expanding the realm of POSSIBILITY®

ROLLING WHEEL DEFLECTOMETER FOR ENHANCED PAVEMENT MANAGEMENT

NYCHSA Summer Conference August 2017

APPLIED RESEARCH ASSOCIATES, INC.
An Employee Owned Company

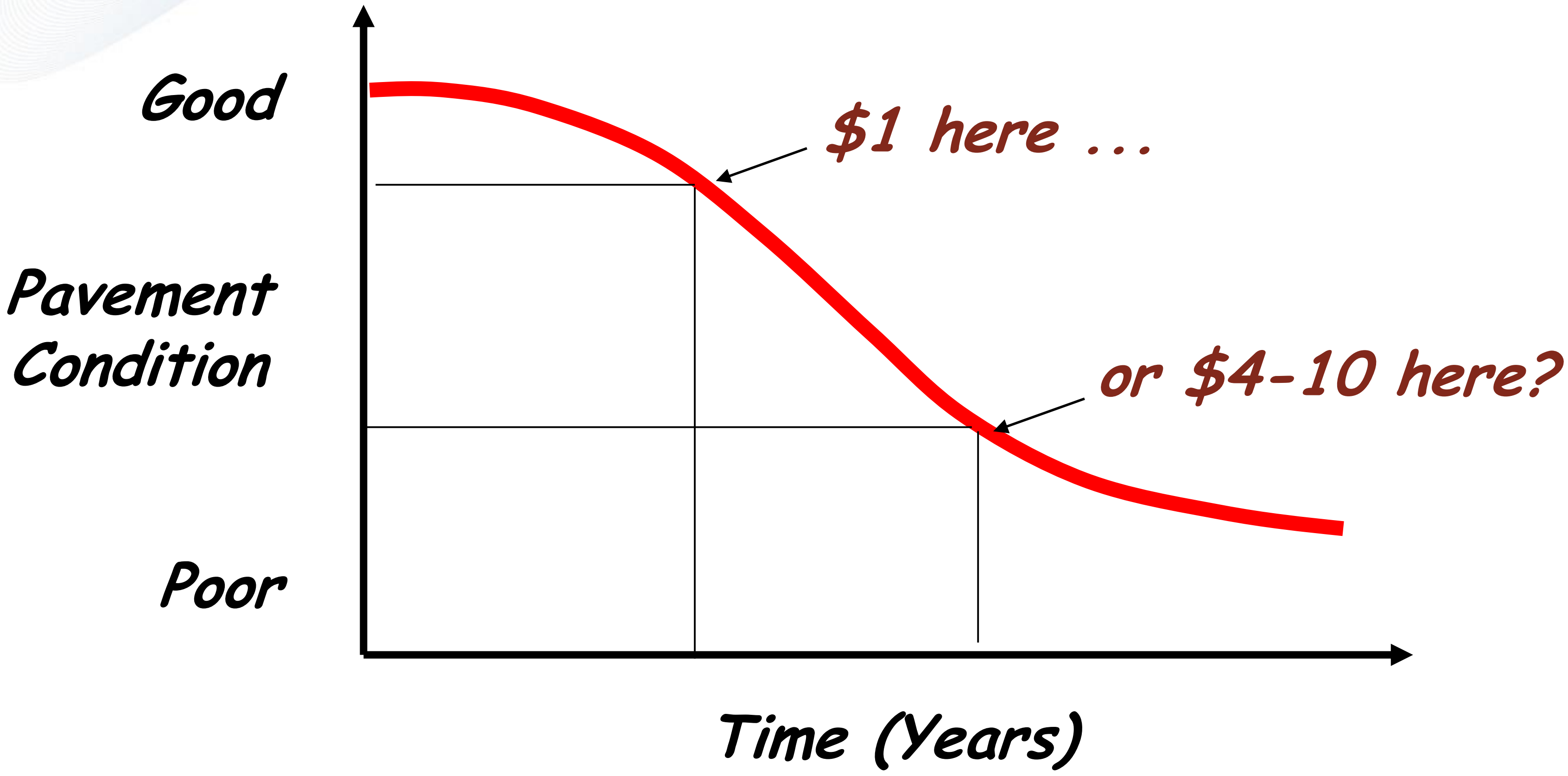
Outline

- Pavement Management Basics
- Alternate Approaches to Pavement Management
- Structural Evaluation of Pavements
- Use of Rolling Wheel Deflectometer for Network Level Structural Evaluation

Why the Interest in Pavement Management?

- Pavement Infrastructure a Huge Investment
- Important to Preserve Investment
- Pavement Management Helps Develop Effective Pavement Preservation Program:
  - Right Pavement
  - Right Treatment
  - Right Time

Fundamental Concept of Pavement Management



Traditional Approach

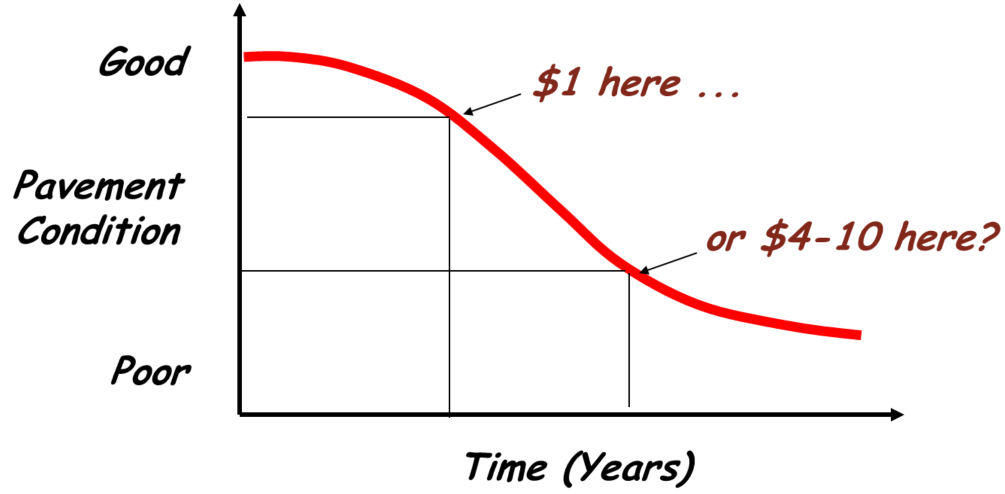
- Allows deterioration to fair to poor conditions
- Major rehabilitation or reconstruction required
- Clearly reactive, not as cost effective

Proactive Approach

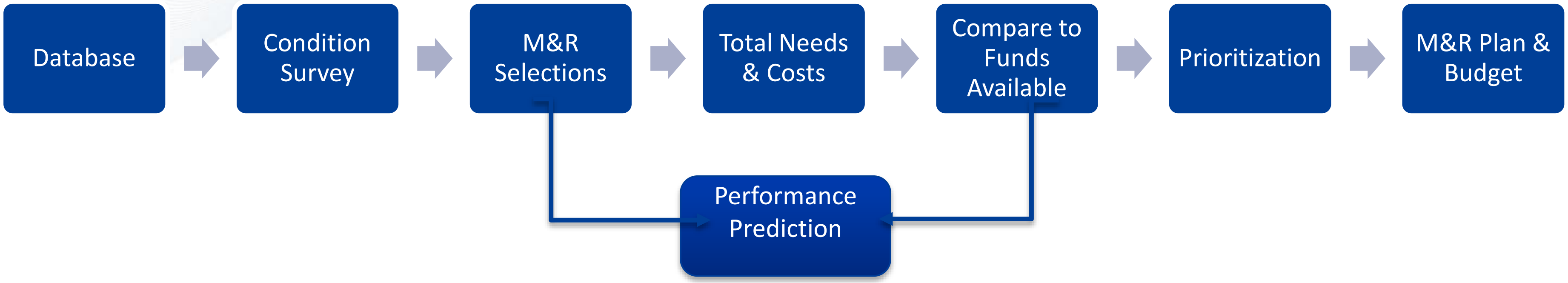
- Applies low-cost preventive treatments
- 5 to 7 year life
- Timing is critical
- Good Condition
- No structural damage

Pavement Management- a Tool to Help Proactively Plan

- Quantifies condition objectively
- Predicts condition (next few years)
- Helps identify optimal type & timing of treatment



Basic Elements of a PMS



Alternative Approaches to Pavement Management

Pavement Condition Assessment

- Windshield Survey
- Semi-Automated Survey
- Automated Survey

Determination of Maintenance & Rehabilitation (M&R) Needs

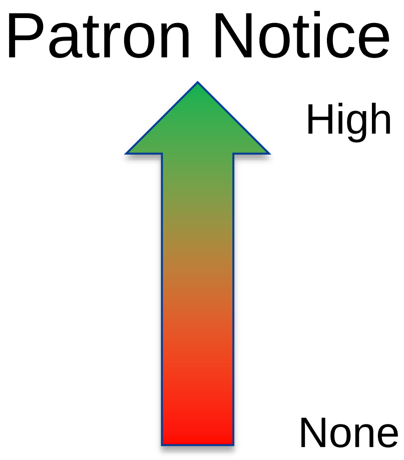
- Road Surface Management System (RSMS)
- Paver
- Proprietary Software

Step 1-Pavement Condition Assessment

- Backbone of the Pavement Management System
- Decide what data will be collected
  - Collect only what will be used
- Decide how the data will be collected

Consideration of Condition Data to Collect

- Ride Quality
- Surface Condition
- Geometrics (rutting, cross fall)
- Structural Condition



Condition Assessment

- **Surface condition**
  - PASER (simple 1-10 ratings)
  - RSMS (limited # of common distresses)
  - PCI (detailed distresses)
- **Other optional assessments**
  - Ride quality (smoothness)
  - Structural capacity

- **Overall condition rating determined based on above data**
  - Data collected & summarized for each pavement management "segment"

PASER Rating

- Ratings are related to needed maintenance or repair
  - Rating 9 & 10: No maintenance required
  - Rating 8: Little or no maintenance
  - Rating 7: Routine maintenance
  - Rating 5 & 6: Preservative treatments
  - Rating 3 & 4: Structural improvement and leveling
  - Rating 1 & 2: Reconstruction

PASER Rating

9-10	Excellent
8	Very Good
6-7	Good
4-5	Fair
3	Poor
2	Very Poor
1	Failed

Detailed Surface Condition Assessment

- **Distress type, quantity, severity**
- **Primary distress types**
  - Alligator cracking
  - Longitudinal & transverse cracking (L&T)
  - Edge cracking (especially rural roads)
  - Rutting
  - Potholes
  - Weathering/raveling
- **Overall condition rating**

Condition Methodology Selection Criteria

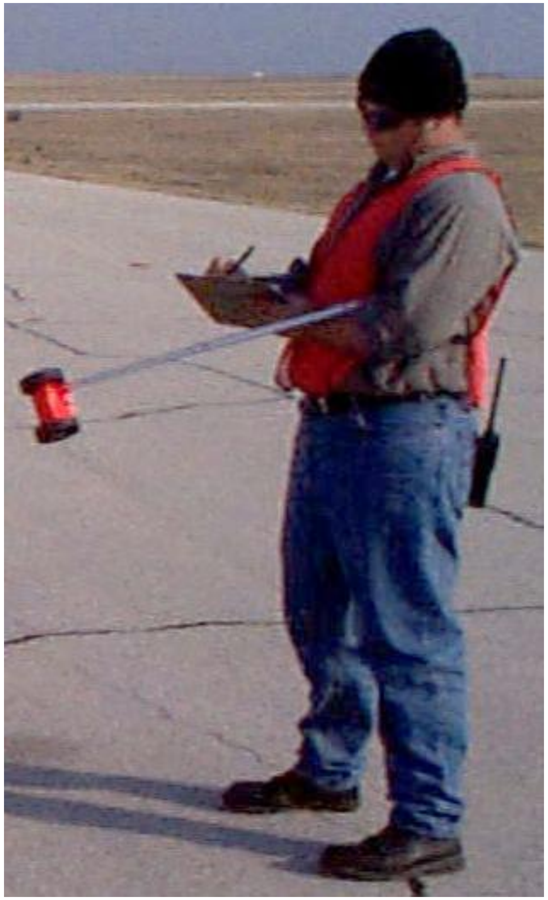
- **Consider Repeatability**
  - Different inspectors
  - Year to year
- **Consider Collection method**
  - Safety
  - Time
  - Equipment
  - Required skills
- **Consider Components included**

Condition Evaluation Alternatives

- Foot on Ground
- Windshield Survey
- Semi- automated equipment
- Automated equipment

Foot on Ground Method

- **Pros:**
  - Any inspector can be trained
  - Equipment requirements minimal
- **Cons:**
  - Safety
  - Time
  - Cost
  - QC Difficult
- **Suitable for small network**



Condition Survey Methods – Windshield

- **Subjective 1-10 rating**
- **Estimate distress type, quantity, severity**
  - Quantity (square feet, lineal feet or L, M, H extent)

- **“Event Board” useful**

Windshield Survey Method

- **Pros:**
  - Simple equipment
  - Time
  - Cost

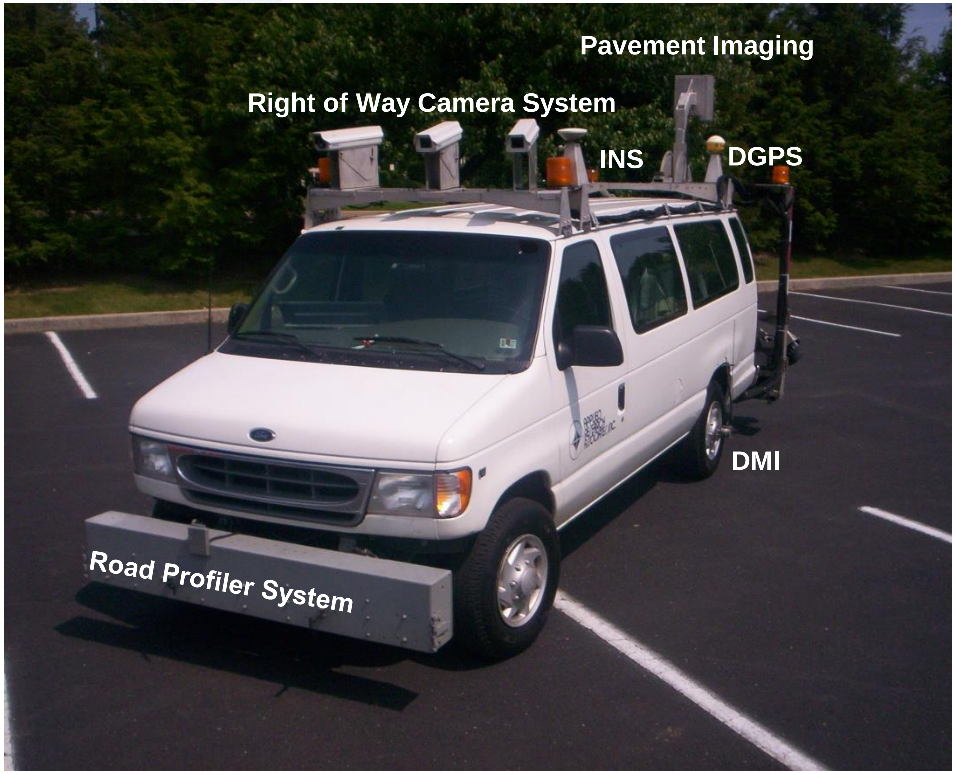
- **Cons:**
  - Accuracy depends on inspector
  - Location of distresses not captured
  - QC difficult
  - Details not easily visible

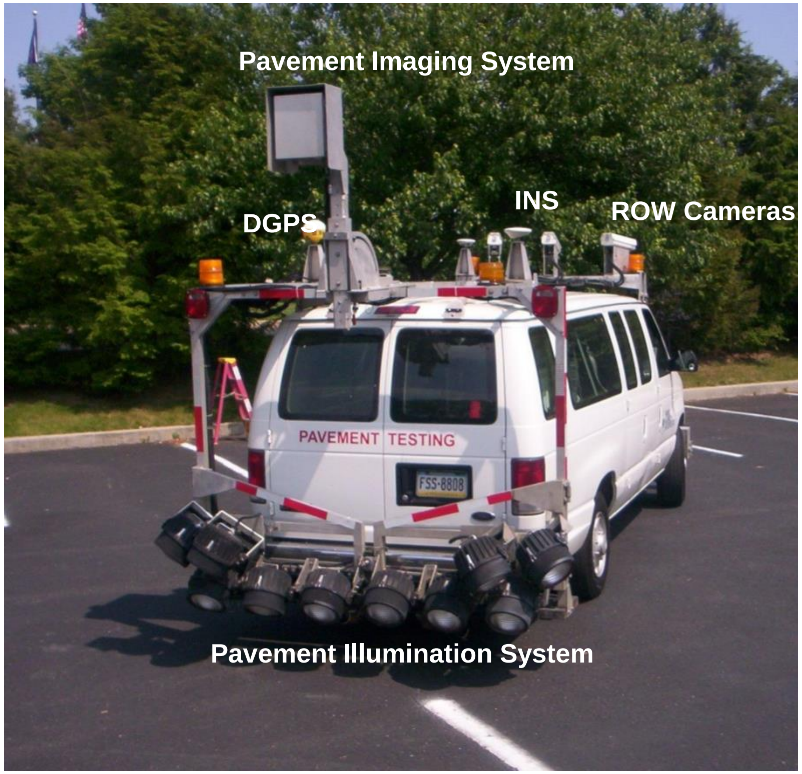
Semi-Automated Data Collection Digital Survey Vehicle (DSV)

Data Collected

- Digital Video Pavement Images
- Multiple Right-of-Way Images
- Longitudinal Profile/Roughness
- Rutting & Faulting
- Cross-slope & Grade
- Macro-Texture
- Linear Distance
- GPS Coordinates

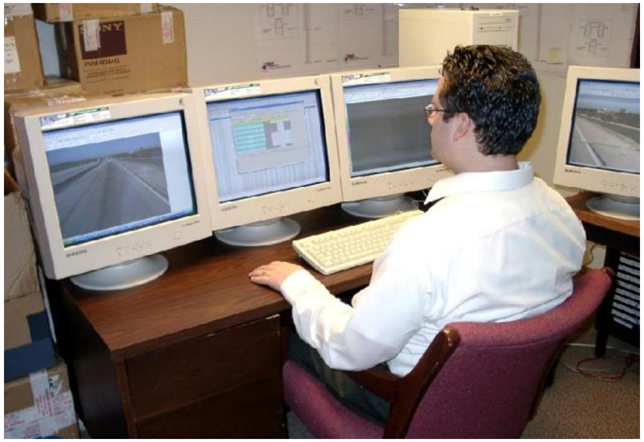
DSV Survey Systems

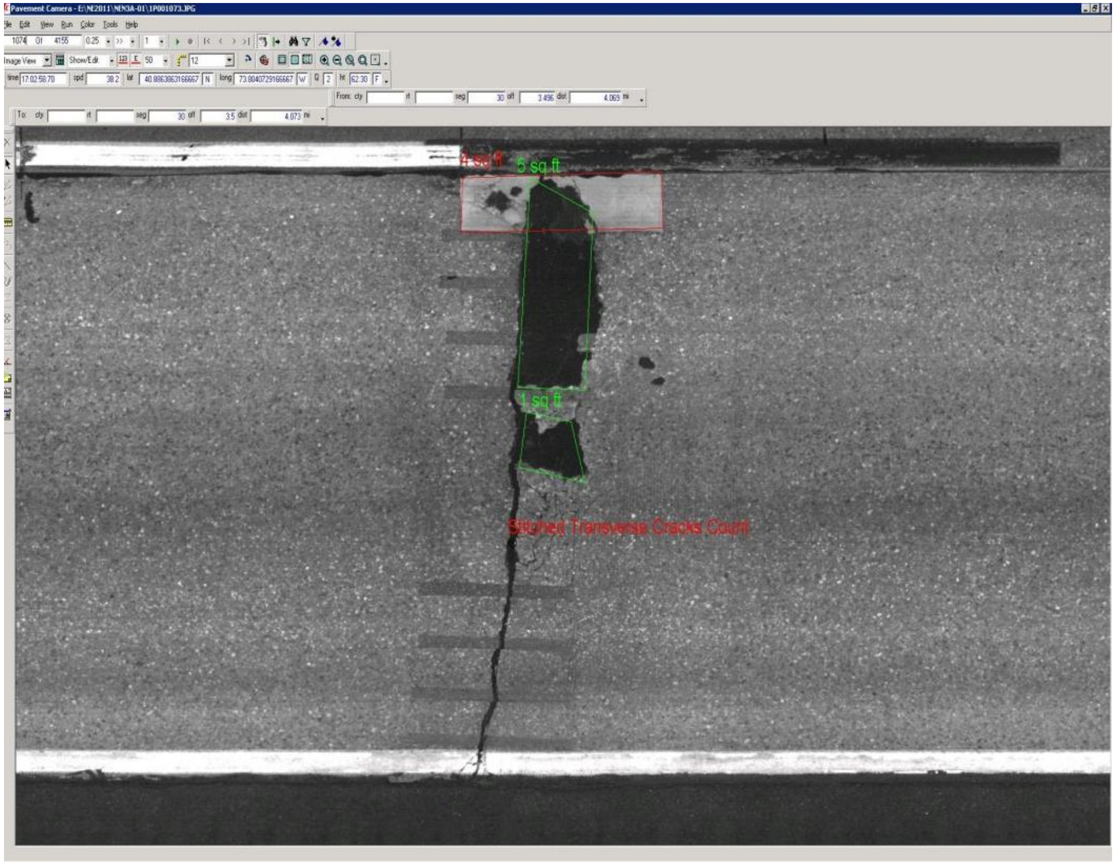




Office Condition Survey Using DSV Images

- High resolution downward pavement images viewed with customized software





Pros & Cons of DSV

- **Pros:**
  - Safety
  - Time
  - Easiest to QC
  - Additional data
    - Video Log
    - Ride Quality
    - Automated Rutting
    - Automated Faulting
- **Cons:**
  - Cost
  - Consultant required to perform work

Pa vision-Simplified Approach

- Highly portable
- Easy to use
- Multiple camera views
- Cloud based storage and processing
- Automated pavement distress detection available

Case 1: Electronics

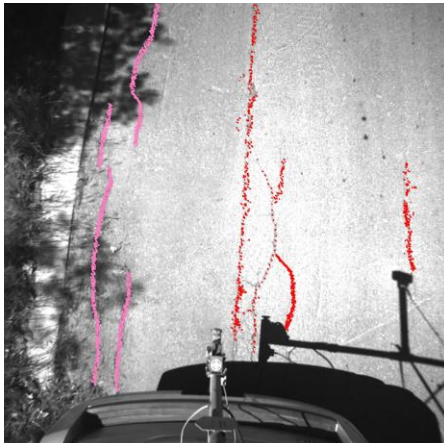
Case 2: Hardware

Pa vision

Pa vision

- **Pa Vision delivers:**
  - Pavement imagery
  - Roughness
  - Distress Quantities
  - Proprietary analysis of images correlated to distress types

Forward Image



Automated Distress Analysis

Advantages & Disadvantages of PaVision

- **Advantages:**
  - Safety
  - Time
  - Highly automated
  - Inexpensive
- **Disadvantages:**
  - Less accurate distress identification

Overall Condition Rating

- **Provides overall assessment of each section**
- **Allows comparison between sections**
- **Provides network level assessments**
  - Examples:
  - Average condition of arterial streets, local subdivision streets,etc
  - Trends over time

Many Condition Rating Methods Available

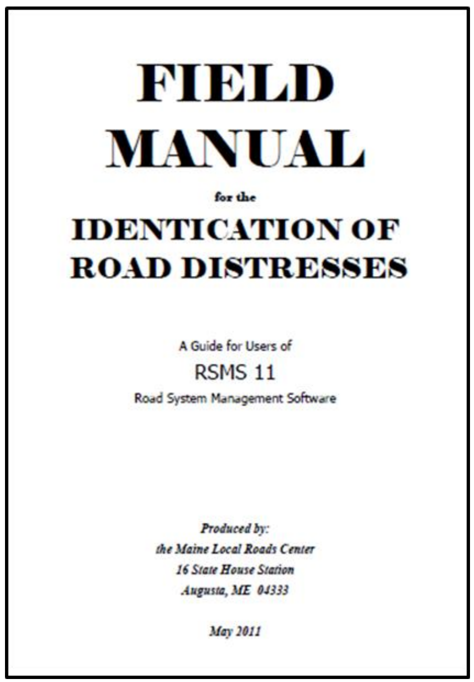
	PASER	Pavement Condition Index (PCI)	RSMS
Type	Subjective	Rigorous Objective	Simplified Objective
Scale	10 – 1	100 – 0	100 – 0
Consider Smoothness	Subjective	NO (Supplemental)	NO (Supplemental)
Differentiate Distress Mechanism	NO	YES	YES
Individual Distresses	Subjective	19 Distresses by Severity & Quantity	Reduced Distress/ Quantity Options
Cost to collect	$	$$$$	$$$

Pavement Condition Index (PCI)

- Based on surface distresses
  - Type, quantity, severity
  - 19 distress types
- Each distress has an associated deduct curve
- Provides an overall condition number
- Repeatable within 5 points, with 95 percent confidence
- Conducted in accordance with ASTM Standard D 6433

RSMS

- **Based on surface distresses**
  - Type, quantity, severity
  - 7 distress types
- **Provides an overall condition number (0-100)**


FIELD
MANUAL
for the
IDENTICATION OF
ROAD DISTRESSES

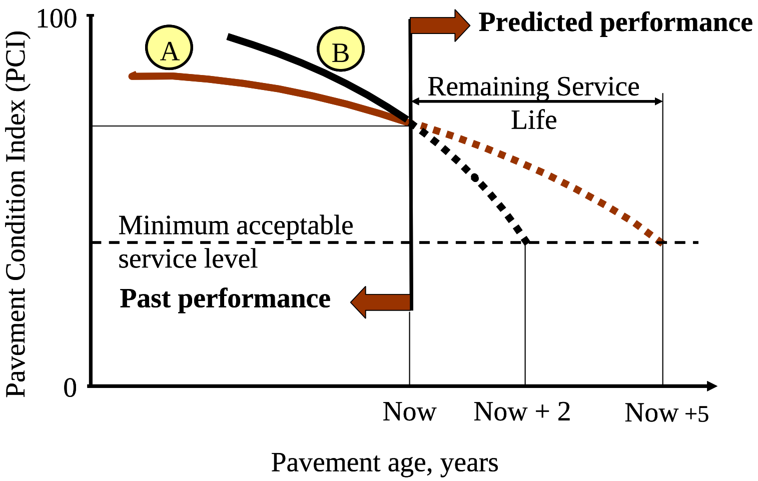
A Guide for Users of
RSMS 11
Road System Management Software

Produced by:
the Maine Local Roads Center
16 State House Station
Augusta, ME 04333

May 2011

Step 2- Performance Prediction

- Typical planning period = 5 yrs
- Need to predict future conditions
- Several methods (many based on “family modeling”)



Step 3- Identification of Needs

- **Identify needs based on:**
  - Distress data
  - performance predictions
  - criteria built into PMS software

- **Criteria based on 3 concepts:**
  - Maintenance policies
  - Level of service
  - Trigger values

Step 3- Identification of Needs

MicroPaver identifies 2 levels of needs:

- Localized maintenance & repair
  - Year 1-specific treatments based on distresses
  - Future years- $ based on PCI ranges
- Global treatments
  - unit $ based on PCI level

Step 3- Identification of Needs

RSMS identifies 2 levels of needs:

- 6 Broad Strategies
  - Defer Maintenance
  - Routine Maintenance
  - Preventive Maintenance
  - Corrective Maintenance
  - Rehab/Reconstruction

- Specific Treatments Within Each Strategy
  - Examples for Preventive Maintenance:
    - ✓ Slurry Seal
    - ✓ Chip Seal
    - ✓ Thin Overlay

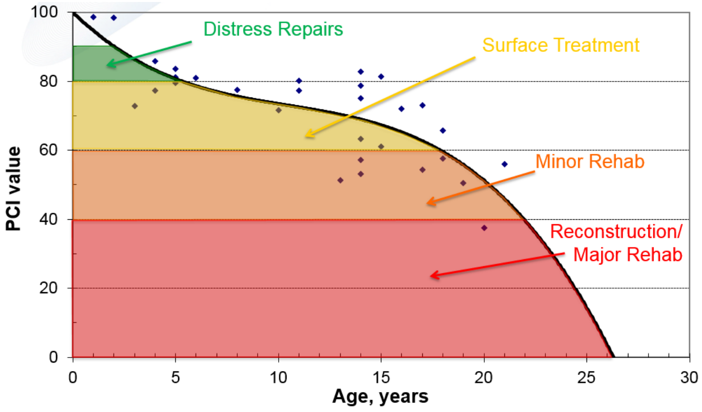
M&R Assignments Based on Surface Condition Alone Can Be Misleading

- **Consider 2 Similar Looking Pavements**
  - A. Recent Chip Seal Over Hot Mix Asphalt
  - B. Multiple Layers of Chip Seal

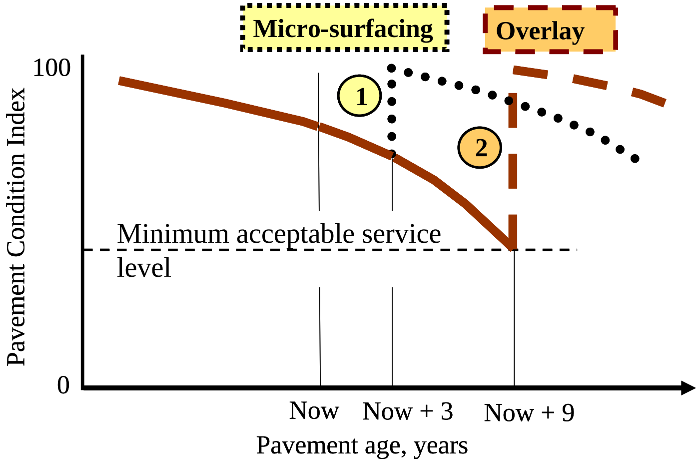
- **Same Surface Condition**
  - Light Alligator Cracking; Isolated Areas Medium & Heavy Alligator
- **2 Very Different Structural Capacities But Same PCI**

M&R Treatments

- PCI of 60, PMS software identifies new Chip Seal or Thin Overlay as Treatment



- Resets PCI to 100



Same Treatment Not Appropriate For Both Pavements

- **Pavement A- structurally adequate**
  - Isolated patching of weak areas & thin surface treatment viable

- **Pavement B- structurally inadequate**
  - Thin surface treatment to fail in few years (not cost effective)
  - Strengthening required (eg.- thick overlay or FDR & overlay)

Useful to Add Pavement Strength (Structural Capacity) To Decision Making

- Provides indication of overall health (adequacy) of road network

- Distinguish between roads
  - Those with significant "remaining life"
  - Those with very little "remaining life"

- "Remaining Life" defined in terms of traffic (ESALs)

Road Name	Avg Daily Traffic	Equivalent (ESALs/Year)	Structural Capacity (ESALs)	Number Years Life Remaining
Co. Route 5	5,527	201,736	1,049,025	5.2
Co Route 28	6,920	250,222	850,755	3.4
Co Route 20	11,125	396,112	2,812,395	7.1
Co Route 63	500	18,100	226,250	12.5
Co Route 31	1,200	42,100	463,100	11

Structural Evaluation of Pavements

- **Structural capacity- measure of ability to carry repeating load over time (ESALs to failure)**

- **Affected by following factors:**
  - Initial pavement structure and subgrade (thickness & quality)
  - Magnitude of applied loads
  - Environmental factors (moisture, temperature, freeze-thaw)
  - Maintenance

- **Decreases with time**

Structural Evaluation of Pavements
Traditional (Destructive) Testing

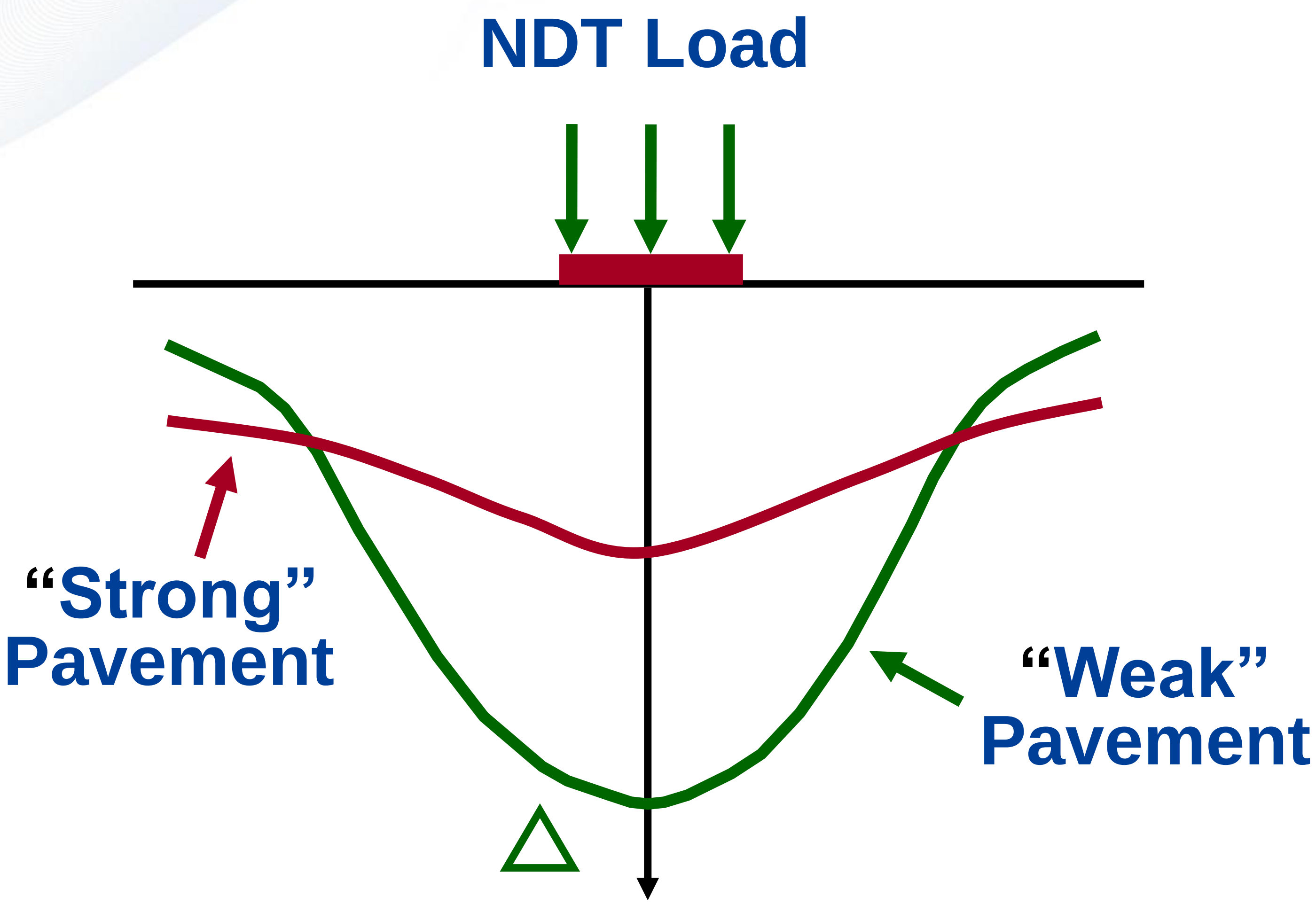
- Conventional cores & borings
- Cone Penetrometer Testing (CPT)

Structural Evaluation of Pavements (Traditional Non- Destructive Methods)

- Benkelman beam testing

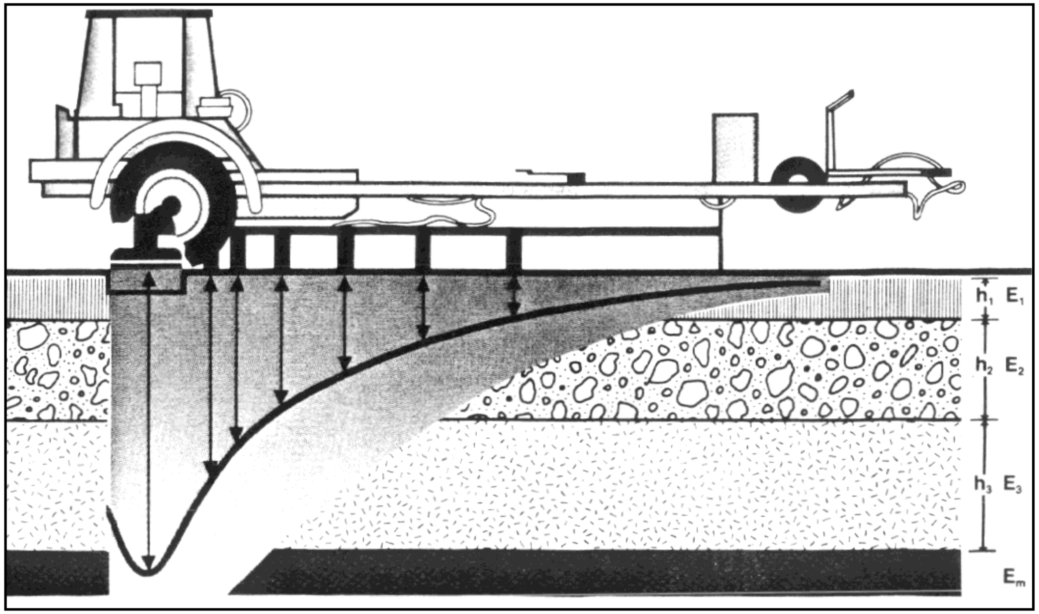
- Falling Weight Deflectometer testing

Strong vs. Weak Pavements



FWD Schematic

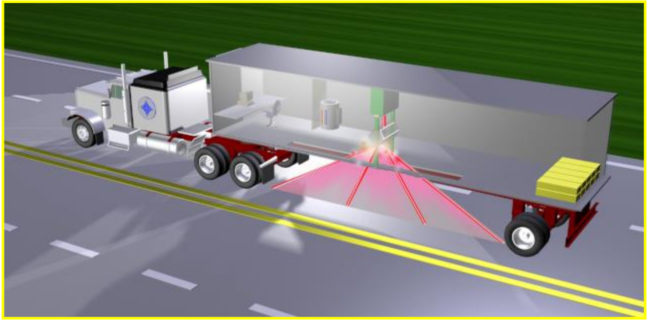
- Weight dropped on load plate
- Deflection measured at series of sensors
- Analysis of “deflection basin” provide strength of pavement layers (asphalt, granular subbase, subgrade soil)



FWD Test Production

- 200 – 300 test points per day
- Significantly more than feasible number of borings & cores
- Requires traffic control (shadow vehicle or flaggers)

Rolling Wheel Deflectomater (RWD)



System

- Laser-based system
- 18-kip, single-axle, dual-tire

Operation

- Operates at posted speeds
- No lane closures

Measurements

- Continuous deflection measurement
- Averages deflections over 0.1-mile intervals
- Spatially-coincident method

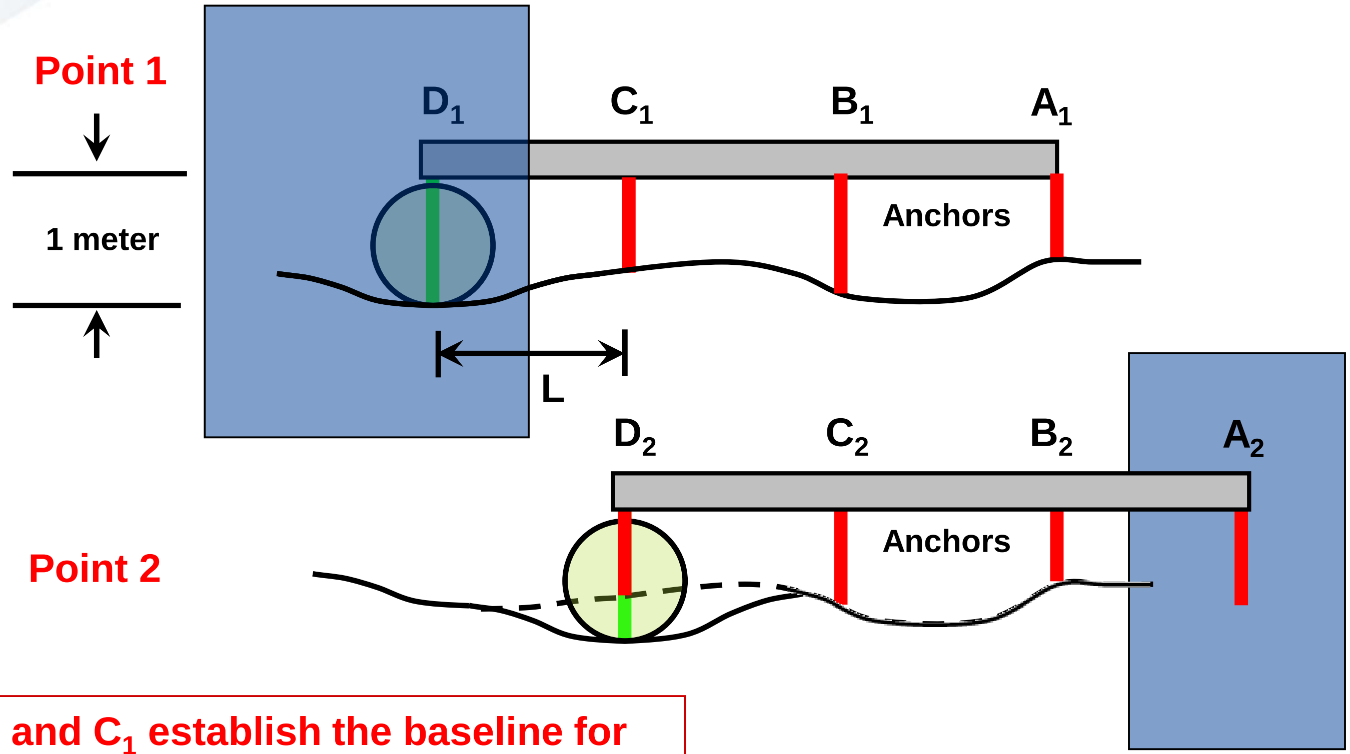
Key Design Features

- Trailer
- Wheels
- Beam
- Lasers
- Calibration
- Software

Reference beam and spot lasers

Laser between dual tires

Spatially Coincident Methodology



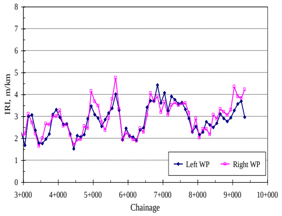
A_1, B_1 and C_1 establish the baseline for comparison to B_2, C_2 and D_2

RWD Role in Pavement Management

Network-Level

PCI

IRI



RWD

1,000s of lane-miles

Preservation

Rehabilitation or Reconstruction

Project-Level

Dozens of lane-miles

FWD

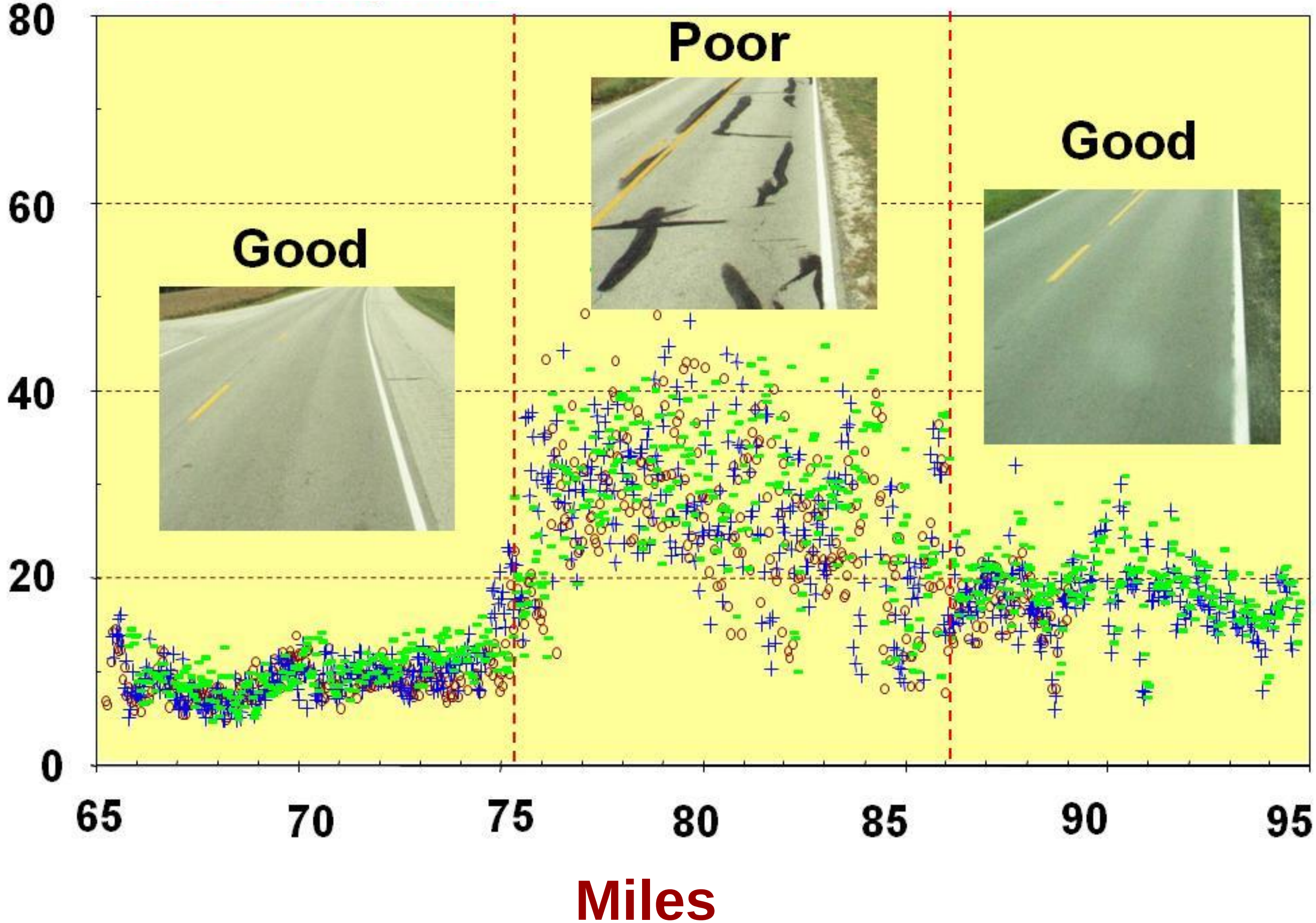
Coring

Lab

How Can The RWD Be Used?

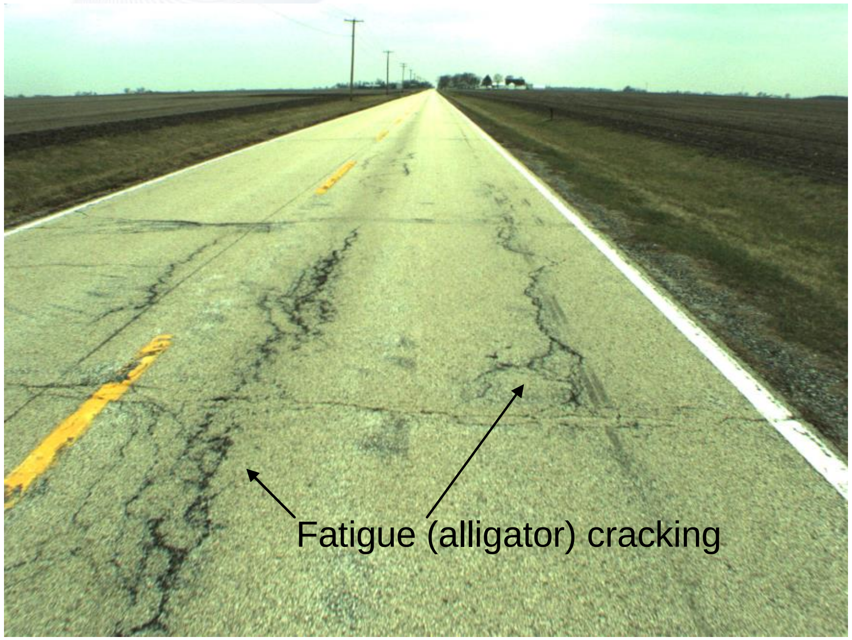
- **Applications**
  - Network-level evaluation (PMS)
  - Pre-screener for focusing project-level efforts (evaluation/design)
- **Limitations**
  - Currently, maximum deflection only
  - Lack of "deflection basin" limits analysis
  - Accuracy is suitable for network-level analysis, but not detailed engineering analysis

Example Structural Classification



Pavement Conditions

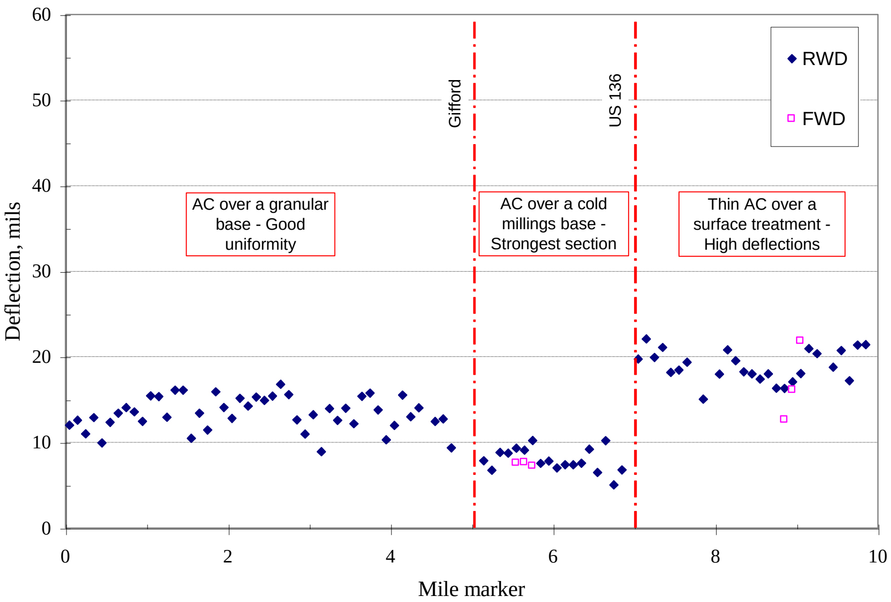
Surface condition recorded by RWD



Percent of Network

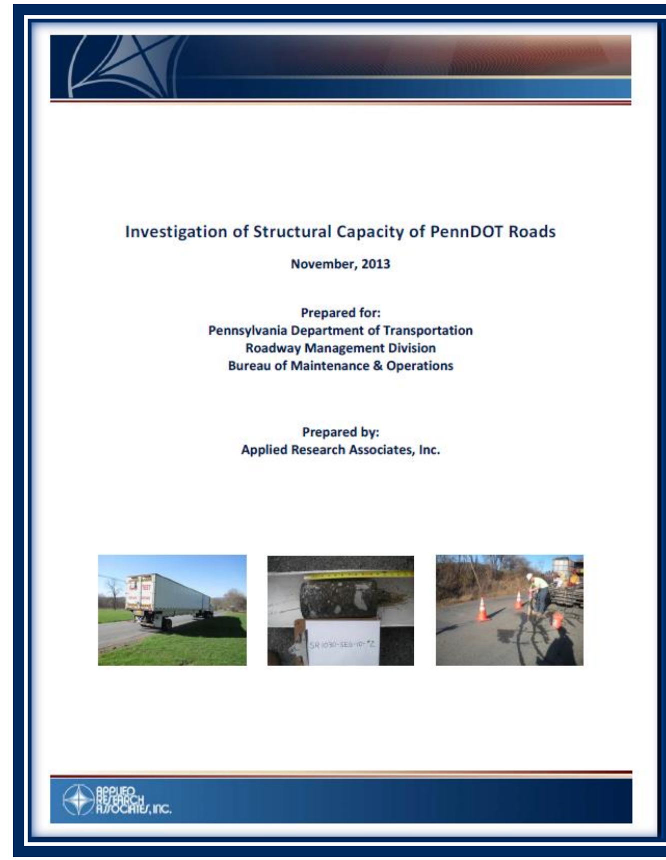
	Good	Fair	Poor
PCI	59	26	15
RWD	57	15	28
IRI	85	10	5

RWD identifies structural changes



PennDOT Study - Compared 3 Methods of Structural Evaluation

- RWD testing of 278 miles
- FWD testing & pavement coring for 16 test segments
- Compared estimates of "structural number" based on RWD, FWD & RMS estimates


Investigation of Structural Capacity of PennDOT Roads

November, 2013

Prepared for:
Pennsylvania Department of Transportation
Roadway Management Division
Bureau of Maintenance & Operations

Prepared by:
Applied Research Associates, Inc.

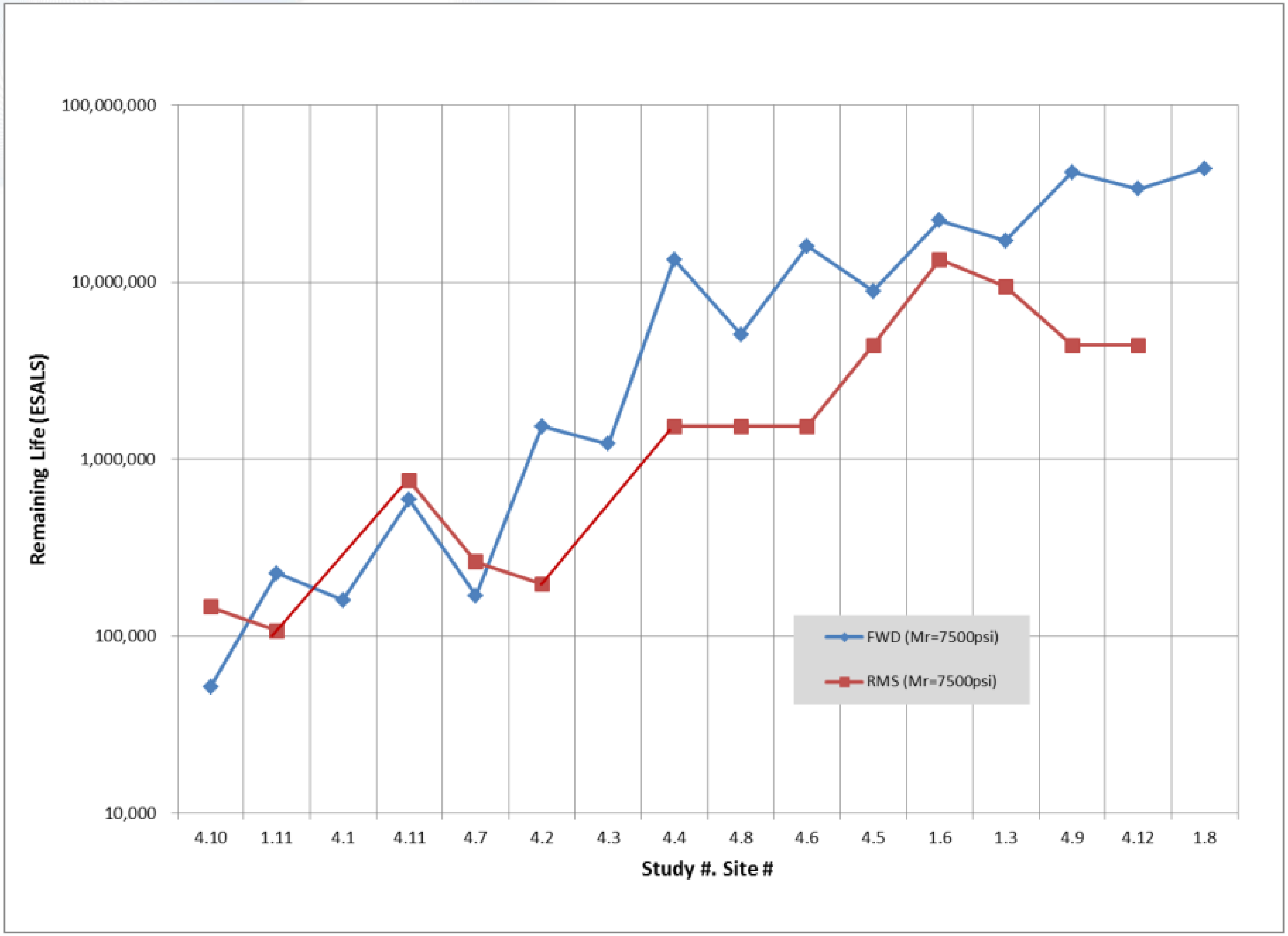
Structural Capacity

- **Commonly expressed in terms of:**
  - Structural number (accounts for thickness & contributing strength from each pavement layer)
  - Remaining life obtained from "effective SN"

Structural Number (SN) Determinations

- **FWD:**
  - Direct output from model (backcalculations)
- **RWD:**
  - Determined remaining pavement life (not SN directly)

Results From PennDOT Study



Louisiana DOT Study by LSU

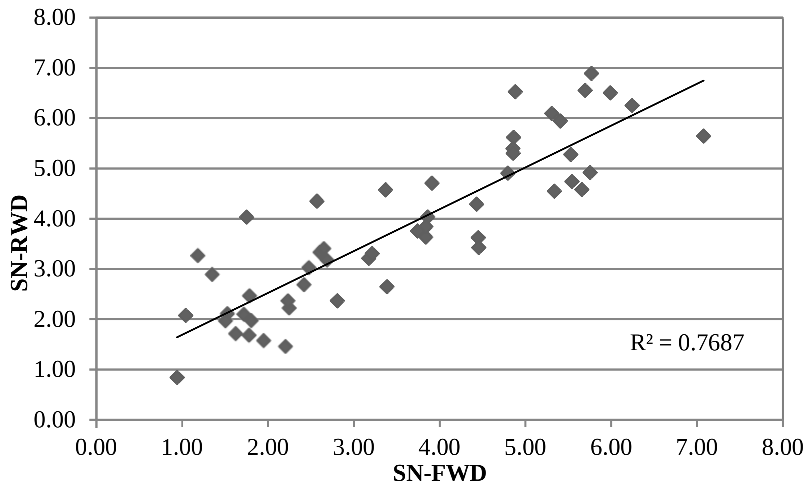
- **2009 Study led by Mostafa Elseifi (LSU)**
- **Developed model to predict SN from RWD data**
  - Based on RWD & FWD data from LA DOT test sites- 16 sites, 1.5 mi each

$$SN_{RWD} = -6.37 - \frac{150.69 * RI^{-0.81}}{RI + 19.04} + 23.52 * RWD^{-0.24} - 1.39 * \ln(SD)$$

RI = RWD Index ($mils^2$) = Avg. RWD deflection * SD of RWD deflection;
SD = standard deviation of RWD deflection on a road segment (mils);
RWD = Avg. RWD deflection measured on a road segment (mils); and

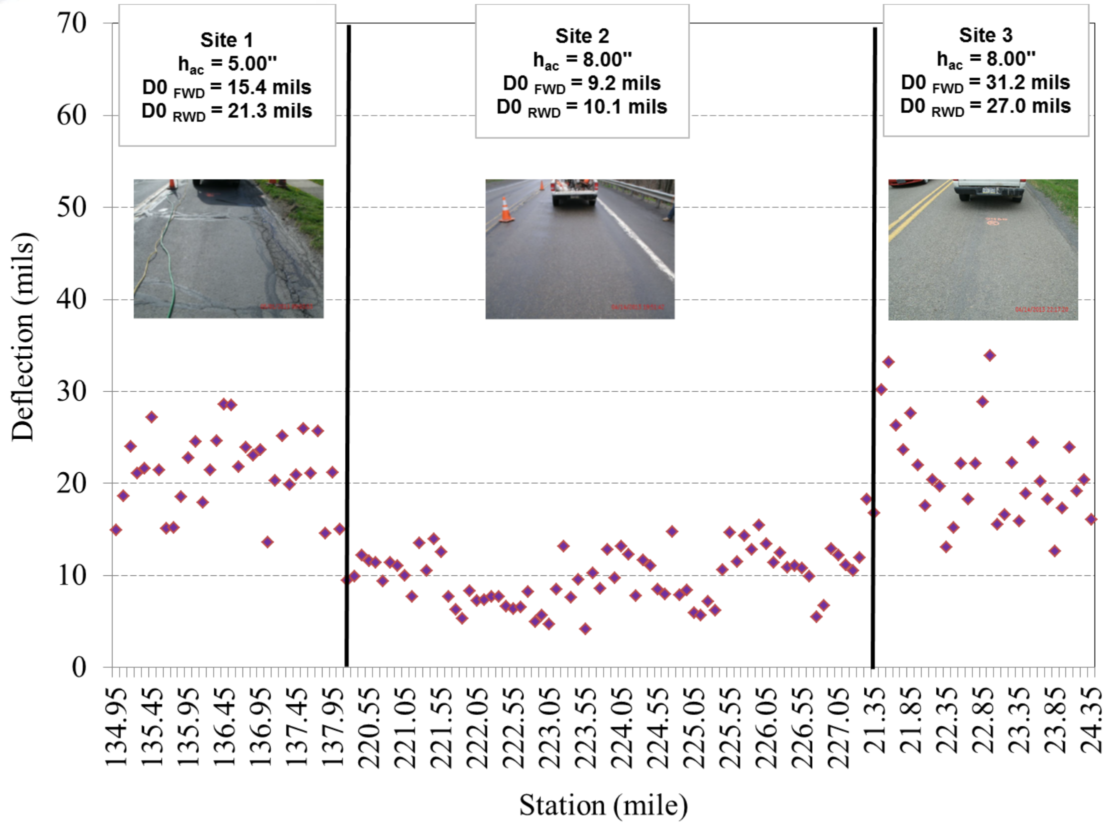
LSU Model Accuracy

- **LSU model tested with PennDOT RWD data**
- **Accuracy deemed acceptable**
  - Coefficient of Determination, $R^2 = 0.77$



Relationships between SN based on FWD and SN based on RWD for the Independent Network Sites

RWD Deflection Variability & Pavement Strength



- From Elseifi et al 2014

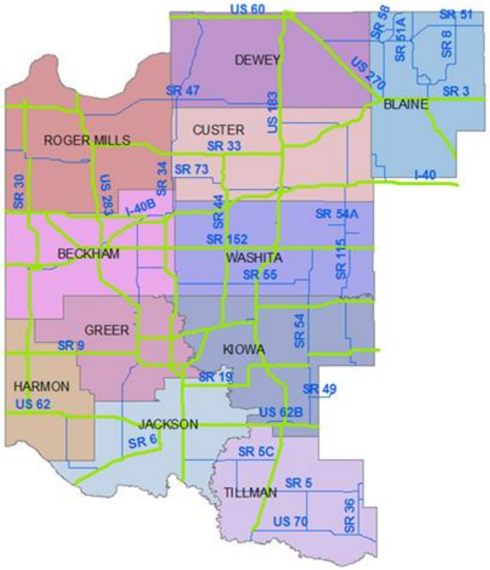
FHWA Case Study - *Oklahoma*

- ***Evaluate* the benefits of integrating RWD data into PMS**
- ***Compare* results with and without RWD data**
  - Treatment selection
  - Costs
  - Network performance

Test Roads

Test Network

- 1,000 miles (ODOT D-5)
- Primarily flexible pavements
- Wide range of functional classifications/traffic



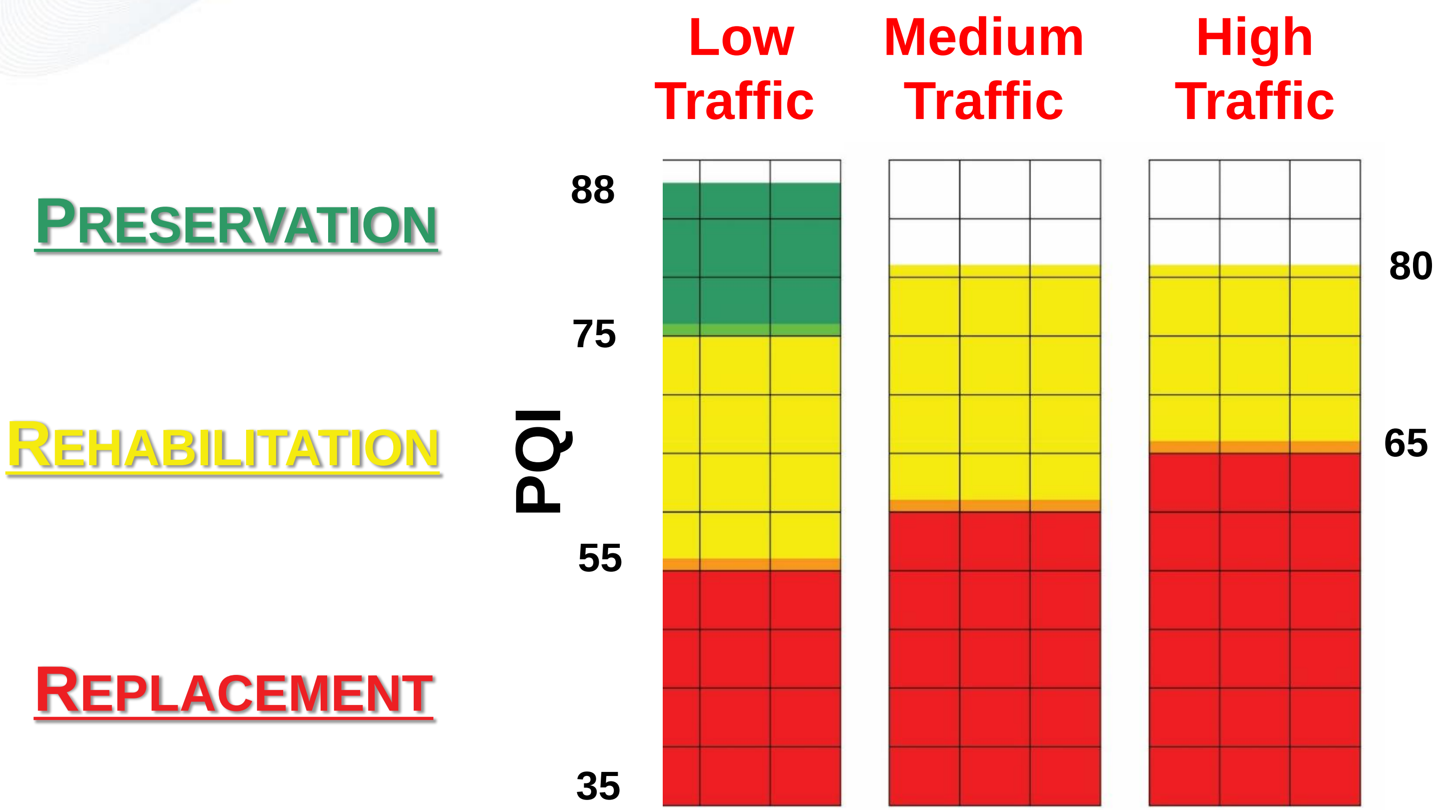
Data Collection

- Continuous data collection
- Averaged data at 0.1-mile intervals
- Testing duration: 4.5 days

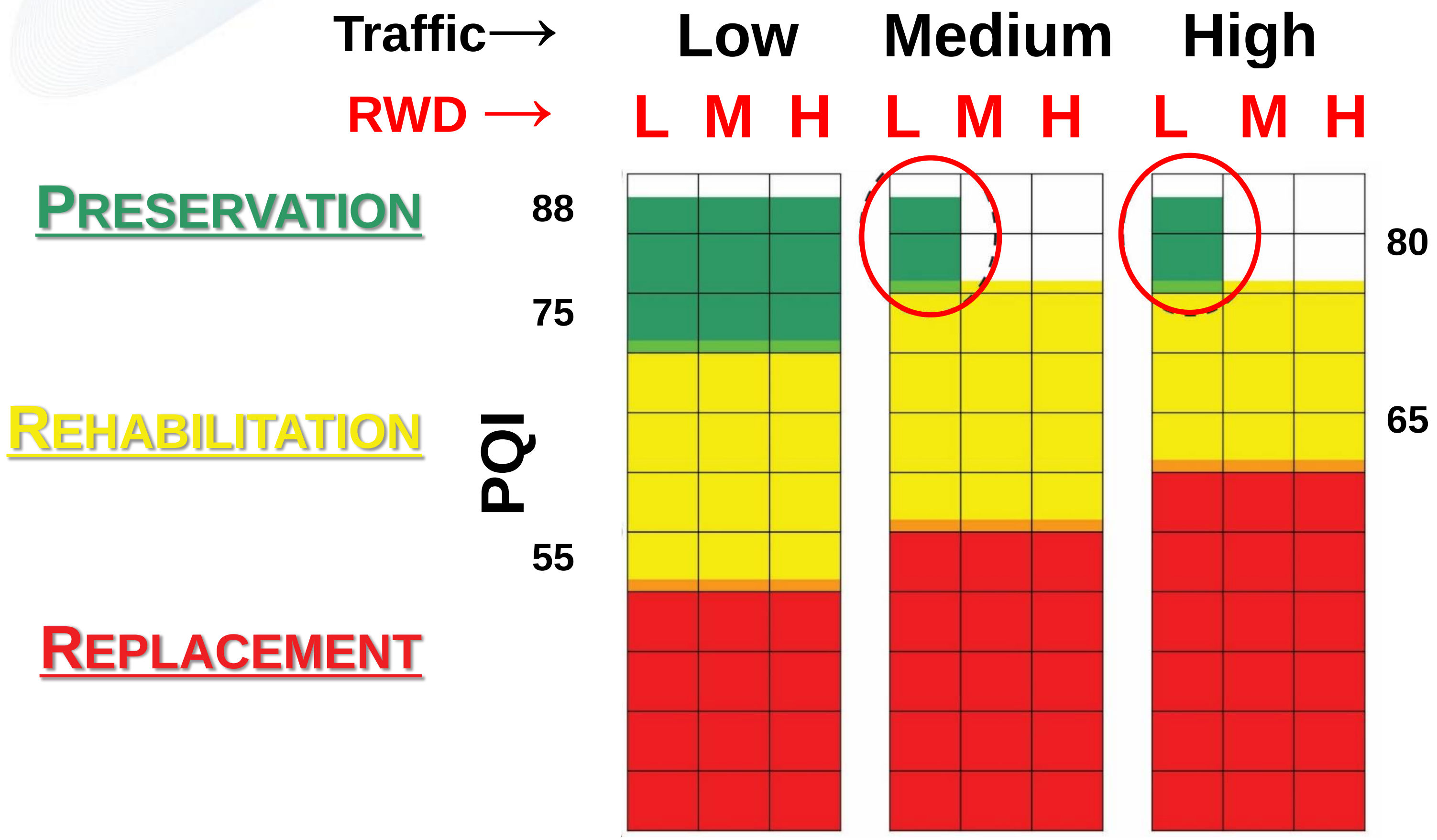
Approach

- Evaluate multiple M&R treatment strategies
  - Base strategy: PQI only
  - Two modified strategies: add RWD data
- Compare results
  - Costs
  - Performance (in terms of PQI)

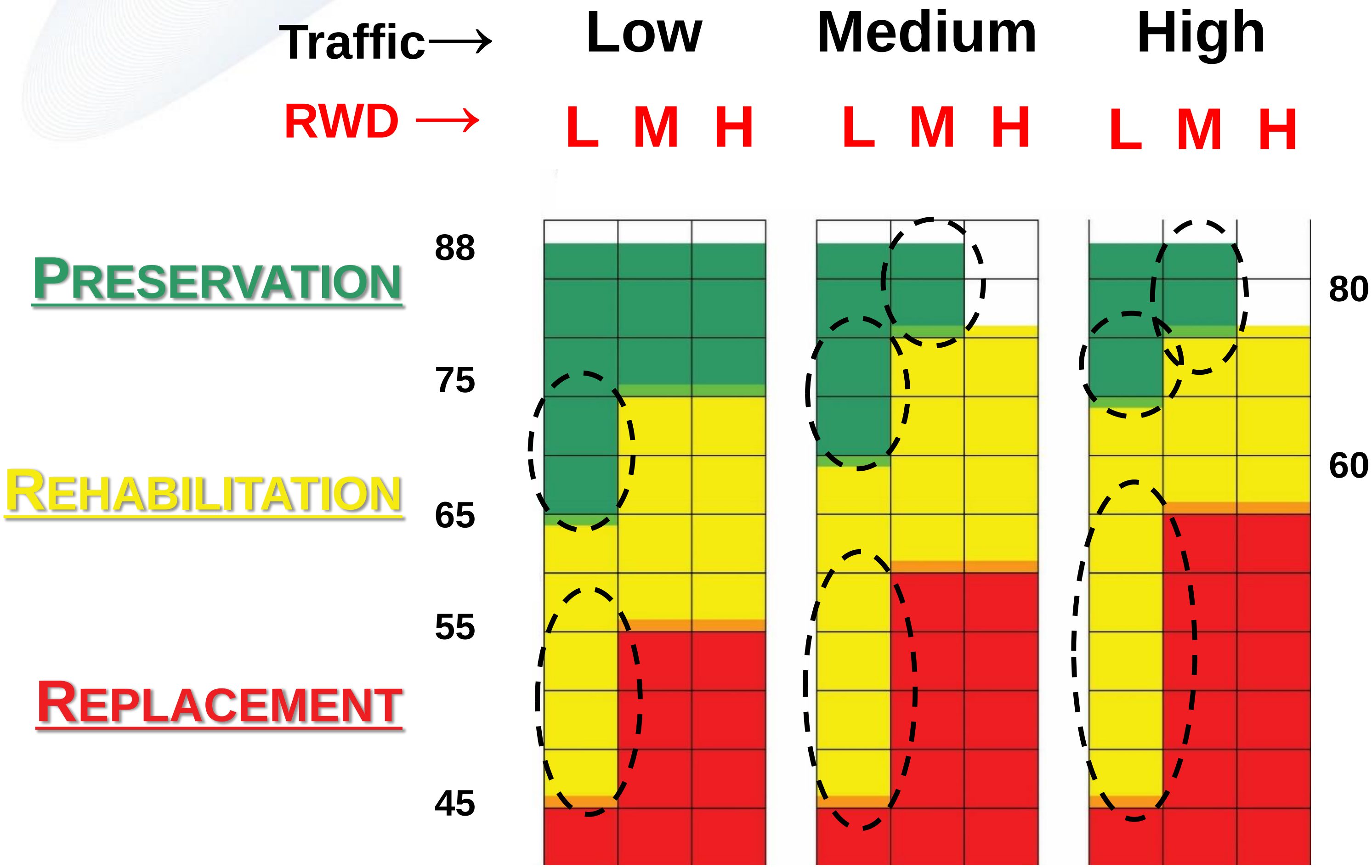
PQI Only – Treatment Matrix



RWD #1 – Treatment Matrix



RWD #2 – Treatment Matrix



Results

Budget Scenario	Percent change in cost (relative to “PQI Only” base case)		
	PQI Only	RWD Option 1	RWD Option 2
Target PQI = 92	0.0%	-10.6 %	-11.5 %

Decision Matrix Developed for Illinois Counties

		SURFACE AND STRUCTURAL CONDITION			TRADITIONAL
PCI Value	PCI Rating	Representative RWD Deflection, mils			*Surface Condition Only*
		< 35	35 - 50	> 50	
		Good	Fair	Poor	
100	Very Good	Defer Maintenance			Defer Maintenance
		PM - Crack sealing (max. 1 time)			Distress Repair
80	Good	Microsurfacing (max. 1 time)		Distress Repair (max. 1 time)	Surface Treatment (Preventive Maint.)
		Cape Seal (max. 2 times)			
60	Fair	*FEASIBILITY*		Mill & Thick ACOL w/ FD Repairs	Minor Resurfacing
		Mill & Thin ACOL	Mill & Thin ACOL w/ FD Repairs		Major Resurfacing
40	Poor	Mill & Thin ACOL w/ PD Repairs	Mill & Thick ACOL w/ PD Repairs	*FEASIBILITY*	
					RECONSTRUCTION
20	Failed	RECONSTRUCTION			
0					

Structural Data allows you to choose the *right* project at the *right* time!

More Detailed Decision Matrix

High Truck Traffic

Design RWD Deflection, mils

PCI Value	PCI Rating	< 35 Good	35 - 50 Fair	> 50 Poor
100 – 80	Very Good	Defer Maintenance		
		Crack sealing (maximum 1 time)		
80 – 60	Good	Microsurfacing (maximum 1 times)	Distress Repair & Crack Seal (max 2 time)	
		Cape Seal (maximum 1 times)		
60 – 40	Fair	Mill 2 - Replace 2	Mill 2 - Replace 3	Mill 2 - Patch - Replace 4
40 – 20	Poor	Mill 3 - Replace 3	Mill 3 - Patch - Replace 4	Mill 3 - Patch - Replace 5
20 – 0	Failed	Reconstruction (FDR, Rubblize, CIR)		

Low Truck Traffic

Design RWD Deflection, mils

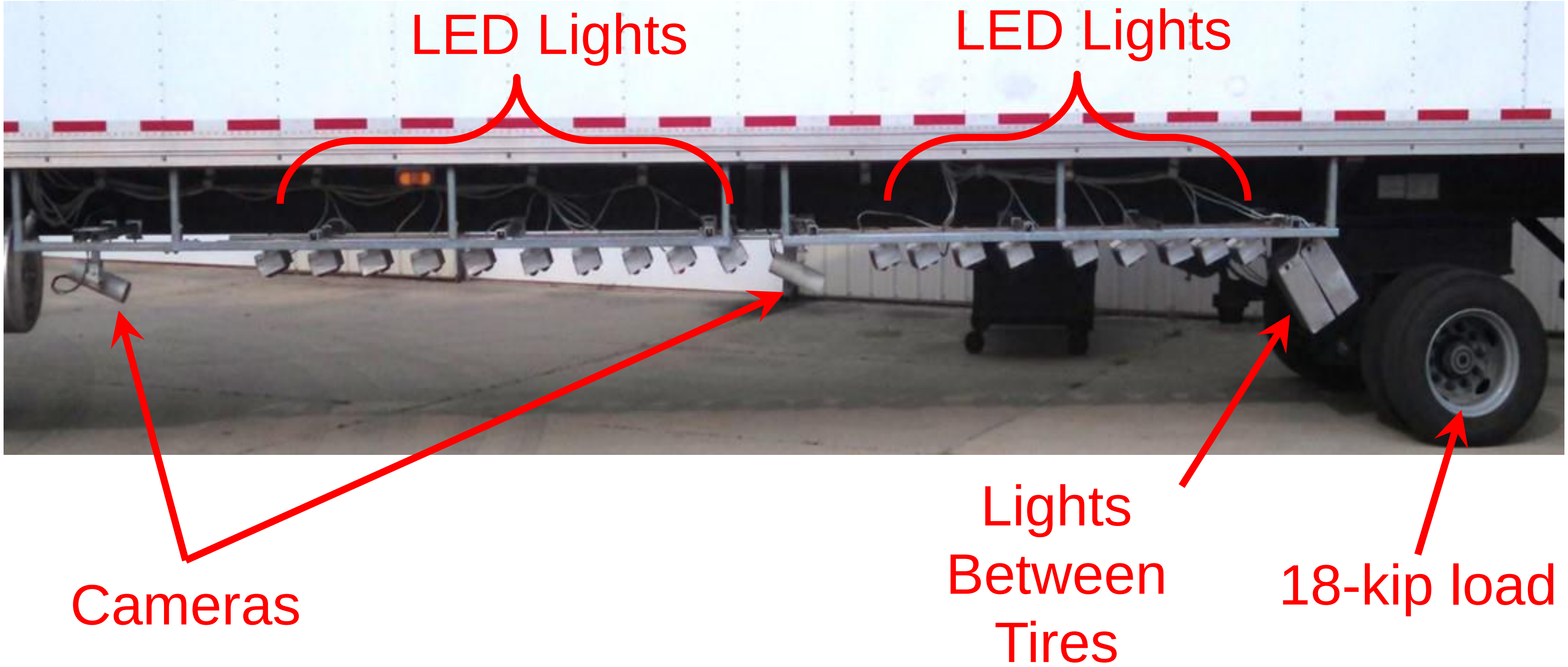
PCI Value	PCI Rating	< 45 Good	45 - 75 Fair	> 75 Poor
100 – 80	Very Good	Defer Maintenance		
		Crack sealing (maximum 1 time)		
80 – 60	Good	Chip seal, (maximum 2 times)	Double Chip Seal (maximum 2 times)	Defer Improvements
60 – 40	Fair	Double Chip Seal (maximum 2 times)	Mill 2 - Replace 3	Mill 2 - Patch - Replace 4
40 – 20	Poor	Mill 2 - Replace 2	Mill 3 - Patch - Replace 4	
20 – 0	Failed	Mill 3 - Patch - Replace 4	Reconstruction (FDR, Rubblize, CIR)	

Conclusions

- **RWD allows broader, more reliable use of pavement preservation**
  - Identifies roads in ***GOOD*** & ***FAIR*** structural condition
  - Prevent heavy loads on roads in ***POOR*** structural condition
- **Cost savings can be significant**
  - In the range of 5 to 10%, in many cases
  - Depends on agency's current strategy and road conditions

Recent Advancements in RWD Technology

RWD-Vision (cameras vs lasers)



Description

Image-based

- Overlaps two spatially coincident, high-resolution images
- First image, undeflected area only. Second image, mainly the deflection basin with small undeflected area

Lighting

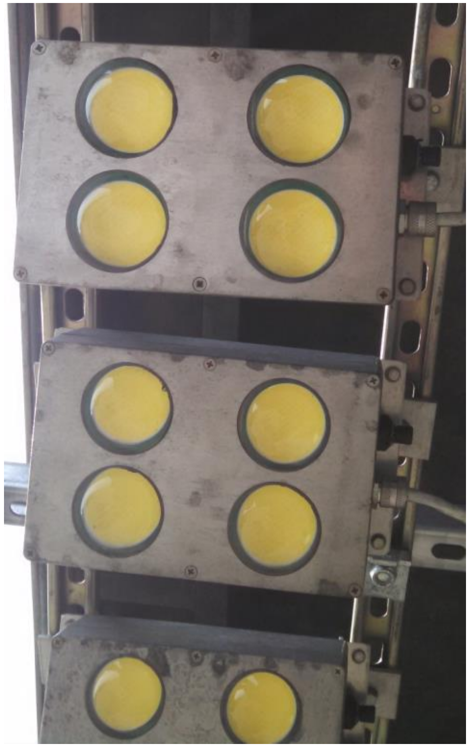
- High-speed flashes, overcome shadows from ambient lighting
- Synchronized with high-speed cameras

Benefits

- **Data Quality**
  - Provides entire basin in front of the RWD wheel (instead of maximum deflection only)
  - Accuracy of individual deflections is much higher than laser system (may not require averaging)
- **Operational**
  - Does not require a thermal chamber to maintain constant temperature
  - Potential to be installed on a shorter trailer with lighter weight tow vehicle

Components

Components, cont.



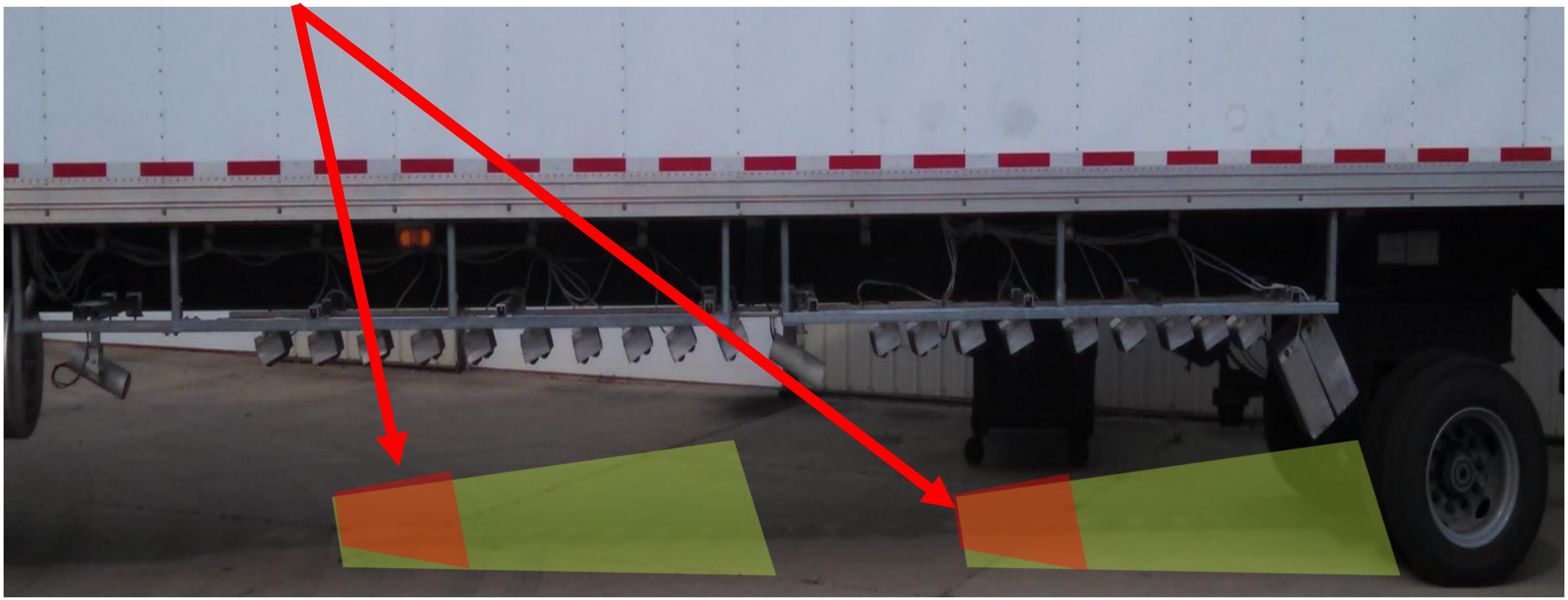
Right Wheel Path Laser RWD
Left Wheel Path Image Based RWD (Shown)

- High Speed LED based Flash
- 2 Camera Positions
- Concentration of Light Between Tires

Method

1. Forward camera takes image of non deflected region
2. RWD moves forward so that same region of pavement is under load
3. Camera 2 takes picture of deflected area
4. Images are processed to compute complete deflection around tire

Overlapping area of no deflection (both images)



Method

1. Forward camera takes image of non deflected region
2. RWD moves forward so that same region of pavement is under load
3. Camera 2 takes picture of deflected area
4. Images are processed to compute complete deflection around tire

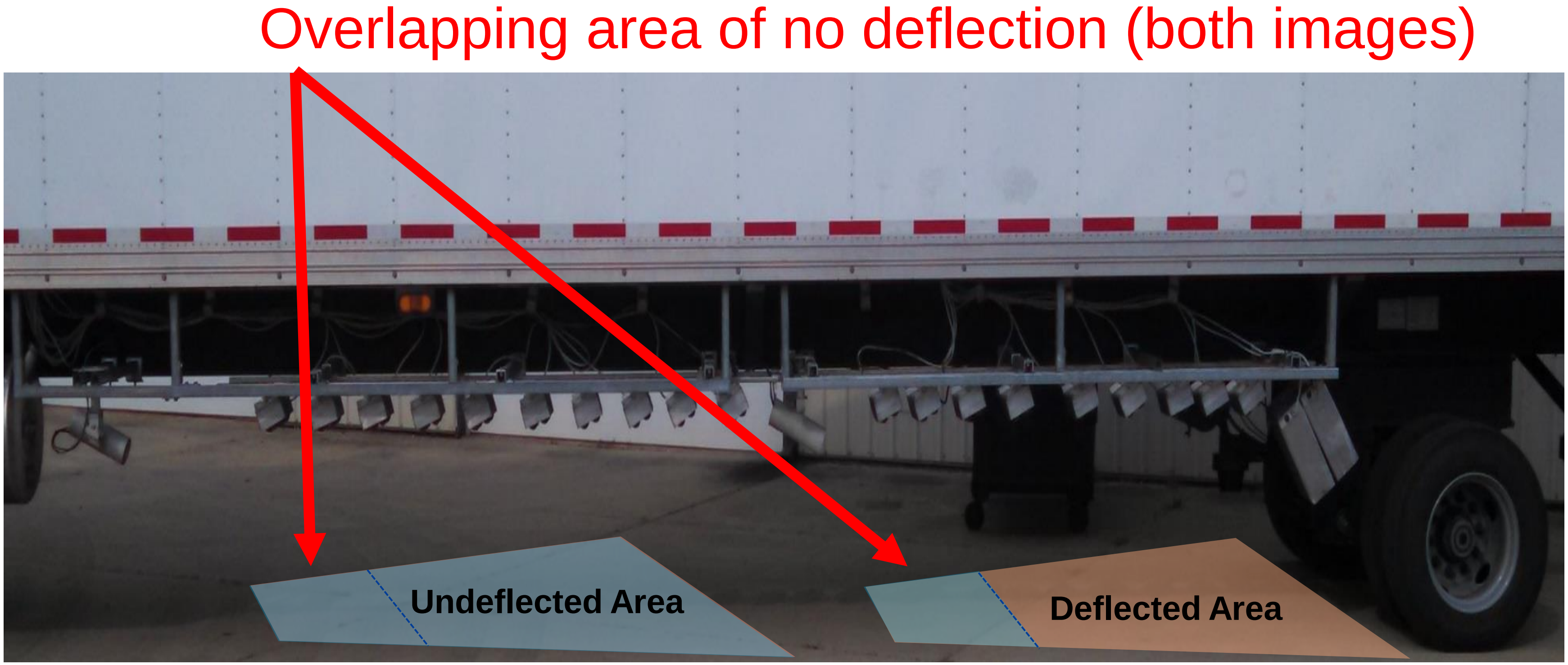
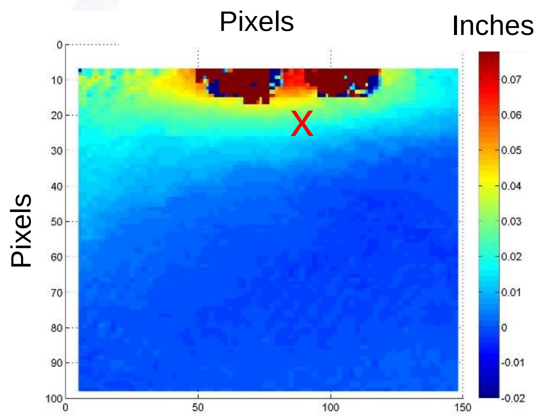
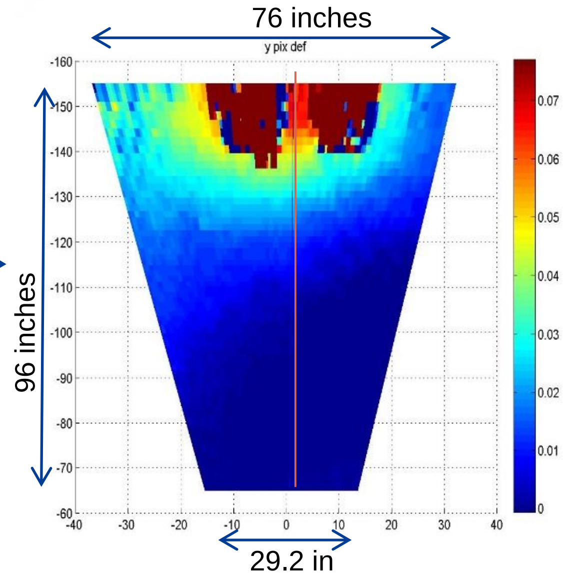


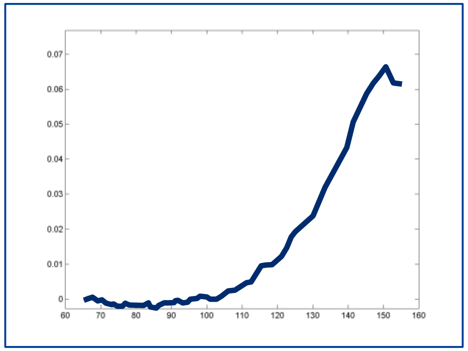
Image Processing



RWD-Vision deflection measurements (in camera images)

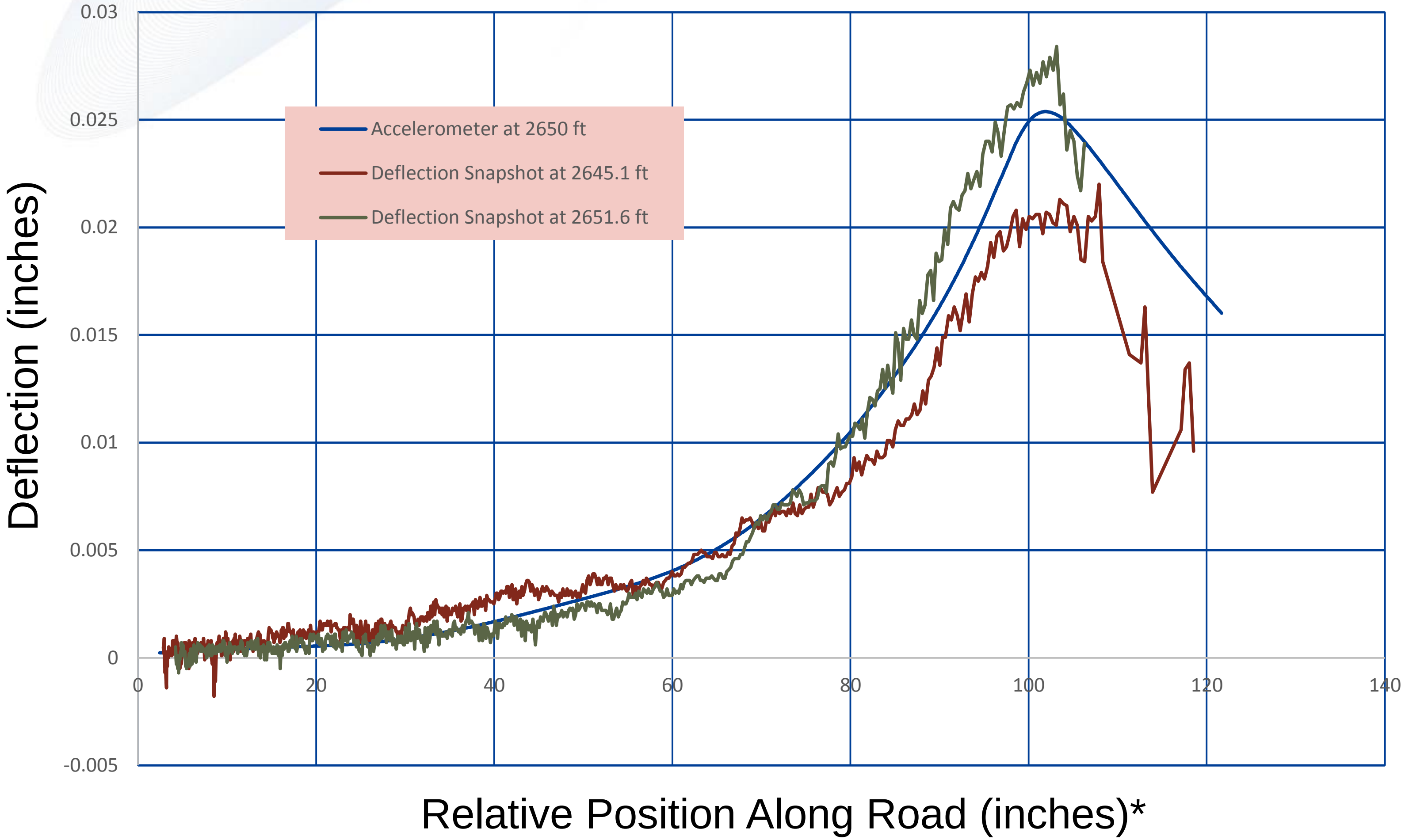


RWD-Vision deflection contour (on pavement surface)
Area = 3.9 ft^2



RWD-Vision deflection profile along wheel path centerline

Full Basin


Accelerometer at 2650 ft
Deflection Snapshot at 2645.1 ft
Deflection Snapshot at 2651.6 ft
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
0
20
40
60
80
100
120
140
Deflection (inches)
Relative Position Along Road (inches)*

Summary

- **PMS a tool to improve cost- effectiveness of M&R program**

- **Several alternatives to PMS implementation**
  - Extent of data collected
  - Methods of data collection
  - PMS software

- **Pavement Management decisions enhanced if structural strength incorporated**

Summary (cont'd)

- **Traditionally obtaining structural data on County-wide basis not economically feasible**
- **Innovative RWD provides cost effective means to obtain network level structural data**
  - Laser based RWD has proven reliable & accurate enough at network level
  - New vision based RWD provides "deflection basin" that allows more detailed analysis

Questions???

- **Contact Information:**

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PDH Quiz

1. A pavement management system can:

- A) quantify pavement conditions objectively
- B) determine an overall condition rating for a specific road
- C) determine an overall condition rating for an entire road network
- D) predict condition ratings in future years
- E) determine optimum time for M&R treatments
- F) all of the above

PDH Quiz

- **2. Which data collection method provides the most accurate data?**
  - A) Foot on ground survey
  - B) Windshield survey
  - C) Digital survey vehicle
  - D) Pa Vision

PDH Quiz

3. **Which data collection method costs the least ?**
   - A) Foot on ground survey
   - B) Windshield survey
   - C) Digital survey vehicle
   - D) Pa Vision
   - E) Depends on size of network

PDH Quiz

- **4. Which data collection method is most suitable to QC checks ?**
  - A) Foot on ground survey
  - B) Windshield survey
  - C) Digital survey vehicle
  - D) Pa Vision

PDH Quiz

- **5. Why can surface condition be misleading when comparing different roads for pavement management decision making ?**
  - A) Pavement composition may be different for 2 identical looking pavement surfaces
  - B) Pavement strength may be different for 2 identical looking pavement surfaces
  - C) Deterioration of underlying layers is not seen
  - D) None of the above
  - E) All of the above

PDH Quiz

- **6. Which of the following can determine a pavement's structural capacity:**

  - A) Cores and borings
  - B) Falling weight deflectometer
  - C) Digital survey vehicle
  - D) PaVision
  - E) Rolling wheel deflectometer

PDH Quiz

- 7. **Which tool provides the most accurate structural assessment?**

  - A) Falling weight deflectometer
  - B) Rolling wheel deflectometer

PDH Quiz

- **8. Which tool is most suited for use on a County-wide (network) basis?**
  - A) Falling weight deflectometer
  - B) Rolling wheel deflectometer

PDH Quiz

- 9. **Which tool requires traffic control during testing?**
  - A) Falling weight deflectometer
  - B) Rolling wheel deflectometer

PDH Quiz

- **10. Use of RWD data can improve pavement M&R decisions by:**
  - A) Distinguishing between 2 similar looking pavements that have different structural capacity
  - B) Lowering the cost of overlays
  - C) Deferring treatment on pavements in fair condition that are structurally inadequate
  - D) Adding confidence that a preservation technique is economically viable
  - E) Can decrease the overall cost of a County-wide M&R program