DEVELOPMENT OF SIMPLIFIED MECHANISTIC-EMPIRICAL DESIGN TOOL FOR PENNSYLVANIA RIGID PAVEMENTS (PITTRIGID-ME)

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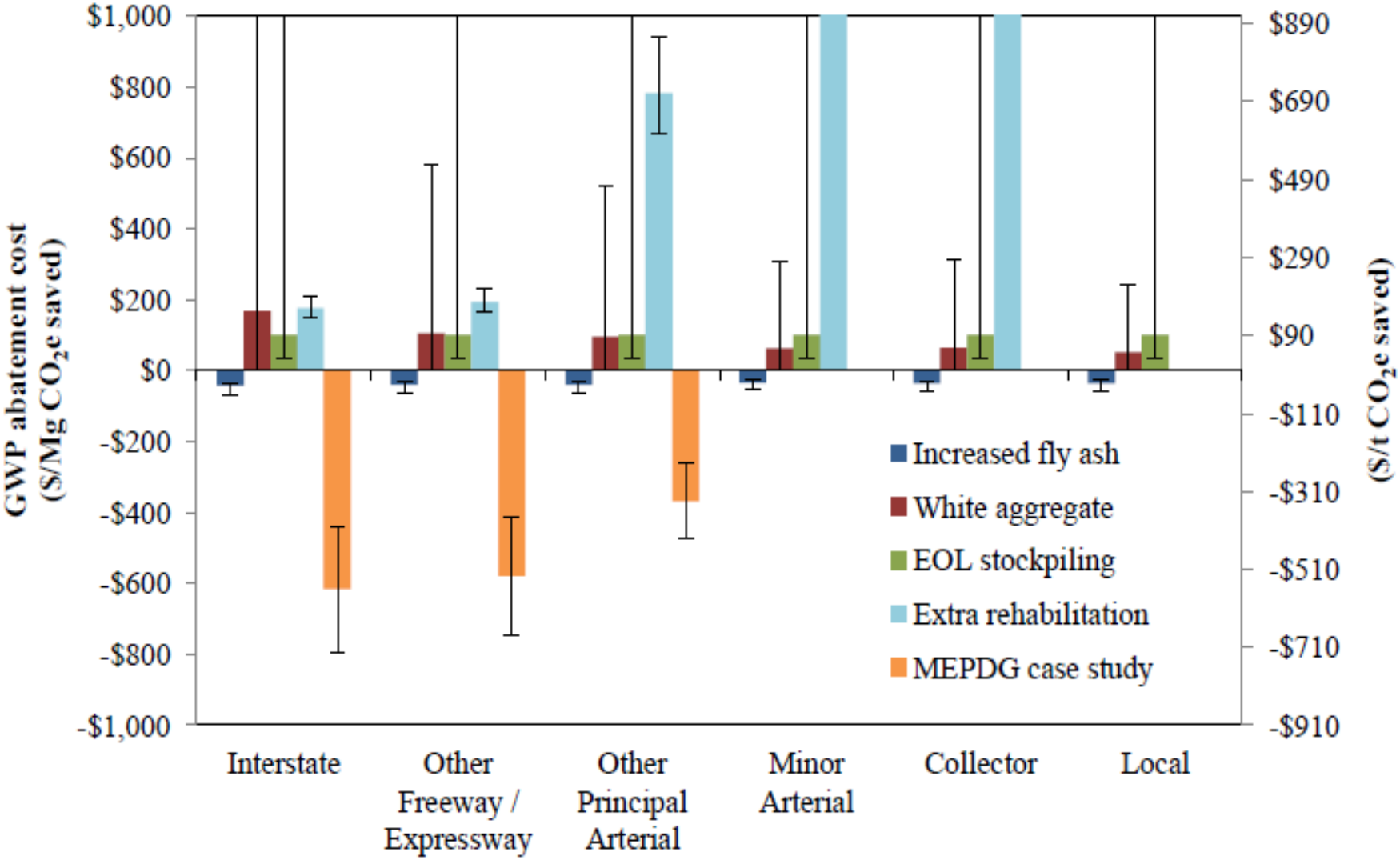
THE PROBLEM

- The current Pennsylvania design method for rigid pavements is outdated
  - AASHTO 93-based procedure (1960-s technology)
  - Not cost-effective: many empirical evidences of overdesign built into AASHTO 93
- Pennsylvania is transitioning to AASHTO ME design, which requires the user:
  - to provide many inputs thus increasing possibilities of the design errors
  - to use AASHTOWare Pavement ME software with an expensive license

WHY AASHTO ME DESIGN?



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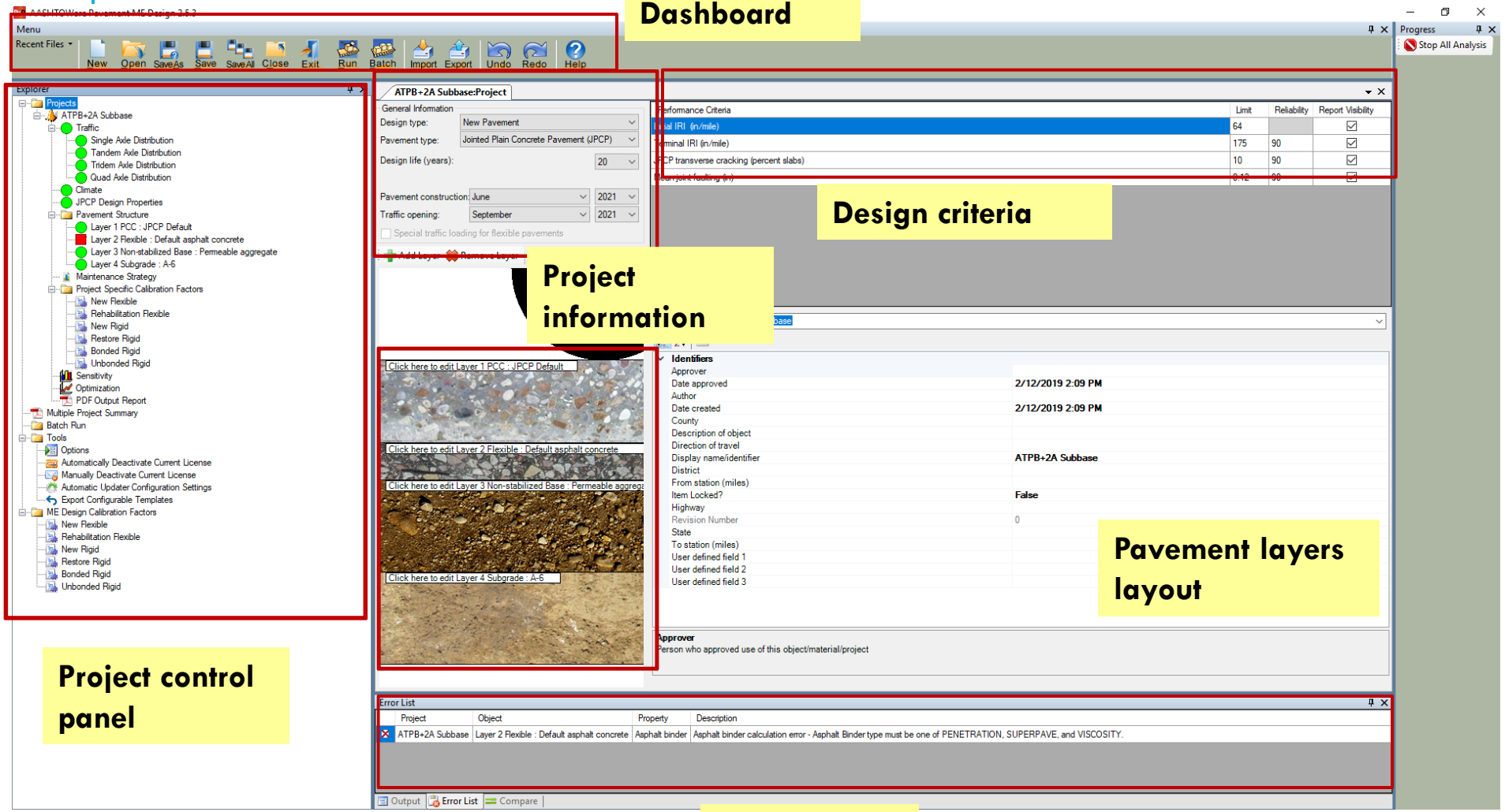
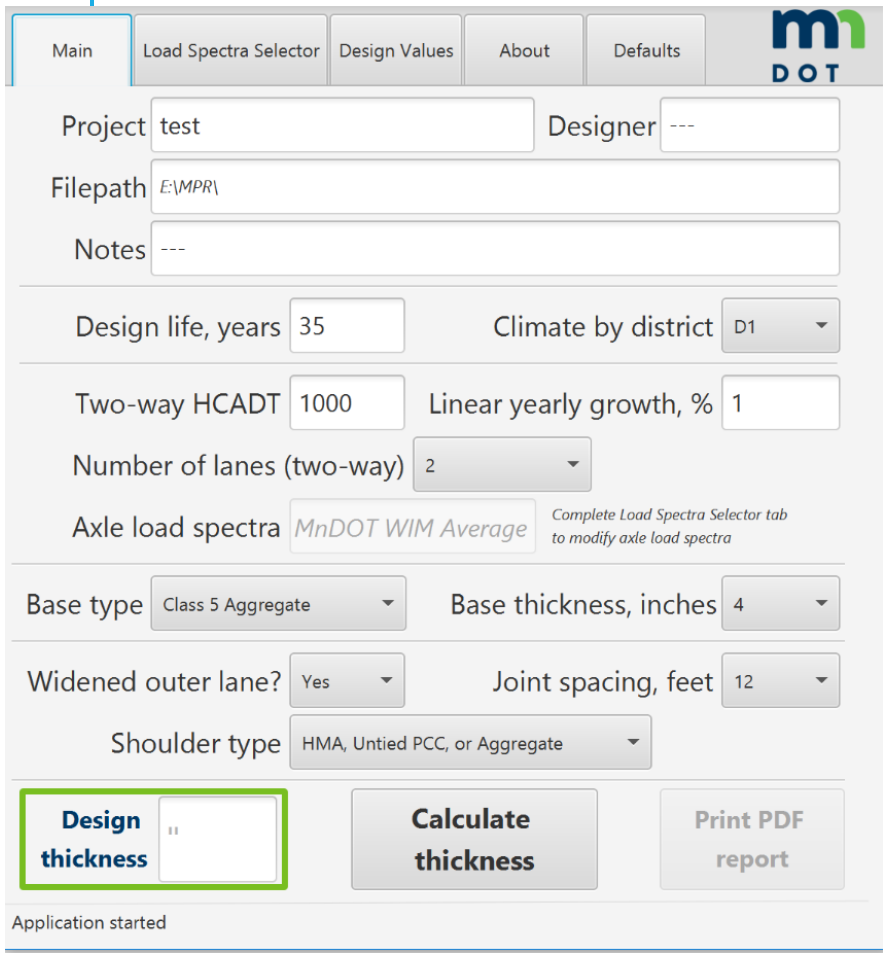
AASHTOWARE PAVEMENT ME

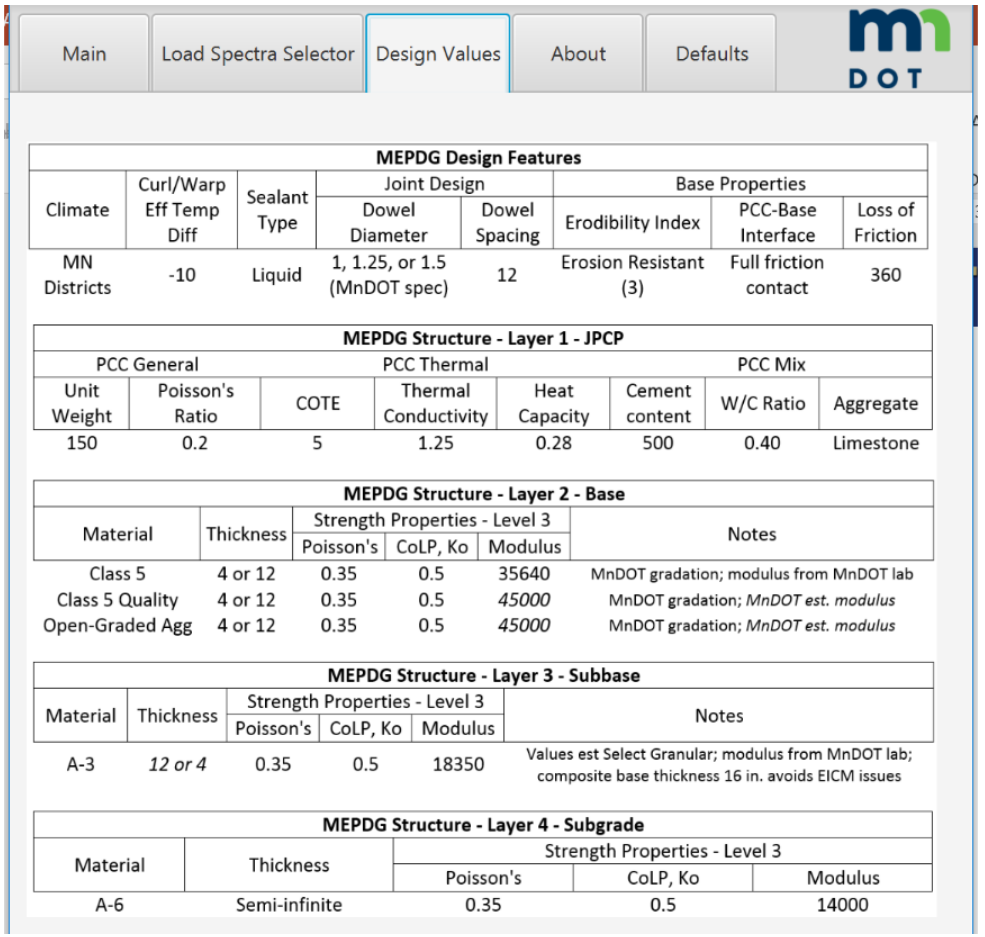


RESEARCH OBJECTIVES

- Provide effective, localized design tool to Pennsylvania pavement engineers compatible with the AASHTOWare Pavement ME program similar to MnPAVE Rigid, the tool used by MnDOT
- Accelerate implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG)
- Reduce potential of design errors from the improper use of the AASHTOWare Pavement ME software
- Reduce or eliminate license fees required to perform MEPDG design using the AASHTOWare Pavement ME software

MNPAVE RIGID





MEPDG Design Features

Climate	Curl/Warp Eff Temp Diff	Sealant Type	Joint Design		Base Properties		
			Dowel Diameter	Dowel Spacing	Erodibility Index	PCC-Base Interface	Loss of Friction
MN Districts	-10	Liquid	1, 1.25, or 1.5 (MnDOT spec)	12	Erosion Resistant (3)	Full friction contact	360

MEPDG Structure - Layer 1 - JPCP

PCC General			PCC Thermal		PCC Mix		
Unit Weight	Poisson's Ratio	COTE	Thermal Conductivity	Heat Capacity	Cement content	W/C Ratio	Aggregate
150	0.2	5	1.25	0.28	500	0.40	Limestone

MEPDG Structure - Layer 2 - Base

Material	Thickness	Strength Properties - Level 3			Notes
		Poisson's	CoLP, Ko	Modulus	
Class 5	4 or 12	0.35	0.5	35640	MnDOT gradation; modulus from MnDOT lab
Class 5 Quality	4 or 12	0.35	0.5	*45000*	MnDOT gradation; *MnDOT est. modulus*
Open-Graded Agg	4 or 12	0.35	0.5	*45000*	MnDOT gradation; *MnDOT est. modulus*

MEPDG Structure - Layer 3 - Subbase

Material	Thickness	Strength Properties - Level 3			Notes
		Poisson's	CoLP, Ko	Modulus	
A-3	*12 or 4*	0.35	0.5	18350	Values est Select Granular; modulus from MnDOT lab; composite base thickness 16 in. avoids EICM issues

MEPDG Structure - Layer 4 - Subgrade

Material	Thickness	Strength Properties - Level 3		
		Poisson's	CoLP, Ko	Modulus
A-6	Semi-infinite	0.35	0.5	14000

APPROACH - TASKS

Task 1. Literature and Software Review and Sensitivity Analysis

Task 2: Perform Pavement ME Factorial and Develop Simplified Design Tool, PittRigid-ME

Task 3: Conduct PittRigid-ME Verification

Task 4: Final Report

PROGRESS TO DATE

- Evaluated relevant literature dealing with Pavement ME inputs and sensitivity studies
- Performed preliminary sensitivity study and evaluated relative significance of the inputs for Pennsylvania conditions
- Recommended design features for PittRigid-ME

PAVEMENT ME INPUTS

- Traffic
  - Annual Average Daily Truck Traffic (AADTT)
  - Vehicle class distribution
  - ….
- Climate (weather stations)
- JPCP Design Features
  - PCC thickness
  - Joint spacing
  - Shoulder type
  - Dowel diameter
  - Base type and thickness

PAVEMENT ME TRAFFIC INPUTS

ATPB+2A Subbase:Project | ATPB+2A Subbase:Traffic

AADTT

Two-way AADTT	2000
Number of lanes	4
Percent trucks in design dire	50
Percent trucks in design lan	95
Operational speed (mph)	60

Traffic Capacity

Traffic Capacity Cap	Not enforced

Axle Configuration

Average axle width (ft)	8.5
Tandem axle spacing (in)	51.6
Dual tire spacing (in)	12
Quad axle spacing (in)	49.2
Tire pressure (psi)	120
Tridem axle spacing (in)	49.2

Lateral Wander

Design lane width (ft)	12
Mean wheel location (in)	18
Traffic wander standard dev	10

Wheelbase

Average spacing of long axl	18
Average spacing of medium	15
Percent trucks with long axl	61
Percent trucks with medium	22
Percent trucks with short ax	17
Average spacing of short ax	12

Identifiers

Approver	
Date approved	1/1/2011
Author	AASHTOWare
~~Date created~~	~~1/1/2011~~
County	
Description of object	Default Traffic File

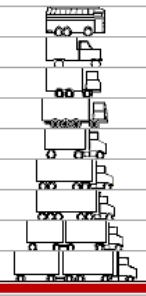
To station (miles)

Traffic Capacity Cap

Basic design lane and traffic configuration

Vehicle Class Distribution and Growth — Load Default Distribution

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	2	Linear
Class 5	34	2	Linear
Class 6	11.7		
Class 7	1.6		
Class 8	9.9		
Class 9	36.2	2	Linear
Class 10	1	2	Linear
Class 11	1.8	2	Linear
Class 12	0.2	2	Linear



Annual growth rate

Monthly Adjustment — Import Monthly Adjustmen

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1	1	1	1	1	1	1	1	1	1
February	1	1	1	1	1	1	1	1	1	1
March	1	1	1	1	1	1	1	1	1	1
April	1	1	1							1
May	1	1	1							1
June	1	1	1							1
July	1	1	1							1
August	1	1	1	1	1	1	1	1	1	1
September	1	1	1	1	1	1	1	1	1	1

Monthly Adjustment Factor (MAF)

Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0

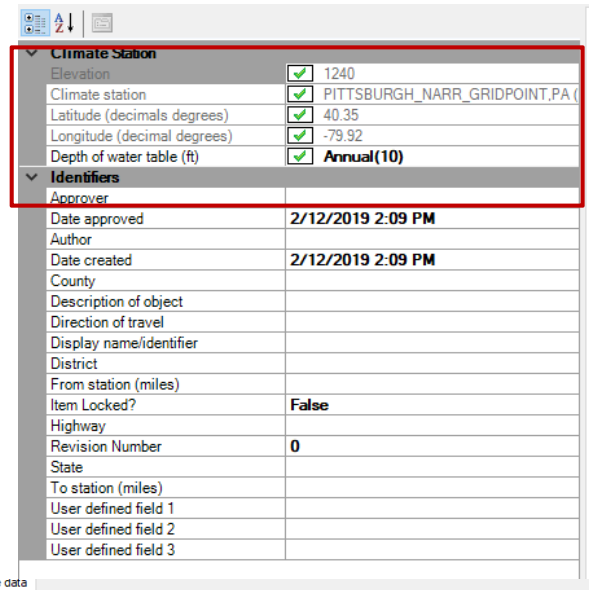
Axle spectrum distribution

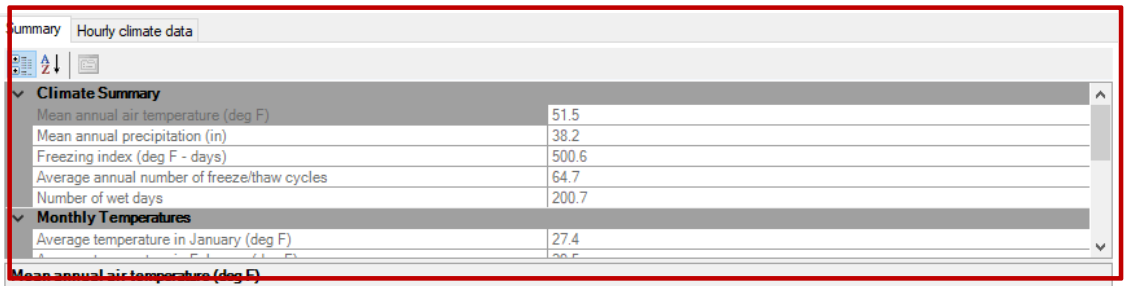
Hourly Adjustment

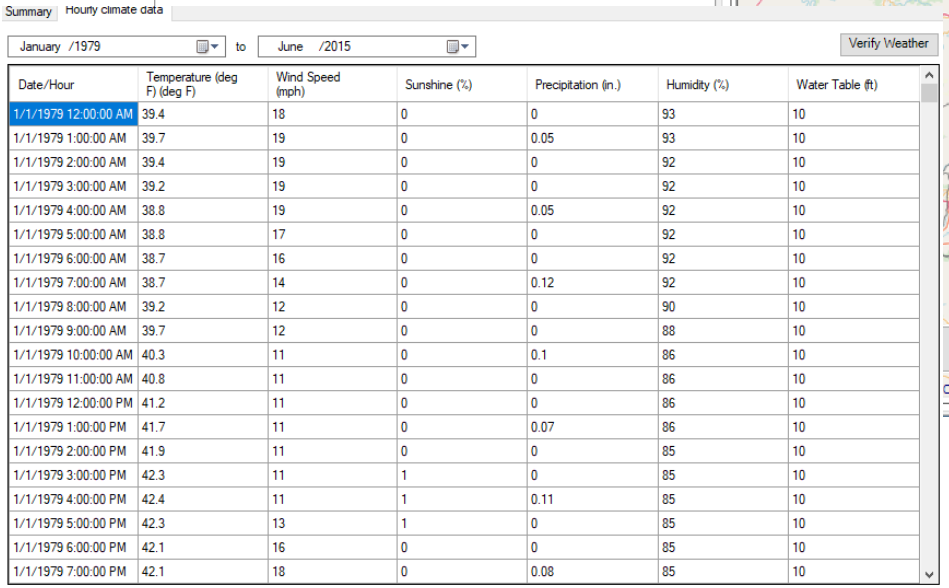
Time of Day	Percentage
12:00 am	2.3
1:00 am	2.3
2:00 am	2.3
3:00 am	2.3
4:00 am	2.3
5:00 am	2.3
6:00 am	5
7:00 am	5
8:00 am	5
9:00 am	5
10:00 am	5.9
11:00 am	5.9
12:00 pm	5.9
1:00 pm	5.9
2:00 pm	5.9
3:00 pm	5.9
4:00 pm	4.6
5:00 pm	4.6
6:00 pm	4.6
7:00 pm	4.6
8:00 pm	3.1
9:00 pm	3.1
10:00 pm	3.1
11:00 pm	3.1
Total	100.0

Hourly Adjustment Factor (HAF)

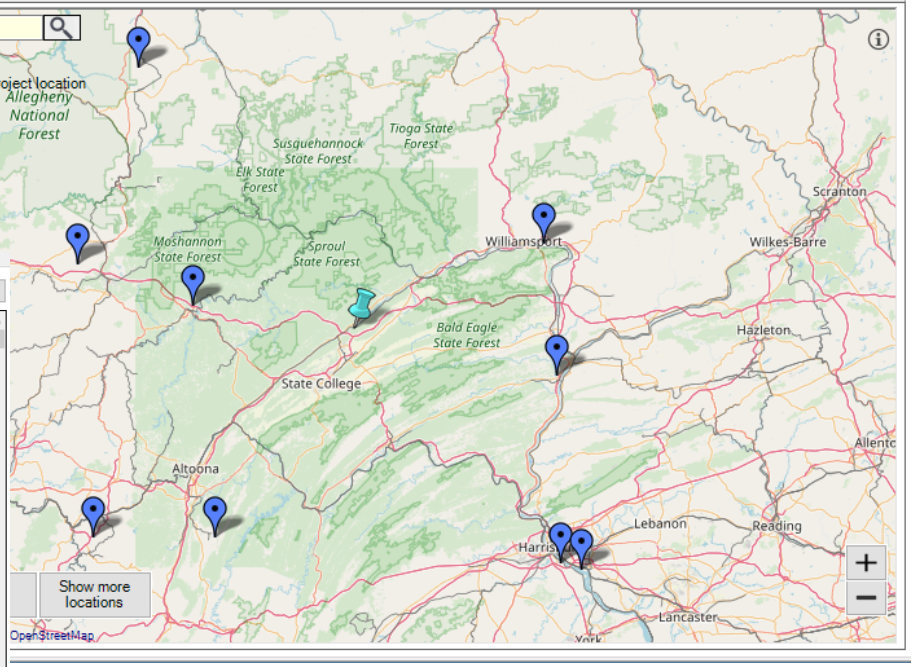
PAVEMENT ME CLIMATE INPUTS





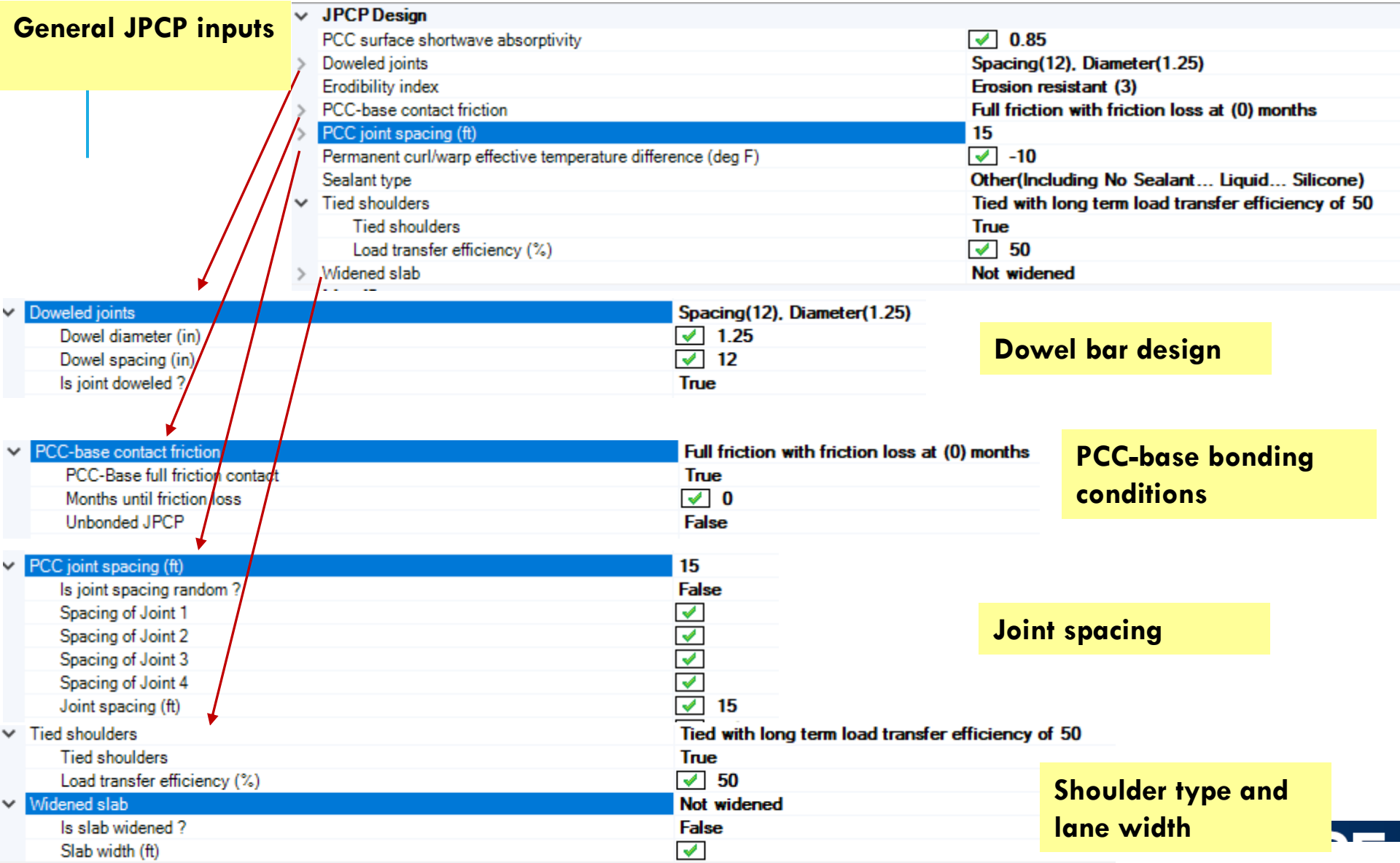


Date/Hour	Temperature (deg F) (deg F)	Wind Speed (mph)	Sunshine (%)	Precipitation (in.)	Humidity (%)	Water Table (ft)
1/1/1979 12:00:00 AM	39.4	18	0	0	93	10
1/1/1979 1:00:00 AM	39.7	19	0	0.05	93	10
1/1/1979 2:00:00 AM	39.4	19	0	0	92	10
1/1/1979 3:00:00 AM	39.2	19	0	0	92	10
1/1/1979 4:00:00 AM	38.8	19	0	0.05	92	10
1/1/1979 5:00:00 AM	38.8	17	0	0	92	10
1/1/1979 6:00:00 AM	38.7	16	0	0	92	10
1/1/1979 7:00:00 AM	38.7	14	0	0.12	92	10
1/1/1979 8:00:00 AM	39.2	12	0	0	90	10
1/1/1979 9:00:00 AM	39.7	12	0	0	88	10
1/1/1979 10:00:00 AM	40.3	11	0	0.1	86	10
1/1/1979 11:00:00 AM	40.8	11	0	0	86	10
1/1/1979 12:00:00 PM	41.2	11	0	0	86	10
1/1/1979 1:00:00 PM	41.7	11	0	0.07	86	10
1/1/1979 2:00:00 PM	41.9	11	0	0	85	10
1/1/1979 3:00:00 PM	42.3	11	1	0	85	10
1/1/1979 4:00:00 PM	42.4	11	1	0.11	85	10
1/1/1979 5:00:00 PM	42.3	13	1	0	85	10
1/1/1979 6:00:00 PM	42.1	16	0	0	85	10
1/1/1979 7:00:00 PM	42.1	18	0	0.08	85	10



PAVEMENT ME JPCP DESIGN INPUTS

General JPCP inputs



Dowel bar design

PCC-base bonding conditions

Joint spacing

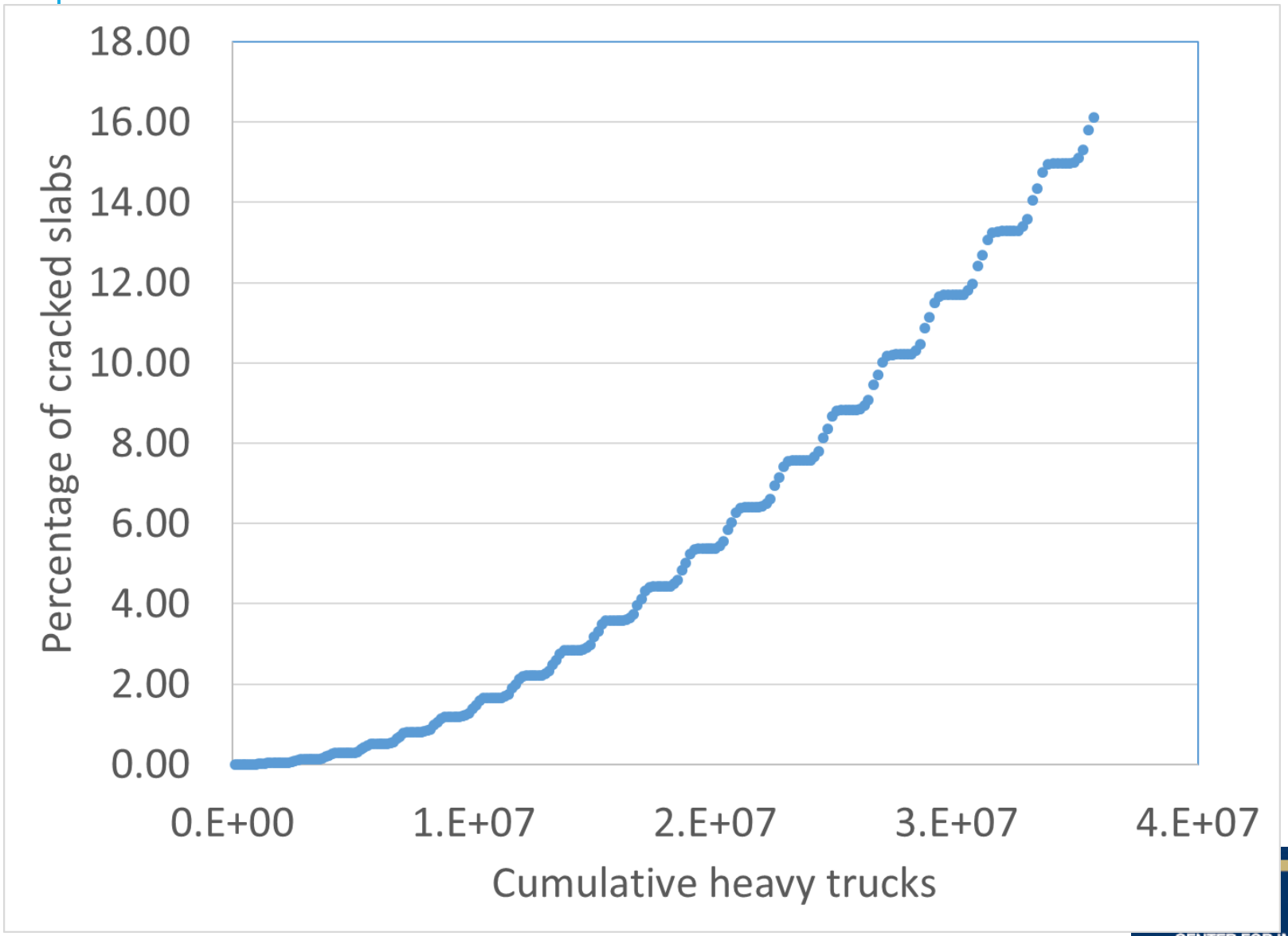
Shoulder type and lane width

SENSITIVITY ANALYSIS

More than 100 Pavement ME runs

- 7-in thick Jointed Plain Concrete Pavement
- 9-in thick Jointed Plain Concrete Pavement

SENSITIVITY ANALYSIS



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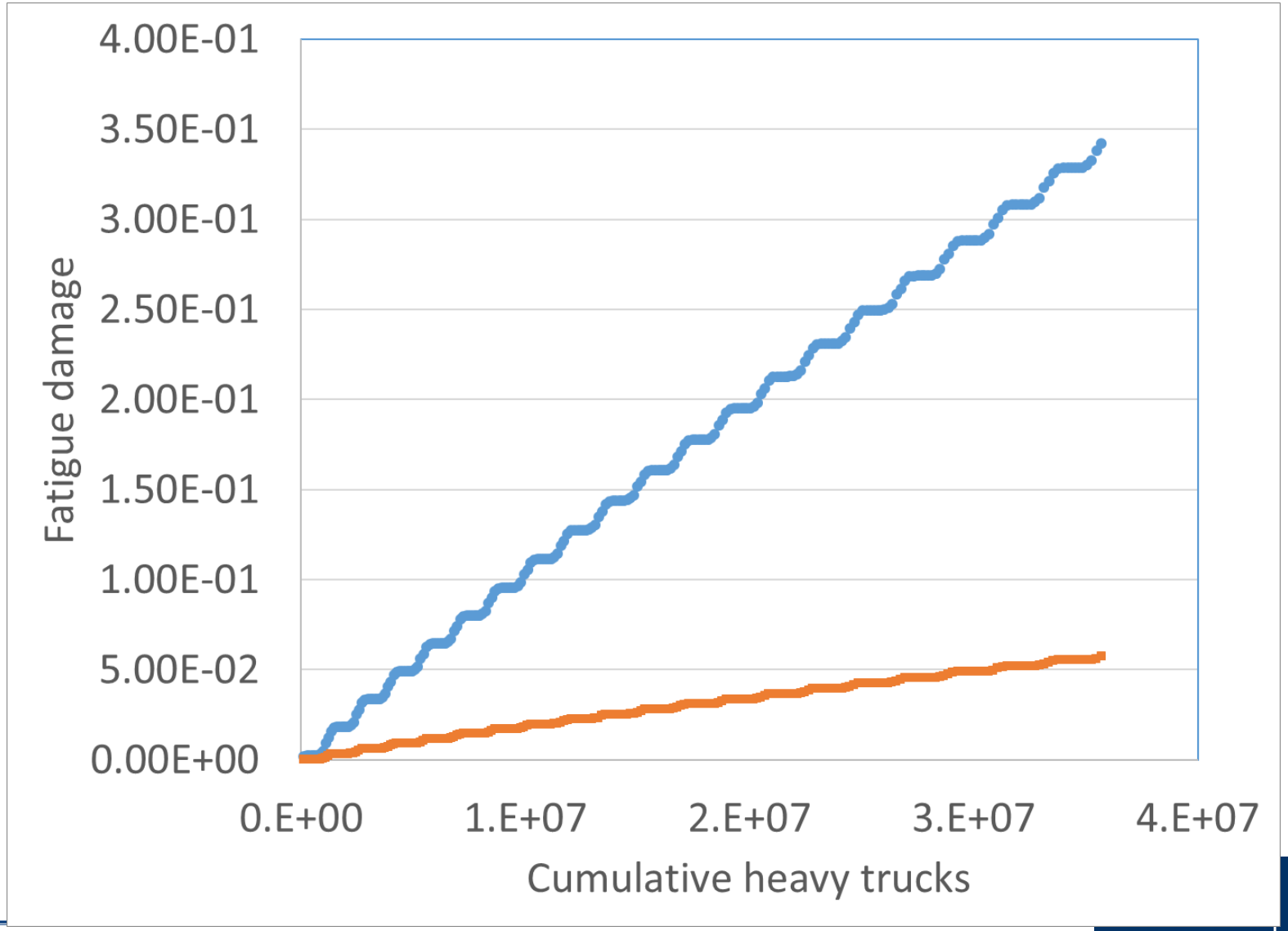

CLIMATE INPUTS

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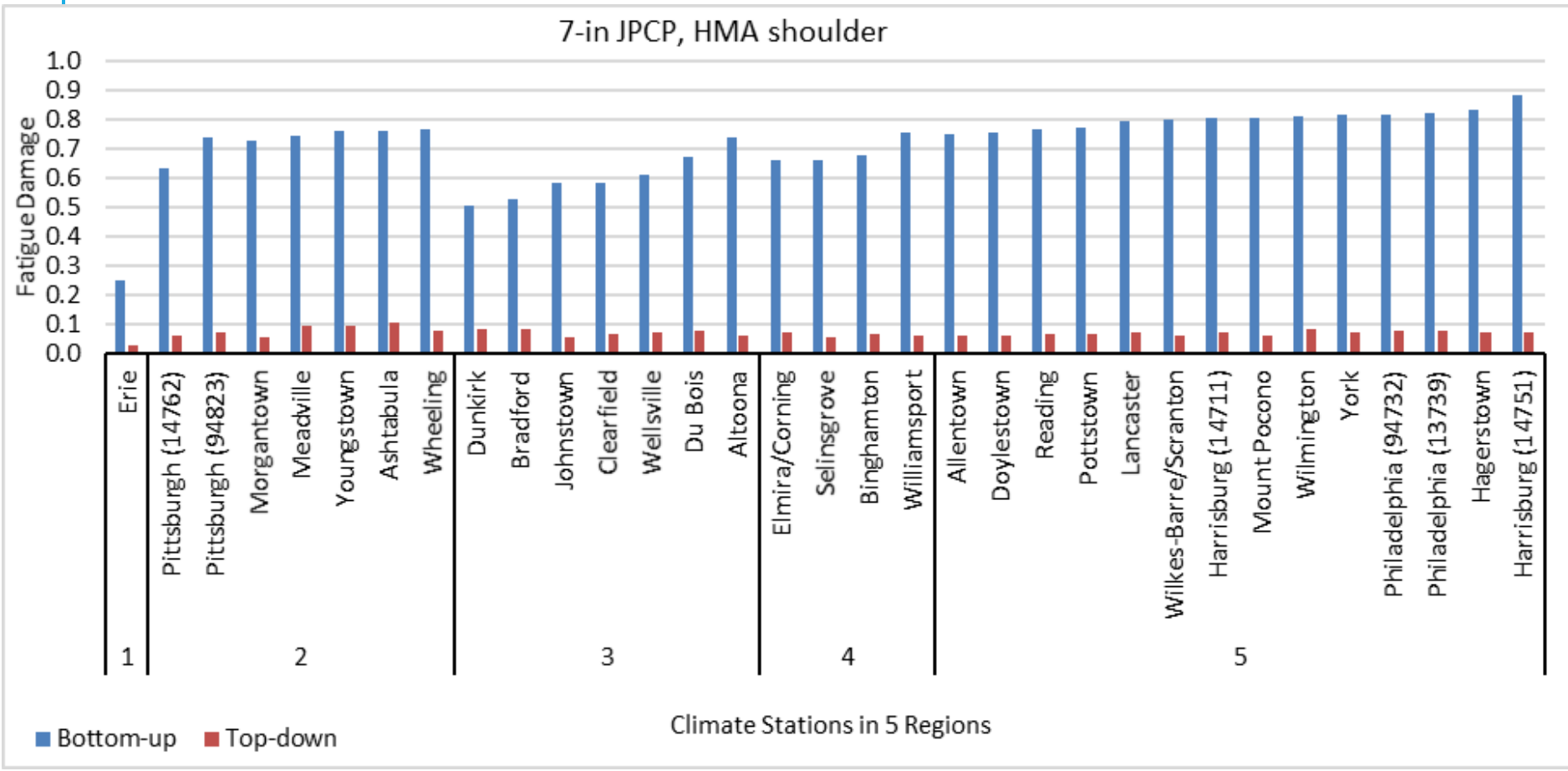

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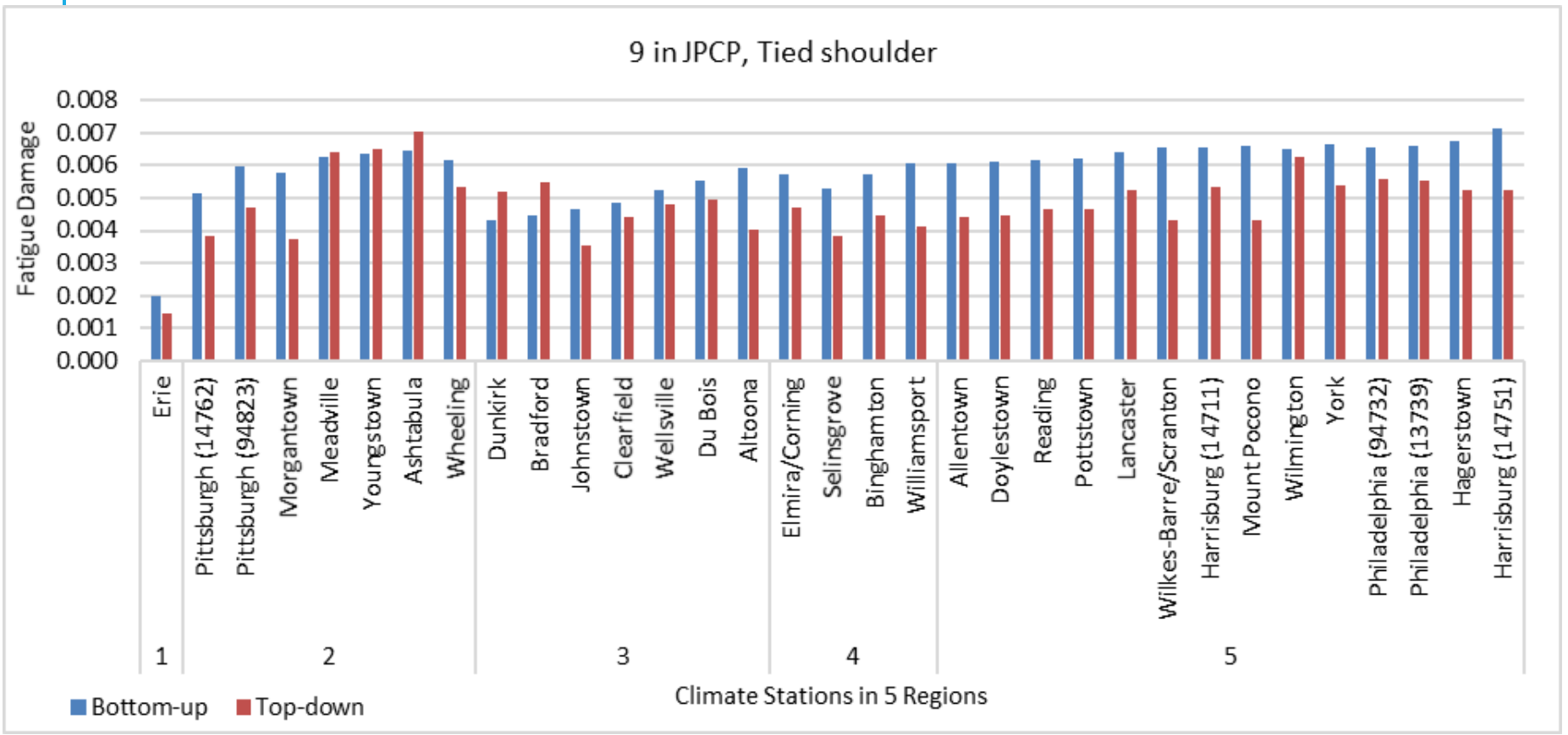
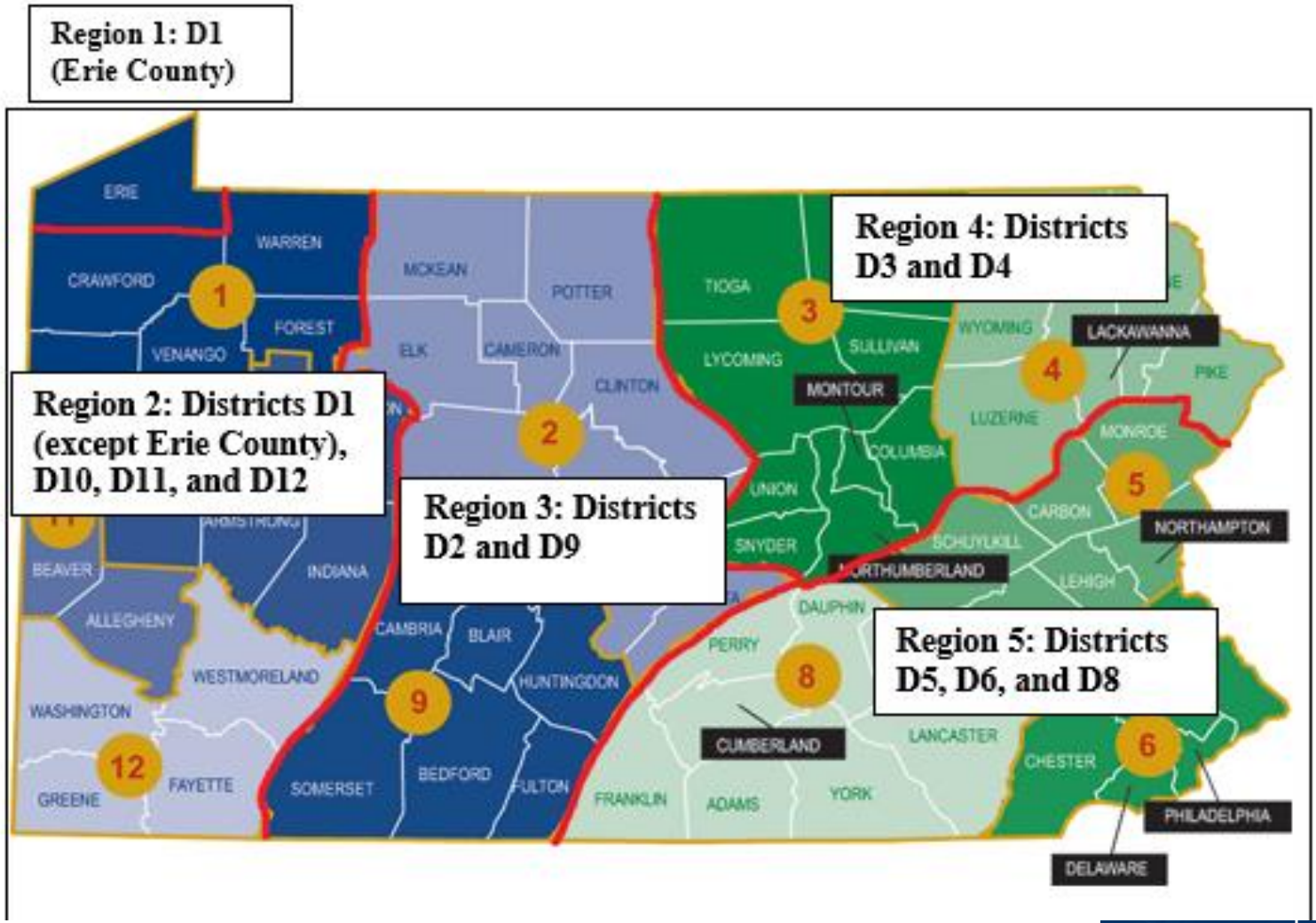
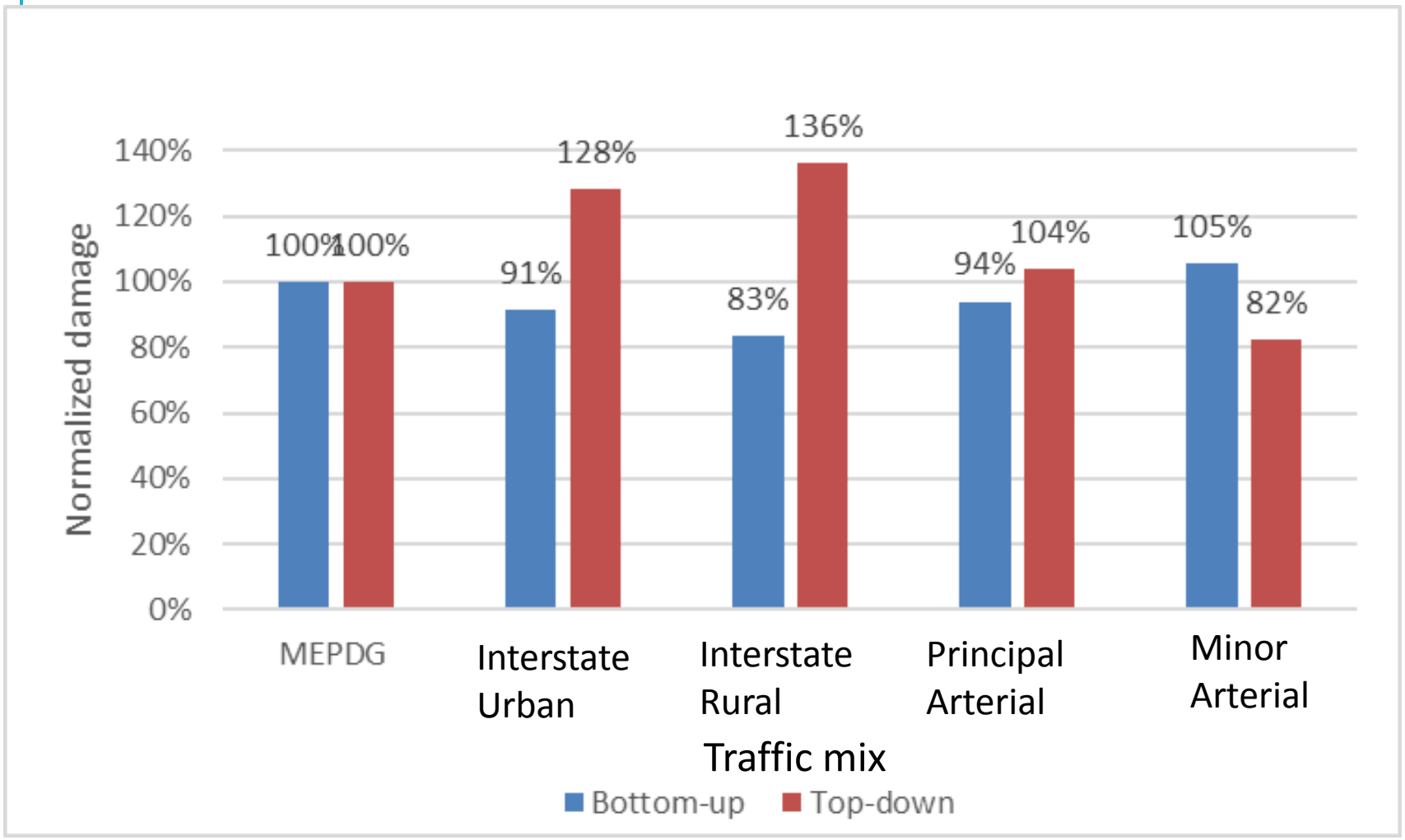


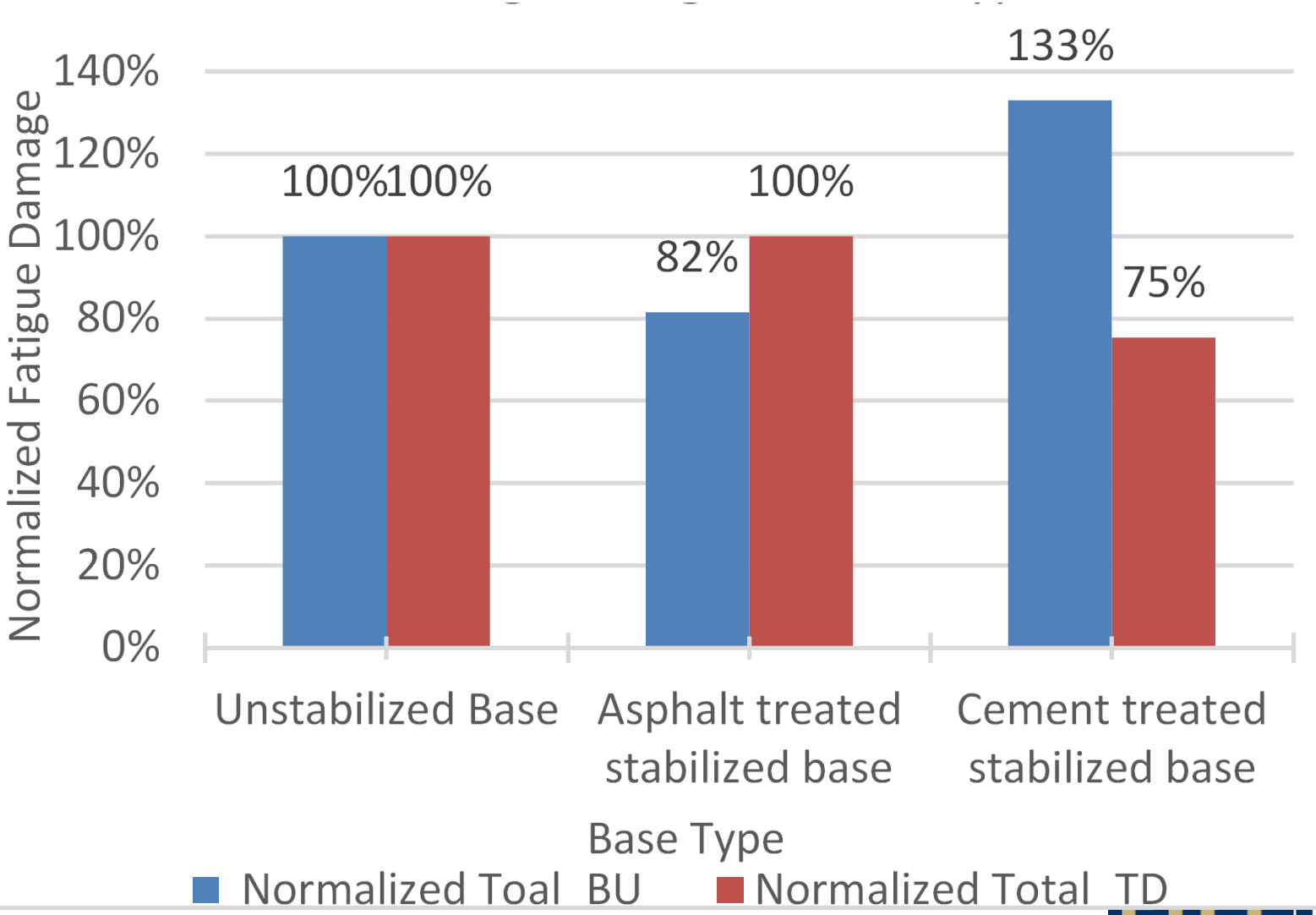
CLIMATE INPUTS RECOMMENDATIONS



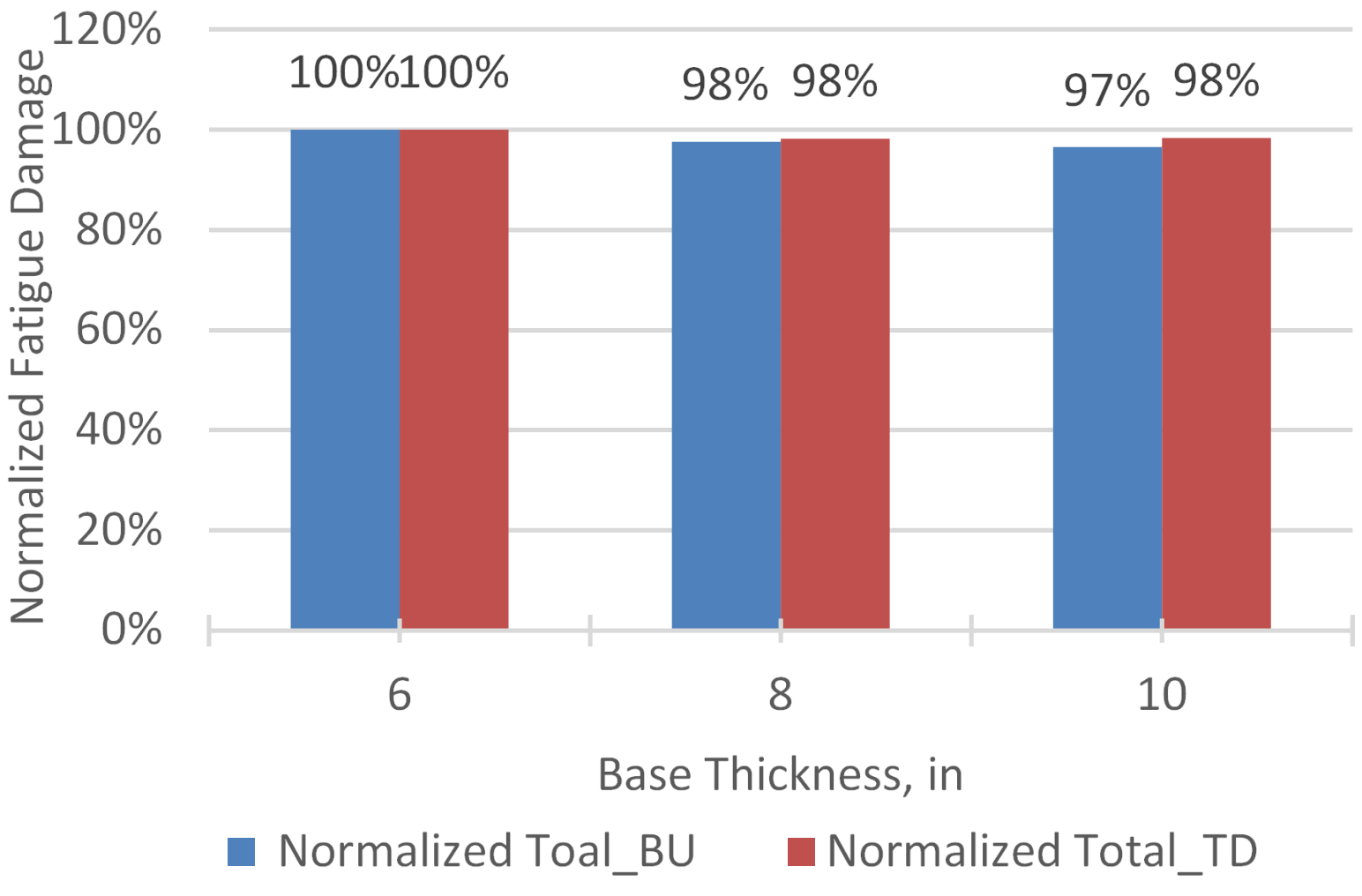
TRAFFIC INPUTS



EFFECT OF BASE TYPE



EFFECT OF BASE THICKNESS



RECOMMENDED PITTRIGID-ME DESIGN INPUTS

- Design life: 1-100 years
- Climate Regions
  - Region 1: Erie County
  - Region 2: PennDOT Districts D1 (except Eire County), D10, D11, and D12
  - Region 3: PennDOT Districts D2 and D9
  - Region 4: PennDOT Districts D3 and D4
  - Region 5: PennDOT Districts D5, D6, and D8

RECOMMENDED PITTRIGID-ME DESIGN INPUTS (CONT.)

- Two-way AADTT: 0-10000
- Yearly compound growth rate: 0-10%
- Traffic Patterns:
  - Urban Principal Arterial-Interstate
  - Rural Principal Arterial-Interstate,
  - Minor Arterials, Collectors, and Recreational
- Number of lanes: 2, 4, 6, or 8

PITTRIGID-ME DESIGN INTPUTS (CONT.)

- Shoulder type
- Concrete slab width
- Base type

PITTRIGID-ME OUTPUT

- Required concrete slab thickness
- Required dowel diameter

NEXT STEPS

- Perform more than 50,000 Pavement ME simulations
- Screen the output files for predicted:
  - Fatigue damages at the bottom and top surfaces of the concrete slab
  - Differential energy of subgrade deformation
- Develop procedures for predicting cracking and faulting for various levels of traffic and concrete strength
- Develop procedures for thickness and dowel diameter prediction

SCHEDULE

	Year 1											
Months	1	2	3	4	5	6	7	8	9	10	11	12
Task 1: Literature and Software Review and Sensitivity Analysis												
Task 2: Develop PittRigidME												
Delieverable: An alpha-version of PittRigidME												
Task 3: Conduct PittRigidME verification												
Delieverable: A Memo comparing PittRigidME and PavementME												
Task 4: Final Report												
Delieverable: Final Report and the final version of the software												

APPLICATION OF RESEARCH PRODUCT

- Design of new concrete pavements
  - Implementation of the AASHTO ME design procedure for concrete pavements in Pennsylvania without software license fees
  - Simplification of design and reduction of design errors
- Pavement type selection
- Improvement/local calibration of AASHTO ME for Pennsylvania conditions