Approaches for Delivering More Sustainable and Multi-Functional Pavement

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The future of local government pavements will be more sustainable and multi-functional

- Public expectations are for more sustainable and multi-functional pavements
  - State and local legislation
  - Public comments
- More sustainable:
  - Less greenhouse gas
  - Less air pollution
  - Less stormwater pollution
  - Less virgin material use
- Multi-functional:
  - Bicycles
  - Cool pavement
  - Permeable pavement

- To avoid unintended negative consequences, we must consider:
  - Full system
  - Full life cycle

Overview of How to Get More Sustainable and Multi-Functional Pavement

- Sustainability = making pavement last longer for less money and reducing pollution:
  - Better use of pavement management system to select and time treatments
  - Smoother pavement
  - Better asphalt compaction
  - Rubberized asphalt
- Making pavement multi-functional:
  - Pavement management of bike routes
  - Pavement for human thermal comfort
  - Consideration of permeable pavement

Impacts must consider full life cycle and full system
Which treatment has more environmental impacts?

- Treatment A:
  - Impact = 1,000 tons greenhouse gas per year across the preservation program from materials production, transportation, construction
  - Lasts 8 years
- Treatment B:
  - 20% less initial impact than Treatment A
  - Lasts 5 years
- Impact comparison over 20 year analysis period:
  - Treatment A: 20,000 tons of GHG
  - Treatment B: = 20,000 tons*(1-0.2)*8/5 = 25,600 tons of GHG
- Conclusion: Treatment A produces less impact over the life cycle

Action: Separate into segments with/without heavy vehicle (bus, truck) traffic
Focus on distresses that control pavement life in cracking-based decision trees

- Fatigue cracking and potholes caused by heavy loads:
  - Alligator cracking
  - Potholes
- Cracking caused by aging:
  - Longitudinal and transverse cracking
  - Joint reflections
  - Block cracking

Use these distresses rather than PCI

- Other distresses
  - Low ride quality
  - Bleeding
  - Bumps and sags
  - Corrugations
  - Depressions
  - Edge cracking
  - Lane/shoulder drop-off
  - Patching and utility cut patching
  - Polished aggregate
  - Rutting
  - Shoving
  - Slippage cracking
  - Swelling
  - Weathering and raveling

Alligator Cracking aka Fatigue Cracking aka Wheelpath Cracking

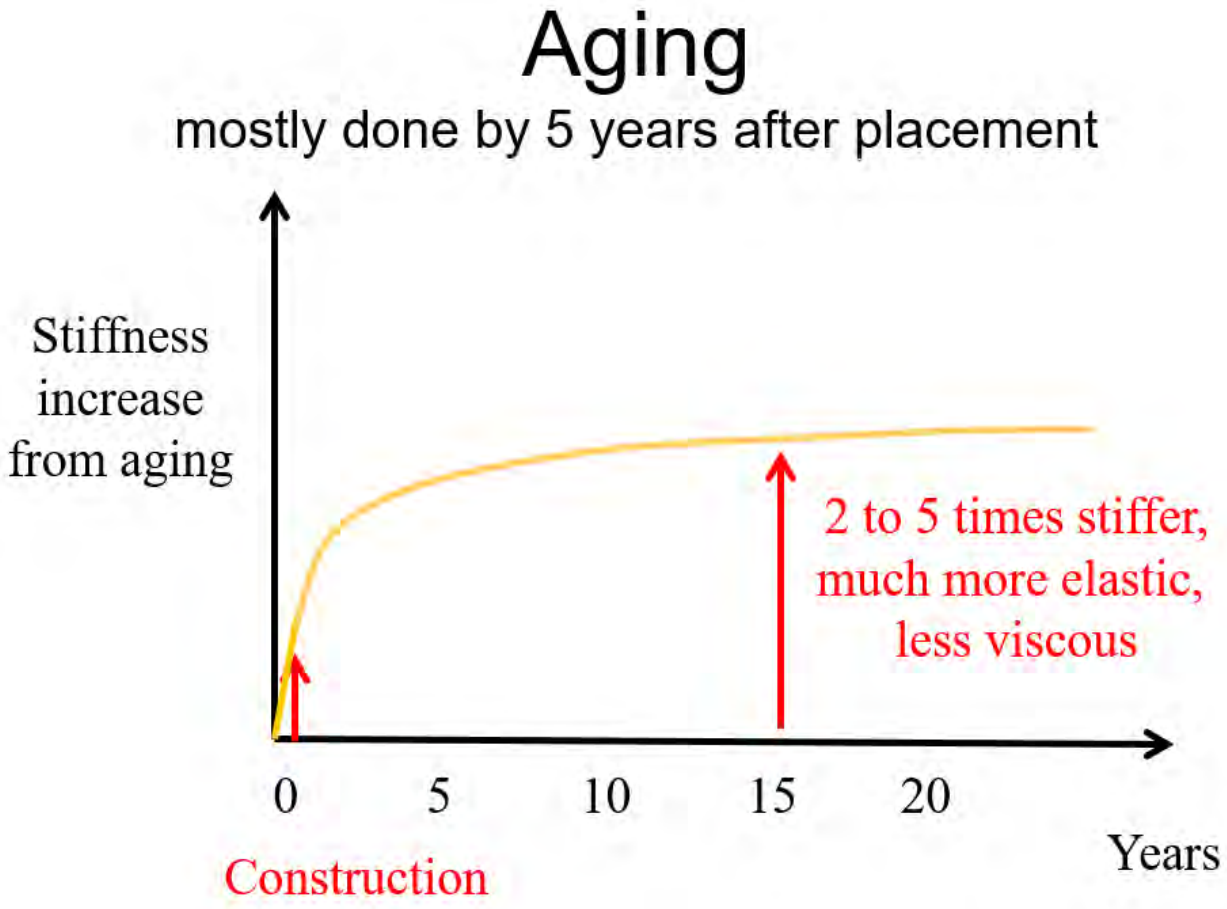
Treatment for load related fatigue cracking

- Fatigue cracking becomes alligator cracking, and eventually forms potholes
- Surface treatments will slow a little, but mostly helps with block cracking, not fatigue
- Will need to do periodic mill and fill with digouts of localized deep cracking
- Mill and fill may not be cost-effective once alligator cracking is extensive
  - Consider partial-depth or full-depth reclamation (FDR) cold in-place recycling depending on crack depth
- Do not let wheelpath cracking become extensive or must reconstruct

Extensive and likely deep alligator cracking, Starting to form potholes

Aging of the Asphalt

- Aging of the asphalt
  - Caused by oxidation, volatilization
  - Faster if high permeability and temperature
  - Permeability greatly reduced with better asphalt compaction
- Effects
  - Stiffening of mix with time
  - Won’t relax stresses from thermal contraction as well

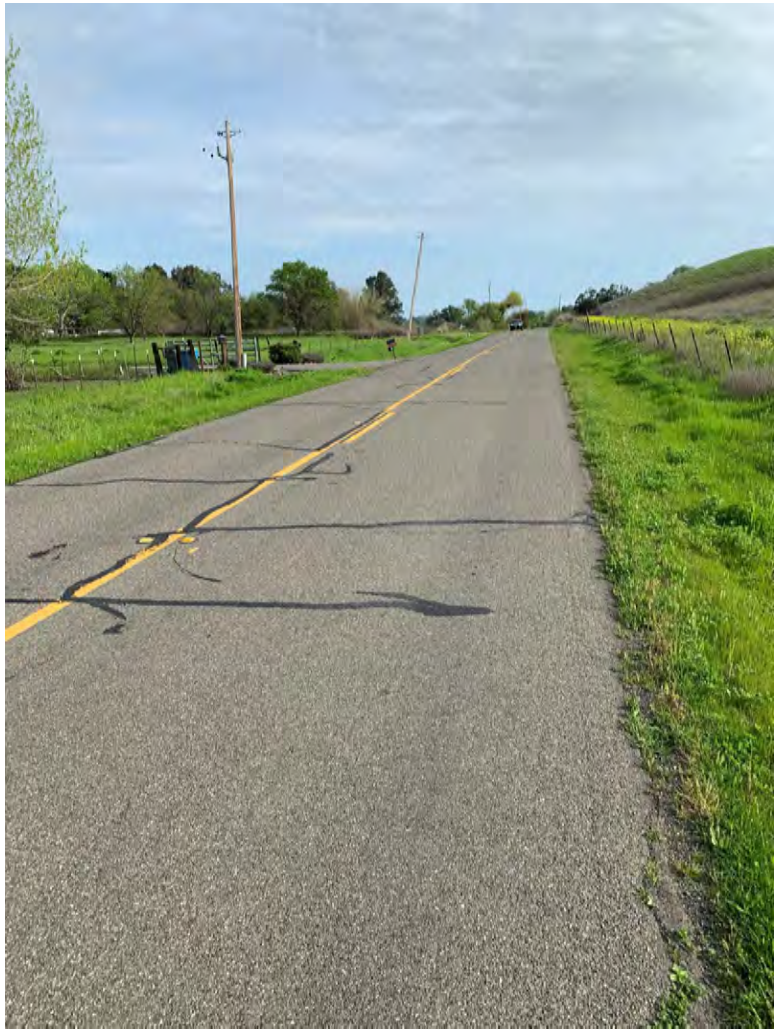


Age Related Cracking

- Typically caused by long-term aging of asphalt concrete and daily temperature cycling (expansion/contraction)
- May also be reflective cracking from shrinkage cracks in underlying asphalt, cemented base, or concrete
- Poor asphalt construction compaction allows air to enter and age the asphalt faster, accelerates aging

Good compaction limits entry of air and slows oxidation

Age related cracking: transverse then block



Lgam.wdfiles.com

Treatment for age-related cracking

- Keep the surface protected from aging
- Can potentially use fogs, slurries or microsurfacings and <u>never</u> have cracking if no heavy vehicles
- What frequency?
  - After aging has progressed but no cracks
    - About 7 to 12 years
  - Before cracking starts
    - Do not let cracking get extensive
  - Doing more frequently than needed can be a waste

Actionable now: Timely use of preservation for age related cracking
Example for urban street

- Timely use of preservation treatments can postpone AC mill and fills
  - Timely = when beginning to age, before cracking
  - Usually about 7 to 12 years

Treatment	Approximate Metric Tons GHG/lane mile
Slurry Seal	4
2.0 inch HMA mill and fill	45
6.0 inch HMA remove and replace	161

LCCA and LCA results: Urban alternatives

Mill and Fill Scenario	$/sy	Year
HMA 2 inch mill and fill	38	0
HMA 2 inch mill and fill	38	20
HMA 2 inch mill and fill	38	40

Remove and Replace Scenario	$/sy	Year
HMA 2 inch mill and fill	52	0
Remove, replace 6 inches HMA	52	25

Preservation Scenario	$/sy	Year
HMA 2 inch mill and fill	38	0
Slurry seal	7	12
Slurry seal	7	19
Slurry seal	7	26
HMA 2 inch mill and fill	38	33
Slurry seal	7	45

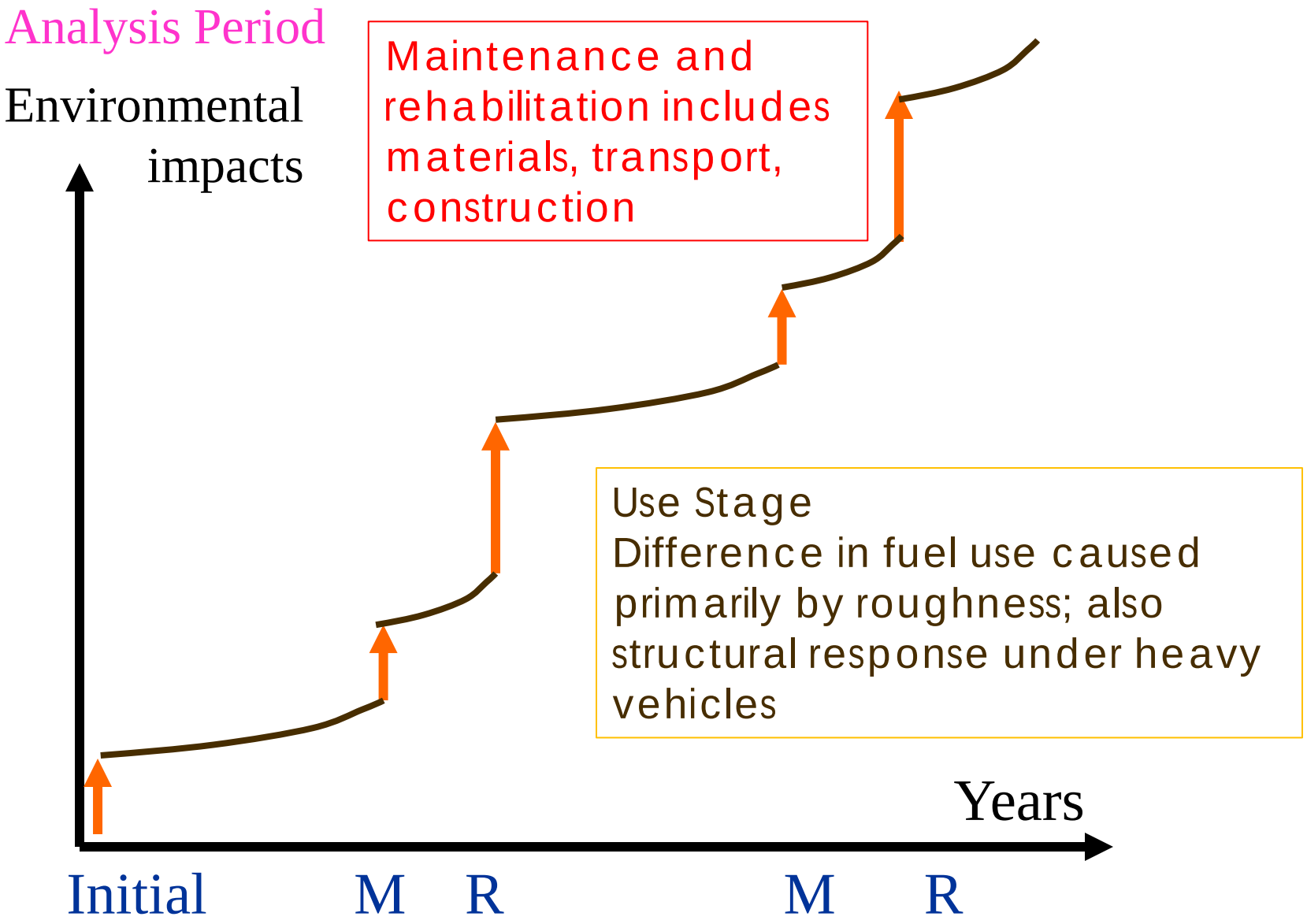
- 50 year analysis, 2% discount rate

- Remove and replace:
  - 14% more cost
  - 60% more GHG
- Preservation:
  - 12% less cost
  - 27% less GHG

GHG adapted from A. Saboori doctoral thesis, 2020

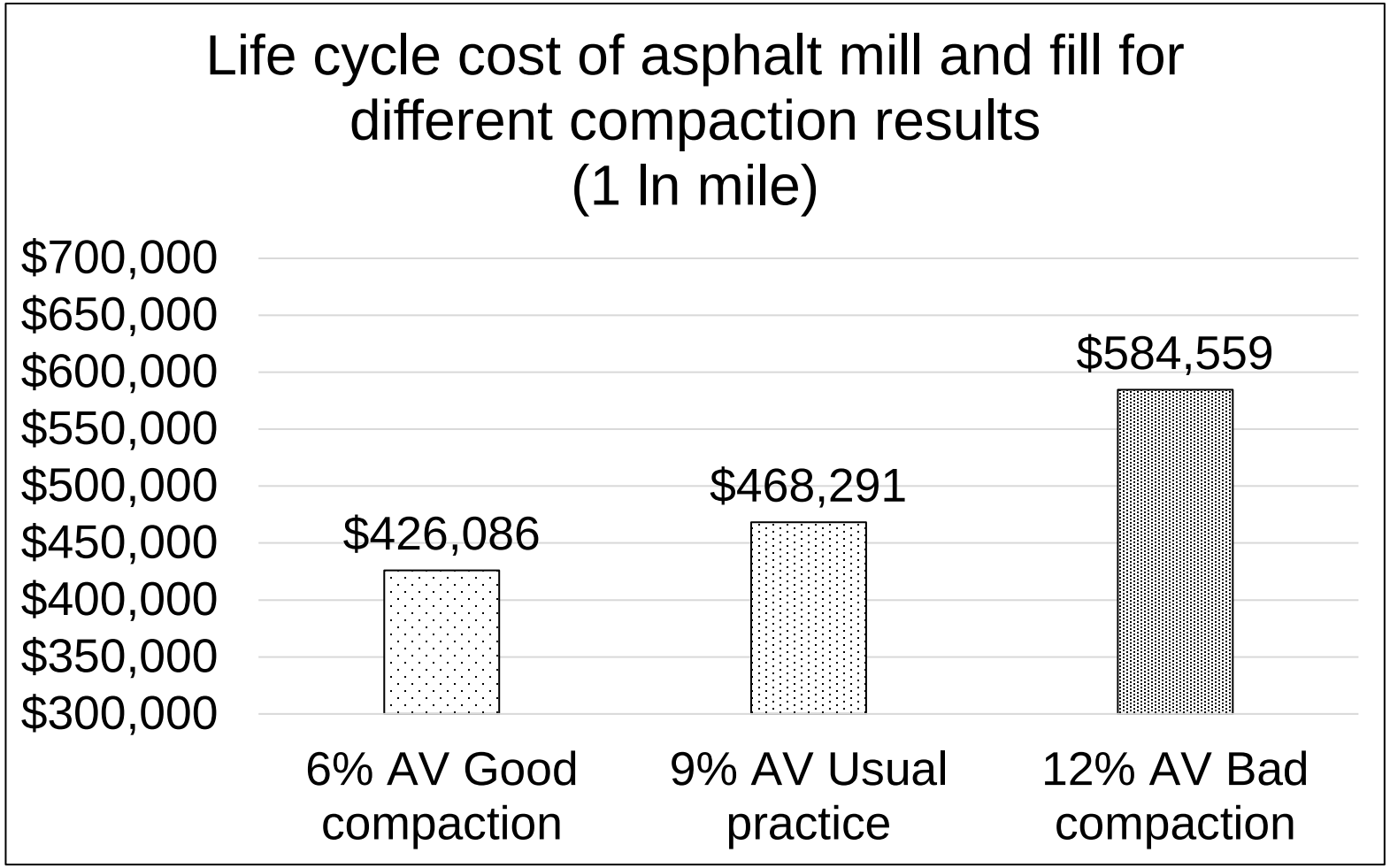
Environmental Impacts over the Pavement Life Cycle
Actionable now: where to focus on smoother pavement

- **Where to focus**
  - Lower traffic volume routes (<2500 veh/lane/day): bigger impacts are from materials, transportation, construction
  - Higher traffic routes (>2500 vehicles/lane/day): bigger impacts from rolling resistance (roughness mostly)



Actionable now: Asphalt Compaction Quality Control

Effect of asphalt construction compaction on axle loads to cracking



General rule:

Load related cracking:
1% increase in constructed air-voids
= 10% reduction in fatigue life under heavy loads

Age related cracking:
Similar effects on residential routes; more air voids = faster aging

How to Get Good Asphalt Compaction

- Include QC/QA construction air-void content specification in each contract
- Measure air voids as % of Theoretical Maximum Density
  - Not laboratory test maximum density
- Test strip, measure, communicate, enforce
- If using Caltrans or Greenbook method specification, likely getting 10 to 13% air voids = half of possible life from asphalt

Model specification on CCPIC web site!

Sample Specifications

Model Specs

- Superpave HMA for Local Government Model Specification Language
- Asphalt Compaction Model Specification Language
- Concrete Pavement Model Specification Language
- Tack Coat Model Special Provisions

Google: CCPIC

www.ucprc.ucdavis.edu/ccpic

Actionable now: use of thinner RHMA overlays Greenhouse Gases HMA vs RHMA

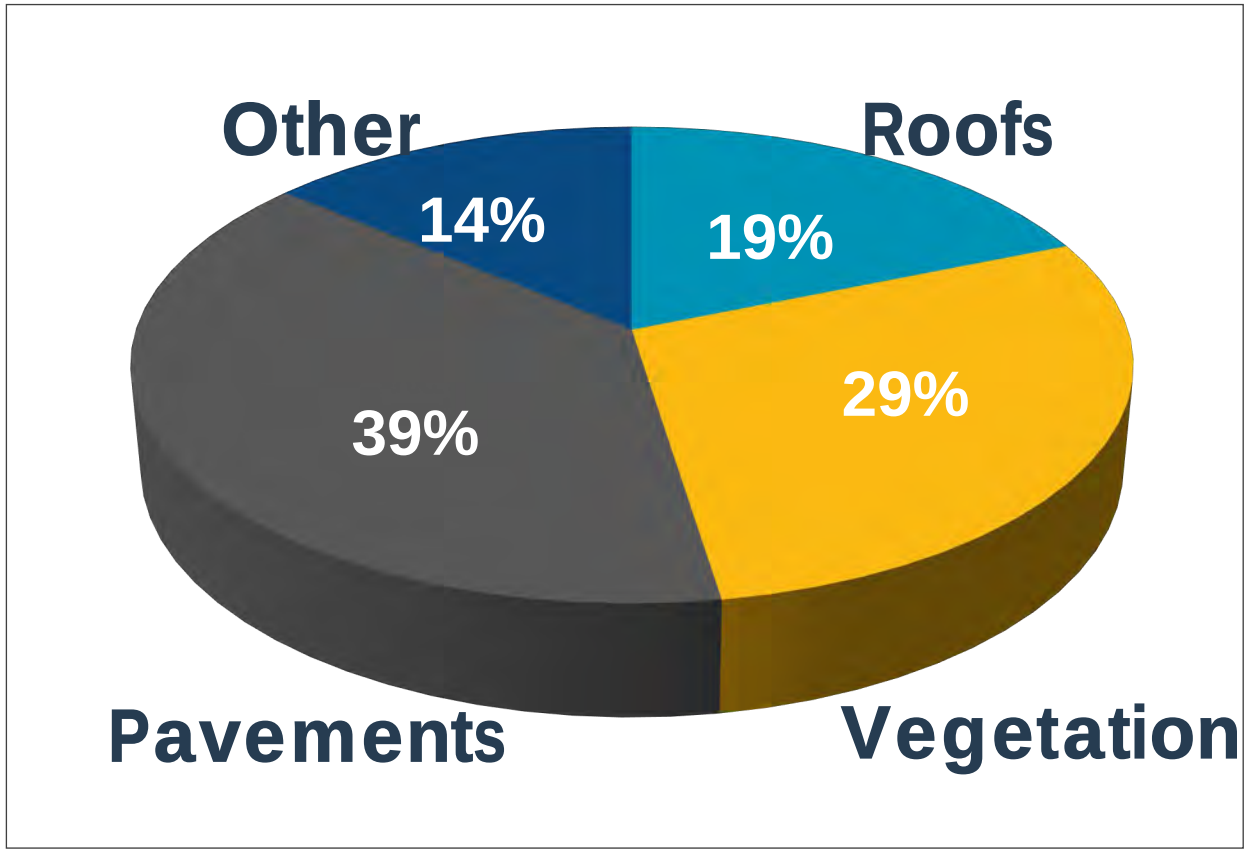
Adapted from T. Wang doctoral thesis, 2013

- Same design for 10 year overlay on county road
- HMA strategy emits 26% more greenhouse gases than RHMA because of increased thickness

Strategy for Overlays	Materials (MTons GHG)	Construction and Transport (MTons GHG)	Total (MTons GHG)
2 inch mill + 3 inch HMA with 15% RAP	1,650	505	2,155
1.25 inch mill + 2.25 inch RHMA	1,310	396	1,706
HMA/RHMA	**1.26**	**1.28**	**1.26**

Challenge for the Future: Multi-functionality

- Traditional goal:
  - Smooth pavement for vehicles at lowest cost
- Pavement dominates the urban landscape



Sacramento

Fractions of land area were measured above tree canopy

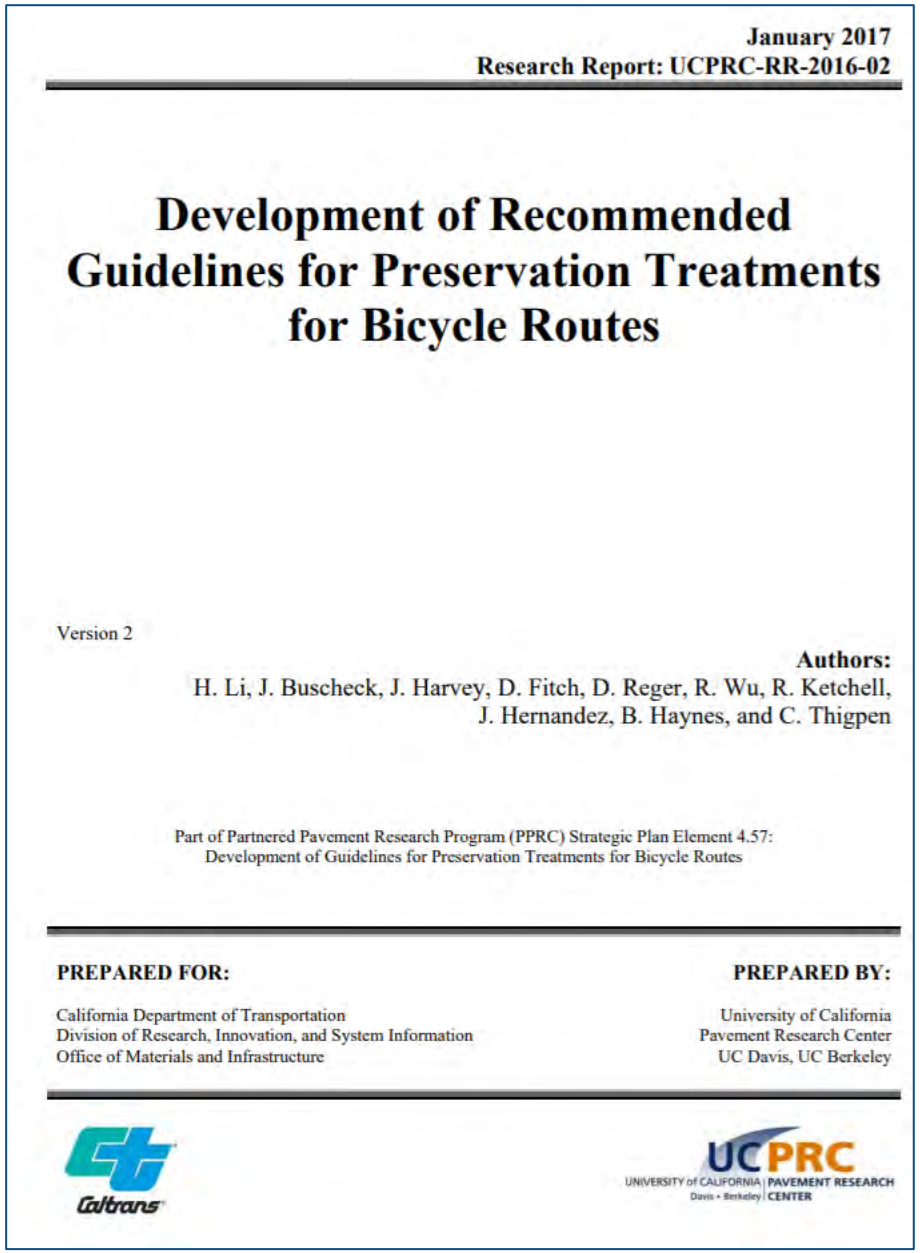
Akbari et al. 2003 <doi:10.1016/S01692046(02)00165-2>

Challenge for the Future: Multi-functionality

- Actionable now:
  - Bicycles
    - Reconfigure to include bike lanes when restriping preservation treatments
    - Selection of treatments to improve bicycle ride quality
    - Minimize cracking and roughness through preservation
  - Cool pavement
    - Balance reflectivity to improve human thermal comfort
  - Stormwater
    - Consider permeable pavement
  - Quiet
    - Raveling and roughness increase noise
    - Manage through timely preservation

Consideration of Bicyclists When Choosing Preservation Treatments

- Caltrans sponsored study
- More than 100 riders surveyed state, county and city pavements
  - HMA
  - Slurry, microsurfacing
  - Chip seals
- County and city roads
- Conclusions:
  - Minimize cracking and roughness with preservation
  - Do not select high texture seal coats
- Guidance on seal coat spec selection: http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2016-02.pdf



January 2017
Research Report: UCPRC-RR-2016-02

Development of Recommended Guidelines for Preservation Treatments for Bicycle Routes

Version 2

Authors:
H. Li, J. Buscheck, J. Harvey, D. Fitch, D. Reger, R. Wu, R. Ketchell, J. Hernandez, B. Haynes, and C. Thigpen

Part of Partnered Pavement Research Program (PPRC) Strategic Plan Element 4.57: Development of Guidelines for Preservation Treatments for Bicycle Routes

PREPARED FOR:
California Department of Transportation
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Office of Materials and Infrastructure

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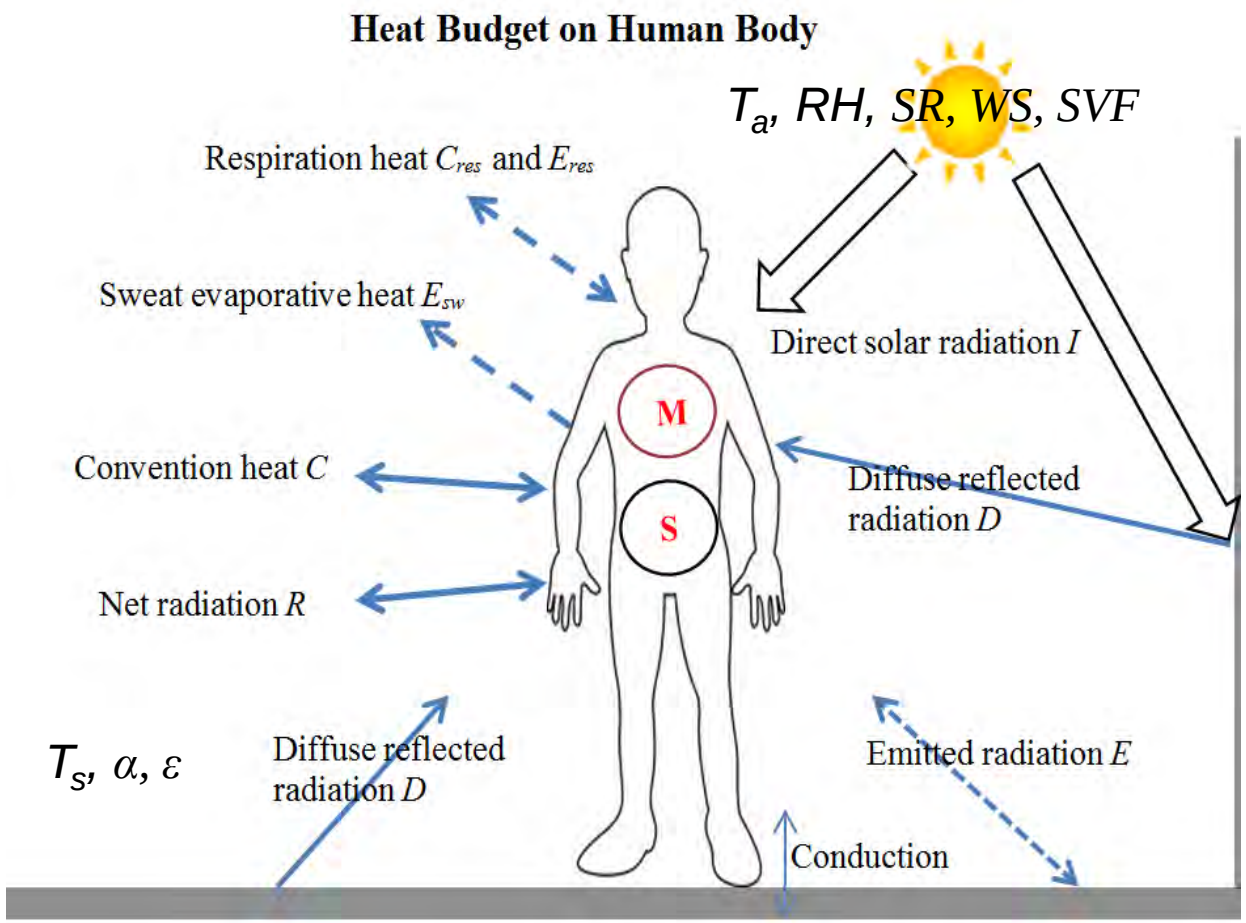
Caltrans

UCPRC
UNIVERSITY of CALIFORNIA | PAVEMENT RESEARCH CENTER
Davis • Berkeley

Li et al
2014

Cool and Reflective Pavement:

- Focus on human thermal comfort, not reduced electricity use
- Use cooler pavements with low GHG
- Reflective coatings have high GHG
- For thermal comfort must balance reflectivity
- Selection of street trees that are pavement-friendly



M is the metabolic rate (W/m^2). *W* is the rate of mechanical work (W/m^2). *S* (W/m^2) is the total storage heat flow in the body.

Conclusions

- Better pavement practices can improve financial and environmental sustainability at the same time
- There are strategies that you can be implementing now!
  - Pavement management based on load and age related cracking
  - Timely preservation
  - Keep high traffic volume routes smooth
  - Better asphalt compaction
  - Rubberized asphalt
- Multi-functionality
  - Use preservation treatments on bike routes; restripe as part of preservation
  - Choose appropriate seal coats for bicycles
  - Cool pavements: select low GHG treatments, balance reflectivity for comfort, pavement-friendly street trees
  - Consider permeable pavement