Life-Cycle Cost Analysis (LCCA)

ICAO Airfield Pavement Workshop

Presented by:

Harold Muniz
Airfield Pavement Engineer
FAA Headquarter, AAS-110

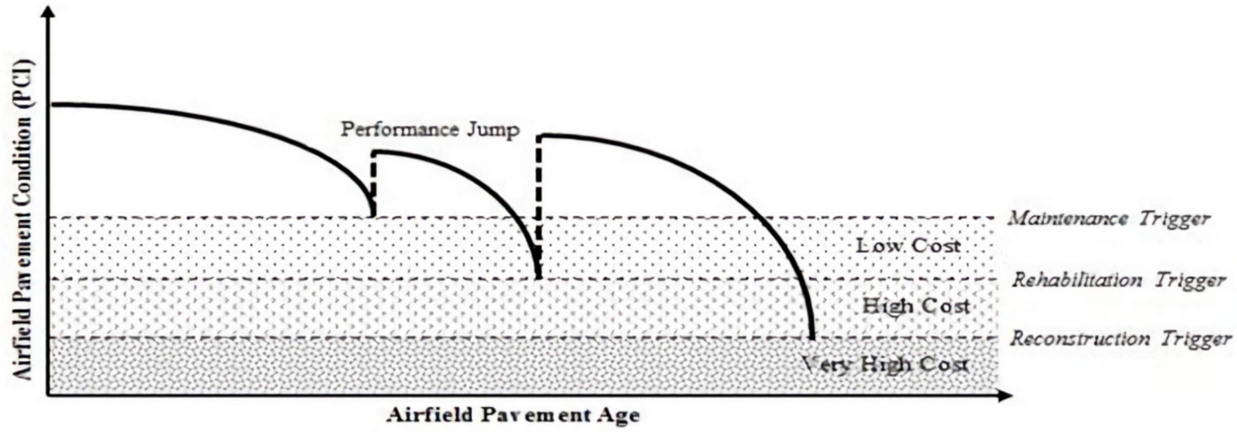
David R. Brill, P.E., Ph.D.
Program Manager – Airport Pavement Technology
FAA Airport Technology R&D Branch, ANG-E262

Overview

- Fundamentals of LCCA
- Analysis methods
- Steps in LCCA analysis
- LCCA Example
  - Using Present Worth
- Resources
- FAA Guidance

Life-Cycle Cost Analysis (LCCA)

- ***Economical analysis tool that allows us to quantify the differential cost of alternatives investment options and determine best value over the lifecycle of the investment***
  - Includes initial construction and future maintenance cost
  - Can consider user benefits over total cost of investment
- ***Common approach to evaluate investment alternatives (best value)***

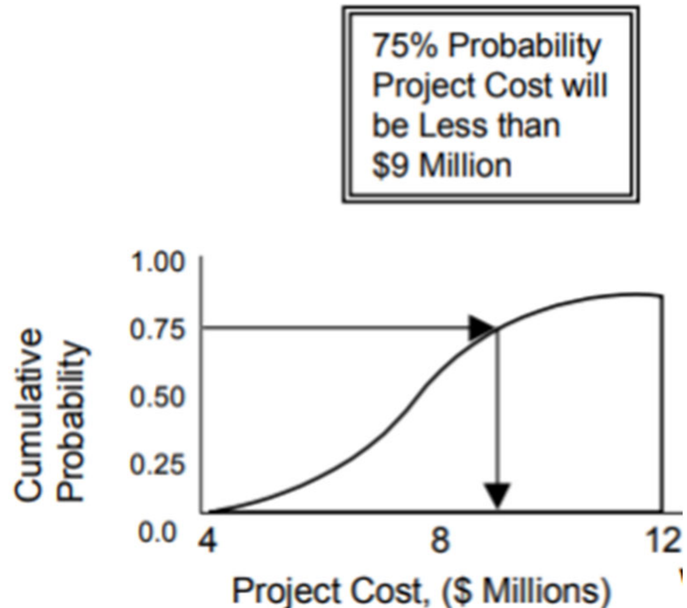


Quantifying LCCA Benefits

- **Benefit-Cost Analysis (BCA)**
  - Evaluates benefit of to users generated by the investment
  - Requires monetization of benefits
  - Ratios > 1.0 indicate benefit exceed investment
- **Present Value, or Present Worth***
  - Converts future cost to present amounts
  - Discount rate applied to future cash flow
  - FAA recommend approach
- **Equivalent Uniform Annual Cost**
  - Expressed cost uniform cost throughout the analysis period
  - Useful in analysis of annual budgets

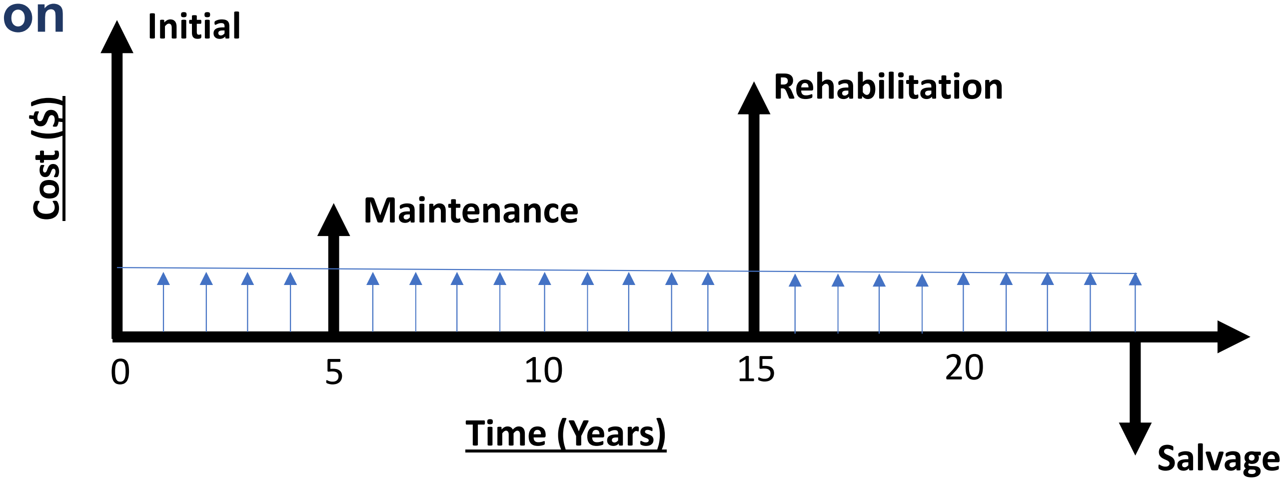
LCCA Analysis Methods

- **Economical analysis tool that allows us to quantify the differential cost of alternatives investment options and determine best value over the lifecycle of the investment**
- *Deterministic*
  - Treats all inputs as discrete values
  - Yields a single number
- *Probabilistic*
  - Inputs accounts for range of values
  - Attempts to capture variation and account for uncertainty
  - Yields a probability distribution



Graphical LCCA Representation

- Initial Cost
- Annual Maintenance
- Scheduled Preventative Maintenance
- Scheduled Rehabilitation



Objective is to bring all future cost to present work to compare alternatives

LCCA Basic Steps

1- Establish Pavement Alternatives

2- Determine Analysis period
- M&R activity and timing

3- Select discount rate

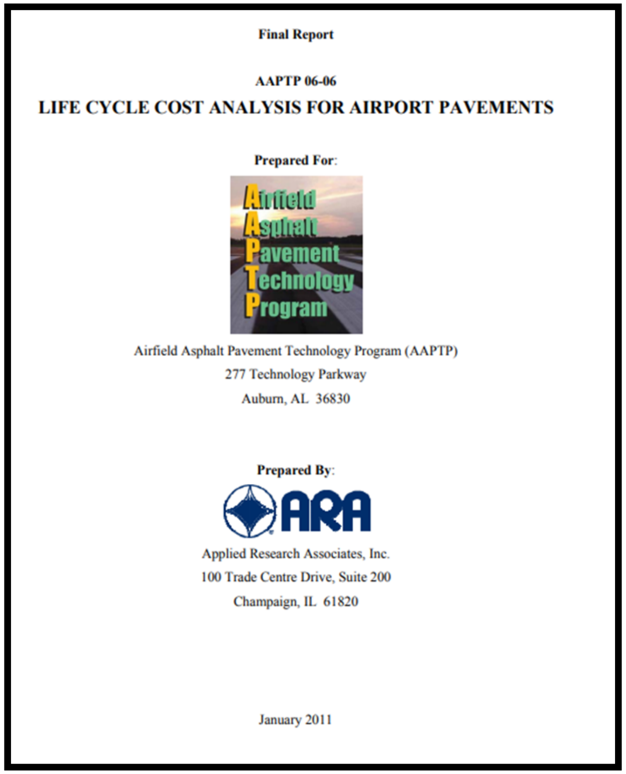
4- Estimate Cost
- Agency Cost
- User Cost

5- Estimate Residual Value

6- Compute (NPV)

7- Compare Alternatives

8- Select Best Value or Revaluate


Final Report

AAPTP 06-06

LIFE CYCLE COST ANALYSIS FOR AIRPORT PAVEMENTS

Prepared For:

Airfield Asphalt Pavement Technology Program

Airfield Asphalt Pavement Technology Program (AAPTP)
277 Technology Parkway
Auburn, AL 36830

Prepared By:

ARA

Applied Research Associates, Inc.
100 Trade Centre Drive, Suite 200
Champaign, IL 61820

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Select Pavement Section Alternatives (1.6.2.2)

- **The selection of a pavement section requires the evaluation of multiple factors including:**
  - *Cost and funding limitations*
  - *Operational constraints*
  - *Construction timeframe*
  - *Material availability*
  - *Cost and frequency of anticipated maintenance*
  - *Environmental constraints*
  - *Future airport expansion plans*
  - *Anticipated changes in traffic*
- **Document the rationale for the selected pavement section, materials and service life in the engineer's report.**

LCCA – Analysis Period

- **Prior guidance in 6D suggested an evaluation 20-year evaluation period**
- **Analysis period is not necessarily the design life used for the pavement life**
  - Consider ~40 year for reconstruction alternative
  - Consider ~30-year life for rehabilitation
  - *Coordinate analysis period with the owner and document in engineer report*
- **Analysis period should include a rehabilitation for each alternative**
  - Mill & overlay, surface treatment, FDR
  - Spall repair, slab replacement, joint seal.
- **Activity Timing**

Discount Rates

- **Represents the value of money over time**
- **Function of both the interest rate and inflation rate**
- **Low Discount Rate**
  - Favors high initial cost and low future cost options long term solutions over short term solutions Capital expansion over preservation
- **High Discount Rate**
  - Favors low initial cost and high future cost options Short term solutions over long term solutions maintaining existing capacity over building new capacity

Discount Rates

- OMB Circular A-94, Appendix C provides guidance to federal agencies on performing Benefit-Cost Analysis and Cost-Effectiveness Analysis.
- Circular is not mandatory for use, agencies can establish their own procedures
- <u>Consider a Sensitivity analysis</u>

Real Interest Rates on Treasury Notes and Bonds of Specified Maturities (in percent)

3-Year	5-Year	7-Year	10-Year	20-Year	30-Year
1.2	1.3	1.4	1.5	2.0	2.0

Analyses of programs with terms different from those presented above may use a linear interpolation. For example, a four-year project can be evaluated with a rate equal to the average of the three-year and five-year rates. Programs with durations longer than 30 years may use the 30-year interest rate.

LCCA- Estimated Cost

- **Agency Cost-** account for initial construction and maintenance during the analysis period
- **User Cost-** cost incurred due to disruption to full pavement access
  - daily, annual revenue
  - delays
- **Salvage Value-** quantifies the value of pavement life at the end of the analysis period
- **Total Value-** summation of agency cost and user cost with salvage value applied as credit

Compute Present Worth of Alternatives

$$\text{PW} = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i} - S \left(\frac{1}{1+r} \right)^{z}$$

Where:

PW	=	Present Worth
C	=	Present Cost of initial design or rehabilitation activity
m	=	Number of maintenance or rehabilitation activities
M_i	=	Cost of the ith maintenance or rehabilitation alternative in terms of present costs, i.e., constant dollars
r	=	Discount rate
n_i	=	Number of years from the present of the ith maintenance or rehabilitation activity
S	=	Salvage value at the end of the analysis period
Z	=	Length of analysis period in years.

$\left(\frac{1}{1+r} \right)^{n}$ is commonly called the single payment present worth factor in most engineering economic textbooks

Compute Present Worth of Alternative

SUM of M&R THROUGH ANALYSIS PERIOD

INITIAL COST

SALVAGE VALUE

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r}\right)^{n_i} - S\left(\frac{1}{1+r}\right)^{z}$$

- C – What is your estimated cost to construct the alternative.
- M_i – Iterate for each maintenance and rehab activity in analysis period
- n_i – Years from initial construction to activity
- *r* – Real Discount Rate based on analysis period (OMB A-94 Appendix C)

Compute Present Worth of Alternative

SUM of M&R THROUGH ANALYSIS PERIOD

INITIAL COST

SALVAGE VALUE

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r}\right)^{n_i} - S\left(\frac{1}{1+r}\right)^{z}$$

- z – Analysis period should include at least one rehabilitation cycle for each alternative.
- Typically the analysis period is set as the shortest functional life of the alternatives
- S – Salvage value is 0 if functional life = analysis period.
- If functional life remains straight-line depreciate value of the alternative at the end of the analysis period.
- r – Real Discount Rate based on analysis period (OMB A-94 Appendix C)

LCCA Example

Example LCCA - Alternates

Project: Construct new 60,000 yd^2 parking apron.

Alternatives:

Concrete Pavement (300 mm)	Asphalt Pavement (100 mm)
Initial Construction Costs	**Initial Construction Costs**
300 mm PCC, \$58.32/m^2	100 mmAsphalt, \$30.11/m^2
125 mm Stabilized Base, \$31.50/m^2	125 mm Stabilized Base, \$31.50/m^2
150 mm Aggregate Base, \$18/m^2	250 mm Aggregate base, \$26/m^2
Functional Life	**Functional Life**
45 years	**30 years**

Example LCCA – Maintenance & Rehab Activities

Concrete Pavement (12 in)	Asphalt Pavement (6 in)
M&R Costs	**M&R Costs**
Joint/Crack Seal, Spall Repair, $4.35/m^2$	Crack Seal, $3.13/m^2$
Joint/Crack Seal, Spall Repair, slab replacement, $17.50/m^2$	Seal Coat, $1.50/m^2$
	50 mm mill and overlay, $25.86/m^2$
M&R Schedule	**M&R Schedule**
Yr 7, Joint/Crack Seal, Spall Repair (Mx)	Yr 4, Crack Seal (Mx)
Yr 15, Joint/Crack Seal, Spall Repair (Mx)	Yr 8, Crack Seal, Seal Coat (Mx)
Yr 20, Joint/Crack Seal, Spall Repair, Slab Replacement (rehab)	Yr 12, Crack Seal (Mx)
Yr 27, Joint/Crack Seal, Spall Repair (Mx)	**Yr 15, Mill and Overlay (rehab)**
Yr 35, Joint/Crack Seal, Spall Repair (Mx)	Yr 19, Crack Seal (Mx)
Yr 40, Joint/Crack Seal, Spall Repair (Mx)	Yr 23, Crack Seal, Seal Coat (Mx)
	Yr 27, Crack Seal (Mx)

Example LCCA – Solve the easy parts

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i} - S \left(\frac{1}{1+r} \right)^{z}$$

- **C** – What is your estimated cost to construct the alternative (60,000 m^2).

Concrete Pavement (12 in)	Asphalt Pavement (6 in)
Initial Construction Costs	**Initial Construction Costs**
300 mm PCC, \$58.32/m^2	100 mm Asphalt, \$30.11/m^2
125 mm Stabilized Base, \$31.50/m^2	125 mm Stabilized Base, \$31.50/m^2
150 mm Aggregate Base, \$18/m^2	250 mm aggregate base, \$26/m^2
\$6,469,200	**\$5,256,600**

Example LCCA – Solve the easy parts

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i} - S \left(\frac{1}{1+r} \right)^{z}$$

- ***z* –** Analysis period should include at least one rehabilitation cycle for each alternative.
  - Asphalt: *Rehab = 15 years, Functional Life = 30 years*
  - Concrete: *Rehab = 20 years, Functional Life = 45 years*
- 20 year analysis includes one rehab, but leaves salvage value for both alternatives
- **30 year analysis leaves salvage value for concrete alternative only**
- 45 year analysis requires a reconstruction of asphalt alternative and would leave salvage value for asphalt alternative

Example LCCA – Solve the easy parts

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r}\right)^{n_i} - S\left(\frac{1}{1+r}\right)^{z}$$

- *r* – Real Discount Rate based on analysis period (OMB A-94 Appendix C)

Real Interest Rates on Treasury Notes and Bonds of Specified Maturities (in percent)

3-Year	5-Year	7-Year	10-Year	20-Year	30-Year
-1.2	-0.6	-0.3	0.0	0.4	0.5

Analyses of programs with terms different from those presented above may use a linear interpolation. For example, a four-year project can be evaluated with a rate equal to the average of the three-year and five-year rates. Programs with durations longer than 30 years may use the 30-year interest rate.

Example LCCA – Solve the easy parts

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r}\right)^{n_i} - S\left(\frac{1}{1+r}\right)^{z}$$

- **S – Salvage value is 0 if functional life = analysis period.**
  - If functional life remains straight-line depreciate value of the alternative at the end of the analysis period.

Concrete Pavement (12 in)	Asphalt Pavement (6 in)
Initial Construction Costs	**Initial Construction Costs**
$6,469,200	$5,256,600.00
Life Remaining	**Life Remaining**
45-30 = 15 years	30-30 = 0 years
S = $2,156,400	**S = $0**

Example LCCA – Where do we stand?

$$\mathrm{PW} = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i} - S \left(\frac{1}{1+r} \right)^{z}$$

- **PW_{PCC} = \$6,469,200 + $\sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i}$ - \$2,156,400 $(1/(1+.005))^{30}$**
- **PW_{PCC} = \$6,469,200 + $\sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i}$ - \$1,856,725**
- **PW_{AC} = \$5,256,600 + $\sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i}$ - \$0**

Example LCCA – Maintenance & Rehab Costs - Concrete

Concrete Pavement (300 mm)
M&R Costs
Joint/Crack Seal, Spall Repair, \$4.35/m^2
Joint/Crack Seal, Spall Repair, slab replacement, \$17.50/m^2
M&R Schedule
Yr 7, Joint/Crack Seal, Spall Repair (Mx)
Yr 15, Joint/Crack Seal, Spall Repair (Mx)
Yr 20, Joint/Crack Seal, Spall Repair, Slab Replacement (rehab)
Yr 27, Joint/Crack Seal, Spall Repair (Mx)
Yr 35, Joint/Crack Seal, Spall Repair (Mx)

$$\sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i}$$

- M_i – Maintenance/Rehab Present Cost
- n_i – Years from initial construction to activity
- *r* – Real Discount Rate based on analysis period

Year	Present Cost	Net Present Value
7	\$261,000	\$252,045
15	\$261,000	\$242,186
20	\$1,050,000	\$950,316
27	\$261,000	\$228,117
Net Present Value of Maintenance and Rehab		
\$1,672,664		

Example LCCA – Maintenance & Rehab Costs - Asphalt

$$\sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i}$$

- M_i – Maintenance/Rehab Present Cost
- n_i – Years from initial construction to activity
- *r* – Real Discount Rate based on analysis period

Asphalt Pavement (150 mm)
M&R Costs
Crack Seal, \$3.13/yd^2
Seal Coat, \$1.50/yd^2
2 in mill and overlay, \$25.86/yd^2
M&R Schedule
Yr 4, Crack Seal (Mx)
Yr 8, Crack Seal, Seal Coat (Mx)
Yr 12, Crack Seal (Mx)
Yr 15, Mill and Overlay (rehab)
Yr 19, Crack Seal (Mx)
Yr 23, Crack Seal, Seal Coat (Mx)
Yr 27, Crack Seal (Mx)

Year	Present Cost	Net Present Value
4	\$187,800	\$184,090
8	\$277,800	\$266,934
12	\$187,800	\$176,890
15	\$1,551,600	\$1,439,756
19	\$187,800	\$170,821
23	\$277,800	\$247,692
27	\$187,800	\$164,139
Net Present Value of Maintenance and Rehab		
\$2,650,322		

Example LCCA – Present Worth

$$\text{PW} = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i} - S \left(\frac{1}{1+r} \right)^{z}$$

- PW_{PCC} = $6,285,139
- PW_{AC} = $7,906,922
- Percent Difference: 23%

	A	B	C	D	E
1	**Life-Cycle Cost Analysis**				
2					
3	Analysis Period	30	Years		
4	Discount Rate	0.50%			
5					
6	Present Worth	$6,285,139			
7					
8	**Initial Construction**				
9					
10	Area:	60000	yd^2		
11					
12	Material Type	Unit Cost (yd^2)	Total		
13	12 in PCC	$58.32	$3,499,200		
14	5 in Stabilized Base	$31.50	$1,890,000		
15	6 in Aggregate Base	$18.00	$1,080,000		
16		Total	$6,469,200		
17					
18	**Maintenance**				
19	Year	Unit Cost	Present Cost	Present Worth Factor	Net Present Value
20	7	$4.35	$261,000.00	0.96568963	$252,045
21	15	$4.35	$261,000.00	0.927916877	$242,186
22	20	$17.50	$1,050,000.00	0.905062904	$950,316
23	27	$4.35	$261,000.00	0.874009861	$228,117
24			$0.00	1	$0
25			$0.00	1	$0
26			$0.00	1	$0
27			$0.00	1	$0
28			$0.00	1	$0
29			$0.00	1	$0
30			$0.00	1	$0
31			$0.00	1	$0
32					
33				Total	$1,672,664
34					
35	**Salvage Value**				
36					
37	Functional Life	45	years		
38					
39	Salvage Value	$2,156,400			
40	Salvage Value (PW)	$1,856,725			

	A	B	C	D	E
1	**Life-Cycle Cost Analysis**				
2					
3	Analysis Period	30	Years		
4	Discount Rate	0.50%			
5					
6	Present Worth	$7,906,922			
7					
8	**Initial Construction**				
9					
10	Area:	60000	yd^2		
11					
12	Material Type	Unit Cost (yd^2)	Total		
13	4 in Asphalt	$30.11	$1,806,600		
14	5 in Stabilized Base	$31.50	$1,890,000		
15	10 in Aggregate Base	$26.00	$1,560,000		
16		Total	$5,256,600		
17					
18	**Maintenance**				
19	Year	Unit Cost	Present Cost	Present Worth Factor	Net Present Value
20	4	$3.13	$187,800.00	0.980247522	$184,090
21	8	$4.63	$277,800.00	0.960885204	$266,934
22	12	$3.13	$187,800.00	0.94190534	$176,890
23	15	$25.86	$1,551,600.00	0.927916877	$1,439,756
24	19	$3.13	$187,800.00	0.909588219	$170,821
25	23	$4.63	$277,800.00	0.891621597	$247,692
26	27	$3.13	$187,800.00	0.874009861	$164,139
27			$0.00	1	$0
28			$0.00	1	$0
29			$0.00	1	$0
30			$0.00	1	$0
31			$0.00	1	$0
32					
33				Total	$2,650,322
34					
35	**Salvage Value**				
36					
37	Functional Life	30	years		
38					
39	Salvage Value	$0			
40	Salvage Value (PW)	$0			

Reminders

- **Thoughts on performing a quality Life-Cycle Cost Analysis**
  - Analysis period should include at least one rehabilitation for each alternative
  - Discount Rates should reflect analysis period
  - Try to use realistic maintenance activities and timings for the specific airport, or similar airports in the region.
  - Reminders Use realistic pavement functional life for each alternative. Base on historical trends at the airport and similar airports in the region.
  - Sensitivity Analysis should be performed to address variability of major input assumptions
- **1.6.3.3 An LCCA in support of a pavement section does not ensure that funds will be available to support the initial construction**
- **1.6.3.6 From a practical standpoint, if the difference in the present worth of costs between two design or rehabilitation alternatives is 10 percent or less, it is normally assumed to be insignificant and the present worth of the two alternatives can be assume to be the same.**

Probabilistic Cost Estimate

- Other Factors to Consider
  - Statistical Computational Approach
  - Supplemental Direct Costs (i.e. engineering)
  - Indirect/User Costs (i.e. aircraft delay costs)
- LCCA can get complicated fast
- AAPTP Report 06-06
  - Provides a framework to perform LCCA for airfield pavements
  - Developed AirCost tool as Excel application (Appendix C)
  - AirCost integrated into FAA PAVEAIR
  - Current FAA PAVEAIR includes modernized user interface.
    - https://faapaveair.faa.gov/DataManagement/LCCA.aspx

LCCA Guidance & Resources

- **Airfield Asphalt Pavement Technology Program (AAPTP)** *Report 06-06 Life-Cycle Cost Analysis for Airport Pavements*
  - Developed LCCA process that is currently in FAA PAVEAIR (more on this later)
- **Federal Highway Administration** *Life-Cycle Cost Analysis Primer*
- **Office of Management and Budget (OMB) Circular A-94, Appendix C** *Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses*
- **FAA Program Guidance Letter (PGL)** *22-01 Guidance on discount rate application for cost effectiveness for airfield pavement projects*
  - https://www.faa.gov/airports/aip/guidance_letters/media/AIP-PGL-22-01-discount-rate-pavement-projects.pdf

David R. Brill, P.E., Ph.D, Program Manager
david.brill@faa.gov
(609) 485-5198

Harold Muniz, Airfield Engineer
harold.muniz-ruiz@faa.gov
(202) 267-5190