Risk Assessment Approach for Airfield Pavement Rehabilitation

Dave Anderson, P.Eng.
2016 CAPTG Workshop “How to Assess and Extend the Service Life of Airfield Pavements”
Overview

• Objective
• Background
• Airfield Pavement Management System
• Risk Assessment Approach
• Comparative Alternative Analysis
• Summary
Objective

- Identify risk assessment approach to establish airfield pavement management priorities that can be used by Airport Authorities to provide a consistent and systematic procedure to evaluate airfield pavement rehabilitation alternatives and support planning and engineering decisions.
Background

- Federal Aviation Administration Advisory Circulars (AC)
- Transport Canada Advisory Circulars (AC)
- International Civil Aviation Organization (ICAO) Circulars
- Airport Cooperative Research Program (ACRP) Reports and Transportation Research Research Circulars (TRB)
Surface of runways Article 3.1.22 stipulates: The surface of a runway shall be constructed without irregularities that would impair the runway surface friction characteristics or otherwise adversely affect the take-off or landing of an aeroplane.

Note 1.— Surface irregularities may adversely affect the take-off or landing of an aeroplane by causing excessive bouncing, pitching, vibration, or other difficulties in the control of an aeroplane.

• Attachment A, Section 5: Runway Surface Evenness

• Attachment A, Section 6: Assessing the surface friction characteristics of snow-, slush-, ice- and frost-covered paved surfaces

• Attachment A, Section 7: Determination of surface friction characteristics for construction and maintenance purposes

• Attachment A, Section 8: Drainage characteristics of the movement area and adjacent areas
3.1.3 Surface of Runways Article 3.1.3.1 stipulates: The pavement of the runway is without irregularities that would result in reduced friction characteristics or adversely affect aircraft operations.

*Note 1:* Surface irregularities may adversely affect the take–off or landing of an aircraft by causing excessive bouncing, pitching, vibration, or other control difficulties.


*Note 3:* See Chapter 9 for standards relating to runway friction levels.
3.1.3 **Surface of Runways Article 3.1.3.1 stipulates**: The pavement of the runway is without irregularities that would result in reduced friction characteristics or adversely affect aircraft operations.

*Note 1*: **Surface irregularities** may adversely affect the take–off or landing of an aircraft by causing excessive bouncing, pitching, vibration, or other control difficulties.

*Note 2*: Guidance on **design tolerances** and other information is in the ICAO Annex 14 and ICAO Aerodrome Design Manual, Part 3.

Guidance on **friction characteristics** of new runway surfaces is given in the ICAO Airport Services Manual. Part 2.

Guidance on methods for improving the **runway surface texture** is given in the ICAO Aerodrome Design Manual, Part 3.

*Note 3*: See Chapter 9 for standards relating to runway friction levels.
## Airfield Pavement Design and Evaluation

### Basic Function

- Provide Adequate Bearing Strength
- Provide Good Riding Qualities
- Provide Good Surface Friction Characteristics

### Design and Evaluation Criteria

- Pavement Structure
- Pavement Geometry
- Surface Texture, Drainage
## Airfield Pavement Design and Evaluation

<table>
<thead>
<tr>
<th>Basic Function</th>
<th>Design and Evaluation Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide Adequate Bearing Strength</td>
<td>Pavement Structure</td>
</tr>
<tr>
<td>Provide Good Riding Qualities</td>
<td>Pavement Geometry</td>
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<tr>
<td>Provide Good Surface Friction Characteristics</td>
<td>Surface Texture, Drainage</td>
</tr>
<tr>
<td>Service Life Ease of Maintenance</td>
<td>Life Cycle Cost, Usability Factor, Availability for Aircraft Operations</td>
</tr>
</tbody>
</table>
Pavement Life Cycle – FAA Advisory Circular

Best Practice: Rehabilitate Pavement As Deterioration Rate Starts to Increase

FIGURE 1. Typical Pavement Condition Life Cycle (Springer 2005)
Pavement Surface Friction Test Results

Pavement Surface Friction Varies Along Runway Length

Tests at 65 km/h, 0.5 mm water

Runway Average Friction Number = 77

Chainage (m)

Transport Canada Maintenance Planning Runway Average Level = 60
Transport Canada Minimum 100m Maintenance Planning Level = 40
Transport Canada Minimum 100m Action Level = 30
## Airfield Pavement Inspection and Maintenance

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Potential Operational Impact/Outcome</th>
<th>Mitigation</th>
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<tr>
<td>Loose Pavement materials/Jet Blast and/or unbonded layers</td>
<td>FOD, lower friction, higher roughness</td>
<td>FOD is a key risk with serious consequences</td>
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<tr>
<td>Loose Joint materials/Jet Blast and/or debonded sealant</td>
<td>FOD, lower friction, higher roughness</td>
<td></td>
</tr>
<tr>
<td>Flooding or ponding in movement area</td>
<td>FOD, lower friction, closed movement areas resulting in delay in operations</td>
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<tr>
<td>Surface Cracking</td>
<td>FOD, Surface irregularities</td>
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<tr>
<td>Surface Ravelling</td>
<td>FOD, Surface irregularities, lower friction</td>
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</tr>
<tr>
<td>Weathering/Freeze Thaw</td>
<td>FOD, Surface irregularities</td>
<td></td>
</tr>
<tr>
<td>Surface Settlement, Depressions, Rutting</td>
<td>Surface irregularities, lower friction</td>
<td></td>
</tr>
</tbody>
</table>

More Inspection, Maintenance, Repairs, Rehabilitation
Airfield Pavement Inspection and Maintenance

Consider…
Structural integrity, Roughness, Surface friction, Surface drainage
Airfield Pavement Inspection and Maintenance

Consider...
Structural integrity,
Roughness,
Surface friction,
Surface drainage
Airfield Pavement Inspection and Maintenance

Consider...
Structural integrity, Roughness, Surface friction, Surface drainage

Don’t forget about subsurface drainage
Overview

- Objective
- Background
- **Airfield Pavement Management System**
- Risk Assessment Approach
- Comparative Alternative Analysis
- Summary
Airfield Pavement Management System (APMS)

• Find optimum strategy for maintaining pavements in a serviceable condition for the least cost with acceptable risk level.

• Best time for major pavement rehabilitation is just as the rate of deterioration of the pavement begins to increase.

• Basis Components:
  • Technical inventory of airside pavement movement areas.
  • Pavement structural condition survey.
  • Pavement Management Plan.
## Airfield Pavement Management System (APMS)

<table>
<thead>
<tr>
<th>Pavement Quality Characteristics</th>
<th>Description</th>
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<tr>
<td><strong>Structural Integrity</strong></td>
<td>Structurally intact; no loose pieces, free of deposits, broken pieces, spalling caused by stripping, oxidation, frost effects, etc.</td>
</tr>
<tr>
<td><strong>Roughness</strong></td>
<td>No irregularities that interfere with aircraft operation or result in loss of friction and/or structural damage</td>
</tr>
<tr>
<td><strong>Surface Friction</strong></td>
<td>Adequate surface friction and texture; no irregularities such as rutting, ravelling and depressions</td>
</tr>
<tr>
<td><strong>Surface Drainage</strong></td>
<td>Adequate surface drainage/runoff during rainstorms; no standing water; minimize pavement surface water depth</td>
</tr>
<tr>
<td><strong>Strength</strong></td>
<td>Adequate strength to support aircraft loads</td>
</tr>
</tbody>
</table>
Airfield Pavement Management System (APMS)

- **Pavement Inventory**: pavement construction history, dimensions, pavement strength, maintenance history, costs, traffic data, pavement condition data.

- **Pavement Structural Condition Survey**: to ASTM 5340 Standard Test Method for Airport Pavement Condition Index Surveys.

- **Pavement Deterioration/Life Cycle Curves/Future Condition Prediction**

- **Past/Future Pavement Performance**

- **Pavement Maintenance and Rehabilitation Recommendations**: what projects need to be done, when work needs to be done, estimated costs.
Airfield Pavement Management System (APMS)

- Pavement Maintenance and Rehabilitation Alternatives:
  - Surface Seal and crack sealing; defer resurfacing overlay
  - Surface milling, resurfacing and/or strengthening overlay
  - Hot in place recycling and resurfacing overlay
  - Cold in place recycling with full depth pulverization/stabilization and overlay

Catalog of Airport Pavement Preservation Treatments: ACRP 22 Appendix B
Airfield Pavement Management System (APMS)

• Integration of Risk Assessment Approach into Airfield Pavement Management System:
  • provide a few general comments on structured decision-making
  • describe briefly the broader context of risk assessment application
  • provide “tips” on using risk assessments in airfield pavement management capital planning and specifically in comparative alternative analysis for major rehabilitation projects
Overview

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• Summary
ACRP Project Risk Management Flowchart
ACRP Project Risk Management Flowchart

- Identify Risks/Prepare Risk Register
- Assess/Prioritize Risks
- Plan/Update Risk Register
- Monitor/Update Risk Register
Risk Assessment Methodology

- Three Part Risk Model:
  - Probability of Event: operating conditions (aircraft performance, type of operation, weather conditions)
  - Severity: consequences including type, size and location
  - Exposure: Location Probability including pavement conditions, characteristics, geometry
- Risk = Probability * Severity * Exposure
Risk Assessment Methodology

- **Three Part Risk Model:**
  - **Probability of Event:** operating conditions (aircraft performance, type of operation, weather conditions)
  - **Severity:** consequences including type, size and location
  - **Exposure:** Location Probability including pavement conditions, characteristics, geometry

- Risk = Probability * Severity * Exposure
Risk Assessment Methodology

- **Low Risk**: Minimum Risk. Proceed after considering all elements of Risk.
- **Medium Risk**: Moderate Risk. Continue after taking action to manage overall level of risk.
- **High Risk**: Stop. Take risk management measures.
## Risk Assessment Methodology

<table>
<thead>
<tr>
<th>Risk Factor Categories (Airfield Pavement)</th>
<th>Individual Risk Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compromised airport operations</td>
<td>• Delays, disruptions, closures</td>
</tr>
<tr>
<td></td>
<td>• Loss of surface friction, loss of structural integrity</td>
</tr>
<tr>
<td></td>
<td>• FOD/Aircraft incidents</td>
</tr>
<tr>
<td>Compromised safety</td>
<td>• Loss of surface friction, loss of structural integrity</td>
</tr>
<tr>
<td></td>
<td>• FOD/Aircraft incidents</td>
</tr>
<tr>
<td>Compromised environmental quality</td>
<td>• FOD/Aircraft incidents</td>
</tr>
<tr>
<td>Negative public perception</td>
<td>• Delays, disruptions, closures</td>
</tr>
<tr>
<td></td>
<td>• FOD/Aircraft incidents</td>
</tr>
<tr>
<td>Inability to meet regulatory requirements</td>
<td>• Loss of surface friction, loss of structural integrity</td>
</tr>
<tr>
<td></td>
<td>• FOD/Aircraft incidents</td>
</tr>
</tbody>
</table>
Triple Bottom Line + Risk explicitly accounts for risk attributes of different solutions or actions, as well as TBL attributes.
Overview

- Objective
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Structured Decision Making - Comparative Options Analysis

GOAL
Airport ABC Pavement Rehabilitation Project

CATEGORY
- environmental
- social
- economic
- risk

CRITERIA
- carbon footprint
- Aircraft traffic volume footprint
- capital cost
- O&M cost
- total risk severity score

ALTERNATIVES
- Surface Seal and Crack Sealing
- Resurfacing Overlay
- Surface Milling and Strengthening Overlay
- Hot-in-place Recycling and Resurfacing Overlay
- Cold-in-place Recycling with Full Depth Pulverization/Stabilization and Overlay
Risk Assessment - DRU Rating System

<table>
<thead>
<tr>
<th>Item</th>
<th>Location</th>
<th>Activity description</th>
<th>Qty</th>
<th>Unit</th>
<th>D</th>
<th>%</th>
<th>R</th>
<th>U</th>
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<td>P12</td>
<td>8. Long &amp; trans Cracking - seal and repair</td>
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<td>8. Long &amp; trans Cracking - seal and repair</td>
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<td>m</td>
<td>M</td>
<td>7</td>
<td>4</td>
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</table>

**SCHEDULE OF WORK**
Development of maintenance and rehabilitation plans and budgets
# Risk Assessment – DRU Rating System

<table>
<thead>
<tr>
<th>DEGREE – D/C</th>
<th>Rating</th>
<th>RELEVANCY – R</th>
<th>URGENCY – U</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree of Severity of Defect</td>
<td></td>
<td>Structural integrity and safety of user</td>
<td>Maintenance priority and urgency of repair</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>No defects, as new condition</td>
<td>No defects, as new condition</td>
<td>Routine maintenance work</td>
<td>Routine</td>
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<tr>
<td>V</td>
<td>Normal wear and deterioration not requiring maintenance/repair</td>
<td>Min relevancy</td>
<td>Work not required before next detailed inspection</td>
<td>4yrs or &gt;</td>
</tr>
<tr>
<td>L</td>
<td>Functioning as intended</td>
<td>No structural integrity or Safety issues</td>
<td>Work required within specified time period</td>
<td>&lt; 3yrs</td>
</tr>
<tr>
<td>M</td>
<td>Minor maintenance/repair required</td>
<td>Minor impact on structural integrity or safety issue</td>
<td>Work required within specified time period</td>
<td>&lt; 2yrs</td>
</tr>
<tr>
<td>H</td>
<td>Not functioning as intended</td>
<td>Structural integrity or Safety compromised</td>
<td>Immediate repair required</td>
<td>ASAP</td>
</tr>
<tr>
<td></td>
<td>More extensive repair required</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major repair required</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Short cut codes for: Location Column*  
A1-First Abutment; A2-Second Abutment; S1-Span1; P1-Pier1; GA-Girder A (left most girder); BA-Bay A (between GA & GB)  
S/M Column: S-Safety related defect; M-Make Safe a Structural Integrity Related Defect; SM-Make Safe a Safety Related Defect

*High Max Relevancy ASAP*
# Risk Matrix – defect & element level

25 defects with this risk rating (3, 20%, 3)

<table>
<thead>
<tr>
<th>Element Banded Risk Matrix:</th>
<th>Vitality Important</th>
<th>Considerably Important</th>
<th>Important</th>
<th>Minor Importance</th>
<th>Not Important</th>
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<td>265/104</td>
<td>31/6</td>
<td>2/3</td>
<td>5/1</td>
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<tr>
<td></td>
<td>315/160</td>
<td>65/18</td>
<td>9/1</td>
<td>1/1</td>
<td>3/1</td>
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<tr>
<td></td>
<td>346/33</td>
<td>211/4</td>
<td>110/1</td>
<td>438/144</td>
<td>45/22</td>
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<td>282/3</td>
<td>307/42</td>
<td>42/18</td>
<td>28/18</td>
<td>5/5</td>
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<td></td>
<td>350/8</td>
<td>8/4</td>
<td>2/1</td>
<td>0/1</td>
<td>0/1</td>
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</table>

Integrity and Safety of Elements
Risk Matrix – defect & element level

Element Risk Matrix (Condition Index):

- Extent of the defect on element considered
- Relevancy & Degree
- Integrity and Safety of Elements

- Worst condition
- CRITICAL
- WARNING

- Maintenance
- Deterioration

Element Banded Risk Matrix:

- Vitially Important
- Considerably Important
- Important
- Minor Importance
- Not Important

- Integrity and Safety of Elements

<100 <90 <80 <70 <60 <50 <40 <30 <20 <10
Comparative Alternative Analysis

Priority Index
Condition Index
Relevancy Index

Functional Index
- Code Class Category
- Aircraft Load
- Flight Frequencies
- Public Availability
- Runway Length/width
- Wait Times
- Etc.

Structural Integrity & Safety

Strategic Importance

Load Rating

Capacity Index
- Aircraft Code - AGN
- Limiting ACN/PCN
- Pavement Condition
# 5-Year Plan

## ORDER OF SORTING

<table>
<thead>
<tr>
<th>PI or RI</th>
<th>Code for RWA</th>
<th>Bridge</th>
<th>Item</th>
<th>Location</th>
<th>Activity description</th>
<th>Qty</th>
<th>Unit</th>
<th>D</th>
<th>%</th>
<th>R</th>
<th>U</th>
<th>U adj</th>
<th>Rate</th>
<th>Cost</th>
<th>R2</th>
<th>Benefit/Cost Ratio</th>
<th>Accumulated Cost</th>
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<td>103</td>
<td>B23</td>
<td>3.6</td>
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<td>5</td>
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### 5 Year Maintenance Plan – WITH BUDGET RESTRICTIONS

<table>
<thead>
<tr>
<th>Year</th>
<th>ASAP &lt; 1yr</th>
<th>&lt;2 years</th>
<th>&lt;3 years</th>
<th>5 years or &gt;</th>
<th>Routine</th>
<th>Monitor</th>
<th>Budget Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR 1</td>
<td>X1$</td>
<td>Y5$</td>
<td>Z5$</td>
<td>K5$</td>
<td>R5$</td>
<td>M5$</td>
<td>X1$+R5$</td>
</tr>
<tr>
<td>YEAR 2</td>
<td>X5$-X1$</td>
<td>A5$+Y5$-Y5$+X5$</td>
<td></td>
<td></td>
<td>R5$</td>
<td>M5$</td>
<td>X1$+R5$</td>
</tr>
<tr>
<td>YEAR 3</td>
<td>Y5$-K5$</td>
<td>B5$+Z1$-Y5$-A5$</td>
<td></td>
<td></td>
<td>R5$</td>
<td>M5$</td>
<td>Z1$+R5$</td>
</tr>
<tr>
<td>YEAR 5 or &gt;</td>
<td>Z5$-K5$</td>
<td>Z5$-R5$</td>
<td>K5$</td>
<td>R5$</td>
<td>M5$</td>
<td>Z5$+K5$+R5$</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>X5$</td>
<td>Y5$</td>
<td>Z5$</td>
<td>K5$</td>
<td>R5$</td>
<td>M5$</td>
<td>X5$+R5$</td>
</tr>
</tbody>
</table>

### Budget Limit

a. **BUDGET LIMIT FOR YEAR 1** __X1$__

b. **BUDGET LIMIT FOR YEAR 2** __Y1$__

c. **BUDGET LIMIT FOR YEAR 3** __Z1$__
Summary

• **Risk assessment approach is a useful tool:**
  • Rational, non-prescriptive, quantitative assessment
  • Readily scaled to large/small airports, large/small airfield pavement rehabilitation projects
  • Engage airport stakeholders to reach consensus on airfield pavement management goals, objectives and establish priorities
  • Enhances overall credibility and acceptance