Improving the Sustainability of Local Government Pavement: A Process and Practical Results

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Some material prepared by Tom Van Dam, NCE

Bed Roll
Canyon Dam, August 2016

What is the University of California Pavement Research Center?

UCPRC
UNIVERSITY of CALIFORNIA | PAVEMENT RESEARCH
Davis • Berkeley | CENTER

- Mission
  - *Dedicated to providing knowledge, the UCPRC uses innovative research and sound engineering principles to improve pavement structures, materials, and technologies.*
- Pavement research begun in 1948 at UCB
- UCPRC begun in 1995
  - UCB 1995 – 2002
  - UCD & UCB – 2002 onwards

Some Recent UCPRC Work

- Caltrans
  - Life Cycle Cost Analysis (LCCA)
  - Mechanistic-Empirical design methods
    - Long life rehabilitation, concrete and asphalt
  - Environmental Life Cycle Assessment (LCA)
  - Construction quality
  - Rapid Rehabilitation construction productivity and work zone traffic management
  - Pavement management
  - Recycling (asphalt, concrete, rubber, etc)
  - Noise, smoothness
  - Freight logistics decisions and pavement condition
- Caltrans and Interlocking Concrete Pave Institute
  - Permeable pavements for storm water infiltration

Some Recent UCPRC Work

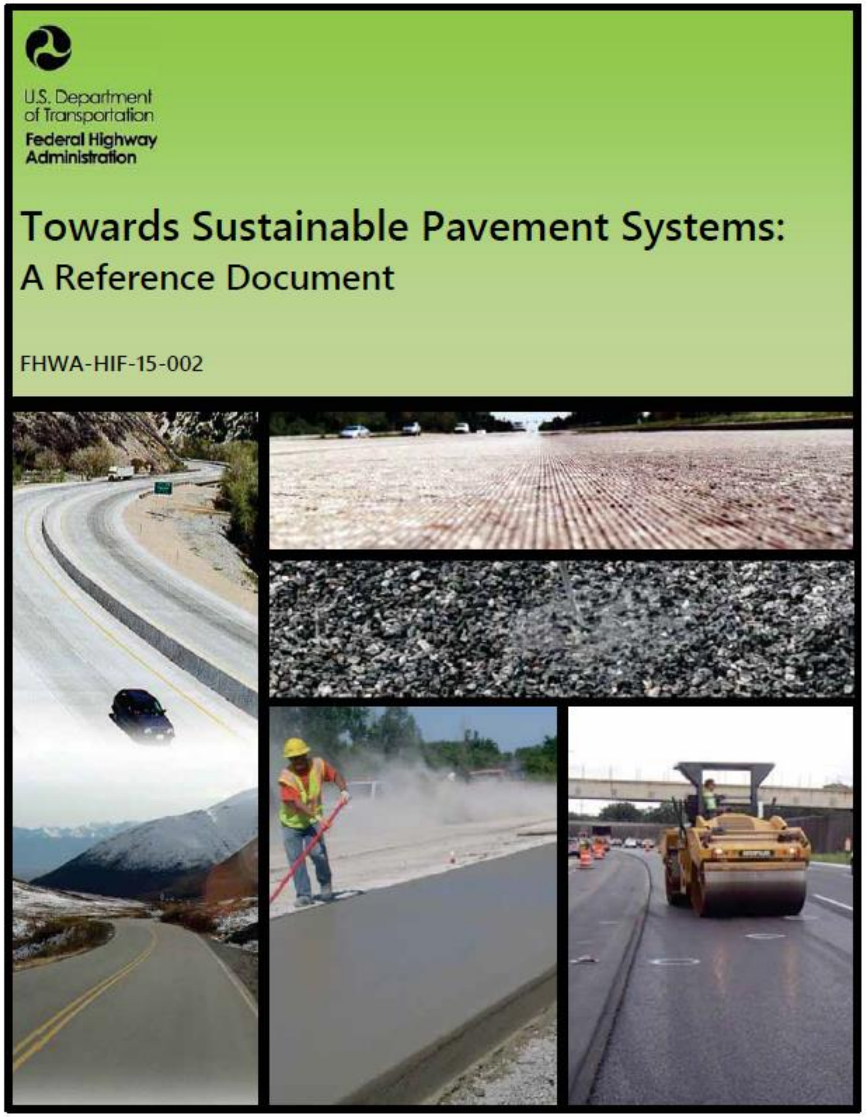
- California Air Resources Board
  - Urban heat island life cycle assessment
- CalRecycle
  - Rubber asphalt mix development and specifications
- Federal Highway Administration
  - Sustainability of pavement
  - Full-depth reclamation
  - Wide base single truck tires
- Federal Aviation Administration
  - Asphalt recycling
  - Mechanistic-empirical design methods
  - Airfield environmental life cycle assessment
- <u>This presentation does not reflect policy or recommendations of any of these sponsors</u>

A Sustainable Pavement is an Aspirational Goal

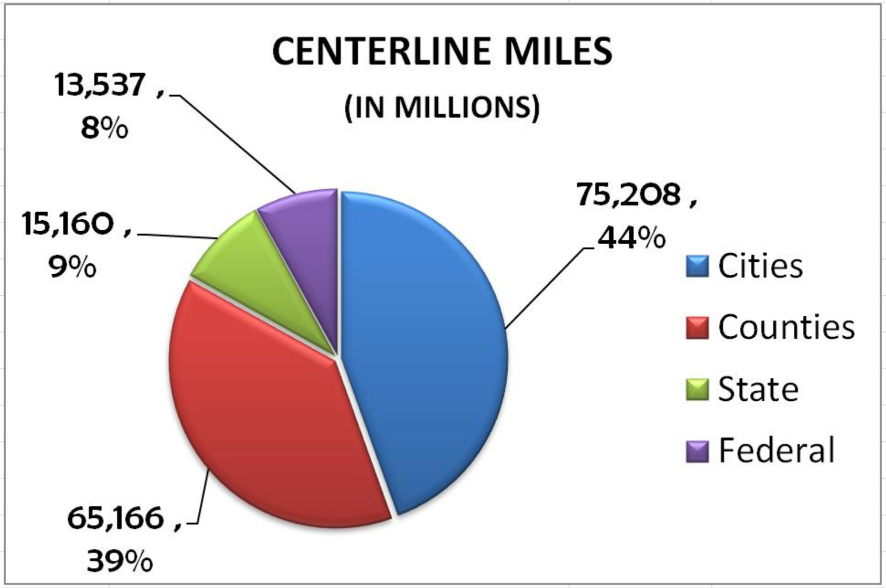
- Might not get there, but we can do a lot better than we are
- Lots of low hanging fruit

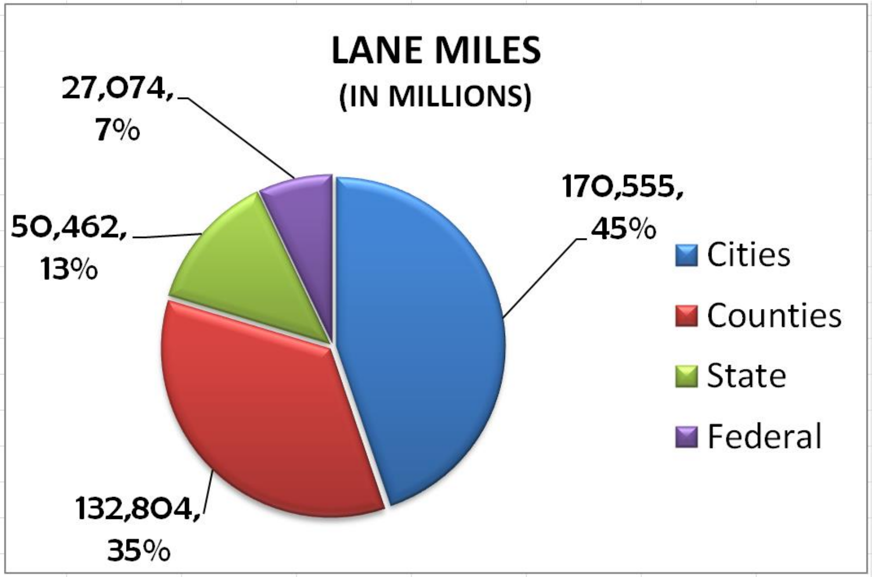
FHWA Pavement Sustainability Reference Document

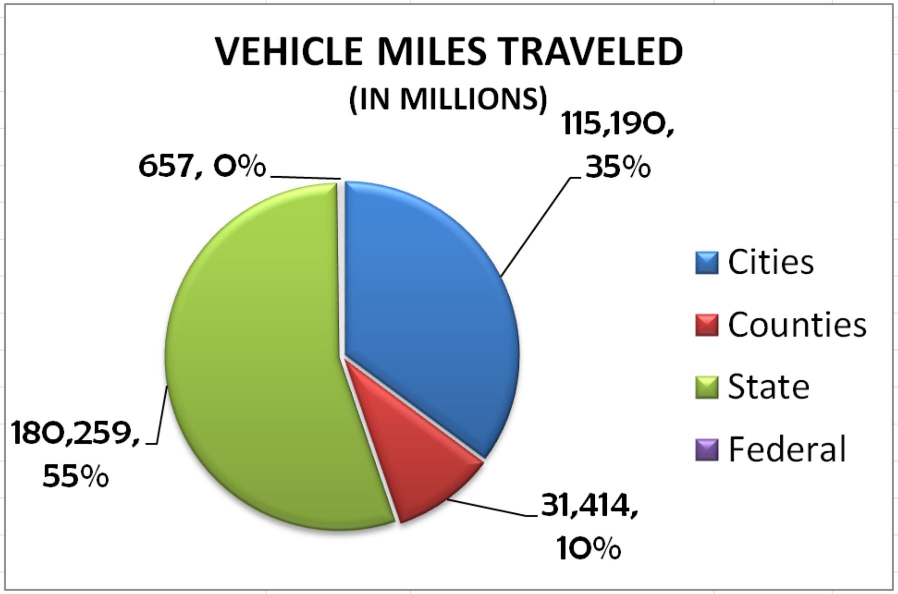
- State of the knowledge on improving pavement sustainability
- http://www.fhwa.dot.gov/pavement/sustainability/ref_doc.cfm
- Search on "FHWA pavement sustainability"
- Recommendations for improving sustainability across entire pavement life
- Organized around Life Cycle Assessment (LCA) framework
- Other information available at same web site
  - Tech briefs
  - Literature database



Why is Local Government Pavement Sustainability Important?







National $ Spent on Transportation in 2008 (US Census Bureau)

STATE GOVERNMENT	LOCAL GOVERNMENT
97,508,989	61,053,150

Measuring Sustainability

- Life Cycle Cost Analysis (LCCA)
  - Economic
- Life Cycle Assessment (LCA)
  - Range of environmental impacts
  - Emerging area
- Sustainability Rating Systems (e.g., INVEST)
  - Environmental and social impacts

Reasons to Measure

Accounting

Decision support

Establish baseline/process improvement

Four Key Stages of Life Cycle Assessment

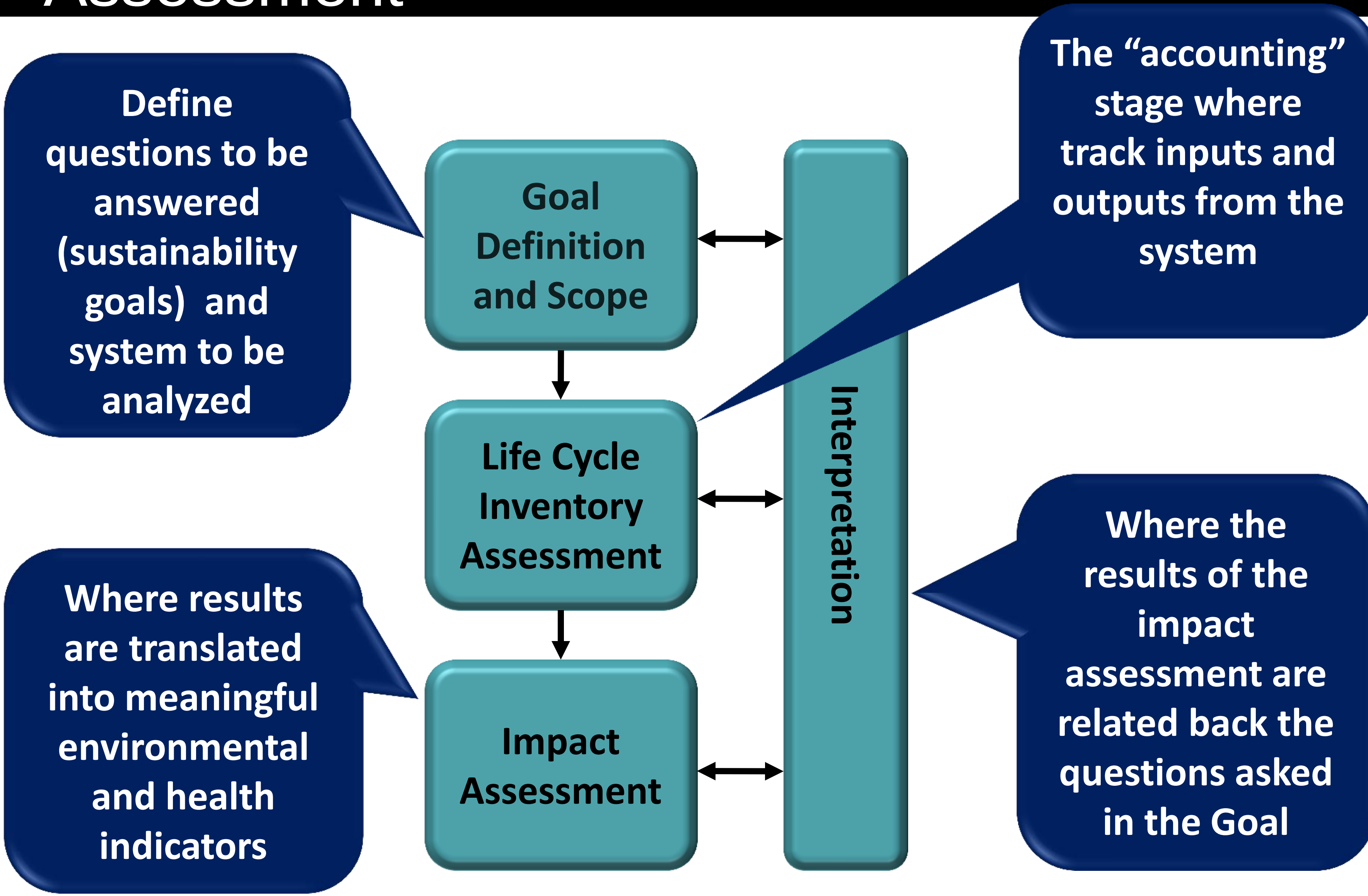


Figure based on ISO 14040, adopted from Kendall

US EPA Impact Assessment Categories

(TRACI – Tool for the Reduction and Assessment of Chemical and other environmental Impacts)

- Global warming
- Stratospheric ozone depletion
- Acidification
- Eutrophication
- Photochemical smog
- Terrestrial toxicity
- Aquatic toxicity
- Human health
- Abiotic resource depletion
- Land use
- Water use

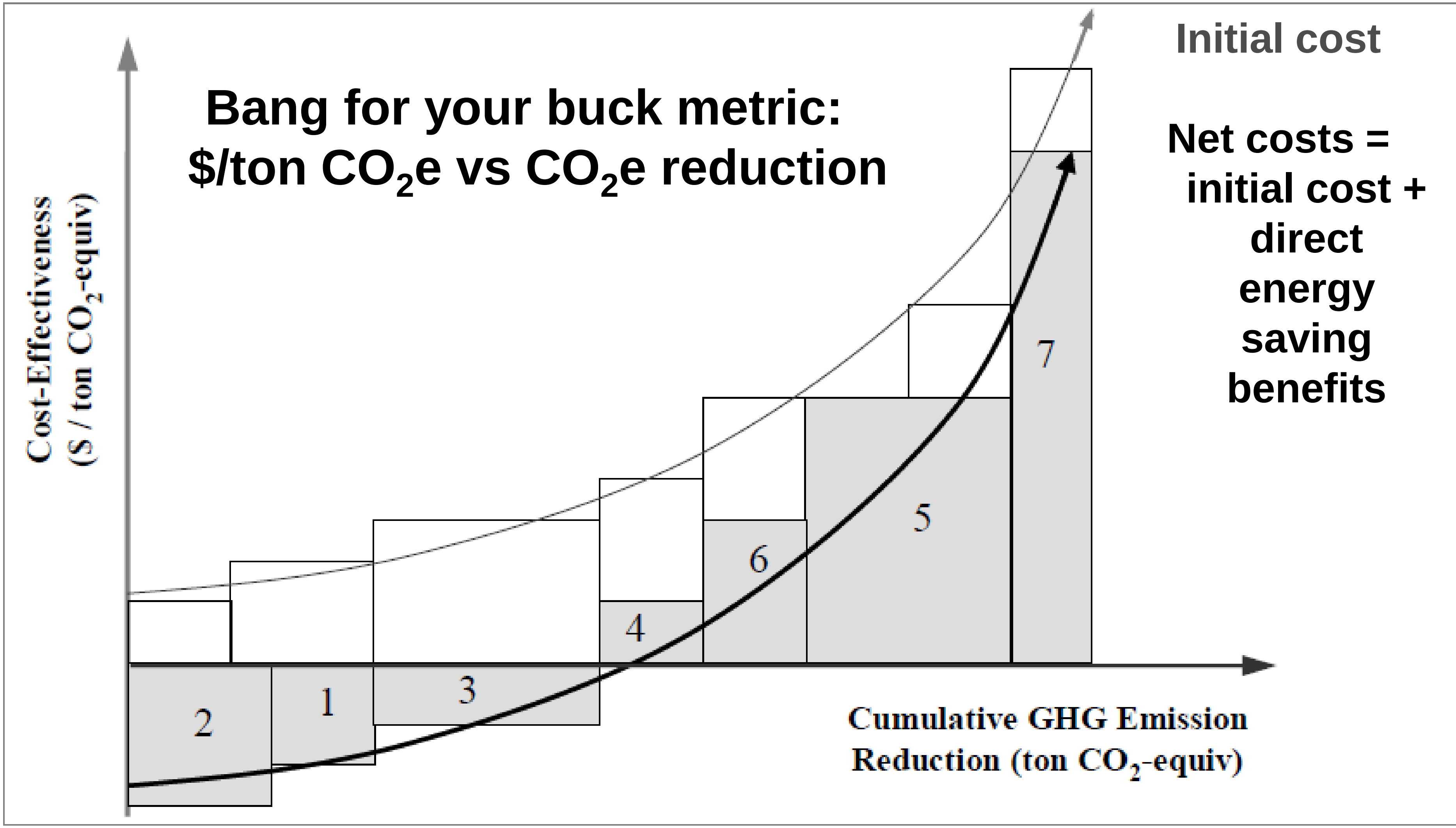
Impacts to people

Impacts to ecosystems

Depletion of resources

Sustainability indices can be used for non-quantitative assessment including social

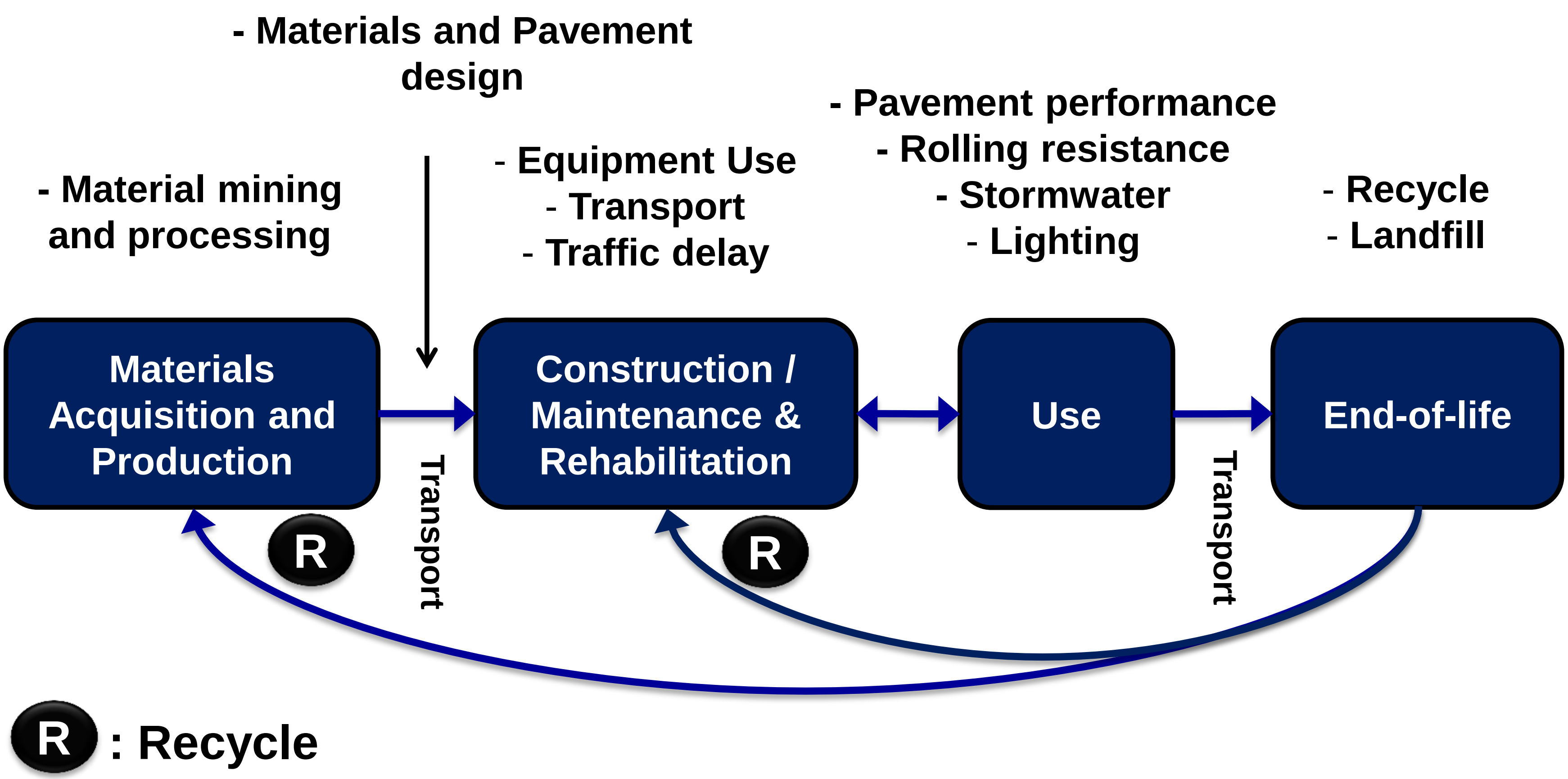
From Saboori ***Image sources: Google***



- **Lutsey, N. (2008)**
  Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-08-15

Where can environmental impacts be reduced?

- **Use Life Cycle Assessment (LCA) to find out**
- **Use Life Cycle Cost Analysis (LCCA) to prioritize based on improvement per $ spent**

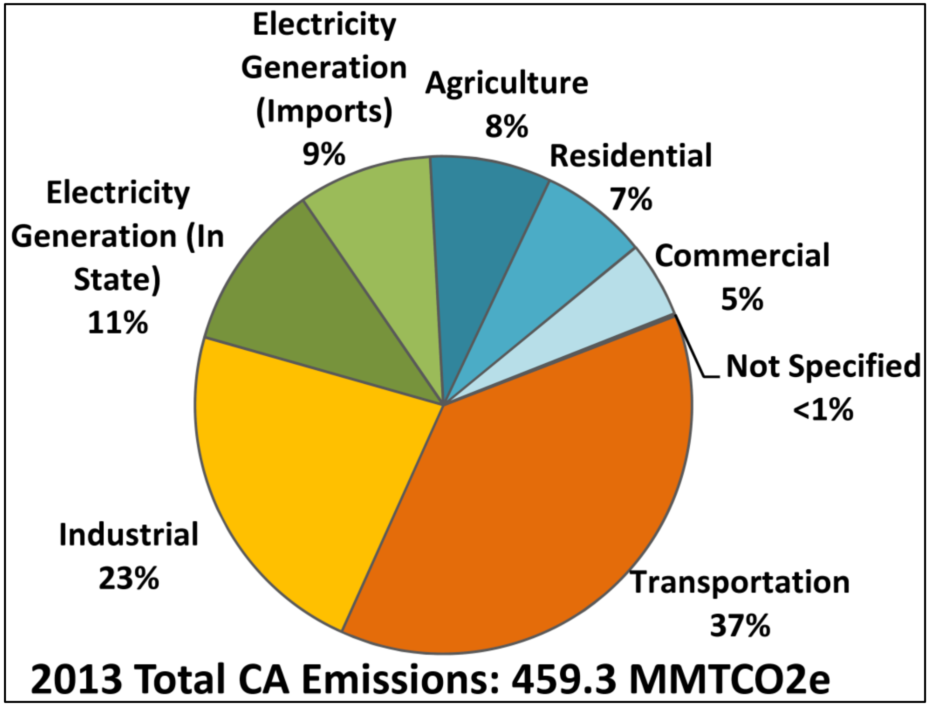


From: Kendall et al., *2010*

How do Pavements Contribute to California GHG Emissions?

Out of 459 MMT CO2e

- On road vehicles 155 MMT
  - Pavement roughness and other effects can change vehicle fuel use by about 0 to 4 %
- Refineries 29 MMT
  - Paving asphalt about 1 % of refinery production
- Cement plants 7 MMT
  - Paving cement about 5 % of cement plant production
- Commercial gas use 13 MMT
  - Very small amounts for asphalt mixing plants
- Mining 0.2 MMT
  - Large portion for aggregate mining



http://www.arb.ca.gov/cc/inventory/data/data.htm

Materials and Construction

- Important for all roads
- More important than use stage for low and medium traffic volume roads

Strategies to Improve Sustainability of Network

- To optimize M&R for the network, requires:
  1. Initial funding to reach sustainable maintenance condition
     a. Catch up on rehabilitation and reconstruction
     b. Preserve segments in good condition
  2. Steady funding afterward for preservation, with few needing rehab or reconstruction
  3. Asset management to program treatments based on predicted condition, not after failure occurs
- UCPRC research indicates that <u>annual cost of maintaining network can be reduced by up to 20 %</u> if this path is followed

Local Government Checklist for Improving Network Sustainability

- Are you using pavement management system?
  - Inventory network
  - Select most appropriate treatments based on:
    - Pavement type
    - Distresses (cracking, rutting, raveling), not PCI
    - Traffic type and levels (cars, buses, trucks)
  - Track performance of treatments
- Have the treatments in your PMS been selected based on Life Cycle Cost Analysis?
- Coming: check for environmental impacts using Life Cycle Assessment

Overlays vs Preservation Treatments

Treatment	Energy Use (MJ/m^2)	GHG (kg/m^2)
2 inch HMA Overlay	7.7 to 15.4	0.7 to 1.3
Heavy Chip Seal	1.5 to 3.0	0.08 to 0.10
Type II Slurry Seal/ Microsurfacing	1.3 to 3.3	0.06 to 0.10

From Chehovits and Galehouse 2010

Consideration of Active Transportation in PMS

- Bike lanes and bike paths are also pavement
- Same considerations apply
- Can be included in PMS
- Consider "Complete Pavement"
  - Do restriping for bike lanes when doing preservation treatments

Strategies to Improve Sustainability of Asphalt

- Improve durability through compaction specifications
  - 1% change in air-voids = about 10% change of cracking life
  - Allow contractors to use warm mix as compaction aid
  - Maintain and enforce strict compaction requirements
- Use reclaimed asphalt pavement (RAP) and tire rubber
- Reduce asphalt needed over the life cycle
  - Improved pavement design methods
  - Better construction quality, more durable materials
- Use In-place recycling
  - CIR, current status, concerns and research
  - FDR, current status, concerns and research

Local Government Check List for Asphalt

- Does your agency have a compaction requirement (% of maximum density) in your standard specifications?
  - If yes, do you enforce it?
  - If you are relying on the contractor, you are potentially getting <u>HALF</u> the possible life out of your asphalt overlays!
- Do you allow use of?
  - Rubberized asphalt
  - Recycled asphalt
  - Warm mix

Strategies to Improve Sustainability of Concrete

- Reduce cement and cementitious content in concrete
  - Context sensitive
  - Current Caltrans specifications allow up to 30 % cement replacement
- Reduce concrete and maintenance needed over the life cycle
  - Improved pavement design methods
  - Better construction quality, more durable materials
- Reduce energy and GHGs
  - during cement production
  - during concrete production
- Increase use of recycled and marginal materials as aggregate

Local Government Checklist for Concrete

- Does your agency allow for high volumes of cement replacing materials?
- Does your agency allow for the use of cement with lower environmental impact?
- Do you have a minimum cement content requirement?
- Do you consider shrinkage? Durability?
- Do you allow for design of thinner concrete pavement for local roads?

Environmental Product Declaration (EPD)

- Results of an LCA for a product
  - Produced by industry
  - Most pavement industries working on EPDs now

Environmental Facts

Functional unit: 1 metric ton **of** asphalt concrete

Primary Energy Demand [MJ]	4.0×10^3
Non-renewable [MJ]	*3.9×10^3*
Renewable [MJ]	*3.5×10^2*
Global Warming Potential [kg CO_2-eq]	79
Acidification Potential [kg SO_2-eq]	0.23
Eutrophication Potential [kg N-eq]	0.012
Ozone Depletion Potential [kg CFC-11-eq]	7.3×10^{-9}
Smog Potential [kg O_3-eq]	4.4

Boundaries: Cradle-to-Gate
Company: XYZ Asphalt
RAP: 10%

Example LCA results

Adapted from N. Santero

Use Phase

- Pavement rolling resistance
  - Important for more than 2500 vehicles per day
  - Trucks count as 1.5 cars
- Storm water
- Heat Island
- Bicycle ride quality

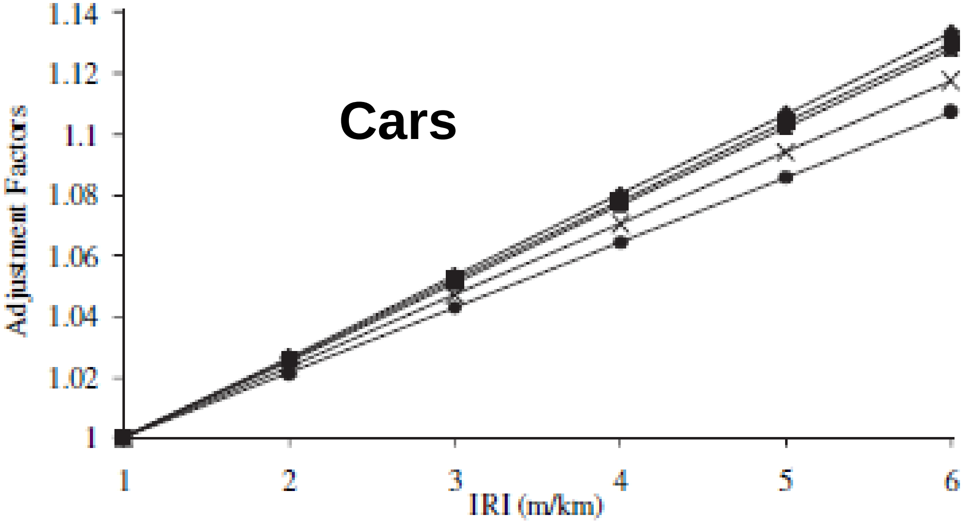
Local Government Pavement and Roughness

- Smoother pavement results in less vehicle damage, happier pavement users
- Roughness and GHG
  - Smoother pavements result in less vehicle fuel use
  - Keeping pavements smooth requires more maintenance, which produces more GHG
  - Only get net GHG benefit only on highest traffic routes
- M&R doesn’t give full benefit if don’t get smoothness from construction
  - Enforce smoothness specifications so not “born rough”
- Roughness measurement (IRI) requested by MAP-21

Caltrans Network: Optimal trigger by traffic group

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**

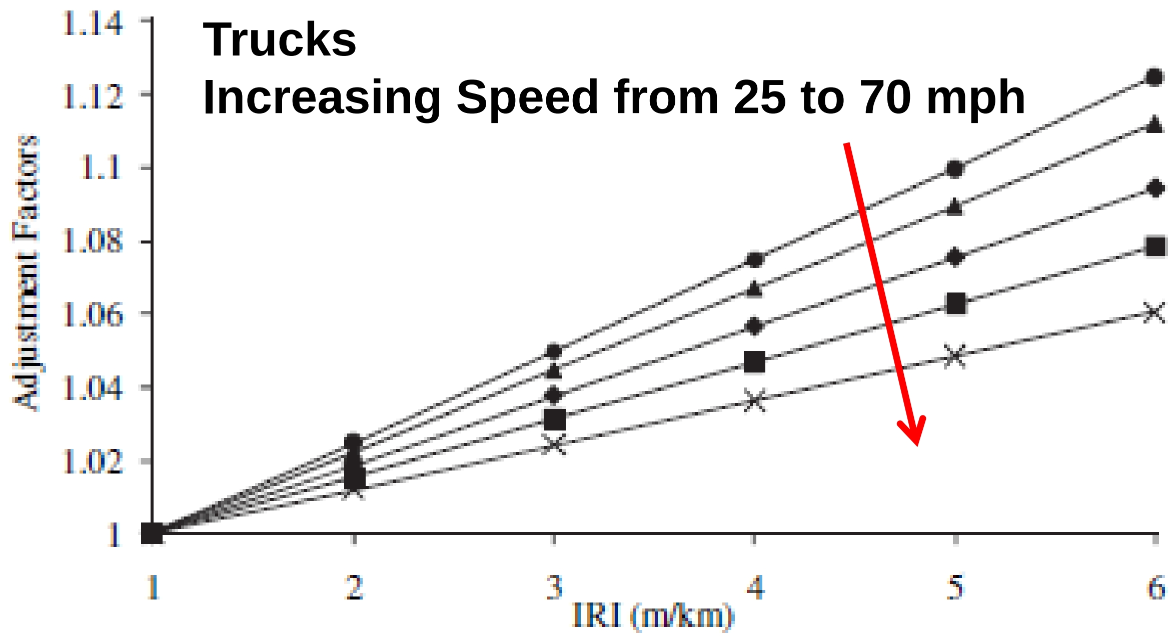
Use Phase: Fuel Use, Speed, IRI



(a) Passenger car

- Cars more sensitive at faster speeds
- Trucks at slower speeds

- Roughness increases vehicle fuel use 0 to 8 percent across range of typical IRI
- Can be some offset from faster driving on smoother pavement



(e) Articulated truck

Conclusions Regarding Roughness

- There are reasons for local government pavements to measure and manage roughness
- Currently no commercially available methods to measure under low speeds and stop-start conditions
  - Viable alternative technologies have been used in past
  - Cost per vehicle is about $500 plus certification cost
  - Can use for identifying locations with maintenance needs
- Cannot get IRI from PCI
  - Pavements can have good PCI and be rough and vice/versa

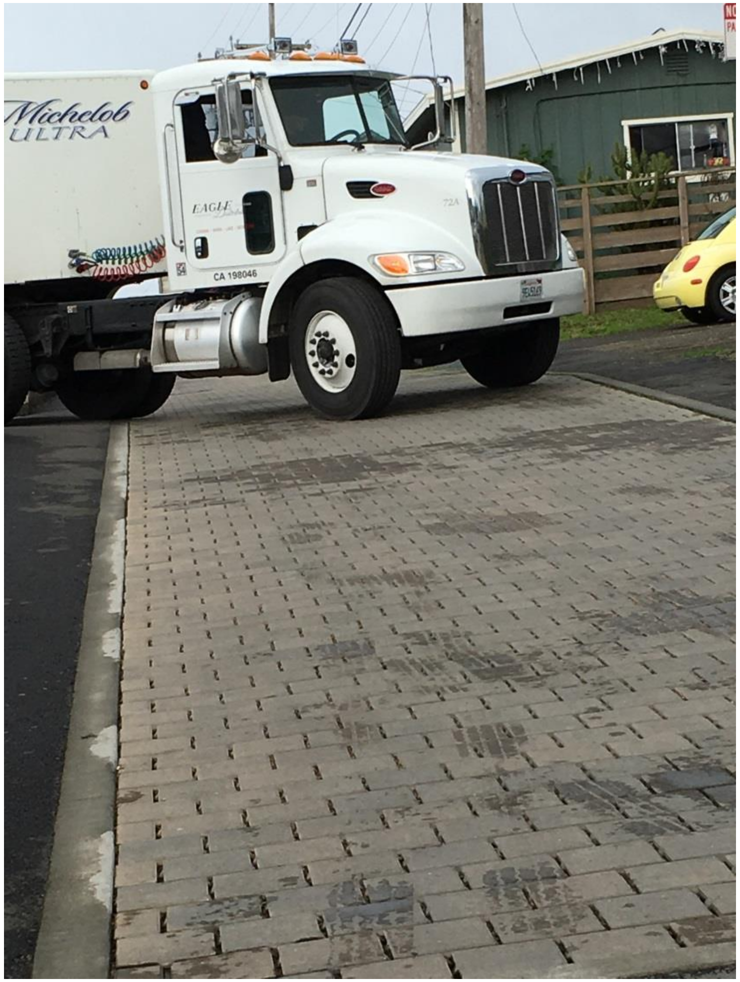
Permeable Pavement for Stormwater Management

- Impervious pavement in urban areas contributes to
  - Water pollution (*oil, metal, etc*.)
  - Reduced groundwater recharge
  - Increased risk of flooding
  - Local heat island effect (*less evaporation*)

- Permeable pavement could help address the issues related to stormwater runoff volume and quality
- Initial analysis indicates that can have lower life cycle cost than other BMPs

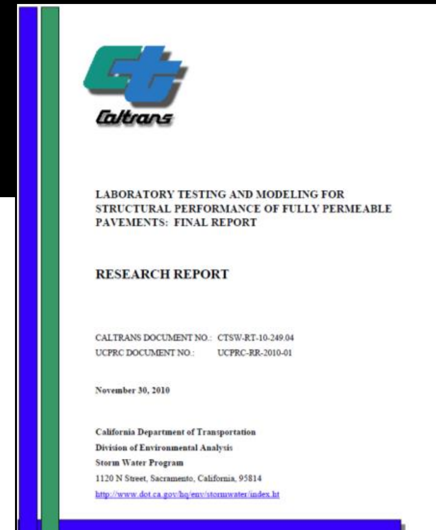
Permeable Pavement Studies by UCPRC

- Growing interest for heavy vehicle applications beyond parking lots and light traffic
- Studies by UCPRC
  - Caltrans Study (2008 – 2010) created design tables for permeable concrete and asphalt pavements; Not yet validated with traffic
  - Industry sponsored study for permeable pavers (2013-2014); developed mechanistic-based design method and tables; validated with Heavy Vehicle Simulator



Getting the Permeable Pavement Results

- Pervious Concrete and Porous Asphalt for Heavy Traffic
  - Preliminary permeable pavement designs that can be tested in pilot studies under typical California traffic and environmental conditions
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2010-01.pdf
- Permeable Interlocking Concrete Pavement for Heavy Traffic
  - Design method and validation results
  - Being incorporated into ICPI and ASCE designs
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2014-04.pdf



Caltrans

LABORATORY TESTING AND MODELING FOR STRUCTURAL PERFORMANCE OF FULLY PERMEABLE PAVEMENTS: FINAL REPORT

RESEARCH REPORT

CALTRANS DOCUMENT NO.: CTSW-RT-10-249.04
UCPRC DOCUMENT NO.: UCPRC-RR-2010-01

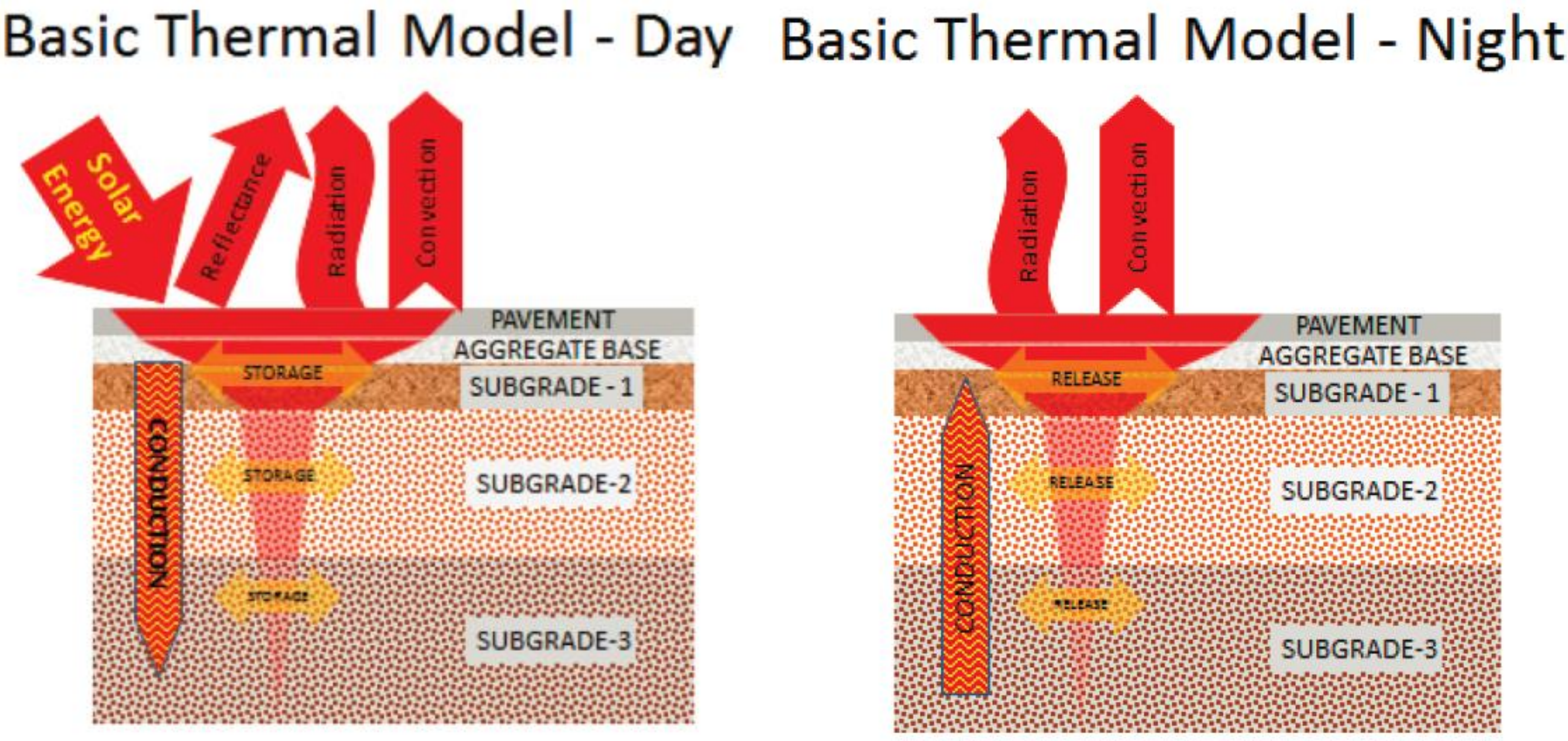
November 30, 2010

California Department of Transportation
Division of Environmental Analysis
Storm Water Program
1120 N Street, Sacramento, California, 95814
http://www.dot.ca.gov/hq/env/stormwater/index.ht

Cool Pavement Basics

- Albedo is solar radiation reflectivity
  - 0 is completely absorptive
  - 1 is completely reflective
- Typical albedos
  - Asphalt and slurries: 0.05 to 0.1 and lighten to about 0.15
  - Concrete: 0.25 to 0.35 and darkens to about 0.20
  - Chip seals depend on aggregate reflectivity 0.05 to 0.20
  - Color is not the only factor
- Paved surfaces account for 25 to 40 % of the land surface in urban areas

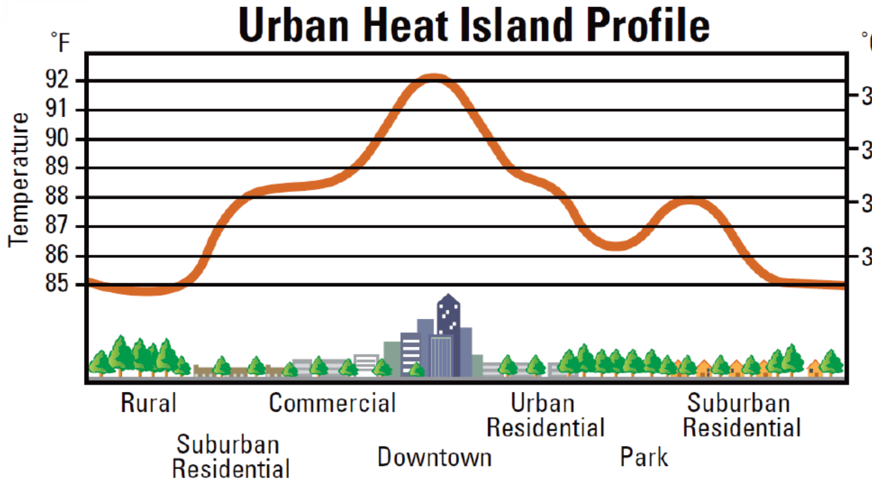
Thermal Model



From NCPTC/NCAT 2013

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
- Affects
  - Human thermal comfort
  - Air quality (ground-level ozone, i.e. smog)
  - Cooling energy consumption



EPA 2003

LBNL/USC/UCPRC Study Currently Recently Completed: Life Cycle Assessment and Co-benefits of Cool Pavements

- Sponsored by CARB, Caltrans, response to AB 296
- Modeled 50 year GHG emissions
  - Change of urban pavements to higher reflectivity materials
  - Change of urban temperatures
  - Change in building energy use
- Preliminary conclusions (currently being critically reviewed)
  - Much larger increase of GHG from changing materials than reduction from building energy savings
- Report to be published in Fall 2016
- Don’t move forward with this until use software

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H Street I St Alley
I St
J St
K St
L St
Kayak Alley
14th St
15th St
16th St
17th St
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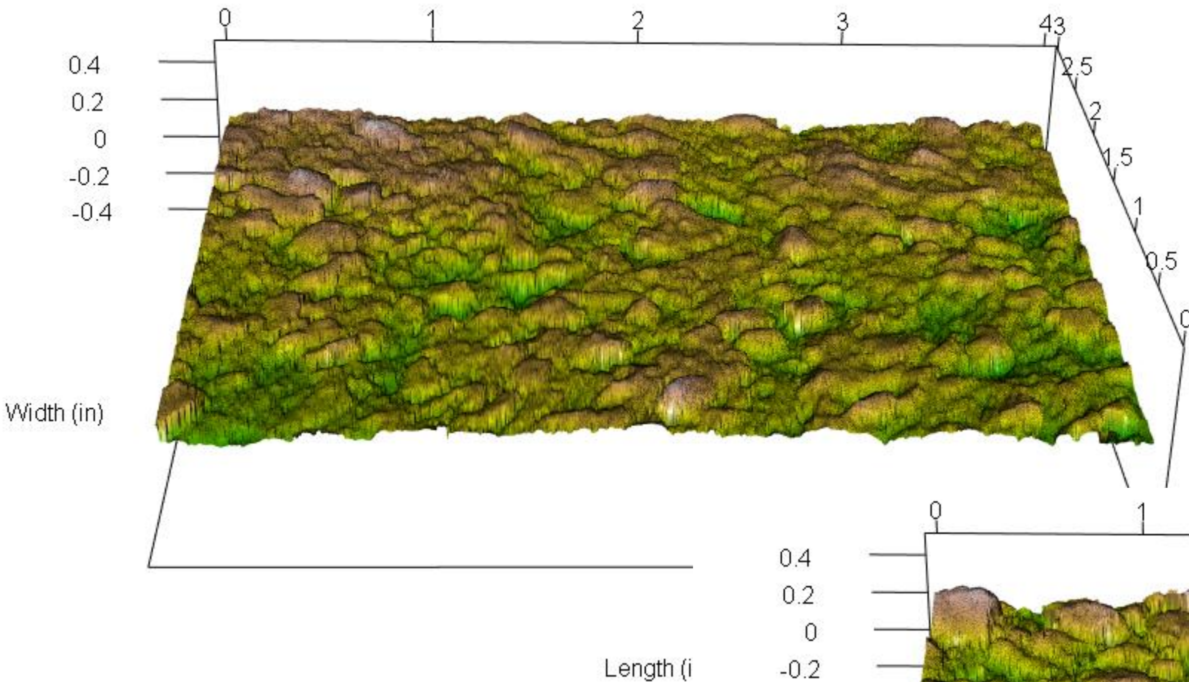
Pavement and Bicycle Riders

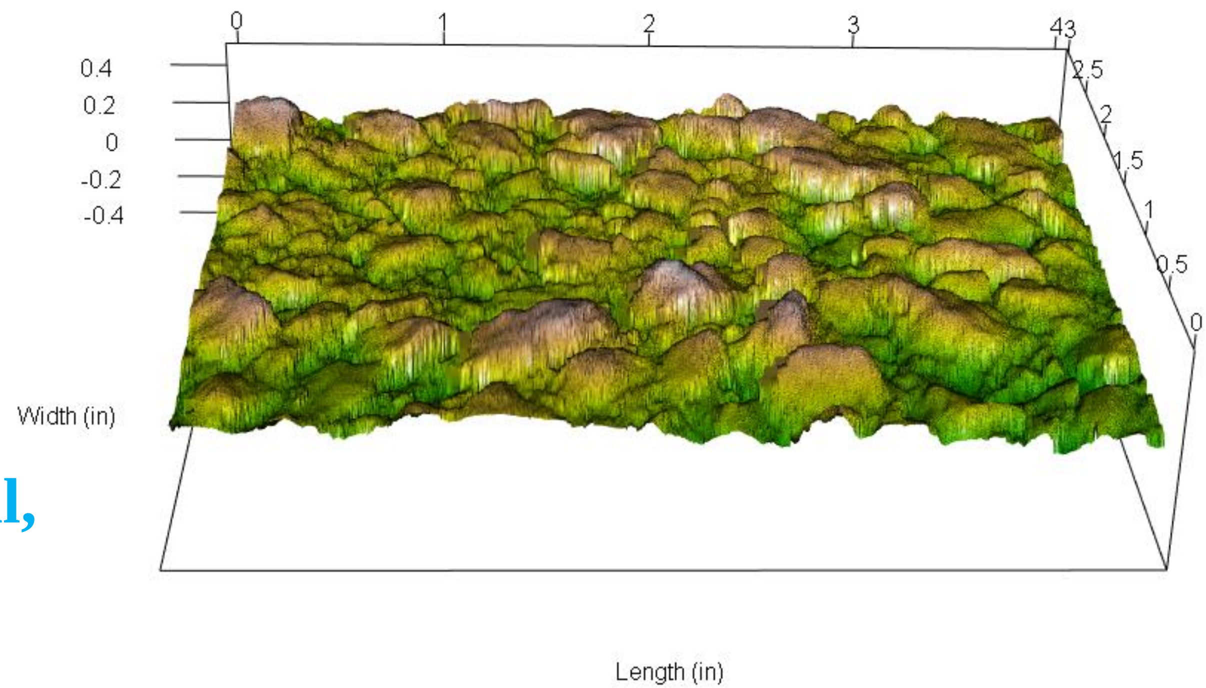
- Develop guidelines for design of preservation treatments suitable for bicycle routes on state highways (Phase I) and local streets (Phase II) in California
- Tasks
  - Pavement texture measurements
  - Bicycle vibration measurements
  - Surveys of bicycle ride quality
  - Correlations between pavement texture, bicycle vibration and ride quality

Instrumented Bicycle

Example 3D Macrotexture Images of MPD



Microsurfacing, MPD = 1.1 mm



Coarser 9.5mm chip seal, MPD = 2.3 mm

Conclusions from Bicycle Studies

- 80% of riders rate pavements with Mean Profile Depth values 1.8 mm or less as acceptable; 50% rate MPD of 2.3 mm or less as acceptable
- Most slurries on city streets produce high acceptability across all cities
- The presence of distresses, particularly cracking, reduces the ratings given to pavement by bicycle riders
- Chip seal spec recommendations in Caltrans report

Conclusions

- “State of the Knowledge” recommendations for improving pavement sustainability are available
  - Cost
  - Environment
- Improving environmental sustainability often also brings lower life cycle cost
  - Agency cost and user cost
- Improvements become permanent from reviewing and changing standard practices
- Everyone focused on getting sufficient funding
  - Sustainability discussion can help get funding
  - Sustainability can also often decrease life cycle cost

Local Government Pavement Improvement Center

- How do we get the Caltrans and FHWA content to local government in an implementable form?
- Working on securing funding ($500k/year) through state legislation, working with LOCC, CSAC
- Organization
  - Local government board of directors
  - Research, pilot project support, model specs and procedures, training
  - Sub to pavement CSUs (Chico, SLO, LB) for regional support
- If you think this is worthwhile, we would like to follow up in next months to get letter of support

Questions:
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