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Pavement Remaining Service Life for National Policy Analysis

National Pavement Management Conference
Norfolk, Virginia
May 6-9, 2007

Maks Alam

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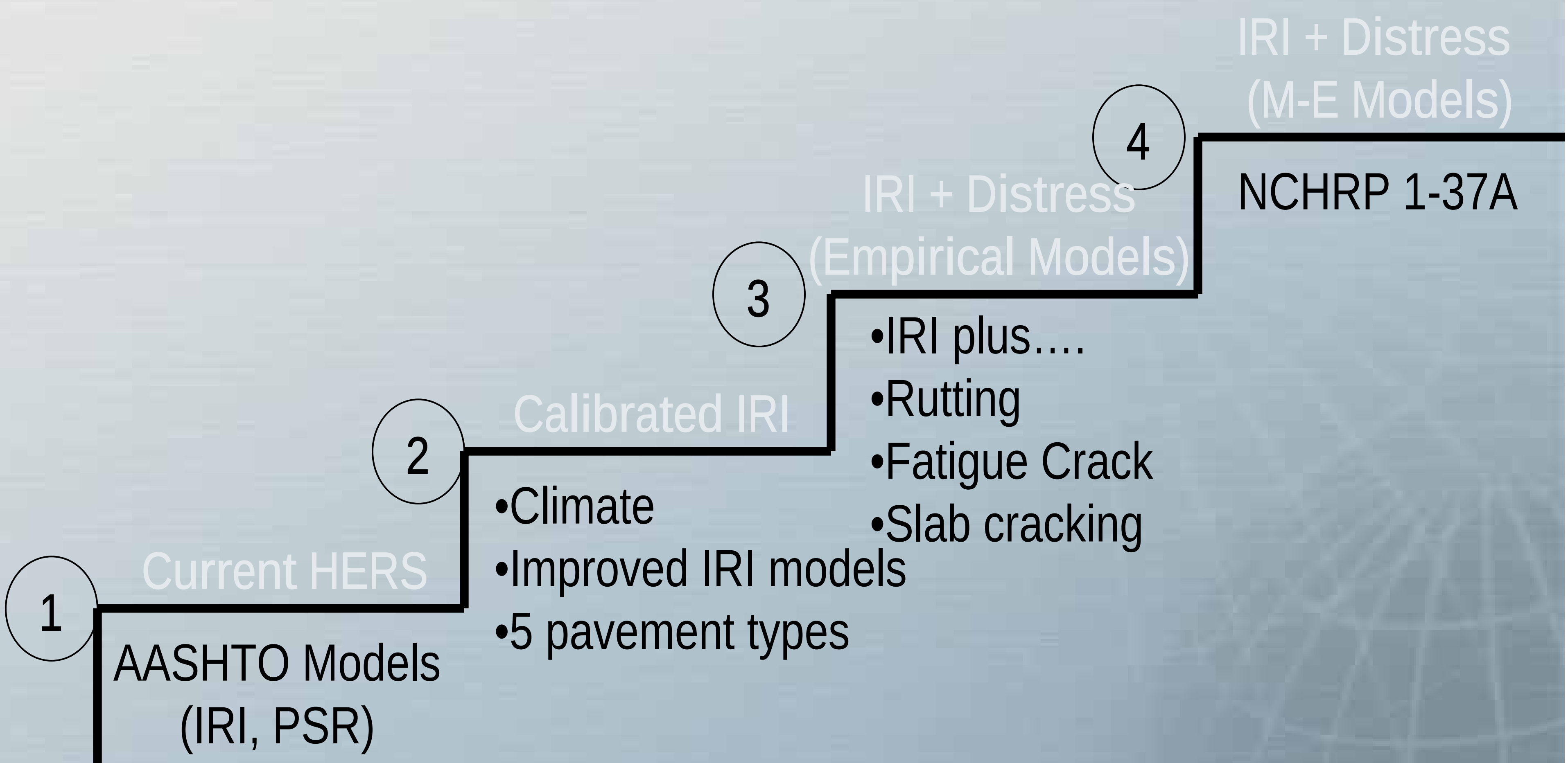
Project Goals

- Improved pavement performance models for HERS and NAPCOM
  - Improved models can be used to quantify pavement remaining service life
  - Remaining life will be estimated based on terminal values of distress/IRI as determined by FHWA for each pavement type, functional class, etc.
- Recommend HPMS (supporting database) + additional data requirements to be included in HPMS reassessment.

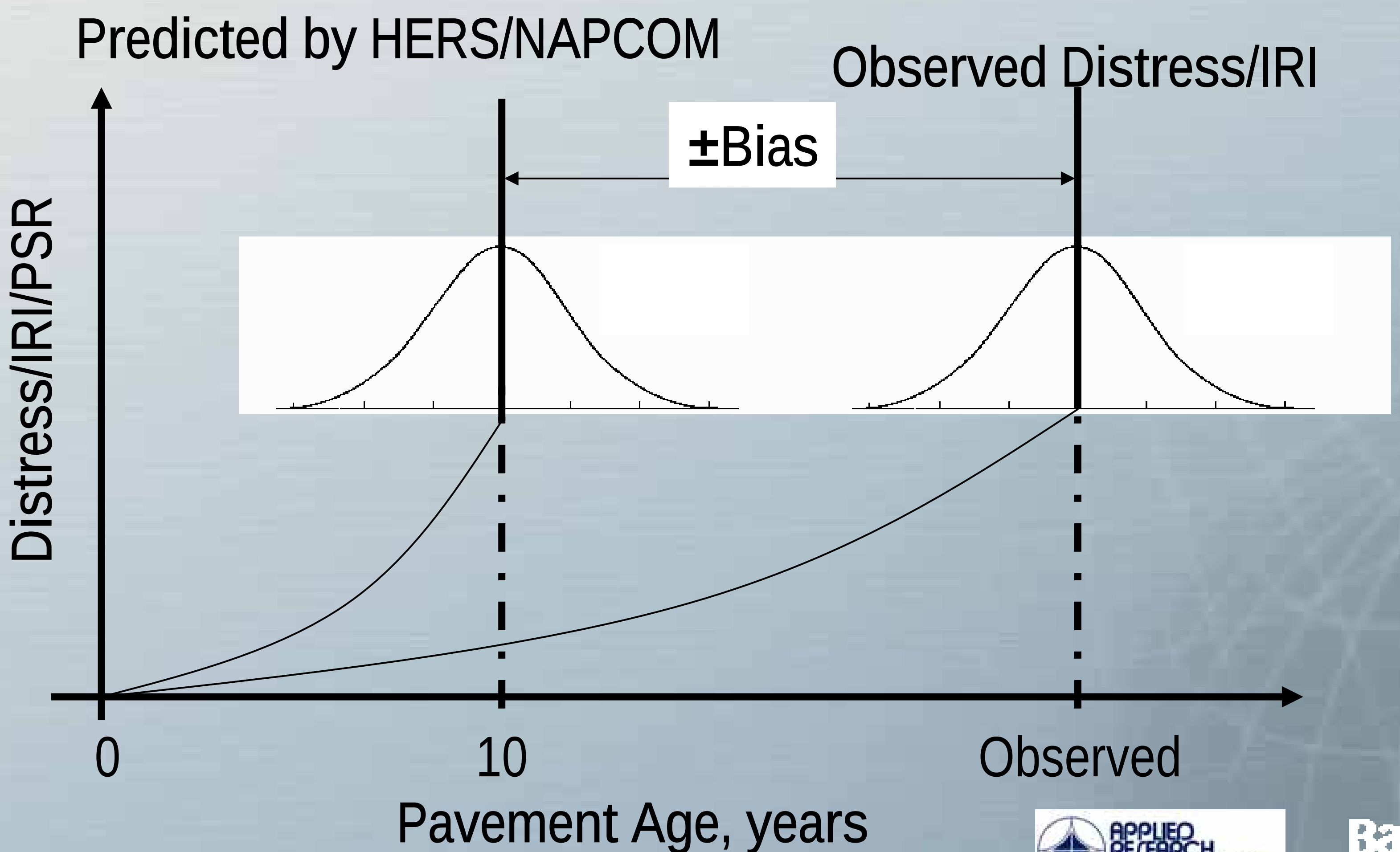
Project Goals (Continued)

Performance Models & Algorithms



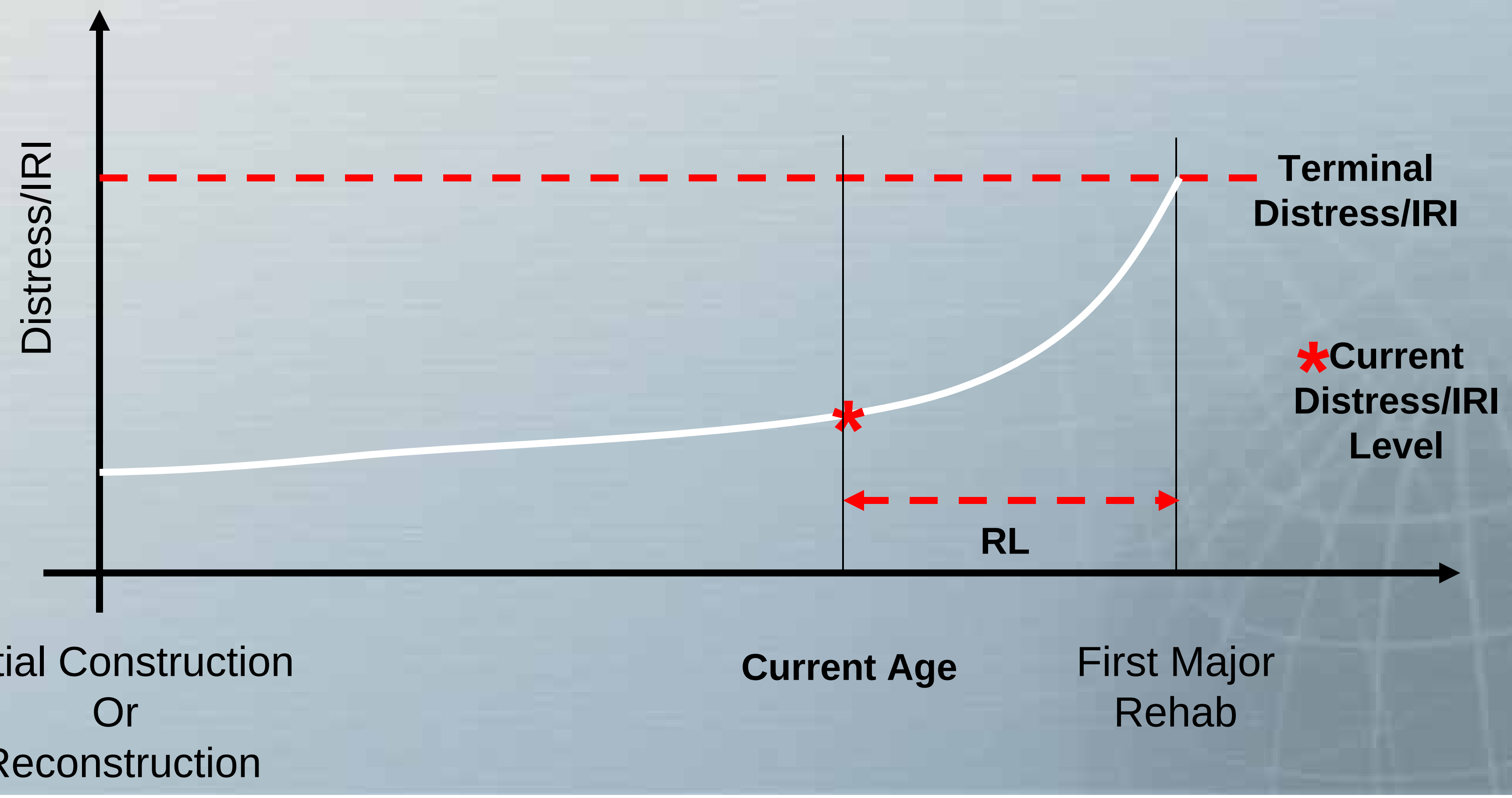
Project Goals (Continued)

- Improved pavement performance prediction



Remaining Service Life

- Defined for this project as the time in age or traffic applications from initial construction or reconstruction to first major rehabilitation



Status to Date

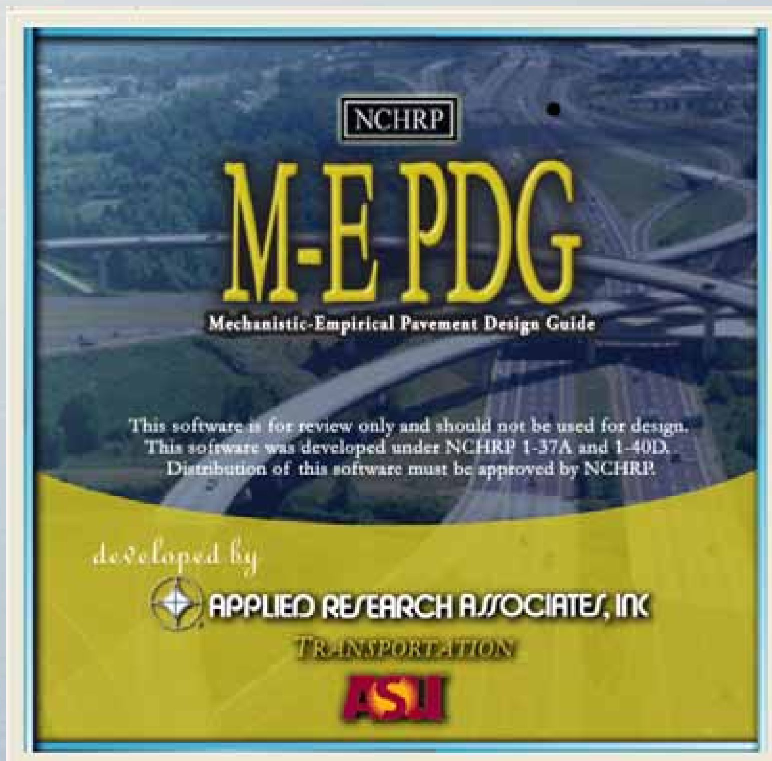
- White Papers, Technical Memos, & Steering Committee Meetings
  - (1) Pavement Performance Model Needs for Highway Policy Analysis and Cost Allocation (HERS & HCAS)
  - (2) Development of Procedures and Criteria for Evaluating Pavement Asset Management Systems for Use in HERS
  - (3) Survey Report on the Evaluation of State Highway Agencies Pavement Management Systems
  - (4) April 2005: Nation-wide Pavement Steering Committee Meeting

Status to Date (Continued)

- White Papers, Technical Memos, & Steering Committee Meetings
  - (5) Implementing the NCHRP Project 1-37A Pavement Models into Highway Policy Analysis
  - (6) Integrating the MEPDG with HERS & NAPCOM
  - (7) March 2006: Nation-wide Pavement Steering Committee Meeting
  - (8) HPMS Key Inputs with a Moderate to High Influence on MEPDG Predicted Distress/IRI
  - (9) Predicting Future Rigid and Flexible Pavement Performance for Highway Policy Analysis

Recommendation……

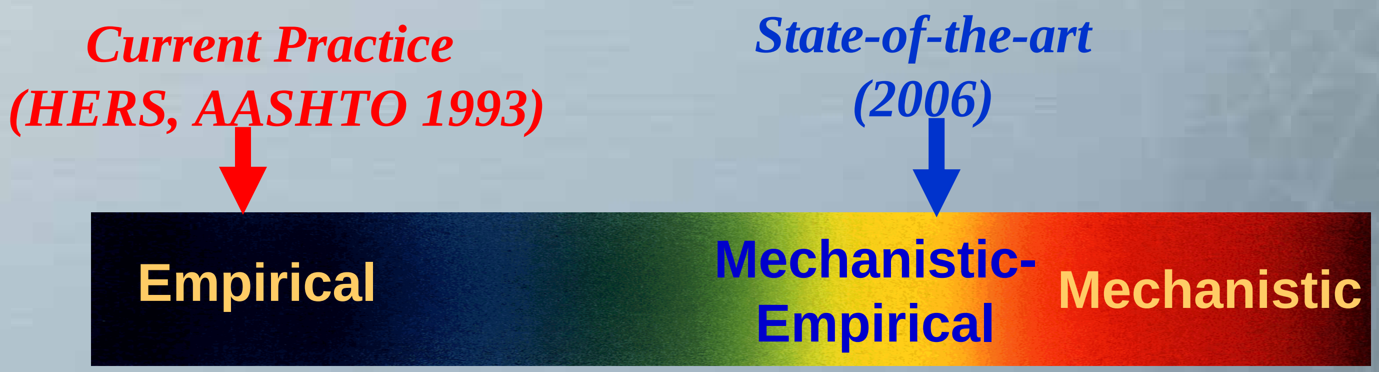
Adapt newly developed ME-PDG mechanistic-empirical pavement prediction models for use in HERS and NAPCOM



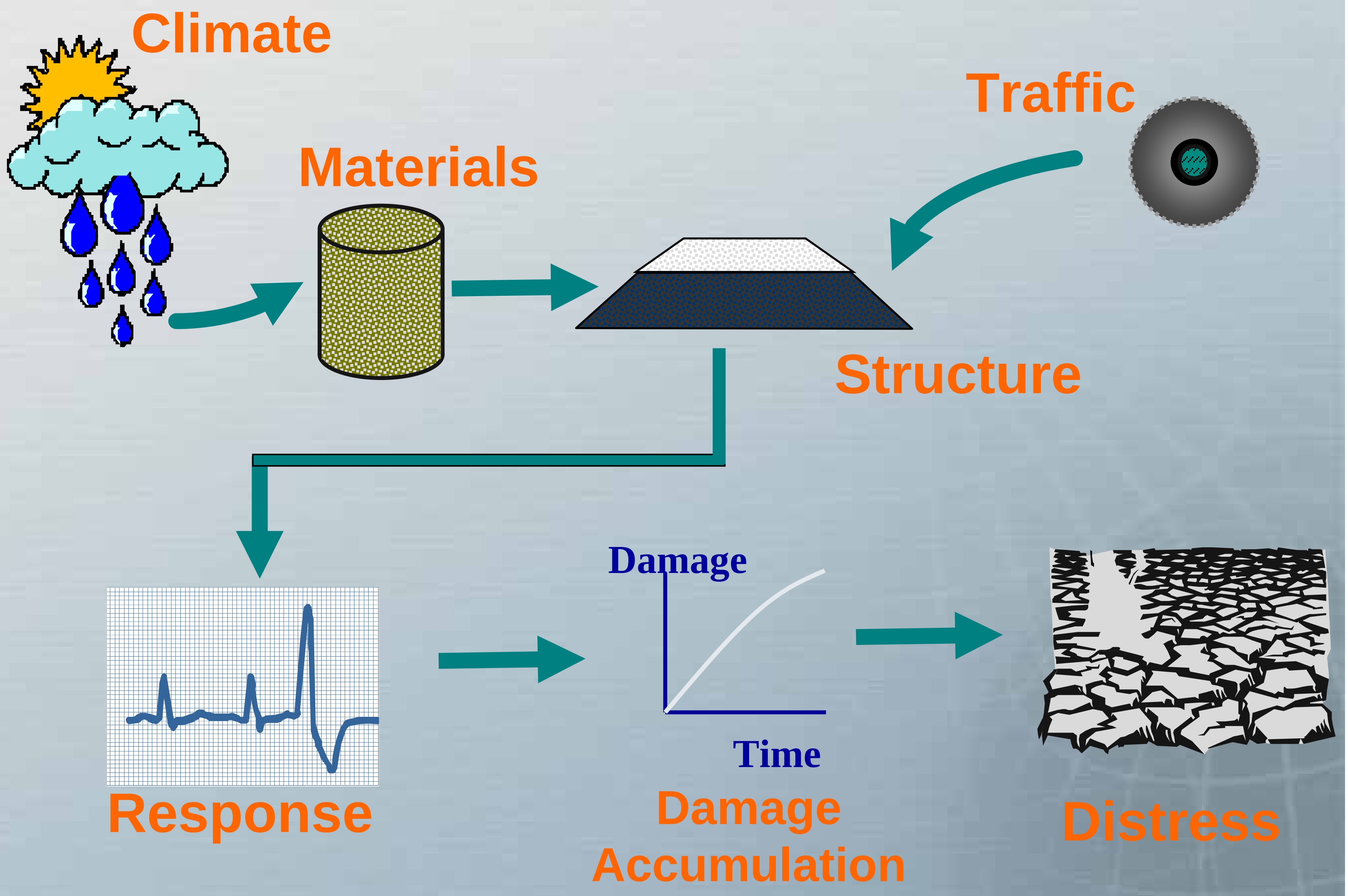
Developed under:
NCHRP Project 1-37A
NCHRP Project 1-40A
NCHRP Project 1-40B
NCHRP Project 1-40D

ME-PDG

- *Mechanistically* calculate pavement response (i.e., stresses, strains, and deflections) due to:
  - Traffic loading
  - Environmental conditions
- Accumulate *damage* over time
- *Empirically* relate damage over time to pavement distresses (e.g., cracking, rutting, faulting)
- *Calibrate* predictions to observed field performance



ME-PDG


Climate
Materials
Traffic
Structure
Damage
Time
Response
Damage Accumulation
Distress

ME-PDG Models Data Inputs

- Depending upon the choice of hierarchical approach of data input – may significantly increase the data collection burden to HPMS.
- M-E PDG offers wealth of default values that can significantly minimize the data collection burden to HPMS

ME-PDG Models Input Data Sensitivity on Prediction

- Sensitivity analysis
  - Determine ME-PDG inputs critical for predicting future pavement performance
  - Determine additional inputs required for HPMS
  - Desired data required for modified ME-PDG models provided to HPMS reassessment team

HPMS Data Items (Reassessment)

Desired Sensitive MEPDG Inputs	Availability in HPMS after Reassessment	Impact on MEPDG Predicted Distress/Smoothness
Pavement type	Yes	High
Original construction date	Yes	High
Latest major rehabilitation date	Yes	High
Existing asphalt layers thickness (incl. past overlays	Yes	High
Latest asphalt overlay thickness	Yes	High
HMA binder type	Yes	Moderate
HMA gradation	No (State defaults)	Moderate
Base type	Yes	Moderate to High
Base thickness	Yes	Moderate to High
Subgrade type	Yes	Moderate

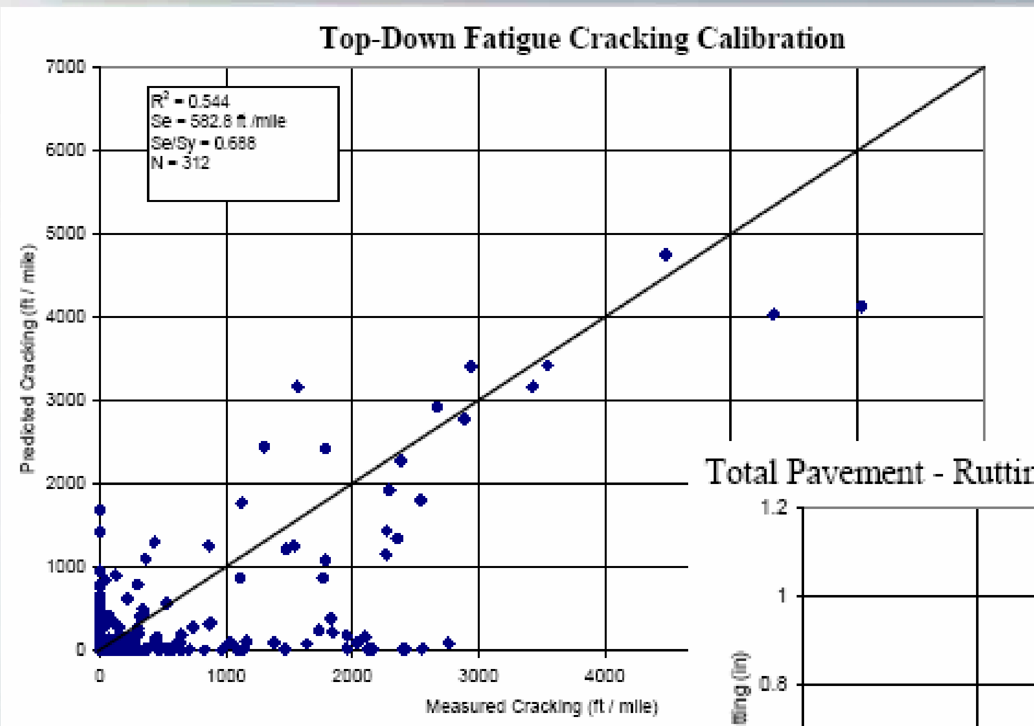
HPMS Data Items (Reassessment)

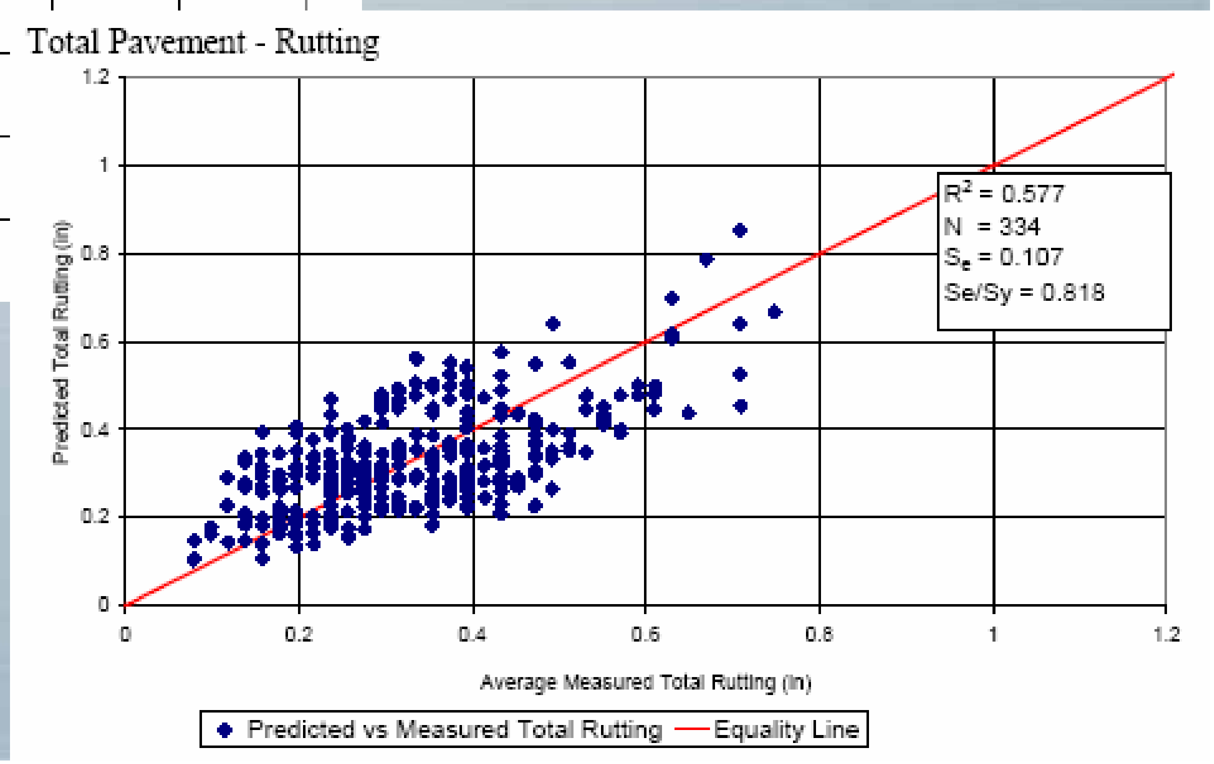
Desired Sensitive MEPDG Inputs	Availability in HPMS after Reassessment	Impact on MEPDG Predicted Distress/Smoothness
PCC permanent curl/warp	No	High
PCC strength	Yes (default)	High
JPCP joint spacing	Yes	High
JPCP dowels?	Yes	High
PCC thickness	Yes	High
PCC CTE	No	High
Shoulder type and lane width	Yes	High
Climate	Yes	High
Truck vol. & composition	Yes	High
Initial and current IRI	Yes	High
Faulting, cracking, rutting, etc.	Yes	-----

Process of Developing New Simplified Performance Prediction Models for HERS

- ME-PDG includes very complex mechanistic based models that predicts pavement performance
- Distress/IRI models were calibrated with hundreds of actual pavement sections across North America (LTPP, MnROAD, AASHO, etc.)
- Simplified empirical models of key distress were derived based on outputs from the MEPDG
- These models are sufficiently accurate to meet the needs of HERS

Examples of Plots of Predicted vs. Measured Distresses for ME-PDG Models





Process of Developing New Simplified Performance Prediction Models for HERS

- Assemble matrix of pavement site/design properties etc., that represent HPMS conditions
- Populate the matrix with selected LTPP representative sections (over 200 sections identified)
- Develop M-E PDG input data for selected sections
- Run ME-PDG and create database ME-PDG inputs and predicted performance
- Develop empirical distress prediction models

LTPP Sections Used for JPCP Performance Models Development

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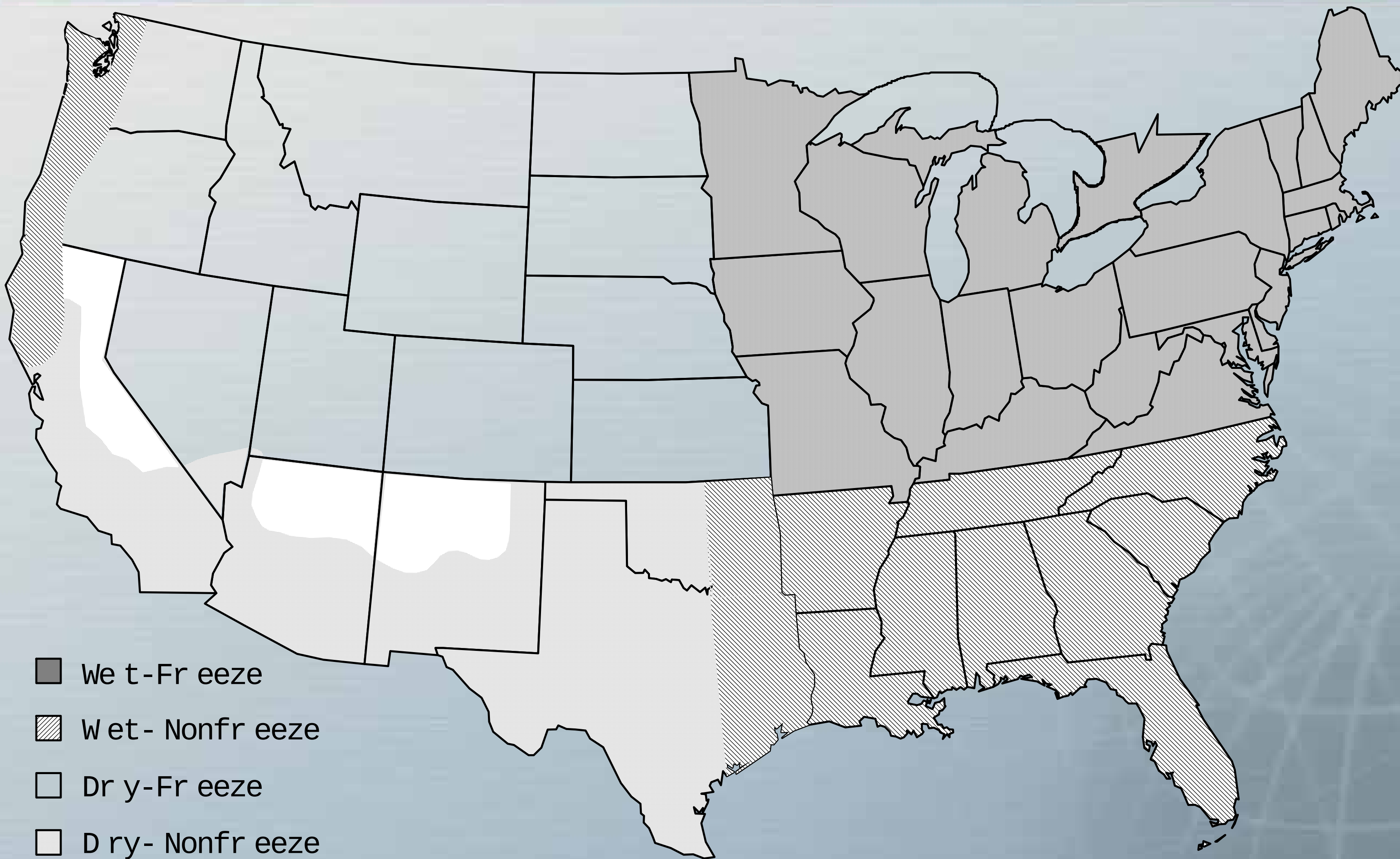
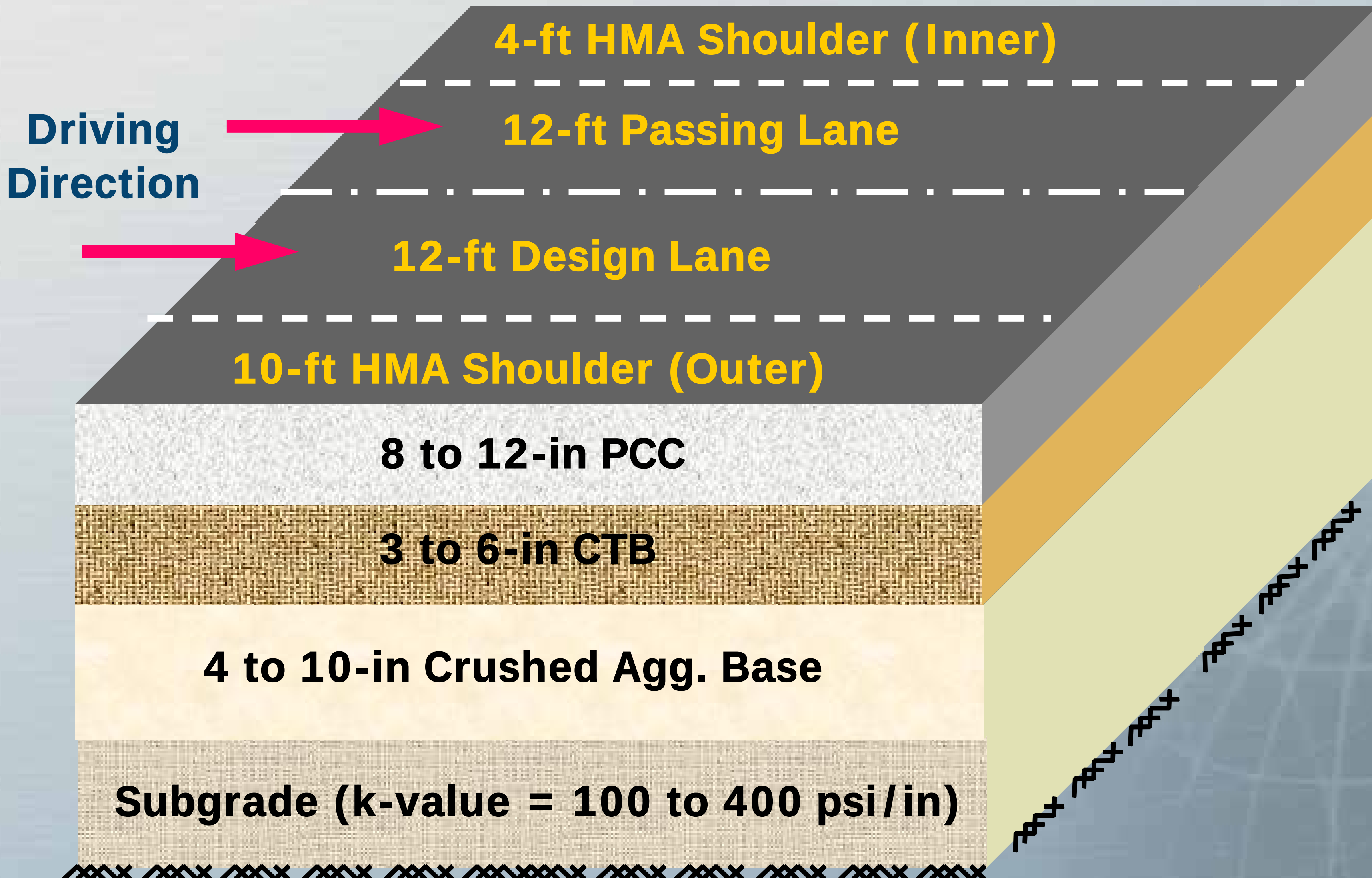
LTPP Climate Zones



Example of Typical LTPP Pavement Section



Proposed JPCP Performance Prediction Models: HERS/NAPCOM

- Developing modified MEPDG JPCP performance models
  - Transverse (slab) cracking (revised ME PDG)
  - Transverse joint faulting (revised ME PDG)
  - Transverse joint spalling (use ME-PDG)
  - IRI, Smoothness model (use ME-PDG)

Proposed HMA Performance Prediction Models: HERS/NAPCOM

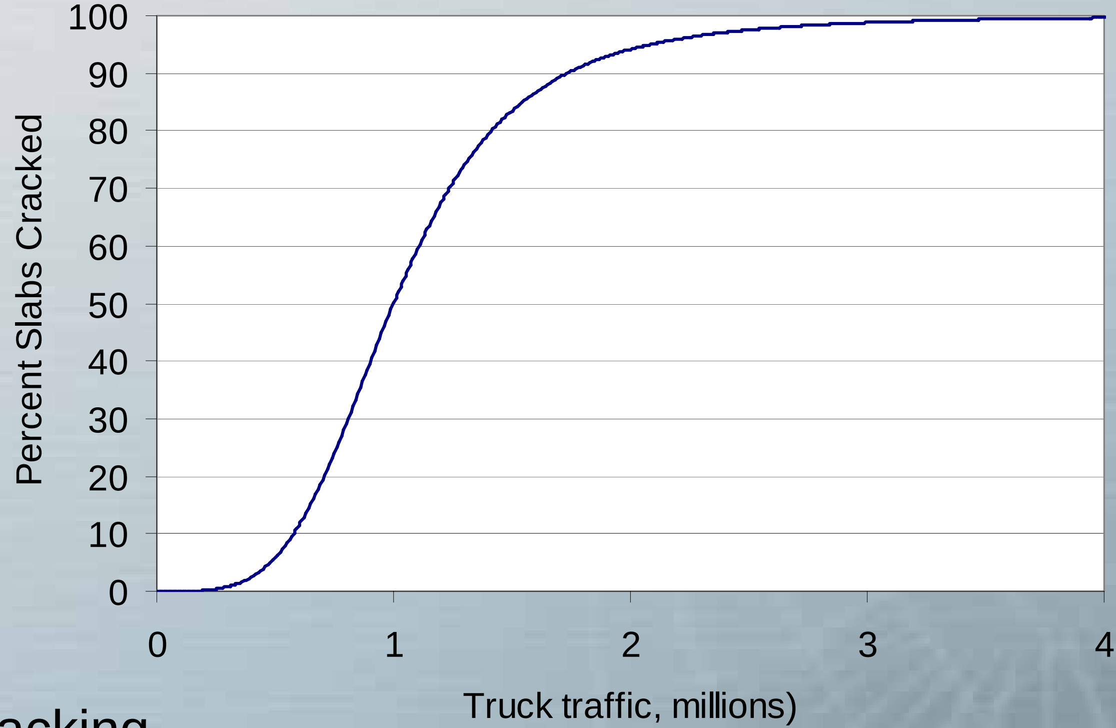
- **New empirical HMA & HMA/HMA models development**
  - **Alligator Cracking (revised ME-PDG)**
  - **Rutting (revised ME-PDG)**
  - **IRI (use ME-PDG)**
  - **Transverse Cracking (revised ME-PDG)**
- **New empirical composite pavement (reflection cracking) model development**
  - **Transverse/Reflection Cracking (use ME-PDG)**

Transverse (Slab) Cracking

- New empirical model derived from ME-PDG outputs of pavements.
- Significant reduction of input data and “simple” model form for HERS/NAPCOM applications
- New empirical model is based on the following variables:
  - *Slab thickness, joint spacing, base type, climate, subgrade type, traffic, shoulder type, lane width, and PCC strength properties (defaults)*

New Transverse Cracking Empirical Model Form

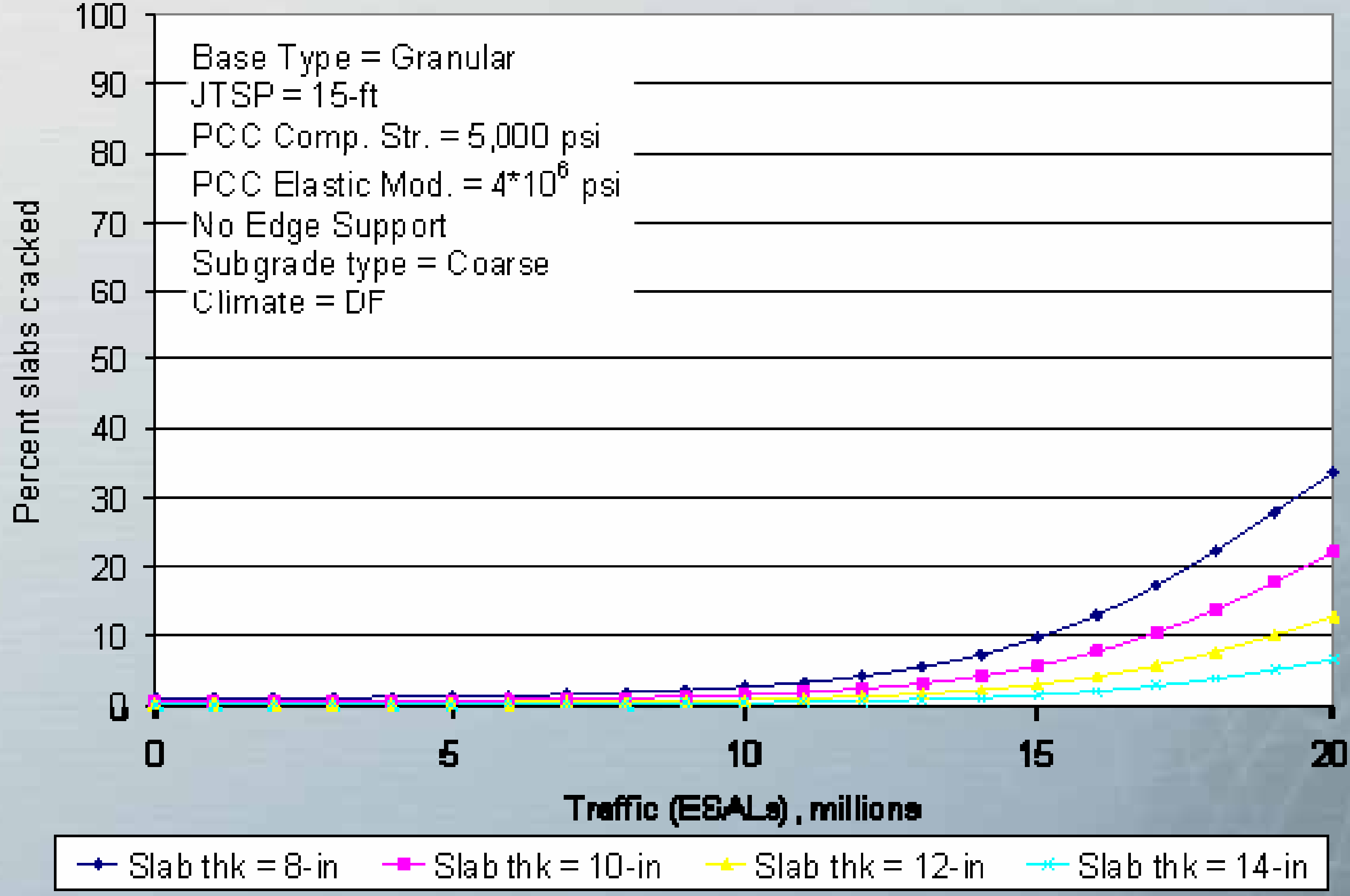
$$CRK = \frac{100}{1 + \beta^{(\alpha * TRAF + \Delta)}}$$



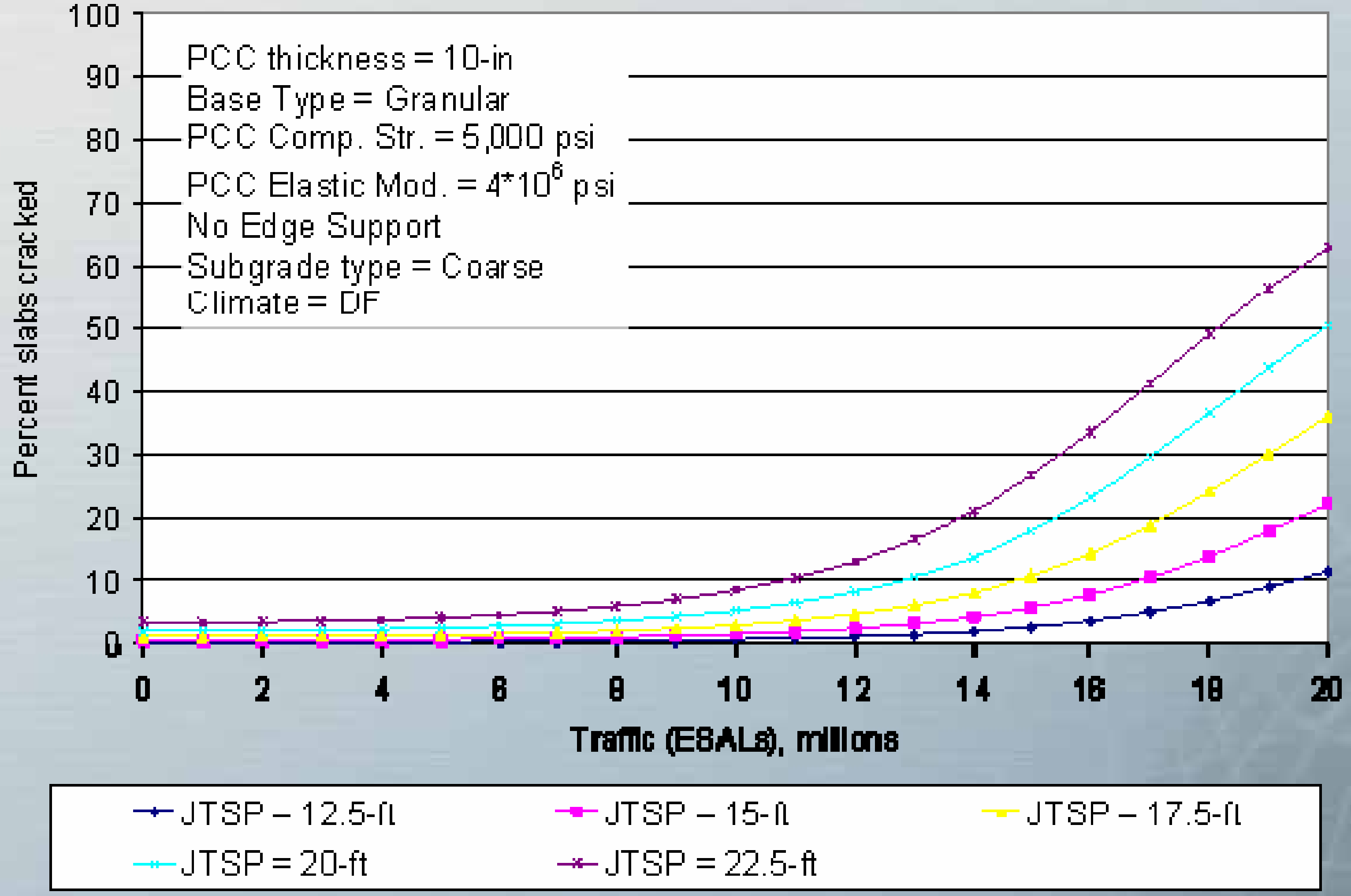
where

CRK	= transverse cracking
TRAF	= estimate of cumulative traffic
Δ	= value based on pavement properties
α, β	= regression constants

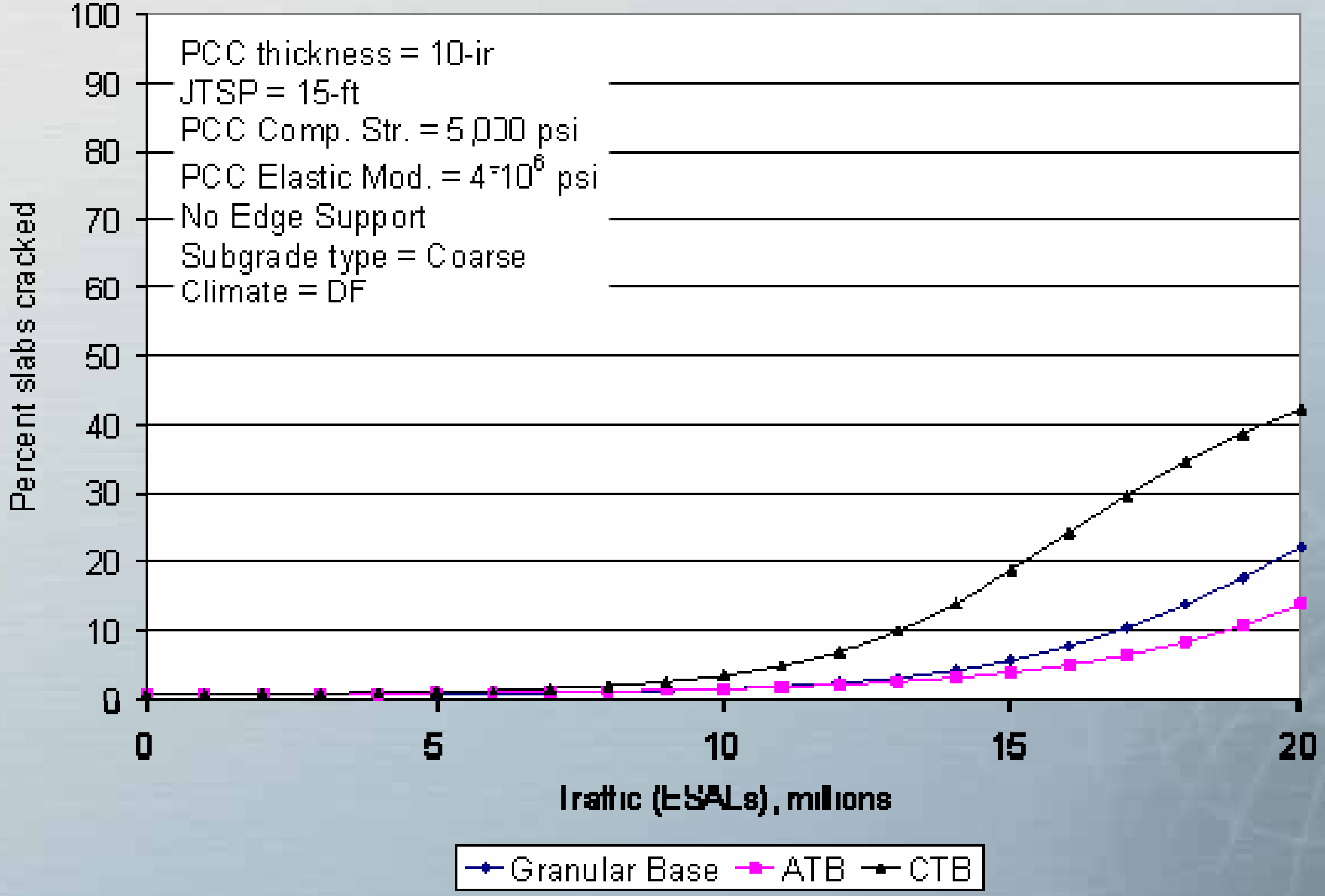
Transverse Cracking – Effect of Slab Thickness



Transverse Cracking – Effect of Joint Spacing



Transverse Crack – Effect of Base Type



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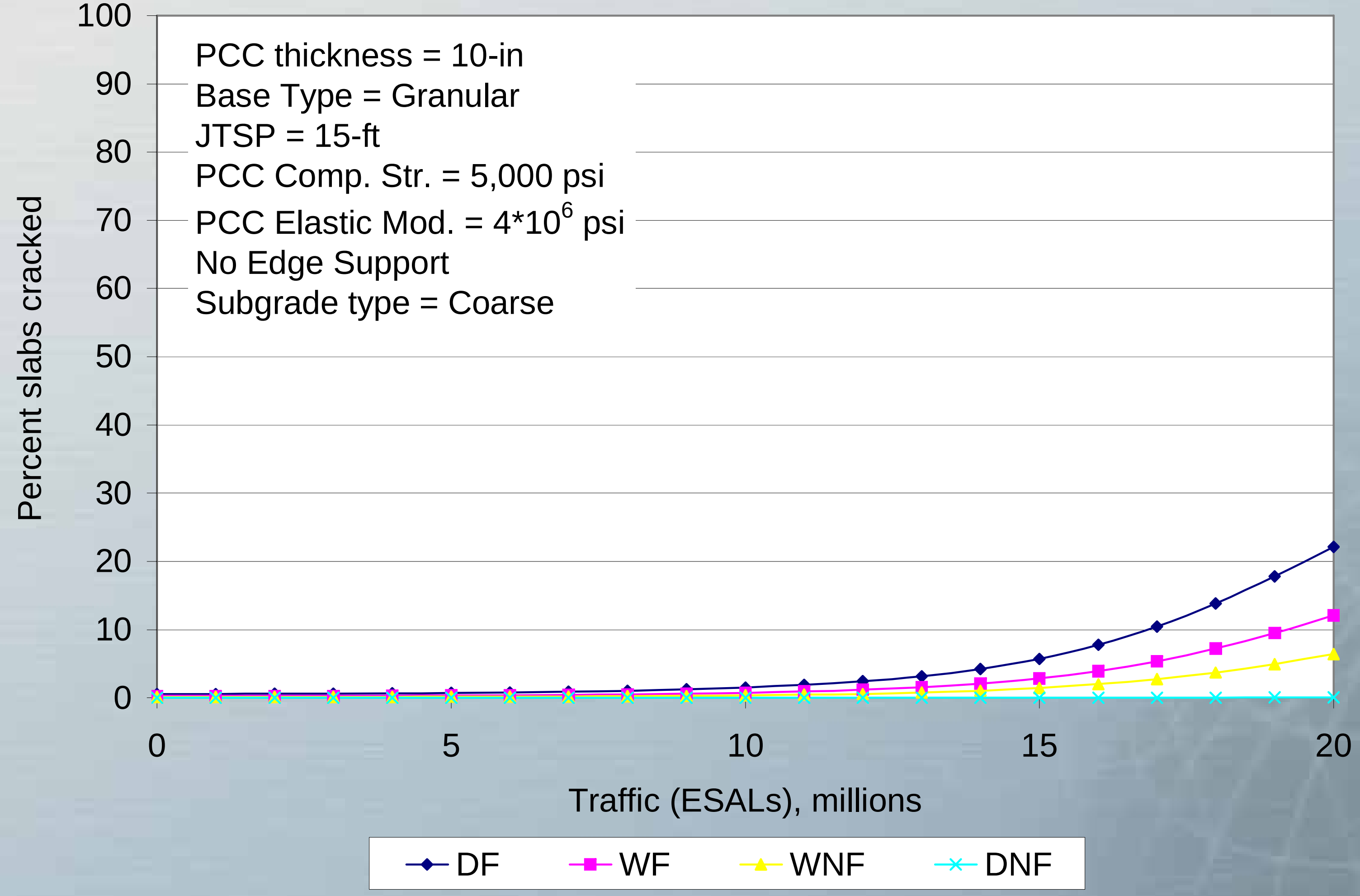
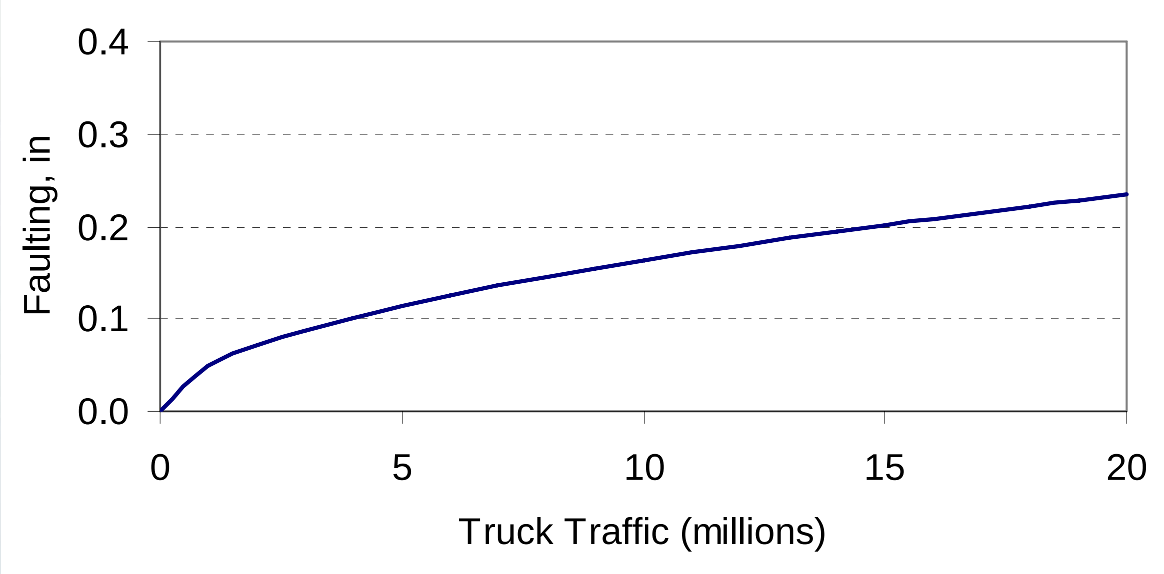
Transverse Crack – Effect of Climate



Transverse Joint Faulting

- New empirical model derived from ME-PDG outputs
- Significant reduction of input data and “simple” model form for HERS applications
- New empirical model is a function of the following variables:
  - *Slab thickness, dowel size, joint spacing, base type, climate, edge support, subgrade type, and truck volume & composition*

New Transverse Joint Faulting Empirical Model Form



$$FAULT = TRAF^{\alpha}(1-\beta DOWDIA)*^{\gamma}$$

where

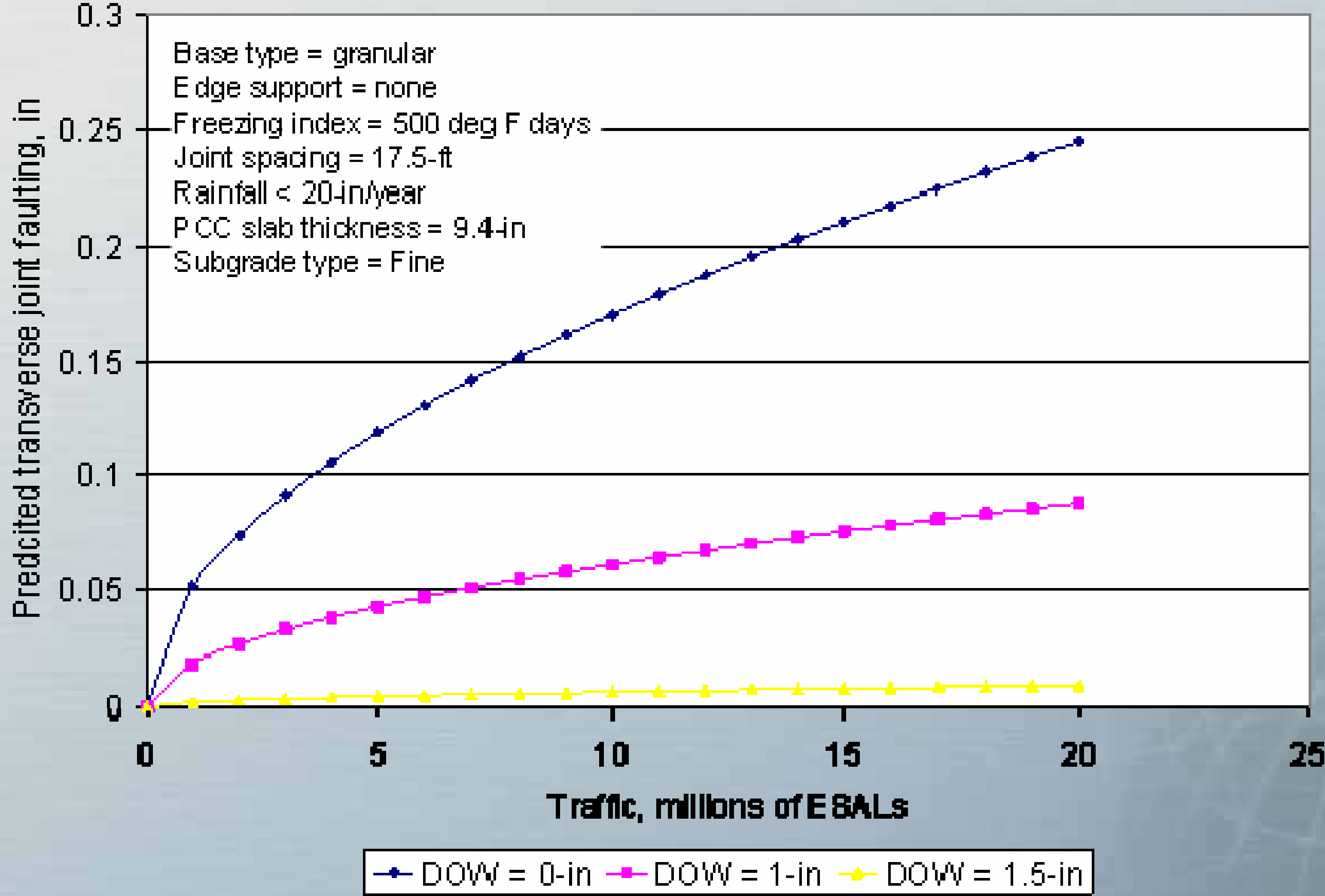
FAULT = transverse joint faulting

TRAF = estimate of cumulative traffic

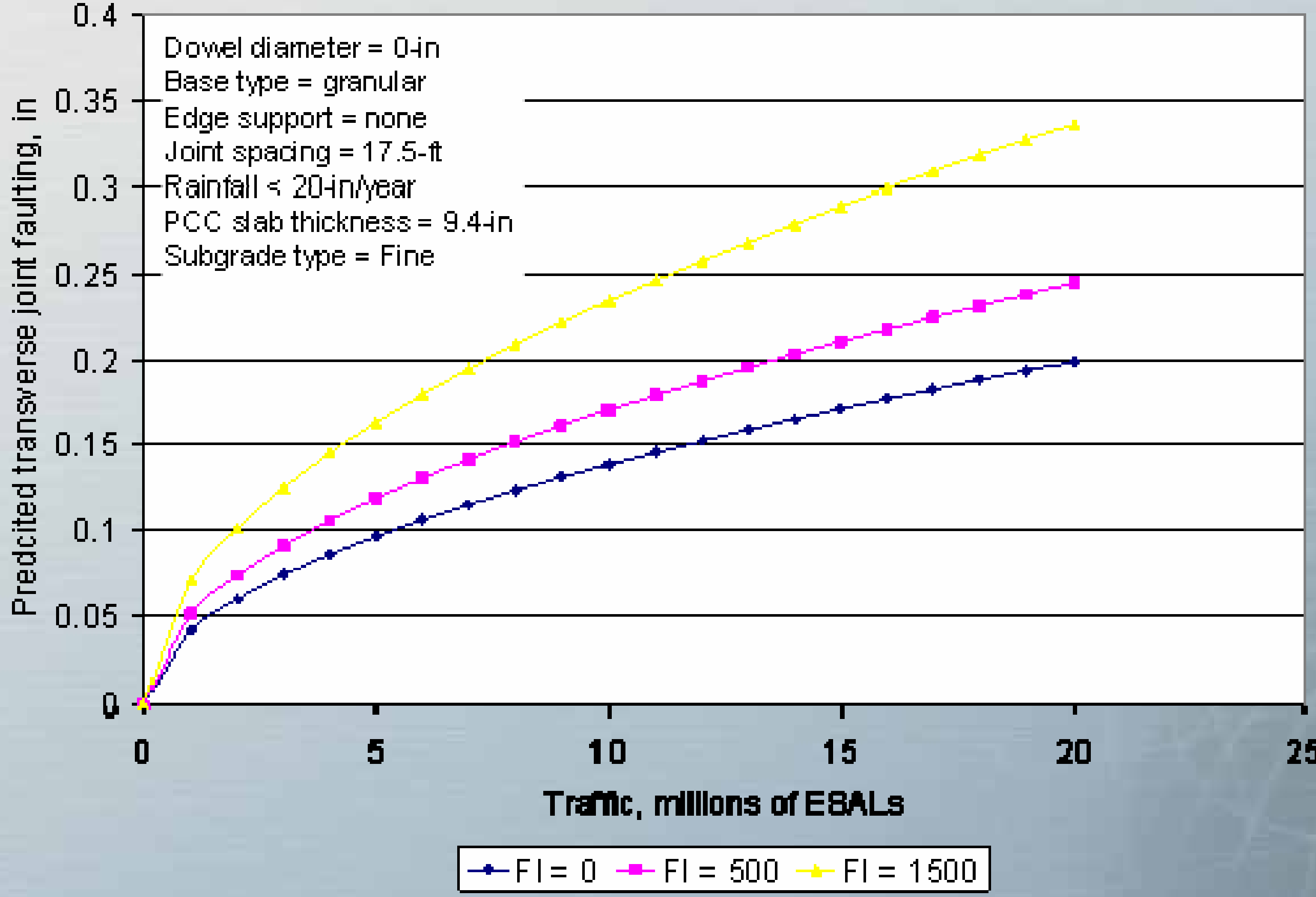
γ = value based on pavement properties

α, β = regression constants

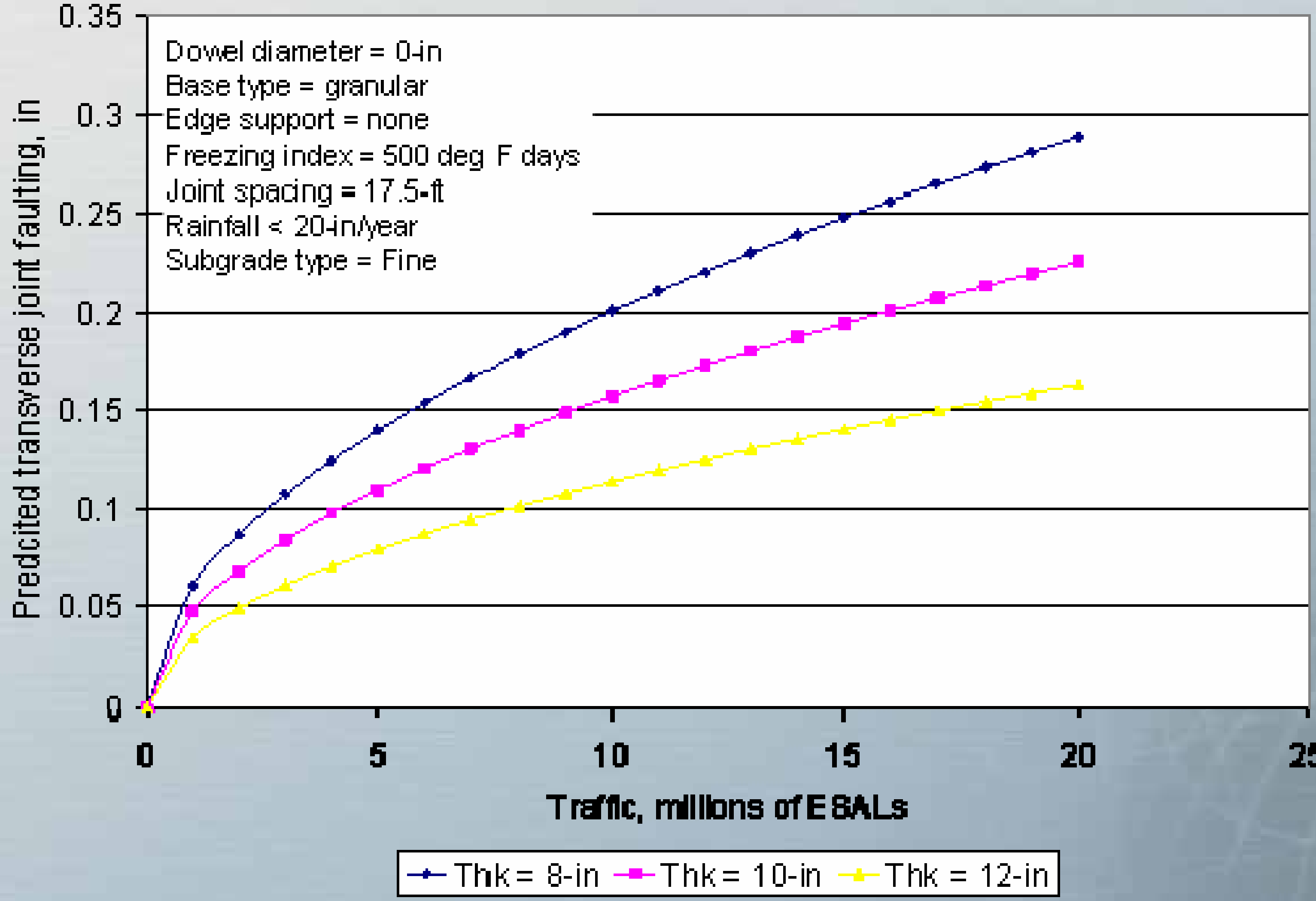
Transverse Joint Faulting –Effect on Dowels



Transverse Joint Faulting – Effect on Climate



Transverse Joint Faulting – Effect on slab Thickness



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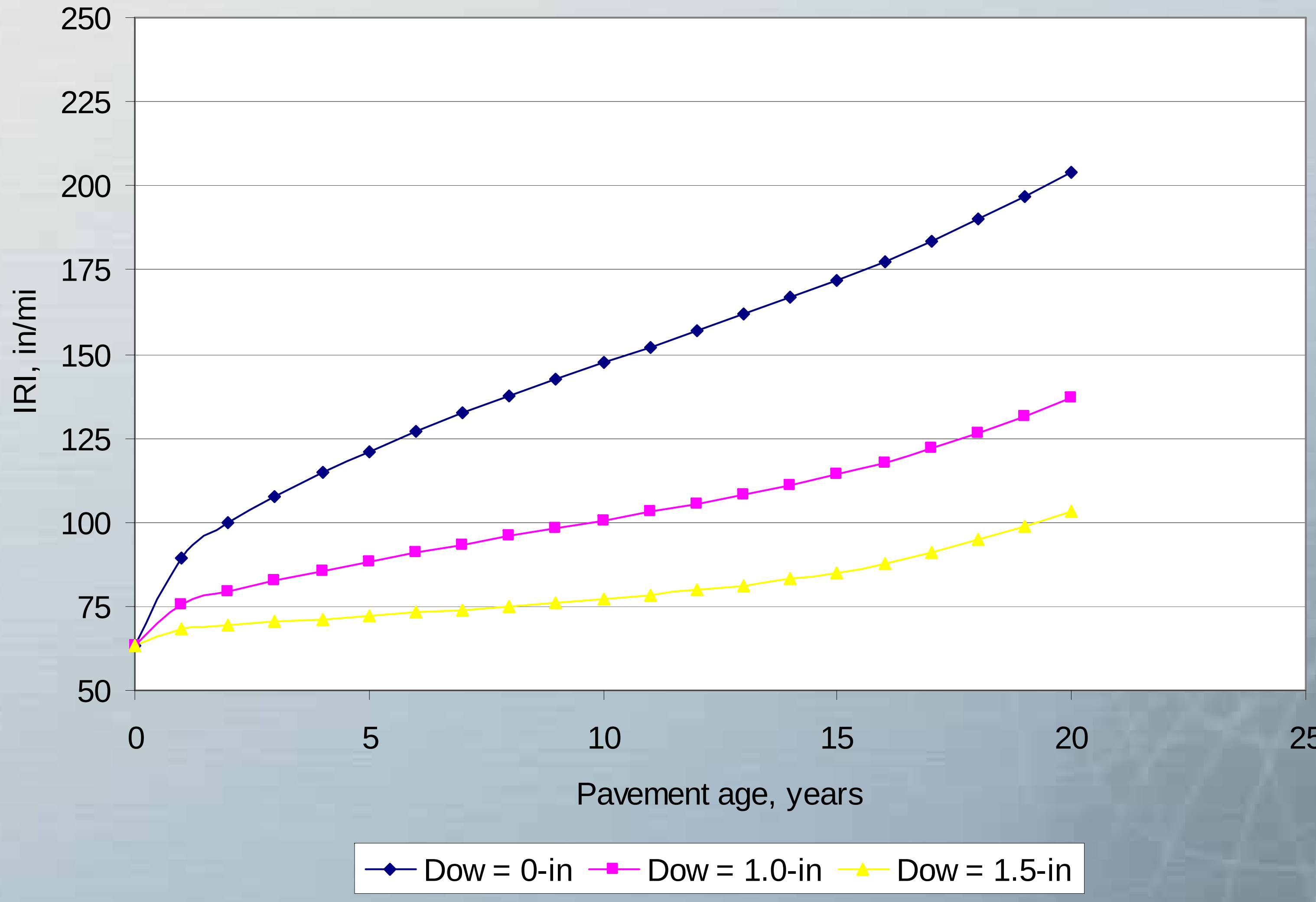
Smoothness Model (Identical to ME-PDG)

$$IRI_a = IRI_I + 0.82*CRK_a + 0.44*SPALL_a$$
$$+ 1.49*TFAULT_a + 25.24*SF$$

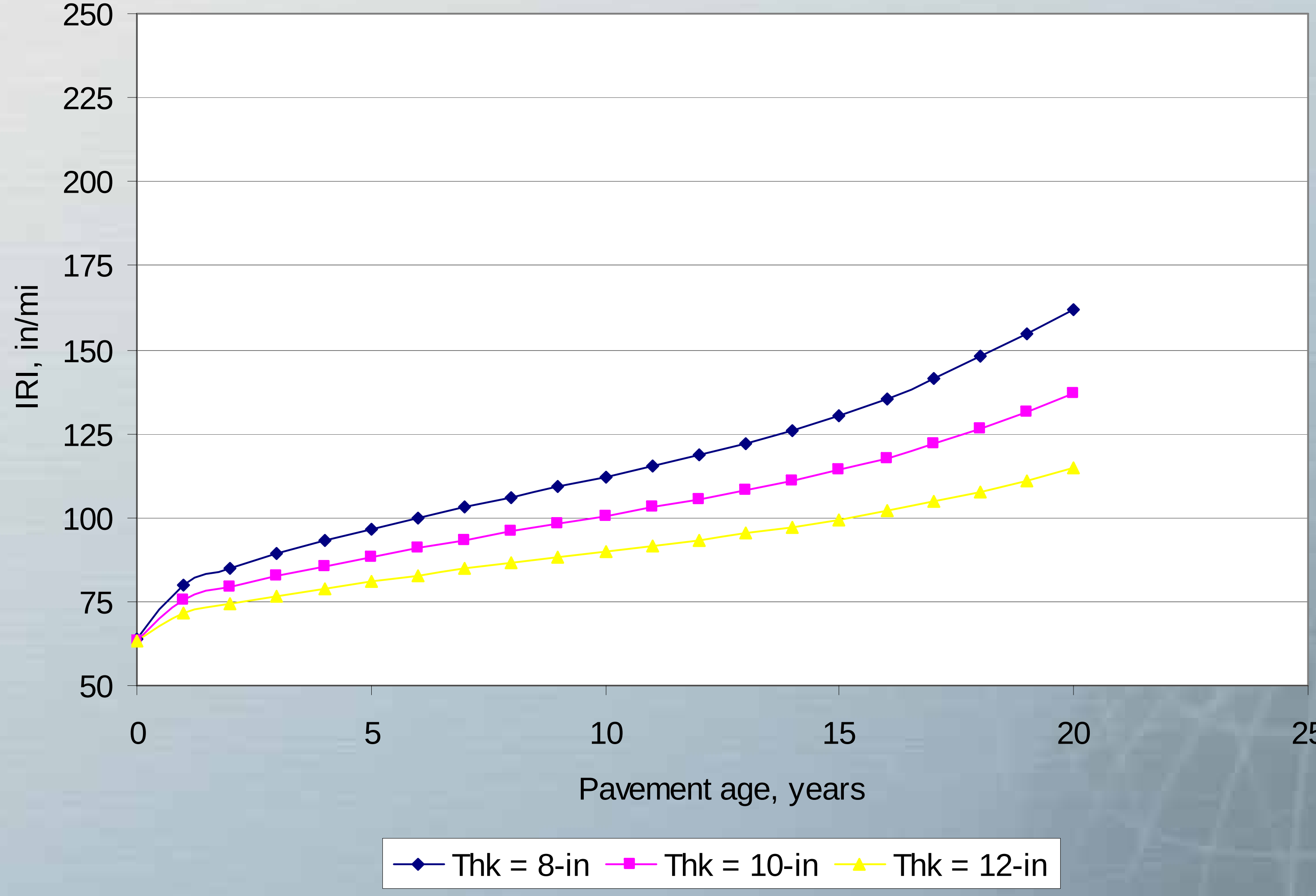
Where

IRI_a	=	IRI in forecast year "a"
IRI_I	=	Initial pavement smoothness
CRK_a	=	percent slabs with transverse crack in forecast year "a"
$TFAULT_a$	=	total joint faulting in forecast year "a"
$SPALL_a$	=	percentage of joints with spalling in forecast year "a" – (predicted using existing MEPDG model)

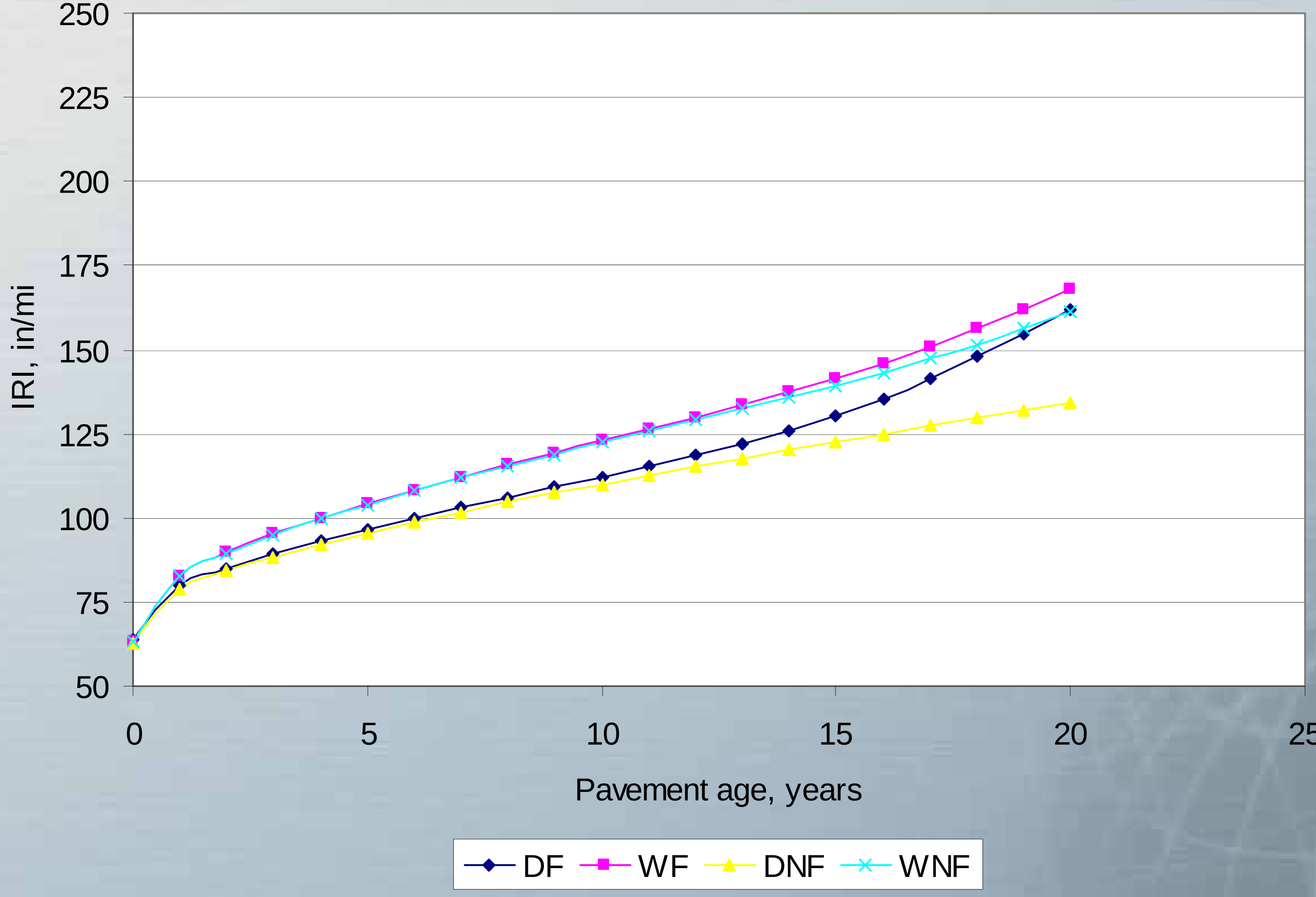
IRI – Effect on Dowels



IRI – Effect on PCC Thickness

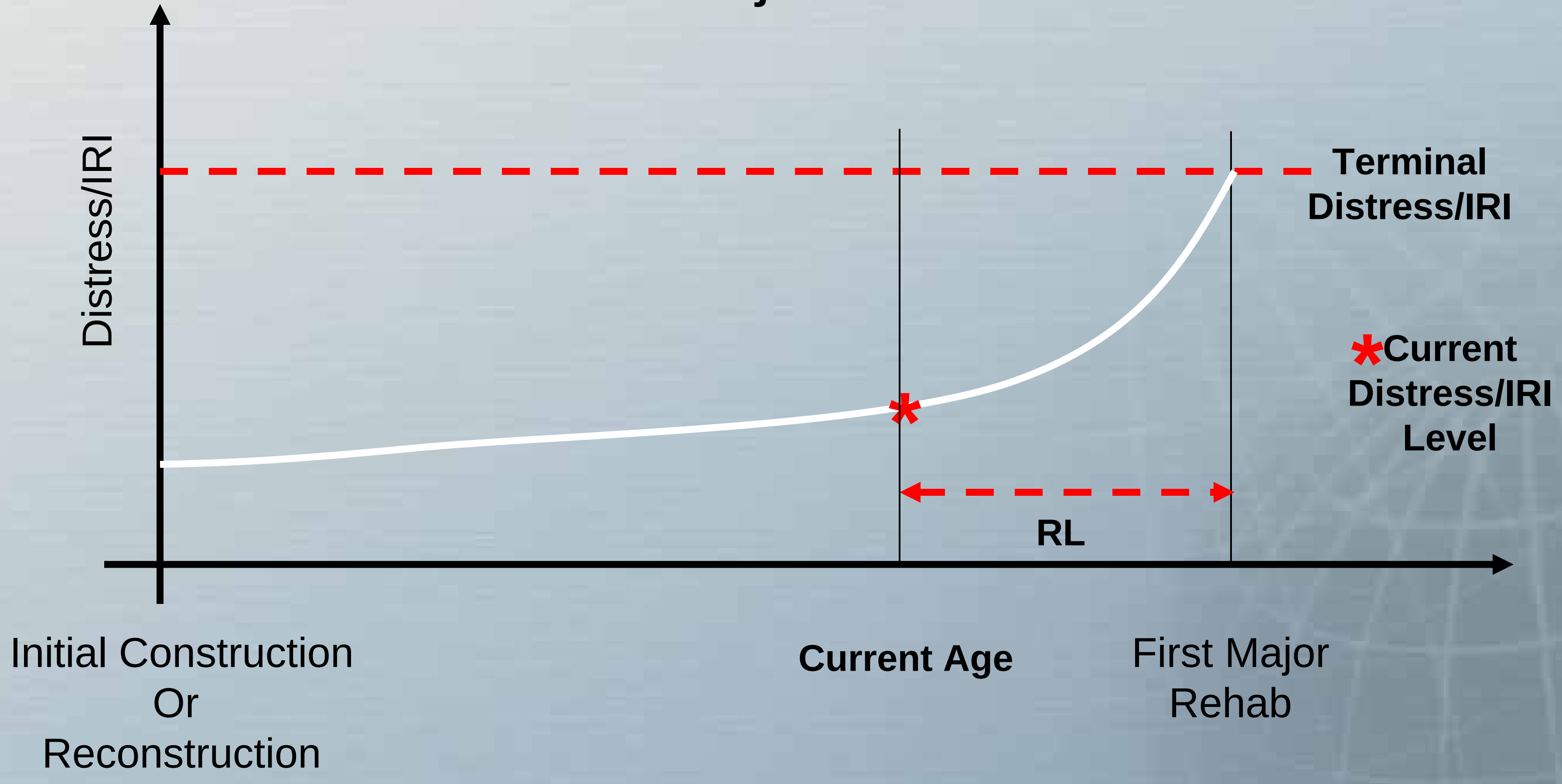


IRI – Effect on Climate



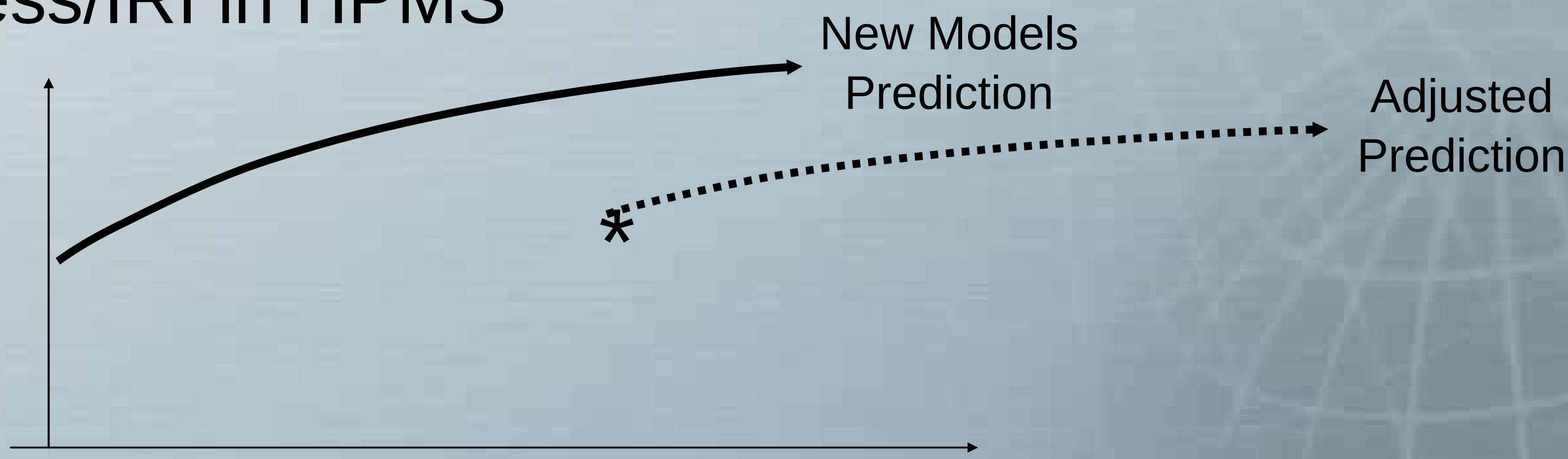
Remaining Service Life

- Defined for this project as the time in age or traffic applications from initial construction or reconstruction to first major rehabilitation



Applying New Empirical Models to Determine Remaining Life-Proposed

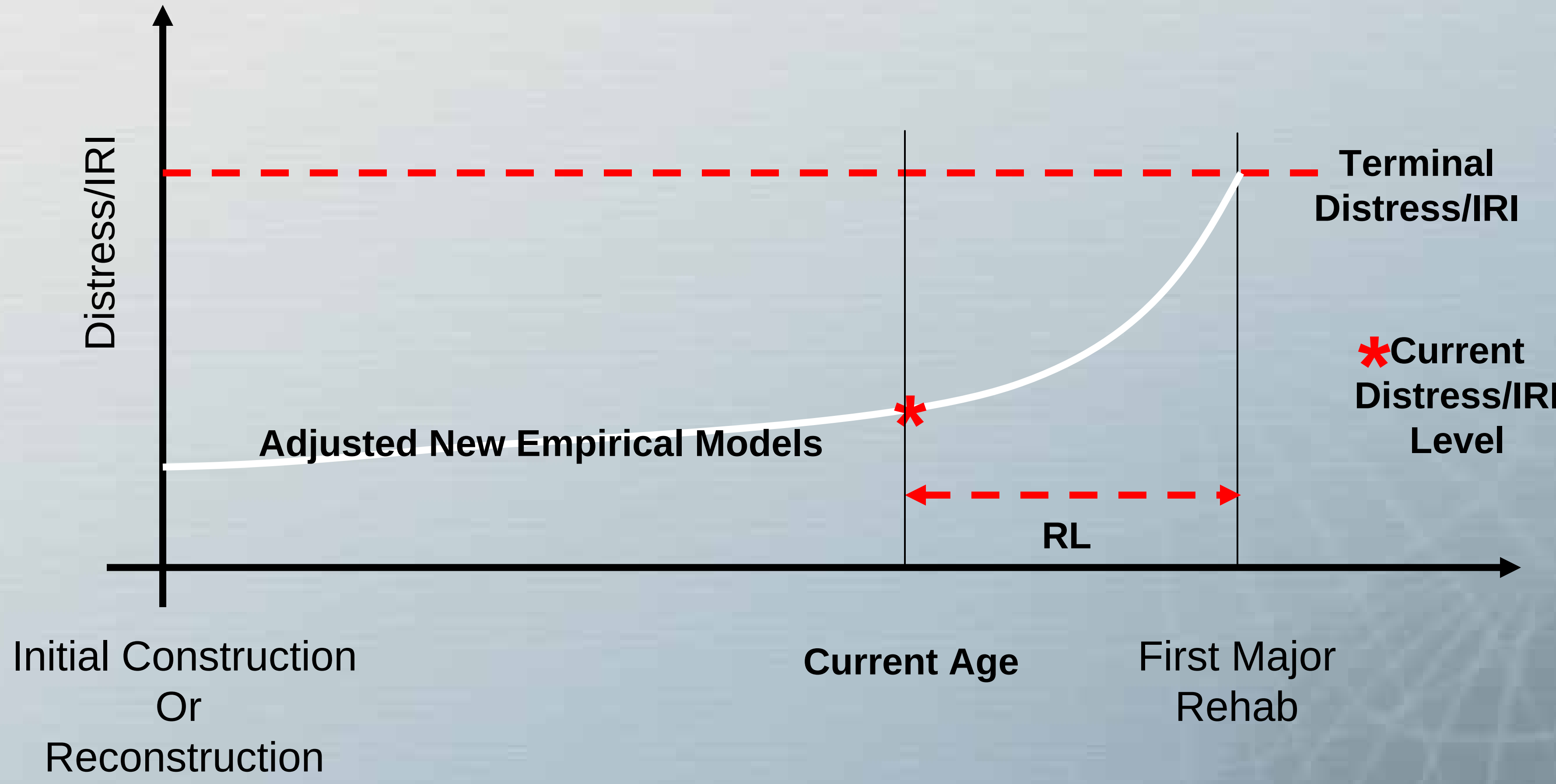
- Step 1: Assemble HPMS project input data
  - Traffic, climate, design, materials, current distress/IRI, etc.
- Step 2: Predict future pavement distress/IRI
  - Slab cracking, faulting, spalling, & IRI
- Step 3: Adjust predicted distress/IRI with current distress/IRI in HPMS



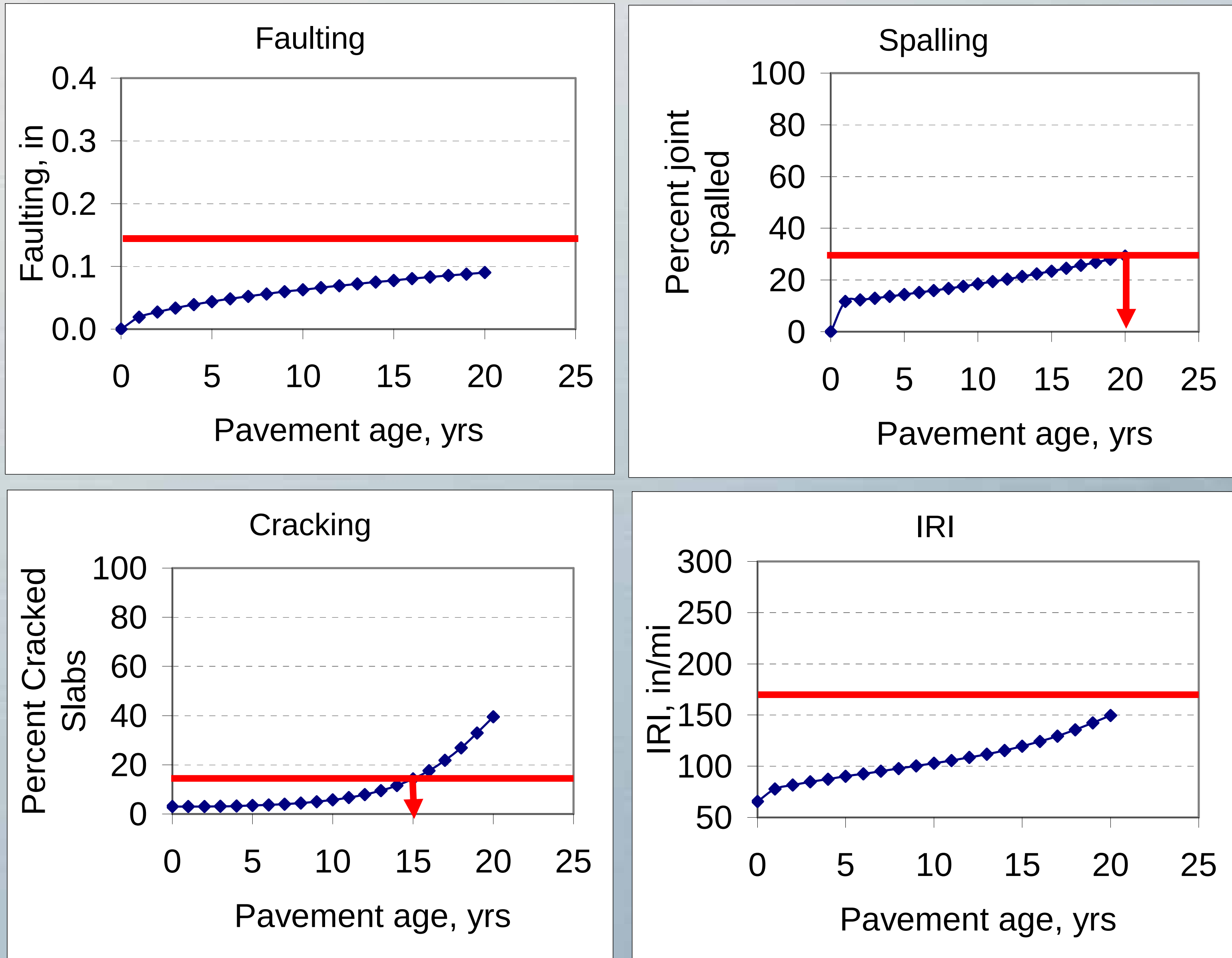
Applying Modified MEPDG JPCP Performance Models to Determine RL

- Step 4: Compare future predictions with FHWA terminal distress/IRI values
- Step 5: Determine time from initial construction or reconstruction to first major rehab. triggered by excessive levels of faulting, cracking, and IRI
- Step 6: Determine current pavement age or traffic applied since initial construction or reconstruction

Estimate of Remaining Life



Example Application of New Models to Determine RL



Example Application to Determine RL

- Current age = 10 years

Desired Sensitive MEPDG Inputs	Predicted Life (Age in Years)	Remaining Life (Age in Years)
Cracking	15	5
Faulting	20	10+
Spalling	20	10
IRI	20	10+

- Critical distress is slab cracking
  - Remaining life based on rehabilitation triggered by excessive cracking is 5 years

Feasible Rehabilitation Treatments

- For excessive cracking a structural improvement will be needed (e.g., thick overlay or reconstruct)
- If excessive faulting were the problem, diamond grinding would be a cost-effective solution

Thank-You

- Any questions?