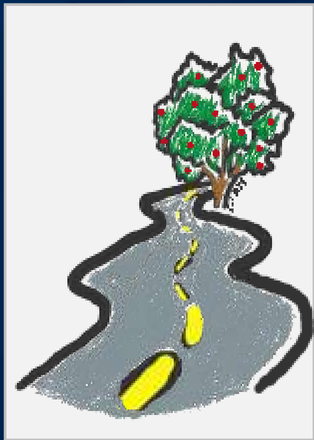
Resilient Pavements & Pavement Performance:

Research Update at WVU

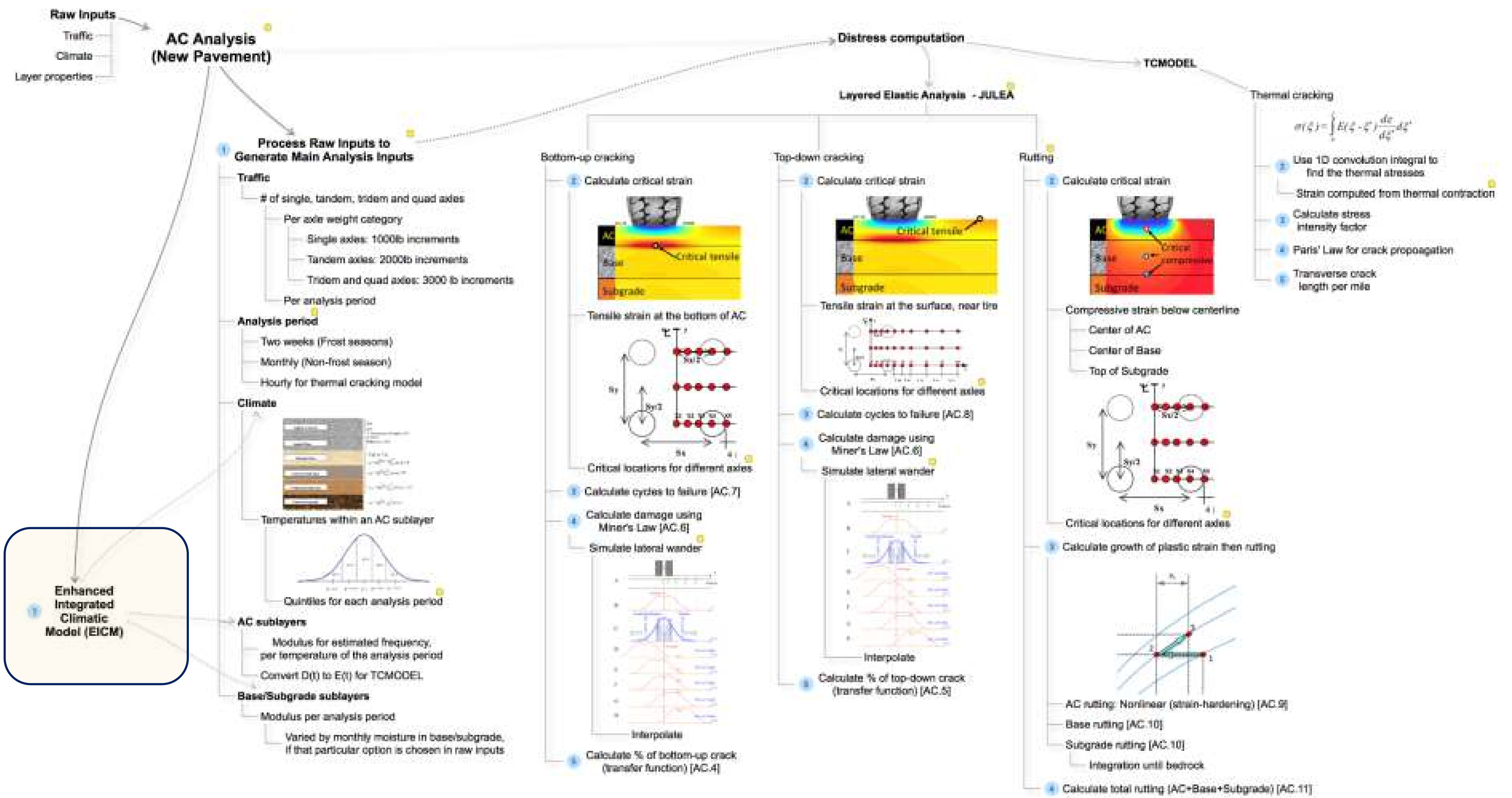
James Bryce
Pat Parsons Faculty Fellow in Asphalt Technology
Assistant Professor, West Virginia University
February 20th, 2024



West Virginia University

Current Students

- **Austin** Jarrell, Expected Graduation (Ph.D.) May 2025
  - Pavement resilience
- Md. Reasad **Samrat**, Began Ph.D. in January
  - Finished MS with Climate Challenge
  - Mix design (BMD), RAP and rejuvenators, Skid
- **Bilal** Al-Oubaidi, Began Ph.D. in January
  - Adaptive pavement performance modeling



Raw Inputs
Traffic
Climate
Layer properties
AC Analysis (New Pavement)
Distress computation
TCMODEL
Layered Elastic Analysis - JULEA
Thermal cracking
Use 1D convolution integral to find the thermal stresses
Strain computed from thermal contraction
Calculate stress intensity factor
Paris' Law for crack propogation
Transverse crack length per mile
Process Raw Inputs to Generate Main Analysis Inputs
Traffic
# of single, tandem, tridem and quad axes
Per axle weight category
Single axles: 1000lb increments
Tandem axles: 2000lb increments
Tridem and quad axles: 3000 lb increments
Per analysis period
Analysis period
Two weeks (Frost seasons)
Monthly (Non-frost season)
Hourly for thermal cracking model
Climate
Temperatures within an AC sublayer
Quintiles for each analysis period
AC sublayers
Modulus for estimated frequency, per temperature of the analysis period
Convert D(t) to E(t) for TCMODEL
Base/Subgrade sublayers
Modulus per analysis period
Varied by monthly moisture in base/subgrade, if that particular option is chosen in raw inputs
Enhanced Integrated Climatic Model (EICM)
Bottom-up cracking
Calculate critical strain
AC
Base
Subgrade
Critical tensile
Tensile strain at the bottom of AC
Critical locations for different axles
Calculate cycles to failure [AC.7]
Calculate damage using Miner's Law [AC.6]
Simulate lateral wander
Interpolate
Calculate % of bottom-up crack (transfer function) [AC.4]
Top-down cracking
Calculate critical strain
Critical tensile
Tensile strain at the surface, near tire
Critical locations for different axles
Calculate cycles to failure [AC.8]
Calculate damage using Miner's Law [AC.6]
Simulate lateral wander
Interpolate
Calculate % of top-down crack (transfer function) [AC.5]
Rutting
Calculate critical strain
Critical compressive
Compressive strain below centerline
Center of AC
Center of Base
Top of Subgrade
Critical locations for different axles
Calculate growth of plastic strain then rutting
AC rutting: Nonlinear (strain-hardening) [AC.9]
Base rutting [AC.10]
Subgrade rutting [AC.10]
Integration until bedrock
Calculate total rutting (AC+Base+Subgrade) [AC.11]

Climate

Stationarity

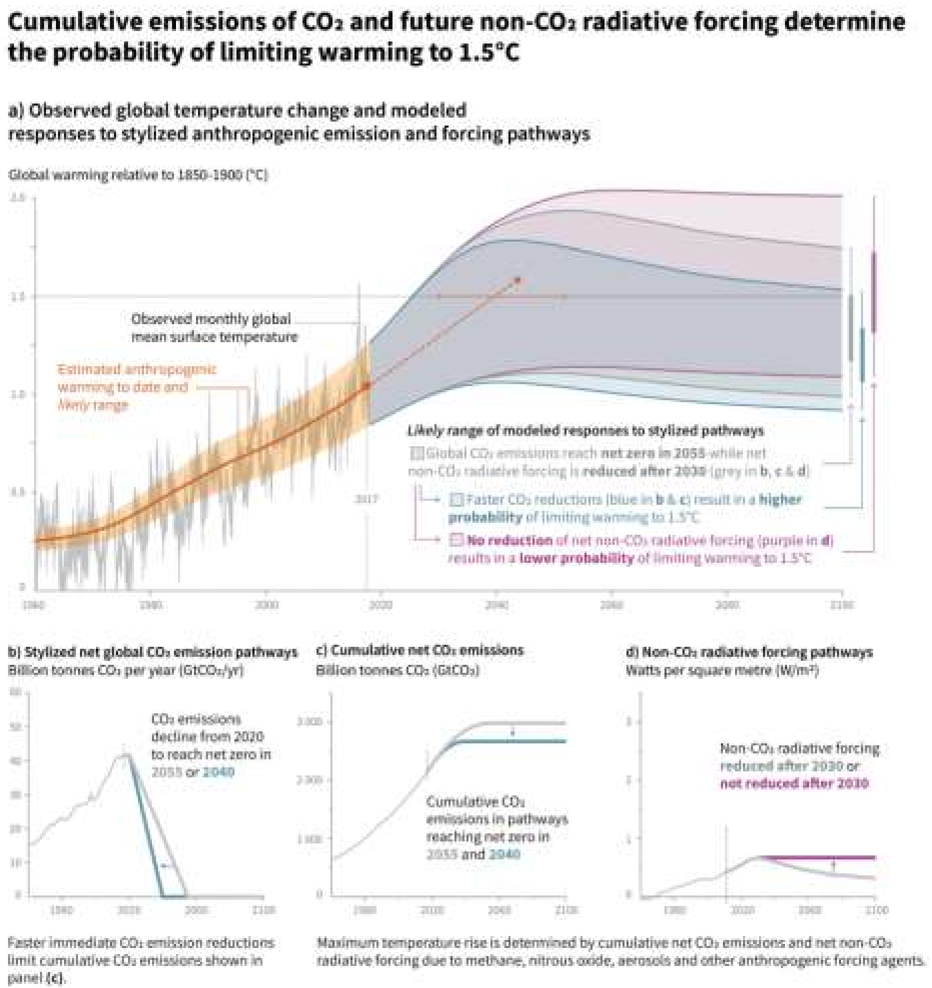
The climate from 1990 **is** representative of the climate in 2040

Non-Stationarity

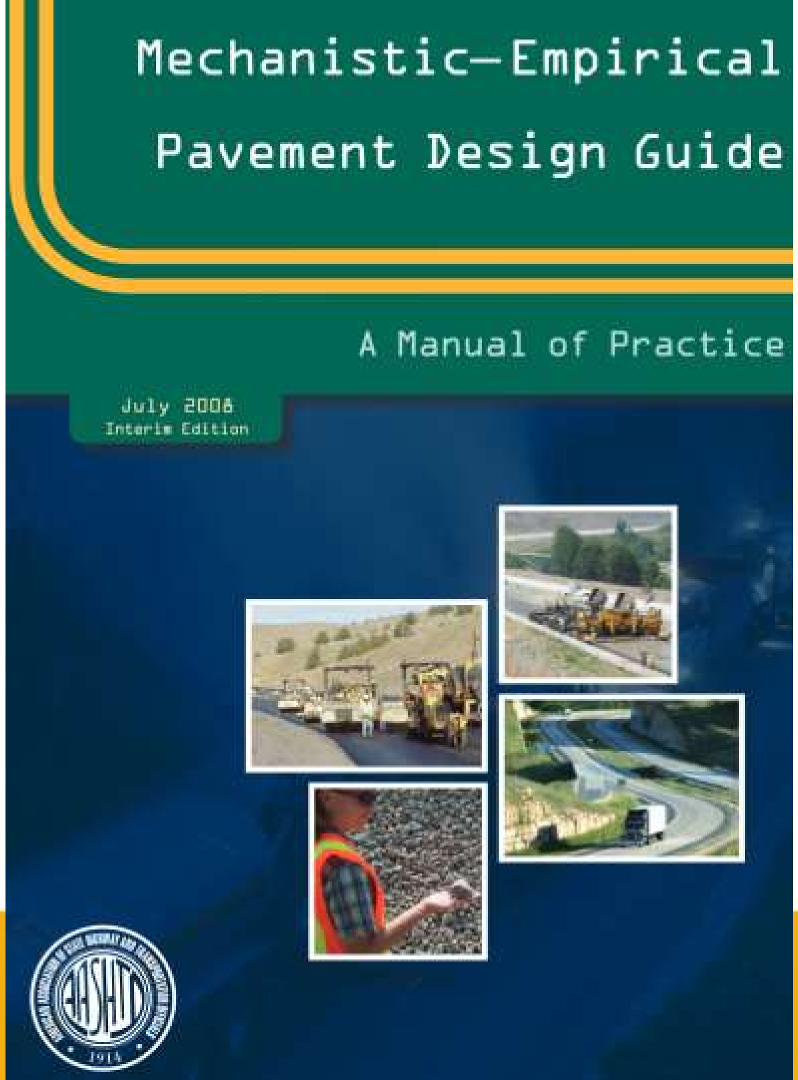
The climate from 1990 **is not** representative of the climate in 2040

West Virginia University

Changing Temperatures: What is effect on models and binder grades?

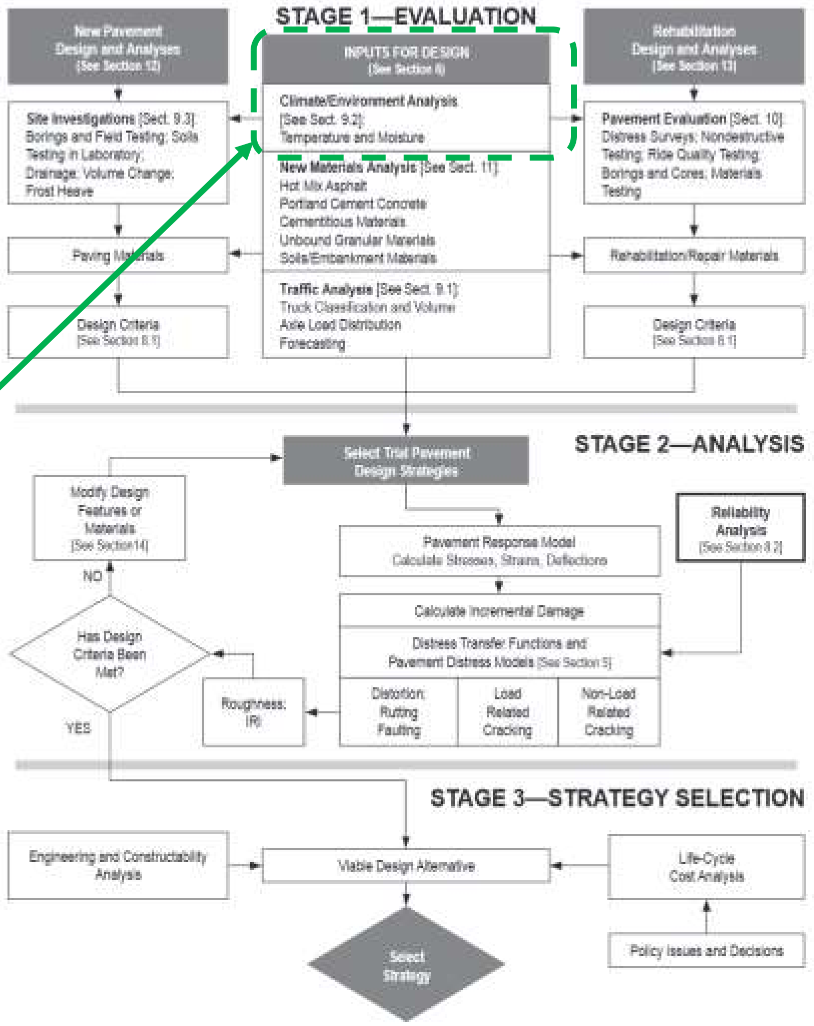


West Virginia University



Enhanced Integrated Climate Model

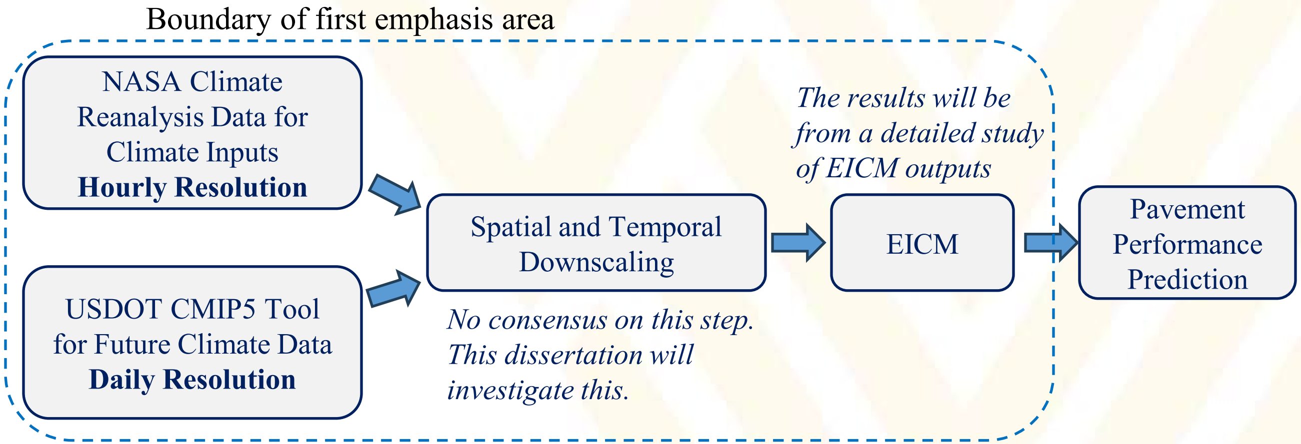
Same model for binder grade selection



gure 1-1. Conceptual Flow Chart of the Three-Stage Design/Analysis Process for the MEPDG

Objective

- Investigate differences between current and future predicted pavement temperatures



- How is binder grade affected?

Temperature Prediction

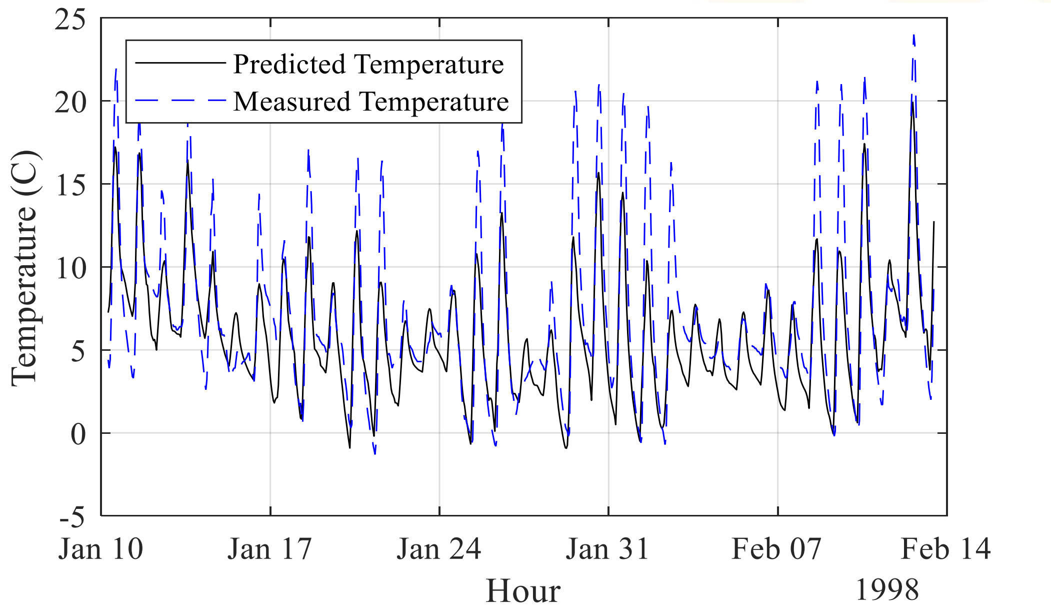
$$\rho C_p \frac{\partial}{\partial t} u(x,t) = \frac{\partial}{\partial x} k \left(\frac{\partial u(x,t)}{\partial x} \right)$$

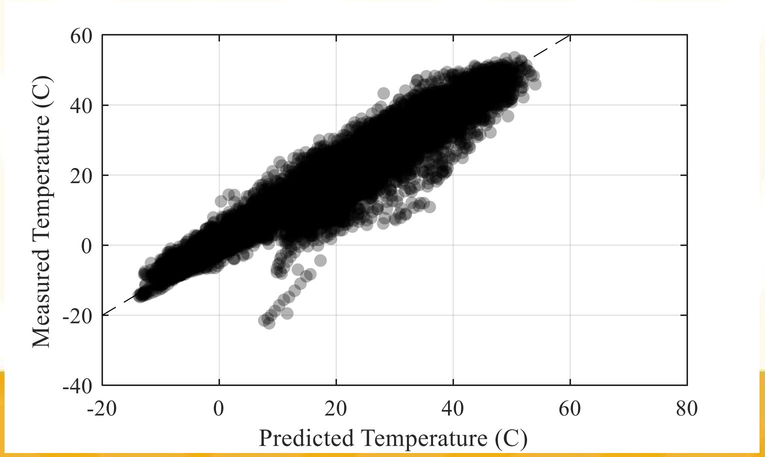
Boundary Conditions

$$u(x,0) = T_i$$

$$-k\left(\frac{\partial u(0,t)}{\partial x}\right) = Q_s - Q_c - Q_R$$

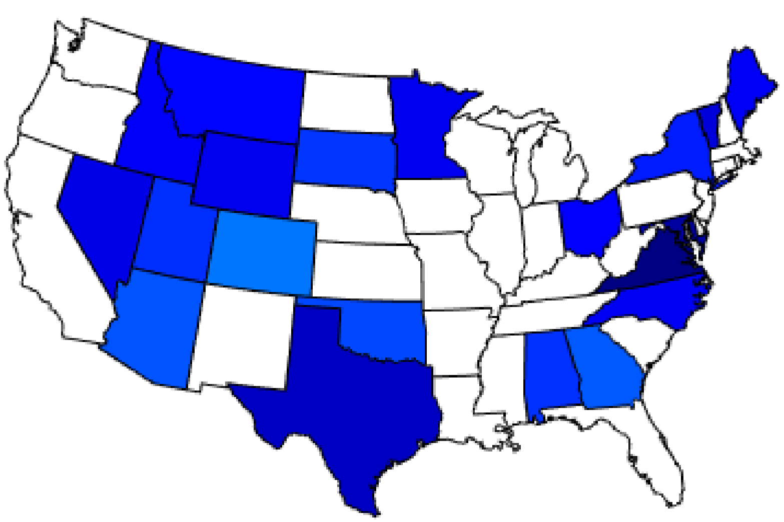
$$u(L,t) = T_c$$



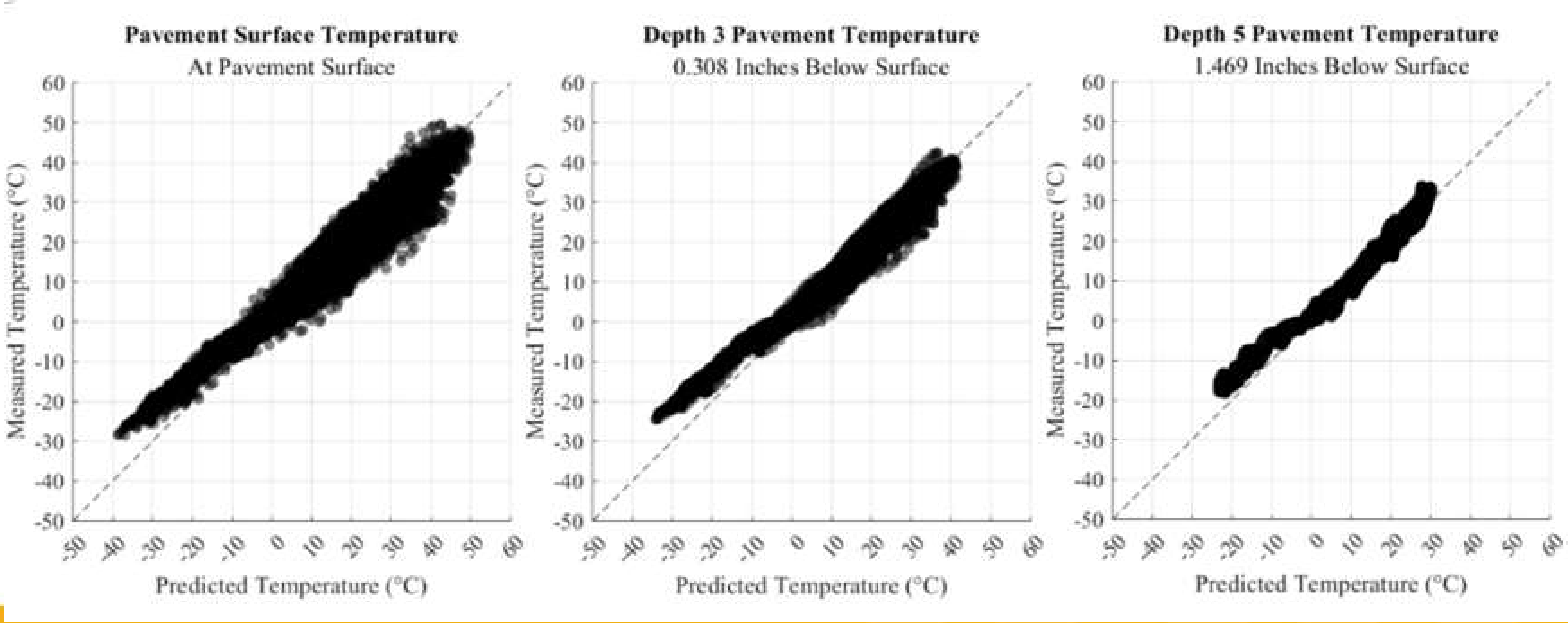


Data

- Climate: MERRA-2 (NASA)
- Measured Temperature (LTPP)
- Pavement Layers (LTPP)
- Future Climate: CMIP 5 (World Climate Research Programme)



Pavement Temperatures

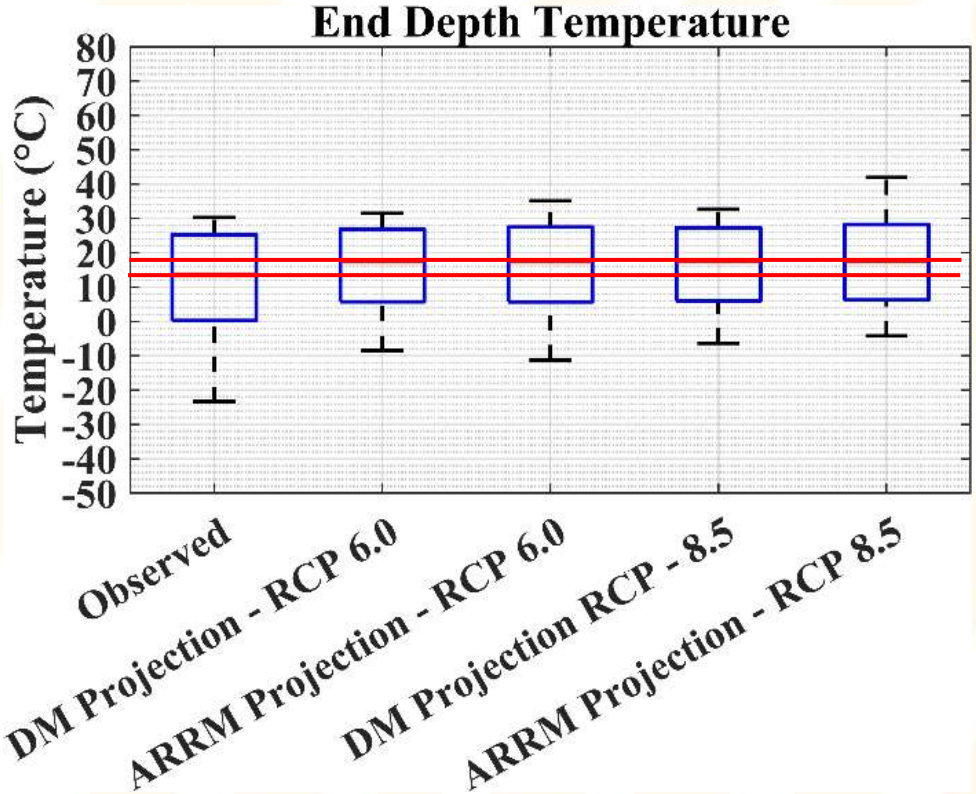


West Virginia University

Analysis Site	Observed	ARRM RCP 6.0	ARRM RCP 8.5
Alabama	PG 70-22	PG 76-28	PG 82-22
Arizona	PG 76-22	PG 76-16	PG 82-16
Colorado	PG 70-40	PG 70-34	PG 76-34
Georgia	PG 70-22	PG 76-28	PG 82-22
Idaho	PG 70-40*	PG 70-34	PG 70-28
Maine	PG 64-40*	PG 70-40*	PG 70-40
Maryland	PG 58-34	PG 64-22	PG 64-28
Minnesota	PG 64-40*	PG 70-40*	PG 70-40
Montana	PG 64-34	PG 70-40	PG 70-28
Nevada	PG 70-28	PG 76-28	PG 76-28
New York	PG 58-28	PG 58-22	PG 64-22
North Carolina	PG 64-34	PG 64-22	PG 70-22
Ohio	PG 64-40	PG 70-34	PG 76-28
Oklahoma	PG 70-34	PG 76-34	PG 76-28
South Dakota	PG 70-40*	PG 70-34	PG 76-34
Texas	PG 70-16	PG 70-10	PG 70-10
Utah	PG 70-34	PG 70-28	PG 76-28
Vermont	PG 64-40	PG 70-34	PG 70-34
Virginia	PG 70-28	PG 76-28	PG 76-28
Wyoming	PG 70-40	PG 70-34	PG 76-40

Findings

- Future climate necessitates change in binder grade
- Changes in temperature are statistically significant
- At all depths

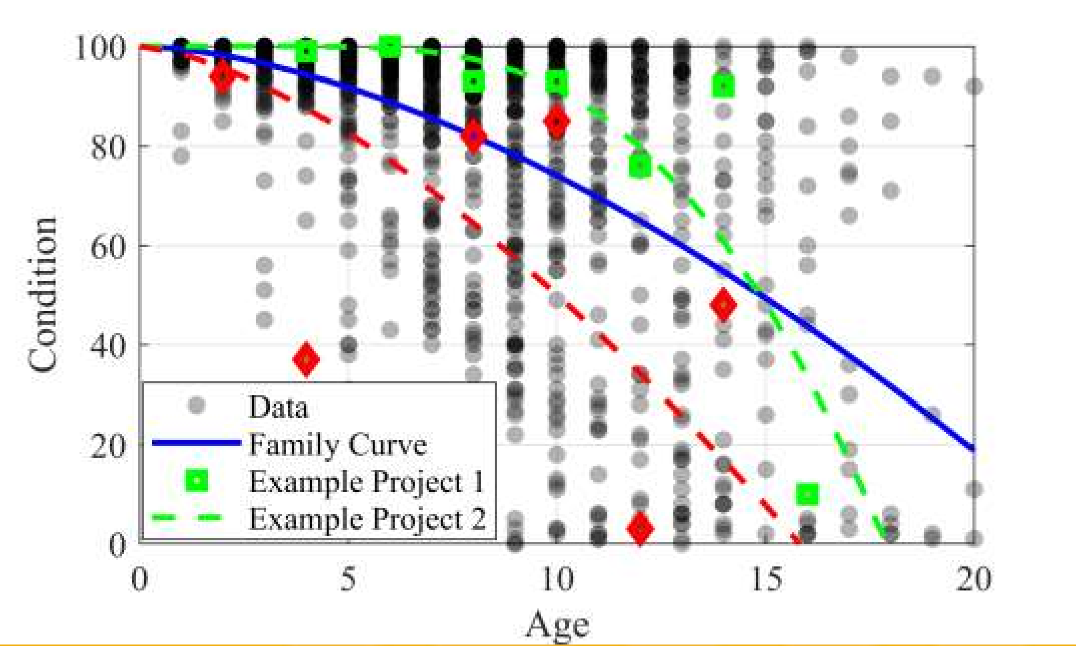


Adaptive Pavement Performance Models

West Virginia University

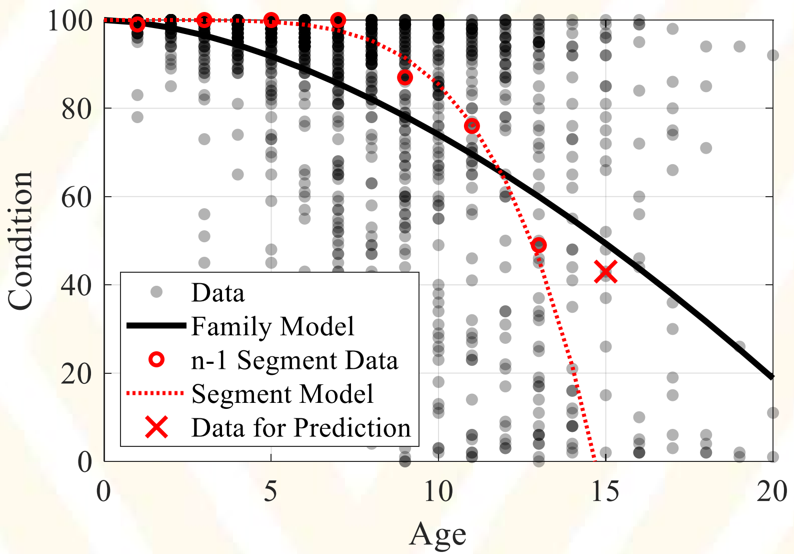
Objective

- **Adapt family performance models, weighed by project specific condition data, towards project section specific performance curve**
- **(let the pavement section speak for itself)**



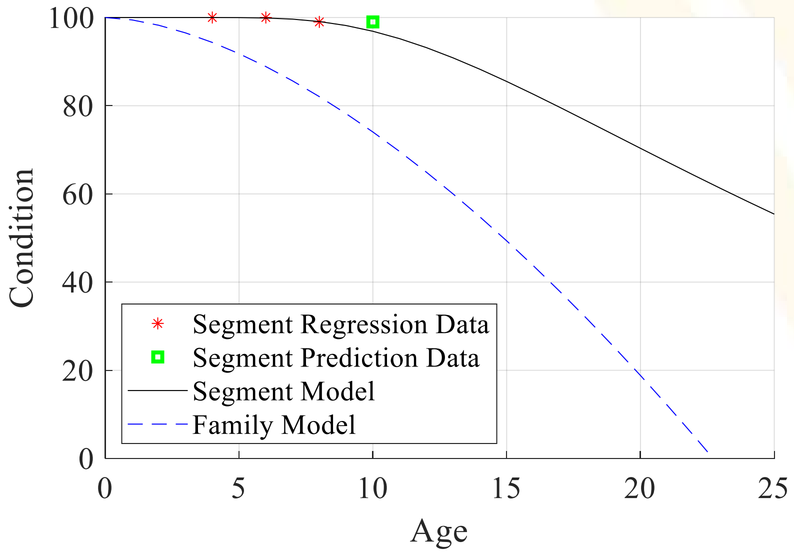
Assessment of Segment Models

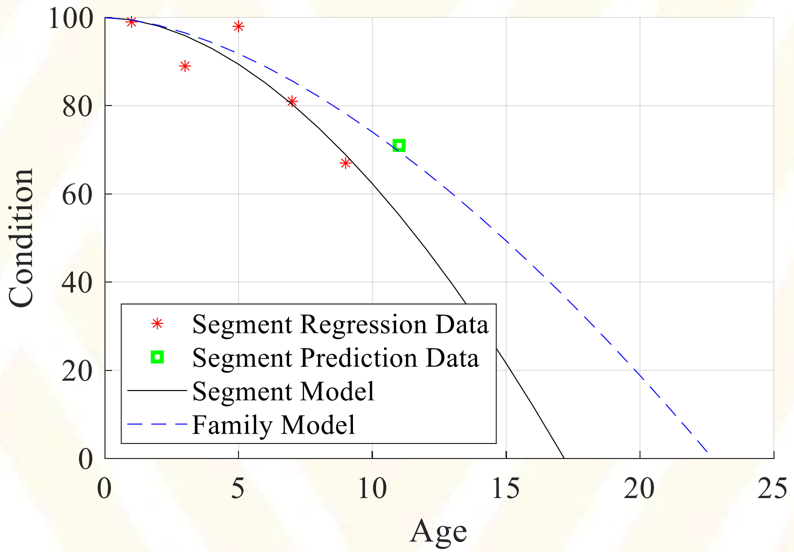
- Identified segments with at least four (n≥4) condition measurements
- Fit segment model to n-1 data assuming gamma distribution for segment data
- Used last condition measurement to compare with family model prediction
- If too few data are available for a segment, compare last condition measurement to family prediction



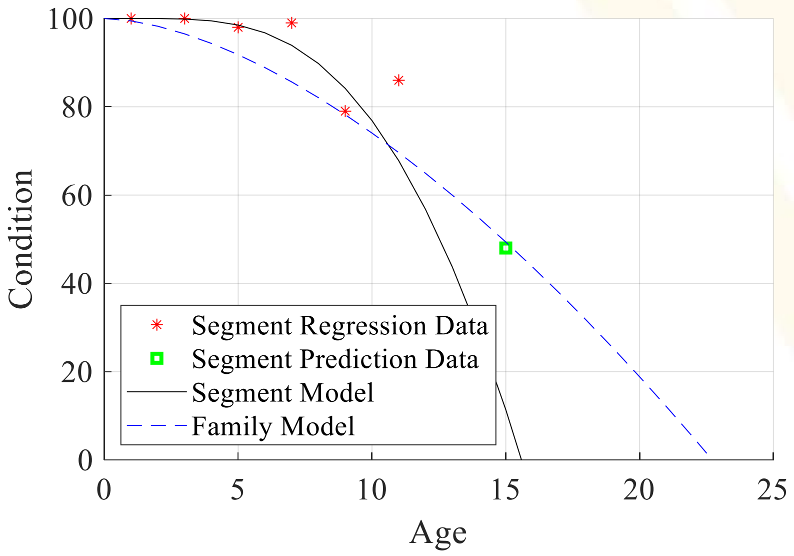
West Virginia University

Examples

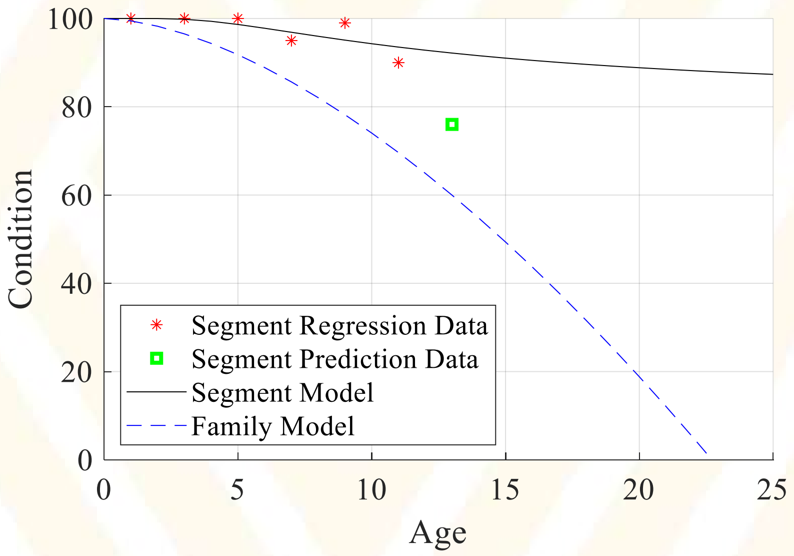

100
80
60
40
20
0
Condition
0
5
10
15
20
25
Age
Segment Regression Data
Segment Prediction Data
Segment Model
Family Model


100
80
60
40
20
0
Condition
0
5
10
15
20
25
Age
Segment Regression Data
Segment Prediction Data
Segment Model
Family Model

Examples

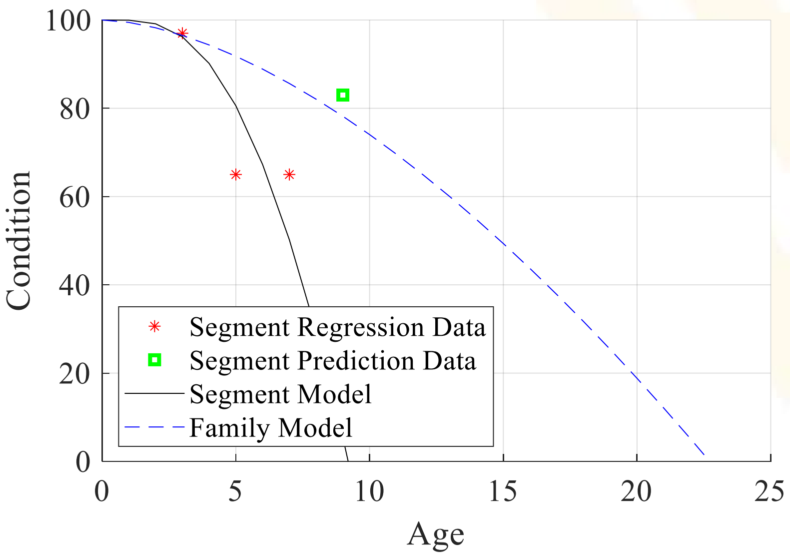


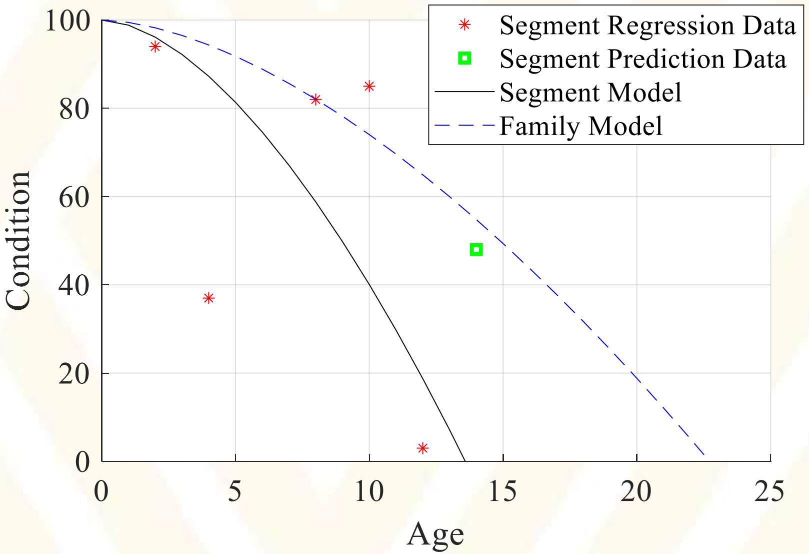
Condition
Age
Segment Regression Data
Segment Prediction Data
Segment Model
Family Model



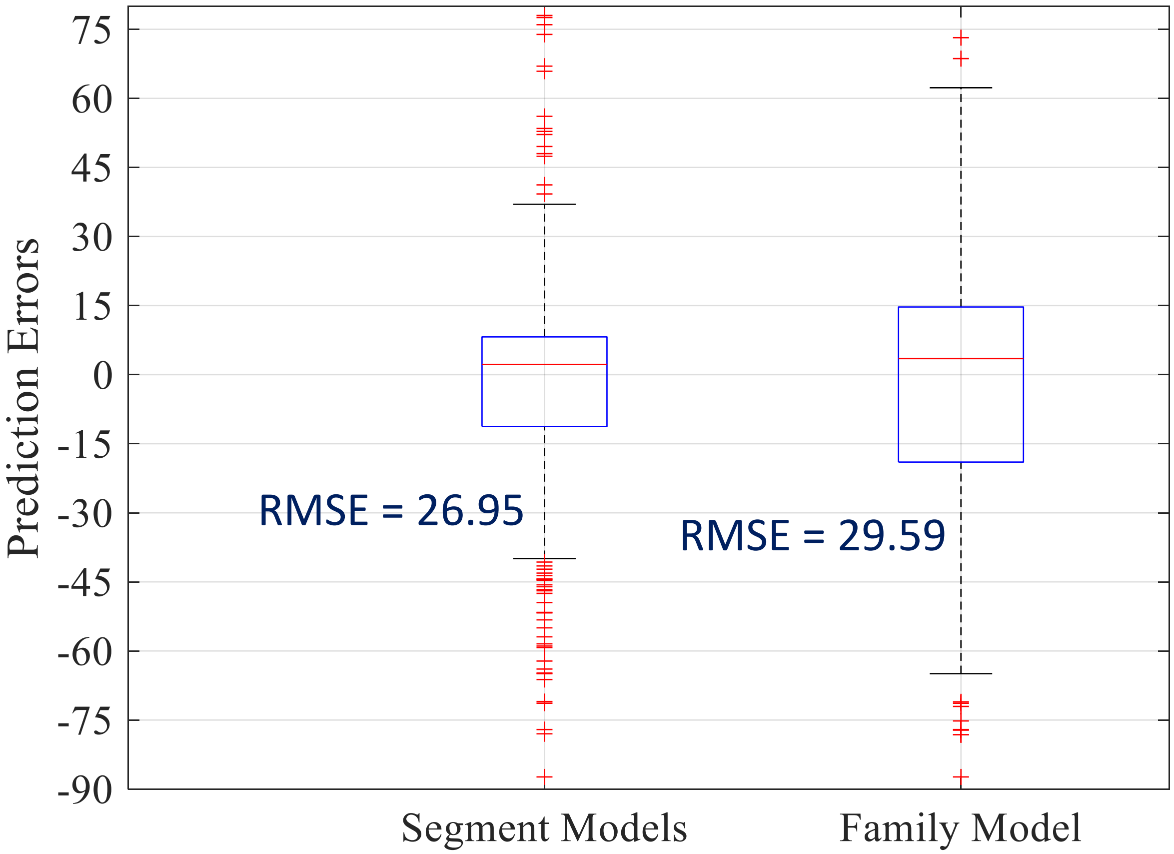
Condition
Age
Segment Regression Data
Segment Prediction Data
Segment Model
Family Model

Examples

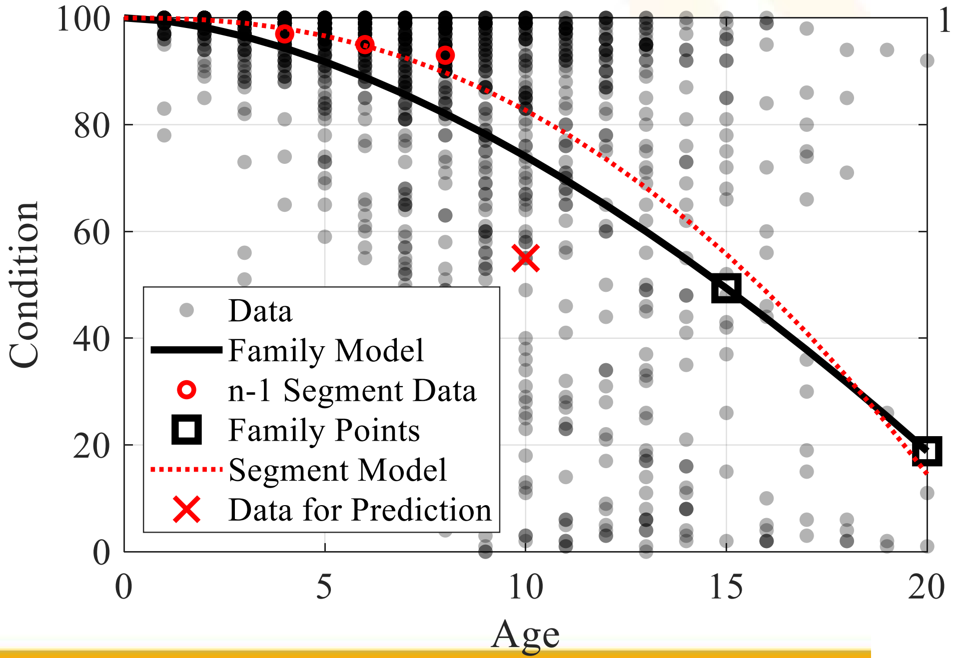

100
80
60
40
20
0
Condition
0
5
10
15
20
25
Age
Segment Regression Data
Segment Prediction Data
Segment Model
Family Model

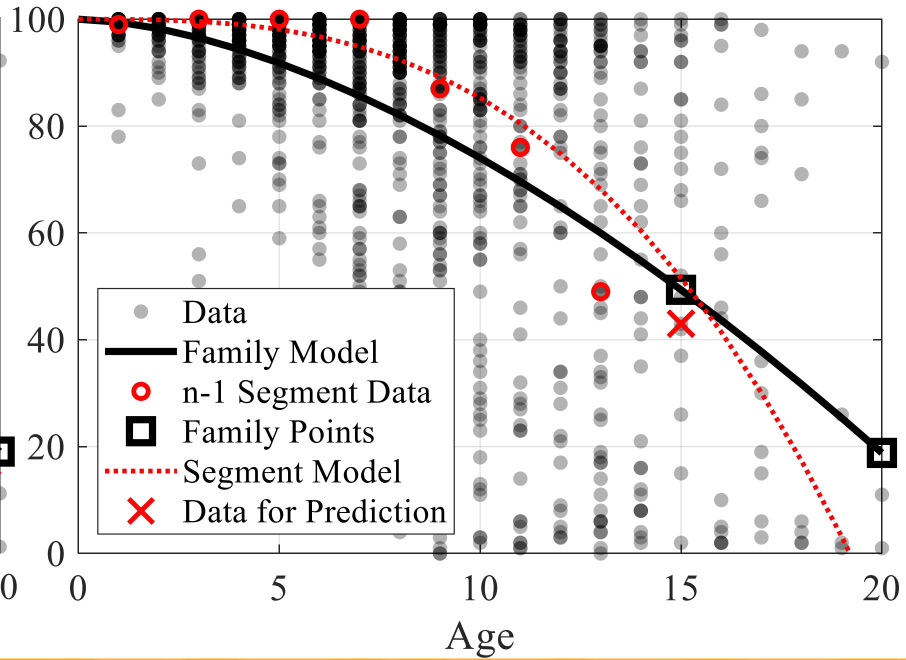

100
80
60
40
20
0
Condition
0
5
10
15
20
25
Age
Segment Regression Data
Segment Prediction Data
Segment Model
Family Model

Is it better to use segment model?



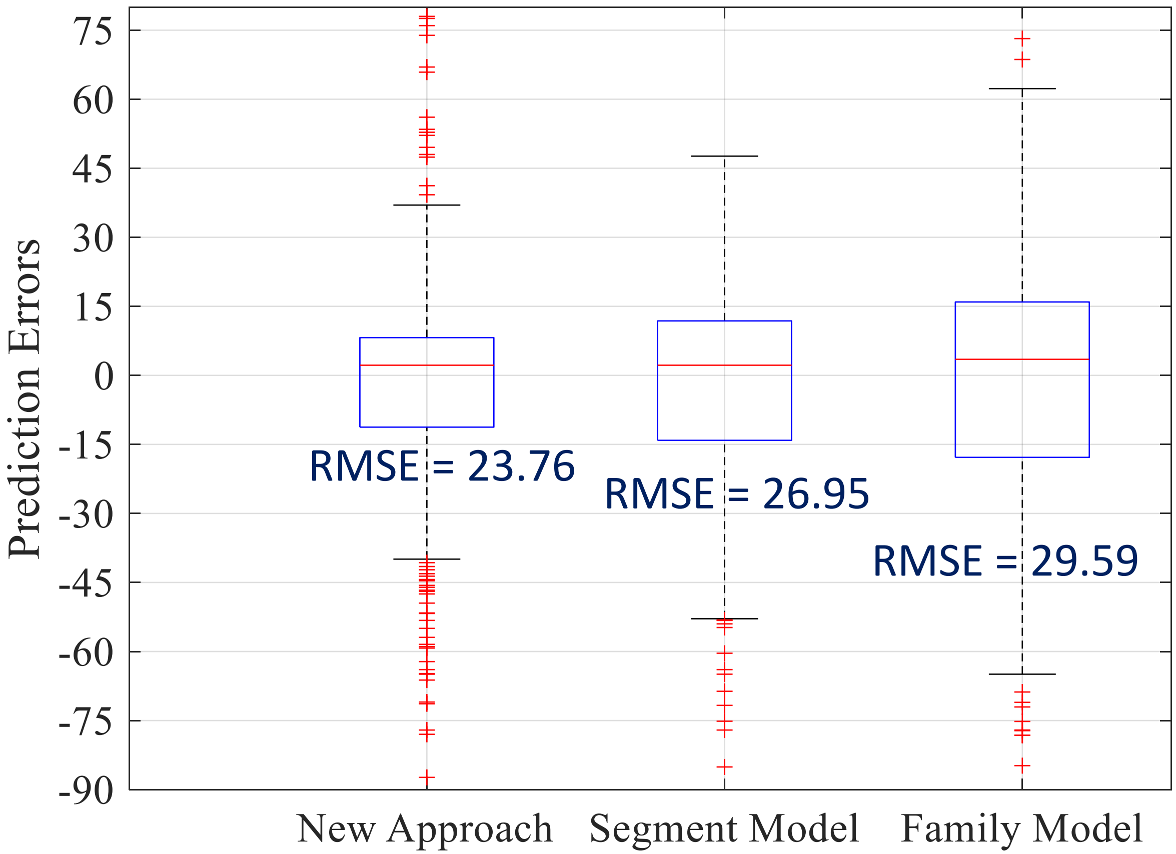
Is there a better way?





Better?

Are there better approaches?



Wrap Up

Conclusions / Future Work

- Climate non-stationarity is best assumption for pavements
- More accurate performance models can be developed
- Upcoming:
  - skid resistance in surface mixes
  - AI in pavement management
  - optimization and tradeoff analysis in asset management

Questions and Discussion?

James Bryce, Ph.D.
Pat Parsons Faculty Fellow in Asphalt Technology
Wadsworth Department of Civil and Environmental Engineering
West Virginia University
James.Bryce@wvu.edu

WestVirginiaUniversity