Environmental Assessment of Pavement Alternatives: Decision-Making in Light of Current Knowledge and Unresolved Questions

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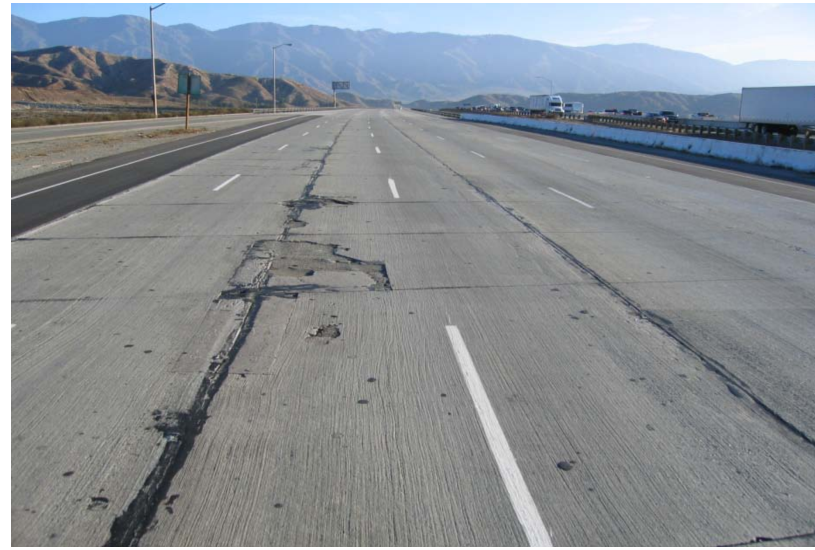
What is the pavement infrastructure?

- Freeways, highways
- Roads and streets
- Railroads and transit lines
- Airfields
- Land-side port facilities (container yards, loading areas)
- All have same issues regarding materials, design, management, environmental impact
- Focus today: streets and highways

Caltrans context



- 24,000 centerline kilometers, 80,000 lane-kilometers
  - 1/3 concrete pavement, urban high-volume freeways, 30-50 years old
  - 2/3 asphalt surfaced: composite, semi-rigid, full-depth and conventional asphalt structures, original structures 20-90 years old, much maintenance and rehabilitation

- 90 % of work is maintenance, preservation, rehabilitation, recycling, reconstruction

California context

- Since 1970, California's
  - population nearly doubled to 37 million
  - not much increase in highway network
  - estimated annual vehicle kilometers traveled quadrupled to 600 billion (400 billion vehicle miles traveled)
- Most state highway and much local work is reconstruction, rehabilitation, preservation work done at night or 24 hours/day working closures
- Need:
  - increased design lives (thicker pavement) for life cycle cost
  - faster construction (thinner pavement and faster materials) for traffic delay

Current situation facing decision-makers

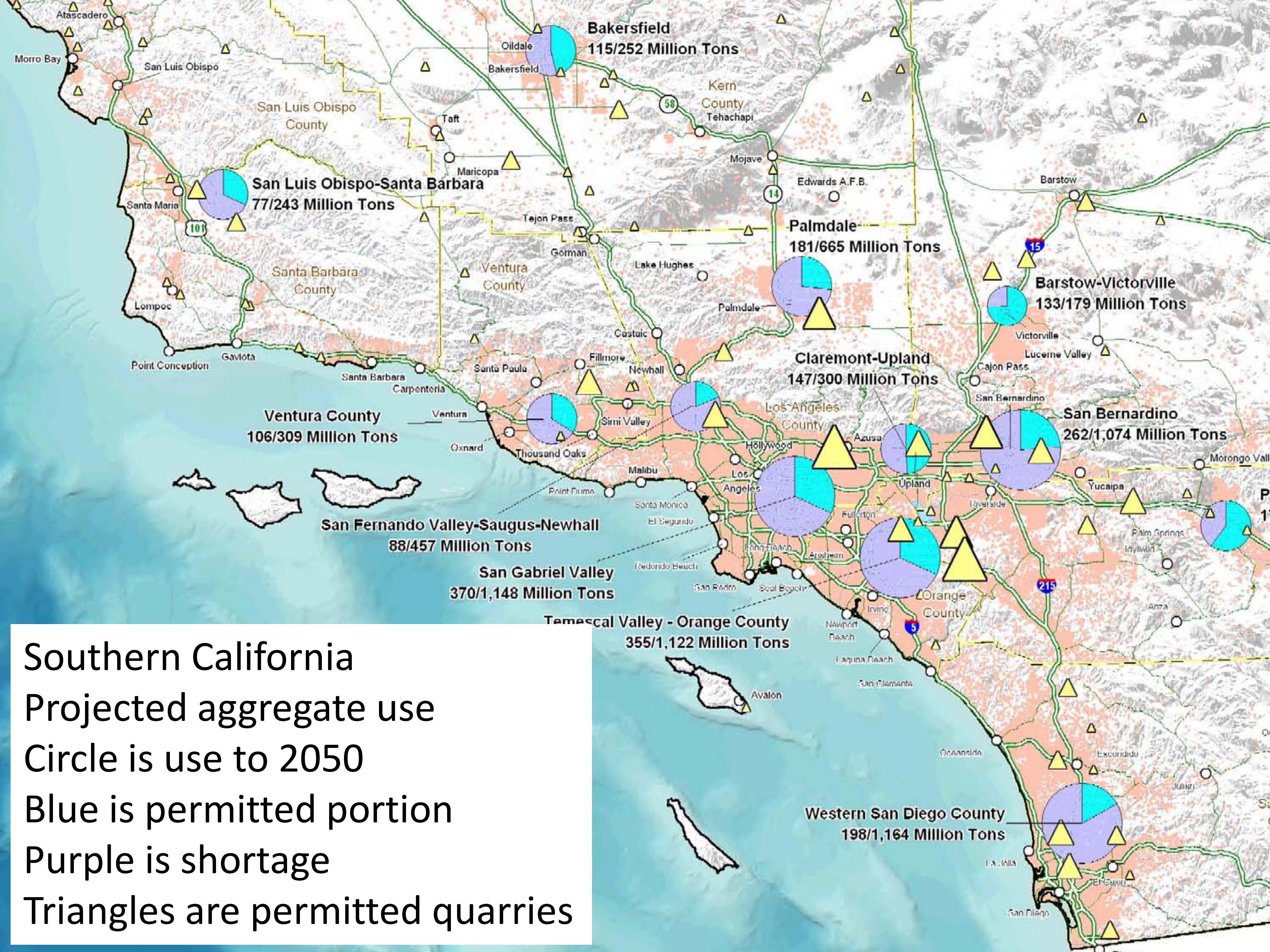
- Funding has not been sufficient to preserve existing infrastructure
  - Rougher pavements,
  - More costly to restore capacity when funding is available
  - Materials price fluctuations
- Intense competition from two competing industries (asphalt and concrete), each currently trying to win market share by "green marketing"
  - A great deal of information, most of it contradictory
- Political pressure for rapid implementation of green "rating" systems
  - Like LEED for buildings

Brief Overview of Life-Cycle Assessment (LCA)

- A method for characterizing and quantifying environmental sustainability
- Applies a "cradle-to-grave" perspective when analyzing products or systems
- Measures inputs and outputs of a product or system
  - Example inputs: energy, water, materials
  - Example outputs: air emissions, waste
  - Can be categorized into *impact categories*
- General standards set by ISO 14040 series
  - Provides general LCA guidance, but lacks detailed information necessary for individual products and systems

Why Apply LCA to Pavement?

- Three part state strategy for transportation for GHG emission reduction
  - Increase fuel economy of vehicles
  - Reduce GHG content of fuel
  - Reduce car and truck travel
- Can pavement be the fourth strategy?
  - Rate of market penetration can potentially be faster than other strategies
- Other environmental benefits: reduce regulated pollutants and non-renewable resource use



Southern California

Projected aggregate use

Circle is use to 2050

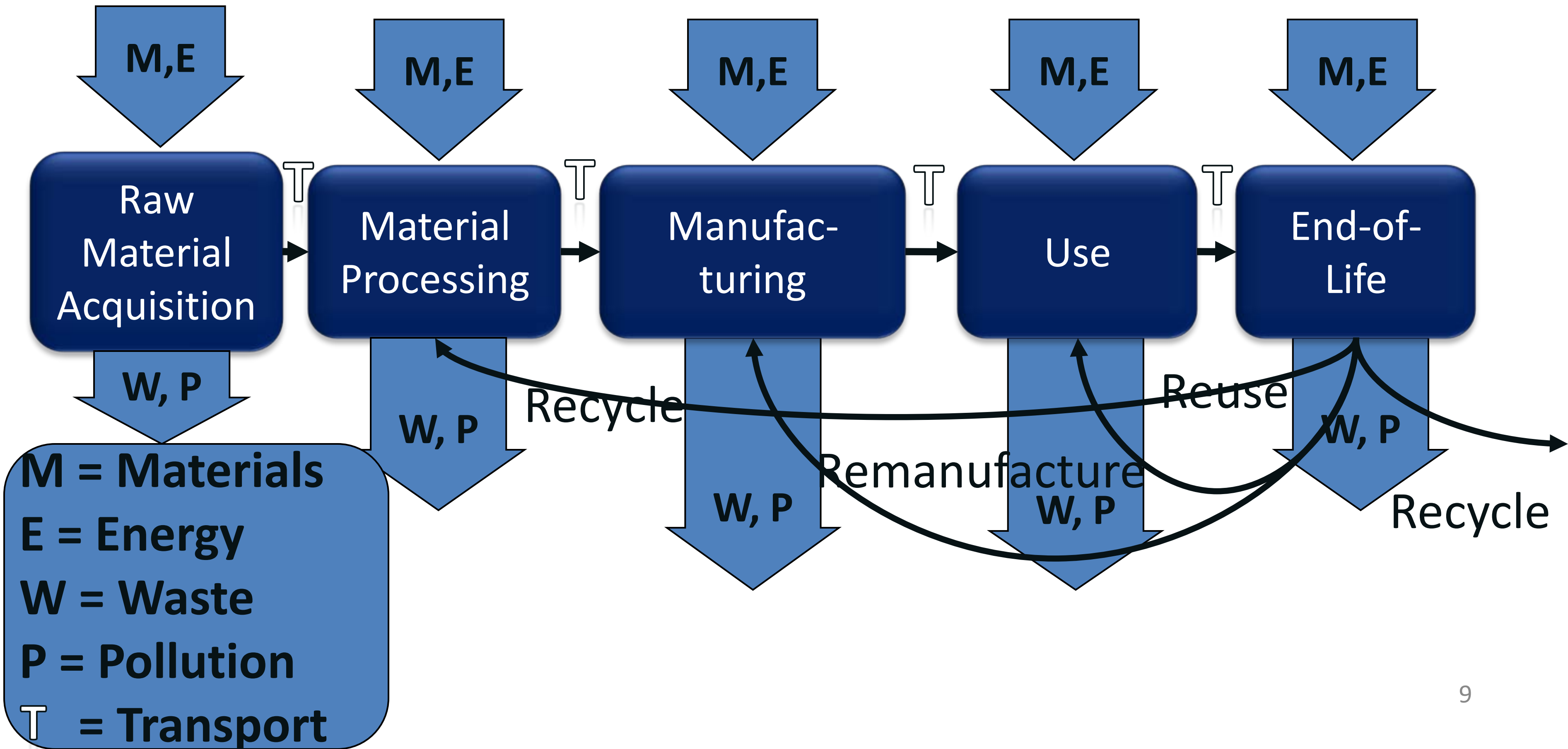
Blue is permitted portion

Purple is shortage

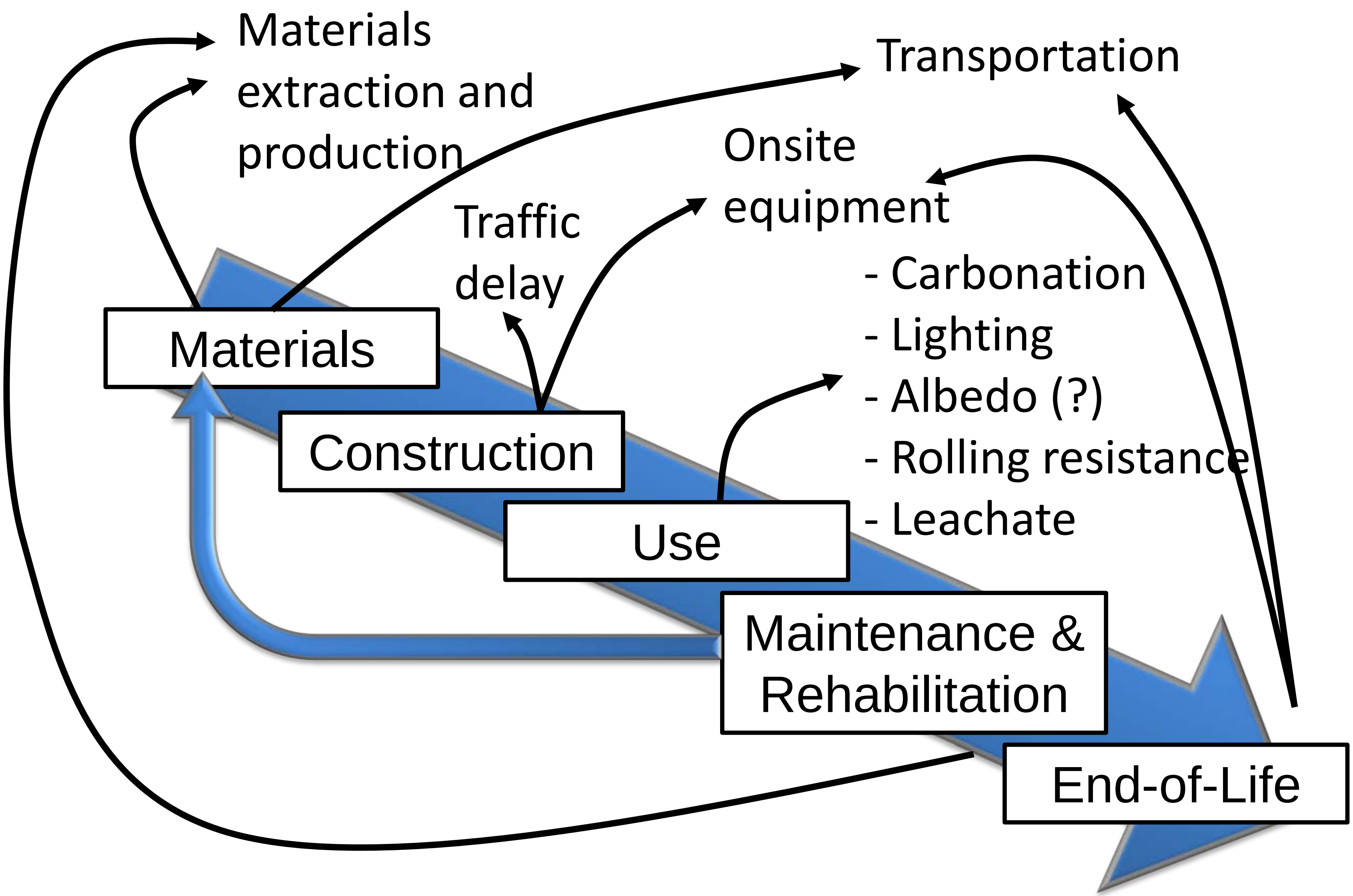
Triangles are permitted quarries

Generic Life cycle assessment

- Evaluates a product or system throughout its entire *life cycle*



The Pavement Life Cycle



Existing Pavement LCA Studies

- Roughly 15 studies since 1995
  - Attempt to quantify the environmental impact of all pavements using a very limited example set
  - Most aim at comparing asphalt versus concrete
  - Differing scopes
    - Region of study
    - Design and design life
    - System boundary
    - Environmental impacts
  - Different assessment criteria
  - Very difficult/impossible to compare results of one study to another due to fundamental differences in scope

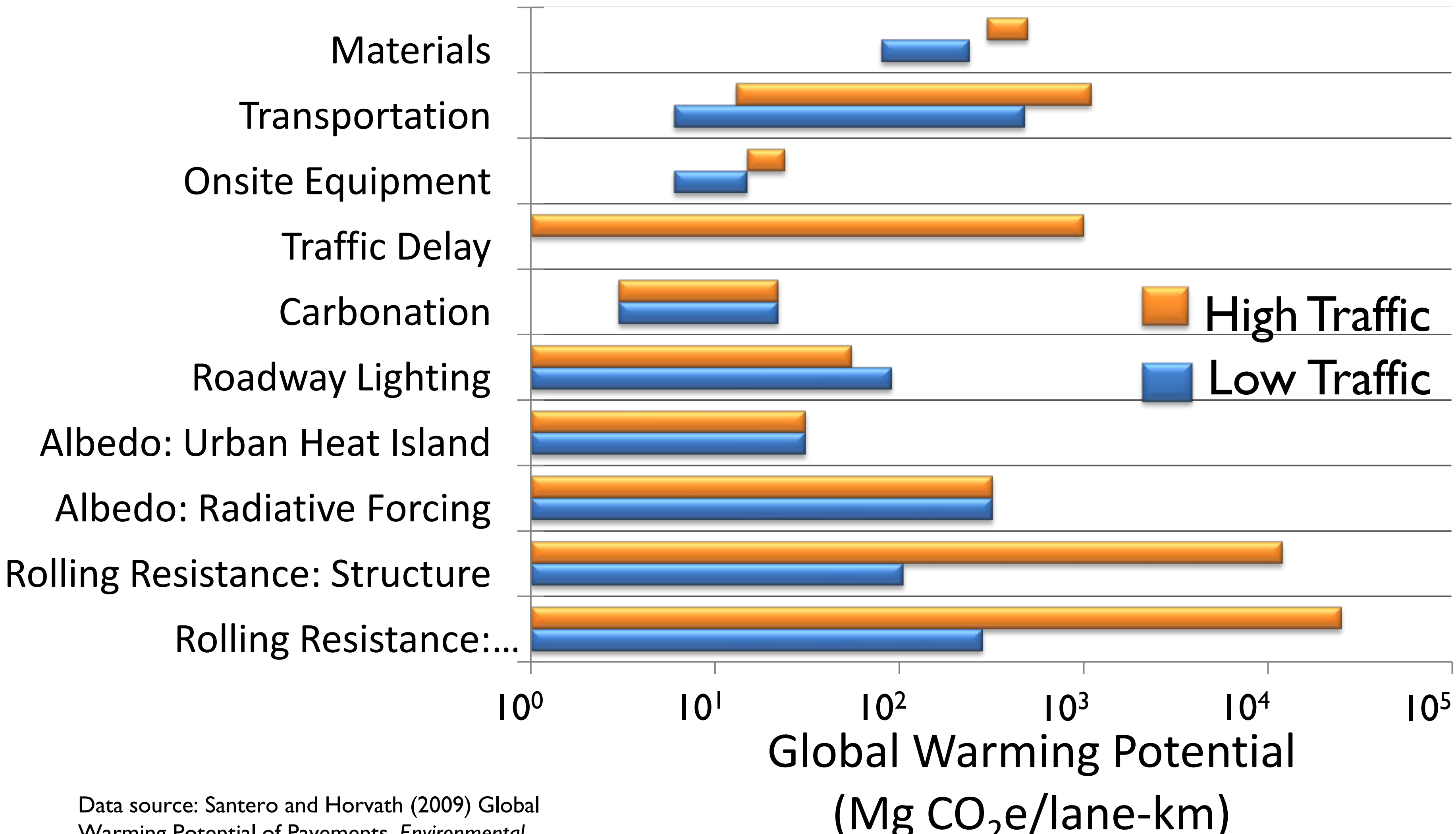
What is being done to improve Pavement LCA?

- Workshop held May, 2010 at UCD
  - Invited international attendees from pavement and infrastructure management researchers; LCA experts; federal, state, local pavement managers; materials producers; contractors
- Reviewed and discussed
  - LCA framework for pavements
  - System boundaries, assumptions; examination of the pros and cons of alternatives
  - Models/data for each phase of the life cycle for project type
    - Gaps and research needs
  - Documentation requirements for pavement LCA studies
  - Multi-criteria decision-making (cost and environment) within different procurement systems:
    - Low-bid
    - Design-build
    - Design-build-operate

What do we know now?

- Best practice depends on project context
  - Decide environmental goals (GHG/fuel use, materials use, etc)
  - High-volume vs low-volume (next slide)
  - Local materials vs transport, traffic delay
- Must consider environmental bang for the buck
- No magic bullets in terms of new materials or processes
- Sometimes Business As Usual is better than change
- Asphalt vs concrete is not the right question
- Be careful of indices
- Two items that will always reduce environmental impact and cost through longer pavement life:
  - *Better construction quality*
  - *Eliminating utility cuts in city streets*

Global Warming Potential Context: *High- versus Low-Traffic Scenarios*



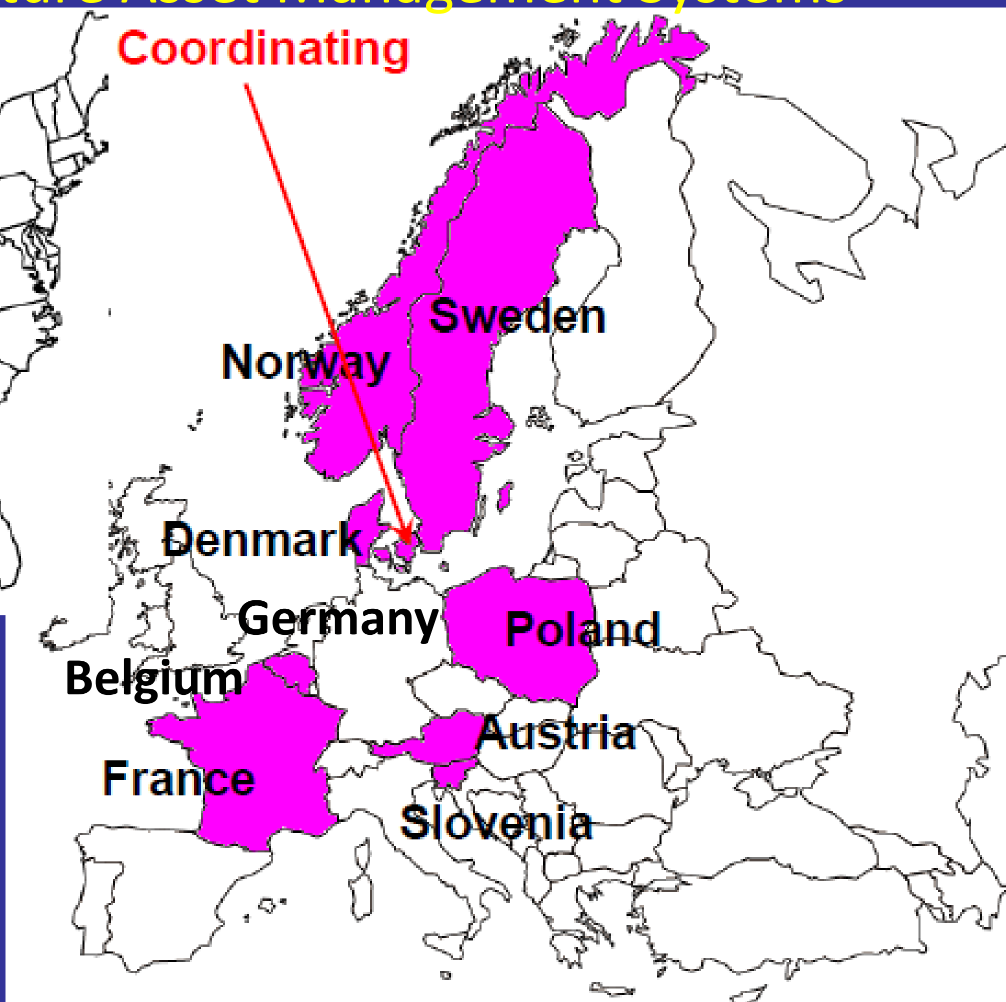
Data source: Santero and Horvath (2009) Global Warming Potential of Pavements. *Environmental Research Letters*. **4**(3), 034011.

Rolling Resistance

- High rolling resistance → higher fuel consumption
  - 2 to 4.5 % increase for typical California freeways at rehab
  - Dominant component of pavement life cycle GHG if heavy traffic volumes
  - Primarily related to roughness, texture
  - Asphalt/concrete only for heavy, slow trucks, hot pavement only)
- Research needed to mechanistically link roughness, texture and structure and fuel consumption
  - Current studies provide limited empirical evidence for steady state speed, MIRIAM project to address this
- Environmental effects of greater vehicle and freight damage from rough pavements?

MIRIAM

Models for rolling resistance in
Road Infrastructure Asset Management Systems



Participating countries and states

MIRIAM
Models for rolling resistance In Road Infrastructure Asset Management Systems

Materials

- Usually most important for low-volume roads
- In-place and local recycling usually beneficial
- Use local data to define and evaluate pavements
  - Pavement design, maintenance, construction vary regionally
- Materials manufacturing and procurement
  - Impacts depend on where materials are manufactured and used: local aggregate availability, refining, cement plants
- Consider transportation costs of non-local materials
- Be careful with environmental tradeoffs of recycled secondary materials
  - Pros: resource conservation, reduced landfilling
  - Cons: remanufacturing processes, long transportation, leaching potential

The future?

- A lot more confusing marketing information
- Continuing push for indices
- Rapid advancements in LCA for pavements
  - Research to fill gaps
  - Simplified guidance for engineers and managers
- Changes in procurement similar to Netherlands and France combining Life Cycle Cost Analysis and Environmental Life Cycle Assessment?

Workshop Documents
at www.ucprc.ucdavis.edu/p-lca
Open for public comment

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