NATIONAL ACADEMIES *Sciences Engineering Medicine*

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: Pavement Friction Management, Measurement, and Safety Analysis

June 11, 2024

1:00 – 2:30 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING RCEP REGISTERED CONTINUING EDUCATION PROGRAM

Purpose Statement

This webinar will cover the implementation of a friction management program, the analysis and interpretation of continuous friction data, development of safety performance functions, the implementation of a safety system approach and the shared responsibilities within a department of transportation to address this topic.

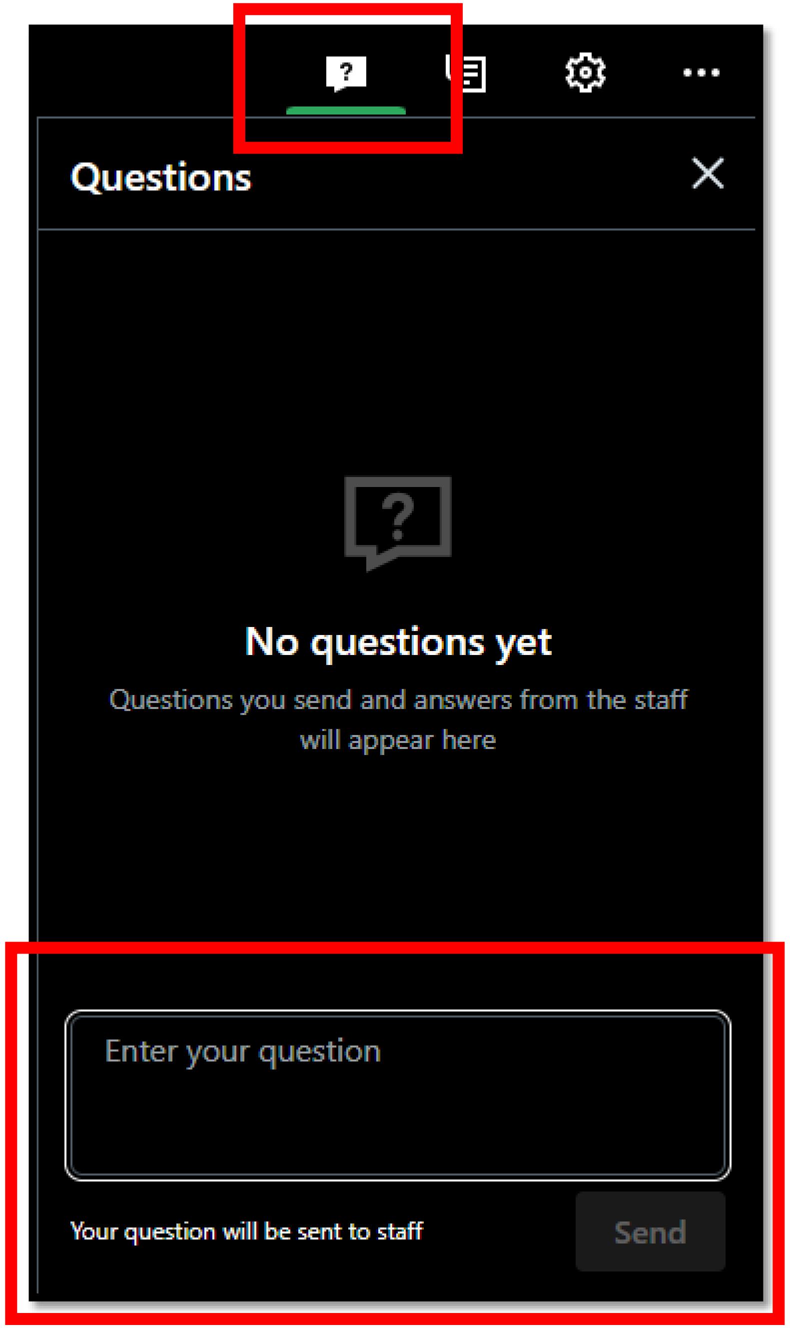
Learning Objectives

At the end of this webinar, you will be able to:

- Develop and implement a friction management program
- Analyze and interpret continuous friction data to develop safety performance functions

Questions and Answers

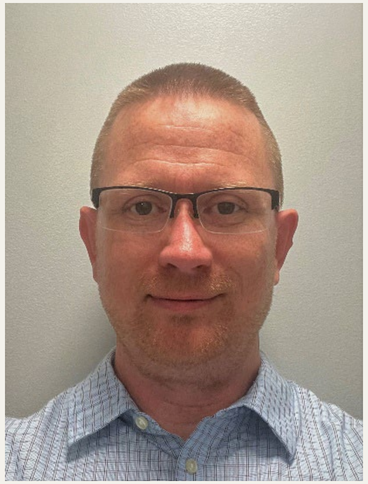
- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters

Gerardo Flintsch
gflintsch@vtti.vt.edu
Virginia Polytechnic Institute and State University

Shane Underwood
bsunderw@ncsu.edu
North Carolina State University



Mike Vaughn
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Kentucky Transportation Cabinet

Brian Schleppi
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VIHSC

TRB Webinar: Pavement Friction Management, Measurement, and Safety Analysis

Brian L. Schleppi, VIHSC LLC
Moderator

June 11, 2024

Pavement Friction Management

Ensuring that Friction Supply exceeds Friction Demand for every segment on a Highway System through each Pavement Segment's Service Life.

Quickly identifying locations where supply falls below demand, identifying a suitable treatment action, and rectifying in a timely manner.

Pavement Friction Measurement

Direct Response Measurements

Microtexture and Macrotexture of the Pavement

Is the pavement doing its part in providing Sufficient Available Wet and Dry Friction?

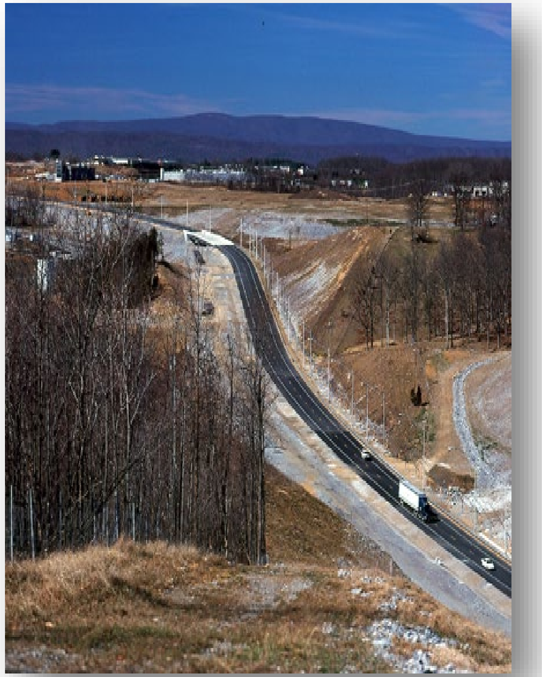
Pavement Friction and Safety Analysis

If we have sufficient available friction, then friction won’t be the primary contributor to crashes.

- Vehicles stay on the road
- Vehicles stay in their lane
- Vehicles can safely maneuver

TRB Webinar: Pavement Friction Management, Measurement, and Safety Analysis

Speaker Introductions



Safety performance function, crash modification factors development, and investigatory thresholds

Gerardo Flintsch, PhD, PE

Dan Pletta Professor, Via Department of Civil and Env. Engineering

Director, Center for Sustainable and Resilient Infrastructure

Chair, PIARC Technical Committee 3.3 Asset Management

Vice-President and Technical Director, FM Consultants

VIRGINIA TECH

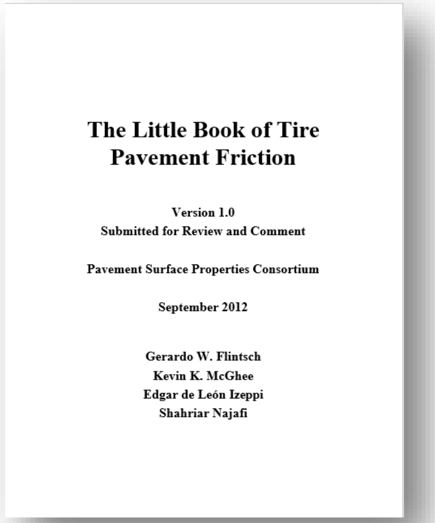
TRANSPORTATION INSTITUTE
VIRGINIA TECH.

FM Consultants

PIARC

1. Introduction

The Physics Behind Friction



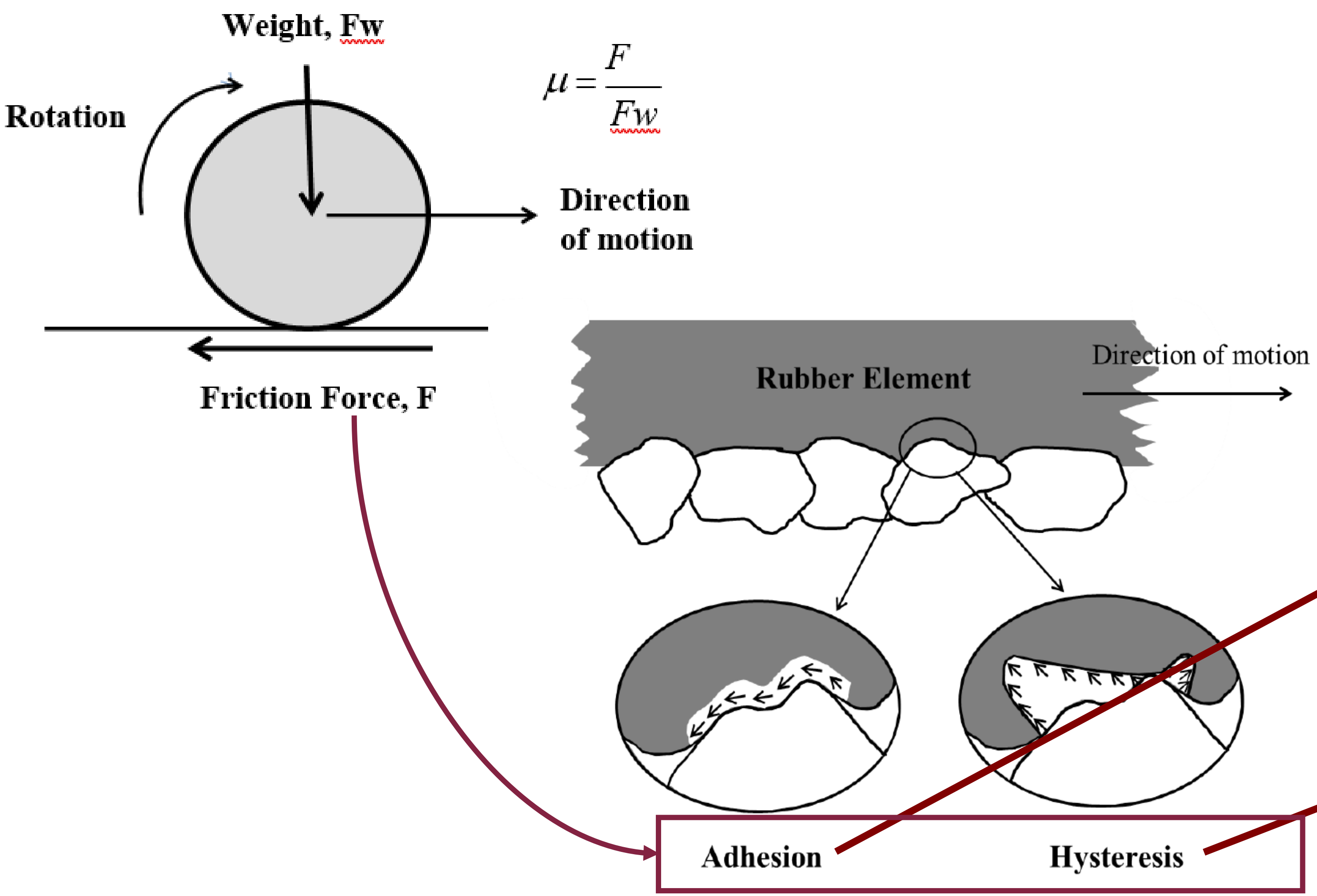
The Little Book of Tire Pavement Friction

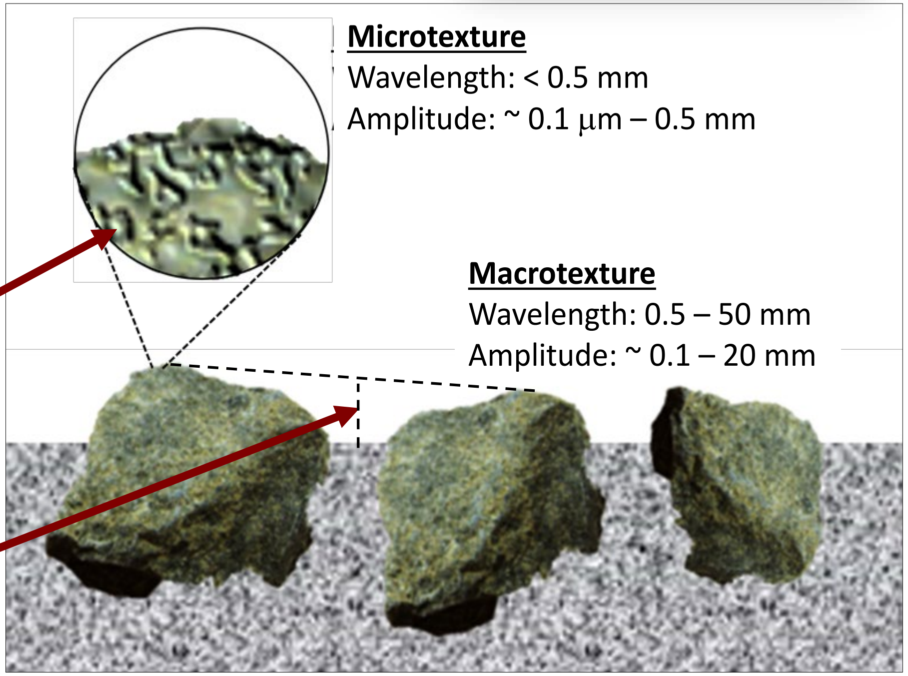
Version 1.0
Submitted for Review and Comment

Pavement Surface Properties Consortium

September 2012

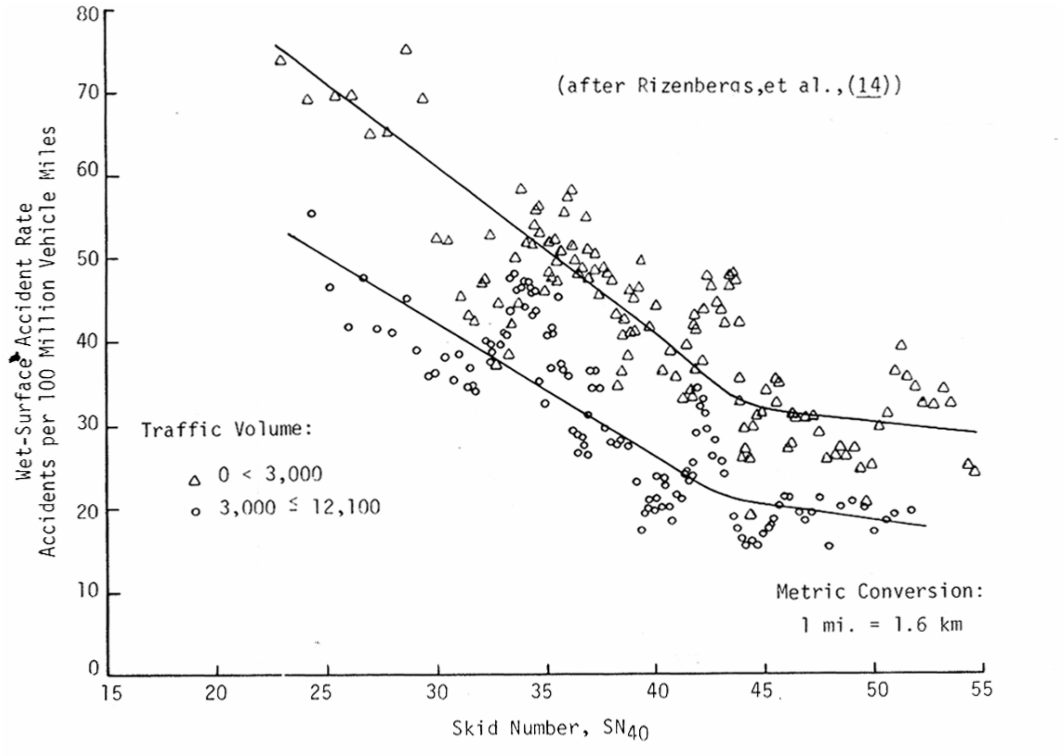
Gerardo W. Flintsch
Kevin K. McGhee
Edgar de León Izeppi
Shahriar Najafi



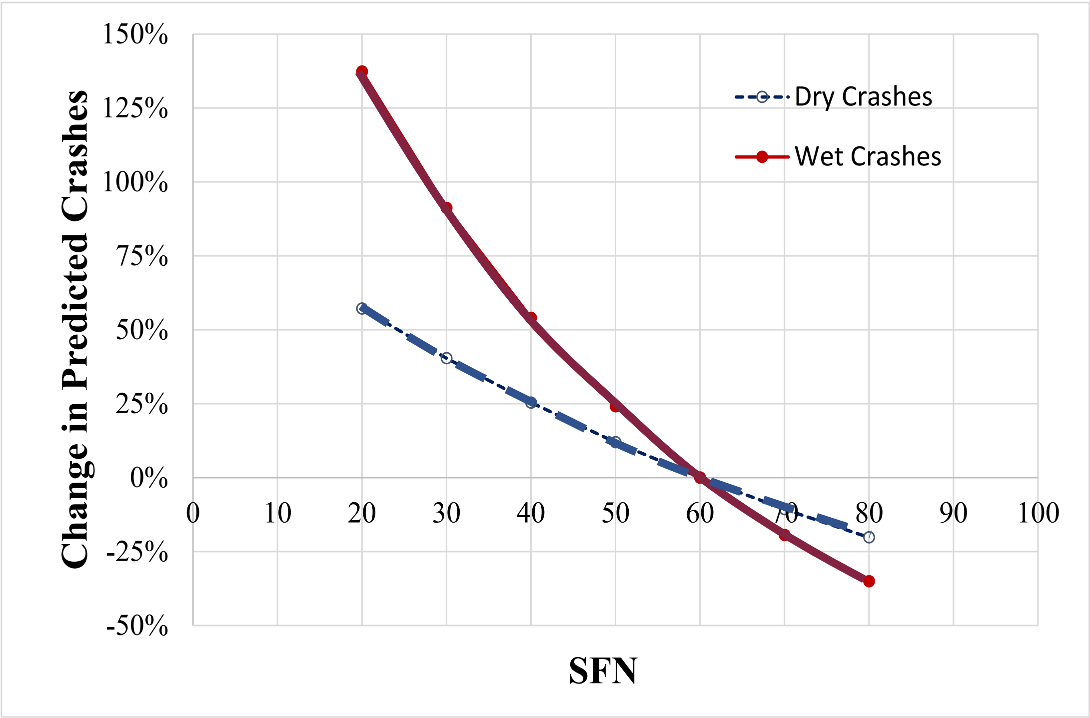


https://www.apps.vtti.vt.edu/1-pagers/CSTI_Flintsch/The%20Little%20Book%20of%20Tire%20Pavement%20Friction.pdf

The Impact of Friction and Macrotexture on Crashes has long been recognized…

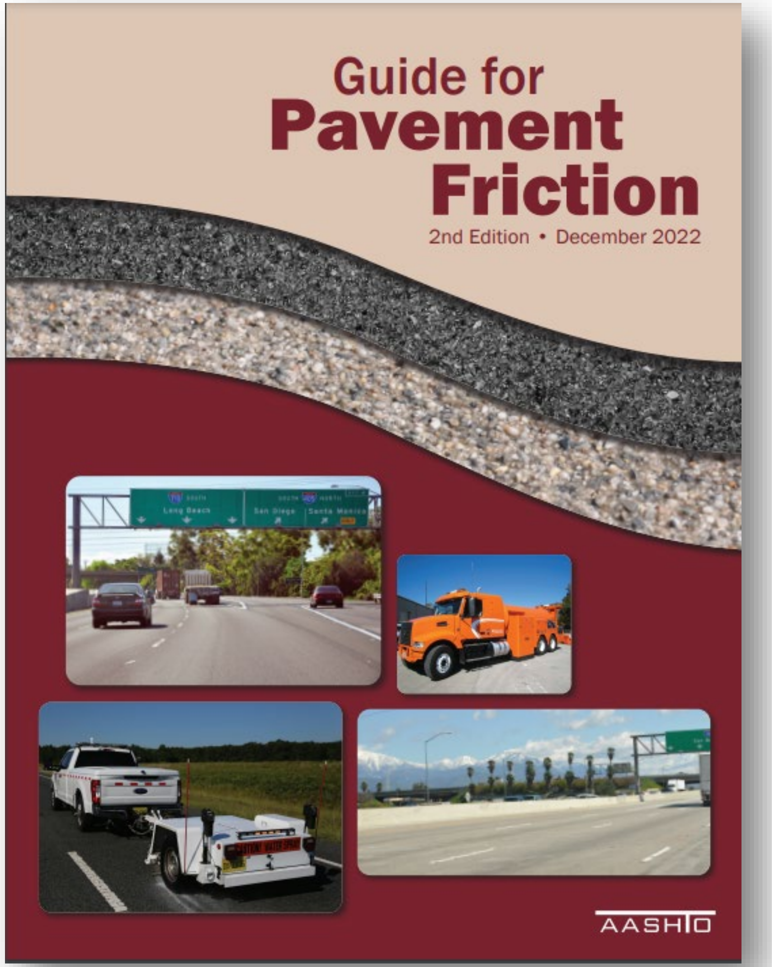


Example of the Relationship between Wet-Weather Crash Rates and Pavement Friction for Kentucky Highways (after Rizenbergs et al. 1973)



Example of estimated changes of Average Wet- and Dry-crash Rates vs. Friction (SFN) (after McCarthy et al., 2021)

2022 AASHTO Guide for Pavement Friction



Based on recent FHWA-sponsored work

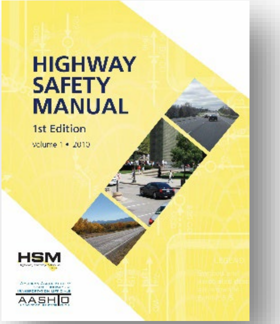
Key updates

- ✓ Friction impact both dry and wet crashes.
- ✓ Importance of continuous friction and macrotexture measurement for improved safety performance
- ✓ **CPFM is part of the Safe System Approach**
- ✓ Friction data is multi-disciplinary in terms of benefits and impacts

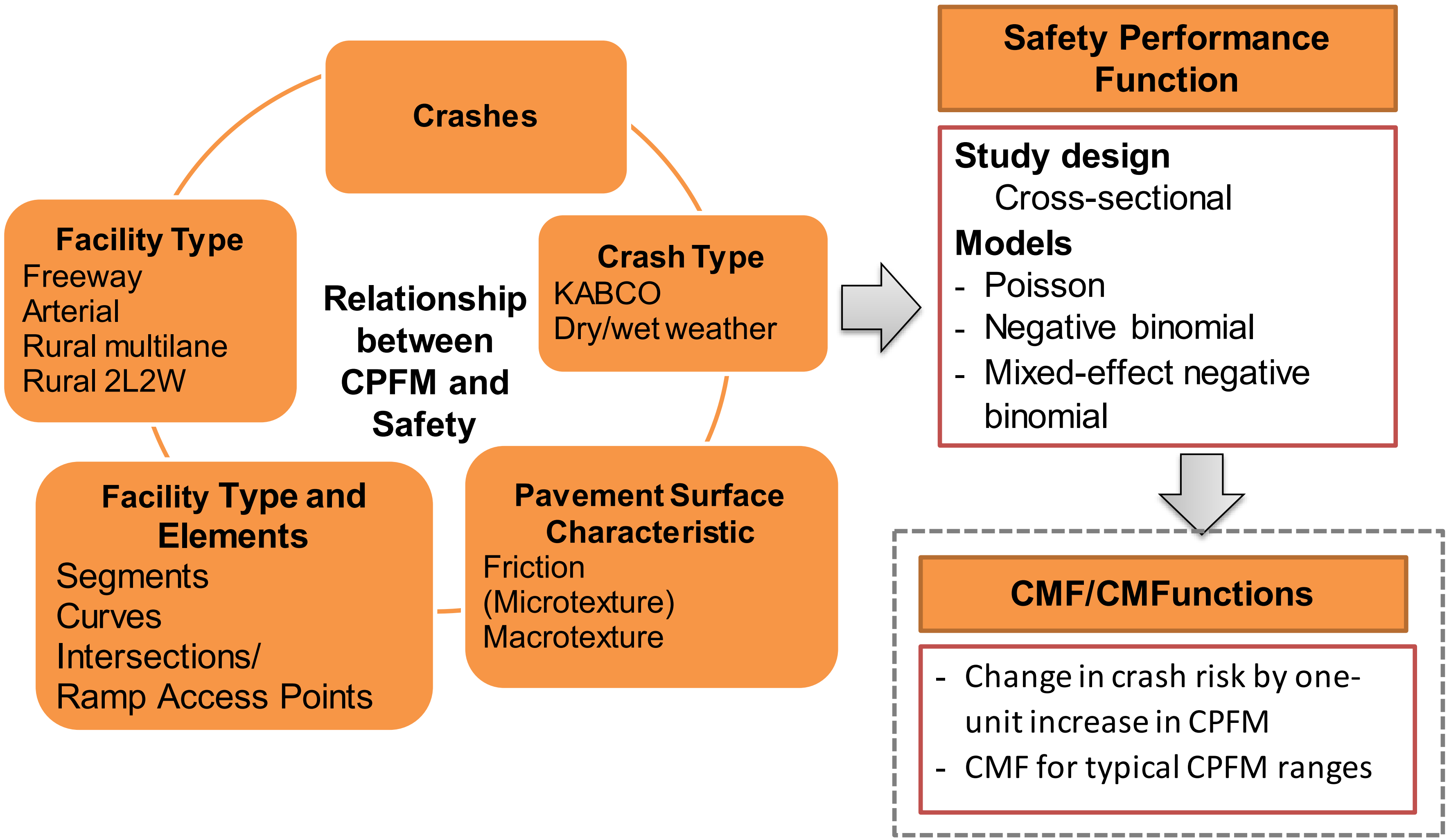
2. Crash Modification Functions & Investigatory Levels


https://www.cincinnati.com/story/news/local/ft-mitchell/2019/11/07/rainy-day-truck-crashes-71-75-south-fort-mitchell-dixie-highway-curve-is-new-trend/2517845001/

Source: *Continuous Pavement Friction Measurement and Pavement Friction Management for Safety*



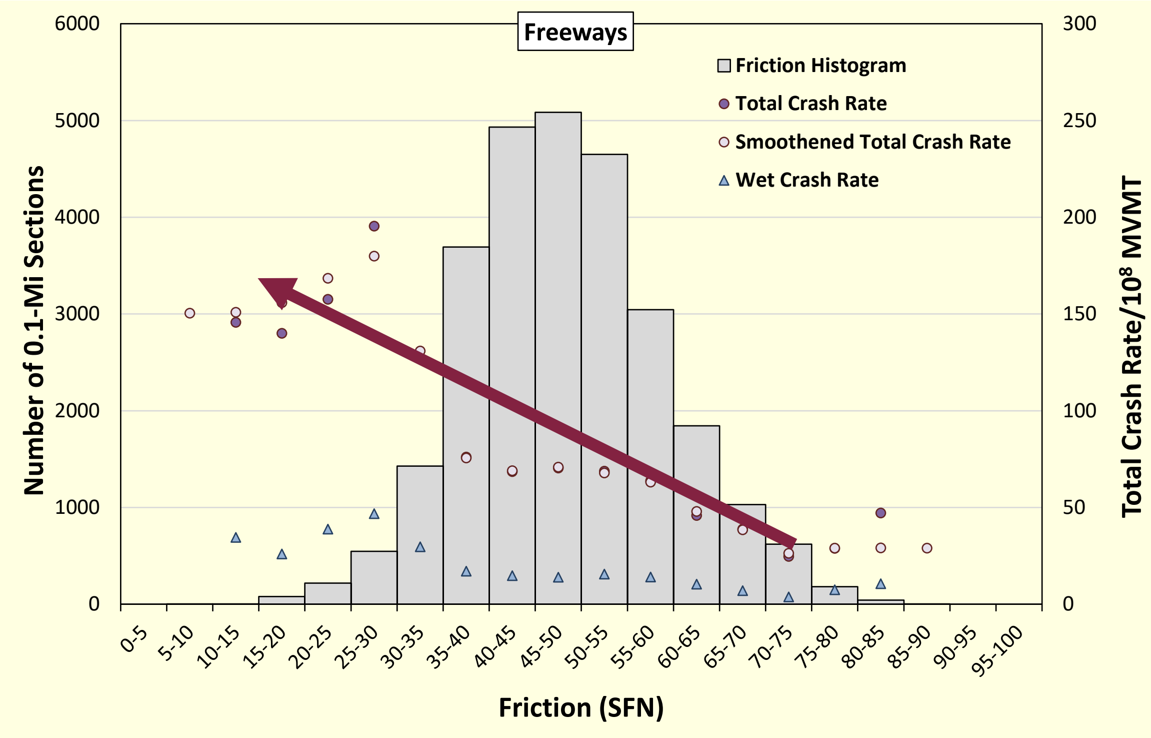
Methodology for the development of the Crash Modification Functions and Factors

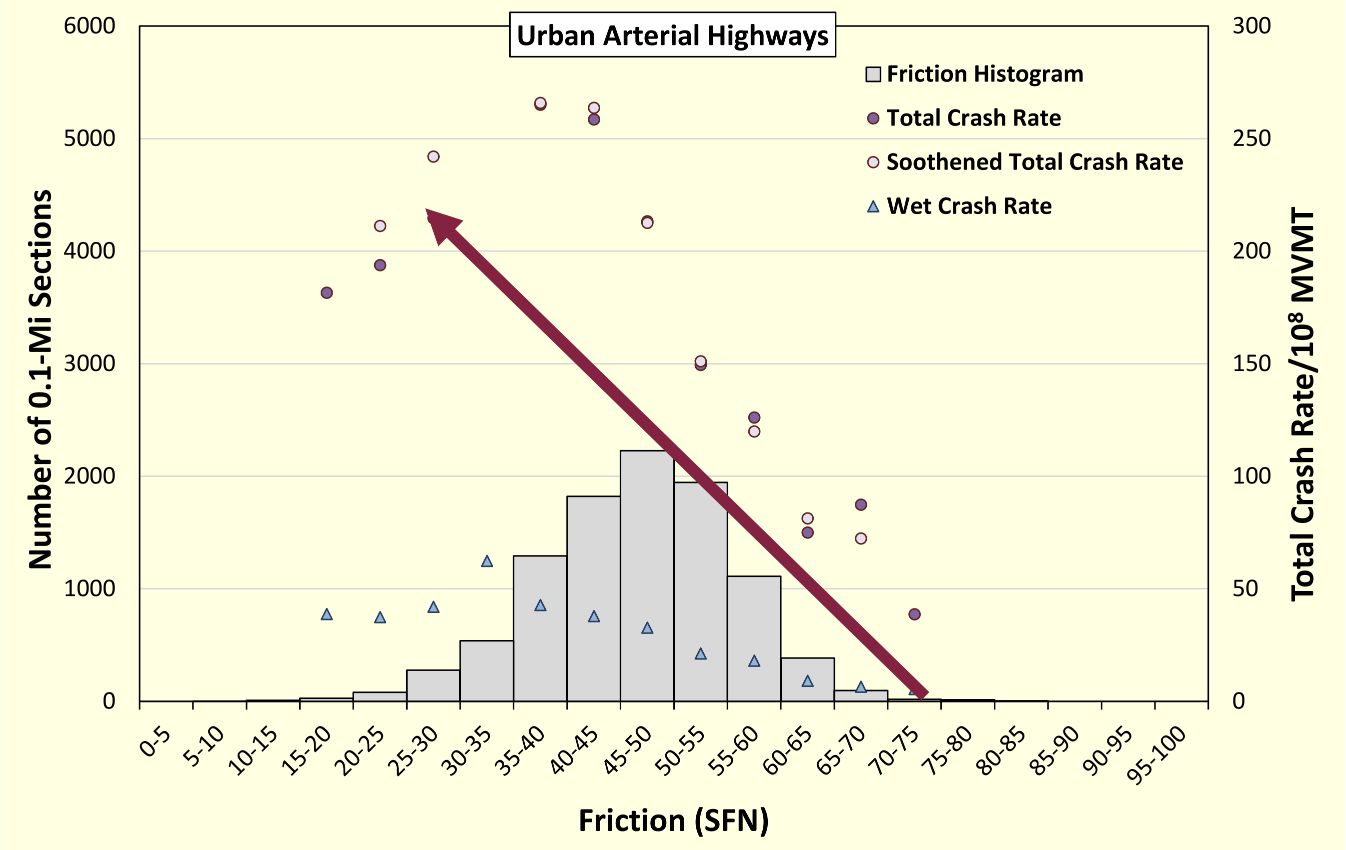


Continuous Pavement Friction Measurement and Pavement Friction Management for Safety - Data

- ✓ 8,000+ Km of roadways from 5 states
- ✓ 160,000+ crashes
- ✓ Include freeways, divided and undivided arterials and rural multilane roads, and 2-lane 2-way roads
- ✓ Variables:
  - Dependent: Crashes (all, wet/dry, KABCO)
  - Predictors: Traffic, State, roadway facility and site type, surface type, macrotexture (MPD), friction (SFN40), grade, cross-slope or super-elevation, curvature (1/R)

Friction and Crash Rates on Different Roadway Types





~ 2700 miles

Avg SFN40 =48.3   MTD = 0.78

~ 1000 miles

Avg SFN40 =46.5   MTD = 0.74

"Base" Model Selection – Tried 3 Model Formulations

Parameters	Poisson with Mixed -Effect		NB with Mixed -Effect		NB without Mixed- Effect	
	β	p-value	β	p-value	β	p-value
Intercept, β_0	-11.2038	<0.0001	-10.6554	<0.0001	-10.9950	<0.0001
ln (AADT)	1.2950	<0.0001	1.2260	<0.0001	1.2263	<0.0001
Friction (SFN40)	-0.0139	<0.0001	-0.0105	<0.0001	-0.0105	<0.0001
Texture (MPD-mm)	-0.1622	<0.0001	-0.2401	<0.0001	-0.2400	<0.0001
Grade (%)	0.0095	<0.0001	-	-	-	-
Curvature (1/m)	107.9594	<0.0001	175.0743	<0.0001	175.3708	<0.0001
Overdispersion	n/a		1.1616		1.1609	
AIC	300,108		177,997		177,907	

Negative Binomial Model Chosen:

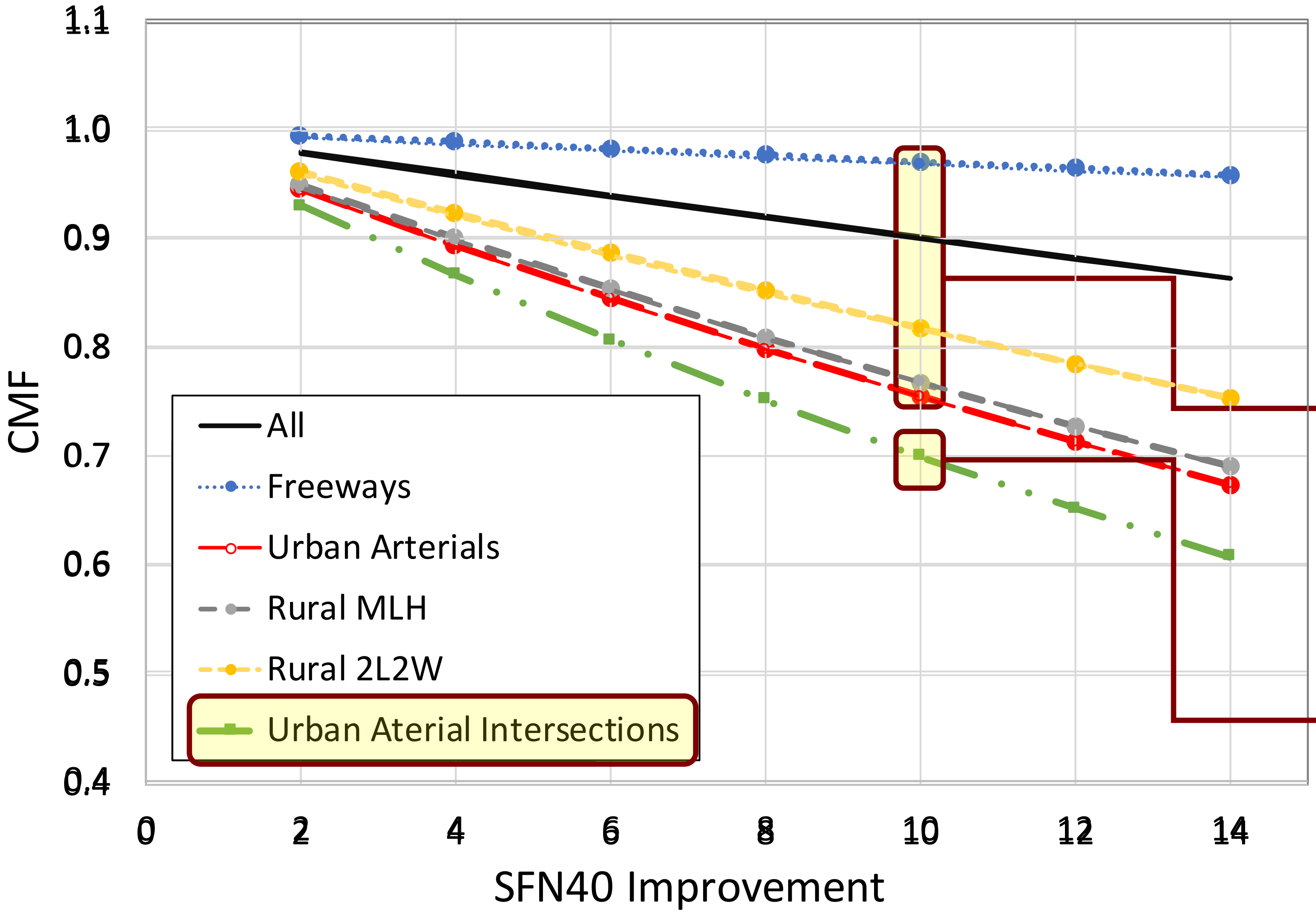
$$\log \lambda_{ij} = \beta_0 + \beta_1 X_{friction,ij} + \beta_2 \log(traffic\,volume) + \beta_3 X_{3,ij}, \ldots + \beta_p X_{p,ij} + \alpha_{ij},$$

Results – CMF for Different Roadway and Site Types

Roadway Facility	Site Type	SFN40 CMFx	CMF for 10-Unit SFN40 Increase	Standard Error (CMF)	% Crash Reduction
All Facilities	**All Site Types**	$\mathbf{CMF = e^{-0.0105\Delta SN}}$	**0.901**	**0.0064**	**9.9**
Freeways	**All Freeways Site Types**	$\mathbf{CMF = e^{-0.0031\Delta SN}}$	**0.9**[illegible]	[illegible]	[illegible]
	Tangent Segments	$CMF = e^{-0.0023\Delta SN}$	0.977	0.0103	2.3
	Ramp Access Points	$CMF = e^{-0.0135\Delta SN}$	0.874	0.0219	12.6
	Curves (1)	$CMF = e^{-0.0169\Delta SN}$	0.844	0.0611	15.6
Urban Arterials	**All Urban Arterials Site Types**	$\mathbf{CMF = e^{-0.0282\Delta SN}}$	**0.754**	**0.0118**	**24.6**
	Divided Tangent Segments	$CMF = e^{-0.0288\Delta SN}$	0.754	0.0221	25.0
	Undivided Tangent Segments	$CMF = e^{-0.0230\Delta SN}$	0.794	0.0286	20.6
	Intersections	$CMF = e^{-0.0357\Delta SN}$	0.700	0.0161	30.1
	Curves (1)	$CMF = e^{-0.0281\Delta SN}$	0.755	0.0625	24.5
Rural Multilane Highways	**All Rural Multilane Site Types**	$\mathbf{CMF = e^{-0.0265\Delta SN}}$	**0.767**	**0.0142**	**23.3**
	Divided Tangent Segments	$CMF = e^{-0.0168\Delta SN}$	0.846	0.0238	15.4
	Undivided Tangent Segments	$CMF = e^{-0.0094\Delta SN}$	0.910	0.0318	9.0
	Intersections	$CMF = e^{-0.0344\Delta SN}$	0.709	0.0218	29.1
	Curves (1)	$CMF = e^{-0.0187\Delta SN}$	0.829	0.0731	17.1
Rural – 2-Lane 2-Way Road	**All R2L-2W Roads Site Types**	$\mathbf{CMF = e^{-0.0202\Delta SN}}$	**0.817**	**0.0196**	**18.3**
	Tangent Segments	$CMF = e^{-0.0096\Delta SN}$	0.909	0.0243	9.1
	Intersections	$CMF = e^{-0.0188\Delta SN}$	0.829	0.0386	17.1
	Curves (1)	$CMF = e^{-0.0188\Delta SN}$	0.829	0.0593	17.1

$$\mathbf{CMF = e^{-0.0105\Delta SN}}$$

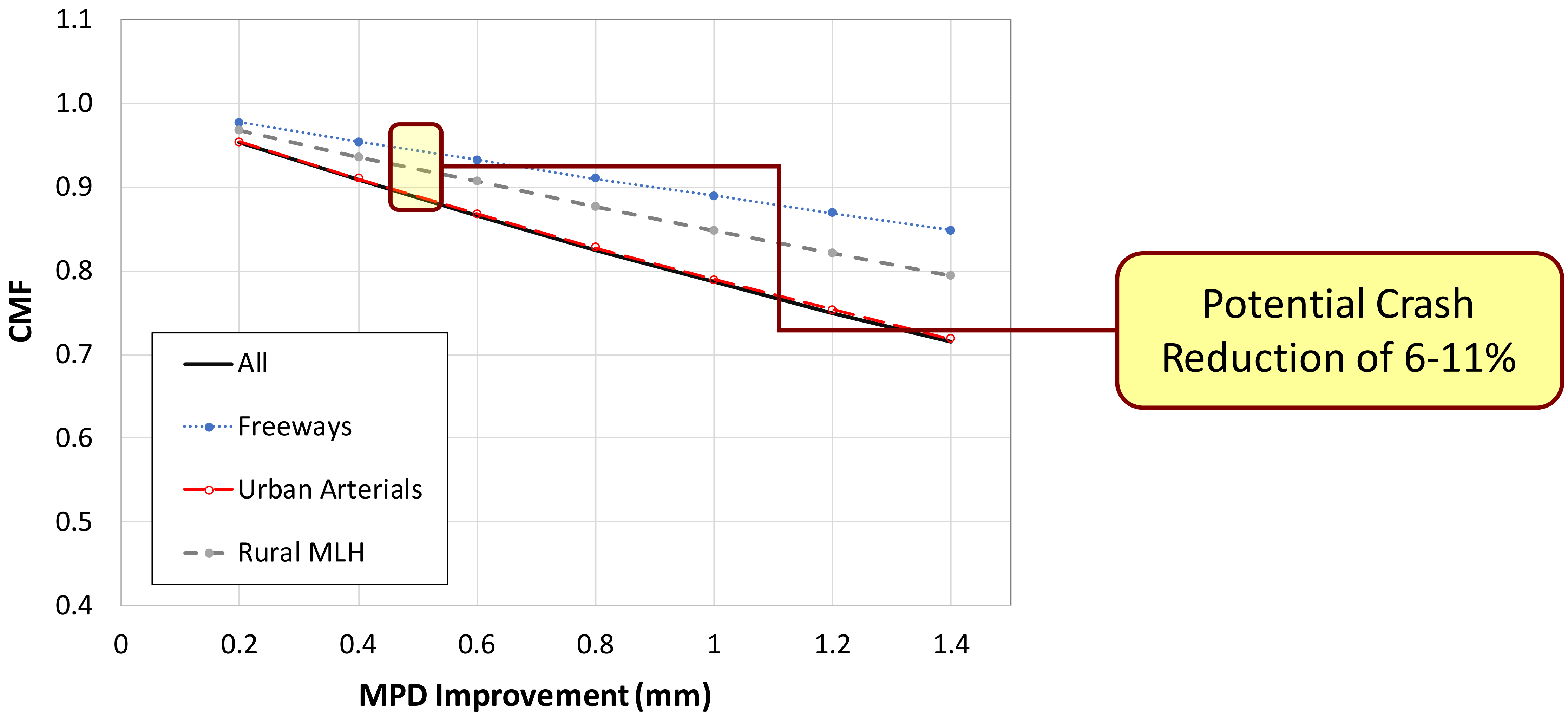
CMFunctions for Friction Improvements



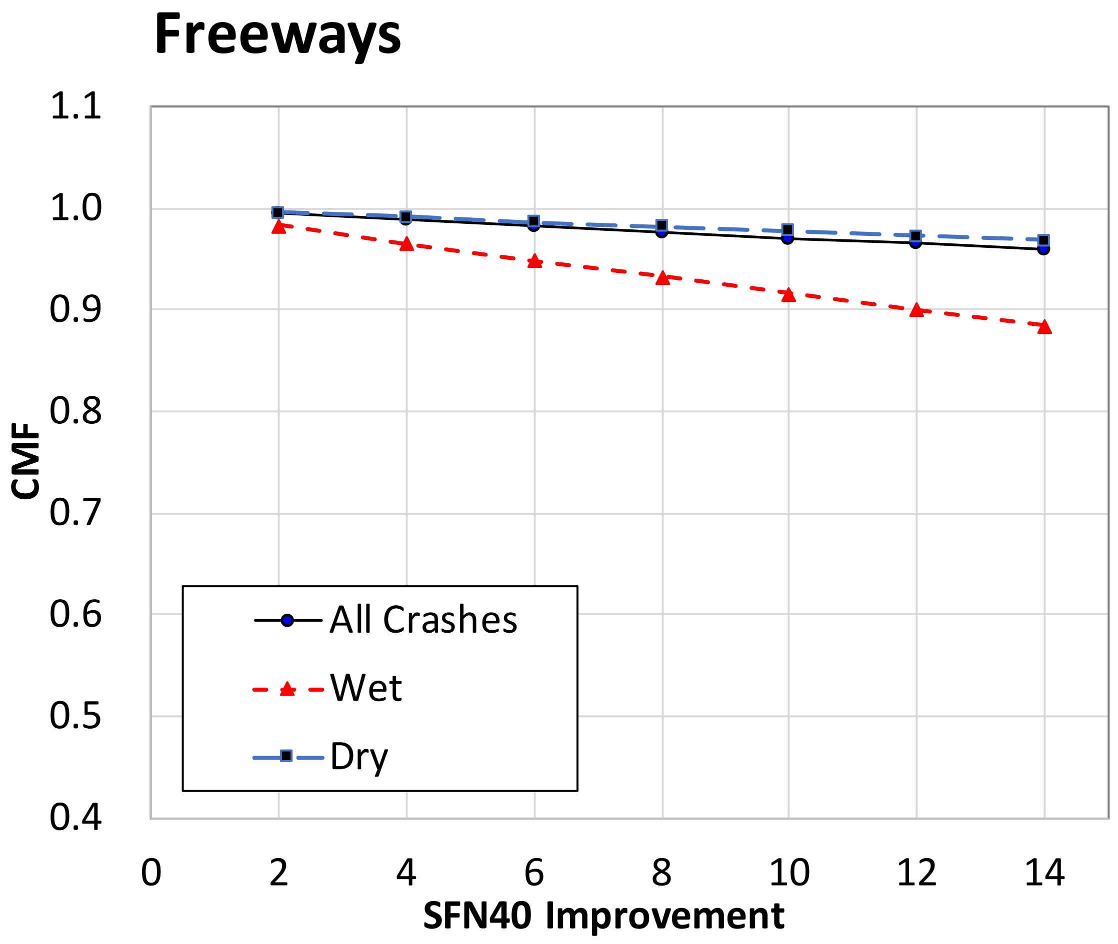
Potential Crash Reduction of 3-25%

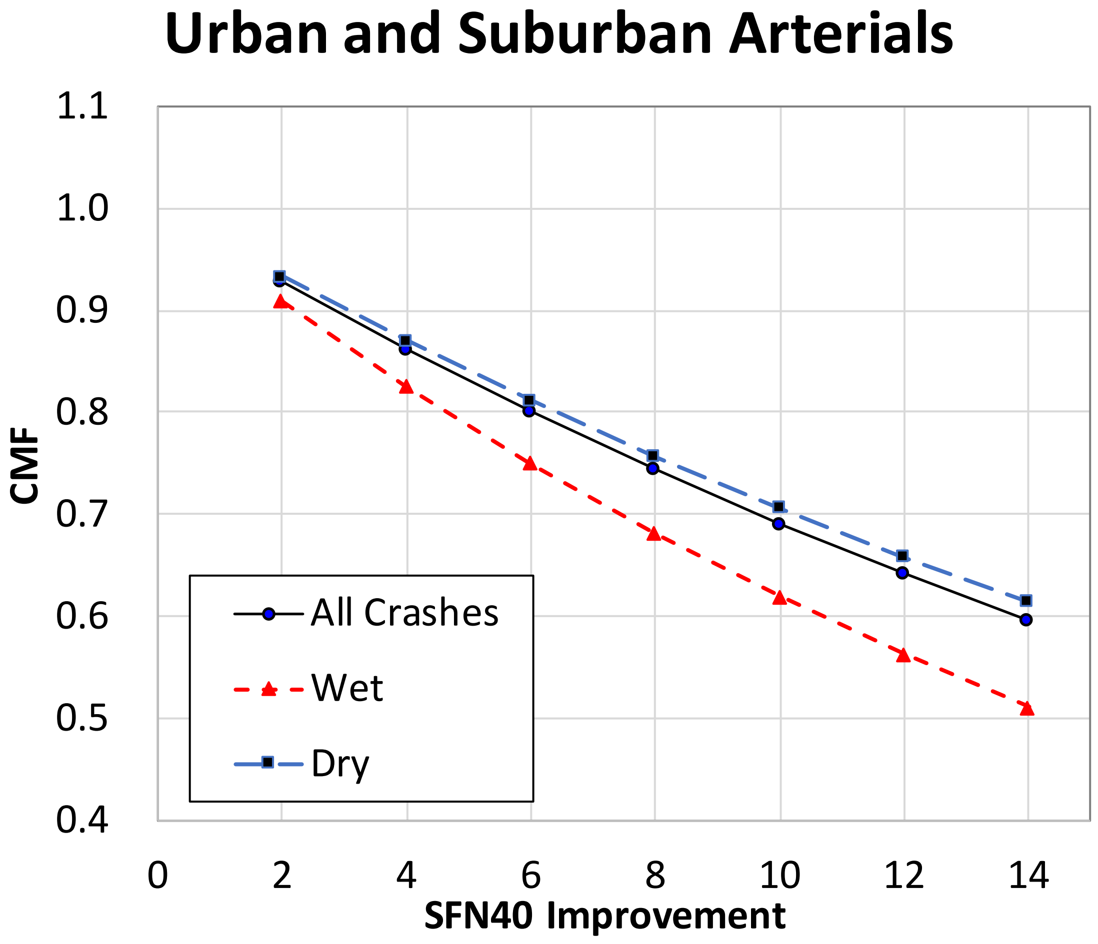
Potential Crash Reduction of 30% on Urban and Suburban Arterial Intersections

CMFunctions for Macrotexture Improvements

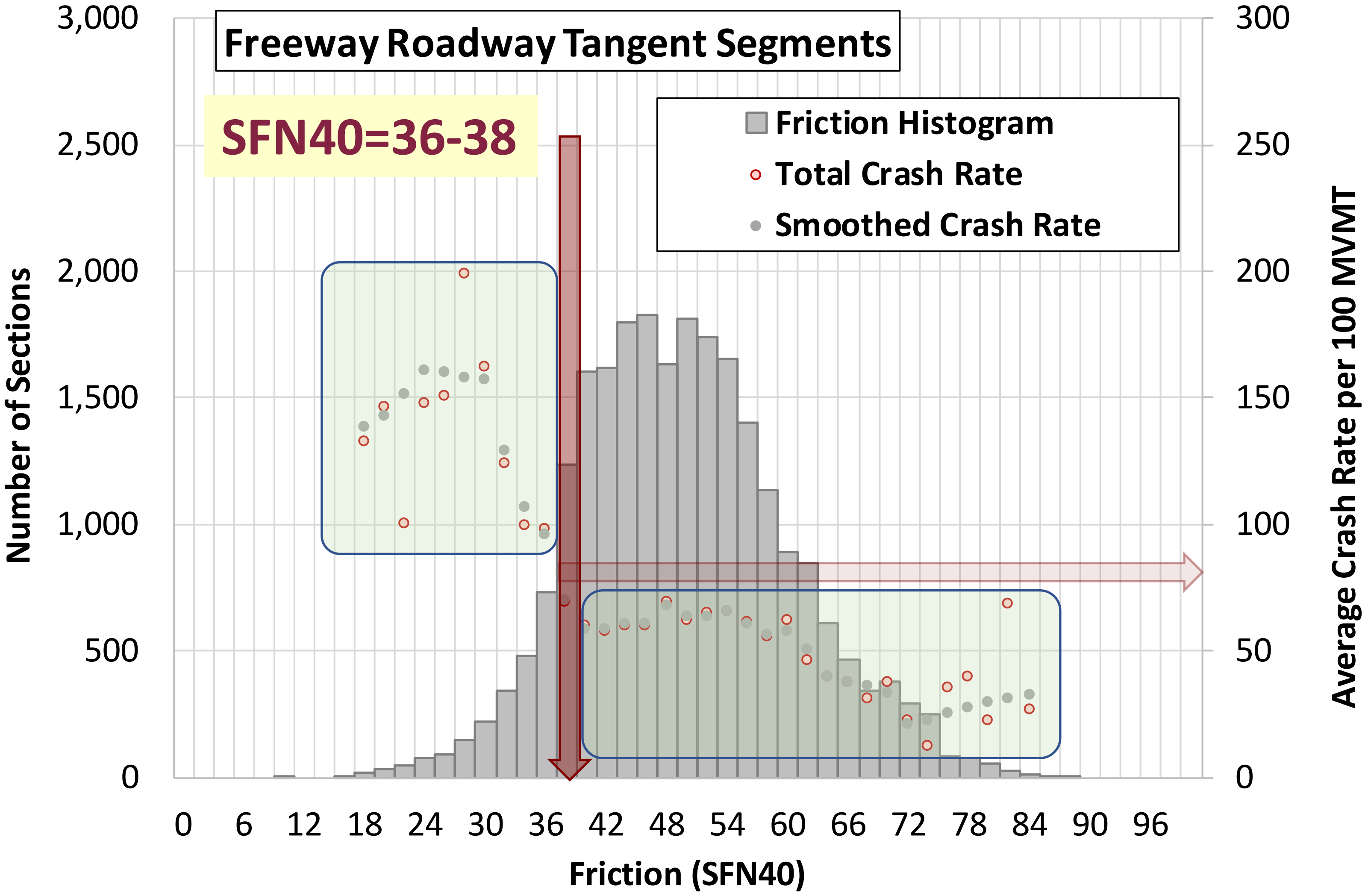


CMF by Types of Crashes

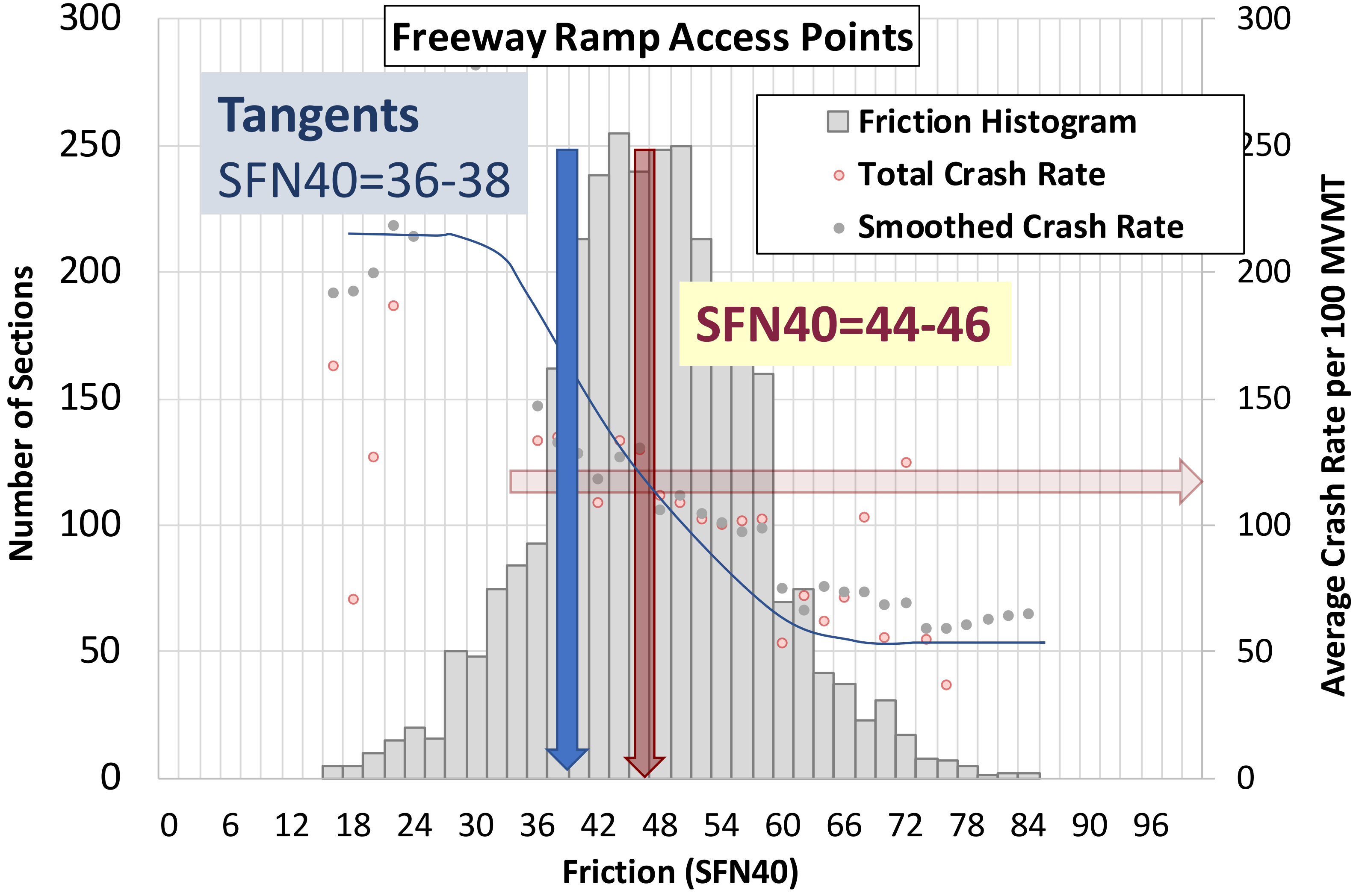




Friction Thresholds - Freeways



Friction Thresholds – Freeway Tangents vs. Access Points



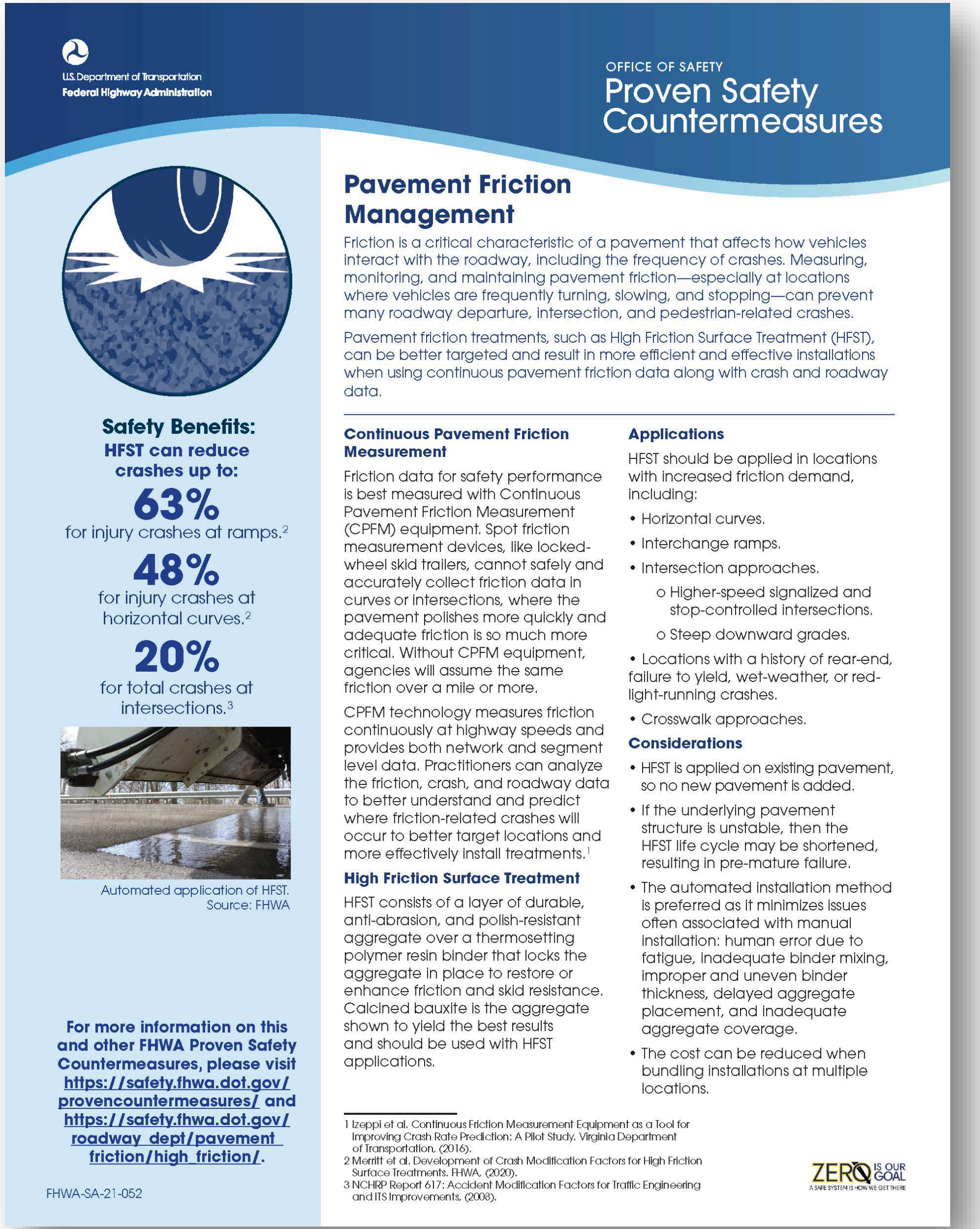
Summary of Illustrative Investigatory Threshold

Roadway Facility Type	Site Type	Suggested	Graphic Threshold	Approximate UK CSC Eq.	CS 228 ST	CS 228 LR
Freeways	Tangents	**40**	36 – 38	0.29 - 0.31	0.35	0.30
	Curves	45	42 – 44	0.34 - 0.36	0.45 - 0.50	
	Ramp Access	45	44 – 46	0.36 - 0.37		
Rural Multilane Roadways	Divided Tangents	**50**	48 – 50	0.39 - 0.41	0.35 - 0.40	0.30
	Undivided Tangents	50	48 – 50	0.39 - 0.41	0.40 - 0.45	0.35
	Curves	55	54 – 56	0.44 - 0.46	0.45 - 0.50	
	Intersections	55	54 - 56	0.44 - 0.46	0.45 - 0.55	0.40
Rural 2-lane, 2-way Roadways	Tangents	**50**	48 - 50	0.39 - 0.41	0.40 - 0.45	0.35
	Curves	55	54 - 56	0.44 - 0.46	0.50- 0.55	0.45
	Intersections	60	54 - 56	0.44 - 0.46	0.45 - 0.55	0.40
Urban and Suburban Arterials	Divided Tangents	**50**	48 - 50	0.39 - 0.41		
	Undivided Tangents	50	48 - 50	0.39 - 0.41		
	Curves	50	48 - 50	0.39 - 0.41		
	Intersections	55	54 - 56	0.44 - 0.46		

Higher for roads with lower geometric standards

Higher for segments with higher friction demand

CPFM has been designated a Proven Crosscutting Safety Countermeasure


U.S. Department of Transportation
Federal Highway Administration

OFFICE OF SAFETY
Proven Safety Countermeasures

Pavement Friction Management

Friction is a critical characteristic of a pavement that affects how vehicles interact with the roadway, including the frequency of crashes. Measuring, monitoring, and maintaining pavement friction—especially at locations where vehicles are frequently turning, slowing, and stopping—can prevent many roadway departure, intersection, and pedestrian-related crashes.

Pavement friction treatments, such as High Friction Surface Treatment (HFST), can be better targeted and result in more efficient and effective installations when using continuous pavement friction data along with crash and roadway data.

Safety Benefits:
HFST can reduce crashes up to:

63% for injury crashes at ramps.[2]

48% for injury crashes at horizontal curves.[2]

20% for total crashes at intersections.[3]

Automated application of HFST. Source: FHWA

Continuous Pavement Friction Measurement

Friction data for safety performance is best measured with Continuous Pavement Friction Measurement (CPFM) equipment. Spot friction measurement devices, like locked-wheel skid trailers, cannot safely and accurately collect friction data in curves or intersections, where the pavement polishes more quickly and adequate friction is so much more critical. Without CPFM equipment, agencies will assume the same friction over a mile or more.

CPFM technology measures friction continuously at highway speeds and provides both network and segment level data. Practitioners can analyze the friction, crash, and roadway data to better understand and predict where friction-related crashes will occur to better target locations and more effectively install treatments.[1]

High Friction Surface Treatment

HFST consists of a layer of durable, anti-abrasion, and polish-resistant aggregate over a thermosetting polymer resin binder that locks the aggregate in place to restore or enhance friction and skid resistance. Calcined bauxite is the aggregate shown to yield the best results and should be used with HFST applications.

Applications

HFST should be applied in locations with increased friction demand, including:

- Horizontal curves.
- Interchange ramps.
- Intersection approaches.
  - Higher-speed signalized and stop-controlled intersections.
  - Steep downward grades.
- Locations with a history of rear-end, failure to yield, wet-weather, or red-light-running crashes.
- Crosswalk approaches.

Considerations

- HFST is applied on existing pavement, so no new pavement is added.
- If the underlying pavement structure is unstable, then the HFST life cycle may be shortened, resulting in pre-mature failure.
- The automated installation method is preferred as it minimizes issues often associated with manual installation: human error due to fatigue, inadequate binder mixing, improper and uneven binder thickness, delayed aggregate placement, and inadequate aggregate coverage.
- The cost can be reduced when bundling installations at multiple locations.

For more information on this and other FHWA Proven Safety Countermeasures, please visit https://safety.fhwa.dot.gov/provencountermeasures/ and https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/high_friction/.

1 Izeppi et al. Continuous Friction Measurement Equipment as a Tool for Improving Crash Rate Prediction: A Pilot Study. Virginia Department of Transportation, (2016).
2 Merritt et al. Development of Crash Modification Factors for High Friction Surface Treatments. FHWA, (2020).
3 NCHRP Report 617: Accident Modification Factors for Traffic Engineering and ITS Improvements, (2008).

FHWA-SA-21-052

ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

- ✓ Can be funded as part of the State's Highways Safety Improvement Programs (HSIP)
- ✓ More details:
  - https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/cpfm/

https://safety.fhwa.dot.gov/roadway_dept/pavement_friction/cpfm/pdfs/FHWA-SA-22-052_CPFM_041822.pdf

3. Final Remarks

Final Remarks

- ✓ **Higher friction and/or macrotexture** → **Lower crash rates** on all roadway types
- ✓ **Potential reductions of up to 30 percent of total crashes with a 10-unit increase in SFN40** (on urban arterial intersections)
- ✓ As expected, the **investigatory levels are higher for higher friction demand sites** (such as curves, ramp access points & intersections)
- ✓ Incorporating friction management into asset management is **multi-disciplinary** in terms of benefits and impacts, involving Safety, Maintenance, Programming, Pavements, and Materials

NC STATE UNIVERSITY Department of Civil, Construction, and Environmental Engineering

Case Study from North Carolina

Shane Underwood
Professor and University Faculty Scholar
North Carolina State University
Department of Civil, Construction, and Environmental Engineering

TRB Webinar - Pavement Friction Management, Continuous Pavement Friction Measurement, and Safety Analysis

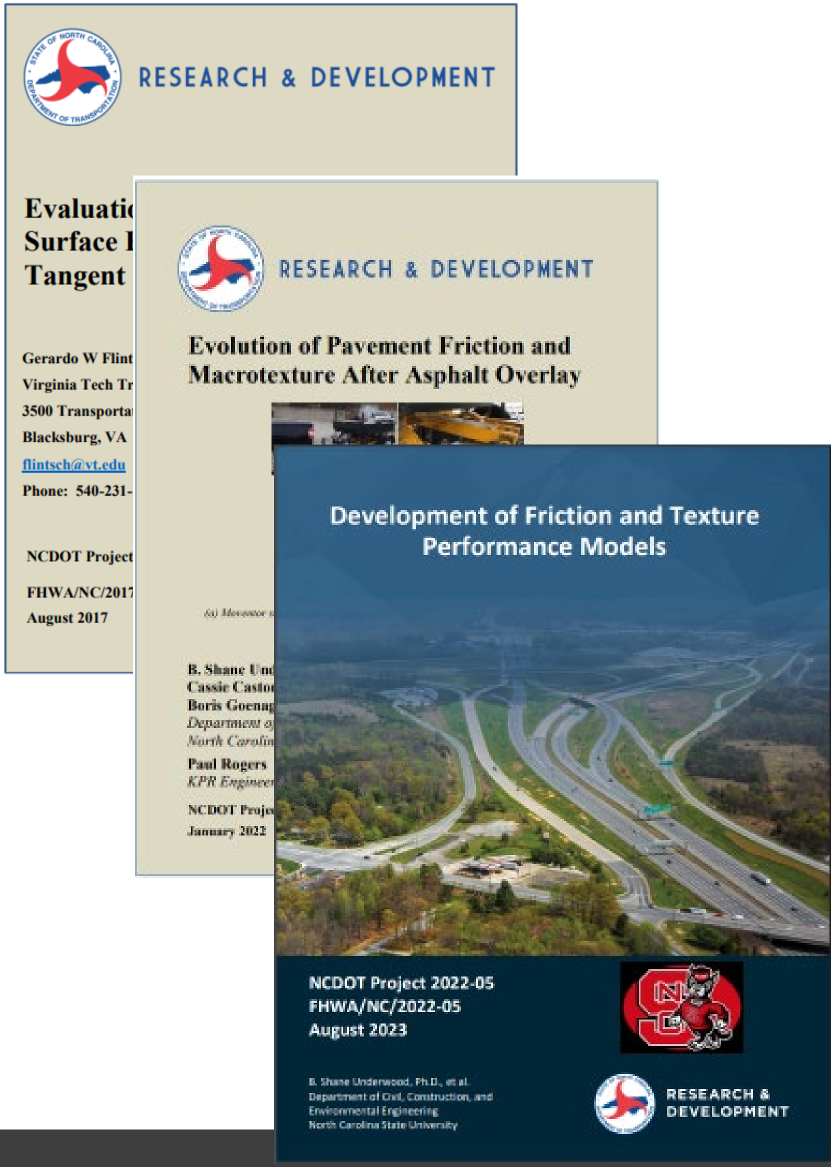
June 11, 2024

Outline

- Studies involving continuous friction measurements in North Carolina.
- Continuous friction measurements used in North Carolina studies.
- Effect of friction following overlays
- Effect of friction on pavement safety
- Wrap-up

Timeline of Studies at NCDOT

- Internal studies on targeted sites (2017-current)
- RP2017-02 - Evaluation of Methods for Pavement Surface Friction, Testing on Nontangent Roadways and Segments (Completed, VT)
- RP2020-11 - Evolution of Pavement Friction and Macrotexture after Asphalt Overlay (Completed)
- RP2022-05 - Development of Friction Performance Models (Completed)
- RP2024-12 - Evaluation of Macrotexture and Friction of Alternative Asphalt Surface Course Material (Ongoing)
- Network Data Collection (2023, 2024)
- RP2025-18 - Updating Friction/Texture Demand Categories for Improved Pavement Design Guidance (Forthcoming)



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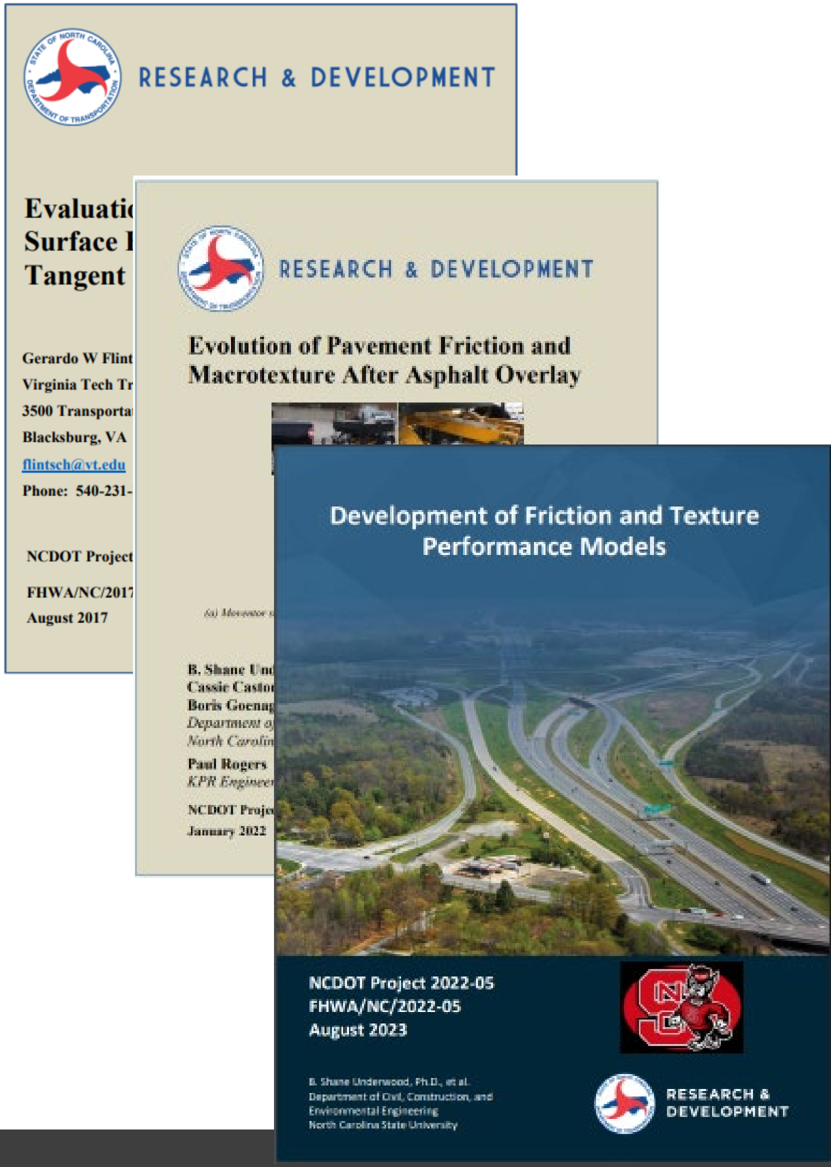
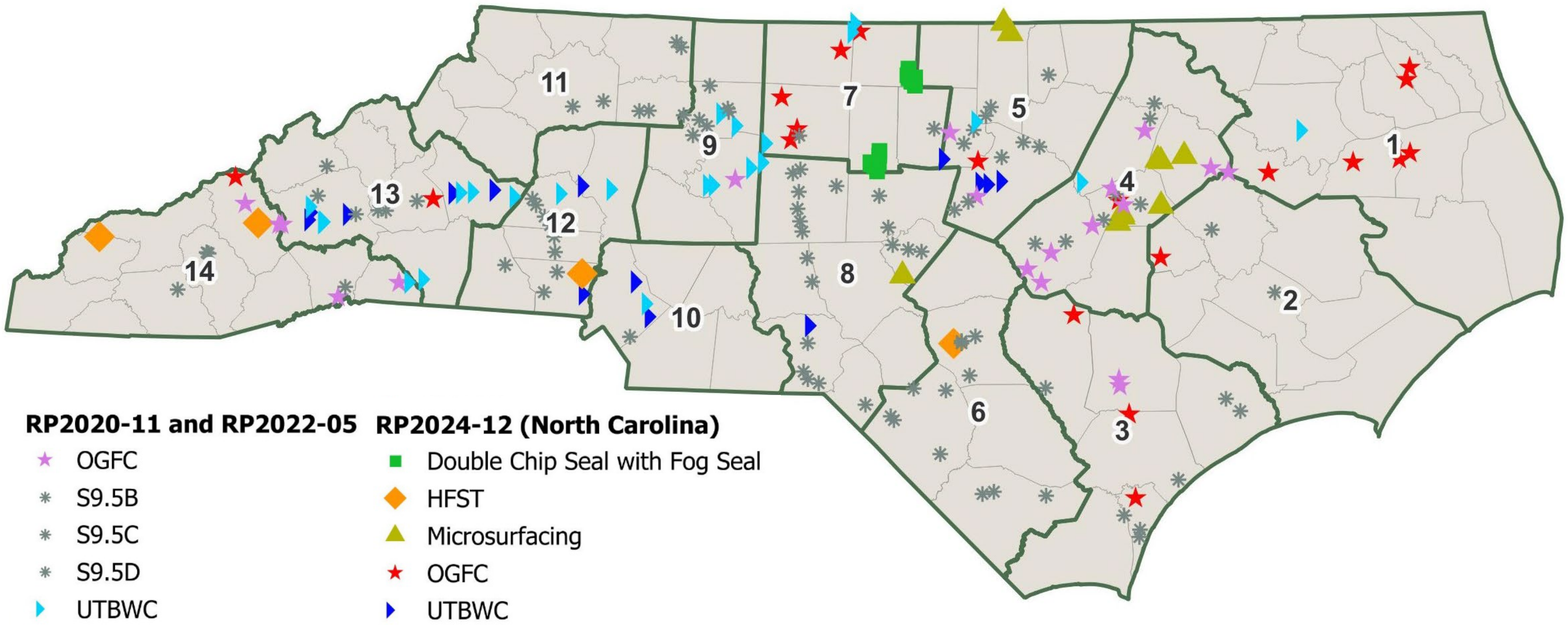


Friction and Texture Measurements in RP Studies

Measurements

- Core Acquisition and Lab Measurements
- Continuous Friction Measurement Equipment
- High-Speed Laser Profiler
- Lane Departure, Wet-Crashes



- Group 1 sites for short term monitoring
- Group 2 sites for long-term monitoring
- Group 3 sites for special surface
- Group 4 sites from Network data collection

Friction and Texture Measurements in RP Studies

Continuous Measurements

<table>
<tr><th></th><th>Device</th><th>Speed</th><th>Location</th><th>Parameter</th></tr>
<tr><td>Friction (CFME)</td><td>Moventor Skyddometer BV-11</td><td>• 60-mph (all sites)
• 40-mph (some sites)</td><td rowspan="2">• Outer most lane
• Right wheel path (RWP)
• Center of the lane (CL)</td><td>Friction value reported every 3 m (9.8 ft)</td></tr>
<tr><td>Texture</td><td>AMES Engineering HSIP (spot laser)</td><td>Posted speed limit</td><td>Texture indices reported every 3 m (9.8 ft)
• MPD
• Skewness
• Kurtosis</td></tr>
</table>

Friction and Texture Measurements in Other Studies

Sideway-Force Machine

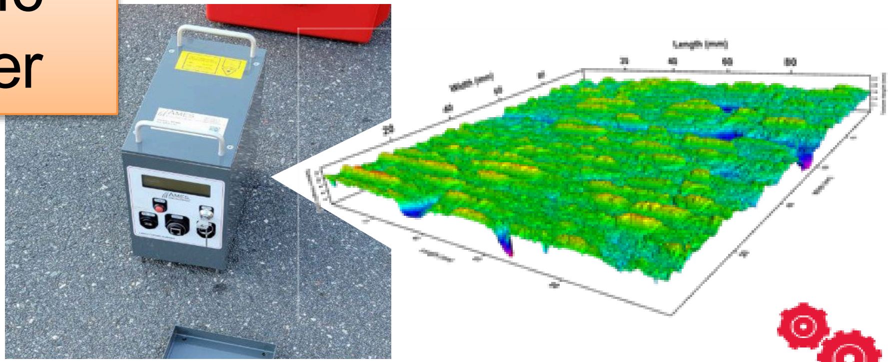
Source: https://www.rosanne-project.eu/

Grip Tester

Source: https://www.aeroexpo.online/prod/findlay-irvine-ltd/product-168674-11770.html

Locked-Wheel

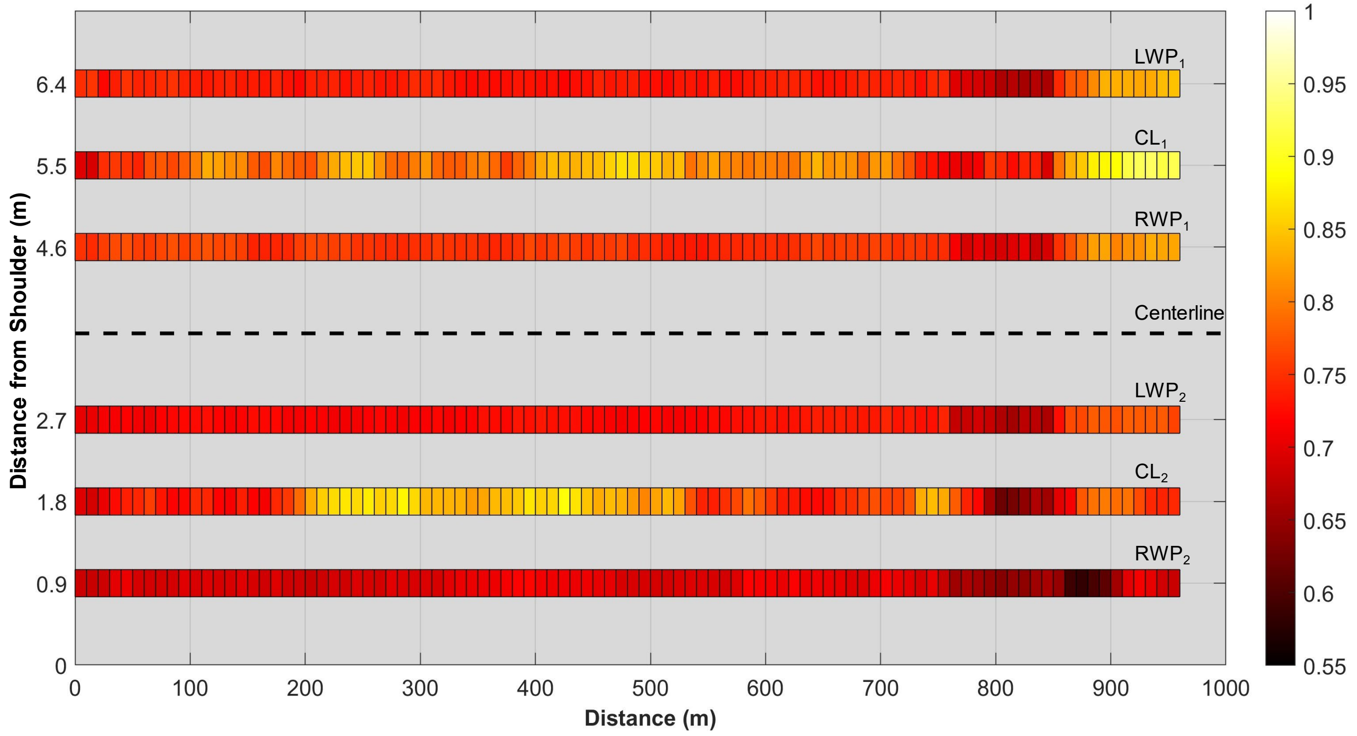
Static Laser

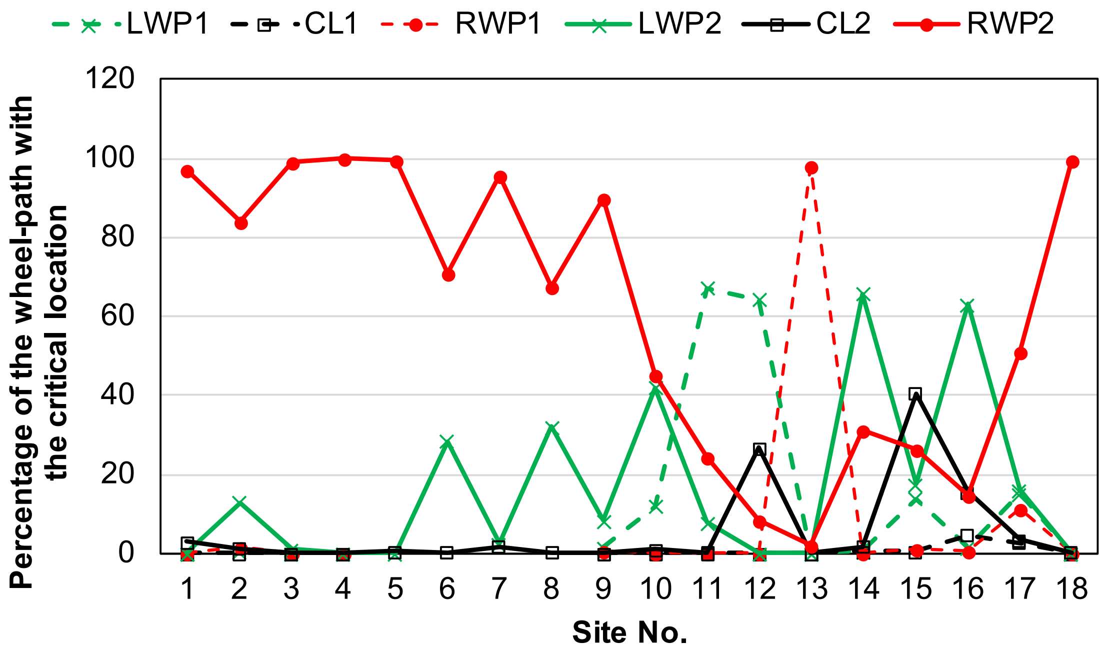


Measurements

Wheel Path Selection

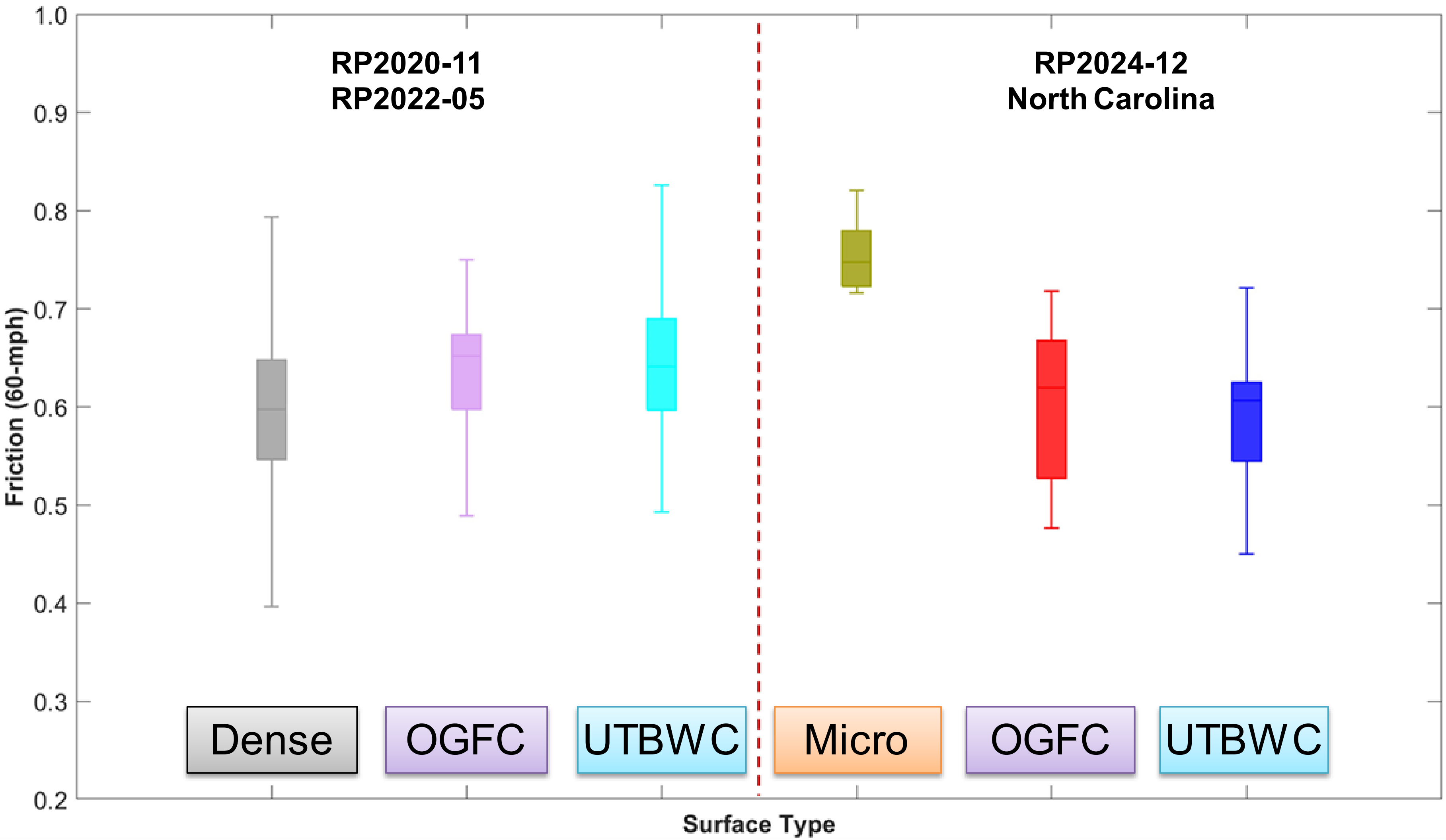
- Measurements taken in the right wheel path of the outer lane.
- Testing in this location gave the best chance to locate potential low friction issues.





Results

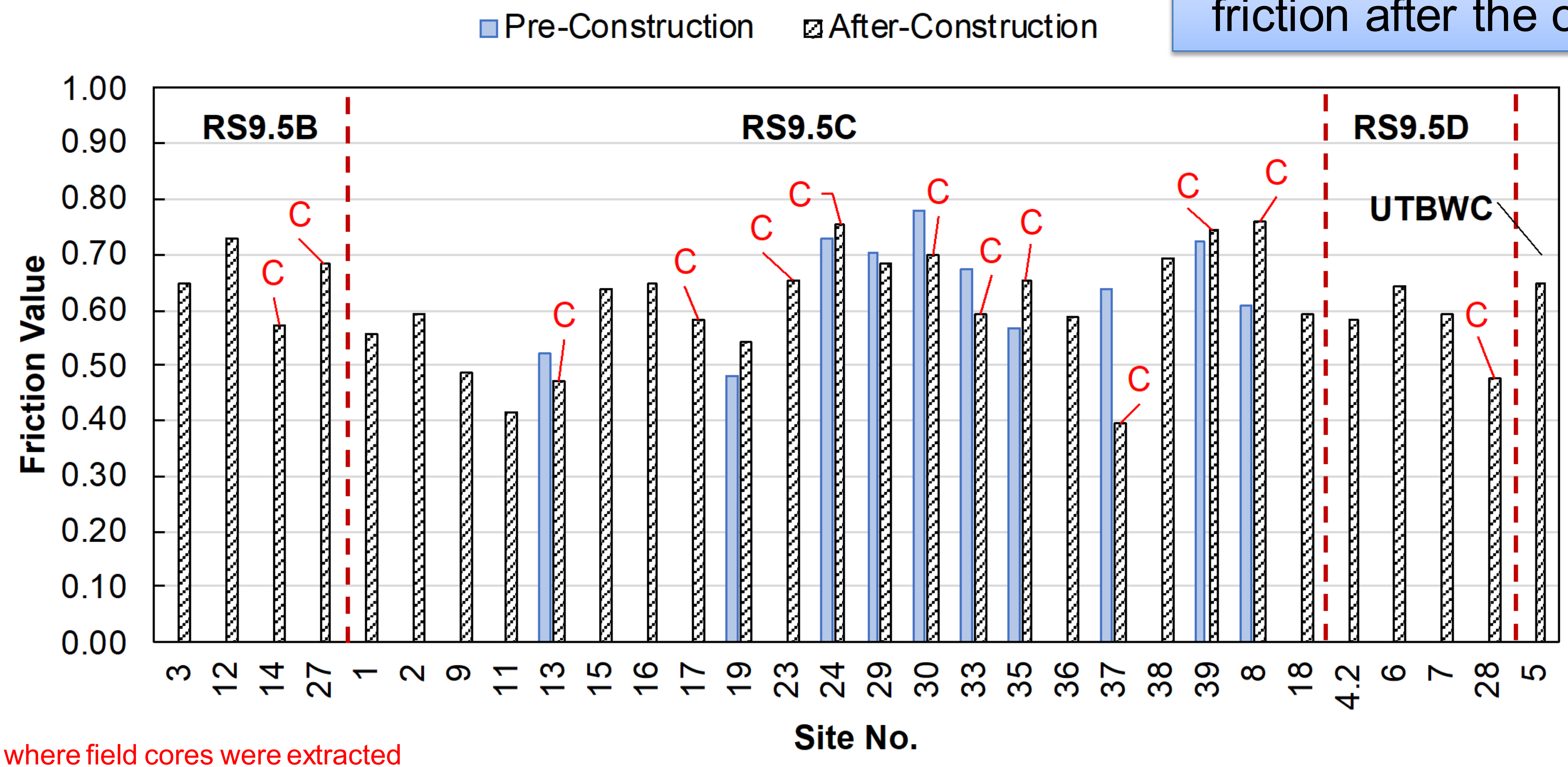
Friction of Different Surface Types



Results

Field Friction After an Overlay

5 out 10 sites with lower friction after the overlay



C: Sites where field cores were extracted

Safety Implications of Friction

Road Network Characterization

Category 1

All demand combined

Category 2

Tangents

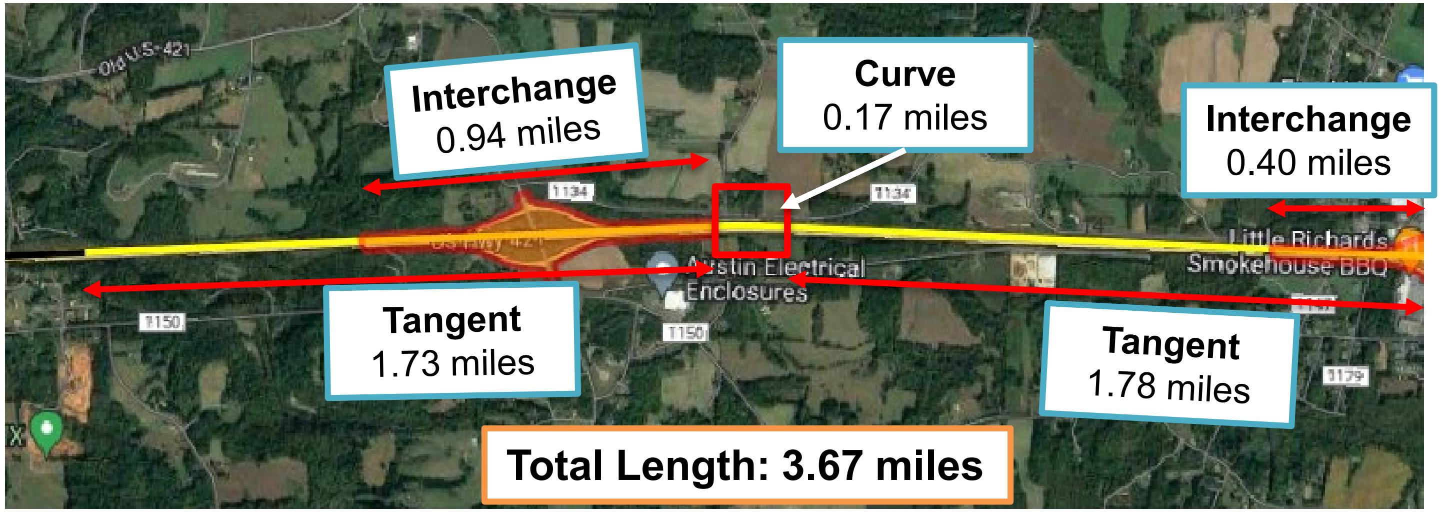
Category 3

Curves

Category 4

Interchanges

Each tested site was categorized as shown in the image below. Then, the total number of miles per category and speed limit were computed.

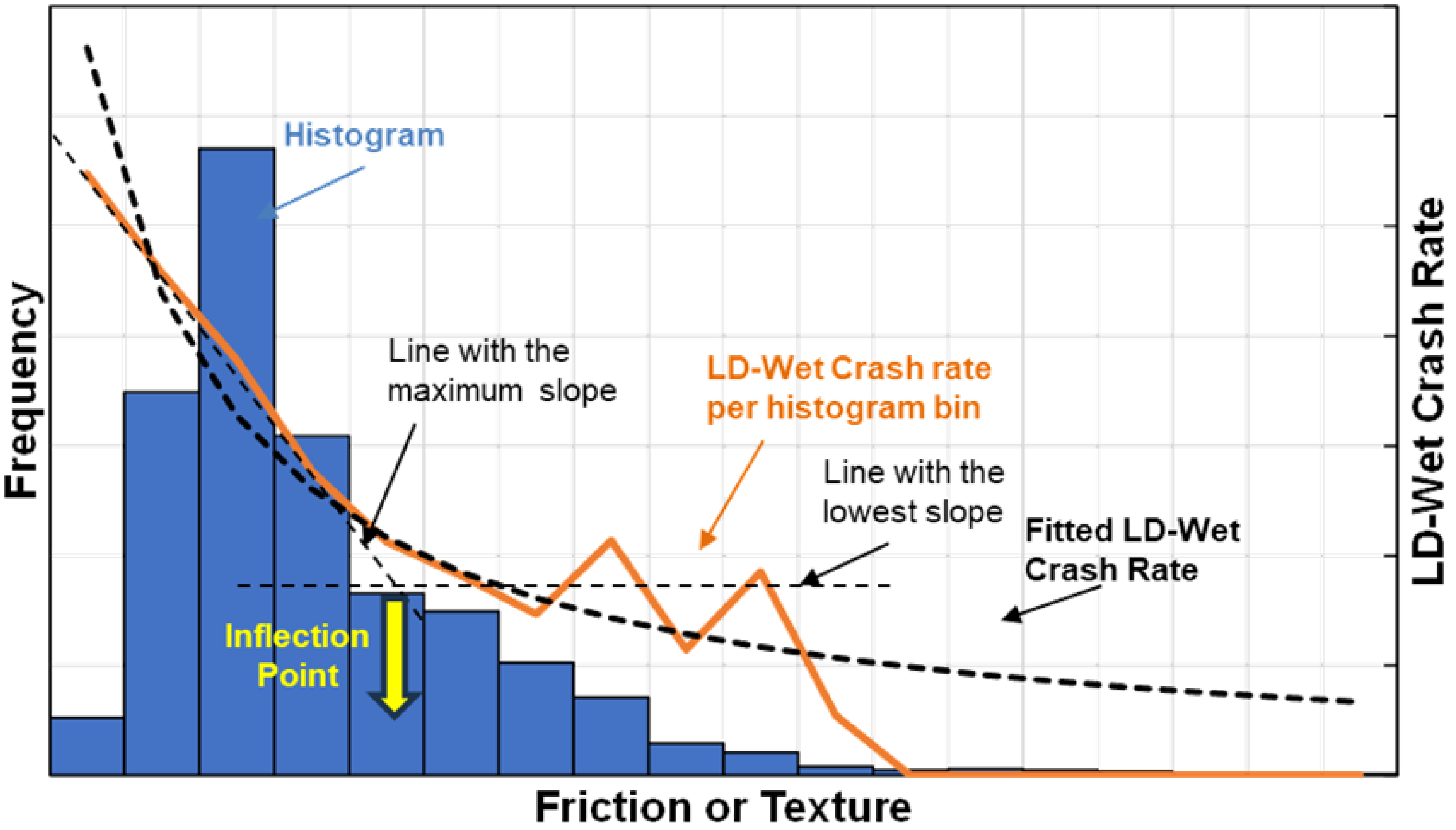


- Different moving average windows were evaluated.
- It was observed that a proper balance between accuracy and sample size was obtained with a 13-month window.
- StreetLight Monthly Traffic counts were used to calculate traffic exposure.

Crash frequency	Vehicle-miles traveled	Aggregate Crash Rate
$N_i = \sum_{j=1}^{13} \#Crashes_j$	$VMT_i = \sum_{j=1}^{13} MADT_{ij} \times 30 \times L_i$	$R_i = \dfrac{N_i \times 10^8}{VMT_i}$

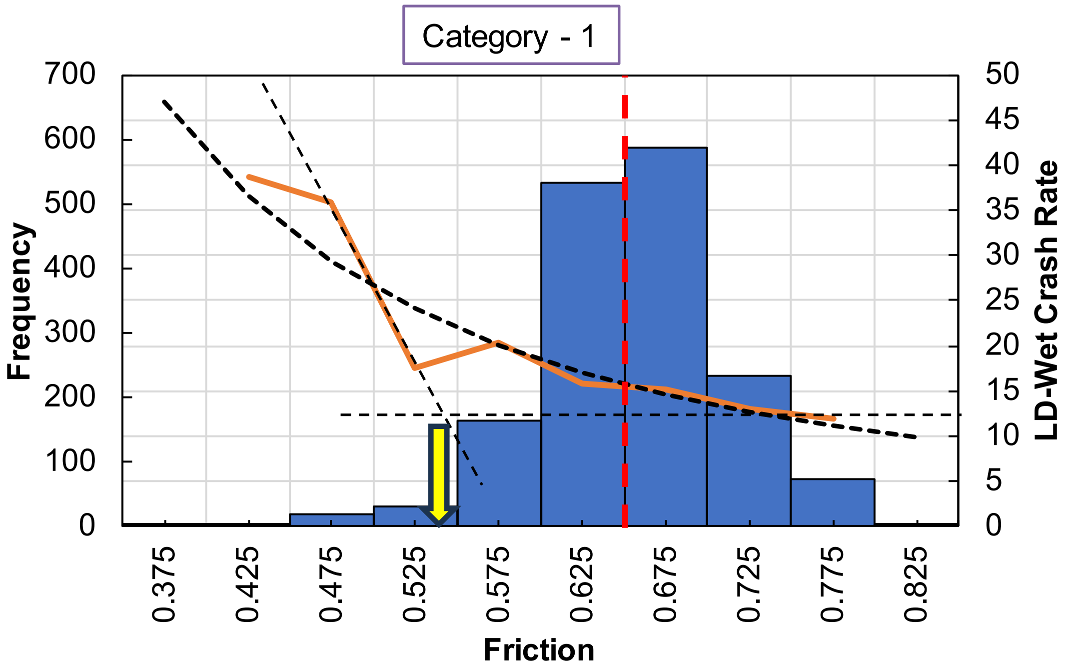
Safety Implications of Friction

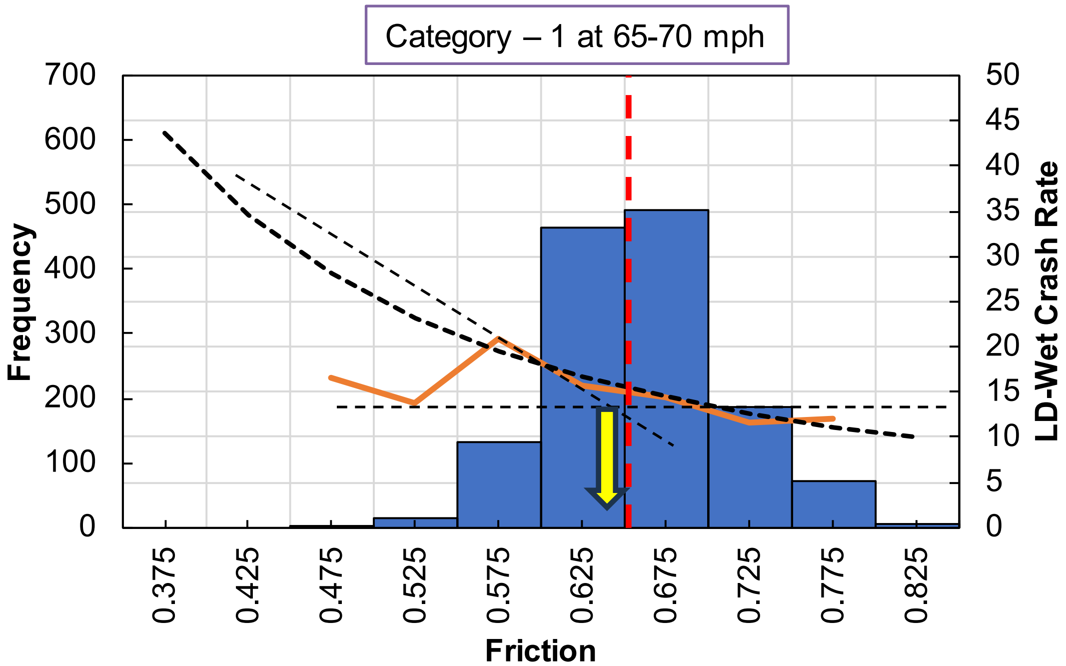
Method 3 from GPF: Crashes, traffic, and length get aggregated and crash rate implications can be estimated.



Safety Implications of Friction

Safety Performance Characterization





Parameter	All Combined	Speed Limit		Tangents	Curves	Interchanges
		65-70	55-60			
FN_{INV}	0.53	0.62	0.51	0.57	0.60	0.65
FN_{INT}	0.39	0.45	0.38	0.43	0.45	0.49

Note: $FN_{INT} = 0.75*FN_{INV}$

Safety Implications of Friction

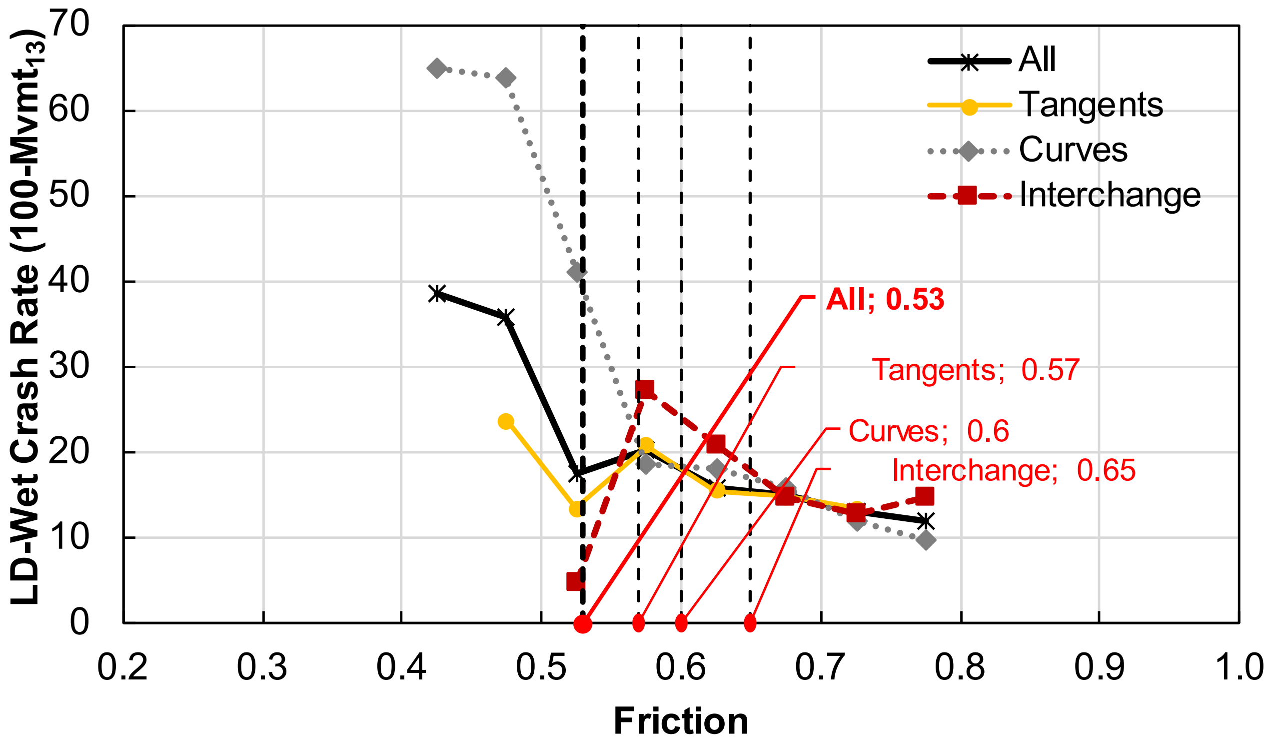
Safety Performance Characterization

- While the values developed by the Method-3 of the GPF are systematically different for each category the evidence between non-interchange and interchanges are the only effect that shows up consistently.

Suggested Investigatory and Intervention Friction Values

Variable	Non-Interchanges	Interchanges
MPD_{INV}	0.57	0.65
MPD_{INT}	0.43	0.49

Note: $MPD_{INT} = 0.75 * MPD_{INV}$



Safety Implications of Texture

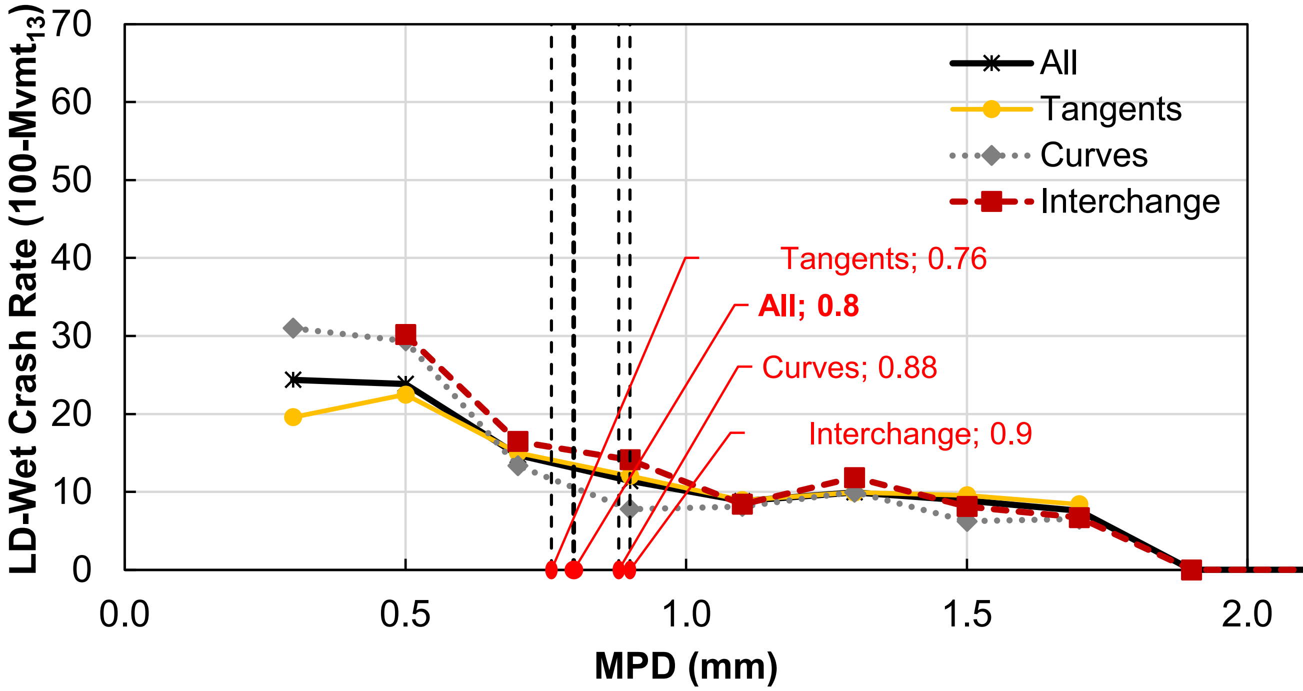
Safety Performance Characterization

- ❑ While the values developed by the Method-3 of the GPF are systematically different for each category, the overall crash rate curves are similar.
- ❑ Thus, choosing a single representative value does not have much impact on the final expected crash rates.

Suggested Investigatory and Intervention Macrotexture Values

Variable	Non-Interchanges	Interchanges
MPD_{INV}	0.80	0.80
MPD_{INT}	0.60	0.60

Note: $MPD_{INT} = 0.75*MPD_{INV}$



Summary

- Surface friction in North Carolina can reduce or increase after asphalt overlays.
- Aggregated crash statistics in North Carolina show a noticeable decrease in wet, lane-departure crashes as friction values exceed approximately 0.57 (interchanges) or 0.65 (non-interchanges)
- Aggregated crash statistics in North Carolina show a noticeable decrease in wet, lane-departure crashes as MPD values exceed approximately 0.8 mm.
- **CRITICAL CAVEAT:** The aforementioned point of increase is equipment specific and if measurements are taken using any other device, the limiting values may be different.

Acknowledgements and Disclaimer

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- This presentation provides the opinions of the authors and is not meant to represent the position or opinions of the NCDOT or its members, nor the official position of any staff members. Any errors are the fault of the authors.


Thank you
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Safety and Friction Enhancement

by Mike Vaughn, PE
Kentucky Transportation Cabinet

June 11, 2024

TEAM KENTUCKY
TRANSPORTATION CABINET

HSIP

Outline

- Why is KY pursuing pavement friction management (PFM), measurement, and safety analysis?
- Essential tools for PFM
- Network analysis
- Prioritization lists
- Site and treatment selection

Why is KY pursuing PFM?

- KY's efforts are being funded with HSIP dollars, so the primary goal is: **To prevent transportation related fatalities and serious injuries in KY**

- Fatalities (K crashes) and serious injuries (A crashes) occurring on KY roadways have an annual economic impact of over $10 Billion

- 60%-70% of KY's yearly highway fatalities are the result of Roadway Departure

Why is KY pursuing PFM?

- From 2013-2017:
  - 1,250+ KA crashes were the result of Roadway Departure on WET pavement
  - 250+ KA crashes per year due to Roadway Departure on WET pavement
  - Friction likely has more importance on these crashes than any other crash type

- A 5% reduction of KY's K & A Roadway Departure crashes occurring on WET pavement would save the public over $28 Million per Year

- **This indicated an opportunity!**

What are the essential tools for PFM?

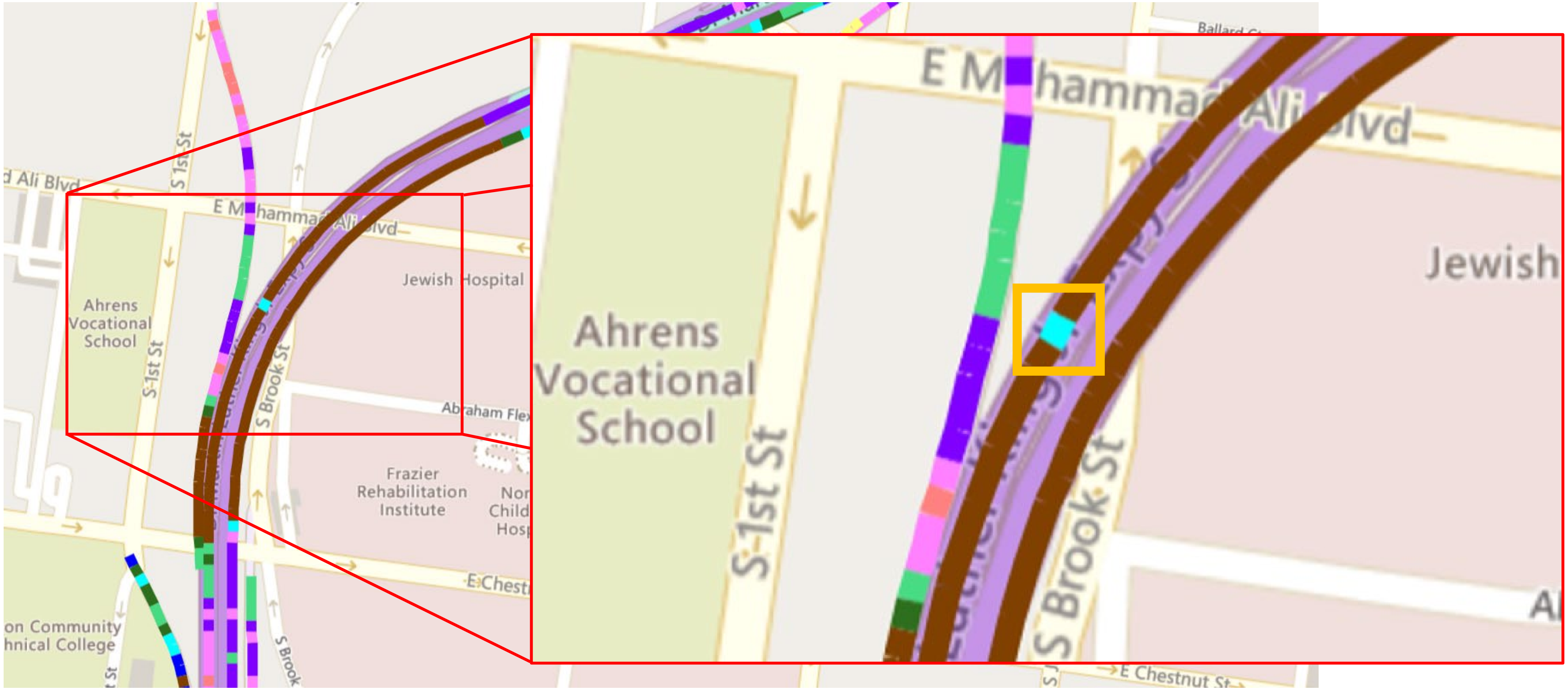
1) **Continuous Friction Data**
   - The best way to manage something is to measure, analyze, and monitor it
2) **Site Categorization**
   - Dividing the network into segments based on key features (curves, intersections, grades, tangents, etc.)
   - Grounded in the principle that friction demand varies based on geometry (and traffic volume and speed)
3) **Friction Demand Levels**
   - Determining the relationship between friction and crash risk
4) **SPFs**
   - SPF = Safety Performance Function (crash prediction model)
   - Allows for a wide variety of analyses

What are the essential tools for PFM?

Continuous Friction Data – what does it look like?

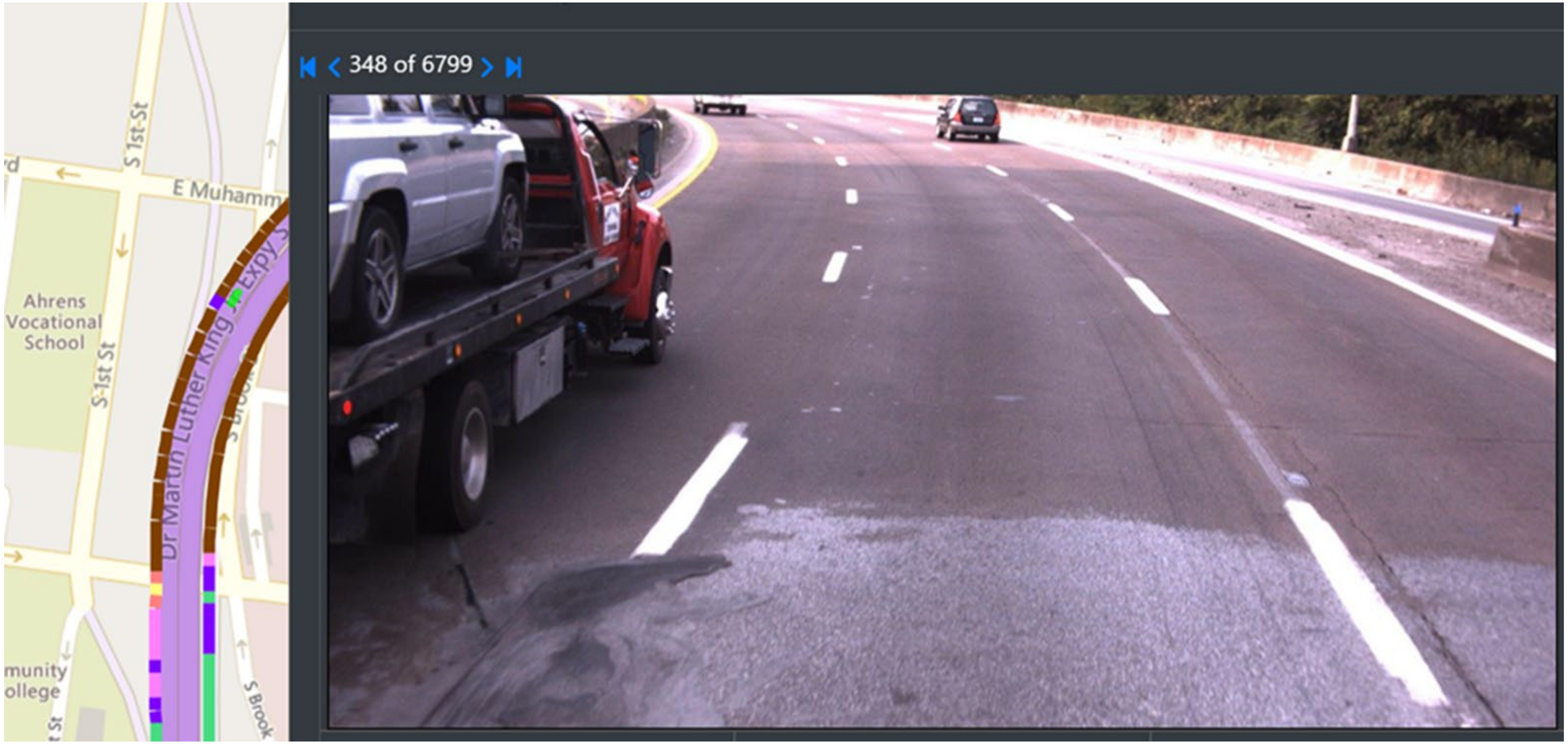
What are the essential tools for PFM?

Continuous Friction Data – what does it look like?



What are the essential tools for PFM?

Continuous Friction Data – what does it look like?



What are the essential tools for PFM?

Site Categorization

- Collected friction and texture data is reported every 0.005 miles (26.4 ft) along KY's network
- Data is averaged over 0.1-mile segments and assigned a **Site Category**
  - **Curves**
    - **C1 curves**: radius < 300 ft
    - **C2 curves**: radius between 300 – 700 ft
    - **C3 curves**: radius between 700 – 1200 ft
    - **C4 curves**: radius between 1200 – 2000 ft
  - **Intersections**
  - **Non-event**

<u>NOTE</u>: if a 0.1-mile segment included both a tangent and curve, the entire segment was labeled as a curve

What are the essential tools for PFM?

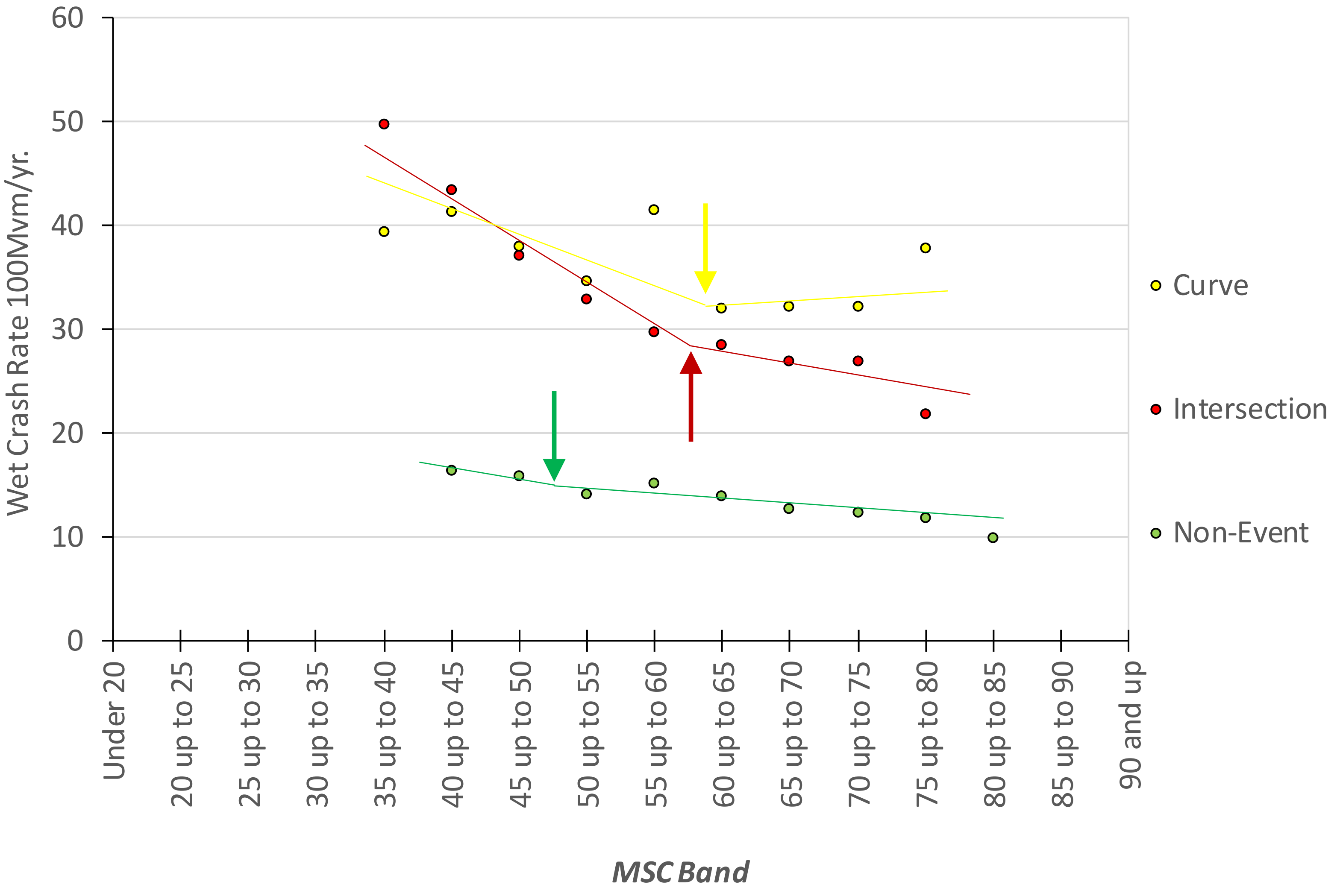
Friction Demand Levels in KY

- Explored multiple methods
  - Traditional method:
    - Each site category's FDL is set where wet crash rate has a noticeable increase as friction decreases
  - Various SPF-driven crash reductions:
    - Predicted crash rates for different Friction Demand Levels
    - % of crashes saved for increases to Friction Demand Levels

What are the essential tools for PFM?

Friction Demand Levels in KY

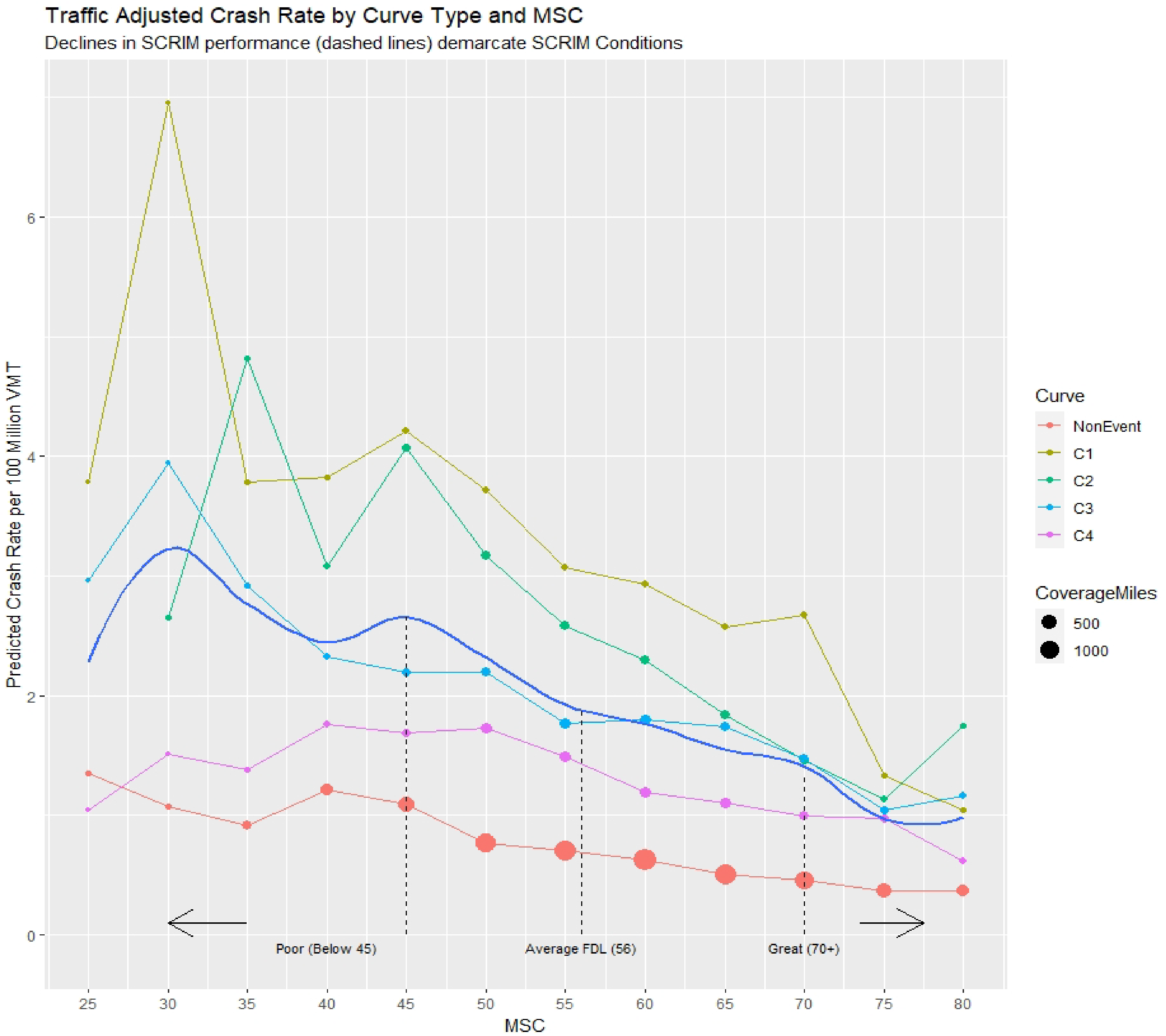
- Explored multiple methods
  - Traditional method:
    - Each site category's FDL is set where wet crash rate has a noticeable increase as friction decreases



Essential tools

Friction Demand Levels in KY

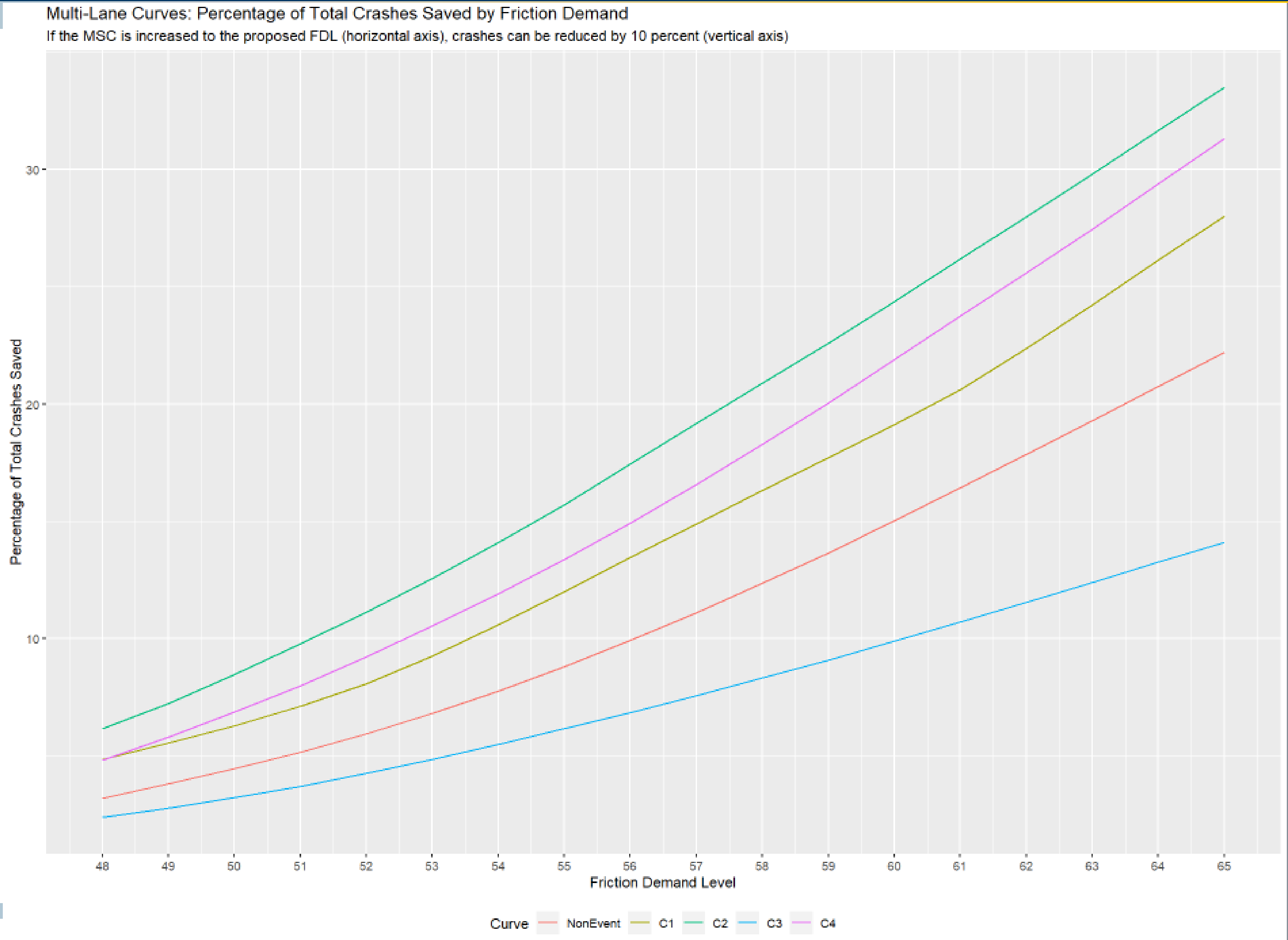
- Explored multiple methods
  - SPF-based methods:
    - Predicted crash rate by curve type and measured friction



What are the essential tools for PFM?

Friction Demand Levels in KY

- Explored multiple methods
  - SPF-based methods:
    - % of Total Crashes Saved by Friction Demand by Curve Type



What are the essential tools for PFM?

SPFs in KY

- In addition to helping us evaluate and understand FDLs, KYTC is using SPFs in three primary ways:
  - Network analysis
  - Prioritization lists
  - Site and friction treatment selection

Network Analysis

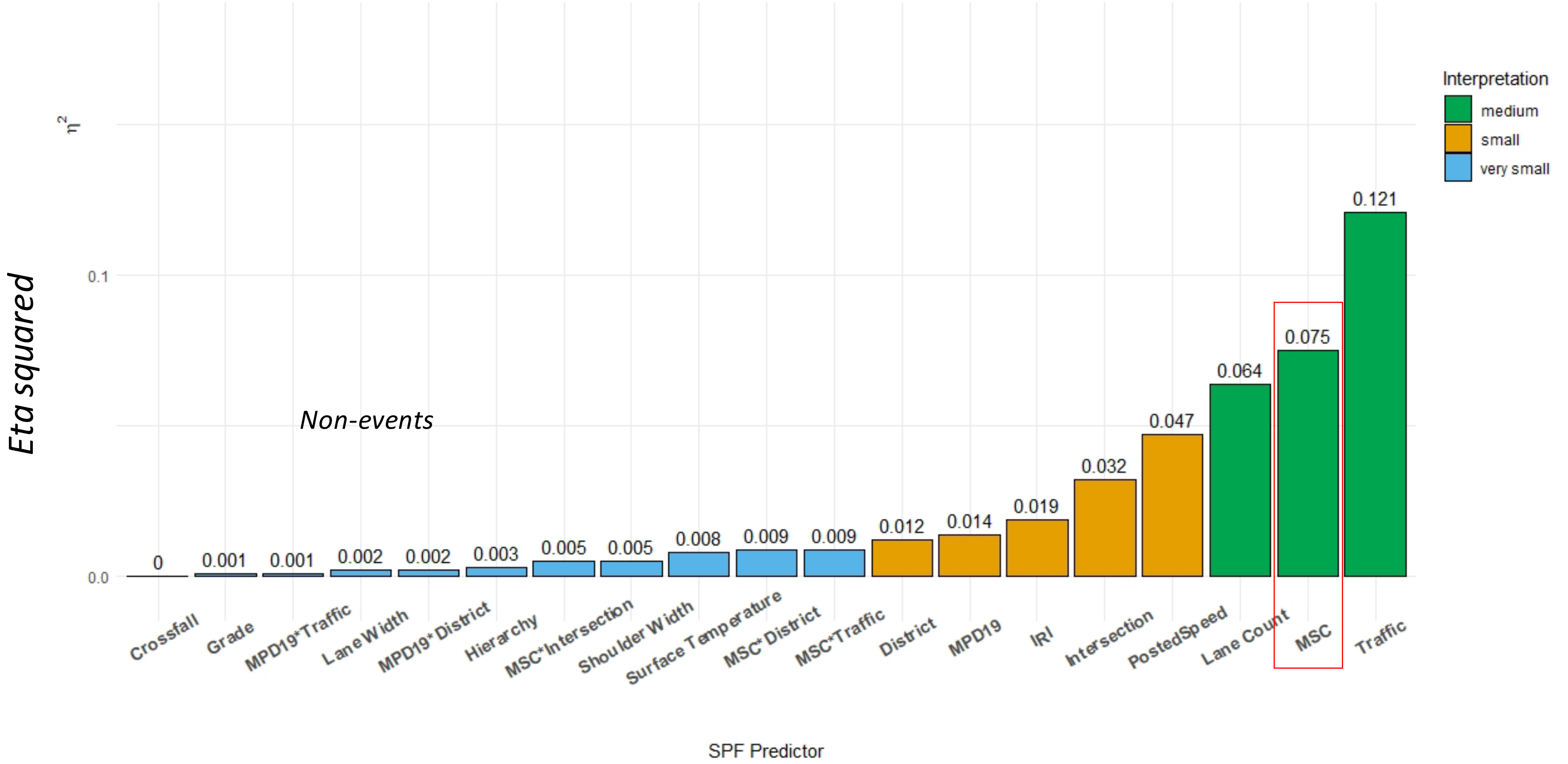
Evaluating the relationship between crashes, friction, and the potential to reduce crashes through improved friction:
% decrease in crash rates over a 5-year period when friction is increased by 10-points

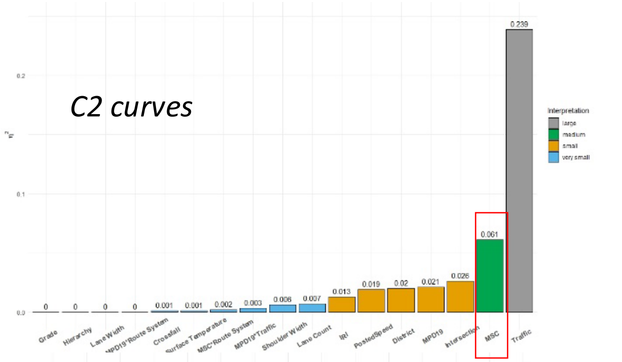
	Site Category	MSC CMF (1 MSC)	% Decrease in Crash Rates	Impact Rank
State Secondary	C1	0.9606	33.09 (27/38)	1
	C4	0.9654	29.70 (26/31)	2
	Non-Event	0.9707	25.71 (24/26)	4
	Intersection	0.9713	25.26 (24/26)	5
	C2	0.9721	24.66 (21/27)	6
	C3	0.9725	24.36 (21/26)	7
State Primary	C1	0.9695	26.64 (21/33)	3
	C4	0.9743	22.92 (20/25)	8
	Non-Event	0.9797	18.55 (18/20)	10
	Intersection	0.9803	18.06 (17/19)	11
	C2	0.9811	17.40 (15/21)	13
	C3	0.9815	17.07 (14/20)	14

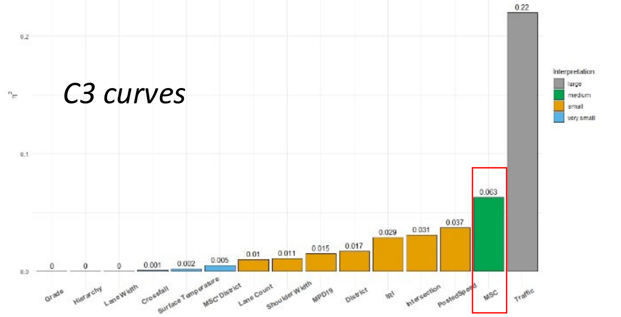
	Site Category	MSC CMF (1 MSC)	% Decrease in Crash Rates	Impact Rank
Interstate	C1	0.9758	21.69 (15/29)	9
	C4	0.9807	17.73 (14/20)	12
	Non-Event	0.9861	13.06 (12/15)	15
	Intersection	0.9867	12.54 (11/14)	17
	C2	0.9875	11.84 (8/16)	18
	C3	0.9879	11.48 (8/15)	19
Parkway	C1	0.9867	12.55 (5/21)	16
	C4	0.9916	8.12 (3/12)	20
	Non-Event	0.9970	2.92 (0/6)	21
	Intersection	0.9976	2.33 (-1/+5)	22
	C2	0.9984	1.55 (-3/+7)	23
	C3	0.9988	1.15 (-4/+6)	24

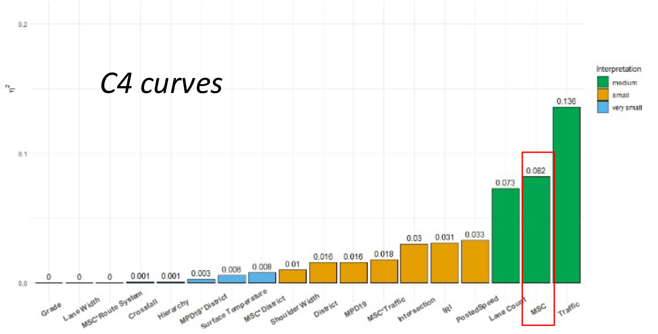
Network Analysis

Large effect sizes indicate a higher association with crash count, where *eta squared* is the proportion of total variance uniquely explained by the predictor. Traffic volume has the largest impact on crashes **followed by pavement friction** in all settings.









Prioritization Lists

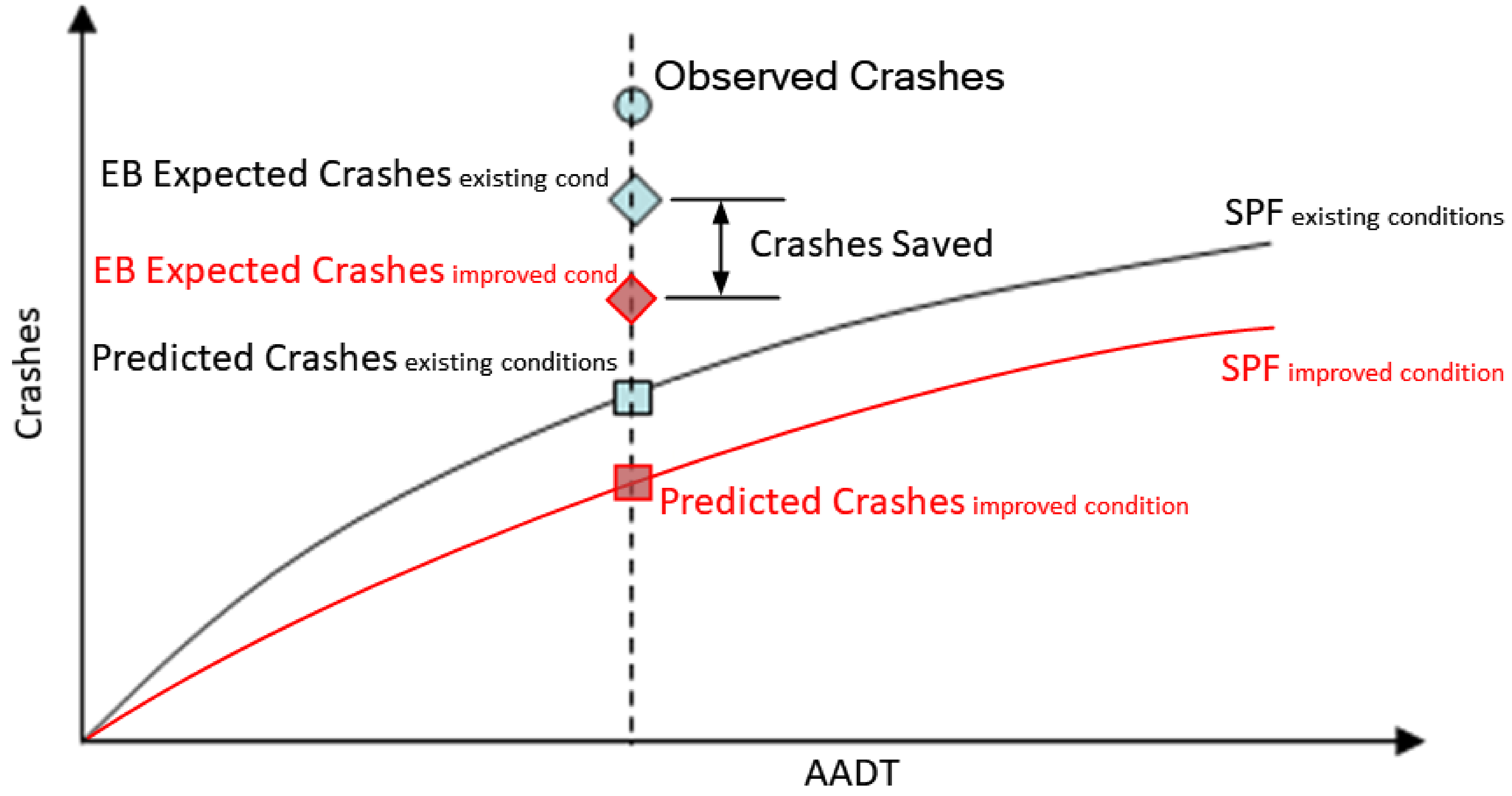
- Solutions Based application of an SPF is used to estimate the potential crash reduction for a specific friction improvement by calculating a “what-if” scenario for the entire network
- Solutions Based SPFs calculates the anticipated Crashes Saved as:

Crashes Saved = [EB expected crash value based on observed friction & texture values]

– [EB expected crash value based on the hypothetically improved friction & texture values]

- Example for HFST analysis: any site with a Friction value below 80 is increased to 80

Solution-Based SPF Analysis



Site / Treatment Selection Process

Four phases:

1) Data Collection
   - CPFM over ~15,000 lane miles of KYTC-managed roads

2) Data Integration and SPF prioritization
   - Friction data merged with crash, roadway, and pavement data
     - Crashes (all, wet) + KABCO severity rating
     - Speed, AADT, # Lanes, Lane width, Shoulder width
     - Last resurface date
   - Locations prioritized using "solutions based" SPF and projected ROI using weighted average crash costs

3) Field Review and Final Site Selections
   - Perform field review
     - Consider context of site
     - Are there other factors leading to skid-related crashes (e.g. clogged pipe/ditch/curb box)?
   - Incorporate industry feedback into site selection – adjust final site selection considering:
     - Realistic minimum treatment lengths
     - Potential to bundle with nearby sites (economy of scale)

4) Construction (advertisement and post-construction)
   - Package and submit construction proposals for advertisement of bids
   - Re-evaluate friction performance at locations using CPFM
   - Conduct before-after analysis of friction, texture, and crashes
     - How good did we do?
     - Is there any we can do to improve?

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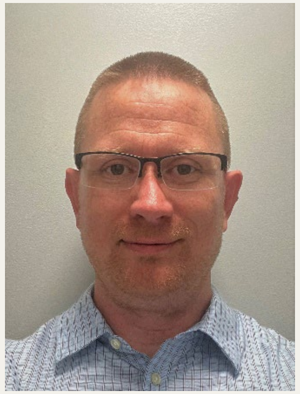

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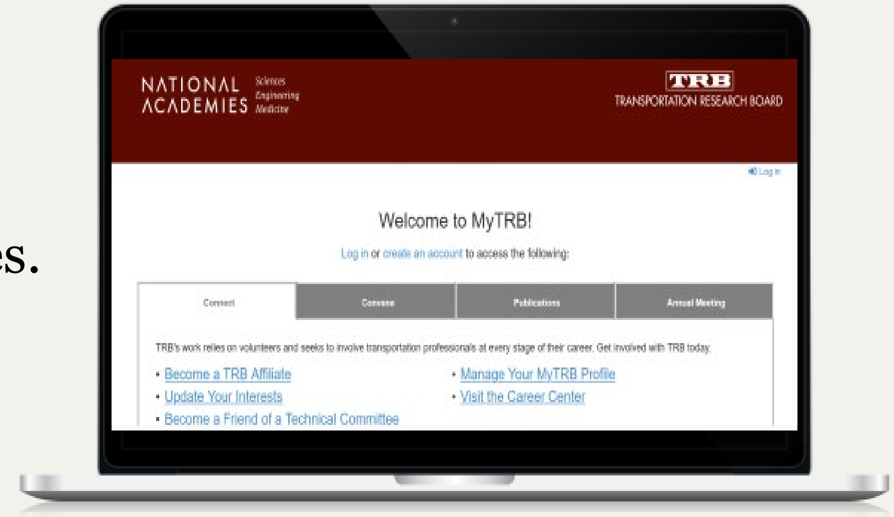

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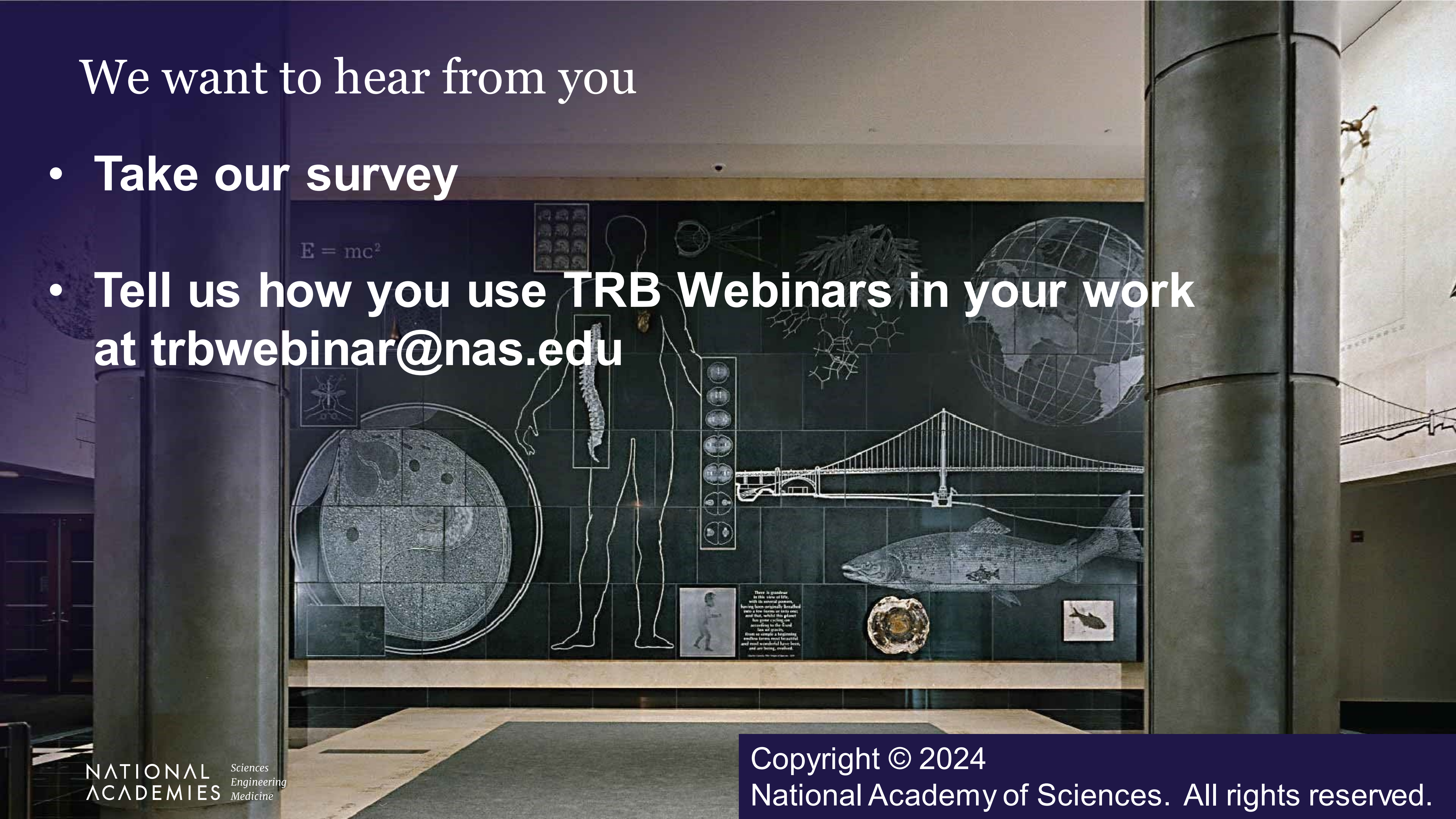

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