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2026 RPUG CONFERENCE ★ PITTSBURGH, PA ★ APRIL 28 – MAY 1

EVALUATING NETWORK-WIDE PAVEMENT ROUGHNESS DATA USING DUAL-LASER LONGITUDINAL PROFILING TECHNOLOGY

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ACKNOWLEDGEMENTS

- City of Toronto
  - Ali Al-Abbasi, M.Sc., PMP, P.Eng. – Senior Engineer, Asset Management, Transportation Services

- ICC-IMS
  - Paul Toom, P. Eng.
  - Dan Dobriceanu – Software Development Manager
  - Michael Nieminen, P.E., P.Eng. – CEO and Technical Director

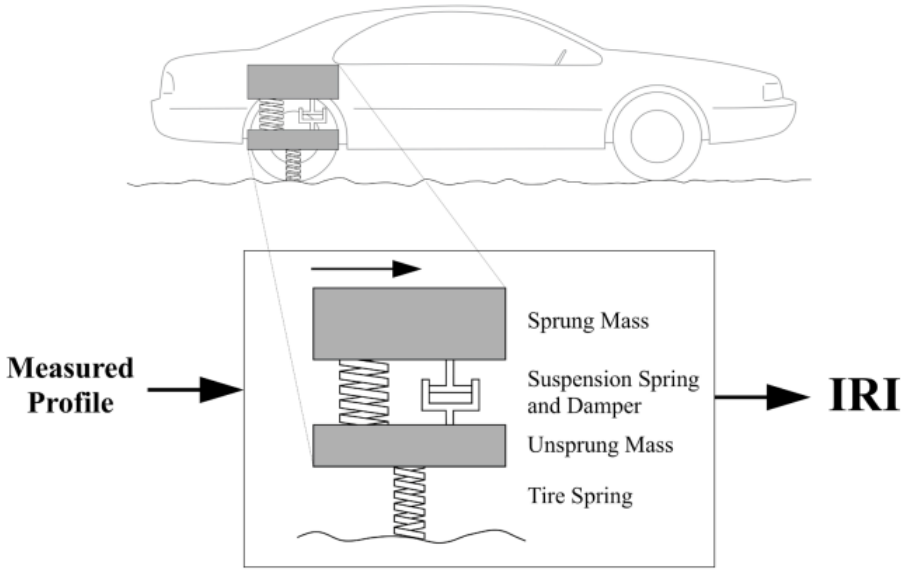
OUTLINE

- Background and Motivation
- Dual-Laser Profiling Technology and Validation
- Case Study
  - Coverage Expansion
  - IRI Comparison of Profiling Systems on Common Segments
  - IRI Characteristics of Newly Covered Segments
  - IRI vs PCI Condition Classification
- Key Findings

INTERNATIONAL ROUGHNESS INDEX (IRI)

- Definition
  - Standardized measure of Pavement roughness
  - Derived from a quarter-car simulation applied to measured longitudinal profile
  - Computed at a Simulated travel speed of 50 mph/80 kph
  - Reported in in/mi or m/km

- Applications
  - Network-level Condition Monitoring
  - HPMS Reporting
  - Maintenance and Rehabilitation Decision-making
  - Program and Budget planning
  - Construction Quality Assessment



Quarter-car model

Illustration credit: Karamihas, S.M. and Sayers, M.W. (2025). The Little Book of Profiling, Second Edition. University of Michigan Transportation Research Institute.

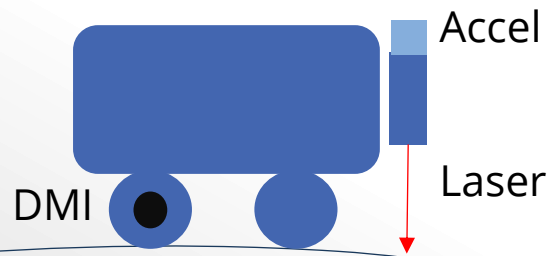
CONVENTIONAL PROFILERS

High-Speed Inertial Profiler (HSIP)

- Primary measurement components:
  - Lasers to measure pavement surface elevation relative to the vehicle
  - Accelerometers to account for vehicle vertical motion
  - Distance Measurement Instrument (DMI) for distance measurement and spatial referencing

Conventional Inertial Profiler

- Operating conditions that can compromise usable IRI coverage:
  - Acceleration and Deceleration
  - Stop-And-Go Conditions
  - Low-Speed operation (Under 20 KPH or 13 MPH)



EVERY SPEED PROFILER (ESP)

US Patent No. 9,404,738, Canadian Patent No. 2,849,225

- Dual-Laser Longitudinal Profiling Technology
- This patented technology addresses the challenges inherent in conventional inertial profilers
- Valid profile and IRI At Any Speed

EVERY SPEED PROFILER (ESP)

US Patent No. 9,404,738, Canadian Patent No. 2,849,225

THE ESP USES A NEW WORKING PRINCIPLE:

- DUAL LINE LASERS IN EACH WHEELPATH
- IMU TO MEASURE ORIENTATION IN EACH WHEELPATH
- NEW PROFILE CALCULATION ALGORITHM

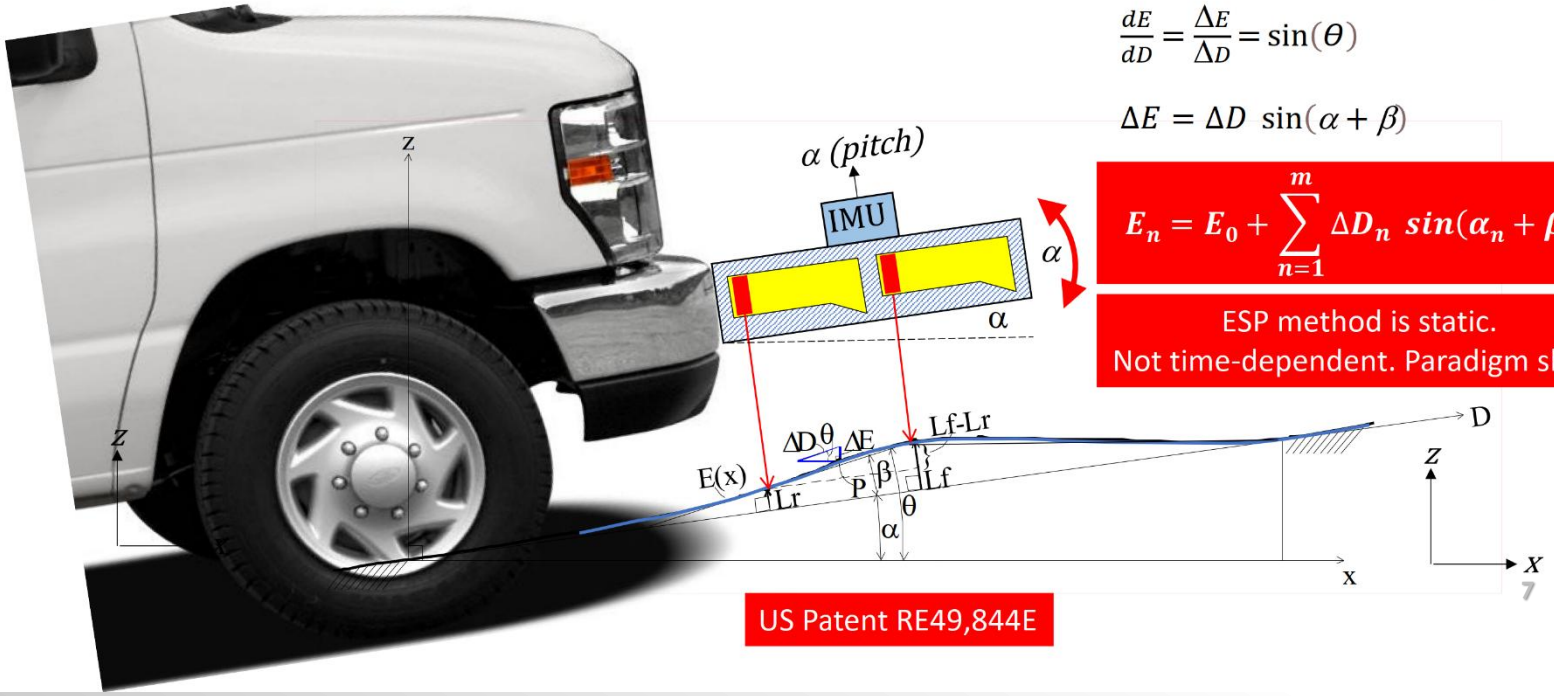
$$\theta = \alpha + \beta \qquad \beta = \tan^{-1}\left(\frac{(L_f - L_r)}{L}\right)$$

$$\frac{dE}{dD} = \frac{\Delta E}{\Delta D} = \sin(\theta)$$

$$\Delta E = \Delta D \ \sin(\alpha + \beta)$$

$$E_n = E_0 + \sum_{n=1}^{m} \Delta D_n \ sin(\alpha_n + \beta_n)$$

ESP method is static.
Not time-dependent. Paradigm shift!



US Patent RE49,844E

ESP VS HSIP

	High-Speed Inertial Profiler (HSIP)	Every Speed Profiler (ESP)
Equipment Required per Wheelpath	1 laser, 1 vertically aligned accelerometer	2 lasers, 1 IMU
Use Cases	Highways and roadways with free-flowing traffic conditions	Any roadway type regardless of traffic conditions (e.g., urban, congested, signalized)
Operation Restrictions	Near constant speed	Any speed, stop and go, hard acceleration, long stops
Min Speed	13 MPH	0 MPH
Max Speed	70 MPH	70 MPH

ESP ICART VALIDATION

- Participated in validation runs at the ICART test track in Illinois (2024, 2025, 2026)
- New certification tests have been proposed for profilers under AASHTO R56 standard

- Five test types:
  1. Constant 45mph
  2. Constant 3mph
  3. Braking 30-15mph
  4. Full Stop 30-0-30mph
  5. Stop Creep 30-0-5-30mph

- Conventional HSIP will fail tests 2-5

Illinois Certification and Research Track (ICART)

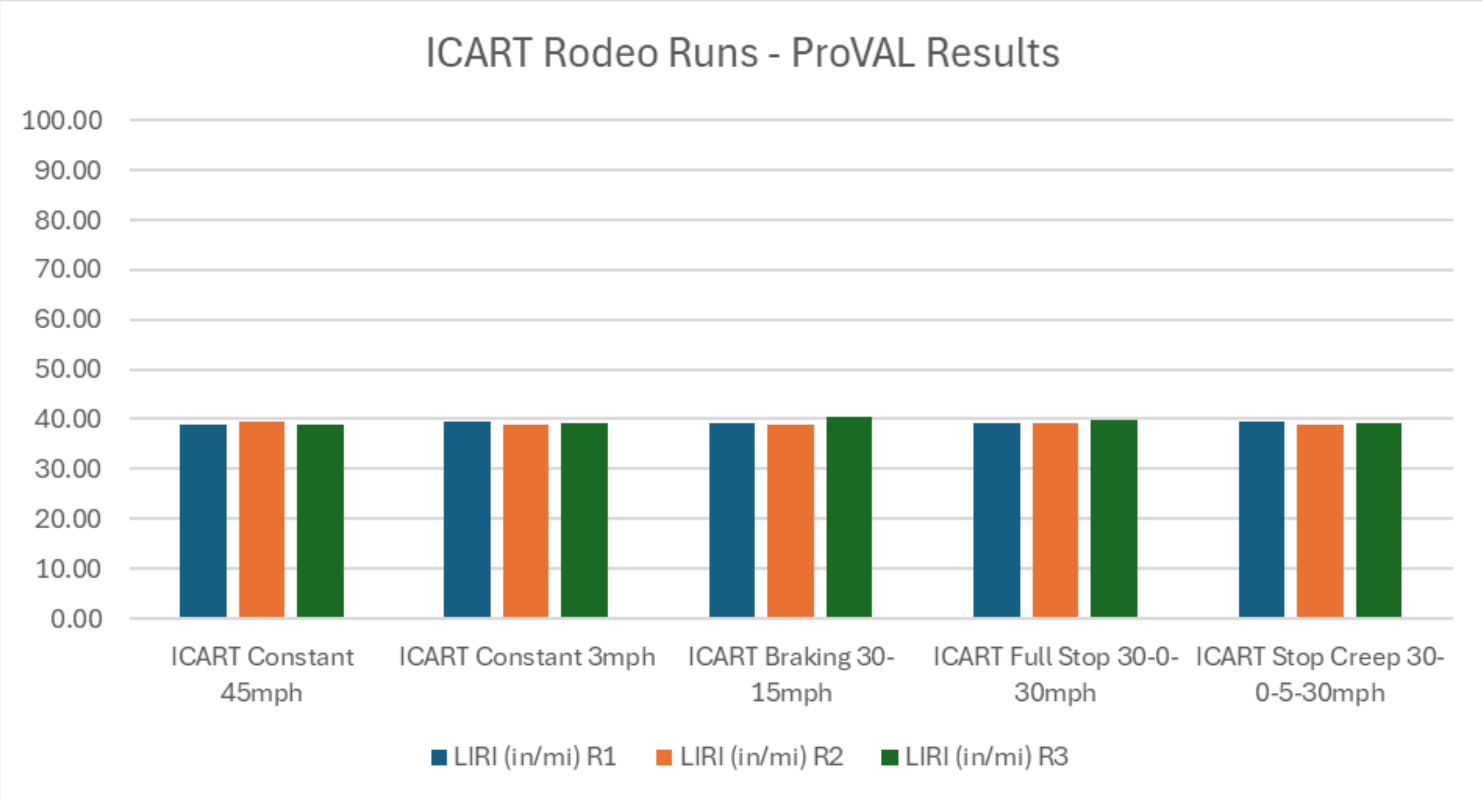
SAMPLE PROFILE OUTPUTS

30-0-30 mph and 30-0-5-30mph runs

ESP ICART VALIDATION RESULTS

ICART Test Results

- We achieved excellent IRI repeatability on all tests!
- The new ESP is performing as expected



ESP ICART CERTIFICATION

- Successfully passed all tests and surface types at the ICART certification in March 2026!
- Two test sections
  - HMA
  - Diamond Ground CRCP
- Test runs
  - 5 passes at 25 MPH
  - 5 passes at 50 MPH
- passing score Requirement:
  - 0.92 for repeatability
  - 0.90 for accuracy
- New Stop-and-Go certification tests Expected in 2027

Illinois Certification and Research Track (ICART)

CASE STUDY

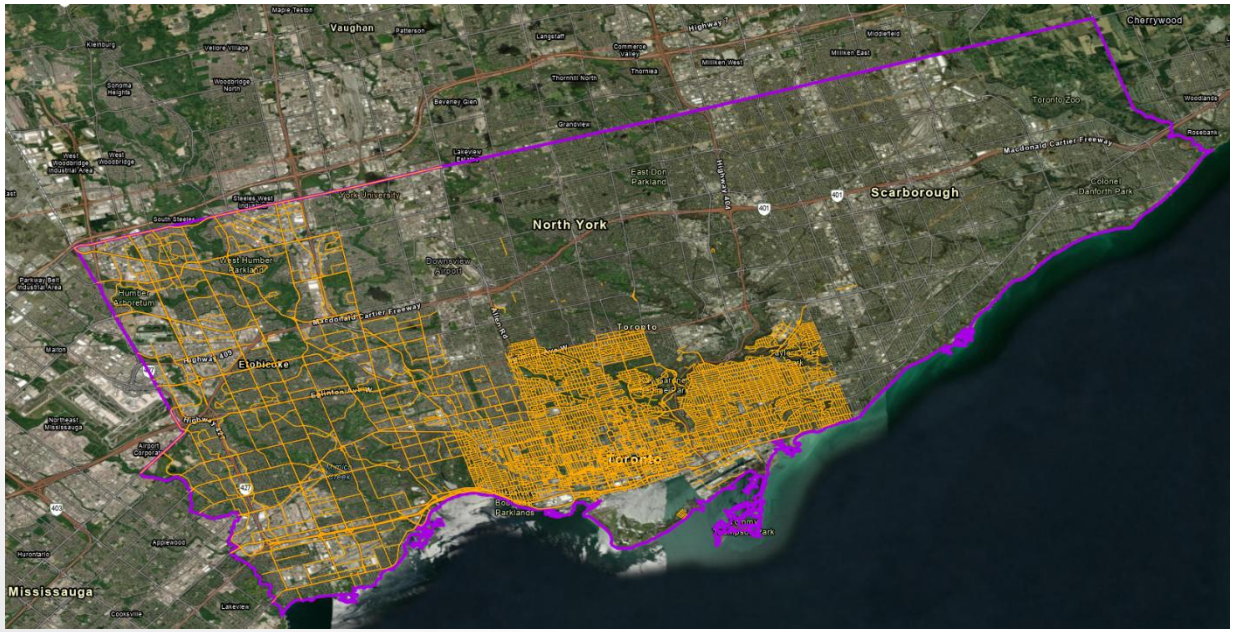
CASE STUDY: CITY OF TORONTO

CITY NETWORK SURVEYED BY ICC-IMS TRUCK EQUIPPED WITH BOTH

- ESP
- HSIP

2025 SURVEY MILEAGE: 1391.78 MILES *(PARTIAL NETWORK)*

- REPORTED SEGMENTS AT 200-FT (60.96 M) INTERVAL

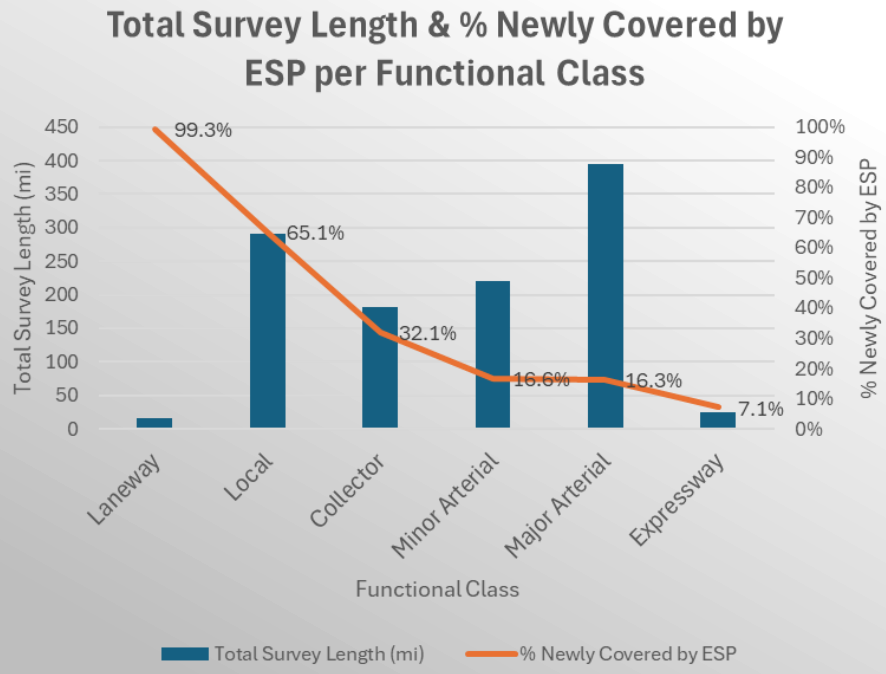


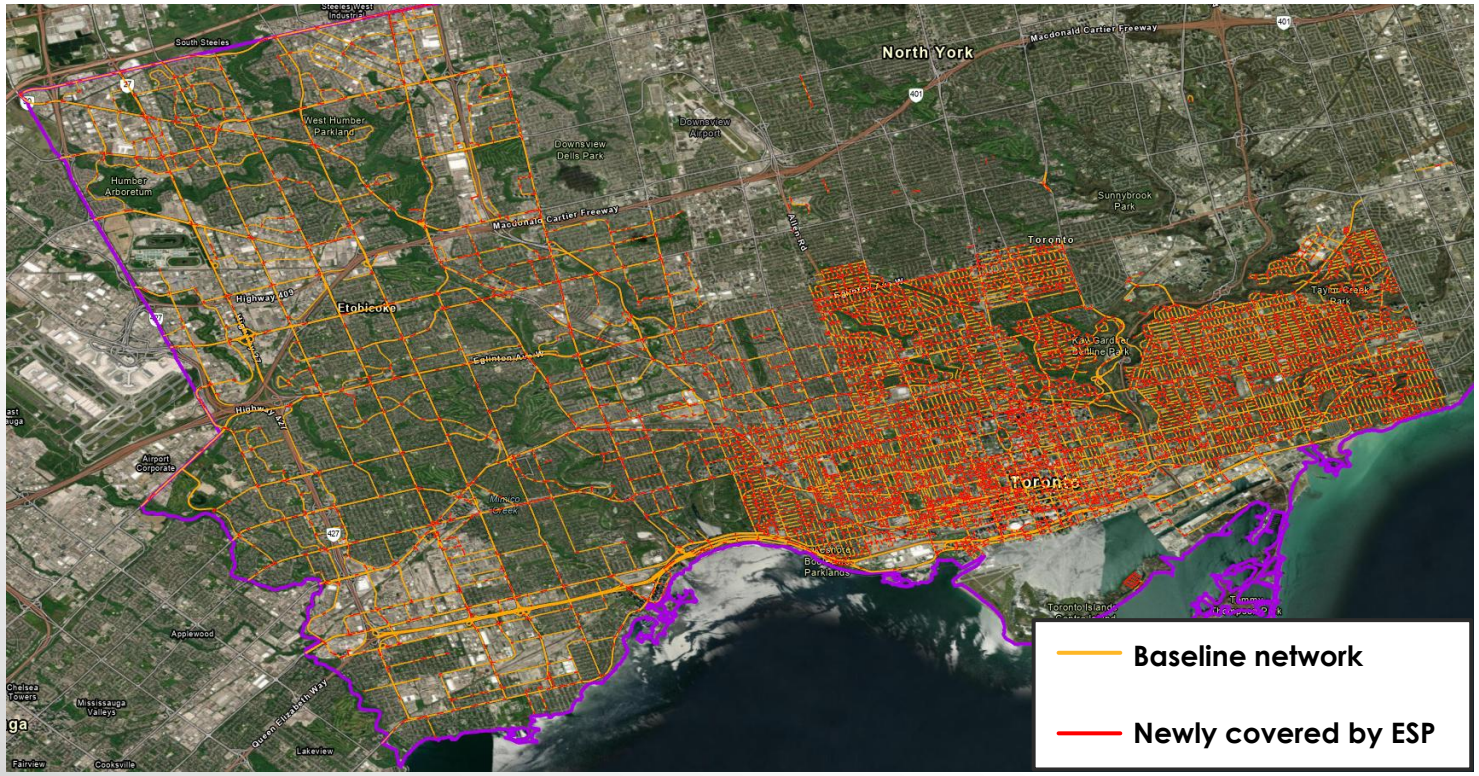
COVERAGE EXPANSION

BASELINE AFTER FILTERING OUT SEGMENTS WITH:
- **EVENTS: BRIDGE, BUMP, LANE DEVIATION, CONSTRUCTION, STREETCAR, RAILROAD**
- **LENGTH < 25FT (7.62 M)**

NEWLY COVERED SEGMENTS BY ESP:

- SPEED MIN < 12.427 MPH (20 KPH)
- 366.7 MILES (32.5% OF BASELINE NETWORK)





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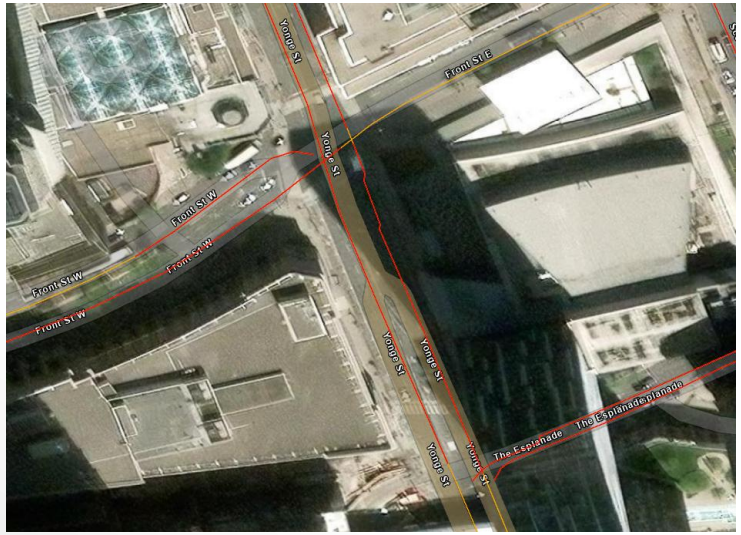
REPRESENTATIVE NEWLY COVERED SEGMENTS

SIGNALIZED INTERSECTION

NON-SIGNALIZED INTERSECTION (STOP SIGN)

REPRESENTATIVE NEWLY COVERED SEGMENTS

URBAN STREET



RESIDENTIAL STREET

REPRESENTATIVE NEWLY COVERED SEGMENTS

CELEBRATING 250 YEARS OF PROGRESS
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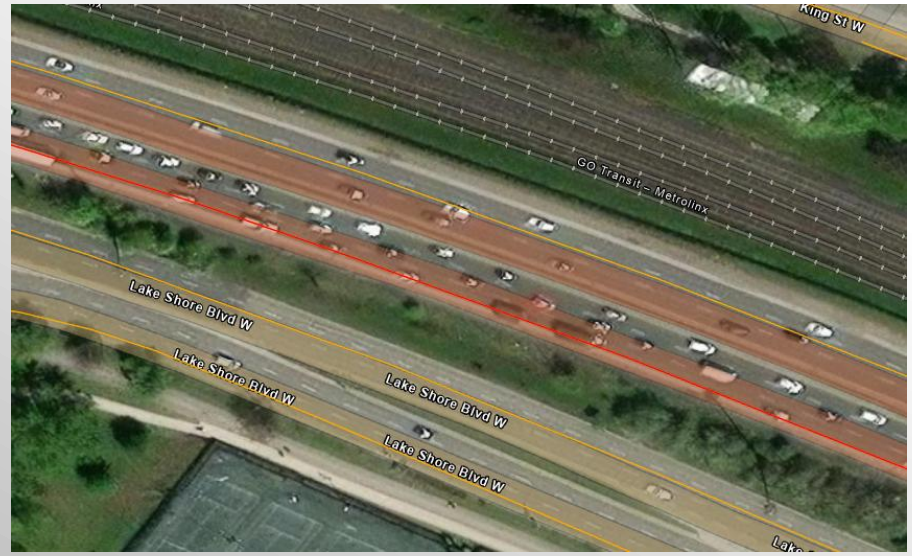
CONGESTED MAJOR ARTERIAL

CONGESTED FREEWAY



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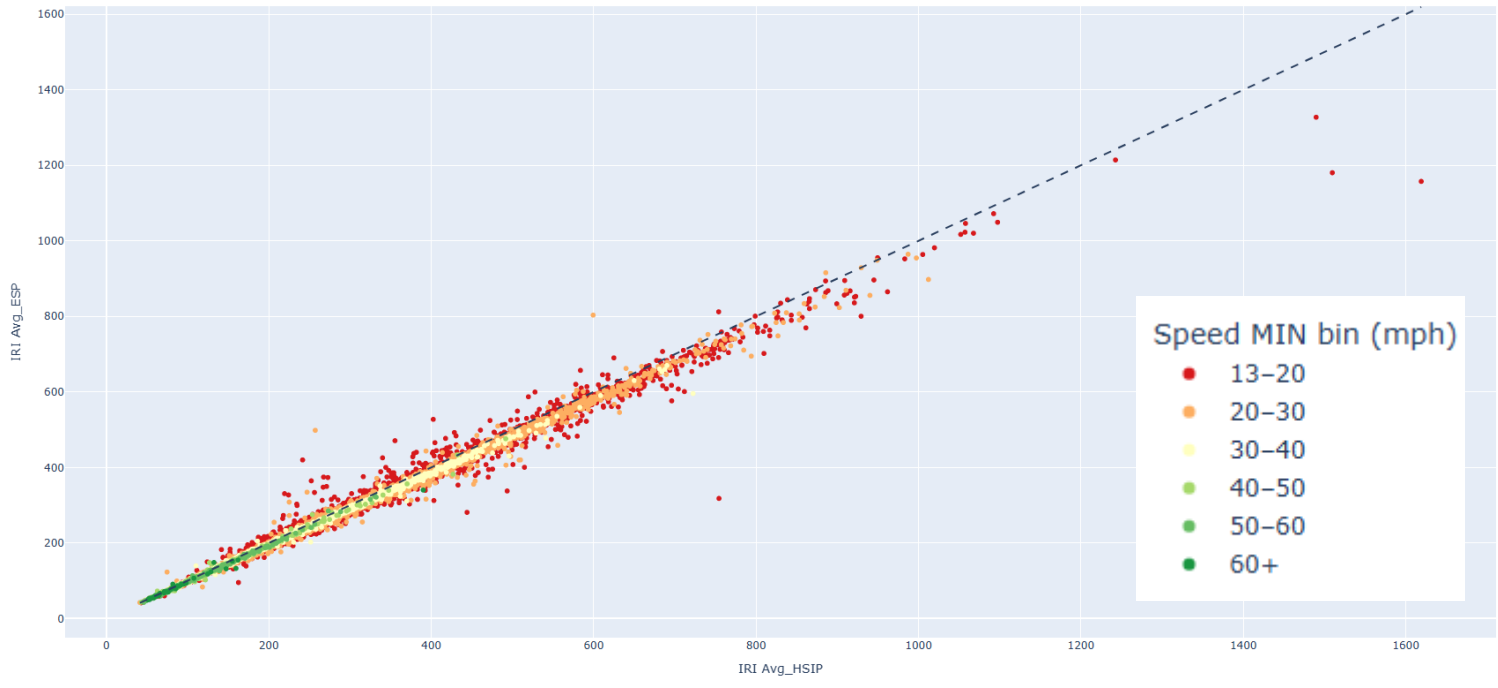
REPRESENTATIVE NEWLY COVERED SEGMENTS

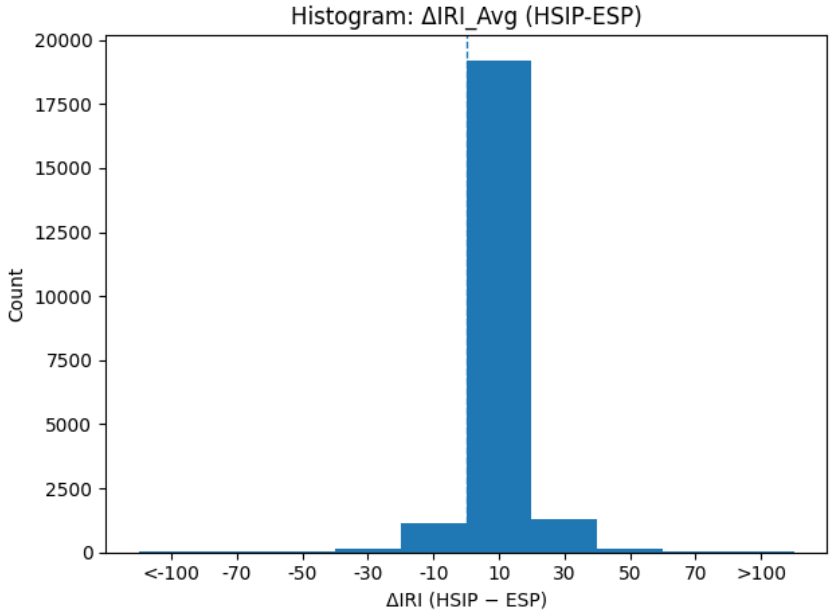
RAMP

IRI COMPARISON OF PROFILING SYSTEMS ON COMMON SEGMENTS

- IRI Average (ESP) vs IRI Average (HSIP) for 200-ft Segments
  - Labeled by Speed Min



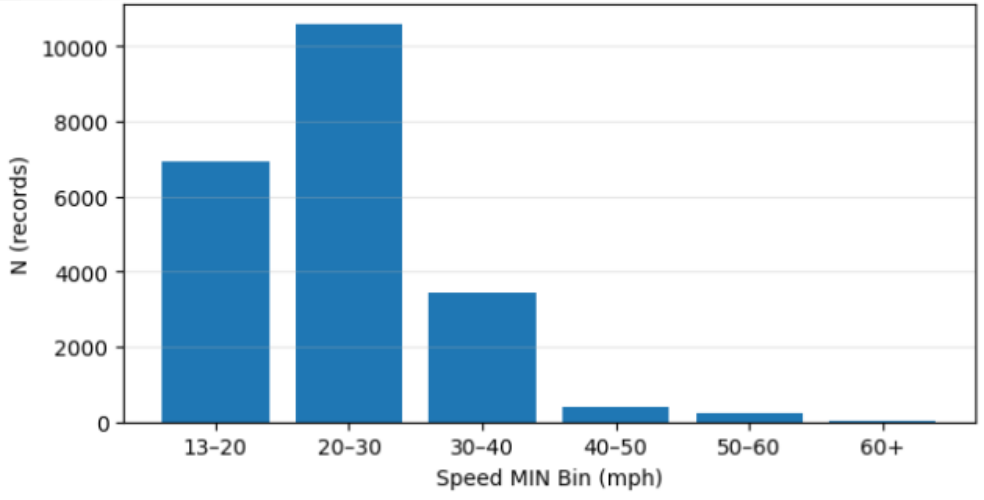
- Histogram of Δ IRI Avg (HSIP - ESP)

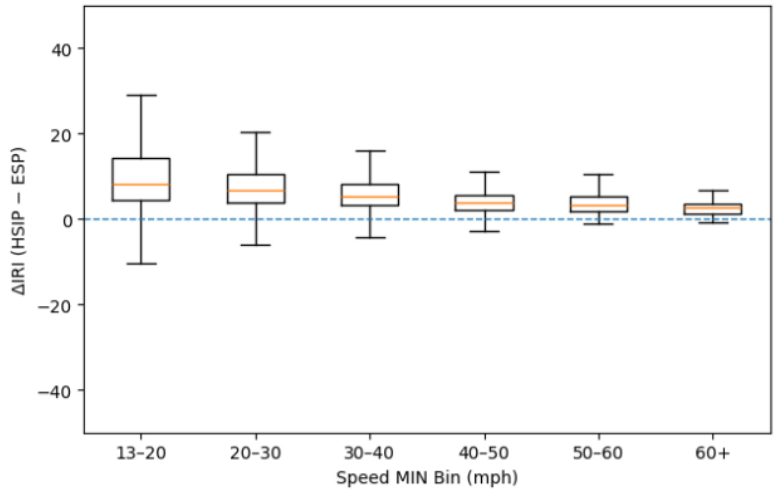


- **Strong agreement between the two profiling systems on common segments**
- **HSIP generally reports slightly higher IRI values than ESP**

IRI COMPARISON OF PROFILING SYSTEMS ON COMMON SEGMENTS

- Δ IRI Avg (HSIP - ESP) vs Speed Min for 200-ft Segments

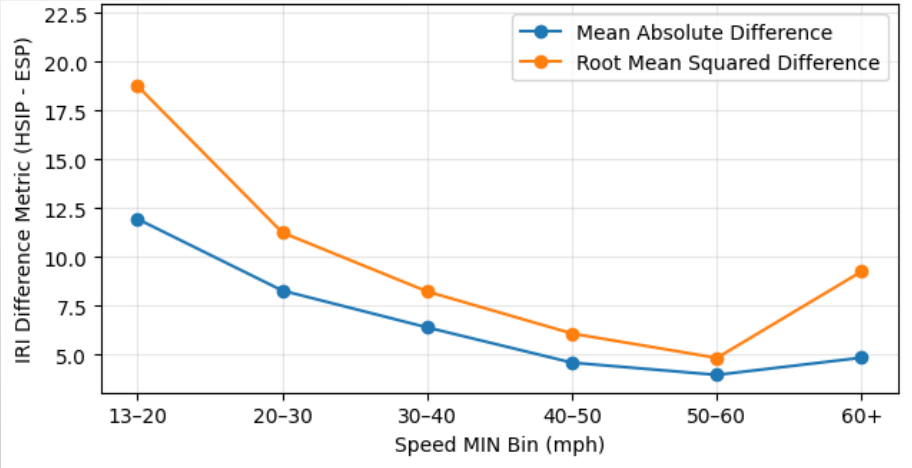


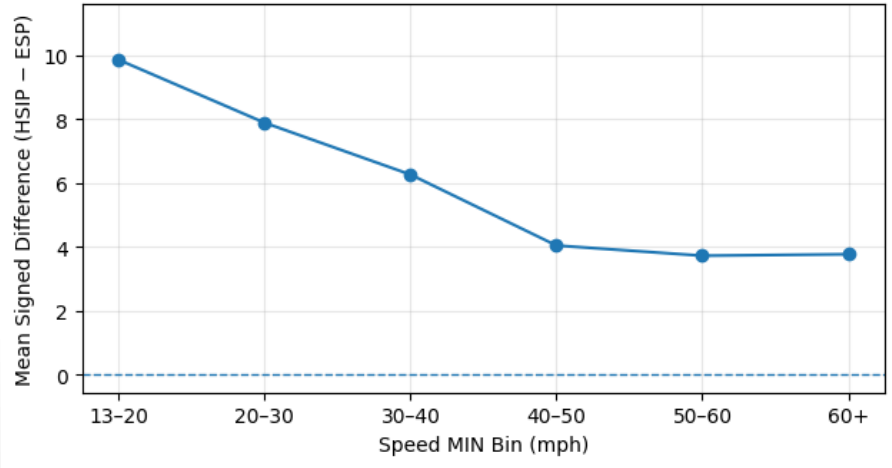


- Most segments were collected under low-speed conditions
- HSIP generally reports higher IRI than ESP across all speed bins
- Bias and variability are greatest at lower speeds and decrease with increasing speed

IRI COMPARISON OF PROFILING SYSTEMS ON COMMON SEGMENTS

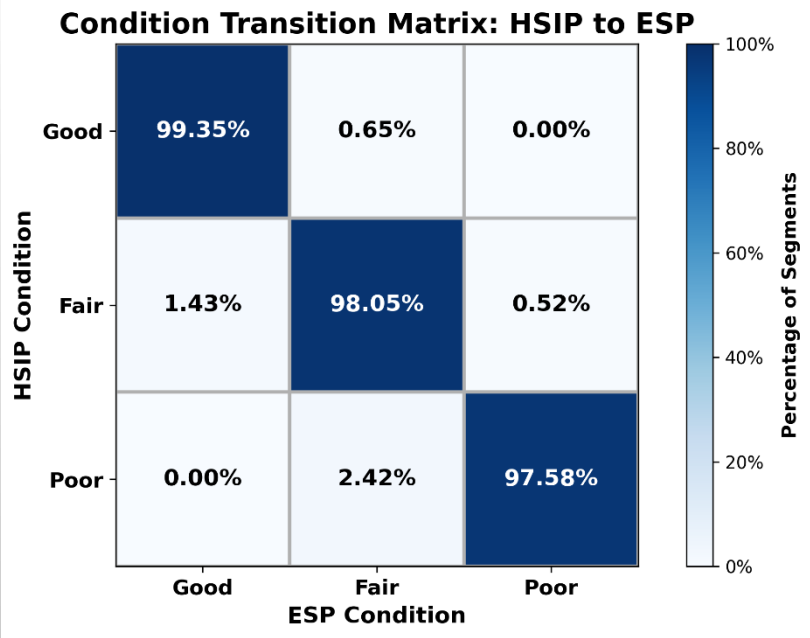
- Difference Metrics (HSIP – ESP) By Speed Min Bins
  - Mean Absolute Difference
  - Root Mean Squared Difference
  - Mean Signed Difference

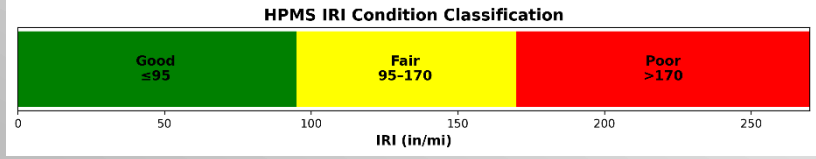


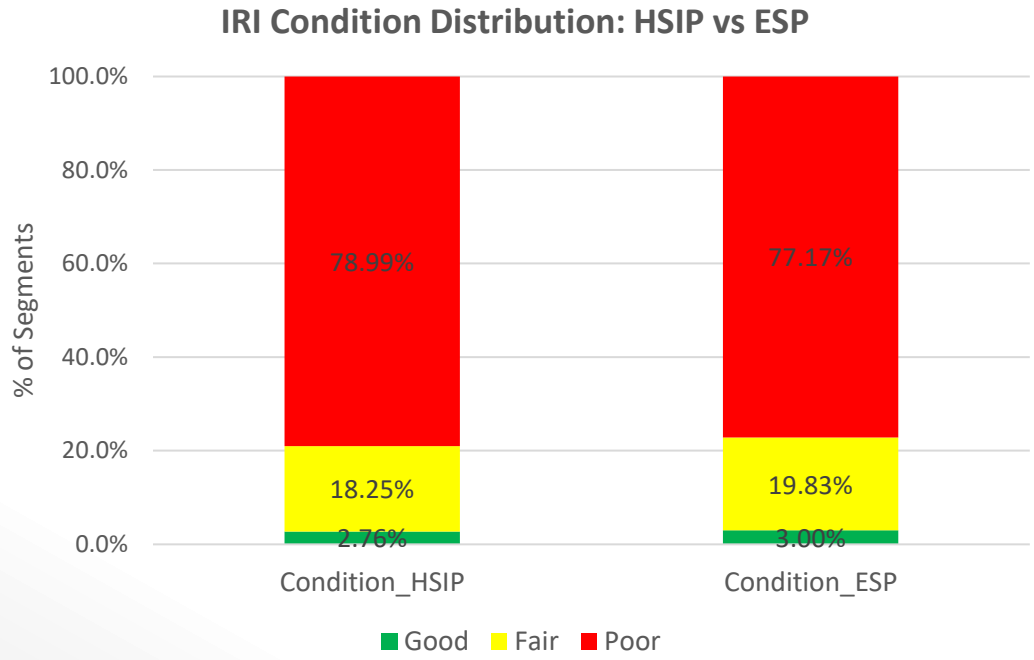


IRI COMPARISON OF PROFILING SYSTEMS ON COMMON SEGMENTS

- IMPACT ON IRI CONDITION REPORTING

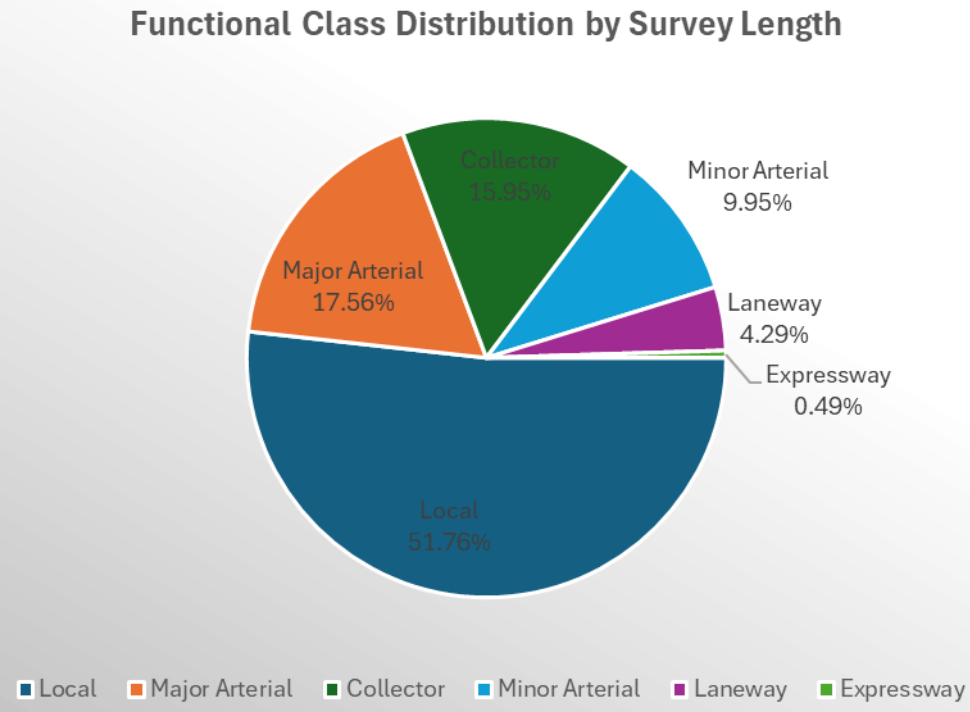


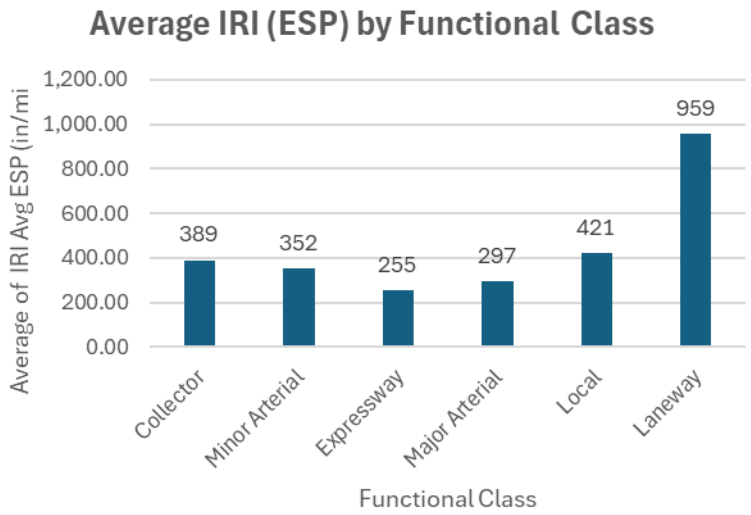


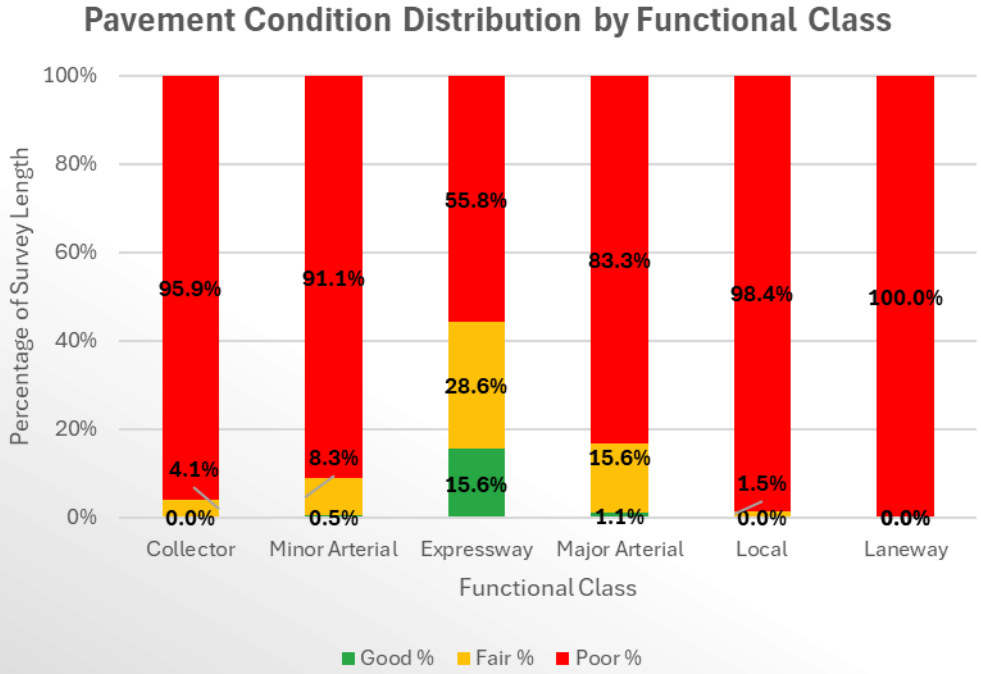


Mean IRI Avg (in/mi)	HSIP	ESP
	272.4	264.4

IRI CHARACTERISTICS OF NEWLY COVERED SEGMENTS

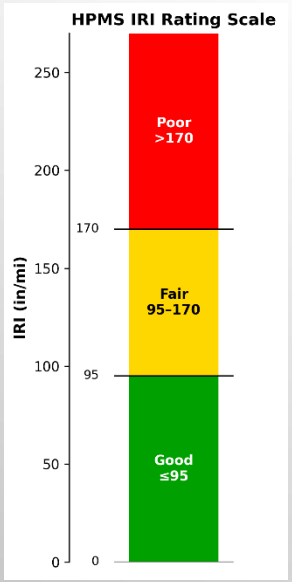


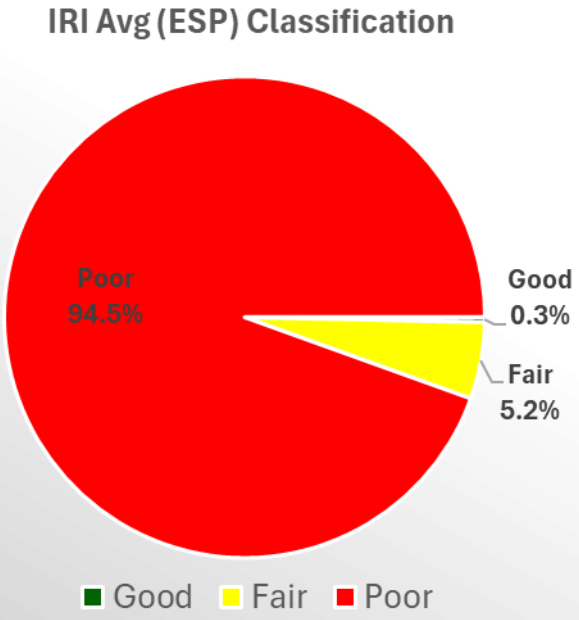


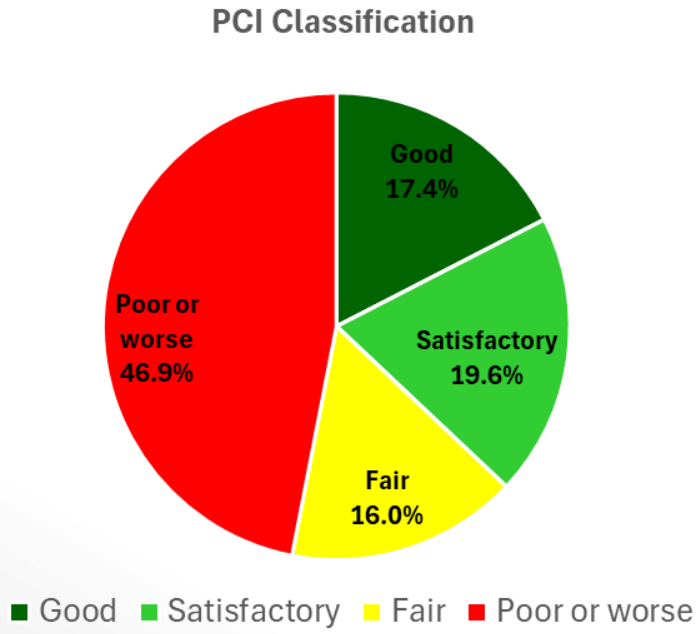


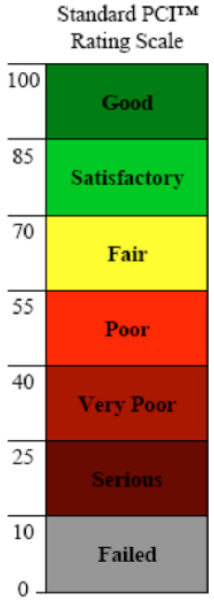
IRI VS PCI CONDITION CLASSIFICATION

Newly Covered Segments by ESP



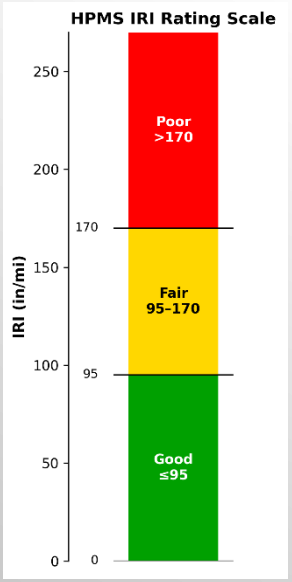


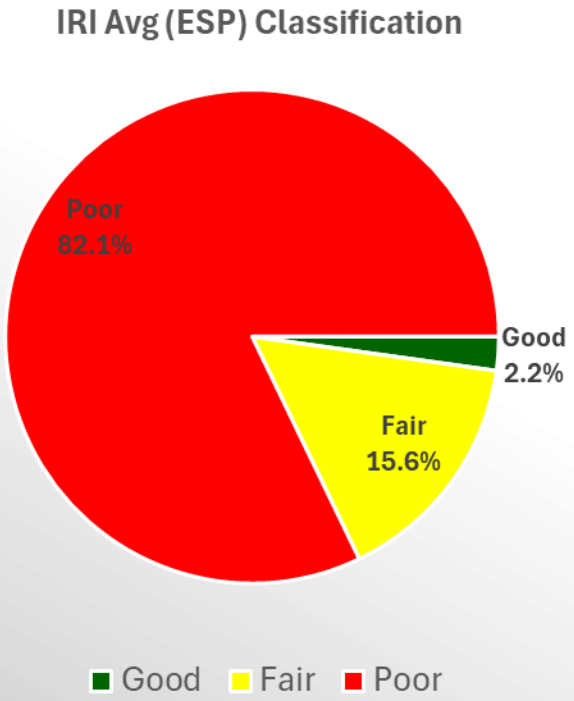


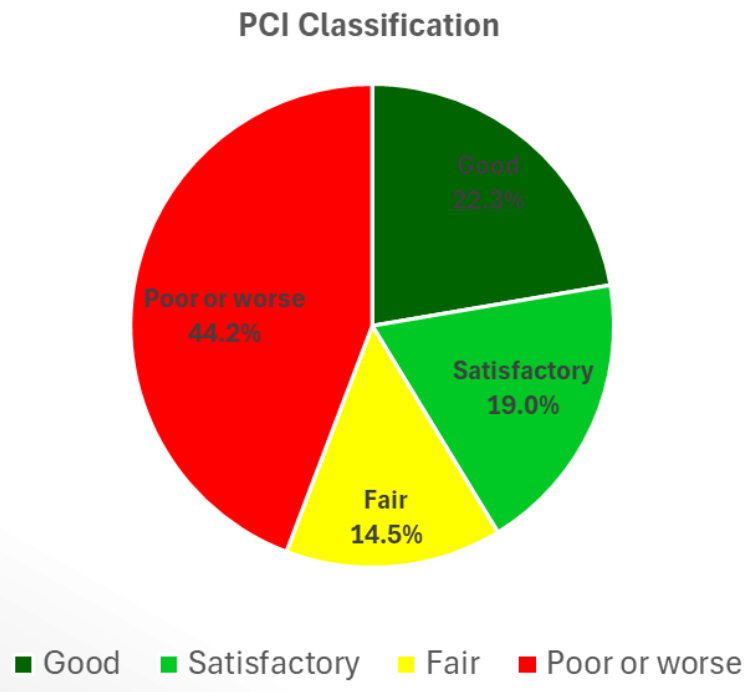


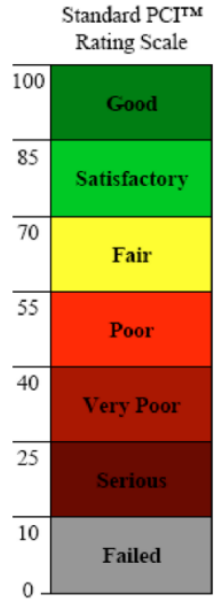
IRI VS PCI CONDITION CLASSIFICATION

Entire Surveyed Baseline Network









KEY FINDINGS

- Dual-laser longitudinal profiling systems, such as ESP, can provide full-coverage IRI data across a broader range of operating conditions.
- Case study results from the City of Toronto network showed:
  - Strong agreement between HSIP and ESP on common segments, with HSIP generally reporting slightly higher IRI values, likely due to greater susceptibility to profile noise.
  - ESP produced consistent IRI condition classifications on segments also measured by HSIP, supporting a smooth transition for agencies considering ESP-based IRI reporting.
  - The large discrepancy between IRI-based and PCI-based classifications for low-speed roads is unlikely to reflect true pavement condition, as IRI classifies most segments as Poor.
- With newly available reliable longitudinal profile data for low-speed roads, a standardized roughness assessment framework should be established.

THANK YOU!

Q/A

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