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Lowering Pavement Evaluation Costs Using Big Data

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T.H.E. 2016

NATIONAL SECURITY | ENERGY & ENVIRONMENT | INFRASTRUCTURE | HEALTH SOLUTIONS

The evolution of pavement data collection

- Manual
- Vehicle based data collection
  - Film
  - Digital
- Current 3D Systems
- PaveVision
- Smart Phone
- Smart Roads

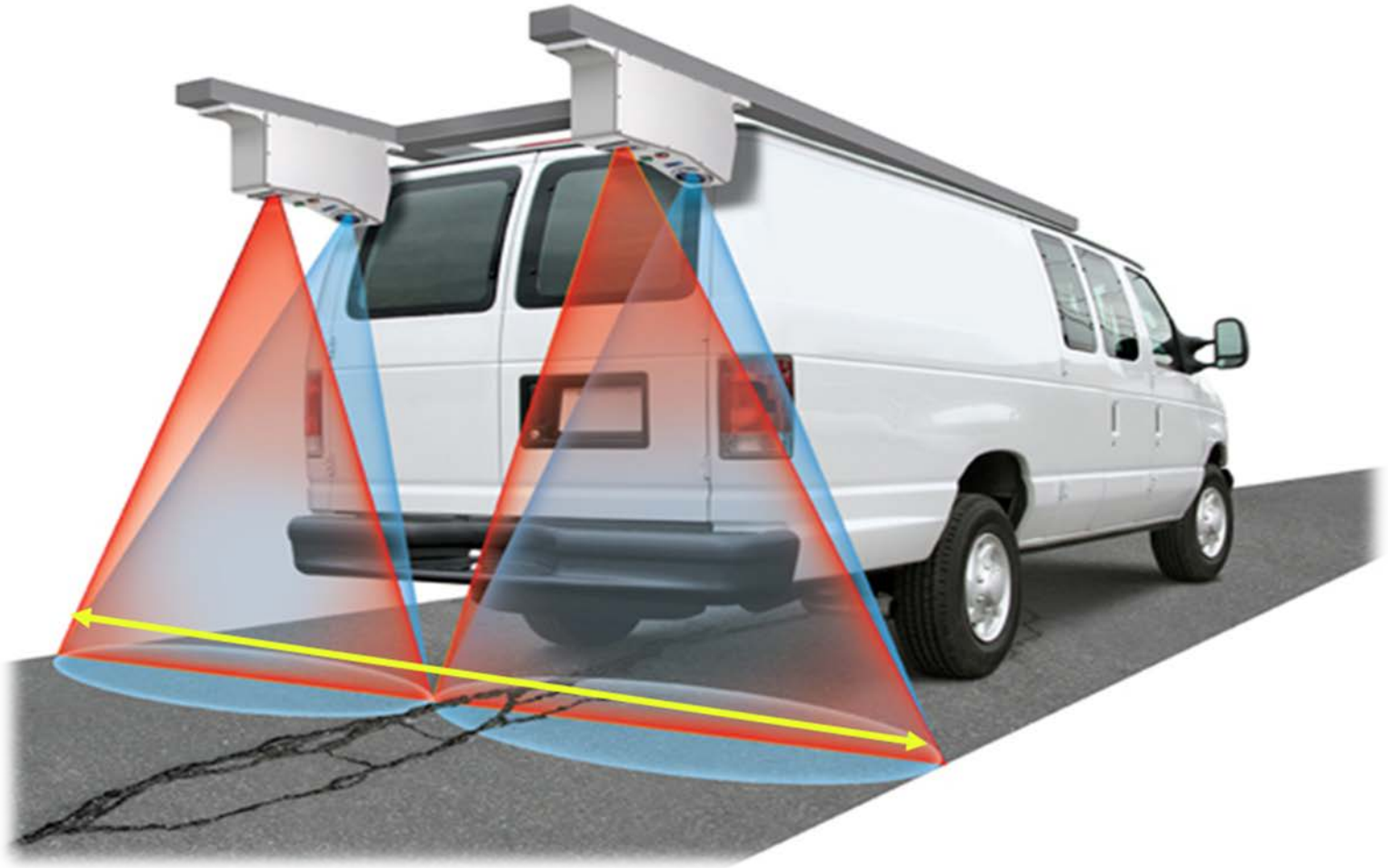
Pavement Evaluation Data Collection Continues to Evolve

Early Attempt at Pavement Data Collection

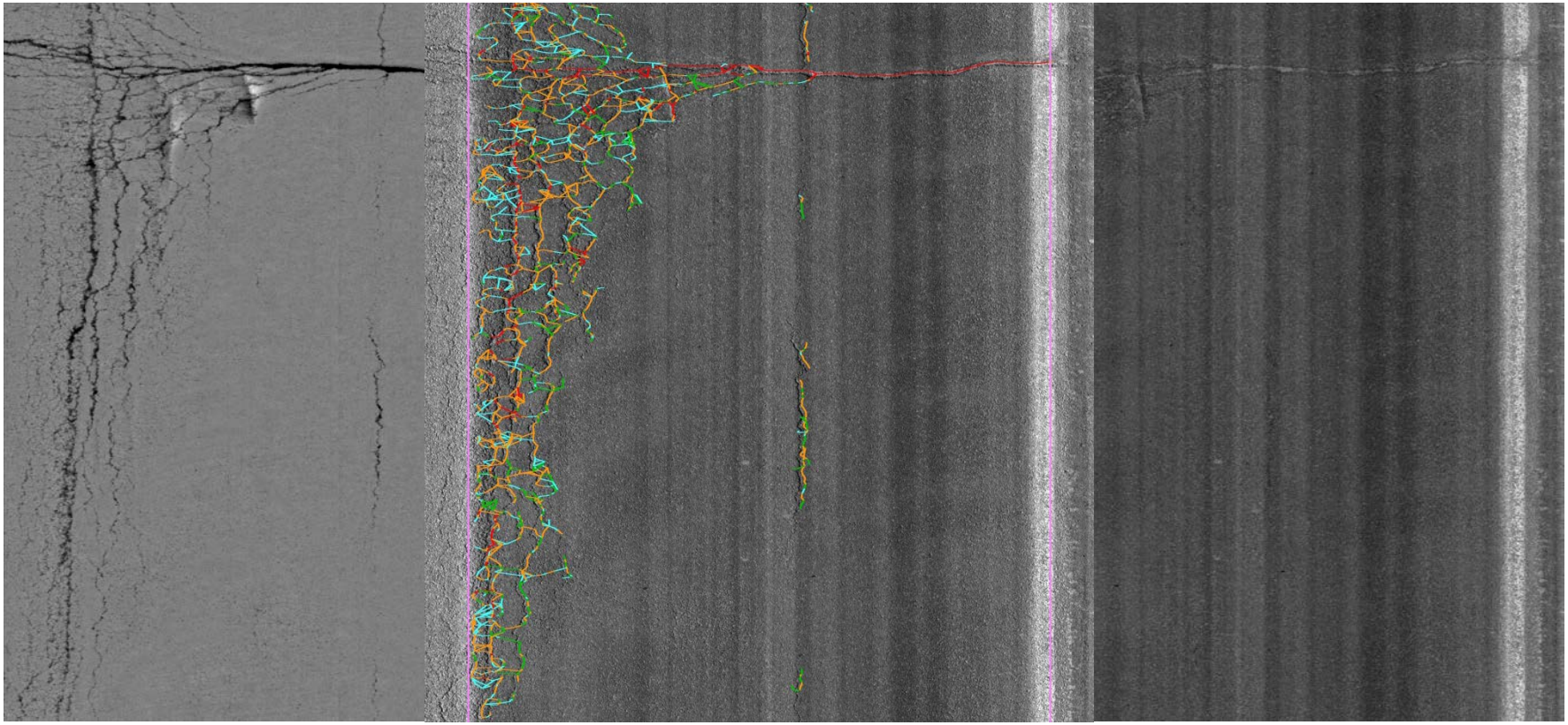
Pavement Evaluation Data Collection Continues to Evolve

Pavement Evaluation Data Collection Continues to Evolve

The Current State of the Art is 3D



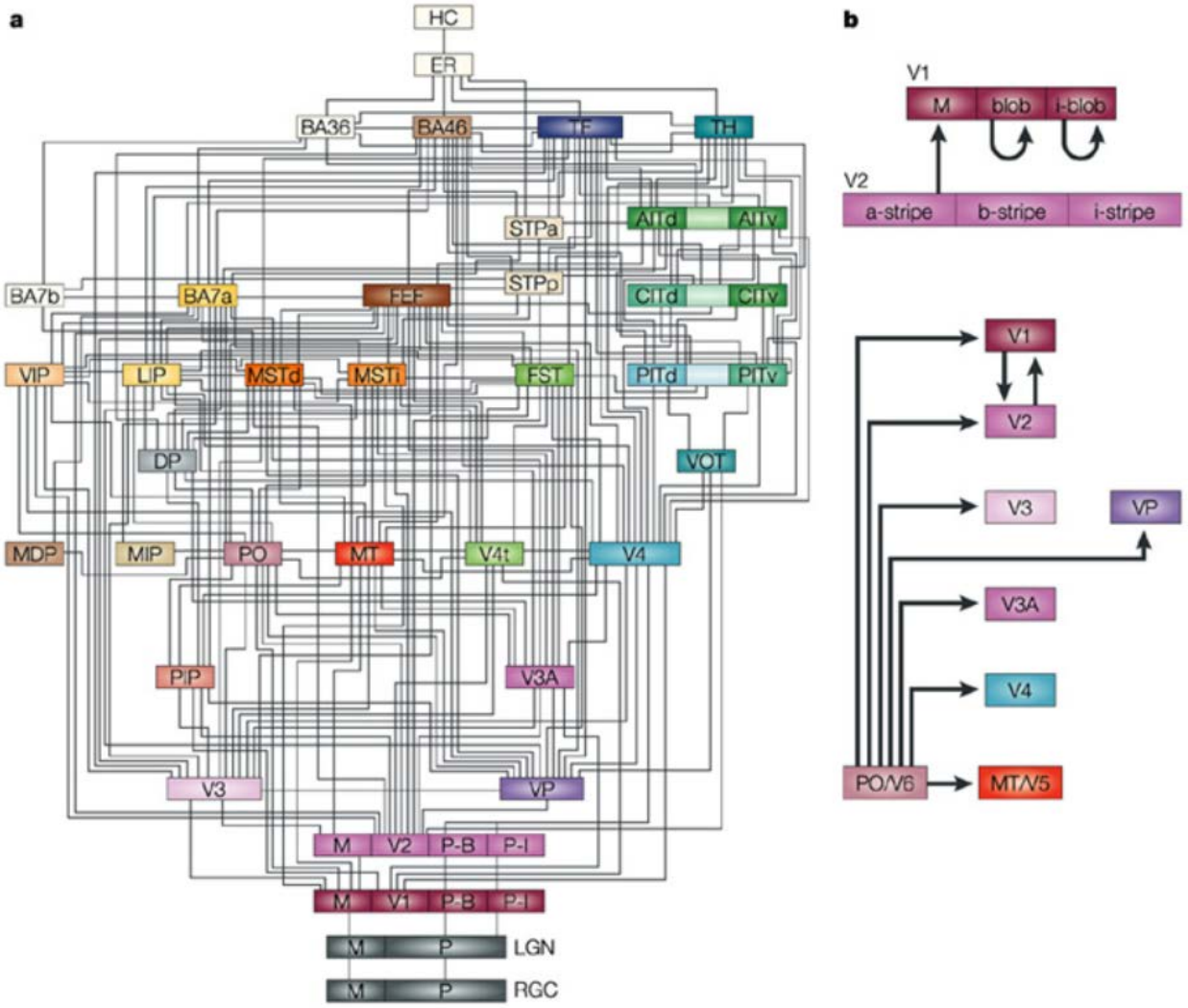
The analysis potential increases



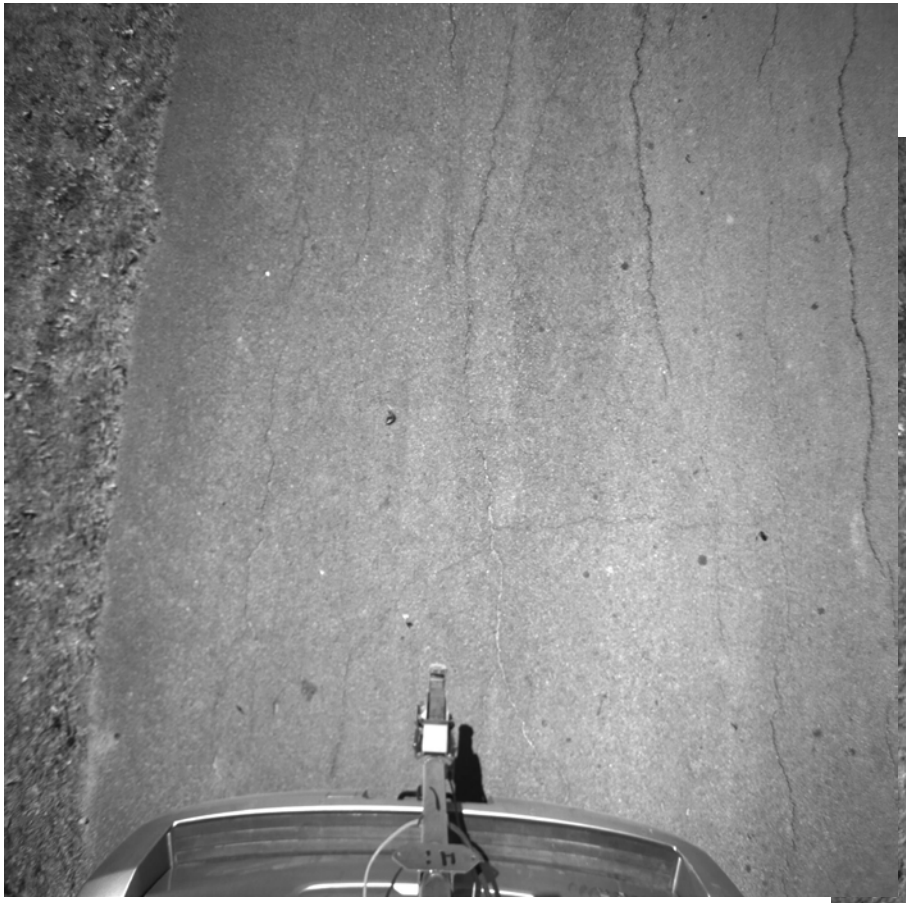
Range **3D** **Intensity**

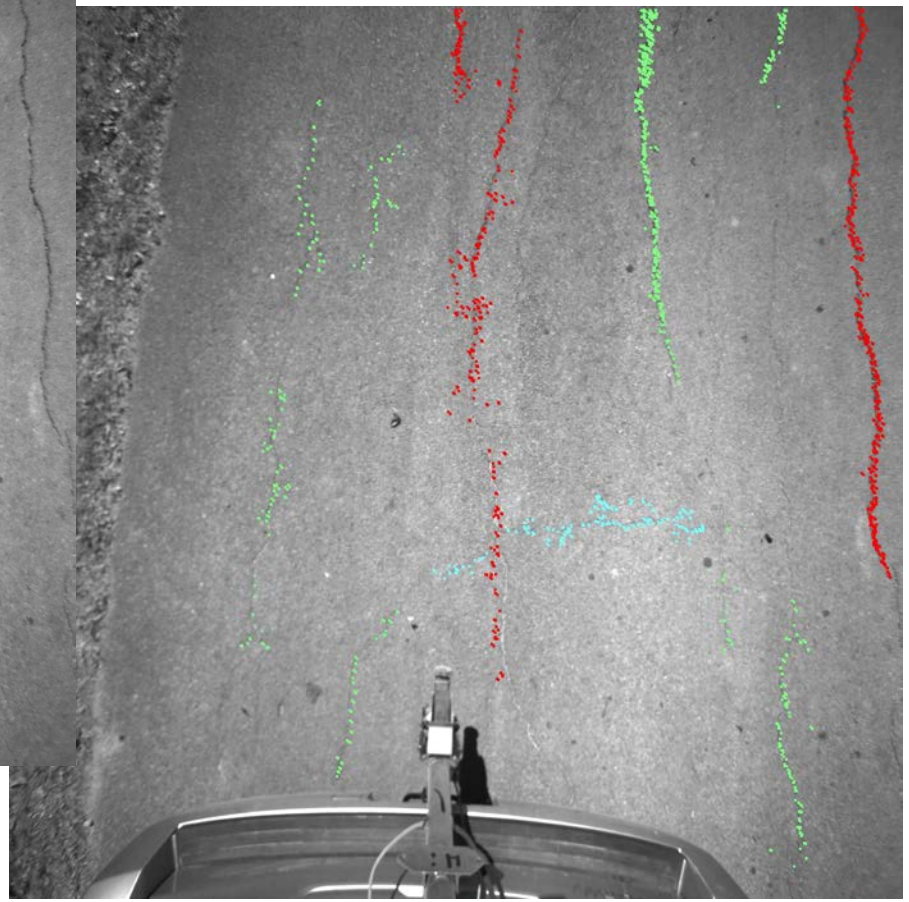
The next generation is now here

Advanced Computer Vision Is Changing Data Analysis



PaveVision is low cost with the ability for automated data analysis





And it will continue to evolve

Road User's Opinion of Roughness

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Nation's Crumbling Roads Put a Dent in Drivers' Wallets

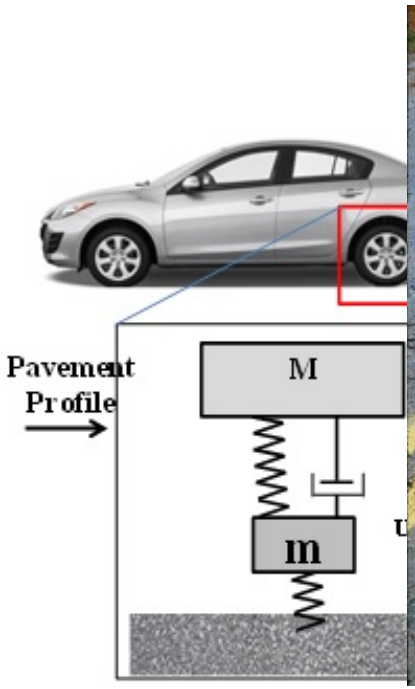
Deteriorating highways are adding to auto maintenance costs in the U.S.

http://www.wsj.com/articles/nations-crumbling-roads-put-a-dent-in-drivers-wallets-1438365456

Road and Highway Conditions

Pavement Roughness

- Defined in engineering practice as surface unevenness which adversely affects ride comfort
- Expressed by a numerical scale called the International Roughness Index (IRI)

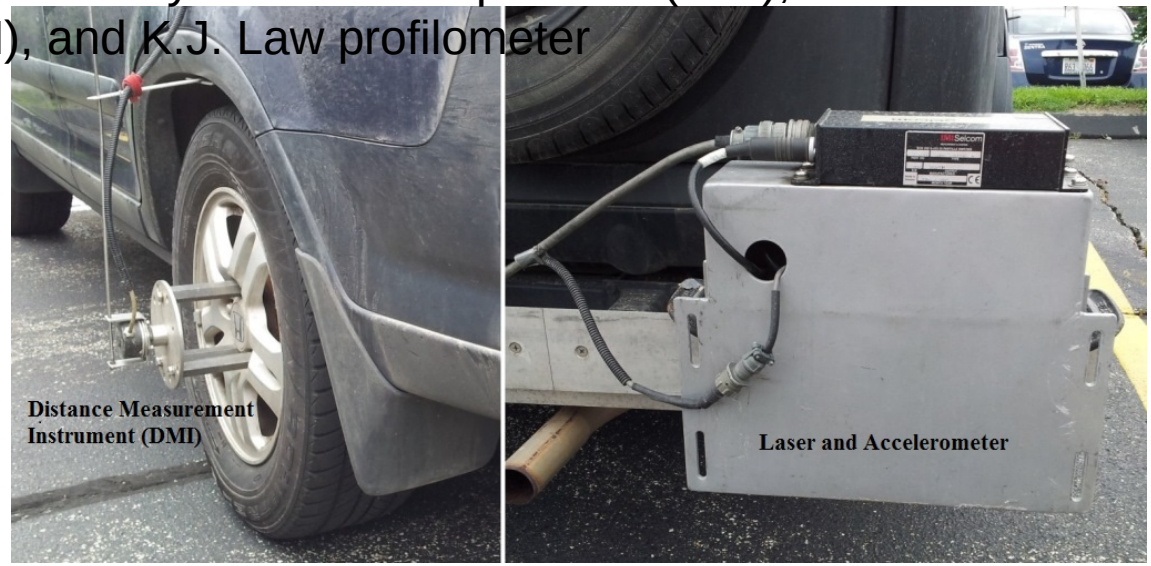


Quarter-car Model

Inertial Profiler

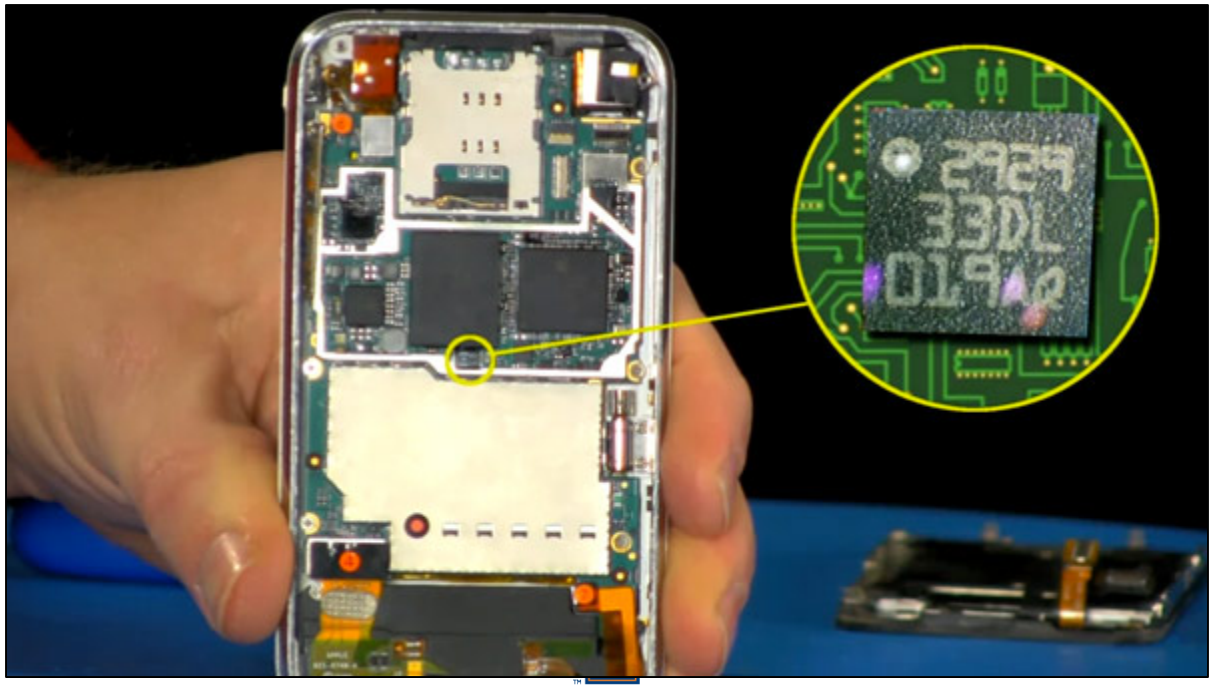
Current Roughness Measurement Systems

- Inertial Profiler
  - First developed by Elson Spangler and William Kelley
  - Modern inertial profilometers require four basic sub-systems:
    - Accelerometers
    - Height sensors
    - Distance or a speed sensor
    - Computer hardware and software
  - International Cybernetics Corporation (ICC), Automatic Road Analyzer (ARAN), and K.J. Law profilometer



Limitations/Challenges of IRI

- Unable to provide distress information
- Multiple pavement sections can have the same IRI value
- Data collected at low speeds can generate false peaks in the profile
  - Create false spikes in the IRI parameter
- Accelerometer sensitivity affects pavement roughness



Motivation

- VDOT reported “a contractor is employed to gather roughness data at an annual cost of $1.8 million”
- Data are collected once-every-five years for secondary roads
- For small transportation agencies such counties and cities with low operating budgets, pavement condition data collection frequency may be limited
- Thus, M&R decisions are often performed using outdated data
- Infrequent roughness measurements also preclude the identification of rapidly developing distress features on pavements, such as potholes
- There is a need for a pavement roughness data collection system which is:
  - Economical and simple
  - Easily accessible
  - Crowd-source based, having the potential to save agencies millions of dollars
  - Providing data for more intelligent route selection

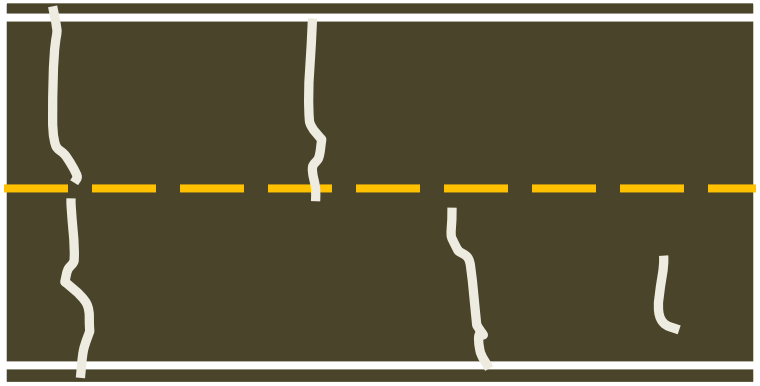
Research Objectives

- Development of a smartphone application, Roughness Capture, to measure pavement roughness
- Initial validation of IRI predictions using Roughness Capture, comparing cell-phone based IRI values to those obtained using an industry-standard inertial profiler

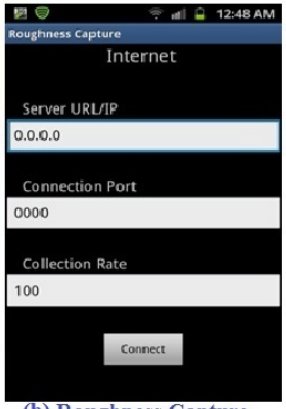
Hypothesis: Vertical Acceleration of Vehicle

- Pavement surface irregularities causes the vehicle wheels to move up and down with respect to the road surface, causing the vehicle cab to accelerate (although cab movement is dampened by suspension)

- “Roughness Capture” has been used to collect vertical acceleration data in the vehicle cab - It is hypothesized that vehicle cab acceleration measured with smart phones can be combined with vehicle dynamics models to arrive at accurate measures of pavement IRI



(a) Cellphone App Capturing Vertical Acceleration



(b) Roughness Capture Interface

(c) Acceleration Data Capturing

Double Integration vs. Inverse State-Space Model

Double Integration Scheme

Roughness Capture

Acceleration Data

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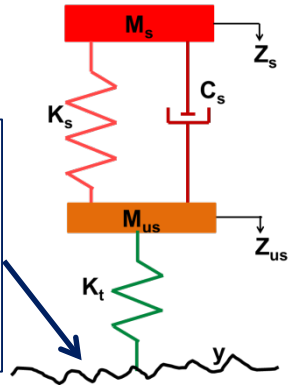
Vehicle Cab (Dashboard) Displacement Profile, y

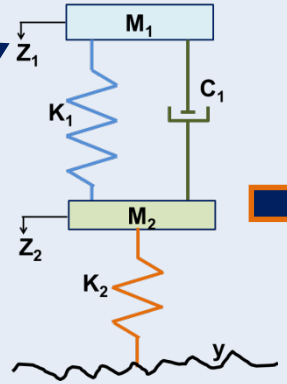


IRI

Quarter-Car Model (ASTM)

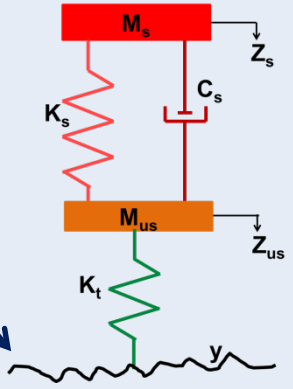
Inverse State-Space Modeling Scheme

Roughness Capture



State Space Modeling of Suspension for Vehicle Actually Used, Solved Inversely

Pavement Profile, y



IRI

Quarter-Car Model (ASTM)

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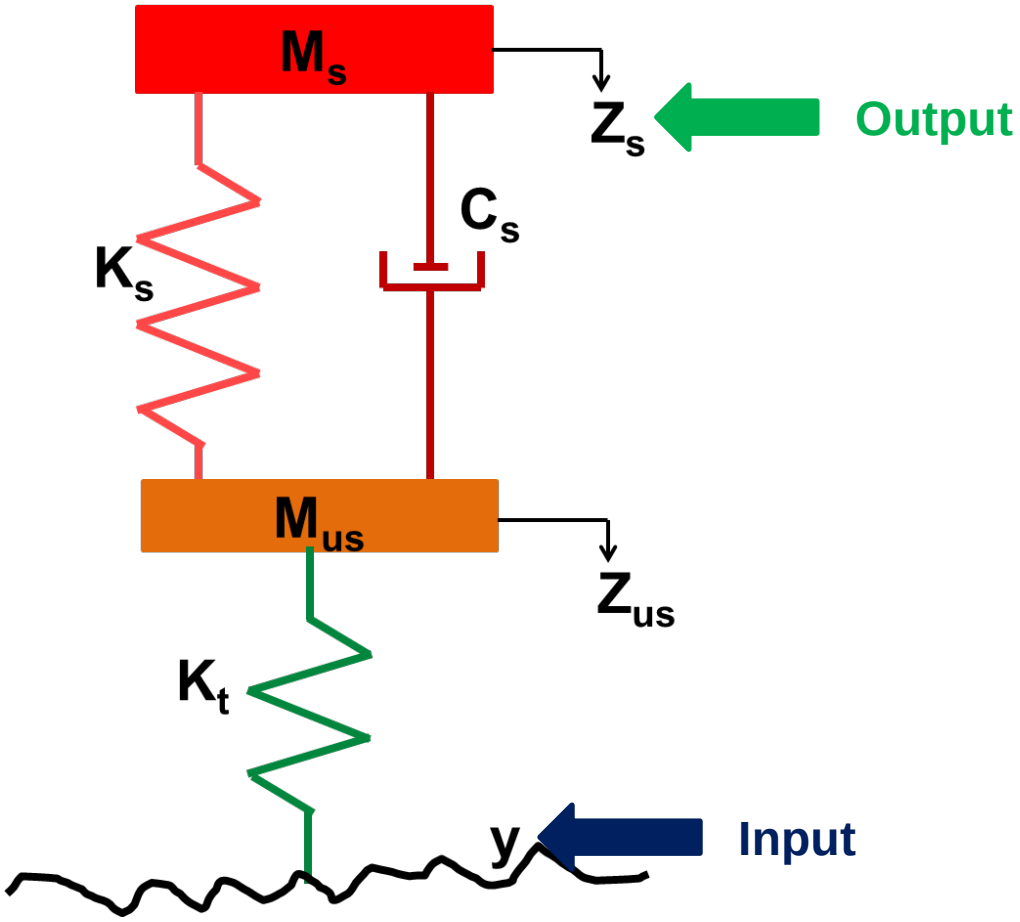
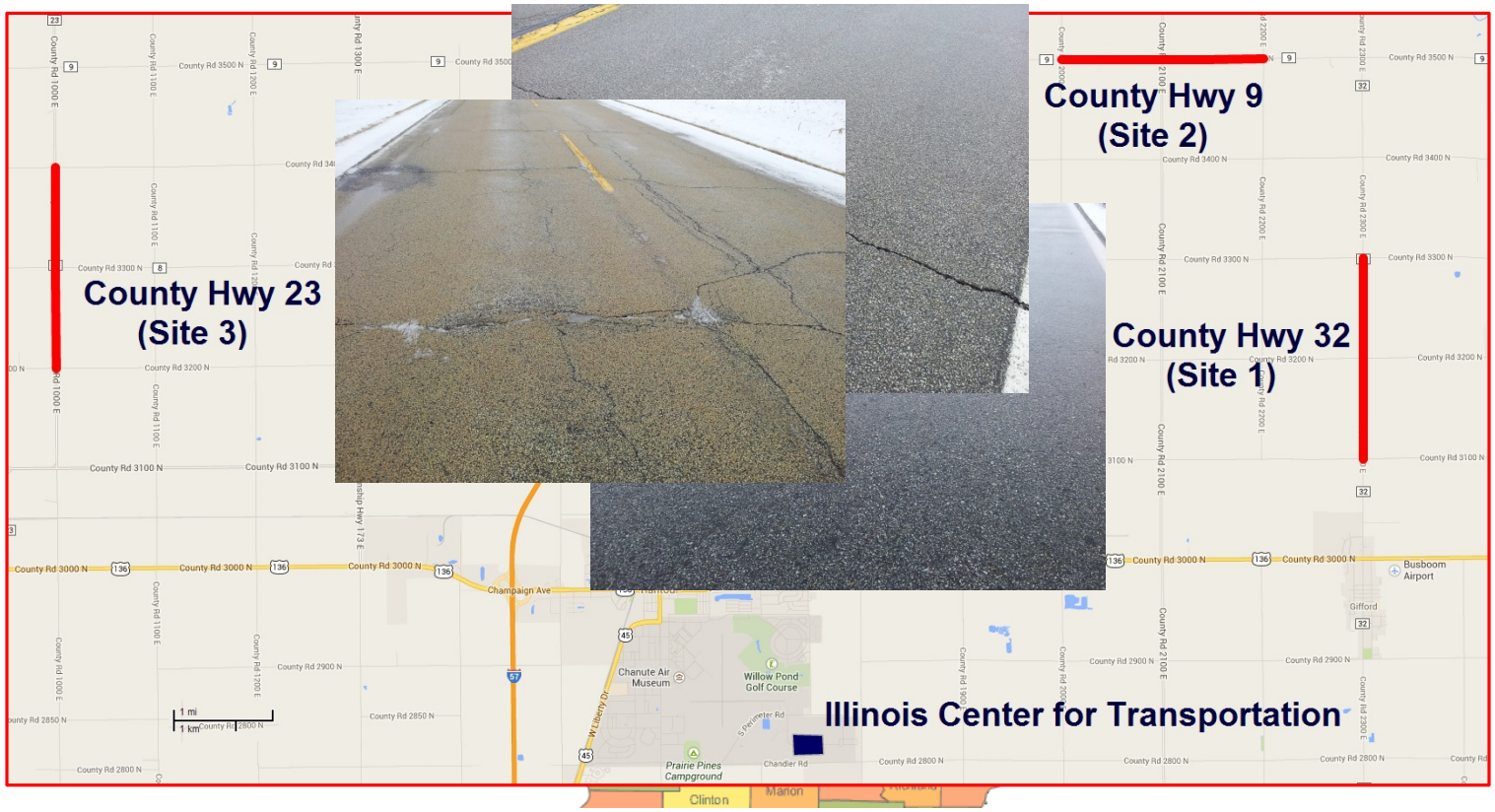
State-Space Model



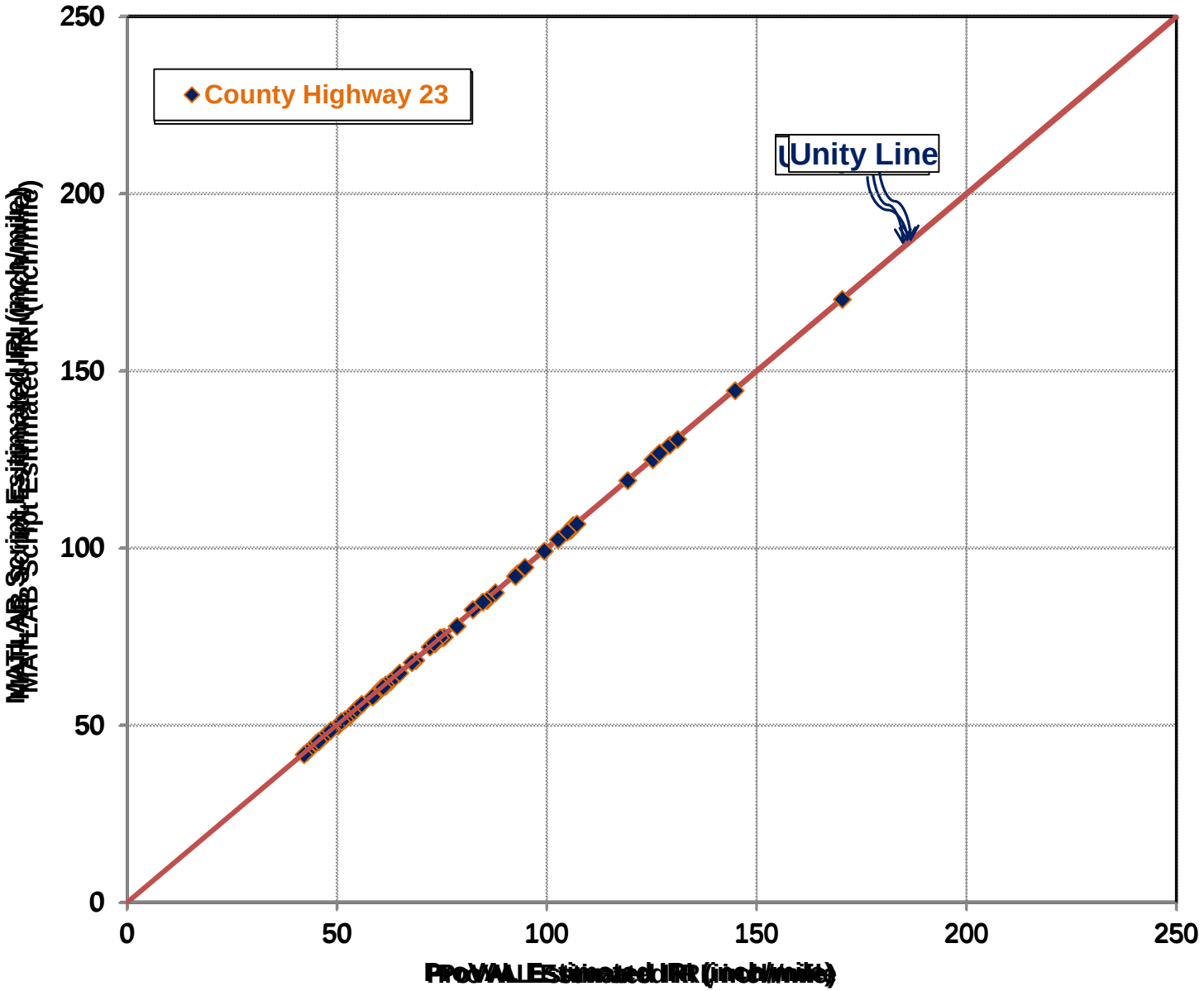
- Zs" is known, y is unknown
- Therefore, it is inverse problem

Data Collection and Site Location

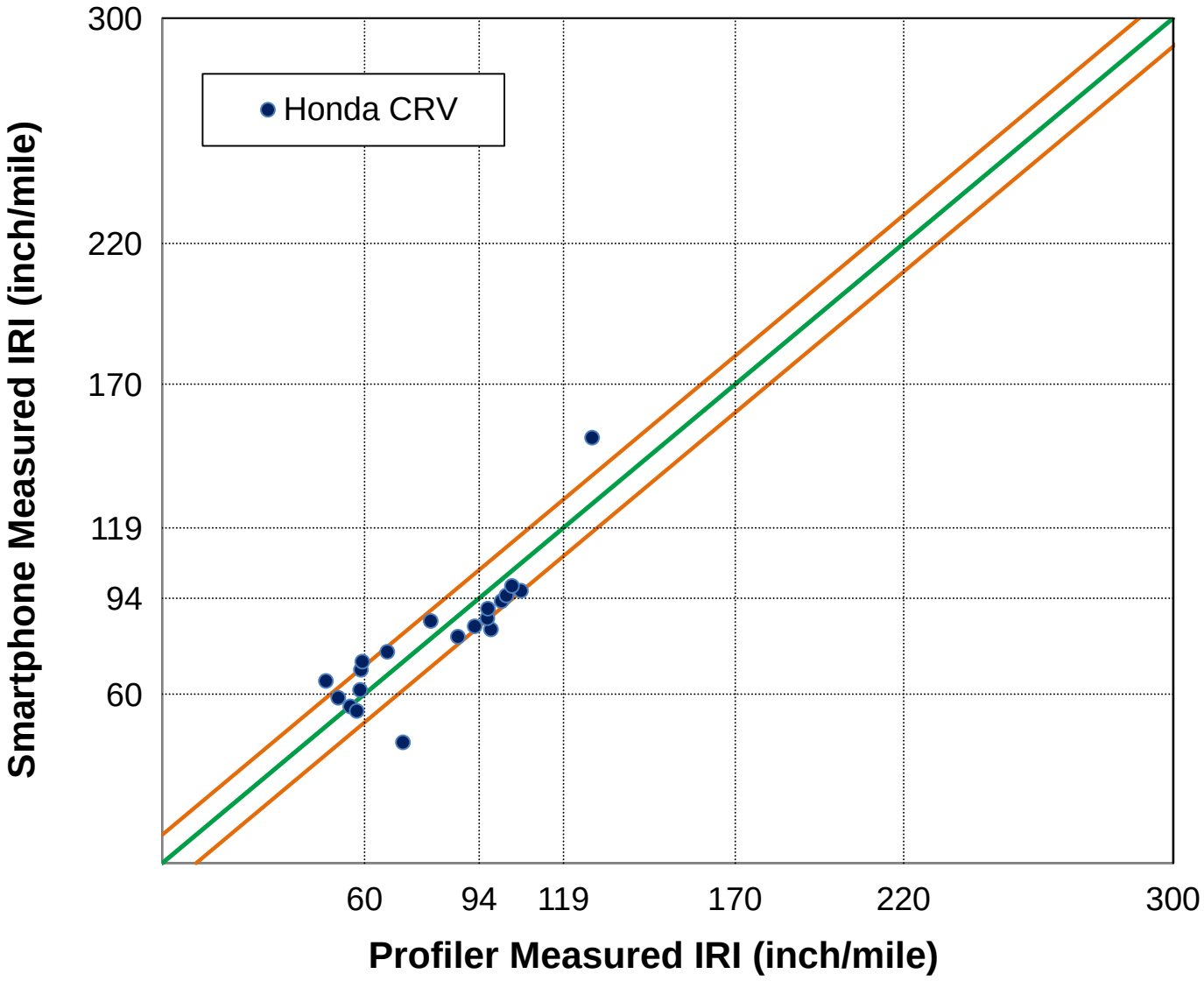


- Three test sites : County Highway 32, 9, and 23
- Test sites were selected with wide variety of distresses
- County Highway 32 is with very low or no distresses, and County Highway 23 is very rough pavement

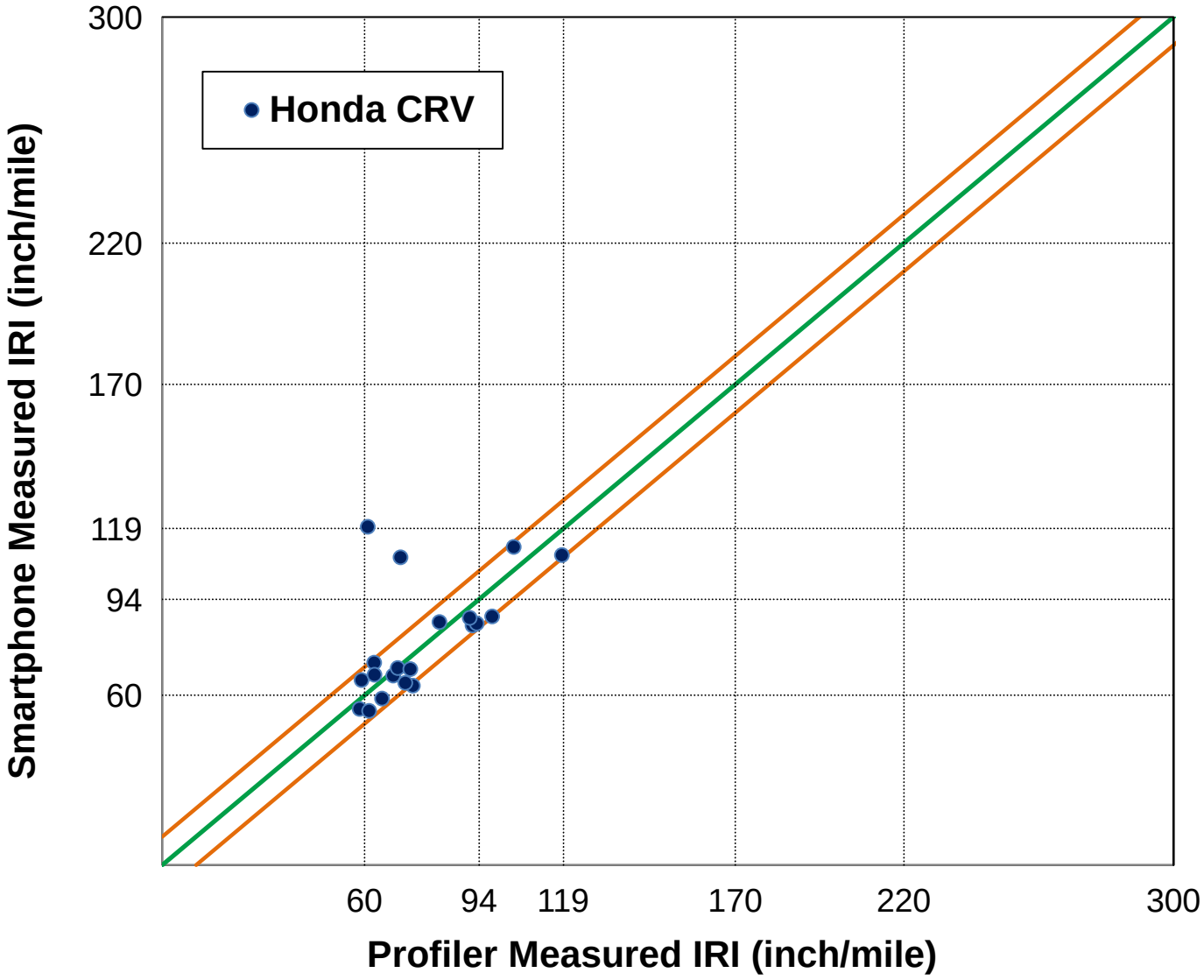
IRI Estimation using ProVAL and MATLAB Script



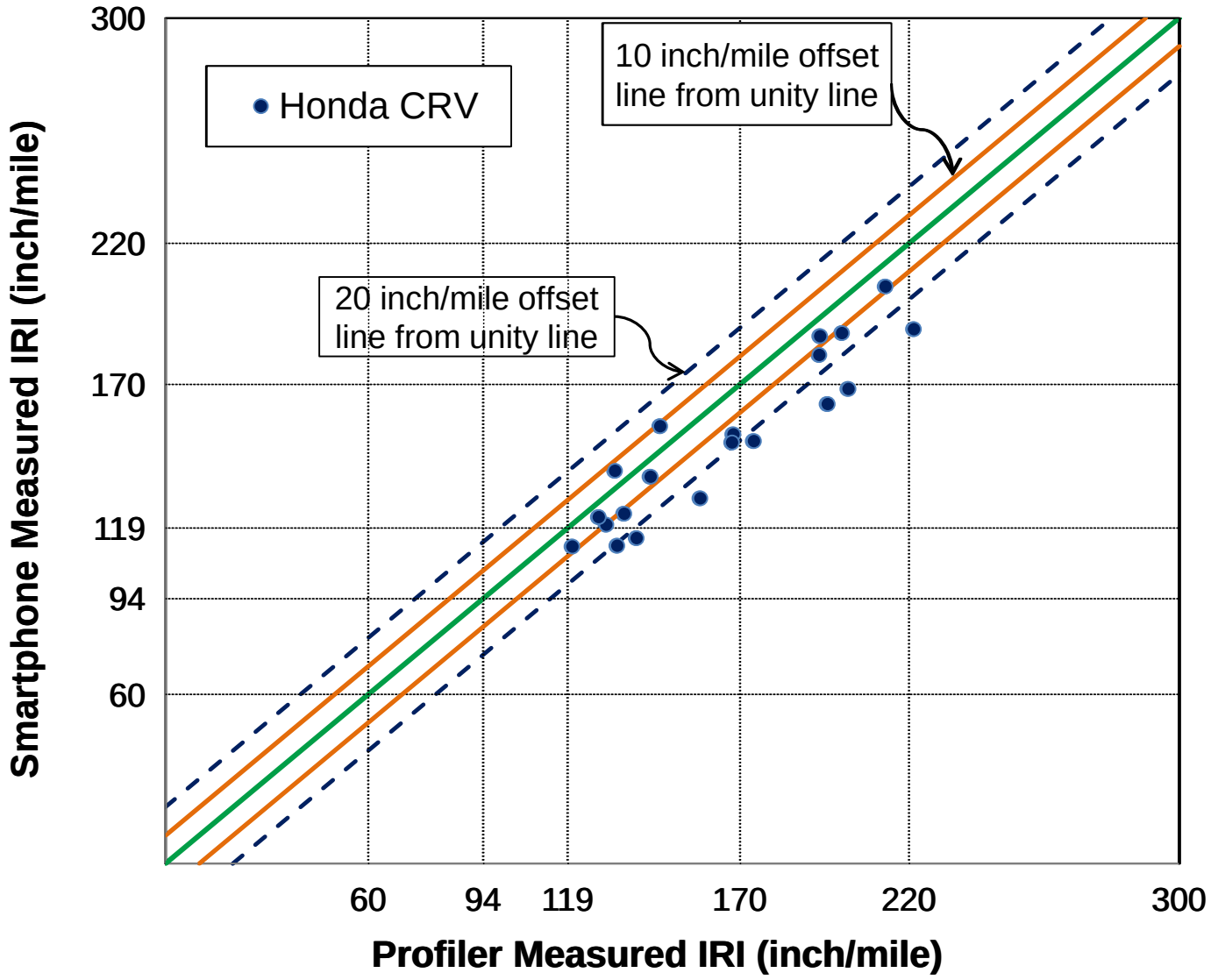
Inverse State Space: County Highway 32



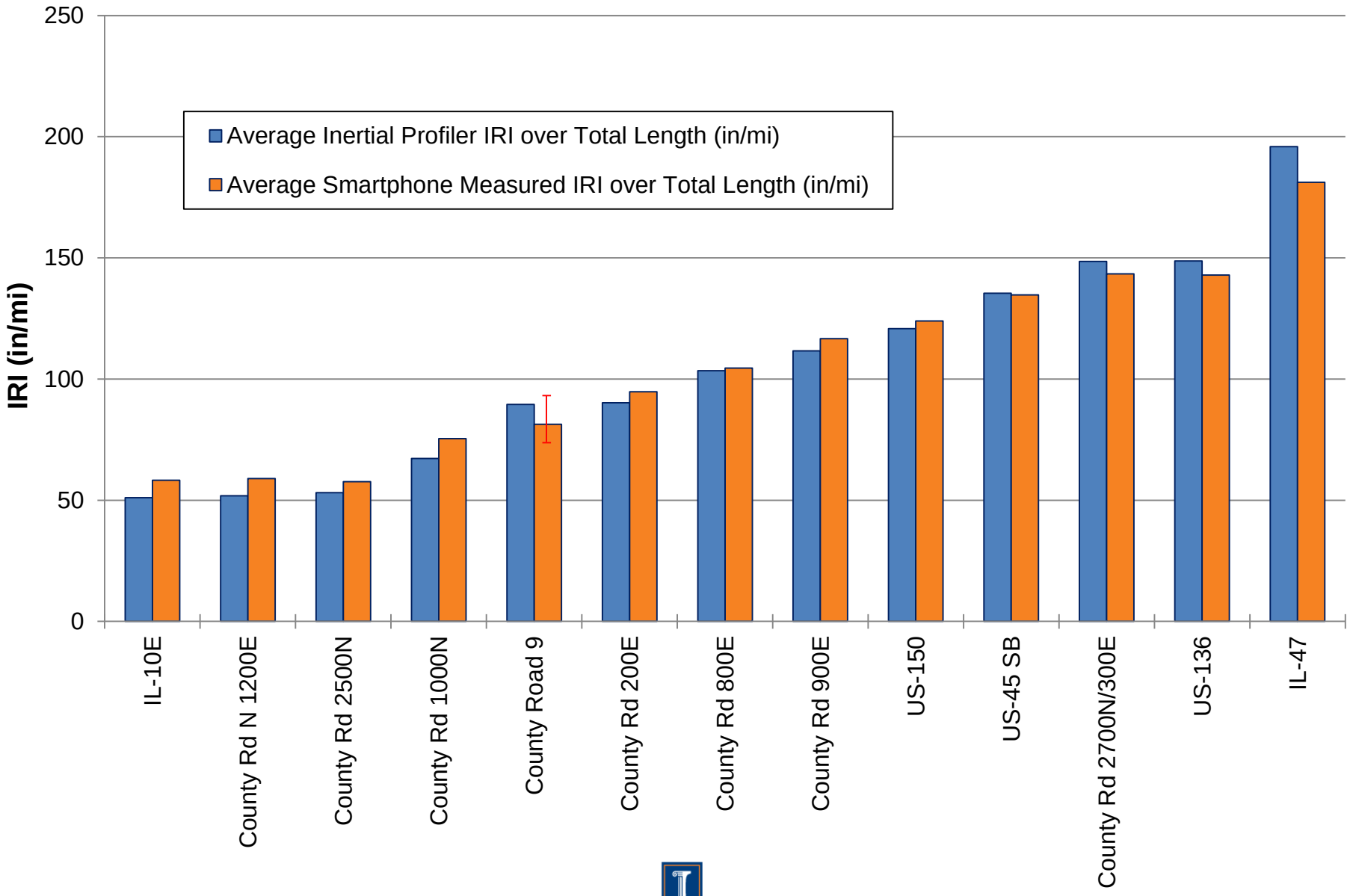
Inverse State Space: County Highway 9



Inverse State Space: County Highway 23



Validation: Profiler vs. App Measured IRI

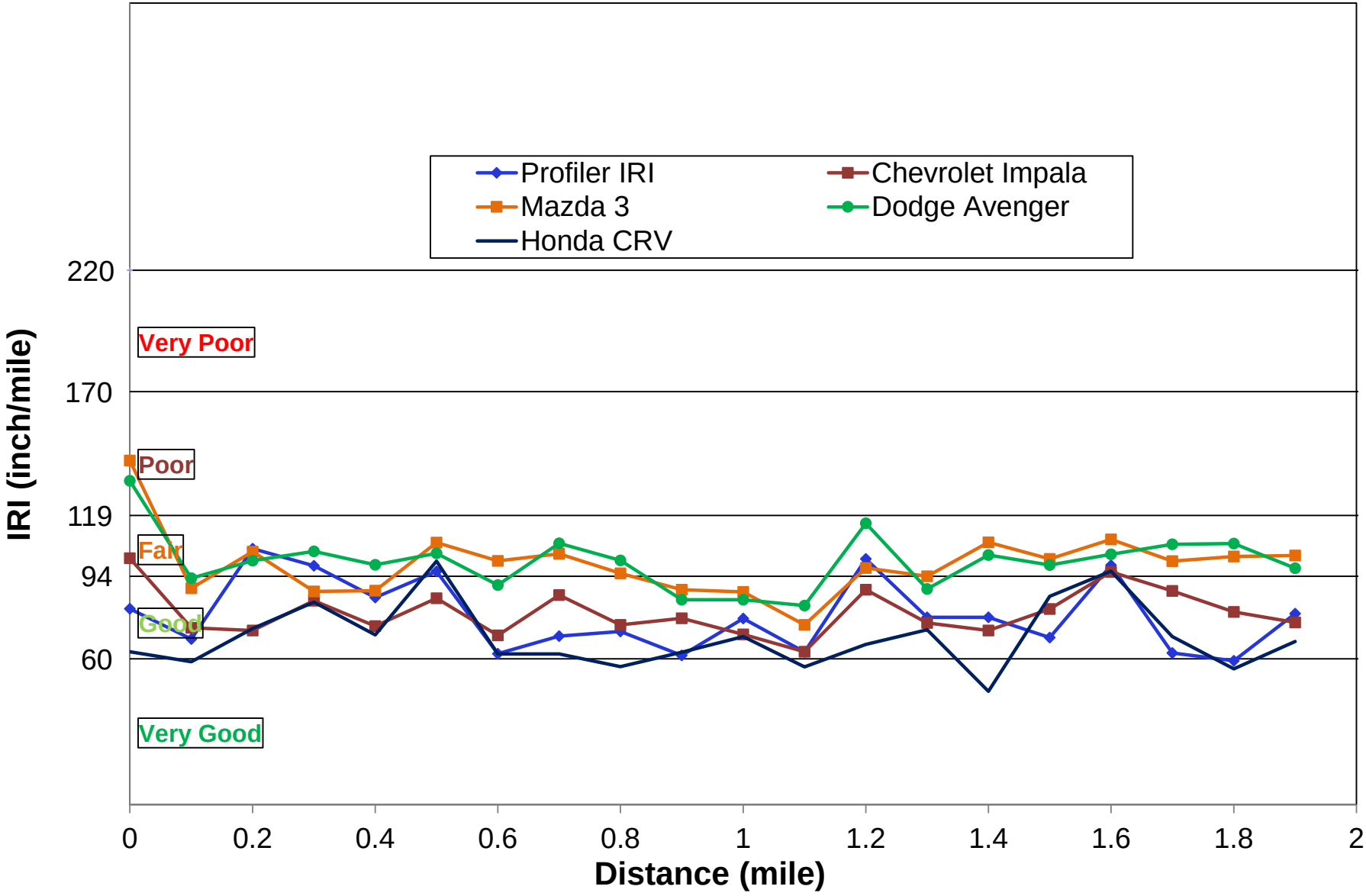


Effect of Different Vehicles on IRI

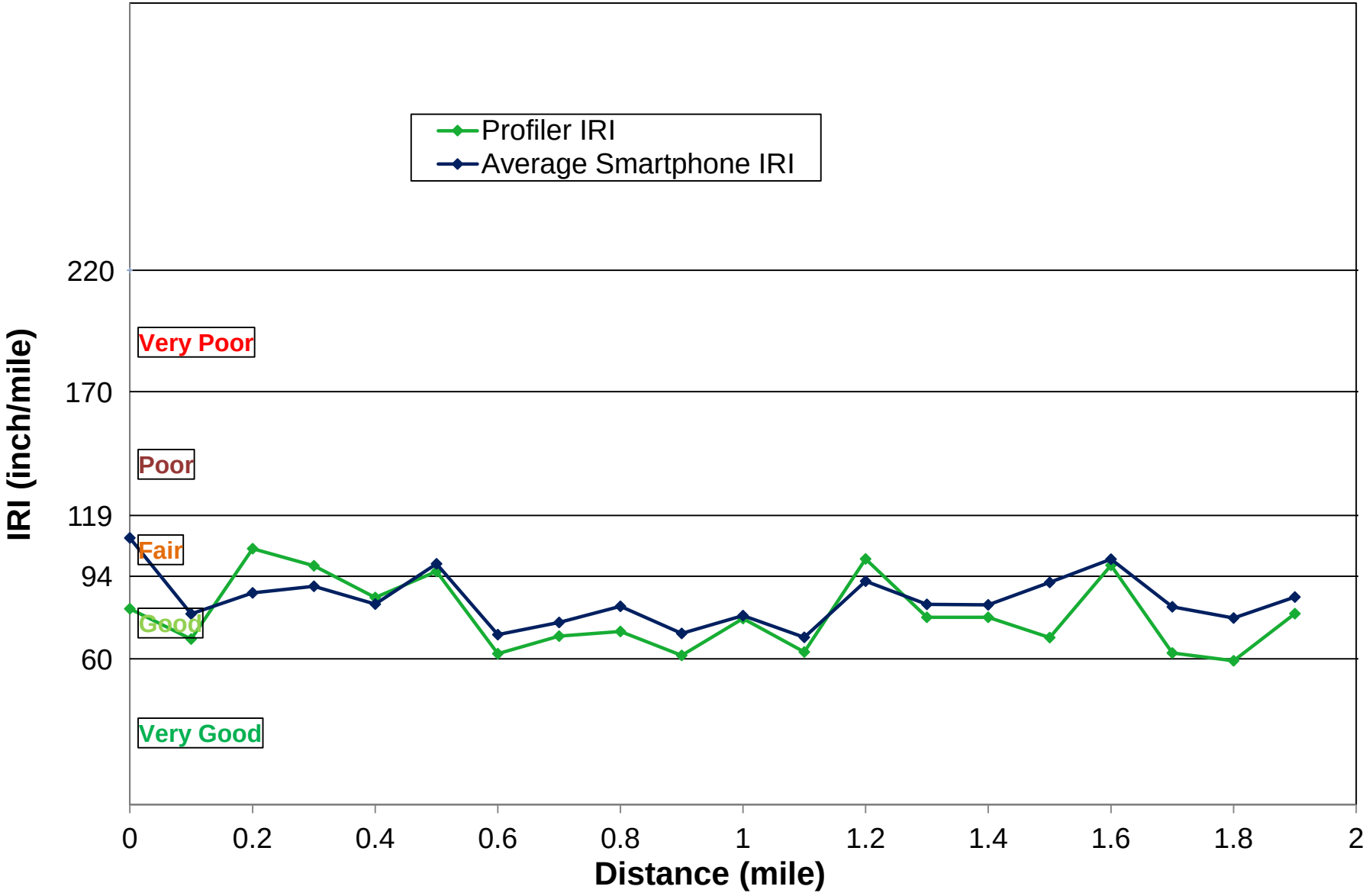



	Mazda 3	Honda CR-V	Dodge Avenger	Chevrolet Impala
M1 (kg)	343	420	494	500
M2 (kg)	40	40	40	45
C1 (N*s/m)	1,500	1,400	1,550	1,500
K1 (N/m)	13,500	11,000	12,000	10,000
K2 (N/m)	200,000	198,000	200,000	200,000

IRI vs. Vehicle at County Highway 9



Average IRI with Vehicles at County Highway 9



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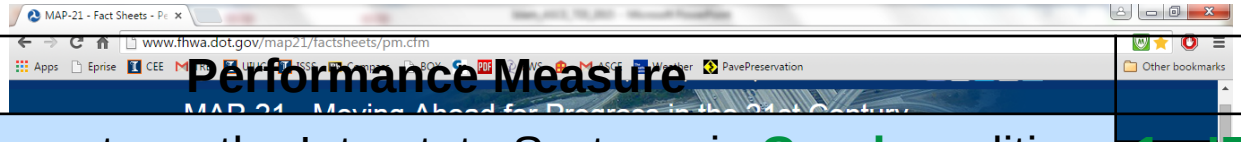
Moving Ahead For Progress (MAP-21)

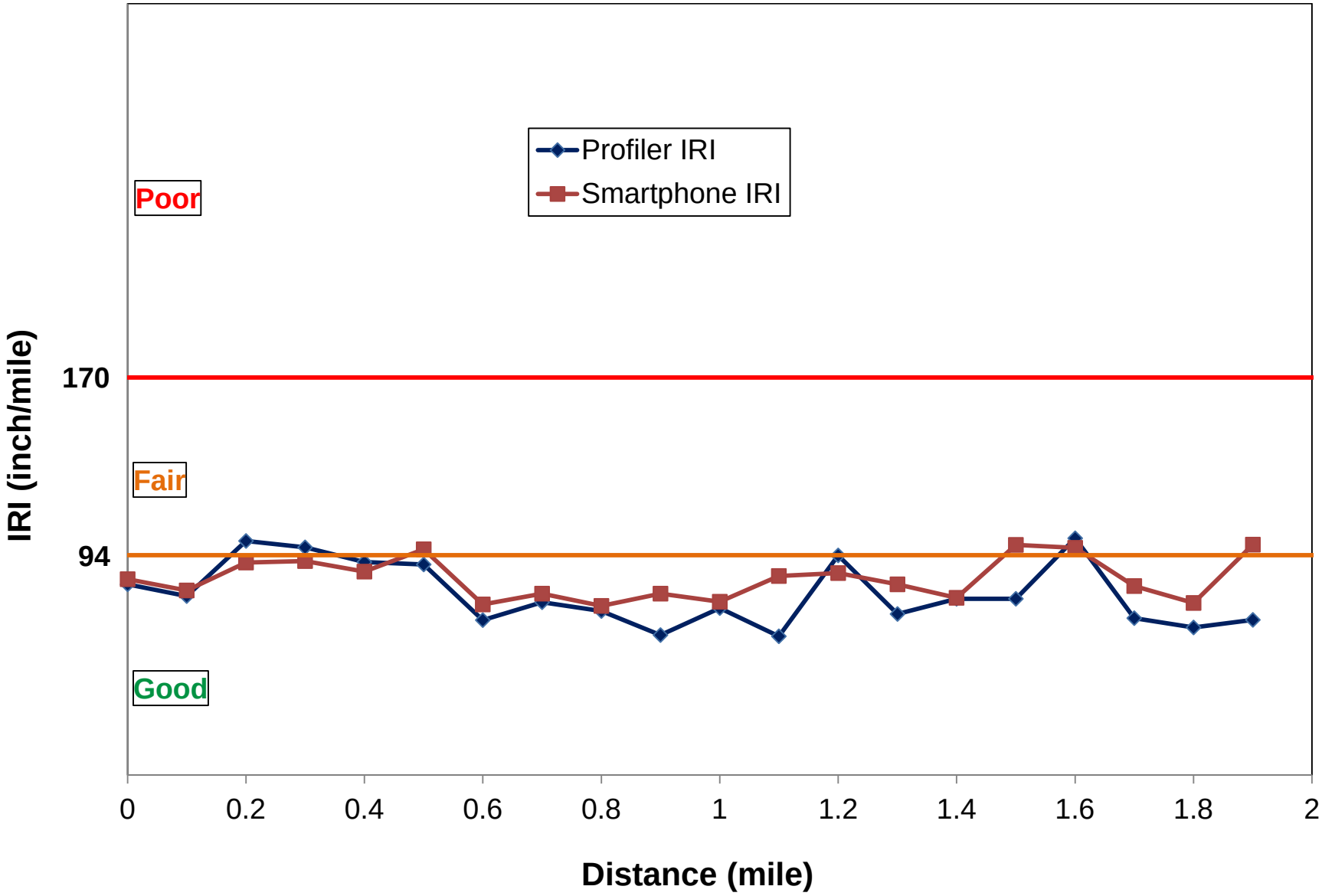


Performance Measure	Data
(1) % pavements on the Interstate Systems in **Good** condition	1. **IRI**
(2) % pavements on the Interstate Systems in **Poor** condition	2. % Cracking
(3) % pavements on the NHS in **Good** condition	3. Rutting
(4) % pavements on the NHS in **Poor** condition	4. Faulting

Goa	
Safety	To achieve a significant reduction in traffic fatalities and serious injuries on all public roads
Infrastructure condition	To maintain the highway infrastructure asset system in a state of good repair
Congestion reduction	To achieve a significant reduction in congestion on the National Highway System
System reliability	To improve the efficiency of the surface transportation system

Type	(inch/mile)		
All Pavements	< 95	Good	
	95 - 170	Fair	Areas with a population <1 million
	95 - 220	Fair	Urbanized areas with population ≥1 million
	> 170	Poor	Areas with a population <1 million
	> 220	Poor	Urbanized areas with population ≥1 million

MAP-21 IRI Data: County Highway 9



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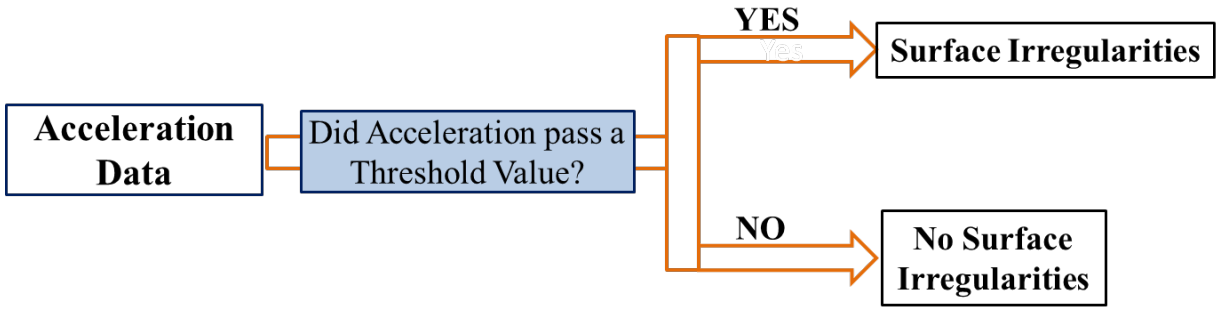
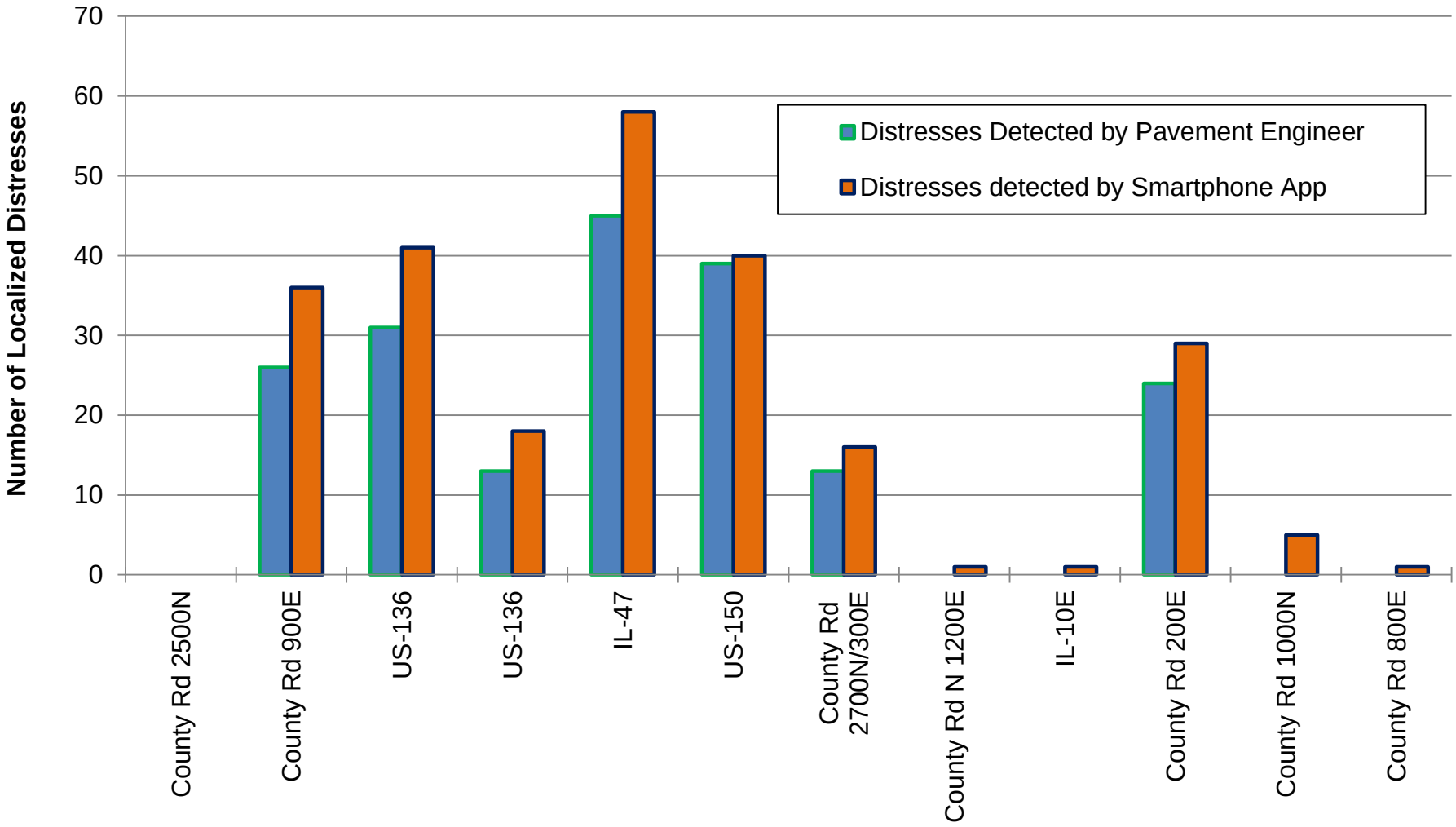
Surface Irregularity Detection

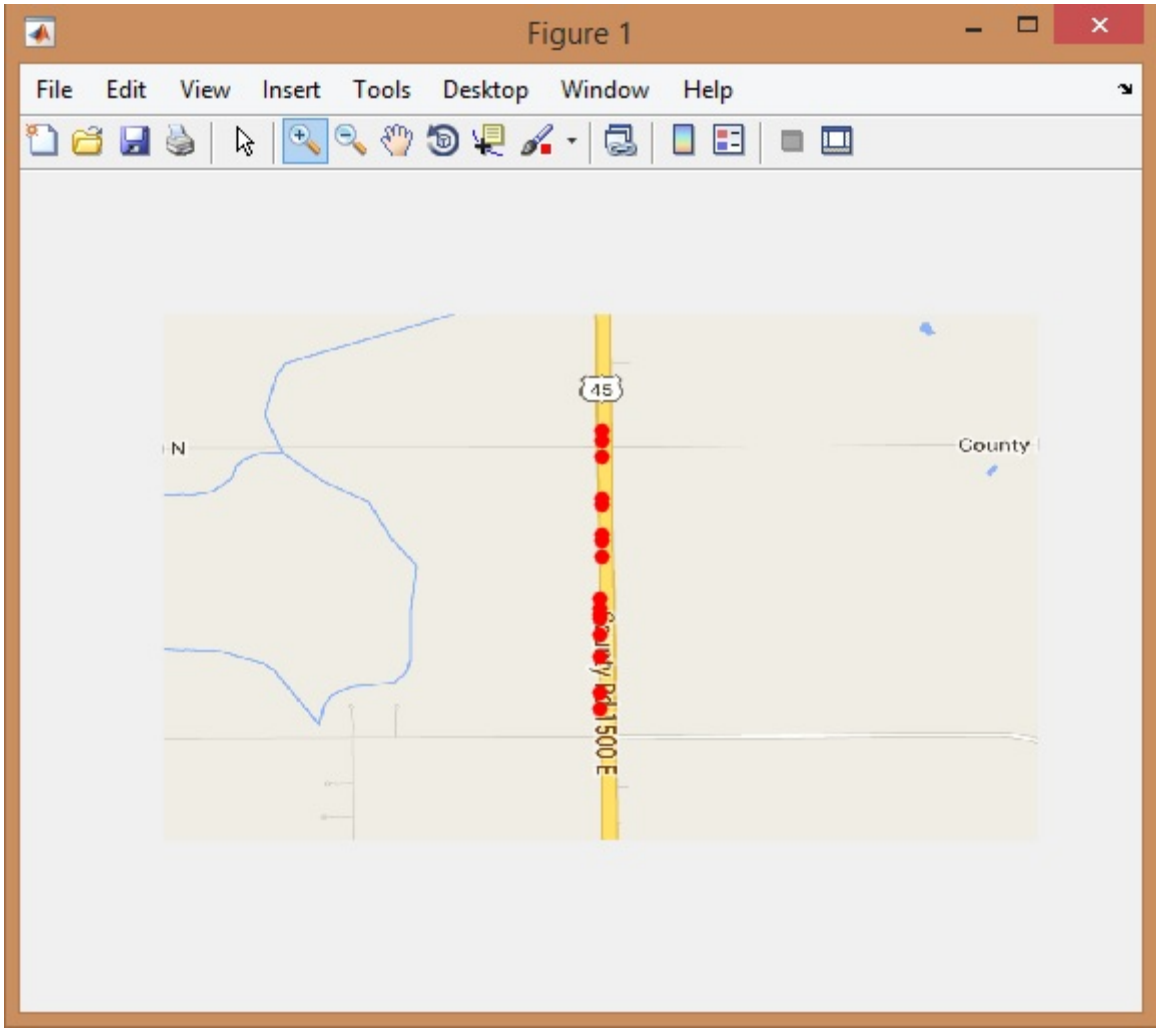
- IRI itself does not offer any idea of presence of surface irregularities
- Two different pavement profiles can generate same IRI values though distress types and locations are different
- Detection of surface irregularities location will give an idea of the severity of distresses



Localized Distress Detection

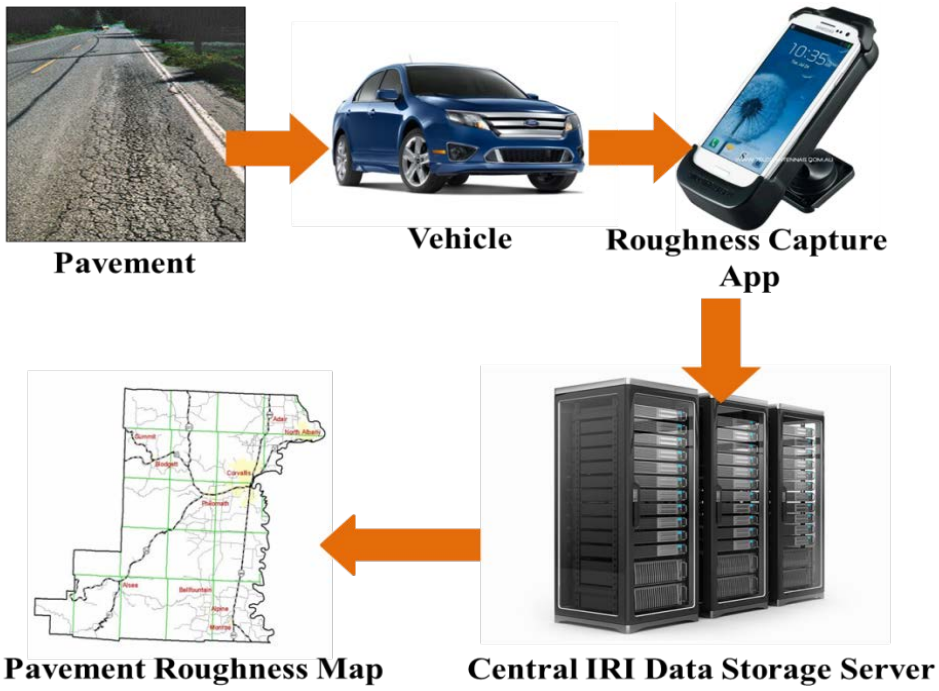


Bump/Pothole Locations

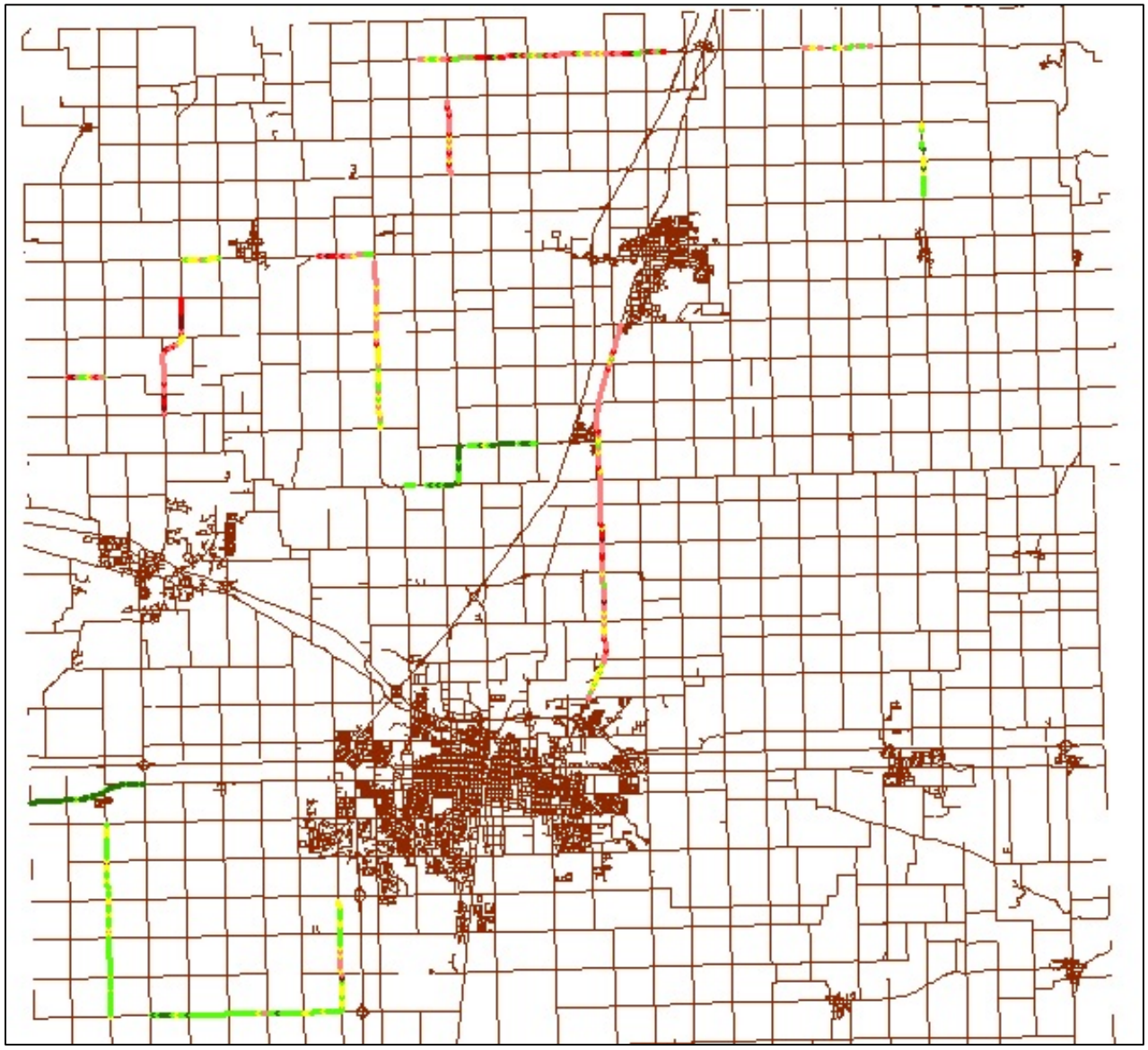


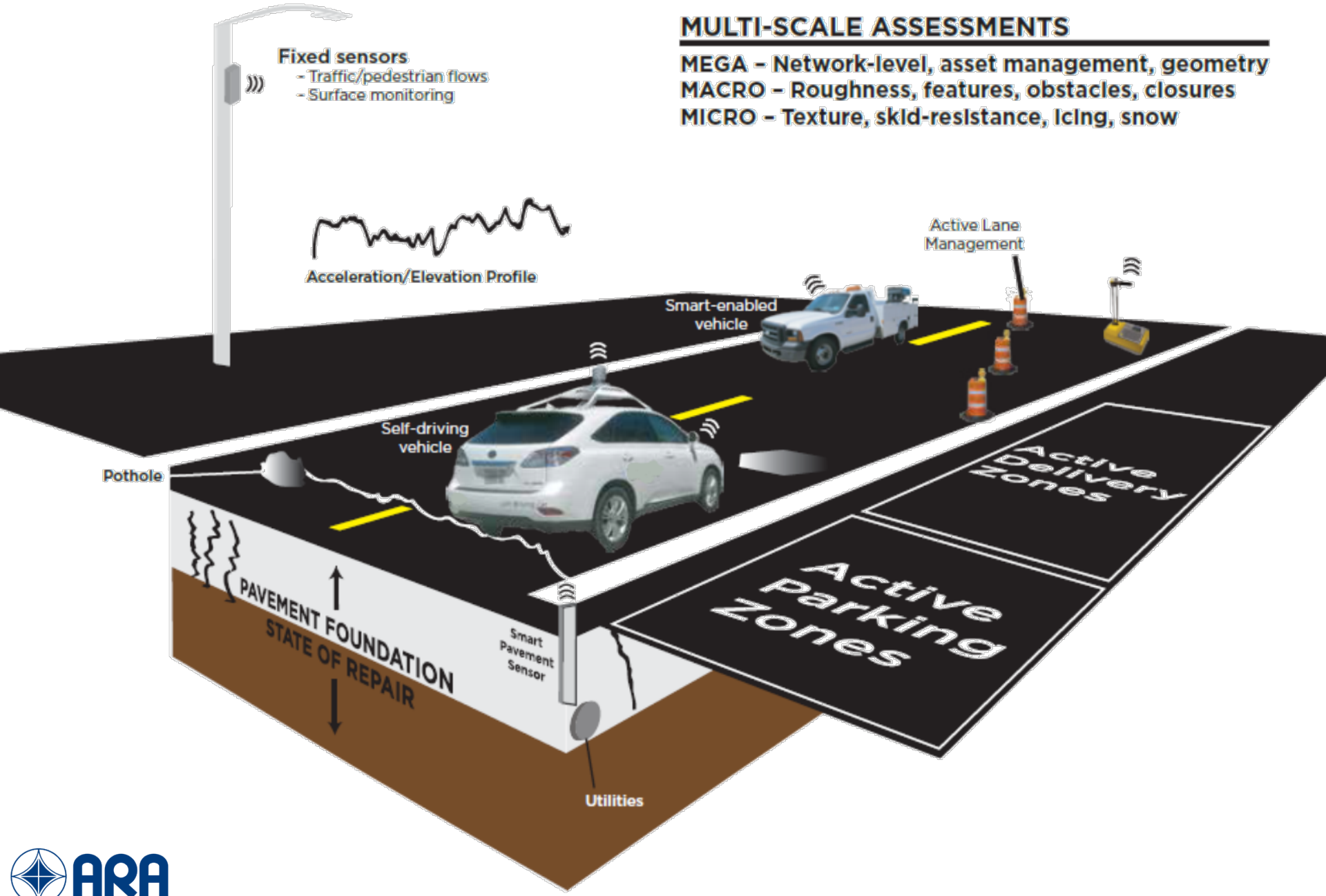
Integration of IRI Data into Roadway Network Map

- Visualization of network condition is an outmost interest to transportation agencies
  - Incorporation of pavement roughness values in the roadway
  - Existing roadway network data
  - Provide a link between PMS and GIS



IRI on Roadway Map using ArcGIS





Acknowledgements

- NexTrans: USDOT Region V Regional University Transportation Center

- Applied Research Associates, Inc.