DEVELOPMENT OF AN APPROACH TO INCORPORATE PAVEMENT STRUCTURAL CONDITION INTO THE TREATMENT SELECTION PROCESS AT THE NETWORK-LEVEL

By

Shivesh Shrestha

Virginia Tech

RPUG Road Profile Users' Group

Contents

Introduction

2000s

World's first Doppler-based Traffic Speed Deflectometer (TSD), configured with 4 Doppler sensors, was developed and patented by Greenwood Engineering.

2011

Rada et al. 2011

commissioned by FHWA

2012

Flintsch et al. 2012

Second Strategic Highway Research Program 2 (SHRP 2) R06(F)

TSD was a promising device for network level pavement management applications.

Introduction

2013

Katicha et al. 2017 – Federal Highway Administration (FHWA) initiated a pooled fund project to perform field demonstration of the TSD. *(9 participating states)*

The study concluded that the TSD was capable of differentiating between relatively structurally strong and weak pavement sections.

2016

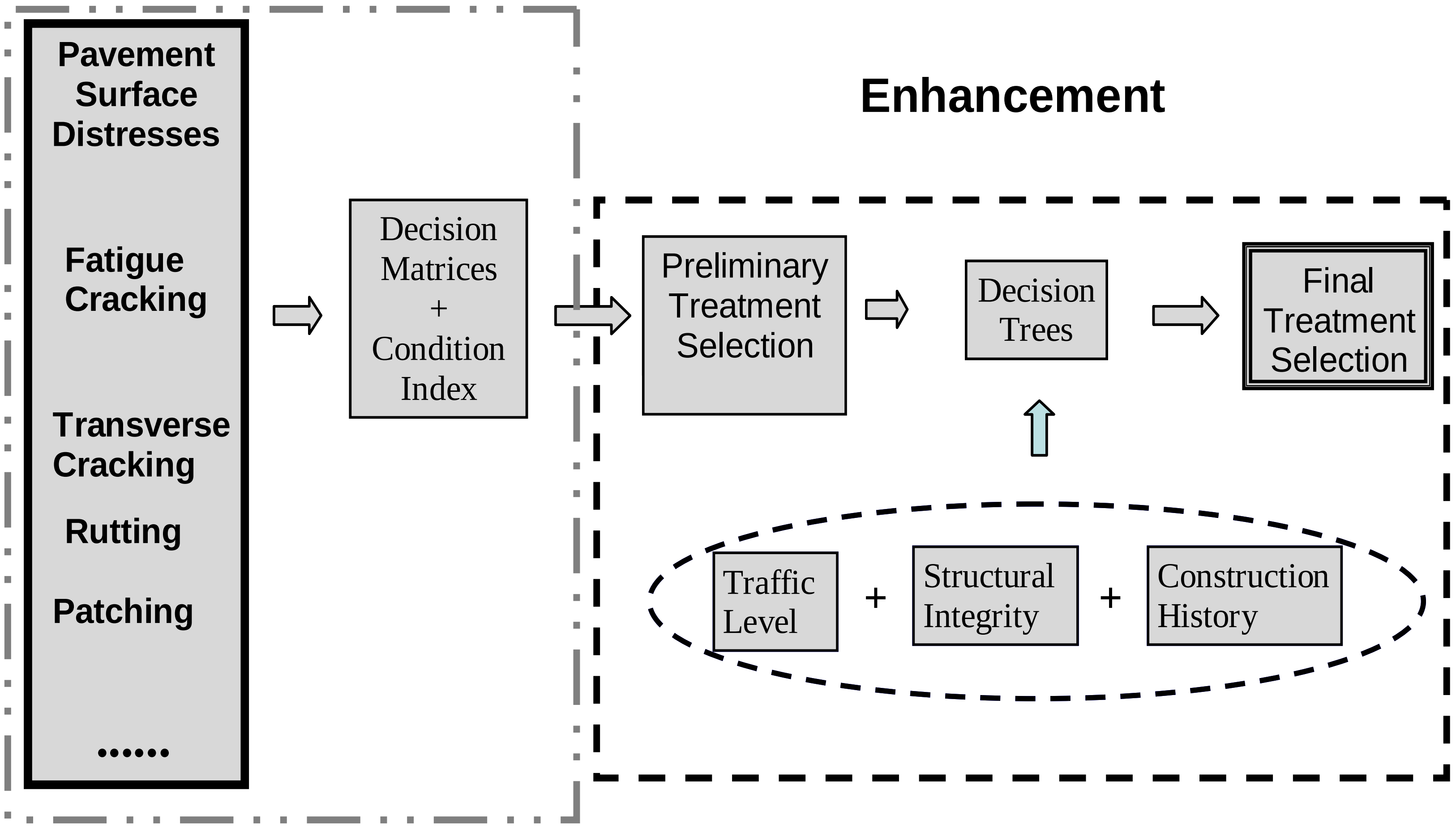
Rada et al. 2016 – FHWA Report

Relationship between the corresponding deflection basin indices and pavement structural response. Recommended deflection indices: SCI300 and DSI.

Introduction

- Katicha et al. 2017
- Rada et al. 2016

VDOT's enhanced decision making process



Introduction

2017

Network Level Structural Evaluation with the TSD

Virginia Department of Transportation – Traffic Speed Deflectometer

Objective

Develop a treatment selection matrix that takes into account the pavement structural condition and augments the existing treatment selection process based solely on the observed surface condition.

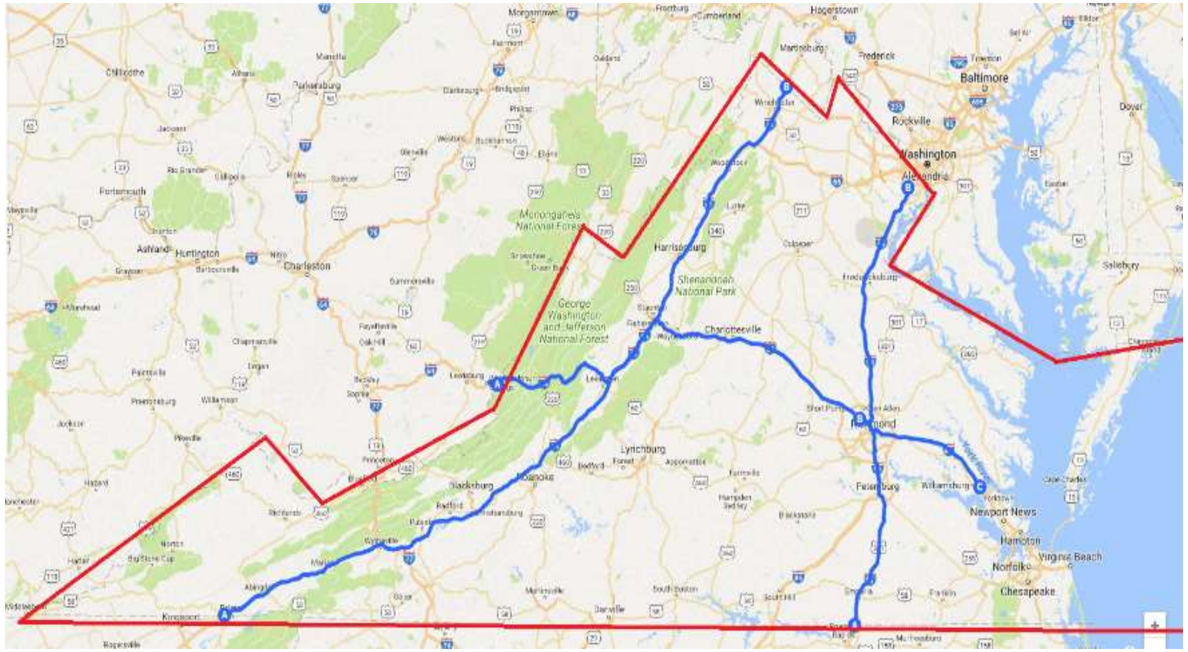
Methodology

1. Data Collection and Processing
2. Development of Deterioration Models
3. Incorporating Structural Condition Information into the PMS Decision making Process

1. Data Collection and Processing

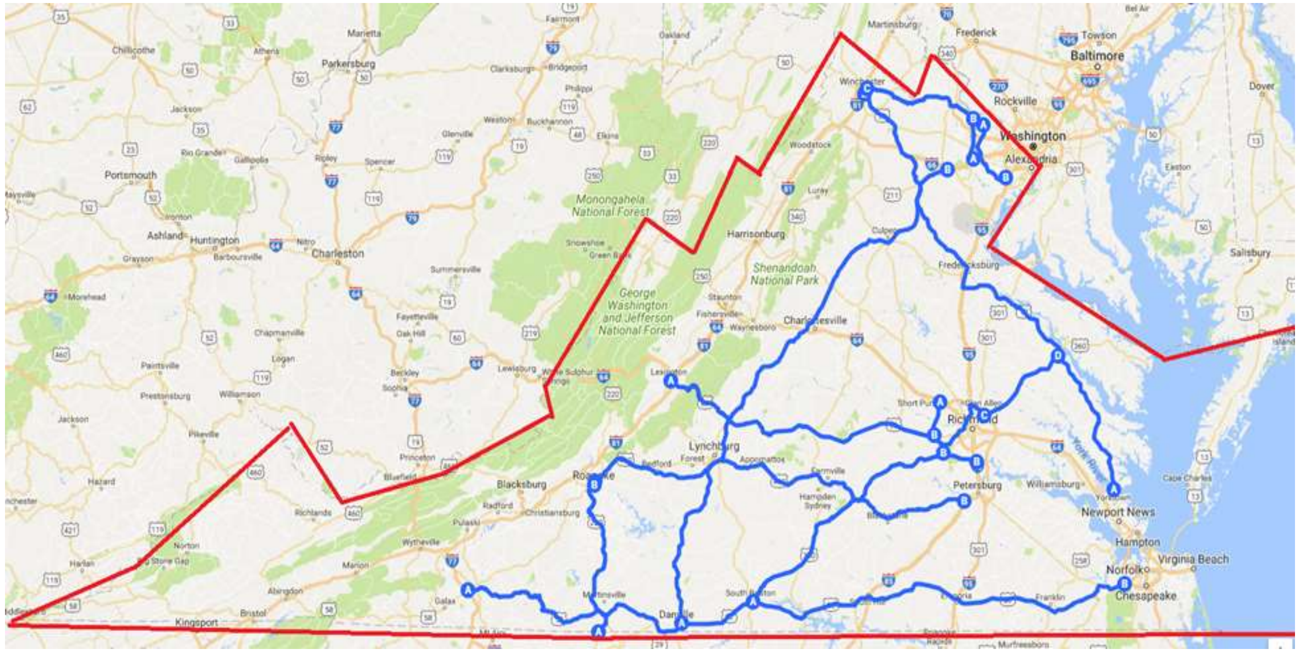
Virginia

Interstate Roads: 1500 miles



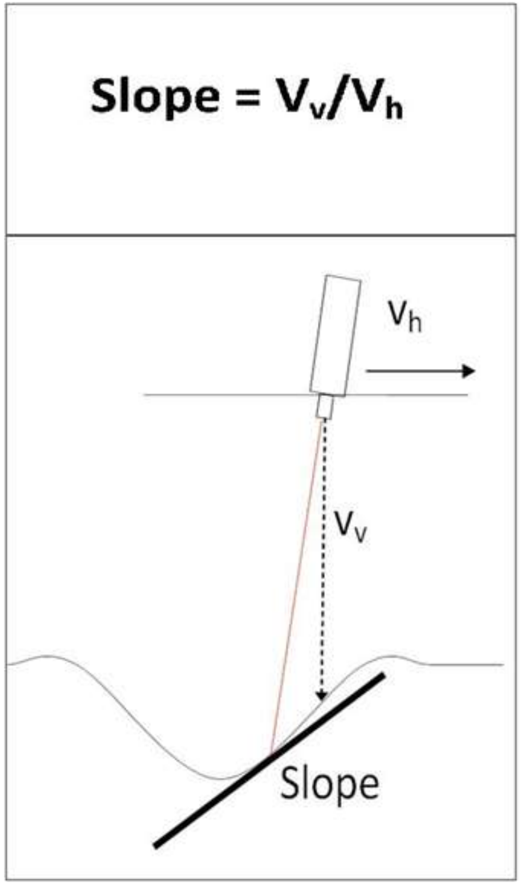
I81, I95 and I64

Primary Roads: 2530 miles



US460, US360, US220, US60, US58, US29, US17, SR28, SR288

1. Data Collection and Processing



Deflection Slope:

$$S = \frac{V_v}{V_h}$$

Where,
S = the deflection slope
Vv = the vertical pavement deflection velocity
Vh =the vehicle horizontal velocity

Deflection:

$$d(x) = \int_x^{\infty} s(y)dy$$

Where,
s(y) = slope at location y measured from the applied load
d(x) = deflection at location x measured from the applied load

1. Data Collection and Processing

- Deflections measurements: D0, D100, D200, D300, D600, D900, D1500

- Structural Condition parameters:

1. SCI300 = $d_0 - d_{300}$: Surface Curvature Index
2. d_0 : Deflection at 0mm
3. SN_{eff} : Effective structural number

(by Nasimifar et al. 2019)

- Temperature Adjustment to 20°C

1. Data Collection and Processing

- Temperature Adjustment for SCI300 (***by Nasimifar et al. 2018***)

$$\lambda = \frac{SCI_{\mathrm{Ref}}}{SCI_T} = \frac{10^{-0.05014T_{\mathrm{Ref}} + 0.019049T_{\mathrm{Ref}} \log(h_{AC}) \log(\varphi)}}{10^{-0.05014T + 0.019049T \log(h_{AC}) \log(\varphi)}}$$

Where, λ =Temperature Adjustment Factor

SCI_{Ref}= Adjusted SCI300 at reference temperature

T_{Ref} = Reference temperature in °C

h_{AC}= Asphalt layer thickness, mm

T= Mid-depth AC layer temperature at time of measurement in °C

φ = Latitude of location of measurement (within 30 to 50 degrees)

1. Data Collection and Processing

- Temperature Adjustment for D0 (***AASHTO temperature adjustment charts***)

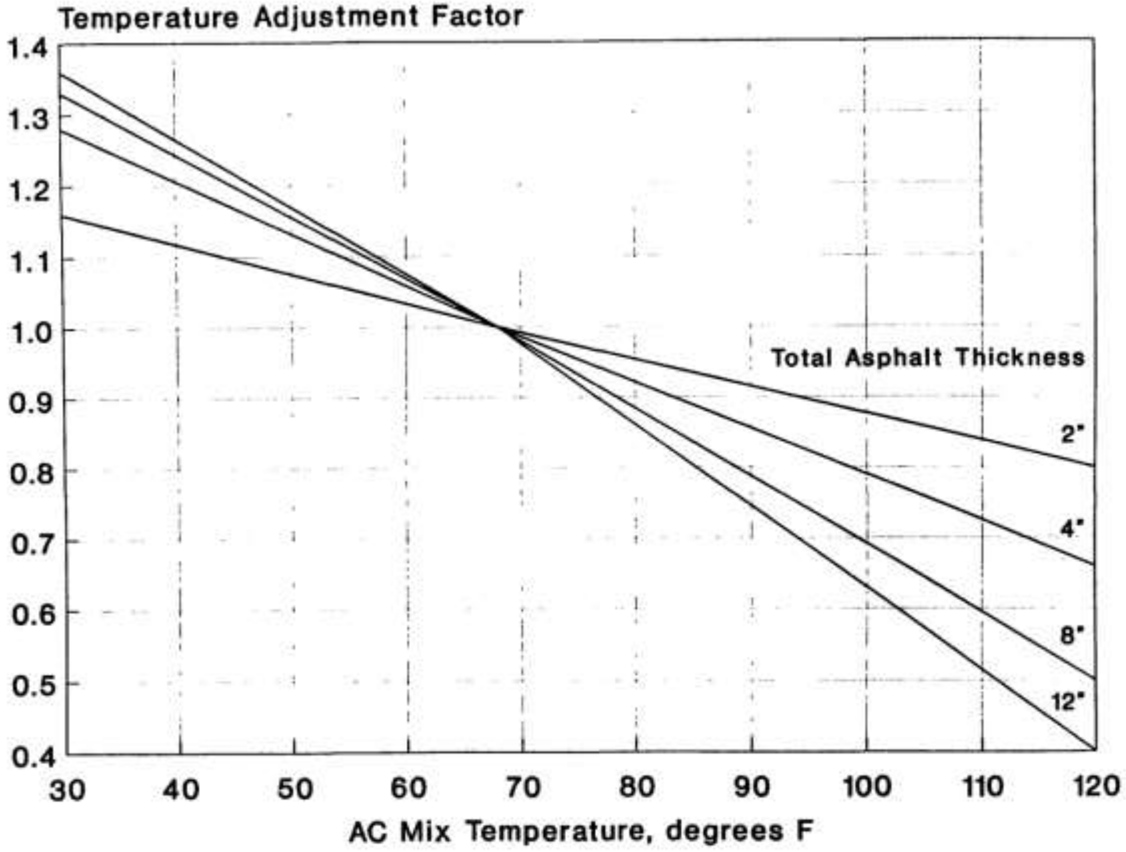


Figure I.5.4. d_0 Adjustment for AC Mix Temperature for Granular and Asphalt-Treated Base Pavements

$$T(t) = \frac{d_0(68)}{d_0(t)}$$

where

$T(t)$ = temperature adjustment factor
$d_0(68)$ = d_0 at 68°F
$d_0(t)$ = d_0 at testing temperature t°F

1. Data Collection and Processing

- Temperature Adjustment for SNeff *(**by Nasimifar et al. 2019**)*

$$SN_{eff} = k_1 SIP^{k_2} H_p^{k_3}$$

$$SIP = d_0 - d_{1.5H_p}$$

K_1, K_2 and K_3 are 0.4369, -0.4768, and 0.8182

- *Temperature Adjusted d_0 was used to calculate the SIP*
- *No temperature adjustment was performed for $d_{1.5Hp}$*

1. Data Collection and Processing

VDOT pavement condition index: Critical condition Index (CCI)

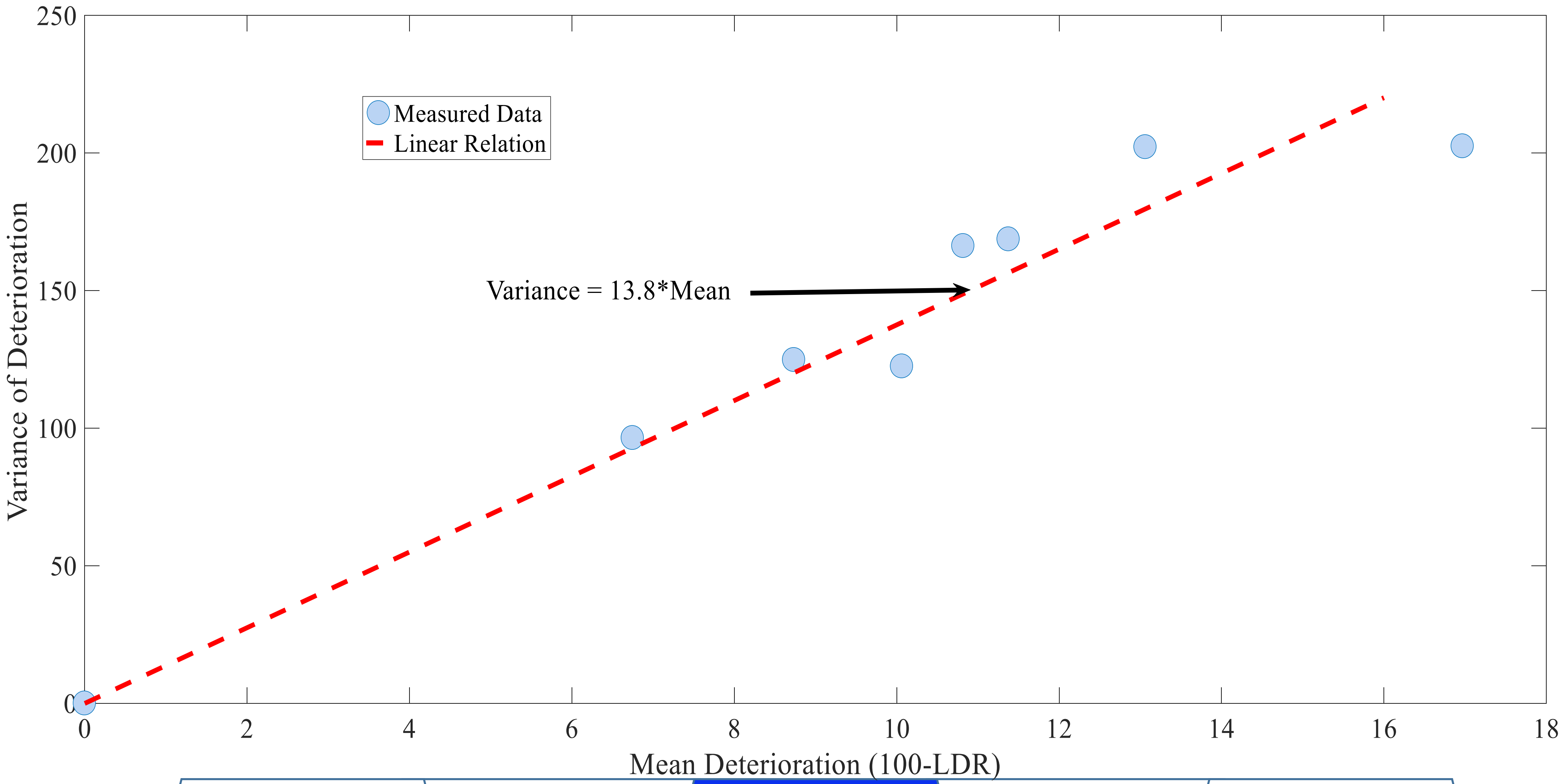
Load Related Distress (LDR):
- Alligator cracking
- Patching
- Potholes
- Delamination
- Rutting

Non Load Related Distress (NDR):
- Transverse cracking
- Longitudinal cracking
- Bleeding

Critical Condition Index (CCI)
(The lowest of the LDR or NDR)

2. Development of Deterioration Models

Deterioration = 100- CCI, 100-LDR, 100-NDR



2. Development of Deterioration Models

Deterioration equations where developed for the LDR, NDR, and CCI with SCI300, D0 and SNeff.

$$LDR = 100 - \exp\left(\beta_0 + \beta_1 \log\left(Age\right) + \beta_2 \log\left(Age\right) \times SCI300\right)$$
$$= 100 - \exp\left[\beta_0 + \beta_1\left(1 + \beta_3 SCI300\right)\log\left(Age\right)\right]$$

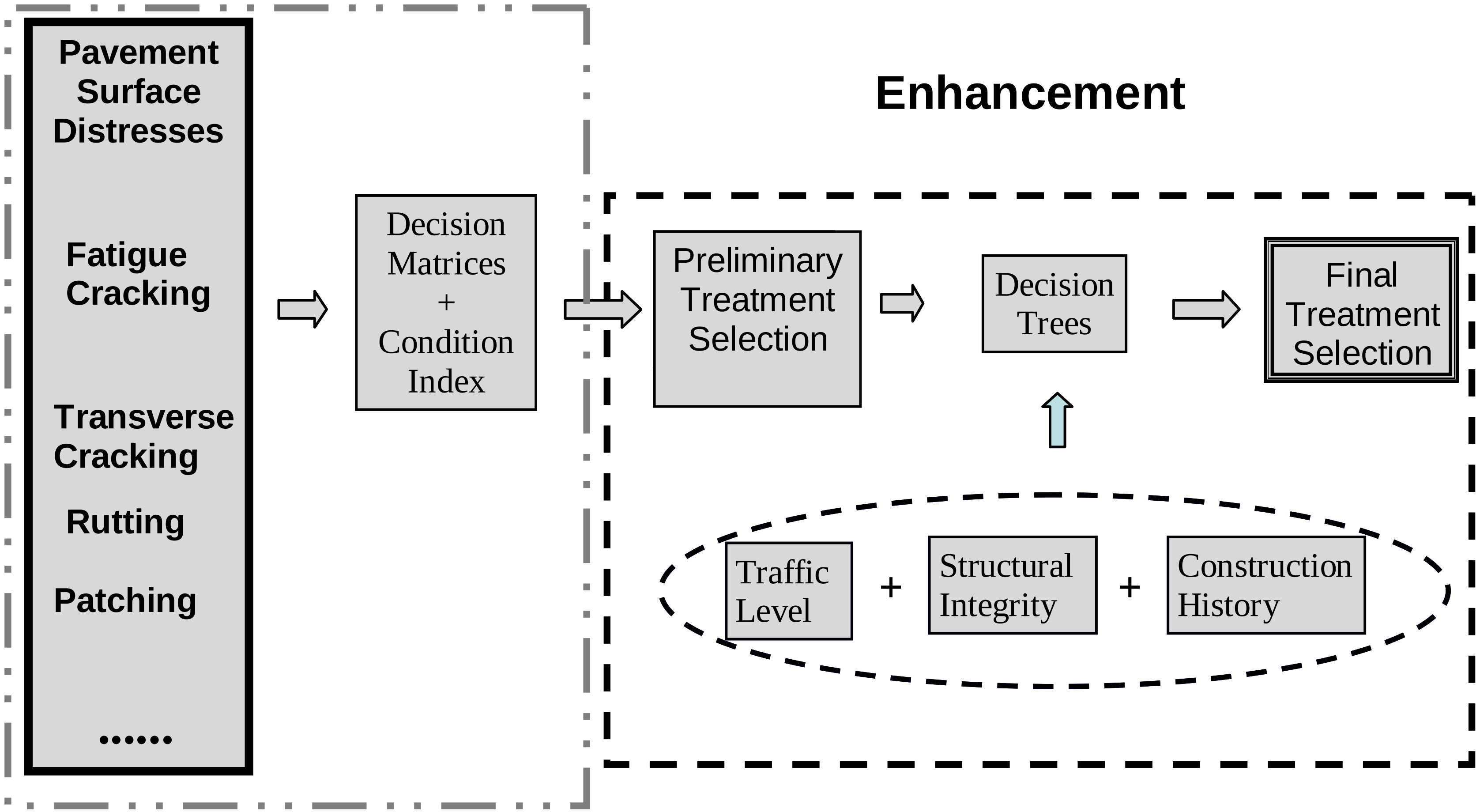
Where, LDR = load related distress

Age = pavement age calculated as the difference between the year at which the LDR is observed minus the year of the last applied treatment recorded in the PMS

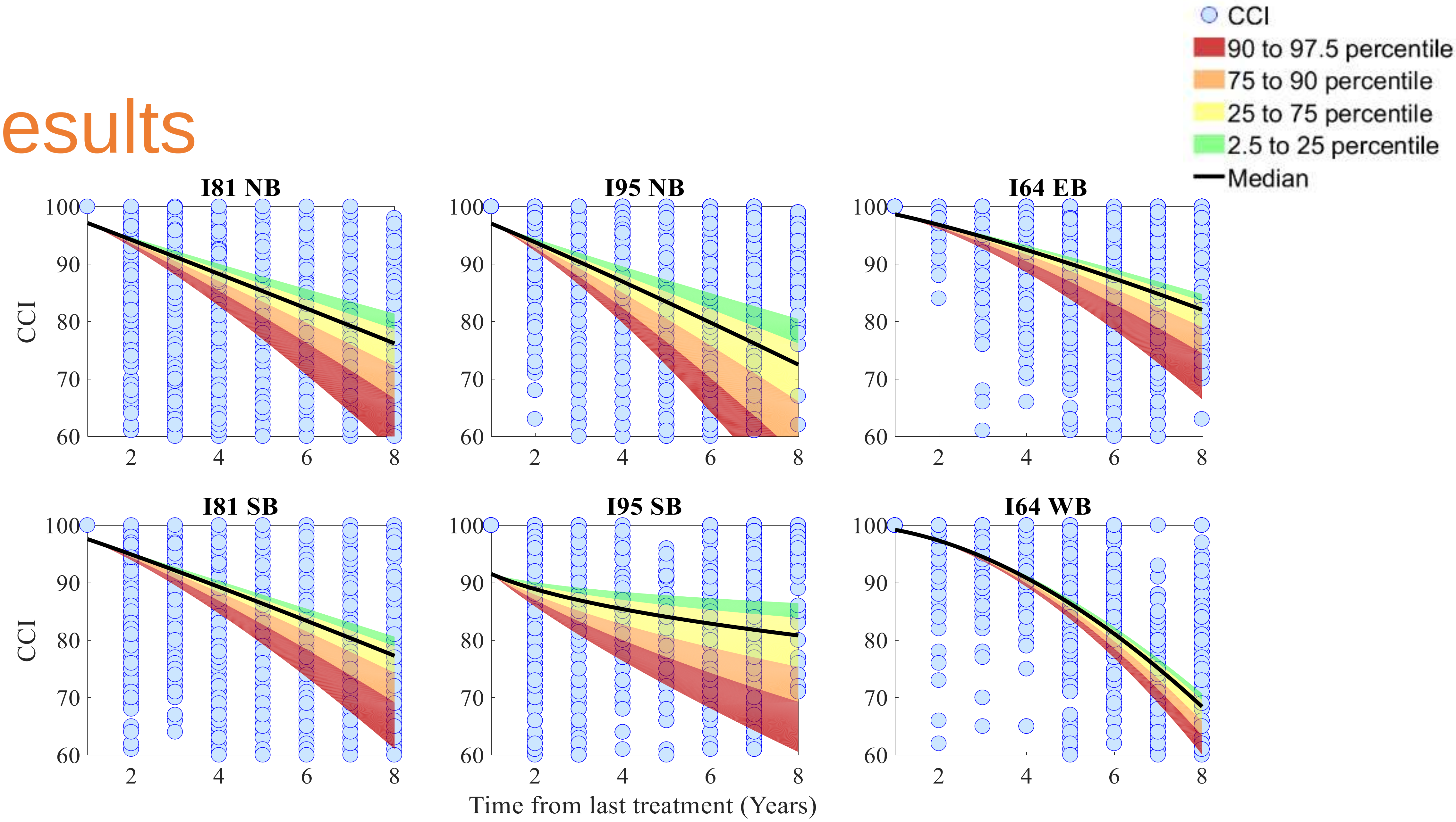
SCI300 = Surface Curvature Index

β_0, β_1, β_2, and β_3 = regression coefficients with $\beta_3 = \beta_2 / \beta_1$.

3. Data Incorporating Structural Condition Information into the PMS Decision Process

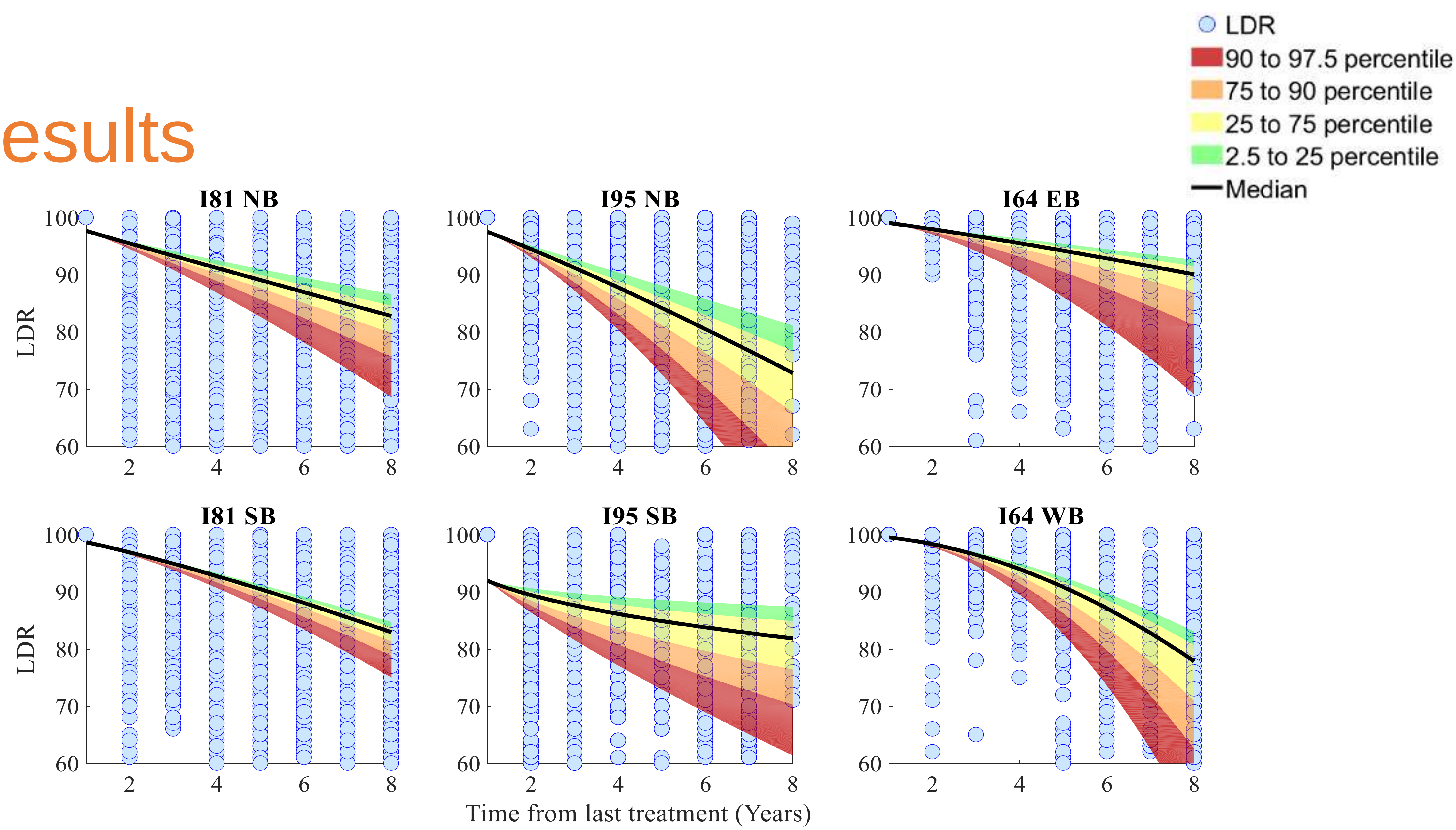


Results



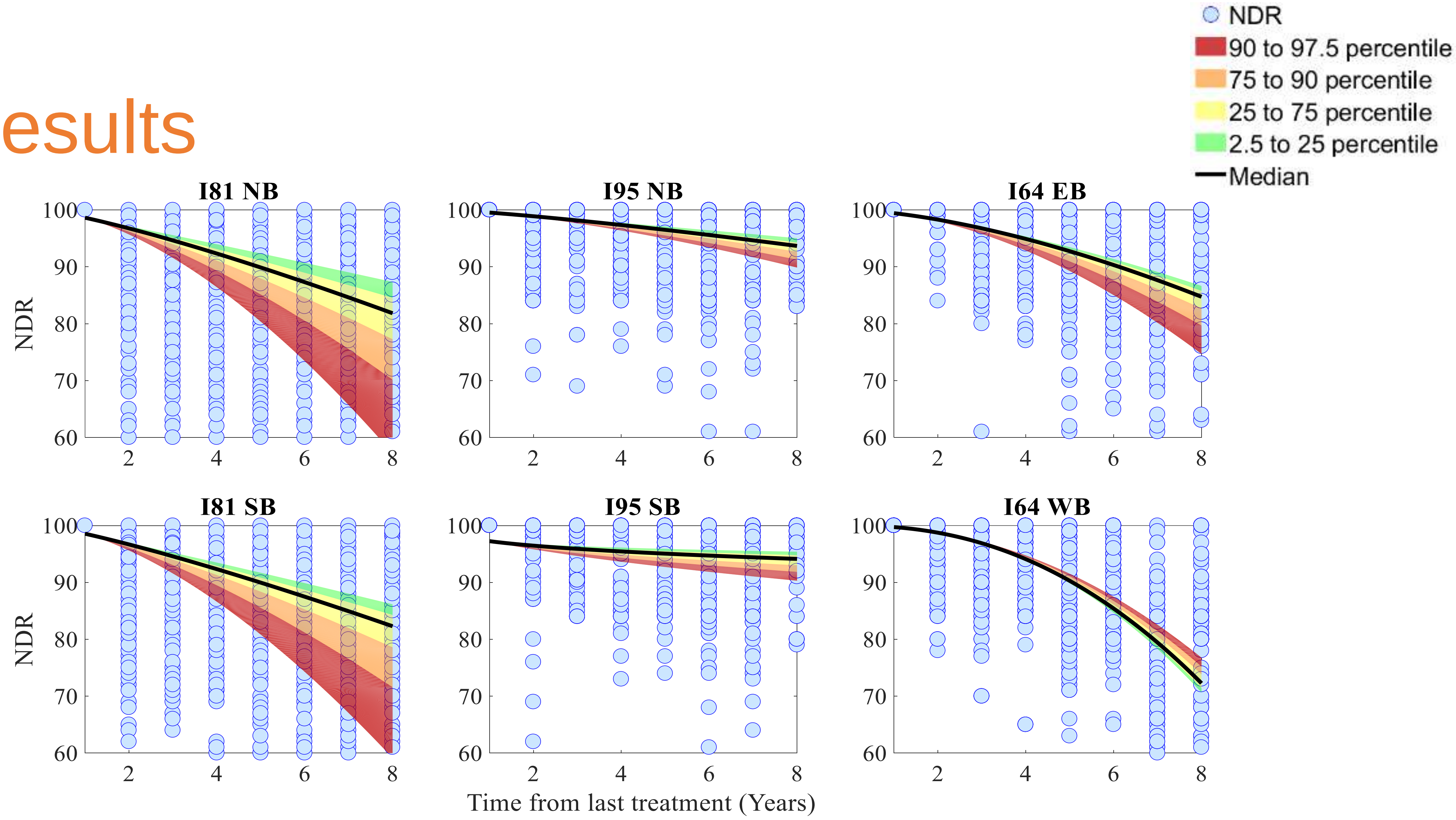
CCI
90 to 97.5 percentile
75 to 90 percentile
25 to 75 percentile
2.5 to 25 percentile
Median
I81 NB
I95 NB
I64 EB
I81 SB
I95 SB
I64 WB
CCI
100
90
80
70
60
2
4
6
8
Time from last treatment (Years)

Results



LDR
90 to 97.5 percentile
75 to 90 percentile
25 to 75 percentile
2.5 to 25 percentile
Median
I81 NB
I95 NB
I64 EB
I81 SB
I95 SB
I64 WB
LDR
Time from last treatment (Years)

Results



NDR
90 to 97.5 percentile
75 to 90 percentile
25 to 75 percentile
2.5 to 25 percentile
Median
I81 NB
I95 NB
I64 EB
I81 SB
I95 SB
I64 WB
NDR
100
90
80
70
60
2
4
6
8
Time from last treatment (Years)

Results

- In general, the results show that sections with higher SCI300 (weaker sections) have a higher rate of deterioration than those with a lower SCI300 (stronger sections). (with a few exceptions)

- Three structural condition parameters, SCI300, d_0, and SNeff were investigate and it was found that SCI300 is the best parameter to use in a deterioration model.

- Structural condition has a significant impact on pavement deterioration.

Results

The threshold for Fair and Strong is the 25th percentile of SCI300 and the threshold between Fair and Weak is the 75th percentile of SCI300.

Initial Treatment Category	Modified Treatment Category with Structural Condition Category		
	Strong	Fair	Weak
DN	DN	DN	DN
PM	PM	PM	DN
CM	PM	CM	RM
RM	CM	RM	RC
RC	RM	RC	RC

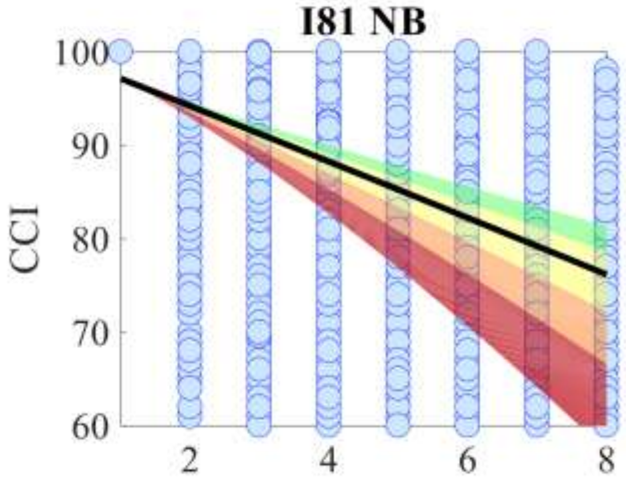
Results

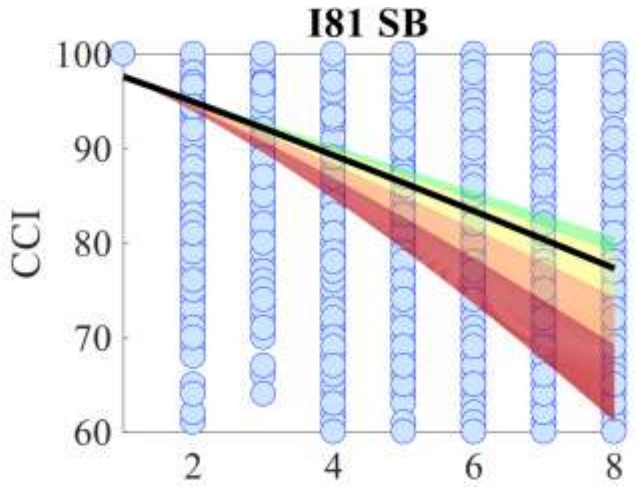
PMS Decision	81NB		81SB		95NB		95SB		64EB		64WB	
	Current	Modified	Current	Modified	Current	Modified	Current	Modified	Current	Modified	Current	Modified
DN	24.4	27.2	28.0	29.4	45.7	47.1	34.1	35.8	11.5	14.3	37.8	40.3
PM	13.3	22.2	10.1	19.5	14.8	21.8	10.9	16.2	22.9	31.2	14.4	17.2
CM	47.6	29.5	52.2	34.4	32.4	19.6	47.4	29.9	51.9	34.0	32.0	22.2
RM	11.7	17.5	8.6	13.4	1.1	6.8	1.0	12.3	6.2	13.4	6.2	12.8
RC	3.0	3.7	1.0	3.3	5.9	4.7	6.5	5.7	7.5	7.2	9.5	7.4

PMS Decision	Average		
	Current	Modified	
DN	30.3	32.4	
PM	14.4	21.4	↑
CM	43.9	28.3	↓
RM	5.8	12.7	↑
RC	5.6	5.3	

Conclusion

1. In general, the deterioration models behaved as expected with the deterioration rate increasing for structurally weaker sections. (with the exception of a small number of the analyzed roads)





It would be beneficial to incorporate the structural condition into the treatment selection decision process.

Conclusion

2. An augmented matrix was presented that modifies the initial pavement treatments based on whether the structural condition is Strong, Fair, or Weak.

The thresholds for determining the state of the pavement structural condition were based on the 25th and 75th percentile of SCI300 values of each route.

Conclusion

3. A treatment selection matrix that incorporates the pavement structural condition into treatment selection tool was presented.

- For the structurally Strong sections CM, RM, and RC were modified to a lighter treatment.
- For the Fair category, the treatments are kept the same as recommended based on the surface condition.
- For the structurally Weak sections CM and RM were modified to a heavier treatment category while PM was modified to DN.

References

1. Rada, G., et al. Moving pavement deflection testing devices: state of the technology and best uses. in Proc., 8th International Conference on Managing Pavement Assets, Santiago, Chile. 2011. Citeseer.
2. Flintsch, G., Katicha, S., Bryce, J., Ferne, B., Nell, S., & Diefenderfer, B. (2013). *Assessment of continuous pavement deflection measuring technologies* (No. SHRP 2 Report S2-R06F-RW-1).
3. Katicha, S., et al., Demonstration of Network Level Structural Evaluation With Traffic Speed Deflectometer: Final Report. Prepared for the Federal Highway Administration, 2017.
4. Rada, G. R., Nazarian, S., Visintine, B. A., Siddharthan, R. V., & Thyagarajan, S. (2016). *Pavement structural evaluation at the network level* (No. FHWA-HRT-15-074). United States. Federal Highway Administration. Office of Infrastructure Research and Development.
5. Nasimifar, M., et al., *Temperature adjustment of Surface Curvature Index from Traffic Speed Deflectometer measurements.* International Journal of Pavement Engineering, 2018: p. 1-11.
6. Nasimifar, M., Thyagarajan, S., Chaudhari, S., & Sivaneswaran, N. (2019). Pavement Structural Capacity from Traffic Speed Deflectometer for Network Level Pavement Management System Application. *Transportation Research Record*, *2673*(2), 456-465.

Source: https://www.linkedin.com/company/arrb-group-inc/

Thank you