Reducing Pavement Life Cycle Environmental Impacts Using LCA

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City and County Pavement Improvement Center

Governance:
League of California Cities,
California State Association of Counties

State and federally funded research and development for highways

City and County Pavement Improvement Center

Training, development, implementation, research
Outline

• Current laws and concerns that LCA can help address
• Quick review of LCA
• Recent results and current UCPRC work on LCA for Caltrans

• Note: views expressed are those of the presenter and NOT necessarily those of any sponsoring agency
Climate Change: road transport related strategies planning to 2030 and 2050

Air Resources Board Climate Scoping Plan
Air Pollution Toxicity

- Transportation related factor of most importance is air pollution, especially diesel trucks

  ✓ Requiring changes in vehicle energy sources, especially trucks

http://graphics.latimes.com/responsivemap-pollution-burdens/

So what can be done to make pavements more sustainable?

- FHWA Sustainable Pavements Task Group
  - Covers everything about pavement and sustainability
  - Tech briefs and webinars

Measuring Sustainability

- Life Cycle Cost Analysis (LCCA)
  - Economic
- Life Cycle Assessment (LCA)
  - Range of environmental impacts, quantitative
- Sustainability Rating Systems (e.g., INVEST)
  - Environmental and social impacts, qualitative

Reasons to Measure

- Decision support
- Establish baselines for process improvement
- Reporting for public, industry and government
Four Key Stages of Life Cycle Assessment

1. **Goal Definition and Scope**
   - Define questions to be answered (sustainability goals) and system to be analyzed.

2. **Life Cycle Inventory Assessment**
   - Where results are translated into meaningful environmental and health indicators.

3. **Impact Assessment**
   - The “accounting” stage where track inputs and outputs from the system.

4. **Interpretation**
   - Where the results of the impact assessment are related back the questions asked in the Goal.

Critical Review

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
Pavement Life Cycle Assessment

Materials Acquisition and Production

- Material extraction and production

Construction / Maintenance & Rehabilitation

- Equipment Use
- Transport
- Traffic delay

Use

- Rolling resistance
- Albedo: heat island & lighting
- Leachate

End-of-life

- Recycle
- Landfill

From: Kendall et al., 2010
Pavement Life Cycle Assessment Framework

FHWA HIF-16-014

FHWA pavement LCA framework 2016

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

- International Standards Organization (ISO) standards for LCA are generic for all materials
- FHWA guidance specific to pavements published in 2016
How do Pavements Contribute to California GHG Emissions?

- Out of 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

http://www.arb.ca.gov/cc/inventory/data/data.htm

Possible Pavement Reductions MMT/year
- Rolling resist to optimum 1.5
- Cement use 50% 0.2
- Asphalt use 50% 0.7
- Demo, oil, stone haul 10% 0.6

2013 Total CA Emissions: 459.3 MMT CO2e

TOTAL 2.9
Quick review of recent and current Caltrans/UCPRC work on developing and using LCA
Sustainability

- Environmental Life Cycle Assessment Updates and Applications
  - Previous work:
    - Developed LCA approach
    - Initial analyses for Caltrans
      - Network level IRI optimization
      - Project level case studies for asphalt and concrete
      - Urban heat island
    - This Project:
      - Further updates to capabilities
Caltrans Network: roughness trigger for maintenance by traffic group optimization for GHG

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<th>Daily PCE of lane-segments range</th>
<th>Total lane-miles</th>
<th>Percentile of lane-mile</th>
<th>Optimal IRI triggering value ( \text{m/km}, (\text{inch/mile}) )</th>
<th>Annual ( \text{CO}_2\text{-e} ) reductions (MMT)</th>
<th>Modified total cost-effectiveness ($/t\text{CO}_2\text{-e})</th>
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Wang et al 2014
Sustainability

• Environmental Life Cycle Assessment Tool for Project-Level Use
  – Previous work:
    • Inclusion of simplified LCA including roughness effects on fuel use in PaveM web-based pavement management software
    • Performance models for IRI
  – This project:
    • Deliver a project and conceptual level tool: eLCAP
    • Web-based
    • Will use
      – Updated, critically reviewed database of treatment LCIs
      – Updated performance models
      – Also being updated in PaveM
Caltrans Pavement Engineering and Database/Software Interactions
eLCAP and PaveM
Functionality and Data Sources

Caltrans Database
- Traffic
  - Traffic and Flow by Lanes
  - Weigh in Motion (WIM)
- Pavement
  - Network Level Cost
- DRISI
  - Linear Reference System (LRS)

Software
- PaveM
  - Network analysis
- eLCAP
  - Conceptual Level Analysis Module
  - Design Level Analysis Module

Output
- California Specific Network Level Estimate of GHG and Other Emissions, Resource Use
- California Specific Conceptual Level Estimate of GHG and Other Emissions, Resource Use for PID
- California Specific Project Level Estimate of GHG and Other Emissions, Resource Use for Design

EPDs from industry
Other inventory data
Districts/Pavement
  - Project Design Details
  - From CalMe and MEDG
Detailed LCA Models
Conceptual/PaveM Level Emissions Characteristic Functions
Sustainability

• Calculation of Benefit/Cost for Alternative Strategies to Reduce GHG

  – This project:
    • Evaluate potential strategies that Caltrans could undertake to improve sustainability
    • Primary focus on greenhouse gases, but also on important local issues: air pollution
What Should be Done for Sustainability?

Bang for your buck metric: $/ton CO$_2$e vs CO$_2$e reduction

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

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

• Fast Model for Energy Consumption Due to Pavement Structural Response
  – Previous work
    • Evaluated models for effects of roughness and texture on vehicle fuel economy
    • Evaluated effects of pavement structural response on vehicle fuel economy
    • Data analysis and simulation being completed by this summer
  – This project:
    • Develop a fast tool for use in design and pavement management to calculate effect
Sustainability

• Consideration of Environmental Product Declarations
  – Previous work:
    • Supported Caltrans and FHWA in approach to implement EPDs
  – This project:
    • Support Caltrans on implementation of AB 262
    • Support Caltrans on pilot projects for requiring EPDs for pavement materials in projects under development in 2018 and 2019; review specs, review results
Goals of Requiring EPDs
from soon to be published FHWA report

• Have good information for reporting emissions and resource use from pavement work

• Have good information for LCA use in:
  – Pavement designs, specifications
    • Different types of structures
    • Different types of materials in structures
    • Different construction quality requirements
  – Pavement asset management
    • Selection and timing of treatments
    • Trigger levels for distresses
Recommended 3 Stage Approach for Implementing EPD Requirements

from soon to be published FHWA report

1. Develop rules and then require reporting, move towards standardization of EPDs (1-2 years)
2. Develop standardization, rigor, review process, level playing field, appropriate applications (3 to 5 years)
3. If desirable and have made sufficient progress, consider using for procurement
   - Defining principle: Must take into account equivalent performance
What happens if industry does not produce EPDs?

• If you don’t produce EPDs, someone will estimate the environmental impact of your product for you

• With whatever information they can find
PMB manufacture causes about 60% more air emissions than straight bitumen in Europe.

An example recently presented to Association of Modified Asphalt Producers (AMAP) will soon be publishing EPDs.

Eurobitume LCI
Bernard et al.
Nantes LCA 2012
AB 262, Bonta. Public contracts: bid specifications: Buy Clean California Act

• What the law requires:
  – By January 2019 establish “average of facility-specific GWP” for each product based on “national and international databases”
  – Facility-specific GWP for products bought by state agencies (State Contracting Manual) cannot exceed “national average”
  – Documented through submission of EPD consistent with ISO 14025
  – Update average every 3 years

• Steel, flat glass and fiberglass insulation are in law

• Concrete, asphalt mix, cement, asphalt binder got “carve outs”
  – Not ready to produce facility-specific EPDs routinely
  – Expect new legislation for asphalt, concrete soon
What are CA agencies trying to do with EPDs?

• Caltrans:
  – Implement AB 262 as best possible

• Caltrans/UCPRC
  – Keep moving ahead with developing technical capacity, good, cost-efficient procedures for asking for EPDs
    • Pilot projects for EPDs in new projects in 2018
  – Try to get implemented ahead of new legislation
  – Use in design, pavement management, specifications

• FHWA Sustainable Pavements Task Group
  – Develop standardized rules and processes, clarify uses
  – Technology transfer
Takeaways: what do our customers want?

• Deliver more in terms of sustainability:
  – Cost, safety, smoothness, construction delay, small environmental impacts, local pollution
  – Asphalt paving: compaction, tack coats, recycling as long as equal or better performance

• Deliver innovation that can be used
  – $9 on development, implementation for each $1 of research

• Find ways to communicate pavement to the public
  – Rightly or wrongly, government is often not seen as cost-effective deliverer of these services
  – Communicate the innovations and quality improvement
  – Use LCCA and LCA results
  – They are interested!