

Evaluation of Accuracy and Precision of Highway Speed Deflection Devices



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Objectives

Session 2: “Network Level Pavement Structural Evaluations – A Way Forward” by Sivaneswaran

1. Assess, evaluate and validate capability of RWD and TSD for pavement structural evaluation at network level for use in PM application and decision making.
2. If one or more are viable, develop analysis methodologies for enabling their use in PMS. If not, develop recommendations to further develop promising device(s) and/or technologies.

“Investigation of Applicability and Use of a Pavement Response Model with High Speed Deflection Devices” by Siddharthan



State of Art: Highway Speed Deflection Devices

- Viable Devices:
 - Rolling Wheel Deflectometer (RWD)
 - Traffic Speed Deflectometer (TSD)
- Concerns:
 - Can one or both be used in pavement structural evaluations for network level PMS applications?

ARA RWD



- 9 kip load; ≤ 65 mph
- Measurements: based on triangulation lasers
- Results: Deflections at 2 locations

Greenwood TSD



- 11 kip load and < 50 mph
- Measurements: based on Doppler technique to measure deflection velocity
- Results: Deflection velocities at 6 points

Field Evaluation Sites

- MnROAD Facility
 - **3.5-mile mainline roadway**
45 sections Typically 500 ft long and varying pavement types
 - **2.5-mile low volume roadway**
28 sections typically 500 ft long and varying pavement types
- 18-Mile Loop In-Service Road
 - **Wright County, MN**
Provides longer test sections, tight turns and rolling hills



Experiment Design: MnRoad

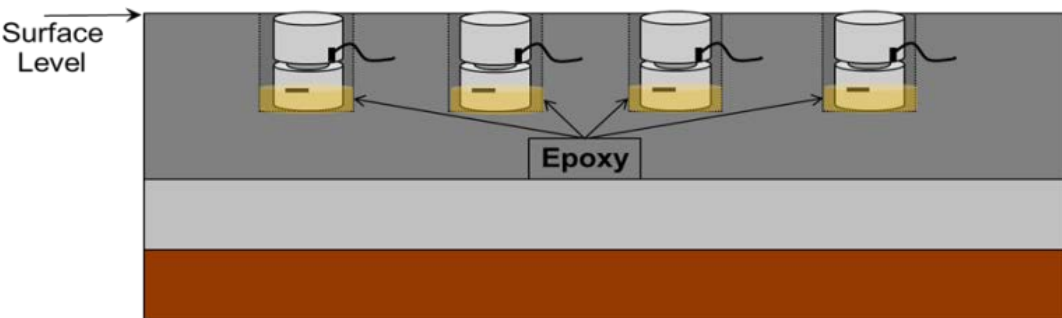
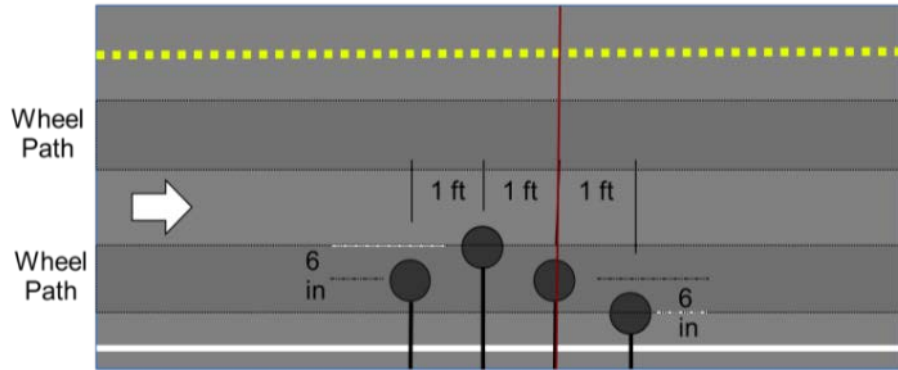
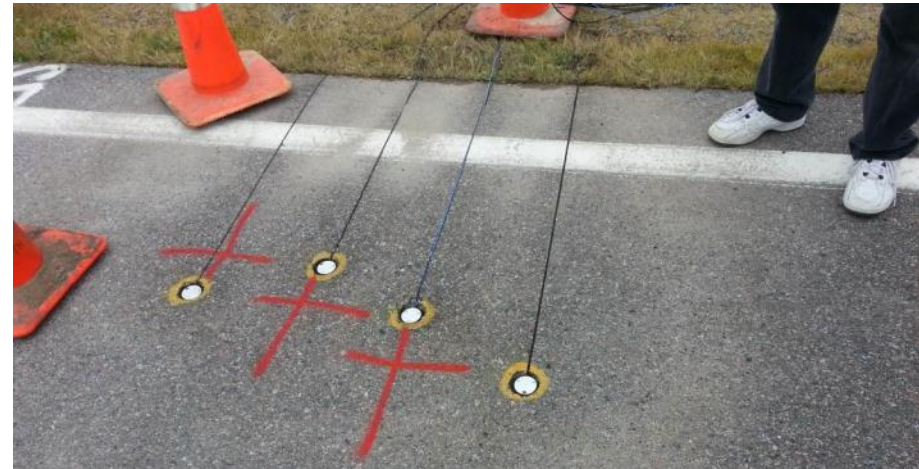
- **Accuracy**

- *Locations (3 cells)*: soft, semi-stiff and stiff
- *Vehicle Speed (3 levels)*: 30 mph, 45 mph and 60 mph
- *Replicates*: 3 times

- **Precision**

- *Locations (all cells)*: up to 62 cells
- *Vehicle Speed (3 levels)*: 30 mph, 45 mph and 60 mph
- *Temperature (2 levels)*: morning and afternoon
- *Replicates*: 3 to 5 times

Placement of Sensors

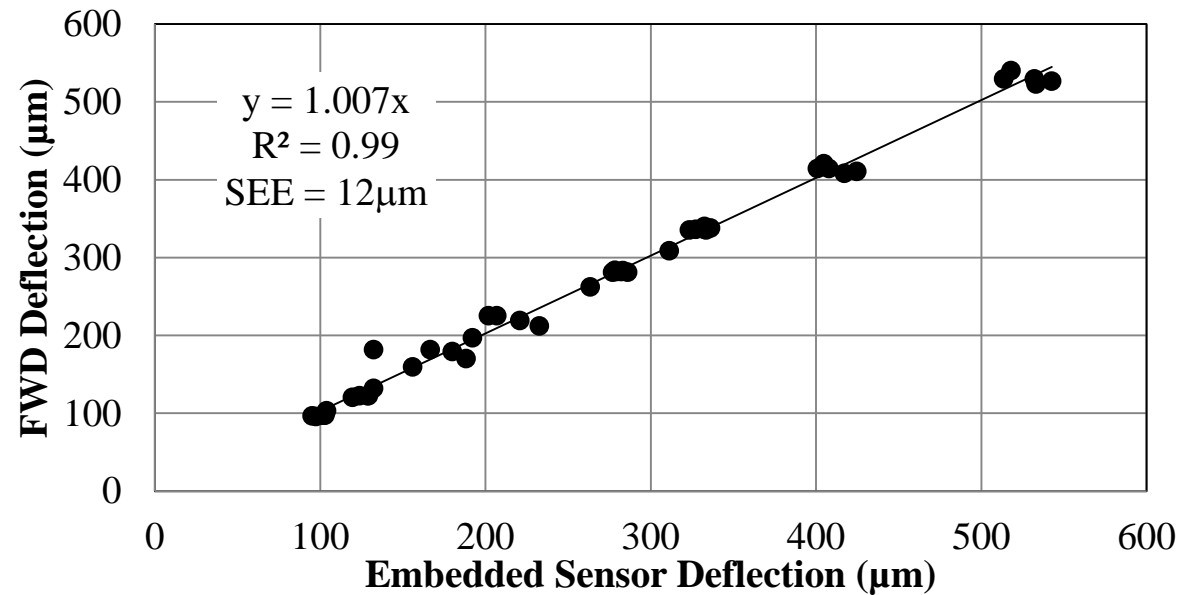


Evaluation with FWD



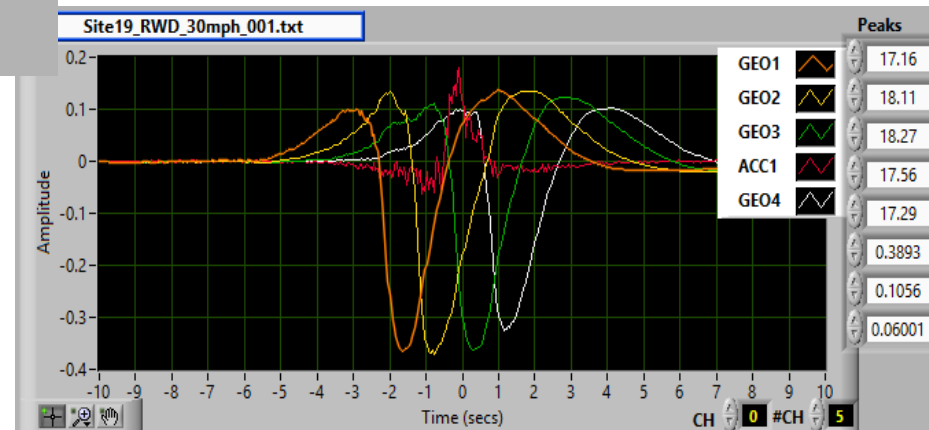
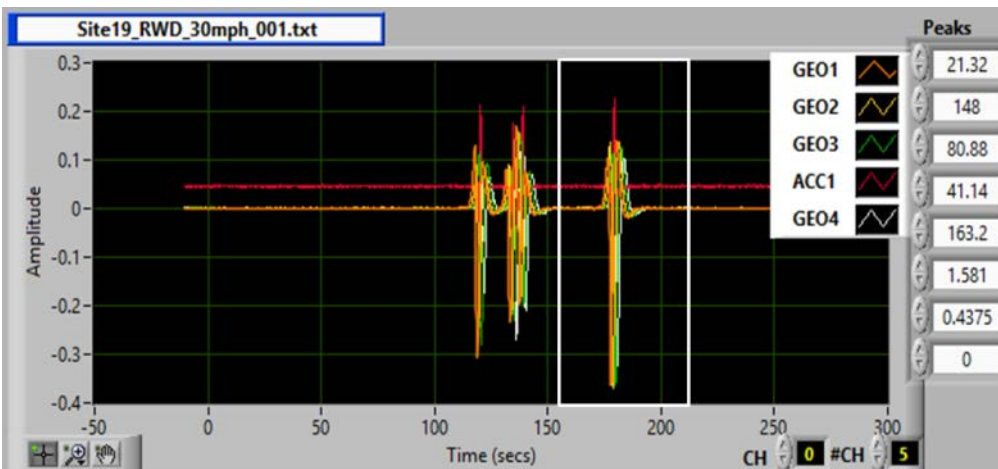
Three Cells Instrumented:

- Cell 3: Stiff
- Cell 19: Semi-Stiff
- Cell 34: Soft

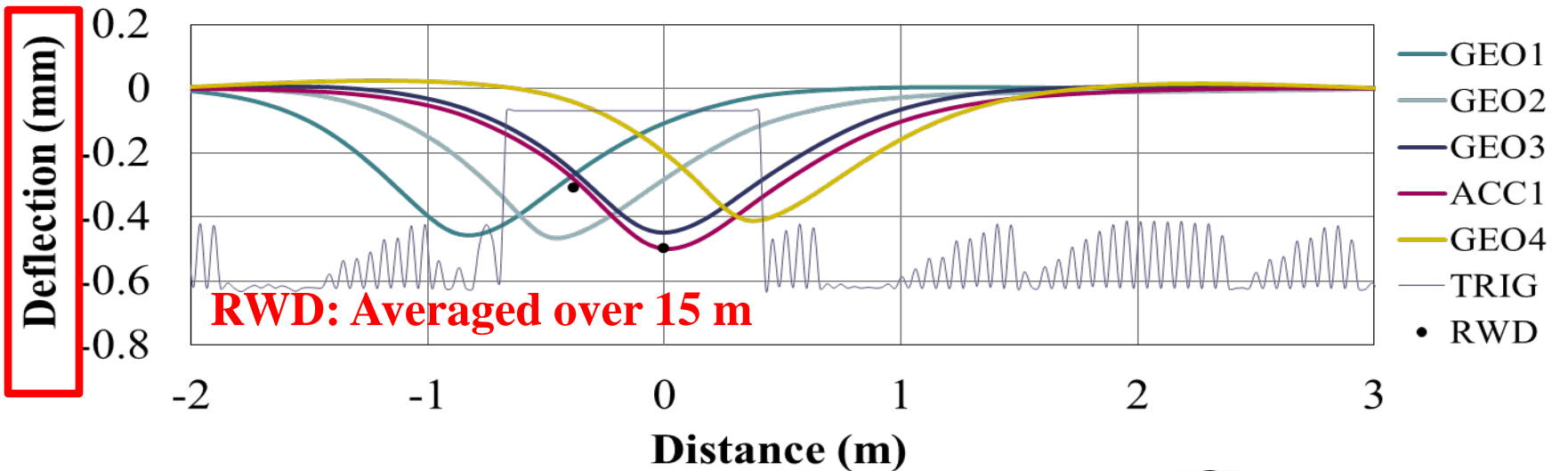
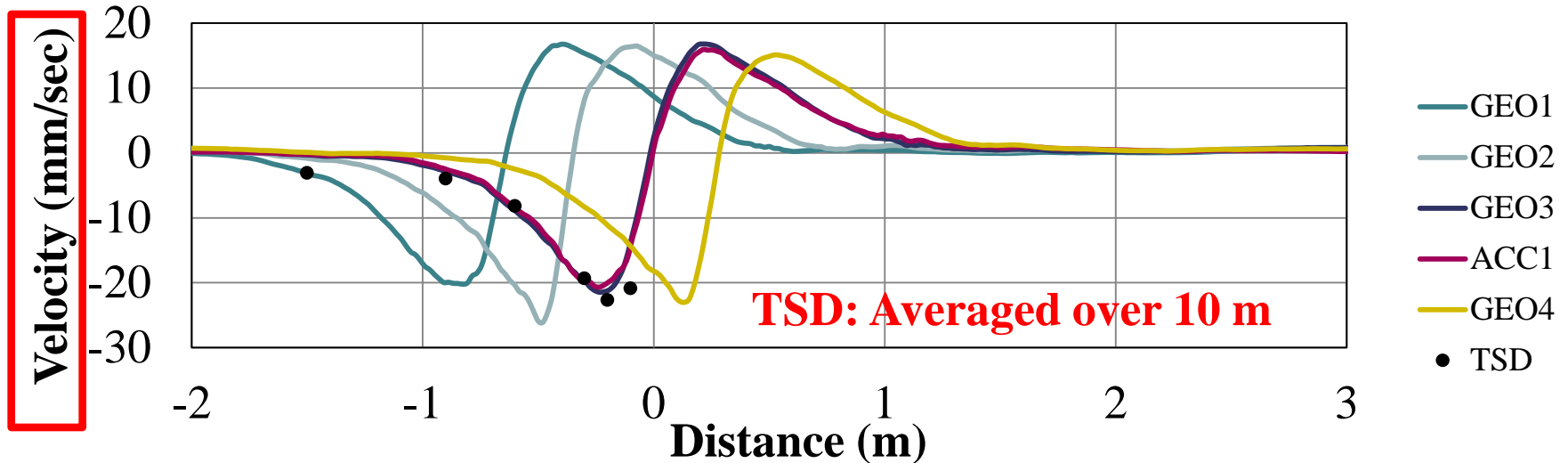


Typical Sensor Responses

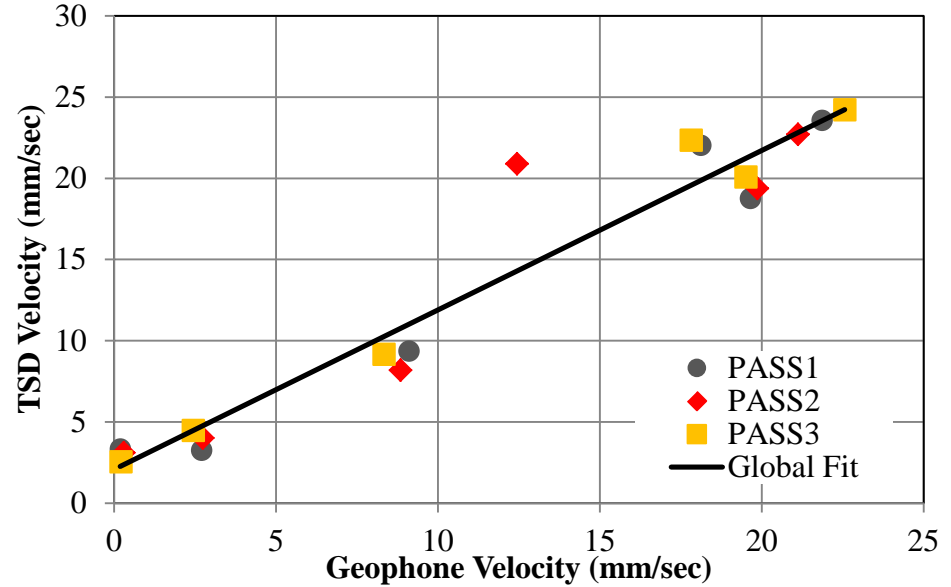
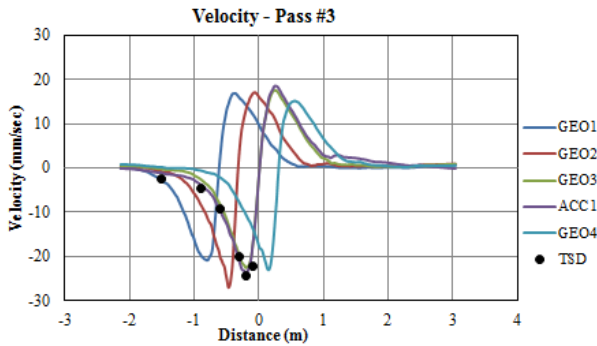
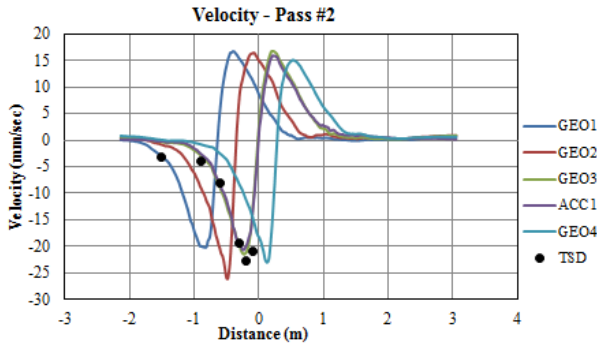
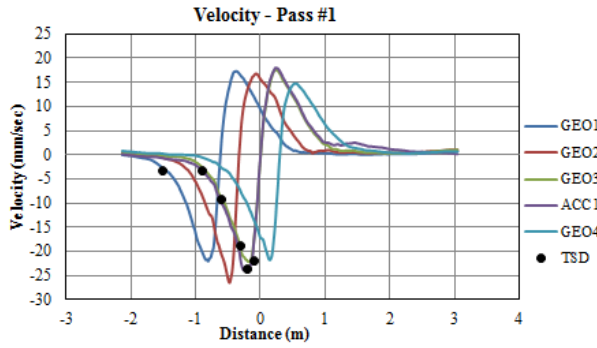
1. Time history data is retrieved.
2. True speed is calculated.
3. Section of data related to rear tire isolated and analyzed.



Typical Measurements



Typical Accuracy: TSD

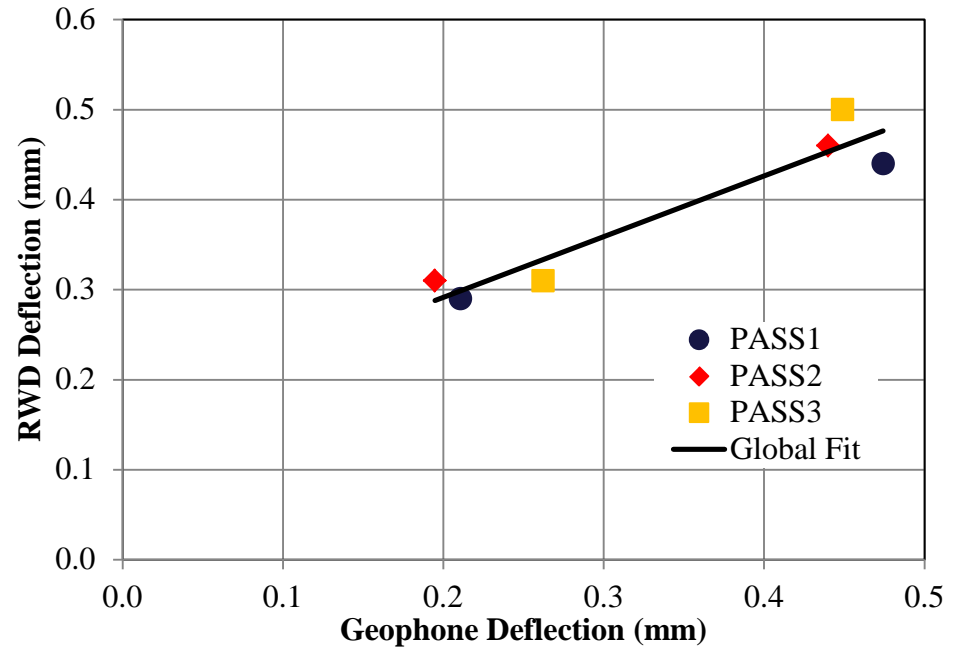
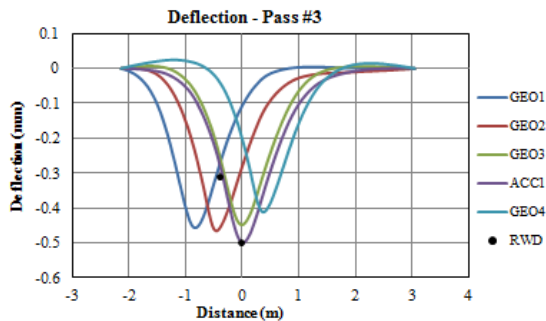
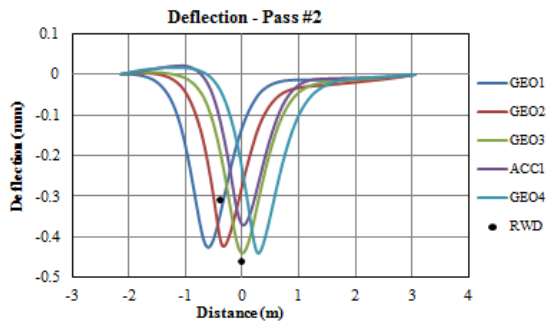
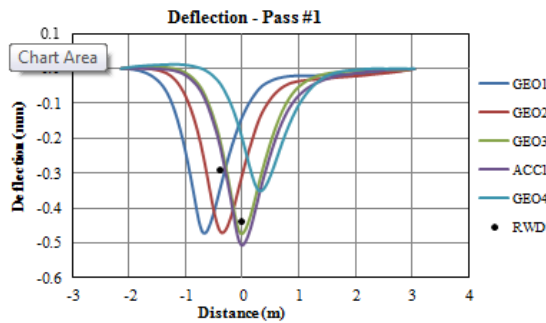


DIST (m)	Avg. Error	StD of Error
1.5	309%	238%
0.9	30%	27%
0.6	22%	8%
0.3	12%	4%
0.2	2%	0%
0.1	25%	23%

Constant	2.08 mm/sec
Slope	0.98
R ² Value	0.93
Standard Error of Estimate	2.29 mm/sec
Inaccuracy	10%



Typical Accuracy: *RWD*

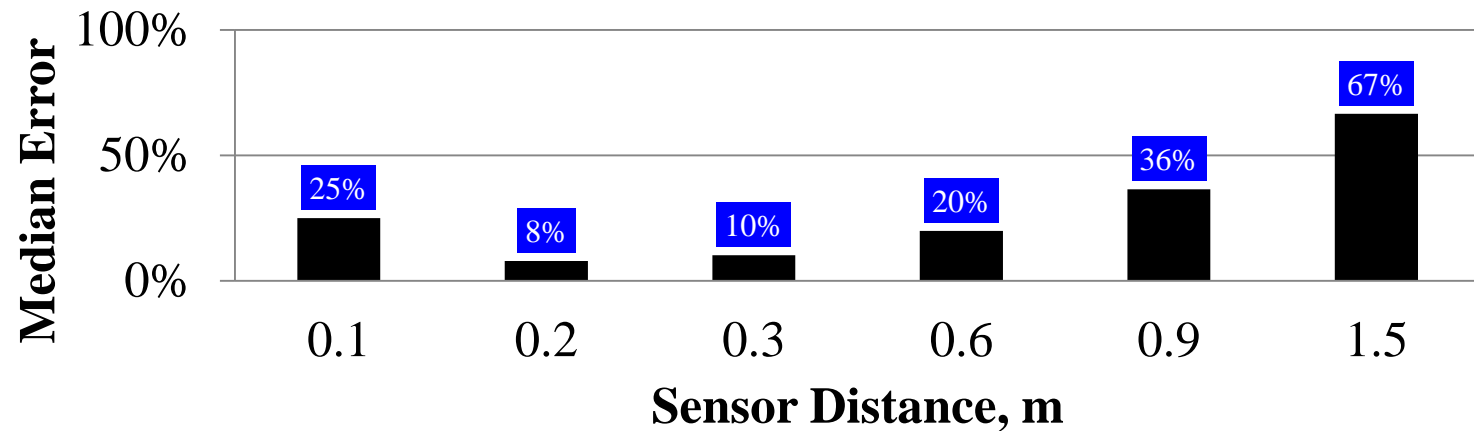


DIST (m)	Avg. Error	StD of Error
0	32%	8%
0.381	33%	11%

Constant	0.16 mm
Slope	0.67
R ² Value	0.90
Standard Error of Estimate	0.03 mm
Inaccuracy	9%

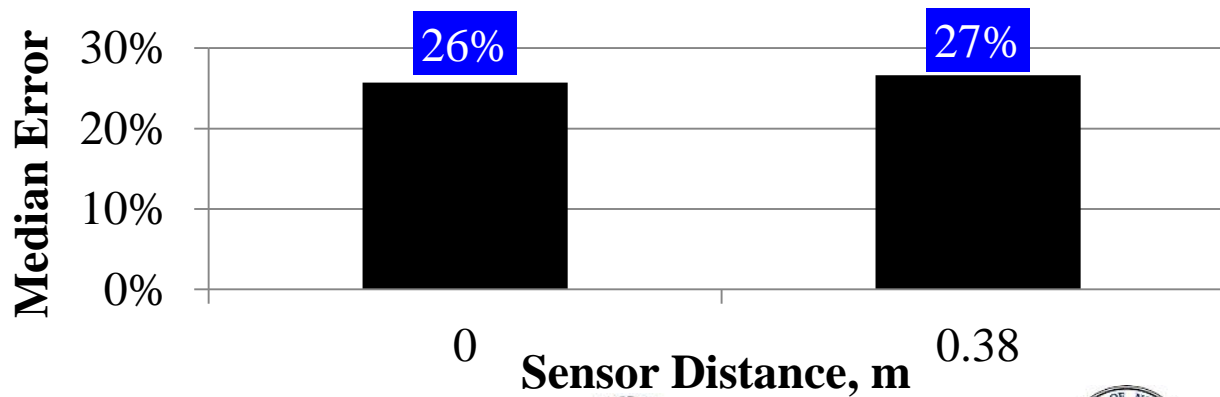
Accuracy Results: TSD

Cell	Speed, mph	Overall Statistics				Avg. Error by Sensor					
		Constant	Slope	R ²	SEE	1.5 m	0.9 m	0.6 m	0.3 m	0.2 m	0.1 m
34	30	0.93	0.96	0.96	2.37	78%	42%	11%	10%	8%	15%
34	45	0.90	1.11	0.95	3.86	73%	71%	10%	2%	9%	39%
3	30	1.42	0.76	0.83	0.96	40%	55%	40%	10%	16%	32%
3	45	1.25	0.91	0.85	1.42	67%	34%	39%	11%	10%	29%
19	30	1.28	0.95	0.97	1.14	-5312%	36%	20%	9%	8%	6%
19	45	2.08	0.98	0.93	2.29	309%	30%	22%	12%	2%	25%
19	60	1.18	1.01	0.96	2.26	-1537%	28%	19%	8%	4%	14%

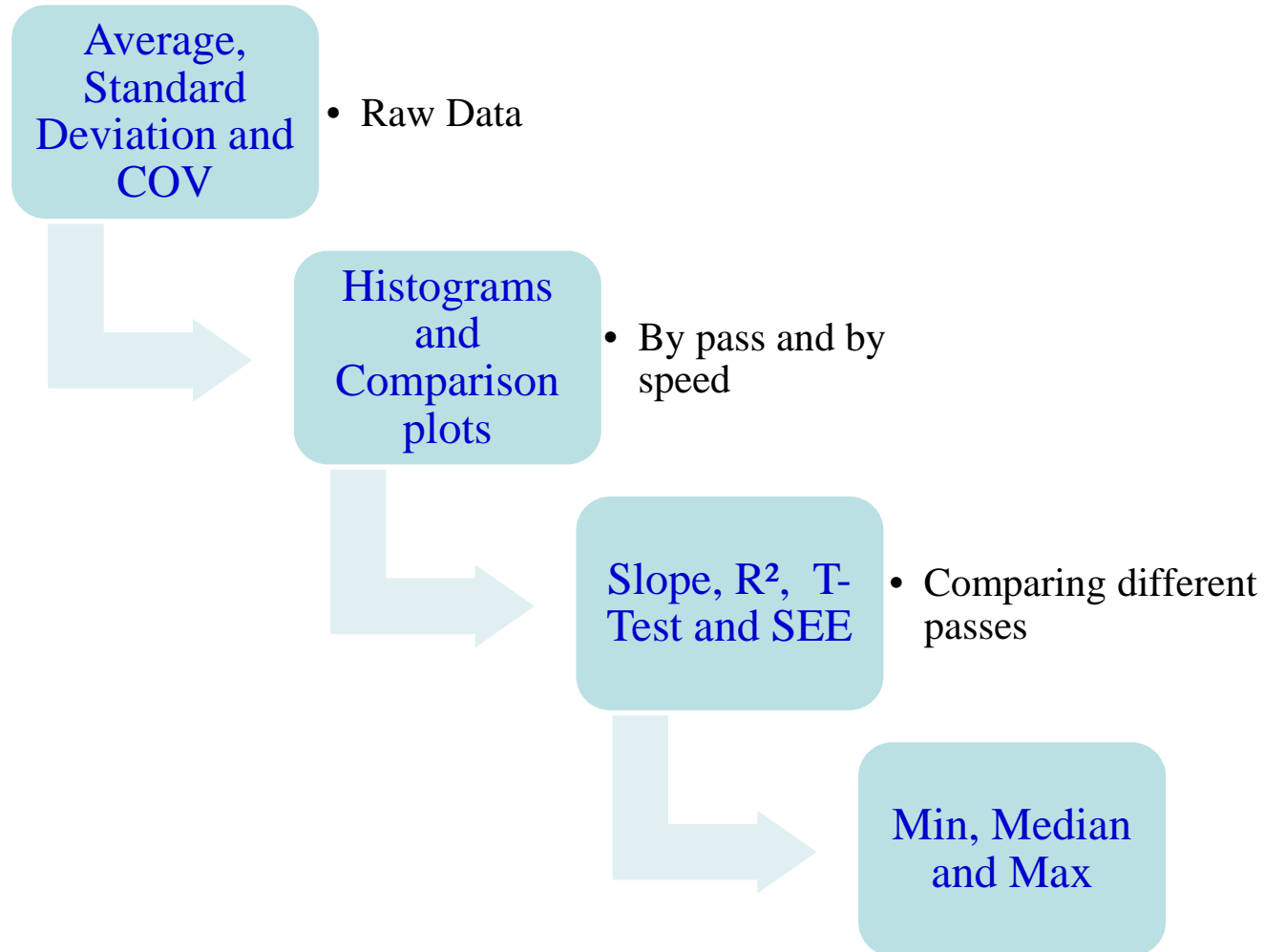


Accuracy Results: *RWD*

Cell	Speed, mph	Overall Statistics				Individual Sensor			
						0 m		0.38 m	
		Constant	Slope	R ² Value	SEE	Avg. Error	StD of Error	Avg. Error	StD of Error
3	30	0.02	1.22	0.71	0.05	25%	18%	38%	11%
3	45	0.07	1.06	0.68	0.06	27%	3%	21%	5%
3	60	-0.06	1.22	0.80	0.05	23%	19%	24%	35%
19	30	0.11	0.70	0.96	0.02	30%	6%	29%	11%
19	45	0.19	0.59	0.90	0.04	41%	5%	41%	23%
19	60	0.16	0.67	0.90	0.03	32%	8%	33%	11%
34	30	0.16	0.84	0.99	0.02	16%	2%	16%	6%
34	45	0.13	0.87	0.98	0.02	13%	3%	12%	11%

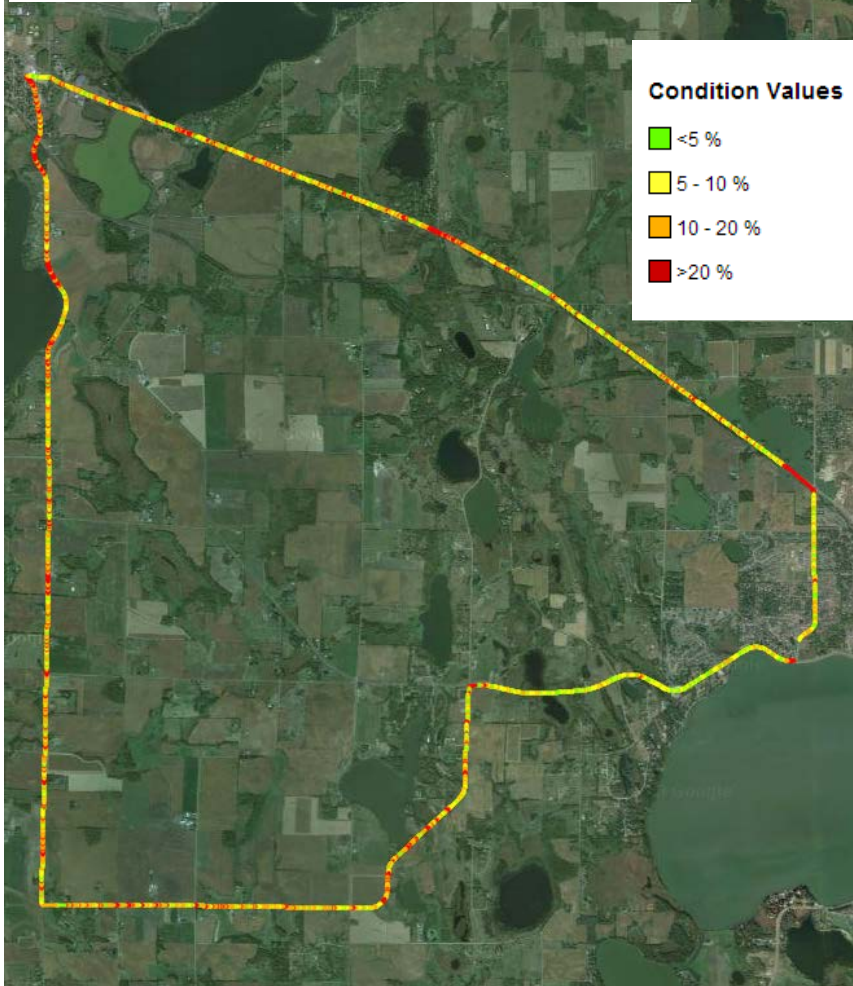


Precision: Steps



Analysis Procedure: *Visual Inspection*

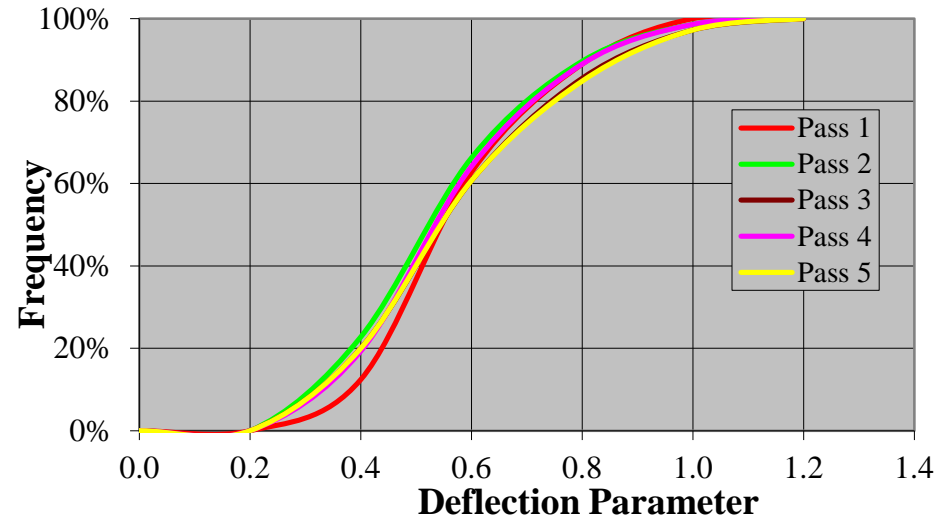
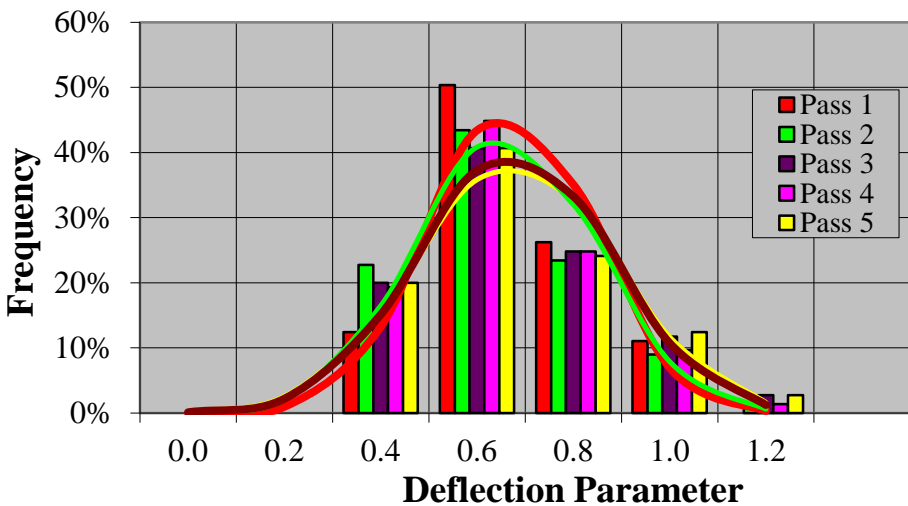
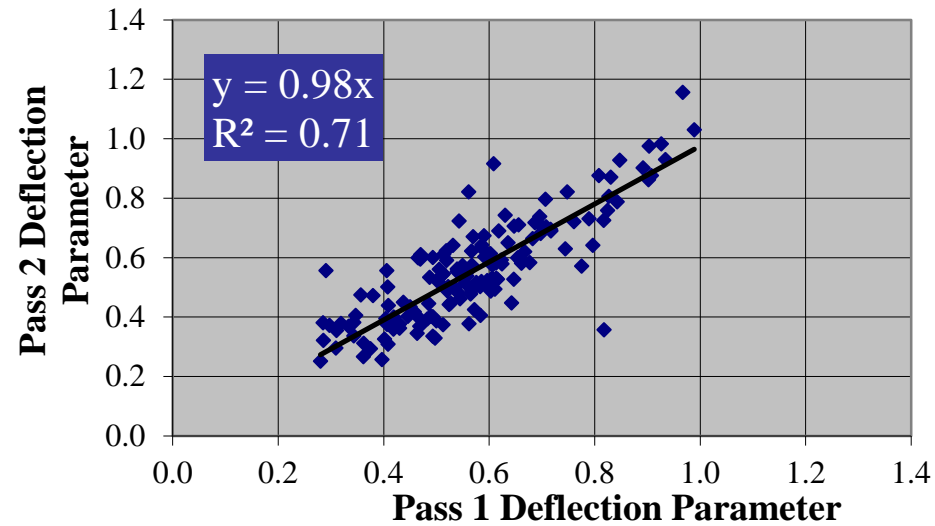
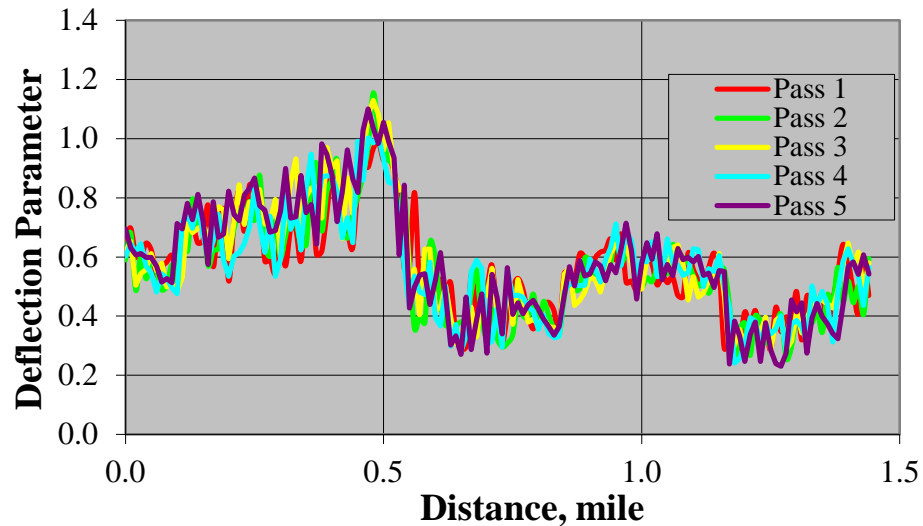
COV of Deflection Parameter



COV of Vehicle Speed



Analysis Procedure: *Plots*



Analysis Procedure: Results

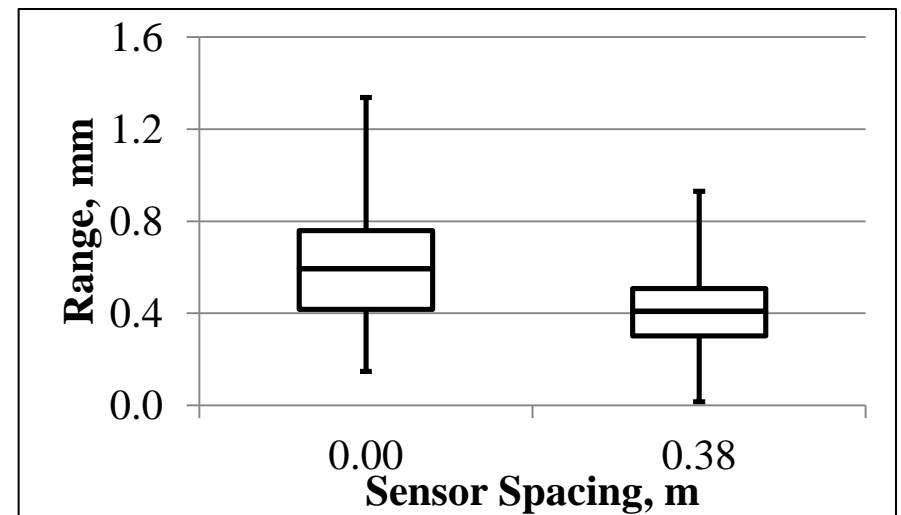
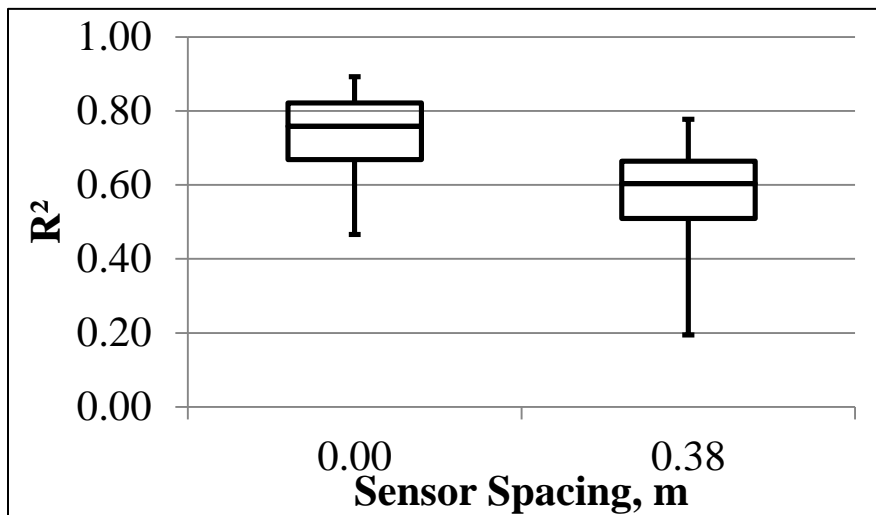
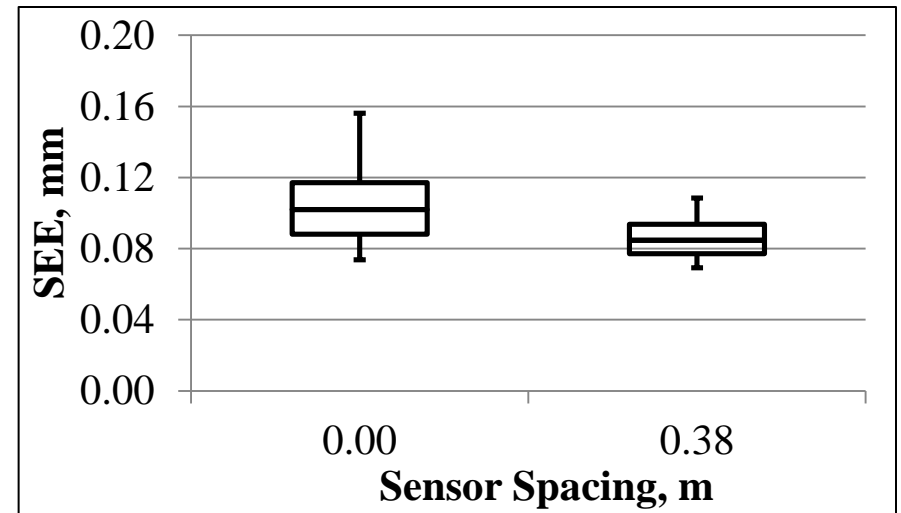
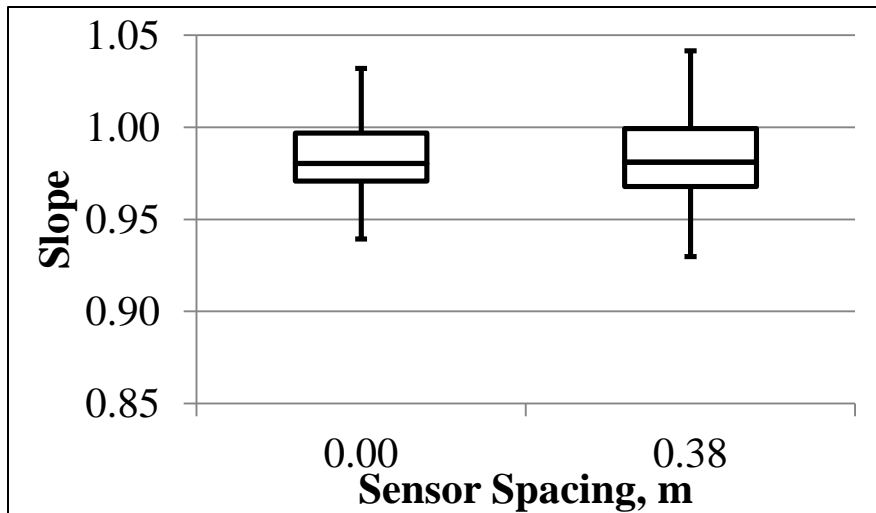
Slope	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	R²	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
Pass 1		0.979	0.953	0.981	1.001	Pass 1		0.784	0.706	0.751	0.750
Pass 2			0.969	0.993	1.009	Pass 2			0.861	0.850	0.794
Pass 3				1.012	1.032	Pass 3				0.821	0.806
Pass 4					1.008	Pass 4					0.834
Pass 5						Pass 5					

T-Test	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	SEE	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5
Pass 1		0.710	0.095	0.845	0.451	Pass 1		0.12	0.14	0.13	0.13
Pass 2			0.050	0.843	0.223	Pass 2			0.10	0.10	0.12
Pass 3				0.060	0.004	Pass 3				0.11	0.12
Pass 4					0.223	Pass 4					0.11
Pass 5						Pass 5					

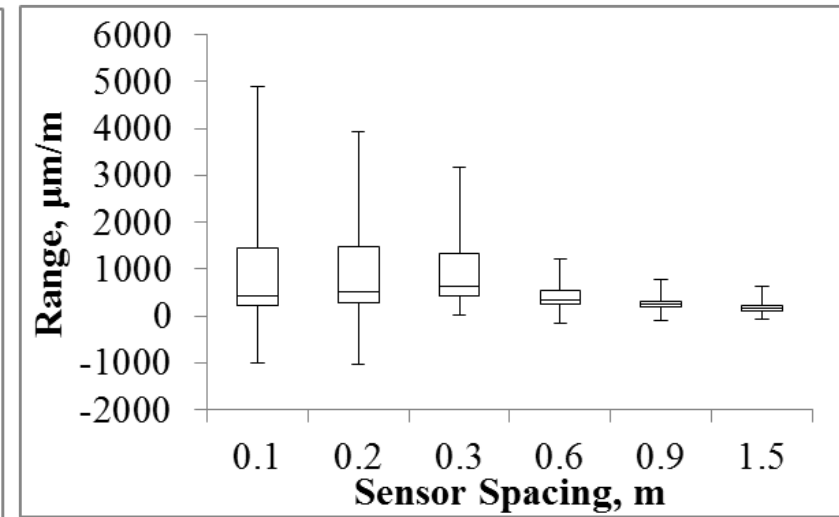
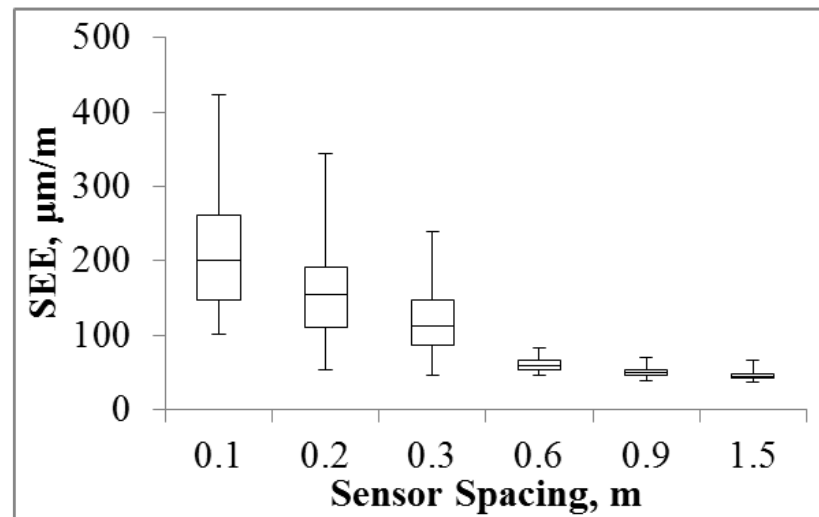
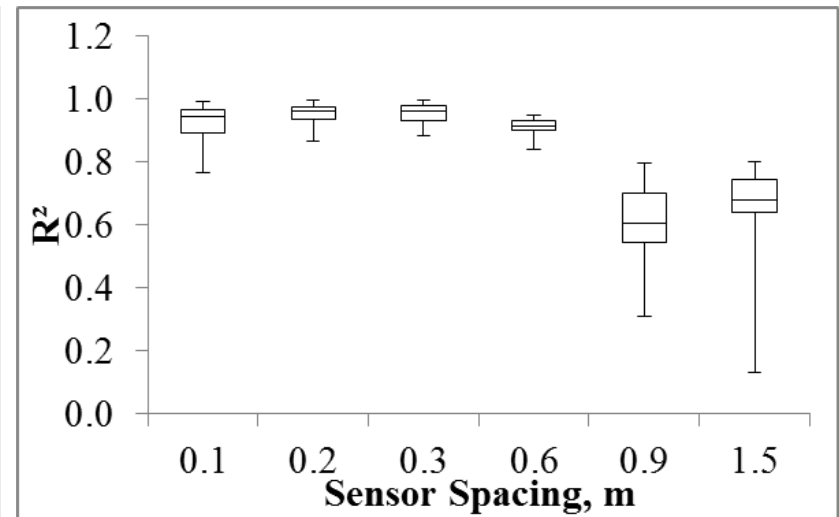
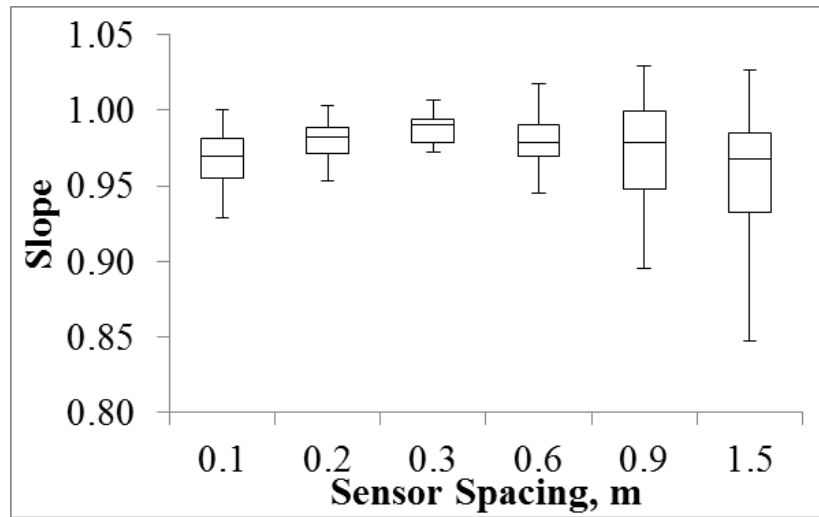
Test Description	# of Data Points	Slope			R²			T-Test			SEE			Range of Measured Value		
		Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max	Median	Min	Max
Sensor 1	145	1.00	0.95	1.03	0.80	0.71	0.86	0.22	0.00	0.84	0.12	0.10	0.14	0.64	0.15	1.33
Sensor 2	145	1.00	0.96	1.04	0.66	0.53	0.77	0.15	0.00	0.81	0.09	0.08	0.11	0.45	0.02	0.91



Precision MnROAD LVR: RWD



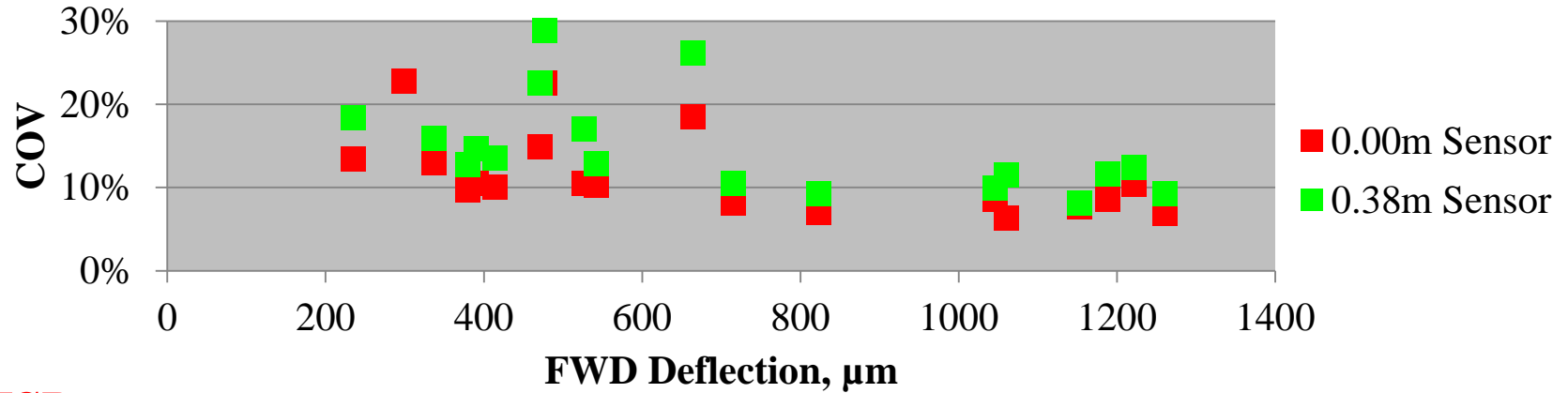
Precision MnROAD LVR: TSD



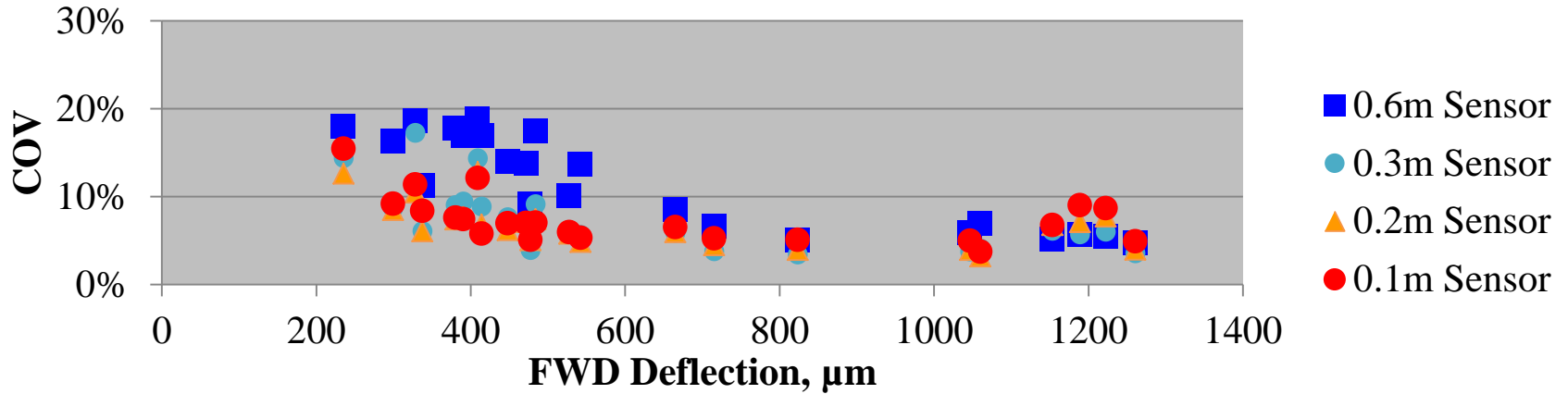
Precision vs. Pavement Structure

Flexible Pavements

RWD



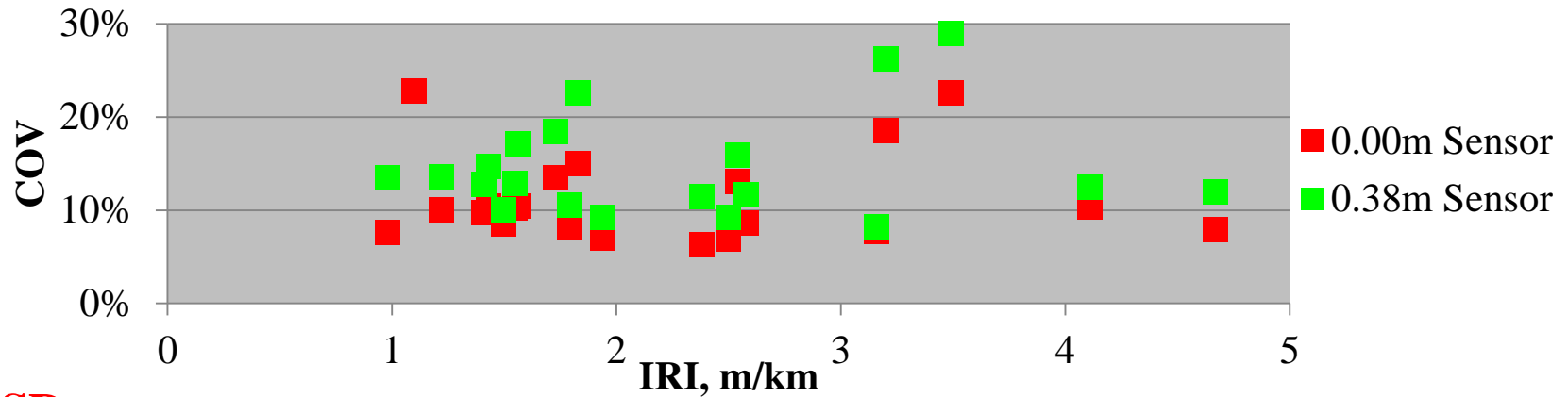
TSD



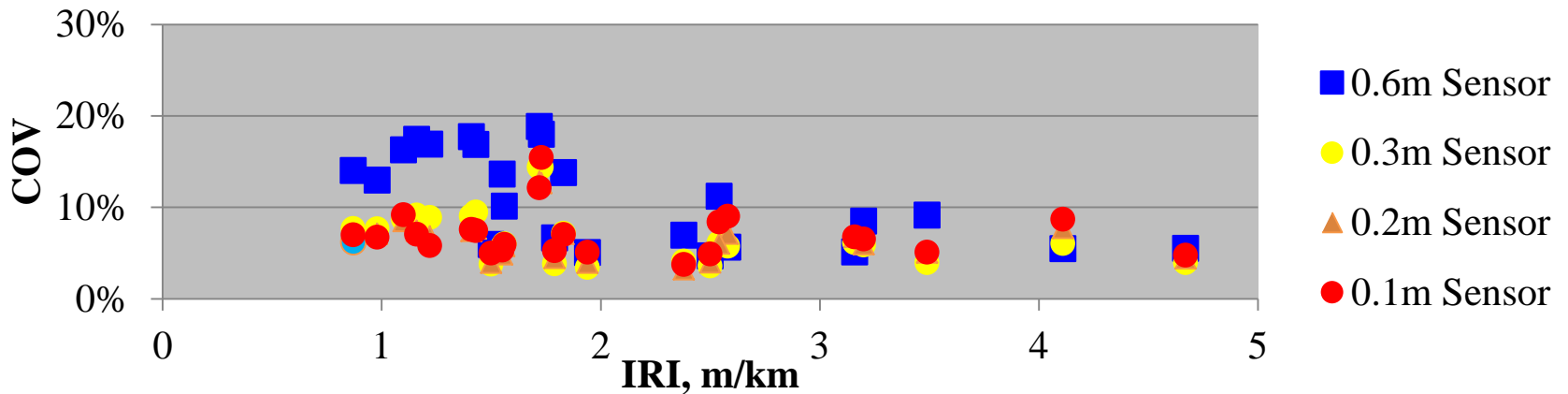
Precision vs. IRI

Flexible Pavements

RWD



TSD



Observations: Accuracy

- *Pavement Structure*
 - Both devices are more accurate on less stiff pavements
- *Vehicle Speed*
 - *RWD* accuracy is marginally impacted
 - *TSD* accuracy improves with higher speed

Observations: Precision

- *Flexible vs. Rigid*
 - Both devices are more precise on flexible pavements as opposed to rigid pavements
- *Vehicle Speed*
 - *RWD* precision gets marginally worse at higher vehicle speed
 - *TSD* becomes less precise at higher vehicles speed

Thank you!!



Sergio Rocha



Paola Gallardo



Jorge Velarde

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- *Len Palek*
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- *Ben Worel*



You are the best!!