CONCRETE
SUSTAINABILITY HUB

What's Your Pavements' Mileage?

LCA-PLUS for Sustainable Development of Our Nation's Pavement Network

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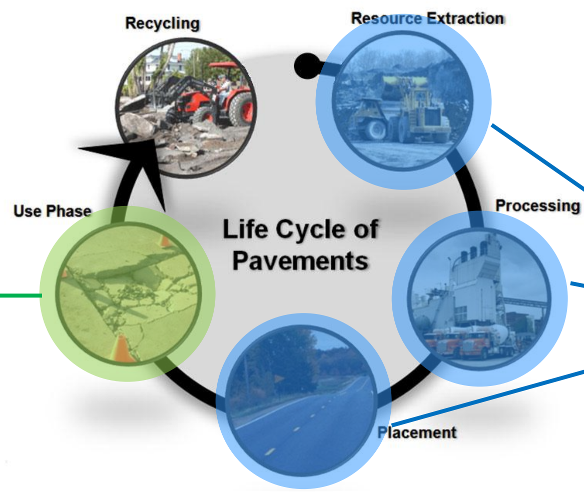
http://web.mit.edu/cshub

Why Pavement-Vehicle Interactions Matter?

Accounts for 82% of emissions:

Pavement Vehicle Interaction: 72%

Others: 10%



Embodied emissions: 18%

LCA & LCCA Boundaries

- US consumes **174 billion gallons** of fuel per year on highways / 10% consumed in California (2010):

  1% CA saving ≈ 9.1 million barrels of crude oil per year

  ≈ \$520 million per year

  ≈ 2 million tons of CO_2 per year

Source: Taylor, et al. 2006. Effects of Pavement Structure on Vehicle Fuel Consumption – Phase III

An Estimate

- Rough Estimate of Extra-Fuel Consumption:
  - Consider your State
  - 6,750–8,500 gal/lane-mile/year (!)
  - Equivalent: 40–50 Tons CO_2/mile/year (!)

- Example California: For the 49,000 CALTRANS lane-miles ALONE:
  ~ **2 Million Tons CO_2/year**

- An opportunity for substantial CO_2 reductions, in EVERY State.

OUTLINE

- This is **not** about **Concrete vs. Asphalt**, this is about unleashing opportunities for Greenhouse Gas Savings.

- Method in place: Pavement-Vehicle Interaction: Roughness + Deflection

- Life Cycle Assessment of…
  - STATUS QUO: Network analysis for the US
  - FUTURE POTENTIAL: Possibilities for Improvement

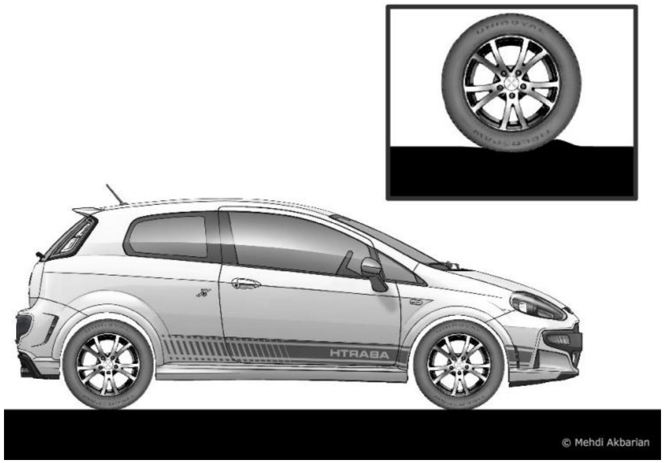
- Moving forward together…

Method in Place

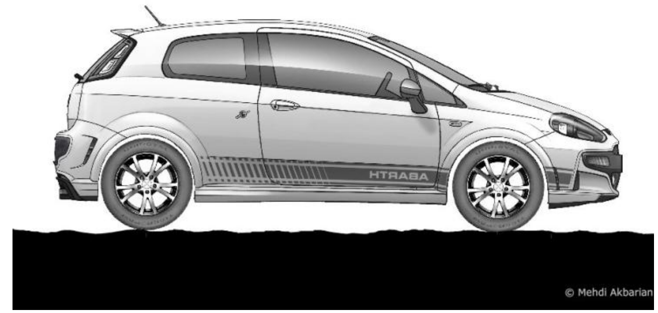
The Good Practice

http://web.mit.edu/cshub

Model-Based Assessment of **Pavement Vehicle Interaction (PVI)**



Pavement Deflection



Pavement Roughness

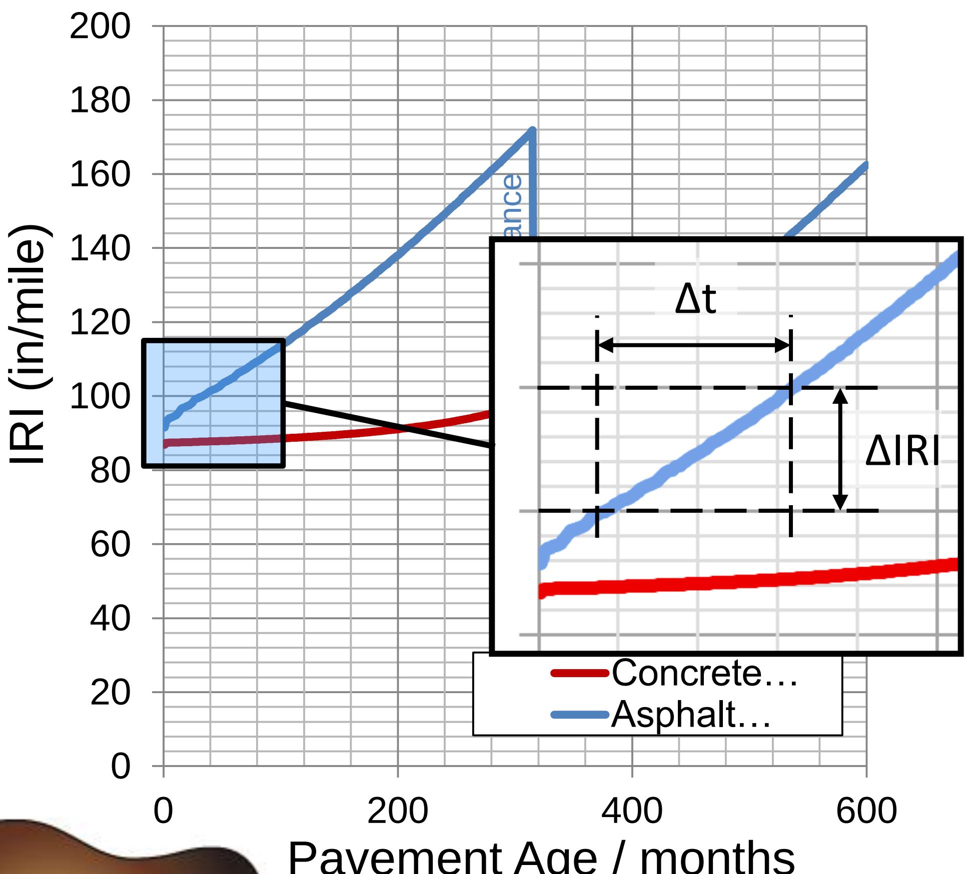
MIT-Model

MEPDG+HDM4

Structure and Material

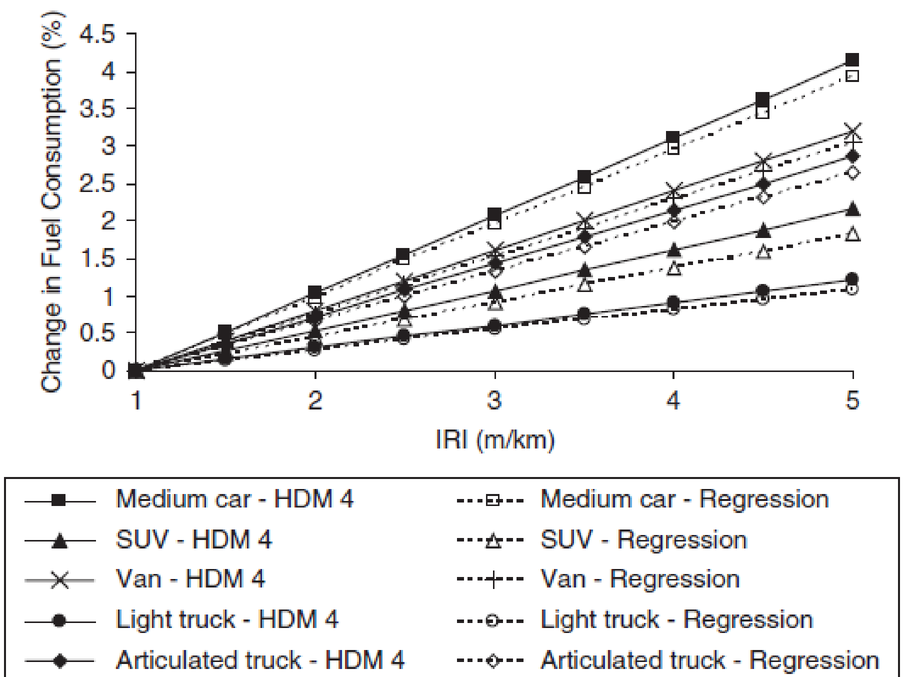
PVI-Roughness Model /(similar to J. Harvey/UCPRC)

- Inputs:



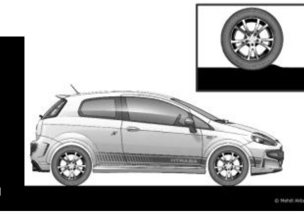
(*) MEPDG Output- 90% reliability level

- HDM-IV Model:



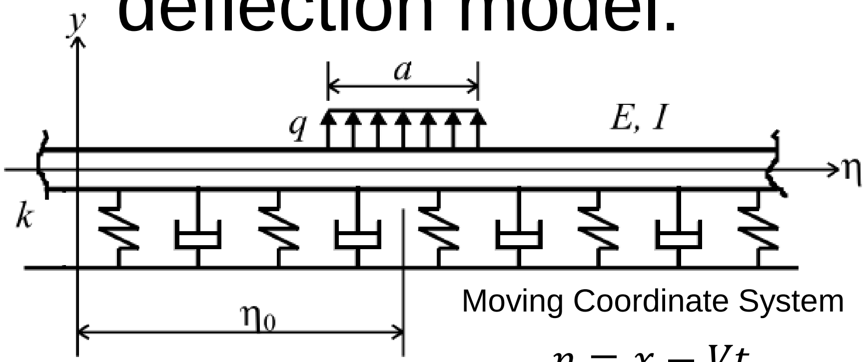
(*) Zabaar and Chatti (2010)

PVI-DEFLECTION MODEL



Akbarian, Ulm, Nazzal (2012)

- Simplest pavement deflection model:

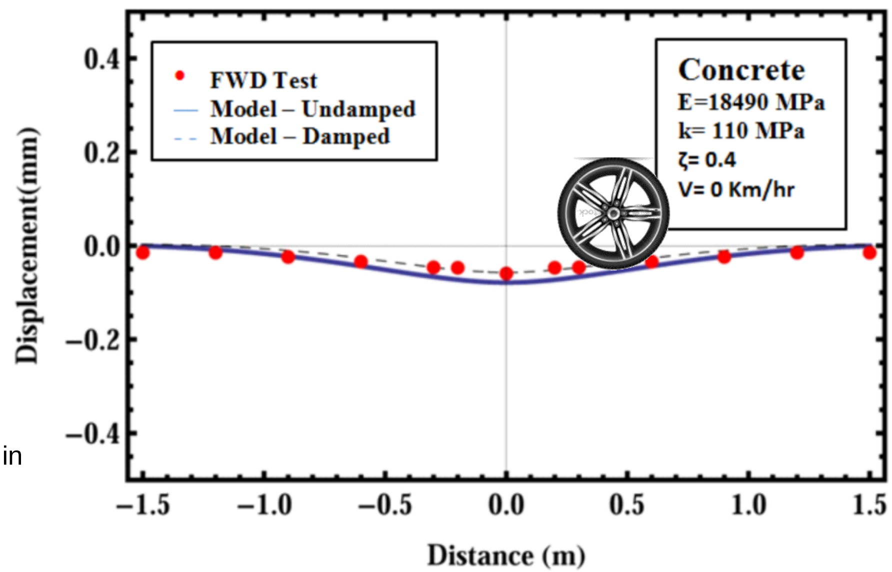


Moving Coordinate System

$$\eta = x - Vt$$

- Input:
  – Pavement stiffness E
  – Pavement Thickness h
  – Substrate stiffness k

- Approach:
  – Calibrate/FHWA
  – Validate/FHWA
  – Scale Fuel Consumption from Gradient Force



* Mechanistic Approach to Pavement-Vehicle Interaction and Its Impact in LCA - *Journal of the Transportation Research Board*, 2012.

The current state of the US Road Network: “mileage”

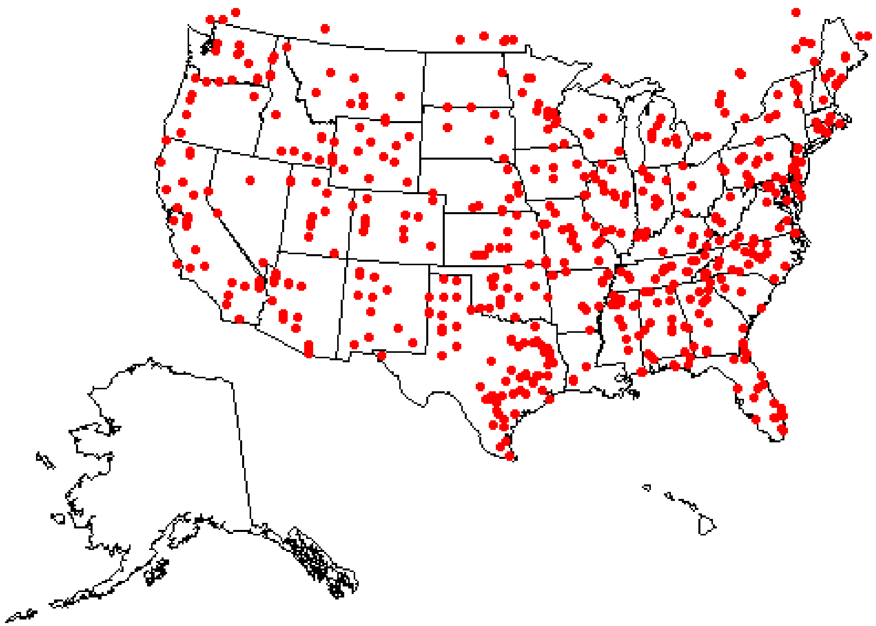
STATUS QUO: WHAT IF BUSINESS AS USUAL

Moving beyond “BaU”

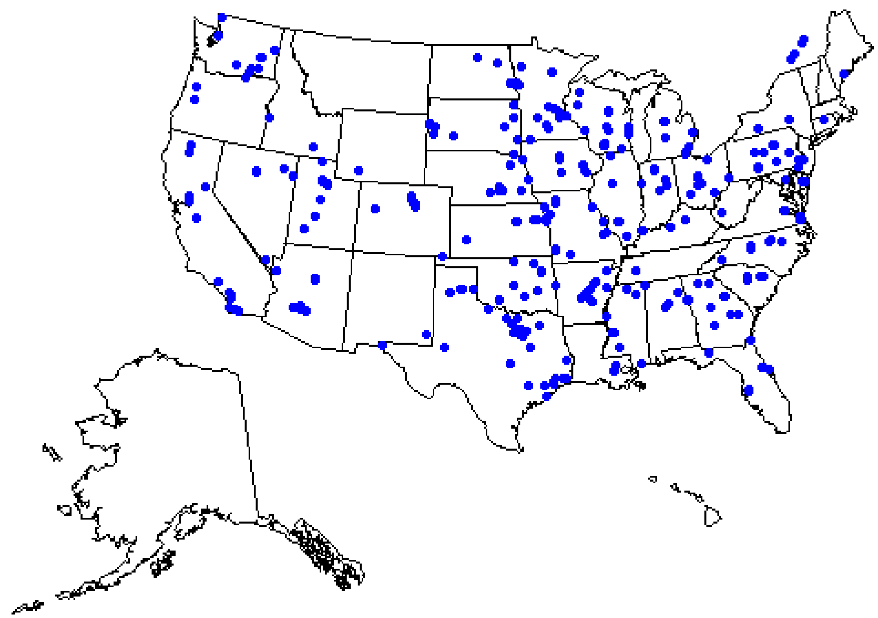
FHWA/LTPP Monitored Sections

Total of 5643 sections: 1079 rigid, 4564 flexible

Asphalt



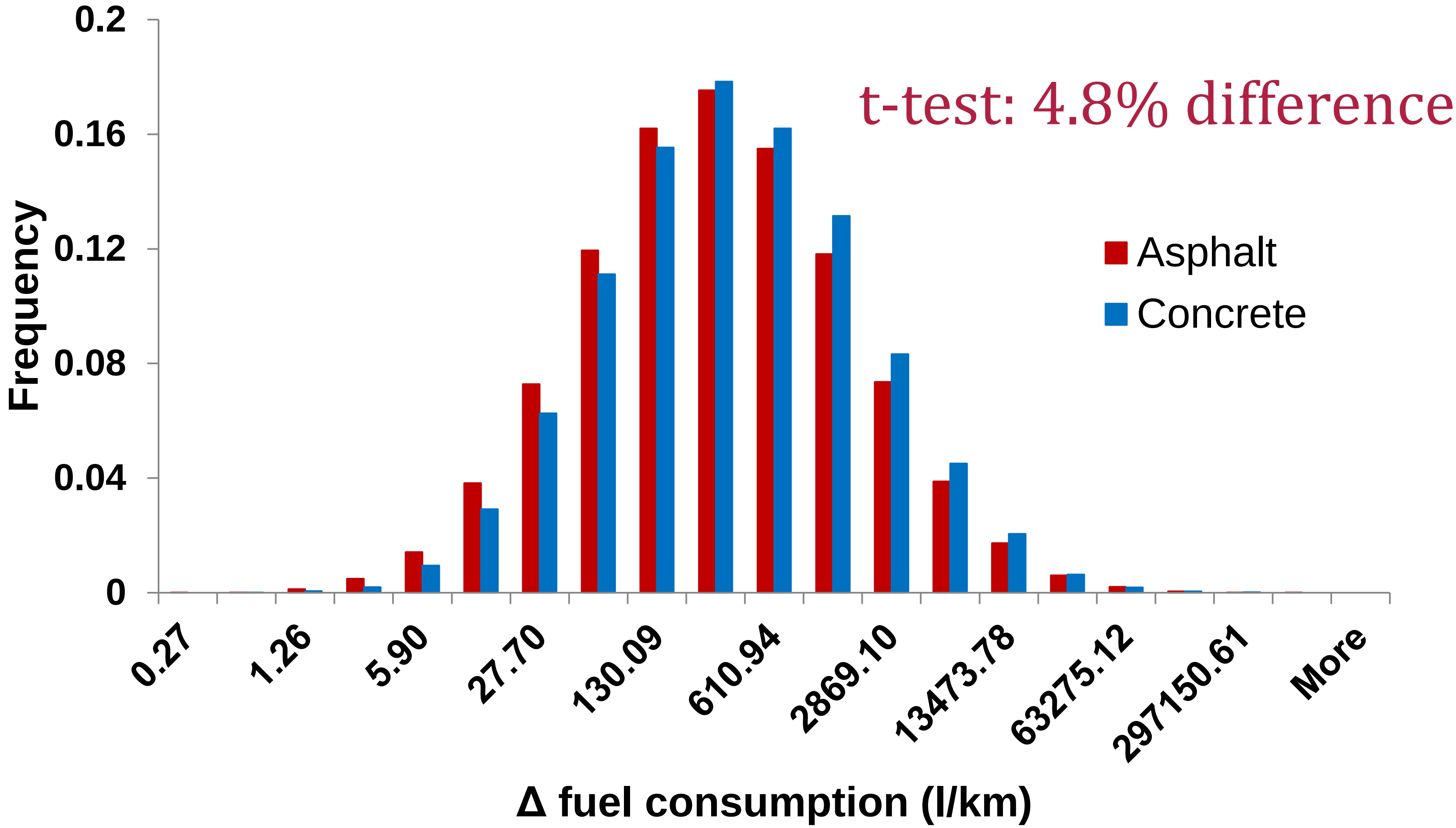
Concrete



Data used:

- Top layer modulus E
- Subgrade modulus k
- Top layer thickness h
- Loading condition q
- Roughness
- Traffic Volume (AADT, AADTT)

Roughness-Induced Extra-Fuel Consumption



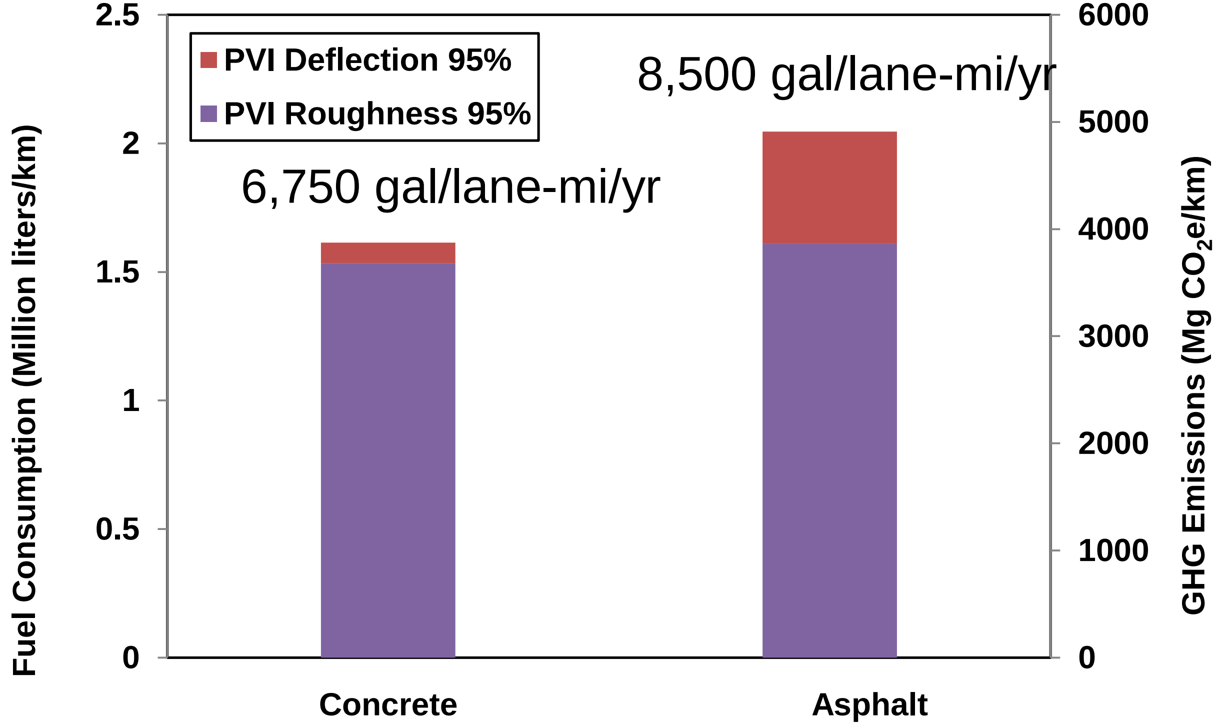
The difference is statistically insignificant

Current State (statistical evaluation) of

Extra-Fuel Consumption due to PVI

50 yr PVI GHG Emissions of Two Pavement Scenarios Relative to a "Flat" Pavement

40 – 50 tons CO2 per lane-mile/Year

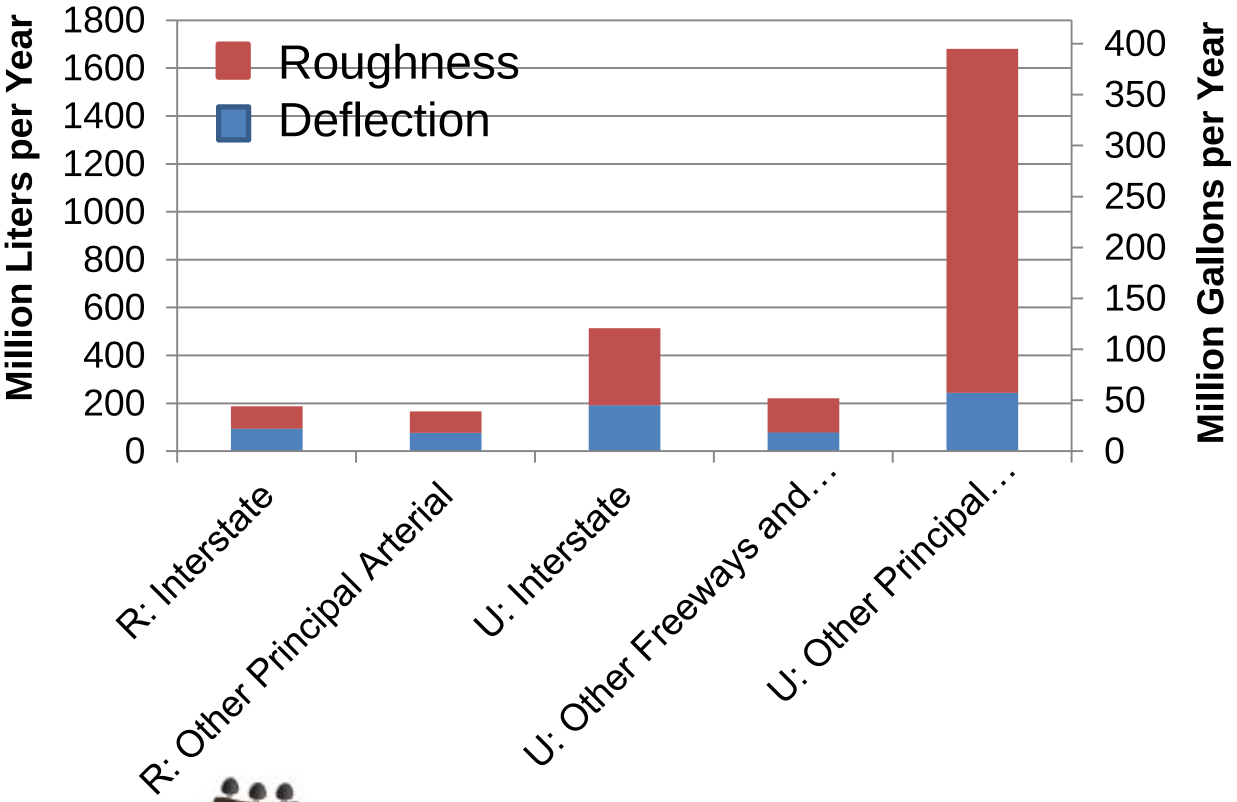


(Two-lane kilometer section design from Athena (2006); AADT=15,000; AADTT 1,500; AC maintenance at years: 17, 28, 38, 47; PCC maintenance at years 20, 40; 95% confidence)

Current State (statistical evaluation) of

Extra-Fuel Consumption due to PVI

The US uses 174 billion gallons of fuel per year on highways.
Excess fuel consumption of 740 million gallons per year.



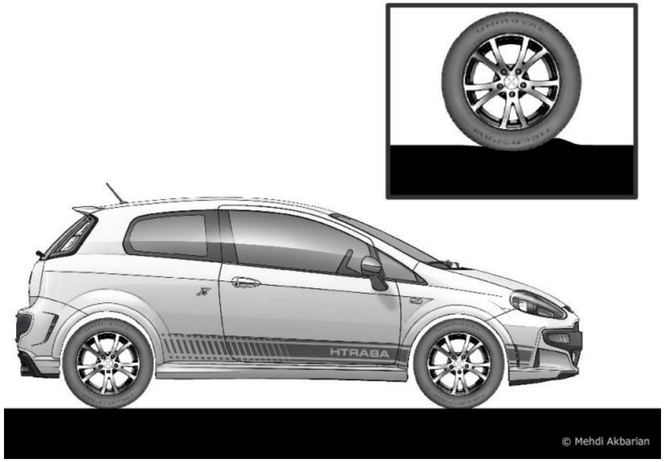
R = Rural
U = Urban

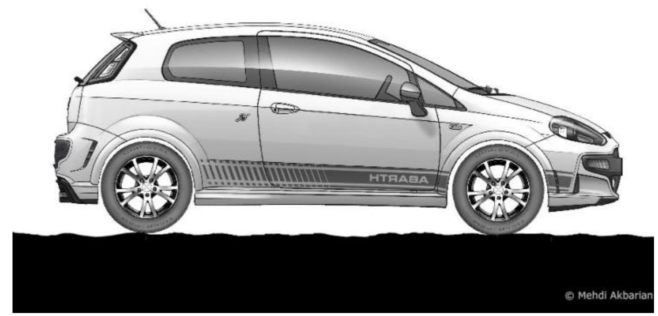
Opportunities for Improvement

Moving beyond Business as Usual

Designing for the Future

Can we do better? – Yes, we can!





Pavement Deflection

Pavement Roughness

2011 MIT-Model

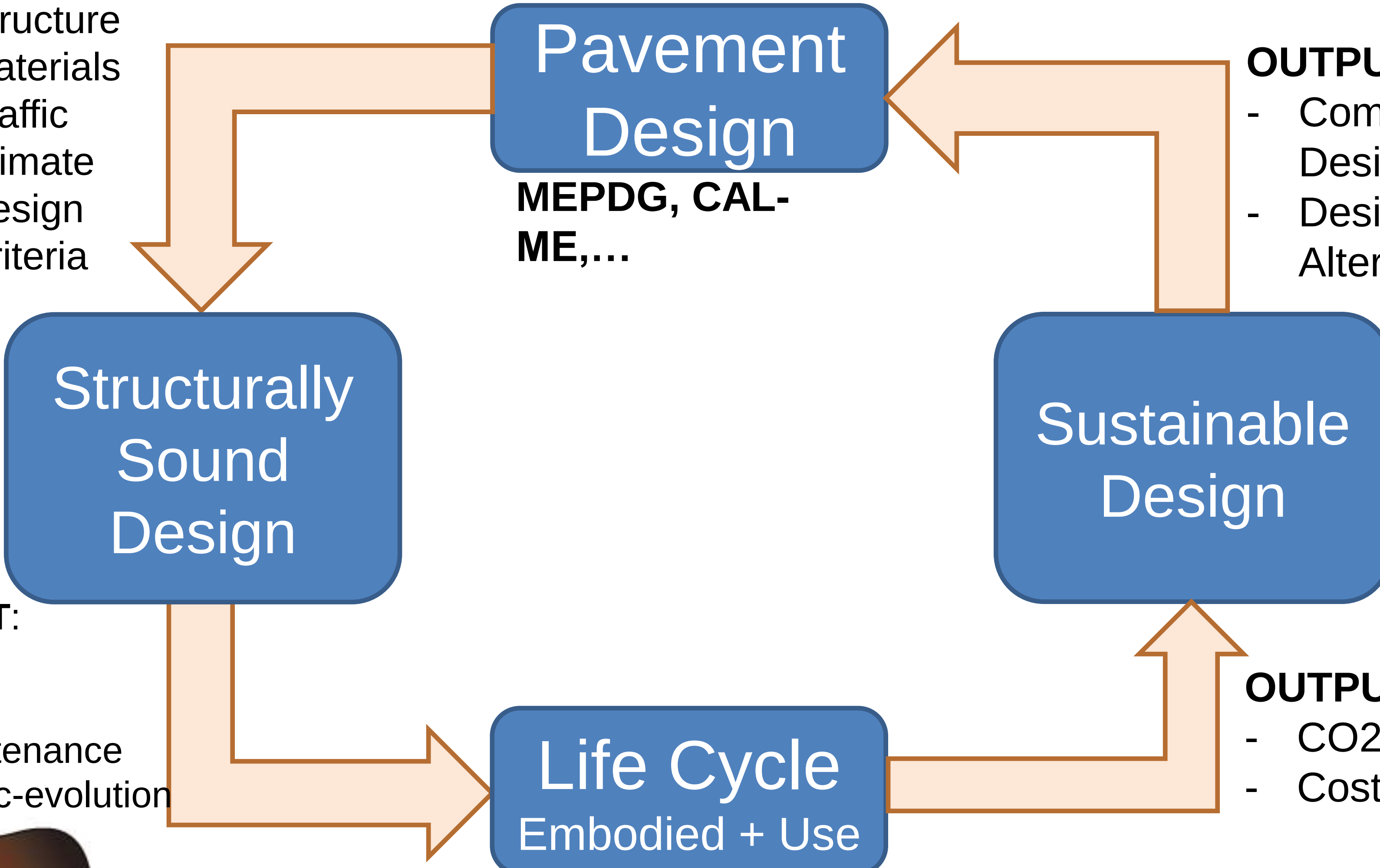
SYNERGY

Pavement Design

Structure and Material

HOW TO MOVE BEYOND BUSINESS AS USUAL?

INPUT:
- Structure
- Materials
- Traffic
- Climate
- Design Criteria



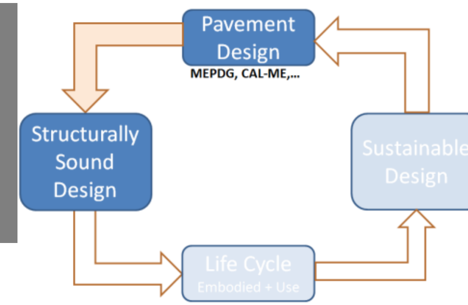
OUTPUT:
- E(t)
- IRI(t)
- Maintenance
- Traffic-evolution

OUTPUT:
- $CO_2eq(t)$
- Costs

OUTPUT:
- Comparative Design
- Design Alternatives

Proof of Concept

State-of-the-Art Pvmt Design



- **Input: MEPDG***

Concrete and Asphalt Pavements	
Design life (years)	50
Location	Columbus, Ohio
AADT (vehicles/day)	15,000
AADTT (trucks/day)	1,500
Traffic growth	4%
Total Lanes	2
Lane width (m)	3.7
Terminal IRI (in/mile)	172

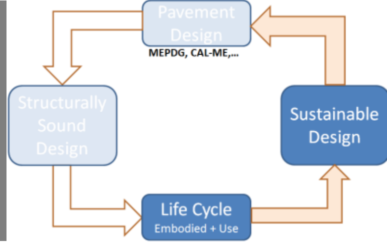
- **Output: MEPDG***

Concrete Section (JPCP)**	
PCC	10”
Non-stabilized	6”
Subgrade	Semi-infinite
Asphalt Section* **	
Flexible	10”
Non-stabilized	10”
Subgrade	Semi-infinite

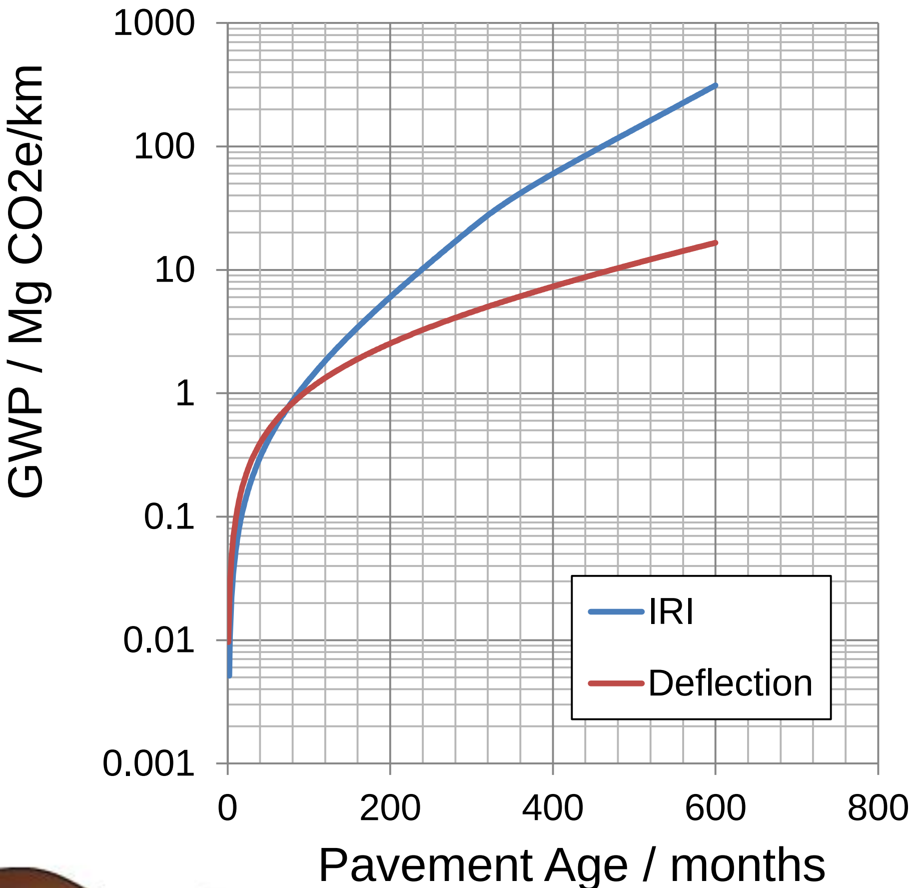
+ E(t,T), IRI(t), k, h, Traffic,…

* MEPDG = Mechanistic Empirical Pavement Design Guide
** JPCP transverse cracking dominates 50yr design
*** IRI, Permanent deformation (AC only) dominates

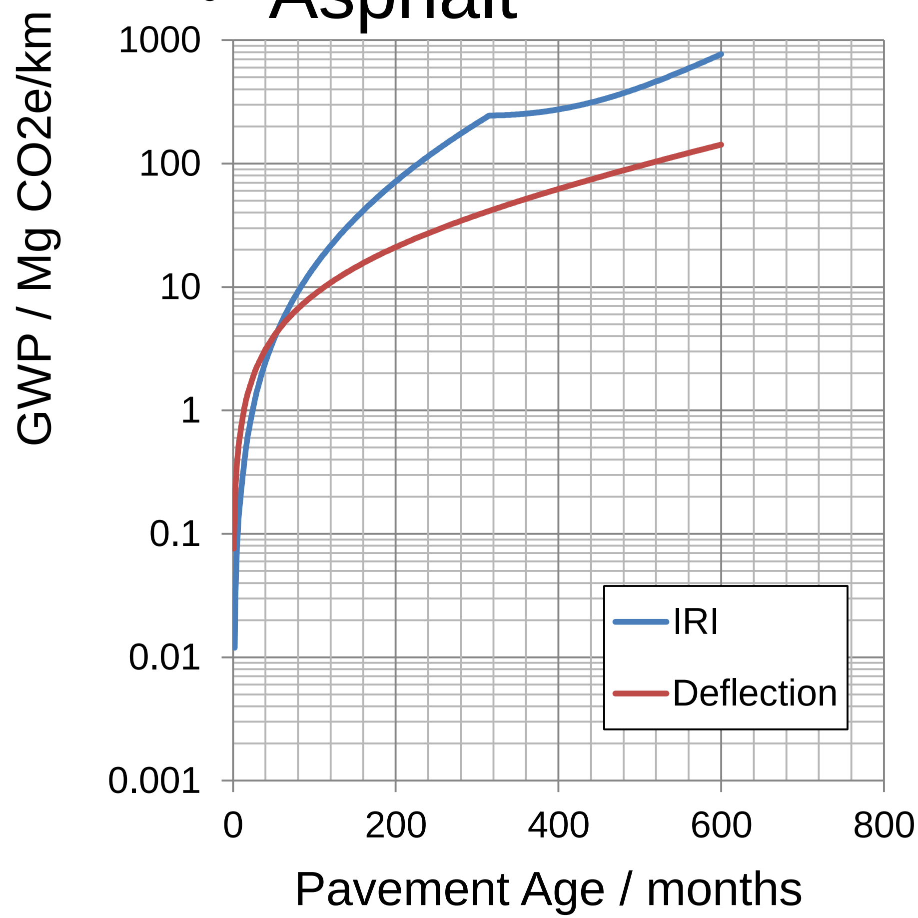
Roughness & Deflection Induced Emissions are EQUALLY important



- Concrete



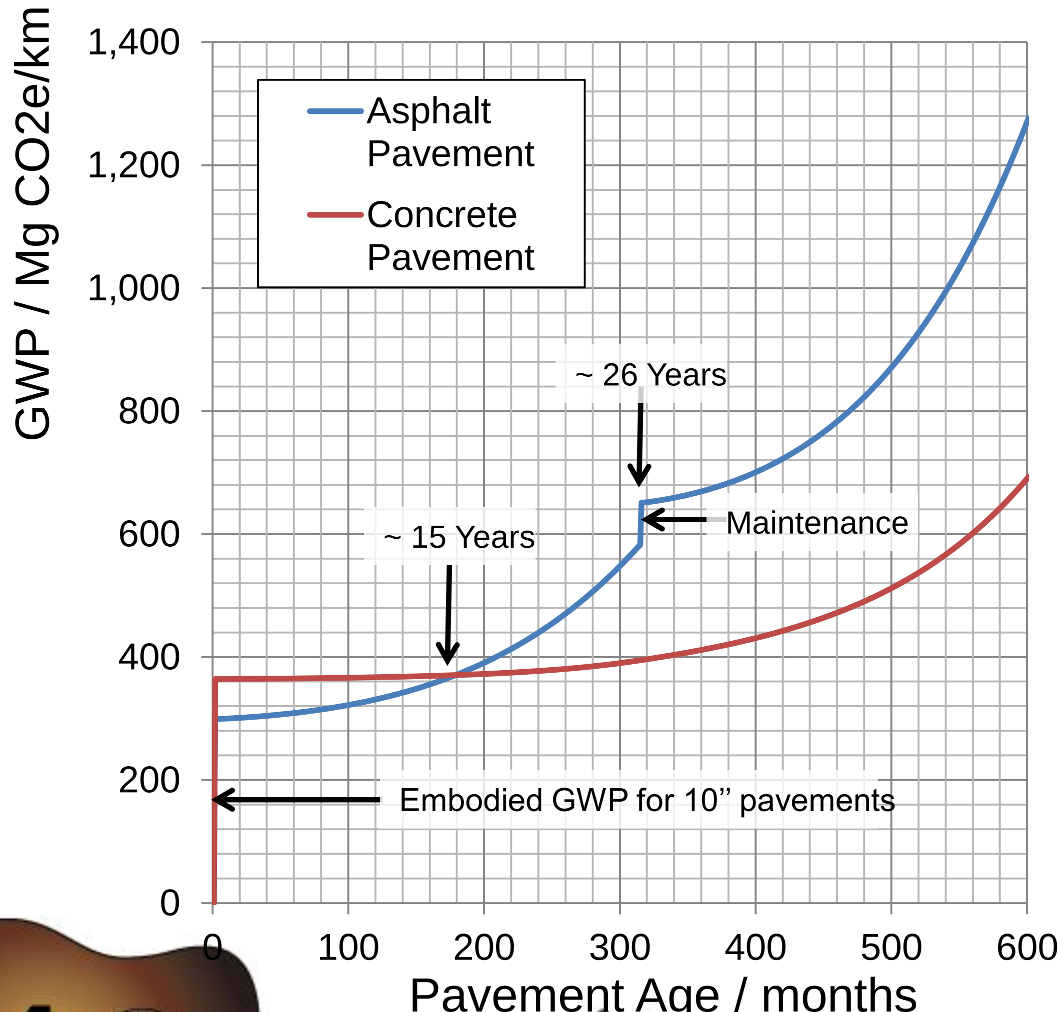
- Asphalt

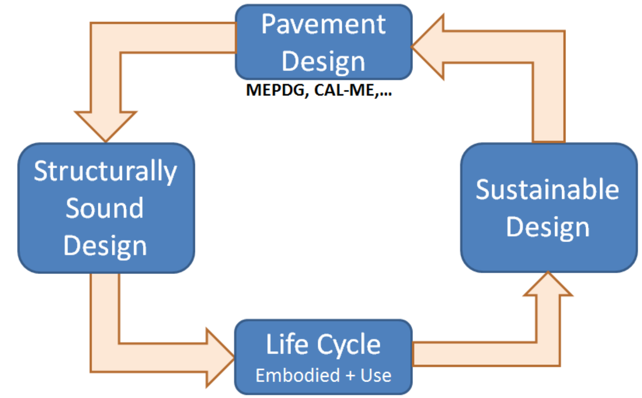


- **Both are of similar order of magnitude and need to be taken into account**

REDUCTION OF CO_2 BY DESIGN

- Design Options For 10” Pavement Structures





LCA Shows:

- STATUS QUO: 5,000/tons CO2/50yr.
- Reduce to: 1,000/tons/CO2/50yr

(for new/reconstruction)

Looking Forward

- This is **not** a matter of concrete vs. asphalt; this is about science-based engineering solutions for sustainable pavement systems.

- **We are inviting you to join our efforts in the CSHub@MIT**
  - Carry the information into your States, to your local DOTs
  - Become a Champion for your State/County to (1) evaluate the mileage of your pavement system.
  - …and (2) to help identify possible improvement scenarios that substantially reduce the environmental footprint: GET MORE MILEAGE OUT OF YOUR PAVEMENT SYSTEM

  - And Costs… !

Come and join us for Industry Day at MIT September 27, 2012 http://web.mit.edu/cshub