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# Incorporating Traffic Speed Deflection Data in PMS Decision Making for Flexible Pavements

***Senthilmurugan Thyagarajan***
***Nadarajah Sivaneswaran***
***Katherine Petros***
Turner-Fairbank Highway Research Center,
FHWA, HRDI-20
McLean, VA

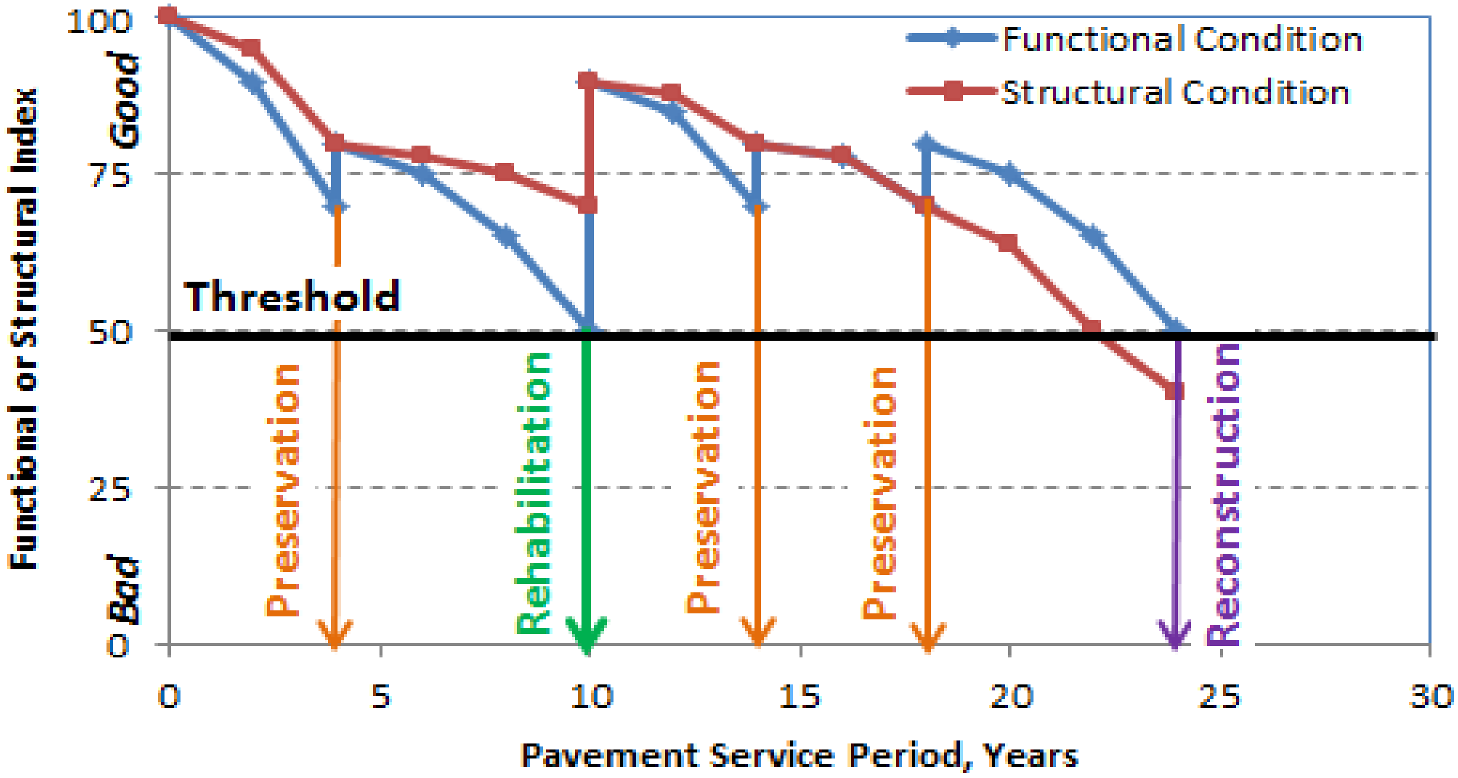
# Outline

- Evaluate and incorporate both structural and functional condition in PMS analysis
- Coupled mechanistic and LCC analyses in optimizing treatment sequence.
- Remaining Service Interval (RSI) to report time remaining until a defined construction type.

# Evaluate and Incorporate Structural and Functional Condition in PMS Analysis

# Network Level Pavement Evaluation

Need both functional and structural condition



# *Network Level Pavement Evaluation*

- Functional threshold is a limit for LOS
  - beyond which the pavement should be subjected to some form of treatment
- Structural condition is required to identify most cost effective treatment
- Surface condition alone is inadequate to assess structural health of the pavement.

# *Limitation of Surface Measurements*

Most PMS use surface cracking as a surrogate for structural condition.

Limitations:

- Most preservation treatments correct surface cracks but not bottom-up fatigue cracking, instead concealing them, while the bottom-initiated cracks continue to develop
- The prevalence of top-down cracking in thicker pavements also makes it difficult to distinguish bottom-up fatigue cracking

# *Structural Evaluation at Network Level*

- Incorporate network level deflection testing to collect
  - Current structural condition
  - Rate of deterioration.
- Utilize Traffic Speed Deflection Devices (TSDD)
  - Applied Research Associate's Rolling Wheel Deflectometer (RWD)
  - Greenwood Engineering's Traffic Speed Deflectometer (TSD)
- Accuracy and Precision of TSDD measurements found to be acceptable for network level application - FHWA research project

# *Structural Condition from TSDD measurements*

- Tensile strains at bottom of HMA or fatigue strains are indicators of fatigue cracking potential
- Curvature indices from TSDD measurements are found to be good predictors of fatigue strains while effectively isolating the effect of seasonal and spatial variation in unbound layers.
  - Computed as difference or ratio between TSDD measurements at two or more lateral distances.

Example: Surface Curvature Index, SCI = $D_0$-$D_{12}$

Thyagarajan, S. et. al., *8th ICMPA,* Chile, 2011.

# Relation between TSDD Measurement and Fatigue Strain

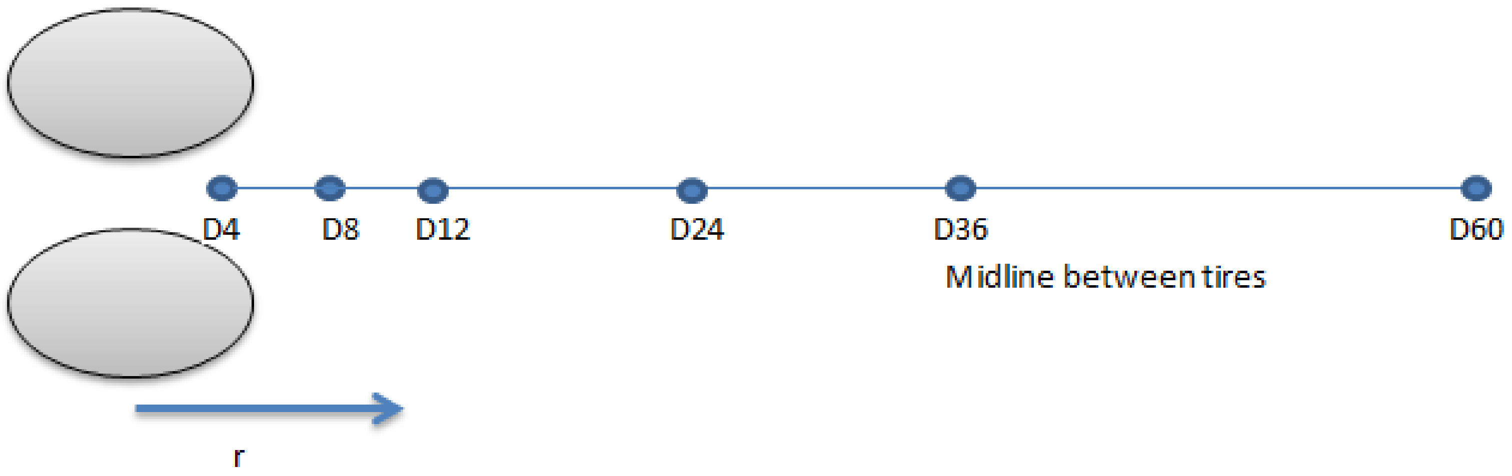
FHWA Project *"Pavement Structural Evaluation at the Network Level"* Status - Completed.

| **Best Indices Relating Fatigue Strain** | | **$R^2$ (3D-Move Analysis)** | **$R^2$ (Measured Values)** |
| --- | --- | --- | --- |
| Surface Curvature Index, $SCI = D_0 - D_r$ | $SCI_{12}$ | 0.95 | 0.86 |
| | $SCI_{18}$ | 0.93 | 0.87 |
| Radius of Curvature, $R = r^2(2D_0(1-D_r/D_0))$ | $R1_{12}$ | 0.95 | 0.86 |
| | $R1_{18}$ | 0.93 | 0.87 |
| Deflection Slope Index, $DSI_{4-r} = D_4 - Dr$ | $DSI_{4-8}$ | 0.93 | 0.83 |
| | $DSI_{4-12}$ | 0.94 | 0.85 |
| | $DSI_{4-18}$ | 0.91 | 0.86 |

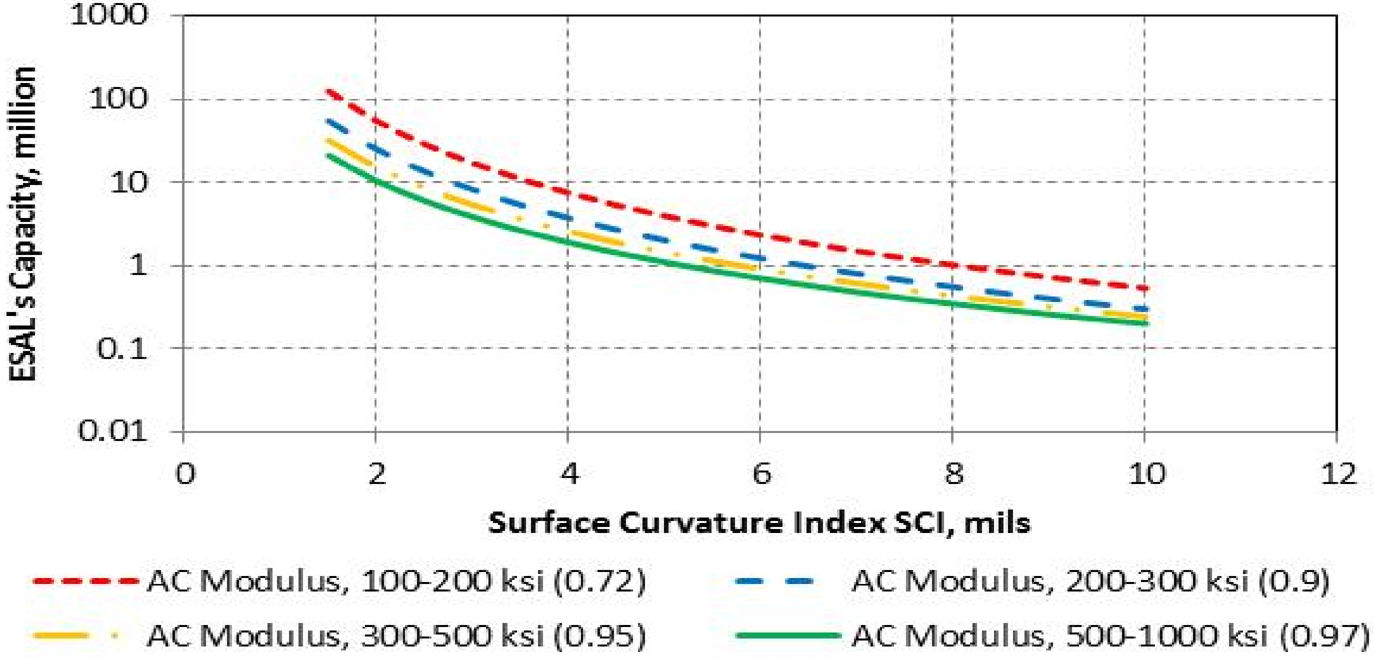
# Greenwood Engineering TSD

Traffic Speed Deflectometer (TSD)

- Multiple measurement points
- Curvature indices can be computed



# TSDD Application: Estimation of Remaining Structural Capacity




**SCI = $D_0$ - $D_{12}$**

SCI computed from TSDD measurement can be used to estimate the remaining ESAL's capacity

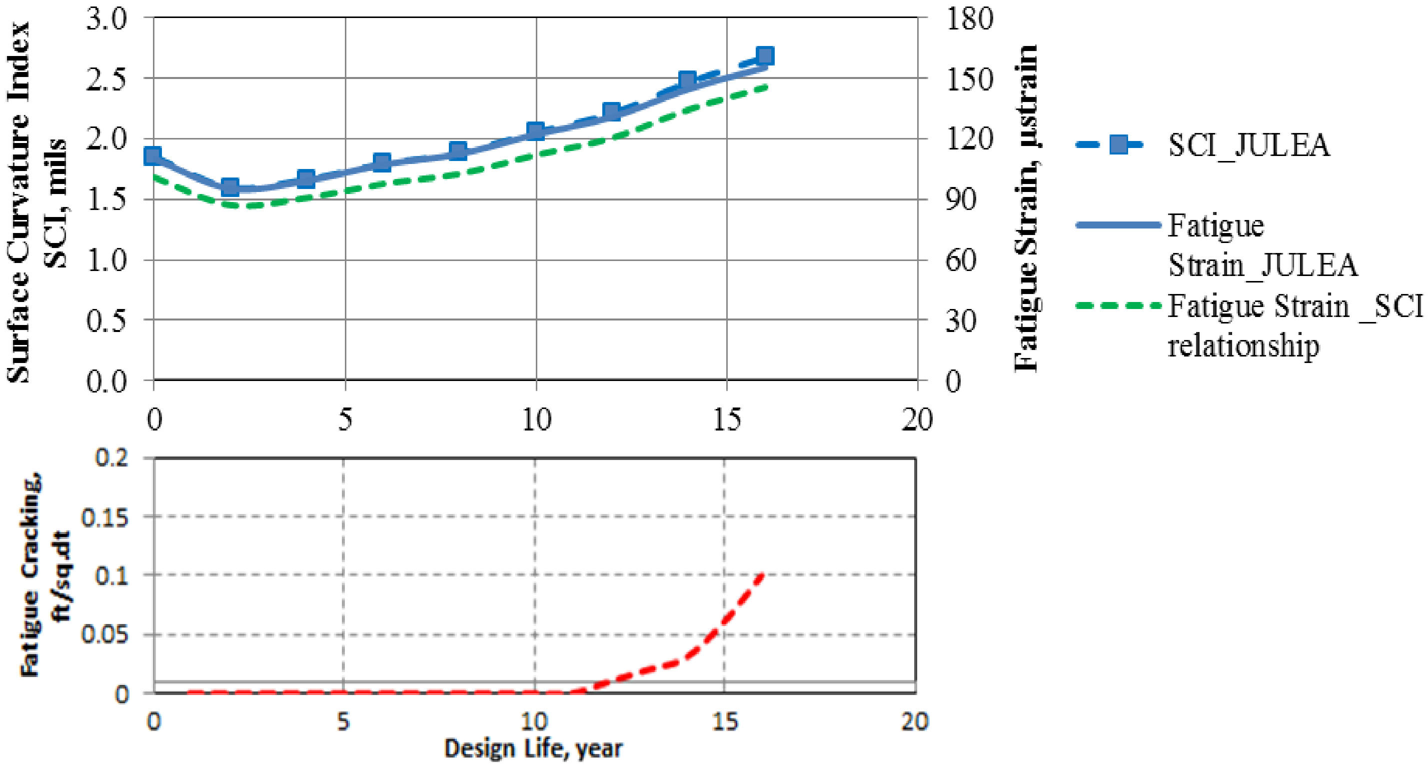
# TSDD Application: Tracking Fatigue Performance

- Pavement section

| Layer No | Material | Thickness, inch | Modulus, psi |
|---|---|---|---|
| 1 | HMA | 8 | 612,800 |
| 2 | Base, AB-Class 2 | 10 | 43,500 |
| 3 | Subgrade, CL | - | 10,200 |

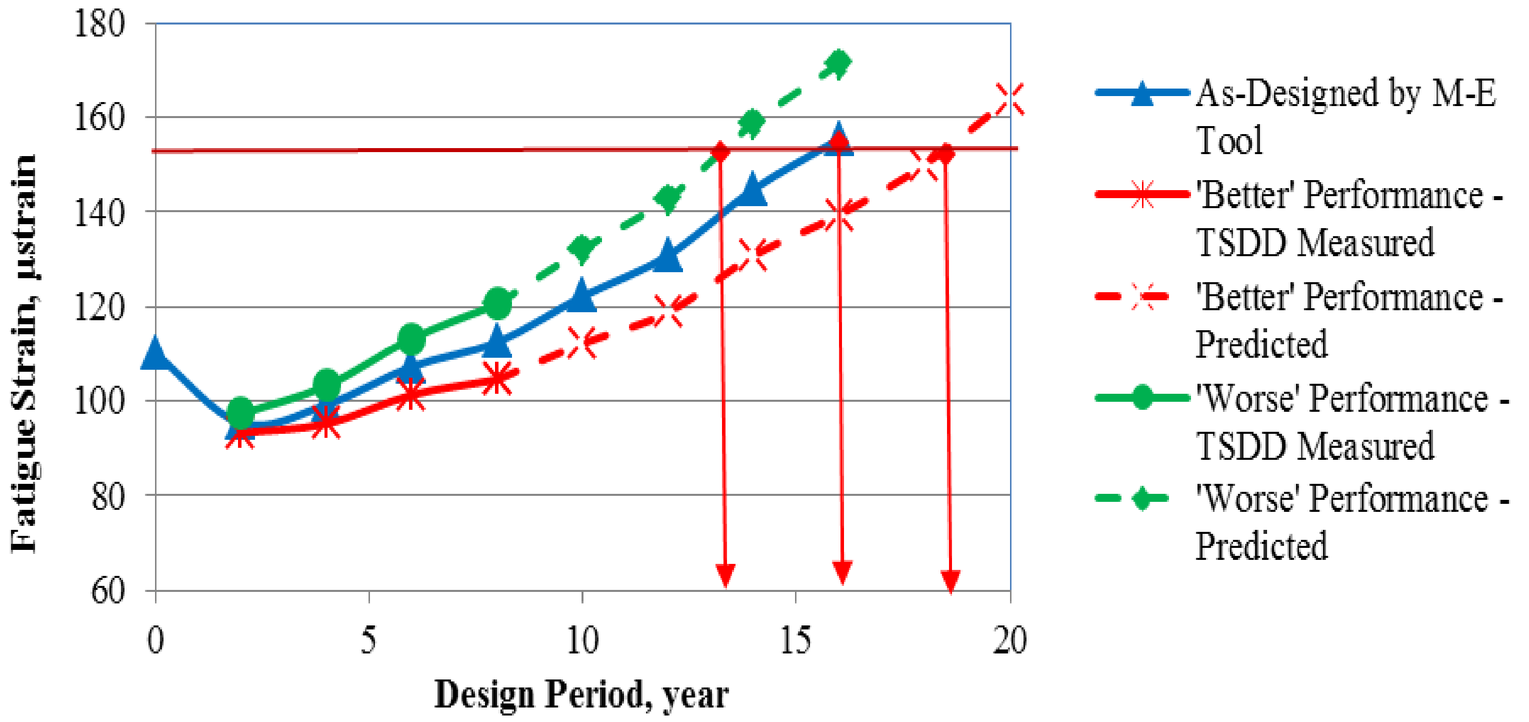
- CalME software was used
  - Accounts for progressive deterioration of the pavement structure over the design period
  - Can also consider sequence of treatments during the design period.

# *TSDD Application: Tracking Fatigue Performance*




- SCI can be an effective leading indicator of structural performance and are reasonably well related to fatigue strain
  - predict future performance even before any cracks are visible

# TSDD Application: Tracking Fatigue Performance



# COUPLED MECHANISTIC AND LCC ANALYSES

# *Coupled Mechanistic and LCC Analyses*

Treatment selection to maintain pavements above LOS

Minimum practical cost over the pavement lifecycle

***Mechanistic Analysis***

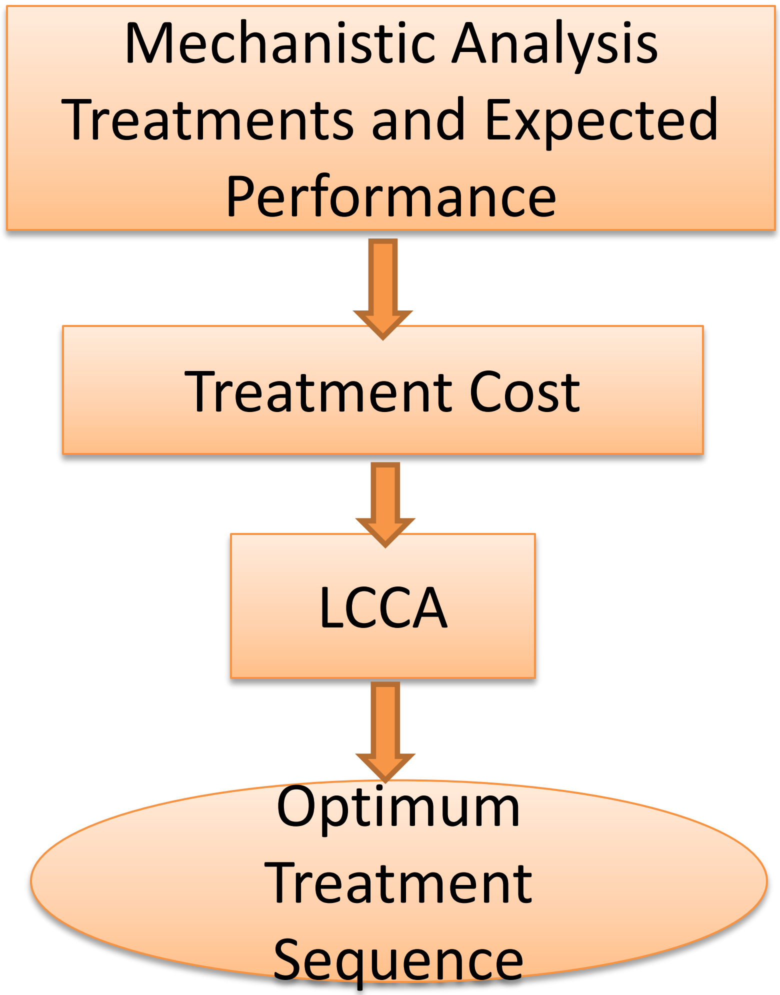
***Life Cycle Cost Analysis***

**Level of Service (LOS)**

**Agency Cost**

Objective is to maintain pavement at or above acceptable LOS to user at minimum practical cost over the lifecycle of asset

# *Coupled Mechanistic and LCC Analyses*



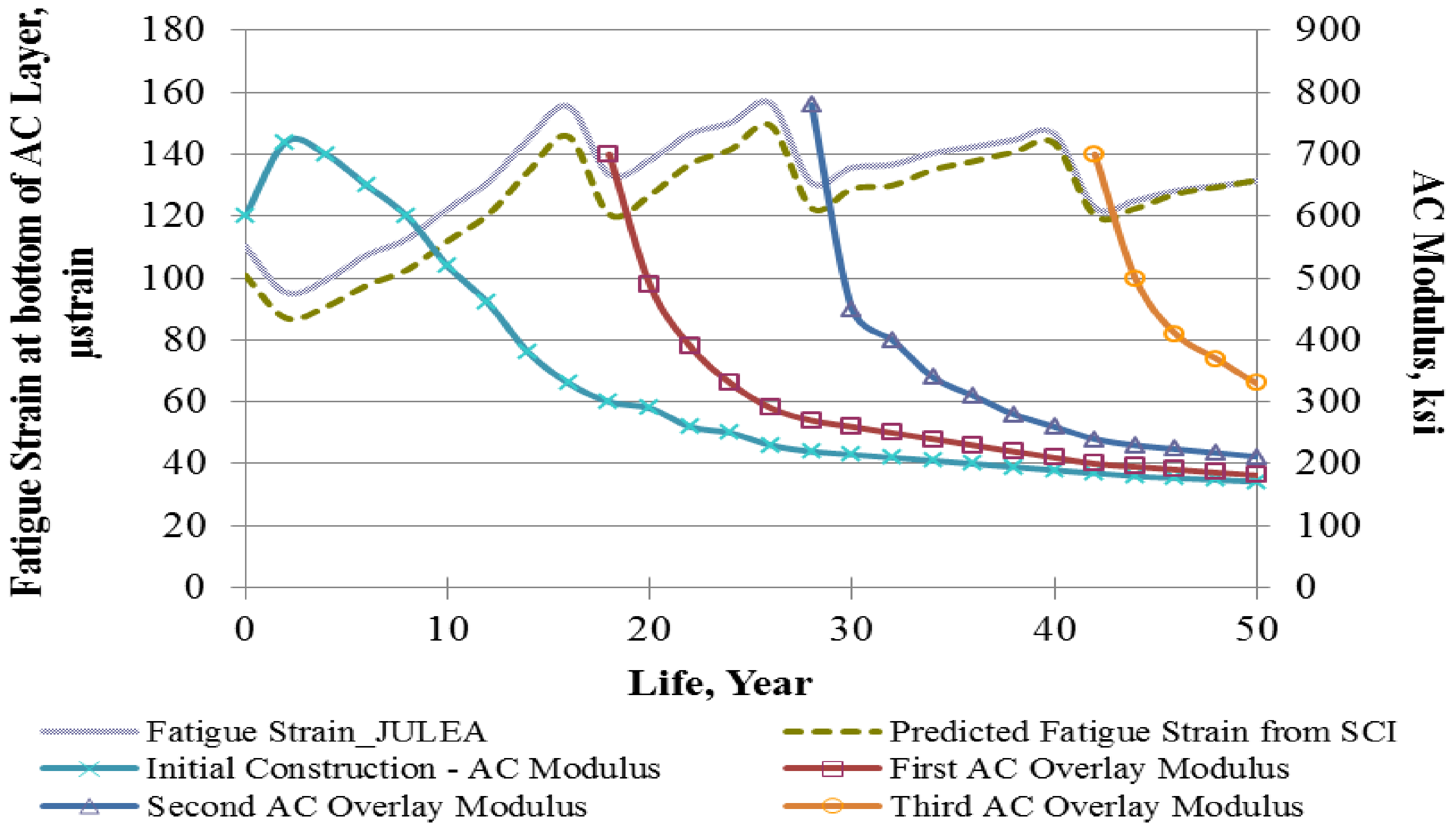
# *Coupled Mechanistic and LCC Analyses*

- Mechanistic analysis tools can
  - Incorporate a range of future treatments
  - Determine structural life extension at a given condition for a selected treatment
  - Account for delayed treatment
- LCC Analysis
  - Compare economic merits of competing design alternatives
- Treatment selection and its performance is a function of the pavement condition at the time of application.

# Optimum Treatment with LCC Analysis

| Overlay Treatment | Cracking ft/sq.ft | Life Extension, year | Total Life, year | Treatment Cost, million USD | Total NPV, million USD | EUAC, million USD |
|---|---|---|---|---|---|---|
| 1.2inch @ 17 year | 0.15 | 10.0 | 27.0 | 1.0 | 7.21 | 0.442 |
| 1.2inch @ 12 year | 0.01 | 17.5 | 29.5 | 1.0 | 7.33 | 0.427 |
| 1.2inch @ 20 year | 0.59 | 2.5 | 22.5 | 1.0 | 7.13 | 0.488 |
| 3.0 inch @ 20 year | 0.59 | 12.0 | 32.0 | 2.5 | 7.84 | 0.439 |

# Evaluation of Sequence of Treatments



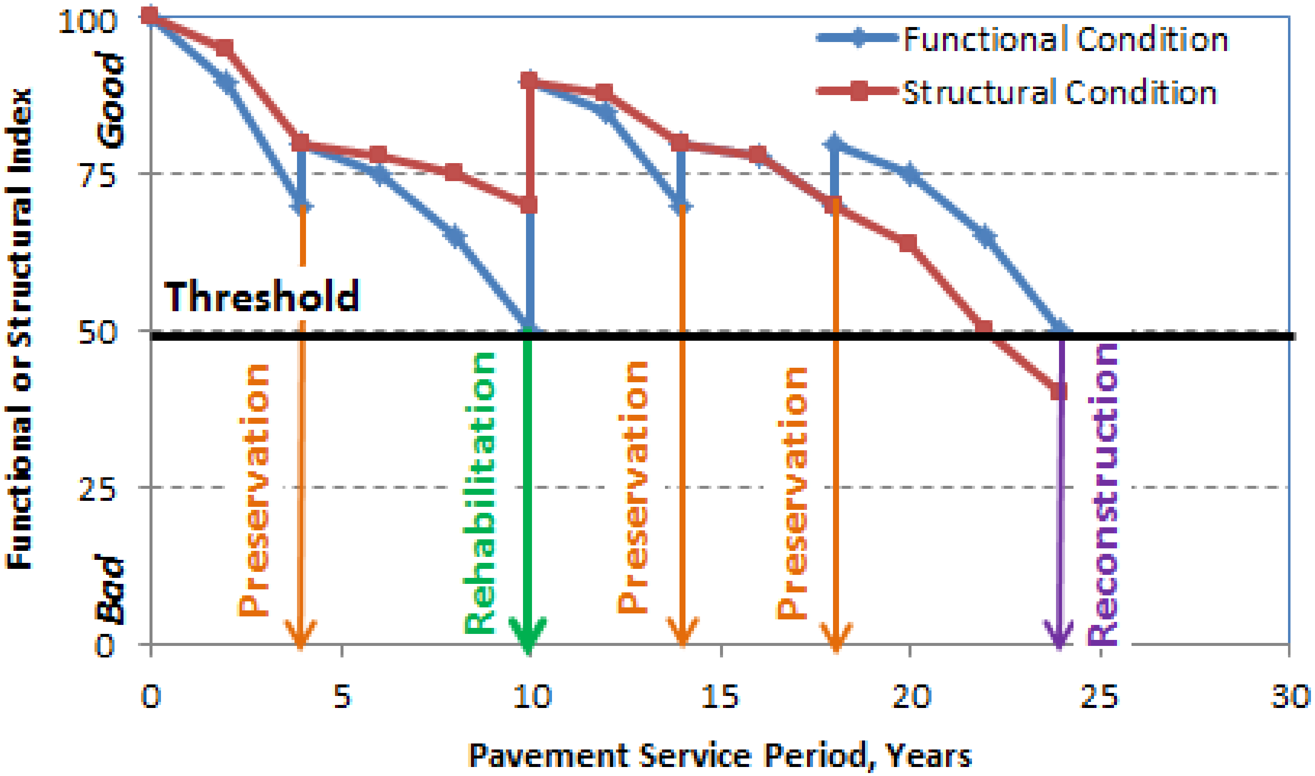

Fatigue strain can be a continuous structural indicator even after successive treatments.

# REMAINING SERVICE INTERVAL

# *Remaining Service Interval (RSI)*

- Remaining Service Life (RSL) is a commonly used measure to report timing of future needs
- Several treatment options are possible and planned
  - Difficult to report using one RSL value
  - RSL value is often misinterpreted
- Remaining Service Interval (RSI), defined as the ***time remaining until a defined construction treatment***

# Results Presented using RSI Terminology - Example



# Results Presented using RSI Terminology

| Pavement Section ID | RSI Preservation, year | RSI Rehabilitation, year | RSI Reconstruction, year |
|---|---|---|---|
| US1 | 4,14,18 | 10 | 24 |
| … | | | |

Companion Presentation - *Pavement Remaining Service Interval: A Logical Replacement to RSL Concept,* N. Sivaneswaran et al.,
Section No. 17 Preservation at 3:30pm

# Summary

- After a new treatment is applied, surface condition measures, such as cracking, becomes inadequate structural indicator of the pavement system as a whole
- Deflection indices derived from TSDD measurements are effective leading indicators of structural performance for in-service pavements and are reasonably well related to fatigue strain.
- Fatigue strains computed from TSDD measurements can be used to compute
  - Remaining structural capacity
  - Track the structural deterioration over time - includes preservation actions that often slow down future deterioration.

# Summary (cont..)

- Periodic TSDD measurements over pavement service life can assess differences in pavement structural performance arising from
  - As-designed versus as-constructed
  - Assumed versus actual traffic, and climatic variations
  - Future treatments can be modified as necessary.
- Coupled mechanistic and LCC analysis can identify the cost effective treatment that will maintain the pavement at or above minimum LOS.
- Use of Remaining Service Interval terminology to report the time until a defined construction treatment can reduce ambiguity.

# Challenges / Issues

- Mechanistic analysis should able to include effect of preservation activities on pavement performance.
- TSDD measurements are sensitive to climatic conditions at time of testing and methods to adjust them to a “standard” condition are critical.

# THANK YOU