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Risk Assessment Approach for Airfield Pavement Rehabilitation

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2016 CAPTG Workshop "How to Assess and Extend the Service Life of Airfield Pavements"

captg

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 Circulars (TRB)

ICAO Annex 14 Aerodromes, 6th Edition, July 2013

- 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.

ICAO Annex 14 Aerodromes, 6th Edition, July 2013

- 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

Transport Canada TP312, 5th Edition, Sept 2015

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.

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Airfield Pavement Design and Evaluation

Basic Function	Design and Evaluation Criteria
Provide Adequate Bearing Strength	Pavement Structure
Provide Good Riding Qualities	Pavement Geometry
Provide Good Surface Friction Characteristics	Surface Texture, Drainage

Airfield Pavement Design and Evaluation

Basic Function	Design and Evaluation Criteria
Provide Adequate Bearing Strength	Pavement Structure
Provide Good Riding Qualities	Pavement Geometry
Provide Good Surface Friction Characteristics	Surface Texture, Drainage
Service Life Ease of Maintenance	**Life Cycle Cost, Usability Factor, Availability for Aircraft Operations**

Pavement Life Cycle – FAA Advisory Circular

Best Practice: Rehabilitate Pavement As Deterioration Rate Starts to Increase

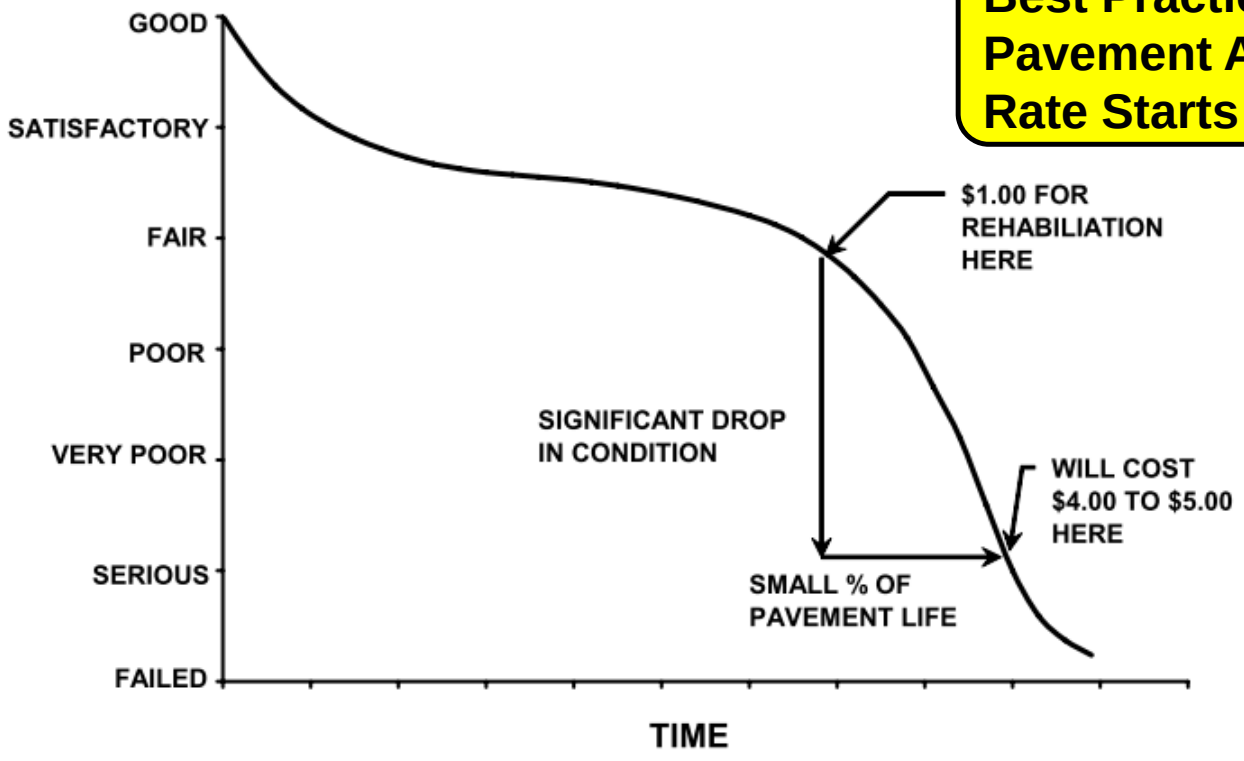
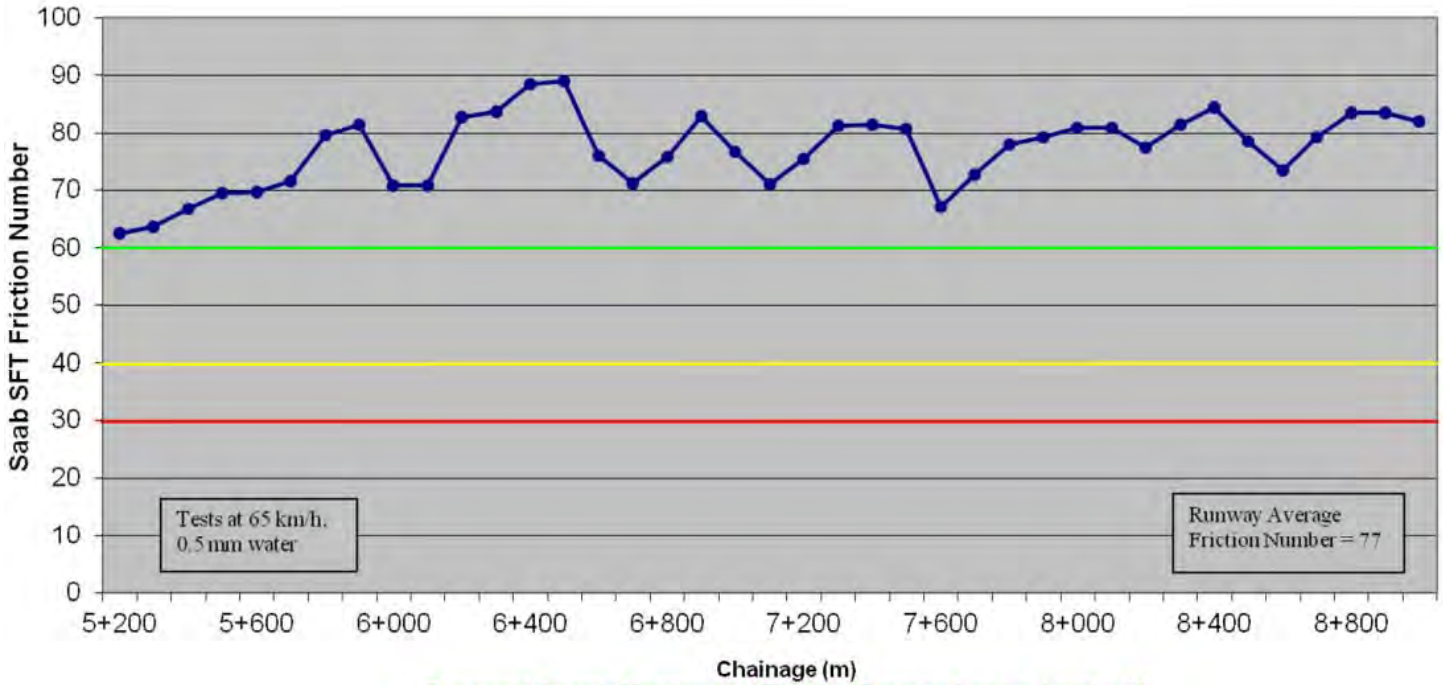


FIGURE 1. Typical Pavement Condition Life Cycle (Springer 2005)

Pavement Surface Friction Test Results

Pavement Surface Friction Varies Along Runway Length



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

Hazard	Potential Operational Impact/Outcome	Mitigation
Loose Pavement materials/Jet Blast and/or unbonded layers	FOD, lower friction, higher roughness	**FOD is a key risk with serious consequences**
Loose Joint materials/Jet Blast and/or debonded sealant	FOD, lower friction, higher roughness	
Flooding or ponding in movement area	FOD, lower friction, closed movement areas resulting in delay in operations	More Inspection, Maintenance, Repairs, Rehabilitation
Surface Cracking	FOD, Surface irregularities	
Surface Ravelling	FOD, Surface irregularities, lower friction	
Weathering/Freeze Thaw	FOD, Surface irregularities	
Surface Settlement, Depressions, Rutting	Surface irregularities, lower friction,	

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

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Airfield Pavement Management System (APMS)

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

FIGURE 9 Pavement performance prediction

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

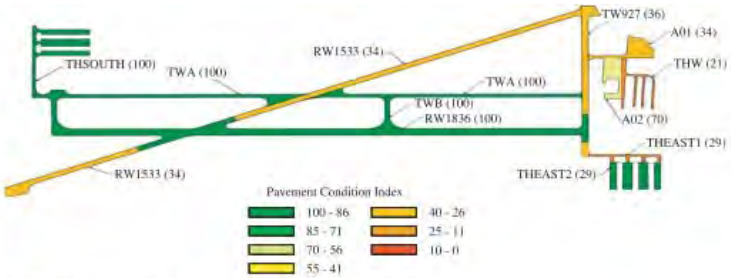

FIGURE 7 Example of a graphical display of Pavement Condition Index.

- Basis Components:
  - Technical inventory of airside pavement movement areas.
  - Pavement structural condition survey.
  - Pavement Management Plan.

Airfield Pavement Management System (APMS)

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

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

TABLE 6
AIRPORT PAVEMENT PRESERVATION TREATMENTS INCLUDED IN THE CATALOG

Both Pavement Types	Asphalt Concrete	Portland Cement Concrete
▪ Texturization using controlled shot blasting ▪ Diamond grinding ▪ Microsurfacing	▪ Sealing and filling of cracks (with fuse- or cold-applied sealants) ▪ Small area patching (using hot mix, cold mix, or proprietary material) ▪ Spray patching (manual chip seal or mechanized spray patching) ▪ Machine patching with AC material ▪ Rejuvenators and seals ▪ Texturization using fine milling ▪ Surface treatment (chip seal, chip seal coat) ▪ Slurry seal ▪ Hot-mix overlay (includes milling of AC pavements) ▪ Hot in-place recycling ▪ Cold in-place recycling ▪ Ultra-thin whitetopping	▪ Joint and crack sealing (with bituminous, silicone, or compression sealants) ▪ Partial-depth repairs (using AC, PCC, or proprietary materials) ▪ Full-depth repairs (using AC, PCC, or proprietary materials) ▪ Machine patching using hot mix ▪ Slab stabilization and slab-jacking ▪ Load transfer ▪ Crack and joint stitching ▪ Hot-mix overlays ▪ Bonded PCC overlay
3 treatments	12 treatments	9 treatments

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

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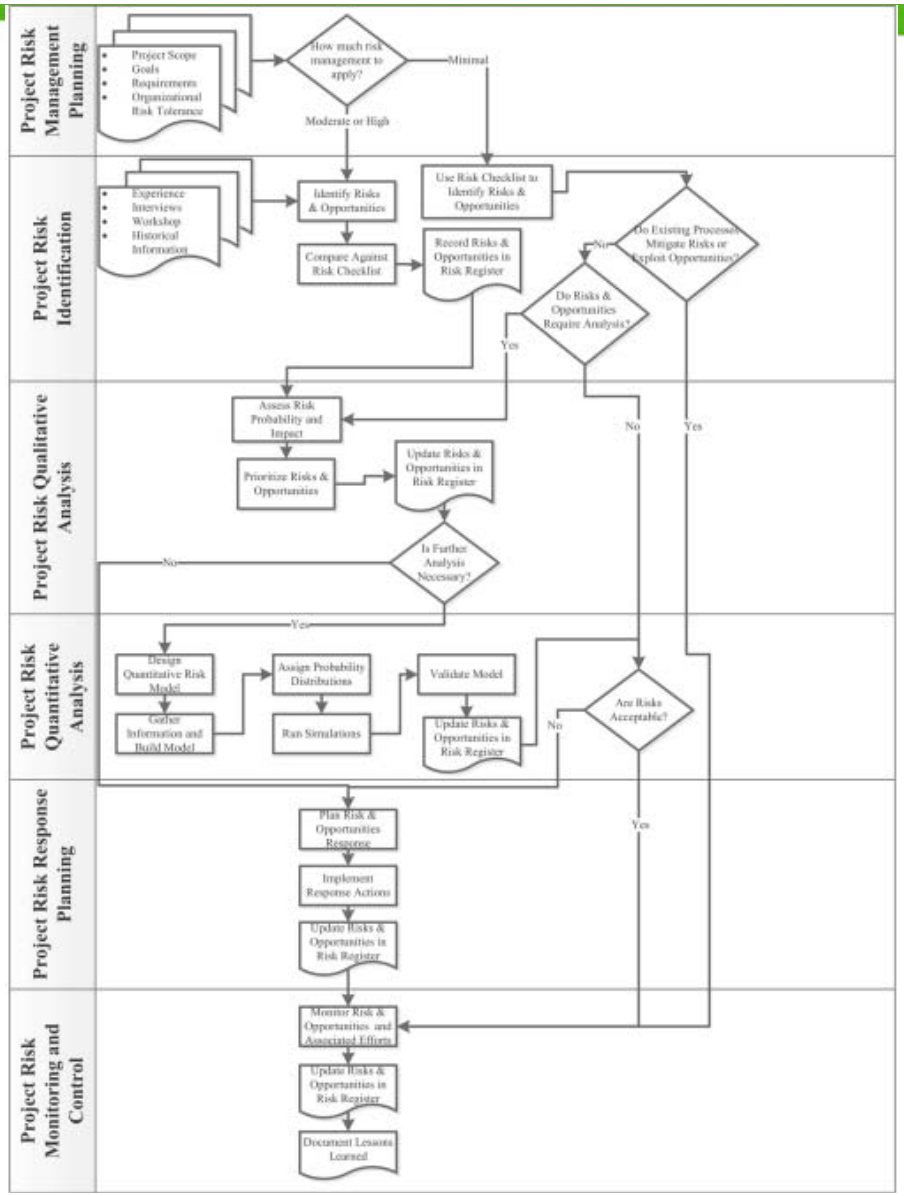
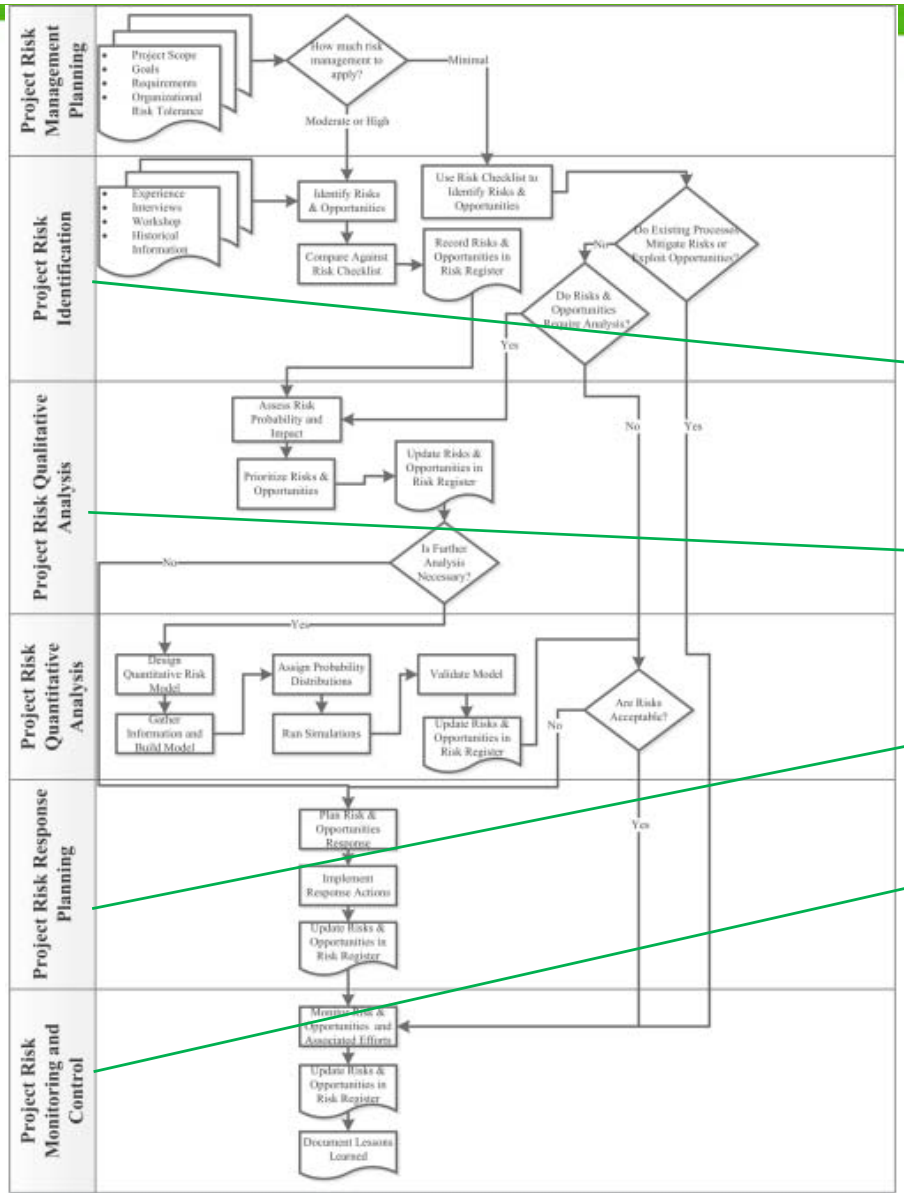


ACRP Project Risk Management Flowchart

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

Level	Probability
Level 0	Rare/impossible
Level 1	Remote/Unlikely
Level 2	Occasional
Level 3	Probable-likely
Level 4	Frequent- Almost certain

Level	Personnel	Equipment
Level 0	No injury (None)	No Damage (None)
Level 1	First aid injury, no disability or lost time (Negligible)	Minor damage, potential downtime or slow-down (Negligible)
Level 2	Lost time injury, no disability (Minor)	Minor Damage, leads to organizational slowdown/minor downtime (Minor)
Level 3	Disability/Severe injury (Major)	Major damage, results in major slowdown/downtime (Major)
Level 4	Fatal, life threatening (Fatal)	Loss of critical equipment, or shutdown of organization (Destroyed)

Level	Exposure
Level 0	No Exposure
Level 1	Seldom
Level 2	Occasional
Level 3	Frequent
Level 4	Constant

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 Matrix

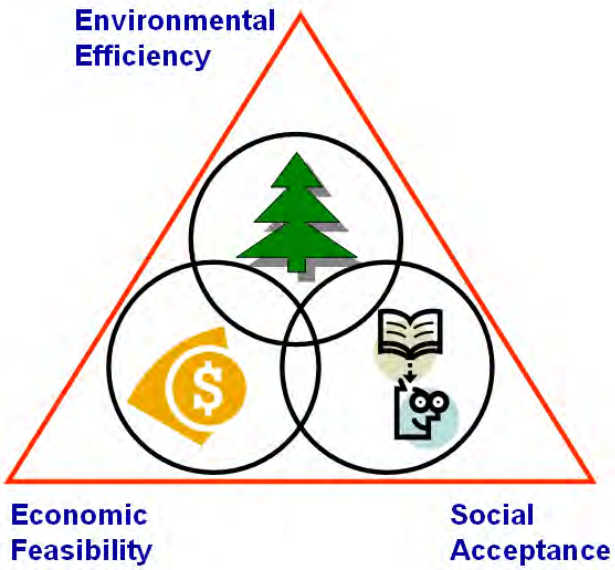
Severity / Likelihood	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A					
Probable B					
Remote C					
Extremely Remote D					
Extremely Improbable E					*

* Unacceptable with Single Point and/or Common Cause Failures

High Risk
Medium Risk
Low Risk

Risk Assessment Methodology

Risk Factor Categories (Airfield Pavement)	Individual Risk Factors
Compromised airport operations	• Delays, disruptions, closures • Loss of surface friction, loss of structural integrity • FOD/Aircraft incidents
Compromised safety	• Loss of surface friction, loss of structural integrity • FOD/Aircraft incidents
Compromised environmental quality	• FOD/Aircraft incidents
Negative public perception	• Delays, disruptions, closures • FOD/Aircraft incidents
Inability to meet regulatory requirements	• Loss of surface friction, loss of structural integrity • FOD/Aircraft incidents



Triple Bottom Line + Risk

Triple Bottom Line + Risk explicitly accounts for risk attributes of different solutions or actions, as well as TBL attributes

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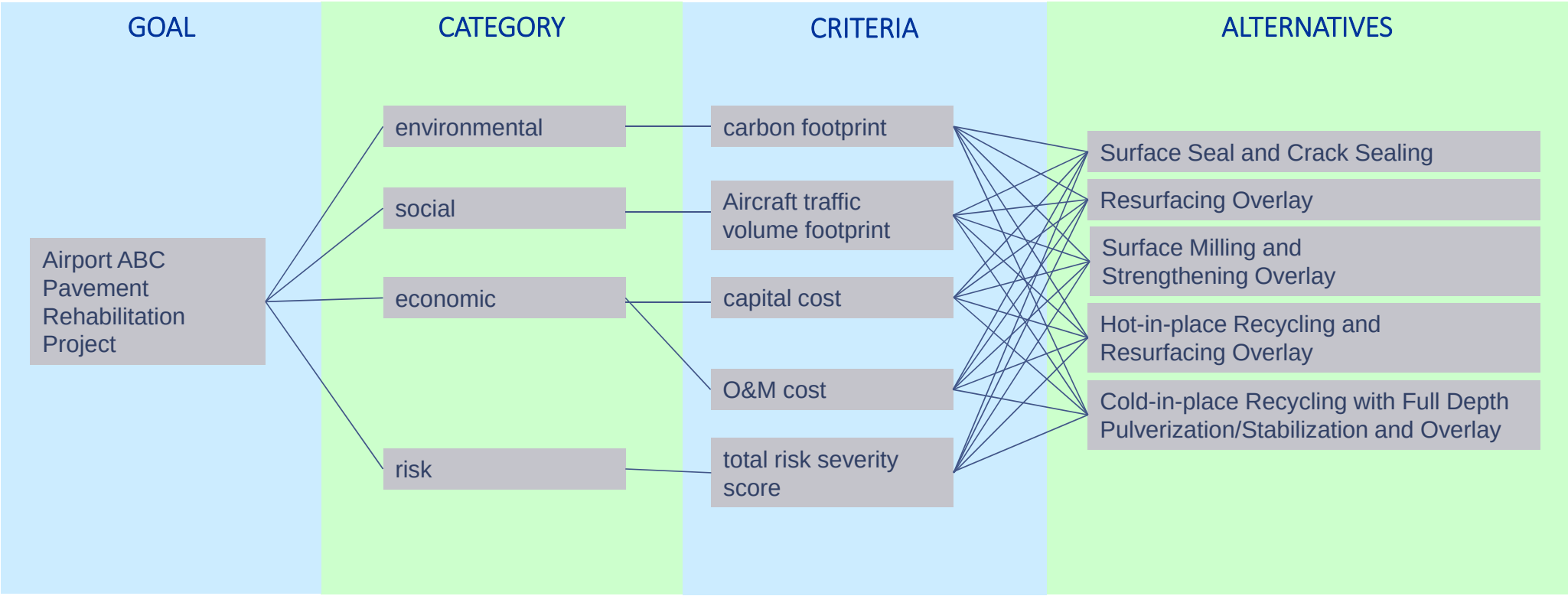
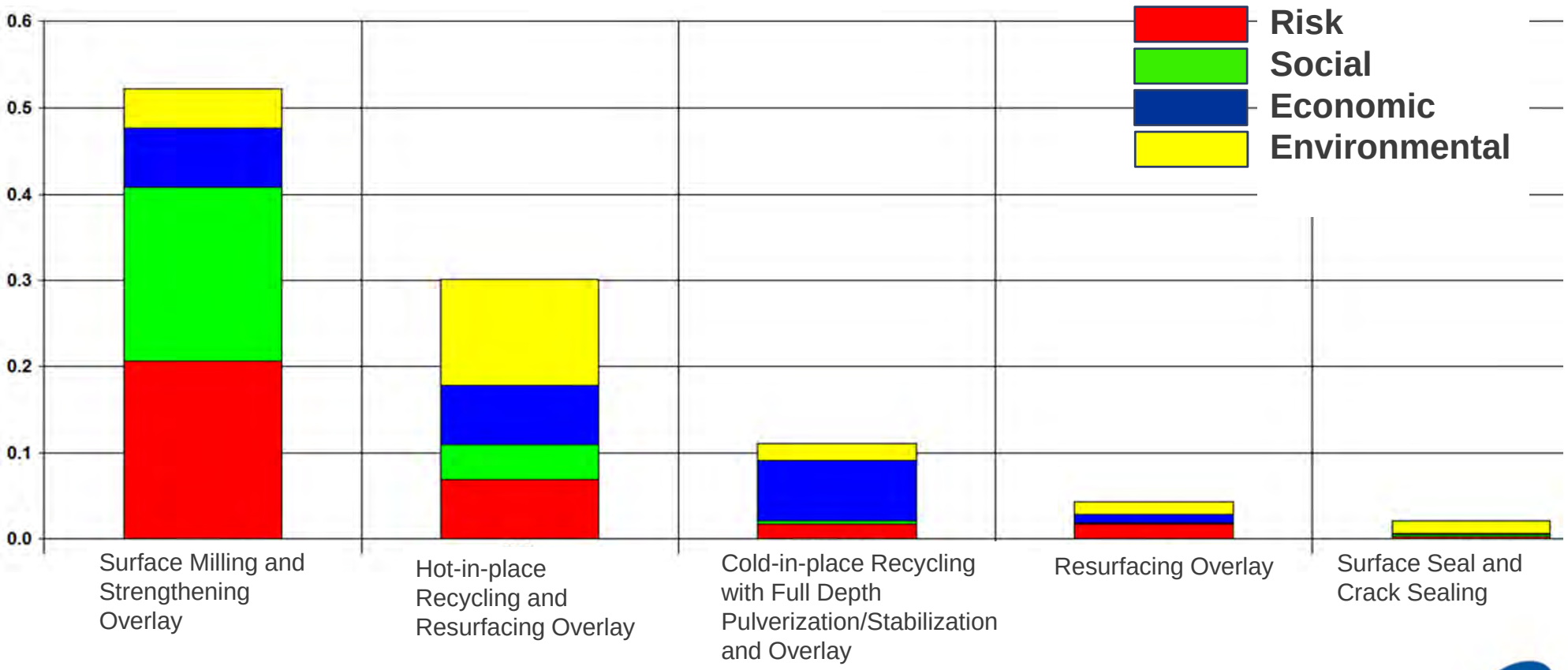
Structured Decision Making - Comparative Options Analysis



Structured Decision Making - Comparative Options Analysis



Risk Assesment - DRU Rating System

MEASURE OF
Deterioration
Level of Service
Life Cycle Plan

Condition

Relevancy

MEASURE OF RISK
Probability
Consequence
Likelihood
Severity

SAFETY

D R U

Urgency

OMR Plan
RISK Matrix
LC Plan

Item	Loca-tion	Activity description	Qty	Unit	D	%	R	U
1.1	P12	8. Long & trans Cracking - seal and repair	10	m2	L	5	2	3
1.1	P23	8. Long & trans Cracking - seal and repair	5	m2	H	2	3	4
1.2	P45	9. Oil Spillage - Clean	15	m2	V	15	1	R
1.5	P51	21. Drain - Unblock	1	No	M	1	2	R
1.7	P105	20. Jt seal - repair	25	m	M	7	4	2

SCHEDULE OF WORK

Development of maintenance and rehabilitation plans and budgets

Risk Assessment – DRU Rating System

Degree Condition of defect
Extent % of element covered by defect
Relevancy Importance of defect
Urgency Time limit to repair defect

High Max Relevancy ASAP

4 pt. defect rating system

Rating	DEGREE – D/C		Rating	RELEVANCY – R		URGENCY - U		Rating
	Degree of Severity of Defect			Structural integrity and safety of user		Maintenance priority and urgency of repair	Monitor	M
E		No defects, as new condition		No defects, as new condition		Routine maintenance work	Routine	R
V	Very Low	Normal wear and deterioration not requiring maintenance/repair	1	Min relevancy	No structural inetegrity or Safety issues	Work not required before next detailed inspection	4yrs or >	1
L	Low	Functioning as intended Minor maintenance/repair required	2		Minor impact on structural integrity or safety issue	Work required within specified time period	< 3yrs	2
M	Medium	Not functioning as intended More extensive repair required	3		Structural integrity or Safety compromised	Work required within specified time period	< 2yrs	3
H	High	Not functioning as intended Major repair required	4	Max relevancy	Structural Integrity and Safety Severely Compromised, collapse imminent and/or danger to users	Immediate repair required	ASAP	4

X-% not inspected; **N**-Not applicable; **%**-percentage of component with rating "**D**"
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

Risk Matrix – defect & element level

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

Relevancy & Degree

Element Risk Matrix (Condition Index):

R	D	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	50	60	70	75	80	90	95	100
4	4					1						1													
	3																								
	2																								
	1																								
3	4		1			7				1	2	1	3	1	2		1	2	1		2				32
	3	5	8			22			1		38	3	25	1	22	2	27	30	10	5	2	12	3		29
	2																								
	1																								
2	4		1			35					1	1	4				1	6	2						21
	3	19	5			17	3			1	53	26	109	13	61	8	73	82	67	29	15	21	9		101
	2	23	17	1		94	4				448	16	502	13	317	2	153	119	53	18	16	23	7		113
	1														1										1
1	4					1		1			6	1		1			1	3							6
	3	28	10	1		30		1			28	11	19	12	6	4	3	47	2	3	13	6	1	14	336
	2	57	45	3	20	133	10		17	1	190	33	100	30	49	11	10	100	26	18	12	13	2		190
	1	742	133	6	1	1377					907	46	479	145	134	4	50	608	36	4	22	21	12	2	897

Extent of the defect on element considered

Element Banded Risk Matrix:

Strategic Importance	<100	<90	<80	<70	<60	<50	<40	<30	<20	<10
Vitally Important	5790	265	184	31	6	2	5	25	0	0
Considerably Important	1389	55	96	18	9	1	1	2	0	0
Important	34693	2118	1101	438	144	45	22	1	0	0
Minor Importance	2823	307	42	28	18	5	5	3	0	0
Not Important	358	8	4	2	1	0	1	0	0	0

Integrity and Safety of Elements

Risk Matrix – defect & element level

Relevancy & Degree

Worst condition

Element Risk Matrix (Condition Index):

R	D	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	50	60	70	75	80	90	95	100
4	4					1						1													
	3																								
	2																								
	1																								
3	4		1			7				1	2	1	3	1	2		1	2	1		2				12
	3	5	8			22			1		38	3	25	1	22	2	27			5	2	12	3		29
	2																								
	1																								
2	4		1			35					1		4				1	6	2						21
	3	19	5			17	3			1	53		39	13	61	8	73	82	67	29	15	21	9		101
	2	23	17	1		94	4				448	6	502	13	317	2	153	113	53	18	16	23	7		113
	1														1										1
1	4					1					6	1		1			1	3							8
	3	28	10	1							28	11	19	12	6	4	3	47	2	3	13	6	1	14	336
	2	57	45	3	20	183	10		17	1	190	33	100	30	49	11	10	100	26	18	12	13	2		190
	1	742	133	6	1	1377					907	46	479	145	134	4	50	608	36	4	22	21	12	2	897
	E	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	50	60	70	75	80	90	95	100

Maintenance

Deterioration

CRITICAL

WARNING

Best condition

Extent of the defect on element considered

Element Banded Risk Matrix:

Strategic Importance	<100	<90	<80	<70	<60	<50	<40	<30	<20	<10
Vitally Important	5790	265	184	31	6	2	5	25	0	0
Considerably Important	1389	55	96	18	9	1	1	2	0	0
Important	34693	2118	1101	438	144	45	22	1	0	0
Minor Importance	2823	307	42	28	18	5	5	3	0	0
Not Important	358	8	4	2	1	0	1	0	0	0

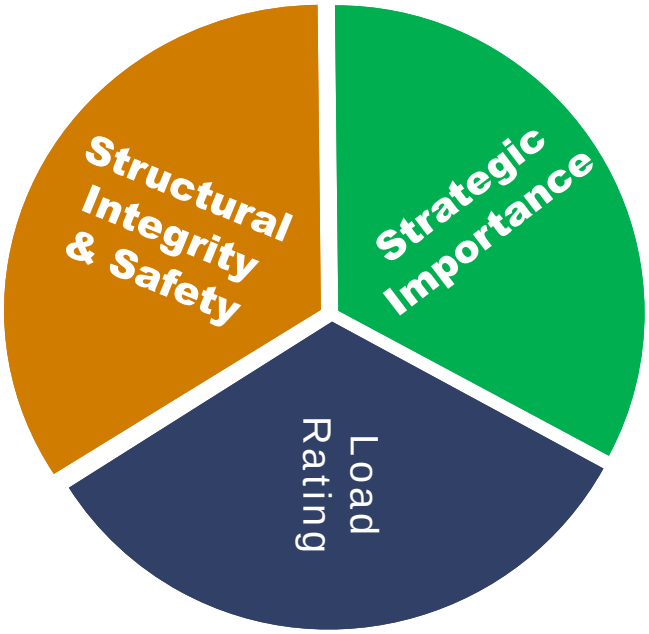
Integrity and Safety of Elements

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.

Capacity Index

Aircraft Code - AGN
Limiting ACN/PCN
Pavement Condition

5-Year Plan

Options in order of preference	Order of ranking				
	1	2	3	4	5
1	PI or RI	Urgency	Relevancy	B/C ratio	-
2	Urgency	PI or RI	Relevancy	B/C ratio	-
3	etc.,				

1					ORDER OF SORTING						3	2				4	
PI or RI	*Code for RWA*	Bridge	Item	Location	Activity description	Qty	Unit	D	%	R	U	U adj	Rate	Cost	R2	Benefit/Cost Ratio	Accumulated Cost
1	*103*	B23	3.6	AS	Barrier connection to deck - repair	120	m	4	10	3	4	4	875	105000	9	8.5714E-05	105000
	193	B23	2.12	SA	Railing Post - relocate	1	No	4	5	1	4	4	700	700	1	0.00142857	105700
	103	B23	1.4	BA	Barrier end section - replace with safer detail	30	m	4	5	3	3	3	875	26250	9	0.00034286	131950
	127	B23	4.1	P1	Spalled concrete - repair	0.01	m3	3	2	2	3	3	15000	150	4	0.02666667	132100
	127	B23	3.6	AS	Spalled concrete - repair	0.5	m3	3	10	2	3	3	15000	7500	4	0.00053333	139600
	164	B23	2.16	BA	Exp jt - new	40	m	3	100	2	3	3	8000	320000	4	0.0000125	459600
	206	B23	2.11	SA	Seal -remove	2	m	1	5	1	3	3	60	120	1	0.00833333	459720
	228	B23	2.9	SA	Waterproofing - new	10	m2	3	5	2	2	2	85	850	4	0.00470588	460570
	127	B23	1.4	BA	Spalled concrete - repair	0.05	m3	3	2	1	2	2	15000	750	1	0.00133333	461320
	206	B23	1.4	BA	Seal - replace	30	m	3	3	1	1	1	60	1800	1	0.00055556	463120
	265	B23	3.13	S1	Levelling concrete - repair	10	m2	1	20	1	1	1	200	2000	1	0.0005	465120
	130	B23	2.17	NA	Bolt - tighten	1	No	1	10	1	R	0	10	10	1	0.1	465130
	116	B23	2.1	BA	Debris - clear	0.5	m3	1	5	1	R	0	25	12.5	1	0.08	465142.5

	5 year Maintenance Plan – WITH BUDGET RESTRICTIONS				As and when scheduled during the year	Non maintenance items that only need monitoring	
	ASAP - < 1 yr	< 2 years	< 3 years	5 years or >	Routine	Monitor	BUDGET LIMITS
NEED	X$	Y$	Z$	K$	R$	M$	
YEAR 1	X1$				R$		X1$+R$
YEAR 2	X$-X1$	A$=Y1$-(X$-X1$)			R$		Y1$+R$
YEAR 3		Y$-A$	B$=Z1$-(Y$-A$)		R$		Z1$+R$
YEAR 5 or >			Z$-B$	K$	R$		K$+(Z$-B$)+R$
TOTAL	X$	Y$	Z$	K$	∑R$		

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