Bang for Buck: Best Practices in Pavement Engineering

John Harvey

Sampat Kedarisetty

University of California Pavement Research Center

City and County Pavement Improvement Center

APWA

Richmond, CA

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City and County Pavement Improvement Center

www.ucprc.ucdavis.edu/ccpic

- Sponsored by League of California Cities and California State Association of Counties
- Chartered 28 September 2018

Mission and Vision for CCPIC

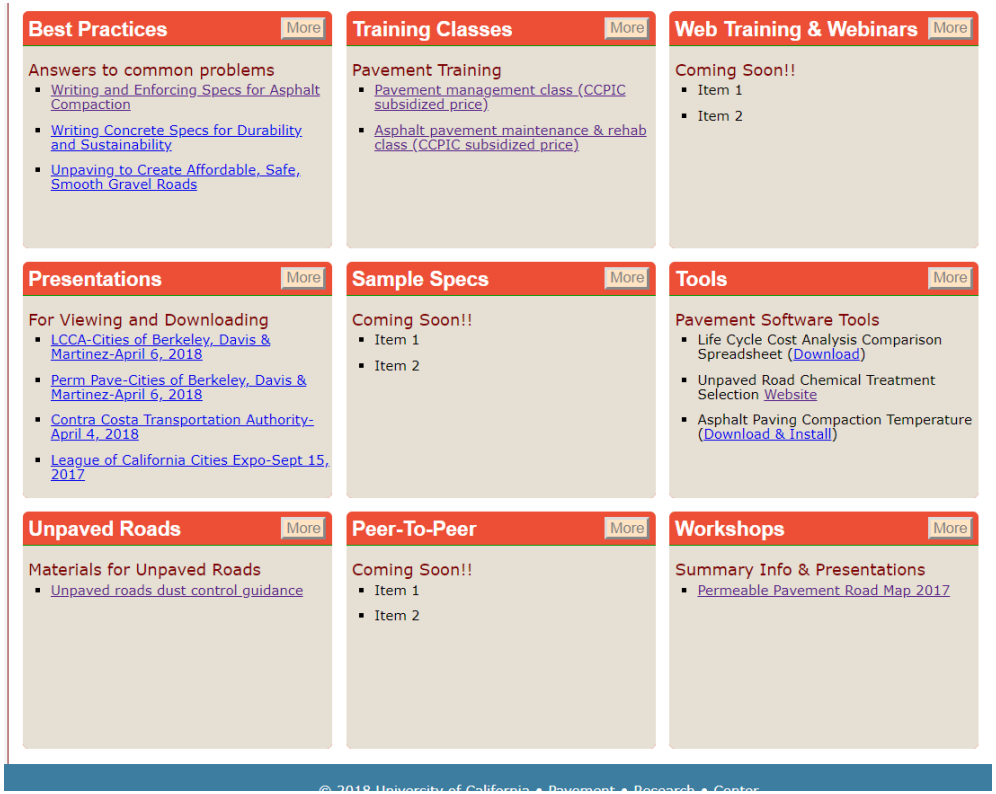
- Mission:
  - *CCPIC works with local governments to increase pavement technical capability through timely, relevant, and practical support, training, outreach and research*
- Vision:
  - *Making Local Government-Managed Pavement Last Longer, Cost Less, and Be More Sustainable*

Organization

- UC Partners
  - University of California Pavement Research Center (lead), administered by ITS Davis
  - UC Berkeley ITS Tech Transfer, administered by ITS Berkeley
- CSU partners
  - CSU-Chico, CSU-Long Beach, Cal Poly San Luis Obispo
  - Funding partner: Mineta Transportation Institute, San Jose State University
- Governance:
  - Governance Board consisting of 3 city and 3 county transportation professionals
- Funding
  - Funding to set up CCPIC and initial activities from the state legislature, SB1 funding through the ITS at UCD and UCB

CCPIC Scope of Work

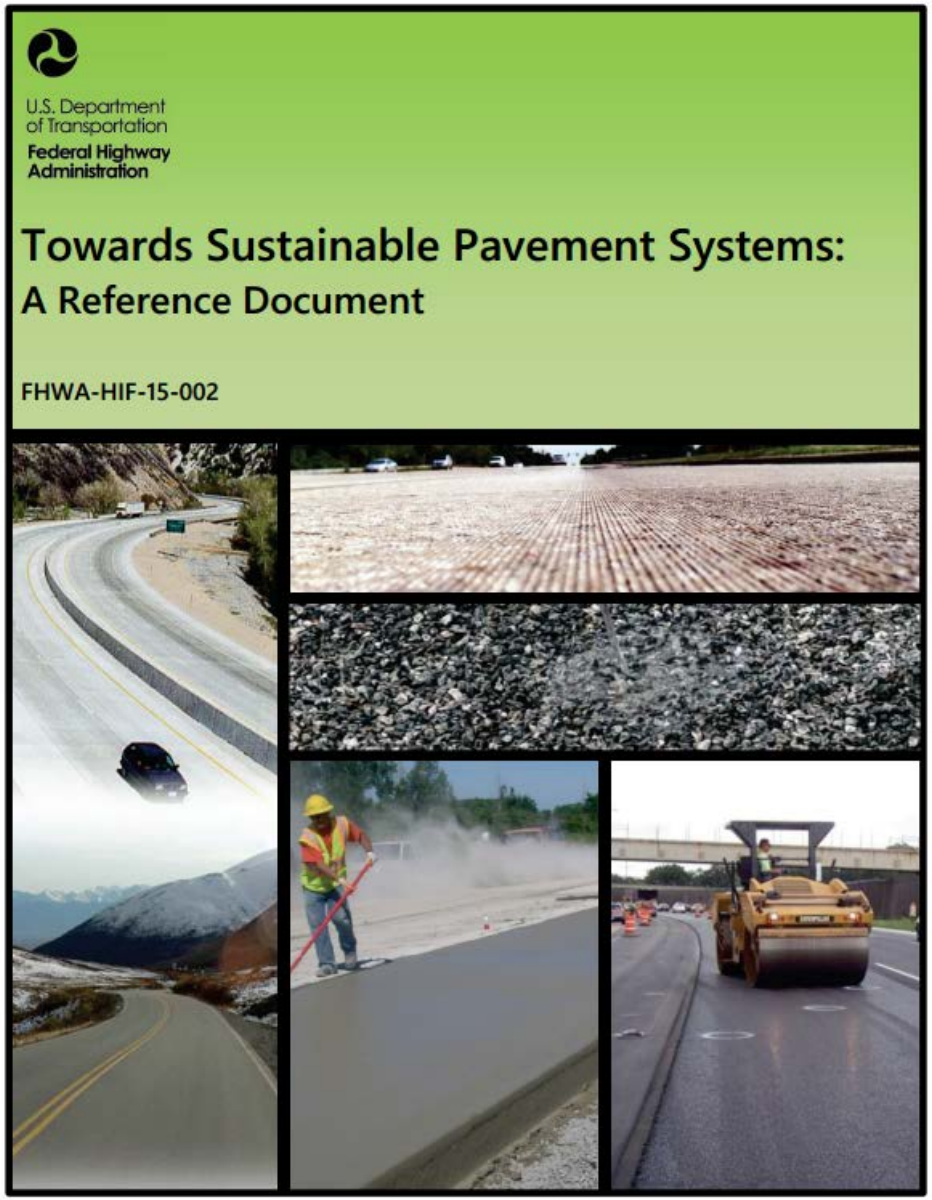
- Deliver training and technology transfer
- Develop guidance, specifications, and tools
- Establish and deliver a pavement engineering and management certificate program



- Create and operate a resource center
- Provide research and development support

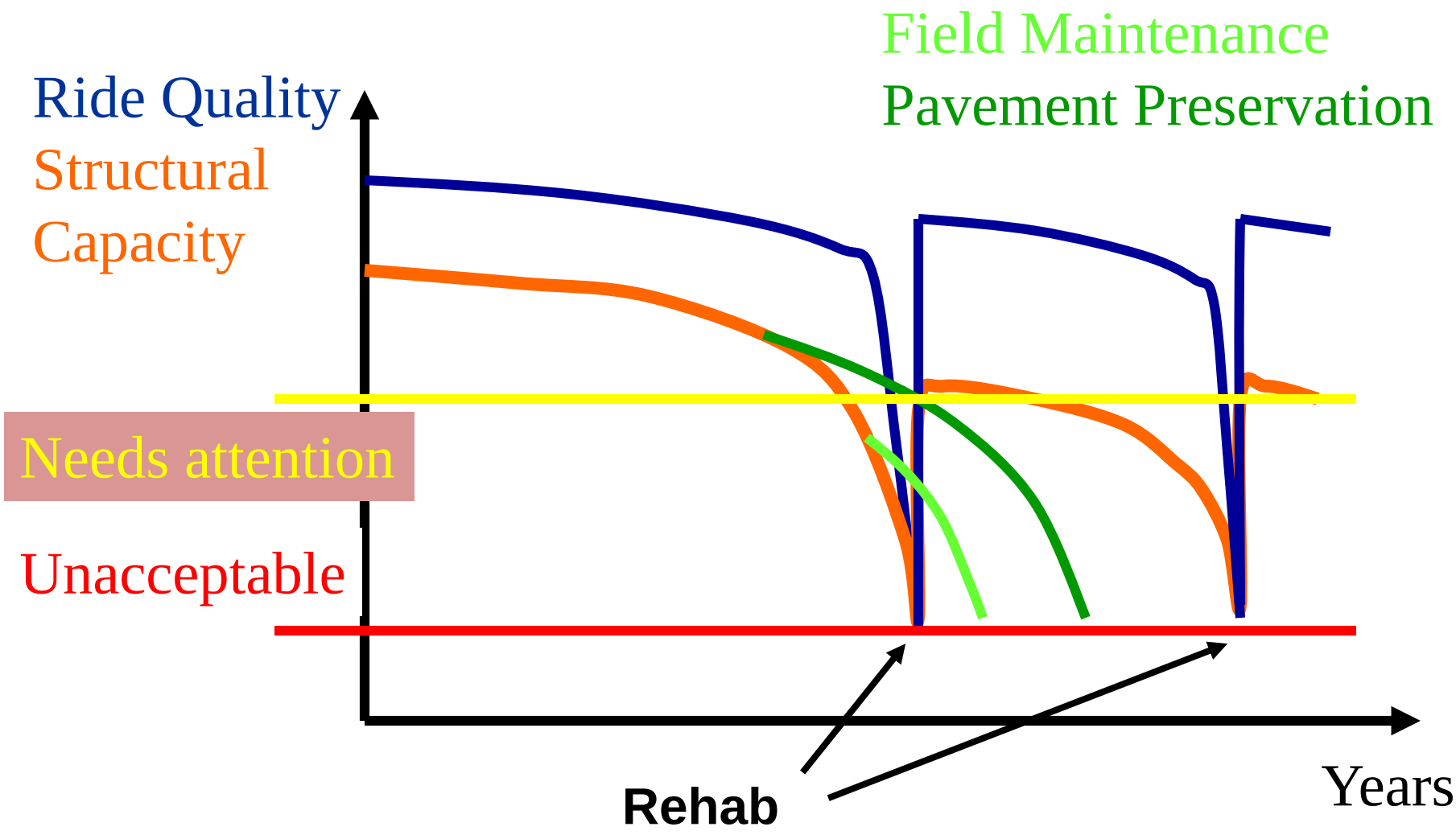
So what can be done to make pavements more sustainable?

- FHWA Sustainable Pavements Task Group
  - More sustainable pavement reference document (2015)
  - Covers everything about pavement and sustainability
  - Tech briefs and webinars
- Google “FHWA sustainable pavement”

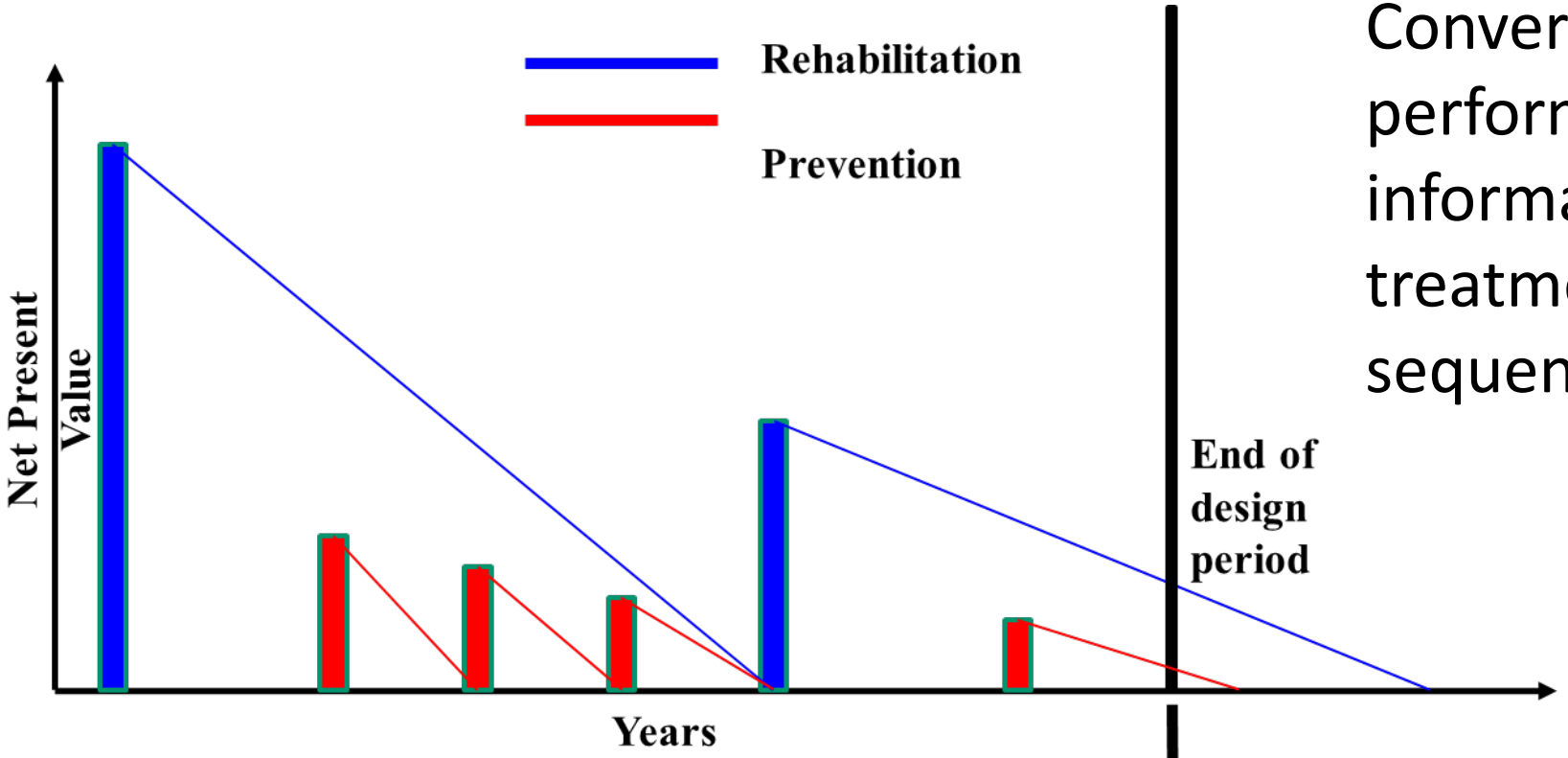


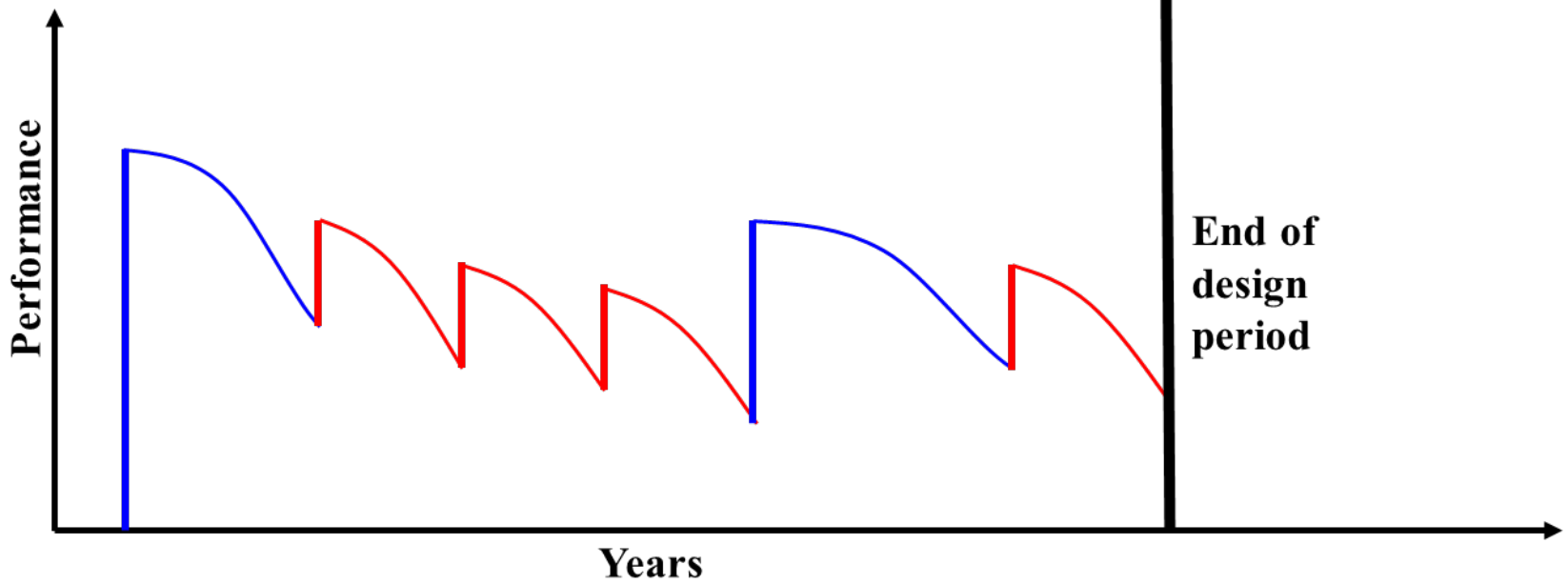
http://www.fhwa.dot.gov/pavement/sustainability/ref_doc.cfm

Life Cycle Cost Analysis (LCCA) Basics



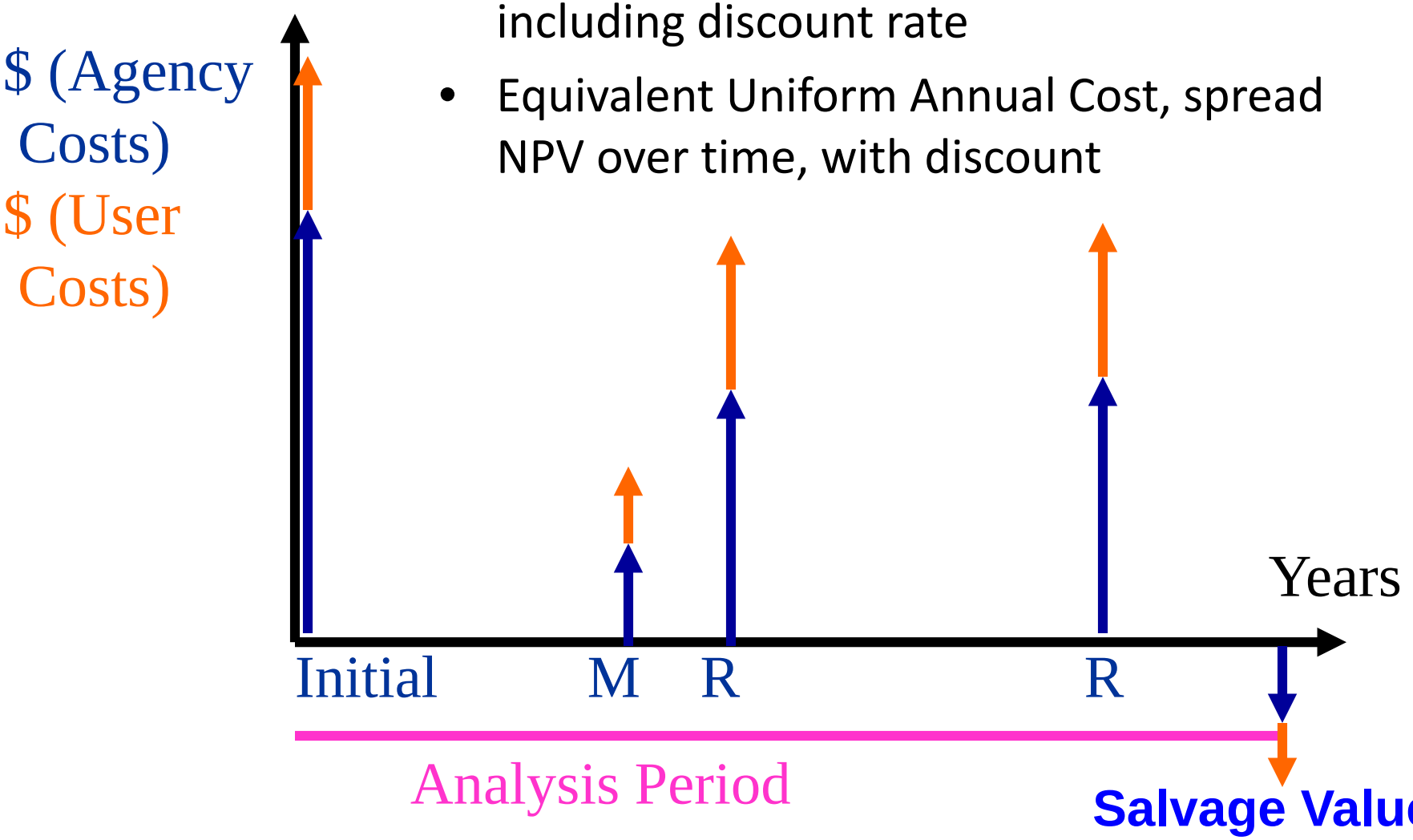
Converting performance information to treatment/cost sequence





LCCA calculations

- Net present value =
  add up the costs over the analysis period, including discount rate
- Equivalent Uniform Annual Cost, spread NPV over time, with discount



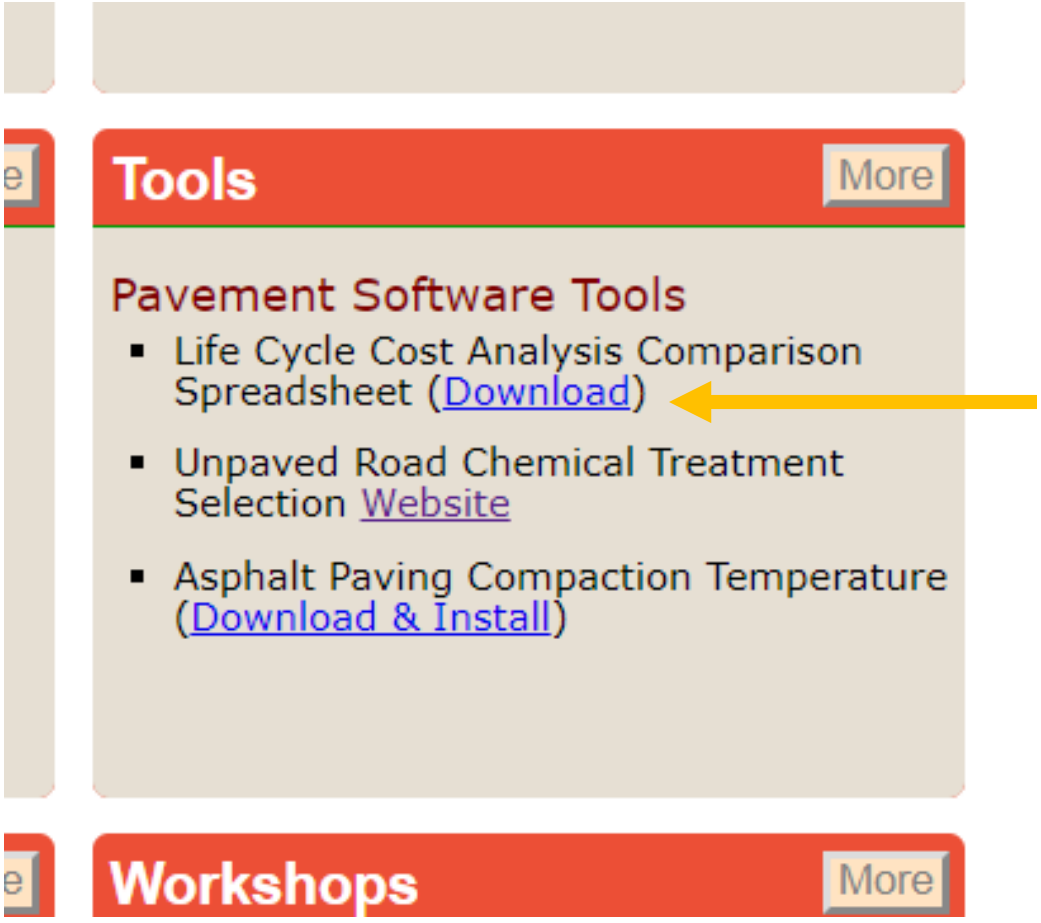
Where can LCCA be implemented?

- PMS decision tree optimization
  - Condition trigger levels for treatment (timing)
  - Treatment selection
- Pavement type selection
- Policy evaluation
  - Materials changes
  - Construction quality specifications
  - Design methods

CCPIC LCCA Excel tool

Download at: http://www.ucprc.ucdavis.edu/ccpic/
or Google "CCPIC UCPRC"

- Excel tool to calculate Net Present Value, Salvage Value and Equivalent Uniform Annual Cost
- Can compare 3 scenarios side by side
- Can choose and edit the list and sequence of treatments



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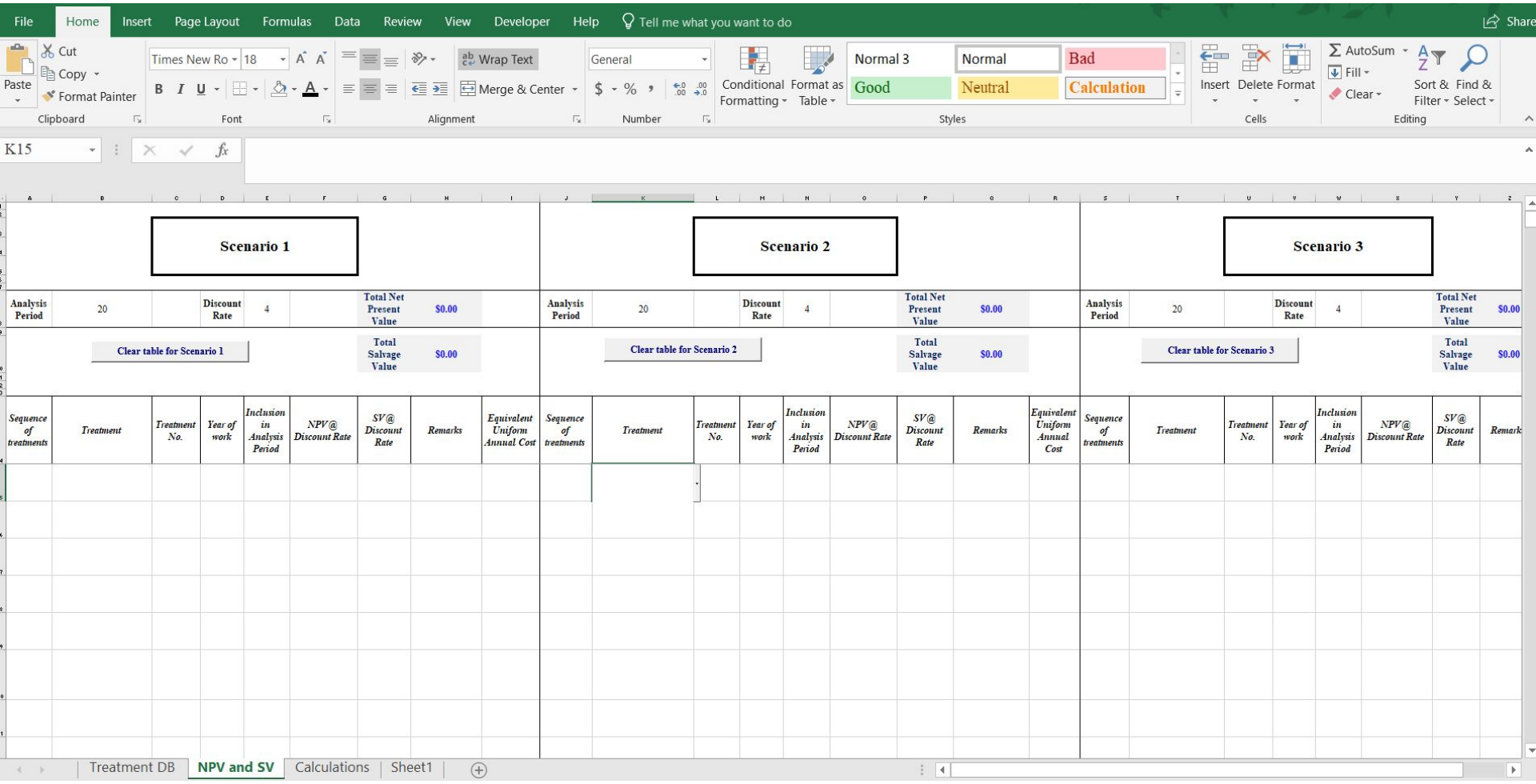


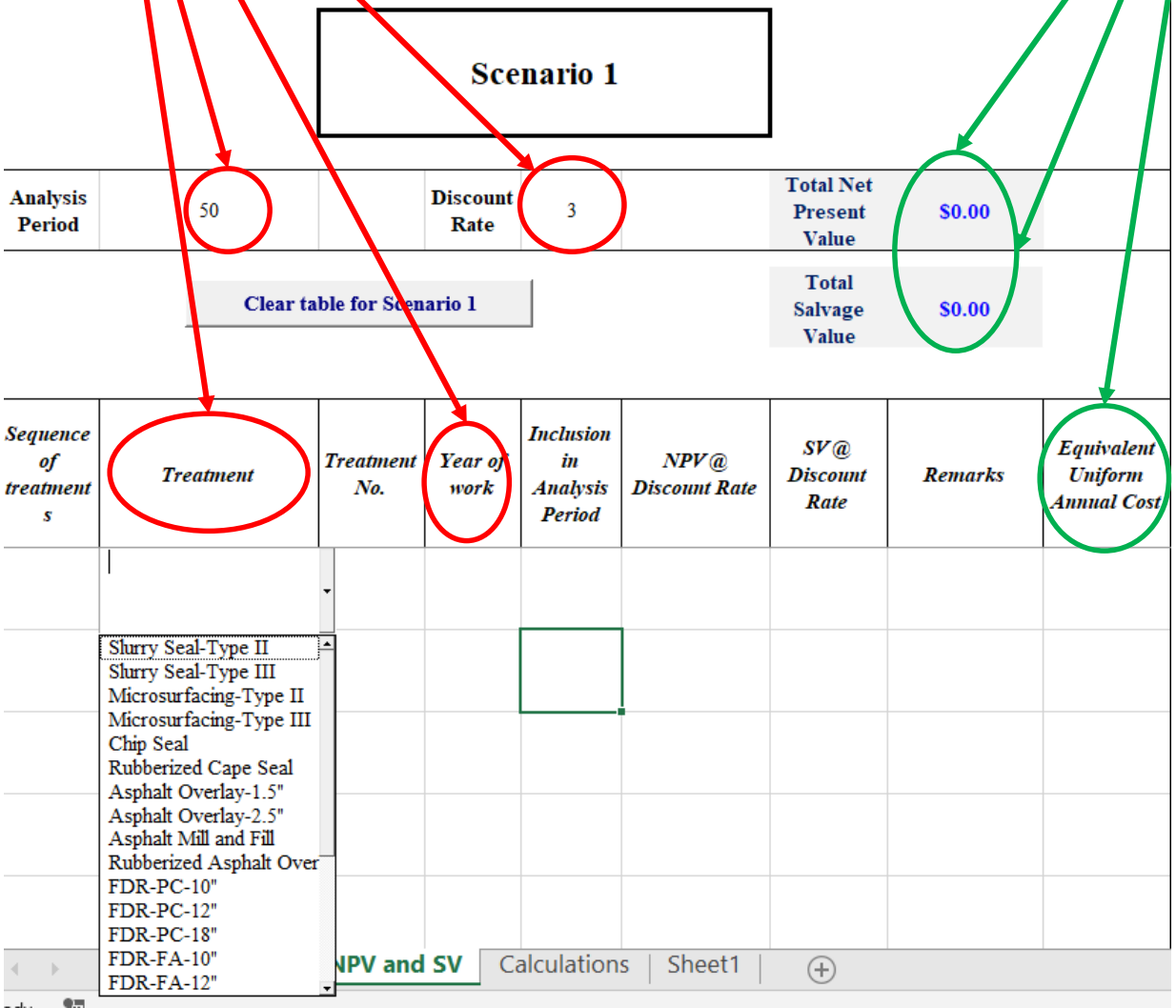
LCCA Excel tool

Inputs

1. Treatment type
2. Year of work
3. Discount rate
4. Analysis period

Outputs

1. Total NPV
2. Total SV
3. EUAC



LCCA Excel tool

Editable:

- Functional Unit
- Treatment List: Cost, Life of Treatment

	SY				
Functional Unit	7040	1 ln mi			
Treatment Name	**Treatment No.**	**Cost/SY**		**Total Cost**	**Life of Investment**
Slurry Seal-Type II	1	7		49280	3
Slurry Seal-Type III	2	7		49280	7
Microsurfacing-Type II	3	7		49280	5
Microsurfacing-Type III	4	7		49280	5
Chip Seal	5	10		70400	5
Rubberized Cape Seal	6	6		42240	7
Asphalt Overlay-1.5"	7	10		70400	10
Asphalt Overlay-2.5"	8	20		140800	13
Asphalt Mill and Fill	9	38		267520	20
Rubberized Asphalt Overlay	10	30		211200	20
FDR-PC-10"	11	40		281600	10
FDR-PC-12"	12	45		316800	15
FDR-PC-18"	13	50		352000	20
FDR-FA-10"	14	35		246400	7
FDR-FA-12"	15	40		281600	10
CIR-4"	16	25		176000	5
CIR-5"	17	27		190080	7
CIR-6"	18	30		211200	10
BCOA-4"	19	35		246400	7
BCOA-5"	20	37		260480	10
BCOA-6"	21	40		281600	12
Cape seal-2.5"	22	10		70400	5
Remove/replace	23	52		366080	20
Pulv HMA/compact	24	26		183040	20

Treatment DB | NPV and SV | Calculations | Sheet1

Performance prediction is key to good pavement management and LCCA

- Pavement Management Systems
  - Performance estimates are typically in terms of pavement condition index (PCI)

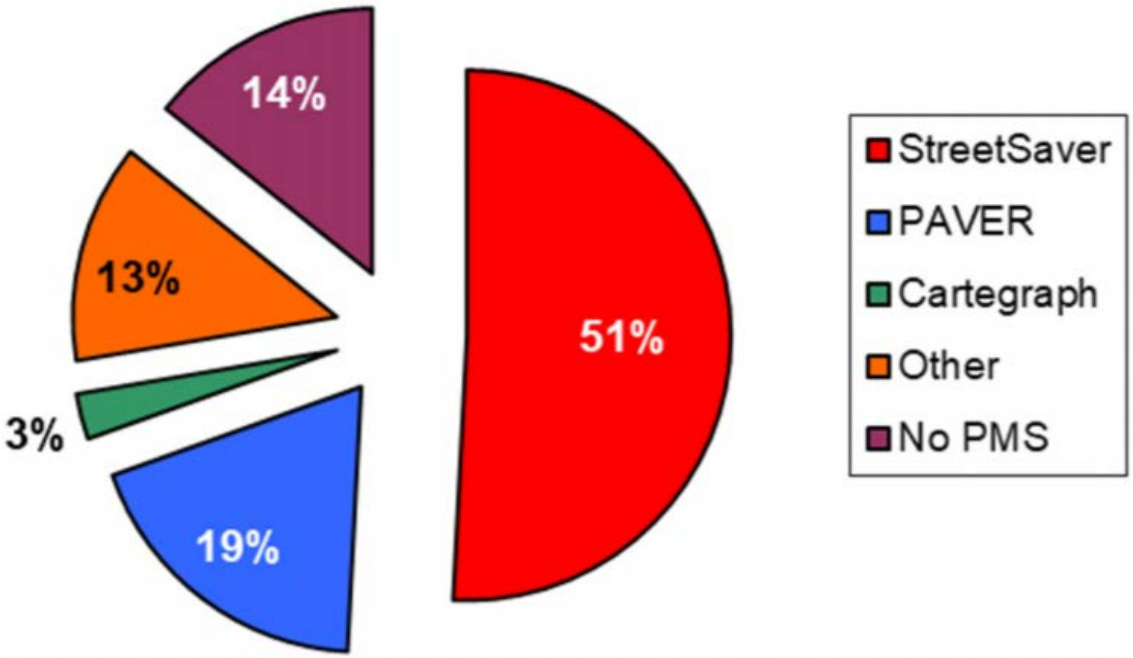


Figure B.4 PMS Software Used By Cities And Counties

Local Streets and Roads 2018

Some changes that can be considered to improve life cycle cost

- Pavement management and preservation
  - Treatment timing
  - Treatment selection
  - Treatment sequence
- Asphalt compaction

Life cycle cost analysis results for alternative scenarios for asphalt pavement

Asphalt Mill and Fill - $38/SY
Microsurfacing - $14/SY

Schedule A

Treatment	Year
Asphalt Mill and Fill	0
Microsurfacing	12
Microsurfacing	20
Microsurfacing	28
Asphalt Mill and Fill	33
Microsurfacing	45

Schedule B

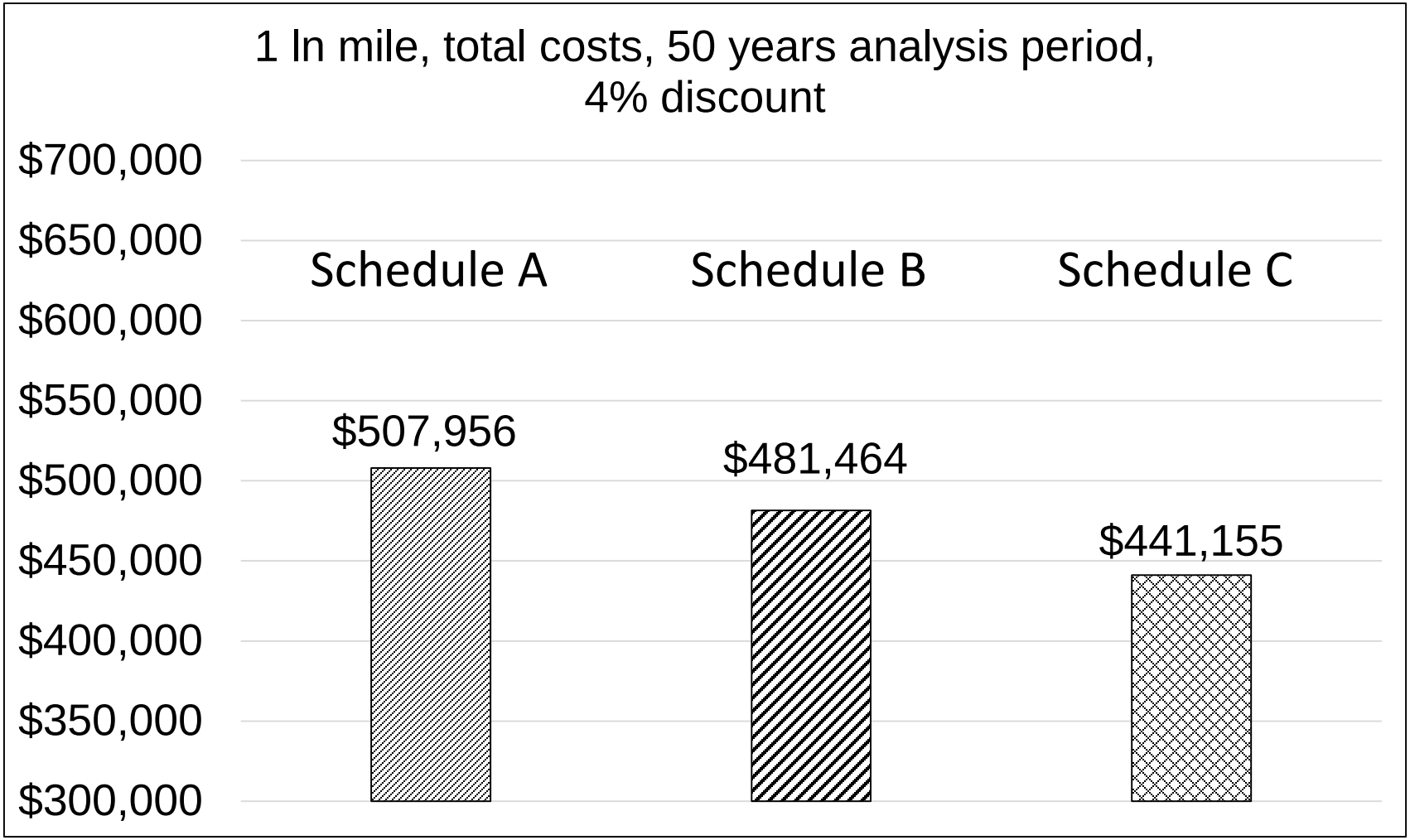
Treatment	Year
Asphalt Mill and Fill	0
Microsurfacing	13
Microsurfacing	23
Asphalt Mill and Fill	29
Microsurfacing	42

Schedule C

Treatment	Year
Asphalt Mill and Fill	0
Microsurfacing	15
Asphalt Mill and Fill	26
Microsurfacing	41

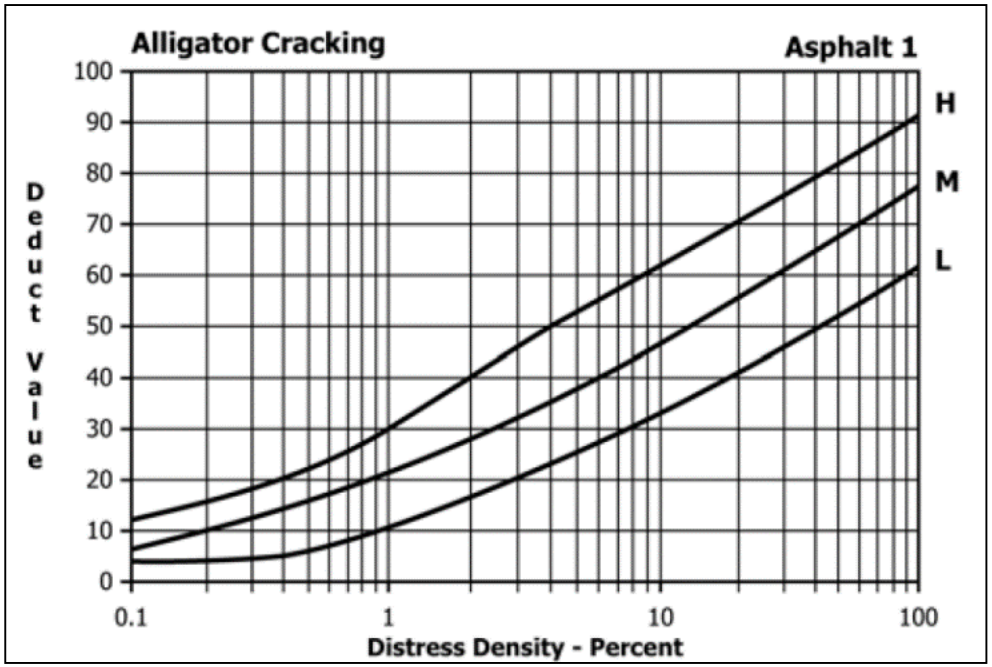
Life cycle cost analysis results

Results will vary depending on relative costs, discount rate, performance estimates



Pavement management: Use of PCI vs measured cracking

- PCI is amalgamation of different distresses
- Can have same PCI for very different conditions
- Engineering meaning in the condition survey is lost
- Recommend
  - Use PCI as communication tool for management/public
  - Manage asphalt pavement considering:
    - Cracking: age and traffic caused
    - Other distresses (rutting, raveling)



Same PCI, different pavement condition

CASE 1: TRAFFIC LOADING RELATED, PCI = 34			
DISTRESS	SEVERITY	QUANTITY	DV
Alligator Cracks	High	1x6	18
Alligator Cracks	Medium	1x4 1x5 1x7	17
Potholes	Medium	3	48
Potholes	Low	3	30
Rutting	Low	2x5 2x8	10
CASE 2: AGE, CONSTRUCTION, UTILITIES, OTHER FACTORS, PCI = 32			
Long/Trans Crack	High	15 20 8 6 12 18 6x7	43
Long/Trans Crack	Medium	25x2 18 13 9 10	20
Patching/Utility	High	25x4 25x2	40
Patching/Utility	Medium	12x6 4x7	20
Block Cracks	High	4x6 6x5	13

Variables in the PCI for asphalt pavement

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

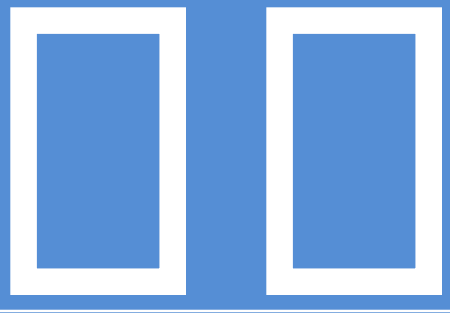
- Other distresses
  - Low ride quality
  - Bleeding
  - Bumps and sags
  - Corrugations
  - Depressions
  - Edge cracking
  - Lane/shoulder drop-off
  - Patching and utility cut patching
  - Polished aggregate
  - Rutting
  - Shoving
  - Slippage cracking
  - Swelling
  - Weathering and raveling

Bottom Up Fatigue Cracking

- Interaction of asphalt concrete layer, support of underlying structure, materials selection, construction compaction
- Traffic loading
  - Only the truck loads count, cars are too light
  - slower speeds = longer durations = bigger strains
- Environment
  - temperature
  - water sensitivity
  - aging

Fatigue Cracking

Bottom up cracking



Asphalt Concrete

Tensile Strain ε_t

Base

Sub-Base

Subgrade

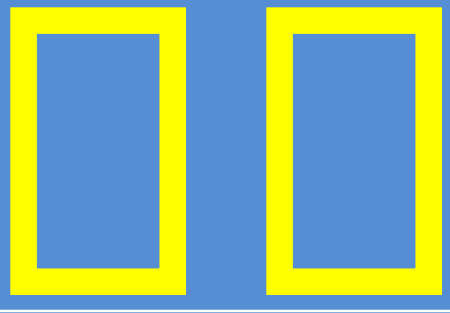
Initial Wheelpath Cracking (transverse or longitudinal)

Cracks connect: Alligator Cracking (Caltrans calls “Type B”)

Fatigue Cracking in Wheelpaths

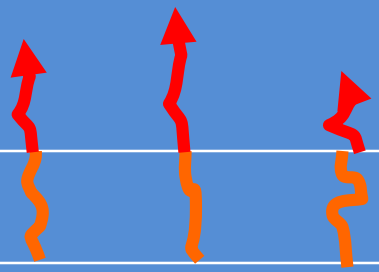
Reflective Cracking

Bottom up cracking



Asphalt Concrete

Cracked AC, PCC or CTB



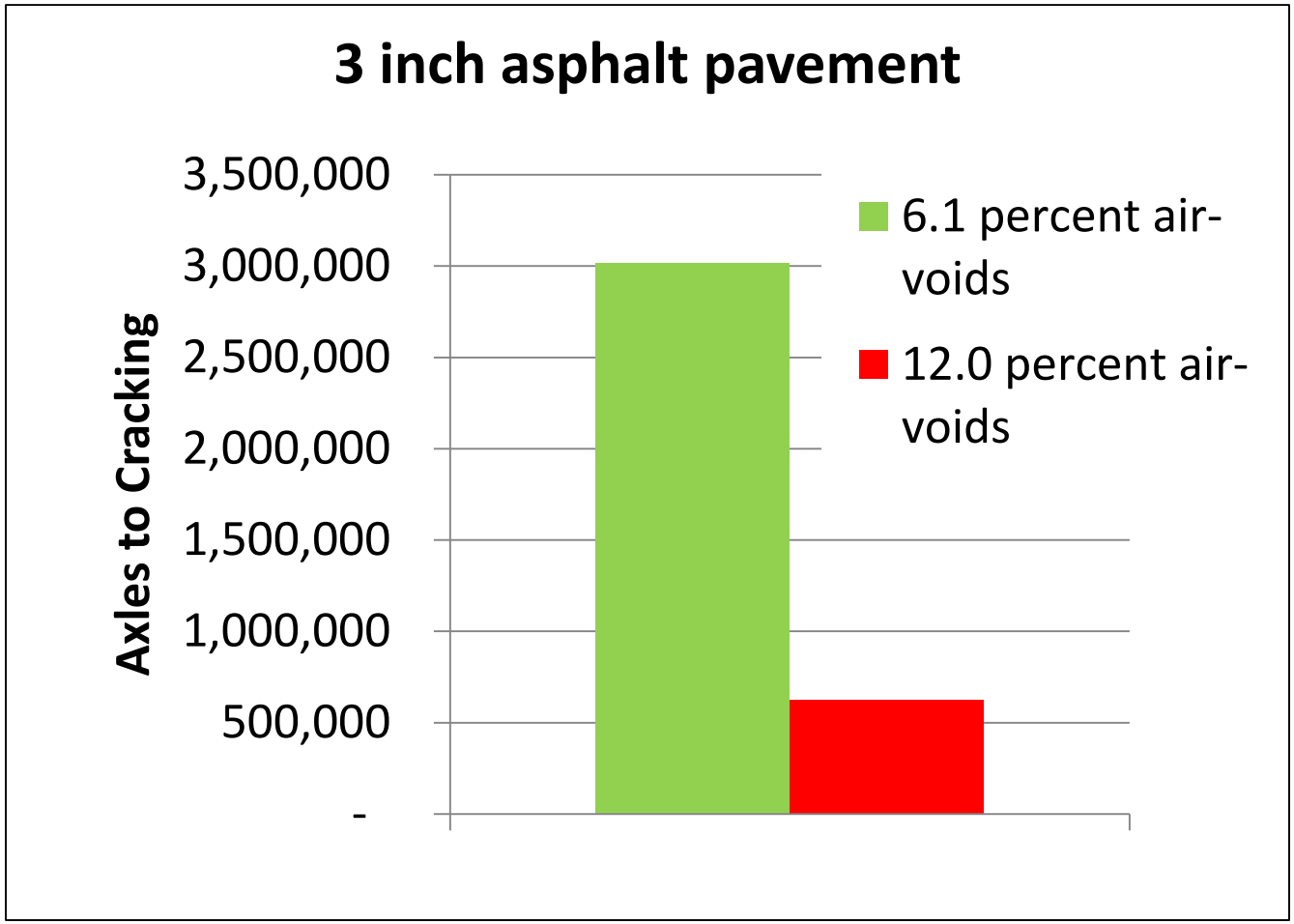
Base

Sub-Base

Subgrade

Reflection Crack over PCC Joint

Effect of asphalt construction compaction on axle loads to cracking



General rule:
1% increase in constructed air-voids
= 10% reduction in fatigue life

Simulation based on FHWA Westrack project field results

Treatment for load related fatigue cracking

- Asphalt will fatigue
- Surface treatments will slow some
- Will need to do periodic mill and fill
- Do not let wheelpath cracking become extensive or must reconstruct

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

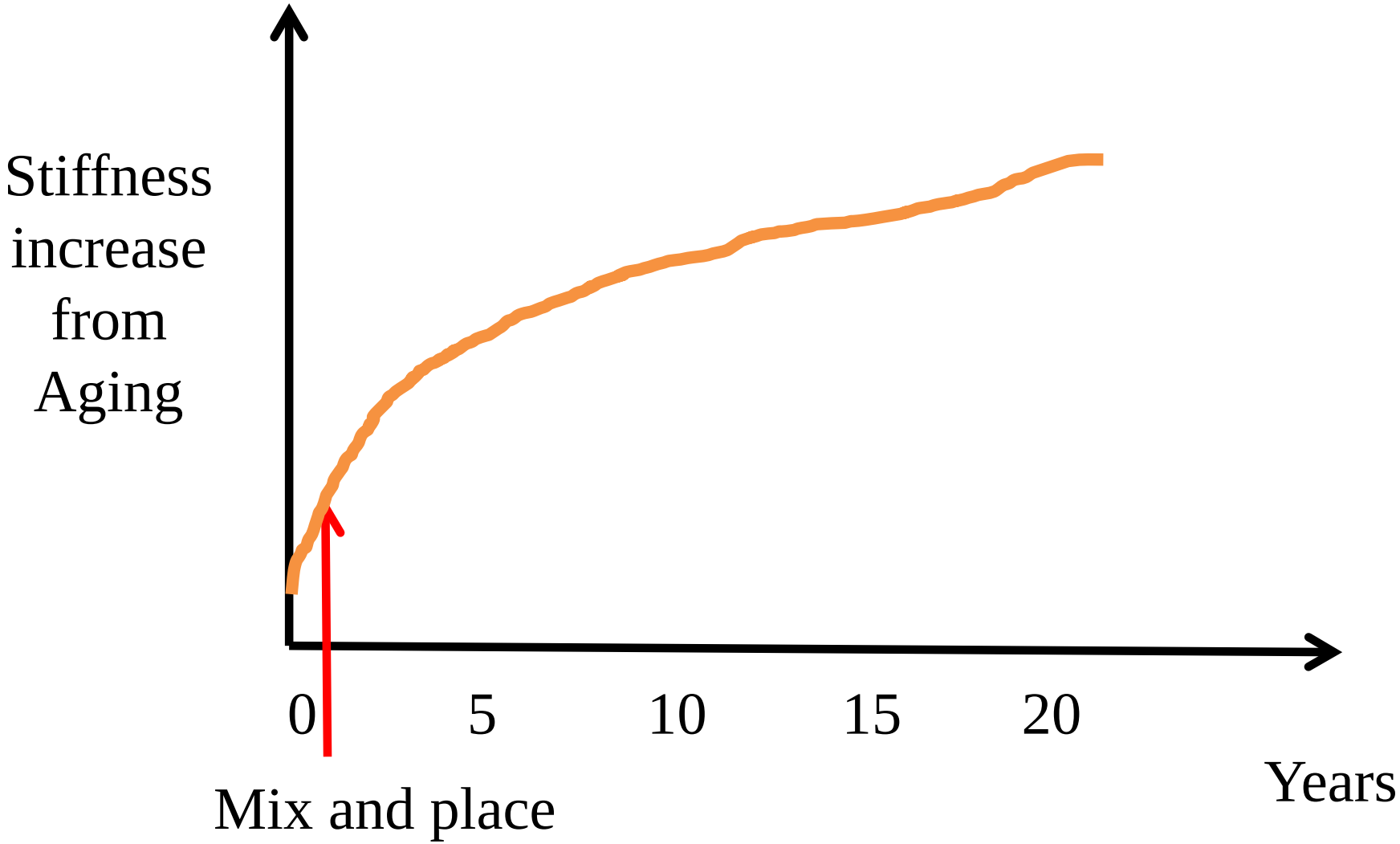
Block Cracking

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

Block Cracking

Aging

mostly done by 5 years after placement



Treatment for age-related cracking

- Keep the surface protected from aging
- Can potentially due perpetual slurries or microsurfacings
- What frequency?
  - Do not let cracking get extensive
  - But doing more frequently than needed can be a waste

Example fatigue vs age-related treatment sequences

Asphalt Mill and Fill - $38/SY
Microsurfacing - $14/SY

Aging related distresses
(no diminishing prevention treatment lives)

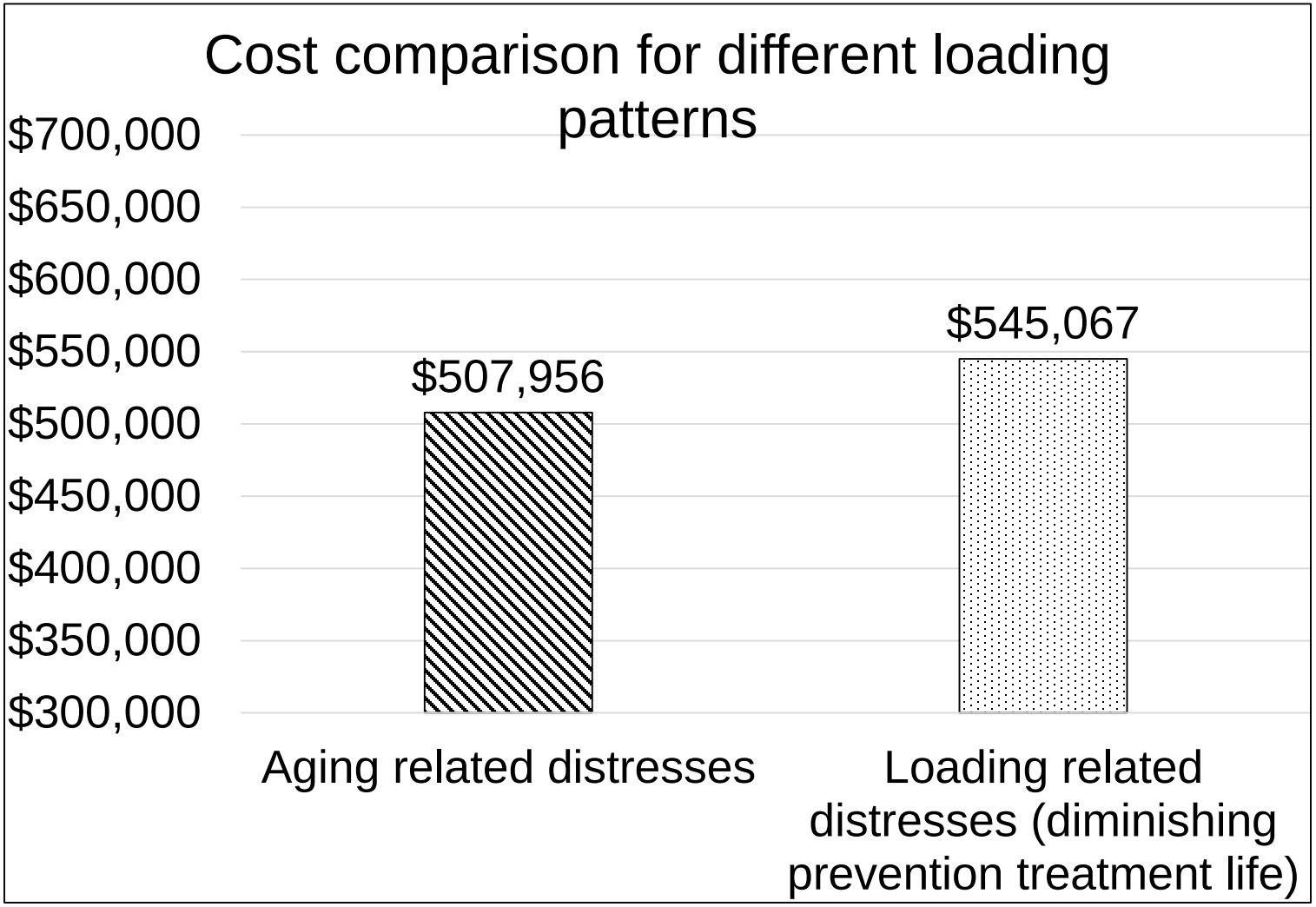
Treatment	Year
Asphalt Mill and Fill	0
Microsurfacing	12
Microsurfacing	20
Microsurfacing	28
Asphalt Mill and Fill	33
Microsurfacing	45

Load related distresses
(diminishing prevention treatment lives)

Treatment	Year
Asphalt Mill and Fill	0
Microsurfacing	12
Microsurfacing	19
Microsurfacing	25
Asphalt Mill and Fill	29
Microsurfacing	41
Microsurfacing	48

Life cycle cost analysis results

Example fatigue vs age-related treatment sequences



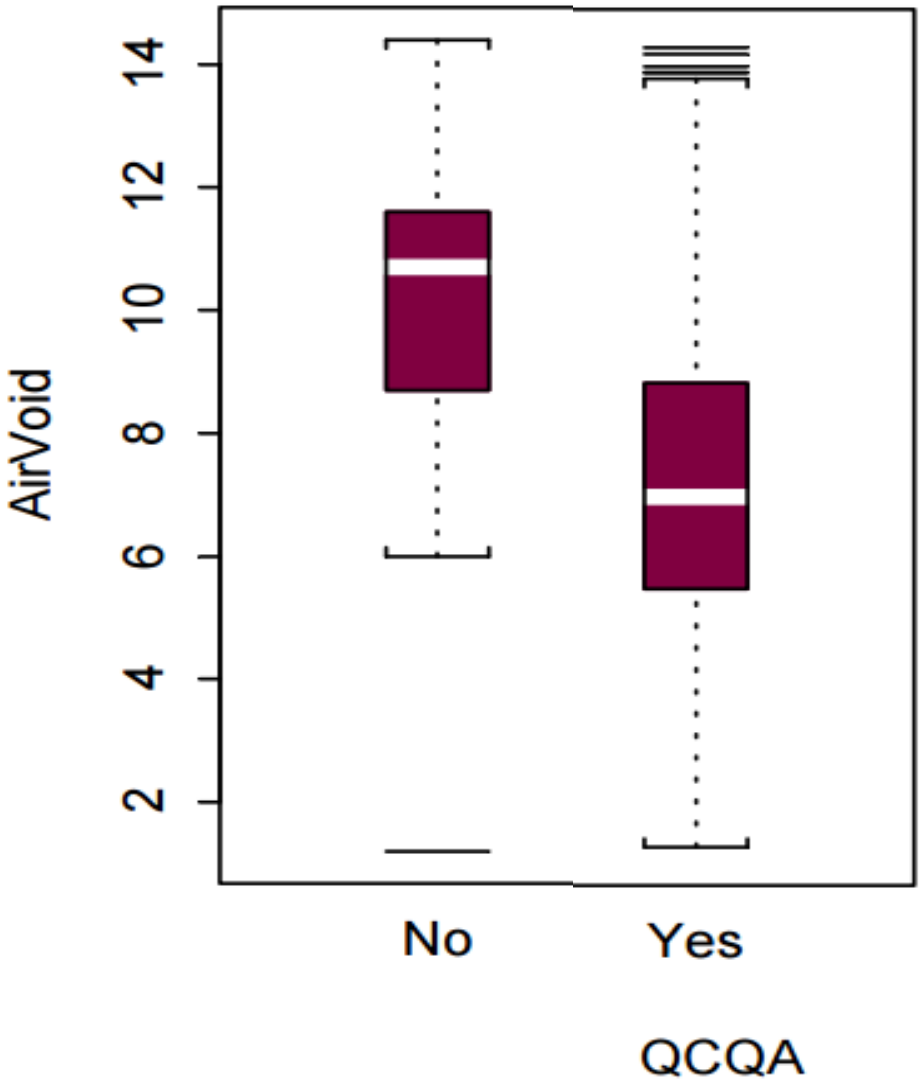
Recommendation for use of LCCA

- Pavement management
  - Use PCI in network-level analysis to set overall budget, measure network condition
  - Do treatment selection engineering work based on truck/bus traffic level, cracking and surface defects data, not PCI
  - Use your costs, cracking predictions and LCCA to develop best sequences of treatments
    - Look at your fatigue and aging-related cracking data
    - Estimate treatment lives
  - Learn to use LCCA to discuss with council/board

Recommendation for how to get good asphalt compaction

- Use a quantitative (QC/QA) specification to measure compaction
- Write spec in terms of *in-place bulk density* and *theoretical maximum density* (TMD) and not *laboratory theoretical maximum density* (LTMD)
- Use cores or nuclear gauges calibrated for the specific mix/project to provide daily feedback to contractor and agency
- Apply payment reductions if they don't meet your specification, and enforce those payment reductions

Caltrans experience with method spec vs using in-place measurement and penalties (QC/QA)



- Spec changed in 1996-98
- Very large culture change in Caltrans

"Trust but verify"

But what about?

- Won't this increase the bid cost for my asphalt?
- Isn't the cost of managing this specification high?
- Won't coring damage my new pavement?
- What can I do to help my contractors meet and exceed the specification and further increase the life of my overlays?

Compaction effects repeated mill and fill

- 3% change in air-voids is about 30% change in cracking life

Asphalt Mill and Fill - $38/SY

9% AV – Usual practice

Treatment	Year
Asphalt Mill and Fill	0
Asphalt Mill and Fill	18
Asphalt Mill and Fill	36

12% AV – Poor compaction

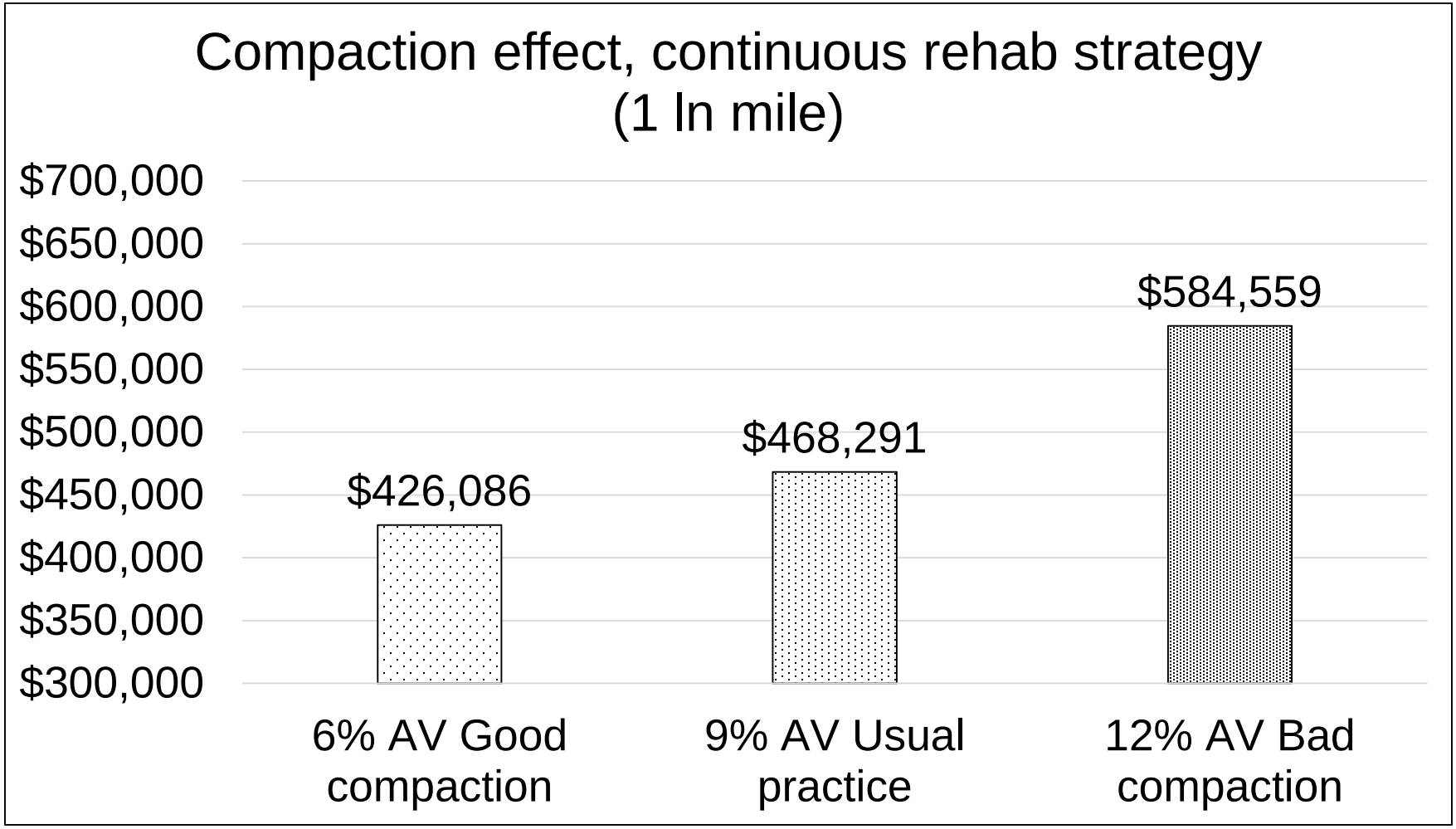
Treatment	Year
Asphalt Mill and Fill	0
Asphalt Mill and Fill	13
Asphalt Mill and Fill	26
Asphalt Mill and Fill	39

6% AV – Better compaction

Treatment	Year
Asphalt Mill and Fill	0
Asphalt Mill and Fill	23
Asphalt Mill and Fill	46

Life cycle cost analysis results

effects of asphalt compaction



Some other changes that can be considered to improve life cycle cost

- Update street and minor concrete mix specifications
  - Reduce cement content and use supplementary cementitious materials
- Full-depth reclamation
- Cold in-place recycling
- Bonded concrete overlays

Questions?

www.ucprc.ucdavis.edu/ccpic

Concrete mix specifications

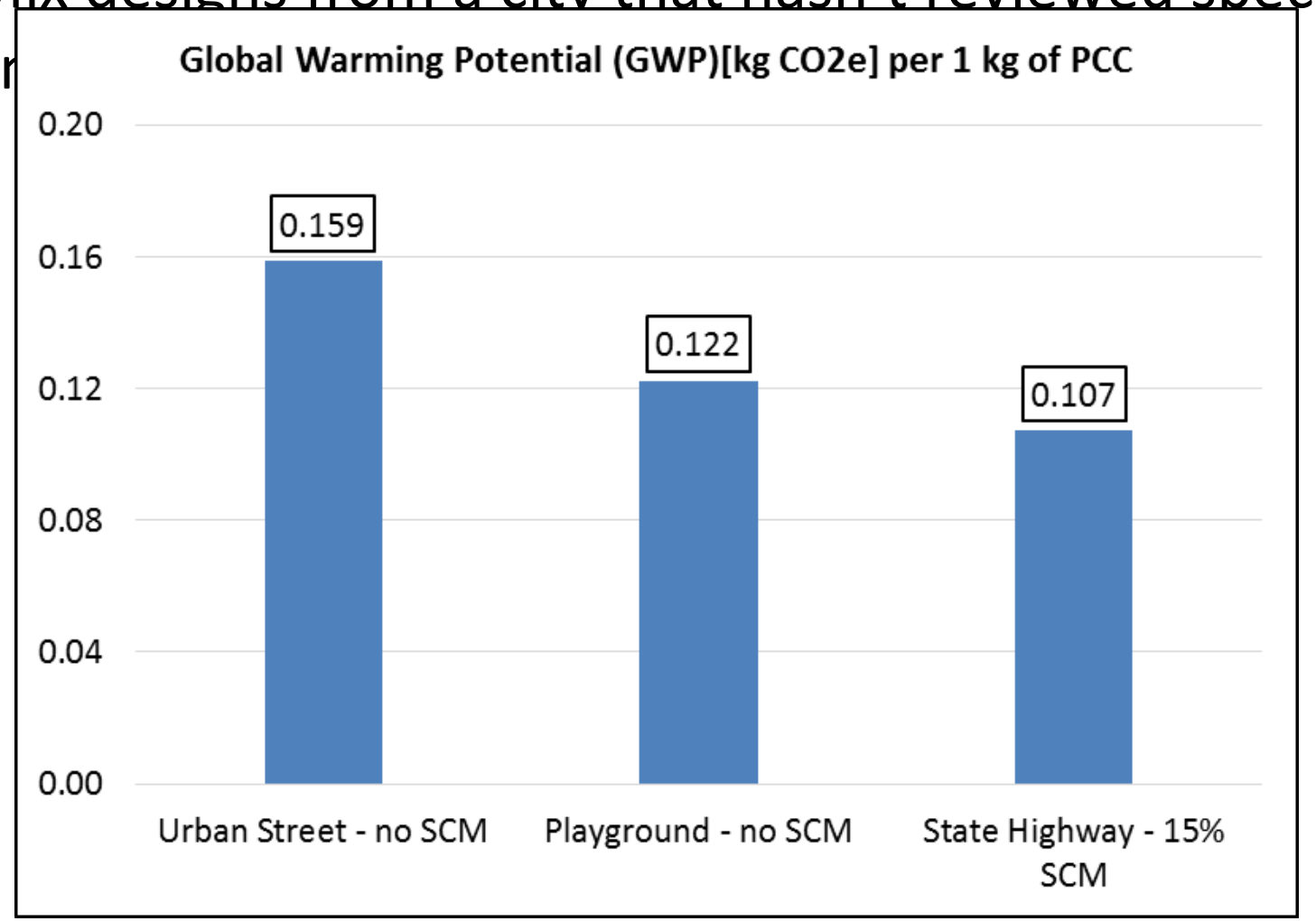
- Older concrete specifications
  - Written to ensure enough cement to meet strength and durability requirements
  - Often included minimum cement content
- Modern concrete mix designs
  - Minimize need for portland cement
  - Replace with supplementary cementitious materials (SCM
  - Minimize amount of cement paste in the mix:
    dense aggregate gradations

Concrete mix specifications

- What are SCMs?
  - Fly ash, natural pozzolans, slag cement
  - These can come pre-blended (new ASTM specs)
  - Caltrans also allows 5% replacement with ground limestone
    - Agencies are evaluating up to 15%
- These changes to mix design specs
  - Increase durability of the concrete
  - Decrease environmental impact
- When was the last time you reviewed your concrete specifications?

Effects on greenhouse gas emissions

- Mix designs from a city that hasn't reviewed specs ar



What you need to do

- *Use dense aggregate gradations:* Reduces cost, shrinkage
- *Specify limits on shrinkage and strength:* Reduces water contents
- *Require quality control and quality assurance testing for strength, shrinkage, other properties of interest.* Small cost for sampling and testing
- *Require use of supplementary cementitious materials.* Tend to reduce shrinkage, improve durability, reduce greenhouse gas emissions, may reduce cost
- *Allow the use of blended cements (ASTM C595)*
- *Work with a concrete mix design expert to review your specifications and change them*

But what about?

- How do I know that these mixes will give me good performance?
- Will these changes in specifications cost me more?
- Are there any other issues such as constructability with these mixes?

Image: robert's ready mix www.rrmca.com/

Full-depth Reclamation (FDR)

- For badly cracked asphalt or to correct cross-slope
- Pulverize and stabilize (one pass), compact, overlay
- Stabilization options
  - Foamed asphalt (about 2.5 %) with cement (about 1%)
    - Need some granular material below the asphalt
  - Cement
    - If no granular material below asphalt
    - Enough cement to reach minimum strength and no more!
  - No stabilizer
    - Acts like granular base
  - Engineered emulsions
    - More work needed to develop recommendations

Cold Central Plant Recycling (CCPR)

- Like FDR but set up a mobile plant on site
- Mill out asphalt, process on site, put back
- Can do any required subgrade stabilization

Cold In-place Recycling (CIR)

- Partial depth (top 2 to 5 inches)
- Mill and stabilize, compact, overlay
- Stabilized with emulsion and a small amount of cement
- Must achieve correct gradation