LCA Case Study for O’Hare International Airport Taxiway A & B Rehabilitation

Presented by:
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Overview

- Criticality of Airports
- LCA-AIR Overview
- Taxiway A&B Background
- Rehabilitation Options
- Results
- Future Research

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Criticality of Airports

- Airports process 3.3B passengers w/3.6T passenger-miles
- Airports process 55M short-tons freight annually
- Accounts for 8.2% of Transportation Sectors greenhouse gas (GHG) emissions (U.S.)
- Accounts for 3% of world GDP (www.wired.com)
Limitations and Assumptions

- Jet fuel consumption is modeled as kerosene combustion in industrial equipment.
- Construction/mx equipment only consider the diesel fuel consumed.
- Feedstock energy is not considered.
- 90% of the maximum take off weight was used for aircraft.
- The aircraft fuel consumption during flight is constant. Air resistance is constant.
- Airfield lights run 12 hrs/day.
- Snow removal consumes fuel but deicing chemical impacts are not included in the LCA.
- 5-mile haul distance for concrete (PCC) and asphalt (AC) for initial construction.
- IRI adapted from roadways.
- Sweeping assumed to occur 1 per week.
LCA-AIR Tool Overview

Geometry of Airfield
- Rigid and Flexible Pavement Structure
- Dimensions and Properties

Material Production Phase
- Mix Design
- Quantities and Transportation

Construction and Maintenance Phase
- Tasks
- Equipment
- Quantities/ Materials
- Fuel Consumption

Use Phase
- Aircraft Operation
- Lighting
- Snow Removal

Environmental Impacts
- TRACI Indicators
Taxiway A & B

- Constructed 1986 - 1988
  - 11,088’ by 75’ (25’ x 25’ slab)
  - 2011 PCI <75 (~40%<50)
    - Longitudinal/transverse crack center lane (primary)
  - Mx plan called for 75% reconstruction by 2013
    - Significant mx on 25%
  - Issues with surface drainage and probable underdrain failure
  - High vol of medium aircraft Group 1-4; <300 kips (90% traffic)
Legend (Number of Projected Operations):

- **0 – 50,000**
- **50,001 – 100,000**
- **100,001 – 150,000**
- **150,001 – 200,000**
- **200,001 – 250,000**
- **250,001 – 300,000**
- **300,001 – 350,000**
- **350,001 – 400,000**
- **400,001 – 450,000**
Rehabilitation Options

- 3 selected for further analysis
  - Rubbilization, Precast Concrete Panel (PCP), Reconstruction
  - Impact to airlines (closures), longevity and elevation constraints to adjacent features
- Analysis included LCA as another decision data tool
LCA Implementation

- Rehabilitation occurs at the 30 yr point
  - Extend pavement life to 50 yrs (20 yrs more)
- Rubbilization with mill/inlay receives mill/inlay 10 yrs later
- PCP & full-depth reconstruction has 20 yrs design life
- Scope include 200 keel section slabs on southern side of each taxiway (125,000 ft²)
- Material production (MP) and construction, maintenance and rehabilitation (CMR) used functional unit of yd²
- Use phase used functional unit pound-mile
Material Production and Initial Construction

- MP impacts are the same for each strategy
- Initial construction equipment impacts
  - Fuel consumption for PCC: 15,794 gal
  - Fuel consumption for AC: 11,899 gal
- Mx activities vary greatly around aircraft (24/7/365)
- Activities were aggregated over time as occurred at specific intervals for analysis
Developed Mx Schedule

- **PCC**
  - Restriping airfield markings – every ten years
  - Joint and crack sealing – every eight years
  - Full and partial depth repairs – every fifteen years
  - Brooming – every other day

- **AC & AC Shoulders**
  - Restriping airfield markings – every ten years
  - Crack sealing – every ten years
  - Asphalt patching – every fifteen years
  - Mill/inlay – every fifteen years
  - Mill/inlay – 10 years after the initial rubblization with mill/inlay section
CMR Phase - Rubblization w/Mill & Inlay

- Rubblization consumed: 954 gal
- AC inlays (no shoulders) consumed: 553
- Brooming – critical; 1/5 days shows a 10% redux (weigh FOD!!)
- Crack sealing time & energy intensive
- Total fuel consumed: 204.6K gals
CMR Phase - Rubblization w/Mill & Inlay

- Reused/left in place the most material of strategies
  - Used 24% less energy than PCP
  - Used 30% less energy than reconstruction

- Used 43% less GWP than PCP
- Used 37% less GWP than reconstruction
CMR Phase - Rubblization w/Mill & Inlay

- Unlike roadways, increase fuel consumption doesn’t dominate....limited time for tire pavement interaction
- Including fuel consumed in flight...Use phase is more dominant than roadways
CMR Phase - Precast concrete Panels

- Slab lift-out method
- Additional 523 gal demolition of PCC
- PCP placement added 2,973 gal
  - Steel and leveling sand added work/material to impacts
- Diamond grinding (whole area) added 761 gal
  - Work w/manufacture can increase tolerance = spot grinding
- Reduction in crack sealant and patching operations
- Total fuel consumed CMR: 206.1K gal (2,052 gal more than rubbilization)

(Kulikowski, 2015) (Fischer, 2002)
CMR Phase - Precast concrete Panels

- Cast on airfield
  - Used 8% less energy than reconstruction
    - Installation is less intensive
  - Used 9% more GWP than reconstruction
    - Attributed to the two mats of steel in the PCP
- Open to traffic after placement (no curing)
CMR Phase - Precast concrete Panels

- Chart shows and increase in the CMR phase impacts
  - Full-depth PCC and steel
CMR Phase - Reconstruction

- Most material removed
  - Removal of PCC, AC base course and aggregate subbase
  - Hydraulic hammer on excavator - rapid breakage and removal
- More activities, but fairly rapid….except curing!
  - Can’t reopen next day
- Total fuel: 205.2K gal
  - 1,175 gal more than rubbilization
  - 877 less than PCP
Strategy Summary Breakdown Per Phase

Rubbilization w/Mill & AC Inlay
- Mat’l Production: 31%
- CMR: 13%
- Use (ΔIRI): 56%

Precast Concrete Panels
- Mat’l Production: 30%
- CMR: 17%
- Use (ΔIRI): 53%

Reconstruction
- Mat’l Production: 30%
- CMR: 28%
- Use (ΔIRI): 42%
## Quantified Impacts

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<th>Rank</th>
<th>Strategy</th>
<th>Impact category</th>
<th>Unit</th>
<th>Total Impact Per yd²</th>
<th>Total Impact Per lb-mile</th>
<th>Total Impact Per yd² (ΔIRI Only)</th>
<th>Total Impact Per lb-mile (ΔIRI Only)</th>
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<tbody>
<tr>
<td>1</td>
<td>Rubblization w/Mill/AC Inlay</td>
<td>Global warming</td>
<td>kg CO2 eq</td>
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<td>Global warming</td>
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<tr>
<td>1</td>
<td>Rubblization w/Mill/AC Inlay</td>
<td>Primary energy consumption (renewable + non-renewable)</td>
<td>TJ</td>
<td>0.1861</td>
<td>3.58E-08</td>
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Further Research Areas

- **LCA Tools for Airports!**
  - Develop complex components of use phase
    - Aircraft tire-pavement interaction
    - Roughness impacts on fuel burn
    - Air resistance/density for in-flight
    - Fuel burn intensity for various flight status
    - Establish allocation standard for aircraft fuel burn
      - Attribute $\frac{1}{2}$ and $\frac{1}{2}$ to each airfield … or … other method to account for fuel burn impacts
  - Partnership with aircraft manufacturers
    - Account for tug (plane & freight) and ground equipment
    - End of life phase – unique opportunities and timeline which differ from roadways
Questions
Vehicle tire-pavement interaction is heavily researched for fuel consumption increase from ΔIRI … not the case aircraft tire-pavement interaction

- No ‘IRI’ models for airfields
- Adapted an IRI deterioration model from roadways

Aircraft are only on pavement for ~30 min/flight

- Limited and short-sighted accounting for combustion of JP-8
- Significant amount of fuel consumption is take-off and cruising (no tire pavement interaction!!)
- Fuel burn intensity for short vs. long flights