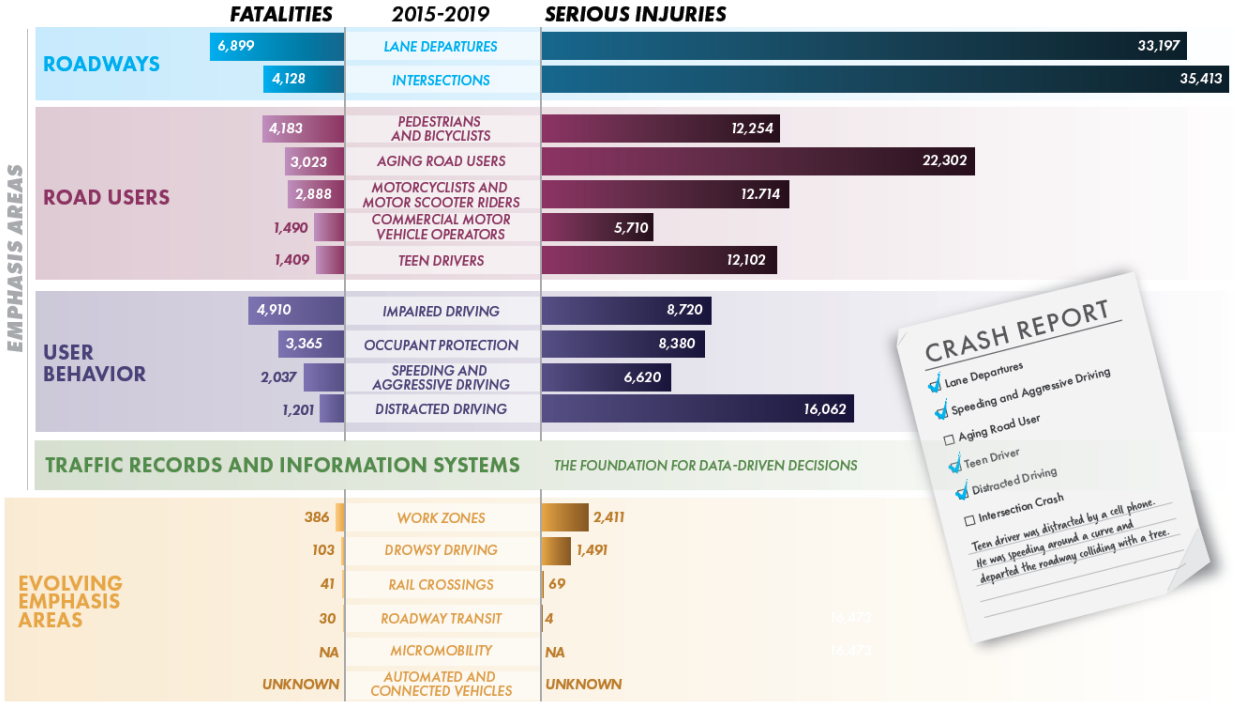
Request for Research Funding for FY 2021-2022			
Requesting Office	FDOT Roadway Design Office or Safety Office	**Priority** Highest	1 of 1 (projects may not have the same ranking – no ties)
Proposed Title	Evaluation on Effectiveness of Audible and Vibratory Treatment (AVT) Installations on Arterials and Collectors based on FDOT Context-based Design Criteria		
Justification	**Describe the current situation, why the research is needed, and how the research affects your office's mission critical focus areas** **Current Situation:** FHWA defines a roadway departure (RwD) crash (or lane departure crash) as a crash that occurs after a vehicle crosses an edge line or a center line or otherwise leaves the traveled way. From 2016 to 2018, an average of 19,158 fatalities resulted from roadway departures, 51% of all traffic fatalities in the US. RwD is also a top contributing factor for traffic crashes in Florida. According the 2016 Florida Strategic Highway Safety Plan (SHSP), more people are killed in lane departure crashes than any other type of crash in Florida. "About one-third of lane departure crashes result in a collision with another moving vehicle, possibly head-on, and two-thirds involve hitting a tree or another fixed object. A little more than one-half of fatal lane departure crashes occur in rural areas where there are more two-lane roadways, narrow shoulders, and long stretches of relatively empty roadway. The most recent Florida crash data (2015–2019) revealed that lane departure was the top contributing factor to traffic crash fatalities and the second highest contributing factor to serious injuries, as shown in Figure 1. Figure 2 illustrates that, in 2015–2019, lane departures accounted for 33% of all crashes and 44% of traffic fatalities on Florida roadways.  **Figure 1. Top Contributing Factors and Emphasis Areas of Traffic Crashes in Florida, 2015-2019**			

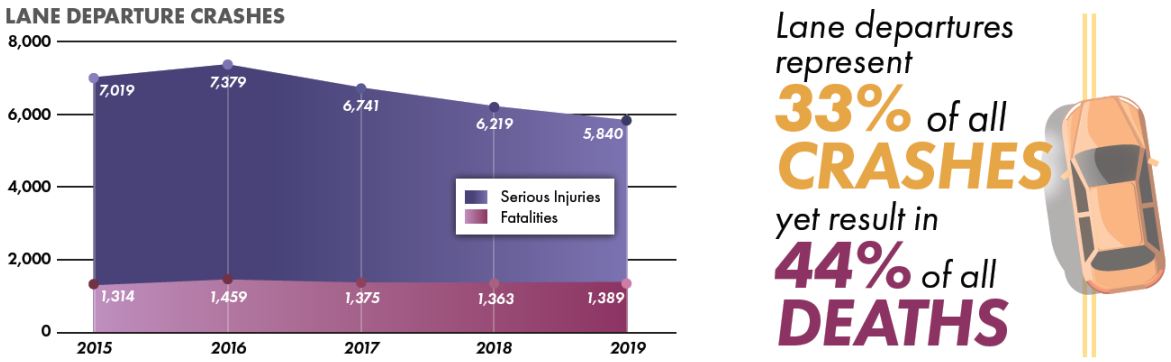


Figure 2. Lane Departure Crash Statistics in Florida, 2015-2019

Longitudinal rumble strips are milled or raised elements on pavement designed to address lane departure crashes caused by distracted, drowsy, or otherwise inattentive drivers by alerting drivers through vibration and sound that their vehicles have left the travel lane. They can be installed on a shoulder, an edge line of the travel lane, or at or near the center line of an undivided roadway. Rumble strips have proved to be an effective countermeasure to reduce the number of roadway departure crashes and mitigate injury severity outcomes in these crashes.

FDOT published Roadway Design Bulletin (RDB) 15-03 and updated accordingly the FDOT Design Manual (FDM) to standardize the implementation of Audible Vibratory Treatments (AVTs) (which include a context-based design policy with the use of ground-in rumble strips or profiled thermoplastic pavement markings) for arterials and collectors. A Development Design Standard (DDS) was also released for rumble stripping on open-graded friction course pavements. After the publication of RDB 15-03, FDOT received complaints from homeowners regarding the noise resulting from vehicular impacts to rumble stripping and from bicyclists regarding the length of the gap on the edge lines. In response, FDOT published RDB 16-07, which requires that all projects must meet the criteria for rumble stripping, including those already in construction where rumble stripping had not yet been placed, and must be evaluated by the State Roadway Design Office (SRDO). FDOT also began the process of evaluating the usage policy and standard configurations of rumble stripping for noise pollution reduction and accommodation of bicyclists and published RDB 18-03 to implement the context-based design criteria for AVTs on arterials and collectors into the FDM and Standard Plans. This new policy, effective on all projects with lettings on or after January 1, 2019, considered potential noise impacts on residents and businesses adjacent to the roadway when selecting an appropriate AVT. Overall, compared with the previous approach for placement of AVTs on arterials and collectors, RDB 18-03 included the following key changes:

- Reduced the depth of cylindrical ground-in rumble strips from 1/2 inch to 3/16 inch based on noise testing of various patterns and depths.
- Reduced the width of centerline rumble strips from 16 inches to 8 inches.
- Modified the array dimensions to better accommodate cyclists.
- Researched and implemented the use of a sinusoidal ground-in rumble strip pattern that lessens the potential for noise pollution.
- Created ground-in configurations (Types A, B, and C) for consistent placement of edge line rumble strips.

Why the research is needed:

Lane departure crashes account for about one-third of all traffic crashes and more than 40% of all traffic fatalities on Florida roadways. Rumble strips are USDOT-proven countermeasures for reducing lane departure crashes and severities by alerting drivers when they leave the roadway across the center line or edge line through the generation of noise and vibration, which have been widely implemented by state and local transportation agencies. The new approach defined in RDB 18-03 and current FDM for the installation of AVTs on arterials and collectors provides considerations for reduction of potential noise pollution and accommodation of cyclists. Given the importance of rumble strips in lane departure crash prevention and injury severity mitigation, it is of critical need to evaluate the safety effectiveness of AVTs implemented on arterials and collectors based on this new context-based approach.

	How the research affects your office's mission critical focus areas: The mission of FDOT is to provide a safe transportation system that ensures the mobility of people and goods, enhances economic prosperity, and preserves the quality of Florida's environment and communities. To support this mission, the SRDO develops and provides policy, procedures, roadway criteria and roadway standards for design of Florida roadways; monitors their implementation; and provides training. The proposed research project fully supports the mission of the SRDO for developing criteria and standards for AVT design and implementation and supports the mission of FDOT on safety and mobility by seeking effective and innovative countermeasures to reduce roadway departure-related fatalities, injuries, and crashes. **Research Objectives:** The overall goal of this proposed research project is to evaluate the effectiveness of AVT installations defined in RDB 18-03 and current FDM on Florida arterials and collectors based on FDOT context-based design criteria in roadway departure crash prevention and injury severity mitigation, taking into consideration reducing noise pollution and accommodating bicyclists. With this goal, this project aims to: 1. Perform a comprehensive literature review on AVT design and implementations in the US for roadway departure prevention. 2. Perform a review of practices of AVT alternative designs and implementations considering reduction of noise pollution and accommodations of bicyclists. 3. Select arterials and collectors with a high number of roadway departure crashes and where AVTs based on the context-based design criteria are installed as candidate analysis corridors. 4. Obtain roadway departure incident data of these candidate analysis corridors before and after AVT implementations based on the context-based design criteria. 5. Conduct in-depth interviews of selected transportation agencies on their implementations of AVTs based on the FDOT context-based design criteria and feedback received from the public. 6. Develop performance measures and conduct in-depth analysis of all information collected from review of literature and practices, in-depth interviews, and before-after roadway departure incident data. 7. Document all research analysis and findings and provide recommendations on AVT design and installations for FDOT future consideration.
Impact	**How shall the results impact practice? Consequences of not doing the research?** Rumble strips are proven safety countermeasures to reduce roadway departure crashes and mitigate injury severities. Evaluation of the effectiveness of rumble strips and the reduction of noise pollution has been conducted at the national level and in many states. FDOT implemented new context-based AVT design criteria taking into consideration noise pollution control and accommodation of bicyclists, effective on all projects with letting dates on or after January 1, 2019. To ensure that the new context-based AVT design criteria are appropriate and effective, it is of critical need to conduct this research to evaluate the effectiveness of AVTs implemented on arterials and collectors based on this new context-based approach in terms of roadway departure crash prevention and injury severity mitigation. This project will also provide valuable feedback and further recommendations to improve the context-based AVT design criteria and future AVT implementations to promote safety and traffic operation efficiency of the Florida roadway system. Consequences of not conducting the research include the following: • FDOT will not obtain the most recent knowledge on AVT design and implementations in the US for roadway departure prevention. • FDOT will not obtain the most recent knowledge on practices of AVT alternative designs and implementations considering reduction of noise pollution and accommodations of bicyclists. • FDOT will not obtain input from transportation agencies on their implementations of AVTs based on FDOT context-based design criteria and feedback received from the public. • FDOT will not obtain evaluation analysis results of all information collected from a review of the literature and practices, in-depth interviews, and before-after roadway departure incident data. • FDOT will not obtain recommendations on AVT design and installations for future consideration.

Affected Offices	**Identify any office that will need to be involved in the scoping or conduct of the research, will be affected by implementation of the results, or will need to participate in the implementation process—including OTIT, if enterprise data/network software application will be a deliverable, and district staff, as appropriate, e.g., through statewide meetings. If the requesting office will not be the implementing office, please identify which office will have to serve in that capacity—has it been involved?** FDOT Roadway Design Office, FDOT Safety Office
Existing Work	Very limited research has been conducted on AVTs in Florida, as they were in the developmental phase in past years and put into effect in 2018. However, existing literature noted below provides some insights regarding their effectiveness in preventing roadway departures, reducing noise pollution, and accommodate cyclists. Research is needed to thoroughly evaluate the effectiveness of rumble strip installations on Florida arterials and collectors based on FDOT context-based design criteria in reducing roadway departure crashes, mitigating noise pollution, and accommodating bicyclists. • *NCHRP Synthesis 515, Practices for Preventing Roadway Departures (2018)* – identifies and summarizes countermeasures being used by state DOTs to prevent roadway departure crashes; identifies data-driven advantages and disadvantages of these countermeasures. • *State of the Practice for Shoulder and Center Line Rumble Strip Implementation on Non-Freeway Facilities (S. Himes, H. McGee, S. Levin, Y. Zhou, FHWA-HRT-17-026 Report, VHB. Inc, 2017)* – includes literature review detailing research related to rumble strip design, noise and vibration testing methods and findings, impacts on bicyclists and motorcyclists, pavement condition impacts, pavement marking visibility, operational effectiveness, and safety effectiveness; reviewed current department policies and standard drawings for rumble strip implementation strategies, systematic installation criteria, currently used rumble strip dimensions, high-crash corridor installation practices, and special considerations and rumble strip modifications; details development of decision support guide and includes gap analysis and action plan for future rumble strip research. Future research can help agencies identify optimal rumble strip design for installations. • *Effect of Rumble Strip Profiles on Noise Levels (G. Wang, E. Offei, Journal of Transportation Engineering, Part B: Pavements, 146(2), 2020)* – evaluated the effect of different shoulder rumble strip profiles, including cylindrical, sinusoidal, and raised audible rumble strips, on tire–pavement interface noise, internal noise (inside the vehicle), and wayside noise. Results show that tire-pavement interface noise level based on FDOT onboard sound intensity (OBSI) noise trailer, internal noise in cab, and wayside noise increase with depth of rumble strips for all cylindrical rumble strips. Both sinusoidal rumble strips and raised audible rumble strips made noticeable increase in internal noise in cab but little discernible increase on external noise in terms of OBSI noise measurements and wayside noise measurements. • *Assessment of Alternative Rumble Strip Construction (D. Bullock, J. Krogmeier, SPR-4016 Report, Purdue University/Indiana Department of Transportation, 2018)* – empirical evaluation of alternative widths, sinusoidal periods, and milling depths to identify construction specifications that can provide adequate lane departure warning with lower noise outside of right-of-way. • *Rumble Strip Design Analysis to Contribute to Low Exterior Noise and the Durability of Inlaid Stripes (Y. Zhang, SPR-829 Report Oregon State University, 2018, ongoing)* – main goal of research is for the Oregon Department of Transportation to identify implementable rumble design (strip, stripe, or combination inlaid) that is acceptable in noise output to communities who live close to the highway but without rumble losing its safety benefit of alerting drivers when they depart the road. • *Mitigating Roadside Noise Pollution: A Comparison between Rounded and Sinusoidal Milled Rumble Strips (D, Horne, H. Jashami, D. Hurwitz, C.M. Monsere, S. Kothuri, Transportation Research Part D: Transport and Environment, 77, December 2019, 37-49)* – evaluated feasibility of using sinusoidal RS as substitute for rounded milled rumble strips on roadway segments in Oregon with lane-departure crash problems. Rumble strip strikes by passenger car and van generated less exterior noise with sinusoidal rather than rounded design. Results for heavy vehicle were complicated due to bridging of narrower rounded rumble strip by tires. Wider cut of sinusoidal RS generated clearly detectable increase in exterior roadside noise for heavy vehicle.

	Rumble Strip Noise Evaluation (E. Terhaar, Wenck Associates, Inc., D. Braslau, David Braslau Associates, Inc. MN/RC 2015-07, 2015) – presented results of sound level monitoring of three types of longitudinal rumble strips installed along edge of two-lane rural roads in Polk County, MN, in response to objections raised by landowners about unwanted noise caused by vehicles traveling over rumble strips when they drift over edge or centerline of roadway.		
Keywords Used in Existing Work Search	Roadway departure, Lane departure, Audible and vibratory treatment, Rumble strip, Noise pollution, FDOT Design Manual, Evaluation		
Related Contracts (Give contract numbers)	No recent FDOT research projects were identified for AVT evaluations. The following national research projects and projects from other states were identified. • NCHRP Synthesis 515 – Practices for Preventing Roadway Departures • FHWA-HRT-17-026 – State of the Practice for Shoulder and Center Line Rumble Strip Implementation on Non-Freeway Facilities • SPR-4016 – Assessment of Alternative Rumble Stripe Construction • MN/RC 2015-07 – Rumble Strip Noise Evaluation • SPR 829 – Rumble Strip Design Analysis to Contribute to Low Exterior Noise and Durability of Inlaid Stripes		
Funding Request	$150,000	**Anticipated Duration**	18 months
Project Manager	Mr. Gevin McDaniel Ms. Brenda Young	**Contracting Method**	Direct contract with the Center for Urban Transportation Research (CUTR) at University of South Florida
Urgency	Score 1–5 (1= highest, most immediate need) Score = 1	According the 2016 Florida Strategic Highway Safety Plan (SHSP), more people are killed in lane departure crashes than any other type of crash in Florida. Specifically, lane departures accounted for 33% of all crashes and 44% of traffic fatalities on Florida roadways. Rumble strips are USDOT-proven countermeasures in reducing lane departure crashes and severities by alerting drivers when they leave the roadway across the center line or edge line through the generation of noise and vibration and have been widely implemented by state and local transportation agencies. FDOT published context-based AVT design criteria for rumble strip installations on arterials and collectors, taking into consideration of reduction of noise pollution and accommodating bicyclists. Therefore, there is an urgency to evaluate the safety effectiveness of AVTs implemented on arterials and collectors based on this new context-based approach in roadway departure crash prevention and injury severity mitigation and provide valuable feedback and further recommendations to improve the context-based AVT design criteria and future AVT implementations.	
Implementability	Score 1–5 1=greatest likelihood of and proximity to implementing results Score = 1	FDOT implemented new context-based AVT design criteria taking into consideration noise pollution control and accommodation of bicyclists, effective on all projects with letting dates on or after January 1, 2019. Evaluation analysis results and findings in this project will verify if the new context-based AVT design criteria are appropriate and effective and will provide valuable feedback and further recommendations to improve the context-based AVT design criteria and future AVT implementations to promote safety and traffic operation efficiency of the Florida roadway system so they will be adequate, practical, and implementable for FDOT and local transportation agencies.	

Project Benefits (succinct, complete explanation)

- Understand the effects of AVT design and implementations in the US for roadway departure prevention,
- Understand AVT alternative designs and implementations considering reduction in noise pollution and accommodation of bicyclists.

• Obtain input from transportation agencies on their implementations of AVTs based on FDOT context-based design criteria and feedback received from the public. • Understand the safety effectiveness of AVTs implemented on arterials and collectors based on the new context-based approach in roadway departure crash prevention and injury severity mitigation. • Provide valuable feedback and further recommendations to improve the context-based AVT design criteria and future AVT implementations in Florida.		
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		
○ Materials Savings		
○ Time Savings		
○ Lives Saved/Injuries Prevented	Reduction in number of crashes, secondary crashes, fatalities, and serious injuries.	Lane departure crashes account for about one-third of all traffic crashes and more than 40% of all traffic fatalities on Florida roadways. Rumble strips are USDOT-proven countermeasures in reducing lane departure crashes and severities by alerting drivers when they leave the roadway across the center line or edge line through the generation of noise and vibration. This project will identify and evaluate the safety effectiveness of AVTs implemented on arterials and collectors based on the new context-based approach in reducing the number of roadway departure crashes, fatalities, and serious injuries and will also provide valuable feedback and further recommendations to enhance the context-based AVT design criteria and future AVT implementations to improve the safety of Florida roadway system. This research is essential to support FDOT for successful implementation of the new approach defined in RDB 18-03 and current FDM for the installation of AVTs on arterials and collectors to significantly reduce roadway departure fatalities, injuries, and crashes, reduce noise pollution, and accommodate bicyclists.
○ Other (Explain)	Understanding of public opinions on AVT installations based on the new context-based design criteria	The new context-based design criteria defined in RDB 18-03 and current FDM for the installation of AVTs on arterials and collectors provides considerations for potential noise pollution reduction and accommodation of cyclists. The proposed research will assist FDOT in obtaining feedback from transportation agencies and public opinion on AVT installations based on the new design criteria.