



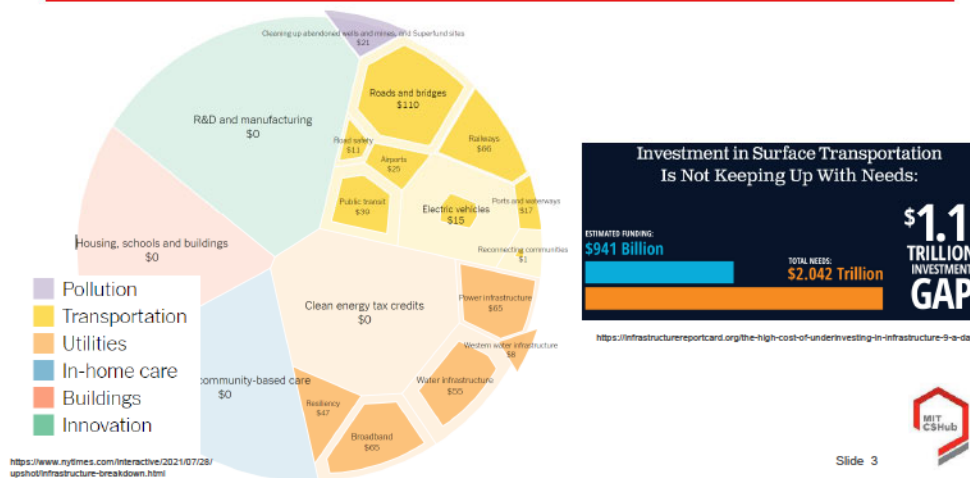
## Today's Learning Objectives

- Recognize the importance of performance-based planning in establishing the environmental and economic impact of pavements
- Articulate the role of a budget constraint in pavement network asset management
- Relate the role of pavement treatment mix of fixes, budget increase, long-term evaluation, and market competition in the efficient allocation of funds to creating and maintaining pavement assets
- Recognize the importance of asset management tools in
  - Getting the most from a limited budget
  - Achieving a carbon neutral transportation system



Slide 2

## Investment from the IIJA alone are important, but.. insufficient to fund the backlog of needed improvements



Slide 3

## FHWA definition of asset management considers whole life cycle, cost, and long-term performance

*"strategic and systematic process of operating, maintaining, and improving physical assets, ..."*



*to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions ...*

*that will achieve and sustain a desired state of good repair over the lifecycle of the assets"*

<https://www.fhwa.dot.gov/asset/plans.cfm>



Slide 5

## FHWA definition of asset management considers whole life cycle, cost, and long-term performance

"strategic and systematic **process** of operating, maintaining, and improving physical assets, ...

with a focus on engineering and economic analysis ...

based upon quality information, ...

to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions ...

that will achieve and sustain a desired state of good repair over the lifecycle of the assets"

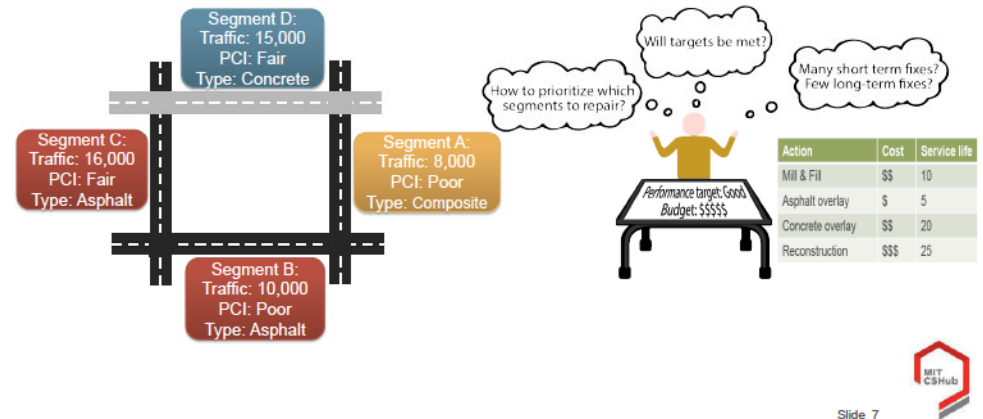
<https://www.fhwa.dot.gov/asset/plans.cfm>



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## Performance-Based Planning: An optimization approach is required to answer the core asset management questions



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## Challenges on maximizing the performance and sustainability benefits of pavement network should be addressed by asset management plan

Making decisions about ...  
 ... which preservation, overlay, or reconstruction activity to apply to ... which segment at ... what time (now or future)?



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## MIT CSHub Asset Management Aims to Overcome Several Challenges in Current Tools and Practice

- Developing fast, multi-metric models of pavement deterioration
  - Data is key to understanding current state of the network
  - To make decisions, I need to estimate how performance will change if I ...
    - Execute Treatment A vs Execute Treatment B vs Do nothing
  - More and better data is still needed to drive better decisions
- Accurately reflecting uncertainty in the decision-process
  - Uncertainty in this system is real and central to beneficial strategies
- Encouraging flexibility in the planning process
  - Research in many systems has shown the benefits of flexibility
  - Requires the ability to accommodate
    - Multiple repair technologies (fixes) and multiple materials
    - Uncertain future
- Removing barriers to long term planning
  - Decision-makers recognize the long term is uncertain
  - Only explicitly address this will encourage longer term planning
- Reflecting the implications of balanced markets

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## Insights into uncertainty came from studying pavement life-cycle cost (LCCA)

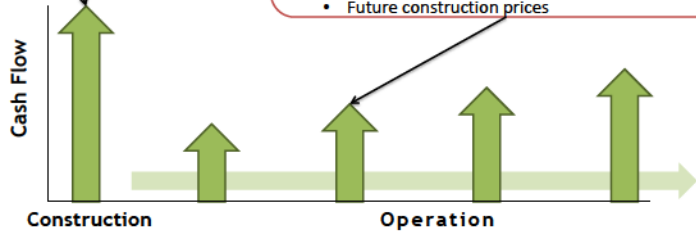
### What are some key sources of uncertainty?

#### Initial:

- Unit-price of inputs
- Quantity of inputs

#### During pavement use & maintenance:

- Traffic
- Pavement deterioration
- Maintenance timing and type
  - Quantity of inputs
  - Future construction prices

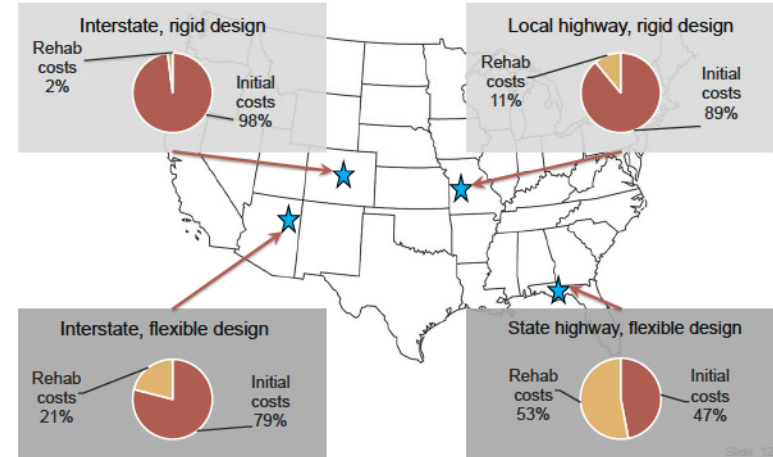


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## Context matters

Costs vary with location, traffic level, & pavement design

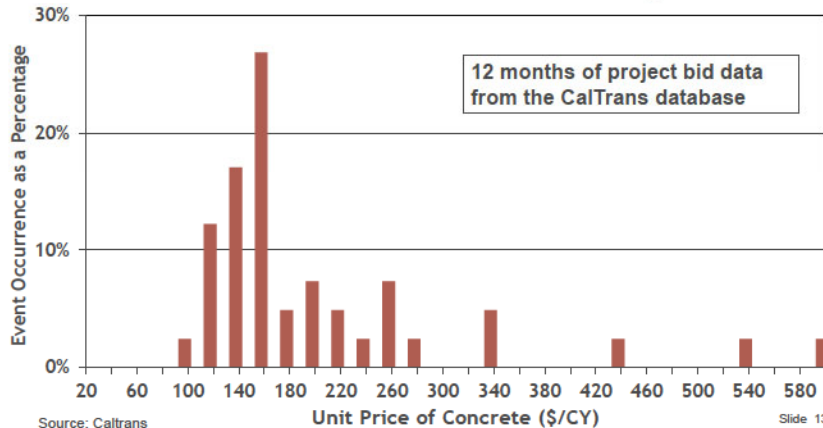


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## There is significant variation in initial costs

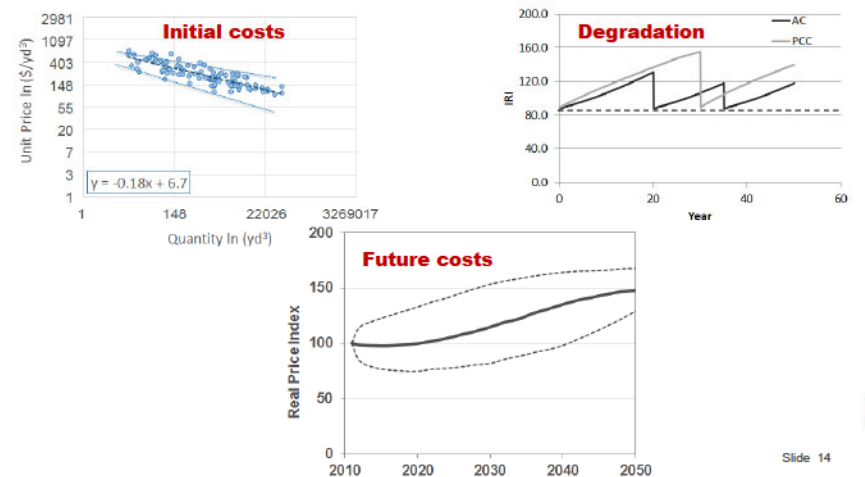
Distribution of Unit Price of Concrete for Pavement Projects



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## Statistical analysis shows pervasive uncertainty in throughout the lifecycle



Slide 14



## Considering uncertainty makes the computational challenges even greater

Making decisions about ...  
 ... which preservation, overlay, or reconstruction activity to apply to  
 ... which segment at  
 ... what time (now or future)?



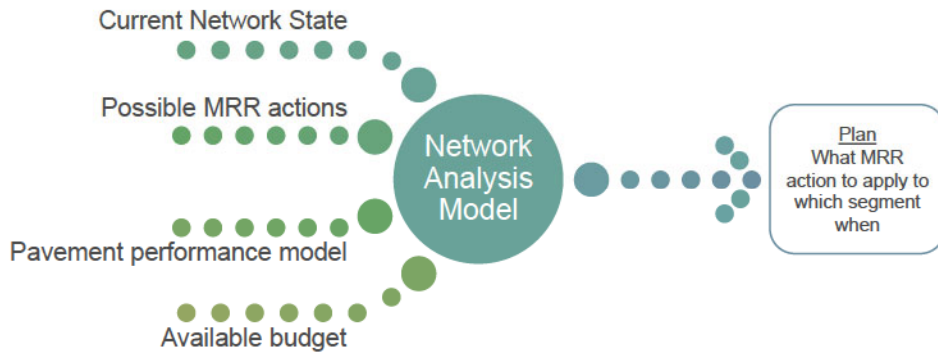
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## Why Consider Uncertainty?

- Its real
- If I don't recognize that the future is uncertain ...
  - I will never put a value on flexibility
  - I will never put a value on diversity of solutions
  - I will never trust long term results
- To address this, we developed an asset management approach that is computationally efficient and considers uncertainty

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## CSHub Pavement Network Asset Management Tool Considers Future Uncertainty and Risk, Allows for Flexible Strategies



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## How to Overcome the Challenge?

Practical network allocation involves two interlinked tasks

### Segment-level Decision

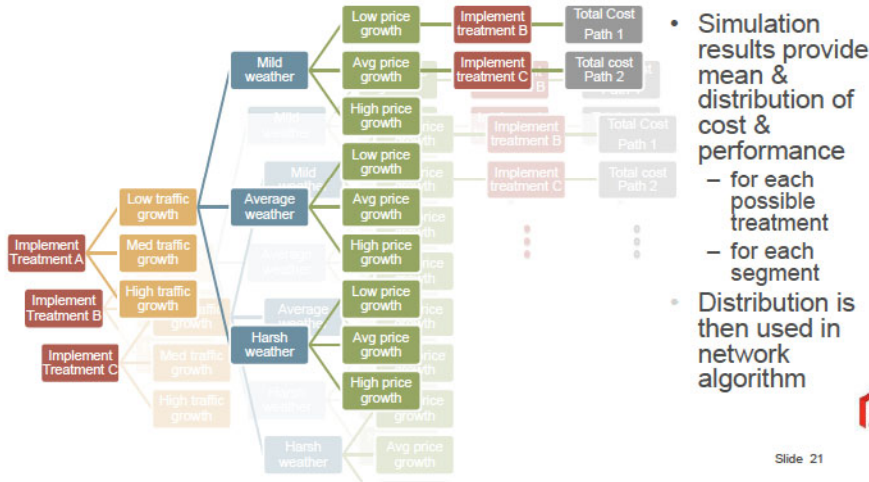
- What is the best treatment strategy **for this segment?** (This will involve a sequence of activities over time)

### Network-level Decision (Allocation)

- What set of best treatment strategies will give us the best **network performance** but still be within budget?

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**To develop a robust understanding of the segment decision, we simulate thousands of possible futures**



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**Key elements of the allocation model**

Conventional models	MIT model
Short analysis periods (~5 yr)	Long analysis period (30+ yr)
Prescriptive decision rules for limited MRR alternatives	Dynamic decision rules for diverse set of MRR alternatives
Deterministic data & analysis	Risk analysis including uncertainty in prices & deterioration

Select segments and strategies based on optimal benefits and costs

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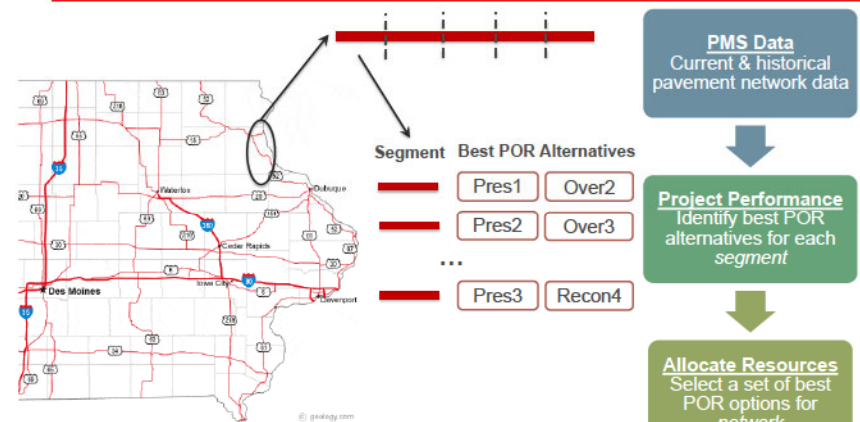
**What have we learned?: Leveraging three strategies will allow states to maximize the return on infrastructure investments**

- Flexible decision-making
- Long evaluation periods
- Mix of pavement technologies
- Asset Management is key pavement carbon neutrality

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**Case study 2: Implementing Two Stage Budget Allocation Algorithms for the Whole Network of U.S. Route in Iowa**



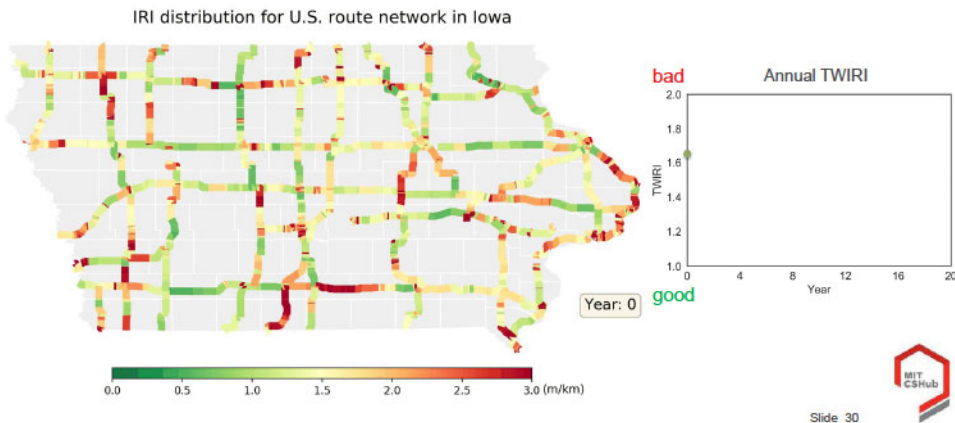
POR = Preservation, Overlay, and Reconstruction

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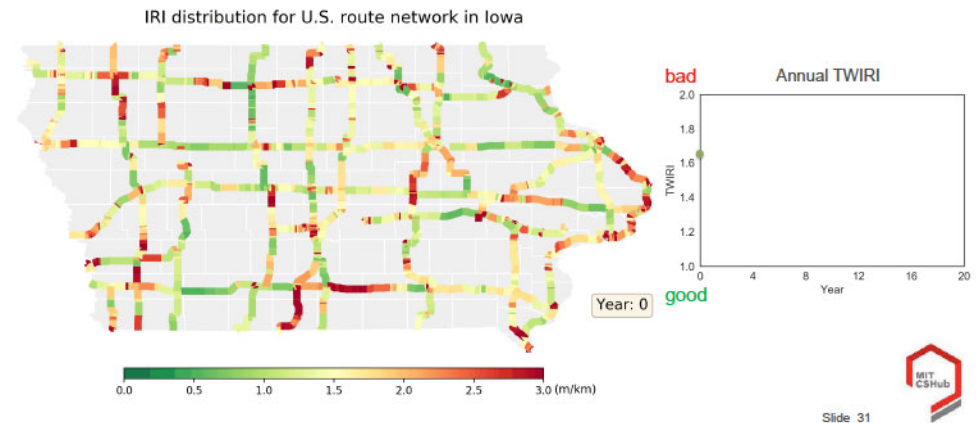
Flexible decision-making

## Using the CSHub Tool We Can Simulate Impact of Management Strategies on Network Performance



Flexible decision-making

## Using the CSHub Tool We Can Simulate Impact of Management Strategies on Network Performance



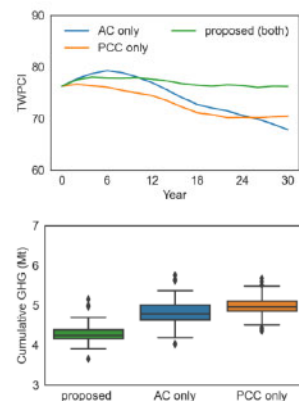
### Detailed Simulations of Iowa Pavement Network Reveals Benefit of Flexibility, Long term, Diverse Materials

- Achieving same result in asphalt only strategy would require spending 32% more
- Multiple materials solution generates 21% less GHG emissions

Flexible decision-making

Long evaluation periods

Mix of pavement types

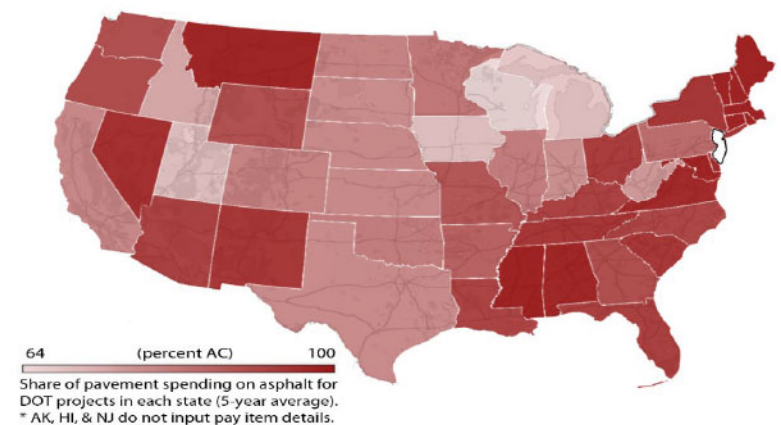


F Guo, et al. 2021. "Environmental and Economic Evaluations of Treatment Strategies for Pavement Network Performance-Based Planning." Trans Res D, 99 (October): 103016.

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### Observation while we were developing these analyses: 5-year average spending on asphalt / concrete varies widely



\*2005-2015, 47 states, 298k pay items, 164k jobs

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## What is the question about balanced spending?

Does an imbalance in spending between material substitutes impact pavement material prices?



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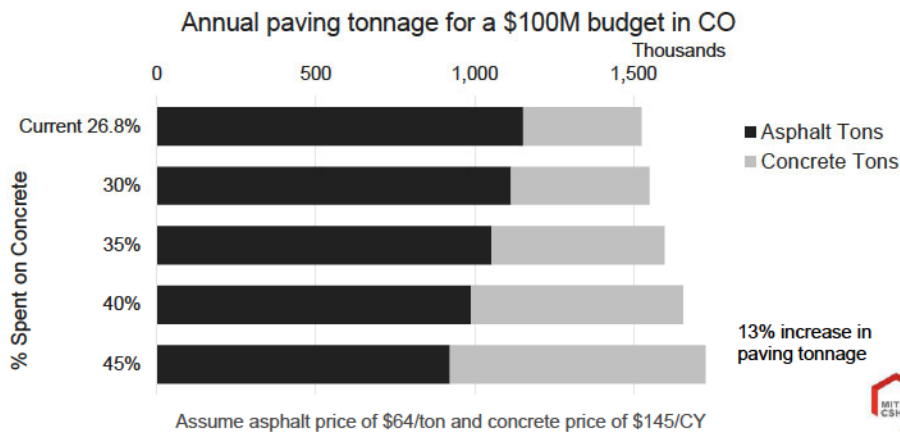
## Increased competition significantly affects bid unit-prices

Significant Factors	Asphalt Jobs	Concrete Jobs
Inter-Industry Competition: percent annual spending on concrete	—	—
Intra-Industry Competition: number of bidders on a job	—	—
Project Size: quantity of material	—	—
Market Size: annual spending on paving activities	+	+
Presence of price adjustment clauses in a state: allow contractors to adjust prices after initial bid	—	N/A

+ Increase in factor *increases* prices   
 — Increase in factor *decreases* prices

Mix of pavement types

## Increased competition in the state of Colorado could translate into more paving



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## In a nationwide scale, what can be accomplished with "Sustainably-efficient Management of Pavement Networks"?

Flexible decision-making

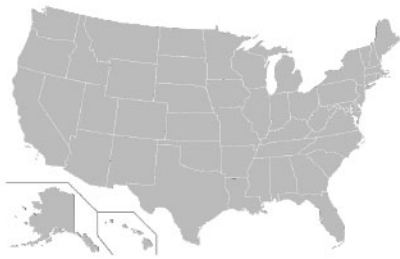
Long evaluation periods

Mix of pavement technologies



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## Impacts on a National Scale: How much vehicle fuel cost can be saved by changing current pavement management policies?



### BAU

- FHWA road statistics
- Treatment selection:
  - Decision tree / treatment type
- Extra vehicle cost caused by PVI

### Decision-making Flexibility

Treatment evaluation is based on the life cycle cost for an analysis period.

### Long-term Planning

Evaluate life cycle cost through a long period to reflect the long-term benefits of a treatment.

### Mix of Tech & Competition

The increase of competition between paving materials could decrease unit cost for both materials.

Enhanced



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\*FHWA: federal highway administration  
PVI: pavement vehicle interaction

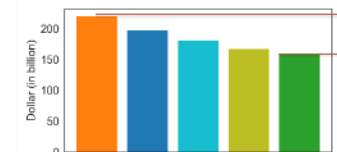
## National scale analysis shows ALL states benefit from combinations of diversification & long-term thinking

- National scale analysis shows
  - ALL states benefit from combinations of diversification & long-term thinking
  - National benefit in fuel savings would exceed \$60 billion over 20 years

All States Show Benefits



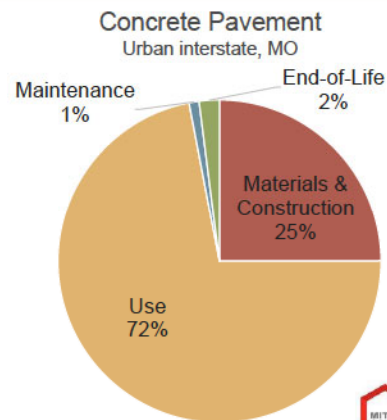
National Fuel Savings  
\$62 billion (28%)



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## Asset Management is key for achieving pavement carbon neutrality: Use phase impacts can drive overall emissions

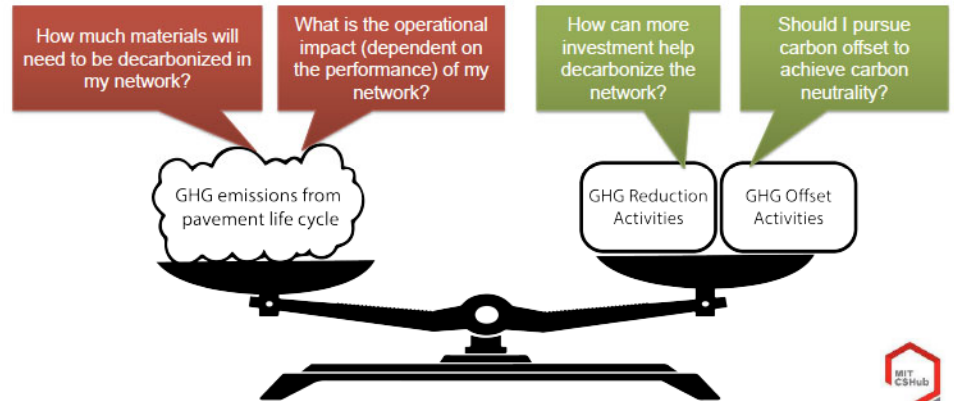
- Life cycle impact of pavements derives mostly from the use phase
- Maintaining network performance reduces this impact



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Pavement design developed by Applied Research Associates (ARA), Inc.:  
AADTT 8k/day; 6 lanes; MO (wet freeze); MEPDG-based rehabilitation schedule.

## Asset Management is key for achieving pavement carbon neutrality



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**Key conclusion: Leveraging three strategies will allow states to maximize the return on infrastructure investments**

Flexible decision-making

Long evaluation periods

Mix of pavement types

Asset Management is key pavement carbon neutrality



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