

Use of Probe Vehicles to Measure Road Ride Quality

Samer W. Katicha

Senior Research Associate,
Center for Sustainable transportation Infrastructure



Outline

- **Smoothness for asset management**
- **Probe vehicles**
- **The experiment**
 - ✓ **IRI calculation from profile**
 - ✓ **IRI calculation from vertical acceleration measurements**
 - ✓ **Sensitivity analysis**
- **Conclusions**

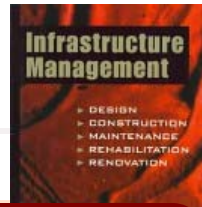
Smoothness for asset management



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Infrastructure Condition/ Performance Indicators → Pavements



W. Ronald Hudson
Ralph Hesse
Wahneema Lubiano

- **Service and User Perception**

Serviceability
(PSI, IRI)



- **Physical Condition**

Distress
(PCI)



- **Structural Integrity / Load-Carrying Capacity**

Deflection
(FWD)



- **Safety and Sufficiency**

**Friction (FN)/
Macrotexture**



- **Environmental Impact**

**Tire/Pav. Noise
Rolling Resistance**



Asset Management



- **Strategic level**

- ✓ **Performance monitoring**

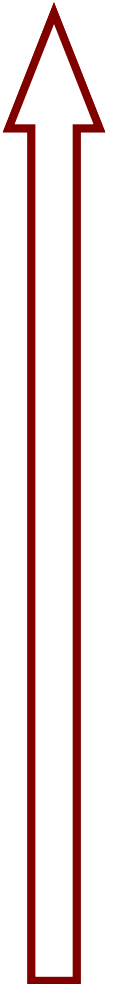
- **Network level**

- ✓ **Pavement management**

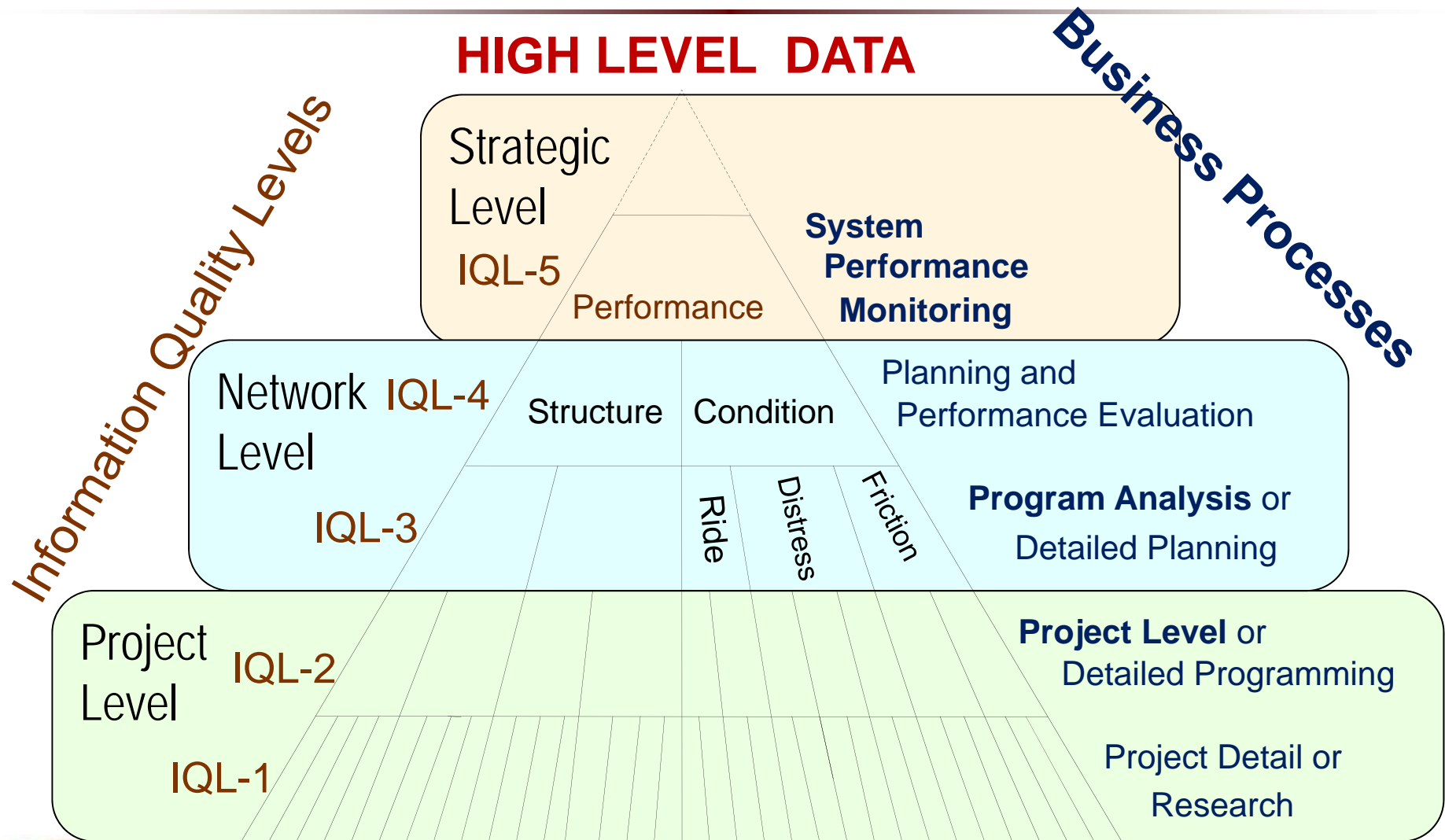
- **Project level**

- ✓ **Smoothness Specification**

- ✓ **Research → LTPP**



Information Quality Levels



Probe Vehicles



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Can we use probe (or regular) vehicles for road infrastructure health monitoring?

- ✓ **At least for supporting high-end strategic- and network-level decisions?**

Pavement Assessment and Management Applications Enabled by the Connected Vehicles Environment – Proof-of-Concept

Objective: To use data collected from probe vehicles to extract information that could be used to remotely and continuously determine road infrastructure health



The experiment



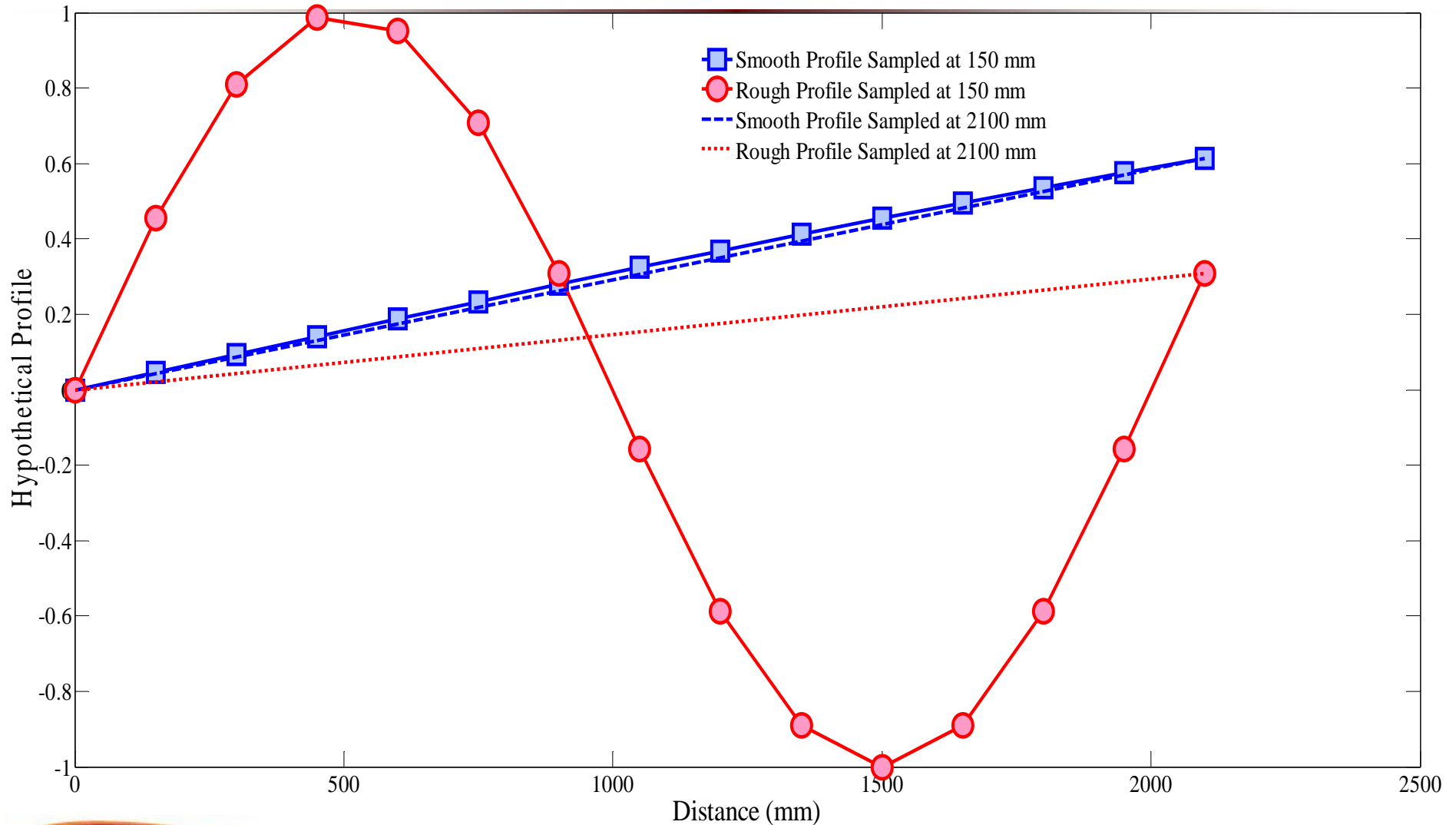
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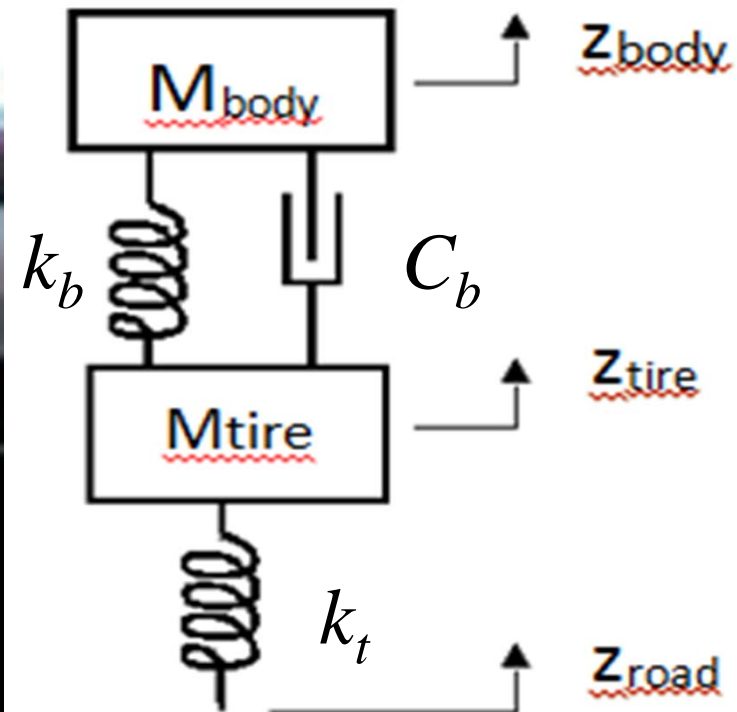
Profile and Acceleration Data

- **Profile data:**
 - ✓ **Collected at the Virginia Smart Road**
 - ✓ **Every 30 mm (1.2 in)**
- **Probe vehicle acceleration data:**
 - ✓ **Collected at the Virginia Smart Road**
 - ✓ **Every 2100 mm (7 ft)**

Data Sampling Problem



Quarter Car Model

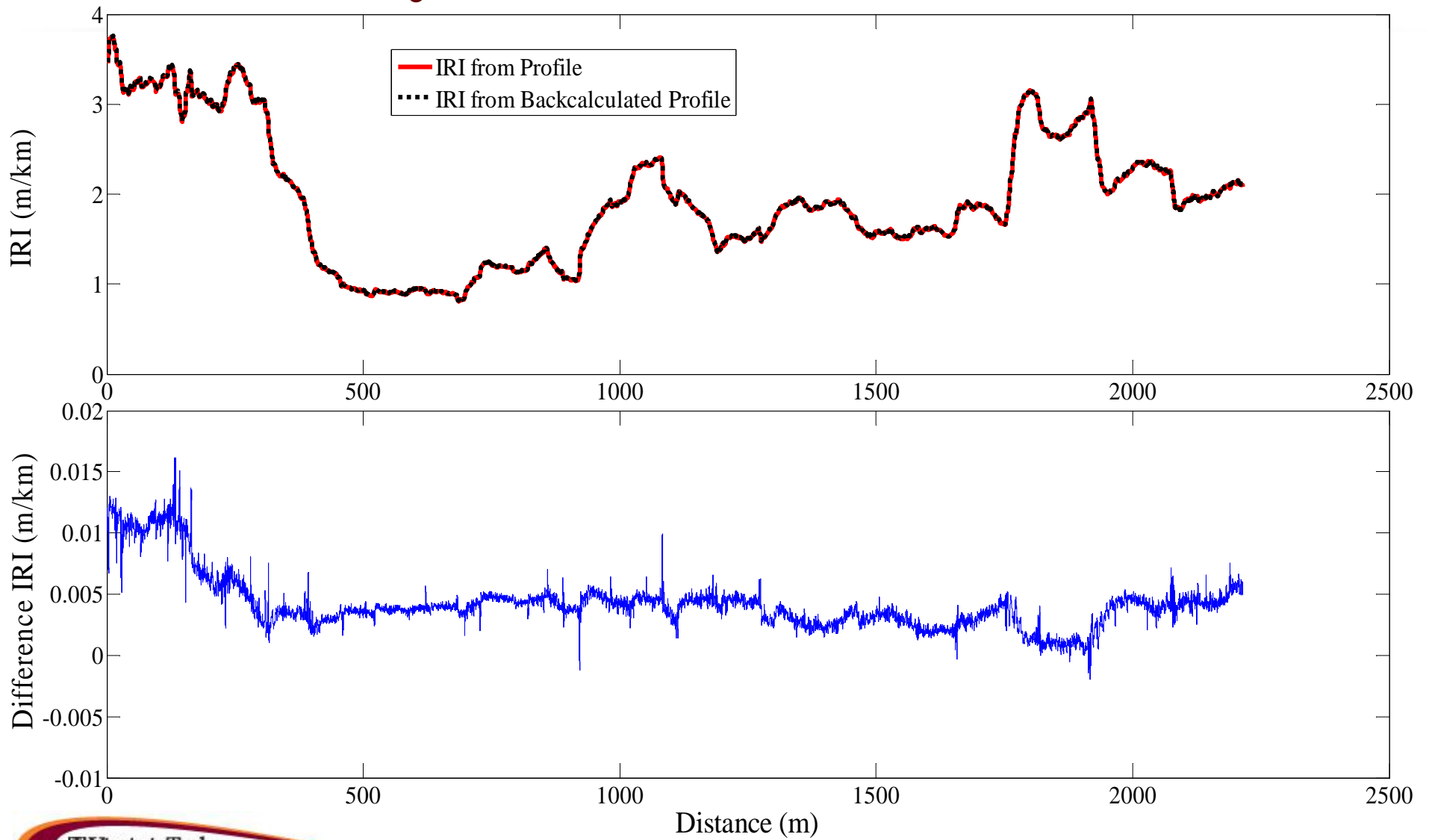


Quarter Car Model

$$\begin{bmatrix} \dot{\mathbf{z}}_{\text{body}} \\ \ddot{\mathbf{z}}_{\text{body}} \\ \dot{\mathbf{z}}_{\text{tire}} \\ \ddot{\mathbf{z}}_{\text{tire}} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -k_1 & -C & k_1 & C \\ 0 & 0 & 0 & 1 \\ \frac{k_1}{\mu} & \frac{C}{\mu} & -\frac{k_1 + k_2}{\mu} & -\frac{C}{\mu} \end{bmatrix} \begin{bmatrix} \mathbf{z}_{\text{body}} \\ \dot{\mathbf{z}}_{\text{body}} \\ \mathbf{z}_{\text{tire}} \\ \dot{\mathbf{z}}_{\text{tire}} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{k_2}{\mu} \end{bmatrix} \mathbf{z}_{\text{road}}$$

$$k_1 = \frac{k_b}{M_{\text{body}}} \quad k_2 = \frac{k_t}{M_{\text{tire}}} \quad C = \frac{C_b}{M_{\text{body}}} \quad \mu = \frac{M_{\text{tire}}}{M_{\text{body}}}$$

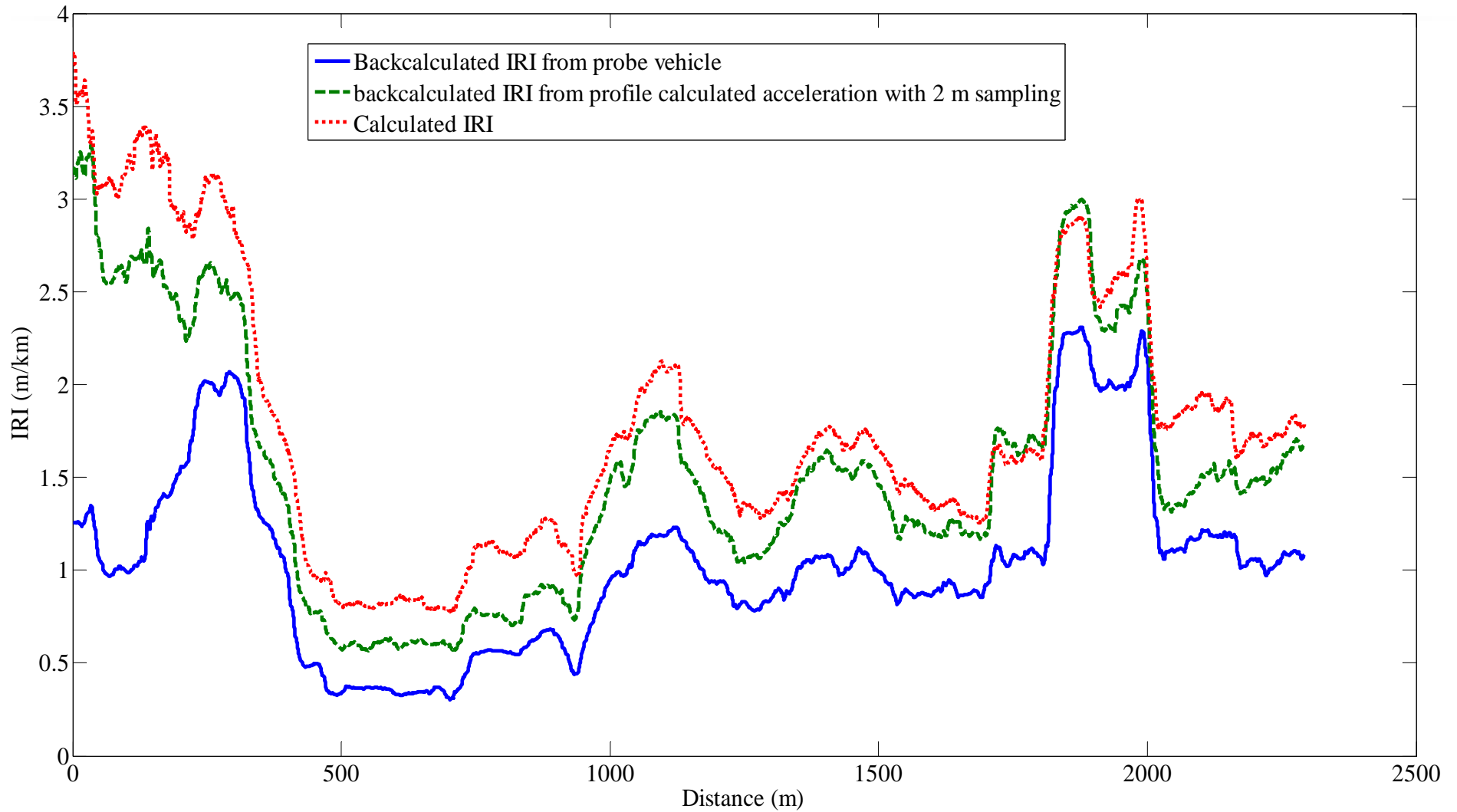
Accuracy of Numerical Calculation



The Probe Vehicle

- **2007 Ford Fusion**
- **Car parameters:**
 - ✓ **Same as golden car**
 - ✓ **Close enough**
- **Test Speed:**
 - ✓ **50 mph**

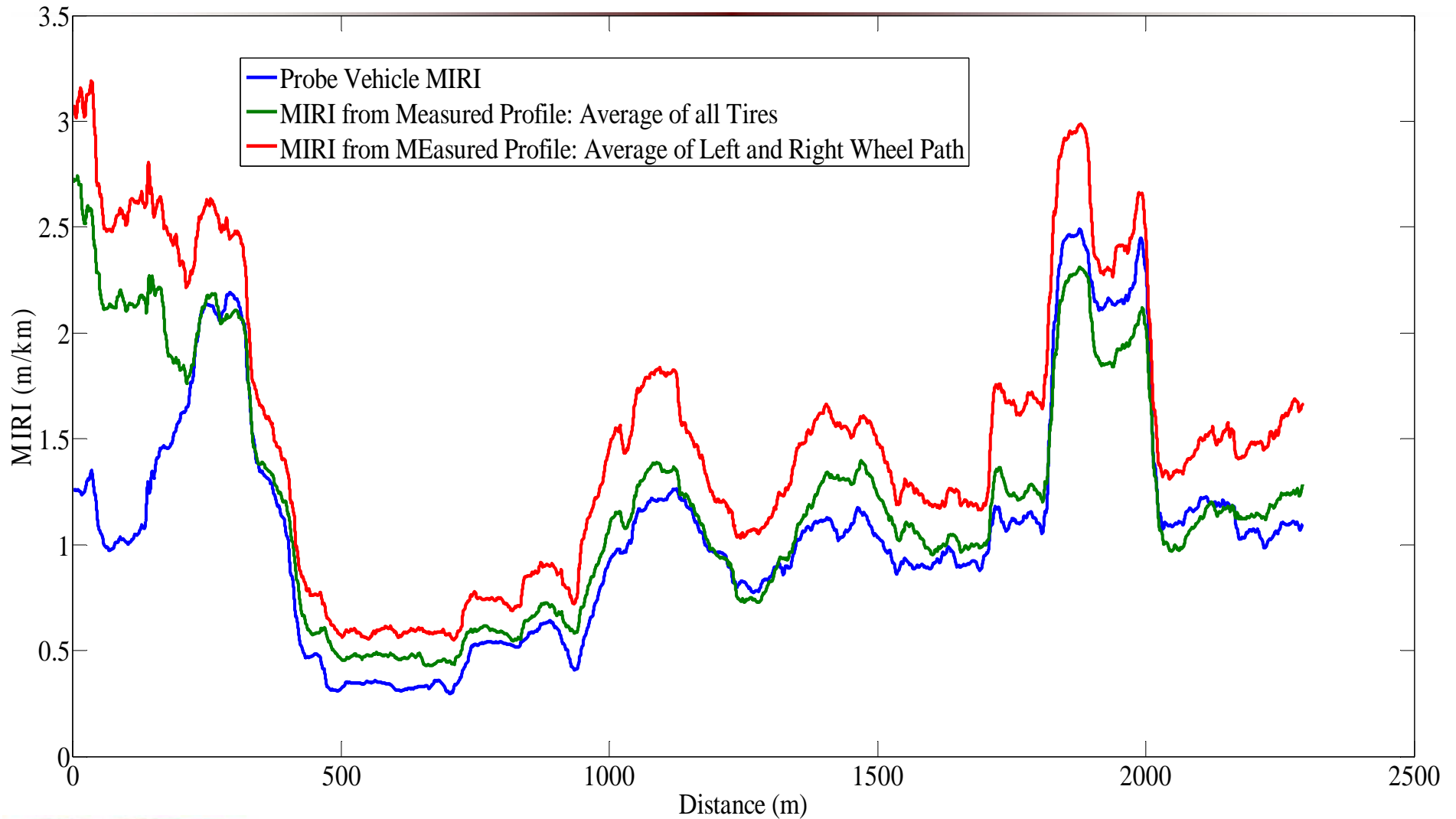
IRI Calculation



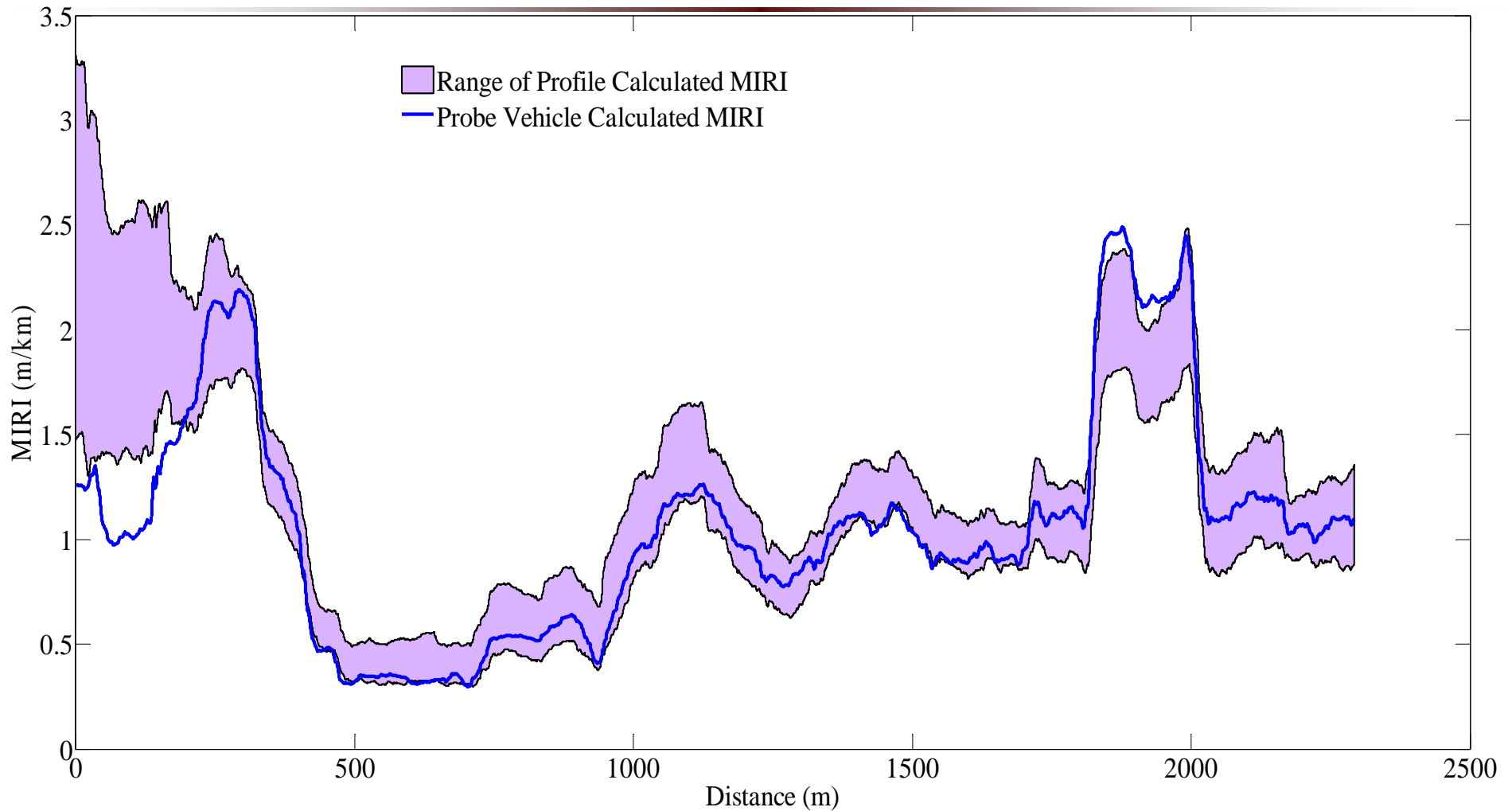
IRI Comparisons

- **Calculated IRI:**
 - ✓ **Follow the same trend**
 - ✓ **Sample over 2 m makes a difference**
- **Problems with quarter car model:**
 - ✓ **Probe vehicle acceleration results from the full car response**
 - ✓ **Approximate full car with average of profile felt by the four wheels**

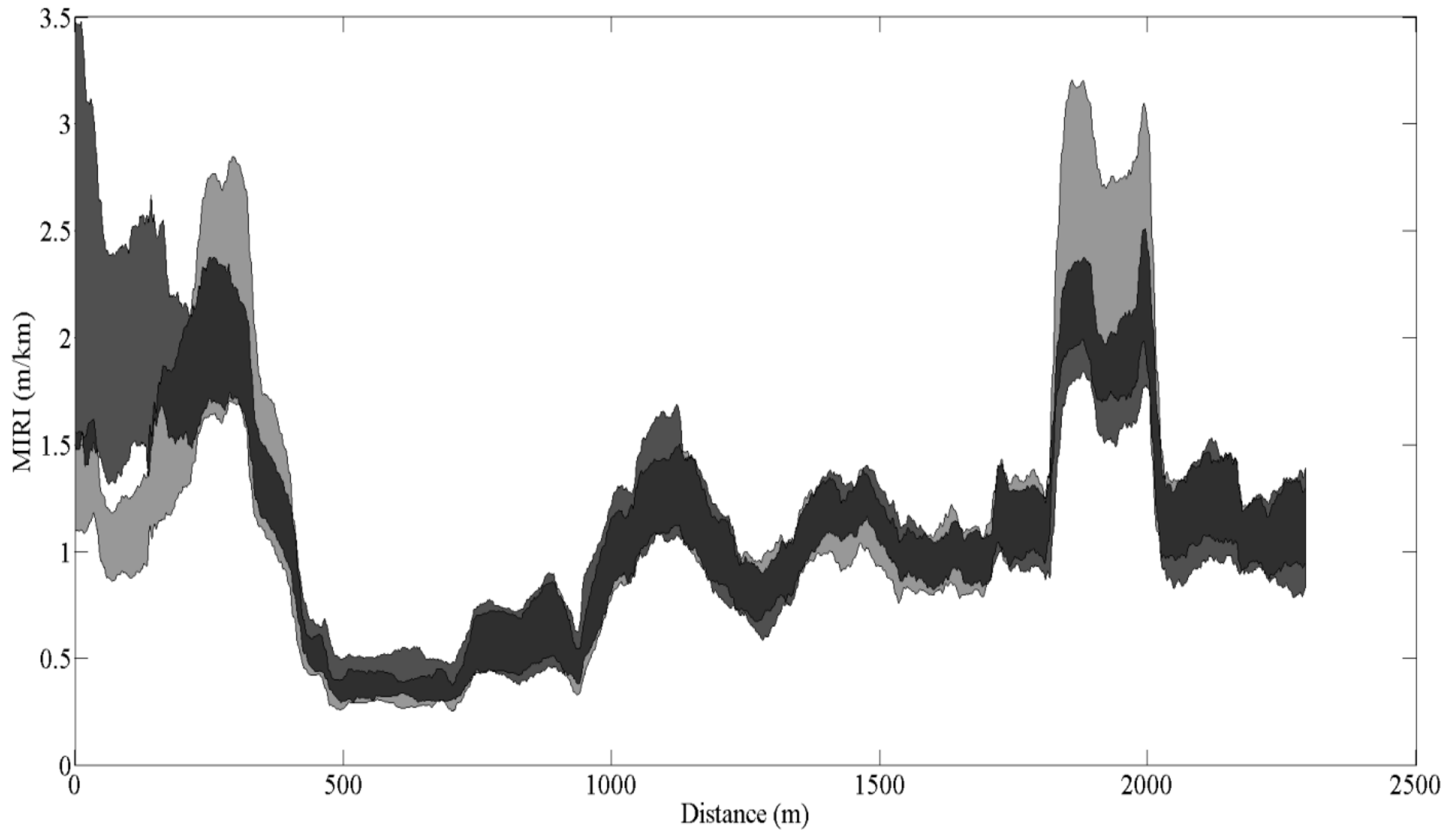
“Full Car” IRI



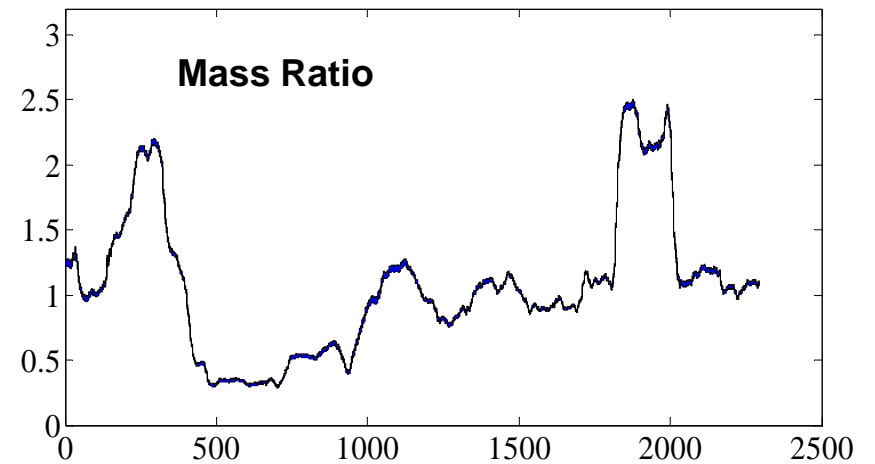
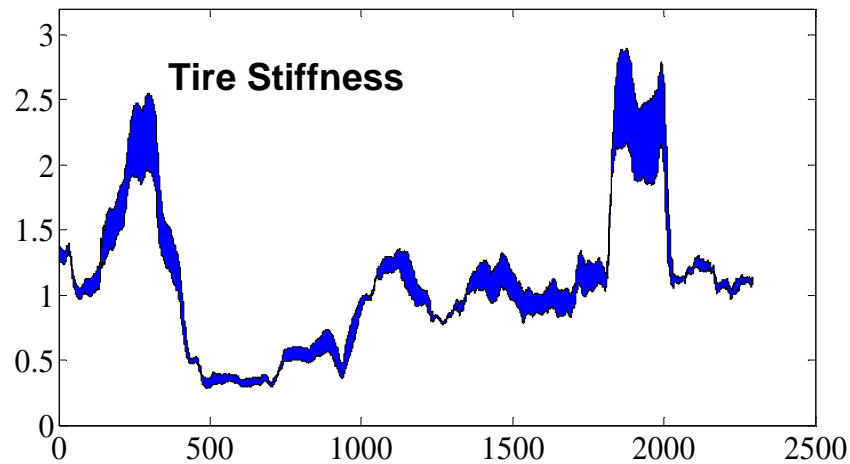
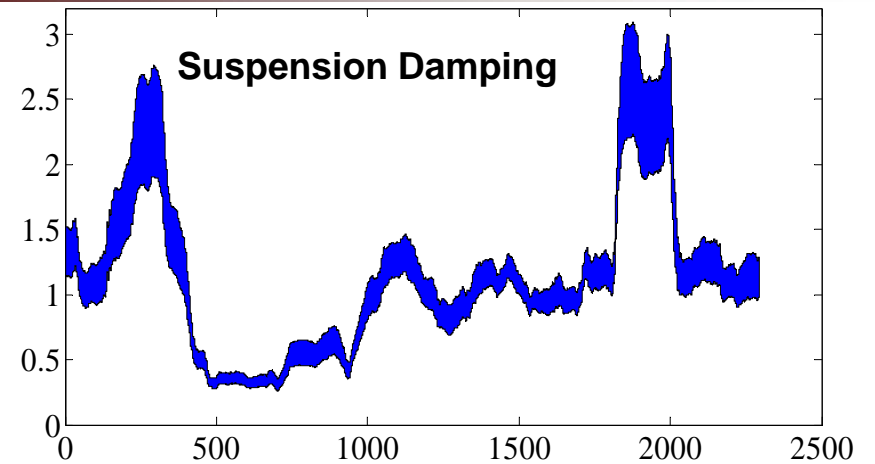
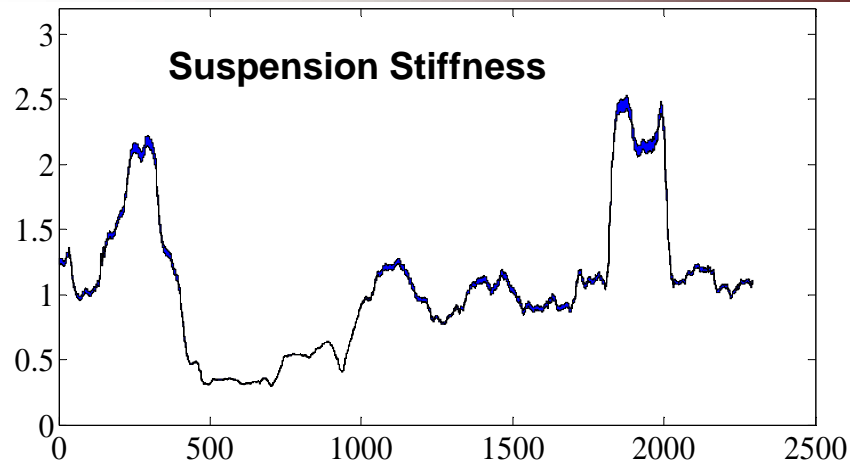
Sensitivity Analysis (Sampling)



Sensitivity Analysis (Quarter Car Parameters)



Sensitivity Analysis (Sampling)



Conclusions

- **Same IRI trend between probe vehicle and profiler:**
 - ✓ **Effect of data sampling**
 - ✓ **Effect of full vs. quarter car**
 - ✓ **Effect of probe vehicle car parameters**
- **Use of the data:**
 - ✓ **To much uncertainty/variation for detailed analysis**
 - ✓ **Maybe useful for strategic level**

PAVEMENT EVALUATION 2014



Originally held in 2002, this conference builds on the previous conference's accomplishments by combining the annual Road Profiler Users' Group meeting with discussions and presentations from other disciplines of non-destructive pavement evaluation. In addition to profiling, other topics of interest include texture and friction measurement, tire-pavement noise, ground penetrating radar (GPR), video distress rating and structural testing. The conference welcomes representatives from government transportation agencies, academia and private industry. It will benefit end-users, operators, researchers, construction and design engineers, and manufacturers who have an interest in the equipment, methods, and use of non-destructive pavement evaluation. It is also highly recommended for consultants, contractors, and construction equipment developers who are in the business of meeting performance requirements for traveled surfaces.

After the meeting, equipment owners and manufacturers will be invited to participate in an equipment comparison rodeo to be conducted at the Virginia Smart Road in Blacksburg, Virginia.

Blacksburg, VA

