Carbon Footprint Cost Index: Measuring the Cost of Airport Pavement Sustainability

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Why?

• Cost comparison index for sustainability
• Allows engineers and owners to more objectively determine the cost of sustainability
Why Airports?

- Airports are the leaders in sustainability
- Airports are choosing to incorporate sustainability into everyday operations and building construction
- Opportunity to add sustainability into the pavement already on site
Sustainable Benchmarks

- Leadership in Environmental and Energy Design for New Development (LEED-ND)
- Greenroads
- No consensus on airport sustainability standard
  - Chicago Department of Aviation published the *Sustainable Airport Manual* (SAM)
  - Vancouver Airport implemented sustainability practices ([www.yvr.ca](http://www.yvr.ca))
  - Toronto annually reports on their sustainability levels ([http://www.torontopearson.com](http://www.torontopearson.com))
Pavement Sustainability Focus

- Recycling/reusing existing materials
- Maintenance and life cycle cost analysis and life cycle assessment
- Alternate materials and designs
- Supplementary cementitious material (SCM)
- Reduce energy and carbon footprint
Pavement

- Some studies have shown that asphalt can be used for tarmacs
- Asphalt is used in auxiliary areas and landside
- Both asphalt and concrete are evaluated
- Four pavement preservation types were evaluated
- Pavement preservation techniques are inherently sustainable
Shotblasting/Lithium Hardener

- Lithium silicate is used as a hardener on the surface of Portland Cement Concrete pavement.

- Shotblasting allows for deeper penetration of the hardener to create a concrete surface that is resistant to deterioration.

- The shotblasting process retextures pavement surface via special purpose a machine that shoots abrasive steel particles onto the pavement surface.
2” HMA Overlay

- A mixture of asphalt binder and graded mineral aggregate
- Mixed at an elevated temperature and compacted to form a relatively dense overlay, or surface layer over existing pavement.
Warm Mix Asphalt

- A mixture of asphalt binder and graded mineral aggregate
- Mixed at a temperature lower than that of HMA
- Compacted to form a relatively dense overlay, or surface layer over existing pavement.
Microsurfacing

- A mixture of high-quality fine aggregates
- Cleaner and harder relative to slurry seal in addition to a polymer-modified emulsion for high-performance.
Slurry Seal

• A mixture of well-graded, fine aggregate and unmodified asphalt emulsion
Supplementary Cementitious Materials (SCM)

- Alternative to traditional Portland cement or can be used with traditional Portland cement (Type K)
- Extends the service life of airport pavements up to as much as 60 times normal
- Assumed 5% reduction in carbon footprint
### Pavement Treatments and Service Life

Pavement Preservation Treatment Carbon Footprint and Service Information

<table>
<thead>
<tr>
<th>Sustainable Treatment Type</th>
<th>Life Extension</th>
<th>Carbon Footprint BTU/yd²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shotblasting / Lithium Hardener</td>
<td>6.3 – 7.1 years</td>
<td>1,290</td>
</tr>
<tr>
<td>2” HMA Overlay</td>
<td>5 – 10 years</td>
<td>61,500</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>3 – 5 years</td>
<td>3,870-5,130</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>3 – 5 years</td>
<td>3,870-5,130</td>
</tr>
<tr>
<td>SCM For 18” Unreinforced Concrete</td>
<td>20 years</td>
<td>3,500</td>
</tr>
<tr>
<td>SCM For 18” Reinforced Concrete</td>
<td>20 years</td>
<td>5,800</td>
</tr>
</tbody>
</table>

- WMA not reviewed in cost analysis
Life Cycle Cost Analysis (LCCA)

- Minimizing life cost as the decision criterion permits a more expensive alternative to compete with the low cost option.
- Many current pavement sustainability rating systems include LCCA as an essential component.
- LCCA only measures the difference between alternatives in financial terms.
- There are drawbacks to LCCA.
Pavement Preservation vs. Replacement

- Runway can deteriorate to removal and replacement
- Long term shut down to remediate the subbase
- Pavement preservation treatments also impact operations
- Surface treatments reduce time of closures
Next Step

• Invest in the treatment types
• Take pavement preservation to a higher level
• Incorporate sustainability
• Select treatments that minimize the impact to the environment
• Justify the added incremental cost of sustainable options
Cost Index Number Theory

- Combines cost and carbon footprint measurements into a single index
- Permits the direct comparison of two or more alternatives simultaneously
- Provides a measure of cost effectiveness for each alternative’s carbon footprint
Cost Index with NPV

• Carbon footprint is a widely accepted metric
  • to gauge relative sustainability among options
  • to furnish an input function to a cost index number analysis

• Service life period assumed for all alternatives was 20 years

• NPV evaluated at minimum, average and maximum life cycles
Carbon Footprint Cost Index

- **Net Present Value**
- \(\text{NPV} = I + R \times \left[\frac{1}{(1+i)^n}\right]\)
- Where: 
  - \(I\) = initial installation cost of a given alternative (\$)
  - \(R\) = cost to rehabilitate the pavement at the end of an alternative’s service life (\$)
  - \(i\) = interest rate (%)
  - \(n\) = service life (years)
Carbon Footprint Cost Index

• **Carbon Footprint**
  • CF = E/A
  • Where: CF = carbon footprint
    (British Thermal Units/Square Yard)
  • E = energy usage (BTU)
  • A = area of treatment (SY)
Carbon Footprint Cost Index

- **Carbon Footprint Cost Index**
- \(\text{CFCI} = \frac{(\text{NPV}_b - \text{NPV}_a)}{\text{NPV}_a \times 100} \times \text{CF}\)
- Where: \(\text{CFCI}\) = carbon footprint cost index (dimensionless)
- \(\text{NPV}_a\) = NPV of lower cost alternative ($)
- \(\text{NPV}_b\) = NPV of alternative of interest ($)
Case Study
(Oklahoma City - Will Rogers Airport)

• Taxiway reconstruction and realignment project utilizes both asphalt and concrete paving

• Bids were opened in 2011 with a low bid of $5,840,687.52
Case Study

- Bid Items

<table>
<thead>
<tr>
<th>Pavement</th>
<th>Units</th>
<th>BTU/yd²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bituminous Surface Course</td>
<td>sy</td>
<td>61,500</td>
</tr>
<tr>
<td>18” P.C. Concrete Pavement (Plain)</td>
<td>sy</td>
<td>25,500</td>
</tr>
<tr>
<td>18” P.C. Concrete Pavement (Reinforced)</td>
<td>sy</td>
<td>42,200</td>
</tr>
</tbody>
</table>
Case Study

- Additional cost for pavement treatment
- Concrete quantities approximately double asphalt
  - 53,000 SY vs 22,700 SY

<table>
<thead>
<tr>
<th>Sustainable Treatment Type</th>
<th>Additional Cost per unit</th>
<th>Percent Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shotblasting / Lithium Hardener</td>
<td>$22,034.13</td>
<td>0.67%</td>
</tr>
<tr>
<td>2” HMA Overlay</td>
<td>$346,269.33</td>
<td>4.44%</td>
</tr>
<tr>
<td>Micro - Surfacing</td>
<td>$38,396.53</td>
<td>1.16%</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>$18,266.31</td>
<td>0.55%</td>
</tr>
<tr>
<td>SCM For Unreinforced Concrete</td>
<td>$849,600.00</td>
<td>25.77%</td>
</tr>
<tr>
<td>SCM For Reinforced Concrete</td>
<td>$51,200.00</td>
<td>1.55%</td>
</tr>
</tbody>
</table>
## Case Study

### Net Present Value Calculations

<table>
<thead>
<tr>
<th>Sustainable Treatment Type</th>
<th>Additional Initial Cost</th>
<th>Min. NPV / Life</th>
<th>Ave. NPV / Life</th>
<th>Max. NPV / Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shotblasting / Lithium Hardener</td>
<td>$22,034.13</td>
<td>1.58% 6.3 years</td>
<td>1.48% 6.7 years</td>
<td>1.40% 7.1 years</td>
</tr>
<tr>
<td>2” HMA Overlay</td>
<td>$346,269.33</td>
<td>25.19% 5 years</td>
<td>14.77% 7.5 years</td>
<td>9.56% 10 years</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>$38,396.53</td>
<td>5.78% 3 years</td>
<td>4.33% 4 years</td>
<td>3.47% 5 years</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>$18,266.31</td>
<td>2.75% 3 years</td>
<td>1.65% 5 years</td>
<td>1.18% 7 years</td>
</tr>
<tr>
<td>SCM For Unreinforced Concrete</td>
<td>$849,600.00</td>
<td></td>
<td>25.77% 20 years</td>
<td></td>
</tr>
<tr>
<td>SCM For Reinforced Concrete</td>
<td>$51,200.00</td>
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<td>1.55% 20 years</td>
<td></td>
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</tbody>
</table>
Case Study

- Evaluate NPV

- Slurry Seal has the least additional initial cost, the minimal expected life increase causes higher NPV

- Shotblasting / Lithium Hardener alternative has higher initial cost, but longer life span

- 2” HMA Overlay and SCM for Unreinforced Concrete have highest initial costs and longest expected lives
Case Study

• Evaluate carbon footprint

• Microsurfacing and slurry seal are very similar

• 2” HMA Overlay has at least one order of magnitude greater carbon footprint

• Shotblasting / lithium hardener has the smallest carbon footprint
Cost Index

- Using the average NPV and the carbon footprint, a cost index can be created

<table>
<thead>
<tr>
<th>Sustainable Treatment Type</th>
<th>Low CFCI</th>
<th>Ave. CFCI</th>
<th>High CFCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shotblasting / Lithium Hardener</td>
<td>18.07</td>
<td>19.14</td>
<td>20.36</td>
</tr>
<tr>
<td>2” HMA Overlay</td>
<td>5,880.60</td>
<td>9,084.46</td>
<td>15,492.19</td>
</tr>
<tr>
<td>Microsurfacing</td>
<td>155.97</td>
<td>194.96</td>
<td>259.95</td>
</tr>
<tr>
<td>Slurry Seal</td>
<td>53</td>
<td>74.2</td>
<td>123.67</td>
</tr>
<tr>
<td>SCM For Unreinforced Concrete</td>
<td></td>
<td>1,122.36</td>
<td></td>
</tr>
<tr>
<td>SCM For Reinforced Concrete</td>
<td></td>
<td>574.89</td>
<td></td>
</tr>
</tbody>
</table>
Methodology for Treatment Selection Decision

- Provides an iterative process
- For owners during project planning
- Allows the scope or budget to be held constant
- Carbon Footprint Cost Index provides a metric for Sustainability
  - Based on:
    - Life Cycle Analysis using Net Present Value
    - Additional Life based on Pavement Preservation Type
    - Known Project Costs and Known Costs of Pavement Preservation Types
Questions?