Department of
Civil, Environmental,
and Geo- Engineering

COLLEGE OF
Science & Engineering
UNIVERSITY OF MINNESOTA

MEPDG – Implementation, Adaptation, and Local Calibration

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Presentation Outline

1. Minnesota early implementation efforts
2. Current implementation status in the US
3. Arizona DOT case study
4. Minnesota update

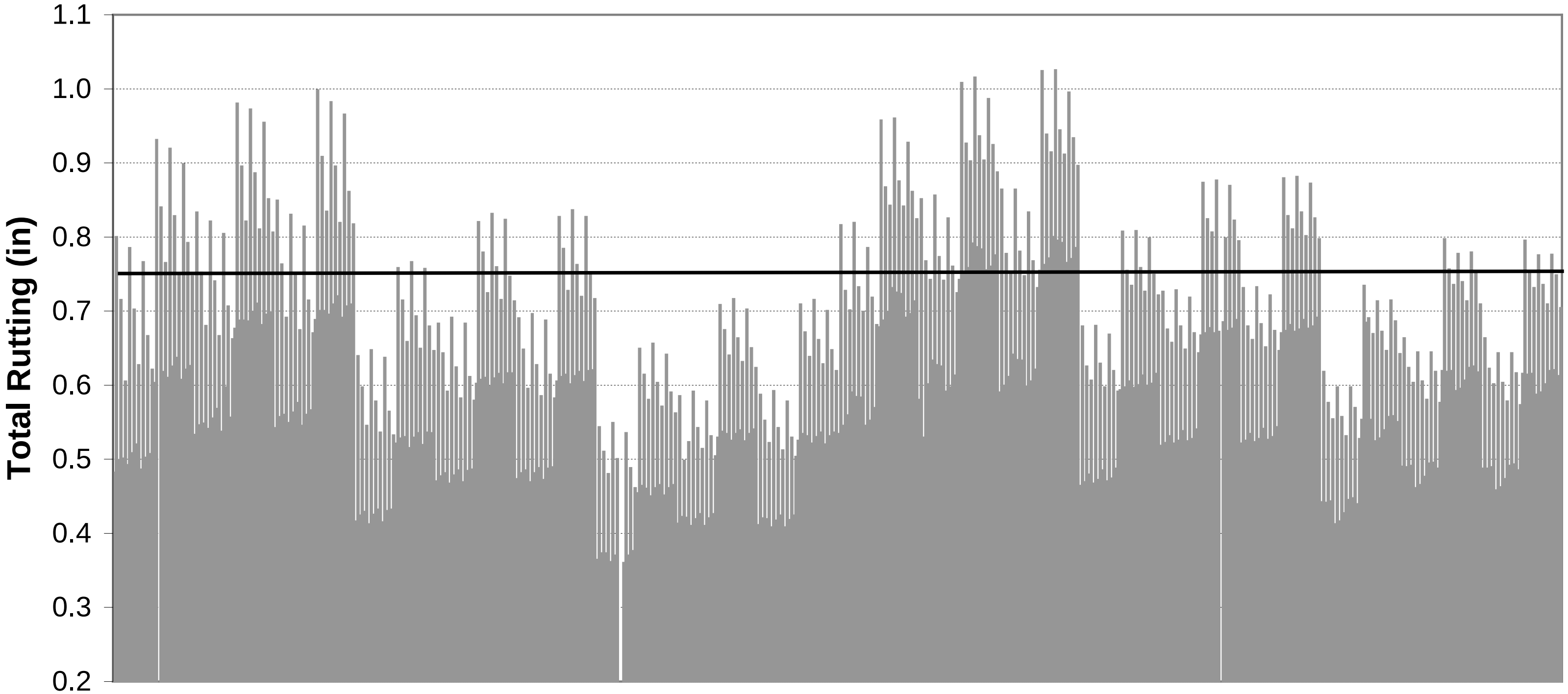
MnDOT Early Implementation Efforts

- MnDOT-sponsored research project *Implementation of the MEPDG for Design of Concrete and Asphalt Pavements in Minnesota* (2005-2008)
  - Reviewed and identified/reported many bugs across multiple versions of the NCHRP MEPDG software
  - Extensive sensitivity study
  - Comparison with MnROAD performance
- Due to mixed results, MnDOT chose to postpone implementation

Sensitivity Analysis – Minnesota Conditions

- Design factorial involved 768 projects
  - Two levels of traffic
    - High, approximately 10-million ESALs (AADTT=2000)
    - Low, approximately 1-million ESALs (AADTT=200)
  - Two levels of climate
    - Northwest (Grand Forks, ND) and Southeast (Rochester, MN)
- Comparison of performance predictions

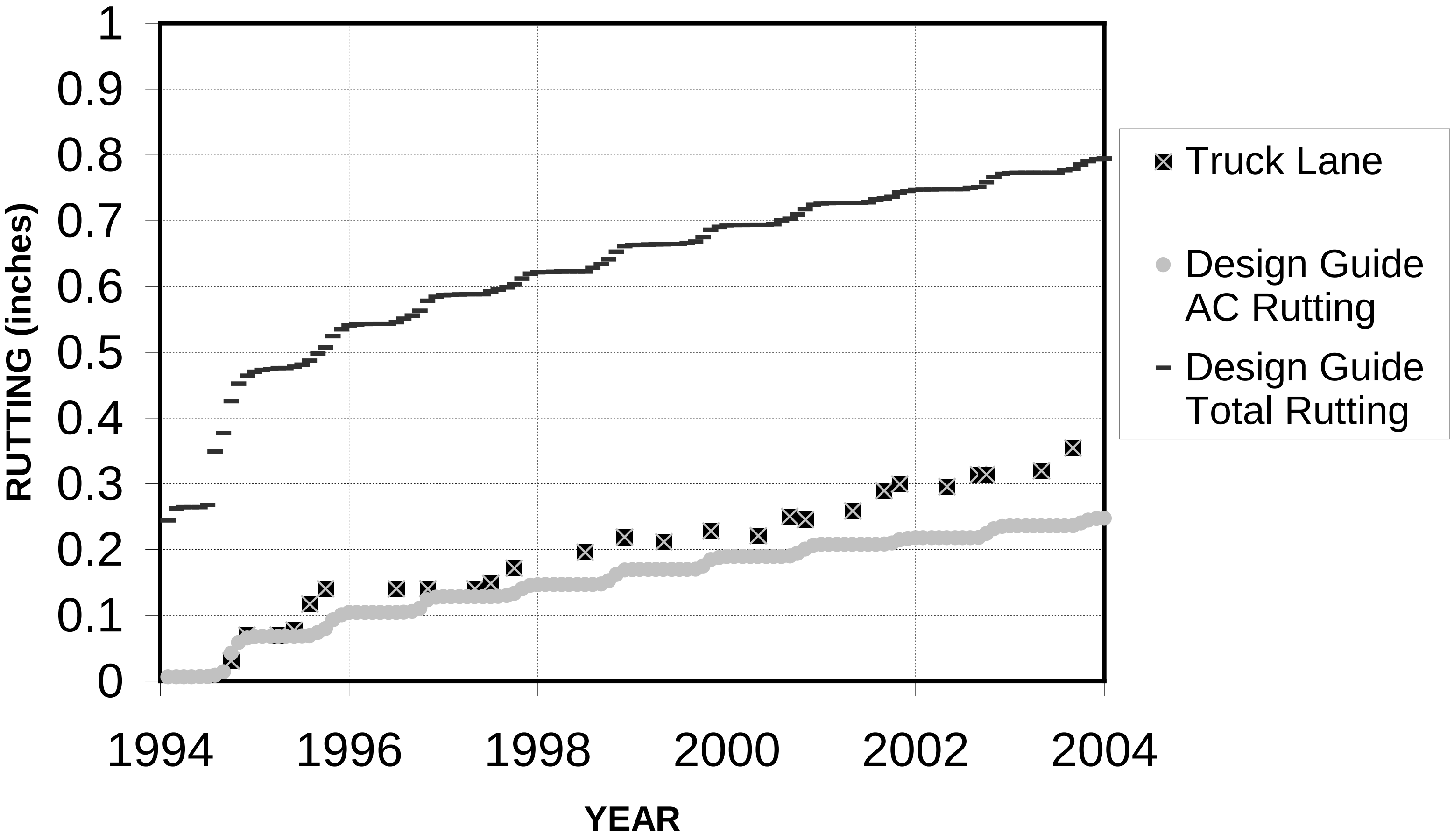
Total Rutting, V 0.900, 10 Million ESALs



NW - AC = 6 in.						NW - AC = 8 in.						NW - AC = 10 in.						SE - AC = 6 in.						SE - AC = 8 in.						SE - AC = 10 in.					
C1		C2		C3		C1		C2		C3		C1		C2		C3		C1		C2		C3		C1		C2		C3		C1		C2		C3	
F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C	F	C
B, SB thickness. SG type changed						B, SB thickness. SG type changed						B, SB thickness. SG type changed						B, SB thickness. SG type changed						B, SB thickness. SG type changed						B, SB thickness. SG type changed					

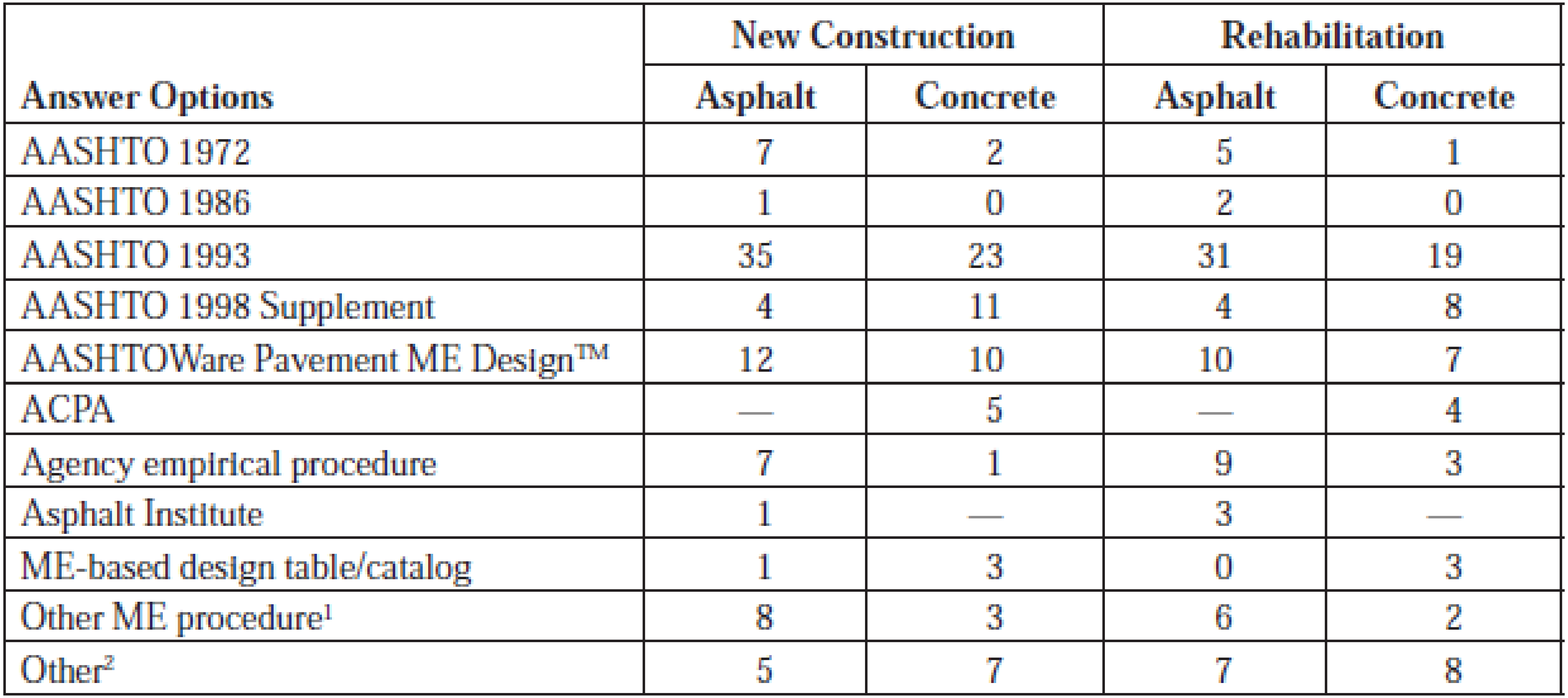
C1 = Top 50% PG 64-34 Bottom PG 58-28
C2 = Top 50% PG 58-34 Bottom PG 58-28
C3 = PG 58-34
F=Fine C=Coarse

Comparison with Measured Distresses



- MEPDG predictions were compared to the observed distresses for MnROAD cell 1 (5.9- in AC layer over a 33-in thick granular base resting on an A-6 subgrade)

Design Methodology Used in USA

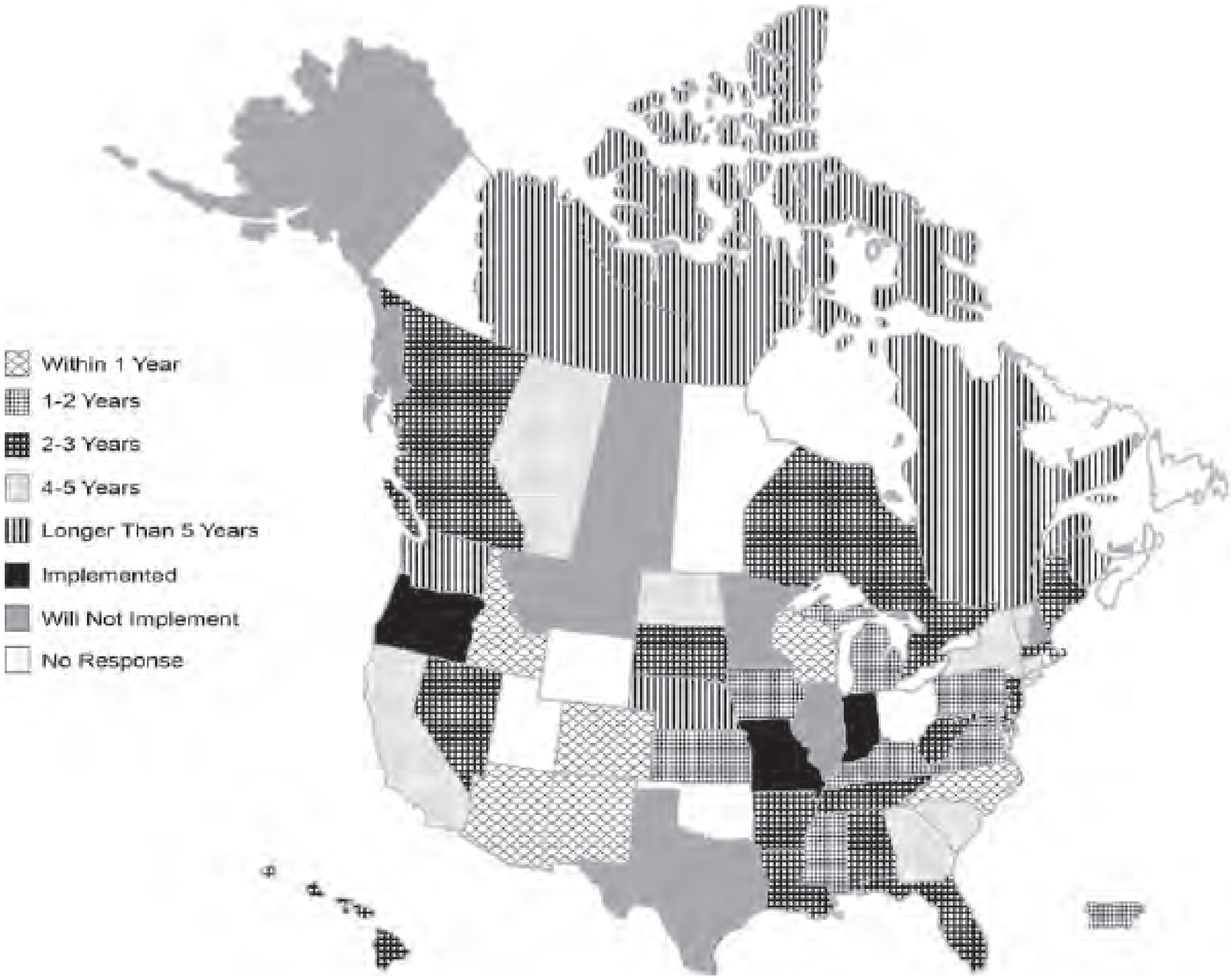


Answer Options	New Construction		Rehabilitation	
	Asphalt	Concrete	Asphalt	Concrete
AASHTO 1972	7	2	5	1
AASHTO 1986	1	0	2	0
AASHTO 1993	35	23	31	19
AASHTO 1998 Supplement	4	11	4	8
AASHTOWare Pavement ME Design™	12	10	10	7
ACPA	—	5	—	4
Agency empirical procedure	7	1	9	3
Asphalt Institute	1	—	3	—
ME-based design table/catalog	1	3	0	3
Other ME procedure[1]	8	3	6	2
Other[2]	5	7	7	8

From Pierce and McGovern (2014), NCHRP Synthesis 457

MEPDG Implementation

AASHTO ME Implementation Status



From Pierce and McGovern (2014), NCHRP Synthesis 457

Data Needs and Required Information

- Climate data—Weather stations with preferably 20 years of continuous data
- Material and traffic input values—existing conditions, laboratory and field testing
- Pavement performance—pavement management system data and other data
- Calibration test sites—Number of pavement segments by pavement type, functional class, distress type, traffic volumes, and climatic regions

From Pierce and McGovern (2014), NCHRP Synthesis 457

Case Study: Arizona DOT Local Calibration

Calibration & Implementation of the AASHTO MEPDG in Arizona

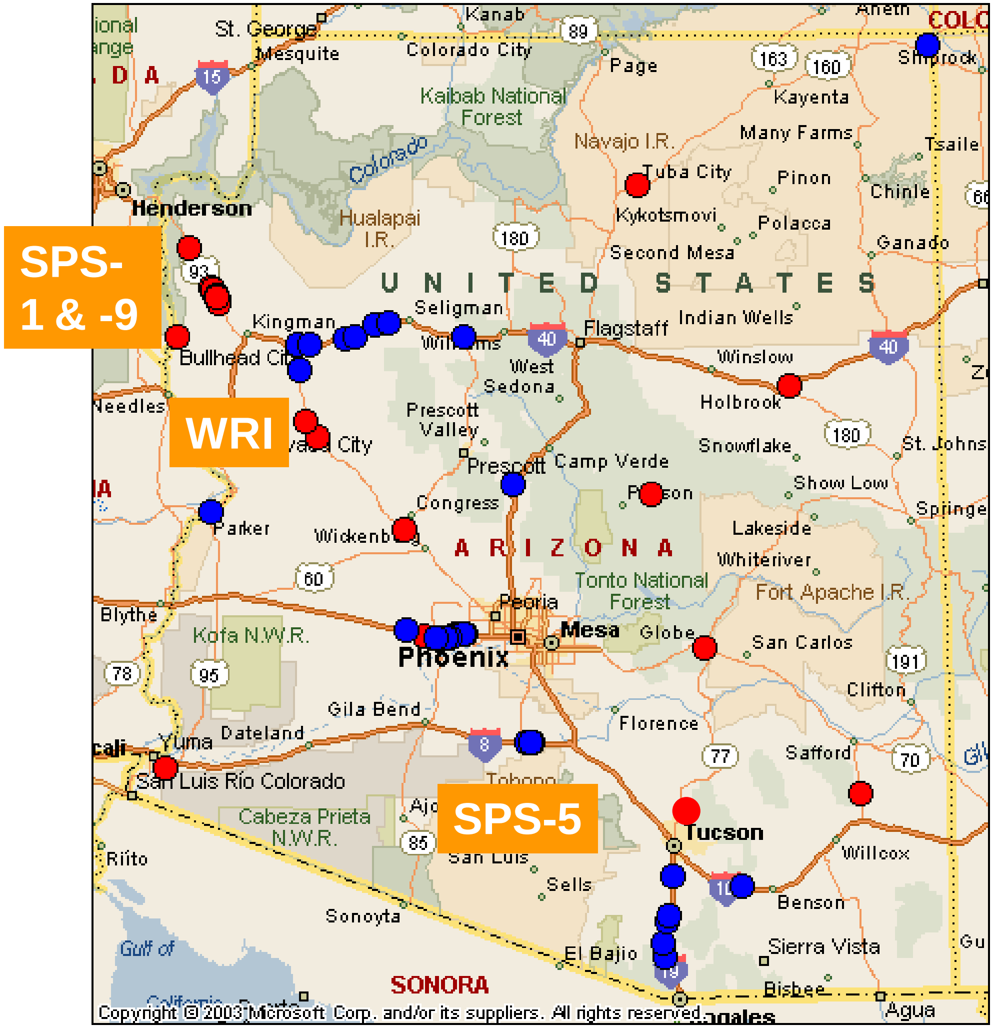
- Sept 2014
- M.I. Darter

  L. Titus-Glover

  H. Von Quintus

  B. Bhattacharya

  J. Mallela of Applied Research Associates

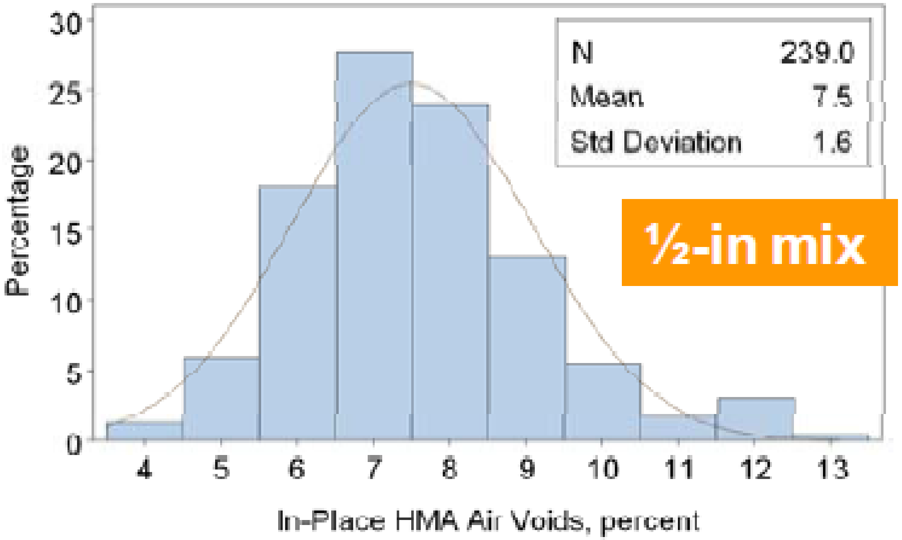


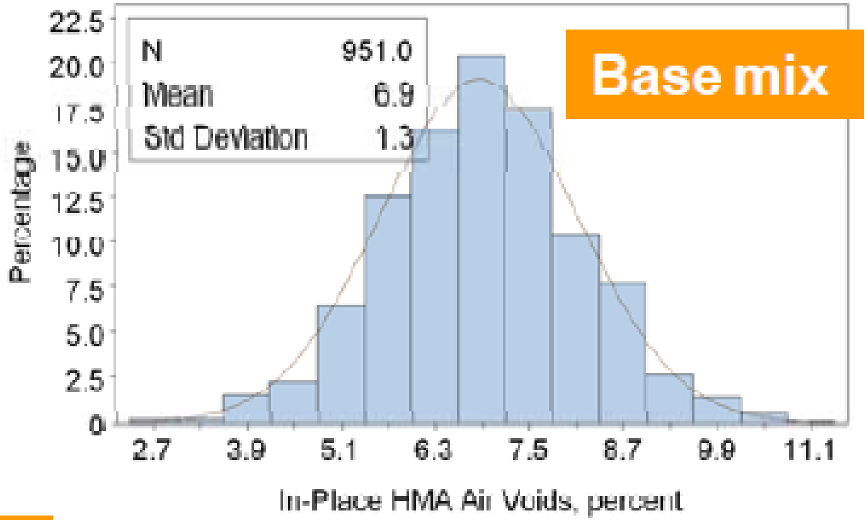
Selected Flexible Pavements in Arizona

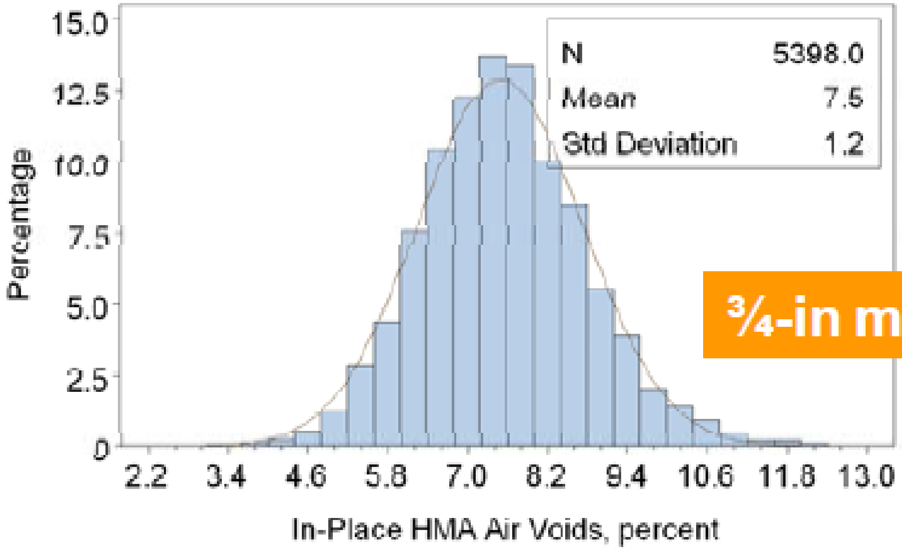
HMA Thickness, in	Base Thickness, in	Subgrade Type	
		Coarse (A-1 through A-3)	Fine (A-4 through A-7)
4 to 8	< 6	161, A901, A902, A903, PMS_98-115	
	≥ 6	113, 114,119, 120, 121,501, 502, 509, 559, 560, 1007_1, 1021_1,1034_1, 1034_5,1036_1, 1037_1, 6053_1, 6055_1, 6055_3, 6060_1, PMS_03-07, PMS_03-15, PMS_03-52, PMS_03-59, PMS_03-71,	AZ1, AZ2, AZ3, AZ4, 505, PMS_03-12
≥ 8	< 6	115, 116, 117, 118, 123, 124, 162, 260, 261, 1001, 1002_1, 1002_3	PMS_03-21_1, PMS_03-21_2, PMS_03-31_1, PMS_03-31_2,
	≥ 6	122, 503, 504, 506, 507, 508, 1003_1, 1003_3, 1006_1, 1006_2, 1007_4, 1015_1, 1015_2, 1016_1, 1016_3, 1017_1, 1017_3, 1021_5, 1022_1, 1022_3, 1024_1, 1024_7, 6054_1, B901, B902, B903, B959, B960, B961, B964 6060_5, PMS_03-28,	1018_1, 1018_4, PMS_03-60

As-Constructed HMA Mix Properties in Arizona

As constructed air void content







¾-in mix

Final Model: Predicted vs Measured

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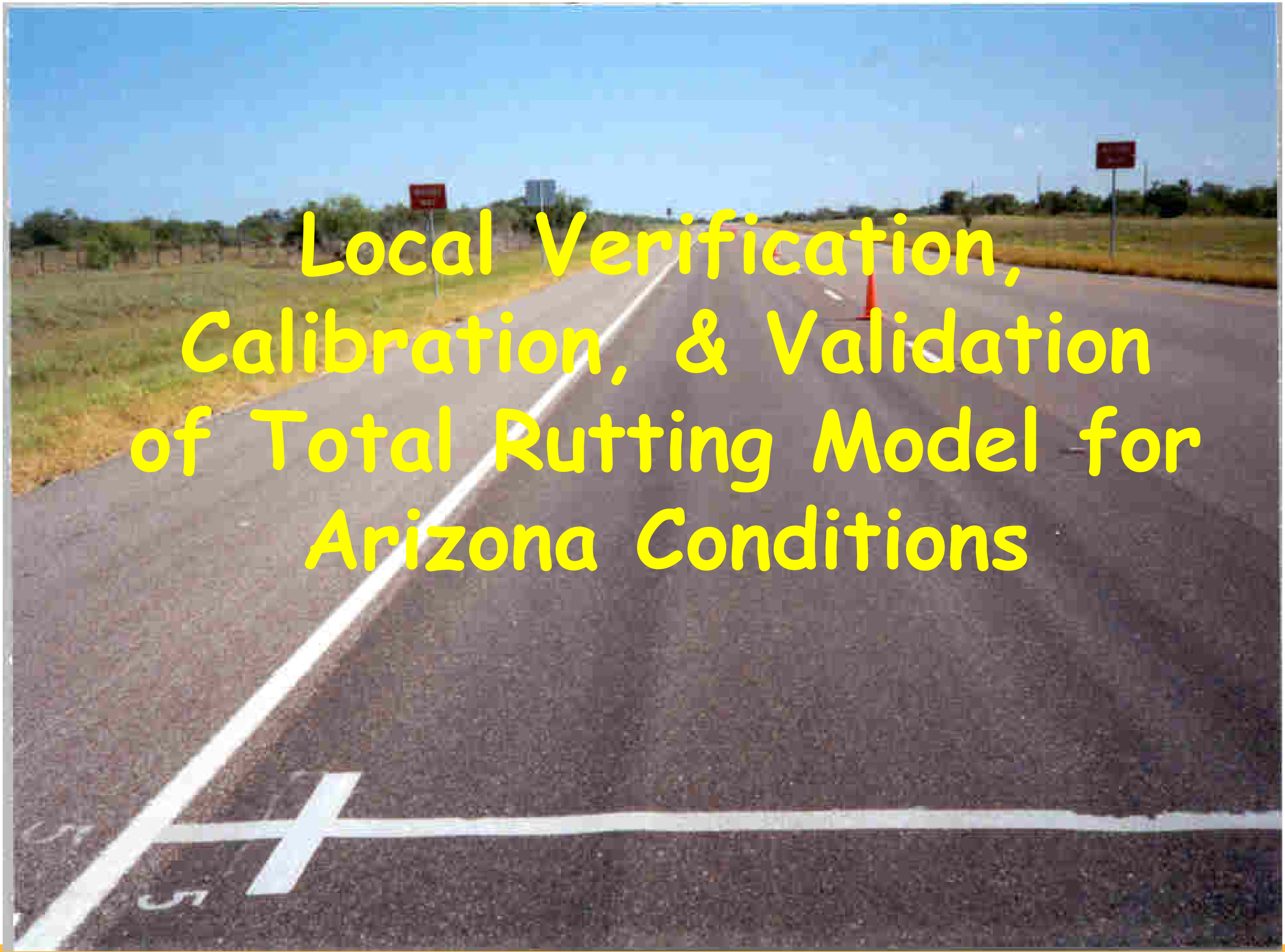
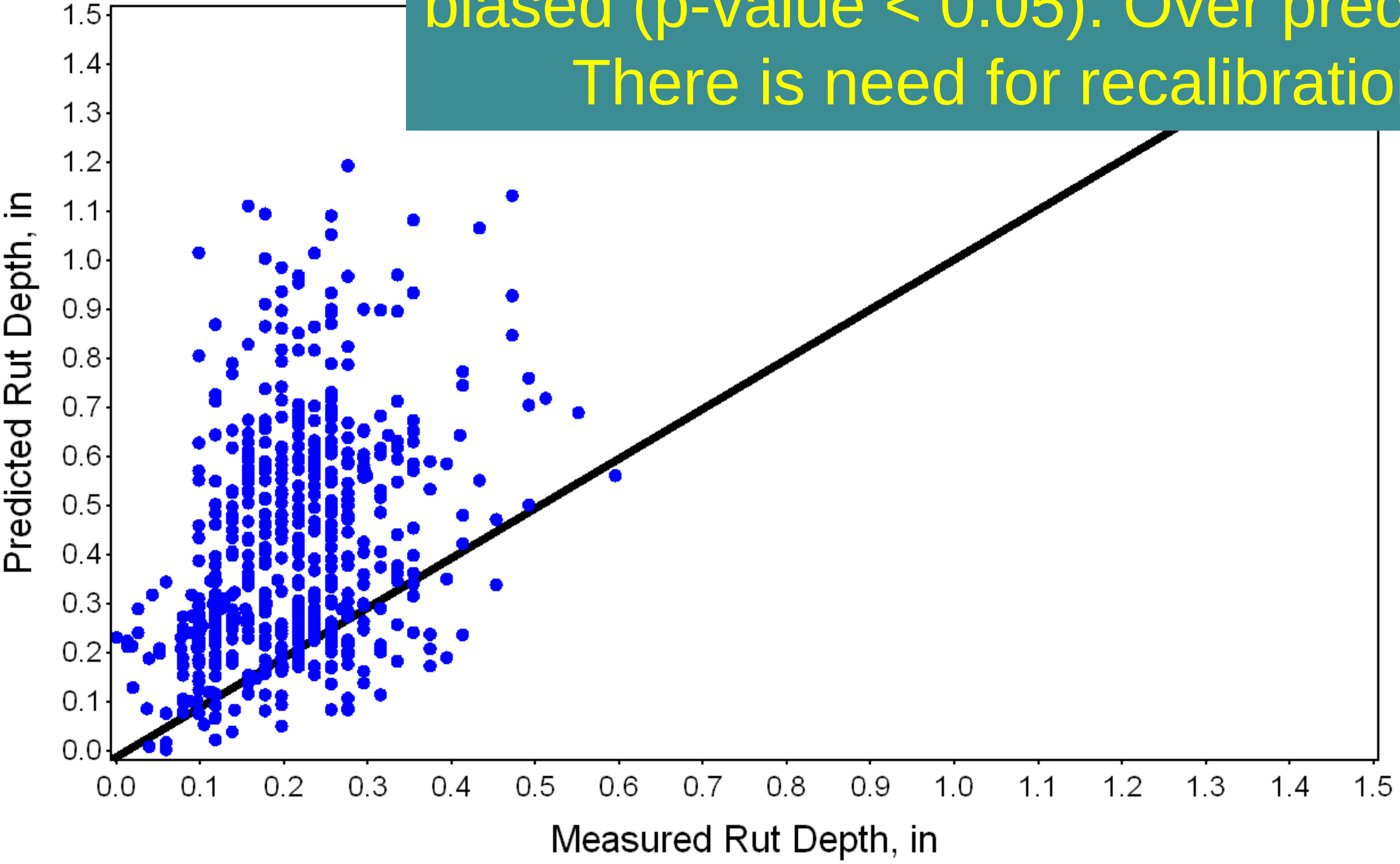


Local Verification, Calibration, & Validation of Total Rutting Model for Arizona Conditions

AZ Measured vs. “Global” Predicted Rutting

Goodness of fit was poor ($R^2 = 4.6$ percent. Total rutting prediction was biased ($p\text{-value} < 0.05$). Over prediction. There is need for recalibration



Improving Rutting Model Adequacy

- From Measured v. Predicted plots one can observe:
  - MEPDG global rutting models tend to **over-predict** total rutting
  - Measured rutting in Arizona usually levels off and does not increase much with traffic application
  - MEPDG predicted rutting trends show significant increase in rutting with increasing traffic
- For local calibration to be successful must:
  - Reduce impact of traffic load applications on rutting
  - Reduce magnitude of predicted total rutting

Rutting Model

- **Models of Interest**
  - AC rutting
  - Unbound aggregate base rutting
  - Subgrade rutting

$$TRUT = RUT_{HMA} + RUT_{BASE} + RUT_{SUBG}$$

Where

$TRUT$ = total rutting
RUT_{HMA} = HMA rutting, in
RUT_{BASE} = base rutting, in
RUT_{SUBG} = subgrade rutting, in

AC Rutting Submodel

$$\Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = \beta_{1r} k_z \varepsilon_{r(HMA)} 10^{k_{1r}} n^{k_{2r}\beta_{2r}} T^{k_{3r}\beta_{3r}}$$

Where

$\Delta_{p(HMA)}$ = AC rutting, in

$\varepsilon_{p(HMA)}$ = acc. plastic axial strain in HMA, in/in

$\varepsilon_{r(HMA)}$ = elastic strain in HMA layer, in/in

$h_{(HMA)}$ = HMA thickness, in

n = number of axle load repetitions

T = HMA mix temperature, °F

k_z = depth confinement factor

k_{1r}, k_{2r}, k_{3r} = global field calibration constants

$\beta_{1r}, \beta_{2r}, \beta_{3r}$ = local calibration constants

Unbound Base/Subgrade Rutting Model

$$\Delta_{p(soil)} = \beta_{S1} k_{s1} \varepsilon_v h_{soil} \left(\frac{\varepsilon_o}{\varepsilon_r}\right) e^{-\left(\frac{\rho}{n}\right)^{\beta}}$$

Where

$\Delta_{p(Soil)}$ = plastic deformation, in

n = number of axle load applications

ε_o = intercept (from lab permanent deformation tests), in/in

ε_r = resilient strain (from lab testing), in/in

ε_v = average vertical resilient in base/subgrade, in/in

h_{Soil} = base/subgrade thickness, in

k_{s1} = global calibration coefficient

β_{S1} = local calibration coefficient for ***base or subgrade***

AC Rutting Model

$$\Delta_{p(HMA)} = \varepsilon_{p(HMA)} h_{HMA} = \boxed{\beta_{1r}} k_z \varepsilon_{r(HMA)} 10^{k_{1r}} n^{k_{2r}\boxed{\beta_{2r}}} T^{k_{3r}\boxed{\beta_{3r}}}$$

Model Coefficients	Global Calibration Coef.	ADOT Local Calibration Coef.
K1	-3.35412	-3.35412
K2	1.5606	1.5606
K3	0.4791	0.4791
BR1	1	0.69
BR2	1	1
BR3	1	1

Base (***Granular Subgrade***) Rutting Model

$$\Delta_{p(soil)} = \boxed{\beta_{S1}} k_{s1} \varepsilon_v h_{soil} \left(\frac{\varepsilon_o}{\varepsilon_r} \right) e^{-\left(\frac{\rho}{n} \right)^{\beta}}$$

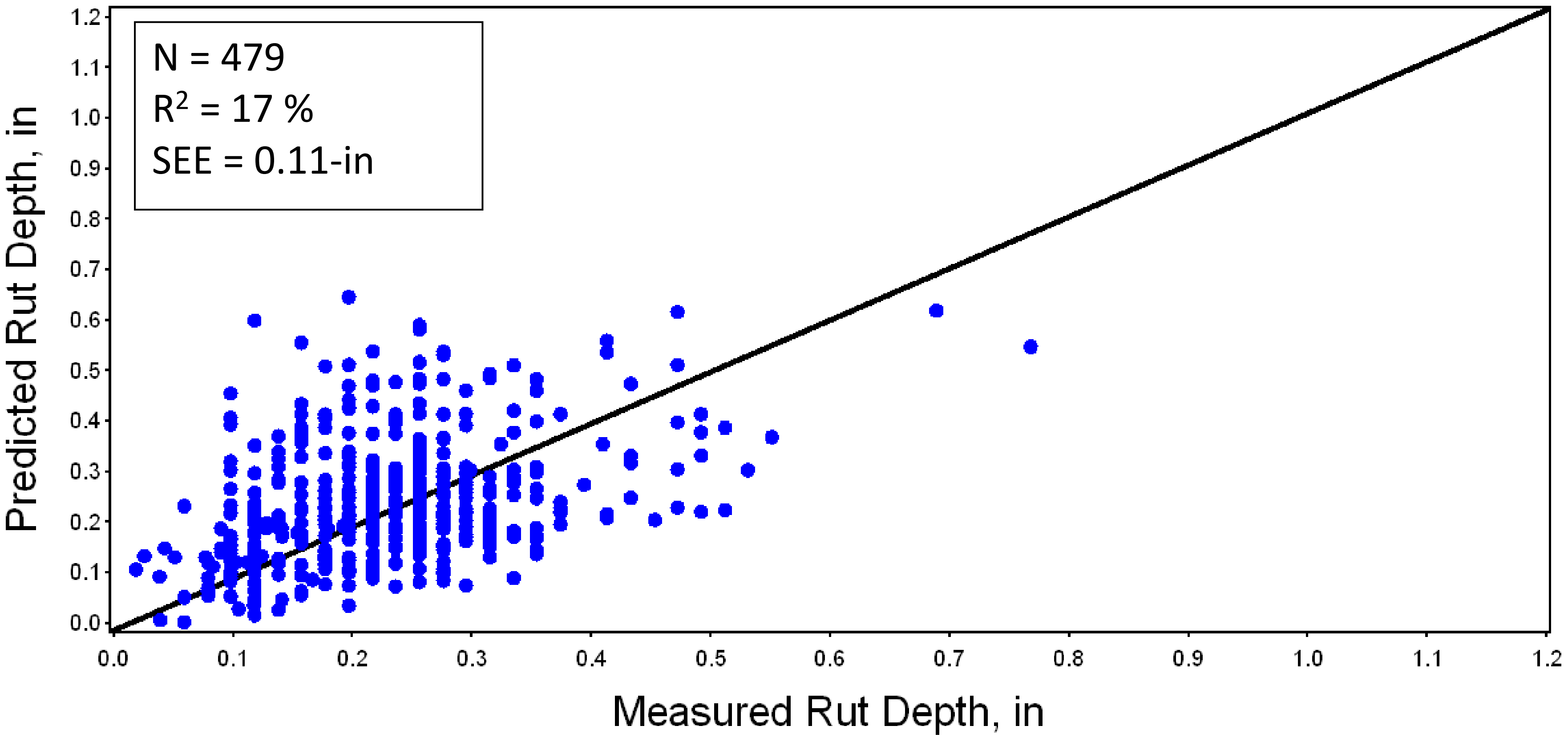
Model Coefficients	**Global Calibration Coef.**	**ADOT Local Calibration Coef.**
BS1	1	0.14

Total Rutting Model

$$\mathrm{TRUT} = \mathbf{0.69} * k_z \varepsilon_{r(HMA)} 10^{k_{1r}} n^{k_{2r}\beta_{2r}} T^{k_{3r}\beta_{3r}}$$

$$+ \mathbf{0.14} * \mathrm{RUT}_{\mathrm{BASE}} + \mathbf{0.37} * \mathrm{RUT}_{\mathrm{SUBG}}$$

Predicted vs Measured Rutting

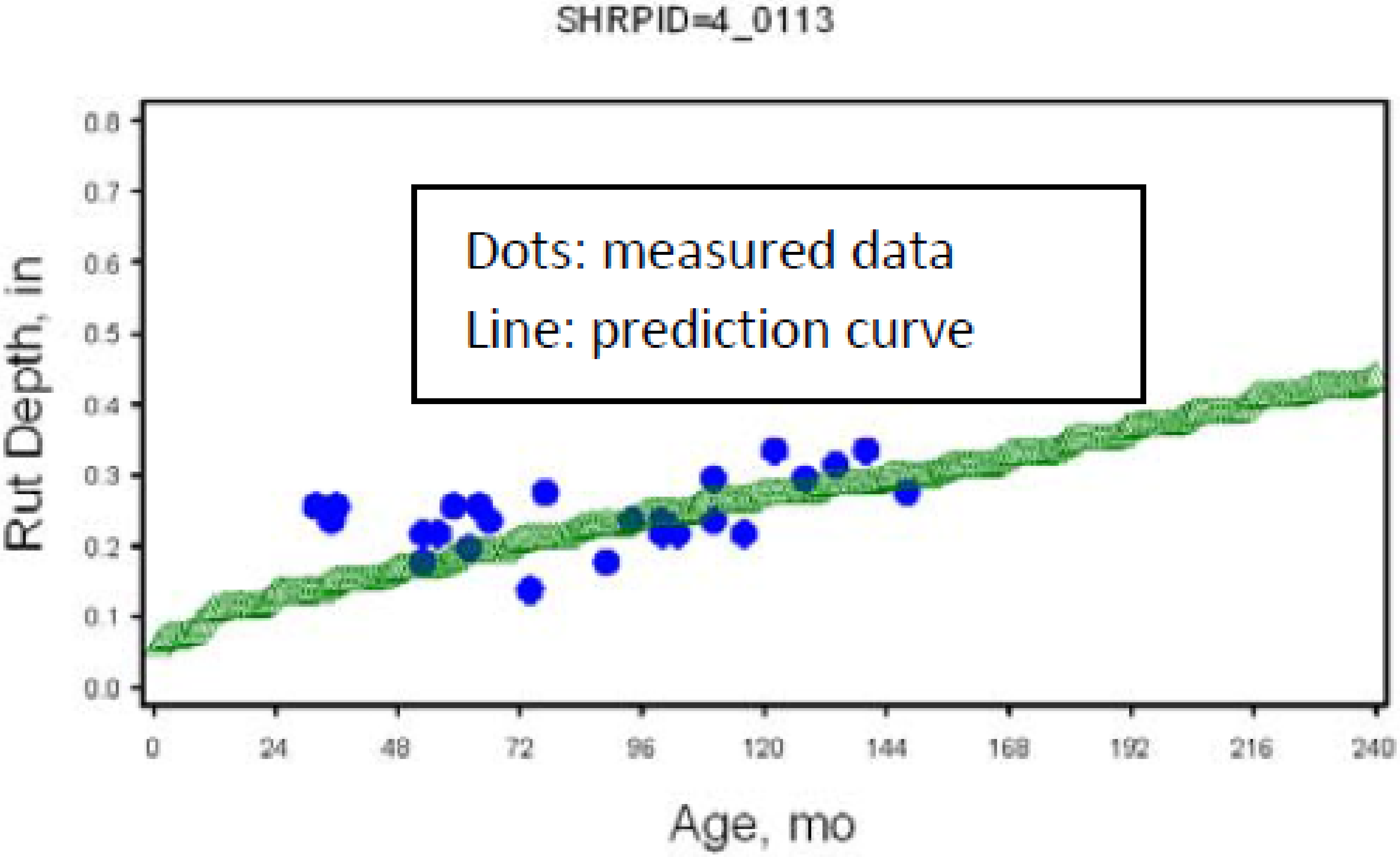


N = 479

R^2 = 17 %

SEE = 0.11-in

Measured vs Predicted Rutting: Case Study


SHRPID=4_0113

Dots: measured data

Line: prediction curve

Lessons Learned from MEPDG Implementation

- Establish realistic timelines for the calibration and validation process.
- Allow sufficient time for obtaining materials and traffic data.
- Obtain the data related to the existing pavements
- Develop agency-based design inputs
- Provide training to agency staff in ME design fundamentals, MEPDG procedures, and the AASHTOWare Pavement ME Design software.

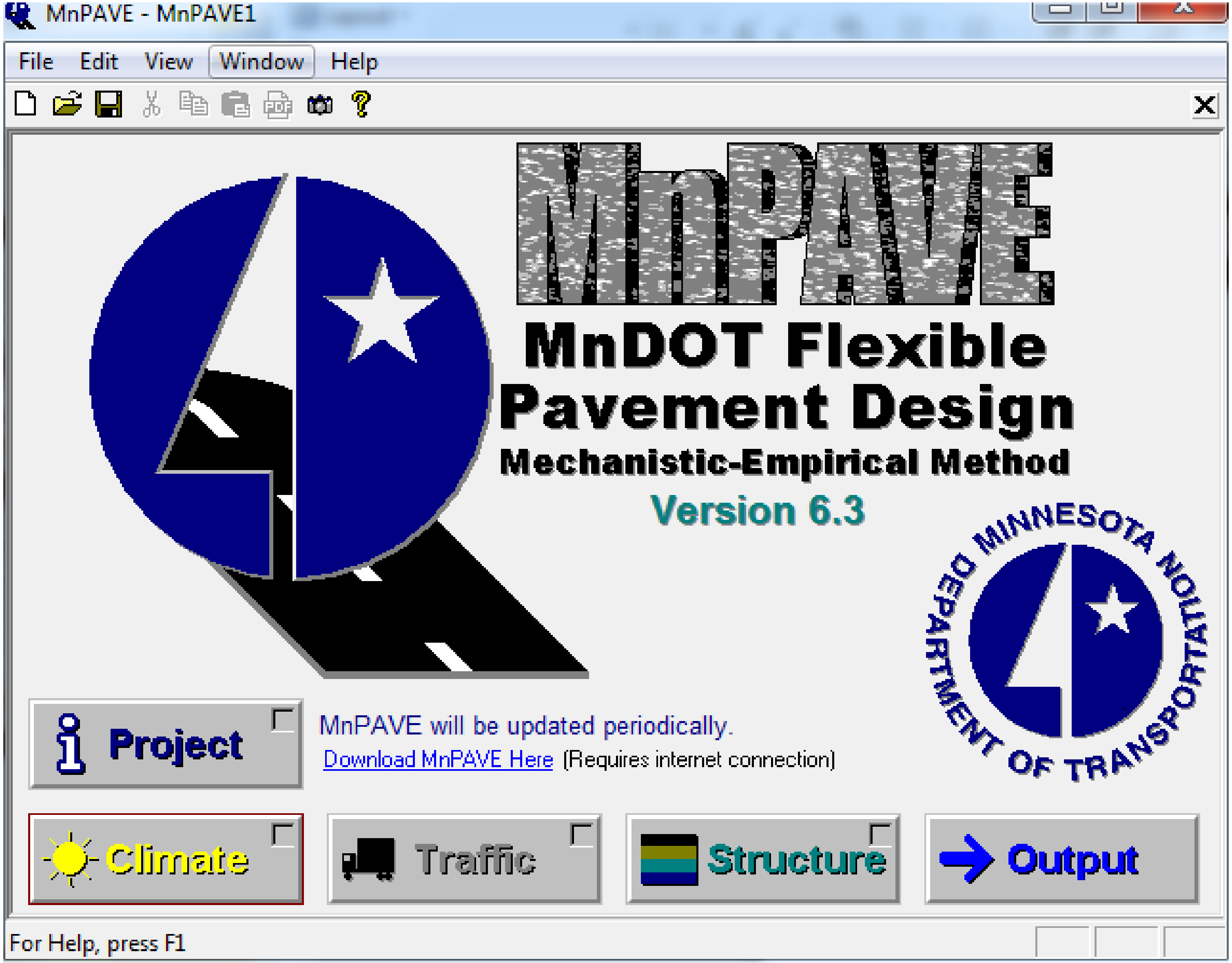
From Pierce and McGovern (2014), NCHRP Synthesis 457

MnDOT Status

- Asphalt pavements: use MnPAVE, no plans to implement MEPDG
  - Introduced in 2000
  - Major calibration in 2006
  - Latest release in spring of 2014

- Concrete pavements: MEPDG-based simplified procedure MnPAVE Rigid
  - Introduced in spring of 2014

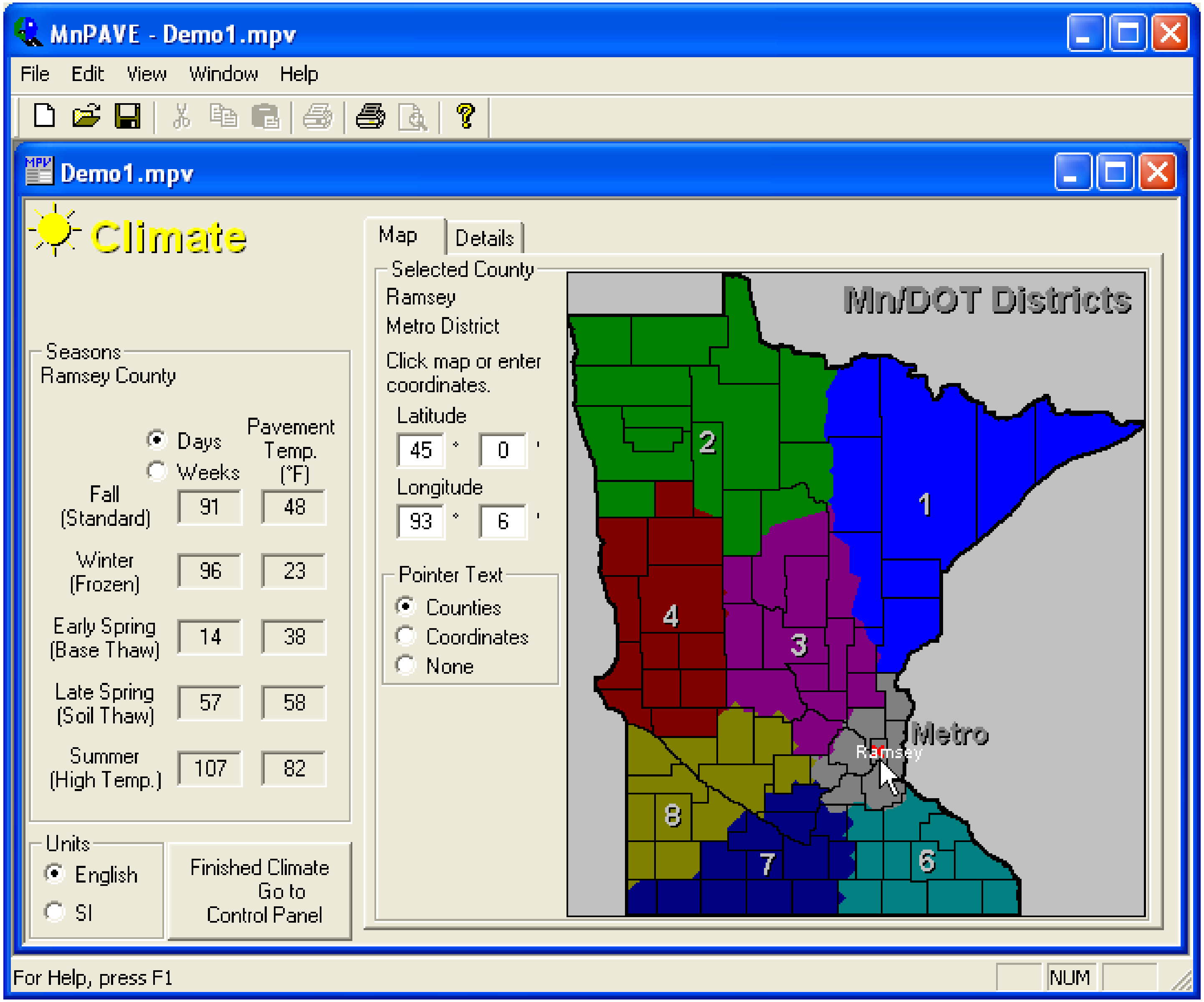
Minnesota ME Design - MnPAVE



MnPAVE will be updated periodically.
Download MnPAVE Here (Requires internet connection)

For Help, press F1

MnPAVE Climate Input



Climate

Seasons
Ramsey County

● Days
○ Weeks

	Days	Pavement Temp. (°F)
Fall (Standard)	91	48
Winter (Frozen)	96	23
Early Spring (Base Thaw)	14	38
Late Spring (Soil Thaw)	57	58
Summer (High Temp.)	107	82

Units
● English
○ SI

Selected County
Ramsey
Metro District

Click map or enter coordinates.

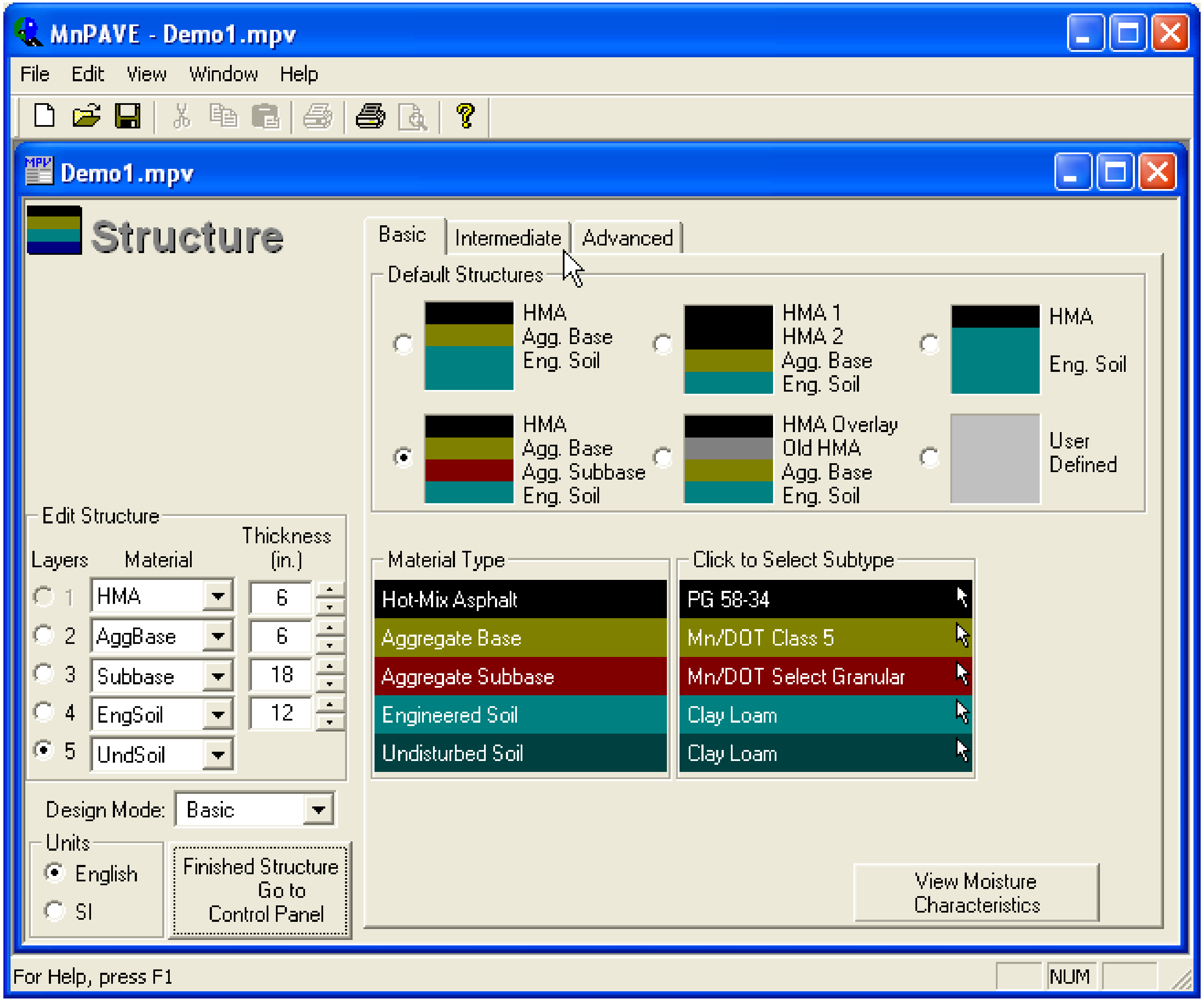
Latitude 45 ° 0 '

Longitude 93 ° 6 '

Pointer Text
● Counties
○ Coordinates
○ None

For Help, press F1

MnPAVE Structure Characterization



Default Structures

- ○ HMA, Agg. Base, Eng. Soil
- ○ HMA 1, HMA 2, Agg. Base, Eng. Soil
- ○ HMA, Eng. Soil
- ● HMA, Agg. Base, Agg. Subbase, Eng. Soil
- ○ HMA Overlay, Old HMA, Agg. Base, Eng. Soil
- ○ User Defined

Edit Structure

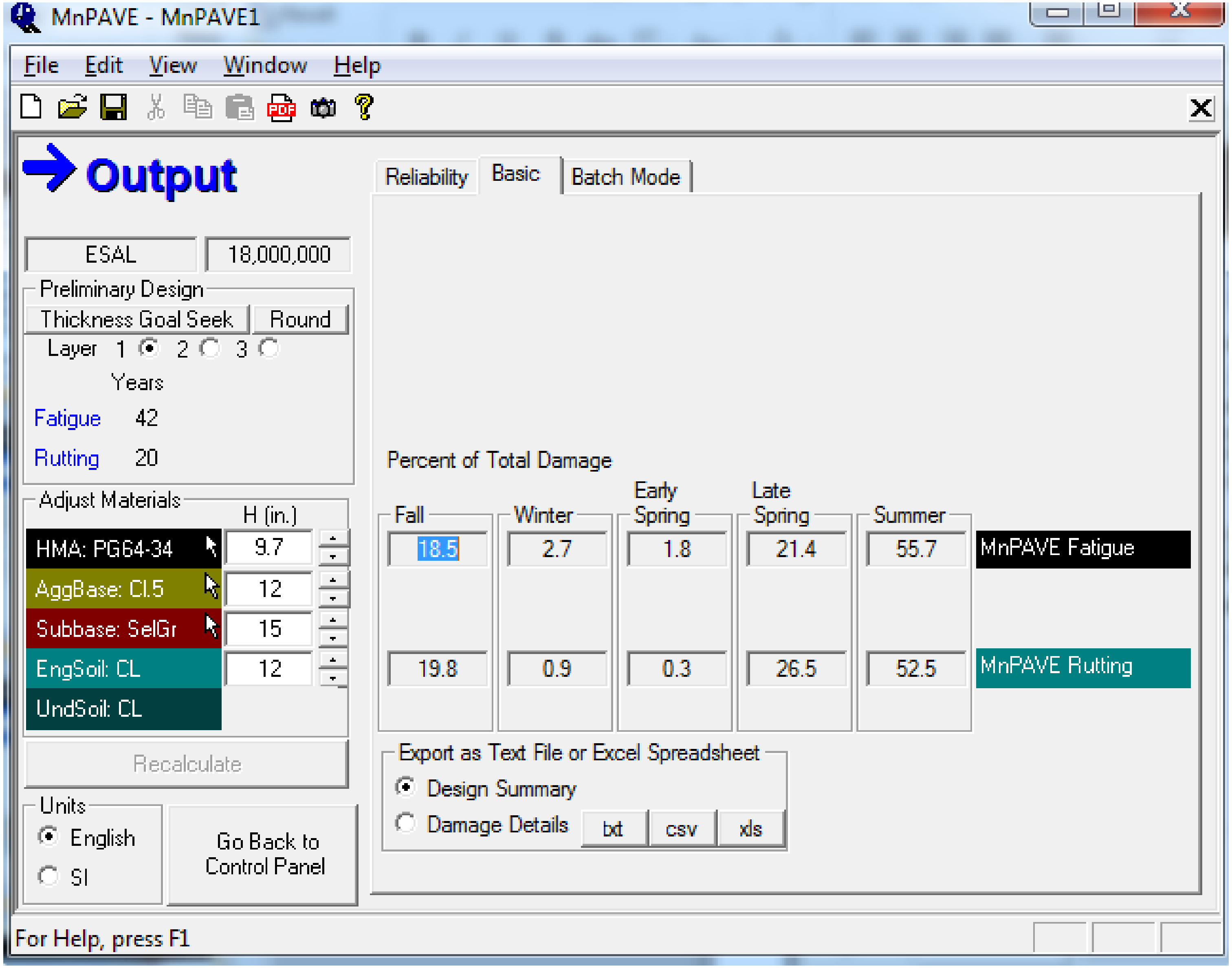
Layers		Material	Thickness (in.)
○	1	HMA	6
○	2	AggBase	6
○	3	Subbase	18
○	4	EngSoil	12
●	5	UndSoil	

Material Type	Click to Select Subtype
Hot-Mix Asphalt	PG 58-34
Aggregate Base	Mn/DOT Class 5
Aggregate Subbase	Mn/DOT Select Granular
Engineered Soil	Clay Loam
Undisturbed Soil	Clay Loam

Design Mode: Basic

Units
● English
○ SI

MnPAVE Outputs



ESAL 18,000,000

Preliminary Design

Layer 1 ● 2 ○ 3 ○

	Years
Fatigue	42
Rutting	20

Adjust Materials

	H (in.)
HMA: PG64-34	9.7
AggBase: Cl.5	12
Subbase: SelGr	15
EngSoil: CL	12
UndSoil: CL	

Units
● English
○ SI

Percent of Total Damage

Fall	Winter	Early Spring	Late Spring	Summer	
18.5	2.7	1.8	21.4	55.7	MnPAVE Fatigue
19.8	0.9	0.3	26.5	52.5	MnPAVE Rutting

Export as Text File or Excel Spreadsheet
● Design Summary
○ Damage Details

Minnesota ME Design - MnPAVE

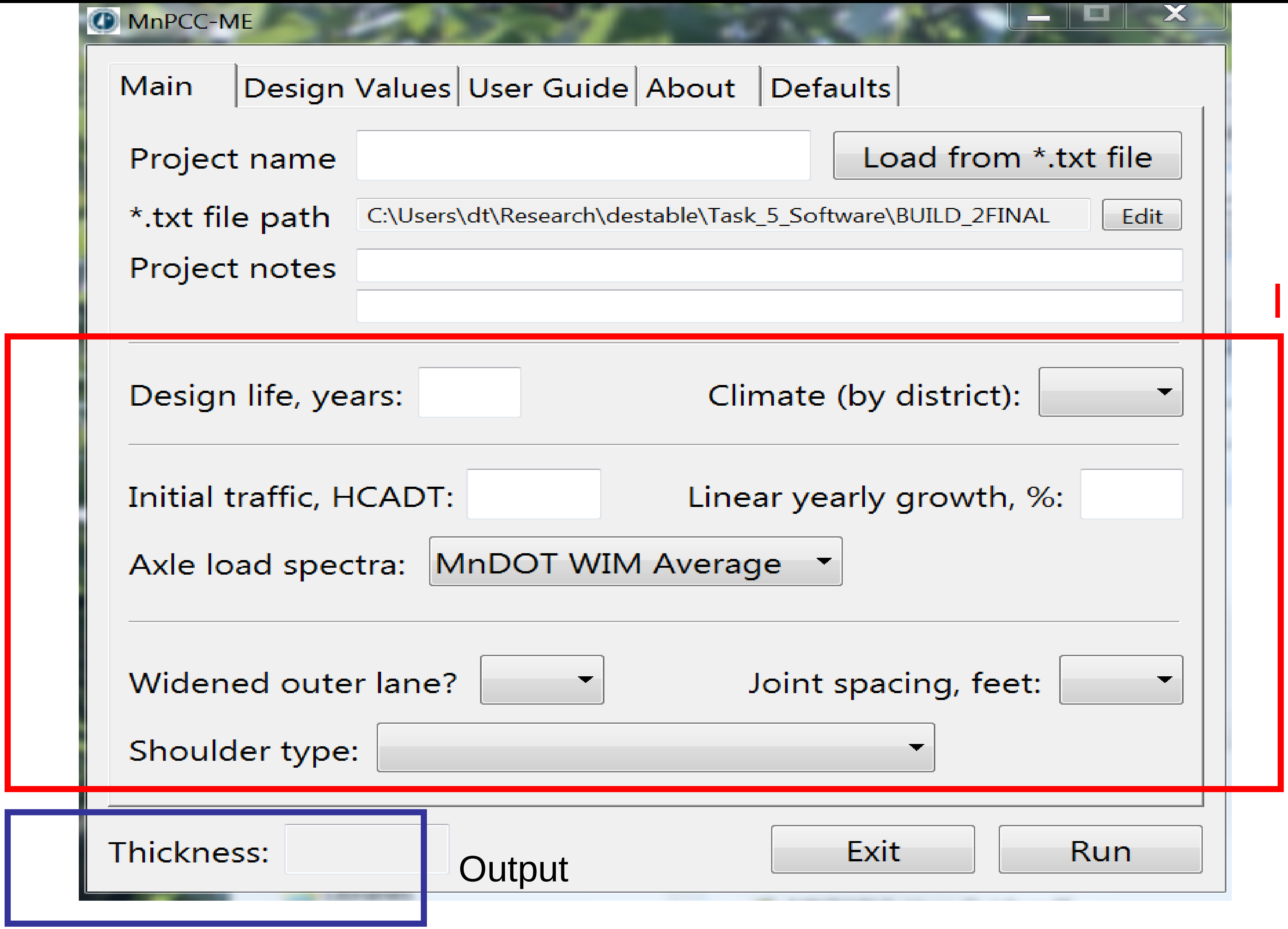
- MnPave Flexible design process is similar to MEPDG, but has differences:
  - Minnesota specific climate
  - Limited to 5 layers
  - Analysis is bottom-up fatigue, subgrade rutting, and base failure
  - Optimization options
- Royalty-free software

MnPAVE Rigid

MEPDG-based simplified procedure for concrete pavements

- Minnesota-specific default inputs
- Limited number of input paramters
- Based on 11,000 MEPDG v1.1 runs
- Royalty-free software

MnPAVE Rigid



MnPCC-ME

Project name:

Load from *.txt file

*.txt file path: C:\Users\dt\Research\destable\Task_5_Software\BUILD_2FINAL

Edit

Project notes:

Design life, years:

Climate (by district):

Initial traffic, HCADT:

Linear yearly growth, %:

Axle load spectra: MnDOT WIM Average

Widened outer lane?

Joint spacing, feet:

Shoulder type:

Thickness:

Inputs

Output

Conclusions

- M-E design procedures offer significant benefits
- M-E design procedures are more complex than empirical design
- Implementation of M-E procedures require significant efforts