Request for Research Funding for FY 2024-2025			
Project Number (Research Center Use Only): D5-25-03			
Requesting Office	District Five	**Priority**	3 of 5 (projects may not have the same ranking – no ties)
Proposed Title	Guardrail Height Safety Requirements Given Recent Crash History and Evolution of Vehicle Design		
Justification	FDOT Standards for Guardrail Heights have changed over the years but may not be keeping pace with the change in vehicle design, especially for large trucks. The center of gravity for these vehicles has drastically changed, warranting a closer inspection of the functionality and safety design of current and future guardrail specifications. In addition to this, there have been a signification number of guardrail breaches from vehicle impact. These incidents need to be more closely examined to determine causation and if design changes are needed.		
Impact	Safer guardrail design and installation can reduce the severity of bodily injury during crashes, including saving lives. In addition, less guardrail breaches have the potential to reduce traffic congestion and safety concerns with vehicles travelling in the opposite direction.		
Affected Offices/ Districts	District Five incidents will be examined. Traffic Operations and local field offices may be asked to provide information in support of this study.		
Existing Work	There have been some studies performed in other states for guardrail height, particularly for the Midwest Guardrail System (MGS), but nothing as comprehensive as what's being proposed with this study for the State of Florida. Additionally, nothing was found relating to the evolution of vehicle design with respect to changes relating to the vehicle's center of gravity. **See additional details for existing work at the end of this request.		
Keywords Used In Existing Work Search **(Cannot leave blank)**	Guardrail, Safety, Breach, Guardrail Height, Impact, Crash, Incident		
Related Contracts (Give contract numbers)	Nothing noted applicable for FDOT.		
Funding Request	$200,000	**Anticipated Duration**	1 year
Project Manager	Scott Kirts	**Contracting Method**	Contract with Embry Riddle
Equipment	N/A		
Urgency	1	Vehicle crashes are impacting guardrail every day throughout the State of Florida. A safer guardrail system that adequately softens impacts and redirects vehicles from impacting oncoming traffic is essential.	
Implementability	1	Proposed changes as a result of this study could immediately be incorporated into FDOT Standard Indexes and incorporated in future design changes. Additionally, current guardrail in place could be more closely inspected to determine changes to be made, resulting in a safer roadway network.	

Project Benefits (Succinct, complete explanation)

FDOT preaches Target Zero routinely, which is a program aimed at reducing traffic fatalities to zero. This study aims to more closely examine the functionality of a critical safety element featured on many roadways, including high speed facilities such as interstates. Proposed changes could have an immediate positive impact on the safety of the travelling public and achieving FDOT's mission.

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	Not able to quantify	Proposed guardrail changes may provide a benefit to material changes.
○ Financial Impact	Not able to quantify	Less severe bodily harm injuries reduce claims and have the potential to create less invasive incidents which would reduce congestion and allow for the safe travel of goods and services.
○ Time Savings	Not able to quantify	Less severe bodily harm injuries reduce claims and have the potential to create less invasive incidents which would reduce congestion and allow for the safe travel of goods and services.
○ Lives Saved/Injuries Prevented	Not able to quantify	Will examine the incidents involving fatalities and other serious bodily harm and how determine how changes relating to the guardrail system may have mitigated safety concerns.
○ Other (Explain)		

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

** **Existing Work**

(Guardrail Height Safety Requirements Given Recent Crash History and Evolution of Vehicle Design)

Over the years, the critical role of guardrail height in effectively redirecting vehicles has been highlighted, particularly as larger vehicles like SUVs and pickup trucks have become prevalent on roads. The Roadside Design Guide recommends specific heights for W-beam guardrails, but variations due to poor installation, settlement, or successive overlays have been noted. The historical focus on standard-sized sedans has shifted, prompting research initiatives to evaluate safety performance considering variations in rail height. Recent studies have used finite element models, simulations, and full-scale crash tests to assess the impact on safety, revealing that the effectiveness of the barrier to redirect a vehicle is compromised when the rail height is lower than recommended. Future trends may involve increased attention to tolerances, adapting guardrail designs to the evolving nature of vehicles, and enhancing safety standards to accommodate diverse traffic conditions. Guardrail designs may become more flexible, allowing for variations in rail height and ensuring effective vehicle containment and redirection. Ongoing research and advancements in crash testing methodologies may contribute to the development of more robust safety standards for guardrail heights, reflecting a comprehensive approach to roadside safety.

Lioi, A; Hazoor, A; Castro, M; Bassani, M.
Impact on driver behaviour of guardrails of different height in horizontal-vertical coordinated road scenarios with a limited available sight distance. *Transportation Research Part F: Traffic Psychology and Behaviour, Volume 84, Issue 0, 2022, pp 287-300* [Link to Paper]

- Guardrail height significantly affects lateral and longitudinal driver behavior.
- Minimum guardrail height keeps drivers closer to the roadside; higher guardrails increase lateral distance.
- Speeds are influenced by guardrail interaction with other factors.
- Male and female drivers react differently, with males adopting more aggressive behavior.
- Safety implications include higher speeds and wider trajectories that must be considered in design.

Molan, Amirarsalan Mehrara; Ksaibati, Khaled.
Factors impacting injury severity of crashes involving traffic barrier end treatments. *International Journal of Crashworthiness, Volume 26, Issue 2, 2021, pp 202-210* [Link to Paper]

- End treatment type A-FLEAT 350 is least likely to result in severe injuries.
- Turned-down end terminal and end anchorage WY-BET associated with higher injury severity.
- End treatments on a flat roadside are less severe.

- Crashes involving pickups have lower severity than other vehicle types.

Rosenbaugh, Scott K; Faller, Ronald K; Schmidt, Jennifer D; Bielenberg, Robert W.
Development of a 34-in. Tall Thrie-Beam Guardrail Transition to Accommodate Future Roadway Overlays.
Transportation Research Record: Journal of the Transportation Research Board, Issue 0, 2019 Link to Paper

- Developed a 34-in. tall thrie-beam guardrail transition crashworthy after 3-in. roadway overlays.
- Evaluated through crash tests meeting AASHTO's Manual for Assessing Safety Hardware (MASH) TL-3 standards.
- Provided implementation guidance for the crashworthy variations.

Pajouh, Mojdeh Asadollahi; Julin, Ramen D; Stolle, Cody S; Reid, John D; Faller, Ronald K.
Rail Height Effects on Safety Performance of Midwest Guardrail System. *Traffic Injury Prevention, Volume 19, Issue 2, 2018, pp 219-224* Link to Paper

- Investigated safe installation height for Midwest Guardrail System (MGS).
- Crash testing and simulation for MGS with rail heights of 864 mm (34 in.) and 914 mm (36 in.).
- Both heights satisfied MASH TL-3 criteria.
- Maximum safe guardrail height determined to be 36 in. for small car vehicles.

Julin, Ramen D; Pajouh, Mojdeh Asadollahi; Stolle, Cody S; Reid, John D; Faller, Ronald K.
Maximum Mounting Height for Midwest Guardrail System (MGS). *Transportation Research Board 96th Annual Meeting, Transportation Research Board, 2017, 18p* Link to Paper

- Investigated safety performance of increased mounting heights for MGS.
- Crash testing and simulation for MGS with rail heights of 34 in. and 36 in.
- Maximum safe guardrail height determined to be 36 in. for 1100C vehicles.

Fang, Howie; Gutowski, Matthew; Palta, Emre; Kuvilla, Daniil; Baker, Ryan; Li, Ning.
Performance Evaluation of 29-inch and 31-inch W-beam Guardrails on Six-lane, 46-foot Median Divided Freeways.
University of North Carolina, Charlotte; North Carolina Department of Transportation; Federal Highway Administration, 2015, 141p Link to Paper

- Finite element modeling and simulations evaluated W-beam guardrails at 29 and 31 inches under MASH TL-3 impact conditions.
- Guardrails demonstrated effectiveness in retaining impact vehicles but showed a risk of tire snagging and spin-out under small angle impacts.
- Simulation proved effective and efficient for studying crash scenarios.

Teng, Tso-Liang; Liang, Cho-Chung; Tran, Thanh-Tung.
Effect of Various W-beam Guardrail Post Spacings and Rail Heights on Safety Performance. *Advances in Mechanical Engineering, Volume 7, Issue 11, 2015, pp 1-16* Link to Paper

- Used LS-DYNA to evaluate the safety performance of AG04-2.0 A-type barrier with three post spacings and various rail heights.
- Crash test simulations satisfied EN 1317 criteria (TB11 test).
- Optimal dimensions for AG04-2.0 were 2000-mm post spacing and 700-mm rail height.

Fredriksson, Göran; Holmén, Hans G.
Functional limits of the W-beam guardrail. *2015, 9* Link to Paper

- Explored functional limits of W-beam guardrail through full-scale tests.
- Investigated effects of positioning, ground conditions, and damages on guardrail performance.
- Highlighted potential concerns for SUVs and sports cars not included in standards.

Julin, Ramen D; Reid, John D; Faller, Ronald K; Mongiardini, Mario.
Determination of the Maximum MGS Mounting Height– Phase II Detailed Analysis Using LS-DYNA®. *Midwest Roadside Safety Facility; University of Nebraska, Lincoln; Nebraska Department of Roads; Federal Highway Administration, 2012, 225p* Link to Paper

- Phase II focused on detailed analysis of increased-height Midwest Guardrail System (MGS) using LS-DYNA.
- MGS satisfied MASH TL-3 evaluation criteria on level terrain with rail heights up to 36 in.
- Successful containment on slopes as steep as 6:1 with 36-in. rail height.

Stolle, Cale J; Lechtenberg, Karla A; Reid, John D; Faller, Ronald K; Bielenberg, Robert W; Rosenbaugh, Scott K; Sicking, Dean L; Johnson, Erin A.
Determination of the Maximum MGS Mounting Height – Phase I Crash Testing. *University of Nebraska, Lincoln; Nebraska Department of Roads, 2012, 240p* Link to Paper

- Investigated potential for increasing maximum rail mounting height of MGS.
- Full-scale crash tests with Kia Rio passenger cars at 34-in. and 36-in. rail heights.
- Both system heights satisfied MASH TL-3 evaluation criteria for test no. 3-10.

Ferdous, M R; Abu-Odeh, Akram; Bligh, Roger P; Jones, Harry L; Sheikh, Nauman M.
Performance limit analysis for common roadside and median barriers using LS-DYNA. *International Journal of Crashworthiness, Volume 16, Issue 6, 2011, pp 691-706* Link to Paper

- Identified performance limits of four common guardrail systems using LS-DYNA simulations.
- Evaluated override and underride limits for each model based on NCHRP Report 350 design vehicles.
- Utilized non-linear finite element methodology for analysis.

Ochoa, Carl M; Ochoa, Tania A.
Guardrail Optimization for Rural Roads. *Transportation Research Record: Journal of the Transportation Research Board, Issue 2203, 2011, pp 71-78* Link to Paper

- Optimized guardrail barriers for lower-cost solutions in rural roadways.
- Introduced a deformable release member to optimize release load in relation to support-post-section properties.
- Successfully crash tested and accepted by FHWA at NCHRP Report 350 test levels and AASHTO MASH TL-3.

Manchas, Brad; Olson, Dave.
Through, Over, or Under Guardrail Penetration by Guardrail Height. *Washington State Department of Transportation; Federal Highway Administration, 2009, 15p* Link to Paper

- Evaluated correlation between guardrail height and penetration in Washington State datasets.
- Examined whether guardrail heights of 27 in. or lower experience more through, over, or under penetrations than 28 in. or greater installations.

Opiela, Ken; Kan, Steve; Marzougui, Dhafer.
Evaluating W-Beam Guardrail Height Tolerances. *National Crash Analysis Center; Federal Highway Administration, 2007, 9p* Link to Paper

- W-beam guardrail height critical for intended function in redirecting vehicles.
- RDG recommends 27 inches above the edge of pavement with a tolerance of +/- 3 inches.
- Variations in rail height due to poor installation, settlement, or successive overlays can impact safety.
- Study evaluates safety performance of W-beam guardrails with variations in rail height.
- Aimed to help DOTs understand safety margins for maintenance decisions.

Marzougui, Dhafer; Mohan, Pradeep; Kan, Steve.
Evaluation of Rail Height Effects on the Safety Performance of W-Beam Barriers. *National Crash Analysis Center; Federal Highway Administration, 2007, 32p* Link to Paper

- Investigated the effect of rail height on G4(1S) w-beam guardrail system safety performance.
- Utilized finite element models, simulations, and full-scale crash tests.
- Simulations indicated compromised effectiveness with lower-than-recommended rail height.
- Full-scale crash tests validated simulation results.

Opiela, Ken; Kan, Steve; Marzougui, Dhafer.
Effects of Shoulder Drop-Off on W-Beam Guardrail Performance. *National Crash Analysis Center; Federal Highway Administration, 2007, 6p* Link to Paper

- Analyzed dynamics of vehicles leaving the roadway and experiencing shoulder drop-off.
- FHWA efforts determined w-beam guardrail height significantly affects barrier effectiveness.
- Resurfacing without milling can create drop-offs affecting guardrail height effectiveness.
- Vehicle suspension effects on interface with guardrail considered.

Marzougui, Dhafer; Mohan, Pradeep; Kan, Cing-Dao; Opiela, Kenneth S.
Evaluation of Rail Height Effects of the Safety Performance of W-Beam Barriers. *National Crash Analysis Center; Federal Highway Administration, 2007, 21p* Link to Paper

- Investigated effect of rail height on G4(1S) w-beam guardrail system safety performance.
- Used finite element models, simulations, and full-scale crash tests.
- Simulations revealed compromised effectiveness with lower-than-recommended rail height.
- Full-scale crash tests validated simulation results.

Strybos, J W; Mayer, J B; Bronstad, M E.
GUARDRAIL TESTING PROGRAM III: FINAL REPORT. *Southwest Research Institute; Federal Highway Administration, 1996, 201 p.* Link to Paper

- Summarizes seven full-scale crash tests on three different longitudinal barriers.
- Tests included stone masonry guardwall, W-Beam Transition to Texas Type 101 Bridge Rail, and Thrie Beam on Wood Post Transition to New Jersey Shaped Parapet.
- Conducted according to NCHRP Report 350 test procedures.

Bronstad, M E; Calcote, L R; Hancock, K L; Mayer Jr, J B.
EFFECTS OF CHANGES IN EFFECTIVE RAIL HEIGHT ON BARRIER PERFORMANCE. VOLUME I. RESEARCH REPORT. FINAL REPORT. *Southwest Research Institute; Federal Highway Administration, 1987, 152 p.* Link to Paper

- Objective to determine critical rail mounting heights to prevent underride and override for traffic barriers.
- Used W-beam guardrails for criteria development through computer simulation and full-scale crash tests.

- Testing on level and sloping terrains with 4500-lb and 1800-lb vehicles.

Bronstad, M E; Calcote, L R; Hancock, K L; Mayer Jr, J B.
EFFECTS OF CHANGES IN EFFECTIVE RAIL HEIGHT ON BARRIER PERFORMANCE. VOLUME II. APPENDICES. FINAL REPORT. *Southwest Research Institute; Federal Highway Administration, 1986, 369 p.* Link to Paper

- Continued findings from Volume I, including appendices.
- Investigated critical rail mounting heights for W-beam guardrails to prevent underride and override.
- Utilized computer simulation and full-scale crash tests on level and sloping terrains with different vehicles.

Hargroves, B T; Tyler, J S.
RANKING LOW GUARDRAIL SITES FOR REMEDIAL TREATMENT. *Journal of Transportation Engineering, American Society of Civil Engineers, Volume 111, Issue 5, 1985, p. 539-545* Link to Paper

- Developed scoring procedure to prioritize low guardrail sites for remedial treatment.
- Estimated relative hazard based on traffic volume, speed, roadway curvature, soil conditions, and severity of vehicular penetration.
- Considered guardrail height, length, type, and location in ranking.

Hargroves, Bradley T; Tyler, J Stuart.
Identification, analysis, and remedial treatment of low guardrail in Virginia. *VHTRC; Virginia Highway and Transportation Research Council, 1981, xii, 29, 2 p.* Link to Paper

- Analyzed data on low guardrails in Virginia, identifying causes like old standards, faulty installation, and inadequate maintenance.
- Developed methods for locating low guardrails and proposed six remedial treatments.
- Created a numerical scoring system to prioritize corrections based on guardrail performance variables, including height, vehicle speed, and expected number of encroachments.