Sustainable Asphalt Pavements
Sustainable Development

“Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs.”

*Our Common Future*, 1987
Triple-Bottom Line
## Triple-Bottom Line

<table>
<thead>
<tr>
<th>Economic</th>
<th>Social</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affordability</td>
<td>Equity</td>
<td>Pollution Prevention</td>
</tr>
<tr>
<td>Resource Efficiency</td>
<td>Human health</td>
<td>Climate Protection</td>
</tr>
<tr>
<td>Cost internalization</td>
<td>Education</td>
<td>Biodiversity</td>
</tr>
<tr>
<td>Trade and business activity</td>
<td>Community</td>
<td>Precautionary action</td>
</tr>
<tr>
<td>Employment</td>
<td>Quality of life</td>
<td>Avoidance of irreversibility</td>
</tr>
<tr>
<td>Productivity</td>
<td>Public participation</td>
<td>Habitat preservation</td>
</tr>
<tr>
<td>Tax burden</td>
<td>Safety</td>
<td>Aesthetics</td>
</tr>
</tbody>
</table>
Industry is trying to figure out how to do sustainability. Owners and organizations are trying to figure out what constitutes sustainability to their organization and how they will be more sustainable. Results of these efforts range from strategic direction, to guidance documents to rating systems.
Right now, private organizations are ahead of the transportation sector.
Right now, private organizations are ahead of the transportation sector.
Sustainable Pavement

- “minimizes the use of energy and renewable resources, while generating a minimum of pollutants, in the most cost-effective manner, while maximizing the benefits to the society.”
- P. Taylor, 2008
Measuring Sustainability Tools

Standards
- Voluntary
- Sets stakeholder metrics
- Defines Industry Best Practices
- No enforcement
- No Review

Codes
- Law
- Permits
- Little Flexibility
- Code Official Review

Rating Systems
- Voluntary
- Aspirational & Elective
- Ratings define achievement
- 3rd Party Review

Measuring Sustainability Tools
Infrastructure Green Rating Systems

- National, State, Local
- Rating Tool
  - Best practices
  - Earn Credits
  - Indicator of sustainability

I-LAST™
US Green Building Council (USGBC)

**Scope:** Buildings and Neighborhoods

**v. 4.0 New Construction**

Subcategories

- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Indoor Environmental Quality
- Materials & Resources
- Innovation and Design
- Regional Priority
LEED and Pavements

- Current version of LEED
  - No more recycled material credit
  - Possibly credit for porous
  - Environmental product declarations
LEED and Pavements

- Past versions of LEED pavement credits
  - Porous asphalt for stormwater design
  - Open-graded asphalt for urban heat island
  - High RAP for construction waste diversion
  - Warm mix asphalt – exceptional performance
Quantifying Sustainability

Life-Cycle Cost Analysis

Economic

Equitable

Social

Sustainable development

Viable

Bearable

Environment

Life Cycle Assessment
Life-Cycle Assessment

- International Organization for Standardization (ISO 2006)
  - “addresses the environmental aspects and potential environmental impacts (e.g., use of resources and the environmental consequences of releases) throughout a product’s life cycle from raw material acquisition, through production, use, end-of-life treatment, recycling, and final disposal (i.e., cradle to grave).”
LCA History

• 1960’s – Energy and raw material concerns
• Harold Smith (1963): calculate cumulative energy requirements for production of chemical intermediates
• *The Limits of Growth* and *A Blueprint for Survival*
• Dozen studies to look at costs and environmental impacts
• Who laid the groundwork?
Life-Cycle Assessment History

• The Coca-Cola Company (1969) developed methods and groundwork for LCA of today
  • Compared different beverage containers to determine environmental releases and required raw materials
• Other companies followed suit
Life-Cycle Assessment Framework
LCA Phases

- Goal and scope definition
  - Determine depth and breadth of LCA
  - System boundaries (i.e., what stages and processes will be included)
- Inventory analysis
  - Accounting phase
  - Inputs (materials, energy, and resources)
  - Outputs (waste, pollution, and co-products)
LCA Phases

- Impact assessment
  - Understand environmental significance
  - Translate environmental flows to impact categories
    - Energy use
    - Resource Use
    - Emissions
    - Toxicity
    - Water
    - Waste
- Interpretation
Pavement LCAs

- Process based
  - Data collected for every process
  - Specific, regionalized, and data intensive
  - Like LCCA, requires some assumptions in terms of material usage, transportation, and ultimately performance/maintenance
Materials

- **LCCA**
  - How much does it cost to buy the asphalt and the aggregate and produce a mixture?

- **LCA**
  - How much energy is required to extract, process, and transport aggregate and asphalt?
  - How much $\text{CO}_2\text{e}$ is produced during this process?
  - How much energy is used and $\text{CO}_2\text{e}$ is produced at the plant?
Example Materials Inputs for LCA

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage by Layer by Total Mixture Weight</th>
<th>Total</th>
<th>Haul Distance (miles)</th>
<th>Weighted Haul for Structure (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
<td>Binder</td>
<td>Base</td>
<td></td>
</tr>
<tr>
<td>Virgin Binder (PG 67-22)</td>
<td>4.3</td>
<td>2.7</td>
<td>3.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Granite</td>
<td>87.1</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Limestone</td>
<td>--</td>
<td>48.6</td>
<td>42.6</td>
<td>--</td>
</tr>
<tr>
<td>Virgin Agg</td>
<td>87.1</td>
<td>48.6</td>
<td>--</td>
<td>54.7</td>
</tr>
<tr>
<td>Sand</td>
<td>--</td>
<td>19.5</td>
<td>20.4</td>
<td>15.6</td>
</tr>
<tr>
<td>RAP</td>
<td>--</td>
<td>24.3</td>
<td>33.9</td>
<td>22.7</td>
</tr>
<tr>
<td>RAS</td>
<td>4.8</td>
<td>4.9</td>
<td>--</td>
<td>3.0</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>3.8</td>
<td>--</td>
<td>--</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Example Materials Inputs for LCA
Construction

- LCCA
  - How much does it cost to construct the mixture through manpower, fuel usage, and machine time?
  - User-delay costs?

- LCA
  - How much CO$_{2e}$ is produced and how much energy is used to place the mixtures?
  - How much CO$_{2e}$ is produced from traffic congestion?
Construction/Production Inputs

- Paver – Working time, efficiency, rate (ft/min)
- Rollers – Working time, efficiency, rate
- MTV – Working time
- Plant – Production rate, temperature, plant type
- WMA – some programs use an assumed drop in energy
Production Energy for Extracting/Processing Raw Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Production Energy (million kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP</td>
<td>4.2</td>
</tr>
<tr>
<td>High RAP</td>
<td>3.7</td>
</tr>
<tr>
<td>RAS</td>
<td>4.0</td>
</tr>
<tr>
<td>GTR</td>
<td>4.6</td>
</tr>
<tr>
<td>Virgin</td>
<td>5.0</td>
</tr>
</tbody>
</table>
Use Phase

- LCCA
  - Not commonly considered

- LCA
  - How much energy is spent lighting the pavement?
  - How much fuel is used driving on the road?
Maintenance and Rehabilitation

- LCCA
  - What is the rehab schedule for pavements?
  - What are economic effects of user-delay?
    - Lost time
    - Fuel costs

- LCA
  - What is the rehab schedule for pavements?
  - What are environmental effects of user-delay?
    - Fuel usage
    - Greenhouse gases
End-of-Life

- **LCCA**
  - Is there any salvage value to the material?

- **LCA**
  - Is the material recycled?
  - Do I have to transport it somewhere?
    - Fuel usage
    - Greenhouse gases
LCA Tools Available

- Highway Impact Estimator - Athena
- AsPECT - TRL
- PaLATE – UC Berkeley (no longer maintained)
- Project Emissions Estimator (PE-2) – Michigan Tech
- RoadPrint – Pavia Systems
- GreenDOT – AASHTO
  - Estimates CO$_2$ from construction, operations and maintenance
Tools must fit Framework

- ISO 14044 defines general requirements and guidelines
  - LCA for all products
  - Not specific enough for pavements
  - Basic framework started in 2010 at UC Davis
  - European framework developed and will be public by 2016
- FHWA Sustainable Pavements TWG – Fall 2014 Meeting
Environmental Impact Reporting: A need for brevity and consistency

![Nutrition Facts Image]
Relationships
PCRs, LCAs, and EPDs

- Product Category Rule (PCR): The Framework
  - “Set of specific rules, requirements, and guidelines for developing Type III environmental product declarations for one or more product categories” (ISO 14025)
- Life-cycle Assessment (LCA): The Process
  - “Compilation and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle” (ISO 14040)
- Environmental Product Declaration (EPD): The Declaration
  - “Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information” (ISO 14025)
Product Category Rules

- PCR – defines the rules for a product LCA and is industry accepted and defines the environmental product declaration (EPD) format
- NAPA has begun the process of developing PCR(s) for asphalt mixtures
  - Heather Dylla, Richard Willis, and Amlan Mukherjee are advising PCR Committee
Environmental Product Declaration

- EPD – declared LCA for a product and is a form of certification
  - Can be specific (producer) or general (industry)
- EPDs follow the framework developed in the PCR
  - NRMCA has already developed PCR using Carbon Leadership Forum and ASTM
- EPDs may be required soon for construction projects which produce specific amounts of CO$_2$
Thank you!