ICAO AERODROME PAVEMENT WORKSHOP

Pavement Management Concepts (Part 2 – APMS Software & PAVEAIR)

Presented to: ICAO Aerodrome Pavement Workshop
Bangkok, Thailand

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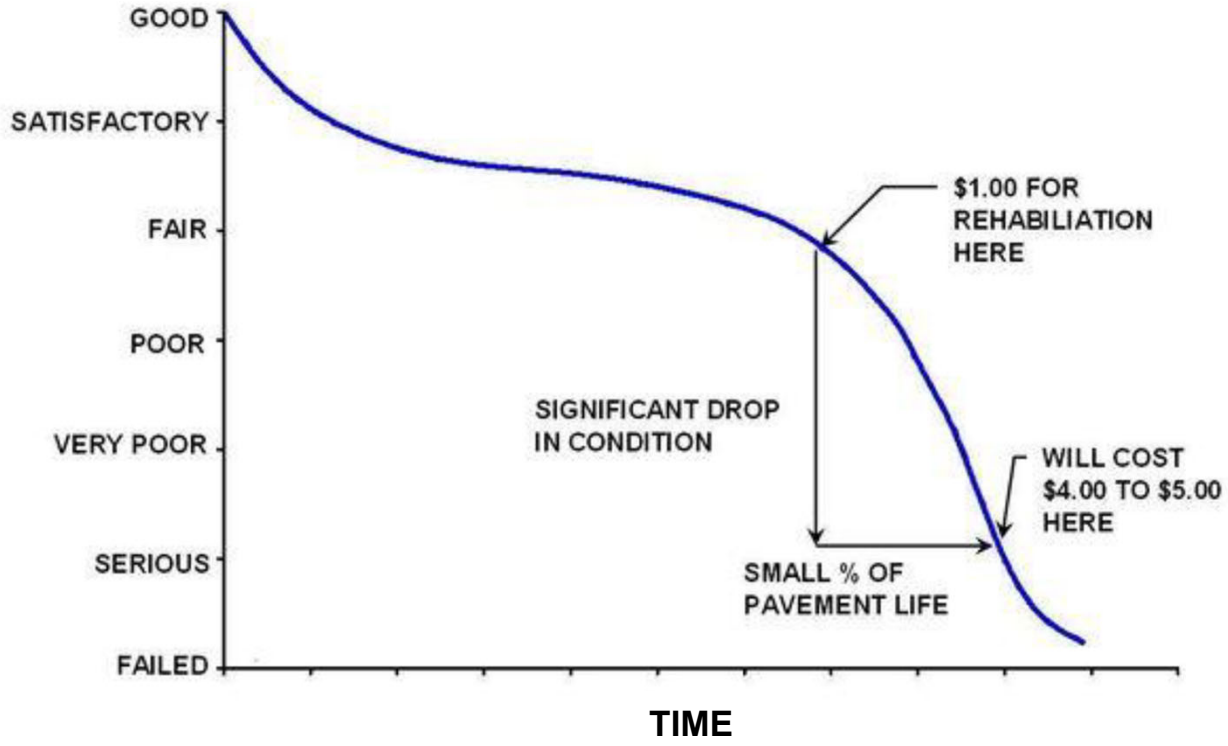
Date: 7 February 2024

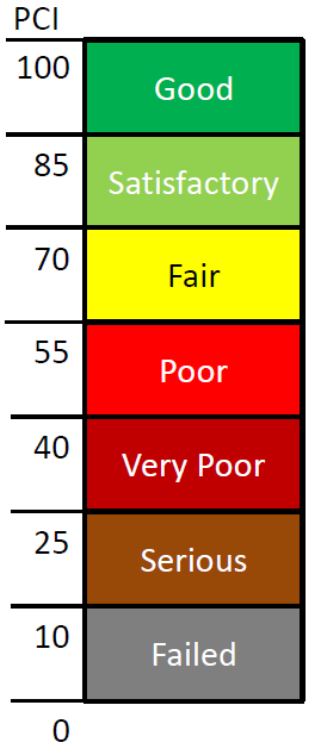
Federal Aviation Administration



PCI Concepts / Distress Identification

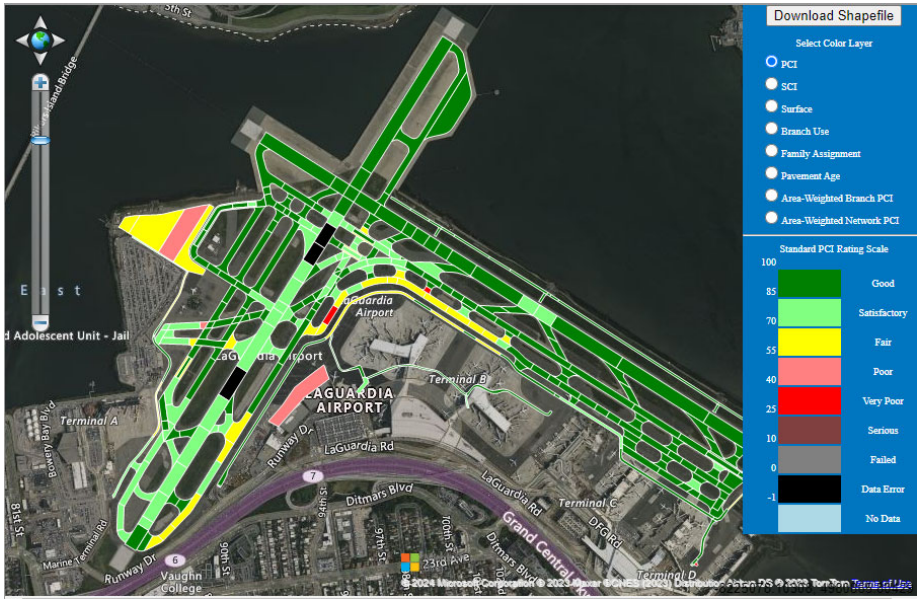
Pavement Condition Index

- **FAA PAVEAIR uses the procedures documented in ASTM D5340 to calculate PCI.**
  - Quantify airport pavement condition based on visual inspection on the surface.
  - Numerical rating of pavement condition (0-100).
  - Does not quantify roughness, structural capacity, friction or surface texture.
- **Originally developed by the US Army Corps of Engineers for airport pavements.**
- **Embeds the division of the airport pavement inventory according to the *network/branch/section* hierarchy.**



APMS Pavement Hierarchy

- **Network**
  - High-level grouping of an organization's pavements for the purposes of maintenance and repair planning
  - Examples: *Ohio State University Airport, LGA Airport*
- **Branch**
  - Identifiable area of a pavement network having a distinct function
  - Examples: *Runway 9L, Taxiway D, Apron*
- **Section**
  - Subdivision of a branch with uniform construction, maintenance, usage, condition, traffic volume, and load intensity conditions
  - Example: *Section A (Runway 32 end to 3,013' west)*



Pavement Condition Survey

Inspection Process

- **ASTM D 5340-23 (Airports) and ASTM D 6433-23 (Roads & Parking)**
  - Provide step-by-step procedure for identifying distresses, filling out survey forms, and calculating section PCI.
- **Create Sample Units**
  - Divide pavement sections into *Sample Units* for inspection.
- **Determine the Number of Sample Units**
  - Calculate the minimum number of sample units that must be inspected.
- **Record Distresses**
  - Condition Survey Forms
- **Enter Inspection Data**
  - Enter inspection data into FAA PAVEAIR's Update Inspection module.

Updated ASTM Standards

FAA PAVEAIR reflects current distress definitions in ASTM D5340-23 and ASTM D6433-23.

ASTM D6433-23 – Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys

Surface Type	Old Distress	New Distress (6433-10 and newer)
Asphalt	19. Weathering / Raveling	19. Raveling
		20. Weathering

ASTM D5340-23 – Standard Practice for Airport Pavement Condition Index Surveys

Surface Type	Old Distress	New Distress (5340-12 and newer)
Asphalt	12. Weathering / Raveling	12. Raveling
		17. Weathering

Surface Type	Old Distress	New Distress (5340-12 and newer)
Concrete	10. Scaling / Map Crack / Crazing	10. Scaling / Map Crack / Crazing
		16. Alkali Silica Reaction (ASR)

Types of Distresses (Airports)

Distress Codes (AC)
1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Corrugation
5. Depression
6. Jet Blast
7. Joint Reflection (PCC)
8. Long. & Trans. Cracking
9. Oil Spillage
10 Patching
11. Polished Aggregate
12. Raveling
13. Rutting
14. Shoving from PCC
15. Slippage Cracking
16. Swell
17. Weathering

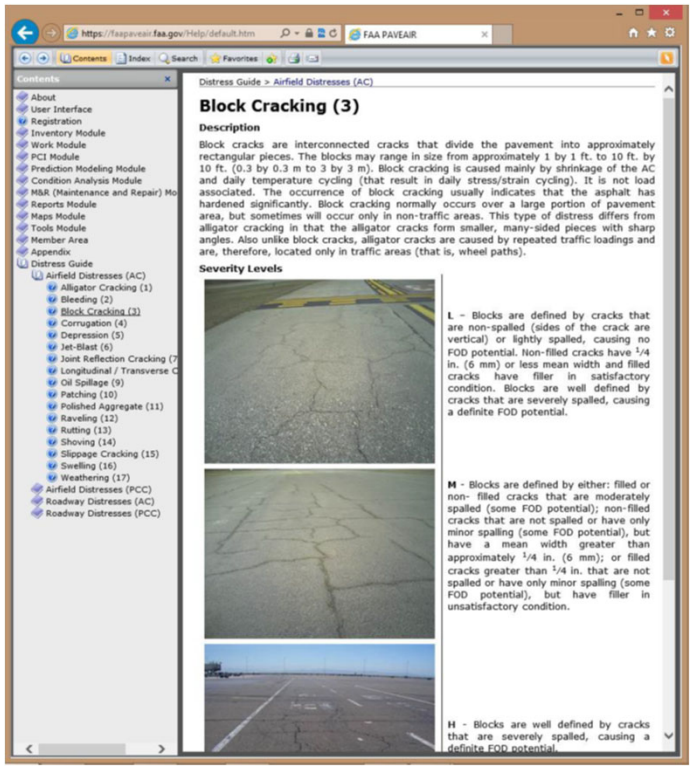
Distress Codes (PCC)
1. Blow up
2. CornerBreak
3. Long / Trans / Diagonal Crack
4. Durability “D” Crack
5. Joint Seal Damage
6. Patching (Small)
7. Patching (Large) and Utility Cut
8. Popouts
9. Pumping
10. Scaling / Map Crack / Crazing
11. Settlement / Fault
12. Shattered Slab
13. Shrinkage Crack
14. Spalling-Joints
15. Spalling-Corner
16. Alkali Silica Reaction (ASR)

Rutting (High Severity)

Alligator Cracking (Medium Severity)

Patching (Small)

Distress Guide



- **Part of FAA PAVEAIR “Help”**
- **High resolution color pictures**
- **Shows distresses at high, medium, and low**
- **Explains how to properly measure each distress**

https://faapaveair.faa.gov/Help/index.html

Create Sample Units

Divide pavement sections into sample units for inspection:

- ***Asphalt*** **– Subdivide into sample units consisting of 464.5 m^2 (5,000 ft^2) of contiguous area (±186 m^2)**
- ***Concrete*** **– Subdivide into sample units consisting of 20 contiguous slabs (±8 slabs)**

Figure 2-1 Example Division of a Jointed Rigid Pavement Section into Sample Units of 20 Slabs

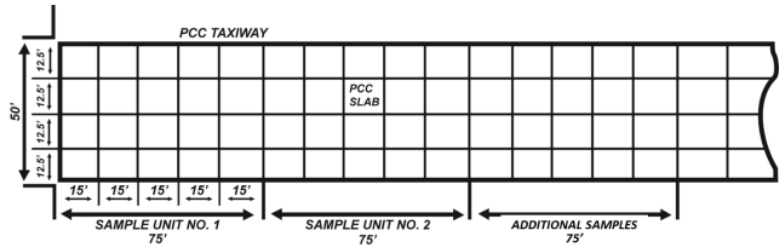
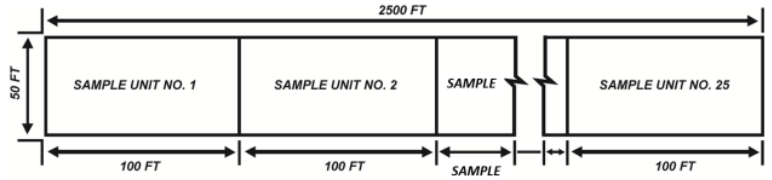


Figure 2-2 Example Division of a Flexible Pavement Section into Sample Units



SECTION DIMENSION = 50 X 2500 FT

SAMPLE UNIT = 50 X 100 FT

NUMBER OF SAMPLE UNITS = 25

Determine Number of Sample Units

- **Total Sampling**
  - Total sampling is desirable for project analysis
  - May not be feasible for routine management due to manpower, funds, and time required.
- **Partial Sampling**
  - Calculate the minimum number of random sample units *n* that must be surveyed to obtain a 95% confidence level.
  - Compute $$n = \frac{Ns^2}{\left(\left(\frac{e^2}{4}\right)(N-1) + s^2\right)}$$ where:

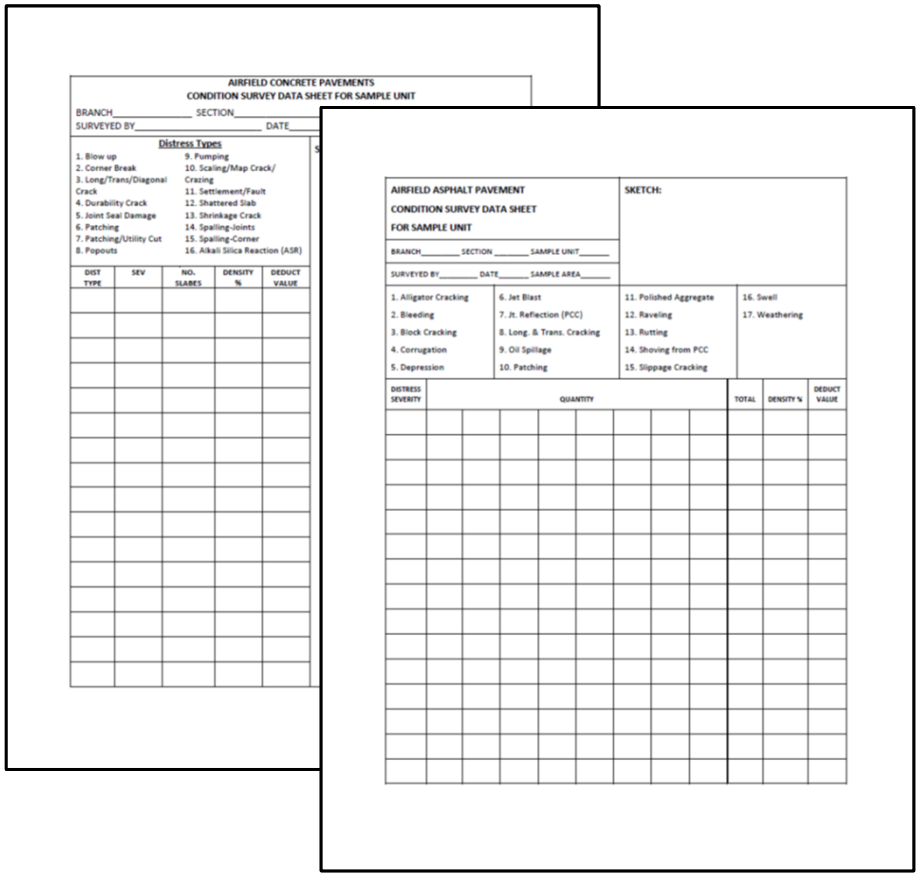
e = acceptable error in estimating section PCI; ± 5 PCI points

s = standard deviation of PCI from one sample unit to another (assume 10 for AC and 15 for PCC)

N = total number of sample units in the section

Record Distresses

- **Record distresses using the procedures documented in ASTM D5340-23 and ASTM D 6433-23**
  - Divide pavements into sample units
  - Perform condition survey of sample units
  - Record distresses, severity, and quantity on survey data sheets
- **Print survey data sheets from FAA PAVEAIR's *Update Inspections* Module**
  - Distresses for Asphalt Pavements
  - Distresses for Concrete Pavements
- **Enter in PMP software.**

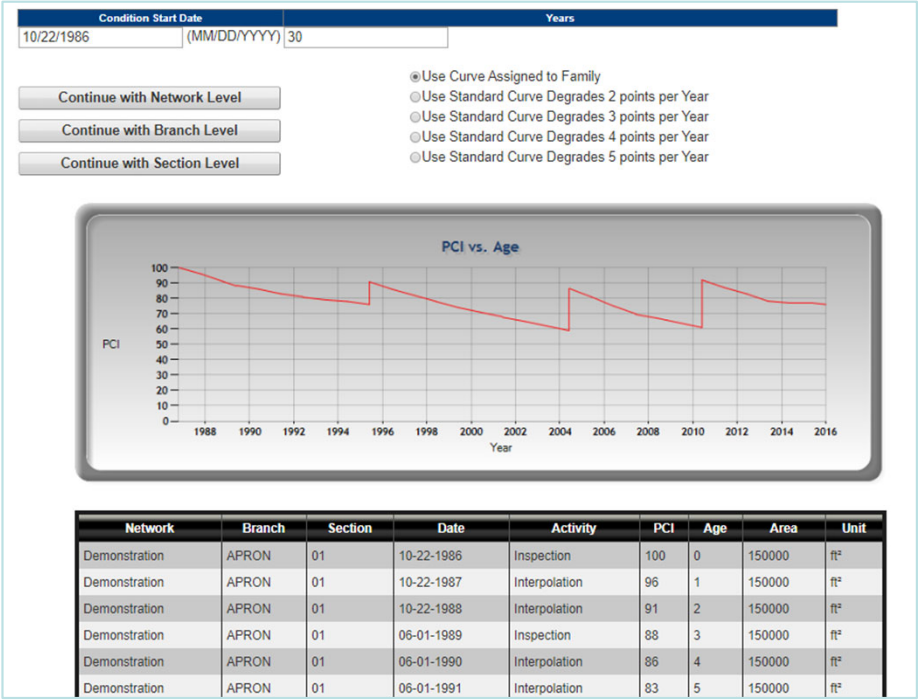


PMP Software

https://faapaveair.faa.gov/

PMP Software

- **Software that fulfills the requirements of an airport PMP as defined in AC 150/5380-7B:**
  - Pavement inventory
  - PMP pavement inspection schedule
  - Record keeping/database
  - Information retrieval
- **Existing software options are:**
  - PAVER™
  - FAA PAVEAIR
  - Other software (e.g., in-house)



Network	Branch	Section	Date	Activity	PCI	Age	Area	Unit
Demonstration	APRON	01	10-22-1986	Inspection	100	0	150000	ft²
Demonstration	APRON	01	10-22-1987	Interpolation	96	1	150000	ft²
Demonstration	APRON	01	10-22-1988	Interpolation	91	2	150000	ft²
Demonstration	APRON	01	06-01-1989	Inspection	88	3	150000	ft²
Demonstration	APRON	01	06-01-1990	Interpolation	86	4	150000	ft²
Demonstration	APRON	01	06-01-1991	Interpolation	83	5	150000	ft²

PAVER™ and FAA PAVEAIR

PAVER™ – Current version 7.1

- Developed by the US Army ERDC Construction Engineering Research Laboratory (CERL).
- Available at: https://paver.colostate.edu/
- Licensed as a desktop application (single install or networked).
- License fee: minimum USD$1000 (+ USD$650 annual renewal).

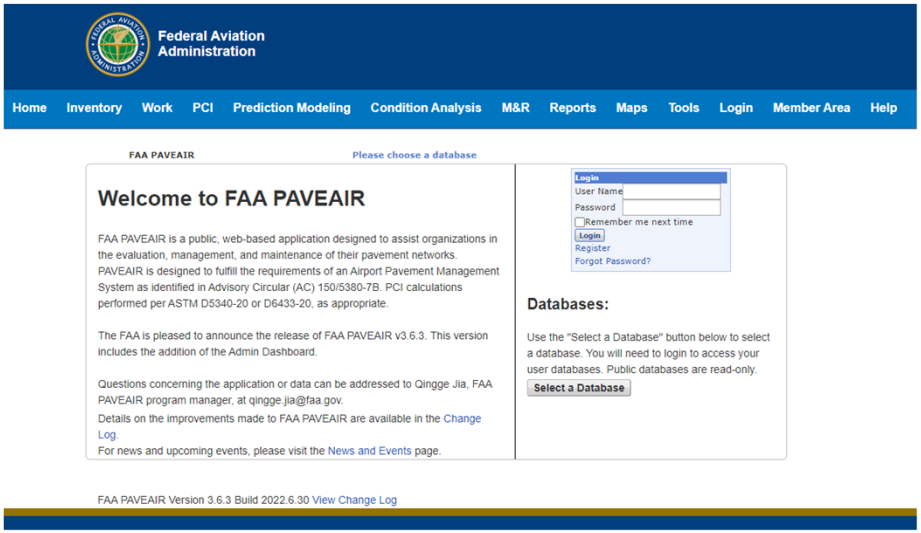
FAA PAVEAIR version 3.7.3

- Developed by FAA.
- Available at: https://faapaveair.faa.gov/
- Web-based software application; access from anywhere.
- Option for self-hosted website (local network install).
- Publicly available & free to use.

About FAA PAVEAIR

- **Airport Pavement Management System**
  - Publicly available and free to use.
  - Source code available.
  - Data can be made public, private, or shared.
  - Meets requirement for PMP software in AC 150/5380-7B.
- **Web-based**
  - Access via internet or company intranet.
  - Multi-user.
  - No software to install.
- **Regional Settings**
  - English / Metric
  - Multiple Languages

https://faapaveair.faa.gov/



History of FAA PAVEAIR

PAVER PMS

In 1968, CERL begins development of a mainframe PMS for the DOD. The first version is completed in 1972.

Public Law 103-305

Requires an airport agency to show that it has an effective PMS in place to be eligible for federal funding.

FAA PAVEAIR

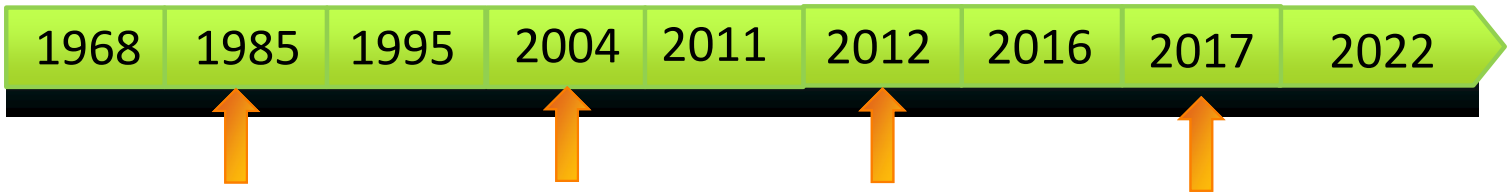
February 2011, FAA releases a beta of FAA PAVEAIR, a public web-based APMS

FAA PAVEAIR

May 2016, FAA releases FAA PAVEAIR 2.6.

FAA PAVEAIR

October 2022, FAA releases FAA PAVEAIR 3.7.0.



MicroPAVER

In 1985, the FAA funds CERL to develop a microcomputer version of PAVER, named MicroPAVER. The first version is released in 1987.

APMS Systems in Use

By 2004, 84% of state aviation agencies in the US use an APMS.

FAA PAVEAIR

June 2012, FAA releases FAA PAVEAIR 2.0.

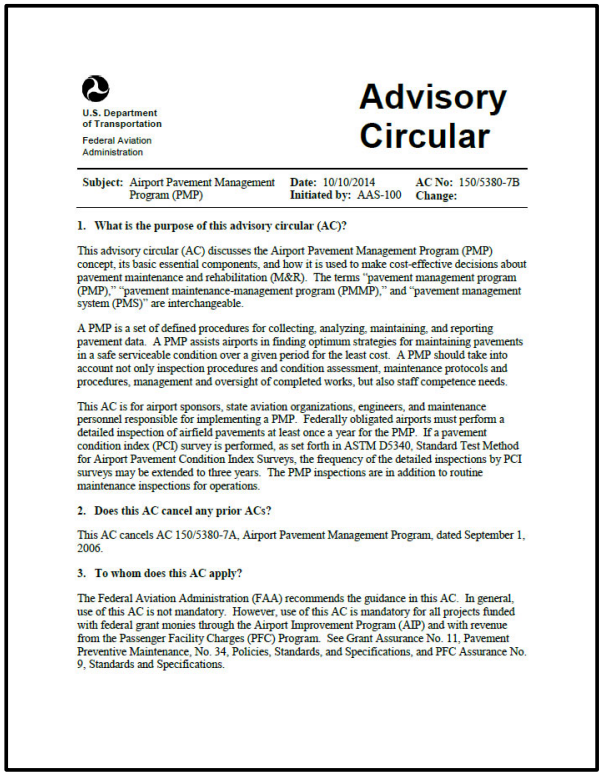
FAA PAVEAIR

October 2017, FAA releases FAA PAVEAIR 3.0.

** CERL (U.S. Army Construction Engineering Research Laboratory)*

FAA PAVEAIR Supports AC 150/5380-7B

- **Inventory**
- **Work History**
- **PCI / Update Inspections**
  - Calculate PCI / SCI / FOD
  - Record Condition Surveys
- **Prediction Modeling**
  - Predict future pavement conditions
  - Plot PCI vs. Age
- **Condition Analysis**
- **Maintenance and Repair Planning**
- **Reports / Maps**
  - Generate reports
  - Mapping support with shapefiles
- **Compatibility**
  - Import data from E50/E60/E65/E70 formats
  - Export data to XML (universal) format



U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Airport Pavement Management Program (PMP) **Date:** 10/10/2014 **Initiated by:** AAS-100 **AC No:** 150/5380-7B **Change:**

1. What is the purpose of this advisory circular (AC)?

This advisory circular (AC) discusses the Airport Pavement Management Program (PMP) concept, its basic essential components, and how it is used to make cost-effective decisions about pavement maintenance and rehabilitation (M&R). The terms "pavement management program (PMP)," "pavement maintenance-management program (PMMP)," and "pavement management system (PMS)" are interchangeable.

A PMP is a set of defined procedures for collecting, analyzing, maintaining, and reporting pavement data. A PMP assists airports in finding optimum strategies for maintaining pavements in a safe serviceable condition over a given period for the least cost. A PMP should take into account not only inspection procedures and condition assessment, maintenance protocols and procedures, management and oversight of completed works, but also staff competence needs.

This AC is for airport sponsors, state aviation organizations, engineers, and maintenance personnel responsible for implementing a PMP. Federally obligated airports must perform a detailed inspection of airfield pavements at least once a year for the PMP. If a pavement condition index (PCI) survey is performed, as set forth in ASTM D5340, Standard Test Method for Airport Pavement Condition Index Surveys, the frequency of the detailed inspections by PCI surveys may be extended to three years. The PMP inspections are in addition to routine maintenance inspections for operations.

2. Does this AC cancel any prior ACs?

This AC cancels AC 150/5380-7A, Airport Pavement Management Program, dated September 1, 2006.

3. To whom does this AC apply?

The Federal Aviation Administration (FAA) recommends the guidance in this AC. In general, use of this AC is not mandatory. However, use of this AC is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and with revenue from the Passenger Facility Charges (PFC) Program. See Grant Assurance No. 11, Pavement Preventive Maintenance, No. 34, Policies, Standards, and Specifications, and PFC Assurance No. 9, Standards and Specifications.

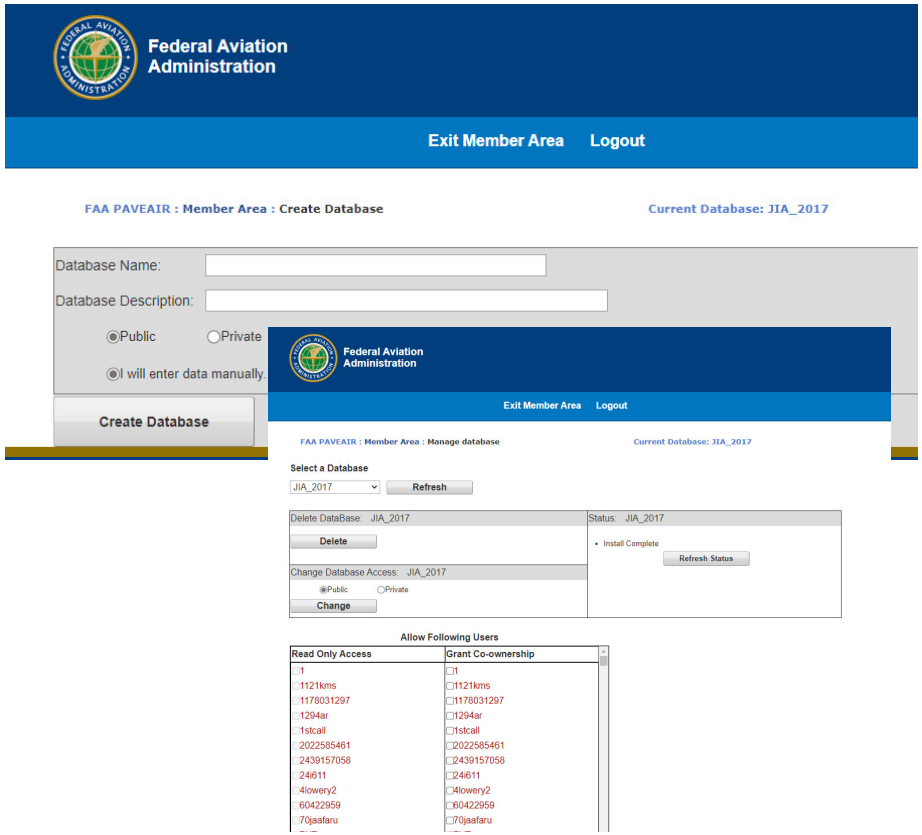
User Options

- **FAA-Hosted Website: Unlimited Use by Public**
  - http://faapaveair.faa.gov
  - Free to register and use
  - FAA shoulders IT burden
  - Users still maintain control of data
- **Self-Hosted Website**
  - Available at http://www.airporttech.tc.faa.gov
  - Support documents, setup files, source code
  - Able to customize for your organizational needs
  - Scalable (intranet, public)
  - Data resides on your servers

User Accounts/Databases

Registered Users can:

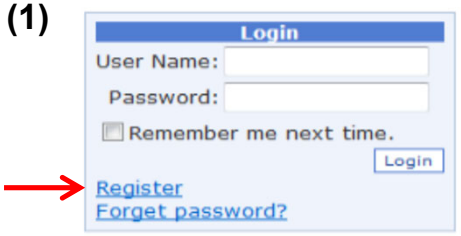
- **Create Databases**
  - Enter a name & description.
  - Select public or private database.
  - Manually enter data; or import an existing Paver™ database.
  - Supported import formats: e50, e6x, e70
  - Multiple databases supported
- **Manage Databases**
  - Delete database
  - Change between “public” and “private”
  - Assign access/permissions to other registered users
  - Export database to XML



Create a User Account and Database

1. From the “Home” page, click on the “Register” link in the “Login” box.
2. Fill out the “User Information Form and click “Next”
3. Fill out the “User Name and Password” form. Here is where you will choose the username and password you will use to access the system. The “security question” and “security answer” are used in case you need to recover your password. Once completed, click the “Create User” button.

(1)



(2)

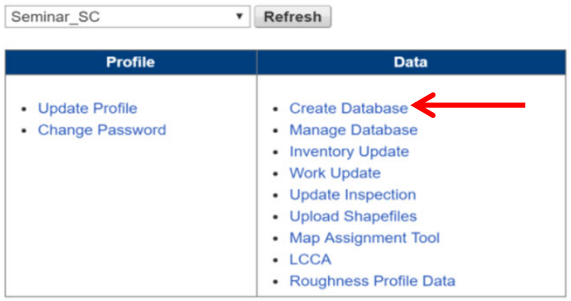
(3)

Create a User Account and Database

4. Click on the “Create Database” link.
5. Choose a name and description for your database and enter it in the form.

[*For workshop participants: it is recommended you use your last name and first initial followed by “_UserDB1” as your database name. Select “Public” and “No. I will enter data manually,” then press “Create Database.”]*

(4) User Profile and Data Management Page



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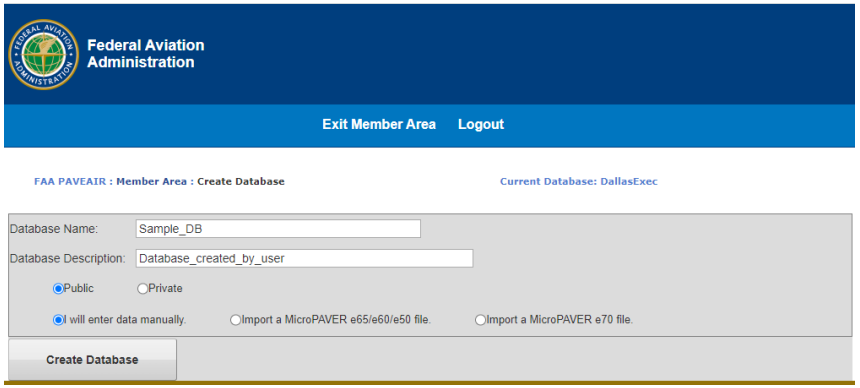
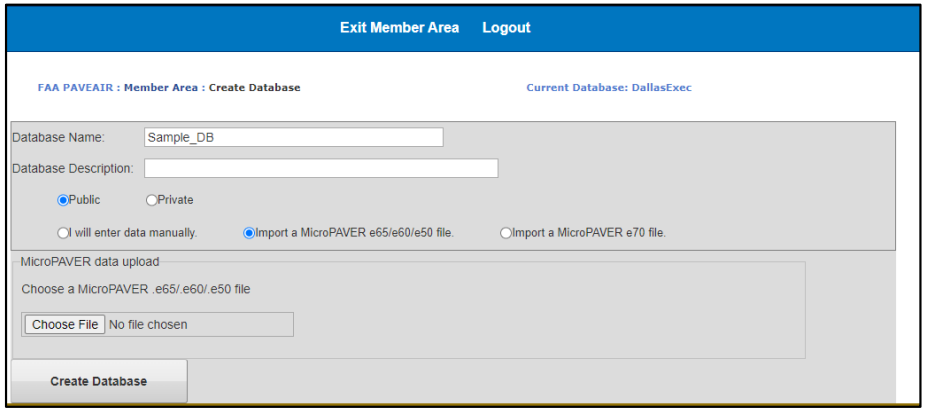


Importing PAVER™ Data

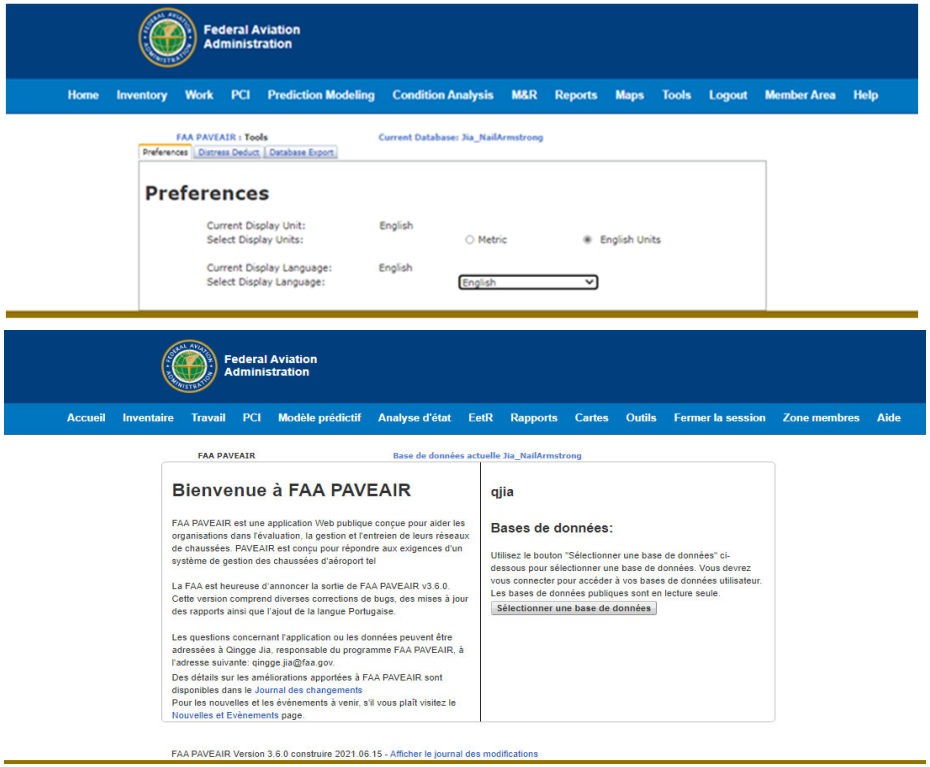
- **Create an e65/e70 file in PAVER™**
  - Paver Database Tools
- **Create a new FAA PAVEAIR database**
  - Select “Import a MicroPAVER e65/e60/e55 file” or
  - Select “Import a MicroPAVER e70 file.”



When complete, you will see the message “The database is created successfully.” Click **FAA PAVEAIR Home** to select your database.

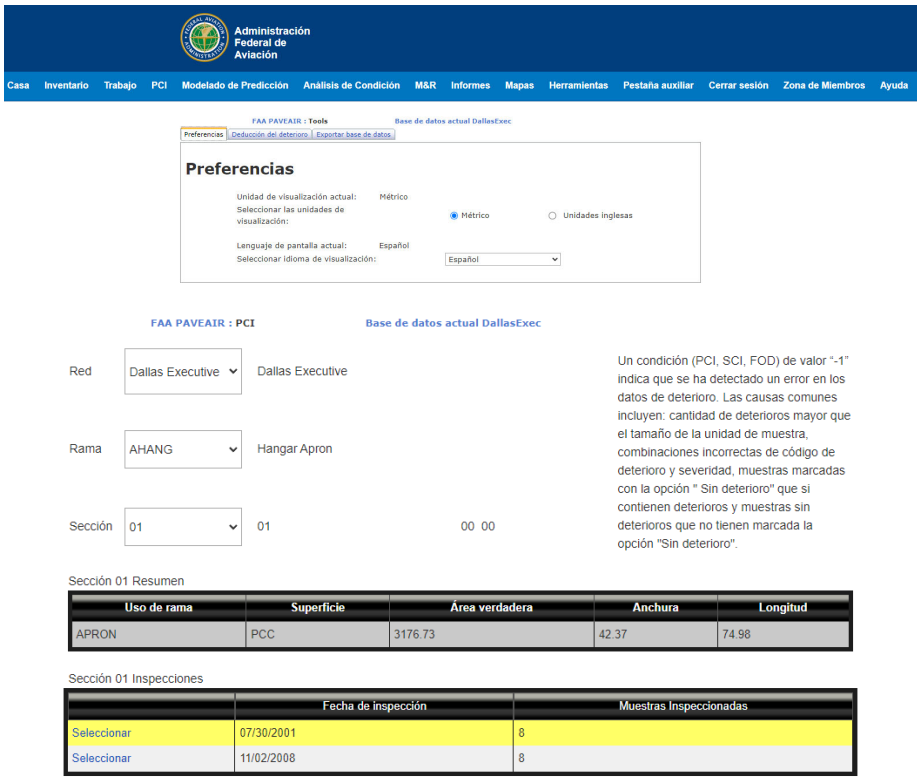
Language & Units

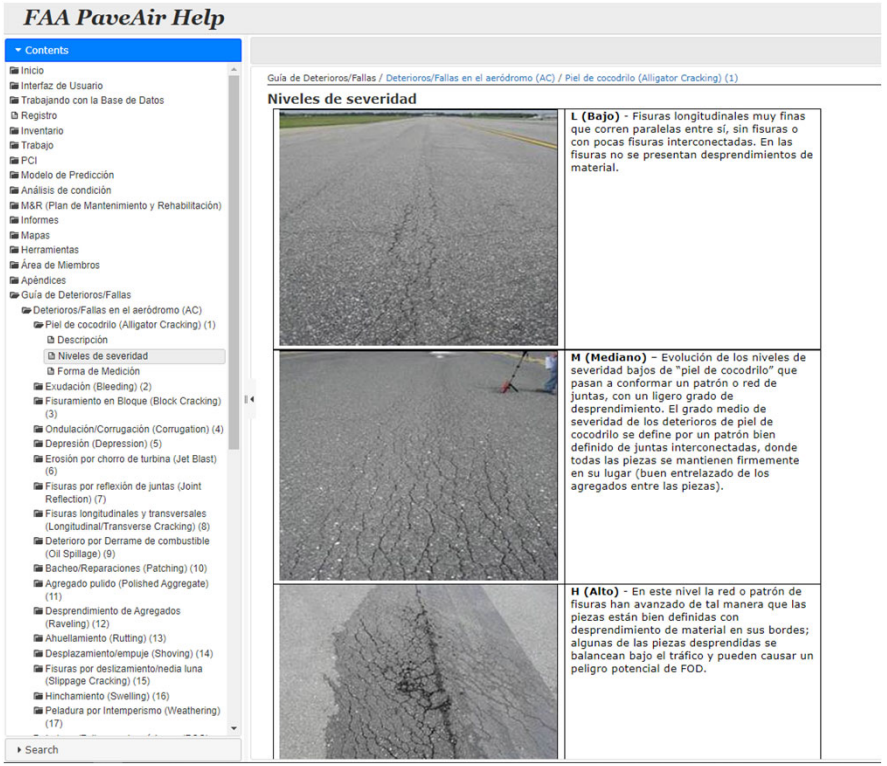
- **Available Languages**
  - English
  - Français
  - Español
  - Português (*Translation courtesy of ALACPA*)
- **Units**
  - U.S. Customary
  - Metric
- ***Only need to select once***



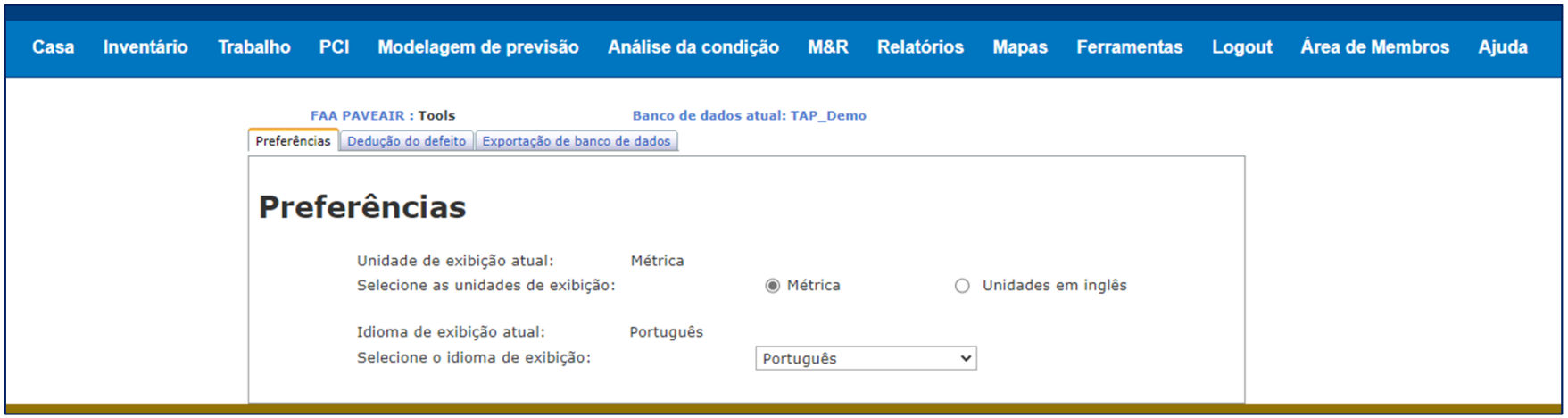
Spanish User Interface

Distress Guide and Manual in Spanish

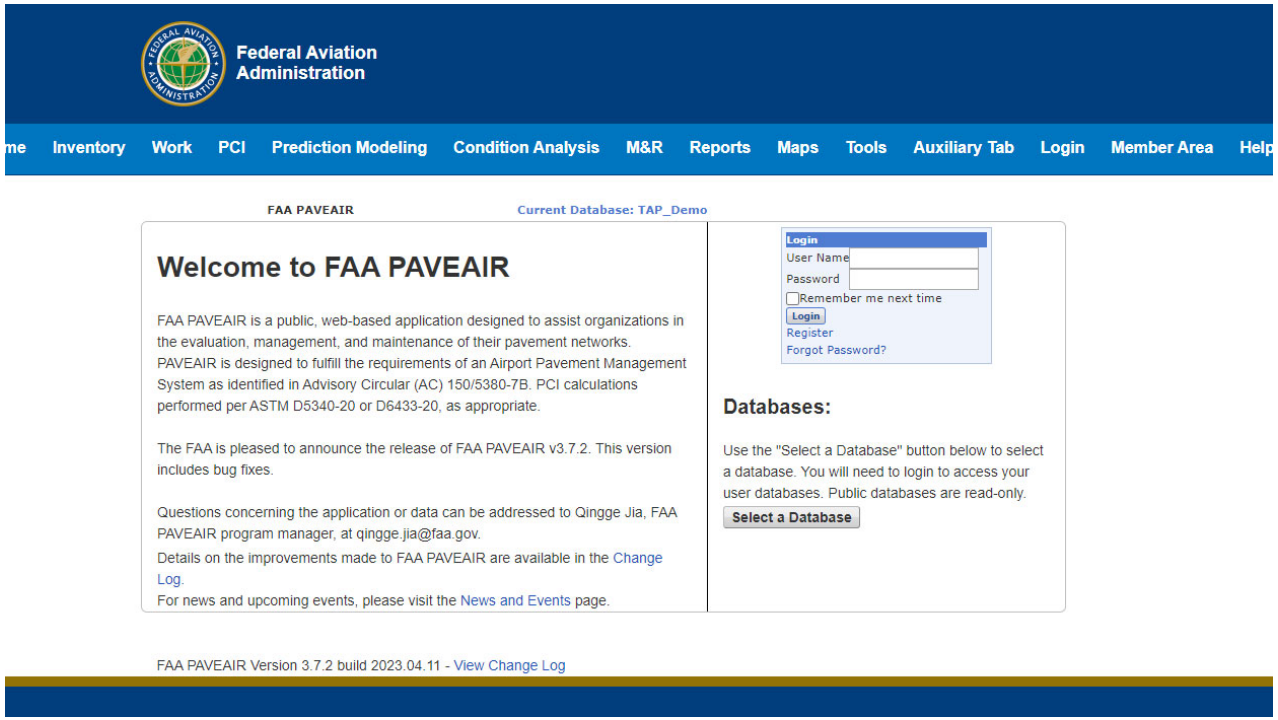




Portuguese Interface



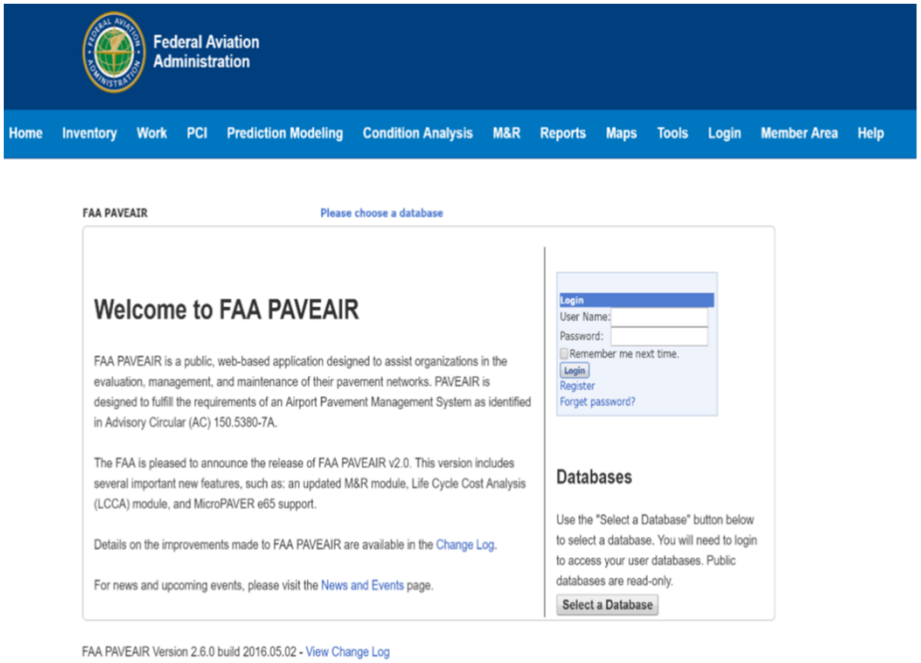
Translation courtesy of ALACPA



FAA PAVEAIR Features and Functions

Primary Functions

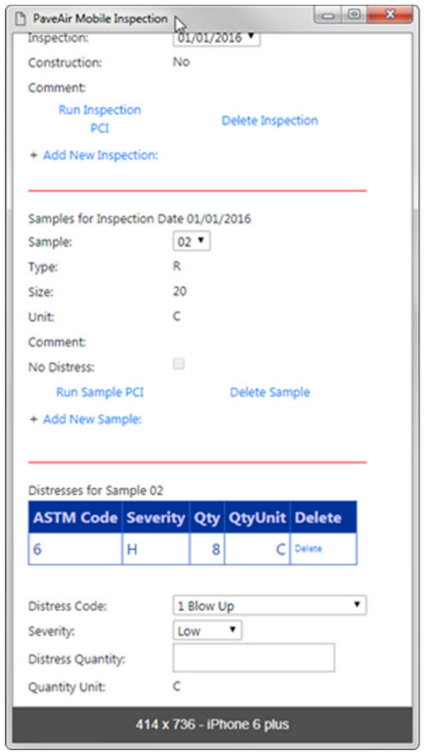
- **Inventory / Manage Pavement Inventories**
- **Work / Record Pavement Work Histories**
- **PCI / Update Inspections**
  - Calculate PCI / SCI / FOD
  - Record Condition Surveys
- **Prediction Modeling**
  - Predict future pavement conditions
  - Plot PCI vs. Age
- **Condition Analysis**
  - Provides projections about the viability of pavements
- **Maintenance and Repair Planning**
- **Reports / Maps**
  - Generate reports
  - Mapping support with shapefiles
- **Compatibility**
  - Import data from MicroPAVER(e60, e65)
  - Export data to XML

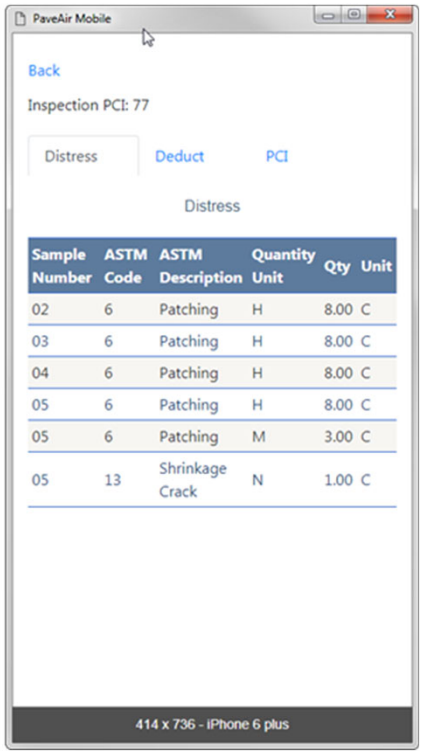


Mobile Data Entry

- **Works on any internet-enabled mobile device.**
  - Expensive Windows tablets not needed.
  - iPhone and Android compatible.
- **System automatically detects mobile users and switches to mobile interface.**
- **Data entered in real time and immediately available to all users.**
  - No synchronization required before or after survey.
  - PCI results immediately available to inspector.

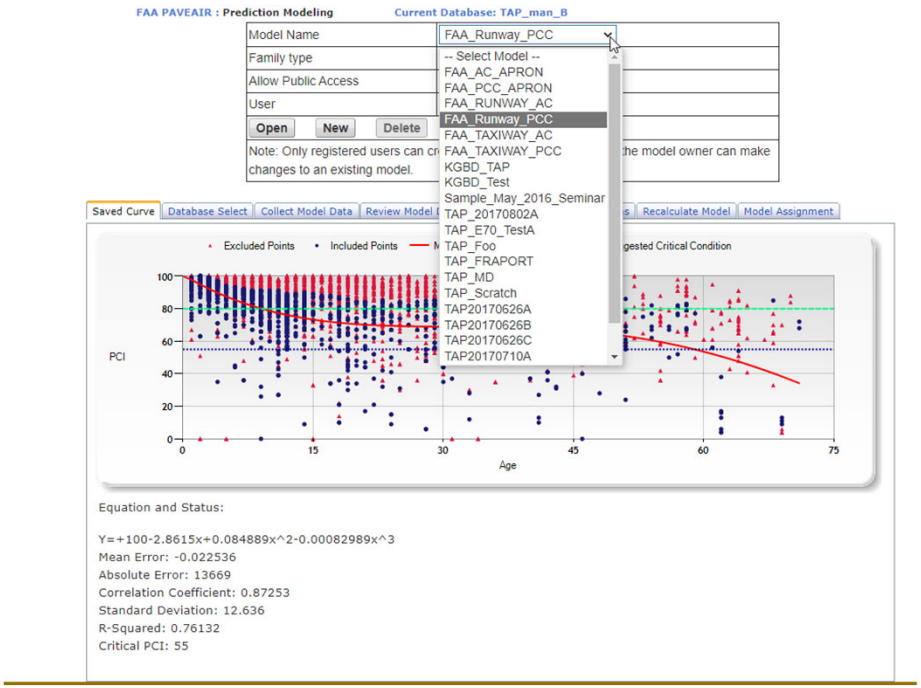
Example Using iPhone 6 plus





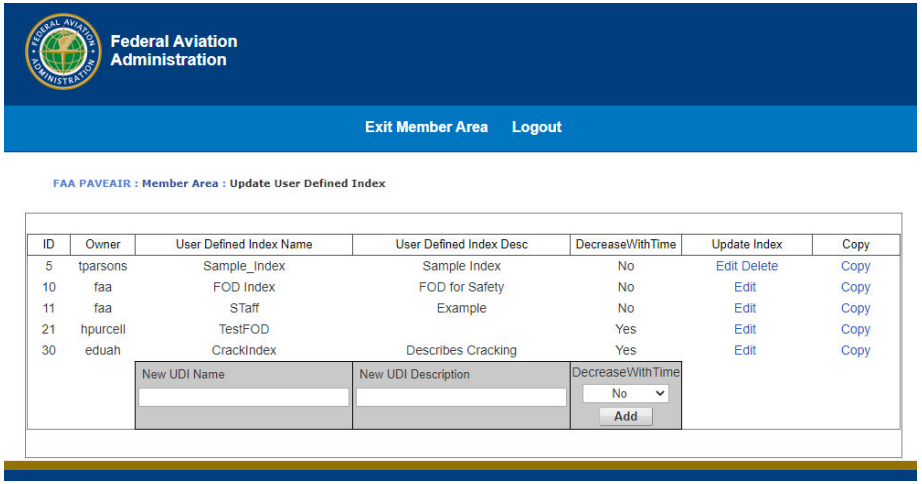
Prediction Modeling Capability

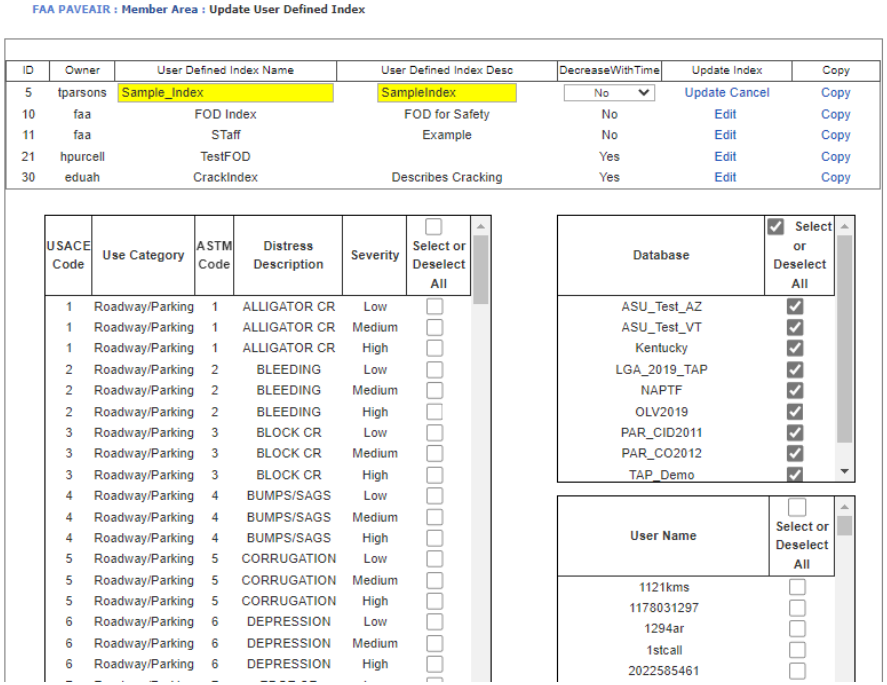
- **FAA prediction modeling library**
  - FAA-developed models.
  - Models for runway, taxiway, apron; asphalt (AC), concrete (PCC).
- **Build a family curve from:**
  - User-owned databases;
  - Databases to which user has read-only privileges; and
  - Public databases.
- **PCI, FOD, SCI versus Age**
- **Option to define critical PCI (default 60)**



User-Defined Indexes

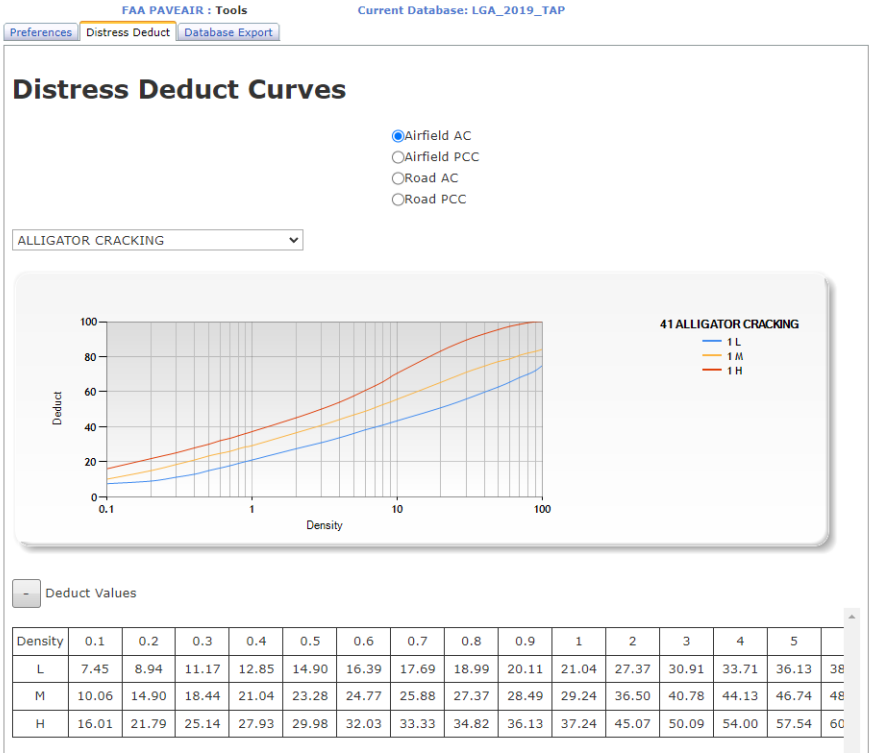
- **Define a custom index based on PCI distresses.**
- **Select the distress/severity combinations that contribute.**
- **Share with specific databases.**





Distress Deduct Curves

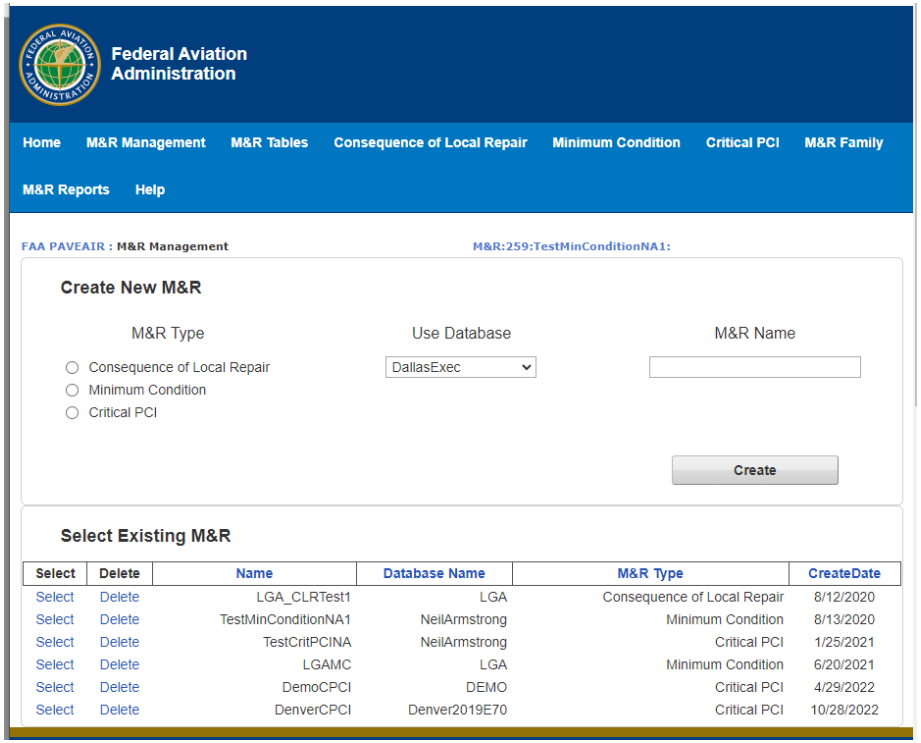
- **Digitized distress deduct values.**
- **Digitized curves.**
  - Curve data provided in tabular and
  - Can be implemented easily in other programs.



Density	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	2	3	4	5	
L	7.45	8.94	11.17	12.85	14.90	16.39	17.69	18.99	20.11	21.04	27.37	30.91	33.71	36.13	38
M	10.06	14.90	18.44	21.04	23.28	24.77	25.88	27.37	28.49	29.24	36.50	40.78	44.13	46.74	48
H	16.01	21.79	25.14	27.93	29.98	32.03	33.33	34.82	36.13	37.24	45.07	50.09	54.00	57.54	60

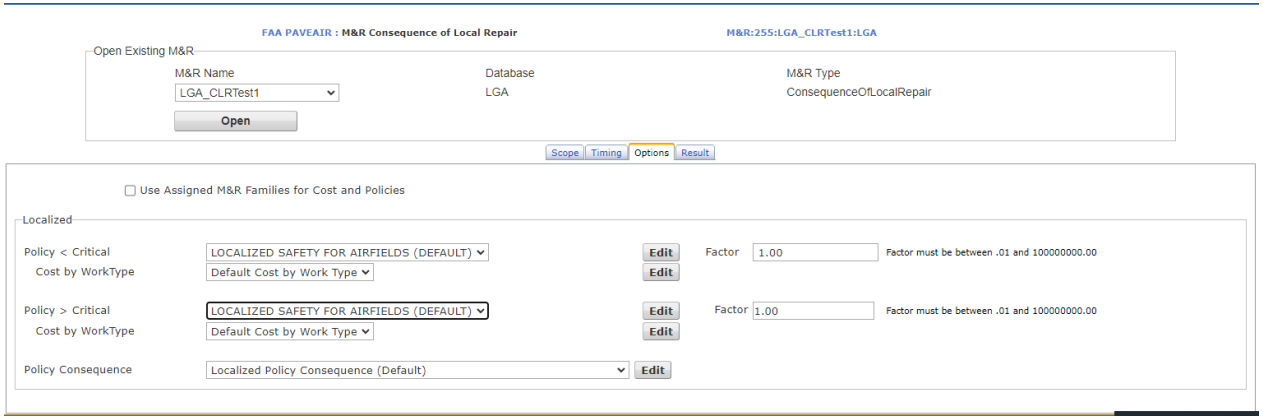
Maintenance and Repair (M&R) Planning

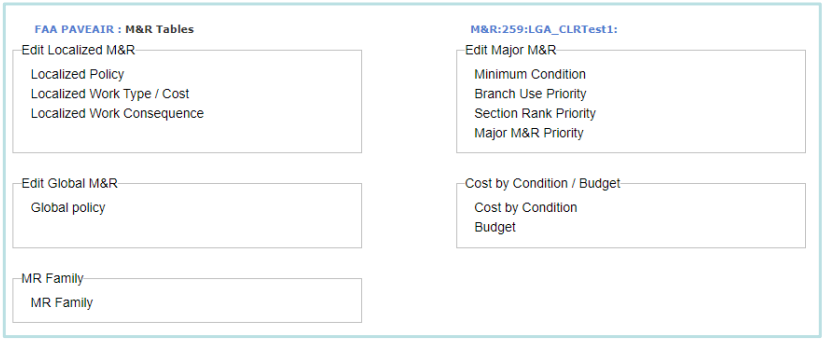
- **Scope**
- **Timing**
- **Plan Mode**
  - Critical PCI Method
  - Minimum Condition
  - Consequence of Local Repair
- **Policies**
  - Apply Inflation Rate
  - Apply Policy in First Year
  - Global
- **M&R Data**
  - Applied Policy Consequence
  - Applied Policy Details
  - Inventory Info



Customizable M&R Settings

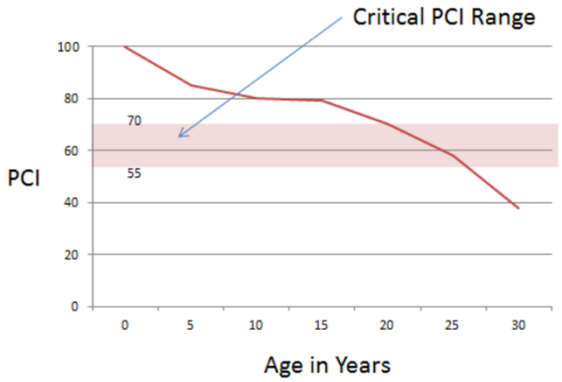
- **Localized M&R**
  - Policy
  - Work Type / Cost
  - Work Consequence
- **Global M&R**
  - Policy
- **Major M&R**
  - Minimum Condition
  - Branch Use Priority
  - Section Rank Priority
  - Major M&R Priority
- **Cost by Condition**
  - Cost by Condition
  - Budget





Supported M&R Types

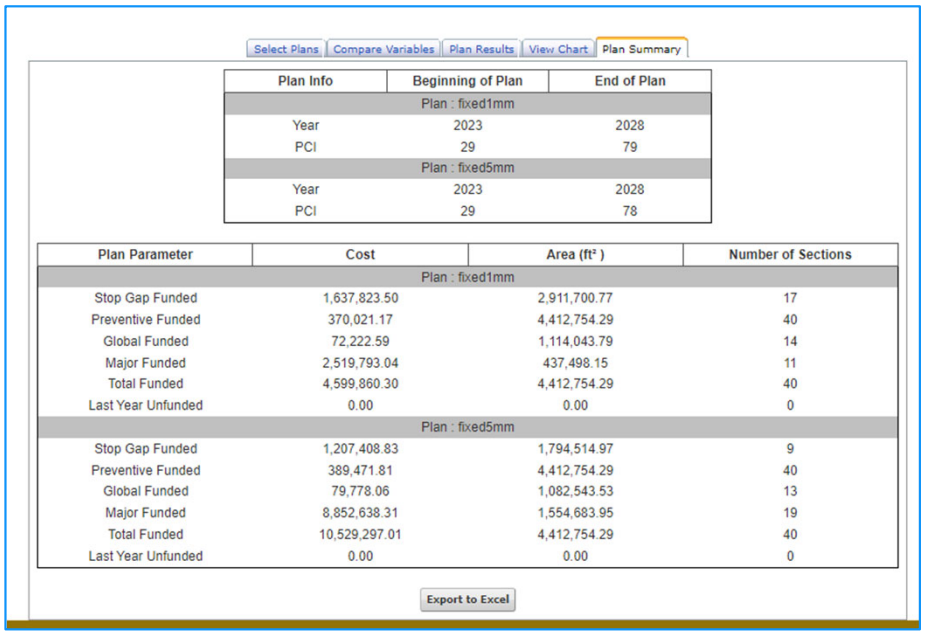
- **Critical PCI Method**
  - Critical PCI = PCI value after which a pavement deteriorates rapidly.
  - Usually between a PCI number of 55-70.
  - More economical to maintain pavements above than below the critical PCI.
  - Cost of applying localized preventive maintenance increases significantly.
- **Minimum Condition**
  - Only concerned with the Major M&R required to maintain a minimum PCI.
  - Major M&R: Any overlay or other major work that results in a PCI of 100.
  - Select the lowest pavement condition that is allowed for each pavement rank.
  - Prioritize the Maintenance and Repair plan to reflect the choice of “Minimum Condition” as the variable for decision making in regard to future work.
- **Consequence of Local Repair**
  - Calculates the cost and resulting condition from the immediate implementation of local maintenance and repair.
  - M&R actions are based on current distresses and their severity.
  - Consider this plan mode for pavements above Critical PCI.



M&R Comparison

- Compare cost and resulting condition of multiple M&R plans.
- Tabular and graphical format.

Compare effects of a $1 million and $5 million M&R budget:

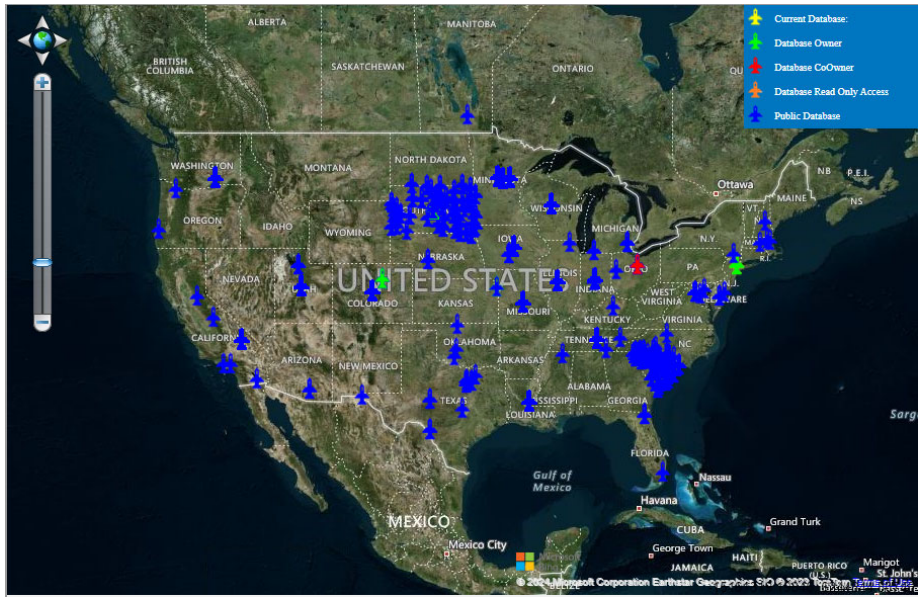


Plan Info	Beginning of Plan	End of Plan
Plan : fixed1mm		
Year	2023	2028
PCI	29	79
Plan : fixed5mm		
Year	2023	2028
PCI	29	78

Plan Parameter	Cost	Area (ft²)	Number of Sections
Plan : fixed1mm			
Stop Gap Funded	1,637,823.50	2,911,700.77	17
Preventive Funded	370,021.17	4,412,754.29	40
Global Funded	72,222.59	1,114,043.79	14
Major Funded	2,519,793.04	437,498.15	11
Total Funded	4,599,860.30	4,412,754.29	40
Last Year Unfunded	0.00	0.00	0
Plan : fixed5mm			
Stop Gap Funded	1,207,408.83	1,794,514.97	9
Preventive Funded	389,471.81	4,412,754.29	40
Global Funded	79,778.06	1,082,543.53	13
Major Funded	8,852,638.31	1,554,683.95	19
Total Funded	10,529,297.01	4,412,754.29	40
Last Year Unfunded	0.00	0.00	0

GIS Mapping Capabilities

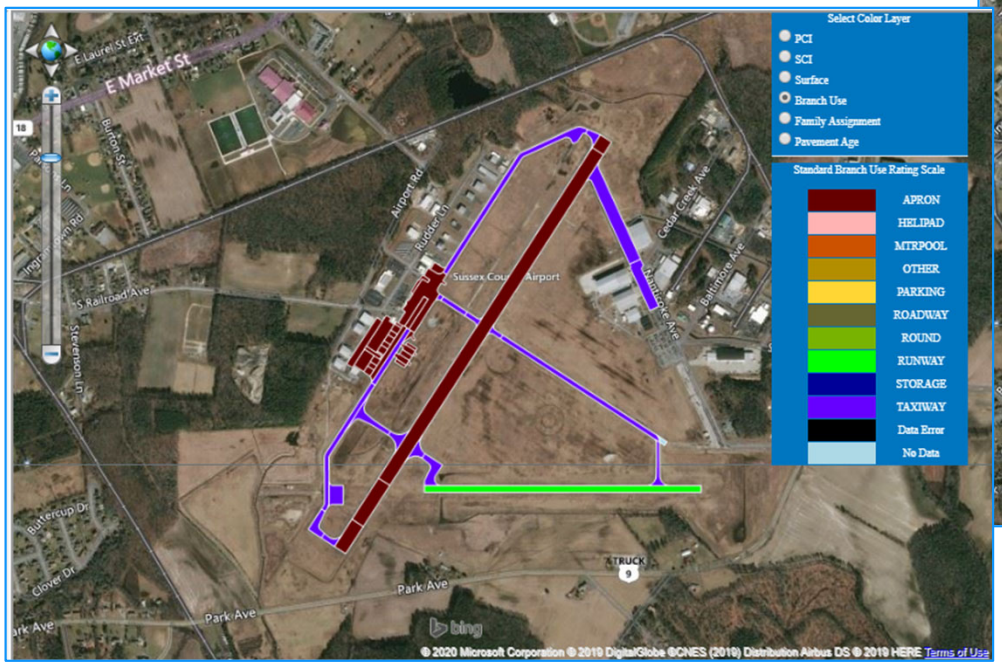
Database Locations

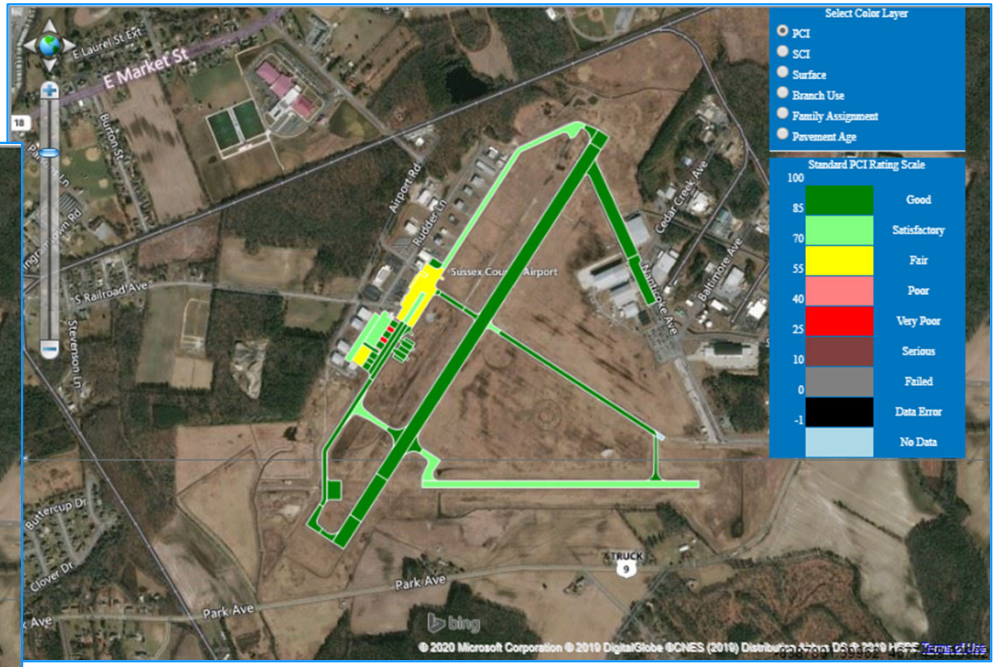


Zoom to Shapefiles

Aerial Photography for GIS

- **Free to user.**
- **PAVEAIR detects if shapefiles are georeferenced and automatically puts them in the correct location.**

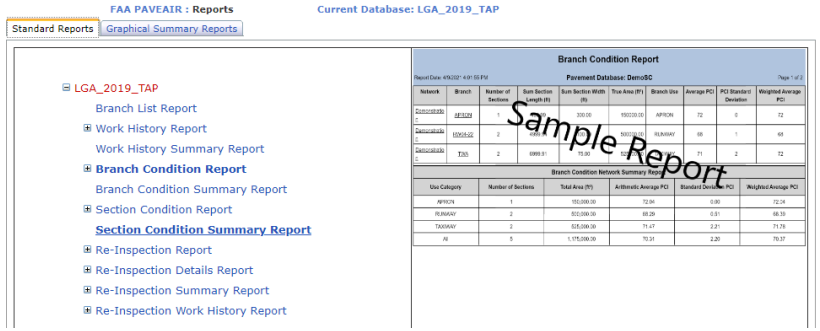




Branch Use and PCI maps on aerial photography background

Reporting Capabilities

- **Standard Reports**

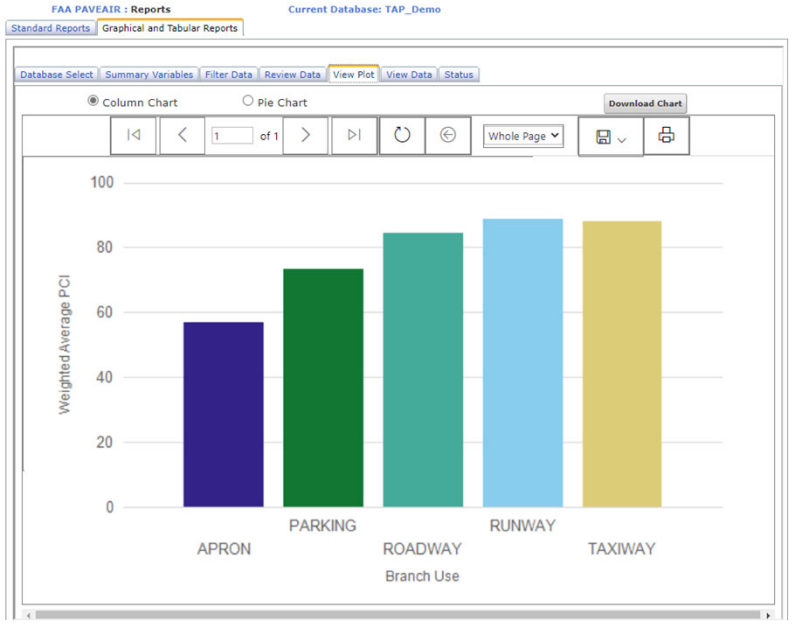


Branch Condition Summary Report

Report Date: 1/18/2024 1:29:41 PM | Pavement Database: LGA_2019_TAP | page 1 of 1

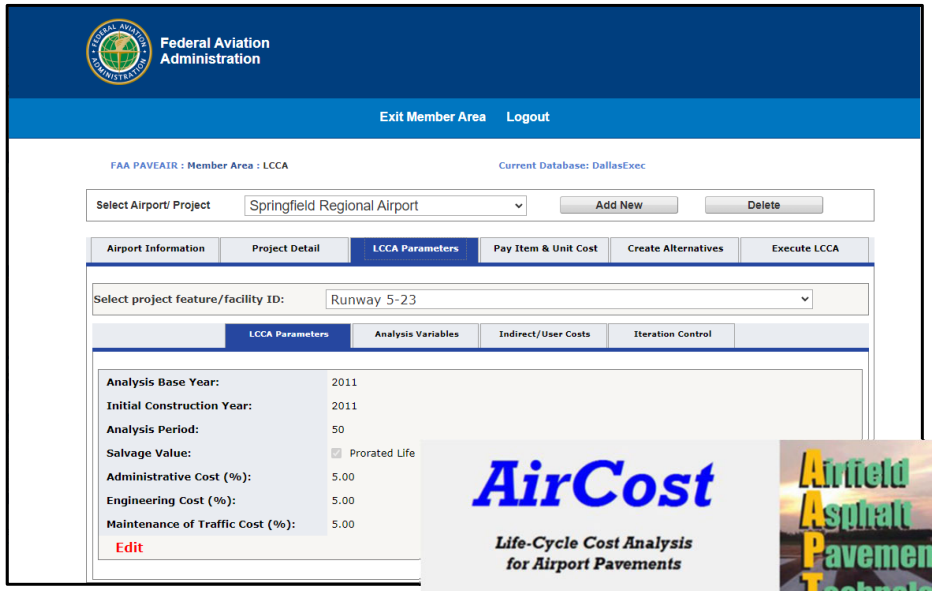
Use Category	Number of Sections	Total Area(ft²)	Arithmetic Average PCI	Standard Deviation PCI	Weighted Average PCI
APRON	5	561,751.00	58.81	9.16	57.06
PARKING	65	958,696.00	76.13	20.84	72.91
ROADWAY	214	1,865,079.00	82.13	19.04	84.04
RUNWAY	34	2,043,268.00	78.28	26.07	82.72
TAXIWAY	241	4,006,468.00	87.23	12.30	88.19
All	559	9,435,262.00	83.19	17.79	82.78

- **Graphical Summary Reports (customizable)**



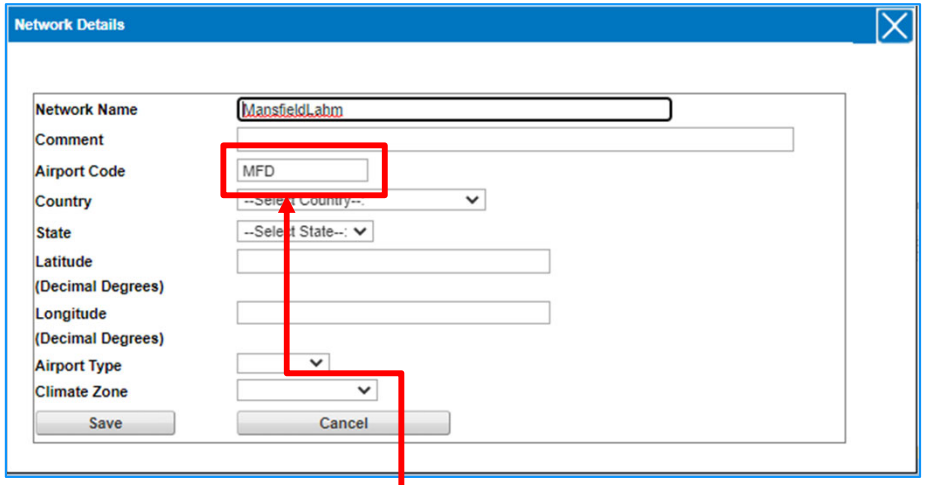
Life Cycle Cost Analysis (LCCA)

- **Implements the AAPTP AirCost LCCA Application**
- **Economic Analysis - evaluates the long-term economic benefit among different pavement design strategies.**
- **Procedures**
  - Establish alternative pavement design strategies
  - Determine the performance period and activity timing
  - Estimate costs
  - Compute Net Present Value (NPV)
  - Analyze results
  - Re-evaluate pavement design strategies



NOAA Weather Data Access

New!

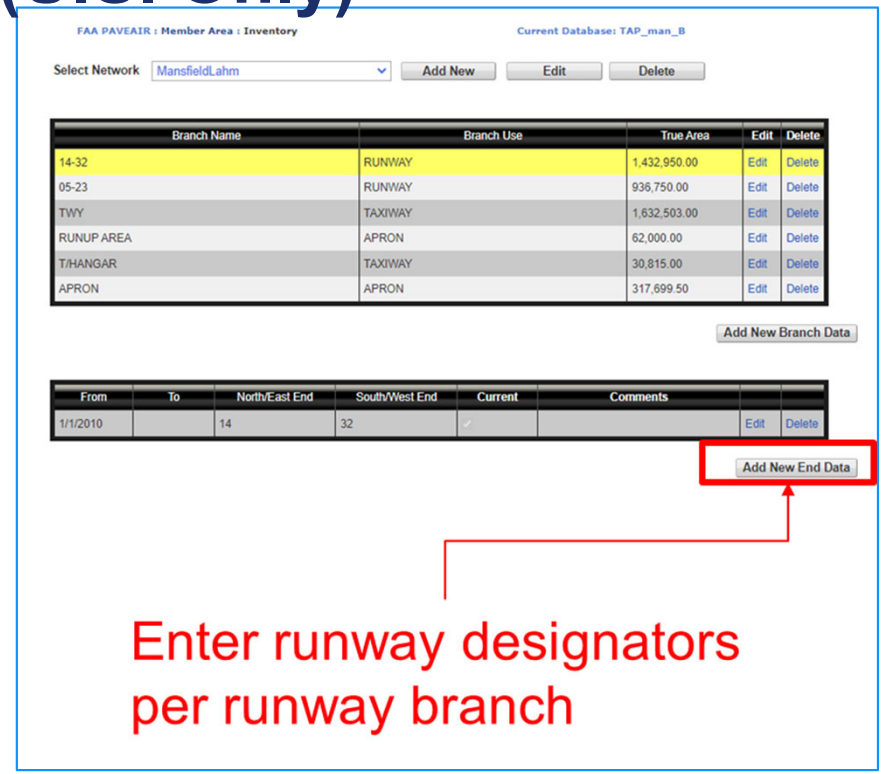


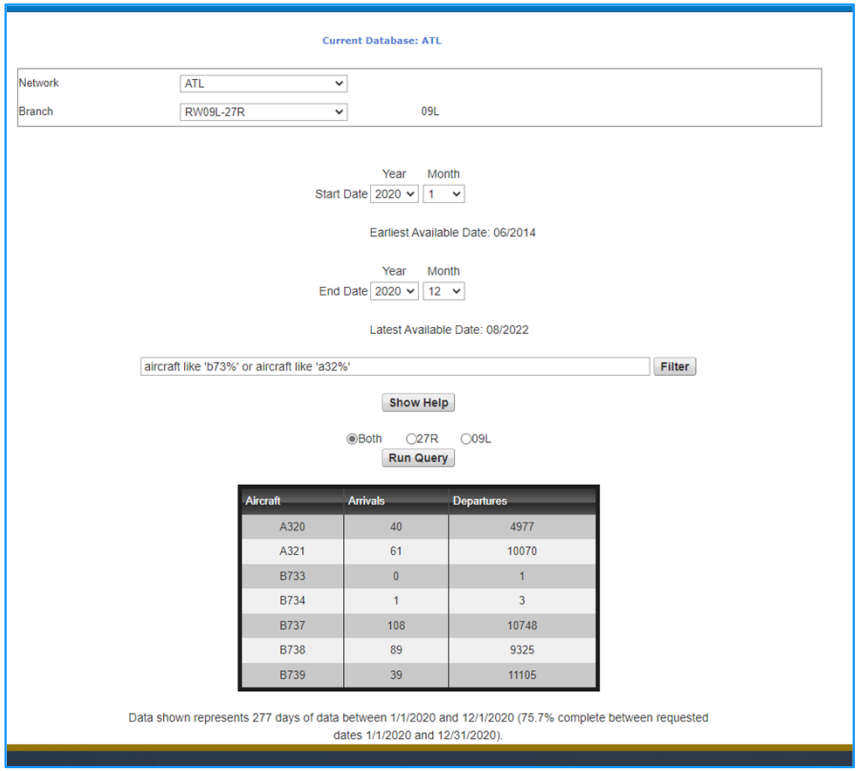
Set airport code for network in Inventory Update

Measurement	Value
Network	ATL
Start Date	Thursday, January 1, 2015
End Date	Thursday, December 31, 2015
Completeness	8,758 of 8,760 hours contained data (i.e., completeness percentage - 99.98%)
Temperature High	95.00 F
Temperature Low	10.94 F
Temperature Average	64.16 F
Average Daily Temperature Range	16.87 F
Freeze Thaw	22 freeze-thaw cycles
Freeze Degree Days	34.10 F
Days Temperature Was Over 90	35 days
Days With Precipitation	146 days
Average Duration of Precipitation	2.26 hours
Precipitation Total	68.82 inches
Thornthwaite	104 %
Relative Humidity High	100.00 %
Relative Humidity Low	5.81 %
Relative Humidity Average	60.41 %
Hydration Days	222 days
Sky Cover	5.08 oktas
Solar Radiation	N/A
Wind Average	7.58 mph
Days With Freeze Precipitation	1 day

Runway Usage (Traffic) Data New!

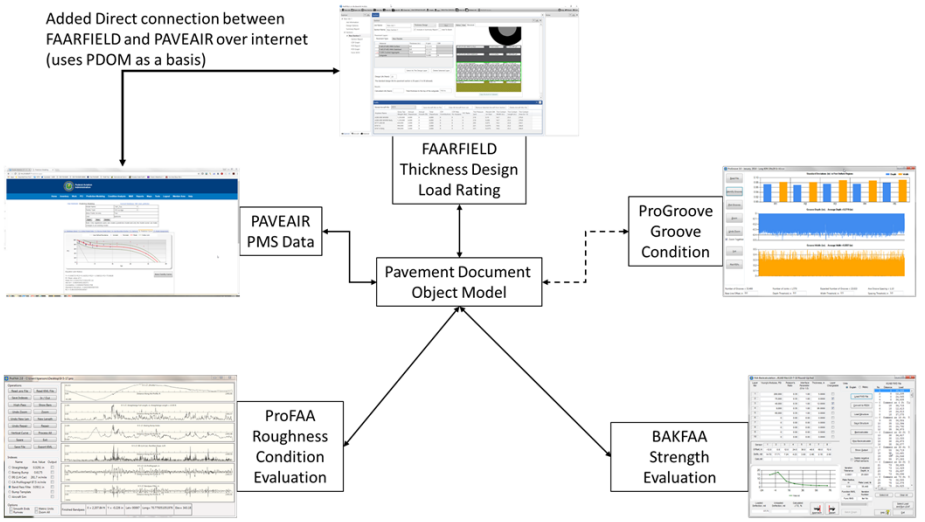
(U.S. Only)





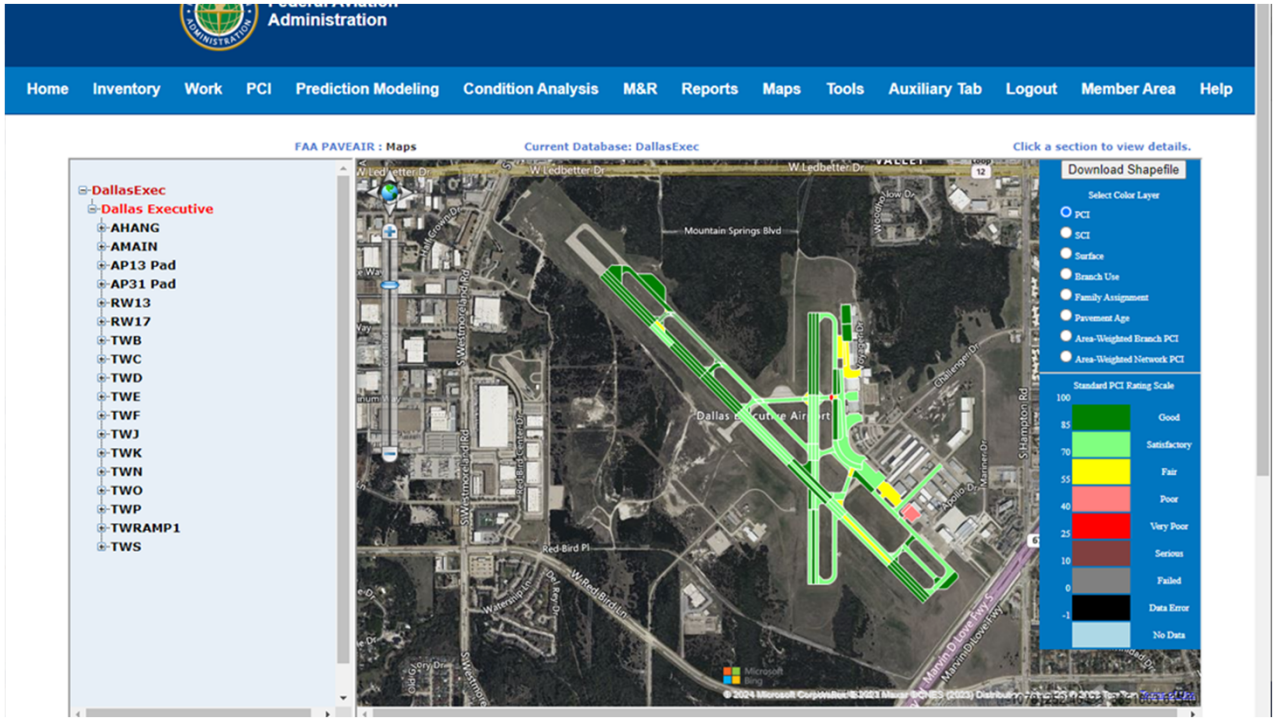
Software Integration

- **FAA has five software programs required or recommended for use by FAA AC's: FAARFIELD; PAVEAIR, BAKFAA, ProFAA, ProGroove.**
- **Developed separately, they each had a unique data format and user experience.**
- **Data types overlap between the applications. Examples:**
  - FAARFIELD uses moduli determined in BAKFAA.
  - PAVEAIR LCCA uses layer thicknesses determined in FAARFIELD.
- **PDOM allows any FAA pavement application to read the data file from any other.**
  - Ease of use.
  - Minimize transcription errors.
  - One file contains full pavement history (design, as-constructed, condition, roughness, NDT, M&R plans).



Pavement Document Object Model (PDOM)

The PDOM is a common data format readable by any FAA pavement software. It can be stored as a file or transmitted over the network.



FAA PAVEAIR 3.7 Demonstration

https://faapaveair.faa.gov/

Looking Ahead:

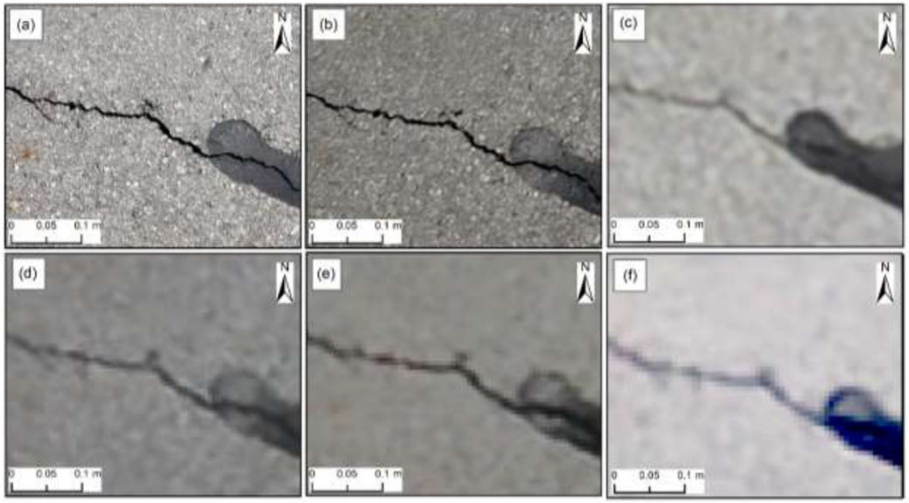
UAS for Pavement Inspections

UAS/sUAS Integration at Airports

- **Uncrewed aircraft systems (UAS) are increasingly popular in recreational, commercial, and public safety settings.**
- **The FAA William J. Hughes Technical Center is collaborating with the FAA's Office of Airports to support the reliable, safe, and effective integration of small UAS (sUAS) into the airport environment for:**
  - Pavement Inspections
  - Construction Monitoring
  - Obstruction Analysis
  - Perimeter Fenceline Inspections
  - Wildlife Dispersal
  - Foreign Object Damage (FOD) Detection
  - Aircraft Rescue and Firefighting (ARFF)

sUAS for Pavement Inspections

- **Purpose:** Evaluate the use of sUAS to conduct airport pavement inspections.
- **Research Lifecycle:** 2020 - 2022
  - Tested at eight airports with different pavement types/severities.
  - Tested various types of sUAS and optical cameras.
  - UAS data was compared to traditional 'foot-on-ground' surveys.
- **Finding:** sUAS are a suitable tool for supplementing, but not replacing traditional foot-on-ground pavement inspections.
- **Reports:**
  - **DOT/FAA/TC-22/48**, Practical Lessons Learned from Planning, Collecting, Processing, and Analyzing Small Unmanned Aircraft System Data for Airfield Pavement Inspection (2022)
  - **DOT/FAA/TC-23/39**, Assessment of Small Unmanned Aircraft Systems for Pavement Inspections (2023)
  - **DOT/FAA/TC-23/50**, Small Unmanned Aircraft System for Pavement Inspection (2023).



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Thank You!

Acknowledgments:

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Qingge (Quinn) Jia, Project Manager

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https://airporttech.tc.faa.gov