and 3, data-driven methodologies will be adopted to quantify the safety benefits of the SWZ strategies. The developed CMFs and other surrogate safety performance measures will be used to calculate the safety B/C ratios of SWZ deployments. As part of Objective 2, the developed prototype will be integrated with the existing D5 SWZ Proactive Safety System to generate alerts to all connected entities such as on-road connected vehicles, on-site sound alert systems, individual alert systems such as smartphones, etc. This application will lead to fewer crashes and fatalities in work zones.
○ Other (Explain)	Efficient Utilization of SWZ system	The SWZ technologies may not be cost-effective for all types of facilities and work zones. This research will help determine the suitability of deploying SWZ technologies based on the duration and type of construction work, work zone length, facility types, etc. The findings from this research project could assist the Department in better utilizing the technologies where they will be most cost-effective.

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