



VIRGINIA TECH   
TRANSPORTATION INSTITUTE



# CRASH ELASTICITY OF SPEED- ADJUSTED PAVEMENT FRICTION ACROSS ROADWAY FACILITY TYPES

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# INTRODUCTION

## WHY WE CARE ABOUT FRICTION?



# INTRODUCTION (CONT.)

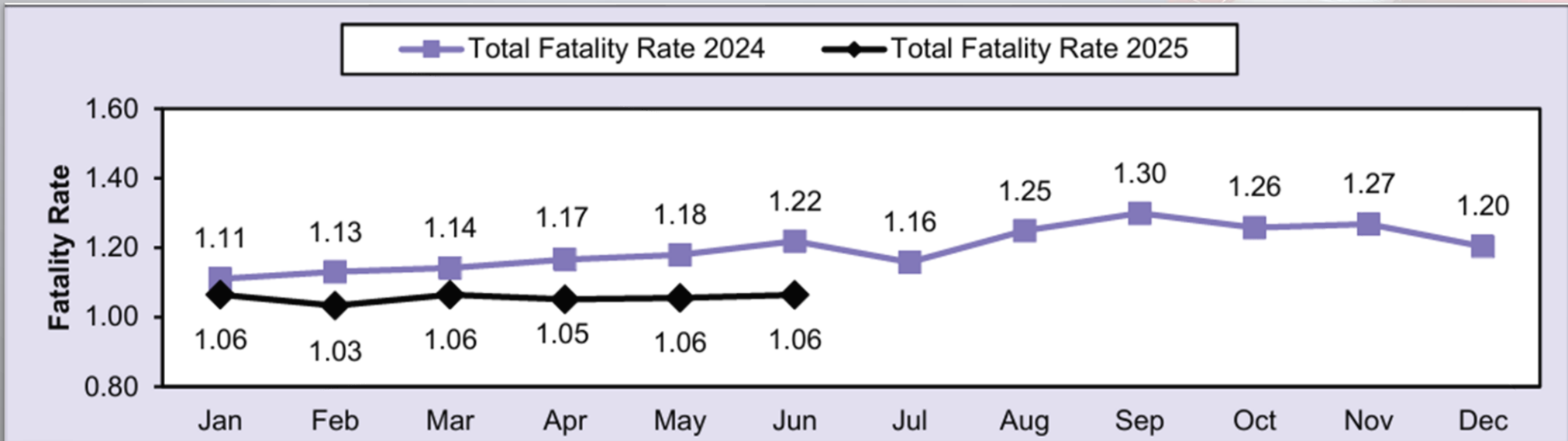


**LOSING TRACTION CAN RESULT IN FATAL CRASHES**

# INTRODUCTION (CONT.)



- **2025 TREND:** THE NATIONAL SAFETY COUNCIL (NSC) REPORTED **APPROX. 37,810** FOR TRAFFIC DEATH IN 2025.
- **2026 PROJECTIONS:** EARLY FORECAST FOR JANUARY-MARCH 2026 ANTICIPATED **5,980** TOTAL TRAFFIC DEATH.
- FATALITY RATE IN RURAL AREAS REMAINS **2.4 TIMES** HIGHER THAN IN **URBAN ROADS**, DEMONSTRATING THE SIGNIFICANT DIFFERENCE IN ASSESSING IN ASESSING SAFETY BETWEEN ROADWAYS & SITE TYPES.



# INTRODUCTION (CONT.)



**TRAVELING  
SPEED**

**ROADWAY  
GEOMETRY**

**TRAFFIC  
EXPOSURE**

**SURFACE  
PROPERTIES**

**ROADWAY  
CLASSIFICATION**



# OBJECTIVES

**SUPPORT REDUCING ROADWAY CRASHES AND IMPROVE SAFETY THROUGH:**

- **DEVELOP A UNIFIED FRICTION—MACROTEXTURE SAFETY INDEX**
- **ASSESS FEASIBILITY OF A NEW PAVEMENT SAFETY METRIC THAT INTEGRATES FRICTION AND MACROTEXTURE ACROSS DIFFERENT ROADWAY TYPES**
- **ENABLE NETWORK-LEVEL FRICTION MANAGEMENT USING THE PROPOSED COMBINED PERFORMANCE INDICATOR**



# MERIT



**THIS STUDY ALIGNS CLOSELY WITH THE SAFE SYSTEM APPROACH, ADDRESSING A CRITICAL ASPECT OF HIGHWAY SAFETY BY INTEGRATING PAVEMENT SURFACE CHARACTERISTICS INTO SAFETY MODELING.**

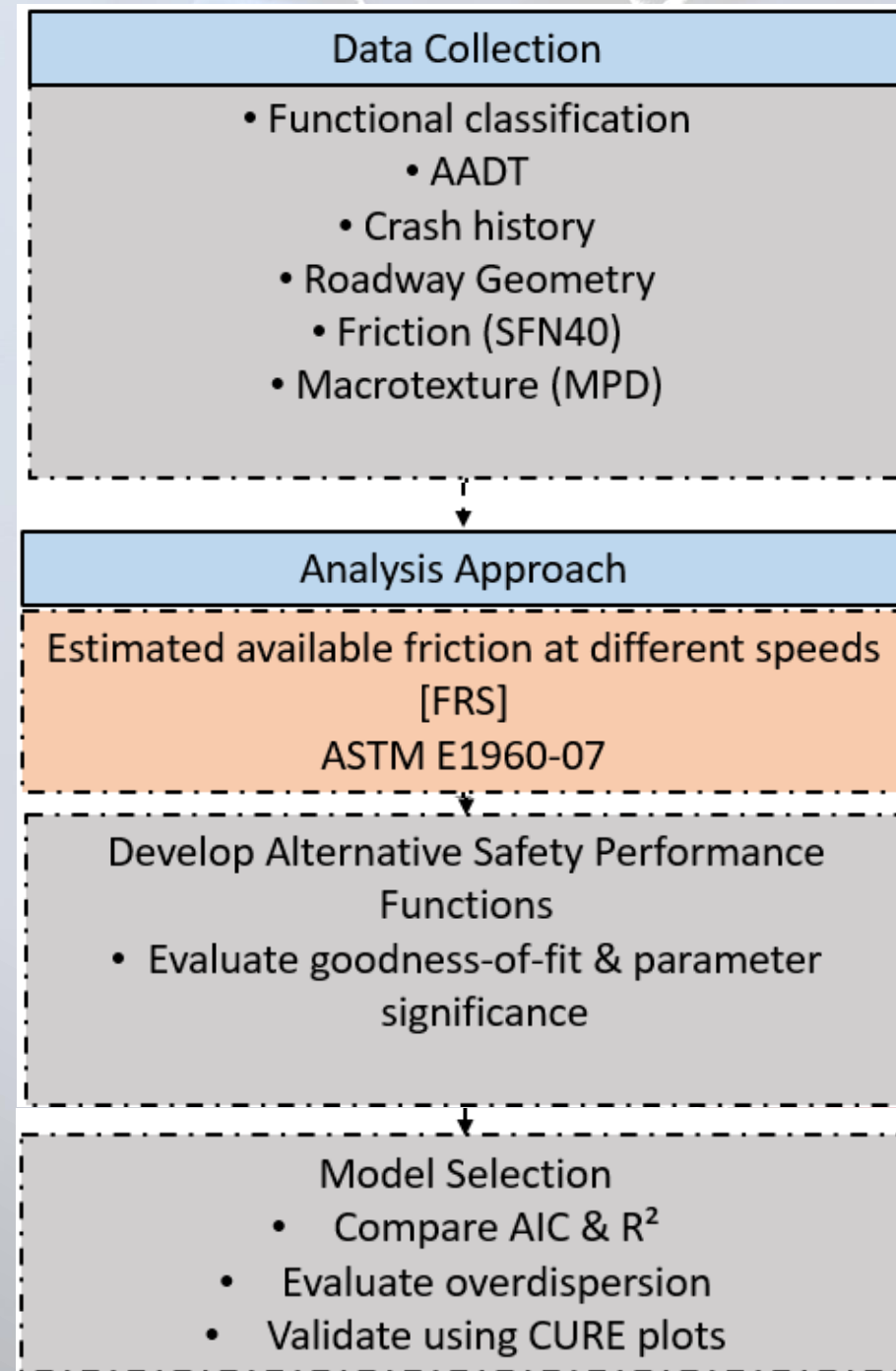
## **PROPOSE A NOVEL APPROACH:**

- **TO ESTIMATE THE AVAILABLE FRICTION AT THE FACILITY OPERATING SPEED**
- **INDEX CAPTURES SPEED-DEPENDENT INTERACTION OF FRICTION & MACROTEXTURE**

# METHODOLOGY

## FRAMEWORK:

### INTEGRATING FRICTION AND MACROTEXTURE INTO A SPEED-DEPENDENT SAFETY METRIC



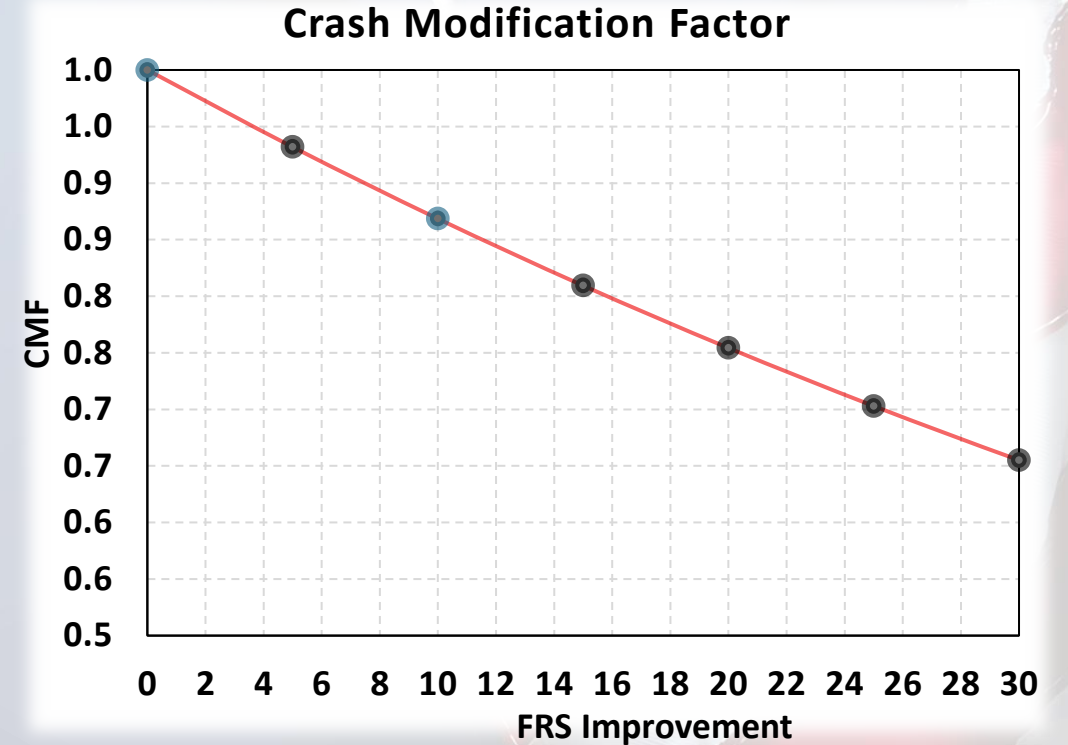
# METHODOLOGY (CONT.)



## FRAMEWORK (CONT.):

### WHAT IS CRASH ELASTICITY:

MEASURES HOW MUCH CRASHES  
CHANGE WHEN FRICTION IMPROVES



$$SPF_i = \exp(\beta_0 + \beta_1 \times \ln(AADT) + \sum_{j=2}^K \beta_j X_{ij})$$

$$\text{Crash Elasticity} = \frac{\% \Delta \text{Crashes}}{\% \Delta \text{Condition}}$$

# LOCATION

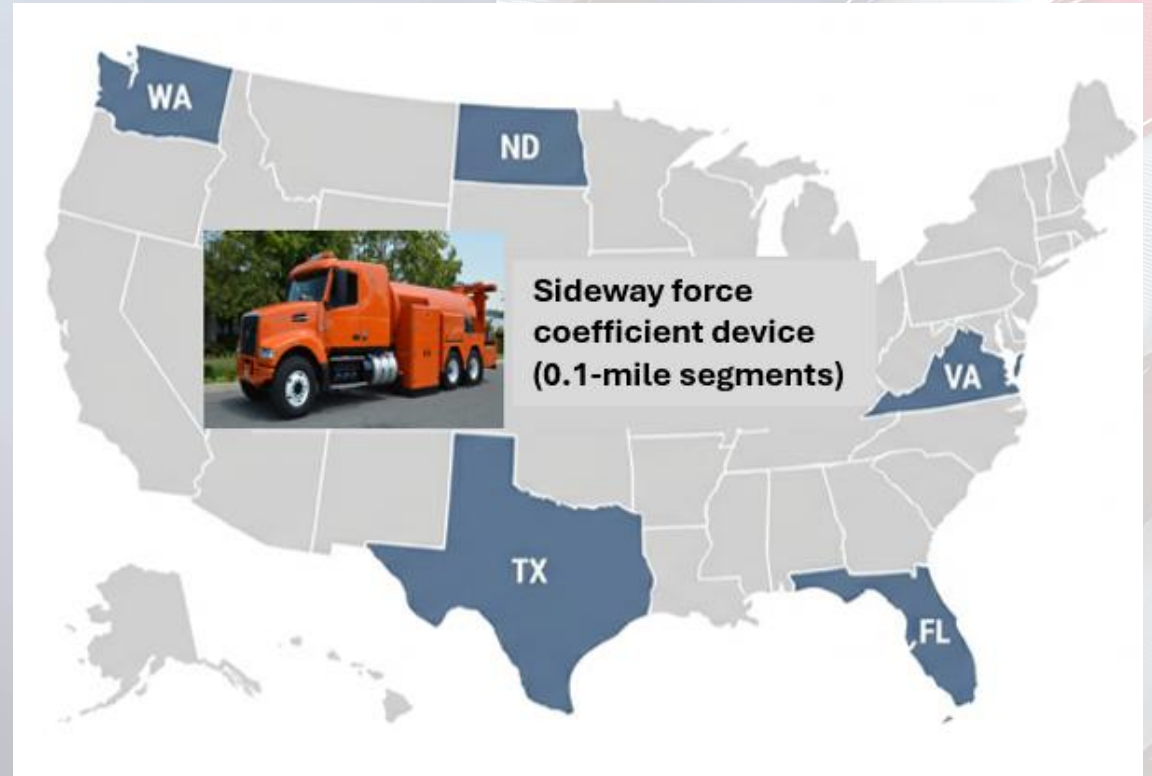


- **Total Network Analyzed: ~7,000 miles**
- **Validation Dataset: 5 States | > 300,000 Crashes**

**Freeways: 2,447 miles**

**Rural Highways: 2,468 miles**

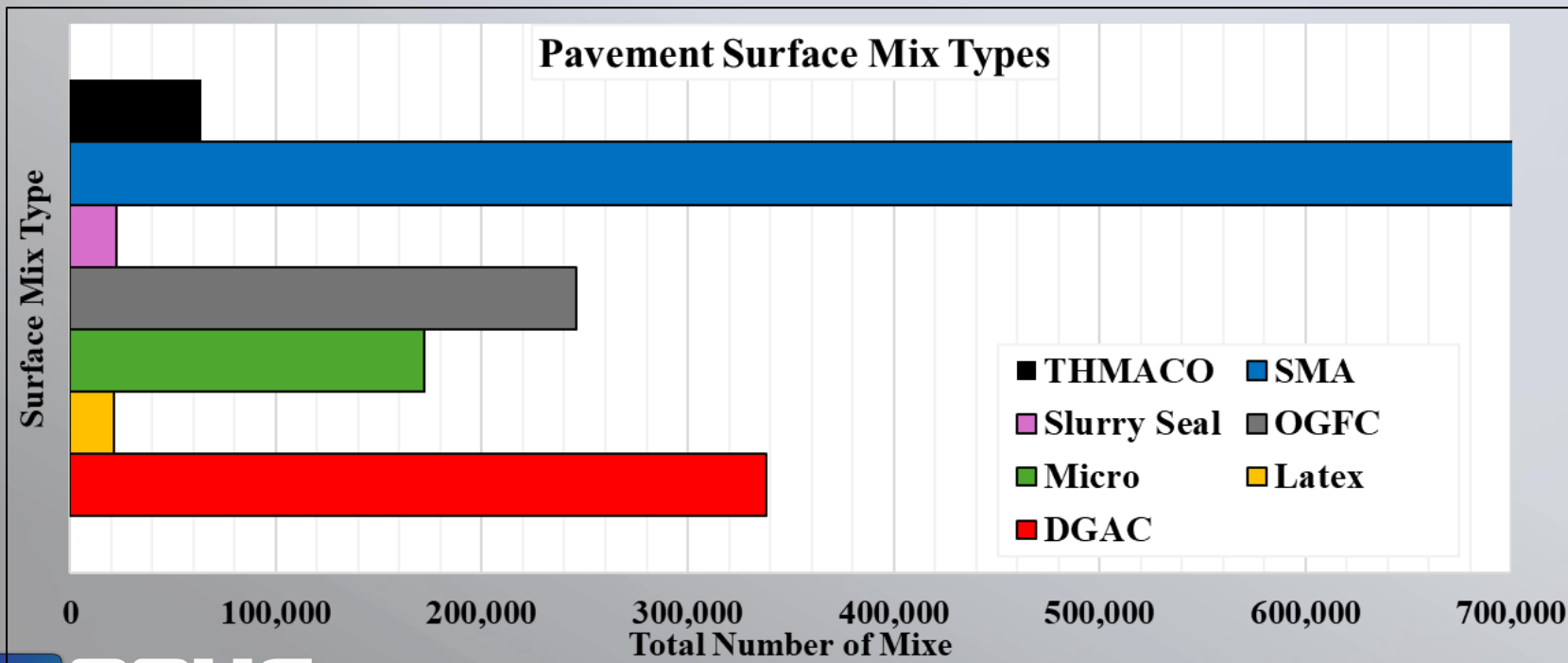
**Arterial: 2,076 miles**



# DATA OVERVIEW

Data for SPF development:

- Distribution of pavement surface mix types in the SPF analysis



AASHTO TP-143



Pavement & Geometric Variables:

- Sideway-force Friction [SFN(40)]
- Macrotexture [MPD]
- Vertical Grade (%)
- Cross-slope (%)
- Horizontal Curvature (1/m)

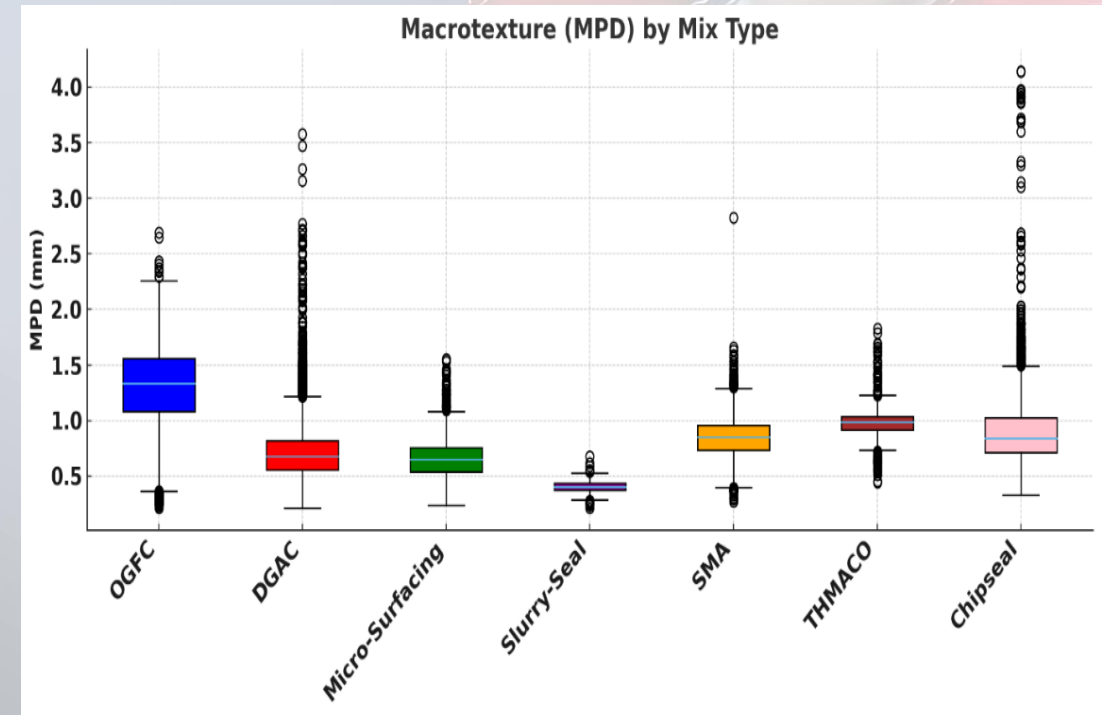
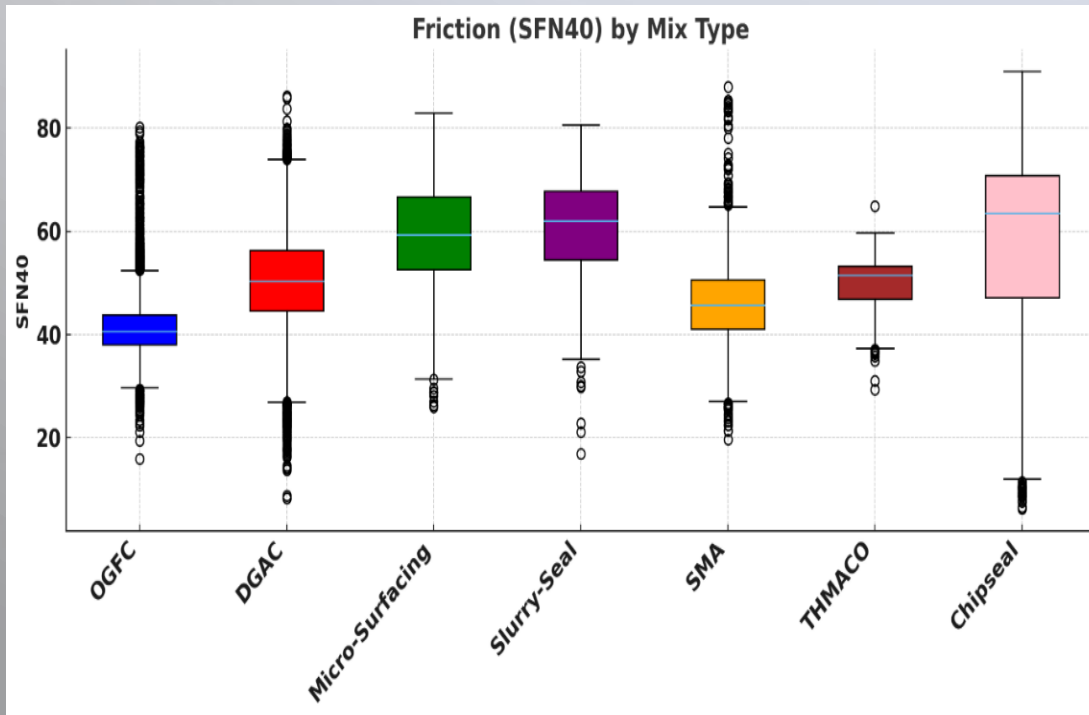


# SURFACE CHARACTERISTICS BY MIX TYPE



*Highway Safety Manual (AASHTO 2010);  
Standard Practice for Calculating IFI of a Pavement Surface (ASTM E1960-07 )*

- No single metric fully captures safety performance
- Joint consideration of friction and MPD is required (FRS)



# RESULTS

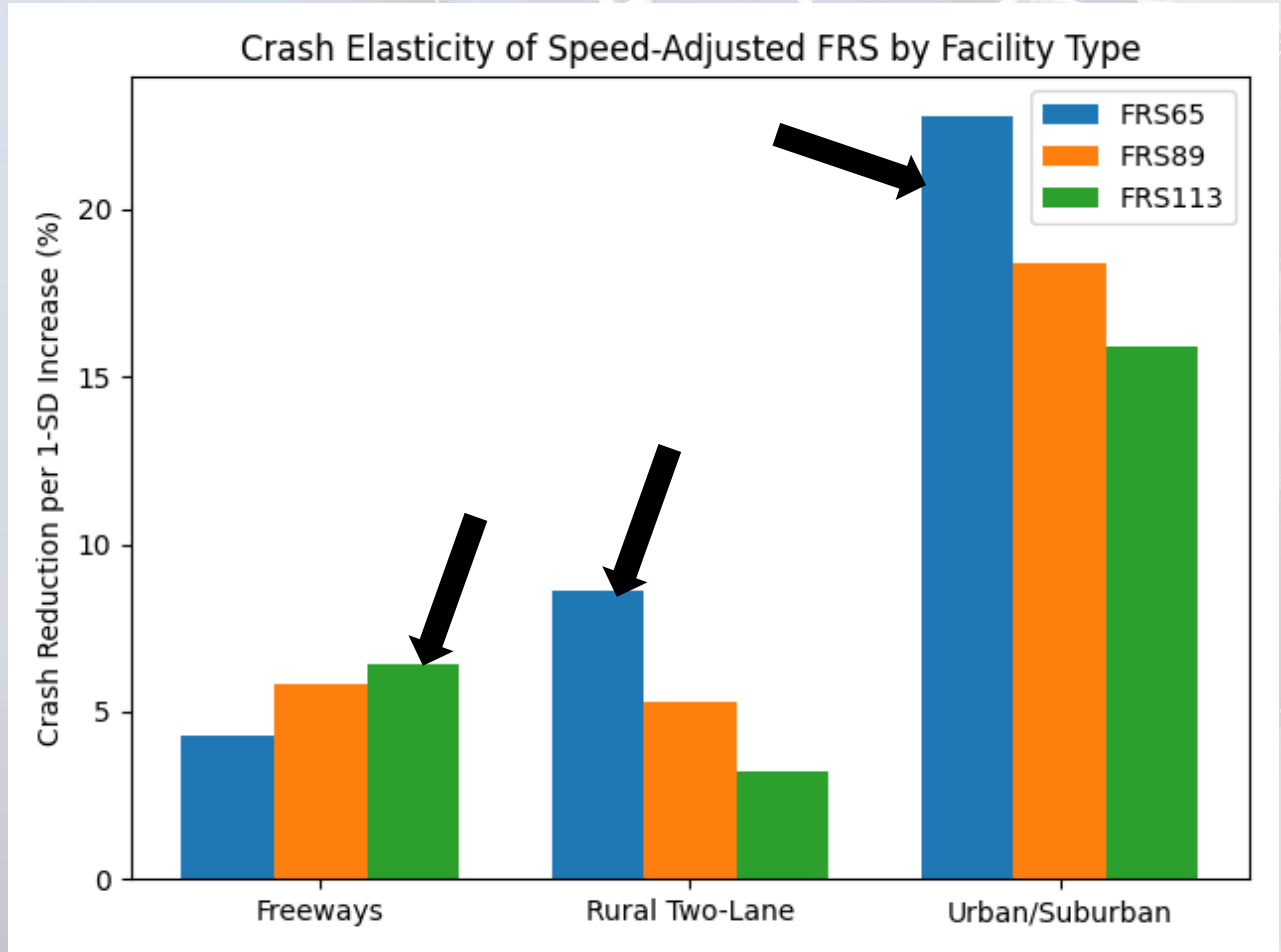


## Crash Elasticity

Freeway (FRS113) → 6–7%

Rural (FRS65) → 8–9%

Arterial (FRS65) → 25–28%

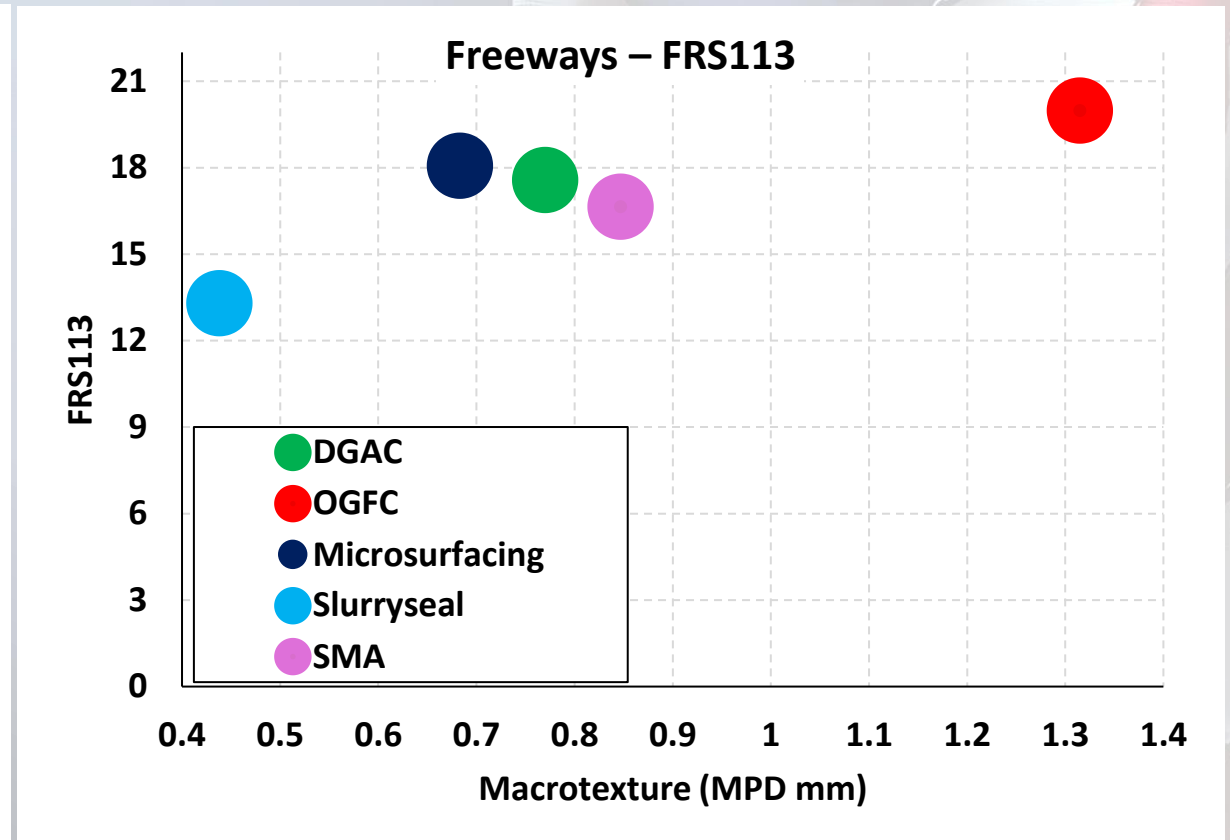
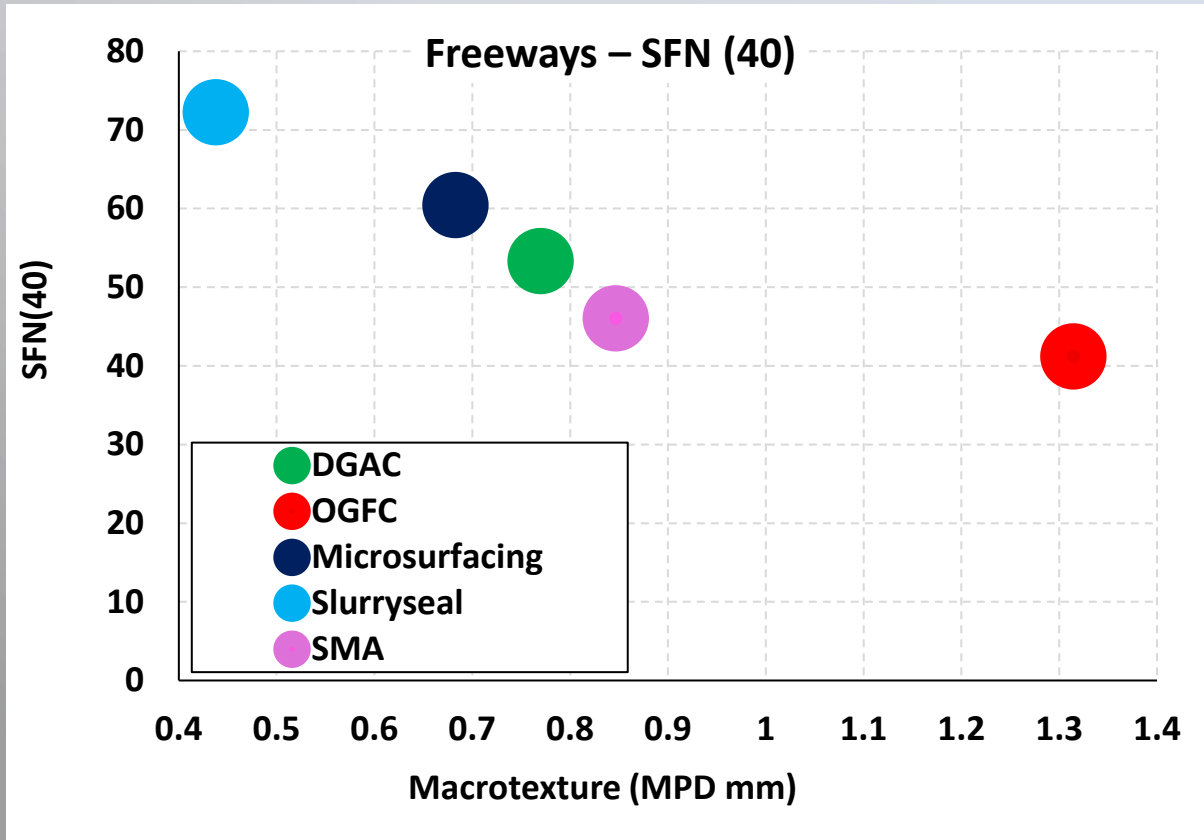


• Effect varies by road type & speed

# MODEL EVALUATION



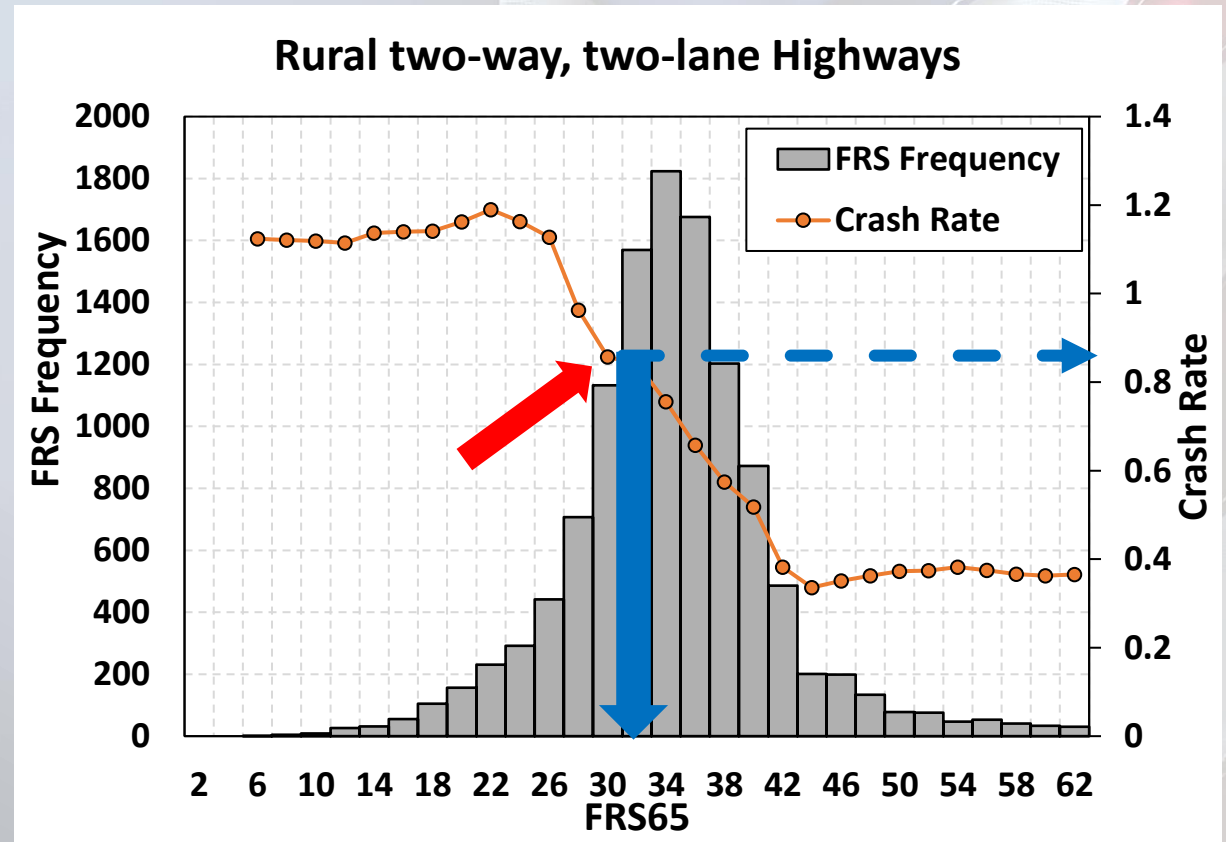
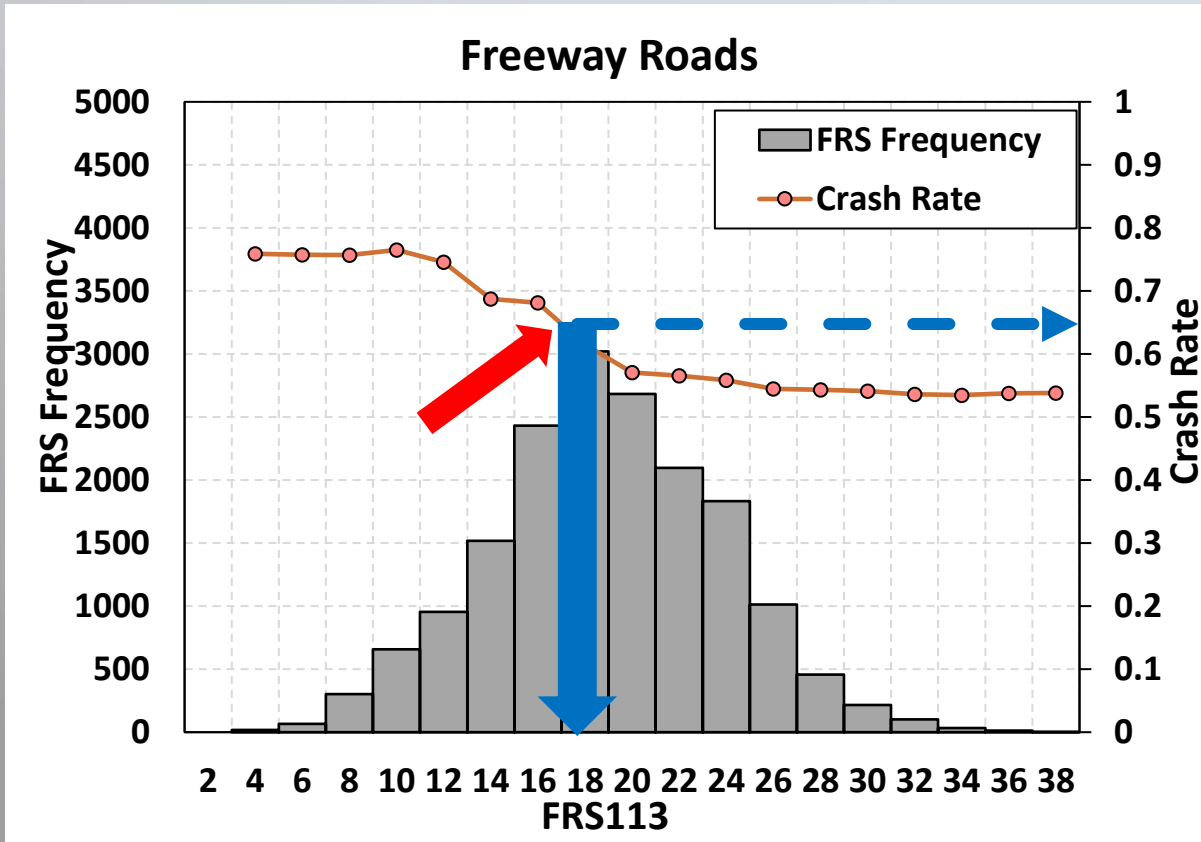
- RELATIONSHIP BETWEEN MACROTEXTURE AND FRICTION



# INVESTIGATORY LEVEL



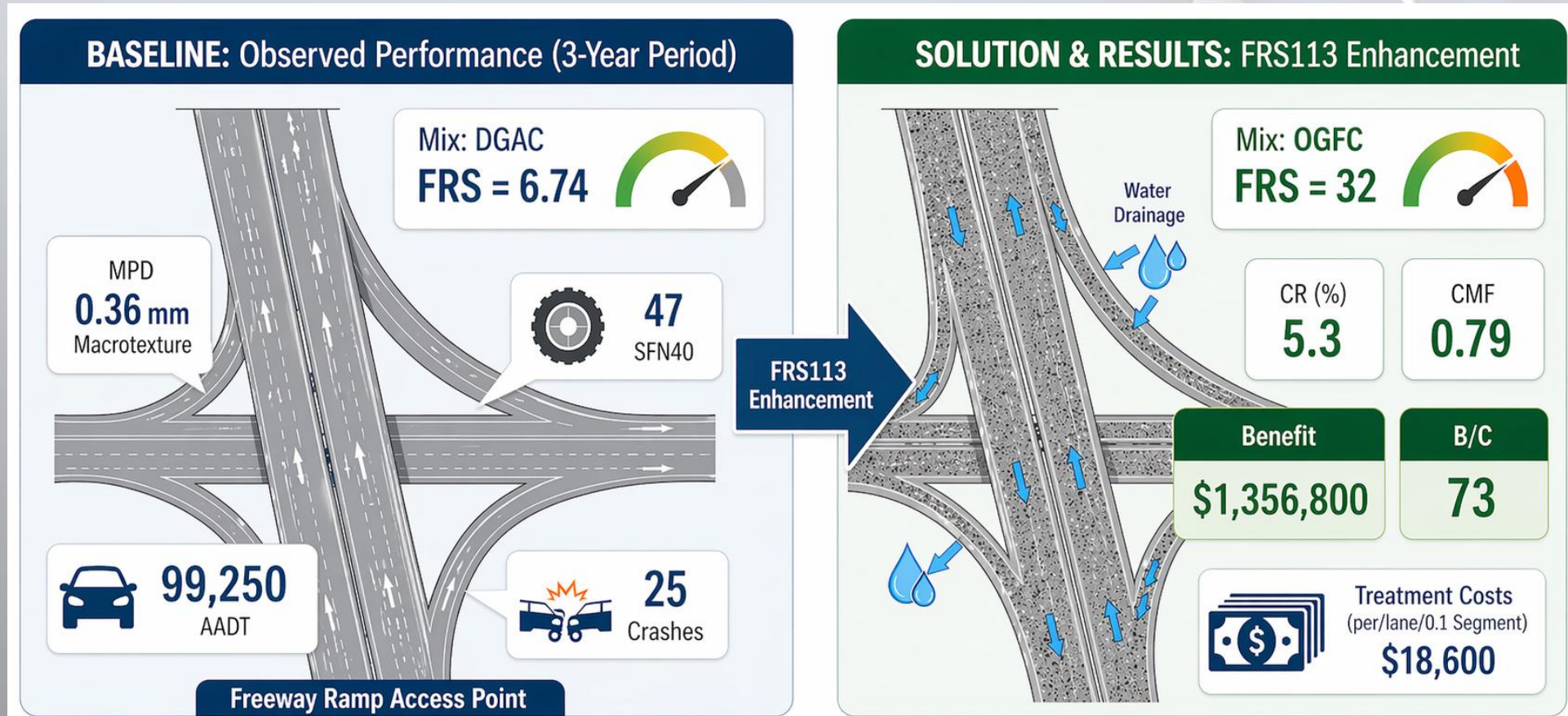
- ILLUSTRATIVE EXAMPLE OF INVESTIGATORY THRESHOLD ESTIMATION FOR FREEWAYS.



# BENEFIT-COST ANALYSIS



- SAFETY AND ECONOMIC IMPACT OF FRS113 IMPROVEMENTS ON FREEWAYS



# FINDINGS

## INTRODUCES A NOVEL FRAMEWORK:

- **AS AN ESTIMATION OF AVAILABLE FRICTION WHEN COMBINING FRICTION WITH AVAILABLE MACROTEXTURE, THE COMBINED INDEX DEMONSTRATES THE IMPORTANCE OF HIGHER MPDs AT HIGHER SPEEDS.**
- **ENABLED:**
  - **ESTIMATION OF SAFETY BENEFITS (CRASH ELASTICITY)**
  - **EVALUATE THE EFFECTIVENESS OF FRICTION IMPROVEMENT TREATMENTS (B-C ANALYSIS)**
  - **HELP DEFINING HIGH RISK, FRICTION-DEFICIENT SEGMENTS (IL VALUES)**



# CONCLUSIONS

**THE WORK OF THIS RESEARCH SUPPORTS REDUCING CRASHES.**

- **A UNIFIED SAFETY METRIC INTEGRATES THE COMBINED EFFECTS OF FRICTION AND MACROTEXTURE ACROSS DIFFERENT ROADWAY TYPES AND OPERATING SPEEDS.**
- **THE ANALYSIS SHOULD BE CONDUCTED AT THE FOLLOWING SPEEDS:**
  - FRS113 → FREEWAYS**
  - FRS65 → RURAL TWO-LANE, TWO-WAY HIGHWAYS**
  - SFN(40) & MPD → URBAN & SUBURBAN ARTERIALS**



# FUTURE WORK

- **INCORPORATE SEGMENT-LEVEL SPEED DATA**
  - **POSTED OR OPERATING SPEEDS**
- **EXPAND DATASETS TO INCLUDE:**
  - **WIDER RANGE OF TRAFFIC VOLUMES (AADT)**
  - **BROADER GEOGRAPHIC REGIONS (SEASONAL VARIATION, TEMPERATURE)**



# REFERENCES



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HONORING THE PAST. PAVING THE FUTURE.

# THANK YOU

## QUESTIONS ?