Pavement Management Systems

IAAE Canada
7th Annual Facility Operations & Airport Managers Conference
Saskatoon, Sk

Tuesday May 14, 2013
1:30 – 2:45 pm

Presented by:
Richard Kohler
Vice President, Airports

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Sr Vice President, Transportation

www.tetratech.com
Agenda

- Background Information
- Structural Condition Survey – Transport Canada ERD 121
- Pavement Management Systems
- PMS Software and GIS
- Data Collection Technologies
What is a Pavement Management System?

- “The effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least life cycle cost” (AASHTO)

- 5 key components:
  
  i. Pavement condition surveys
  
  ii. Database containing all related pavement information - GIS-based spatial interfaces to enable users to view and manipulate data in a meaningful way

  iii. Analysis scheme - algorithms used to interpret data in a meaningful way - focused on advancing or refining life-cycle costing analysis, optimization algorithms and performance prediction

  iv. Decision criteria - rules developed to guide pavement management decisions

  v. Implementation procedures - those methods used to apply management decisions to pavement sections
Why do you need a Pavement Management System?

Protect your investment

- $1-5+M for runway rehabilitation
- $10-150k for PMS
- $10-200k for annual maintenance
- cheaper to apply limited funds to a pavement when the condition is relatively good rather than applying additional funds to improve the condition from a lower value
Why do you need a Pavement Management System?

- To prevent severe deterioration of your pavement structures
Why do you need a Pavement Management System?

- To minimize risk of blowouts / damage to aircraft
Why do you need a Pavement Management System?

- To identify pavement distresses for rehabilitation and capital planning purposes
Background Information

Why do you need a Pavement Management System?

- Limit liability for small general aviation to large international airports
Why do you need a Pavement Management System?

- Obtain an overview of the current condition of the pavement network
- Predict future conditions of the pavement network
- Identify candidate projects for maintenance and rehabilitation
- Develop a prioritized list of candidate sections for rehabilitation
- Generate budget requirements for planning purposes
- Analyze "what-if policy questions for various budget scenarios
- Forecast future conditions based on various funding levels
- Retrieve data of pavement segments for informational purposes
Background Information

- **What is right for your airport?**
  - Transport Canada reporting requirements
  - Funding requirements (ACAP, municipality, government)
  - Operations / liability requirements
  - Maintenance and rehabilitation planning requirements
  - Size of airport
  - Future planning requirements – balance between maintenance and rehabilitation $$

- **What is the difference between a Pavement Management System and a Pavement Condition Survey?**

  **Pavement Management System**
  - Assessment of pavements using ASTM standards
  - Manual or automated data collection
  - Ability to conduct predictive modeling
  - Estimate of remaining life based on modeling options (decisions on spending)
  - Provides database of assets and distresses for continued assessment
  - And a whole lot more!

  **Pavement Condition Survey**
  - A visual inspection and condition of pavements
  - Provides structural condition number
  - Estimate of remaining life (allows for 5-10 yr planning)
  - Least cost option

  $$
Agenda - status

- Background Information
- Structural Condition Survey – Transport Canada ERD 121
- Pavement Management Systems
- PMS Software and GIS
- Data Collection Technologies
Structural Condition Survey

- Historically based on Transport Canada ERD No.121 (previously AK-68-32)
  - Airport Pavement Structural Condition Survey

- 5 Pavement Quality Characteristics
  - Strength (structurally sound to support aircraft loads)
  - Smoothness (free of irregularities which create roughness)
  - Skid Resistance (adequate surface friction and texture)
  - Structural Integrity (structurally intact and free of broken material – ie: FOD)
  - Surface Drainage (adequate drainage / runoff of water)

- Subjective visual evaluation using rating forms and graphs
  - Identify type of defects
  - Rated in terms of extent and severity
  - Overall Structural Condition Rating (SCR) assigned to pavement sections
### Structural Condition Survey

#### PAVEMENT CONDITION SURVEY - RATING SUMMARY

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>SECTION I.D. NO.</th>
<th>AREA (m²)</th>
<th>Structural Condition Rating</th>
<th>Program Restoration</th>
<th>Maintenance Required</th>
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</tbody>
</table>

#### PAVEMENT SURFACE DEFECTS (Extent/Severity)

<table>
<thead>
<tr>
<th>ASPHALT SURFACES</th>
<th>CONCRETE SURFACES</th>
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#### PAVEMENT DEFECT RATINGS

EXTENT - 1: Minor 2: Moderate 3: Major 4: Extreme
SEVERITY - L: Low M: Medium H: High
EXTENT/SEVERITY

#### Structural Condition Rating

- Very Poor: 0-2
- Poor: 2.5-4
- Fair: 4.5-6
- Good: 6.5-8
- Very Good: 8.5-10

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**Critical Aircraft:**

Operating Weight (kN):

Tire Pressure (MPa) 1.38:

Aircraft Load Rating (ALR):
Structural Condition Survey
Structural Condition Survey

Pros
- Inexpensive
- Satisfies TC funding requirements – ACAP
- Identifies critical distress areas
- Assists with 5-10 year capital planning

Cons
- Subjective based on inspector experience / less repeatable
- Provides a snapshot of pavement condition
- GIS compatible only if location referencing applied
- Survey does not provide structural condition information
Bearing Strength Reporting

- **Transport Canada Advisory Circular AC 302-011**
  - Airport Pavement Bearing Strength Reporting
  - Formerly Engineering Reference Document (ERD) 133 – ‘Transport Canada and ICAO Methods for Reporting Airport Pavement Bearing Strengths’
  - Revised correlation for PLR to PCN conversions for flexible pavements

- **PLR vs PCN**
  - PLR system introduced in late 1970’s at Transport owned / operated airports
  - PCN system adopted by ICAO in mid 1980’s as an international standard

- **Pavement Load Rating (PLR)**
  - A number expressing the bearing strength of a pavement for unrestricted aircraft operations
  - Determined from field measured data on pavement thickness and subgrade bearing strength
  - Aircraft tire pressure restriction may be added in brackets (megapascals)
  - PLR’s expressed on a scale of 1 (weakest) to 13 (strongest) - PLR xx (yy)
Bearing Strength Reporting

- **Pavement Classification Number (PCN)**
  - 5 part strength code, eg: 40/F/B/1.0 MPa/T
    - PCN - number expressing the bearing strength of a pavement for unrestricted aircraft operations
    - Pavement Type, R – Rigid, F – Flexible
    - Subgrade Strength Category, A – High, B – Medium, C – Low, D – Ultra Low
    - Maximum Allowable Tire Pressure
    - Strength Evaluation Method, T – Technical, U – Using Aircraft Experience
  - Determined from field measured data on pavement thickness and subgrade bearing strength
  - Or, on the basis of past experience with aircraft using facility without causing damage
Agenda Status

- Background Information
- Structural Condition Survey – Transport Canada ERD 121
- Pavement Management Systems
- PMS Software and GIS
- Data Collection Technologies
Basic Steps of a PMS

- **Inventory**
- **Condition Assessment** – through data collection
- **Valuation**
- **Indexing (PCI, FOD, RCI, PCN…)**
- **Predictive Modeling (use of Software )**
  - Highway Development and Management (HDM) distress prediction modeling
  - Input Parameters / Analysis Variables
- **Performance Models**
  - Develop Strategies - Networks predicted condition under various treatments
  - Input parameters
- **Life Cycle Costing Analysis – Net Present Value**
- **Run Scenarios / Optimize**
- **Recommended Program**
Pavement Management Systems

Cross Asset Optimization

Optimization – What is the best thing to do?
LCCA - How much will it be worth if I do something?
Predictive Modeling – What will the condition (value) be X years from now?

Condition - What is it worth now?
Value - What was it worth initially?
Inventory - What do I have and where is it?
Asset / Pavement Management

- Program
  - Review & Adjust
  - Integrate Spatially (GIS)
- Draft Program
- Cross Asset Optimization
- Strategy Database
  - Generate
  - Utility
  - Strategies
- Strategy Database
  - Generate
  - Structure (Bridge)
  - Strategies
- Strategy Database
  - Generate
  - Pavement
  - Strategies

LCC & Inventory
Pavement Condition Index (PCI)

- Scale of 100 to 0 (Very Good to Very Poor)
  - Not a percentage
- Composite index that includes numerous distresses
- Difficult to visualize the pavement condition based on a PCI. Index - weighted value!
- Treatments are predicted less accurately
  - Individual distress information is not used

- Underlying problems need to be addressed before a rehabilitation strategy can be applied
- Different distress types will require different treatment strategies
- Geo-referencing with a GIS is critical to understanding where and why problem areas exist

<table>
<thead>
<tr>
<th>PCI</th>
<th>Repair Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>EXCELLENT</td>
</tr>
<tr>
<td>85</td>
<td>Preventive Maintenance</td>
</tr>
<tr>
<td>70</td>
<td>GOOD</td>
</tr>
<tr>
<td>55</td>
<td>Major Rehabilitation</td>
</tr>
<tr>
<td>40</td>
<td>FAIR</td>
</tr>
<tr>
<td>25</td>
<td>Rehabilitation</td>
</tr>
<tr>
<td>10</td>
<td>POOR</td>
</tr>
<tr>
<td>0</td>
<td>Reconstruction</td>
</tr>
<tr>
<td></td>
<td>VERY POOR</td>
</tr>
<tr>
<td></td>
<td>FAILED</td>
</tr>
</tbody>
</table>

Proprietary information
### Distresses identified during PCI Procedure

<table>
<thead>
<tr>
<th>AC Distresses</th>
<th>PCC Distresses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator cracking</td>
<td>Blow up</td>
</tr>
<tr>
<td>Bleeding</td>
<td>Corner break</td>
</tr>
<tr>
<td>Block cracking</td>
<td>Longitudinal/transverse cracking</td>
</tr>
<tr>
<td>Corrugation</td>
<td>Durability cracking</td>
</tr>
<tr>
<td>Depression</td>
<td>Joint seal damage</td>
</tr>
<tr>
<td>Jet blast erosion</td>
<td>Patching</td>
</tr>
<tr>
<td>Reflective erosion</td>
<td>Popouts</td>
</tr>
<tr>
<td>Longitudinal/transverse cracking</td>
<td>Pumping</td>
</tr>
<tr>
<td>Oil spill damage</td>
<td>Scaling/map cracking</td>
</tr>
<tr>
<td>Patching</td>
<td>Settlement/faulting</td>
</tr>
<tr>
<td>Polished aggregate</td>
<td>Shattered slab</td>
</tr>
<tr>
<td>Raveling/weathering</td>
<td>Shrinkage cracking</td>
</tr>
<tr>
<td>Rutting</td>
<td>Joint spalling</td>
</tr>
<tr>
<td>Shoving</td>
<td>Corner spalling</td>
</tr>
<tr>
<td>Slippage cracking</td>
<td></td>
</tr>
<tr>
<td>Swelling</td>
<td></td>
</tr>
</tbody>
</table>
Condition - Strength Testing

- PCN (Pavement Classification Number) is compared to ACN (Aircraft Classification Number)
- When PCN is greater than ACN, the number of movements can be unrestricted without early pavement distress

Heavy Weight Falling Deflectometer (HWD)
- 2010 Riding Comfort Index (RCI) is determined from measured IRI
  - General indicator of smoothness at highway speeds
  - Does not account for large isolated bumps that can be excessive at aircraft take-off / landing speed
- Boeing Bump Index
  - Used to check for isolated bumps and dips
Inputs – Aircraft Movements

- EIA Example - recent growth for B737-600, B737-700, B737-800 (ACN of 44, 48, 55)
Predictive Modeling

- Modified HDM (Highway Development and Maintenance) models
- Calibrated so that the models replicate the measured condition

- Structure
- Age
- Aircraft Movements
- Environment
- Condition

Crack Initiation → Crack Progression → Rutting

Rutting → Shoving → FOD

Rutting → Raveling

Proprietary information
Predictive Modeling

- Predicting Individual Distresses – how it’s done

Input Parameters

- Structure
- Age
- Aircraft Movements
- Environment
- Condition

Analysis Variables

- Crack Initiation
- Crack Progression
- Rutting
- Shoving
- FOD
- Raveling

Proprietary information
Numerous Strategies are Evaluated for Each Pavement Segment Using Life Cycle Cost Analysis

Sample pavement strategies (combination of treatments)
# Input Parameters

## Maintenance / Rehabilitation Treatments and Costs Used

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack Sealing</td>
<td>$4 /L-m</td>
</tr>
<tr>
<td>Patching</td>
<td>$150 / m²</td>
</tr>
<tr>
<td>Overlay (50 mm)</td>
<td>$17 / m² + $267 / m² (deeper treatment of moderate and high severity cracking)</td>
</tr>
<tr>
<td>Mill &amp; fill (50 mm)</td>
<td>$22 / m² + $250 / m² (deeper treatment of moderate and high severity cracking)</td>
</tr>
<tr>
<td>Panel Replacement</td>
<td>$334/m² to replace all cracked panels + $17 / m² inlay</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>$295 / m²</td>
</tr>
<tr>
<td>Crack Stitch and Overlay</td>
<td>$966 / lineal-m + $34/m² for 100 mm overlay</td>
</tr>
</tbody>
</table>

- 4% real discount rate
- Growth in movements and weights  
  - 2%/year growth in movements
  - Continued shift to 737-800

Proprietary information
Basics of Life Cycle Cost Analysis (LCCA)

- Initial Construction
- Rehabilitation
- Maintenance
- Salvage

Net Present Value

Time

Proprietary information
Run Scenarios

- What ifs?

- Planning at a Network Level
  - Average conditions for entire airport

- Planning at a Project Level
  - Specific conditions for each facility

- Recommended Spending for 10 Year Capital Program
### Budget Scenarios Presented

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Optimization Method</th>
<th>Annual Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Minimize FOD Potential</td>
<td>$1.5 M / year</td>
</tr>
<tr>
<td>B</td>
<td>Minimize FOD Potential</td>
<td>$1.5 M / year (2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3.5 M / year (2012-2029)</td>
</tr>
<tr>
<td>C</td>
<td>Minimize FOD Potential</td>
<td>$1.5 M / year (2011)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$3.5 M / year (2012-2015)</td>
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<tr>
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<td></td>
<td>Variable (2016-2029) $3.7 M average</td>
</tr>
</tbody>
</table>
### Condition Distribution - FOD

- **Scenario B - Annual Budget**
  - $1.5 M / year (2011)
  - $3.5 M / year (2012-2029)

- **Scenario C - Annual Budget**
  - $1.5 M / year (2011)
  - $3.5 M / year (2012-2015)
  - Variable (2016-2029) $3.7 M avg
Funding Scenarios - FOD

The graph above illustrates the average FOD Index over the years from 2010 to 2030 for different funding scenarios. The scenarios include:

- **$1.5 Million/year**
- **$1.5 Million (2011), $3.5 Million thereafter**
- **$1.5 Million (2011), $3.5 Million (2012 - 2015), Recommended after**

The graph shows a decline in the FOD Index over the years, with different slopes for each scenario, indicating the impact of varying funding amounts.
Optimization – Minimizing FOD Potential (Segment Results)

- Optimizing on FOD
- Results at Segment Level
Example Program - EIA

- Facility is generally under-strength
  - Most of facility will need strengthening
- New runway planned parallel to and west of Runway 02-20
  - At 15-20 years
  - Existing Runway 02-20 to become a taxiway
- Recent failure in centre area of Runway 02-20
  - Between Taxiway B4 and touchdown area
  - Core extraction found rubble in one test at the south end
- Staging Assumptions
  - One full runway must be open and access to button ends
  - Only one runway under construction per year
  - Overlay the year after crack stitching or combine budget years
  - Mill/inlay can be done anytime
EIA Current Condition - PCI

2010 PCI 84

- 85 - 100 Good
- 70 - 85 Satisfactory
- 55 - 70 Fair
- 40 - 55 Poor
- 25 - 40 Very Poor
- 0 - 25 Serious
EIA Current Condition - FOD

2010 FOD Potential 5.8
2010 Riding Comfort Index 5.9

- Roughness is the reason for 15 to 20% of airfield rehabilitation projects (Transport Canada)
  - Desirable average RCI greater than
    - 4.5 (runways)
    - 3.5 (taxiways)
Recommended Program
2011 - 2022
Recommended Program
2023 - 2030
Recommended Program

Treatment Type
- Red: Reconstruct
- Orange: Panel Replacement
- Yellow: Stitch + Overlay
- Blue: Mill 50mm
- Green: Overlay 100mm
- Cyan: Overlay 50mm

Proprietary information
Agenda Status

- Background Information
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- Pavement Management Systems
- PMS Software and GIS
- Data Collection Technologies
PMS Software Considerations

PMS Software
- Excel
- Paver (Micro Paver), i-WorQ,
- D-TIMS, V-Max, MPMS

Selection Considerations
- Owner Defined Requirements
- Data Base support
- Flexible: what are the limitations (data, models), hard wired vs. open source.
- Expandable: Other assets? (bridges, utilities, signage, electrical, buildings…)
- Scalable: Can it handle more data? (clipboard to LiDAR)

Other Considerations
- Free vs. proprietary
- In-house operator vs. service bureau
- Data collection flexibility
A Typical Agency uses several different location referencing methods
  – Fixed link segments used for Capital Planning
  – Different fixed link segments used for Maintenance Management
  – Reference point descriptions
  – Linear referencing used for runway/taxiway inventory/condition
  – Spatial referencing, (longitude/latitude or x,y coordinates), GPS locations – signs, paint markings, lights, manholes, etc
  – Geo-referencing (land use)
GIS Data Integration

Data from any other application can be linked to the management system through GIS

- Incidents (reference points)
- Maintenance Costs (fixed links)
- Groundside road fixtures (x,y coordinates)
- Bridges
- Buildings
- Water/Sewer
- Sidewalks
- Street lights
- Incidents
- Etc, etc
Understanding through GIS
Agenda Status

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Where are we?
Infrastructure Testing Technologies

- Pavement Condition Data Collection
  - Automated / semi-automated visual survey
  - GPS linked video
  - Roughness/Profile
  - LiDAR

- Subsurface thickness using Road Radar technology

- Strength testing using Heavy Weight Deflectometer (HWD)
Pavement Condition

PSP-5000
• Wheelpath Profile
• Rut Measurements
• Geometrics
• Distress
• GPS
• ROW Digital Video
• Panoramic Video
• LiDAR
Pavement Condition

Semi-Automated Distress

ASTM 6433-99/03/07
- 12 Programmable Distresses
- 3 Levels of Severity
- 5 Levels of Extent
Pavement Condition

PSP-7000

- IMU Augmented GPS Referencing
- Wheelpath Profile
- Rut Measurements
- Geometrics
- Distress
- GPS
- ROW Digital Video
- Panoramic Video
- LiDAR
- 3D Surface Profile
- Surface Texture
Pavement Condition

Fully Automated Distress and Inventory System

- Spatially referenced
- Continuous 3D surface analysis
- Crack severity
- Crack location
- Surface defects (potholes, FOD)
Pavement Condition

3D Surface Profiling System
- Vehicle speed: up to 100km/h
- Profile spacing: 5mm
- Transverse field of view: 4m
- Transverse resolution: 1mm
- Rutting, Paint Line Markings
- Automated Distress Measures
  - Trans cracks, long cracks, sealed cracks, pot holes, patching, joints, corner cracks, FOD
- Texture Measures
  - Mean Profile Depth (ASTM E1845-01)
  - Estimated Mean Texture Depth (Friction)
  - Raveling, Segregation
- Day or night operation

RPI - Road Porosity Index = (Volume under the surface — Cracks) divided by a surface area

\[
RPI = \frac{Vol_{air\ void} - Vol_{cracks}}{Area_{Total}}
\]
Pavement Structure

- Max Penetration Depth: 2m
- Min Layer Thickness: 50mm
- Accuracy (uncalibrated): +/- 5%
- Maximum Survey Speed: 100 kph
Pavement Structure – Sample Output

Proprietary information
PCC Material Properties

Failing PCC

Performing PCC

Proprietary information
Subsurface Anomalies - Voids

Failing PCC

Performing PCC

Station (m)

Offset (m)

18 sq.m (1.1%) - Joints
8 sq.m (0.5%) - Re-bar
17 sq.m (1.1%) - Delaminations
332 sq.m (20.1%) - Potential Voids

Surveyed Area: 1652 sq.m

Proprietary information
Runway Structure - Sample Output

![Runway Structure Diagram]
Falling Weight Deflectometer (FWD)
Heavy Weight Falling Deflectometer (HWD)
Dynamic Strength Testing

Dynatest FWD/HWD
- Completely non-destructive
- Accurate and fast (up to 60 tests/hr).
- Wide loading range:
  FWD: (7-120 kN) or (1,500-27,000 lbf)
  HWD: (30-240 kN) or (6,500-54,000 lbf)

Pavement Analysis
- Determine pavement layer in-situ modulus (stiffness) values develop load ratings (e.g., Pavement Classification Number (PCN) or axle load limit)
- Inputs for pavement rehabilitation and design
LiDAR (Light Detection And Ranging)

**Reigl LMS-Q120i**
- Range 150-250m
- 10,000 pts/sec
- 5 – 100 scans/sec
- 20mm Range Accuracy
- Scan Angle ±40° (80°)
LiDAR Applications

Survey: 20 Minutes
Points: 27M
Range: 250m
Range Err: +/-10mm
LiDAR Applications
LiDAR Applications
LiDAR Applications
Thank-You

Questions ?
Questions?

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