How to Get More Bang for Your Bucks, Best Practices in Pavement for Local Government

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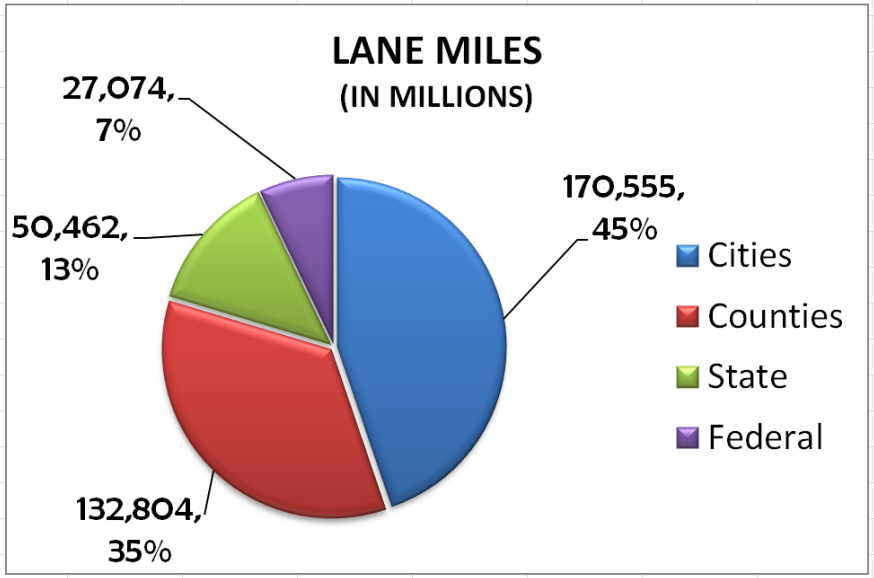
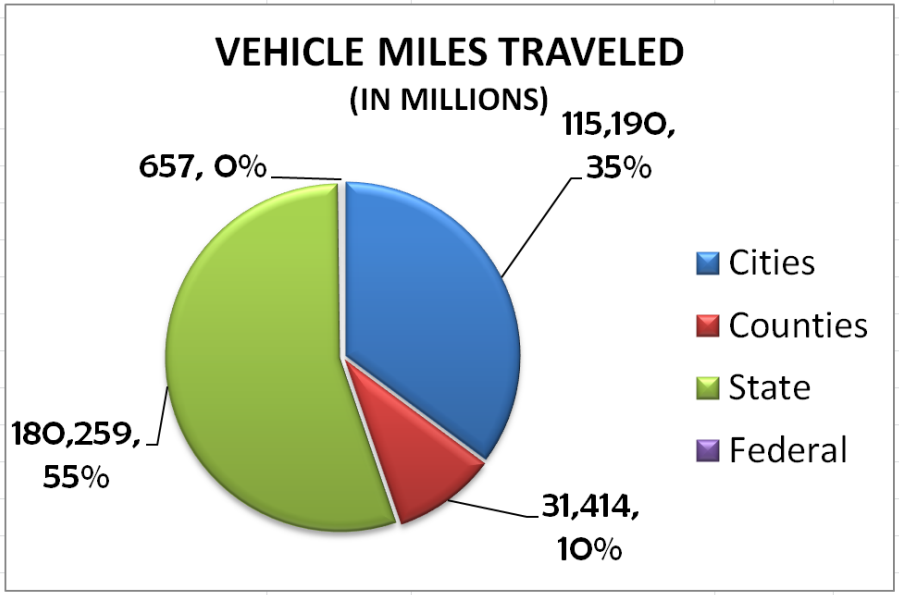
www.ucprc.ucdavis.edu/ccpic

- League of California Cities and County Engineers Association of California will be setting up governing board in next months

Why is Local Government Pavement Important to Sustainability?





Pavement Spending

Local $/State $ usually about 0.8 to 1

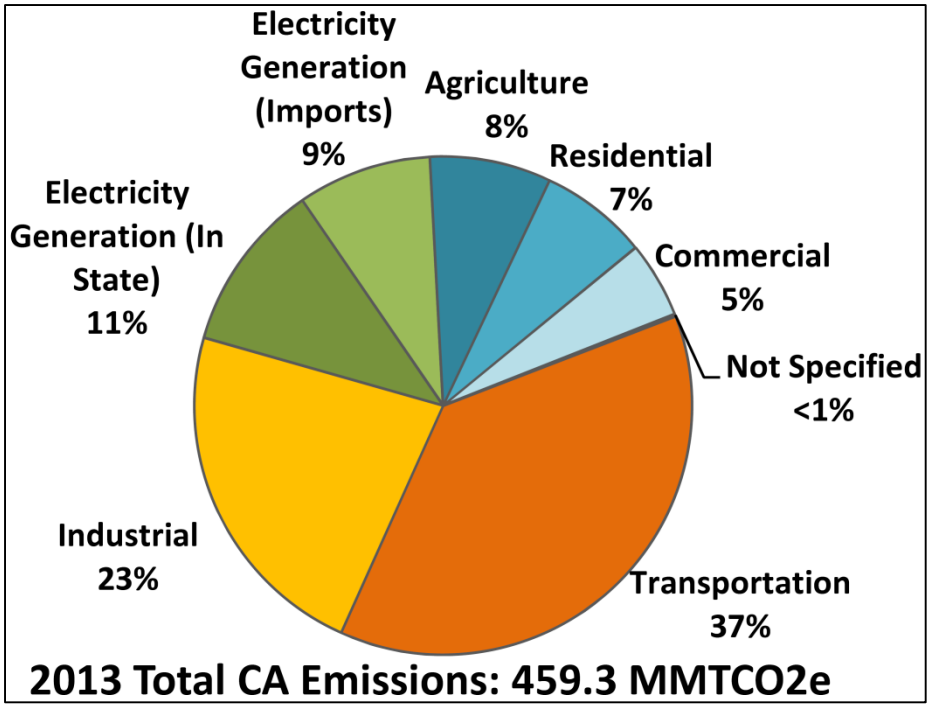
SB 1

$ 2.5 billion for state highways

$ 2.0 billion for local government

How do Pavements Contribute to California GHG Emissions?

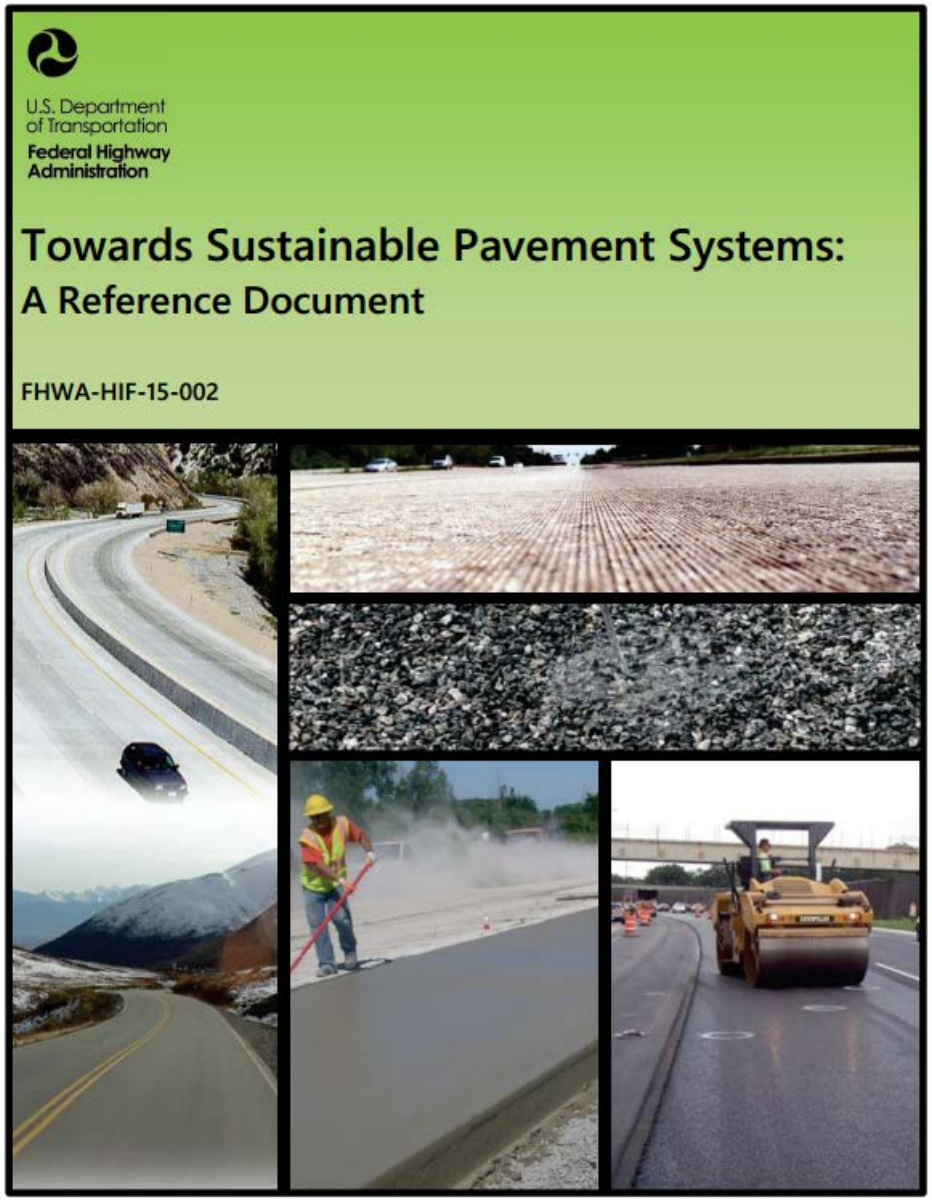
- 459 MMT CO2e in 2013
  - On road vehicles 155 MMT
    - Optimizing smoothness, texture, deflection energy on state network reduces by 1% of this
  - Refineries 29 MMT
    - Paving asphalt about 1 % of refinery production
  - Cement plants 7 MMT
    - Paving cement about 5 % of cement plant production
  - Commercial gas use 13 MMT
    - Very small amounts for asphalt mixing plants
  - Mining 0.2 MMT
    - Large portion for aggregate mining



Possible Pavement Reductions	MMT/year
Rolling resist to optimum	1.5
Reduce cement use 50%	0.2
Reduce asphalt use 50%	0.7
Reduce hauling 10%	0.6
TOTAL	**2.9**

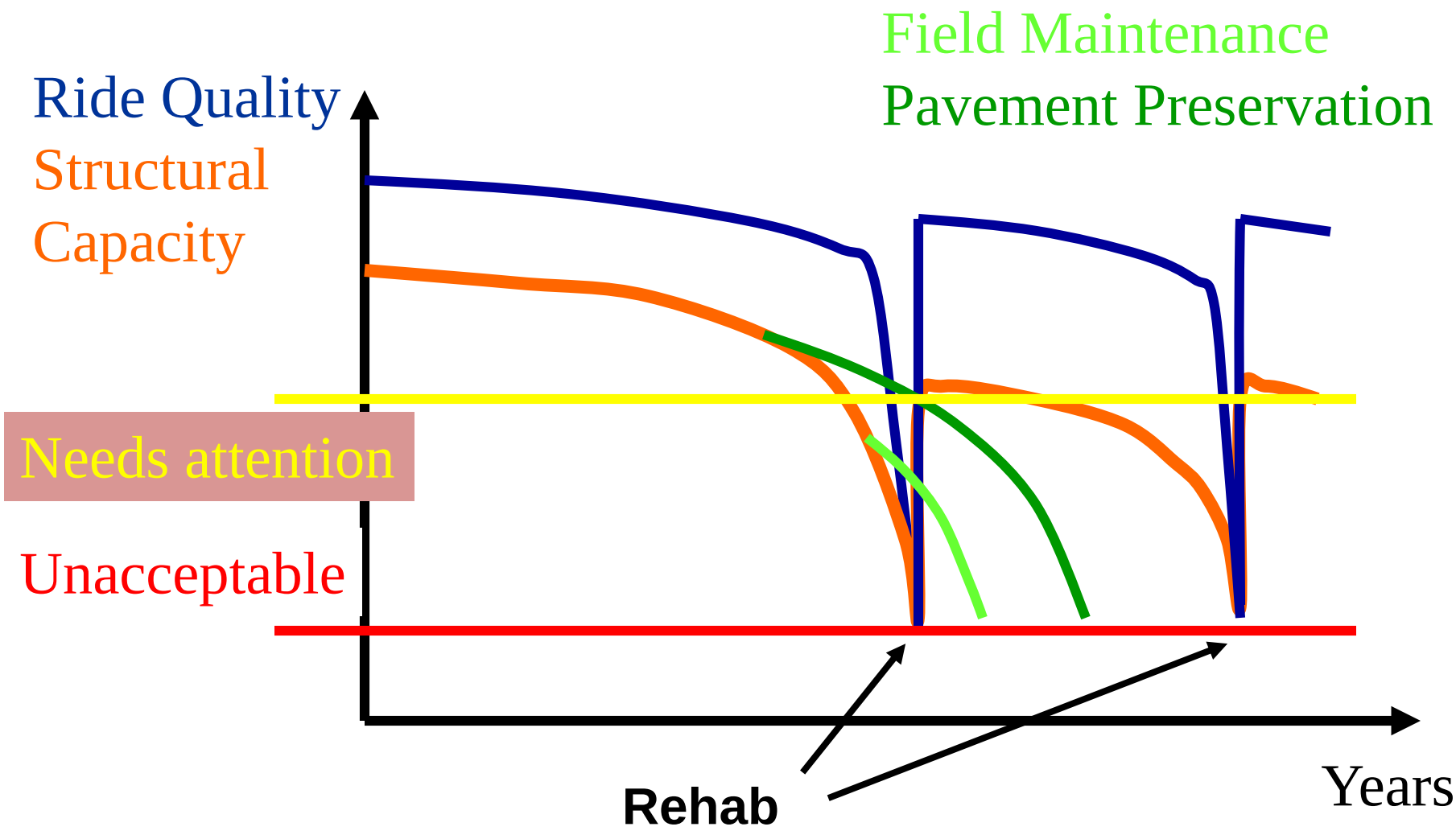
So what can be done to make pavements more sustainable?

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



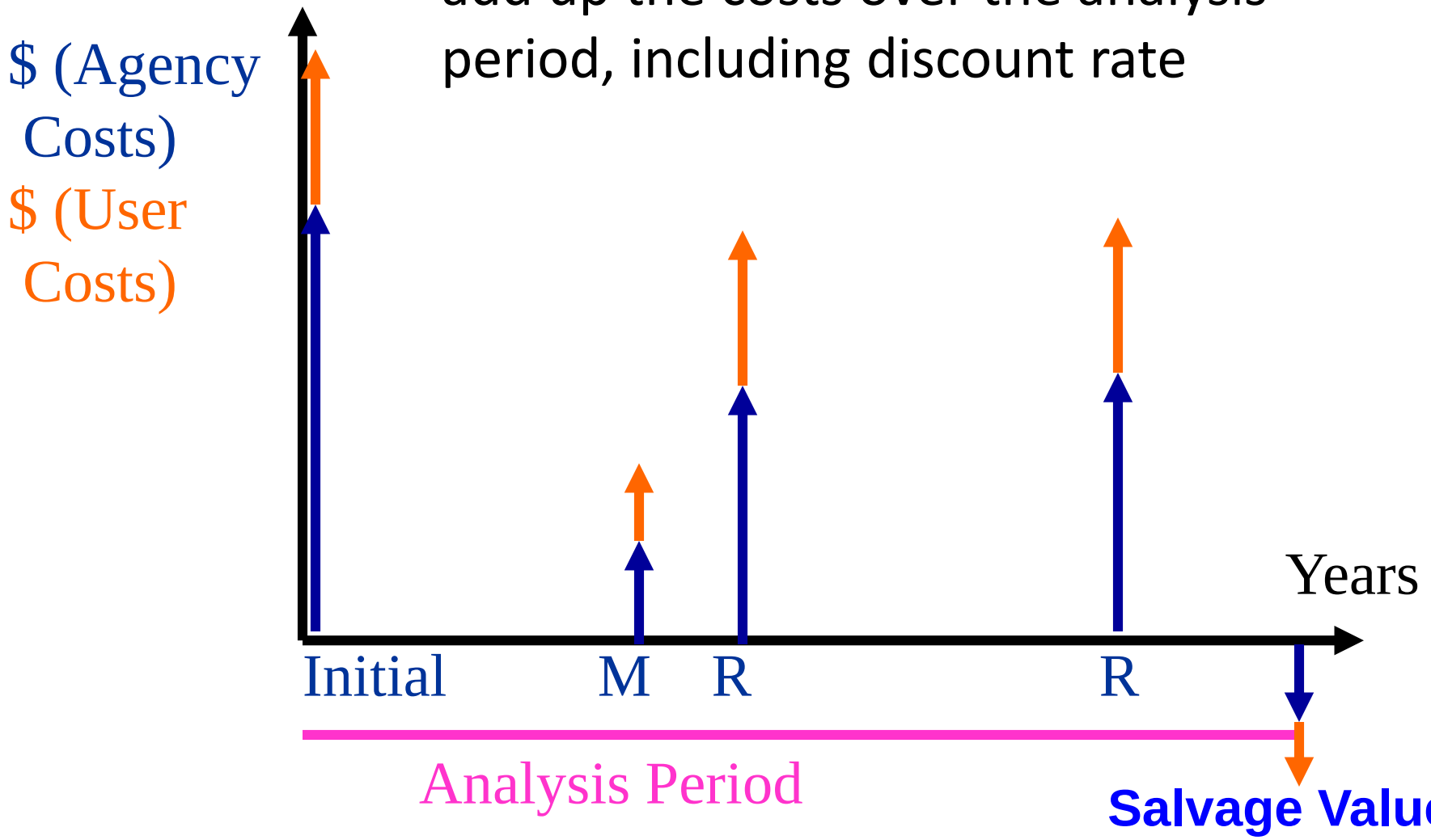
http://www.fhwa.dot.gov/pavement/sustainability/ref_doc.cfm

Life Cycle Cost Analysis (LCCA) Basics



LCCA calculations

- Net present value =
  add up the costs over the analysis period, including discount rate



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

Four Key Stages of Life Cycle Assessment

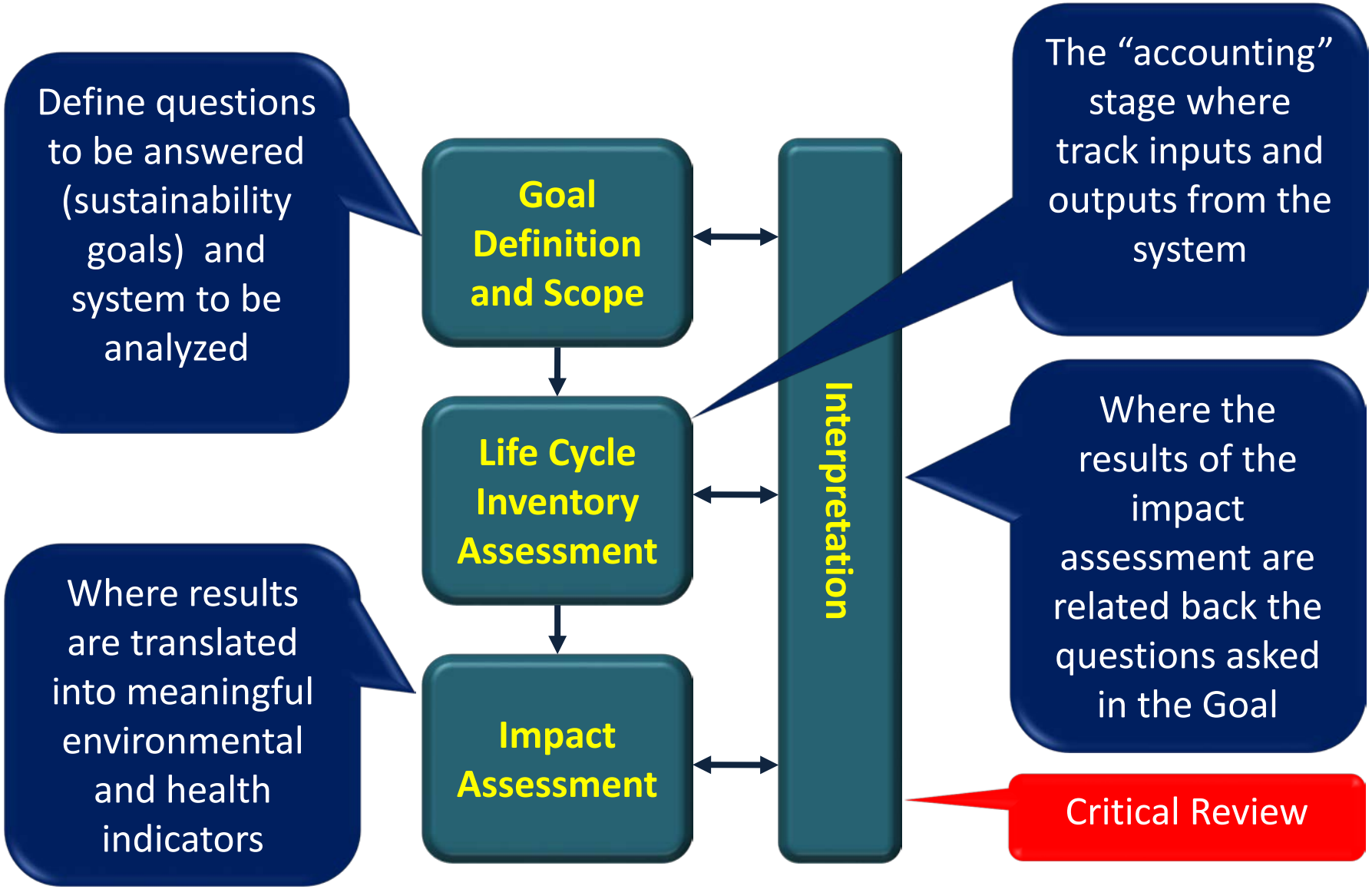


Figure based on ISO 14040, adopted from Kendall

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

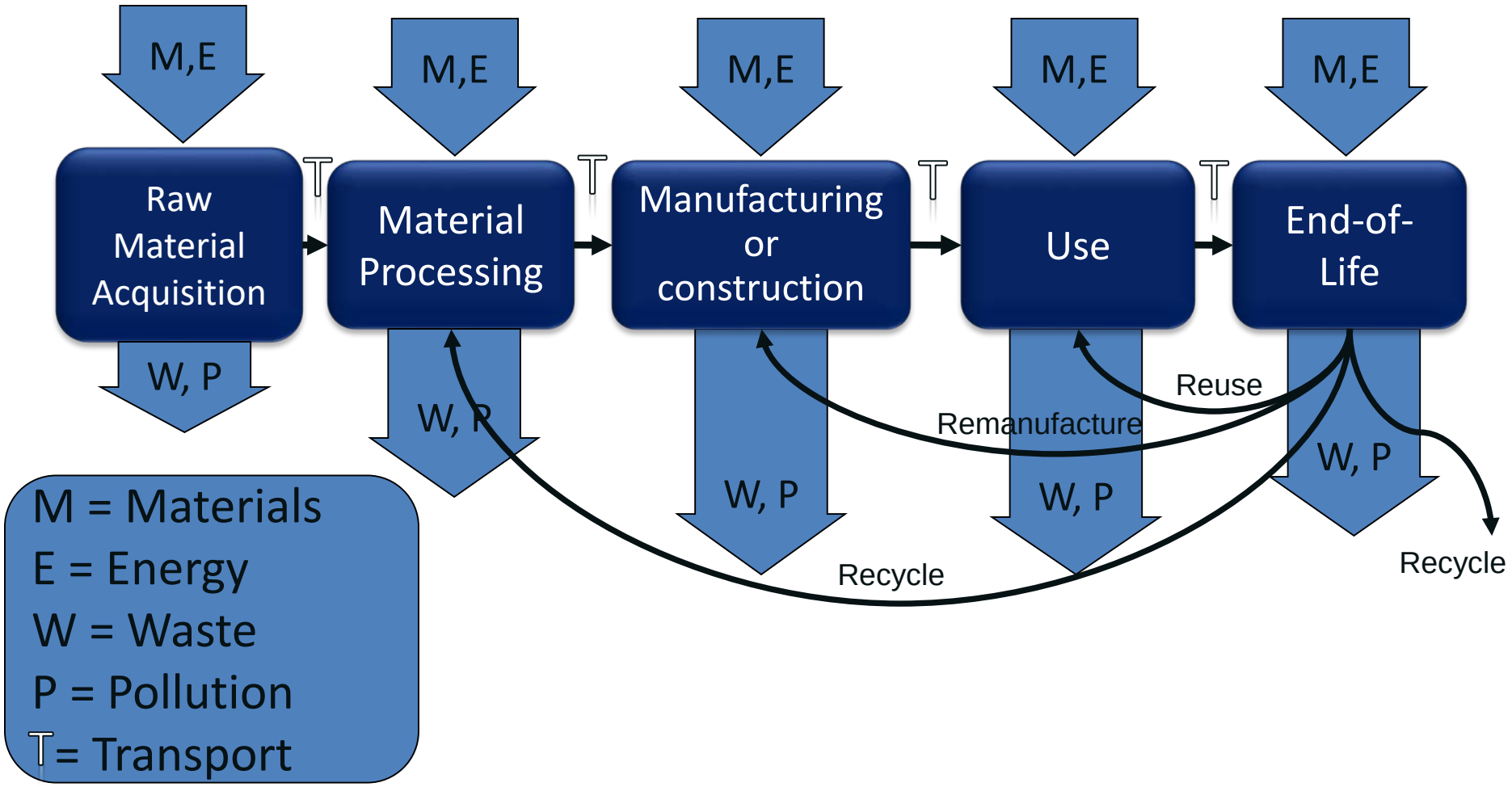
Impacts to people

Impacts to ecosystems

Depletion of resources

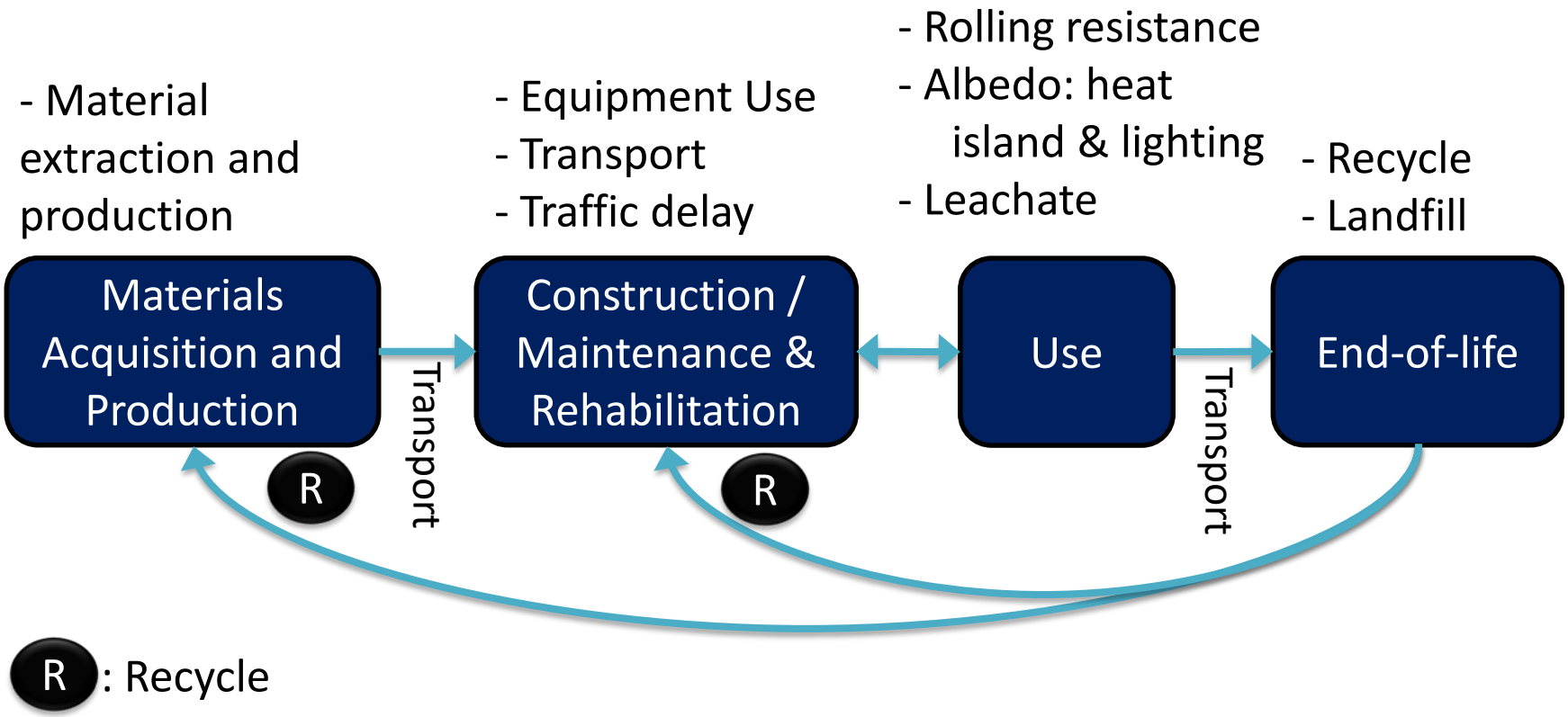
From Saboori Image sources: Google

Generic Life Cycle Assessment



Kendall, A., Keoleian, G. A., 2009

Pavement Life Cycle Assessment



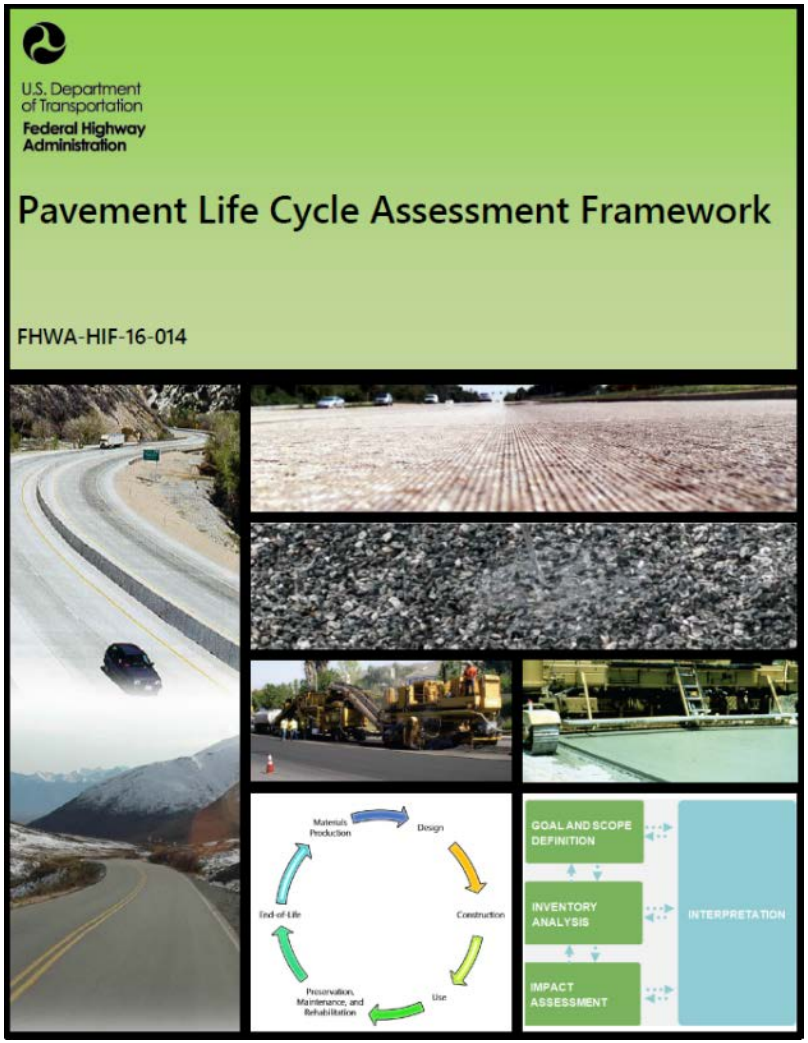
From: Kendall et al., *2010*

Why use LCA for evaluating environmental performance?

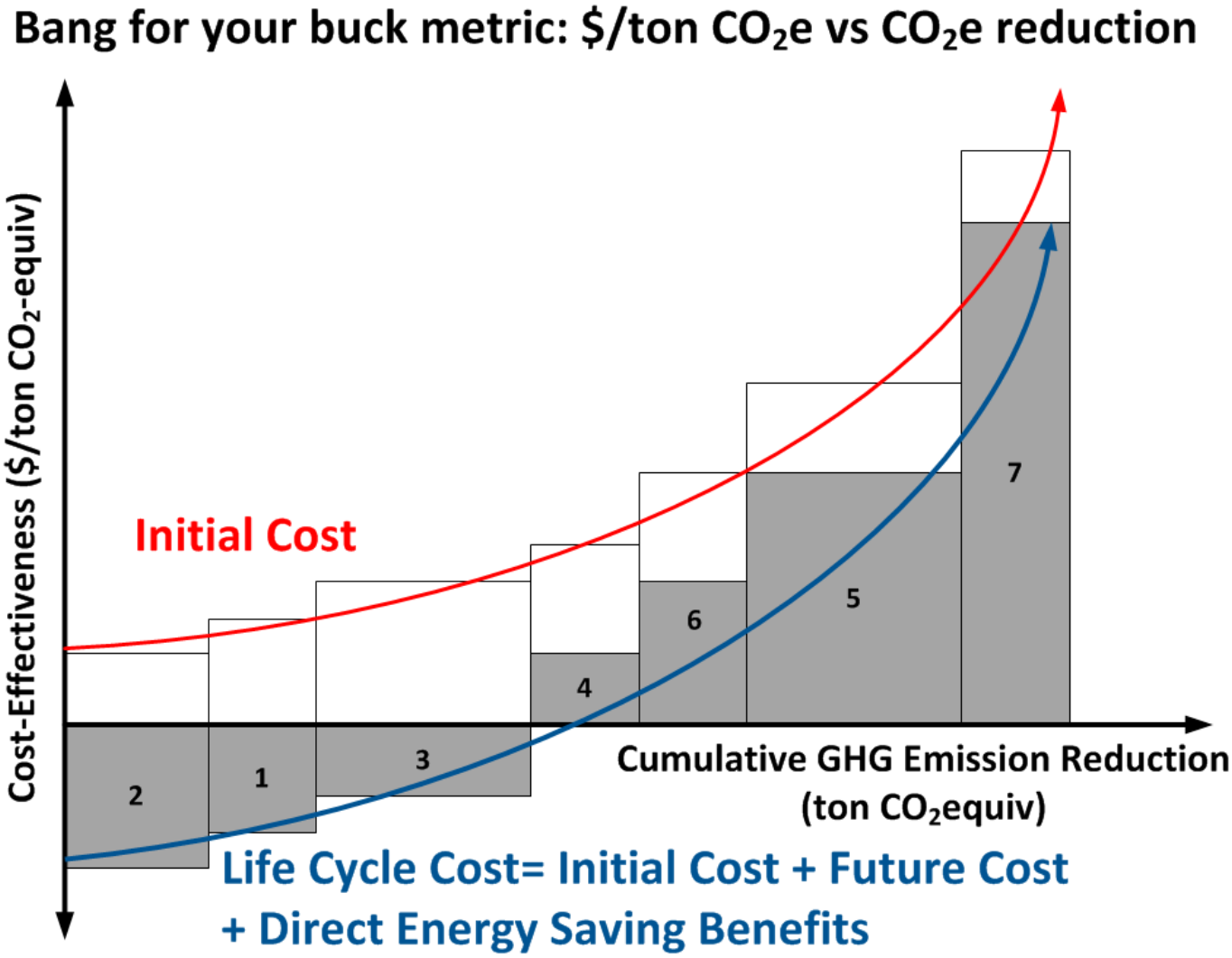
- Quantifies outcomes:
  - GHG, energy, pollutants, finite resources
- Uses project-specific inputs:
  - materials, transport, construction, traffic levels, re-use
- Requires explicit prioritization of outcomes for decision-making
- Can account for regional and time variability, and other uncertainties in data sets and analysis

ISO Standards and FHWA Pavement LCA Framework Document; LCA tools

- International Standards Organization (ISO) standards for LCA are generic for all materials
- FHWA guidance specific to pavements published in 2016
- New web-based pavement LCA tool being developed for Caltrans now: *eLCAP*
- New spreadsheet tool being developed for FHWA now



What Should be Done for Sustainability?



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

- Many alternatives to improve sustainability
- How to prioritize?
- Cost from Life Cycle Cost Analysis (LCCA)
- Environment from Life Cycle Assessment (LCA)

Some Applications and Results

Changes to improve sustainability

- Asphalt compaction
- Concrete mix specifications
- Unpaving
- Pavement management and preservation
- Measuring impacts of material you buy
- Heat island
- Preservation and bicycles

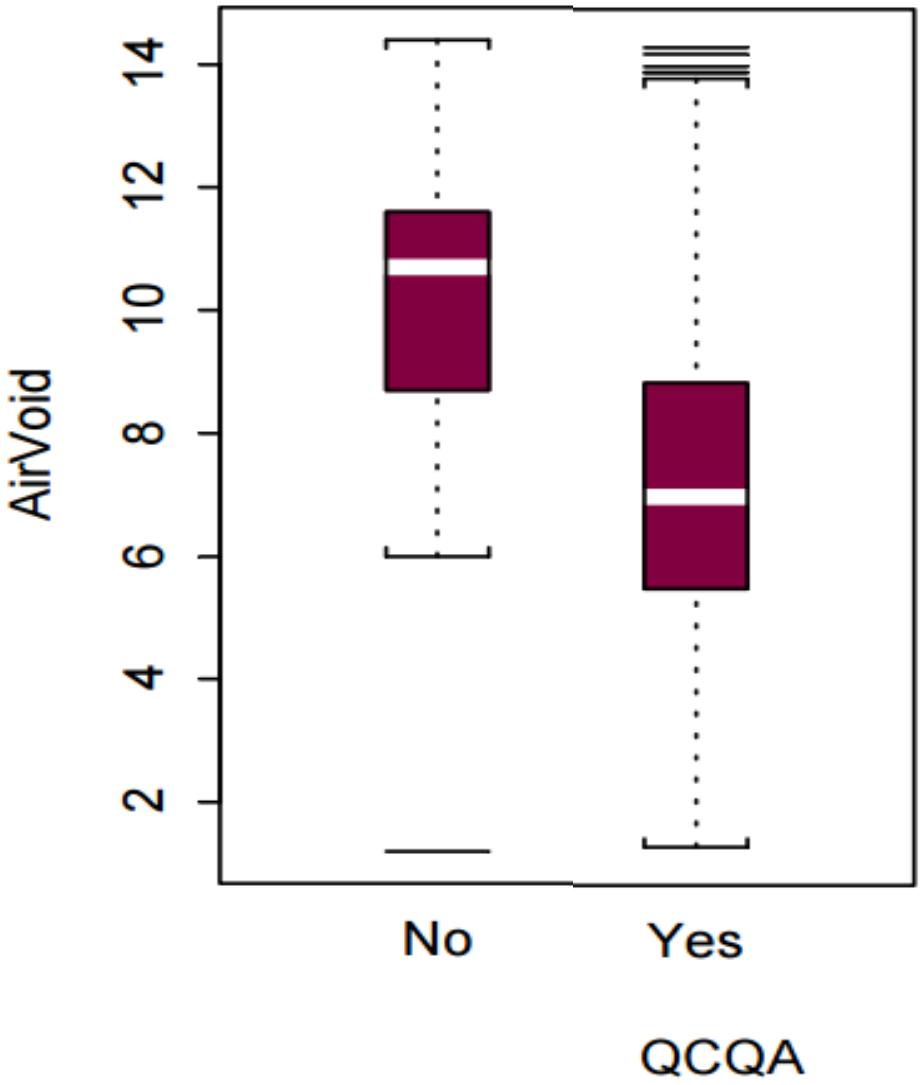
LCA evaluation of Materials and Construction

- For most local roads the impacts of materials impacts greater than construction equipment, transport impacts and smoothness
  - And most of the impacts in the materials are in the asphalt or cement binder
  - Recycling that minimizes use of new asphalt and cement has benefit
  - Must consider full life cycle not initial impact
- Construction quality is very important
  - Getting longer life per ton or cy of material is usually the most effective way to reduce environmental impacts
  - Better compaction has no downsides

Asphalt compaction specifications

- Is your asphalt living only half as long as it could?
  - Increase in air-voids of 1% = 10% shorter life
  - Typical air-voids achieved
    - If no measurement/penalties = 10 – 14%
    - If measurement/penalties if > 8% = 6 to 8%
    - Difference in life = -40% = -8 years
  - Why?
    - More air permeability = aging = raveling + cracking
    - More holes in it = cracking
    - More water permeability = moisture damage + aging

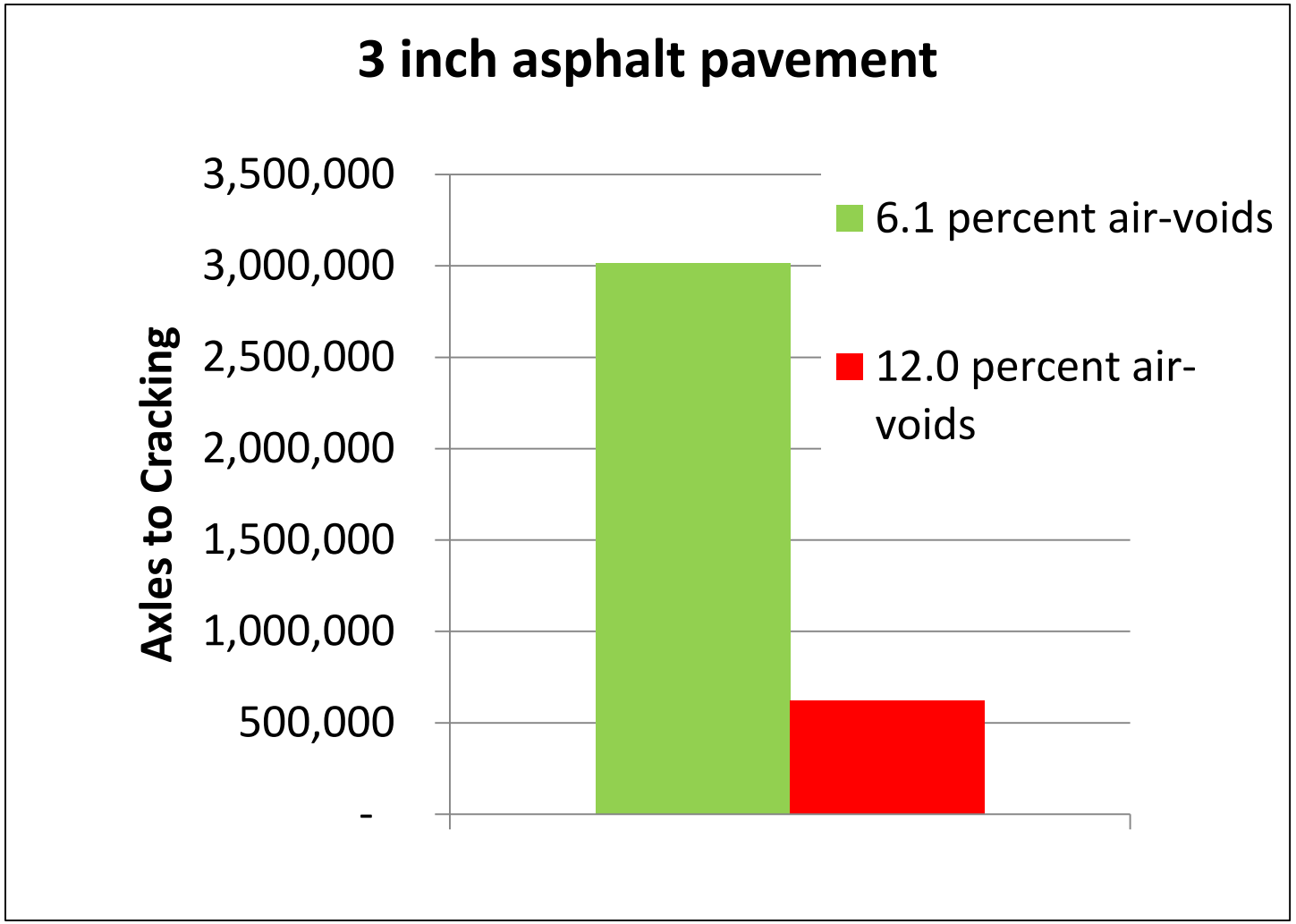
Caltrans experience with method spec vs using in-place measurement and penalties (QC/QA)



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

"Trust but verify"

Effect of compaction on axle loads to cracking



Simulation based on FHWA Westrack project field results

What you need to do

- Use a quantitative (QC/QA) specification to measure compaction, do not mix method requirements (how to do the compaction) in the specification
- 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
- Collect and keep cores in case of a dispute
- Apply payment reductions if they don't meet your specification, and enforce those payment reductions

LCCA and LCA example: 8% vs 12% air-voids

- Assumptions:
  - Rural pulverize HMA, compact, 4 in. HMA
  - $26/sy
  - 12% air-voids = 12 year life
  - 8% air-voids = 18 year life
- Net present cost* over 50 year period:
  - 12% air-voids = $4.36 million
  - 8% air-voids = $3.09 million = **29 % less cost**
- Greenhouse gas emissions are **34% less**

*2% discount rate

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?

Concrete mix specifications

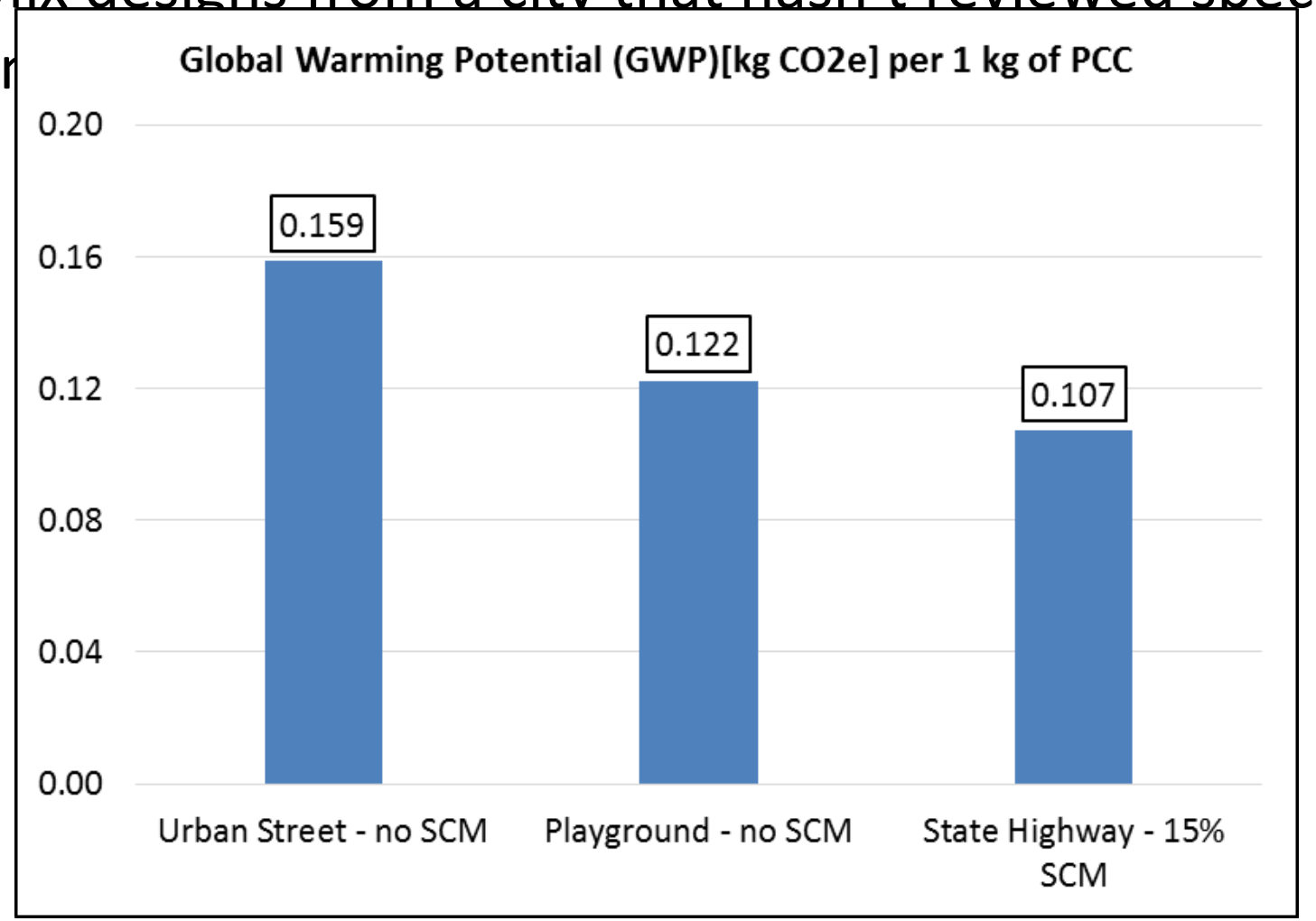
- Older concrete specifications
  - Written to ensure enough cement to meet strength and durability requirements
  - Often included minimum cement content
- Modern concrete mix designs
  - Minimize need for portland cement
  - Replace with supplementary cementitious materials (SCM
  - Minimize amount 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
  - Decrease cost
  - Decrease environmental impact
  - Increase durability of the concrete
- 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/

Other options that can have both cost and environmental benefits

- Reclamation/recycling of asphalt pavements
- Use of concrete demolition as aggregate base
- Use of RAP in asphalt mixes
- Bonded concrete overlays on asphalt with high supplementary cementitious material content
- Rubberized asphalt
- Rubberized cape seals
- In all cases, need to have good pavement engineering and especially good construction quality control
- Guidance regarding many of these items will be coming to CCPIC this year based on Caltrans and federally funded work

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)

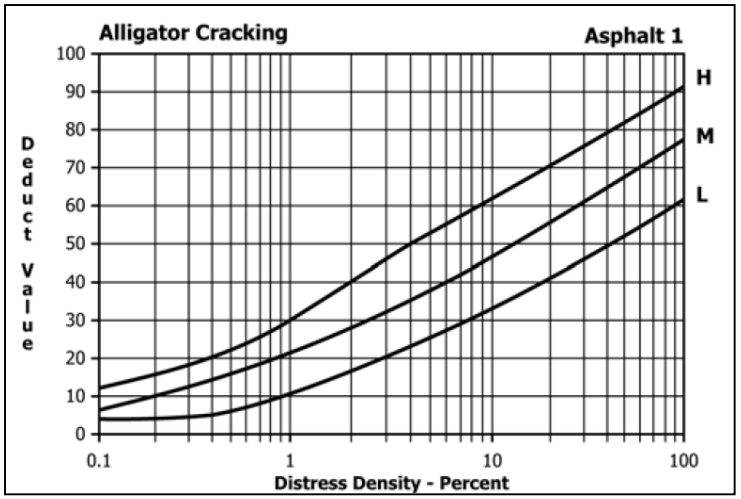
- Like FDR but set up a mobile plant on site
- Mill out asphalt, process on site, put back
- Can do any required subgrade stabilization

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

Pavement management
Use of PCI vs measured cracking, rutting

- PCI is amalgamation of different distresses
- Can have same PCI for very different conditions
- Engineering meaning in the condition survey is lost



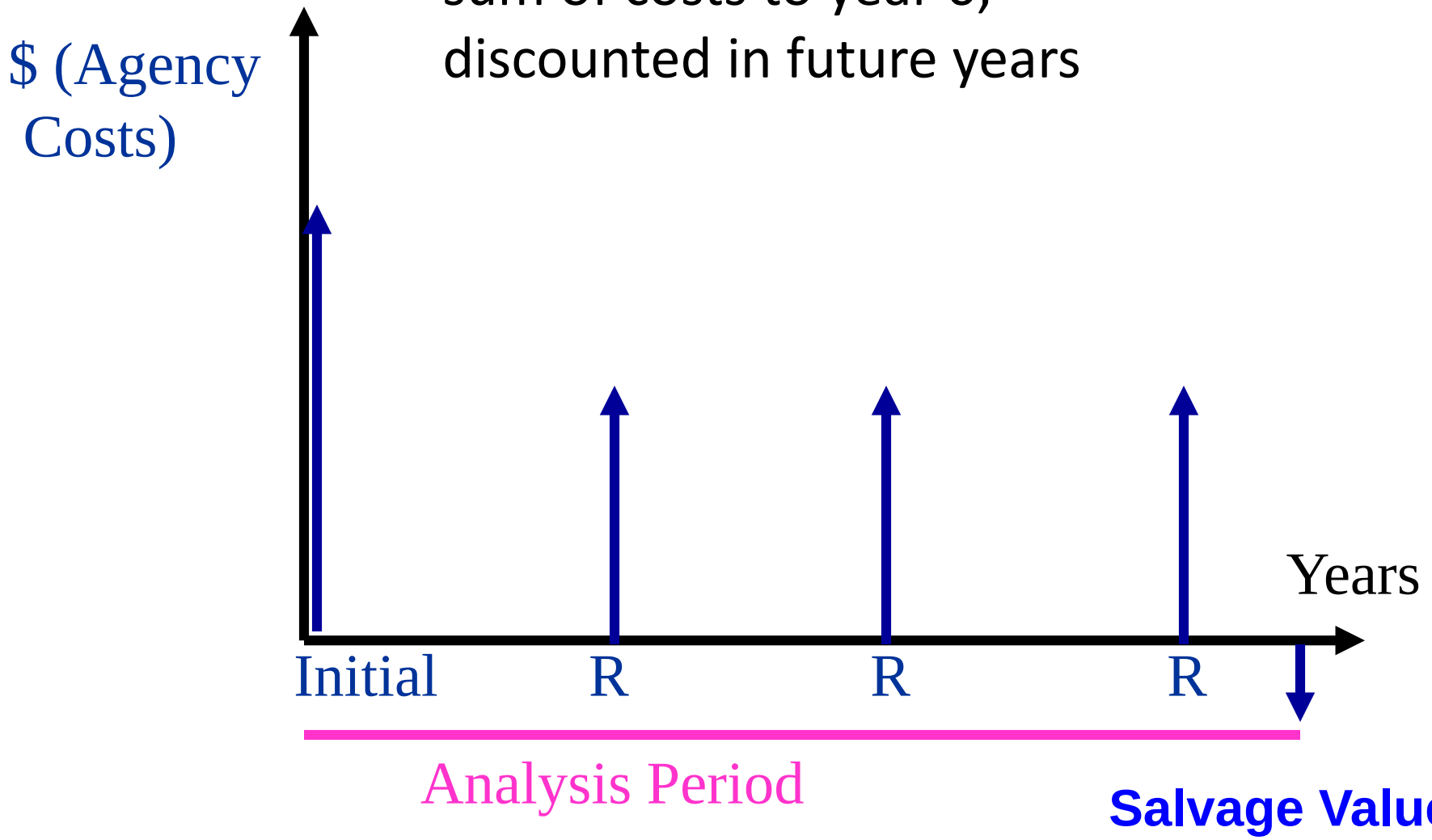
- Recommend
  - Use PCI as communication tool for management/public
  - Manage asphalt pavement conside
    - Cracking type (traffic related wheelpath cracks, aging/shrinkage related out of wheelpath cracks)
    - Other distresses (rutting, raveling)

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

Pavement management
Rehab with no preservation

- Net present value = sum of costs to year 0, discounted in future years



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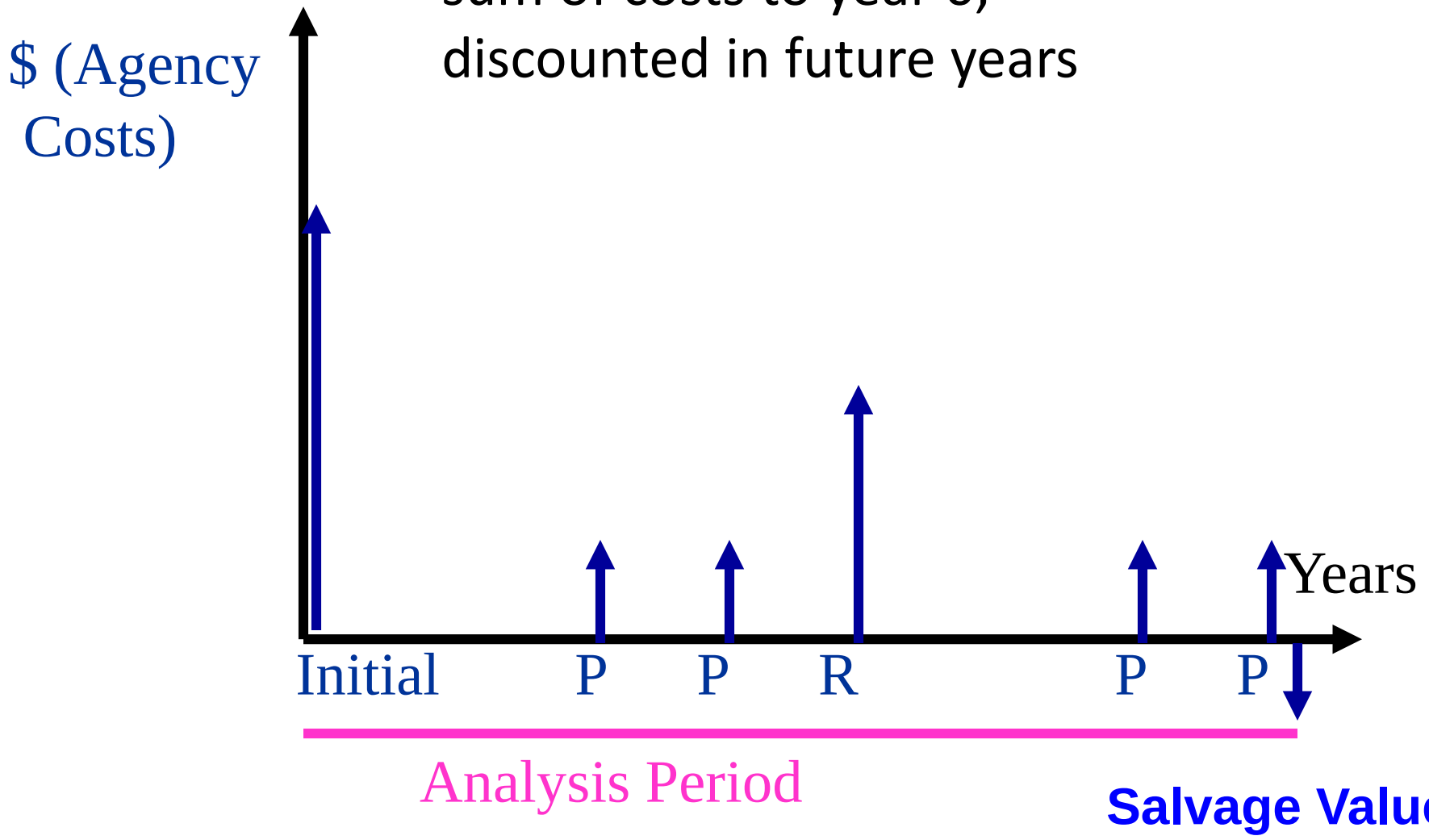


LCCA results
Urban alternatives

Activity	$/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

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

Activity	$/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 scenario 14% more cost
- Preservation scenario 12% less cost; 8% less GHG

What you need to do

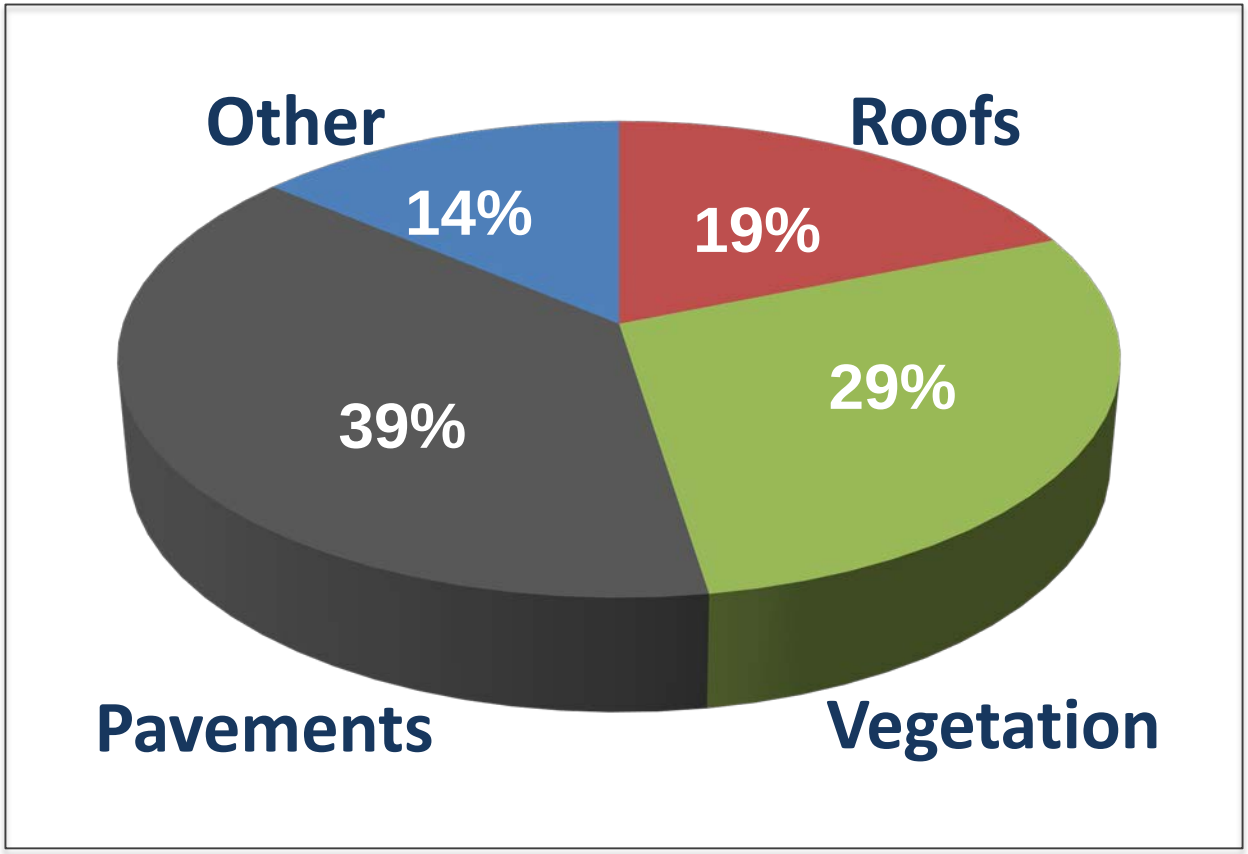
- Pavement management
  - Do engineering work based on truck traffic level, cracking and surface defects data, not PCI
  - Use your costs and LCCA to develop best treatment practice and preservation timing
    - Need performance models
    - Requires condition survey, traffic and as-built data
  - Learn to use LCCA to discuss preservation spending with council/board
  - CCPIC has created simple LCCA spreadsheet tool, currently being piloted

Building pavement knowledge and getting it into practice

- CCPIC is developing a Pavement Engineering professional development certificate
  - Aimed for local government staff and their consultants
  - Through ITS Berkeley Tech Transfer
- Are you selecting pavement consultants based on pavement knowledge?
  - What questions are you asking in the interview?

Pavements are no longer just about carrying cars and trucks

Pavements are an important part of the urban environment



Sacramento

Akbari et al. 2003 <doi:10.1016/S0169204 6(02)00165-2>

Pavements = urban hardscape
not just roads and streets

- Stormwater management, groundwater infiltration
- Tire pavement noise
- Human thermal comfort
- Pedestrian and bicycle functionality
- Better interaction with urban forestry

Final Thoughts: Communicating with the Public about Pavement

- What is our message about what is being done that is positive and better
- Livability and Quality of Life, relate to people's lives and wallets/purses
  - Access by different modes, shared prosperity, environmental impact, public participation, safe and healthy communities, wise use of resources
- Set goals and measure and report progress
- Have the right messengers
  - Trusted messengers who are informed about pavement progress, not necessarily pavement engineers!

Thank you, Questions?

- Tech briefs and other information at:
  - www.ucprc.ucdavis.edu/ccpic
- John Harvey
  - University of California Pavement Research Center (Davis, Berkeley)
  - jtharvey@ucdavis.edu