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Balanced Mix Design (BMD)–Challenges & Opportunities

Insights from Regional Peer-to-Peer Exchanges

Derek Nener-Plante

Principal, DNP Infrastructure LLC

DNP INFRASTRUCTURE LLC

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Our Visit Today

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

Tech Brief

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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*

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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

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Why is the performance of asphalt pavements important?

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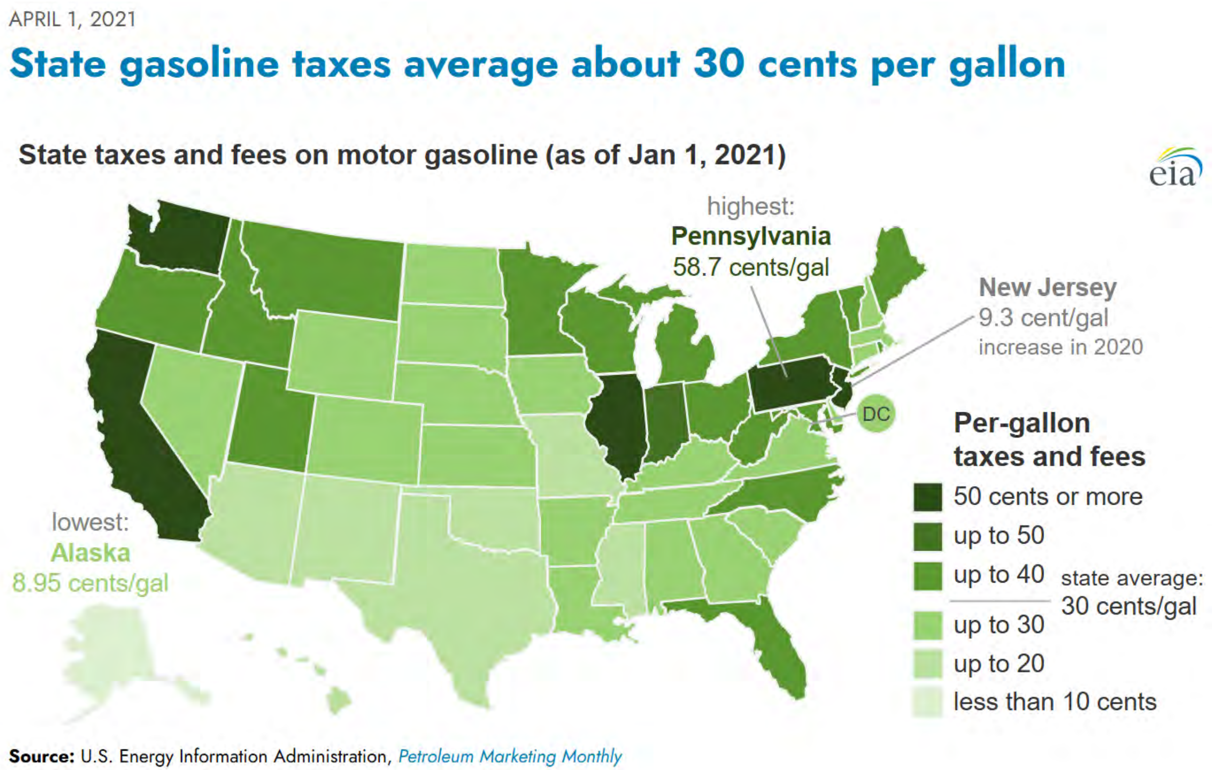
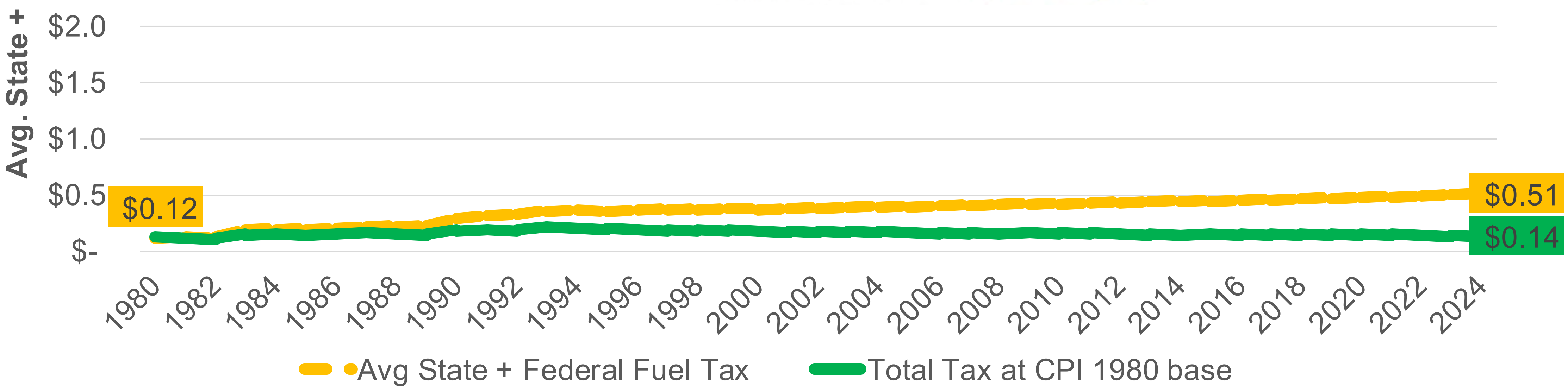
- Our Roadways are a major asset in terms of replacement cost.
- Pavements are the biggest part of construction spending in the Federal-Aid system:
  - **~60%+ of all federal-aid**
  - $30+ billion in 2024

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

Independent Statistics and Analysis
U.S. Energy Information Administration





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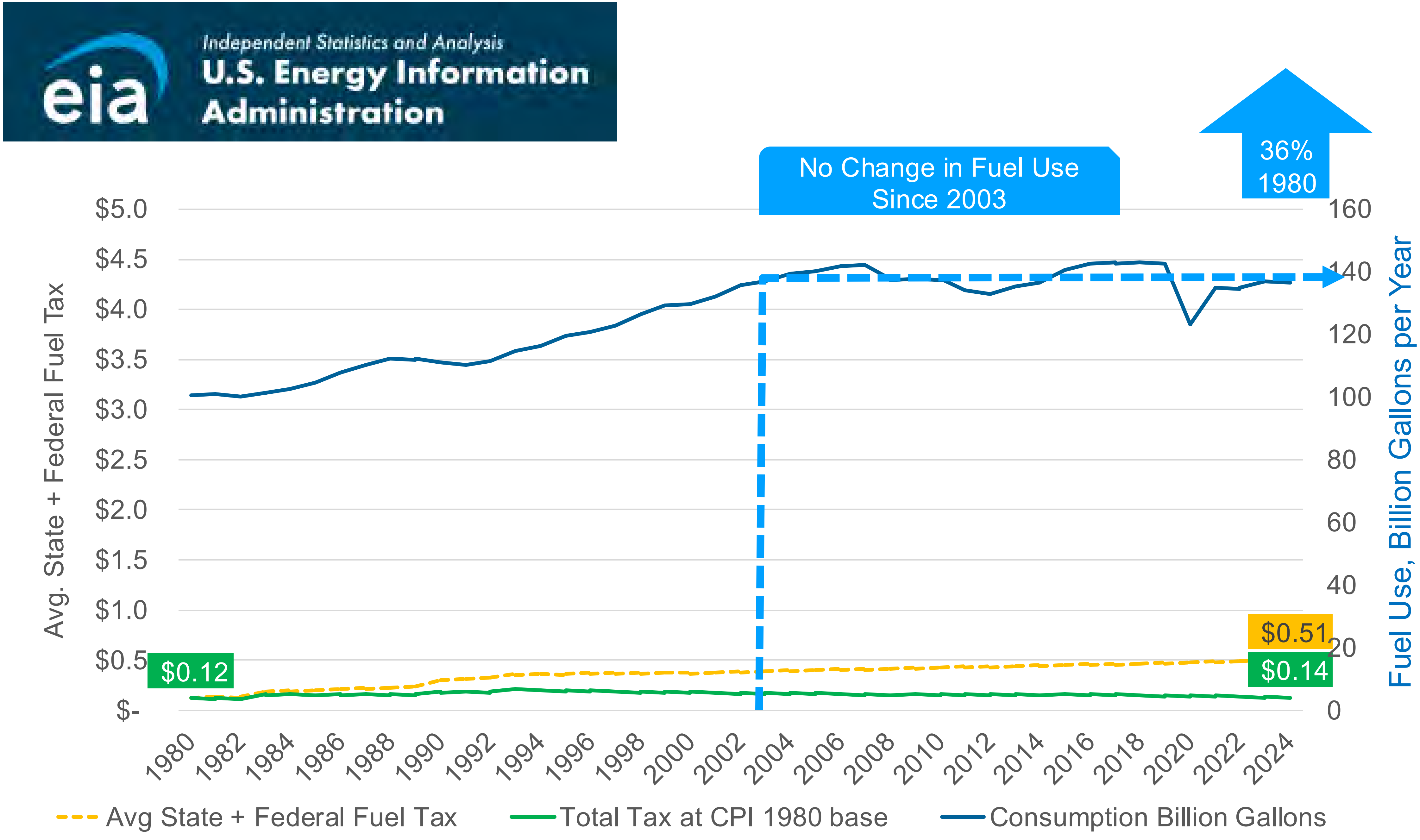

Independent Statistics and Analysis
U.S. Energy Information Administration
No Change in Fuel Use Since 2003
36% 1980
$5.0
$4.5
$4.0
$3.5
$3.0
$2.5
$2.0
$1.5
$1.0
$0.5
$-
Avg. State + Federal Fuel Tax
160
140
120
100
80
60
40
20
0
Fuel Use, Billion Gallons per Year
$0.12
$0.51
$0.14
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022 2024
Avg State + Federal Fuel Tax
Total Tax at CPI 1980 base
Consumption Billion Gallons
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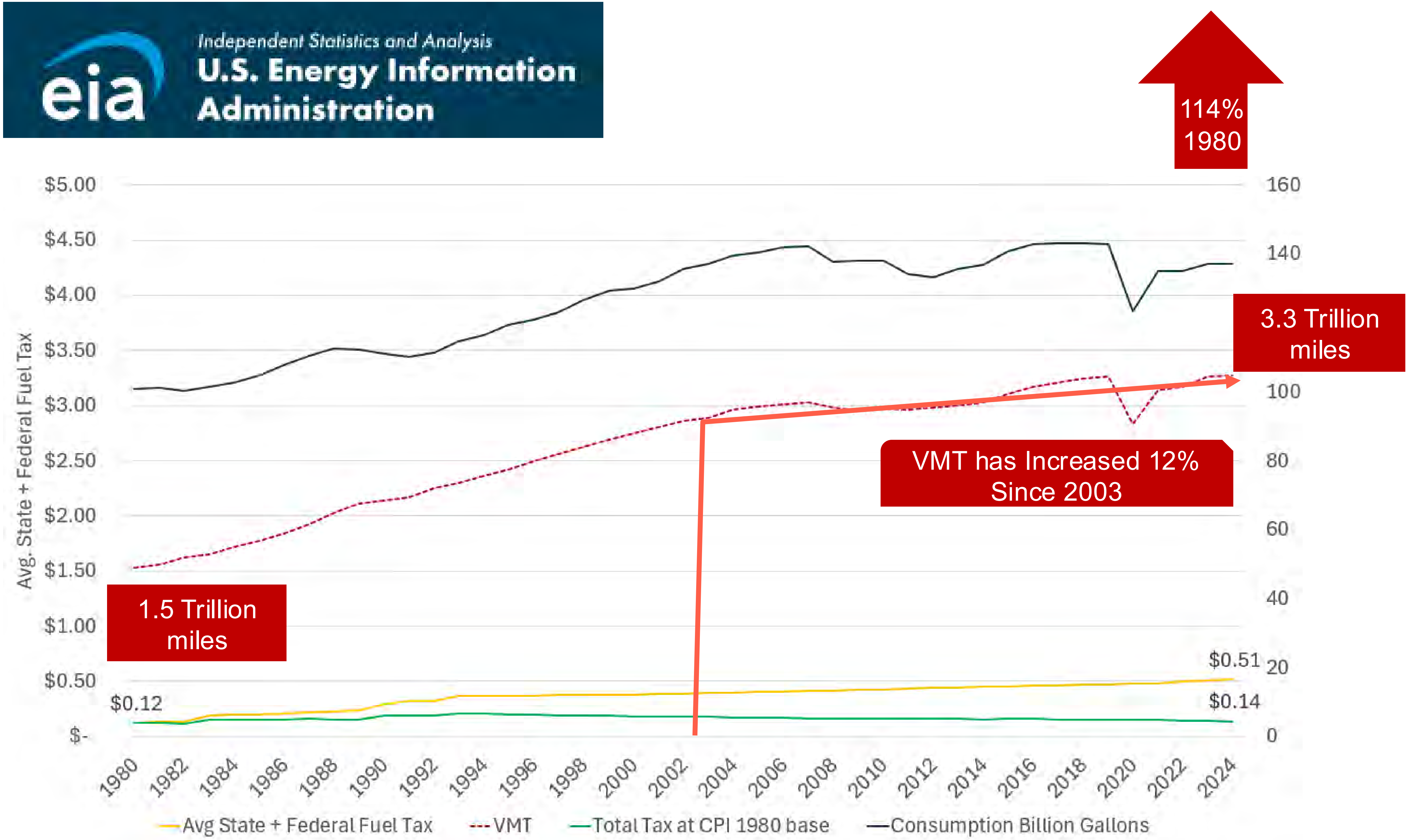
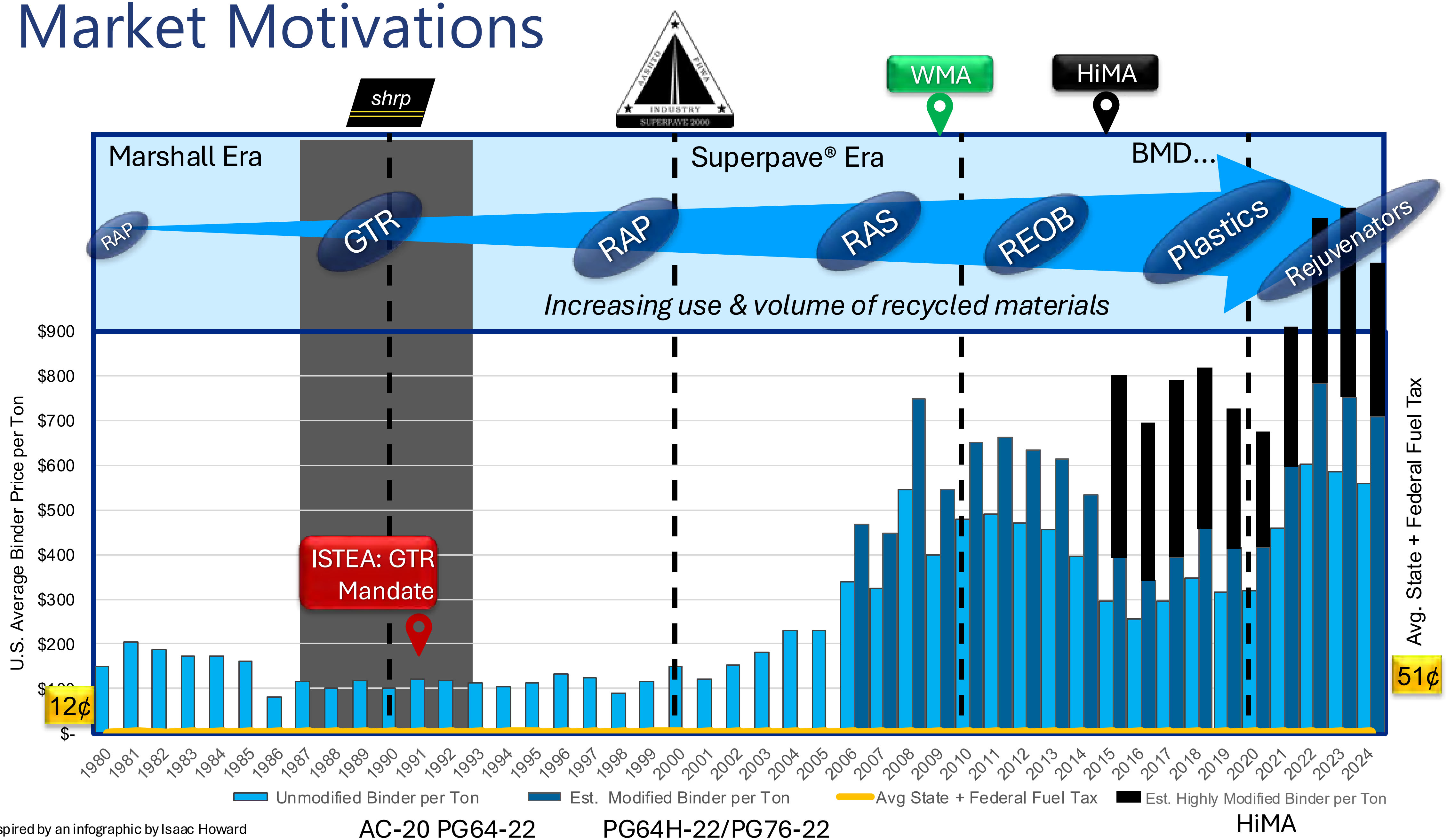

Independent Statistics and Analysis
U.S. Energy Information Administration
114%
1980
3.3 Trillion miles
VMT has Increased 12% Since 2003
1.5 Trillion miles
$5.00
$4.50
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$-
160
140
100
80
60
40
20
0
$0.12
$0.51
$0.14
Avg. State + Federal Fuel Tax
1980
1982
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

Image: Grok

Market Motivations



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

Market Trends – RAP (million tons)

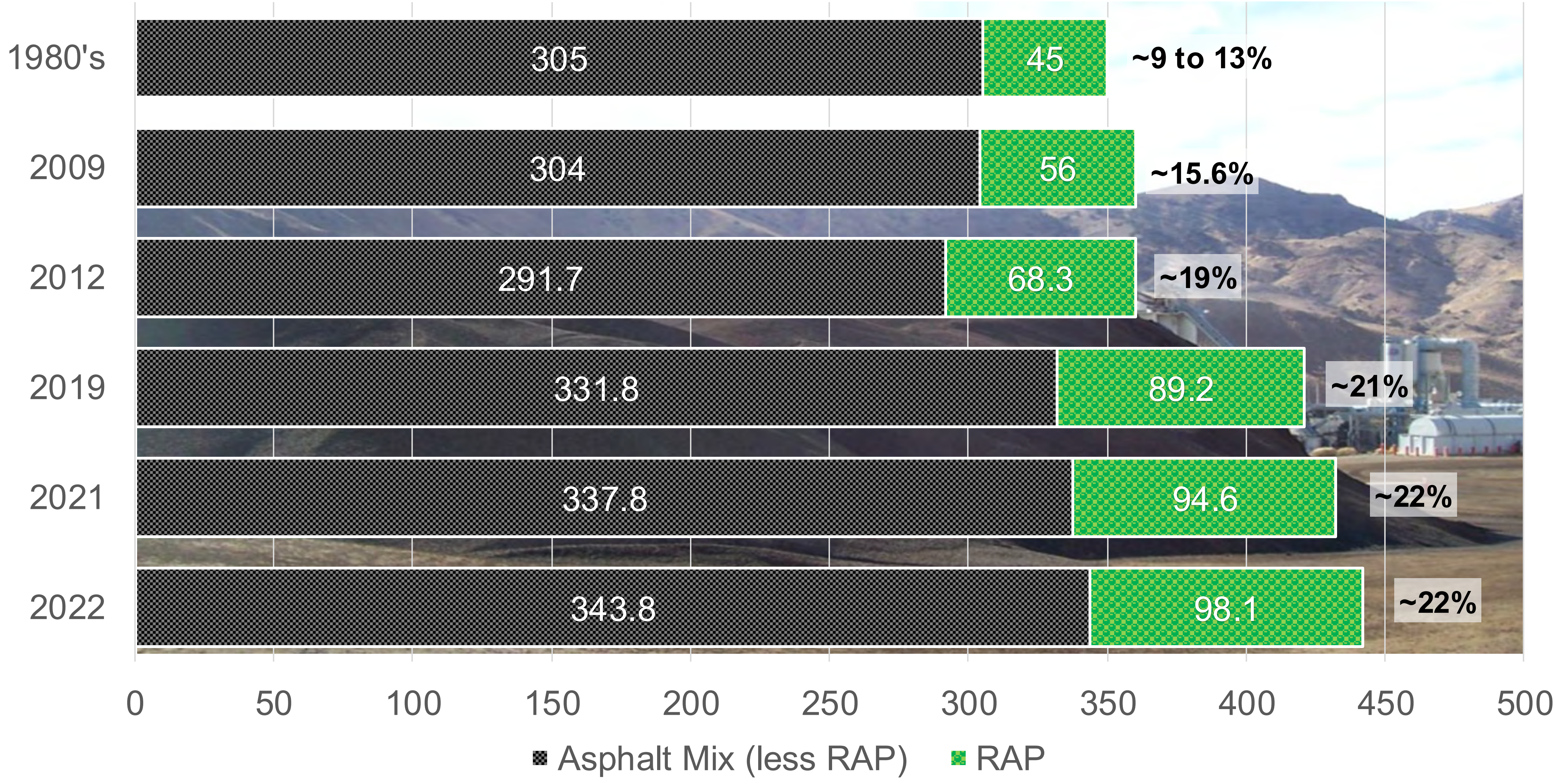


Image Source: A. Hand (UNR)

Why

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In three words or less, describe why your State is moving to BMD?

38 responses

less prescriptive specs
effective simple straighf
rutting and cracking
improved performance dura
check a box
improve quality
follow the pack
increase performance
longer lasting pavements
utilize more rap
push to do so
less cracking
volumetrics not working
improved quality
to better quality
quality
the feds
durability sustainability
better performing pavemen
innovation
better mix
improve mixes
better performance
cost effective mixes
improve
better performing mixes
cost reduction
workability
roadway longevity
baseline data field test
improved pavement perform
premature failed pavement
more applicable testing
measurable better options

BMD Peer-to-Peer Exchange Participants

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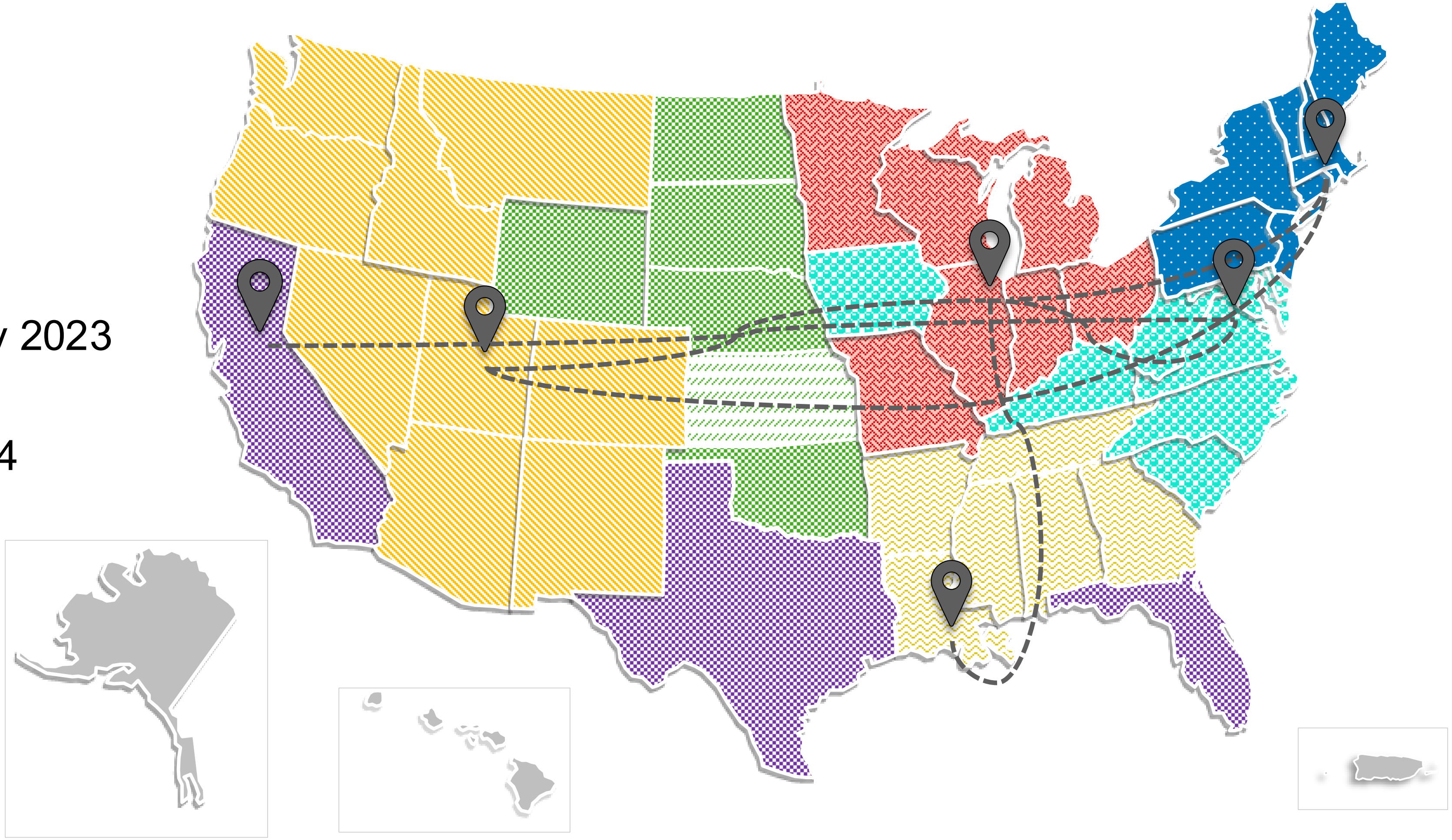
- Meeting Location
- Southeast, Mar 2023
- North Central, Mar 2023
- Northeast, Mar 2023
- Rocky Mountain West, Nov 2023
- Midwest, Dec 2023
- Mid-Atlantic Plus, Nov 2024
- Mega-States, Jun 2025



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

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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

Performance Challenges & Solutions

What are Your Common Performance Challenges?

Challenges

- Block Crack
- Thermal Cracking
- Cracking
- Rutting
- Stripping
- Raveling

Solutions

- Pvt Preservation
- Testing
- Modifiers/Additives
- Mix Design
- Spec.'s
- Pvt Design

What

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Key Challenges

- Management (M)
- Technical (T)
- Overlapping (TM)

Management (M)

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

✓ - Northeast

Microsoft Stock Image

Technical (T)

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

✓ - Northeast

Microsoft Stock Image

Overlapping (TM)

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TM1-Integration Existing Practices

TM3-Collaboration Info Sharing ✓

TM2-Education & Training ✓

✓ - Northeast

Microsoft Stock Image

Now

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M1-Change Management

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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.

M4-Resource Allocation

- Phase investment plans.
- Find and develop a qualified workforce.
- Assess equipment & staffing needs.
- Secure funding.

Resource planning to justify investments & support sustainable BMD adoption.

Limited funding, personnel, or equipment for implementation.

U.S. Department of Transportation
Federal Highway Administration

M6-Stakeholder Engagement

- Establish an agency – industry task force.
- Organize stakeholder forums, feedback loops, & workshops.
- Tailor outreach to small & large contractors, highlighting mutual benefits.

Early engagement & improved communication to unify support for better implementation.

Uneven buy-in across stakeholders.

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Communication: Got Taskforce?

Image: ChatGPT 4o

T1-BMD Test Validation

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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.

ACTION

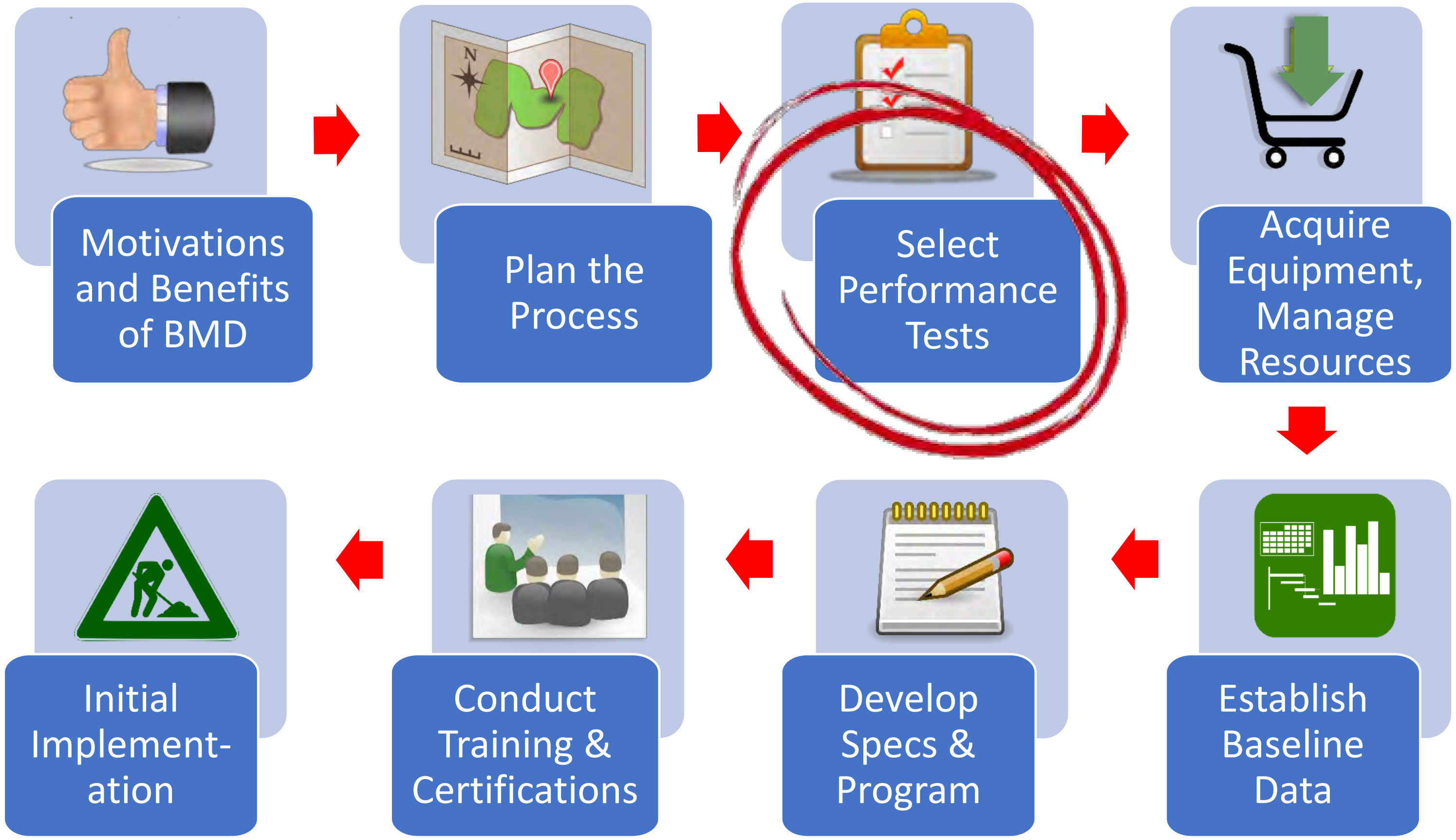
- Create a standardized test validation framework.
- Conduct validation experiments & leverage peer knowledge on validation practices
- Monitor in-service performance of asphalt mixtures & refine BMD test criteria.
- Collect & store field samples for future testing

Validation

Image: ChatGPT 4o

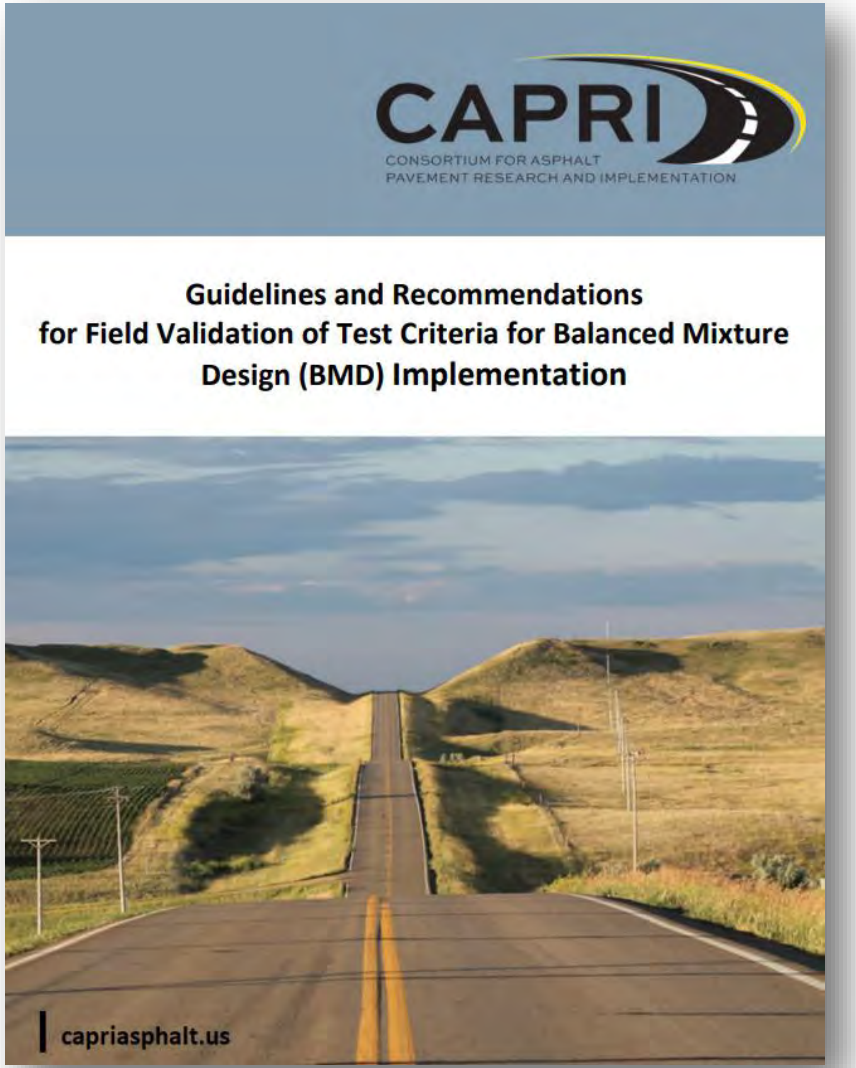
8 Major Tasks for BMD Implementation…

- 3.4 Relationship Confirmation and Criteria Development (60 months)



CAPRI Guidance for Open-Road Field Validation Sections

- Advantages, Disadvantages, and Limitations
  - *Open-Road*
  - *Closed Test Track*
  - *Accelerated Pavement Testing*
  - *Network-level PMS*
- Types of Distresses
- Mixtures and Materials
- Test Sections (Number/Length)
- Geometry to Avoid
- Sampling, Conditioning, and Testing
- Performance Monitoring
- Forensic Investigation
- Data Analysis



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Open Road BMD Validation Sections (CAPRI Style)

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ALDOT

2024
Preliminary Benchmarking
Focus: Surface Mixes
6 Sections
Goal: Validating Test Criteria

2026
Additional Validation Study

NORTH Dakota | Transportation
Be Legendary.

2024
Preliminary Benchmarking
Focus: Surface Mixes
6 Sections
Goal: Validating Test Criteria

WisDOT
WISCONSIN DEPARTMENT OF TRANSPORTATION

2022
Preliminary Benchmarking
Focus:
2 Virgina Mixes
High-RAP
3 10-15% RAP
6 Sections
Goal: Validating Test Criteria

2025
odot
TN TDOT Department of Transportation

Beyond the Guide

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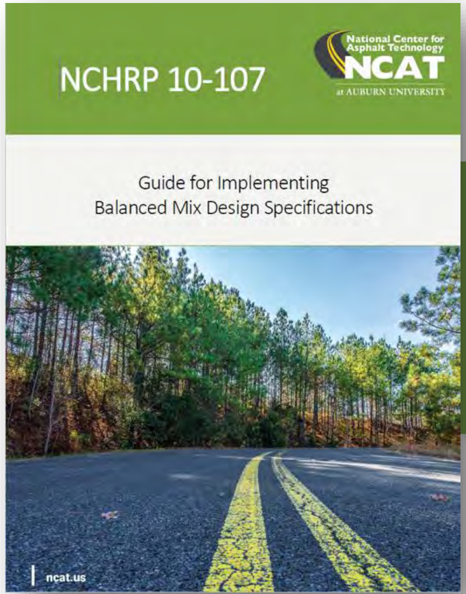
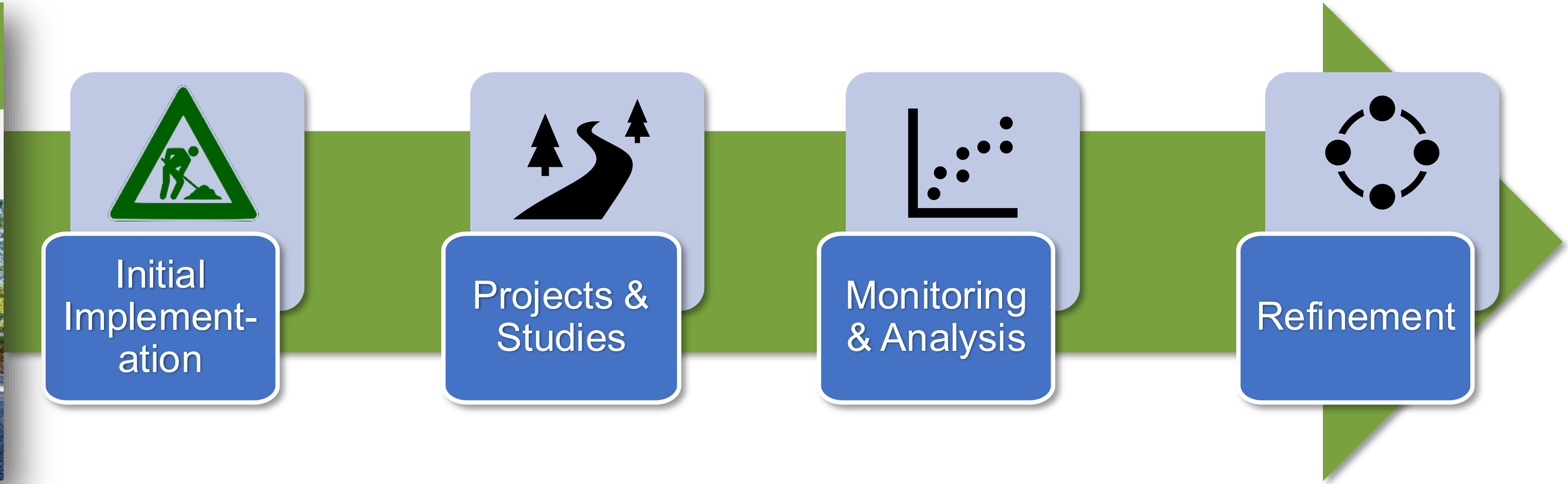
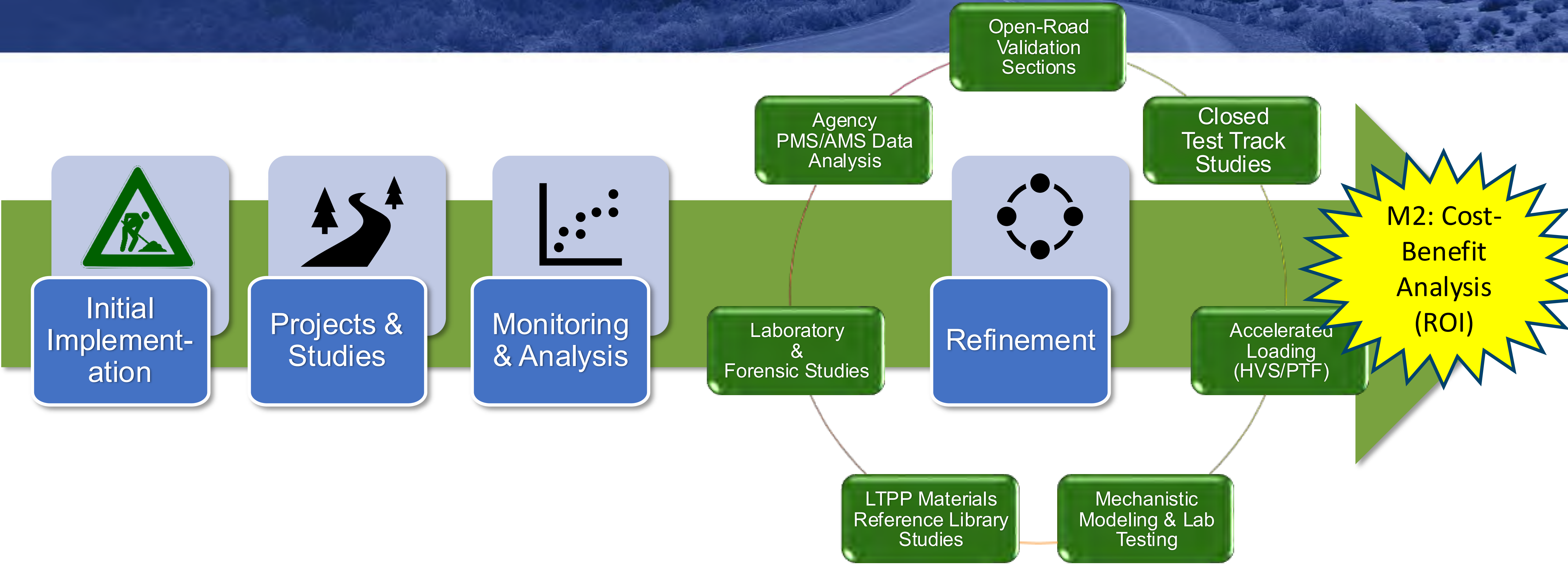
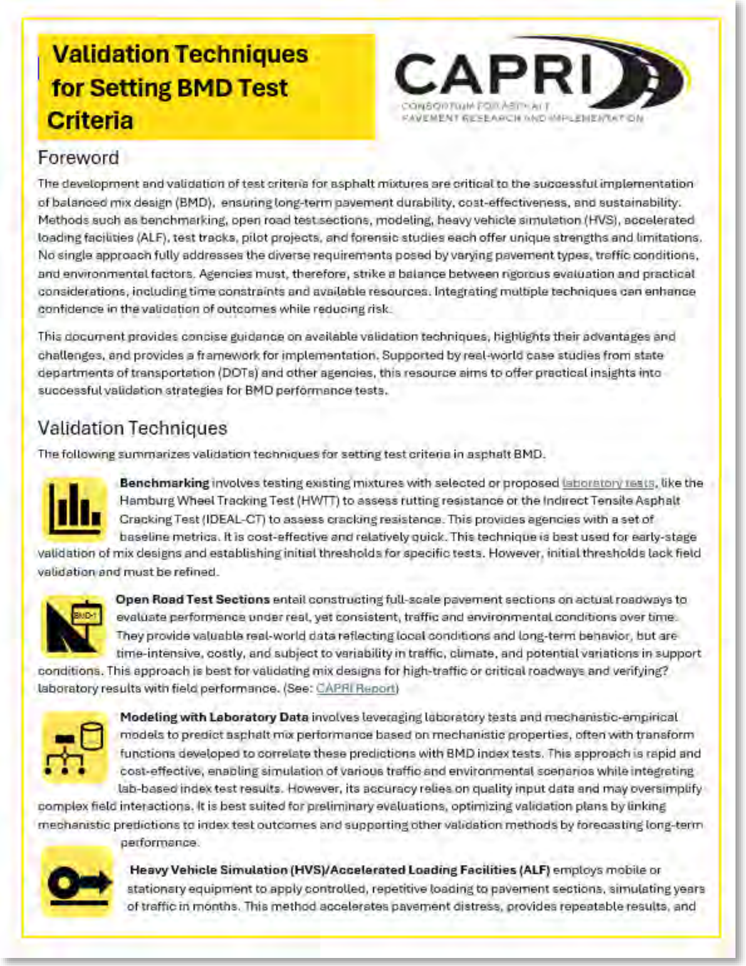




Beyond the Guide



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

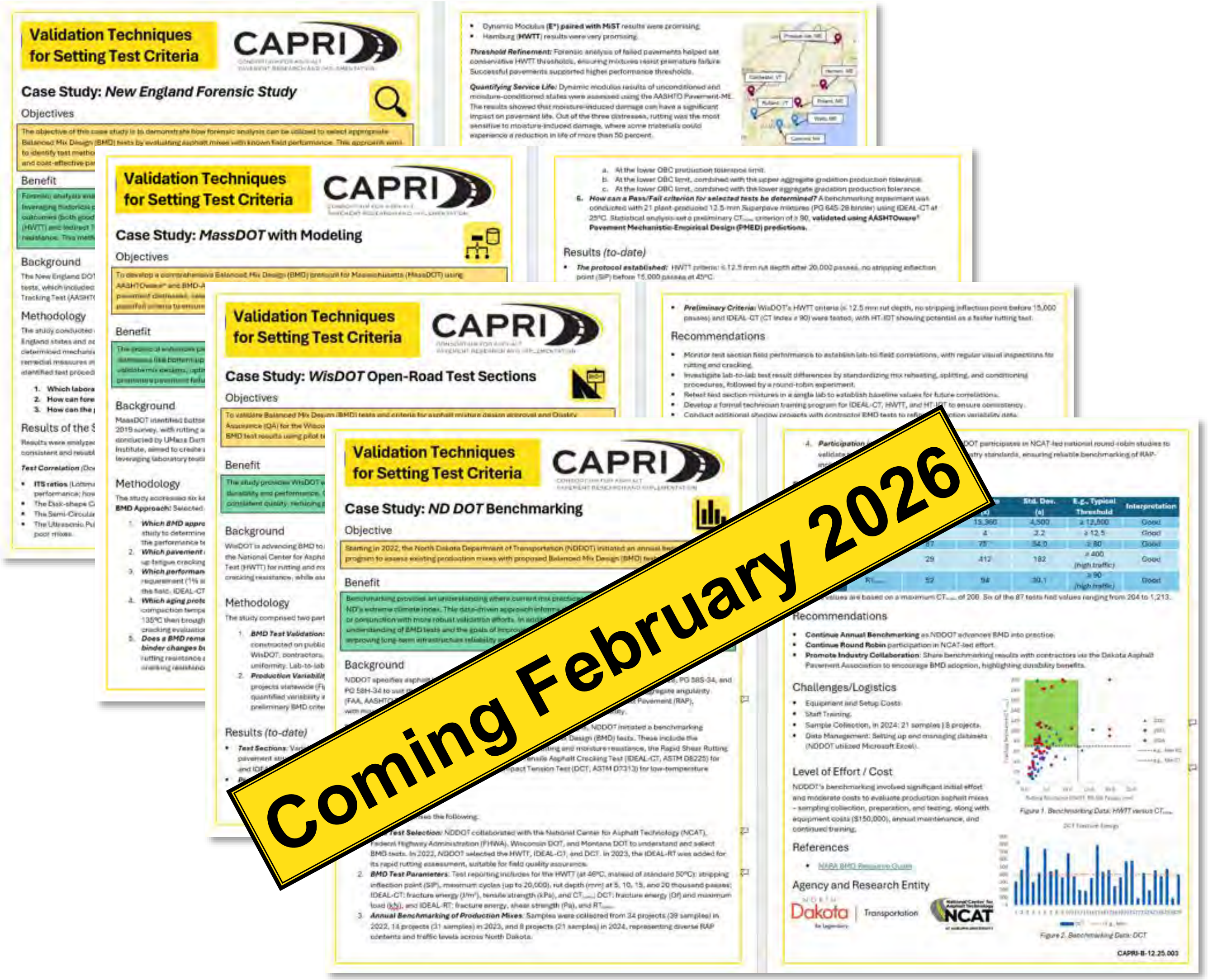
The following summarizes validation techniques for setting test criteria in asphalt BMD.

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



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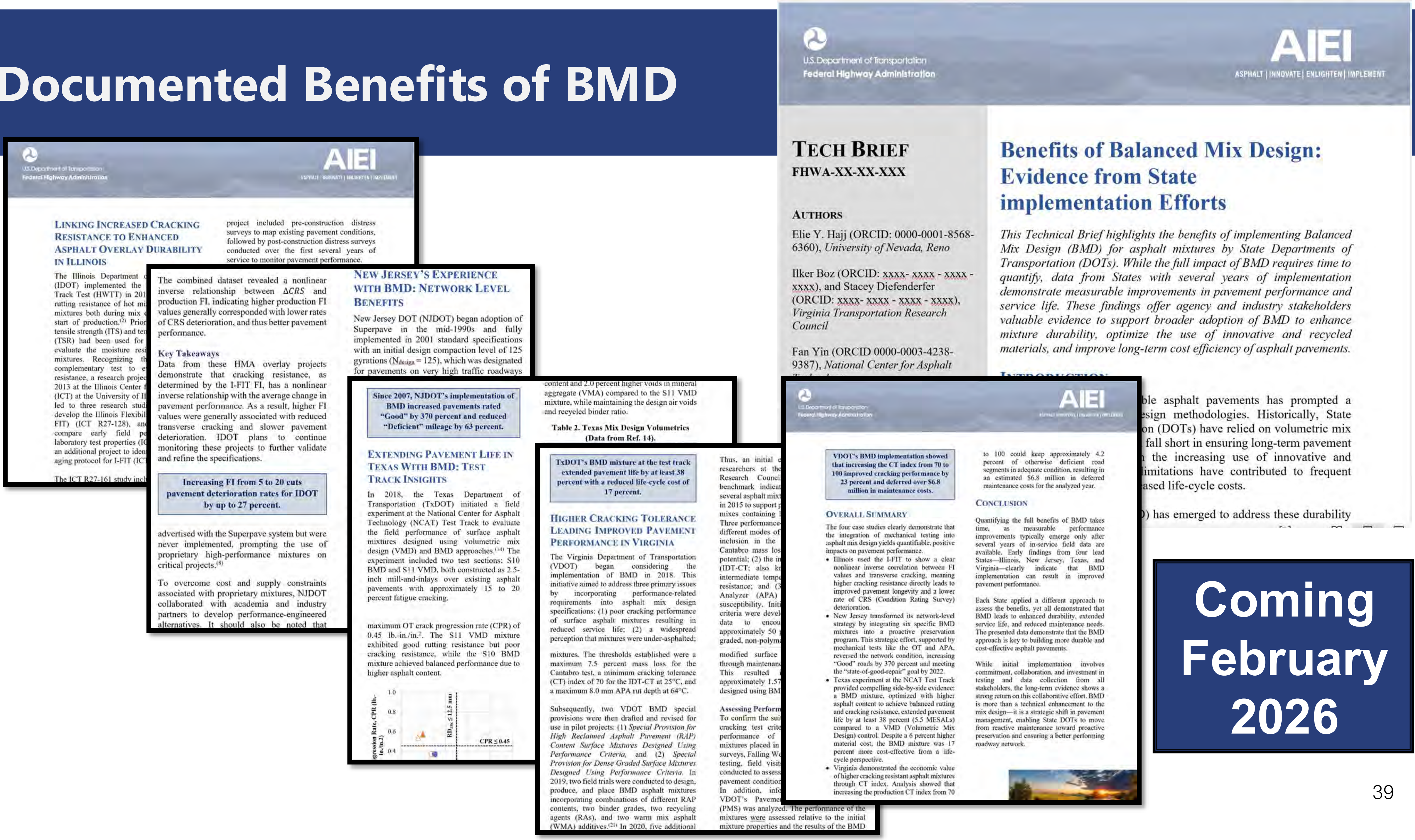
Documented Benefits of BMD



Coming February 2026

U.S. Department of Transportation
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T2-Testing Procedures & Protocols

- Develop protocols for handling, short-term and long-term aging, and conditioning of asphalt mixtures for BMD testing.
- Assess the need for multiple tests to address different cracking types and varying climatic zones.

Standardization improves test repeatability by greater focus on consistent specimen fabrication and provides tailored testing conditions for climate-specific cracking types.

Inconsistent or lack of sample handling, aging, & conditioning methods, including lag & dwell.

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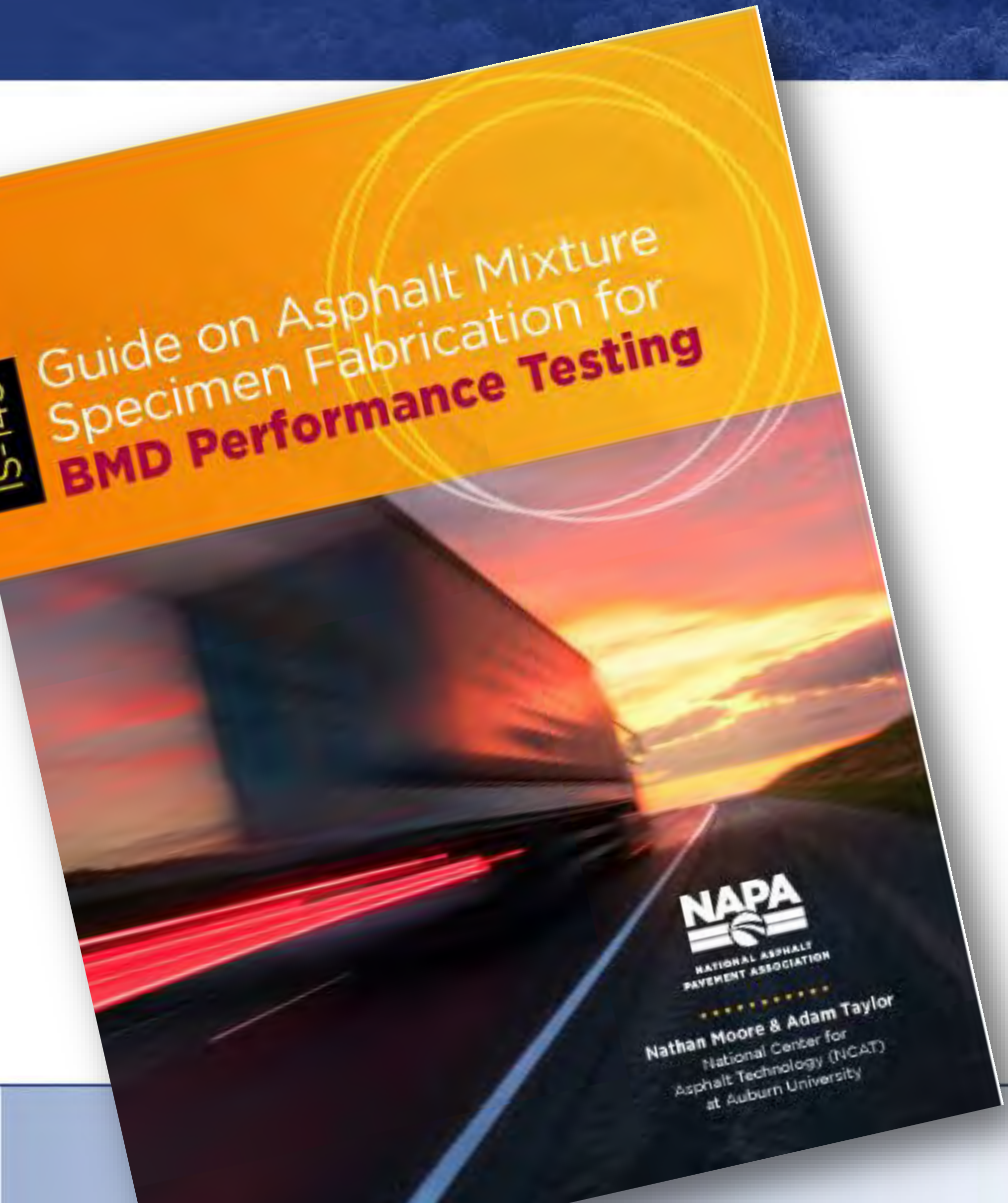
Sample Preparation Guide



- As the asphalt industry moves toward BMD and performance testing it is important to remember that the preparation of the samples being tested can affect the results of the testing.

- The *Guide on Asphalt Mixture Specimen Fabrication for BMD Performance Testing* is helpful in obtaining consistent results

The Challenge of Time/Logistics

Sample Mix for QA

Lag Time
(with & without Reheating)

Compact Test Specimen

Dwell Time

Condition & Test Specimen

AASHTO R 121-24 (TS 2c)

Method A	Method B	Method C	Method D	Method E
Compacted Specimen 85°C	Uncompacted Loose Mixture 85°C	Uncompacted Loose Mixture 95°C	Uncompacted Loose Mixture 100-125°C	Uncompacted Loose Mixture 135°C
120 ± 0.5 h 85 ± 3°C	120 ± 0.5 h 85 ± 3°C	t_{oven} = CAI	20 ± 0.5 h	8 ± 0.5 h 135 ±3°C

$$t_{oven} = \mathrm{CAI} = \sum_{i=1}^{N} 0.0437 d^{-0.426} e^{\frac{-1601.167}{T_i}}$$

AASHTO R 121-24 (TS 2c)

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State	Short-Term Aging		Long-Term Aging		AASHTO R 121-24
	Mixture	Conditioning	Mixture	Conditioning	
CA	Uncomp.	4 hrs at Tcomp.	Uncomp.	20 h at 100°C	Method D
IL	Uncomp.	2 hrs at 135°C	Comp.	72 h at 95°C	N/A
LA	Uncomp.	2 hrs at 135°C	Uncomp.	120 h at 85°C	Method A
ME	Uncomp.	2 hrs at 135°C	Uncomp.	20 h at 100°C	Method D
MA	Uncomp.	2 hrs at 135°C	Uncomp.	20 h at 100°C	Method D
OR	Uncomp.	2 hrs at 135°C	Uncomp.	24 h at 95°C	Method C
TX	Uncomp.	2 hrs at 135°C	Uncomp.	20 h at 100–125°C	Method D
WI	Uncomp.	4 hrs at 135°C	Uncomp.	6 h at 135°C	Method E

NCHRP

PROJECT NO. 09-70

Guidelines for Incorporating Aging Effects on Balanced Mix Design for Quality Assurance

Method A	Method B	Method C	Method D	Method E
Compacted Specimen 85°C	Uncompacted Loose Mixture 85°C	Uncompacted Loose Mixture 95°C	Uncompacted Loose Mixture 100-125°C	Uncompacted Loose Mixture 135°C
120 ± 0.5 h 85 ± 3°C	120 ± 0.5 h 85 ± 3°C	t_{oven} = CAI	20 ± 0.5 h	8 ± 0.5 h 135 ±3°C

TM2-Education & Training

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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

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AIEI Training Opportunities

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

Thoughts

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Sub-Category	Challenge	Opportunity	Action
M1— Change Management	Resistance to replacing traditional specifications with BMD due to unclear goals and priorities.	Alignment of BMD with performance goals through clear communication and understanding across various stakeholders.	• Identify internal champions to foster culture shift. • Document and share BMD goals and scope. • Emphasize improving asphalt mixture performance. • Align with State internal priorities
M2— Cost-Benefit Analysis	Limited business case for BMD investments.	Demonstration of lifecycle cost savings and performance gains to decision-makers and stakeholders.	• Develop a comprehensive business case outlining costs and benefits.
M3— Specifications and Risk Management	Uncertainty around acceptance of BMD mixtures, recycled material usage, and associated budget risks.	Co-development of adaptable performance specifications aligned with BMD, while managing performance risks.	
M4— Resource Allocation	Limited funding, personnel, or equipment for implementation.	Resource planning to justify investments and support sustainable BMD adoption.	
M5— Implementation Planning	Lack of formalized plan for BMD rollout.	Structured implementation into manageable, trackable tasks for streamlined adoption.	
M6— Stakeholders Engagement	Uneven buy-in across stakeholders	Early engagement and improved communication to unify support for better implementation.	• Tailor outreach to small and large contractors, highlighting mutual benefits.

Sub-Category	Challenge	Opportunity	Action
TM1— Integration with Existing Practices	Lack of integration of BMD into existing workflows and specifications, coupled with technical and operational disconnects between key agency groups/divisions (e.g., materials, construction, pavement management).	Compatibility of BMD with existing workflows and specifications, streamlined testing procedures, and improved coordination across agency groups for effective adoption.	• Adapt workflows and specifications to integrate BMD. • Define roles and responsibilities across agency groups, consultants, and contractors. • Establish clear communication channels to ensure seamless coordination.
TM2— Education & Training	Limited formal training on BMD test methods and data interpretation, leading to skill gaps in BMD implementation and analysis.	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. • Plan for continuous training of new staff to address high turnover.
TM3— Collaboration and Information Sharing	Lack of cross-agency collaboration and knowledge sharing, with agencies working in isolation.	Increased cross-agency collaboration, pooling resources, and expertise to accelerate shared learning and adoption.	• Facilitate regional working groups and roundtables for cross-agency collaboration. • Share specifications, lessons learned, and templates across agencies. • Seek industry feedback to align with effective practices. • Bridge gap between research and practice.

Sub-Category	Challenge	Opportunity	Action
T1— BMD Tests Validation	Lack of a standard validation framework and timely data collection; need for linking laboratory BMD test results with field performance.	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.
T2— Testing Procedures	Inconsistent or lack of sample handling, aging, and conditioning methods	Standardization improves test repeatability by greater focus on consistent specimen fabrication and provides tailored testing conditions for climate-specific cracking types.	• Develop protocols for handling, short-term and long-term aging, and conditioning of asphalt mixtures for BMD testing. • Assess the need for multiple tests to address different cracking types and varying climatic zones.
		Reducing variability increases confidence in test results, enabling greater trust in mixture performance and supporting innovation.	• Conduct inter-laboratory and sensitivity studies to assess variability of and improve consistency in BMD test results. • Quantify variability between laboratory and plant-produced asphalt mixtures. • Identify and raise awareness of production factors that may influence BMD test results. • Offer technical training to stakeholders. • Consider the number of replicates.
		Data can inform decision-making and specifications.	• Create a centralized and structured database template. • Build or adopt templates to link mix design results with field performance. • Incorporate many data fields with raw data.
		Acceptance based on performance ensures quality and expected value while maintaining in-place density and smoothness.	• Adopt mix design verification protocols using verification lots, test strips, or batch mixtures at the start of production. • Implement go/no-go BMD test criteria. • Define lot and sublot sizes, along with sampling frequency while considering testing time and variability. • Establish payment structures closely aligned with validated BMD tests that reliably reflect field performance and account for production variability to enable justified performance-oriented incentives or penalties. • Address sampling responsibilities and lag/dwell time impact on dispute resolution.*
Usage	specification criteria.	Advance specifications while balancing innovation and risk. BMD tests may replace some volumetric properties.	• Determine which volumetric and aggregate properties can be relaxed or eliminated. • Transition towards performance-oriented quality measures, such as percent within limits.

State Participants Key Takeaways (1/3)

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

State Participants Key Takeaways(2/3)

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

State Participants Key Takeaways(3/3)

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

Wrap Up

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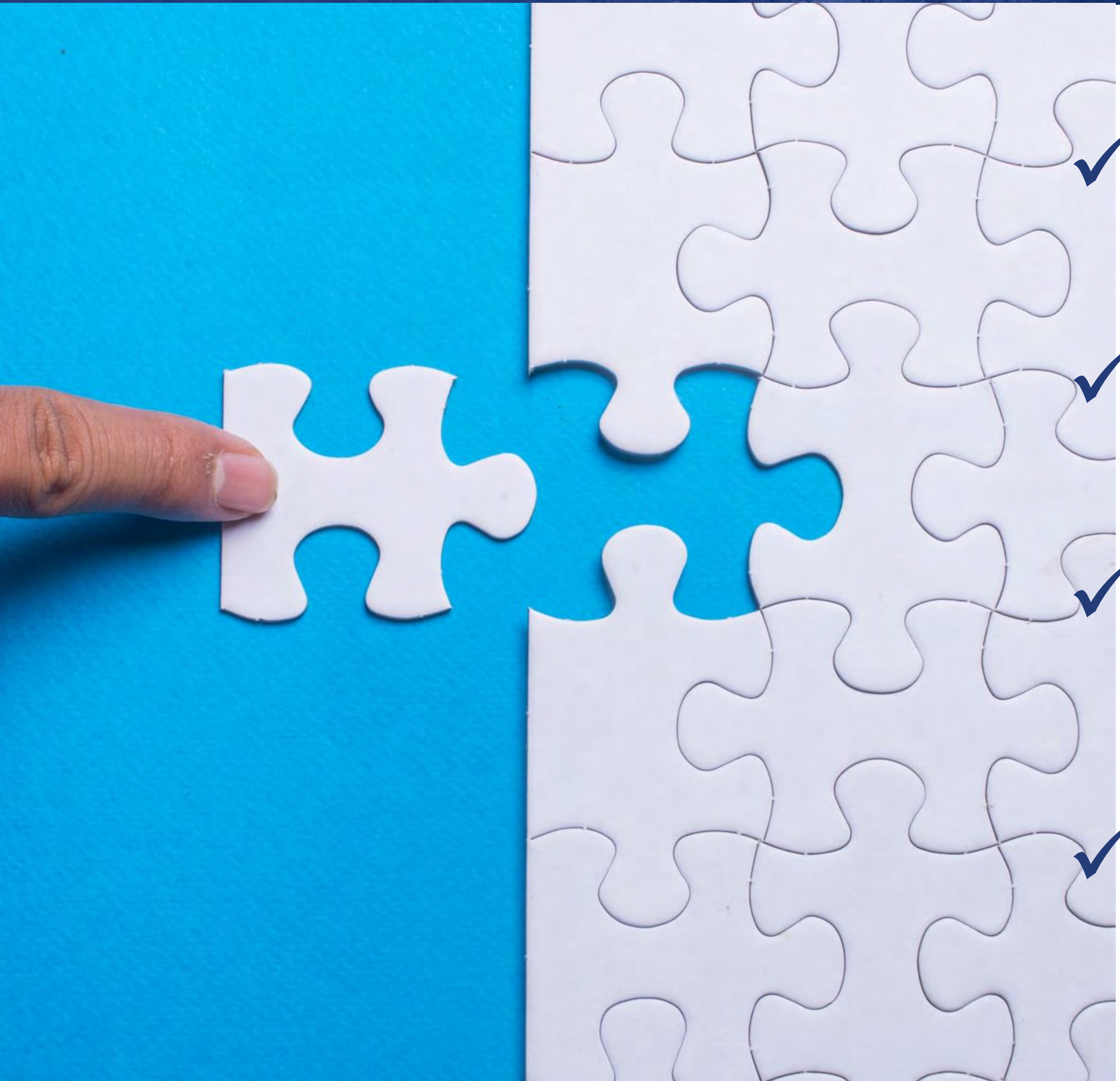
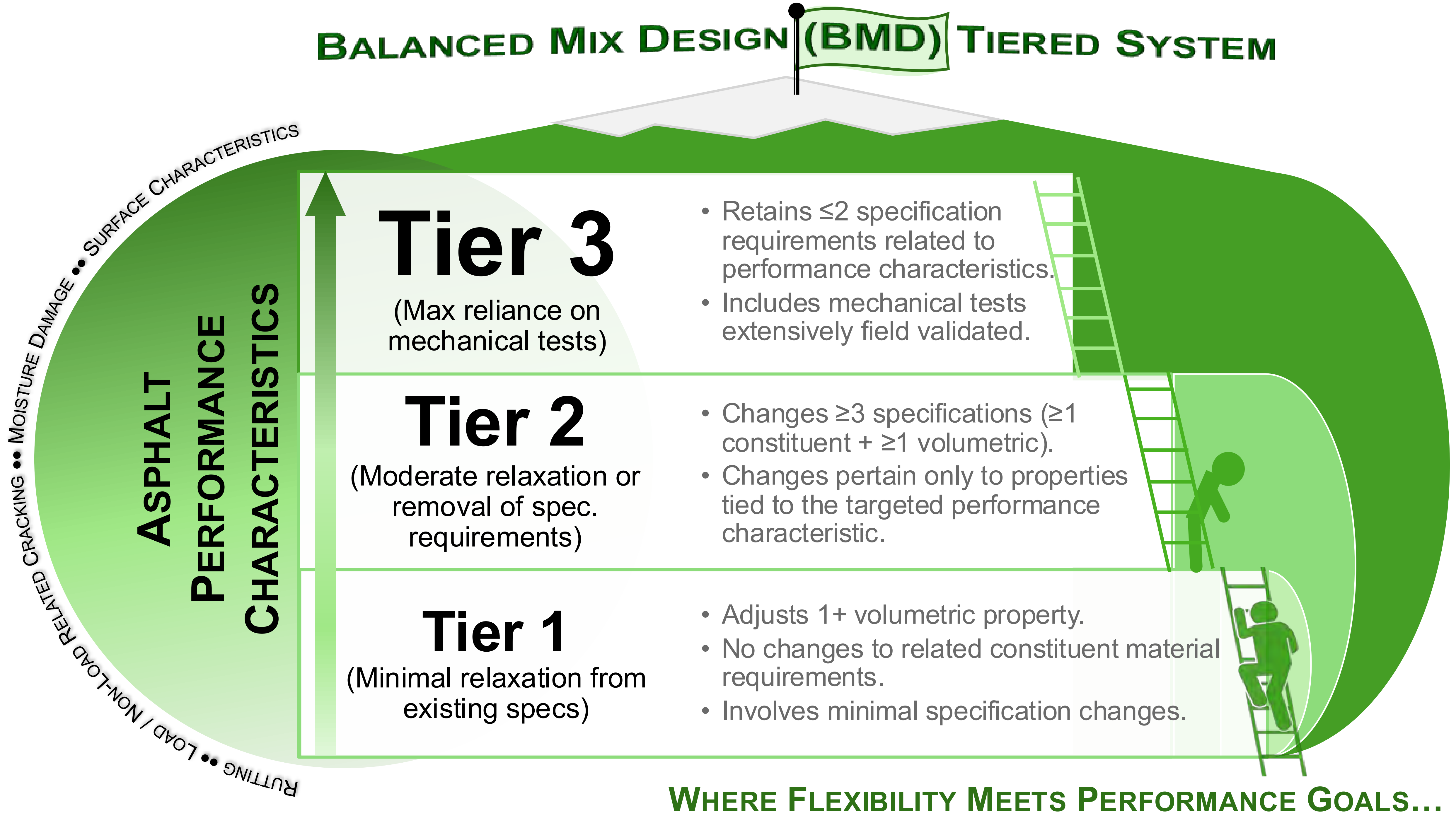
What are Your Takeaways?



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


Balanced Mix Design (BMD) Tiered System
Rutting •• Load / Non-Load Related Cracking •• Moisture Damage •• Surface Characteristics
Asphalt Performance Characteristics
Tier 3
(Max reliance on mechanical tests)
• Retains ≤2 specification requirements related to performance characteristics.
• Includes mechanical tests extensively field validated.
Tier 2
(Moderate relaxation or removal of spec. requirements)
• Changes ≥3 specifications (≥1 constituent + ≥1 volumetric).
• Changes pertain only to properties tied to the targeted performance characteristic.
Tier 1
(Minimal relaxation from existing specs)
• Adjusts 1+ volumetric property.
• No changes to related constituent material requirements.
• Involves minimal specification changes.
Where Flexibility Meets Performance Goals…

Q & A

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Thank you!

Derek Nener-Plante
derek@dnpinfrastructure.com

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