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)
  - Toronto annually reports on their sustainability levels (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

Sustainable Treatment Type	Life Extension	Carbon Footprint BTU/yd^2
Shotblasting / Lithium Hardener	6.3 – 7.1 years	1,290
2" HMA Overlay	5 – 10 years	61,500
Microsurfacing	3 – 5 years	3,870-5,130
Slurry Seal	3 – 5 years	3,870-5,130
SCM For 18" Unreinforced Concrete	20 years	3,500
SCM For 18" Reinforced Concrete	20 years	5,800

- 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**
- $NPV = I + R*[1/(1+i)^n]$
- 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**
- $CFCI = ((NPV_b – NPV_a)/NVP_a*100)*CF$
- Where: CFCI = carbon footprint cost index (dimensionless)
- NPV_a = NPV of lower cost alternative ($)
- NPV_b = NPV of alternative of interest ($)

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

Pavement	Units	BTU/yd^2
Bituminous Surface Course	sy	61,500
18” P.C. Concrete Pavement (Plain)	sy	25,500
18” P.C. Concrete Pavement (Reinforced)	sy	42,200

Case Study

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

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

Case Study

- Net Present Value Calculations

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

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

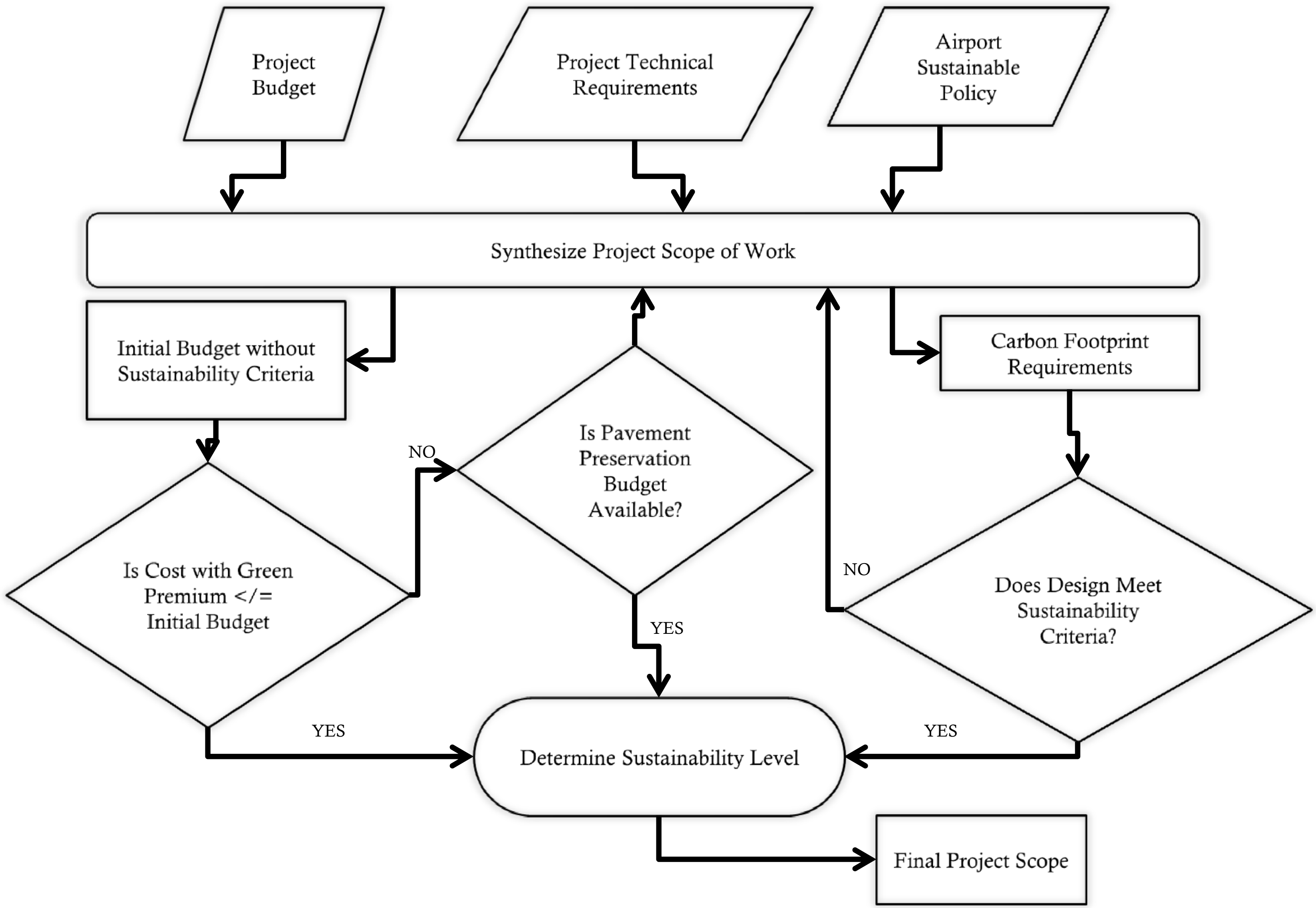
Cost Index

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

Sustainable Treatment Type	Low CFCI	Ave. CFCI	High CFCI
Shotblasting / Lithium Hardener	18.07	19.14	20.36
2” HMA Overlay	5,880.60	9,084.46	15,492.19
Microsurfacing	155.97	194.96	259.95
Slurry Seal	53	74.2	123.67
SCM For Unreinforced Concrete		1,122.36	
SCM For Reinforced Concrete		574.89	

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 Know Costs of Pavement Preservation Types


Project Budget
Project Technical Requirements
Airport Sustainable Policy
Synthesize Project Scope of Work
Initial Budget without Sustainability Criteria
Carbon Footprint Requirements
Is Pavement Preservation Budget Available?
NO
Is Cost with Green Premium </= Initial Budget
NO
Does Design Meet Sustainability Criteria?
YES
YES
YES
Determine Sustainability Level
Final Project Scope

Questions?