FHWA Sustainable Pavements Program

Towards Sustainable Pavement Systems: Webinar Series

Webinar #5:

Use Phase, Livable Communities, Path Forward

September 9, 2015

Webinar Series

- Sponsored by Federal Highway Administration
- “Towards Sustainable Pavement Systems: A Reference Document”
  - http://www.fhwa.dot.gov/pavement/sustainability/
- Total of 5 webinars from April to September
- Webinars recorded for posting on FHWA website

Housekeeping

- Formal Presentations:
  - 1 hour 40 min
- Questions:
  - 20 minutes
  - Use chat box to submit your questions
- Professional Development Hours (PDHs) Certificates
  - 2 hours per webinar

Today’s Webinar

- Topic: Use Phase, Livable Communities, Path Forward
- Speakers:
  - Gina Ahlstrom, FHWA
  - John Harvey, University of California, Davis
  - Tom Van Dam, NCE
  - Joep Meijer, theRightenvironment
- Moderators:
  - Kurt Smith, Applied Pavement Technology, Inc.
  - Tom Van Dam, NCE

FHWA Sustainable Pavements Program

Background and Overview

Gina Ahlstrom

US DOT is Committed to Advancing Sustainability

- DOT will incorporate sustainability principles into our policies, operations, investments and research through innovative initiatives and actions such as:
  - Infrastructure investments and other grant programs,
  - Innovative financial tools and credit programs,
  - Rule- and policy- making,
  - Research, technology development and application,
  - Public information, and
  - Enforcement and monitoring.

U.S. Department of Transportation
Federal Highway Administration

Policy Statement

Signed Secretary Anthony R. Foxx, June 2014

FHWA
Sustainable Pavements Program

- Support the US DOT goals for sustainability
- Increase the body of knowledge regarding sustainability of asphalt and concrete materials throughout the pavement life cycle
- Increase the use of sustainable technologies and practices in pavement design, construction, preservation, and maintenance

"Towards Sustainable Pavements: A Reference Document"

- Guidelines for the design, construction, preservation and maintenance of sustainable pavements using asphalt and concrete materials
- Educate practitioners on how sustainability concepts can be incorporated into pavements
- Encourage adoption of sustainable practices

A Collaborative Effort

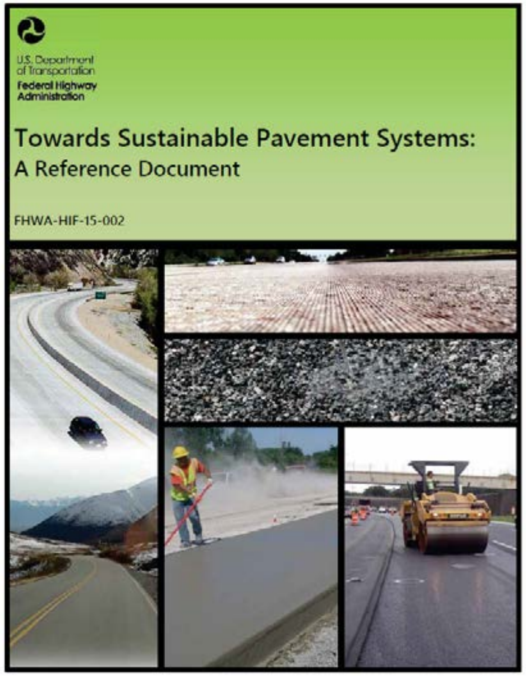
- Comprehensive review of current literature
- Extensive review by representative from key stakeholders groups:
  - State Departments of Transportation
  - Other Public Agencies
  - Asphalt and Concrete Industries
  - Academia

- Use Phase Considerations
- Vehicle Fuel Consumption and Pavement Characteristics
- Tire/Pavement Noise
- Stormwater Runoff

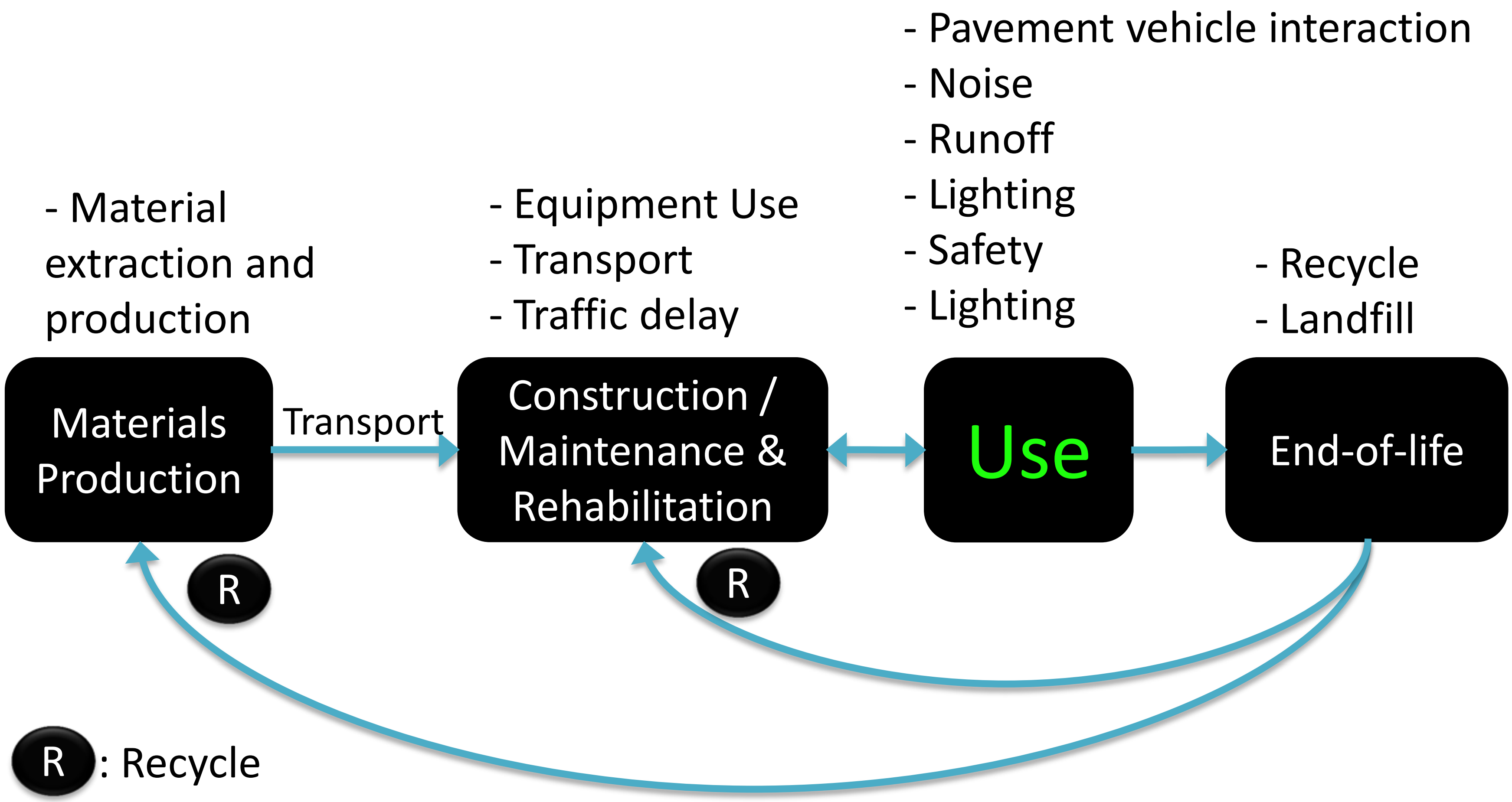
John Harvey

Use Phase Considerations

- What is the use phase?
  - Processes during operation of the pavement affected by pavement decisions
- Use phase processes considered in FHWA Reference Document
  - Fuel use by vehicles
  - Tire/pavement noise
  - Stormwater runoff
  - Thermal performance, contribution to urban and global climate
  - Lighting
  - Safety related to skid resistance

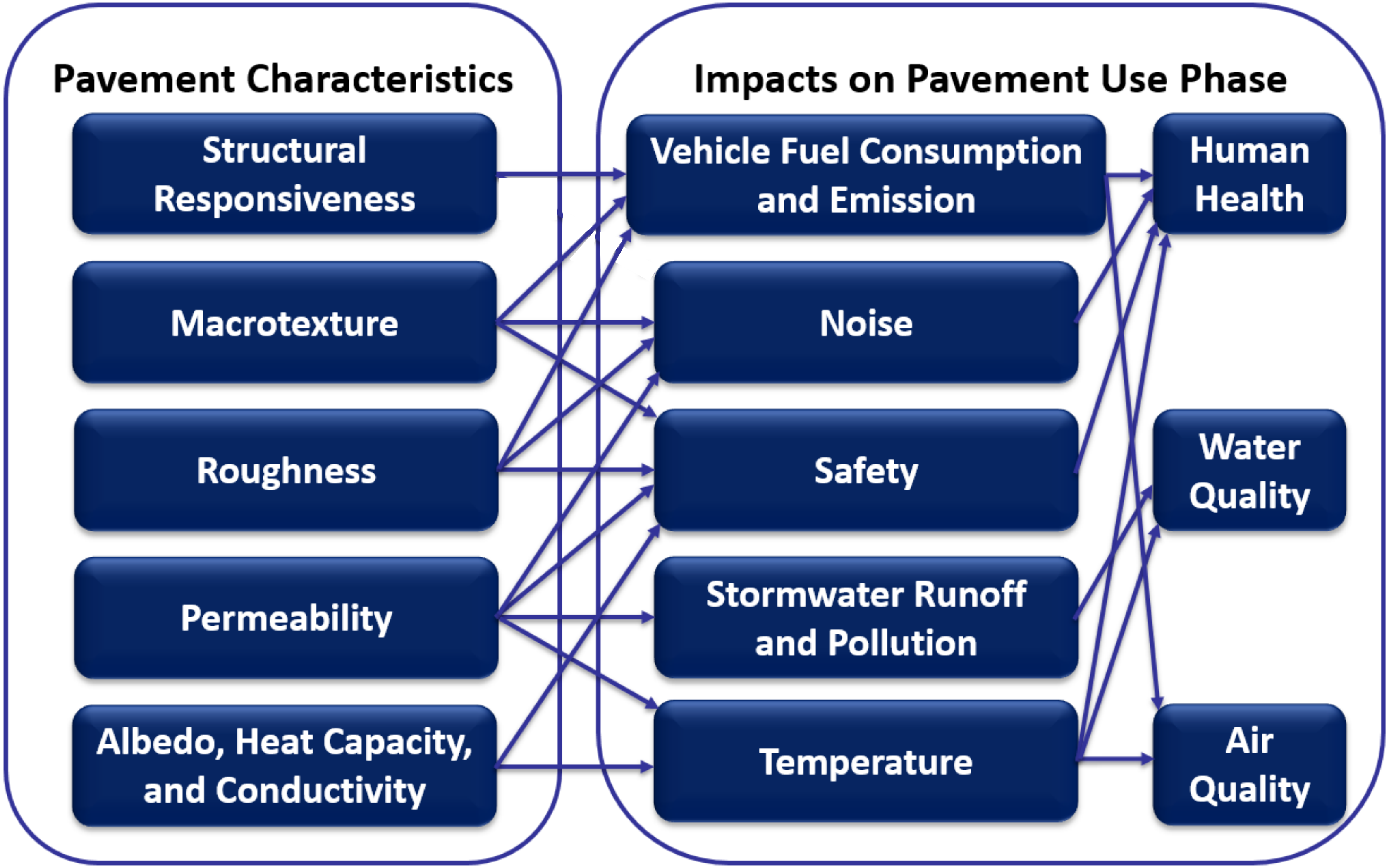


Pavement Life Cycle



From: Kendall et al, *2010*

Use Phase Considerations



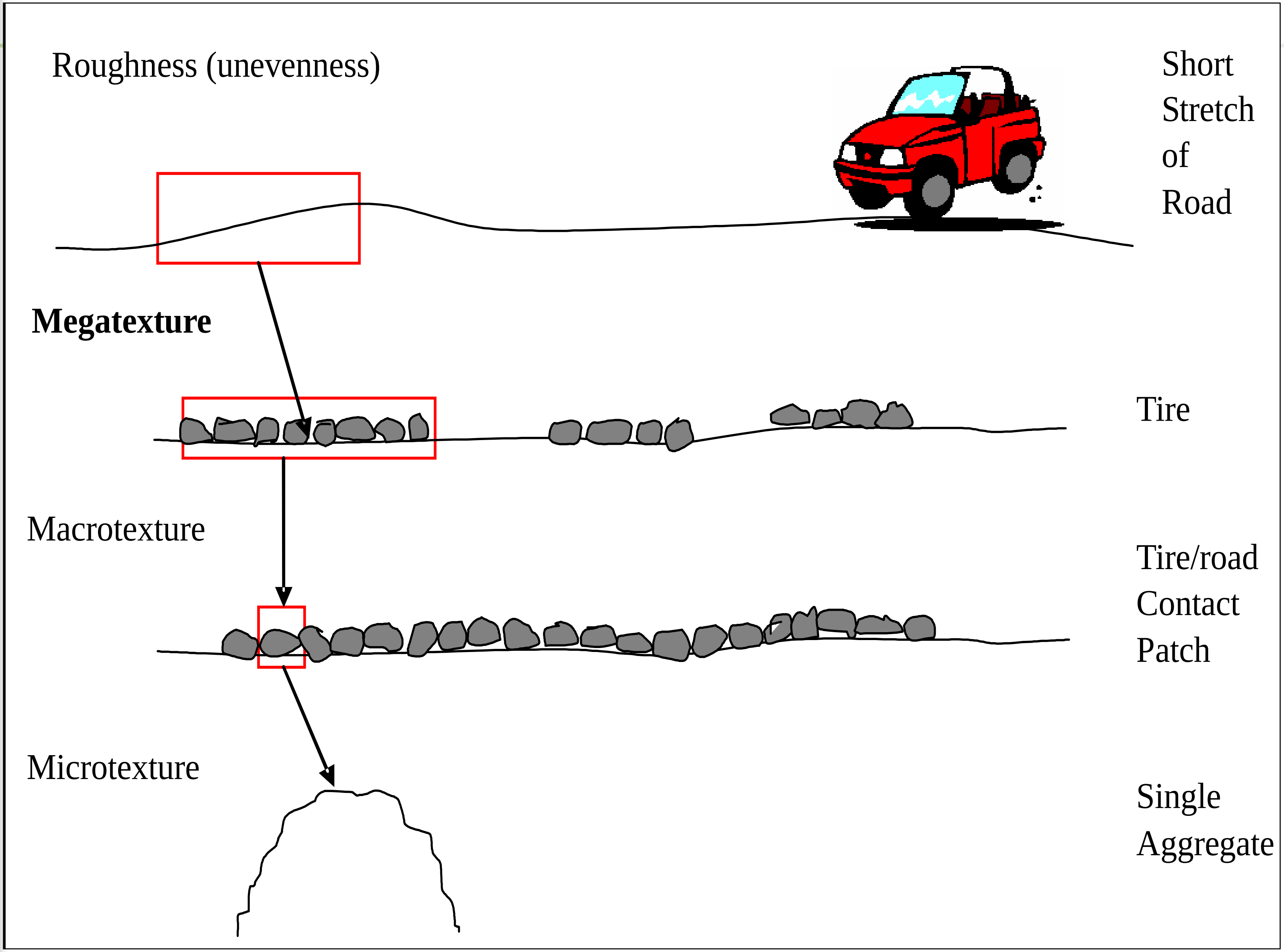
Processes Generally Not Considered In Pavement Use Phase

- Addition of new lanes to existing roads
- Selection of new road locations and alignments
- Vehicle operation impacts not influenced by pavement decisions
  - Fuel consumption not affected by pavement, poor tire inflation, vertical and horizontal alignment
- Some processes that could be considered
  - Influence of pavement on other vehicle consumption items: tires, maintenance, vehicle replacement time
  - Any emissions to water, air from pavement during use
    - Generally have been found to be negligible or occur at such a slow rate that little effect

Pavement Rolling Resistance
(also called Pavement Vehicle Interaction)

- Roughness of pavement surface
  - Measured with International Roughness Index (IRI)
  - Dissipates energy through suspension and tire walls
- Macrotexture of pavement surface
  - Measured with Mean Texture Depth or Profile Depth (MPD)
  - Dissipates energy through tire tread distortion
- Structural response of pavement, two approaches
  - 1: dissipates energy through deflection of viscoelastic or damped pavement materials (HMA or subgrade under PCC)
  - 2: wheel moves up side of delayed deflection bowl

Pavement surface characteristics



0.5 to 50 m

(1.6 to 164 ft)

50 to 150 mm

(0.2 to 2 inch)

0.5 to 50 mm

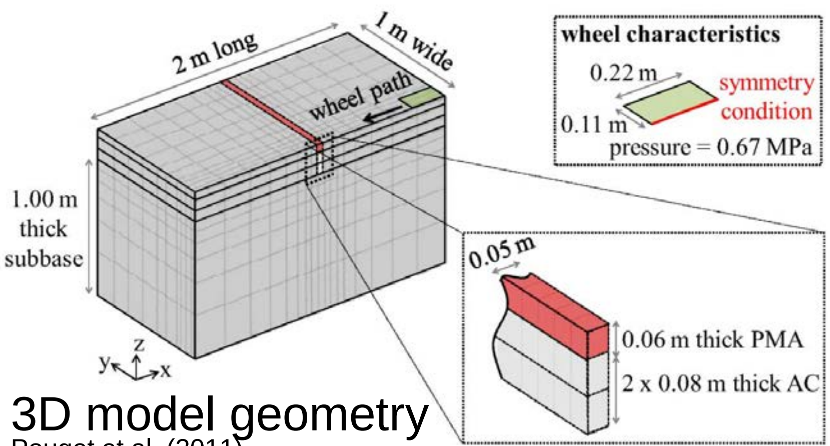
(0.02 to 0.2 inch)

<0.5 mm

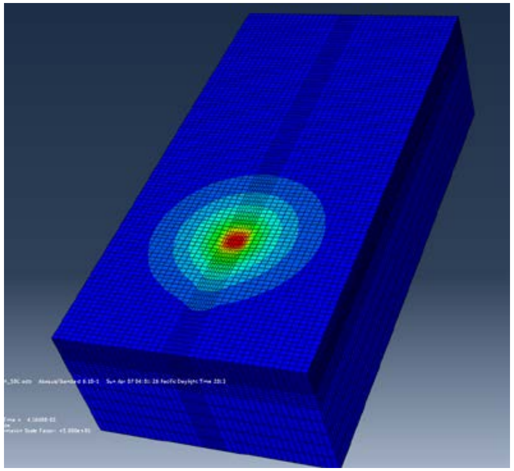
Adapted from Sandberg 1997

Approach 1: Energy dissipated in viscoelastic or damped pavement layers

Coleri et al.
after Pouget et al.



3D model geometry
Pouget et al. (2011)



Abaqus model

- Calculate material properties and model coefficients using the relaxation modulus master curves developed from FWD
- Calculate viscous energy dissipation using viscoelastic FE modeling (W)

Equation to calculate dissipated energy:

$$W = \iiint (\pi . \sin(\phi_E) . \sigma_{0z} . \varepsilon_{0z}) . dV$$

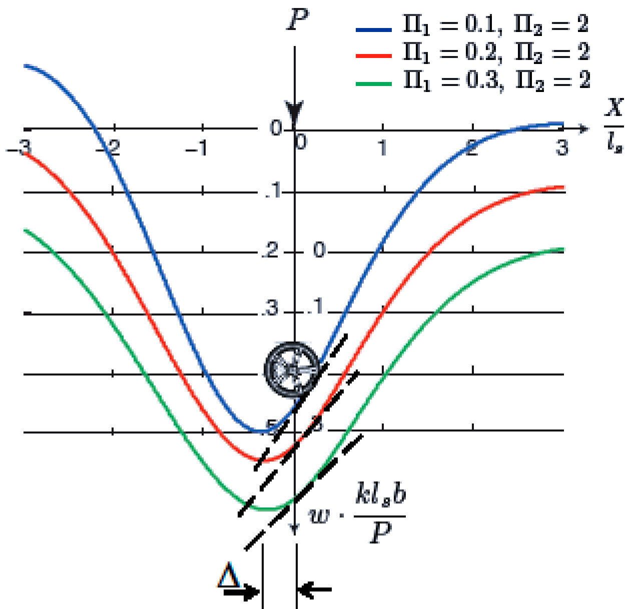
The dissipated energy per time **w(t)** is integrated on a **Δd** long slice of the asphalt layer, located in the center of the structure.

$$W_{truck} = \left(\int w(t) . dt \right) . \frac{X}{\Delta d} . Z$$

Approach 2: Wheel moving up side of viscoelastic deflection bowl

Loughalam et al.

Model Gen II



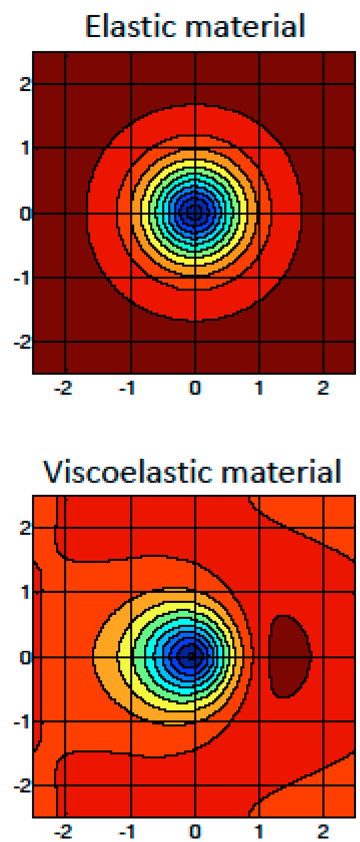
Dissipated Energy

$$\delta E = -\int_c P\frac{dw}{dX}dX = -P\left\langle\frac{dw}{dX}\right\rangle$$

Average Slope across tire pavement contact trajectory

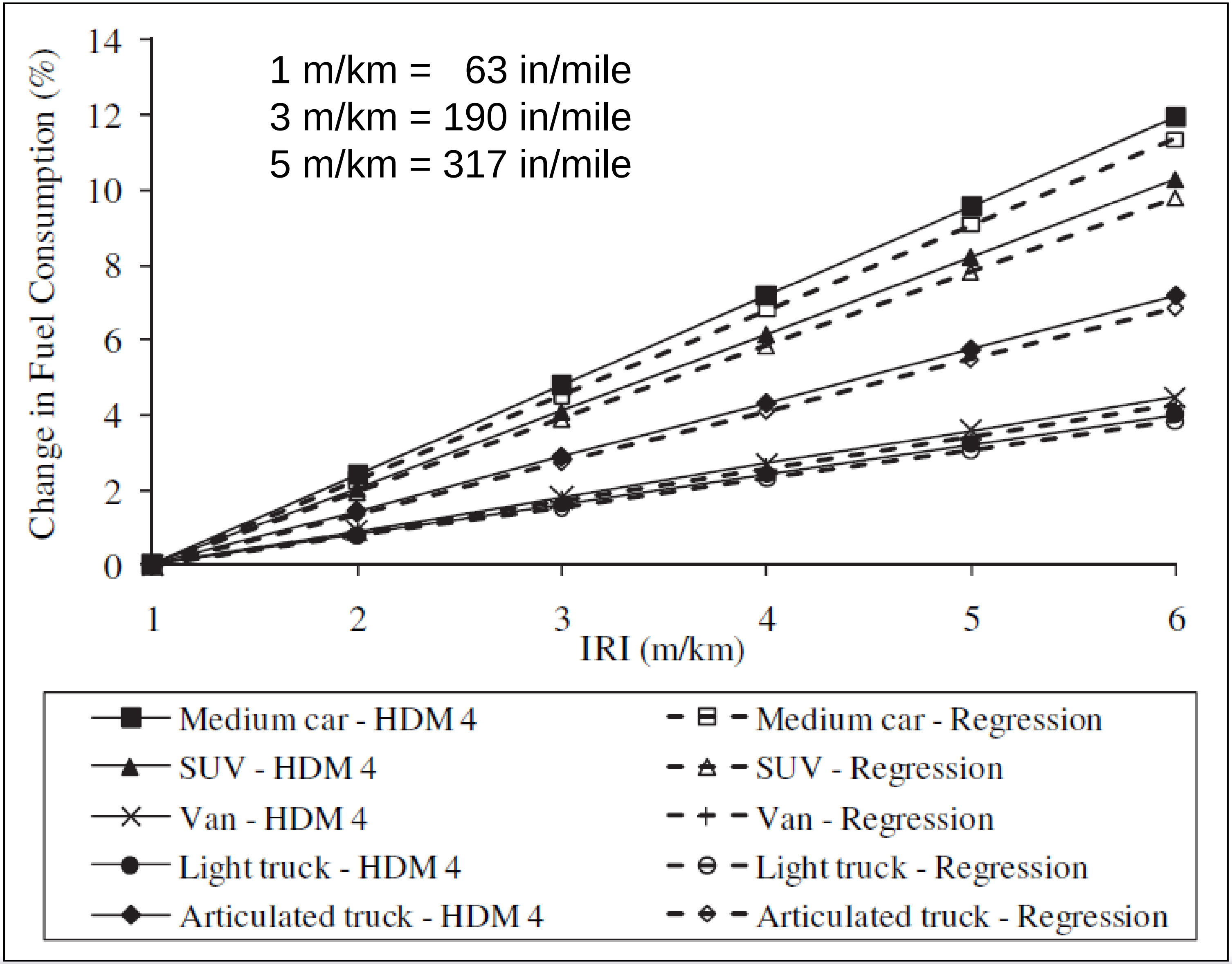
Tire pavement contact trajectory

Slope in moving coordinate system

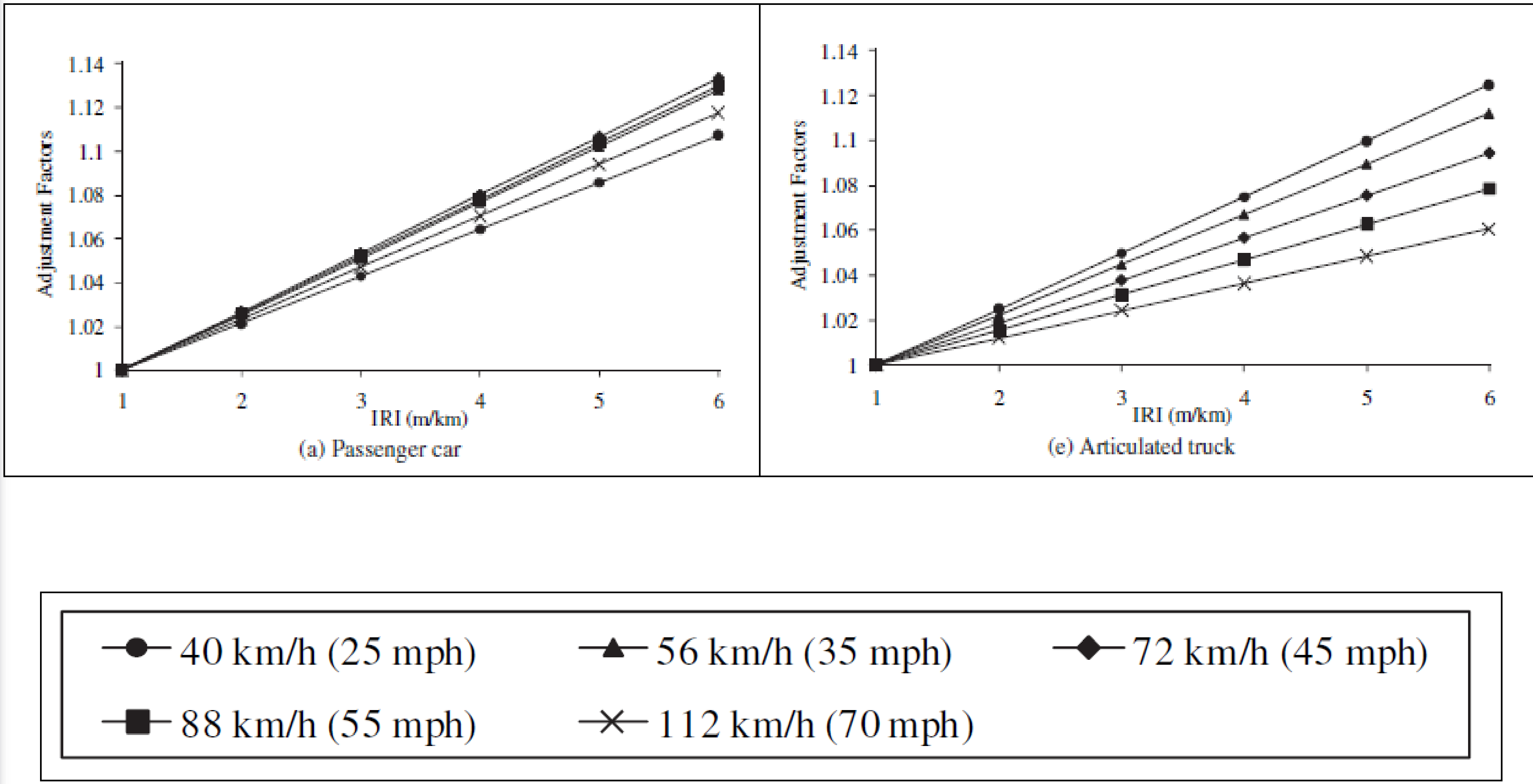


Calibration of HDM 4 Models: NCHRP Report 720 (Chattti & Zaabar)

NCHRP 720: Roughness at 96 km/hr (55 mph)



NCHRP 720: Interaction of speed and IRI



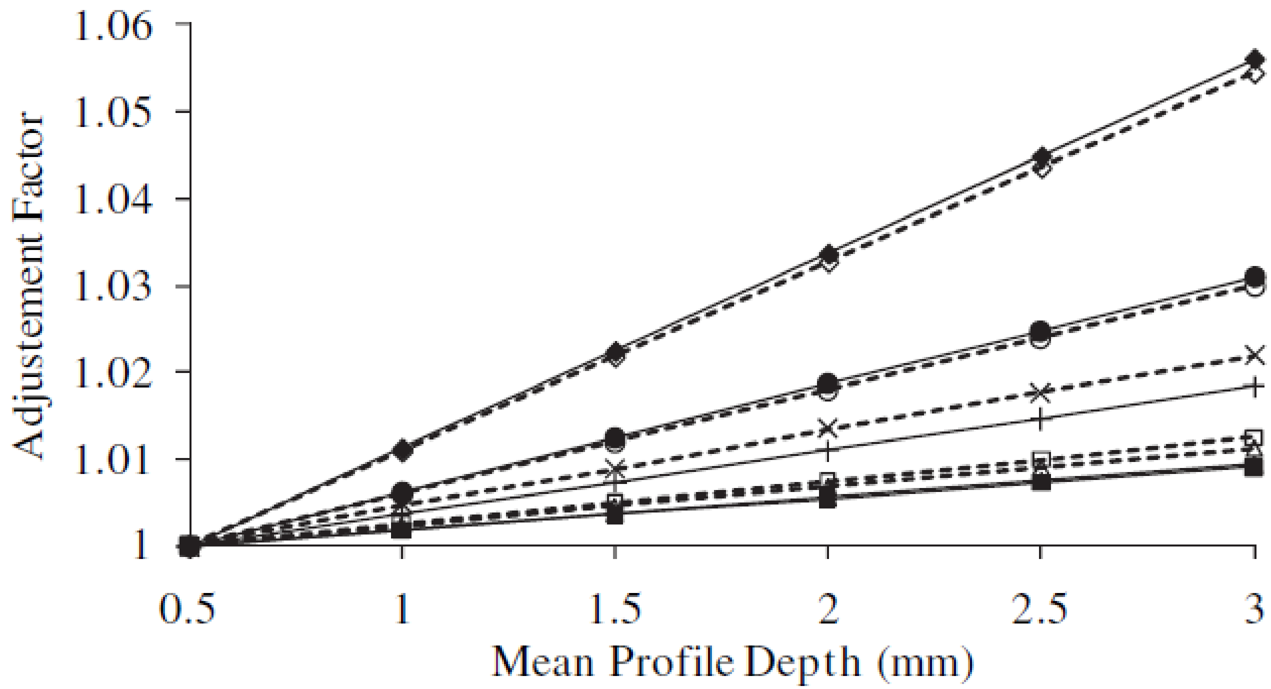
Do People Go Faster on Smoother Roads, Canceling Benefits?

- Fuel economy goes down for speeds above 45 mi/hr
- Hammarström et al. (2012), using Swedish driver speed behavior measurements (Ihs and Velin 2002): increased driver speeds cancel benefits of improved smoothness
- Wang et al. (2013) in California using large number of measurements before and after pavement maintenance on same asphalt and concrete pavements: reduction of IRI of 63 inches/mi leads to 0.3 to 0.4 mi/hr change in free-flow speed on freeways, negligible effect on vehicle emissions or energy consumption

Drivers on California State Route 1
blogs.wsj.com, www.hercampus.com

NCHRP 720: Macrotexture

- Only significant for heavy trucks at 35 mph



(a) 56 km/h (35 mph)

Heavy trucks

Other vehicles

NCHRP 720 Summary of Field Tests in Michigan

- Field tests confirmed the effect of roughness on fuel consumption
  - *An increase in IRI of 1 m/km (63.4 in/mi) will increase the fuel consumption of passenger cars by about 2% irrespective of speed. For heavy trucks, this increase is about 1% at normal highway speed (96 km/hr or 60 mph) and about 2% at low speed (56 km/hr or 35 mph).*
- Effect of texture depth on fuel consumption could only be seen for heavy truck at low speed (35 mph)
  - *An increase in MPD of 1 mm (0.039 in) will increase fuel consumption by about 2% at 56 km/hr (35 mi/hr) for heavy slow trucks*
- Effect of pavement type could only be seen in summer conditions, only for trucks and only at low speed (35 mph)
  - *3.8 to 4.0% for slow heavy and light trucks on summer days*

What about Wet Pavement?

- All field studies done under dry conditions
- Modeling results from Sweden indicate that water depths of 0.039, 0.078, and 0.156 inches (1, 2 and 4 mm) can increase vehicle fuel use by 30 percent, 90 percent, and nearly 80 percent, respectively, compared to dry pavement
- Textures that can get water off the surface can improve fuel use under wet conditions

www.nydailynews.com

Issues and Tradeoffs of Keeping Pavements Smooth

- Keeping pavements smooth requires more frequent maintenance and rehabilitation
  - Increased environmental impact from M&R
- M&R doesn't give full benefit if don't get smoothness from construction
  - Smoothness specifications so not "born rough"
  - Based on IRI not profilograph or bump indicator
- Benefit increases on higher traffic lanes
  - Focus on keeping higher traffic routes smooth
  - Doesn't mean let low volume roads go bad

Case Study (LA-5): Concrete CPR B on rural/flat freeway

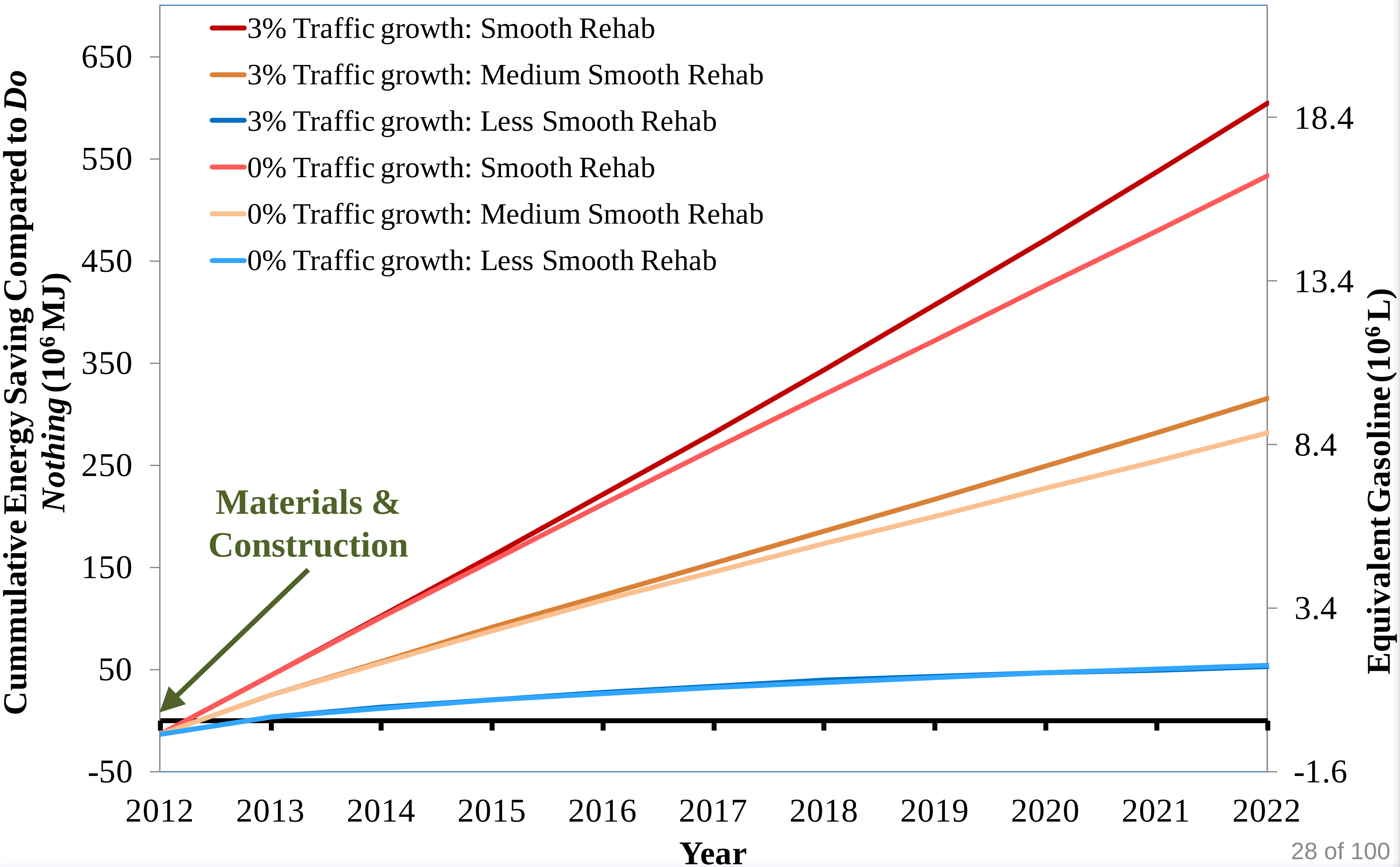
10 mile (16 km) segment in need of rehab

- Rural freeway
- 4 lanes, southbound
- AADT: ~80,000; ~25% trucks

	Cars	Trucks	IRI
Lane 1 (Inner)	38%	0.2%	3
Lane 2	34%	8%	3
Lane 3	16%	42%	3.5
Lane 4 (Outer)	13%	49%	4

Compare:
- Reactive Maintenance
- 10 year CPR B

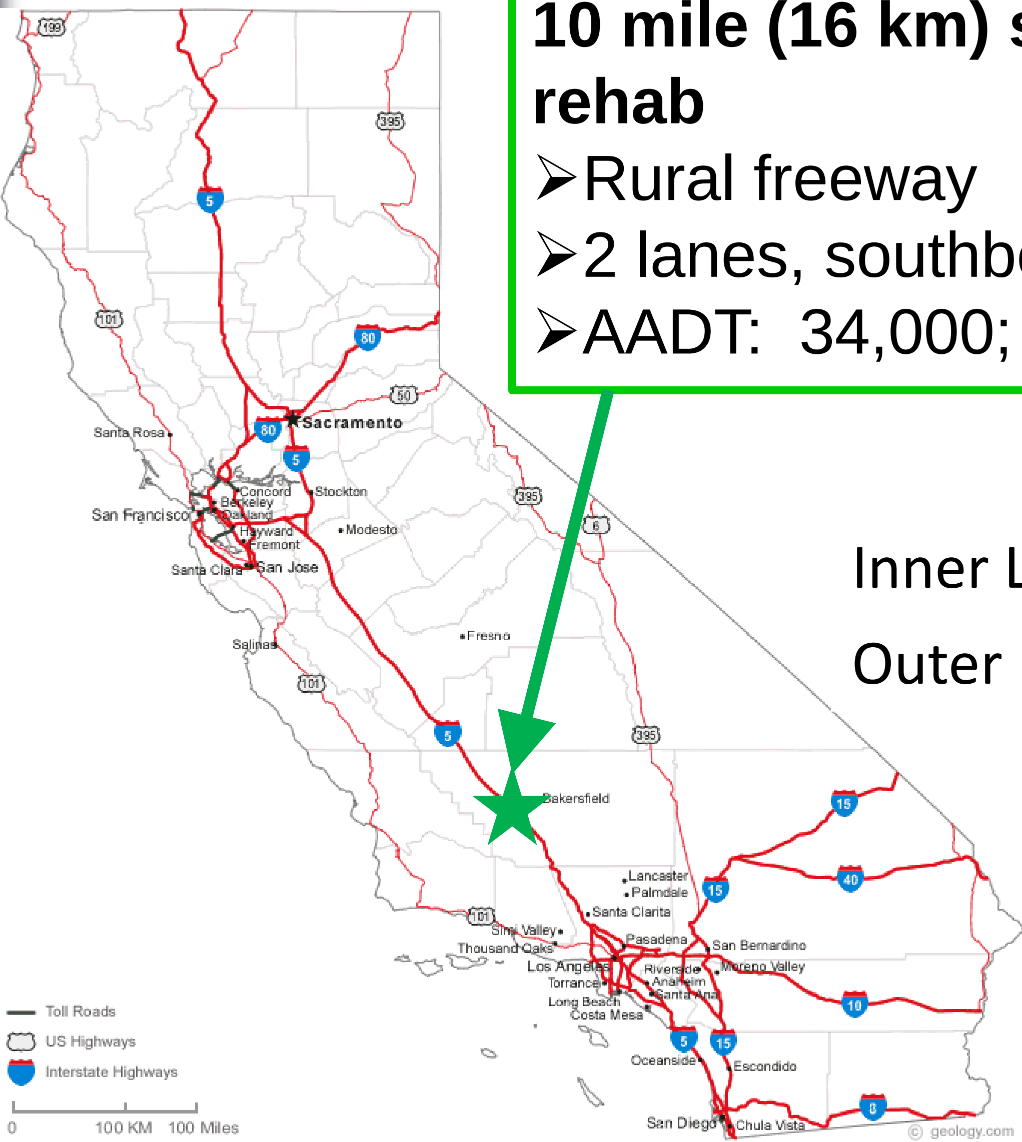
LA-5 (Type III PCC): Cumulative life cycle energy savings grind/slabs vs. reactive maintenance *"pay back time"*



Case Study (KER-5): Asphalt overlay on rural/flat freeway

10 mile (16 km) segment in need of rehab

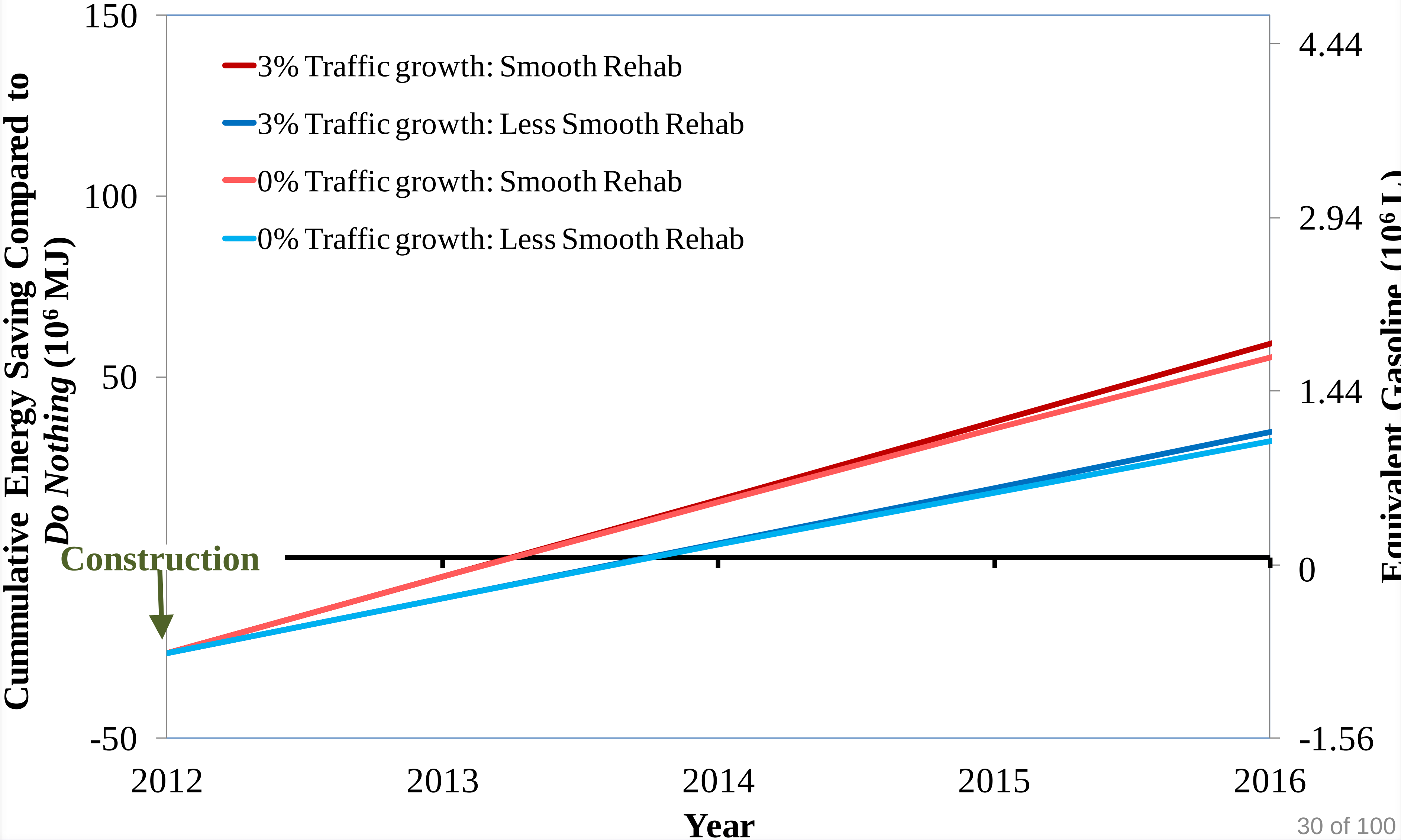
- Rural freeway
- 2 lanes, southbound
- AADT: 34,000; ~35% trucks



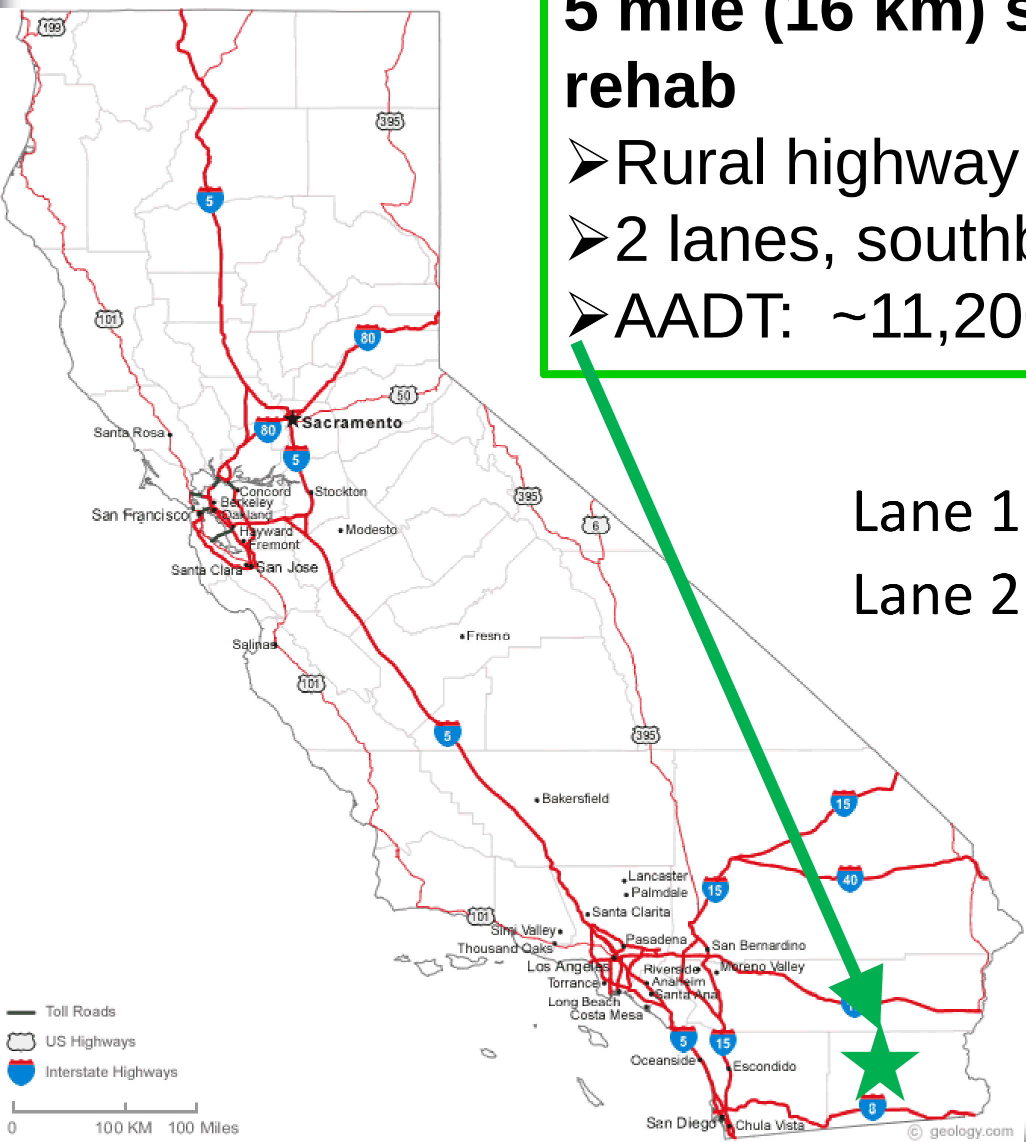
	Passenger	Trucks
Inner Lane	77%	9%
Outer Lane	23%	91%

Compare:
- Reactive Maintenance
- 5 year HMA overlay

KER-5 (HMA): Cumulative life cycle energy savings asphalt overlay vs. reactive maintenance "pay back time"



Case Study (IMP-86):
Concrete CPR B on rural/flat highway



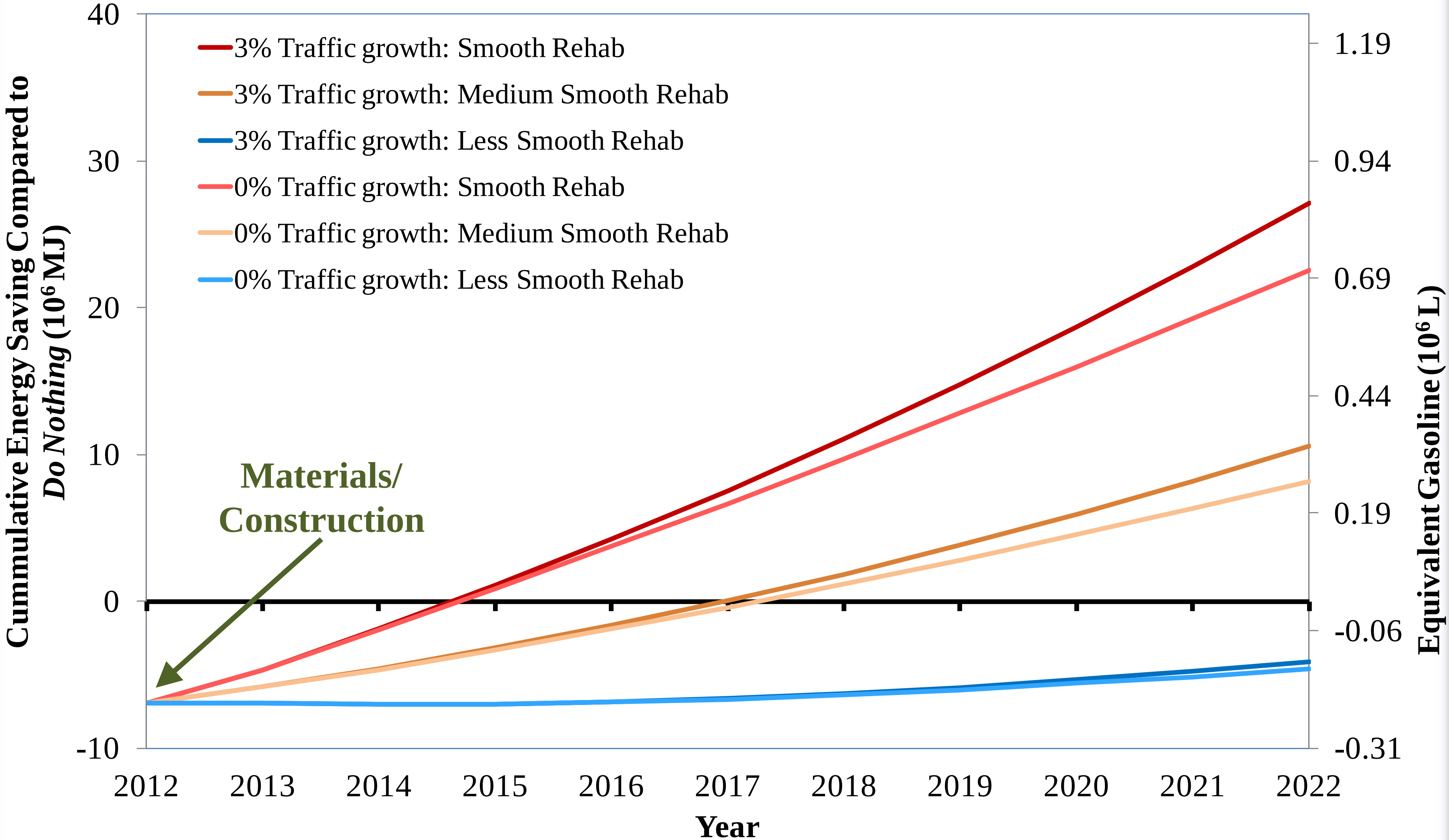
5 mile (16 km) segment in need of rehab

- Rural highway
- 2 lanes, southbound
- AADT: ~11,200; ~29% trucks

	Cars	Trucks	IRI
Lane 1 (Inner)	76%	8%	2.5
Lane 2	24%	92%	2.7

Compare:
- Reactive maintenance
- 10 year grind/minor slab replacement

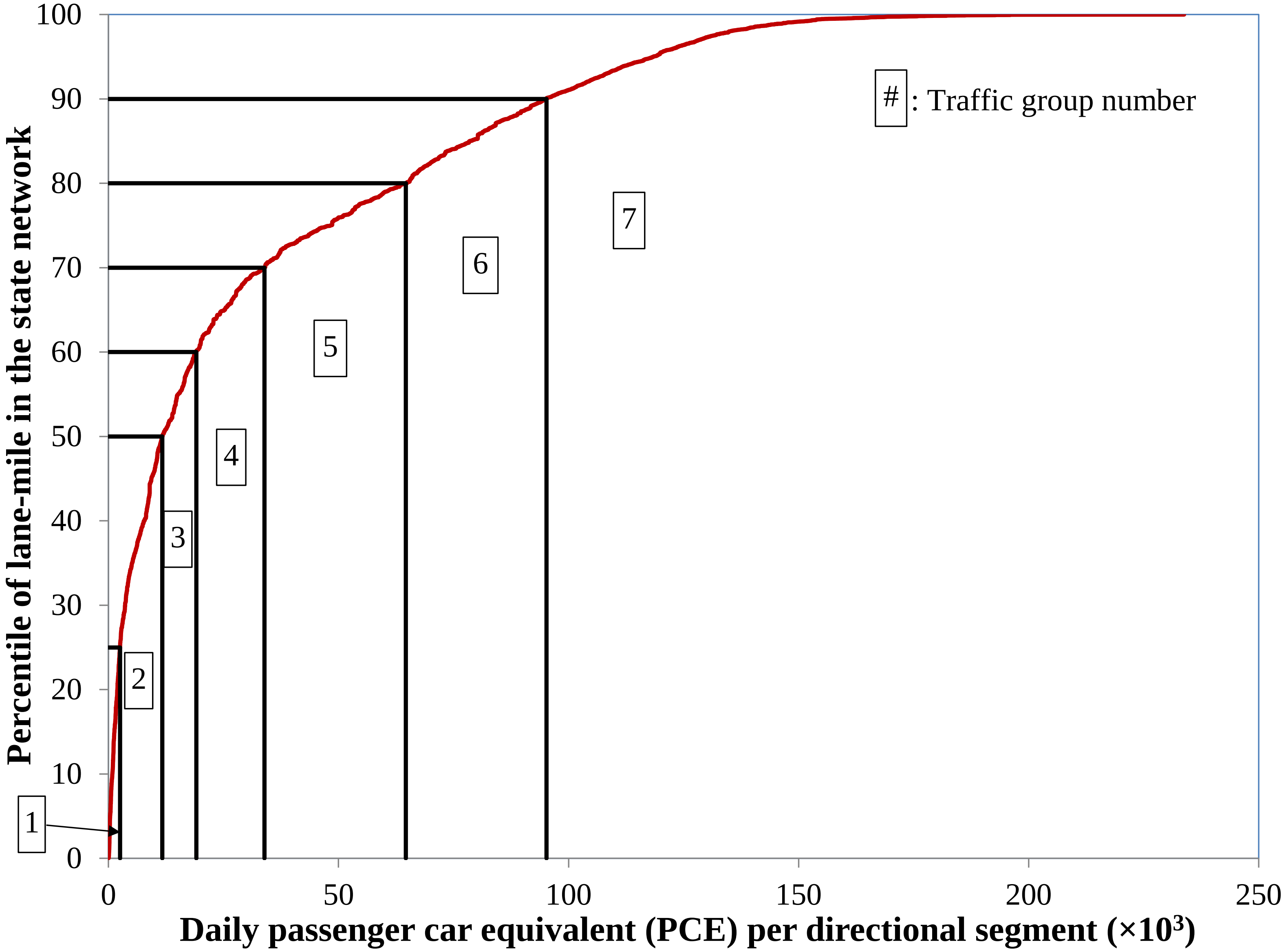
IMP-86 (Type III PCC): Cumulative life cycle energy savings grind/slabs vs. reactive maintenance *"pay back time"*



Example Application to California Network for Use in PMS

- Optimization for greenhouse gas emissions (GHG) of IRI trigger levels for preventive maintenance
  - Asphalt overlays on asphalt
  - Grinding/slab replacement on jointed concrete
  - Net effect of materials/construction and use
- Dependent on traffic level
- Agency cost or Total cost of reducing energy use and GHG can be calculated for comparison with strategies in other sectors of economy

Method: Divide network based on traffic level



Result: GHG optimal trigger by traffic group and GHG reduction vs. reactive maintenance

Traffic group	Daily PCE of lane-segments range	Total lane-miles	Percentile of lane-mile	Optimal IRI triggering value (m/km, inch/mile in parentheses)	Annualized CO_2-e reductions (MMT)	Modified total cost-effectiveness ($/t$CO_2$-e)
1	<2,517	12,068	<25	-----	0	N/A
2	2,517 to 11,704	12,068	25~50	2.8 (177)	0.141	1,169
3	11,704 to 19,108	4,827	50~60	2.0 (127)	0.096	857
4	19,108 to 33,908	4,827	60~70	2.0 (127)	0.128	503
5	33,908 to 64,656	4,827	70~80	1.6 (101)	0.264	516
6	64,656 to 95,184	4,827	80~90	1.6 (101)	0.297	259
7	>95,184	4,827	90~100	1.6 (101)	0.45	104
Total					**1.38**	**416**

Vehicle class	Speed (km/h)	Mean Fuel Consumption (mL/km)									
		Summer					Winter				
		AC	PCC	Mean Difference	Number of Data Points	Sig. (p-value)*	AC	PCC	Mean Difference	Number of Data Points	Sig. (p-value)*
Medium car	56	52.9	53.1	-0.2	138	0.71	56.2	56.1	0.2	138	0.8
	72	63.9	64.6	-0.7	138	0.22	67.2	68.2	-1.0	138	0.1
	88	78.9	79.1	-0.2	138	0.9	82.6	82.4	0.2	138	0.8
Van	56	81.8	81.1	0.7	138	0.35	85.7	85.6	0.2	138	0.8
	72	96.9	97.6	-0.7	138	0.38	102.0	103.0	-1.1	138	0.2
	88	113.7	115.3	-1.6	138	0.29	119.1	121.4	-2.3	138	0.2
SUV	56	101.7	100.2	1.5	138	0.2	106.6	106.1	0.5	138	0.6
	72	119.9	119.1	0.8	138	0.4	125.8	125.5	0.3	138	0.8
	88	159.6	160.5	-0.9	138	0.7	164.8	162.6	2.2	138	0.3
Light truck	56	156.7	151.1	5.6	138	0	159.6	159.3	0.2	138	0.9
	72	188.4	187.8	0.6	138	0.6	198.2	198.3	0.0	138	1.0
	88	219.9	225.2	-5.3	138	0.1	227.2	228.1	-1.0	138	0.7
Articulated truck	56	209.4	201.4	8	138	0	No tests were conducted in winter				
	72	225.2	222.9	2.3	138	0.2					
	88	247.6	248.4	-0.8	138	0.9					

3.8 % difference
4.0 % difference

Table 1 Summaries of Mean Fuel Consumption and Test Statistics for All Vehicles

Source: Chatti et al.(2012)

Other Fuel Economy/Pavement Structural Response Field Tests

- A number of field studies have been performed measuring vehicle fuel economy on different pavement structures under different conditions
  - Differences between pavement types varied
  - Mostly characterized as “asphalt” and “concrete” without characterization of responses under different loads and temperatures for specific pavements
  - See discussion in Reference Document)
- Structural response vs. fuel economy and models not yet comprehensively validated with well characterized pavement structures
- Validated models will permit evaluation of under ranges of traffic, climatic conditions that occur daily, seasonally, and different pavements
- Caltrans sponsored model comparison recently completed
  - Oregon State University/Massachusetts Institute of Technology/Michigan State University models
  - Report being prepared for review
  - Field validation study being prepared

Conclusions and Recommendations for Rolling Resistance

- Roughness (IRI)
  - Generally has the greatest effect on fuel economy for typical ranges of IRI on U.S. highway networks, compared with structural responsiveness, macrotexture
  - Important for all vehicles, speeds and temperatures
  - Consider smoothness performance over life cycle in design and management
  - Implement IRI based smoothness specifications
  - Timely M&R considering traffic levels
- Texture (MPD)
  - Generally only significant for slow heavy trucks
  - Need sufficient texture for safety

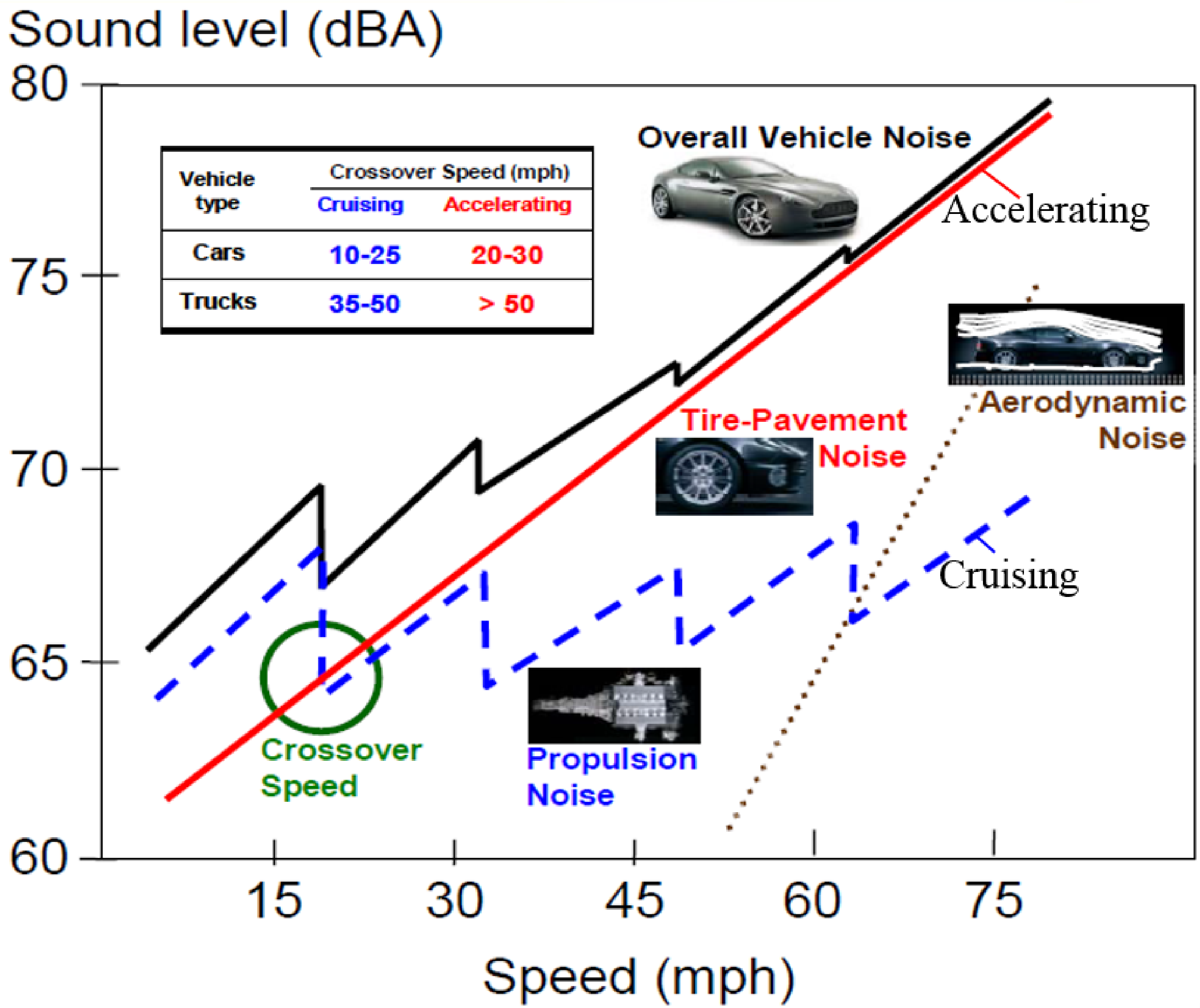
Conclusions and Recommendations for Rolling Resistance

- Structural response, knowledge to date
  - Under certain conditions structural responsiveness can have a significant measureable effect
  - Lighter and faster vehicles, colder conditions, cause smallest differences between different pavements
  - Highly variable, depending on temperature, underlying support conditions, which change daily and seasonally
  - Range from approximately no difference to same order of magnitude as high roughness
  - Need to simulate interaction of vehicle types, speeds, temperatures for specific cases to find net impact
- Models currently being calibrated

Why Worry About Tire/Pavement Noise?

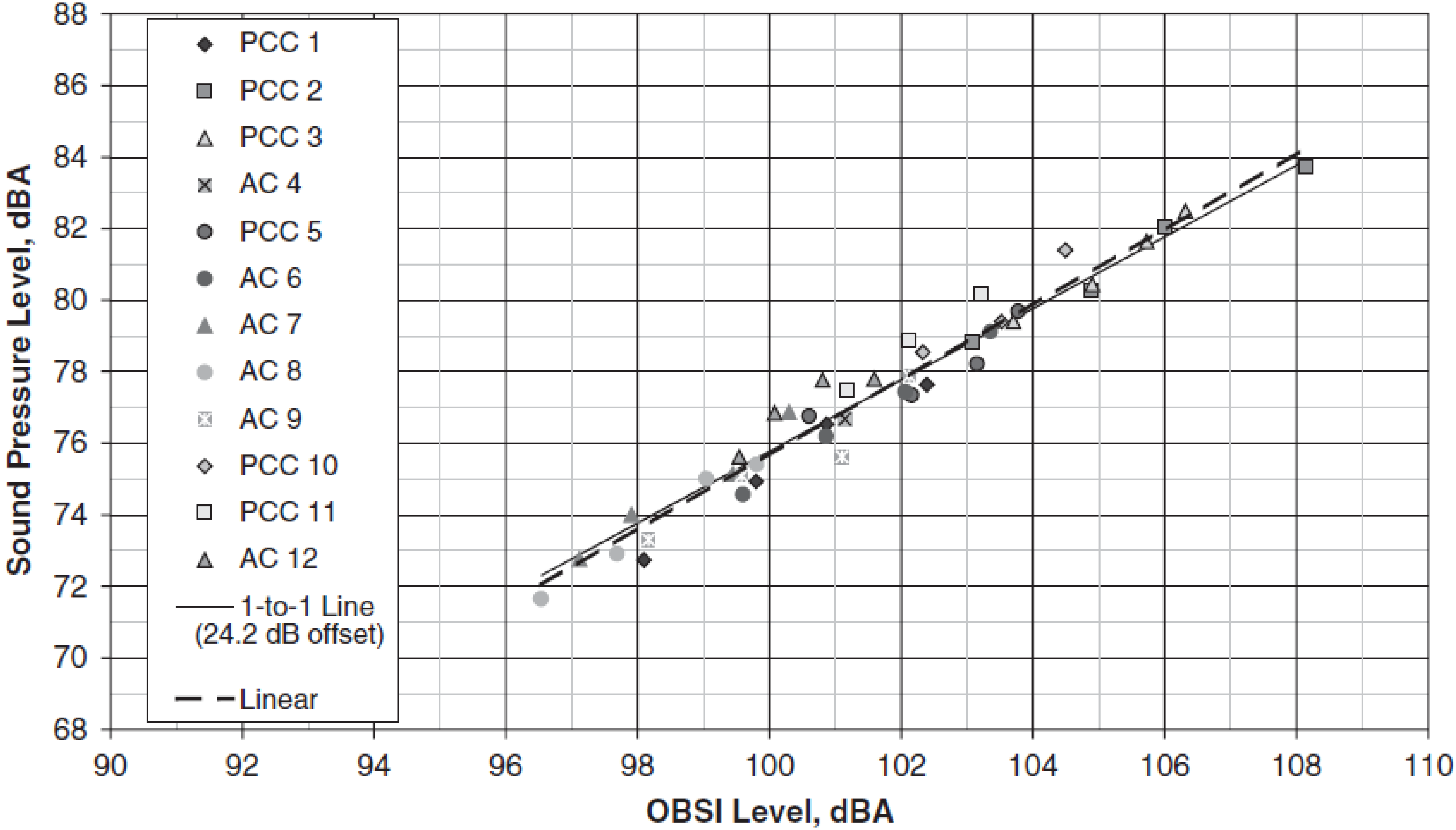
- Noise pollution increasing concern in U.S. and worldwide
- Highway noise affects people in adjacent residences and businesses and people in vehicles
- Health, quality of life effects on humans from noise pollution identified by World Health Organization
- Public awareness of road noise increased over the past 40 years
  - FHWA and other agencies are dealing with highway noise

Estimated light vehicle noise due to tire-pavement noise, powertrain noise, and aerodynamic noise at cruise speed (Rasmussen et al. 2008)

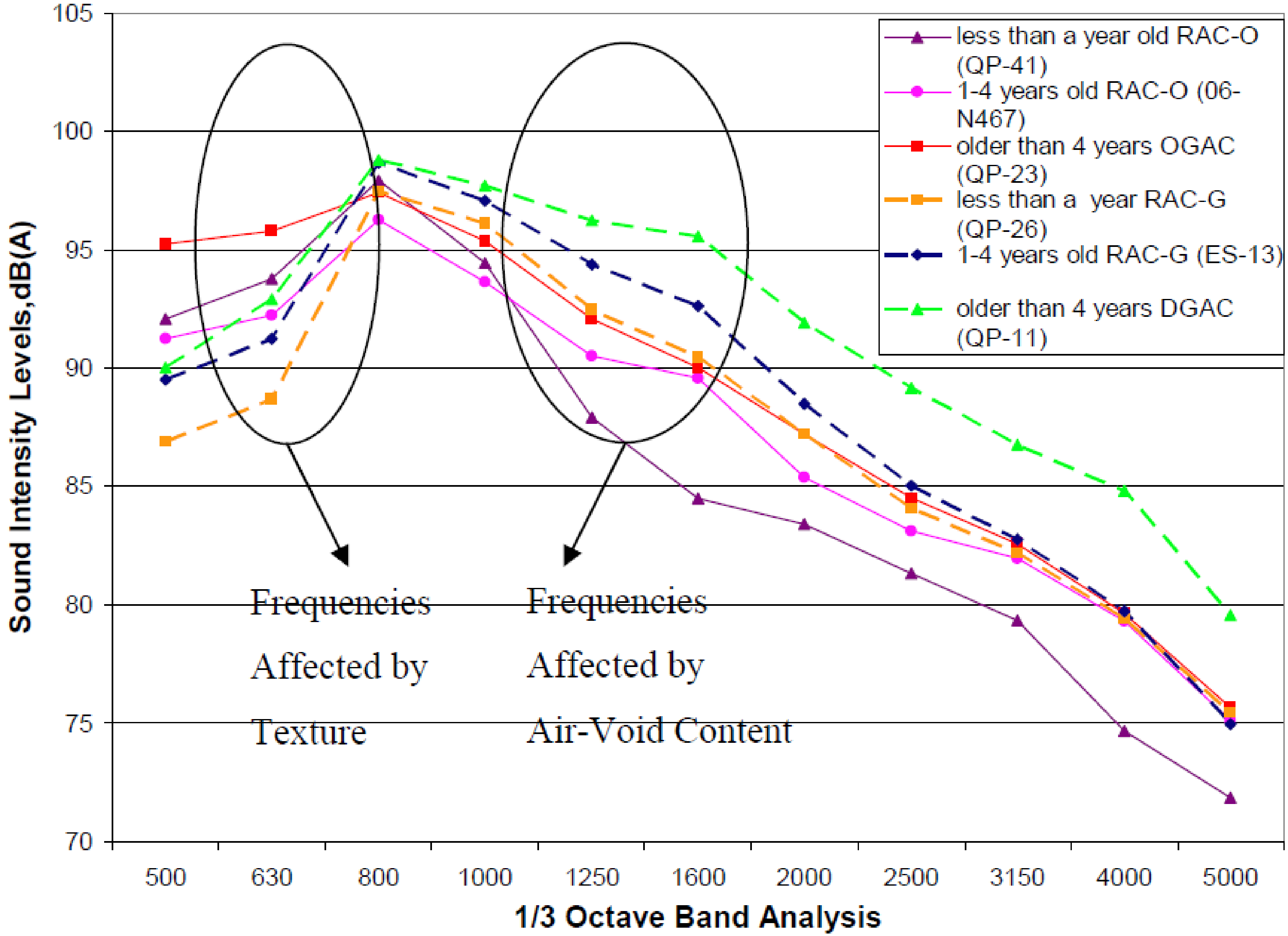


On Board Sound Intensity (OBSI) measurement for tire/pavement noise

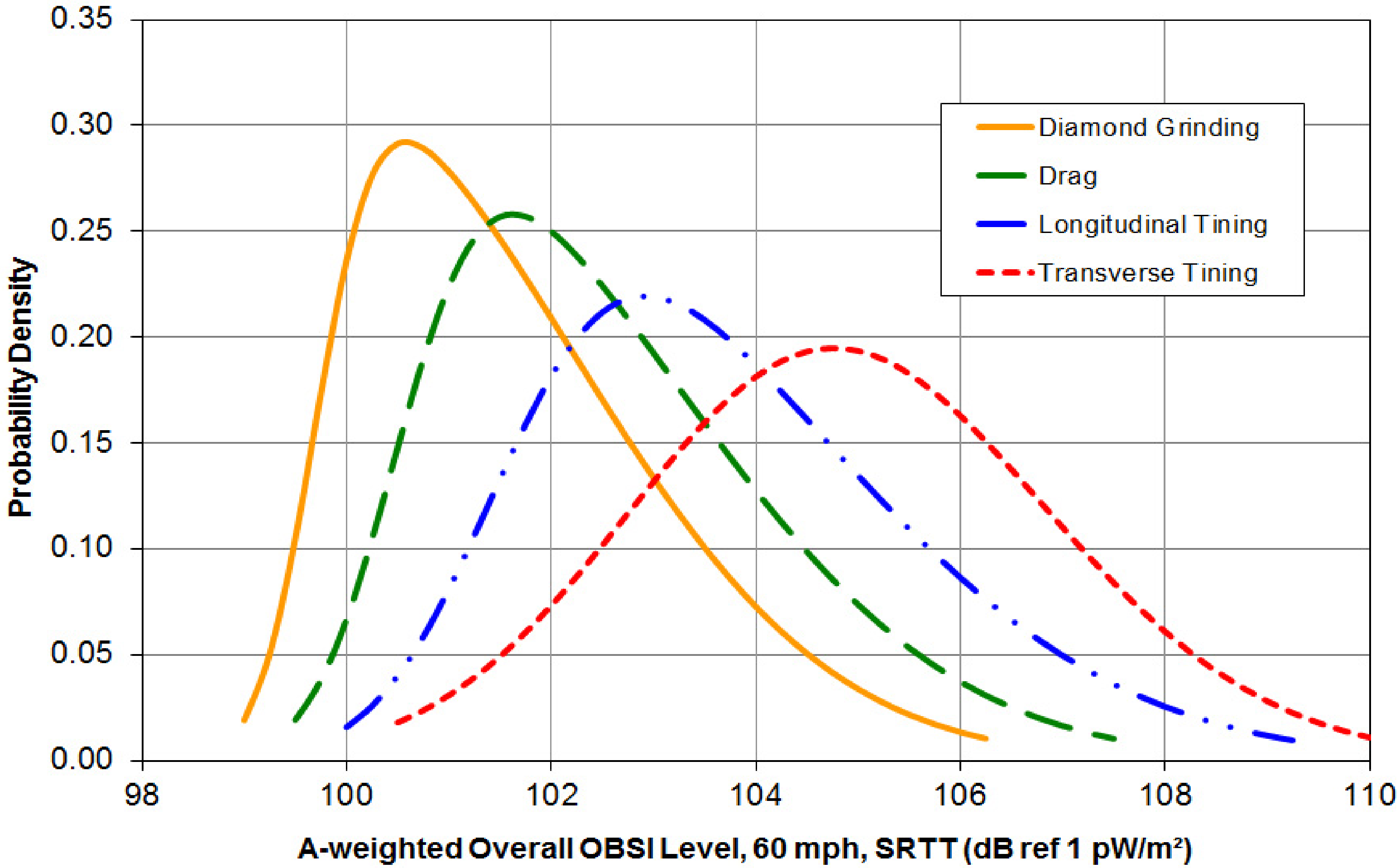
Vehicle pass-by levels at 25 ft (7.6 m) versus OBSI level for the SRTT at all test sites and speeds—normalized data (Donavan and Lodico 2009



Mechanisms of Asphalt Tire/Pavement Noise (Ongel et al.)



Concrete Textures and Tire/Pavement Noise (Rasmussen et al.)



Conclusions for Tire/Pavement Noise

- Noise can be important
  - Passengers
  - Surrounding people and wildlife
- Asphalt pavement
  - Open-graded and SMA overlays
  - Improved durability from rubberized and smaller stone mixes
- Concrete pavement
  - No transverse tining; longitudinal for new, grinding or grooving for M&R
  - Grind and groove (new generation concrete surface) can further reduce noise

Stormwater runoff issues for pavement

- Conventional paved pavement surfaces relatively impermeable
- Water runs off much faster than from vegetated or undeveloped surfaces, often straight into stormwater collection systems
  - Can overwhelm collection systems, and if combined system, can overflow sewage
- Stormwater is unfiltered
- Stormwater can raise stream temperatures where there is summertime rain

Columbiariverkeepers.org

Pavement Solutions

- Permeable asphalt surfaces can slow flows, provide some filtering
- Fully permeable pavement
  - Capture water and drain to subgrade or store for slow release (where subgrade impermeable)
  - Can potentially help with local urban cooling
  - Concrete, asphalt, interlocking concrete (paver) solutions
  - Primarily used for light vehicle, slow speed applications
  - Designs for heavier vehicles developed for all types
    - Calibrated for pavers, not yet for concrete and asphalt
  - Vegetated pavements also available
- Must consider durability, clogging for all solutions

Fully Permeable and Vegetated Pavements

John Kevern, NAPA, Soil Retention Products, UCPRC

- **Pavement Thermal Performance and Contribution to Urban and Global Climate**
- **Artificial Lighting and Safety**

Tom Van Dam

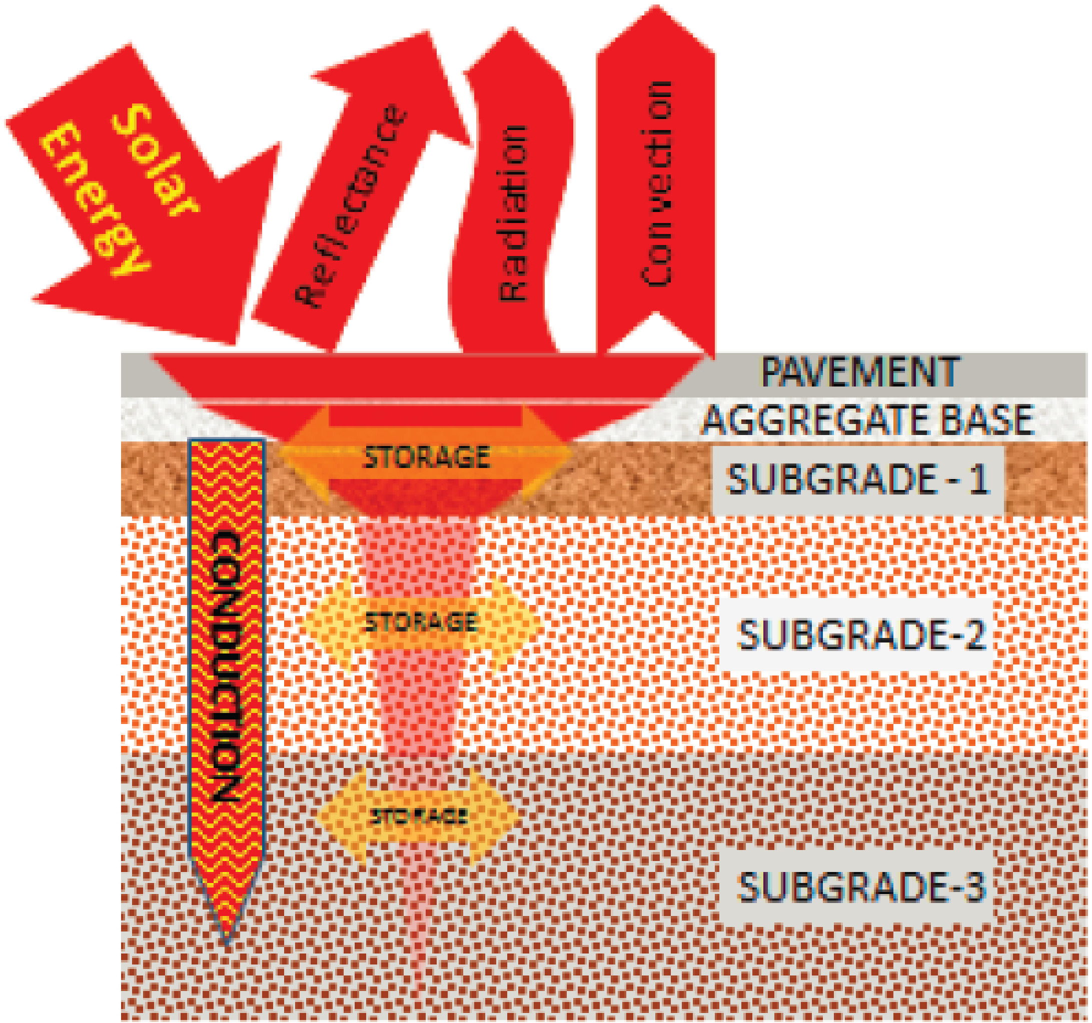
Pavement Thermal Performance

- Thermal performance is defined as the change in pavement temperature over time as influenced by:
  - Properties of the paving materials
  - Ambient environmental conditions
- Properties of interest include albedo, thermal emittance, thermal conductivity, specific heat, and surface convection
- Environmental factors include sunlight, wind, air temperature, and evaporative cooling

Thermal Performance

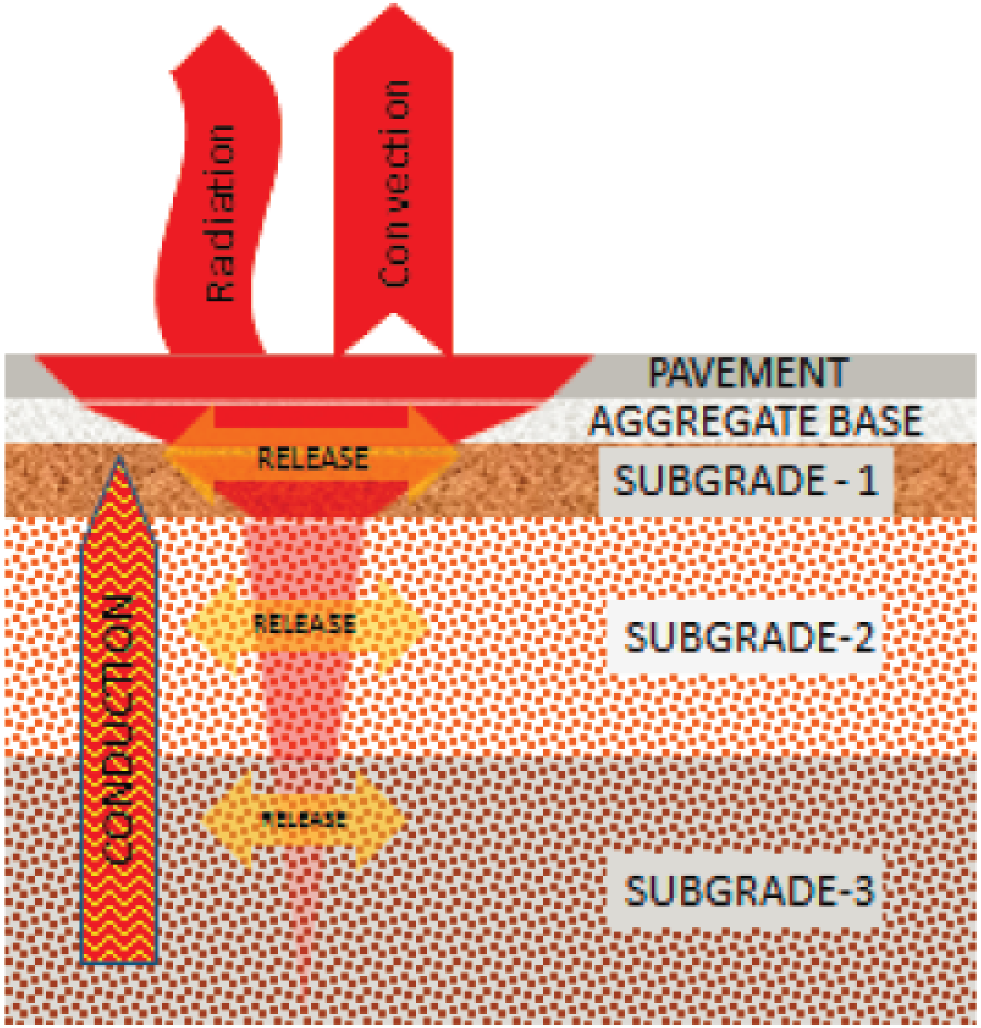
- It is complicated and not always intuitive
- Models continue to be developed and validated that are improving our understanding
- Major considerations include pavement surface temperature and reflectivity
- Impacts can be local, regional, and possibly global

Basic Thermal Model - Day



From NCPTC/NCAT 2013

Basic Thermal Model - Night



From NCPTC/NCAT 2013

Albedo

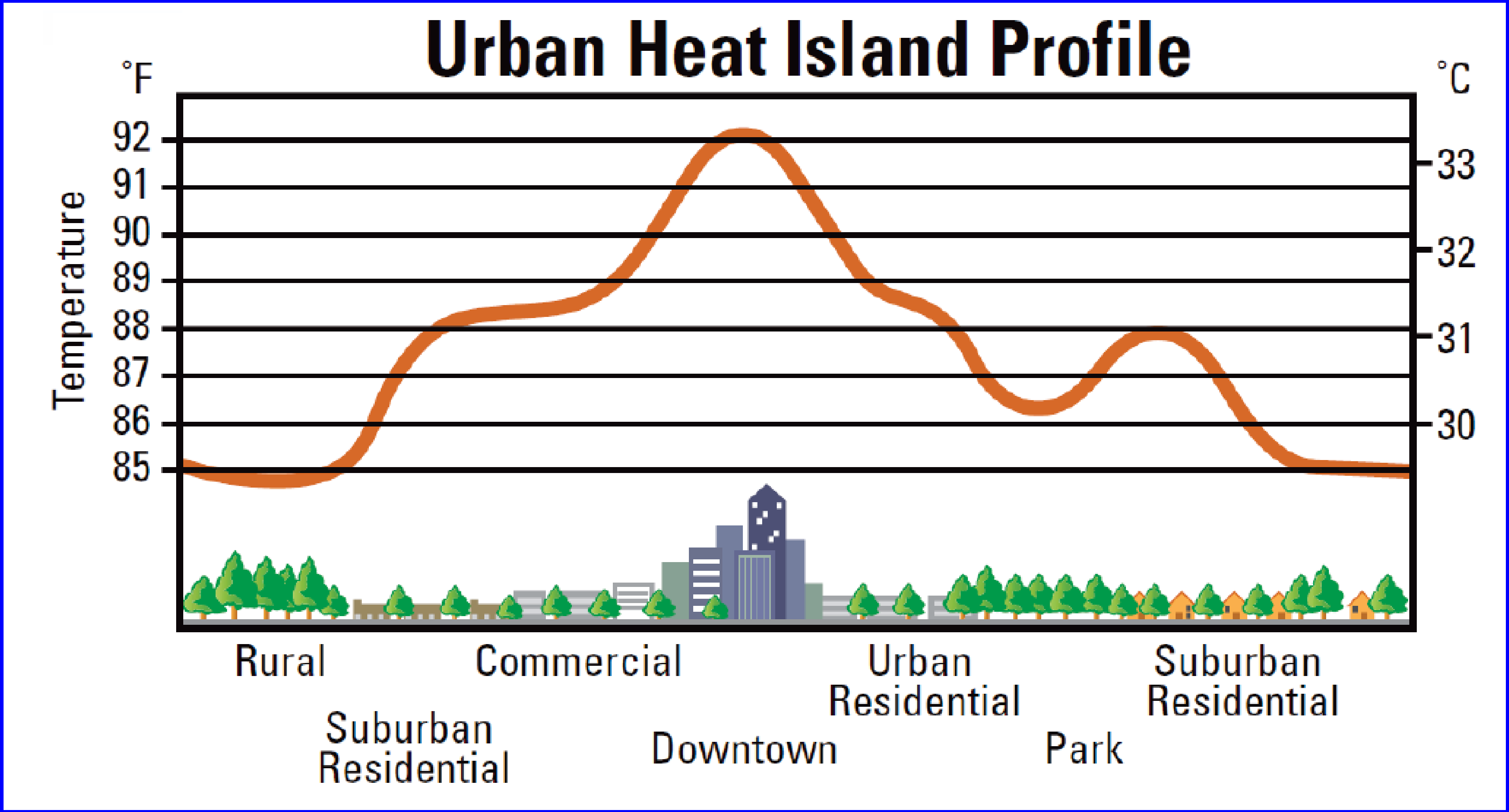
- Albedo (or solar reflectance) – Measure of the ability of a surface to reflect solar radiation
  - Ranges from 0 (no sunlight reflected) to 1 (all sunlight reflected)
- Generally light-colored materials have a higher reflectance than dark-colored materials
  - Color is not the only factor

Other Properties

- Emittance – efficiency with which a surface emits radiant energy
- Thermal conductivity – the ability of a material to conduct or transmit heat
- Specific heat – energy needed to raise a unit mass of a substance by one unit of temperature

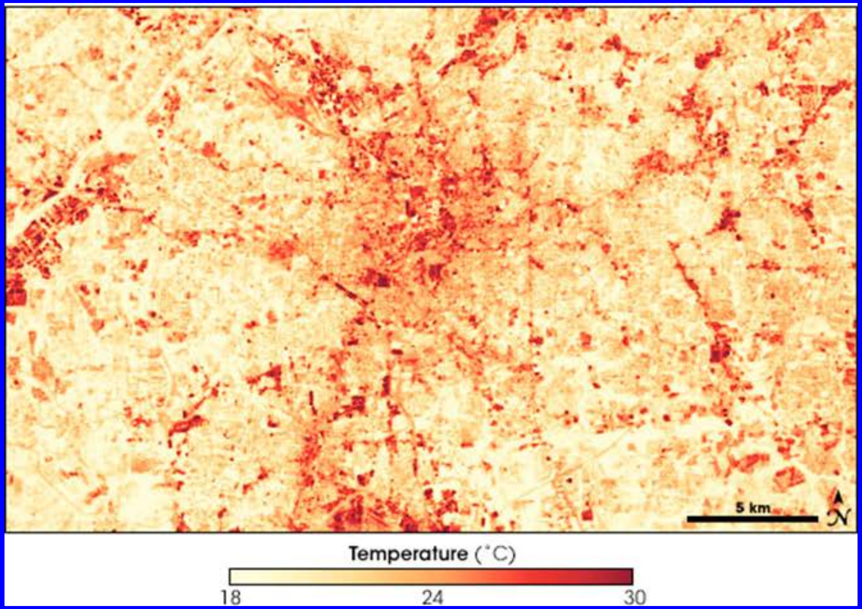
The values for each property are similar for dense-graded asphalt and concrete, thus albedo is the one property where significant differences may exist

Urban Heat Island Effect (UHIE)



EPA 2003

Cities Can Be Hot



From Amy Dickie – Global Cool Cities Alliance

Urban Heat Island Effect

- The formation of urban heat islands is well documented
  - Created, at least in part, by the presence of dark, dry surfaces in heavily urbanized areas
- Exist at many different levels
  - Ground/pavement surface
  - Near-surface (3 – 6 ft)
  - Above street level
  - Atmospheric

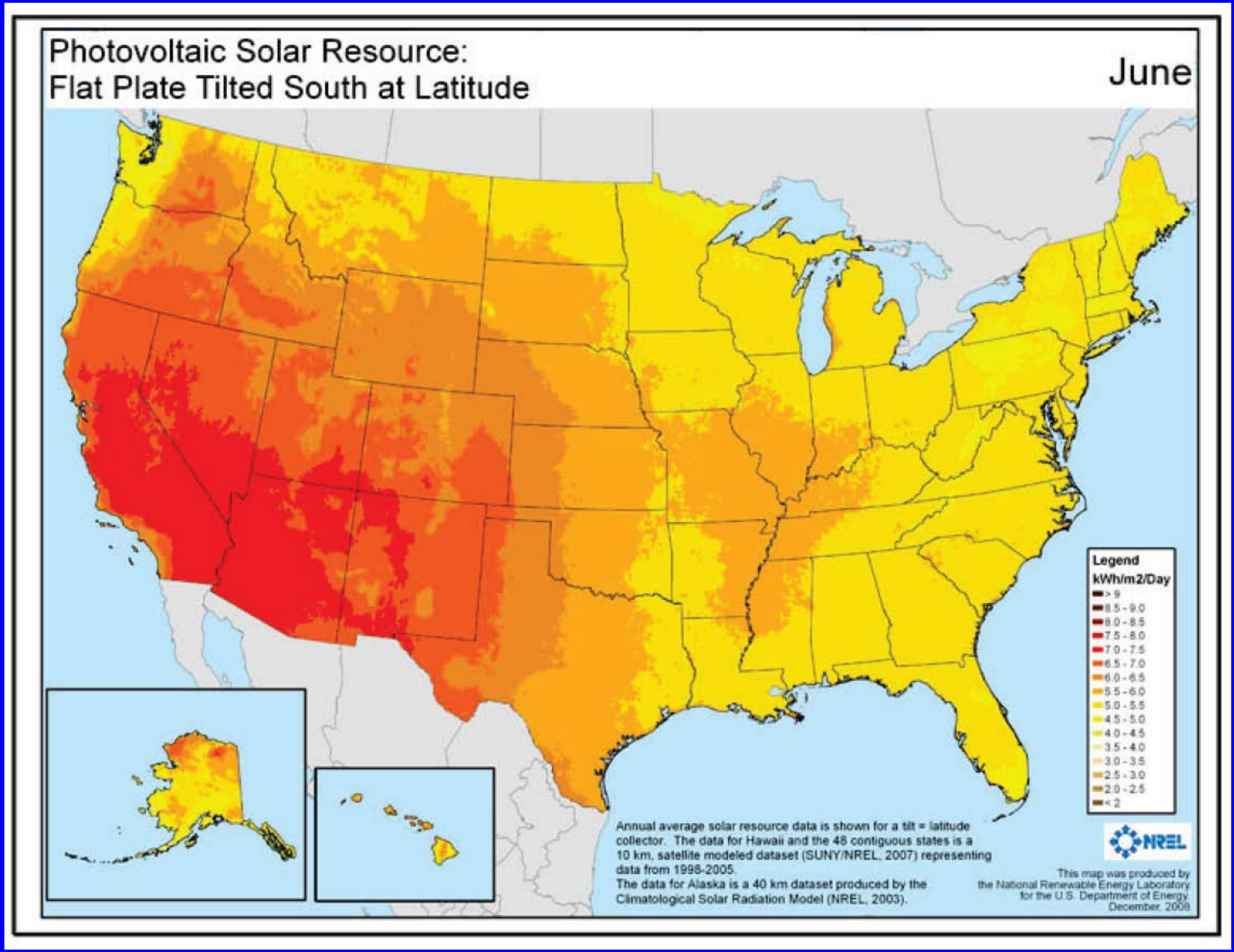
Heat Islands

- Surface and near-surface heat islands can affect human comfort, air quality (ground-level ozone formation), and energy use of buildings and automobiles
- Atmospheric heat islands can impact summertime peak energy demand, electrical grid reliability, and GHG emissions
  - Highly dependent on increased temperatures resulting in increased air conditioner use
  - Heat-related illness and death, pollution, and water quality also increases

Contribution of Pavements

- Paved surfaces account for roughly one-third of the land surface in urban areas
- Multiple computer simulations suggest that paving materials can contributes to the UHIE
  - Related to albedo
  - Field data lacking
- Recent studies incorporate urban canopy models that consider urban complex urban morphology
  - Three-dimensional modeling include the impacts of vertical surfaces and shadowing

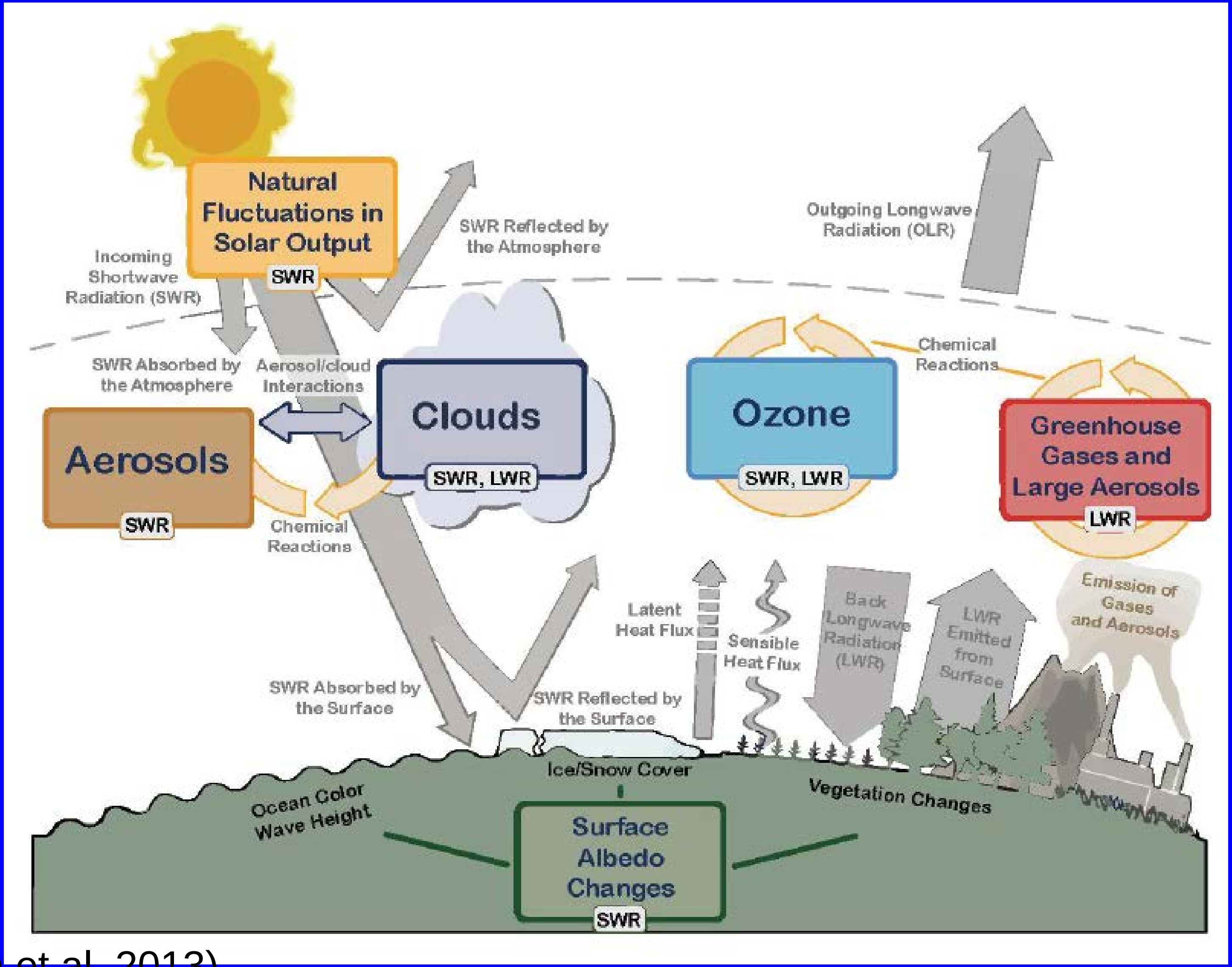
Direct Solar Radiation is Critical



Other Factors

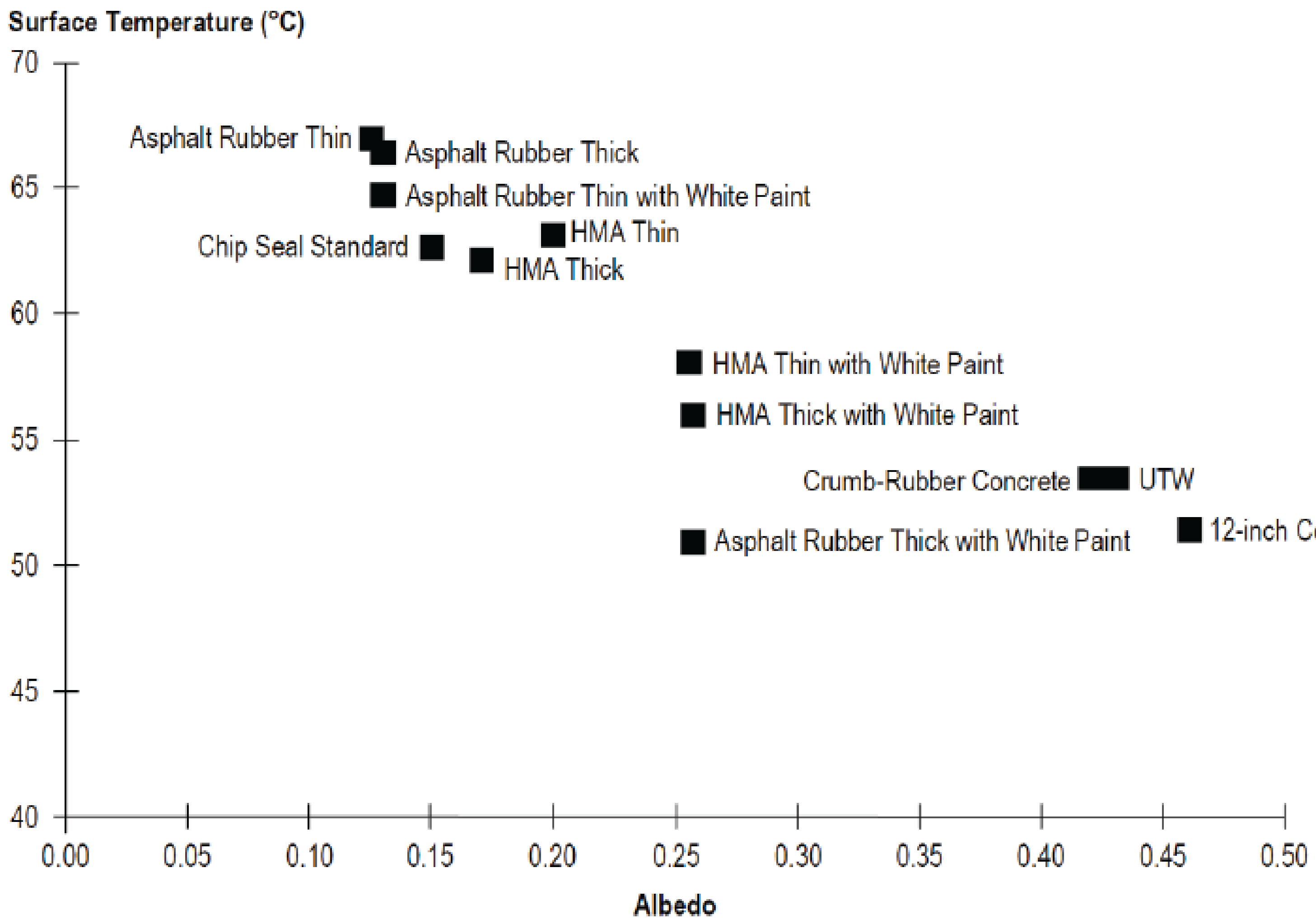
- Light reflected from a pavement can have negative impacts
  - Human comfort (warming, glare)
  - Adsorbed onto the building envelop
    - Can increase need for air conditioning but may reduce artificial lighting needs
- The problem is complicated
- The source of electricity and heating fuel makes a difference

Also Consider Radiative Forcing



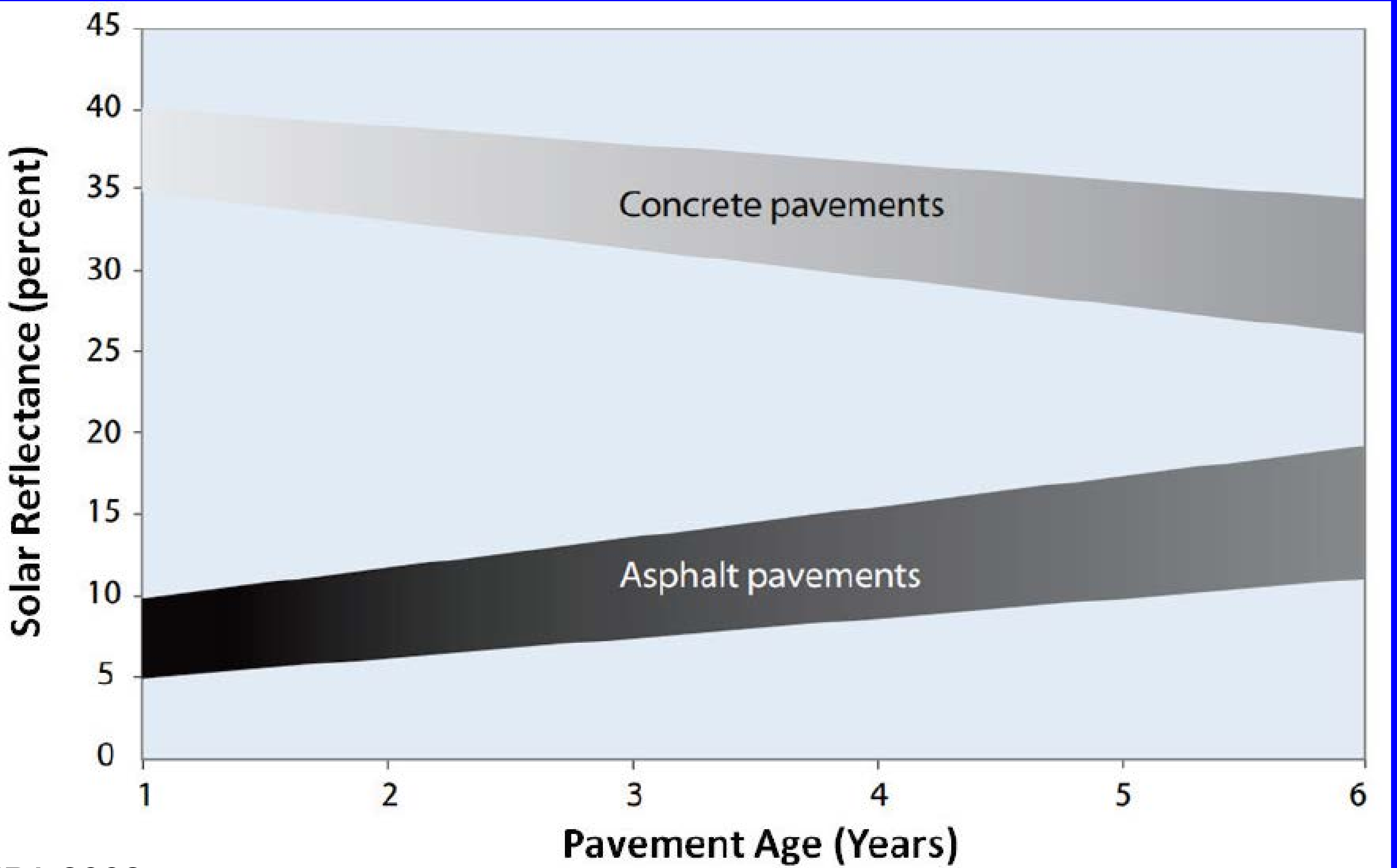
Cubasch et al. 2013)

Pavement Type and Albedo



Source: Redrawn from data by Jay S. Golden and Kamil Kaloush, SMART Program, and Arizona State University, July 24, 2004.

Albedo Changes With Age



EPA 2008

Preservation/Rehabilitation Can Alter Albedo

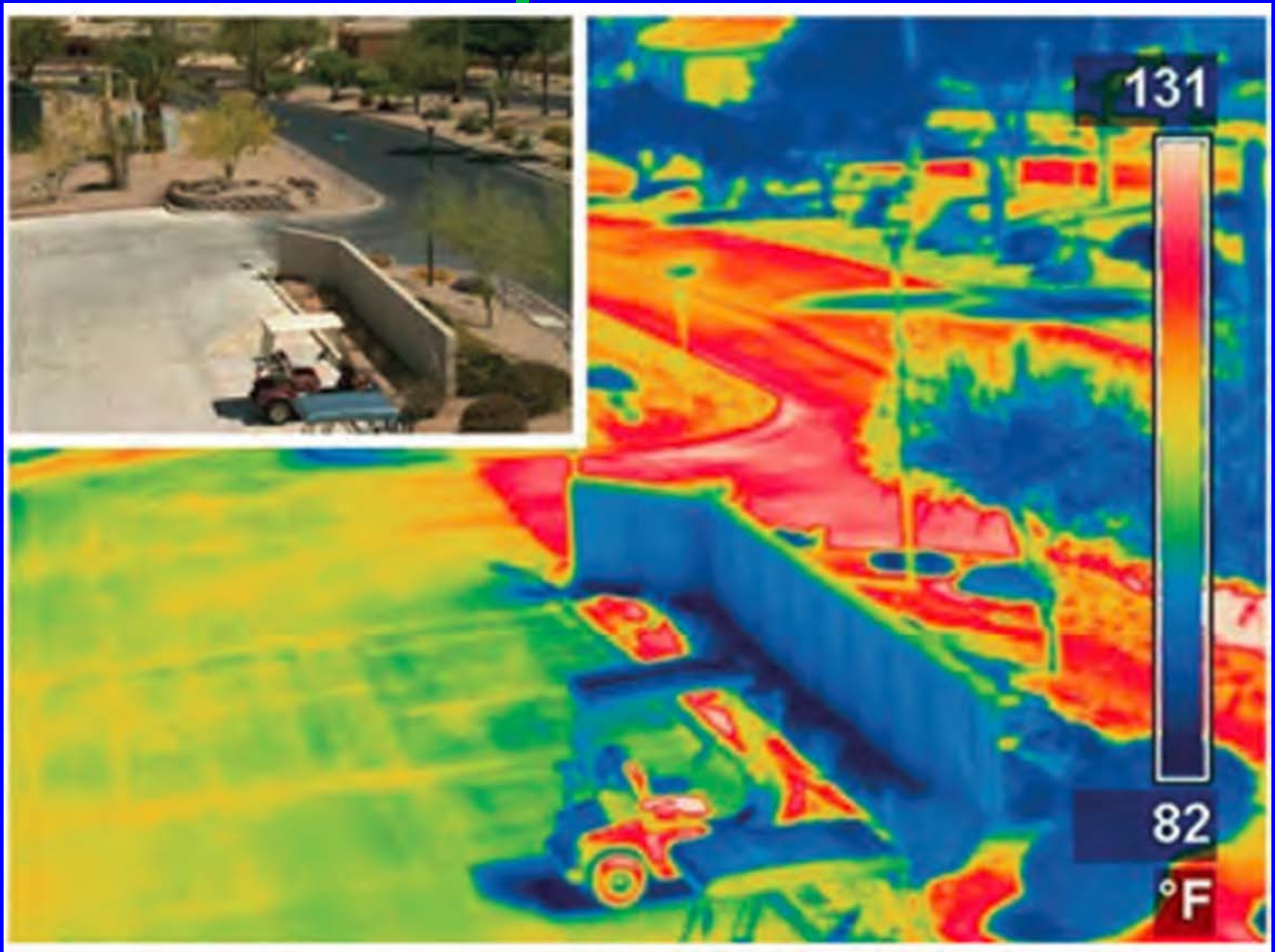
- Treatments that darken the surface decrease albedo
  - e.g. fog seals, slurry seals, microsurfacing, dark overlays
- Treatments that lighten the surface will increase albedo
  - Chip seals with light-colored aggregates
  - Light-colored overlays
  - Light-colored coatings?
- Diamond grinding can go either way

Diamond Grinding

Albedo, Pavement Temperature, and the UHIE

- All things equal, pavements with lower albedo get hotter when directly exposed to solar radiation
  - Results in higher air temperature within inches of the surface
- Most studies suggest that this can lead to a slight increase in atmospheric heat island
  - Regional impacts less certain (some studies suggest localized heating “downstream”)

Impact of Albedo on Surface Temperatures



Kamil Kaloush, Arizona State University. Presentation entitled, “Pavements and the Urban Heat Island Effect,” during EPA’s Cool Pavement Webcast, January 20, 2010.

Pavement Reflectivity and Artificial Lighting

- Advances in adaptive LED lighting are resulting in large energy savings
- The color and texture of a pavement influences the required level of illumination
  - Light-colored surfaces require less lighting (lower lumens per luminary or less luminary
  - Adaptive lighting can take full advantage of this
- No clear consensus regarding impacts on nighttime safety
  - Contrast very important

Contribution of Pavement Surface Conditions to Safety

- Roadway condition is a leading cause of crashes – Keep roads smooth
- Crashes increase in work zones – minimize the number and duration of work zones
- Adequate surface friction is required to provide safe stopping distances
  - Macrotexture is essential
- Uniform cross slopes provide drainage
  - Drains water off the surface

Concluding Remarks

- Concrete pavements are typically more reflective than asphalt pavements
  - Reflectivity changes with age
  - Preservation and rehabilitation activities can profoundly alter reflectivity
- In locations where solar reflectance is deemed important, it should be maintained
- Proprietary treatments to establish high reflectivity may have a high environmental impact over the life cycle

Concluding Remarks

- If lower pavement temperatures are desired, a systems approach should be used
  - Not just pavement albedo
  - Consider shading and pervious pavements
- Research is on-going to determine to what extent pavement albedo influences the UHIE or global climate change

Concluding Remarks

- Adaptive lighting techniques with LEDs offers the opportunity for large energy savings
- Trade-offs exist with regards to pavement reflectivity and nighttime and daytime safety
  - Improved luminance versus improved visibility due to contrast
- Good friction is required to enhance braking
  - Other important pavement characteristics include maintaining ride quality
  - Surface drainage is also important

- **Pavement Sustainability within Larger Systems**

Joep Meijer

Pavement Sustainability within Larger Systems

- Overview of how pavements can interact with larger system sustainability goals
  - Social context systems
  - Ecosystem context systems
  - Innovation and potential market expansion

Pavement Sustainability within Larger Systems

- Sustainable communities
- Ecosystems
- Strategies for improving sustainability
  - Enhance Aesthetics
  - Historical and cultural identity
  - Minimize impact of utility cuts
  - Improve worker and community health
  - Balanced approach to allowable hours of construction
- Future directions and emerging trends

Sustainable Communities

- Partnership for Sustainable Communities
  - Provide more transportation choices
  - Promote equitable, affordable housing
  - Increase economic competitiveness
  - Support existing communities
  - Leverage federal investment
  - Value communities and neighborhoods

Sustainable Communities

- Sustainable communities
  - Partnership for Sustainable Communities
    - Combined DOT, HUD, EPA effort
  - National Complete Streets Coalition
    - Advocacy for multimodal/connected streets
  - National Scenic Byways Program
    - FHWA program recognizing roads for cultural, historic, natural, recreational, scenic qualities
  - U.S. National Register of Historic Places
    - 6,800 transportation-related listings
  - Walk Score
    - Private company that provides walkability, transit service, and bike friendliness scores

Sustainable Communities

- More transportation choices (roads, trails, bike paths, sidewalks)
- Investing in walkable neighborhoods (sidewalks, paths, aesthetics)
- Increase mobility (roads, paths, trails)
- Reduce GHG emissions (materials, construction, use)
- Community revitalization (aesthetics, cultural identity)
- Efficiency of public investments (LCCA, long-life)
- Expanded markets (integrated design)

Ecosystems

- Eco-Logical (2006)
  - o Provides guidance to mitigate effects of infrastructure with ecosystem.
- Federal Lands Highway Program (FLHP)
  - o Key partners: NPS, USFS, USFWS, Bureau of Indian Affairs
  - o Partner agency goals: stewardship of the

Ecosystems

- **Des Plaines River Valley Bridge**
  - The total height of the bridge ranges from 80 to 100 feet (24 to 30 m).
  - The height allows the endangered Hine's Emerald Dragonfly to fly safely beneath the bridge, away from the flow of traffic.

Ecosystems

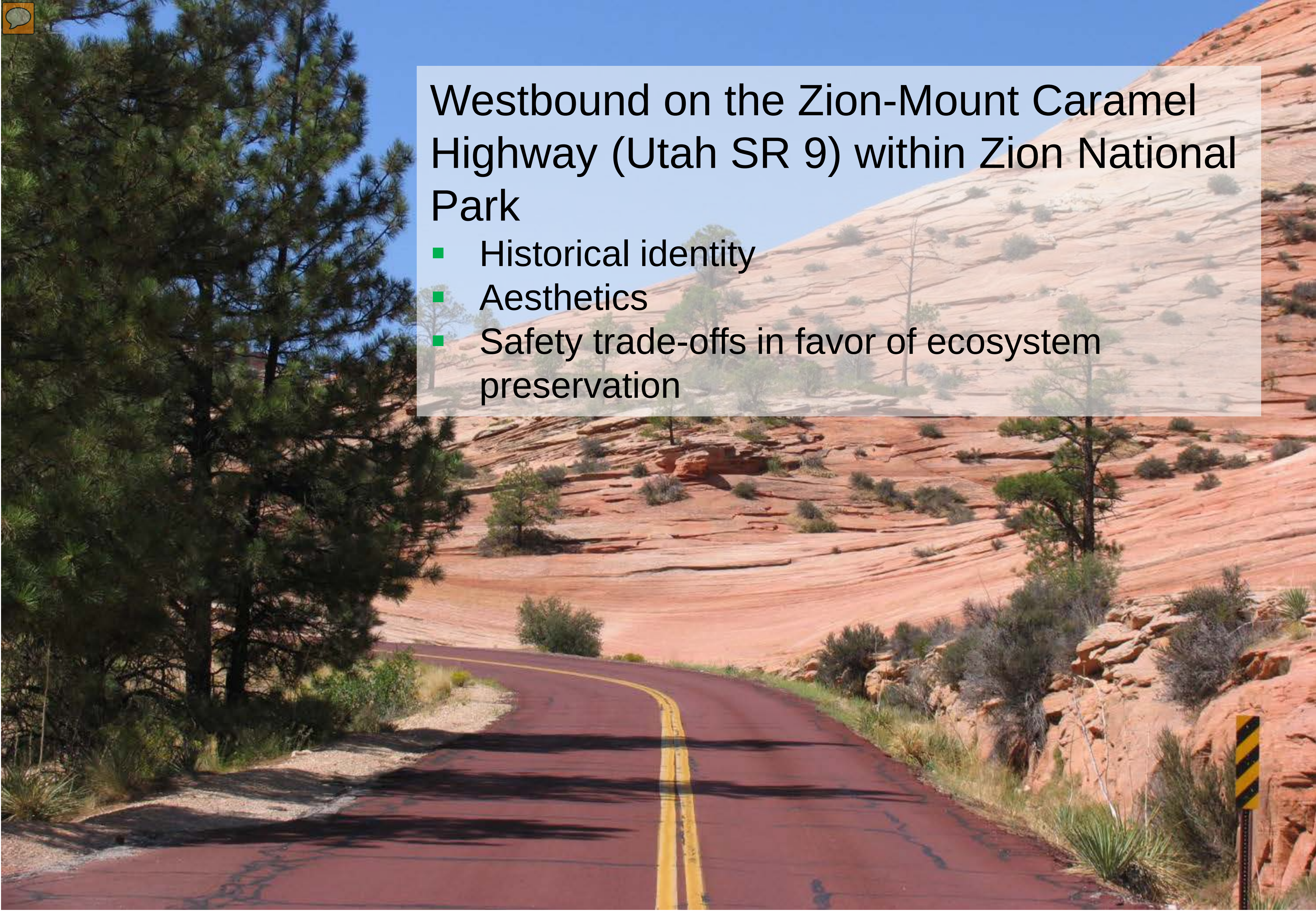
- **Wildlife Crossings – Dutch example**
  - Interstate cutting wildlife habitat in two parts
  - Crossing build to accommodate migration
  - Part of ecological infrastructure map
  - 25+ in place

Strategies for Improving Sustainability

- Enhance Aesthetics
- Historical and cultural identity
- Minimize impact of utility cuts
- Improve worker and community health
- Balanced approach to allowable hours of construction

Westbound on the Zion-Mount Caramel Highway (Utah SR 9) within Zion National Park

- Historical identity
- Aesthetics
- Safety trade-offs in favor of ecosystem preservation



Utility Work

- **Pavers**
  - Utility cut repairs
  - Machines for paving
  - Pervious

Improve Worker and Community Health

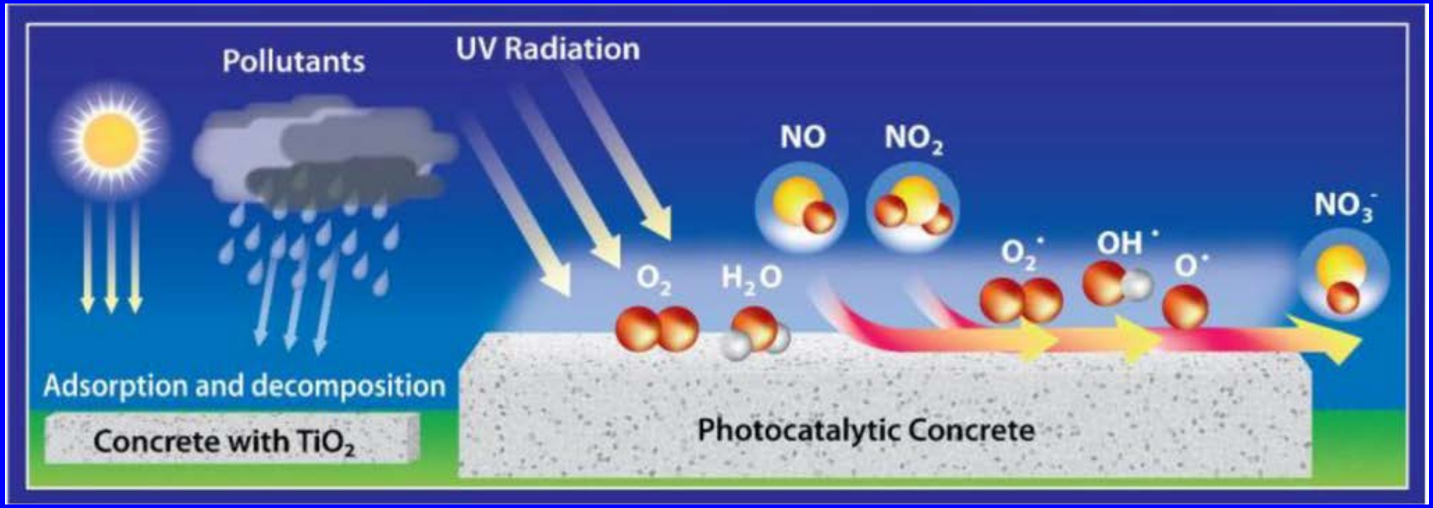
- Emission reductions using warm mix

Future directions and emerging trends

- Photocatalytic pavement
- Energy production

Photocatalytic Pavement

- Catalytic conversion of emissions to reduce ozone
- Titanium dioxide

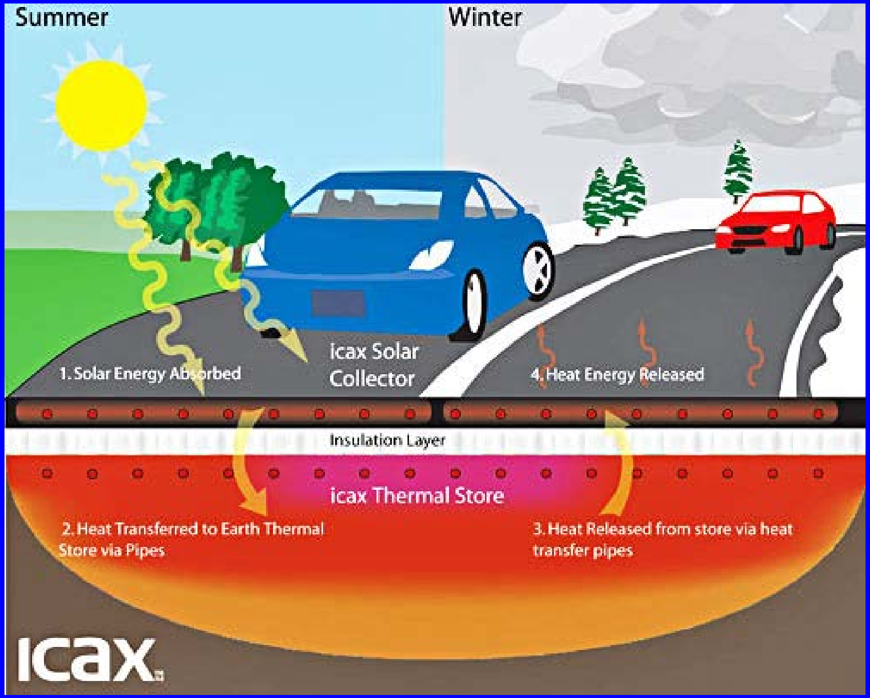


Solar Noise Barriers

- Safety
- Noise
- Integrated solar PV
- Aesthetics

Energy Harvesting Road

- Safety
- Heating
- Cost and durability



Pavement Sustainability within Larger Systems

- Overview of how pavements can interact with larger system sustainability goals
  - Social context systems
  - Ecosystem context systems
  - Innovation and potential market expansion

- **Where do we go from here?**

The Path Forward

Tom Van Dam

Review of Technologies, Innovations, and Trends

- Sustainability inspires innovation
  - It is a journey, not a destination
  - Considering economic, environmental, and societal factors over the life cycle is a game changer
- There is considerable “low hanging fruit” that can make an immediate difference
- Emerging trends offer even greater advancements

Low Hanging Fruit

- Increased use of recycled materials (e.g. RAP, RAS, RCA, in-place recycling)
  - Illinois Tollway
- Full adoption of WMA technologies
  - Use effectively to reduce temperatures <u>and</u> extend life
- Increased use of SCMs to reduce GHGs
  - Challenges exist but innovations abound

Low Hanging Fruit

- Improved pavement design
  - Mechanistic-empirically based
- Use materials wisely
- Permeable pavement systems
- Precast pavements and interlocking pavers
- Innovative construction technologies
  - Improved smoothness, quality, and MOT
- Intelligent preservation
  - Keep good pavements in good condition

Emerging Trends

- Recognition of the importance of the use phase
  - We are all in this together
- Recognition of pavements as being part of larger systems
- Development/adoption of sustainability assessment tools

And Finally….

- The reference manual represents a single step in the journey
- Stay informed
- Challenge convention
- And as Garrison Keillor says, “Be Well, do good work, and stay in touch”

Thank You!

- Gina Ahlstrom:
- Kurt Smith:
- John Harvey:
- Tom Van Dam:
- Joep Meijer:

You may access all webinars at:

http://www.fhwa.dot.gov/pavement/sustainability/webinars.cfm