Improving Environmental Sustainability Throughout the Pavement Life Cycle

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What is “Sustainability”?

Good pavement is needed to access jobs, education, health care, food, social connections, and to move freight

Sustainability has always been the goal, the system boundaries have changed

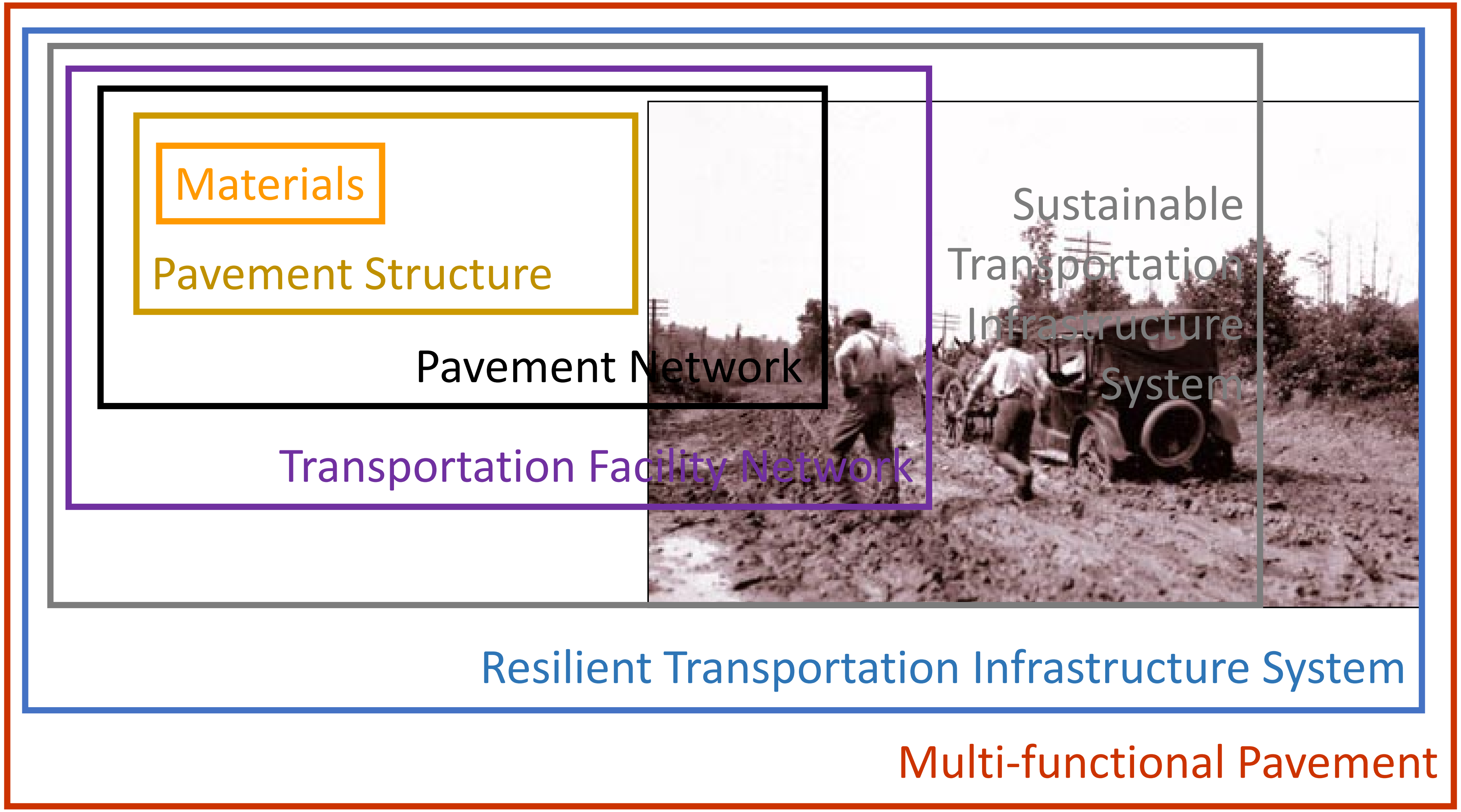
System boundaries historically have been based on:

- Engineering functionality goal of serving motor vehicles
- Financial goal of minimizing either initial cost or life cycle cost

“Sustainable” in the context of pavements now refers to ability to:

- Achieve the engineering goals for which it was constructed
- Preserve and (ideally) restore surrounding ecosystems
- Use financial, human, and environmental resources economically
- Meet basic human needs such as health, safety, equity, employment, comfort, and happiness

Changing System Boundaries for Pavement Thinking over Last 80 Years



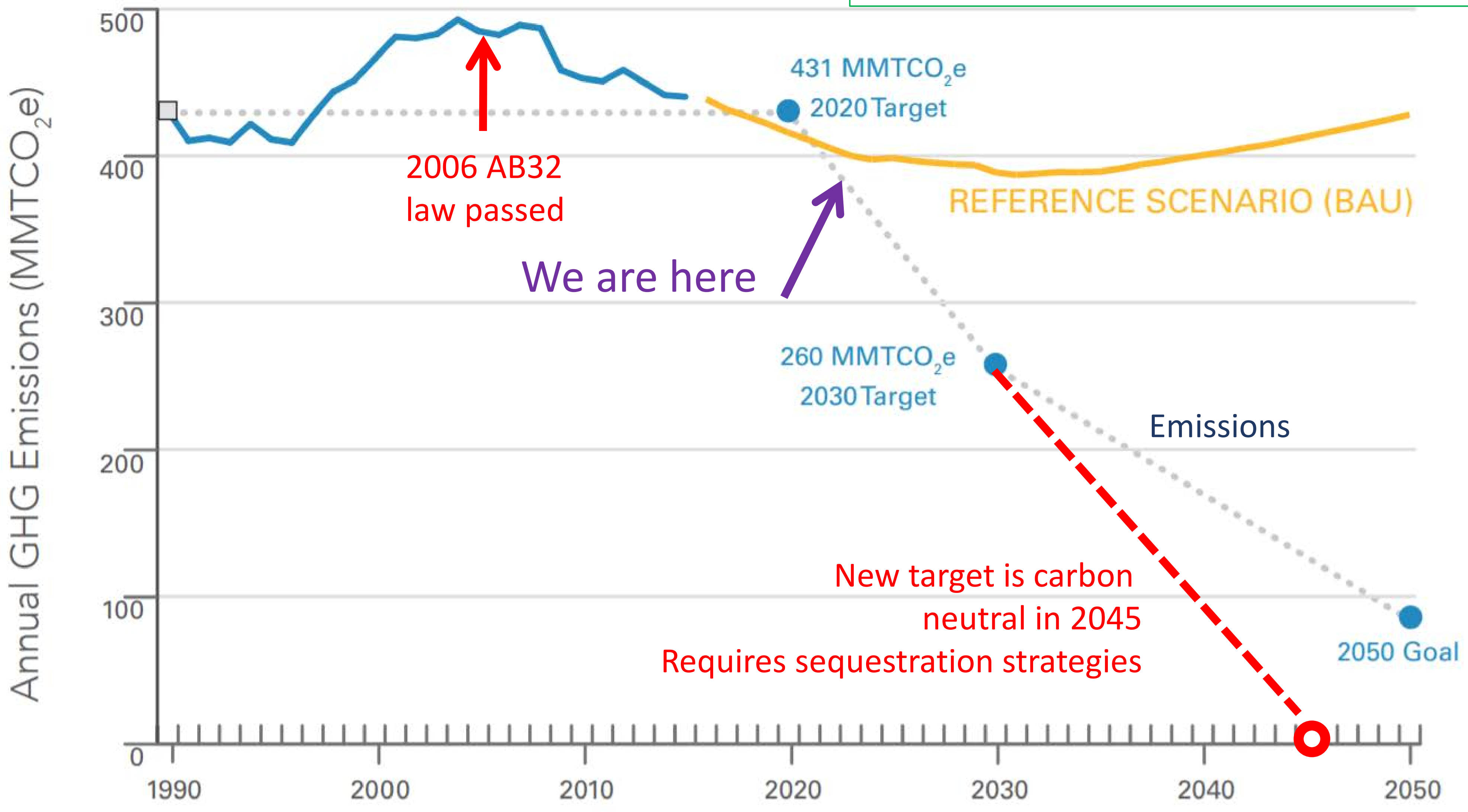
Aspirational Goals for Pavement

- Cost-effective
- Minimal environmental impacts (or benefits) and finite resource use
- Costs, environmental impacts and benefits, and social benefits equitably shared
- Quantification in everyday practice is needed to move with a faster pace of change towards achieving these goals

California Climate Change Targets and Transportation Strategies (ref 2015)

1. Land use planning
2. Change trucks and cars to natural gas, electric, fuel cell 3. Reduce vehicle travel

Role of pavement?



https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf

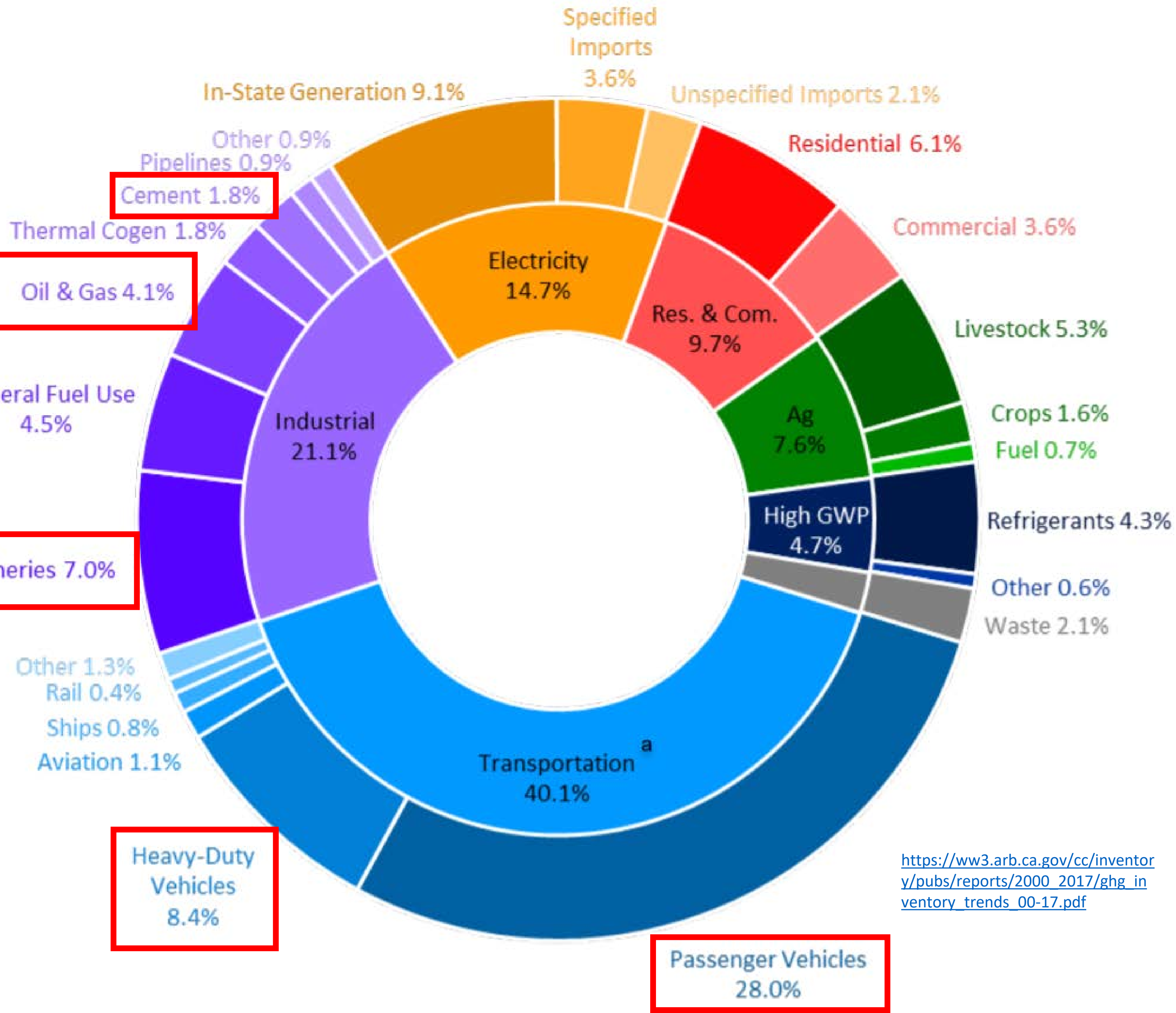
2017 California GWP inventory, 2019 similar

Possible Pavement Reductions	MMT/ year
Rolling resist to optimum	1.5 to 3.0
Reduce cement use 50%	0.2
Reduce virgin asphalt use 50%	0.7
Reduce hauling demolition, oil, stone haul 10%	0.6
TOTAL	**3.0 to 4.5**

Pavement contributions to California GWP

0.7 to 1.0 % of 429 MMT state total

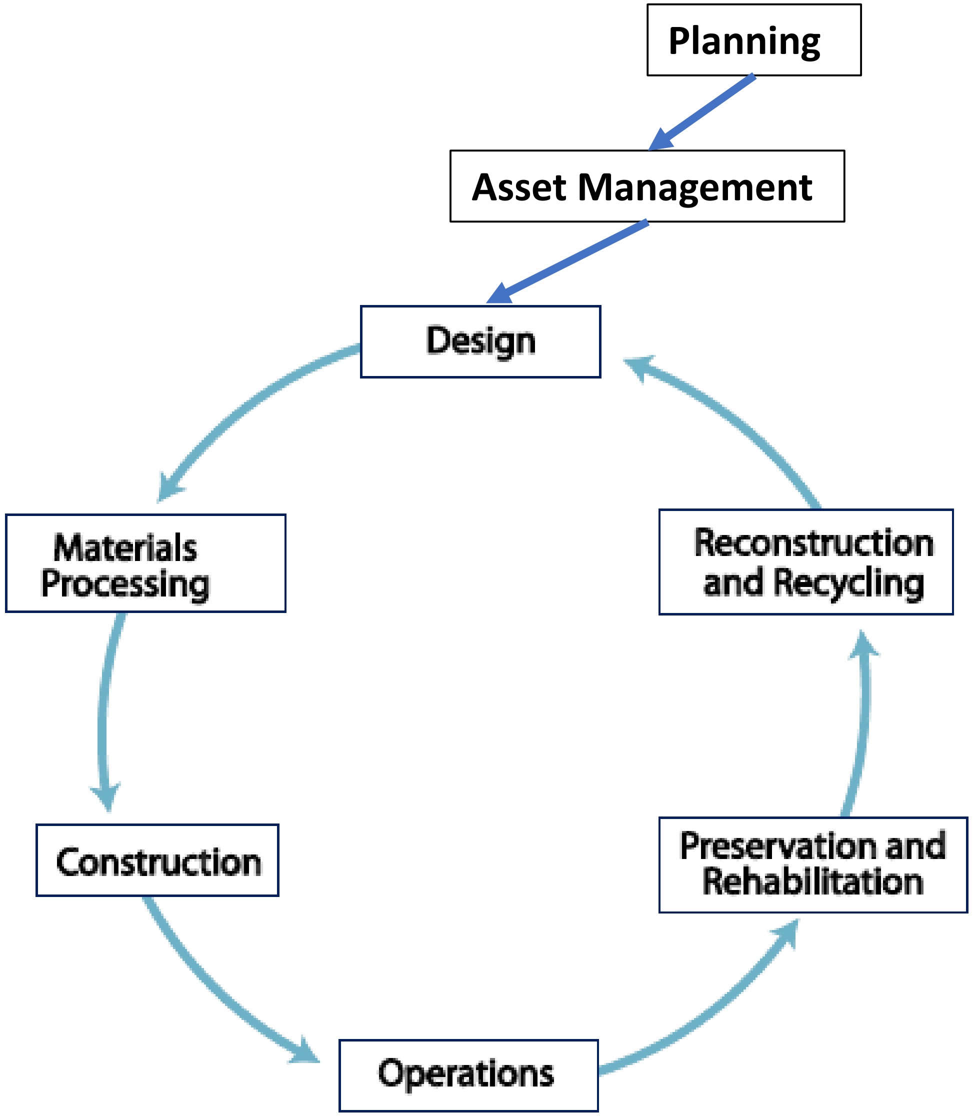
1.0 to 3.6 % of 126 MMT transportation total



https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf

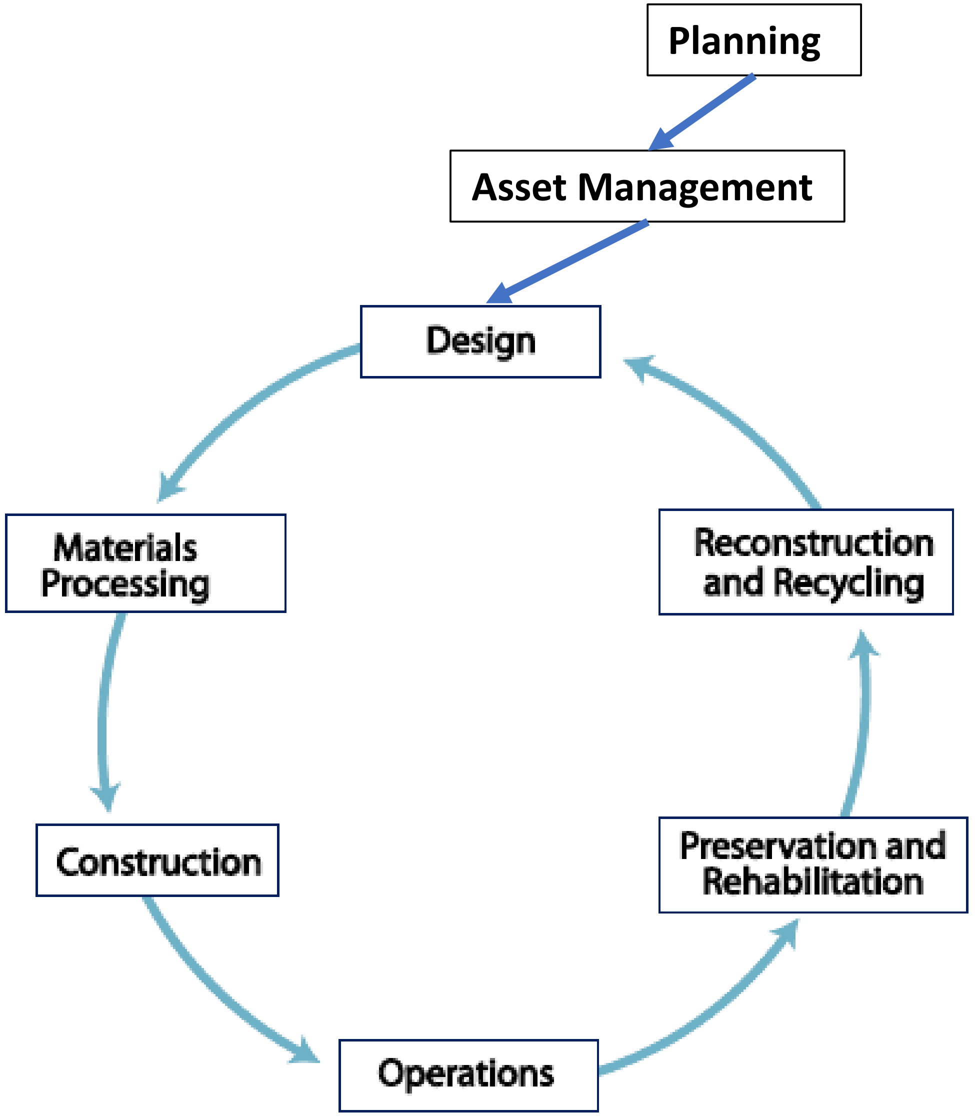
Reducing Pavement Costs and Environmental Impacts

- Planning:
  - Environmental justice of impacts and benefits of pavement
  - Inclusion of active transportation & multi-modal
- Asset management:
  - Optimizing programming of preservation, maintenance, rehabilitation, reconstruction
- Design:
  - Use less material or less impactful materials to achieve same life
- Materials Processing
  - Contractor optimizes material for cost to meet performance and environmental impacts (EPD)

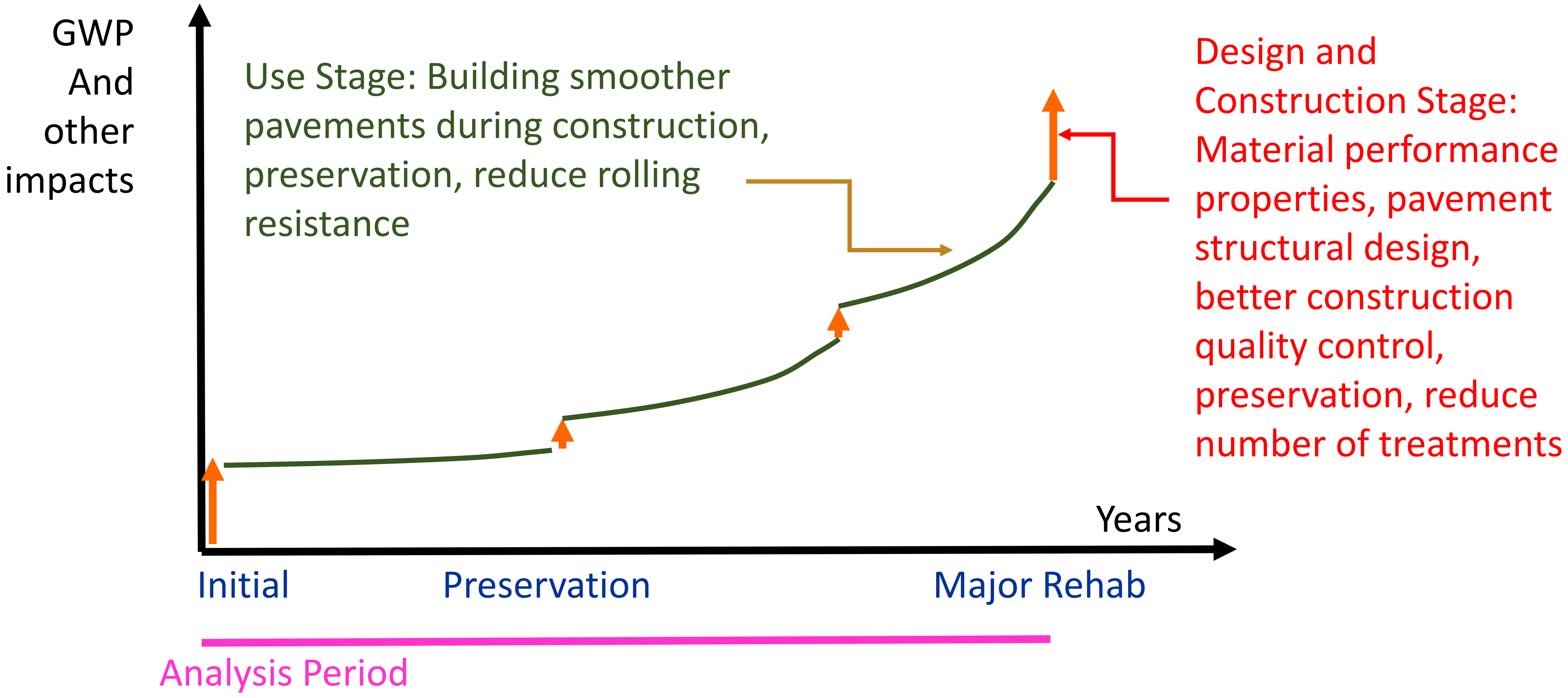


Reducing Pavement Costs and Environmental Impacts

- Construction Specifications:
  - Use construction quality control to get maximum life from materials; Measure the quality; Enforce the specifications
  - Allow use of lower impact materials if same or better life
- Operations:
  - Minimizing construction work zones
  - Minimizing energy/fuel use from pavement vehicle interaction
- Preservation, Maintenance, Rehabilitation
  - Extend the life of materials with preservation
  - Provide structural capacity for heavy vehicles
- Reconstruction, Recycling
  - Rebuilding worn out pavements with minimal new materials



Environmental Impacts over the Pavement Life Cycle

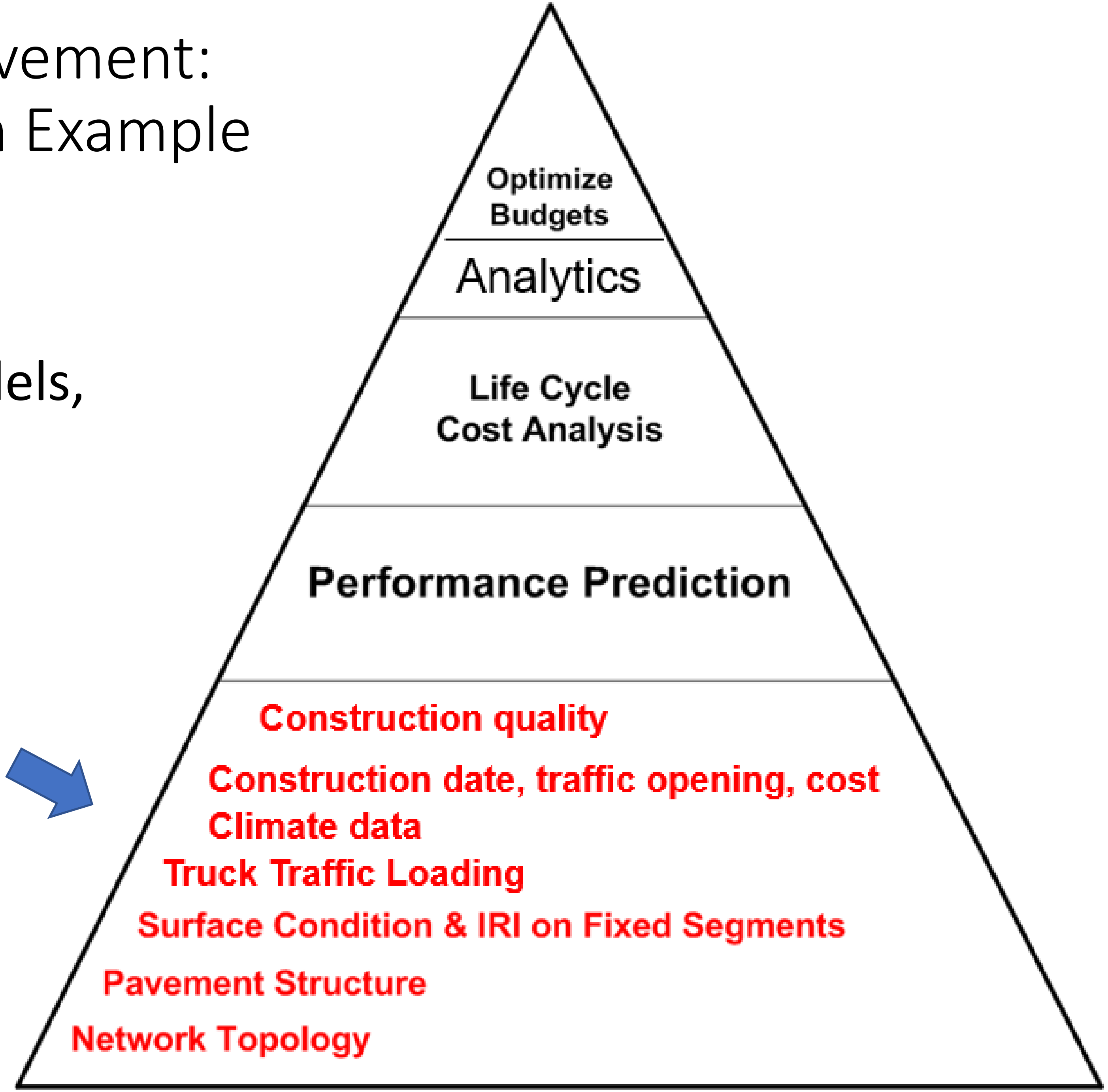


Information Technology and Pavement: Pavement Management System Example

- Databases first, then models, software last

Data

Need strong foundation to perform desired operations

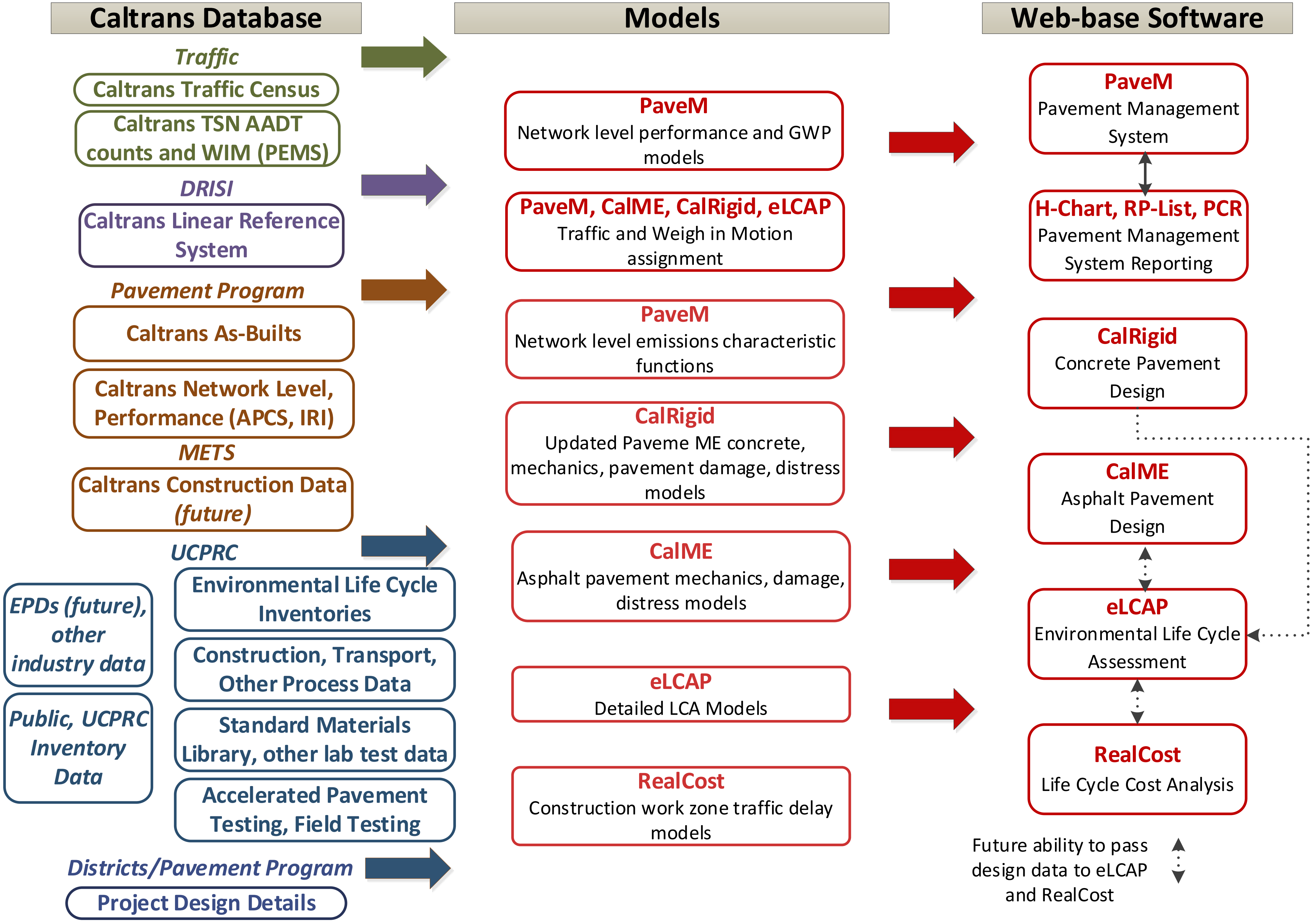


Integration of Data Definitions in Caltrans Pavement Tools

- Tools
  - Pavement asset management tool
  - Materials testing methods
  - Construction materials performance related specifications
  - Pavement design tools
    - Asphalt (Pavement ME)
    - Concrete (CalME)
  - Project life cycle cost analysis tool
  - Project environmental life cycle assessment tool

- Data definitions
  - Materials names and definitions
  - Treatment names and definitions
  - Mechanistic properties of materials
  - Pavement distress definitions
  - Truck type definitions
  - Traffic data definitions
  - Pavement failure definitions (distresses and smoothness) and M&R treatment trigger levels
  - Location reference system

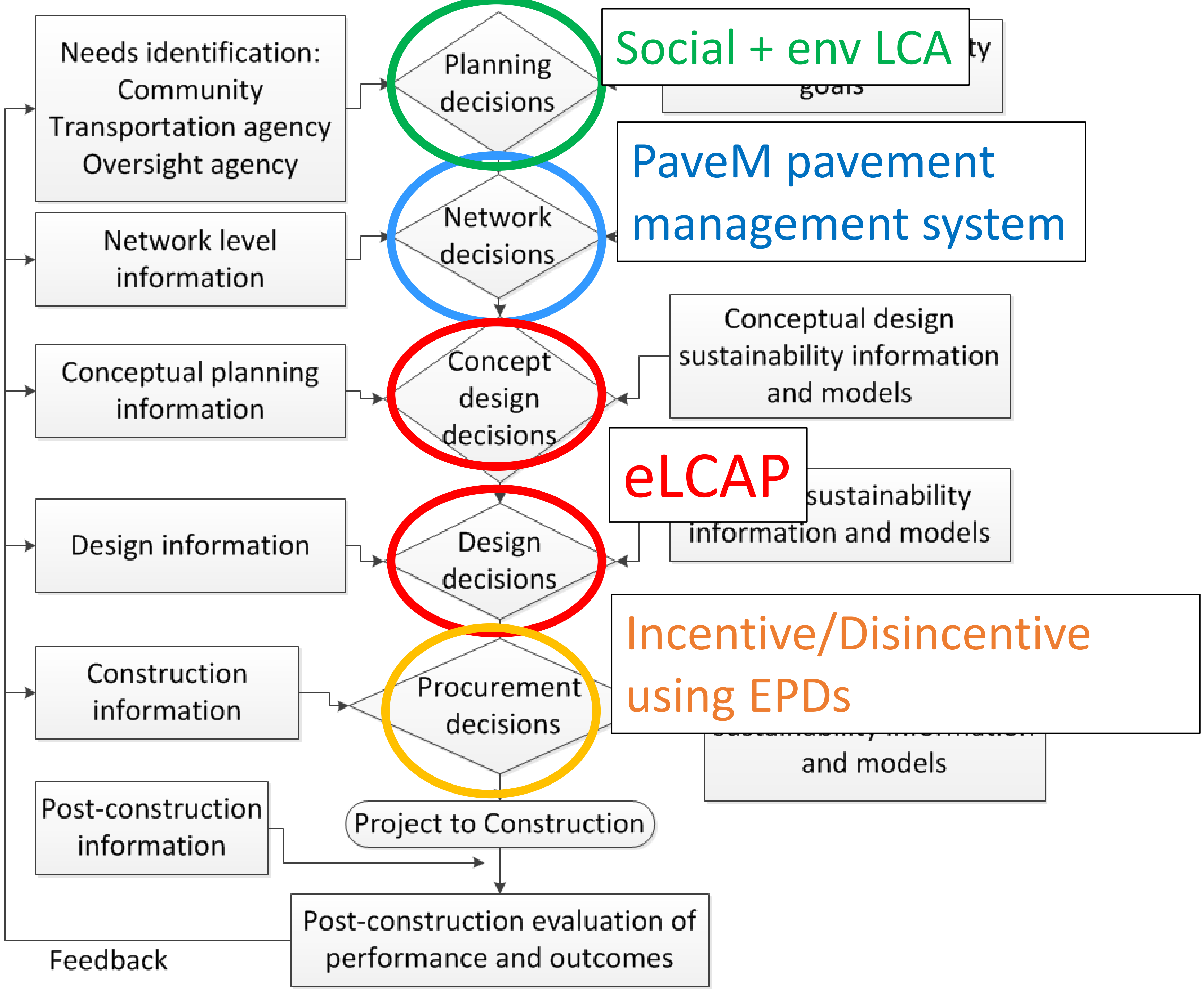
Caltrans integrated data, models, software tools



Objective: web-based integrated LCA tools for:

- Planning
- Network
- Concept
- Design
- Procurement

With complete life cycle regionally applicable data



Good materials performance can reduce emissions; Materials must be in same category for comparison

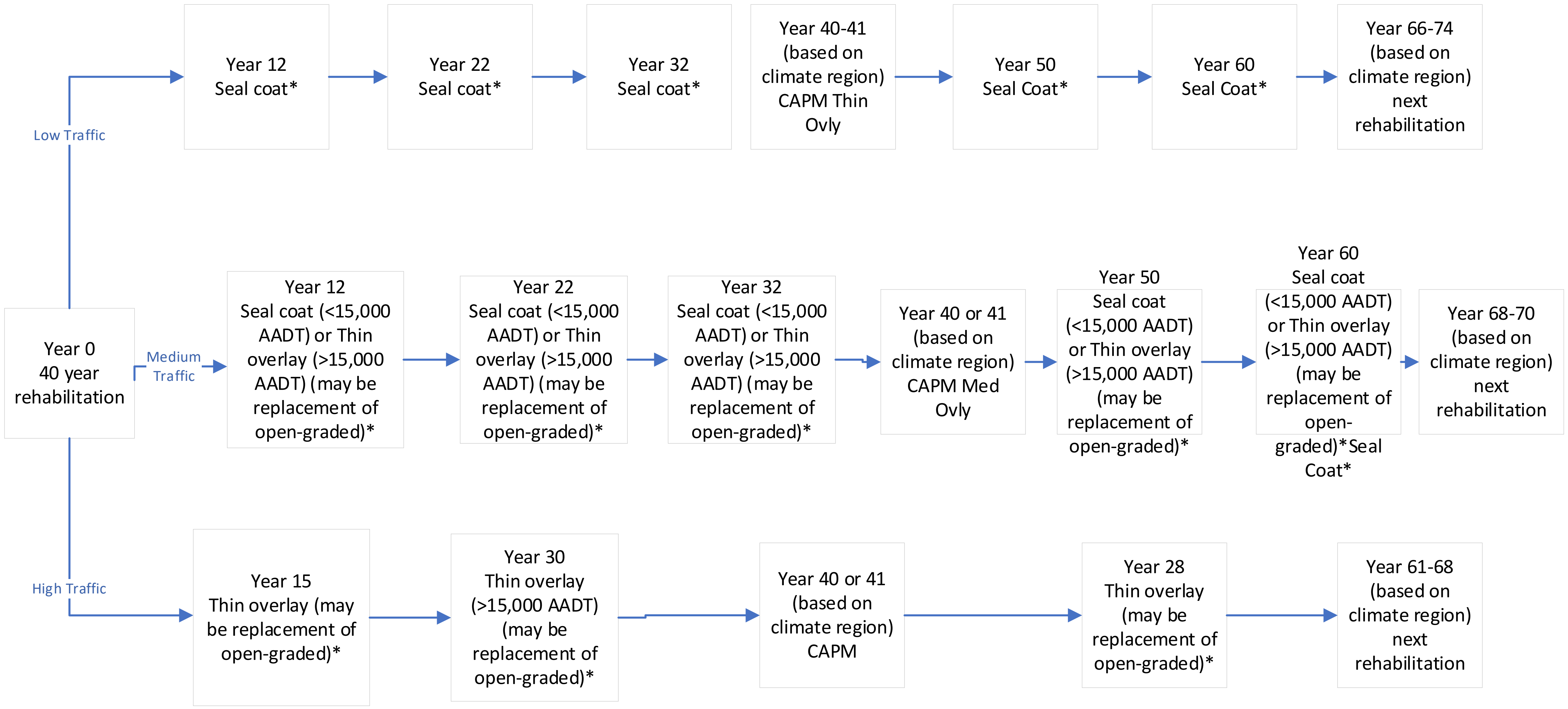
- A material with low GWP on their cradle-to-gate EPD may produce more GWP over the life cycle of the infrastructure

- Greater use of EPDs in procurement will require greater use of performance related specifications and tests to categorize materials to avoid this potential unintended negative consequence

Analysis period = 60 yrs	
Material A	Material B
0.85 GWP	1.0 GWP
15 year life	20 year life
15	20
30	40
45	
Total GWP	Total GWP
3.4	3.0

Project level environmental life cycle assessment

- eLCAP project-level life cycle assessment software uses:
  - Same treatment and material definitions as design, PMS and LCCA tools
  - Materials mix designs from State-wide Materials Library database used in CalME and Pavement ME design tools
  - Roughness models for pavement-vehicle interaction causing excess fuel use from PMS
  - PMS emissions models are simplified from eLCAP data and models
- Pavement treatment life cycles can be determined from:
  - New life cycle cost analysis tables (based on CalME or Pavement ME, and PMS)
  - Design simulations from CalME, Pavement ME for unique design problems



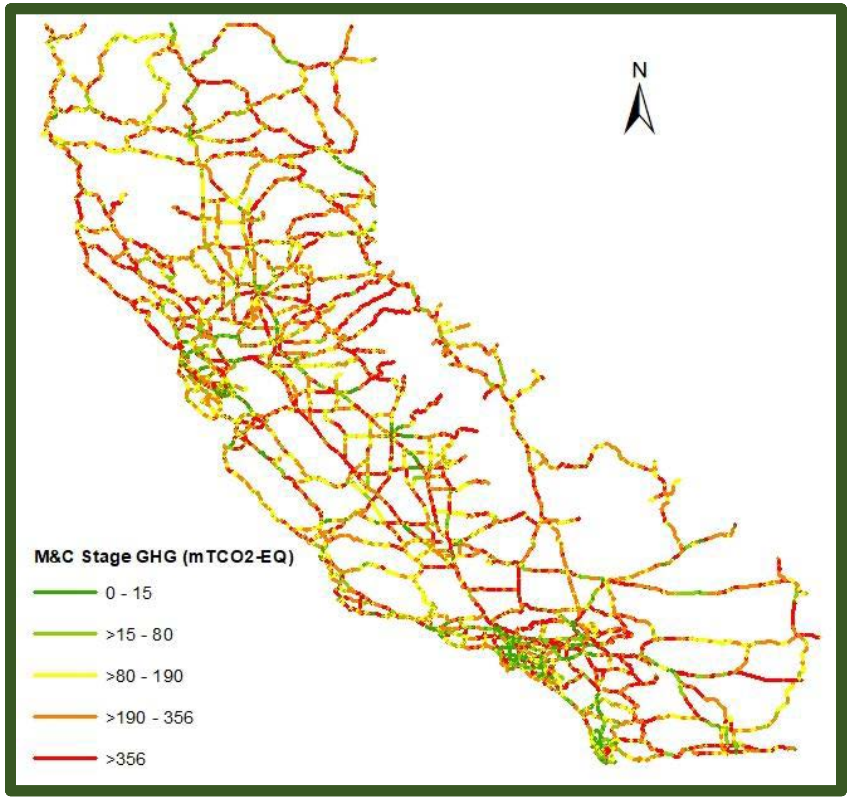
* HM-1 included in Annual Maintenance Coast

Low Traffic AADTT = < 350
Medium Traffic AADTT = 351 to 1400
High Traffic AADTT > 1400

ME Design calibrated with PMS data used to produce LCCA and LCA M&R life cycles

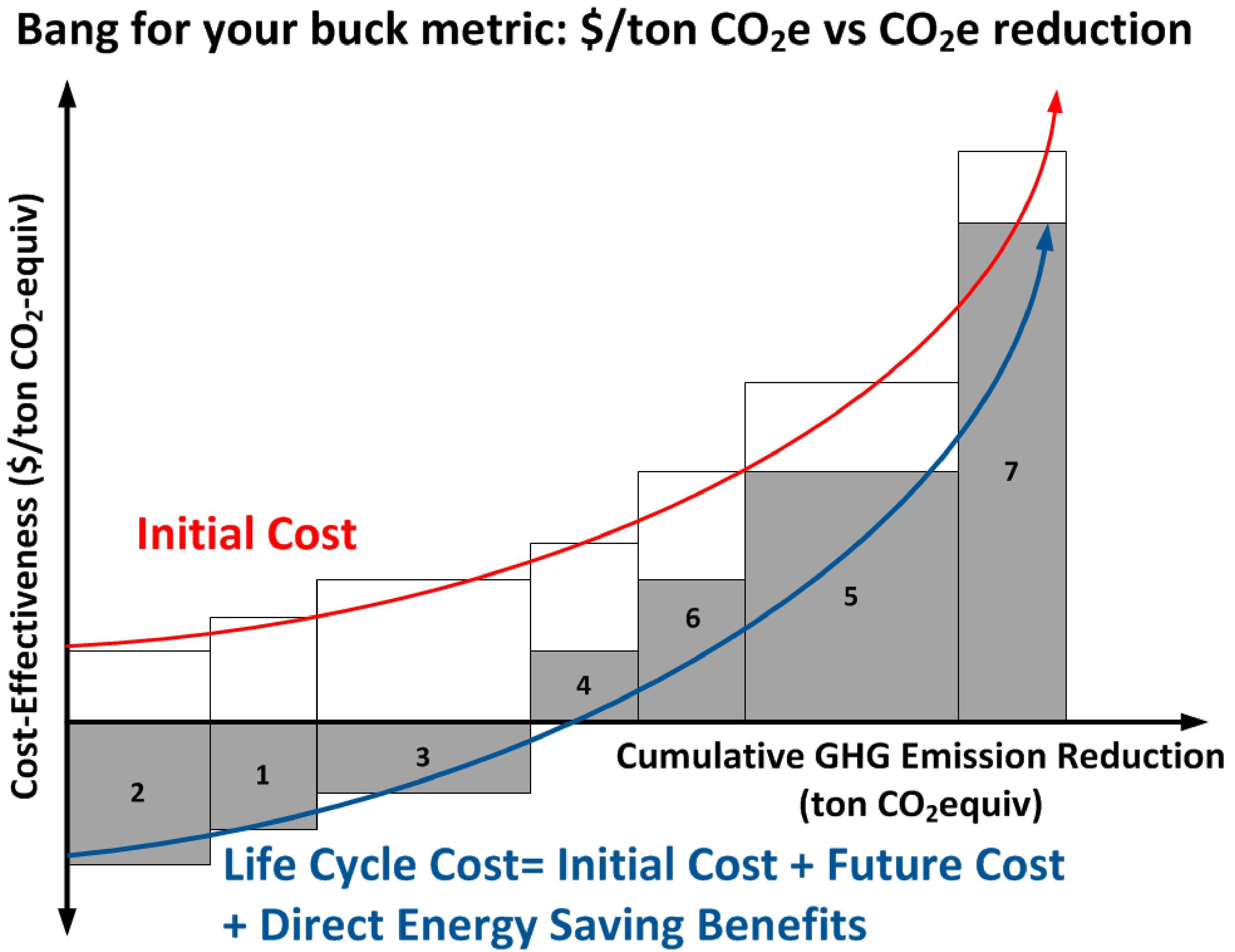
Environmental impact analysis in the PMS
40 year look ahead at M&R program
Materials, construction, pavement IRI/vehicle

- Information needed to calculated GHG in PMS
  - Materials & Construction GHG for each treatment
  - Traffic per lane
  - IRI for all lanes on the section and IRI prediction models
  - GHG from vehicles
- NAPA sponsored framework for implementation of these ideas into other state PMSs



Need first-order analysis to prioritize which ideas to further investigate

- "Supply curve" or "Marginal Cost of Abatement Curve"
- Combines LCA and LCCA
- Has been used for:
    - Caltrans changes to internal operations
    - Local government review of climate action plans

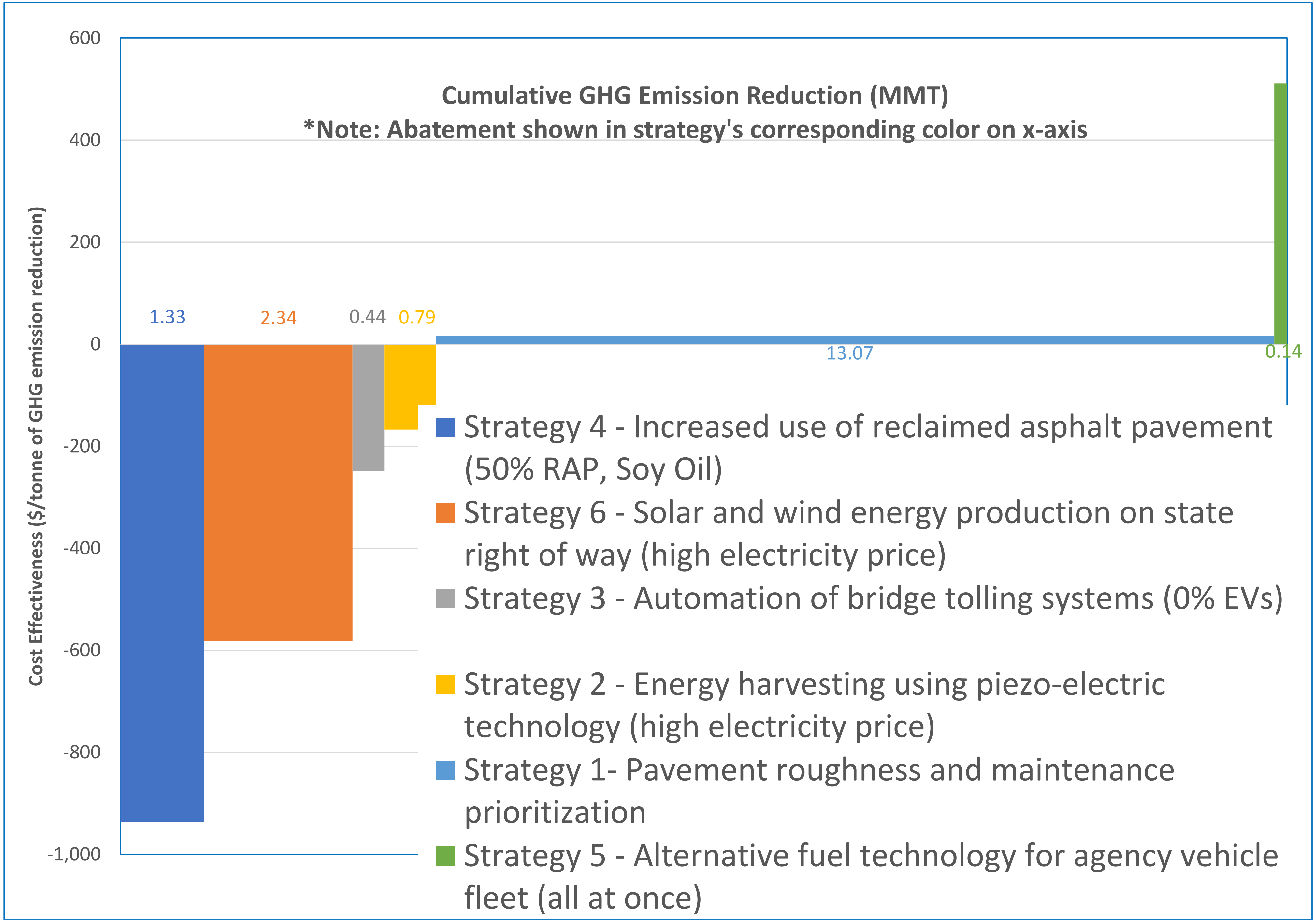


Adapted from Lutsey, N (2008) Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-08-15 http://www.ucprc.ucdavis.edu/PDF/UCPRC-WH-2019-01.pdf

Example Supply Curve Output

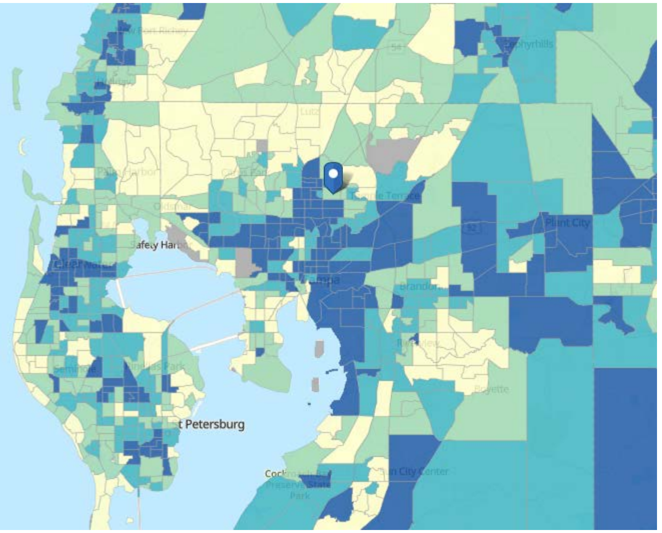
Includes Sensitivity Analysis

Optimistic scenarios shown



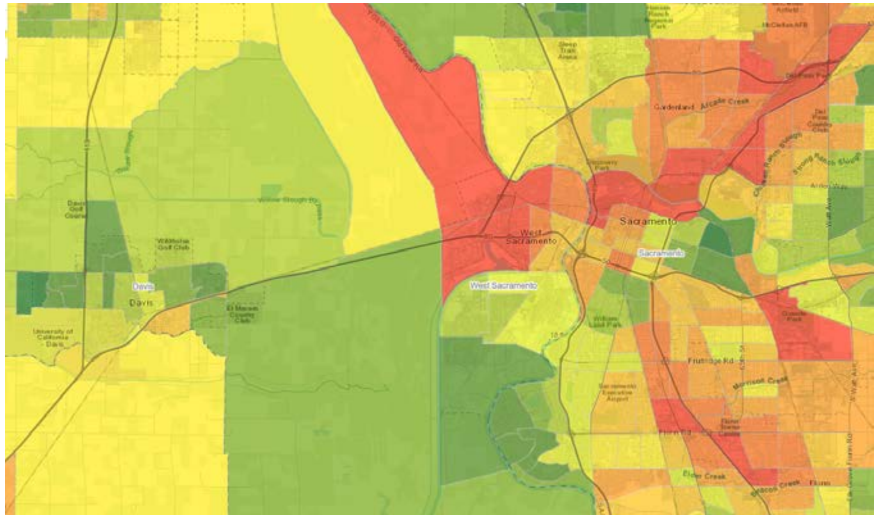
Integration of social vulnerability in LCA and decision support

- Quantification of impacts from pavement life cycle assessment tools
  - Impacts need to be geographically tied to census tract locations
- Quantification of access to good and bad pavement from PMS
  - Done by City of Oakland
- Mapping of social vulnerability + environmental burdens at “neighborhood” scale:
  - Social vulnerability based on age, race, income, existing health conditions, etc.
  - Existing burdens based on mapping of existing air pollution, water pollution, etc.



Social Vulnerability Index (federal)

CalEnviroScreen 4.0 (state)

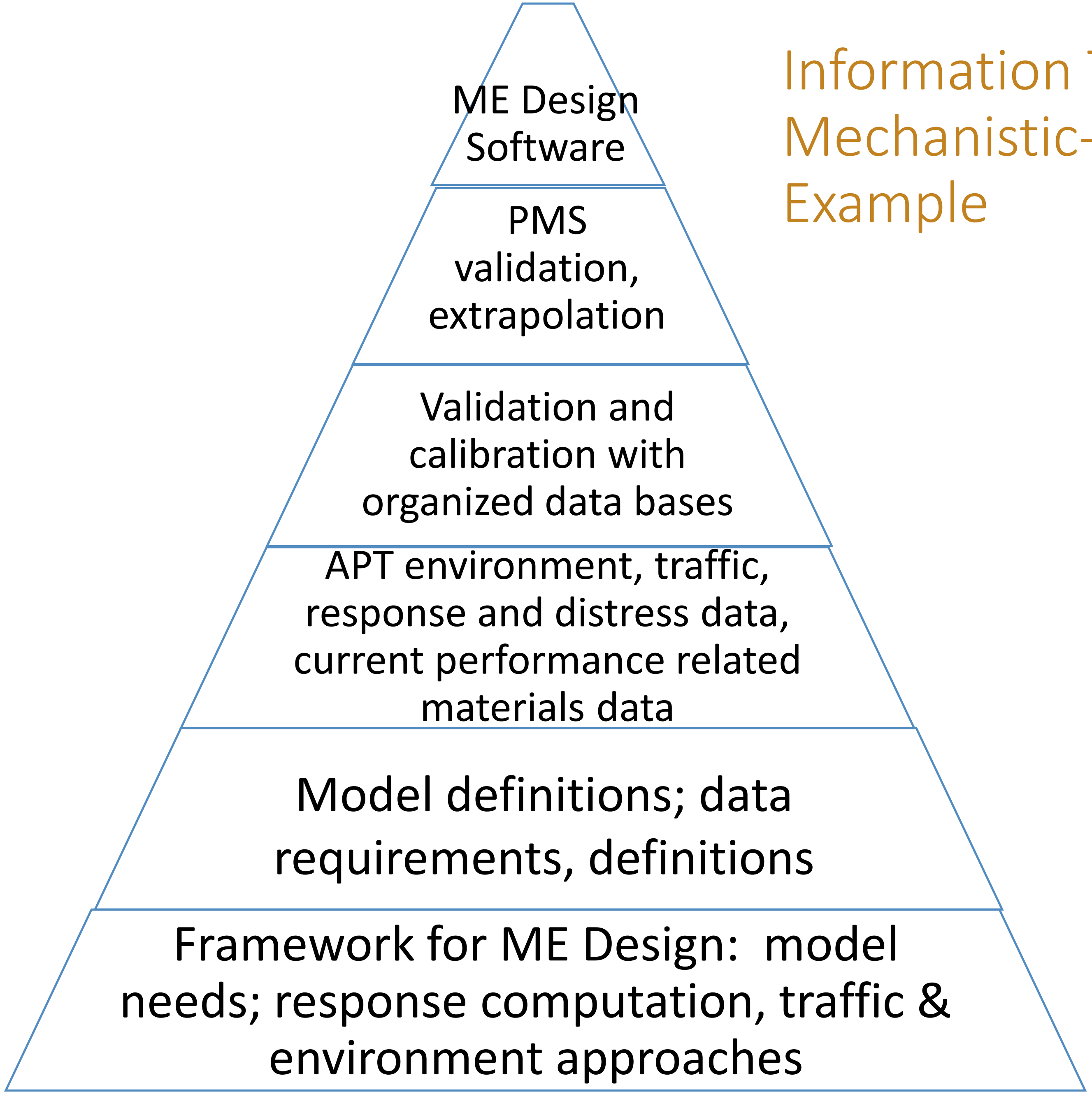


Takeaways

- Implementation
  - Requires planning and a coordinated strategy
  - Requires data and tools that can be readily used, updated, improved
- In pavement, implementation and continuous improvement facilitated by integration of data and tools
- Implementation of integrated data and tools can help achieve cost savings, reduce environmental impacts, answer important questions
- Investment in human capital is essential for successful implementation
- Now is the time


Thanks to many
colleagues
Questions?

Information Technology and Pavement: Mechanistic-Empirical Pavement Design Example



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- Models
  - Empirical performance models (distress and IRI, not pavement condition index)
  - Traffic and truck growth models
  - Mechanistic-empirical damage models
  - Mechanistic-empirical distress models
  - Mechanistic-empirical design reliability approach
  - Cost models
  - Life cycle environmental impact models

Integration of social vulnerability into decision support

- Social LCA
  (S-LCA) will consider neighborhoods affected by environmental impacts and access to good pavement
- Goal is to make benefits of less pollution and impacts more equitable

Often tied to historical discrimination

California mapping shown