

FAA 40-Year Life Pavement Extension R&D

Presented to: XI ALACPA Seminar on Airport Pavements and
IX FAA Workshop, Santiago de Chile

By: David R. Brill, P.E., Ph.D.

Date: 3 September 2014



Federal Aviation
Administration



Origins of 20-Year Design Life

- **Early CBR method for airports (1940's) did not explicitly consider traffic.**
 - “Full” (100%) thickness was considered to be adequate for about 5,000 coverages of wheel passes from a B-36 bomber.
 - Designers assumed that a pavement adequate for 5000 coverages would support traffic indefinitely.
- **Dick Ahlvin (*Origin of Developments for Structural Design of Pavements, 1991*):**

*“The ‘Capacity’ or ‘Zone of Interior’ (ZI) design criteria were accepted as representing a 5,000 coverage use life (**nominally 20 years**).”* (my emphasis)

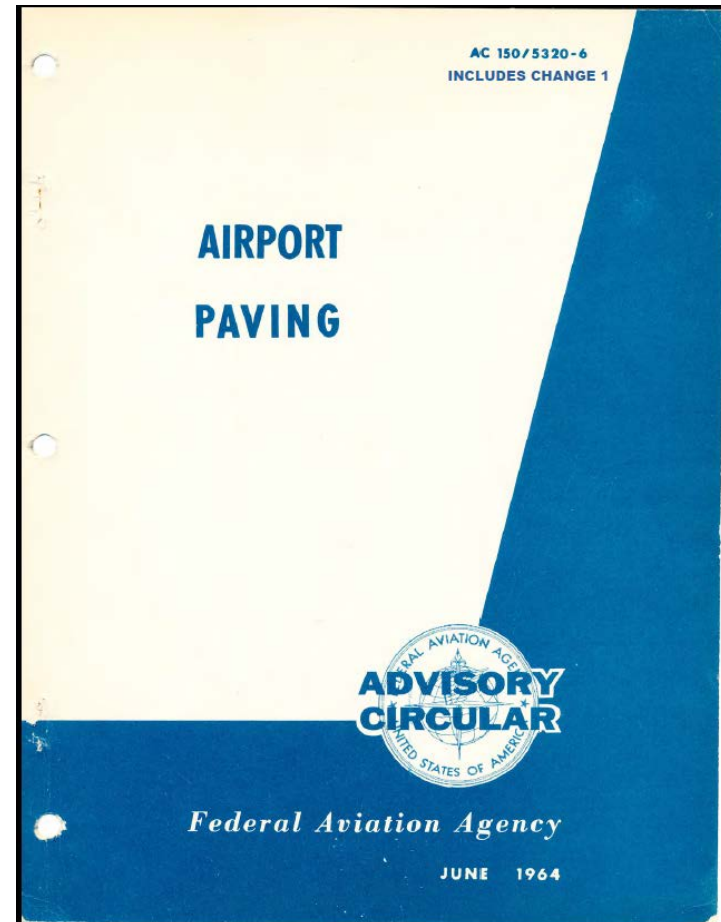
Channelized Aircraft Traffic

- **B-47 aircraft introduced 1951-53.**
 - “Bicycle” gear; much better centerline control vs. B-36.
 - Less wander led to early flexible pavement failures.
 - Forced recognition that, in general, pavements sufficient for 5000 coverages would not provide 20 years service.
- **New designs applied “percent of thickness”:**
 $\%t = 0.23 \log C + 0.15$



Timeline – FAA Design Procedures

- **1964 – AC 150/5320-6**
 - Design charts for “capacity operations” of critical aircraft.
 - No explicit consideration of traffic in design procedure.
- **1978 – AC 150/5320-6C**
 - New design charts.
 - Annual departures are taken to occur over a 20-year life.
- **1995 – AC 150/5320-16**
 - LEDFAA 1.2 introduced.
 - Program accepts design life other than 20 years, but 20 years remains standard.



Extended Pavement Life Initiative

- In 2011 the FAA Airports organization (ARP) identified as a core activity:
“doubling the expected life of runways at large hub airports from the current standard of 20 years to 40 years.”
- Large hub airport: Enplanes at least 1% of the US national total (includes passengers on connecting flights).
 - 29 large hub airports.
 - 68% of all enplanements in 2008.
 - 33.8% of all NPIAS costs 2011-2015.



Why Go Past 20 Years?

- **Longer service periods will translate into life cycle cost savings to the FAA.**
 - Fewer major interventions = fewer eligible costs.
 - Avoid expensive delays/downtime due to reconstruction.
- **Evidence exists that many airport pavements built to current standards already provide useful life in excess of 20 years.**
- **Challenges:**
 - Need to establish a pavement life definition that is realistic and meaningful over 40 years.
 - May require changes to the FAA's current funding rules.

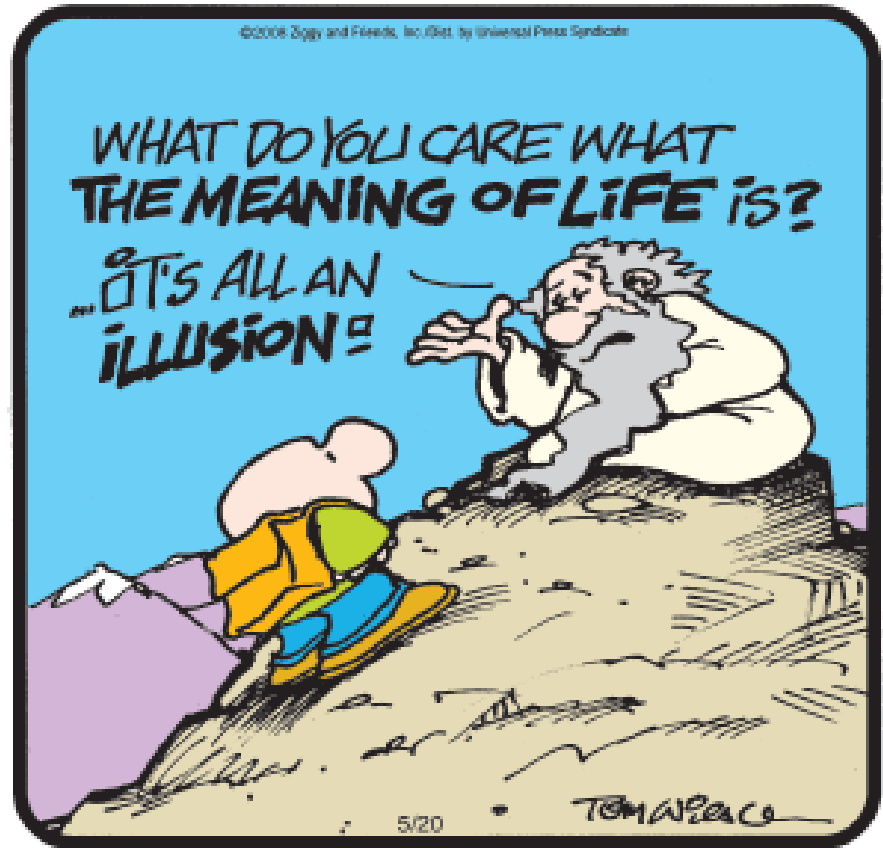
20-Year Design and the FAA's Airport Funding Mechanism

- Airport Improvement Program (AIP) funds eligible capital projects at US NPIAS airports.
- From the AIP Handbook: *“The reconstruction, rehabilitation, pavement overlays, or major repairs of facilities and equipment are defined as eligible capital costs generally considered permanent with a 20-year life expectancy.”*
- Thus, the expectation of 20 year life is embedded in the FAA's funding structure,
- But ...



What Is Life?

- **Some different kinds of pavement life:**
 - Design life
 - Structural life
 - Functional life
 - Service life
 - Operational life
 - Economic life
 - “Useful” life
- **What airport operators mean by “life” is often quite different than design engineers.**



Structural Life vs. Functional Life

- **Structural Life**

- Applies only to the ability of the pavement structure to support the forecast aircraft loads.
- Failure characterized by fatigue cracks, shear flow.
- FAA NAPTF testing is mostly focused on structural life.



- **Functional Life**

- Considers non-structural distresses such as low friction, surface rutting and distortion, etc., that can impact safety of aircraft operations.



Pavement Condition Index (PCI)

- **ASTM standard based on visual survey data.**
 - PCI lumps together structural and functional distresses into a single index.
 - But fails to consider other factors (e.g., ride quality deterioration) that may trigger replacement.
 - ASTM D5340-10 defines component distresses.
- **Structural Condition Index (SCI).**
 - Attempts to extract the structural damage component from the PCI by defining a limited set of “load-related” distresses.
 - Currently no accepted definition for flexible pavements.
 - FAA rigid pavement structural failure corresponds to SCI 80.

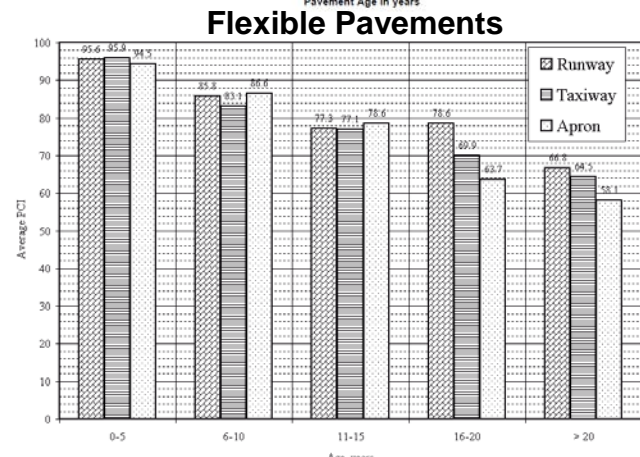
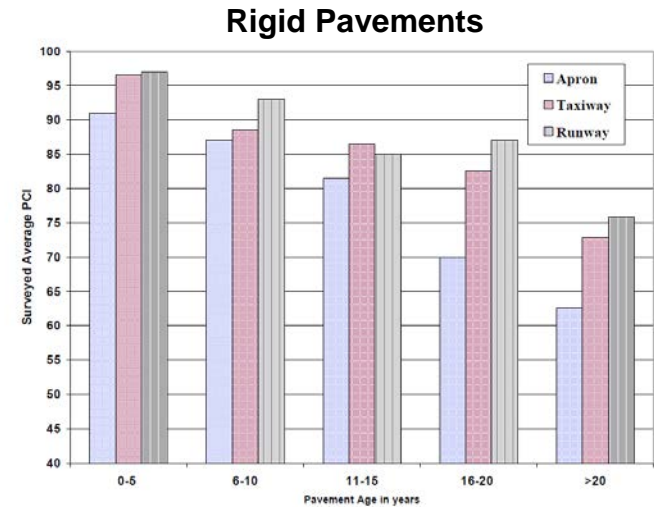
PCI	
100	Good
85	Satisfactory
70	Fair
55	Poor
40	Very Poor
25	Serious
10	Failed
0	

Design vs. Operational Life

- **Failure is keyed to structural distresses.**
 - Subgrade rutting for flexible pavements.
 - Extensive structural cracking for PCC.
- **FAA does consider non-structural distresses in its thickness design, but only indirectly.**
 - Experience: Designs that satisfy structural design criteria also provide operational life of 20 years.
 - Data: FAA Operational Life Study (2004) confirmed 20-Year PCI performance.
 - No confidence that this correlation extends to 40 years.

FAA 2004 Operational Life Study

- Evaluated field data from 30 airports in 10 U.S. states.
 - 15 million m² (161 million square ft.).
 - Rigid and flexible.
 - Grouped by feature, age & size.
- Concluded that flexible and rigid pavements designed to FAA standards provided in excess of 20 years of structural life (SCI > 80).
- *“While the structural performance of flexible and rigid pavements were comparable, a difference in functional performance was noted.”*



Developing a Natural Pavement Life Definition

- **Define a new metric DL (“distress level”).**
 - Represents some combination of pavement distress indexes.
 - “Mega-Index” – May include both SCI and some combination of functional indexes (friction, roughness, etc.).
 - Assume DL is on a numerical scale of 1 – 100.
- **A pavement has reached the end of its useful life when DL decreases below a lower threshold value (DL_{lower}) and cannot be restored to an upper threshold value (DL_{upper}) with probability p of remaining above the lower threshold for a period of 10 years or more.**
- **The value of p , the upper and lower thresholds, and the specific component indexes, need to be determined.**
- ***Acknowledgment: Dr. Gordon Hayhoe (retired).***

Why A New Definition?

- **This definition explicitly recognizes that useful life includes both structural (structural distresses in PCI, HWD) and non-structural (other PCI distresses, friction, roughness, etc.) components.**
- **Also recognizes that *DL* can be restored by periodic interventions, and the pavement can continue to function, but eventually there is a point of diminishing returns (at which point the pavement is truly “failed”).**
 - Agrees more with what airport owners/operators think of as pavement life.
 - Note that ordinary maintenance work (e.g., rubber removal on the keel) would not be considered a restoration for the purpose of this definition.
- **Can be used in conjunction with life cycle analysis to compute life cycle costs. In contrast, the structural definition of life is not adequate for LCCA.**

Maintenance Activities Affecting Life

- **Major maintenance activities associated with the 40-year life cycle include:**
 - Surface grinding and/or milling to restore profile.
 - Surface treatments to restore friction (milling, seal coat, etc.)
 - Groove restoration.
 - Pavement preservation techniques.
 - Individual slab replacement / dowel bar retrofit.
 - Joint seal replacement.
- **These activities may be effective in restoring the DL as defined in the previous slide.**

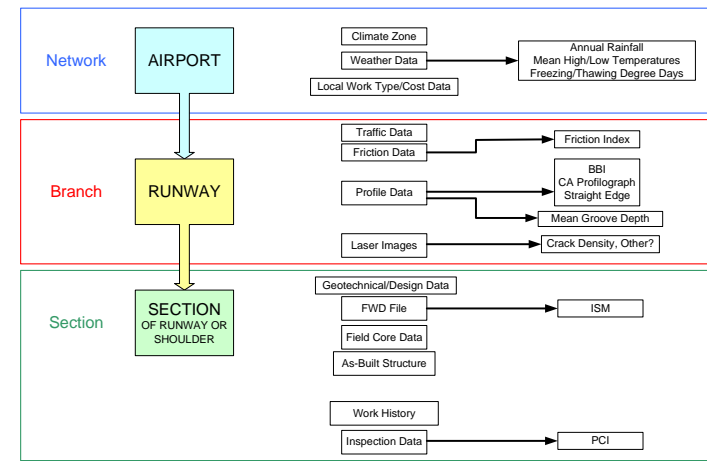


40-Year Pavement Life Extension

- **Runway data collection.**
 - 4-year project - in year 3.
 - Construction and performance data on medium- and large-hub runway pavements.
 - Field data collection.
- **FAA PAVEAIR database development (PA40).**
- **Performance/pavement life model development.**



Level Data Type/File Index



40-Year Life – Runway Data Collection

All Airports

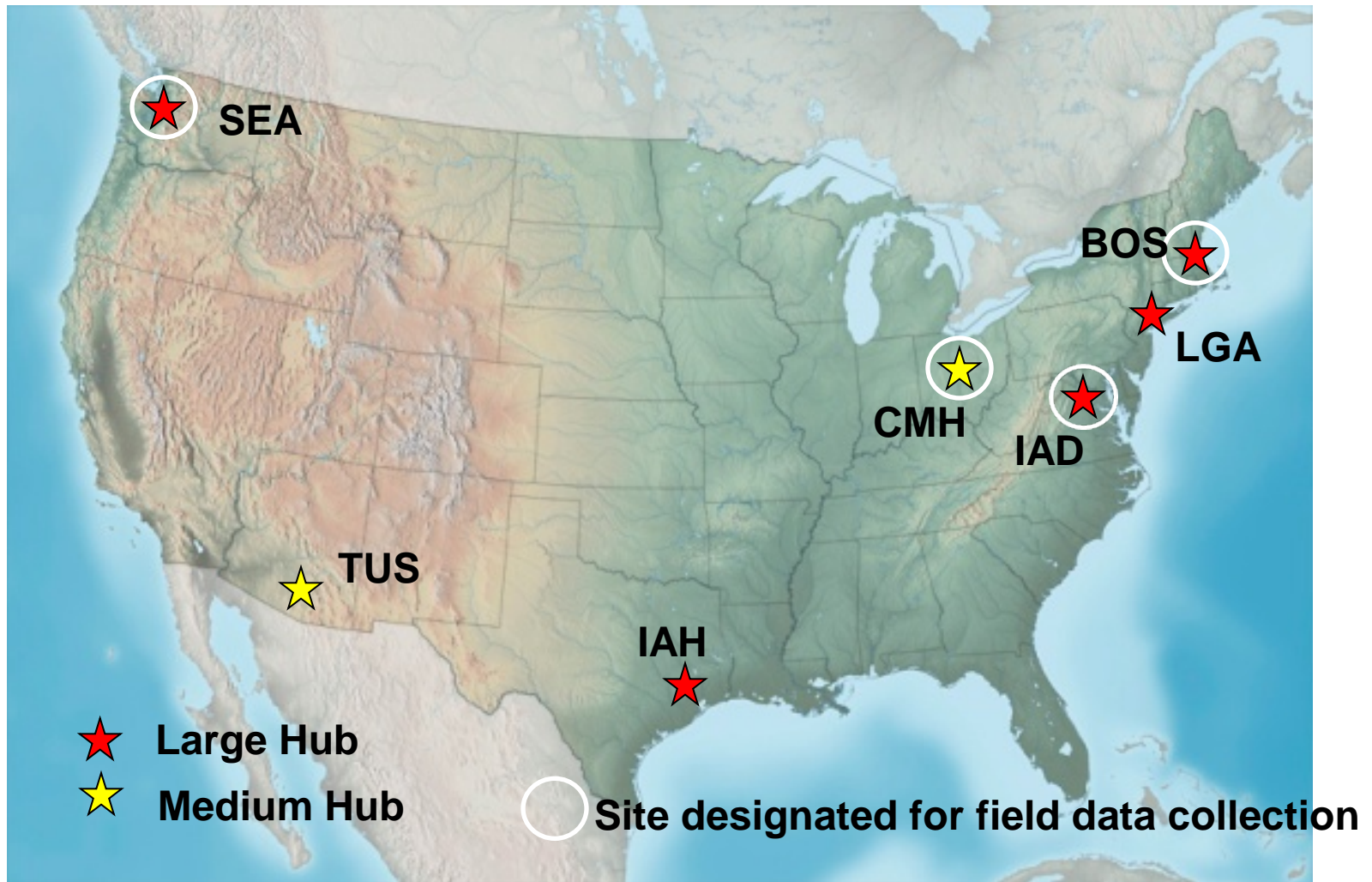
- Design and construction data (with costs).
- Maintenance activities and costs.
- Pavement performance data. PCI, friction, roughness, groove condition, etc. Not limited to current fields in FAA PAVEAIR.
- Traffic history (aircraft type, history, weight).



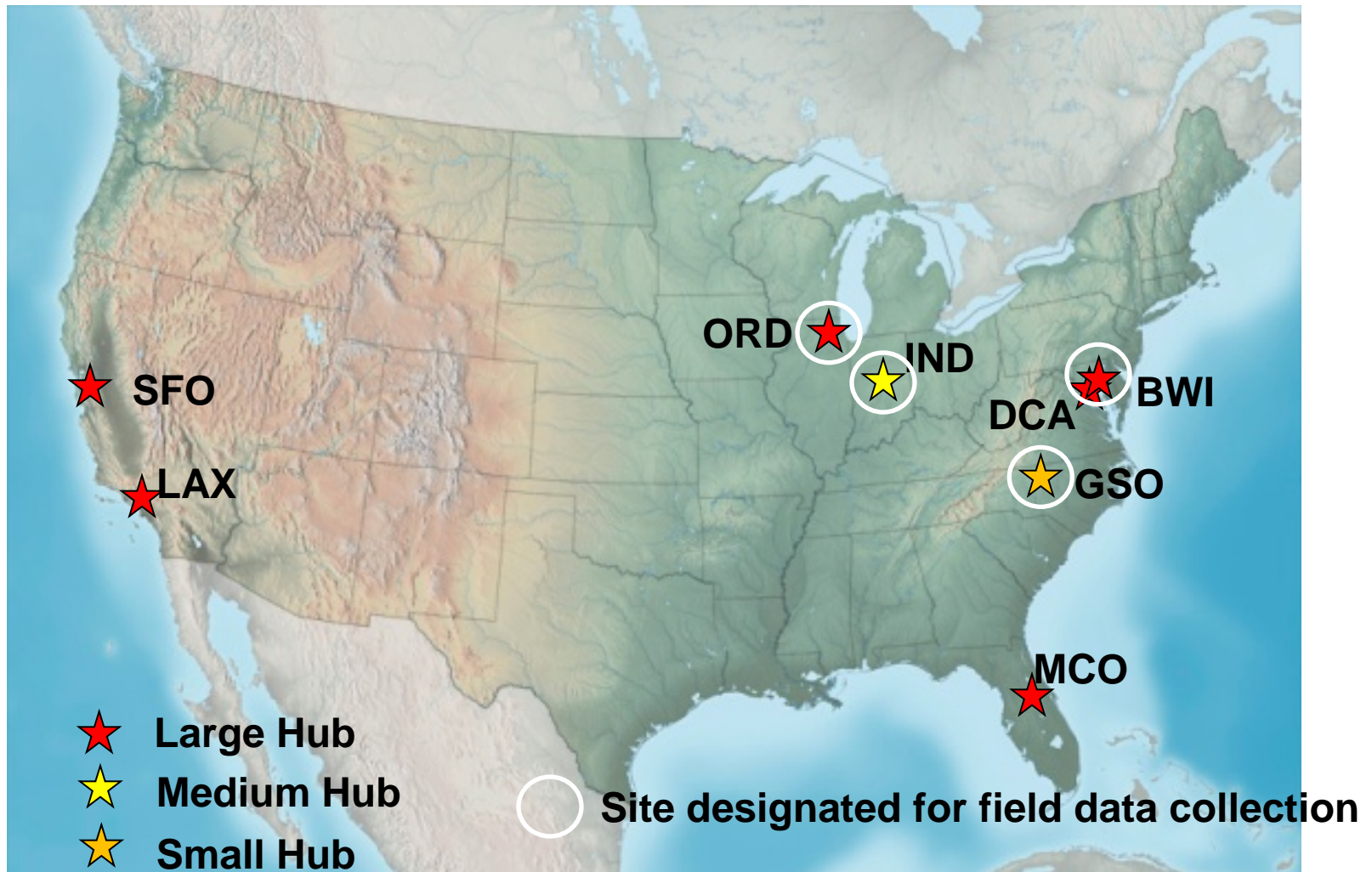
Field Data

- PCI (visual survey).
- Heavy Falling-Weight Deflectometer (HWD).
- Material samples (concrete and asphalt) for laboratory characterization. Sample testing will be done at the NAPTF lab.
- Longitudinal roughness profiles (SurPRO) & FAA portable profiler (if feasible).
- Grooving (longitudinal texture) data.
- Laser imaging by FAA (if feasible).

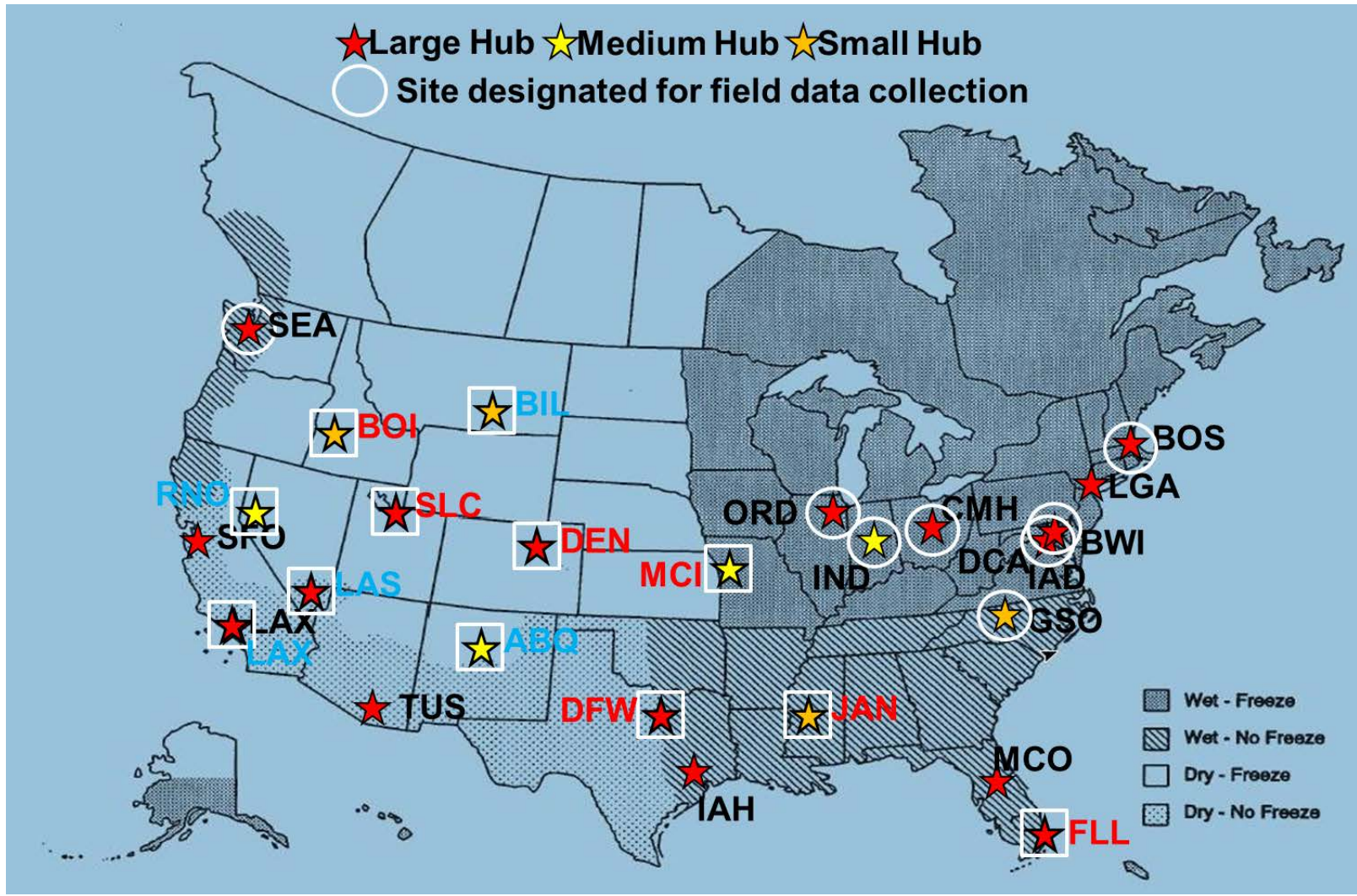
Year 1 Airport Locations



Year 2 Airport Locations

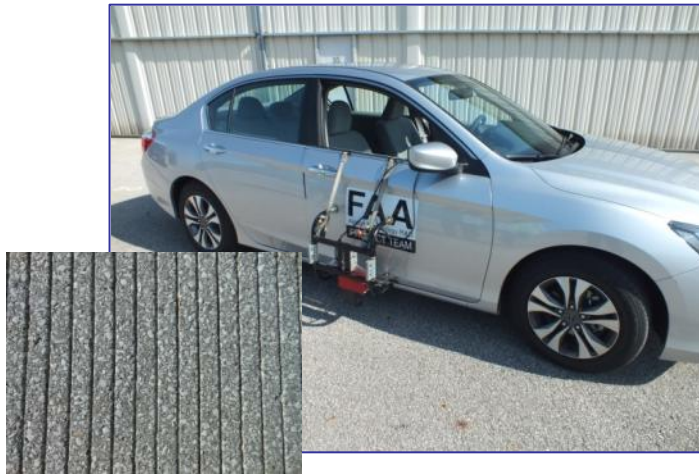


Year 3 Proposed Locations with Climatic Zones



Data Collection Activities

Groove Profiling



Pavement Imaging



Heavy-Weight Deflectometer



Field Core Testing



Field Data Collection – April 2013

Runway at Medium-Hub U.S. Airport 30+ Years Old



FAA PAVEAIR Implementation

- **Data collected falls into 2 categories:**
 - Exists in current FAA PAVEAIR (e.g., PCI, certain maintenance activities).
 - Not in the current version of FAA PAVEAIR.
- **All collected data for the 40 year project will be stored in a dedicated, standalone FAA PAVEAIR implementation (“PA40”).**
 - Data are anonymized.
 - No PA40 databases are accessible from the public FAA PAVEAIR implementation.
- **Enhanced functionality in PA40.**

PA40 – PAVEAIR Databases

FAA PAVEAIR

Federal Aviation Administration

Home Inventory Work PCI Prediction Modeling Condition Analysis M&R Reports Maps Tools Logout Member Area Help

FAA PAVEAIR : Inventory

Select Network

Current Database: CPT

Name	Branch Use	True Area
RW5L23R	RUNWAY	1,183,650.00 Details

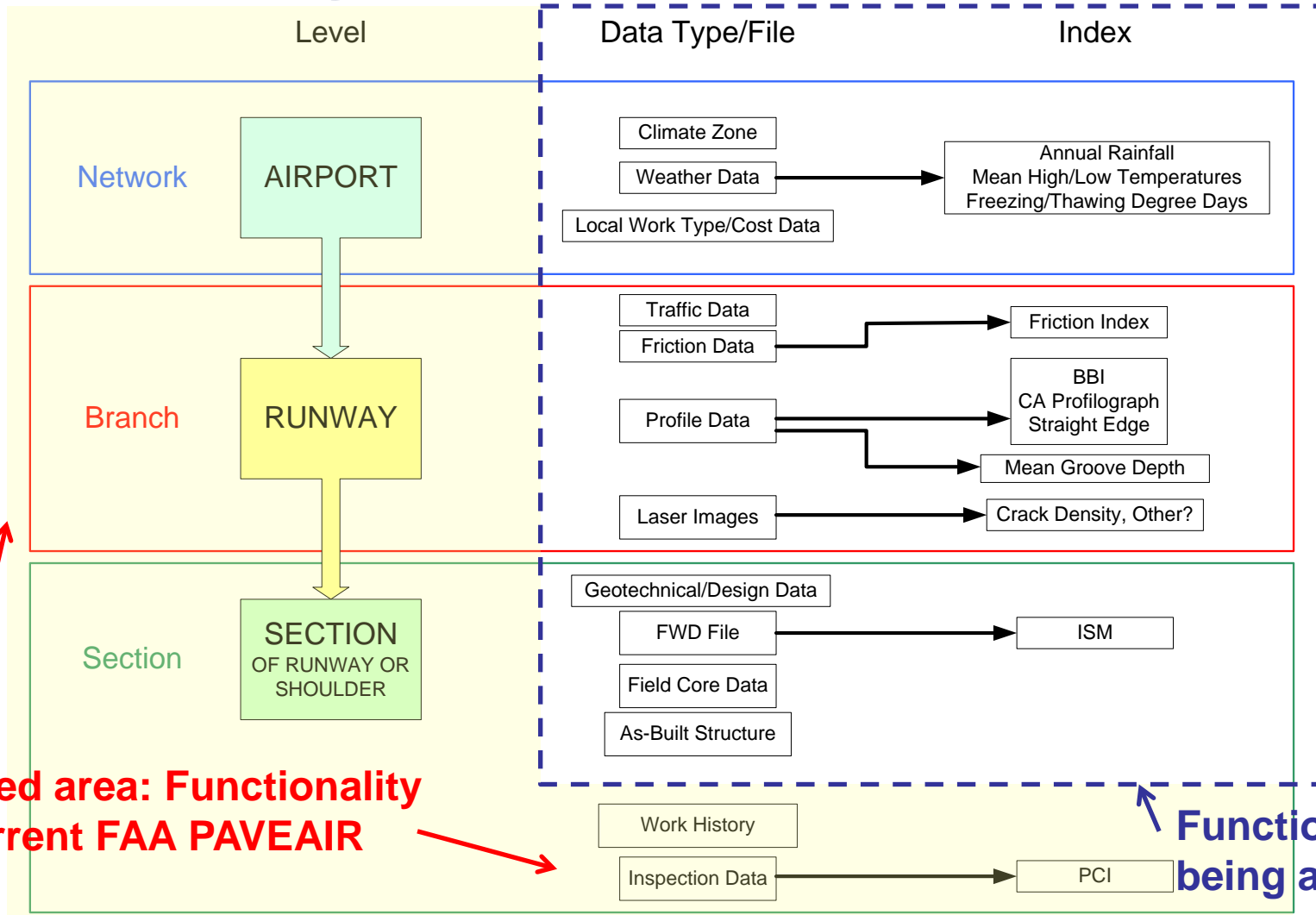
Name	Start	End	Construction	Rank	Surface	Length	Width
9174-1L	23R (Left)	2+42 (Left)	12/31/1947	P - Primary	AC	242	50 Details
9174-2L	2+42 (Left)	4+00 (Left)	12/31/1947	P - Primary	AC	158	50 Details
9165	23R (Keel)	2+42 (Keel)	12/31/1947	P - Primary	AC	242	50 Details
9176L	4+00 (Left)	8+17 (Left)	12/31/1947	P - Primary	AC	417	50 Details
9166L	8+17 (Left)	13+50 (Left)	12/31/1947	P - Primary	AC	533	50 Details
9154L	13+50 (Left)	22+50 (Left)	12/31/1947	P - Primary	AC	900	50 Details
9142L9138L	38+71 (Left)	40+96 (Left)	12/31/1947	P - Primary	AC	225	50 Details
9138L	40+96 (Left)	44+93 (Left)	12/31/1947	P - Primary	AC	397	50 Details

1 2 3 4 5 6

FAA.gov Home | Privacy Policy | Web Policies | Contact Us

- **Enhanced Functionality**
- **Fields for:**
 - HWD data, raw profile data, groove geometry data.
 - Computed roughness indexes (ProFAA) and groove characteristics (ProGroove)
 - Traffic data.
 - Climate data.
 - Structural layers and material properties.
- **Coordinate with FAA PAVEAIR development.**

PA40 Organization Concept



Shaded area: Functionality in current FAA PAVEAIR

Functionality being added

Developing New Performance Models

New performance models relate design inputs to distress index *DL* and/or its individual component indexes.

Current Design Procedures:

• Inputs

- Structural Layers
- CBR or *k*-value
- Aircraft Traffic
- Concrete Strength (rigid)

• Output

- Passes to structural failure*

*defined as 2.5 cm upheaval for flexible pavements or 50% of slabs cracked for rigid pavements

40-Year Design:

• Inputs

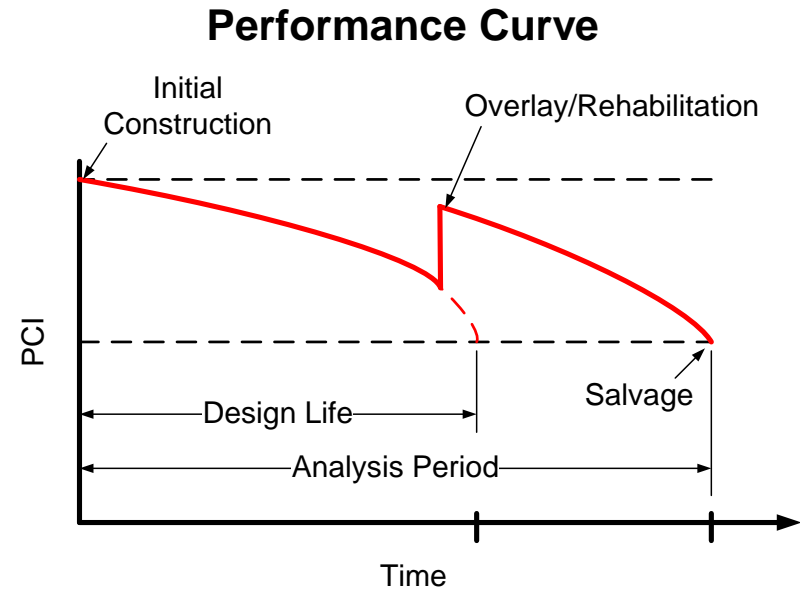
- Everything to the left, plus ...
- Age, Climatic Data
- Soil/Material Properties
- Maintenance Data
- Airport Feature (runway, apron, etc.)

• Outputs

- Passes to structural failure, plus ...
- Roughness index prediction
- Surface friction prediction
- Other functional indexes

Economic Life

- **Limited FAA guidance now.**
- **AC 150/5320-6E, Appendix 1, suggests that the analysis period for LCCA should be the same as the design life (i.e., 20 years).**
- **AAPTP Report 06-06 (2011) recommended use of a longer analysis period.**
 - 40 years for new construction
 - 30 years for rehabilitation/overlays
 - Only about half of airport projects surveyed used 20 years for the LCCA analysis period.



Analysis Period = Time period over which initial and future costs associated with alternative pavement strategies are evaluated.

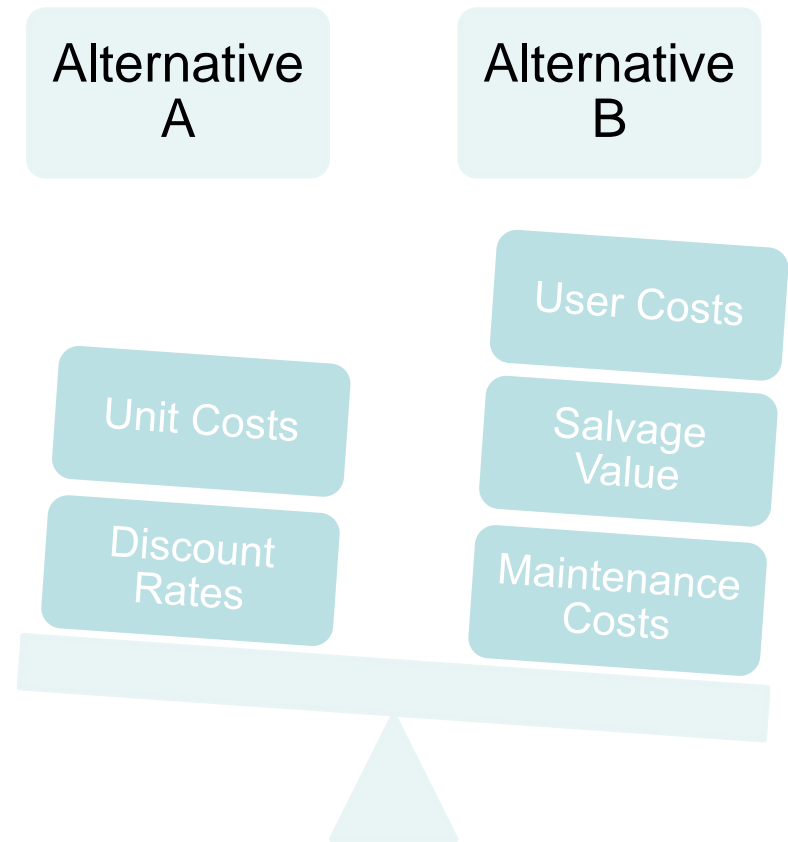
(AAPTP Report 06-06, ARA, 2011)

Key Elements of LCCA- Based Design Procedures

- **Consideration of multiple design alternatives over an extended analysis period.**
- **Structural design as one element within a larger economic framework.**
- **Design-time access to cost, performance, and other non-structural data.**
- **Accept and plan for future interventions (e.g., mill-and-fill operations, groove restoration, etc.) to achieve the desired operational life.**
- **Initial costs must be balanced against the costs of programmed maintenance, planned future rehabilitation, and other future factors, ideally resulting in the optimal design choice.**

Standardizing LCCA Inputs

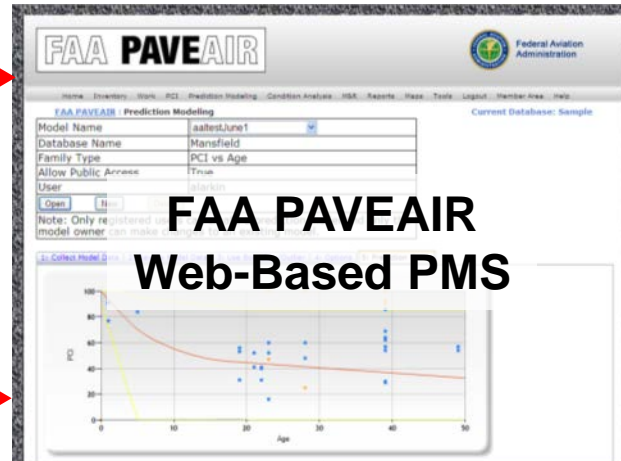
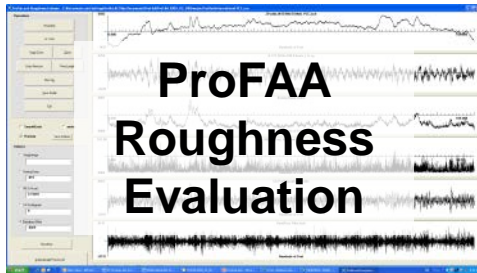
- **Need to limit the ability of end users to manipulate life cycle cost inputs to favor a predetermined outcome.**
- **Key to a reliable design procedure.**
- **Provides a uniform basis on which to evaluate designs requesting FAA funds.**



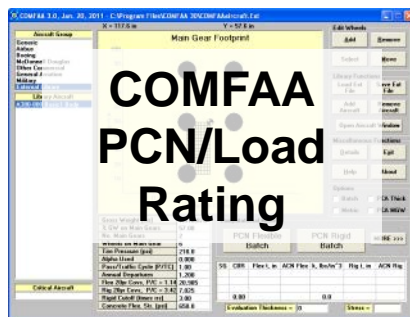
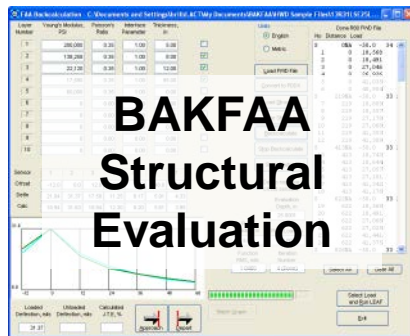
Design Strategies Incorporating Future Overlays

- **Allow for projected surface replacements or overlays during the overall design period.**
 - Base structure has a design life of 20 or 40 years (depending on the requirements).
 - Upper or surface layer may have a functional life that is considerably less than the design period.
 - Therefore, overlay design (HMA-on-flexible or HMA-on-rigid) becomes a more significant element within the LCCA-based design procedure.
- **Upgraded overlay design models need to consider:**
 - Deterioration of base structure under forecast traffic.
 - Degradation of material properties (over 40 years).
 - Current model assumes all materials have “new” properties.
 - Reflection cracking as a failure mode.

Integrated Design Procedures



**Output: Optimal
40-Year Design**



**New LCCA
Procedures**



Thank You! ¡Muchas Gracias!

<http://www.airporttech.tc.faa.gov/>

david.brill@faa.gov

Acknowledgments:

FAA Airport Technology R&D Branch:

Dr. Michel Hovan, Branch Manager;

Jeff Gagnon, Airport Pavement Section Manager;

Dr. Navneet Garg; Al Larkin; Dr. Charles Ishee; Murphy Flynn; Ryan Rutter; Quinn Jia, Wilfredo Villafane

FAA Airport Engineering Division:

Doug Johnson; Greg Cline

SRA International:

Jerry Connelly; Dr. Injun Song; Jeff Stein, Clarence Royal, Matt Willson, Renee Norcross, Monir Haggag

Gemini:

Dr. Hao Yin

Applied Research Associates (ARA):

Dr. Jim Hall, Richard Speir, Tim Parsons

Consultants:

Dr. Edward Guo; Roy McQueen

ERI International:

Dr. Abbas Butt