Identifying Deficient Pavement Sections using an Improved Acceleration-based Metric

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Agenda

- Introduction
- Data Collection
- Data Analysis Results

1. Acceleration-based metric
2. Identification of deficient pavements

- Conclusions

Introduction- Background

- Measuring pavement roughness is essential for pavement management
- Currently one of the most commonly used roughness measurements is the International Roughness Index (IRI)
- Collection of network level roughness data requires significant resources with accurate profiler

Connected Vehicle Environment

- A connected, data-rich transportation system

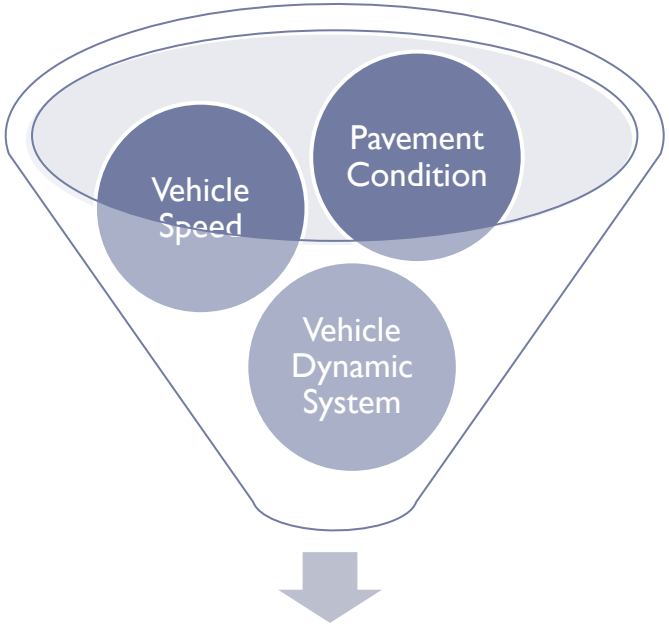
  thanks to the development of sensor and wireless communication techniques
- Acceleration, GPS location, Vehicle Speed, etc…
- How can this new data be used to improve pavement assessment and management?

Introduction- CVI-UTC Project

- "Pavement Assessment and Management Applications Enabled by the Connected Vehicles Environment- Proof-of-Concept"
- To use data collected from "probe" vehicles to extract information that could be used to remotely and continuously monitor pavement health

Introduction- Challenges

- Root Mean Squared Acceleration = IRI ?

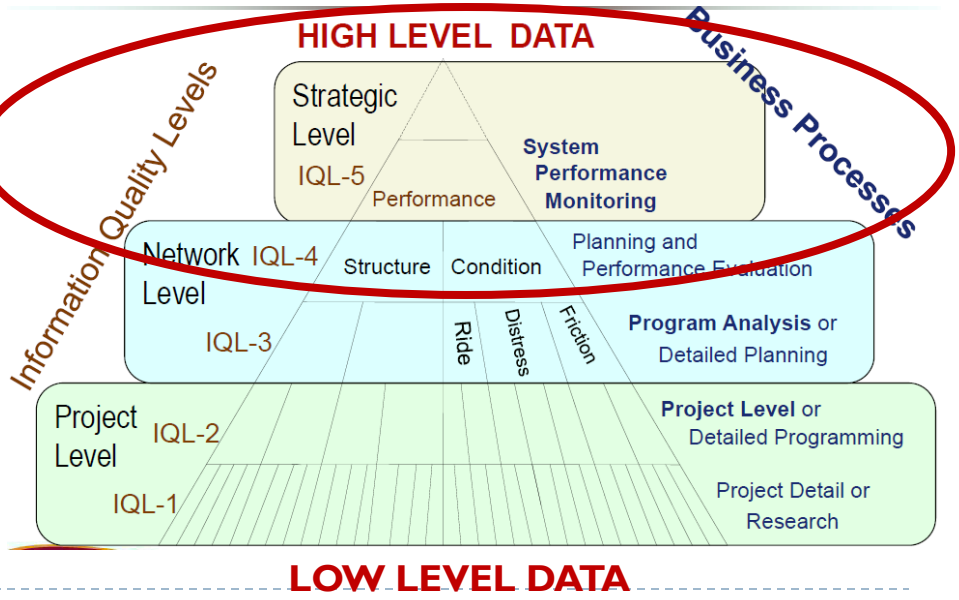


- Acceleration-only metric may not be good enough

Introduction- Objectives

- An acceleration-based metric by incorporating speeds
- Identify deficient pavement sections

Serve as a **supplemental** method for current IRI practice- network screening.



Data Collection System

- RoLine profiler
- Smartphone data (50 Hz)

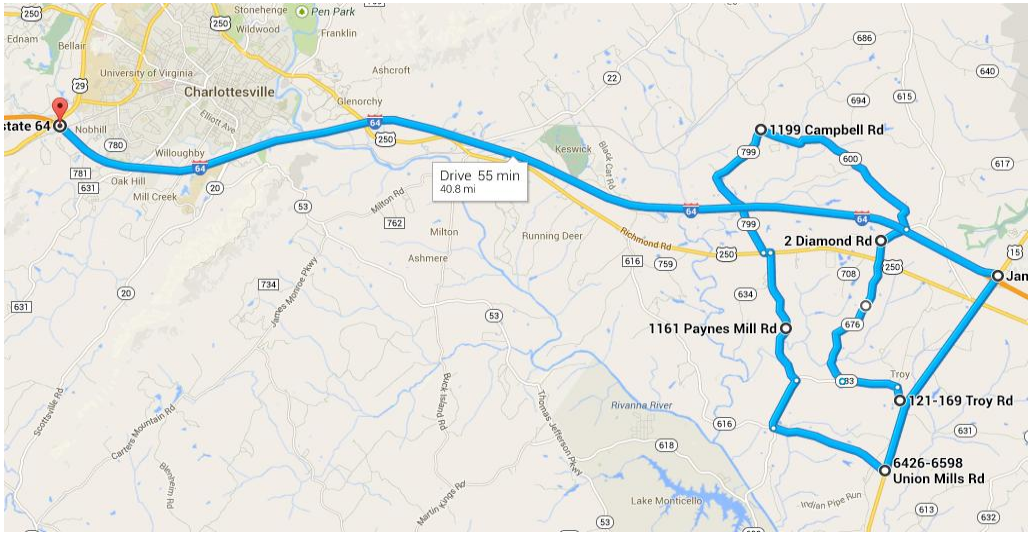
  3-way accelerations

  GPS location, and speed
- IRI and RMS aggregated at 0.1-mile interval

	A	B	C	D	E	F	G	H	I	J
1	_id	latitude	longitude	time	speed	accuracy	x	y	z	stime
2	11820	37.62951	-77.5643	1.36E+12	28.17035	4	-0.07661	0.584185	10.26634	2.45E+13
3	11821	37.62951	-77.5643	1.36E+12	28.17035	4	-0.20111	0.6608	9.883265	2.45E+13
4	11822	37.62951	-77.5643	1.36E+12	28.17035	4	-0.43096	1.024718	10.69729	2.45E+13
5	11823	37.62951	-77.5643	1.36E+12	28.17035	4	-0.49799	0.919373	10.25676	2.45E+13
6	11824	37.62951	-77.5643	1.36E+12	28.17035	4	-0.29688	0.871489	10.30465	2.45E+13
7	11825	37.62951	-77.5643	1.36E+12	28.17035	4	-0.33519	0.517148	9.5385	2.45E+13
8	11826	37.62951	-77.5643	1.36E+12	28.17035	4	-0.56503	0.756568	10.18015	2.45E+13
9	11827	37.62951	-77.5643	1.36E+12	28.17035	4	-0.33519	1.024718	10.60153	2.45E+13
10	11828	37.62951	-77.5643	1.36E+12	28.17035	4	-0.45969	1.005565	10.51533	2.45E+13

Data Collection Routes

- Three types of roadways
- 50-mile in total
- Speed limit range from 30 to 70 mph



Route	IRI Summary (in/mile)			Speed (mph)			Number of Sites		Length
	Med.	Min.	Max.	Med.	Min.	Max.	Deficient	Non-Def.	(mile)
IS-64E	75.5	45.5	256.8	65.9	63.9	67.5	16	162	17.8
IS-64W	76.9	37.3	267.5	64.8	64.0	74.3	17	162	17.9
US-15	82.6	63.4	125.5	52.4	50.2	54.1	0	35	3.5
SR-616	124.7	86.1	172.0	45.4	41.2	47.8	6	15	2.1
SR-600	121.2	85.7	219.3	40.8	34.0	50.4	9	25	3.4
SR-799	87.4	123.9	228.5	39.3	32.0	49.3	8	20	2.8
SR-676	189.9	151.8	248.2	40.5	33.5	45.8	25	0	2.5
Total	85.0	37.3	267.5	64.8	32.0	67.5	81	419	50

An Acceleration-based Metric

- Finding from previous studies (Ahlin and Granlund, 2002)

$$\frac{vib}{IRI} = 0.16(v/80)^{(n-1)/2}$$

- Recommended format: indicates the vibration level that a vehicle is expected to experience at 50 mph (80 km/h).

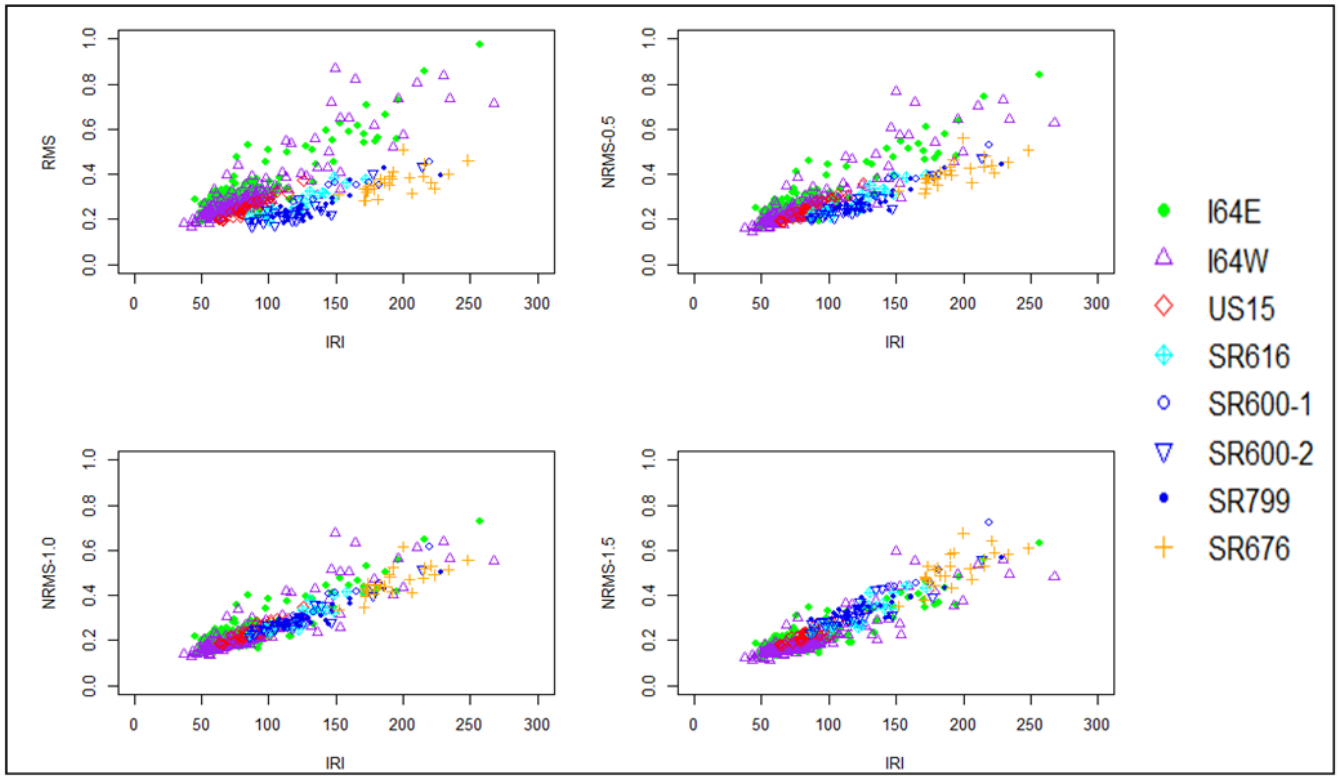
$$NRMS = (80/v)^{w} a_{z,RMS}$$

Where:

vib = vehicle vibration responses;
v = vehicle speed, km/h;
$a_{z,RMS}$ = RMS vertical acceleration;
NRMS = normalied RMS acceleration; and
n, *w* = exponent values that are related to pavement wavelength, and *w* = (*n*-1)/2.

An Acceleration-based Metric

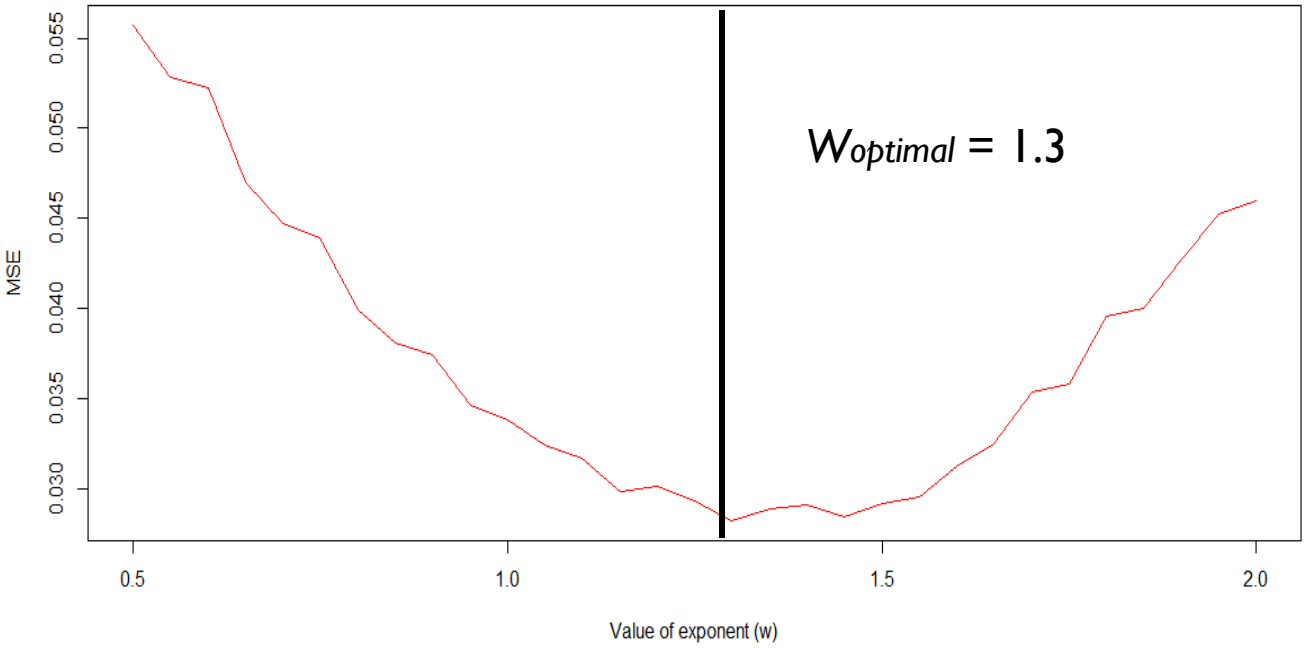
- Scatter plots of IRI Vs. RMS/NRMS (w = 0, 0.5, 1, 1.5)



- For network screening, what's the optimal value of w?

An Acceleration-based Metric

- Classification error curve



$$NRMS = (80/v)^{1.3} a_{z,RMS}$$

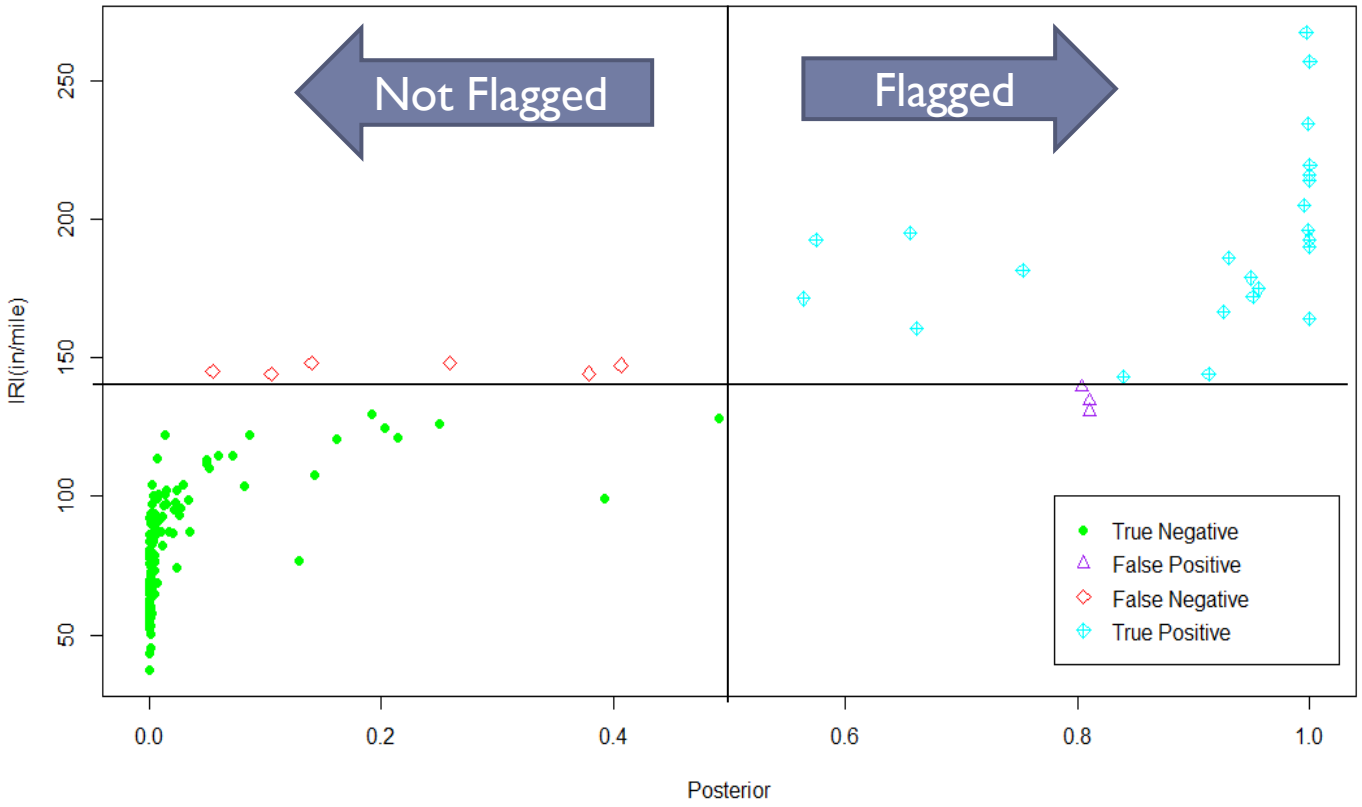
Identification of Deficient Pavements

- $Y_i = \begin{cases} 1 & If\ the\ pavement\ is\ deficient\ (IRI_i \geq 140\ in/mile) \\ 0 & If\ the\ pavement\ is\ not\ deficient\ (IRI_i < 140\ in/mile) \end{cases}$
- $\log(Odd) = \alpha + \beta NRMS_i$

Model	Variable	Coefficient	S.E.	Significant	Odds Ratio[1]	Nagelkerke R Square[2]	AIC	$NRMS_0$
Default Model	Intercept	-14.20	2.16	0.000	1.48	0.84	69.46	0.36
	NRMS	39.04	6.16	0.000				

A pavement section will be flagged as deficient if its NRMS ≥ 0.36 m/sec^2.

Identification of Deficient Pavements



- Identify correctly 80% (24/30) of deficient pavements
- The IRIs of those mis-identified sections are close to 140 in/mile

Conclusion and Future Research

- This study developed a normalized acceleration-based metric (*NRMS*) that can generalize to different functional classes of highway by incorporating vehicle speed.
- Feasibility of using *NRMS* for the purpose of network screening
- Future Research:

1. Identify IRI > 220 inch/mile situation
2. Vehicle dynamic system impacts
3. Filters to remove invalid data
4. Prototype system using state-own vehicles

Questions?

Thank You!

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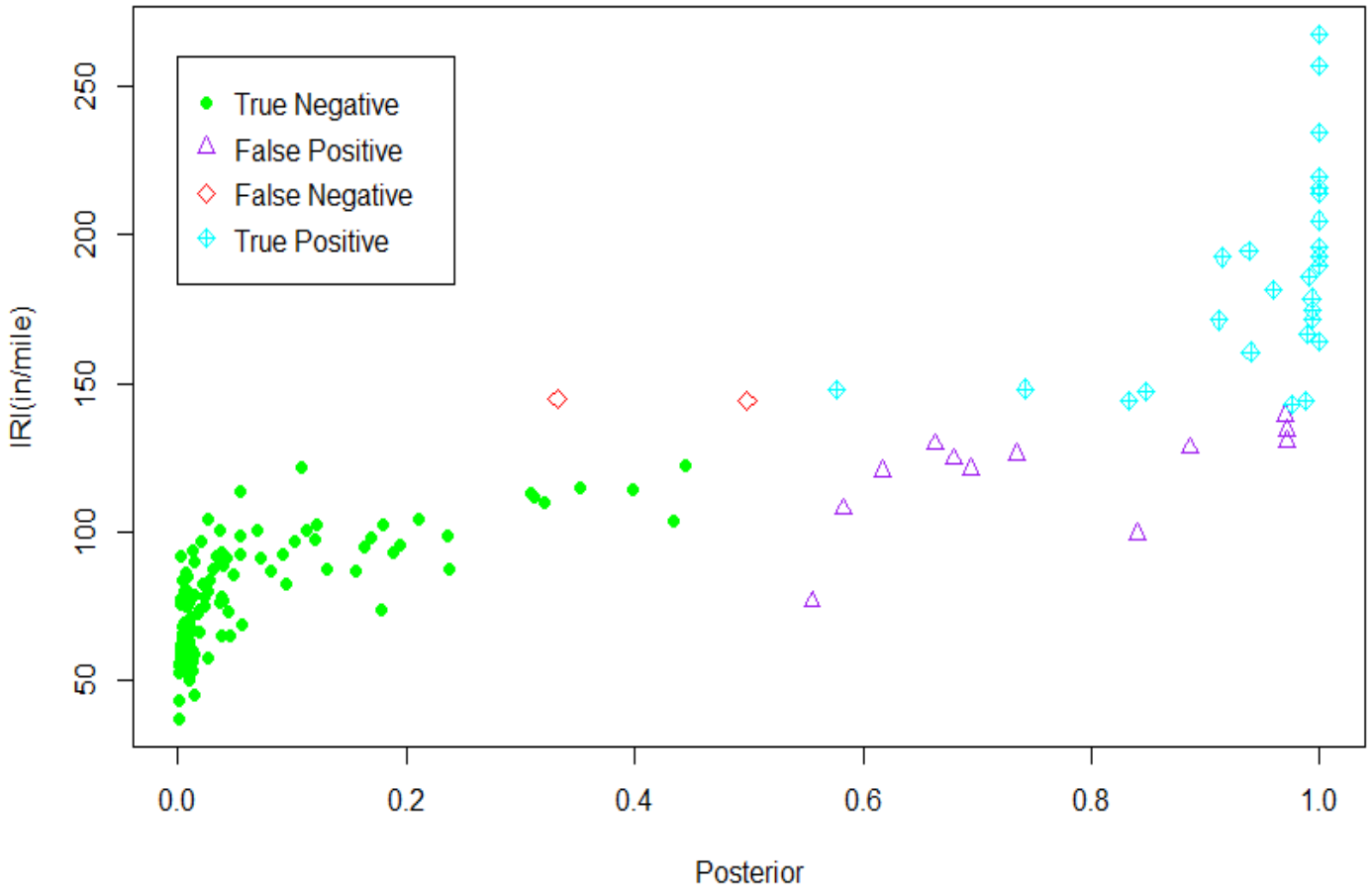
Classification Results Summary

TABLE 3 Classification Results Summary

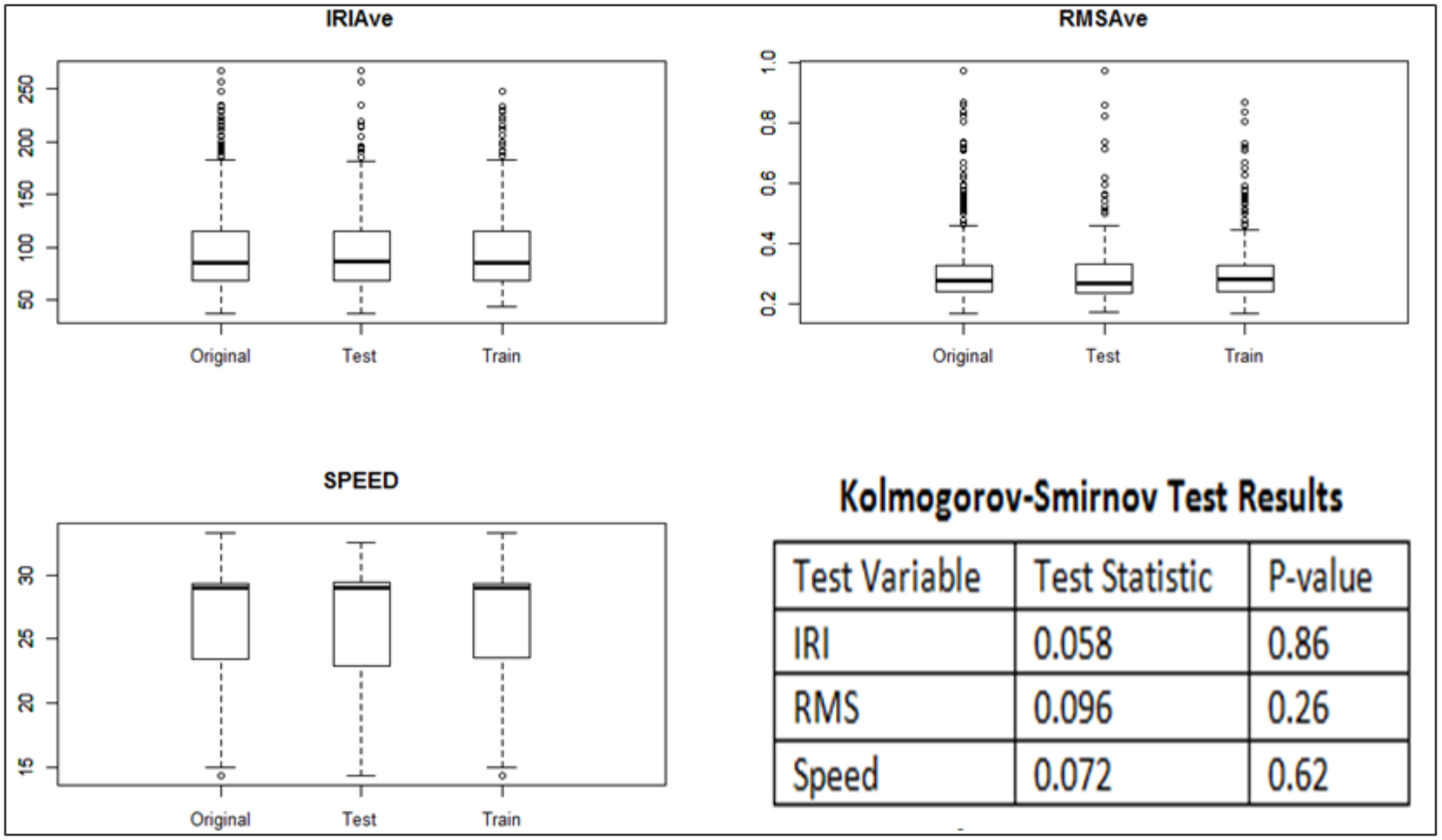
Model	Observed	Testing Data Predicted		
		Non-Def.	Deficient	Correct Percentage
Default Model	Non-Def.	132	3	97.78
		(99, 33)[1]	(0, 3)	(100.00, 91.67)
	Deficient	6	24	80.00
		(3, 3)	(13, 11)	(81.25, 78.57)
Shifted Model	Non-Def.	123	12	91.11
		(96, 27)	(3, 9)	(96.97, 75.00)
	Deficient	2	28	93.33
		(1, 1)	(15, 13)	(93.75, 92.86)
No Speed	Non-Def.	133	2	98.51
		(98, 34)	(1, 1)	(98.99, 97.14)
	Deficient	13	17	56.66
		(7, 6)	(9, 8)	(56.25, 57.14)

Note: 1. The first value in the parenthesis indicates the number of interstate sections and the latter the number of non-interstate sections.

Classification Results- Shifted Model



Training and Testing Dataset



Kolmogorov-Smirnov Test Results

Test Variable	Test Statistic	P-value
IRI	0.058	0.86
RMS	0.096	0.26
Speed	0.072	0.62

FIGURE 1 Comparison of IRI, RMS and Speed Data in the Testing and Training Datasets

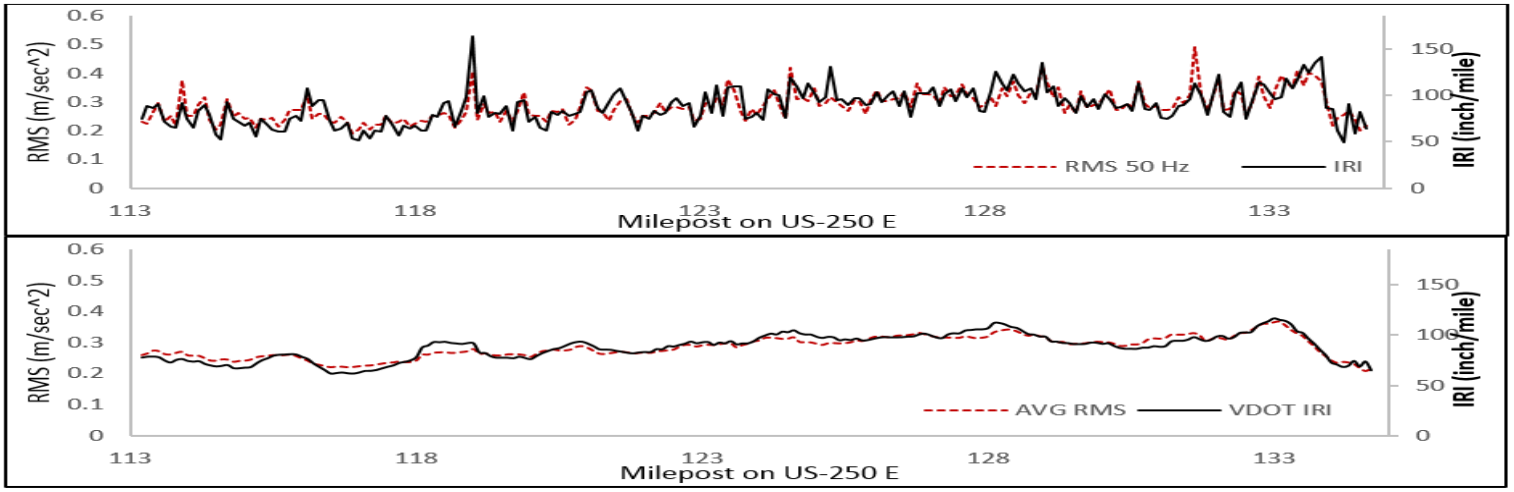


Fig. 4 IRI compared to RMS acceleration on US-250 E; Top: Original 0.1-mile data; Bottom: Moving average using a 1-mile window.

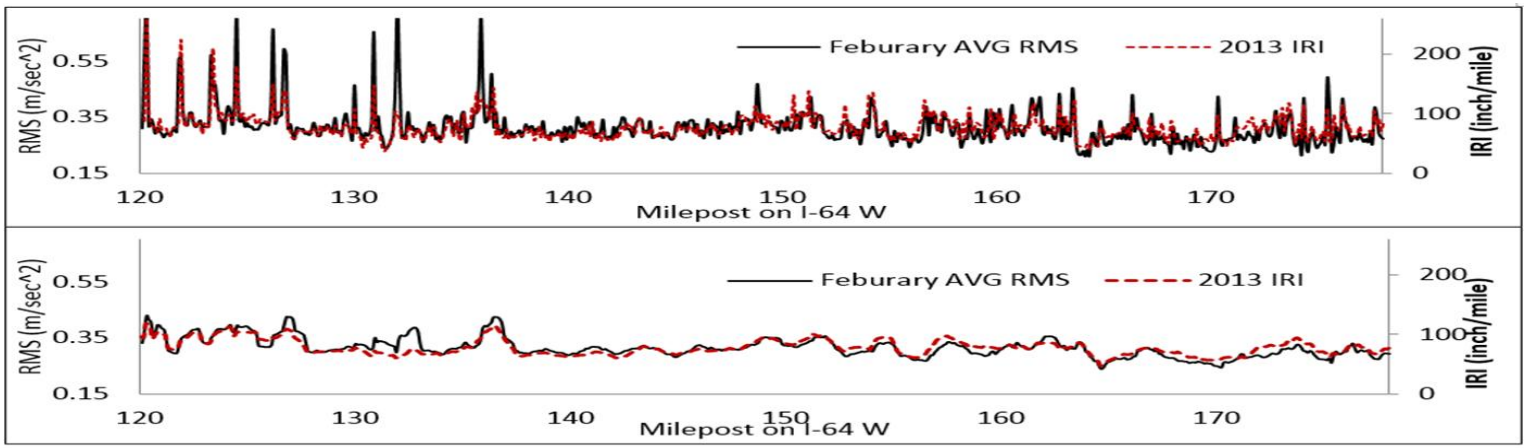


Fig. 3 IRI compared to RMS acceleration on I-64 W; Top: Original 0.1-mile data; Bottom: Moving average using a 1-mile window.