Balanced Mix Design BMD – Challenges and Opportunities

Insights from Regional Peer-to-Peer Exchanges

Cheese-Addition

Tom Harman

Senior Research Engineer

National Center for Asphalt Technology NCAT at Auburn University

Wisconsin Department of Transportation

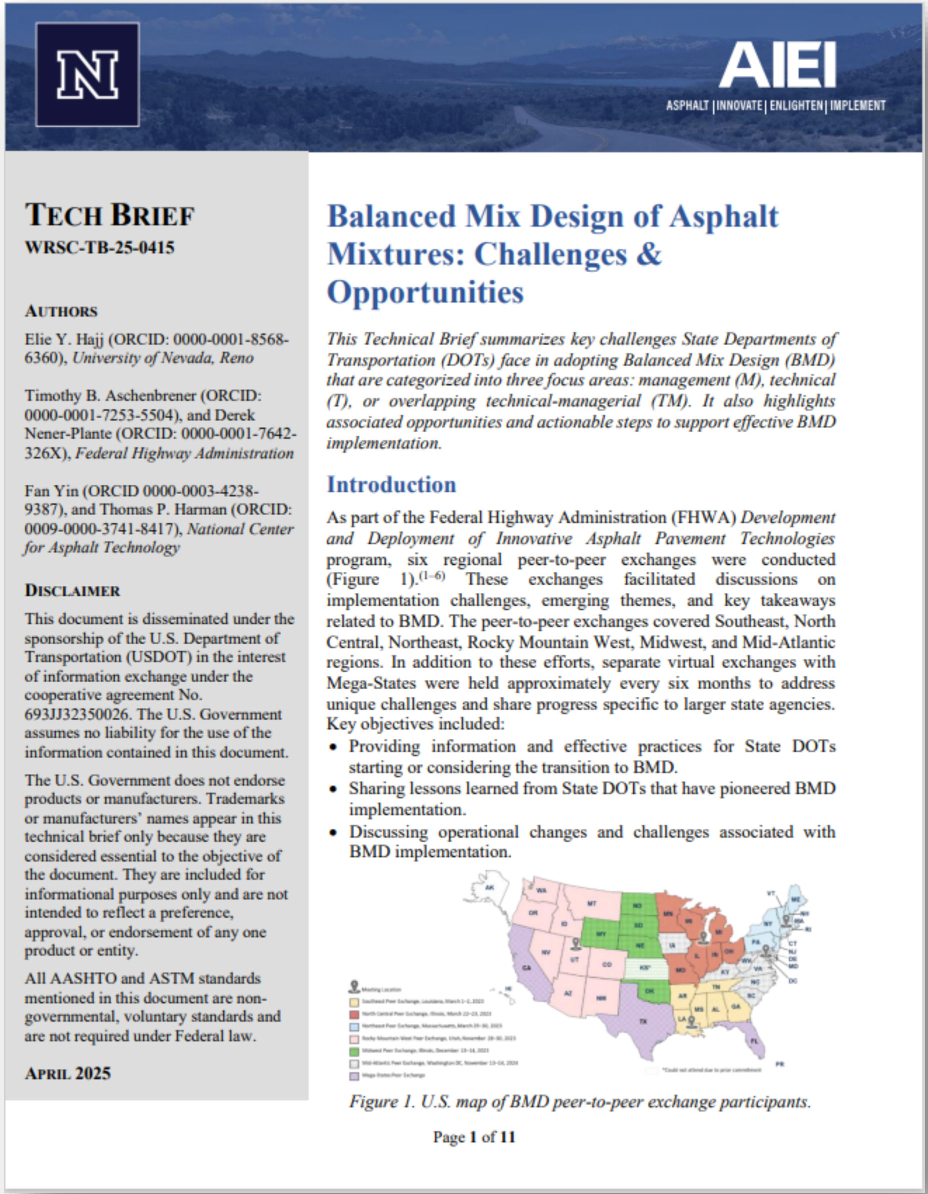
AIEI — ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

WAPA — Wisconsin Asphalt Pavement Association

Our Visit Today

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Where	• Market Motivators
Why	• The Transition to BMD
What	• Key Challenges
Now	• Opportunities and Actionable Steps
Thoughts	• Conversation



AIEI

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

TECH BRIEF

WRSC-TB-25-0415

AUTHORS

Elie Y. Hajj (ORCID: 0000-0001-8568-6360), *University of Nevada, Reno*

Timothy B. Aschenbrener (ORCID: 0000-0001-7253-5504), and Derek Nener-Plante (ORCID: 0000-0001-7642-326X), *Federal Highway Administration*

Fan Yin (ORCID 0000-0003-4238-9387), and Thomas P. Harman (ORCID: 0009-0000-3741-8417), *National Center for Asphalt Technology*

DISCLAIMER

This document is disseminated under the sponsorship of the U.S. Department of Transportation (USDOT) in the interest of information exchange under the cooperative agreement No. 693JJ32350026. The U.S. Government assumes no liability for the use of the information contained in this document.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this technical brief only because they are considered essential to the objective of the document. They are included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.

All AASHTO and ASTM standards mentioned in this document are non-governmental, voluntary standards and are not required under Federal law.

APRIL 2025

Balanced Mix Design of Asphalt Mixtures: Challenges & Opportunities

This Technical Brief summarizes key challenges State Departments of Transportation (DOTs) face in adopting Balanced Mix Design (BMD) that are categorized into three focus areas: management (M), technical (T), or overlapping technical-managerial (TM). It also highlights associated opportunities and actionable steps to support effective BMD implementation.

Introduction

As part of the Federal Highway Administration (FHWA) *Development and Deployment of Innovative Asphalt Pavement Technologies* program, six regional peer-to-peer exchanges were conducted (Figure 1).[(1–6)] These exchanges facilitated discussions on implementation challenges, emerging themes, and key takeaways related to BMD. The peer-to-peer exchanges covered Southeast, North Central, Northeast, Rocky Mountain West, Midwest, and Mid-Atlantic regions. In addition to these efforts, separate virtual exchanges with Mega-States were held approximately every six months to address unique challenges and share progress specific to larger state agencies. Key objectives included:

- Providing information and effective practices for State DOTs starting or considering the transition to BMD.
- Sharing lessons learned from State DOTs that have pioneered BMD implementation.
- Discussing operational changes and challenges associated with BMD implementation.

Figure 1. U.S. map of BMD peer-to-peer exchange participants.

Where

AIEI

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Why is the performance of asphalt pavements important?

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

- Our Roadways are a major asset in terms of replacement cost.

- Pavements are the biggest part of construction spending in the Federal-Aid system:
  - **~60%+ of all federal-aid**
  - $30+ billion in 2024

Source: FHWA Memo HICP-50 5/20/2025 Methodology for Determining Pavement Costs
Image: Grok

Why is the performance of asphalt pavements important?

For Wisconsin…

- **~115,000 miles of pavement**
- WisDOT is responsible for 11,746 miles

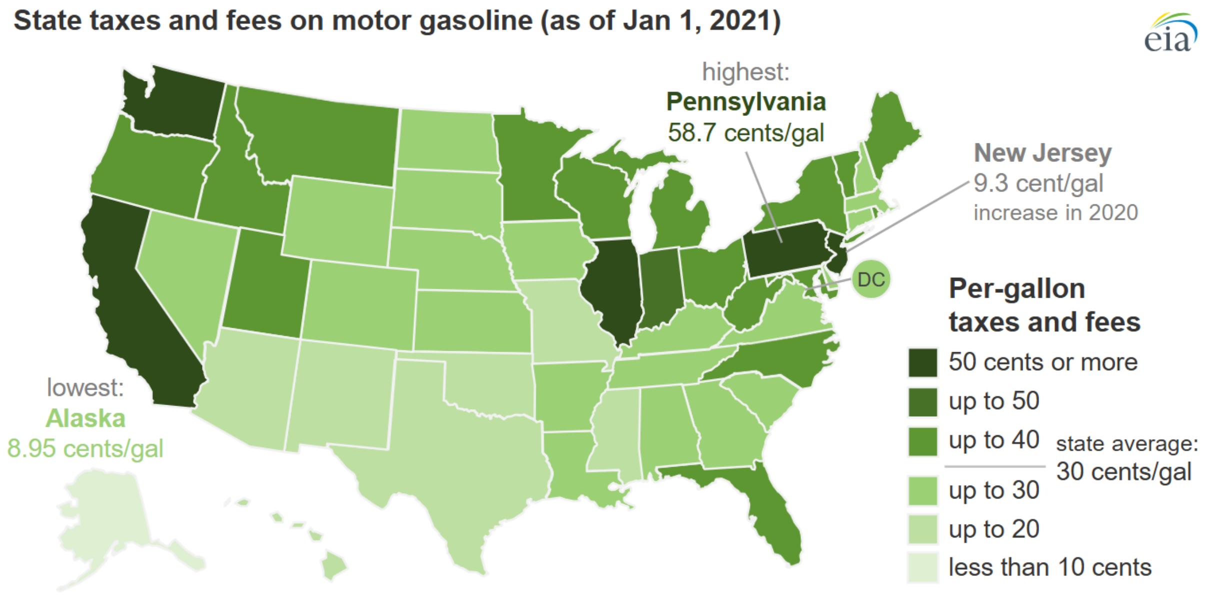
- Overall State Highway Construction Program (2025-2030): **~$4.5–$5 billion**

- **Challenges:** Wide temperature range, varying materials, & traffic loadings

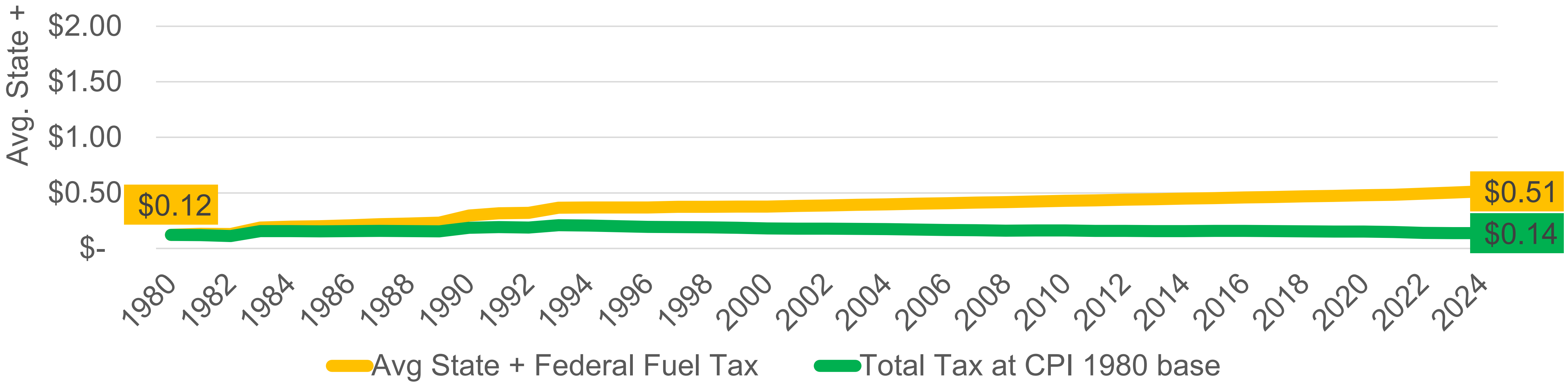
Independent Statistics and Analysis
U.S. Energy Information Administration

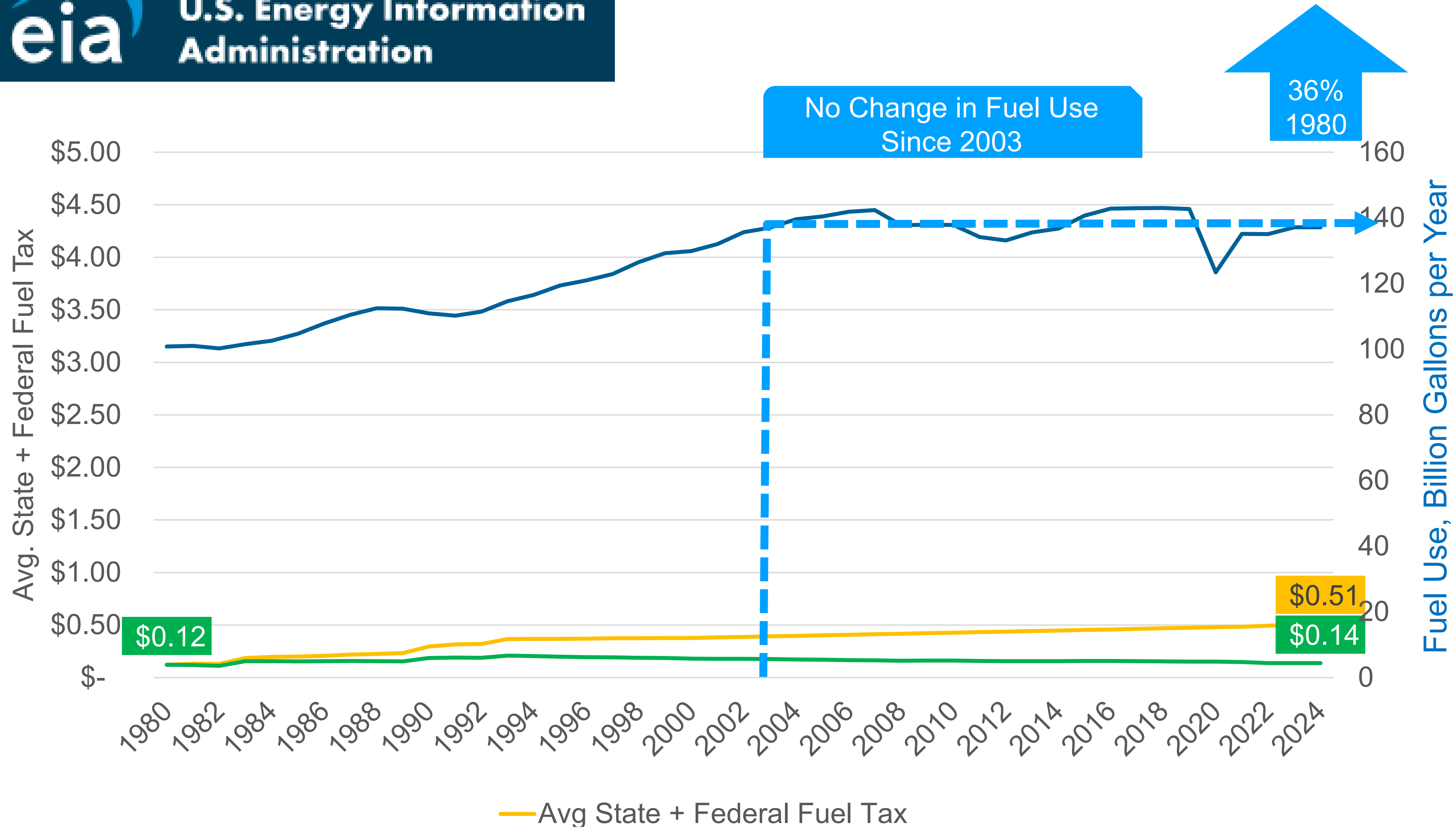
APRIL 1, 2021

State gasoline taxes average about 30 cents per gallon



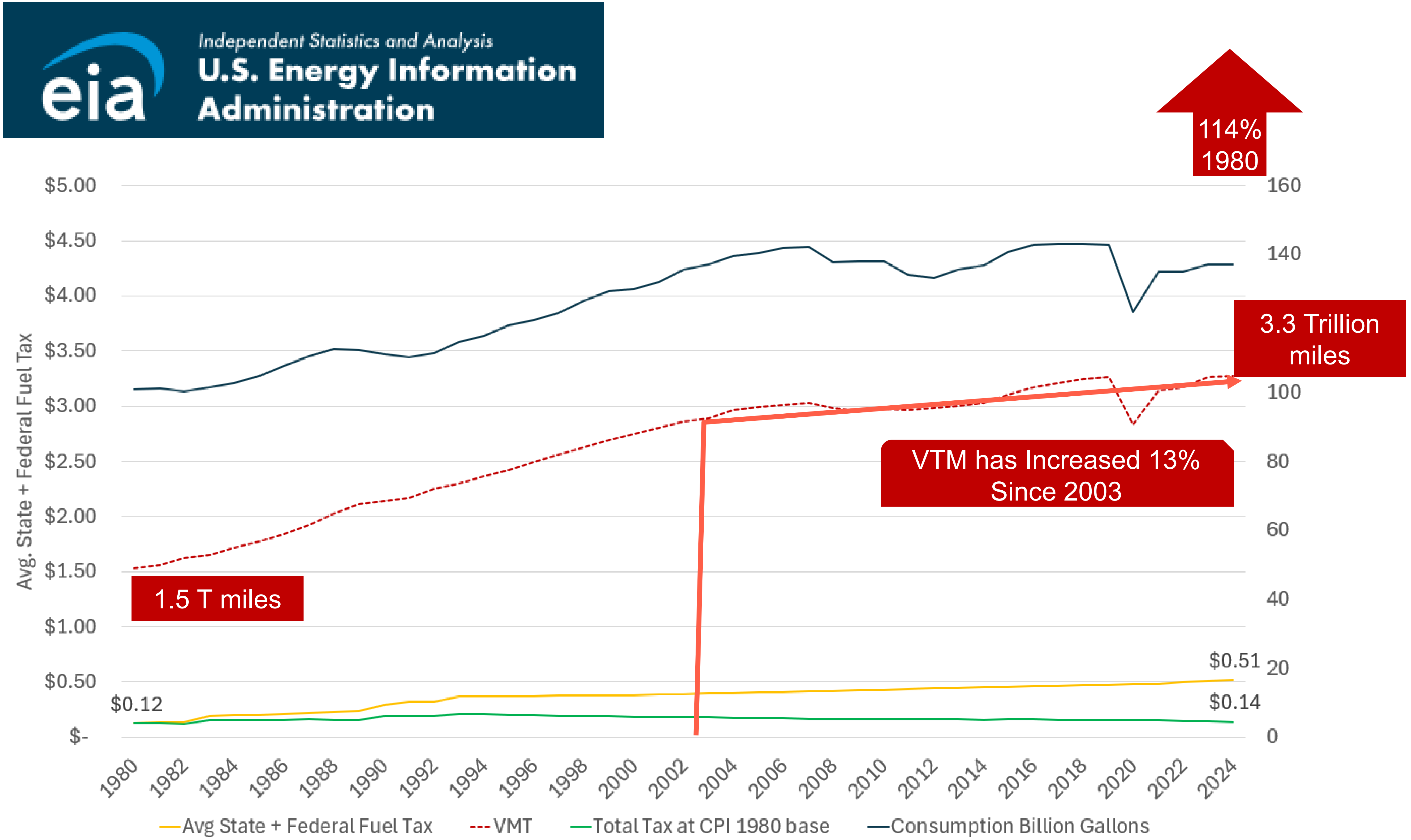
Source: U.S. Energy Information Administration, *Petroleum Marketing Monthly*





No Change in Fuel Use
Since 2003
36%
1980
$5.00
$4.50
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$-
Avg. State + Federal Fuel Tax
160
140
120
100
80
60
40
20
0
Fuel Use, Billion Gallons per Year
$0.12
$0.51
$0.14
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
Avg State + Federal Fuel Tax

AIEI

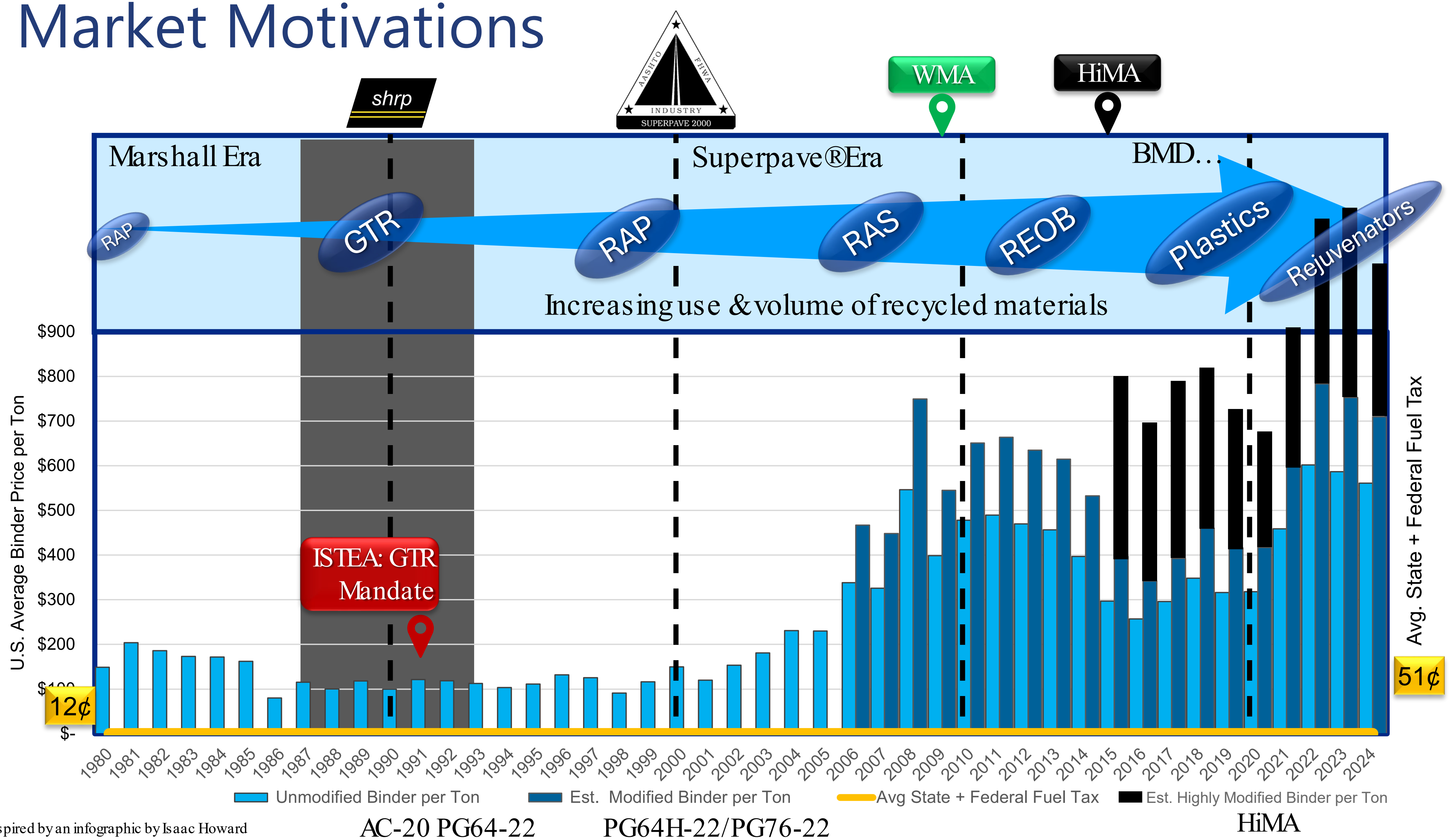


Independent Statistics and Analysis
U.S. Energy Information Administration
114%
1980
3.3 Trillion miles
VTM has Increased 13% Since 2003
1.5 T miles
$0.12
$0.51
$0.14
Avg. State + Federal Fuel Tax
$5.00
$4.50
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$-
160
140
100
80
60
40
20
0
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Avg State + Federal Fuel Tax
VMT
Total Tax at CPI 1980 base
Consumption Billion Gallons

AIEI

Image: Grok

Market Motivations



Inspired by an infographic by Isaac Howard
Reimagined by Tom Harman (NCAT)

Market Trends – RAP (million tons)

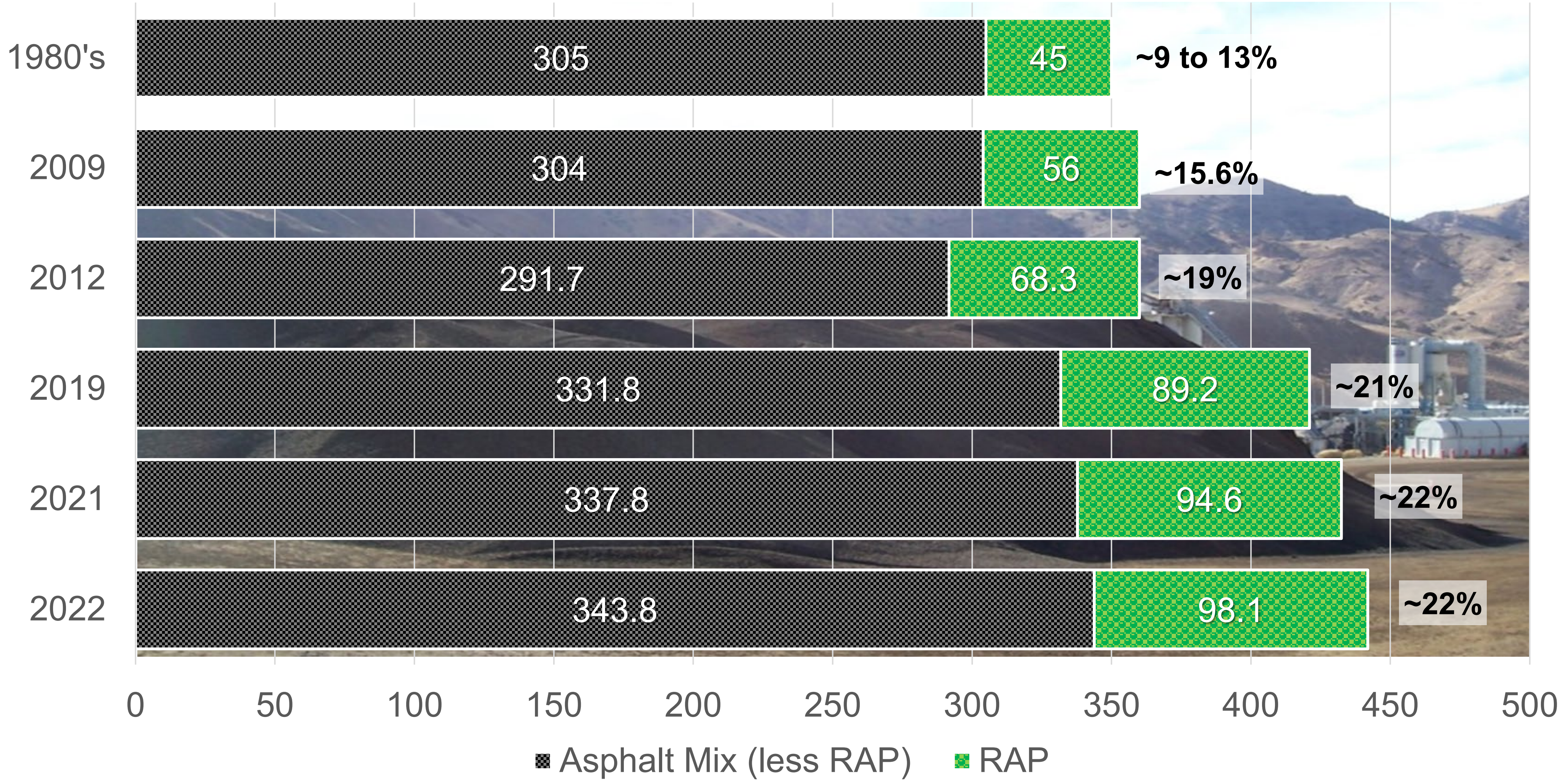


Image Source: A. Hand (UNR)

Why

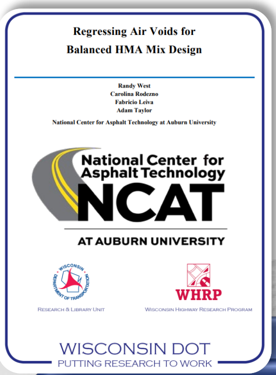
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

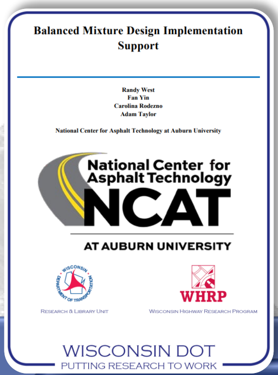
Image: ChatGPT 4o

Wisconsin is a Leader in Asphalt Research and BMD!

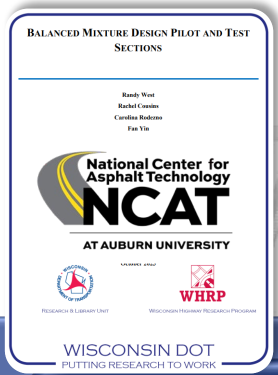
AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT



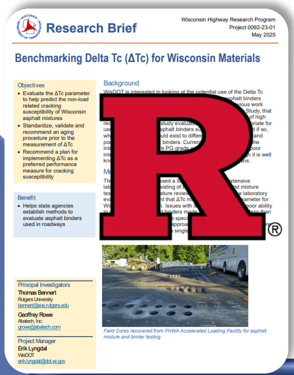
Regressed Air Voids 2016-18



BMD Implementation 2020-21



BMD Pilot & Test Sections 2023-24

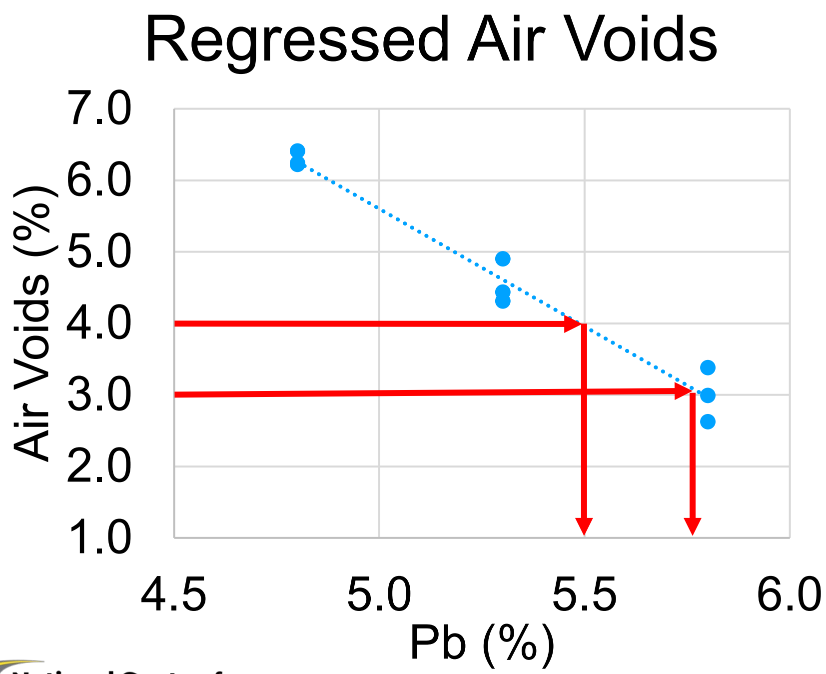


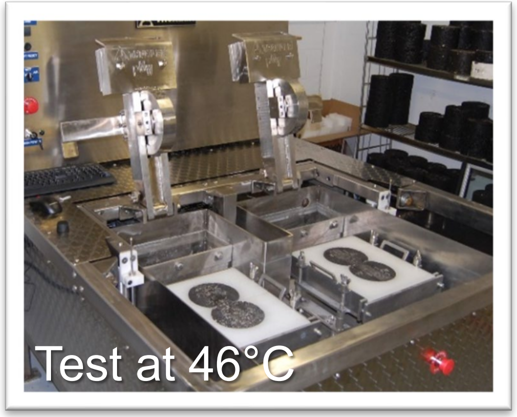
Benchmarking ΔTc↓ & GRP↑ 2025

Regressing Air Voids for BMD

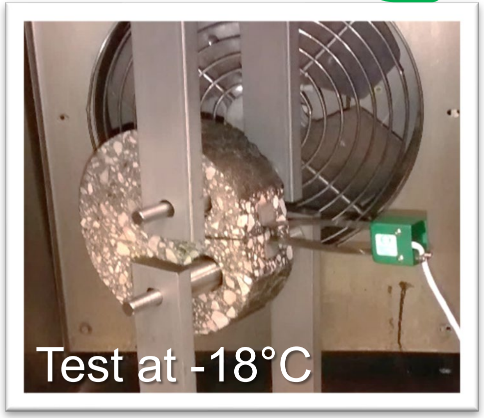
2016-18 (PI – Dr. Randy West)

- 6 JMFs, 40-75-100 N_{design}, PG 58-28/-34, 15-37% RAP, 0-3% RAS
- Regressing 4.0 to 3.0% V_a increases P_b by 0.3 to 0.4%

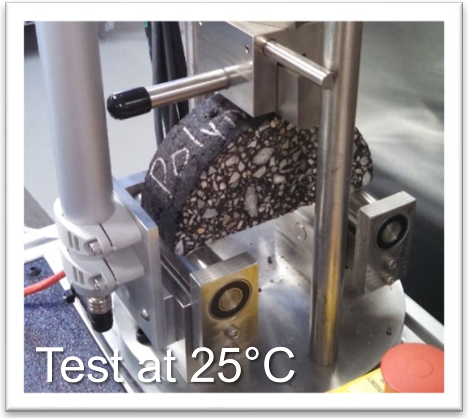




Hamburg
(AASHTO T 324)



DCT
(ASTM D7313)



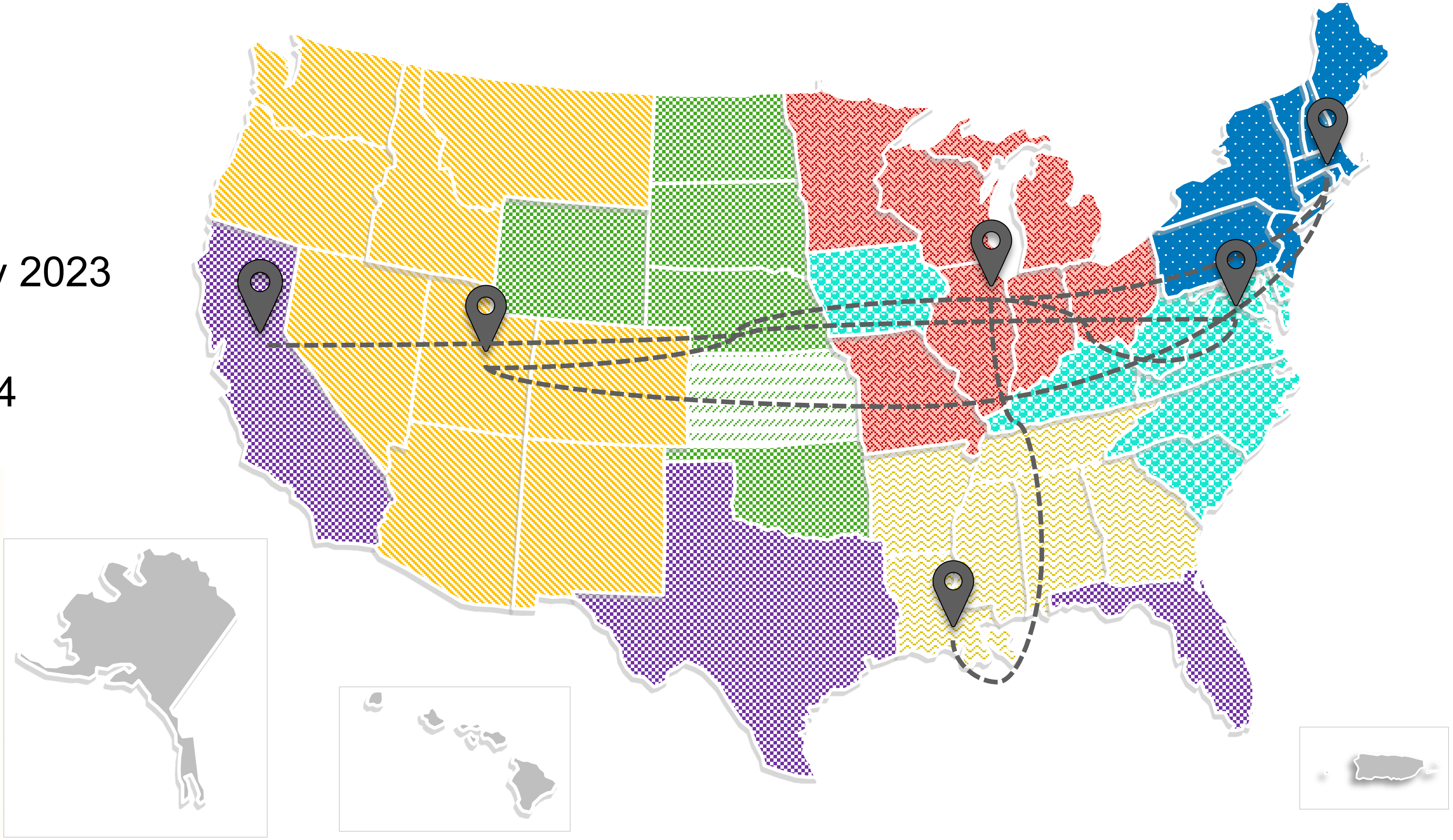
IFIT
(AASHTO TP 124)

National Center for Asphalt Technology
NCAT
AT AUBURN UNIVERSITY

BMD Peer-to-Peer Exchange Participants

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

- Meeting Location
- Southeast, Mar 2023
- North Central, Mar 2023
- Northeast, Mar 2023
- Rocky Mountain West, Nov 2023
- Midwest, Dec 2023
- Mid-Atlantic Plus, Nov 2024
- Mega-States, Jun 2025

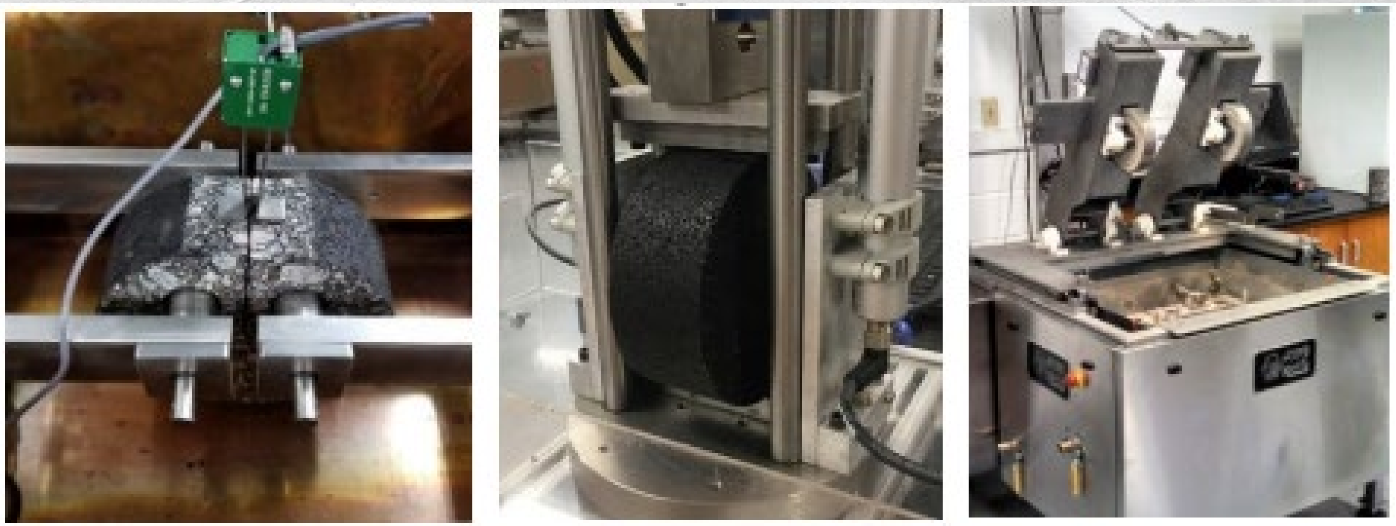



PEER-TO-PEER EXCHANGES
BALANCED MIX DESIGN
BEST PRACTICES
BMD
Hello
Dan K.

AIEI

BMD Implementation Support
Primary Criteria for DCT, IDEAL-CT, HWTT

- Interview Mix Designers
- Benchmarking/BMD Modifications
- Economic Analysis
- Proposed WisDOT Specs…Continue Regressed Air Voids &…



Specimen testing with (from left to right) DCT, IDEAL-CT and HWTT.

National Center for Asphalt Technology NCAT AT AUBURN UNIVERSITY

Randy, Fan, Adam, Carolina

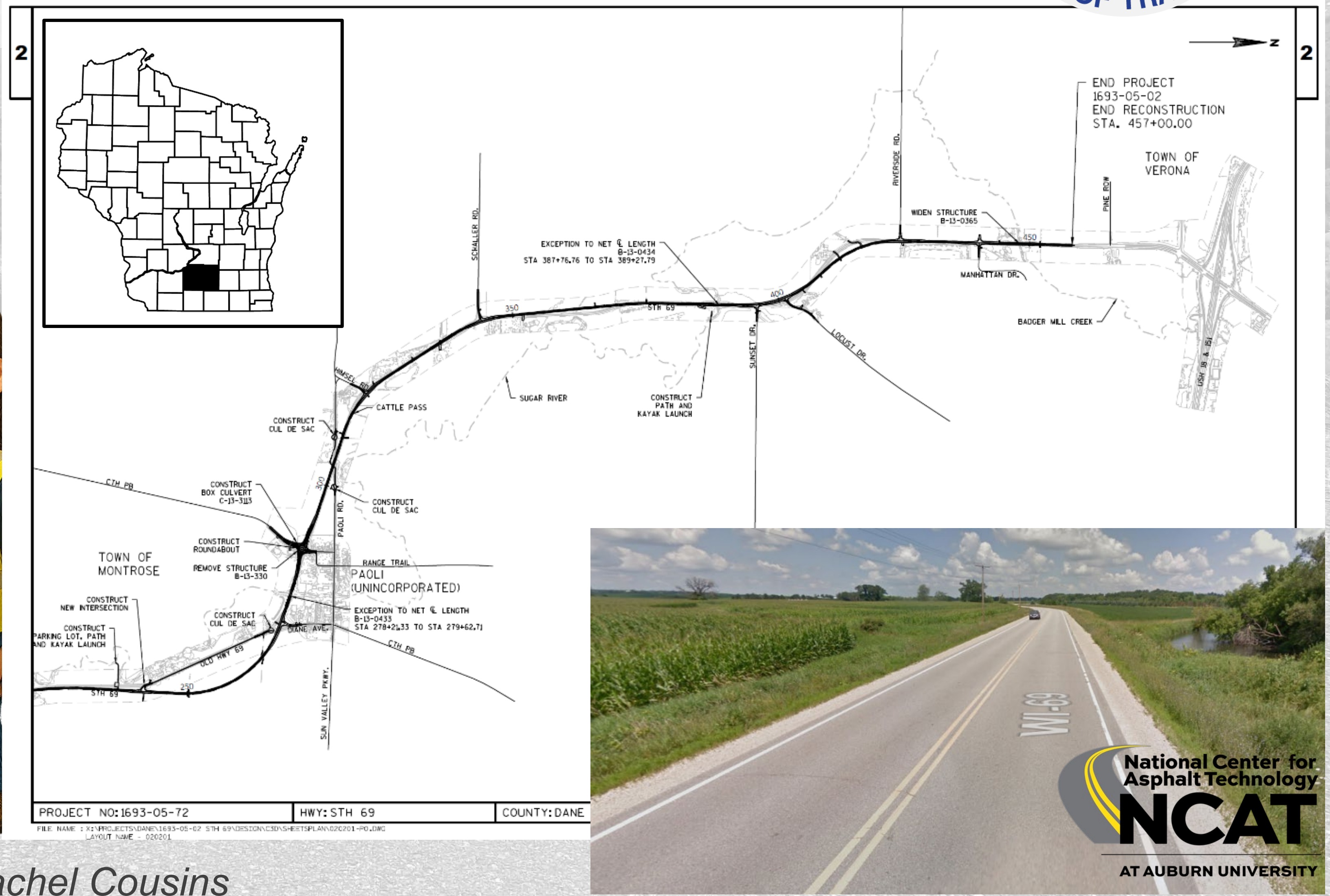
BMD Implementation Support

Primary Criteria for DCT, IDEAL-CT, HWTT

- BMD Mix Optimization Strategies (attempted)

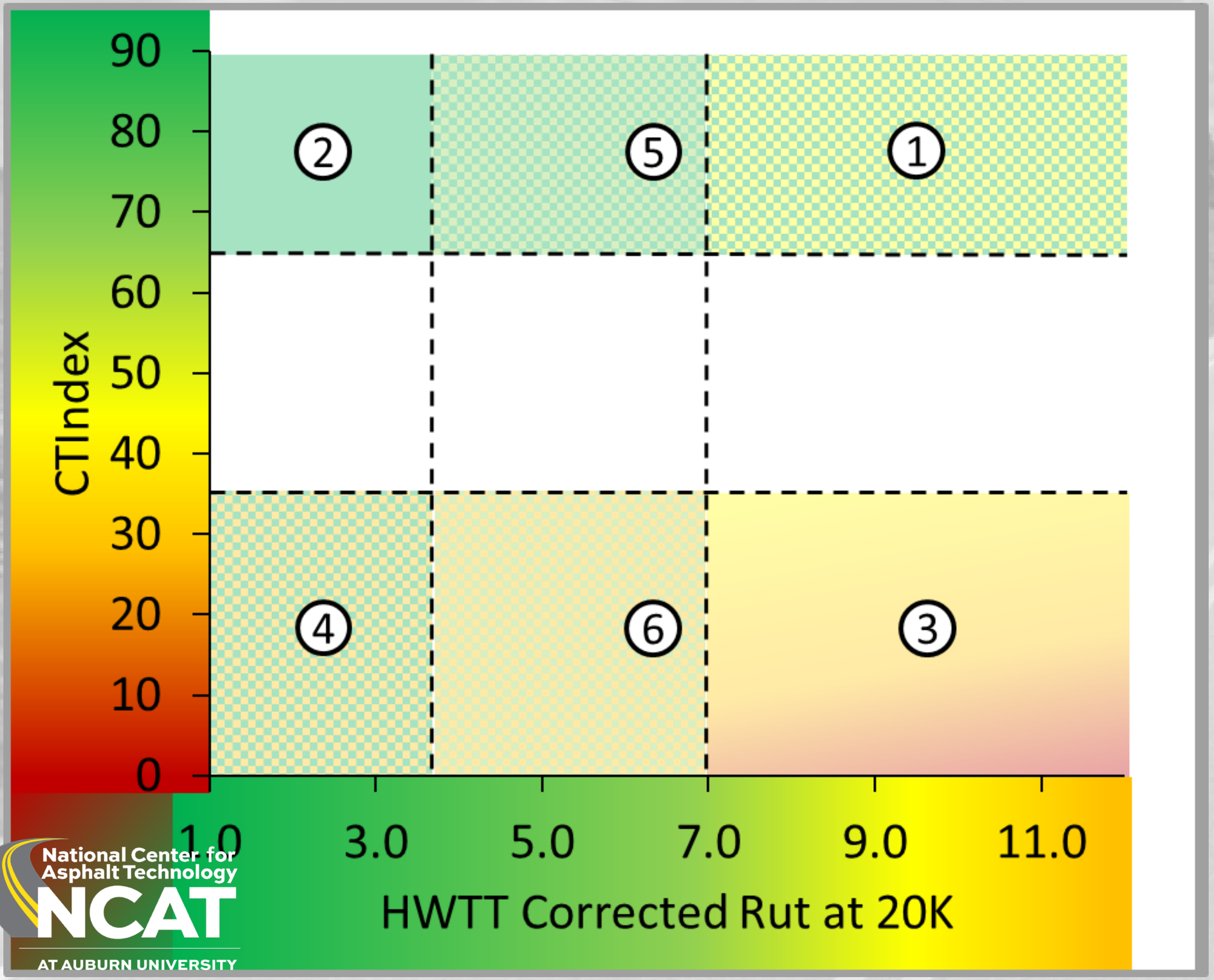
To Improve…	Strategy
Cracking	Add additional binder
	Remove/limit RAS
	Add rejuvenator (RA)
	Lower LT-PG grade
Rutting	Higher MSCR grade
Stripping	Add liquid anti-strip (LAS)

BMD Open Road Test Sections
STH 69, Dane County, South of Verona



Randy, Fan, Carolina, Grant, Matt, and Rachel Cousins

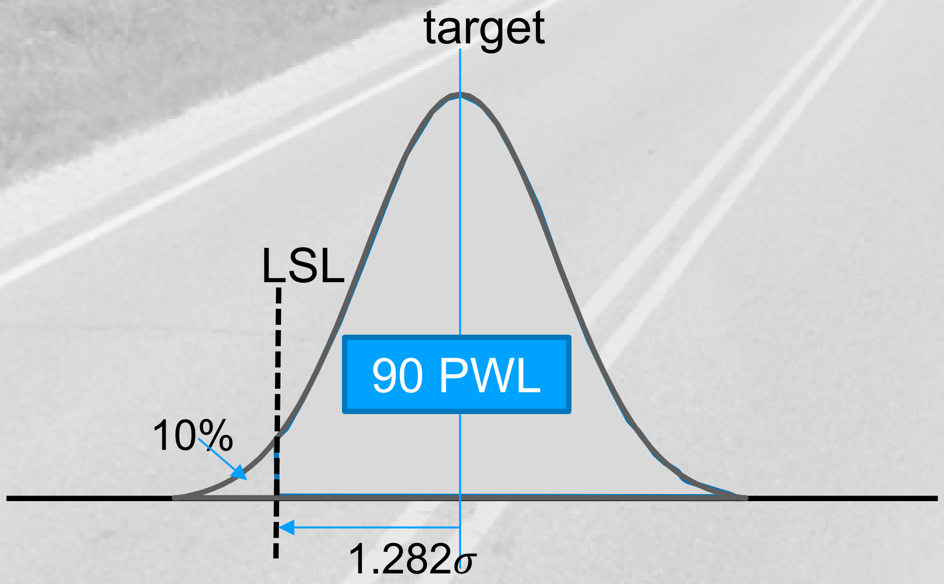
BMD Open Road Test Sections
STH 69, Dane County, South of Verona



"Outcomes from this project advanced implementation of BMD for WisDOT, as well as provided valuable lessons learned on how to build test sections."
– Tirupan Mandal, WisDOT

10 Shadow Projects
Exploring BMD test variability

- Recommendations
  - Investigate lab-to-lab differences
  - Formal training on BMD tests
  - Continue monitoring shadow projects…



What is the Primary Motivation for State DOTs Moving to BMD?

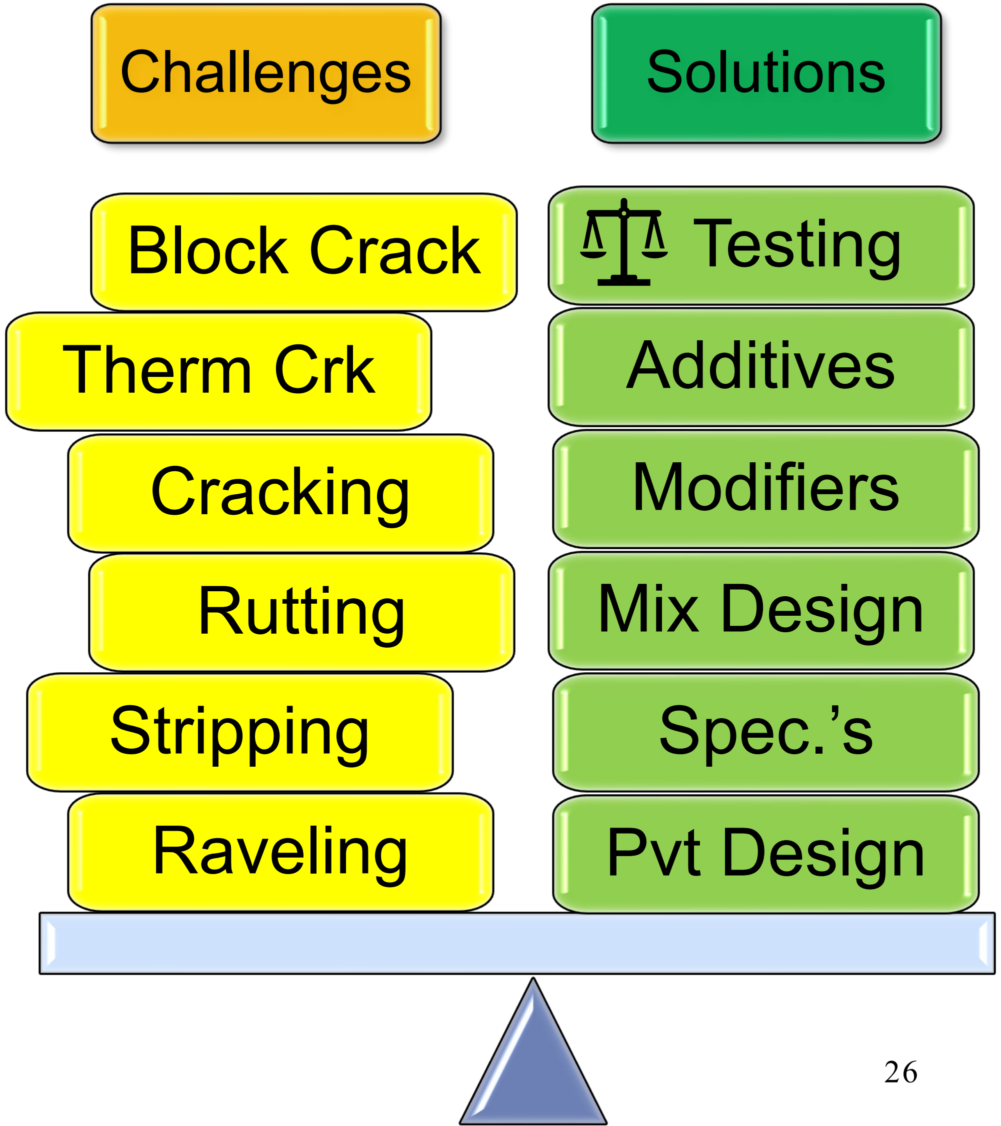
AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

A. Greater Flexibility in Material Selection
B. Volumetrics Do Not Always Yield Optimal Performance
C. Support Responsible Use of Recycled Materials
D. Greater Opportunity for Innovation
E. A Combination of Motivators

What are Your Common Performance Challenges?

Image: Google Maps

Performance Challenges & Solutions



What

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Key Challenges

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Management (M)

Technical (T)

Overlapping (TM)

Microsoft Stock Image

Management (M)

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

- M1-Change Management ✓
- M2-Cost Benefit Analysis
- M3-Spec & Risk Management
- M4-Resource Allocation ✓
- M5-Implementation Planning
- M6-Stakeholder Engagement ✓

✓- North Central

Microsoft Stock Image

Technical (T)

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

- T1-BMD Test Validation ✓
- T2-Test Procedures & Protocols ✓
- T3-Variabilities ✓
- T4-Data Management ✓
- T5-Pathway to QA ✓
- T6-Volumetric Usage ✓

✓ - North Central

Microsoft Stock Image

Overlapping (TM)

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

TM1-Integration Existing Practices

TM2-Education & Training

TM3-Collaboration Info Sharing

- North Central

Microsoft Stock Image

Now

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

M1-Change Management

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Challenge

Resistance to replacing traditional specifications with BMD due to unclear goals and priorities.

Opportunity

Alignment of BMD with performance goals through clear communication and understanding across various stakeholders.

ACTION

- Identify Champions
- Document and share BMD goals and scope
- Emphasize eliminating poor-performing mixes
- Align with State internal priorities

Communication: Is Key!

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

T1-BMD Test Validation

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Challenge

Lack of a standard validation framework and timely data collection; need for linking laboratory BMD test results with field performance.

Opportunity

Validation, using multiple approaches, builds credibility and confidence in BMD tests and their criteria.

- Create a standardized test validation framework.
- Conduct validation experiments and leverage peer knowledge on validation practices
- Monitor in-service performance of asphalt mixtures and refine BMD test criteria.
- Collect and store field samples for future testing.

Validation

Image: ChatGPT 4o

In 1939, how did Bruce Marshall establish Criteria for Stability?

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

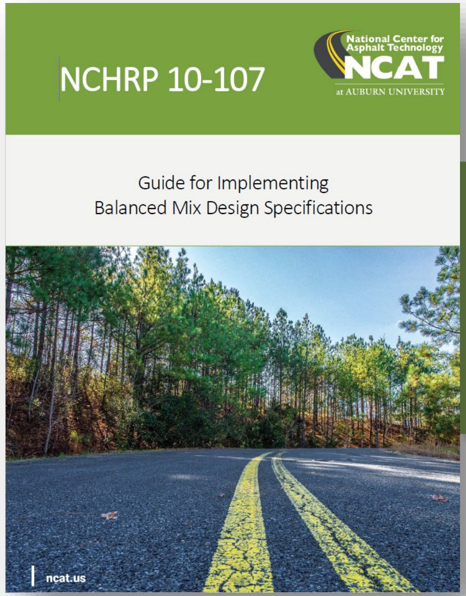
500 pounds minimum light traffic
1,800 pounds minimum for heavier traffic

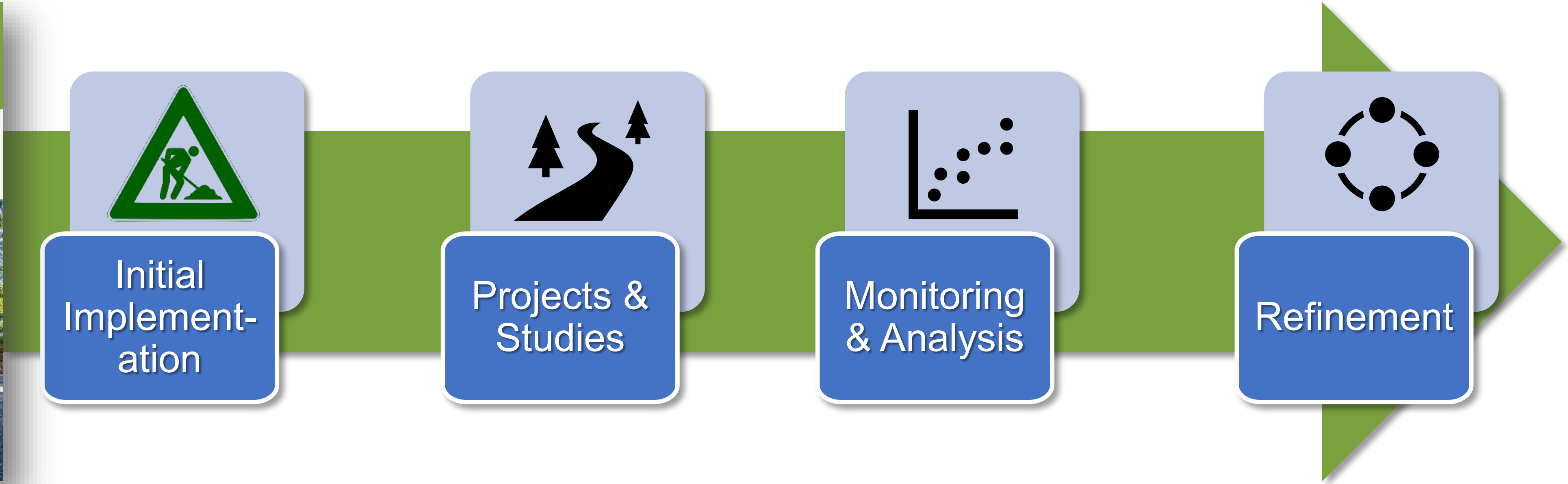
A. Laboratory Study: Various Asphalt-Aggregate Combinations
B. Benchmarking of Good and Bad In-service Pavements
C. Empirical Thresholds through Trial and Error
D. Empirically Adjusted over Time
E. All the Above

Bruce G. Marshall (1908-1977)
Mississippi Department of Highways

Beyond the Guide

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT





A few of The Players

CAPRI
CONSORTIUM FOR ASPHALT PAVEMENT RESEARCH AND IMPLEMENTATION

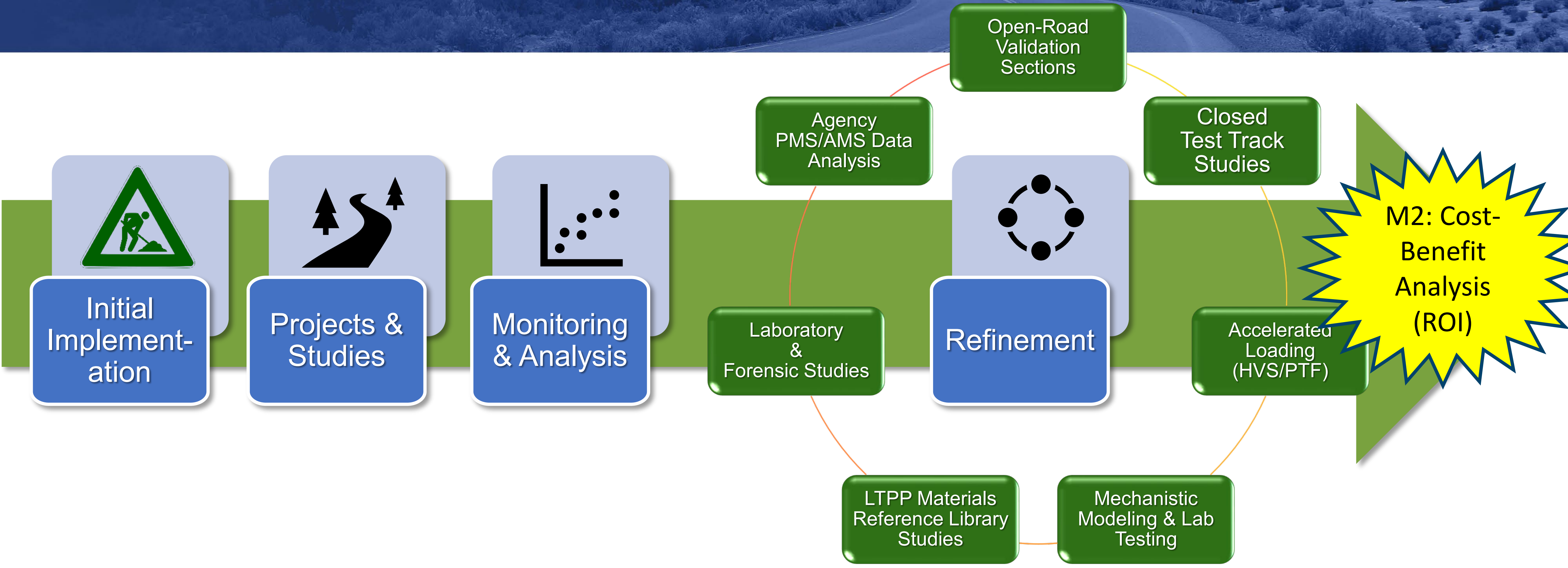
NCAT / Our Sponsors

Projects & Studies

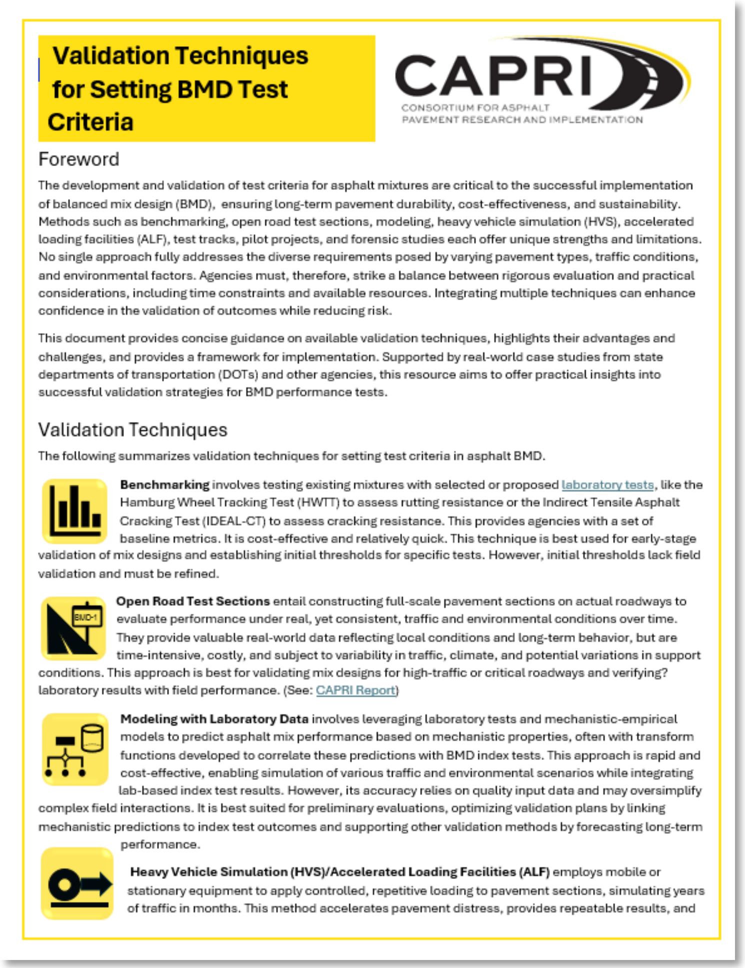
- **Open-Road Validation Sections**
- **Closed Test Track Studies**
- **Accelerated Loading (HVS/PTF)**
- **Mechanistic Modeling & Lab Testing**
- **LTPP Materials Reference Library Studies**
- **Laboratory & Forensic Studies**
- **Agency PMS/AMS Data Analysis**

AIEI

Beyond the Guide



Validation Techniques & Case Studies



Validation Techniques for Setting BMD Test Criteria

CAPRI
CONSORTIUM FOR ASPHALT PAVEMENT RESEARCH AND IMPLEMENTATION

Foreword

The development and validation of test criteria for asphalt mixtures are critical to the successful implementation of balanced mix design (BMD), ensuring long-term pavement durability, cost-effectiveness, and sustainability. Methods such as benchmarking, open road test sections, modeling, heavy vehicle simulation (HVS), accelerated loading facilities (ALF), test tracks, pilot projects, and forensic studies each offer unique strengths and limitations. No single approach fully addresses the diverse requirements posed by varying pavement types, traffic conditions, and environmental factors. Agencies must, therefore, strike a balance between rigorous evaluation and practical considerations, including time constraints and available resources. Integrating multiple techniques can enhance confidence in the validation of outcomes while reducing risk.

This document provides concise guidance on available validation techniques, highlights their advantages and challenges, and provides a framework for implementation. Supported by real-world case studies from state departments of transportation (DOTs) and other agencies, this resource aims to offer practical insights into successful validation strategies for BMD performance tests.

Validation Techniques

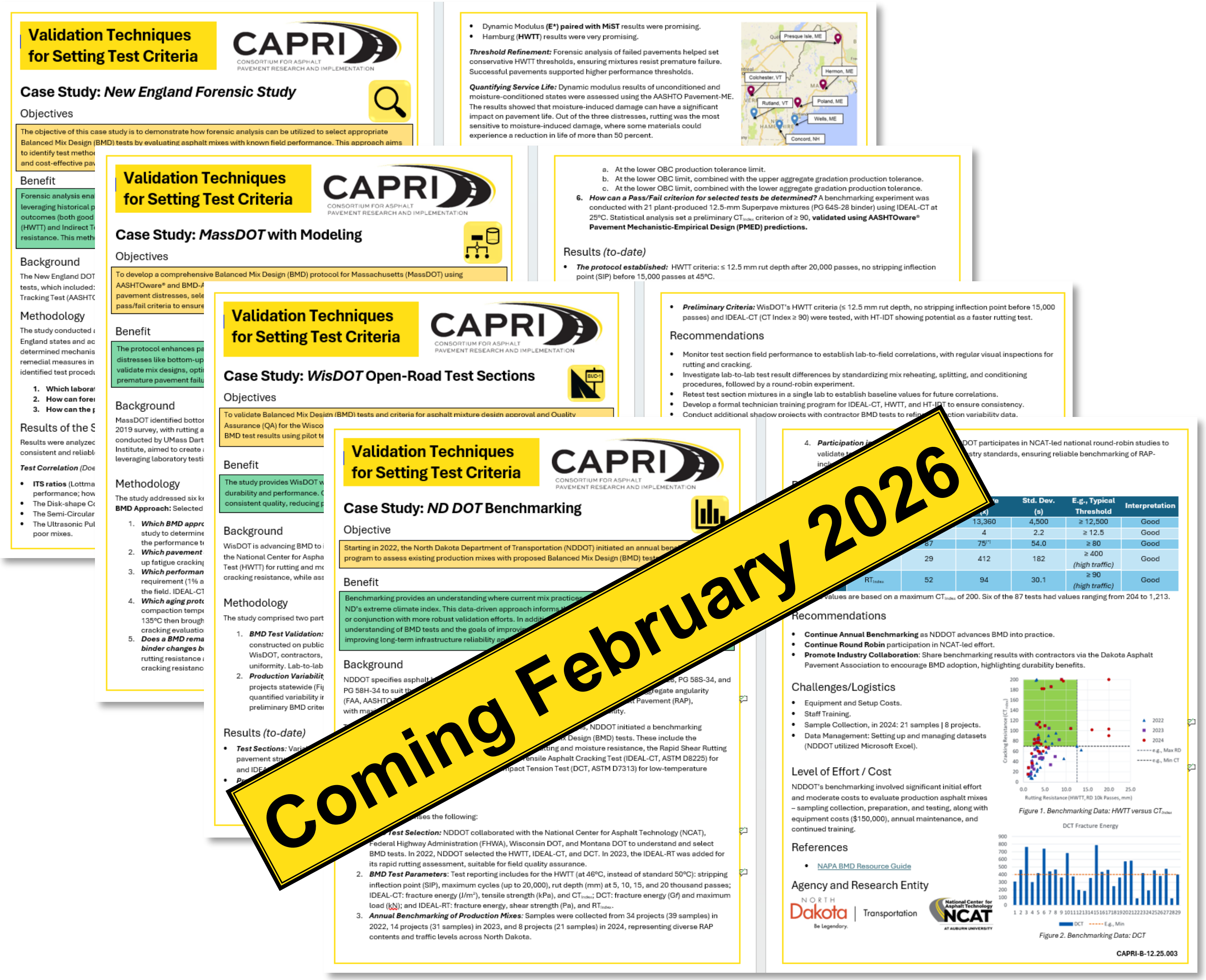
The following summarizes validation techniques for setting test criteria in asphalt BMD.

Benchmarking involves testing existing mixtures with selected or proposed laboratory tests, like the Hamburg Wheel Tracking Test (HWTT) to assess rutting resistance or the Indirect Tensile Asphalt Cracking Test (IDEAL-CT) to assess cracking resistance. This provides agencies with a set of baseline metrics. It is cost-effective and relatively quick. This technique is best used for early-stage validation of mix designs and establishing initial thresholds for specific tests. However, initial thresholds lack field validation and must be refined.

Open Road Test Sections entail constructing full-scale pavement sections on actual roadways to evaluate performance under real, yet consistent, traffic and environmental conditions over time. They provide valuable real-world data reflecting local conditions and long-term behavior, but are time-intensive, costly, and subject to variability in traffic, climate, and potential variations in support conditions. This approach is best for validating mix designs for high-traffic or critical roadways and verifying laboratory results with field performance. (See: CAPRI Report)

Modeling with Laboratory Data involves leveraging laboratory tests and mechanistic-empirical models to predict asphalt mix performance based on mechanistic properties, often with transform functions developed to correlate these predictions with BMD index tests. This approach is rapid and cost-effective, enabling simulation of various traffic and environmental scenarios while integrating lab-based index test results. However, its accuracy relies on quality input data and may oversimplify complex field interactions. It is best suited for preliminary evaluations, optimizing validation plans by linking mechanistic predictions to index test outcomes and supporting other validation methods by forecasting long-term performance.

Heavy Vehicle Simulation (HVS)/Accelerated Loading Facilities (ALF) employs mobile or stationary equipment to apply controlled, repetitive loading to pavement sections, simulating years of traffic in months. This method accelerates pavement distress, provides repeatable results, and



TM2-Education & Training

Challenge

Limited formal training on BMD test methods and data interpretation, leading to skill gaps in BMD implementation and analysis.

Opportunity

Training programs and workshops on BMD test methods and data interpretation, developing skilled staff for continued implementation.

- Collaborate with universities and industry partners to develop hands-on BMD training modules.
- Develop and deliver BMD certification programs.
- Include test method demonstrations, data analysis, and interpretation exercises in the training.

Lots of Resources

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

AIEI Training Opportunities

- ✓BMD Implementation Workshop
- ✓High-Reclaimed Asphalt Pavement (RAP) Mixture Strategies

Thoughts

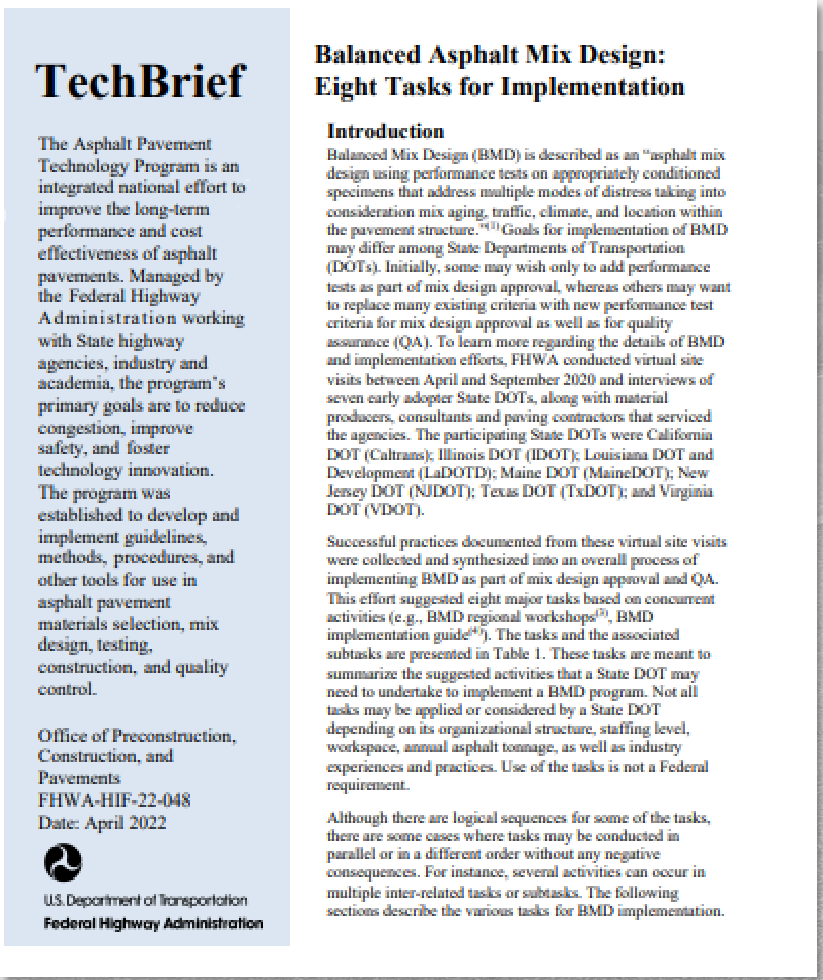
AIEI

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

State Participants Key Takeaways (1/3)

- Start with a Plan
- Define Your “Why”
- Identify Champions
- Account for Staffing Needs
- Invest in Training

8 Tasks for Implementation



TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration working with State highway agencies, industry and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures, and other tools for use in asphalt pavement materials selection, mix design, testing, construction, and quality control.

Office of Preconstruction, Construction, and Pavements
FHWA-HIF-22-048
Date: April 2022

U.S. Department of Transportation
Federal Highway Administration

Balanced Asphalt Mix Design: Eight Tasks for Implementation

Introduction

Balanced Mix Design (BMD) is described as an "asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate, and location within the pavement structure."[1] Goals for implementation of BMD may differ among State Departments of Transportation (DOTs). Initially, some may wish only to add performance tests as part of mix design approval, whereas others may want to replace many existing criteria with new performance test criteria for mix design approval as well as for quality assurance (QA). To learn more regarding the details of BMD and implementation efforts, FHWA conducted virtual site visits between April and September 2020 and interviews of seven early adopter State DOTs, along with material producers, consultants and paving contractors that serviced the agencies. The participating State DOTs were California DOT (Caltrans); Illinois DOT (IDOT); Louisiana DOT and Development (LaDOTD); Maine DOT (MaineDOT); New Jersey DOT (NJDOT); Texas DOT (TxDOT); and Virginia DOT (VDOT).

Successful practices documented from these virtual site visits were collected and synthesized into an overall process of implementing BMD as part of mix design approval and QA. This effort suggested eight major tasks based on concurrent activities (e.g., BMD regional workshops[3], BMD implementation guide[4]). The tasks and the associated subtasks are presented in Table 1. These tasks are meant to summarize the suggested activities that a State DOT may need to undertake to implement a BMD program. Not all tasks may be applied or considered by a State DOT depending on its organizational structure, staffing level, workspace, annual asphalt tonnage, as well as industry experiences and practices. Use of the tasks is not a Federal requirement.

Although there are logical sequences for some of the tasks, there are some cases where tasks may be conducted in parallel or in a different order without any negative consequences. For instance, several activities can occur in multiple inter-related tasks or subtasks. The following sections describe the various tasks for BMD implementation.

Task		Sub Task	Description
1	Motivations and Benefits of Performance Specifications		
2	Overall Planning	2.1	Identification of Champions
		2.2	Establishing a Stakeholders Partnership
		2.3	Doing Your Homework
		2.4	Establishing Goals
		2.5	Mappin
		2.6	Identifyi
		2.7	Develop
3	Selecting Performance Tests	3.1	Identifyi
		3.2	Identifyi
		3.3	Validatir
4	Performance Testing Equipment: Acquiring, Managing	4.1	Acquirin
		4.2	Managir
		4.3	Conduct
		4.4	Evaluati
		4.5	Conduct
5	Establishing Baseline Data	5.1	Reviewi
		5.2	Conduct
		5.3	Conduct
		5.4	Analyzir
		5.5	Determi
6	Specifications and Program Development	6.1	Samplin
		6.2	Pay Adju
		6.3	Develop
		6.4	Conduct
		6.5	Final An
7	Training, Certifications,	7.1	Develop
		7.2	Establis
8	Initial Implementation		

FHWA TechBrief: FHWA-HIF-22-048

State Participants Key Takeaways(2/3)

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

- Start Validation Early
- Transition Mindset
- Collaborate with Industry
- Leverage Peer Resources
- Utilize Existing Funding

State Participants Key Takeaways(3/3)

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

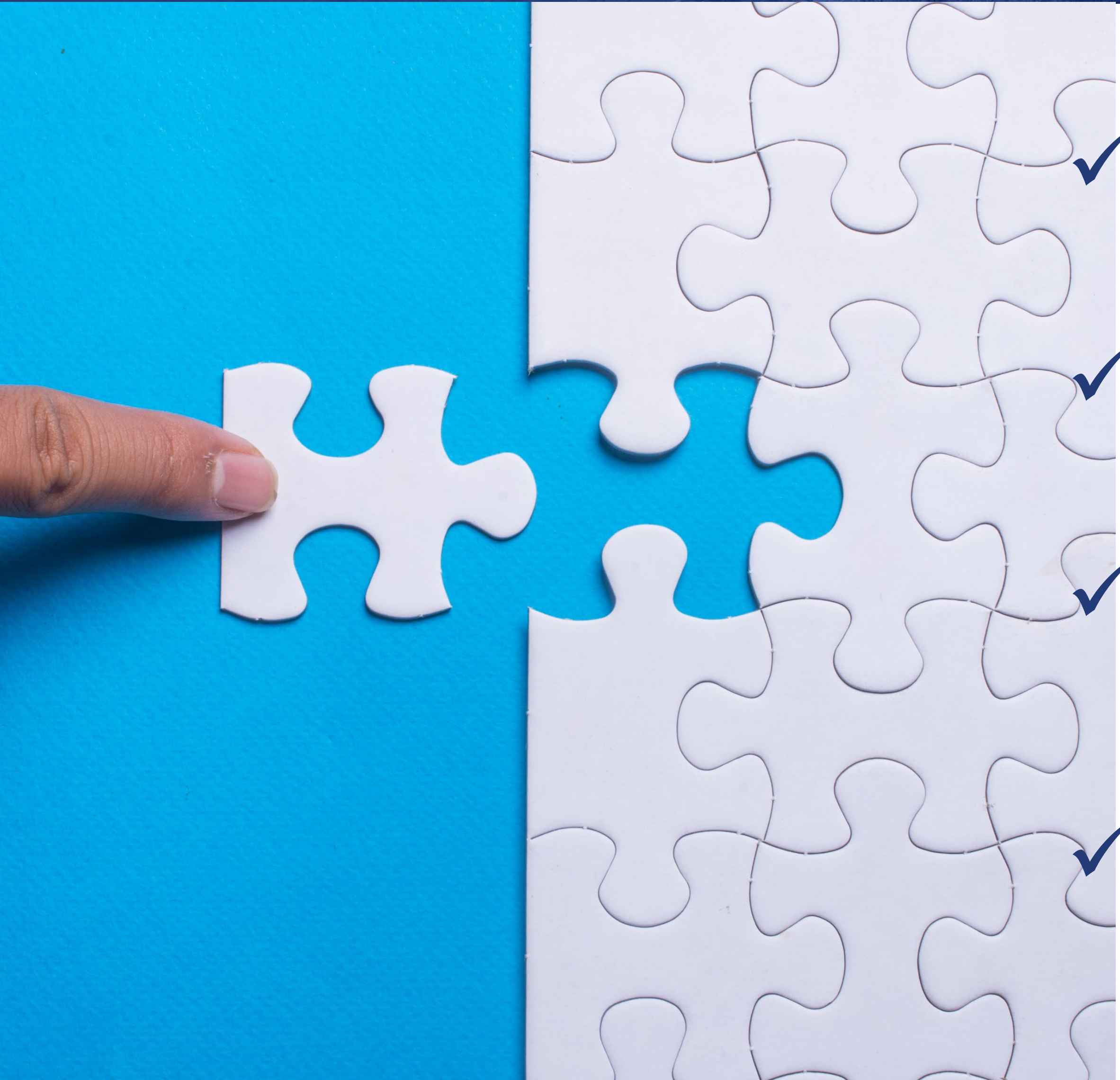
- Build a Strong Data System
- Encourage Regional Collaboration
- Plan for Setbacks

Wrap Up

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Microsoft Stock Image

What are Your Takeaways?



- ✓ Resource Constrained Environment
- ✓ Volumetrics do/will not address our current/future needs
- ✓ BMD will continue to evolve
- ✓ Are you part of the solution?

Q & A

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Microsoft Stock Image

War Eagle!

ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT

Thank you!

Tom Harman
Senior Research Engineer

tom.harman@auburn.edu

National Center for Asphalt Technology
NCAT
AT AUBURN UNIVERSITY

AIEI
ASPHALT | INNOVATE | ENLIGHTEN | IMPLEMENT