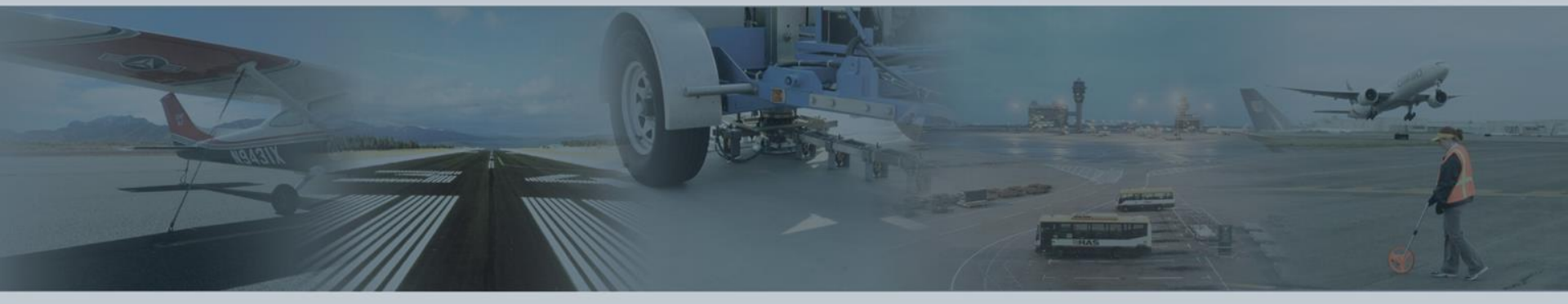

Evaluating Deterioration Rates in Asphalt Concrete Pavement

Presented by:

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SWIFT
WORLD'S PREMIER AIRFIELD OPERATIONS CONFERENCE

applied pavement TECHNOLOGY
providing engineering solutions to improve pavement performance

Purpose

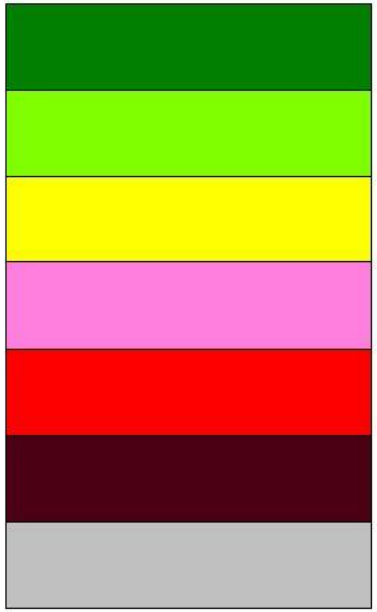
- Evaluate deterioration rates of asphalt surfaced pavements
  - Identify trends in deterioration rates
  - Identify what can be defined as normal deterioration
  - Compare normal deterioration ranges to historical data used in pavement management

Outline – Background

- Utilizing deterioration rates
- Historical deterioration rates
- ASTM standard change
  - Weathering and raveling redefined
- Northern climate airfields
  - Canadian and northern U.S climate airfields

Linear Lifetime Deterioration Rate

- Pavement Condition Index (PCI) rating scale:



86-100, GOOD

71-85, SATISFACTORY

56-70, FAIR

41-55, POOR

26-40, VERY POOR

11-25, SERIOUS

0-10, FAILED

- $$Lifetime\ det.rate = \frac{100 - PCI}{Age\ (years)\ at\ inspection}$$

Utilizing Deterioration Rates

- Identify rapidly deteriorating pavements
  - Provides warning, allows for corrective action
- Identify slowly deteriorating pavements
  - Reuse these construction and maintenance practices on other pavements
- Predict future conditions
  - Planning of maintenance and rehabilitation

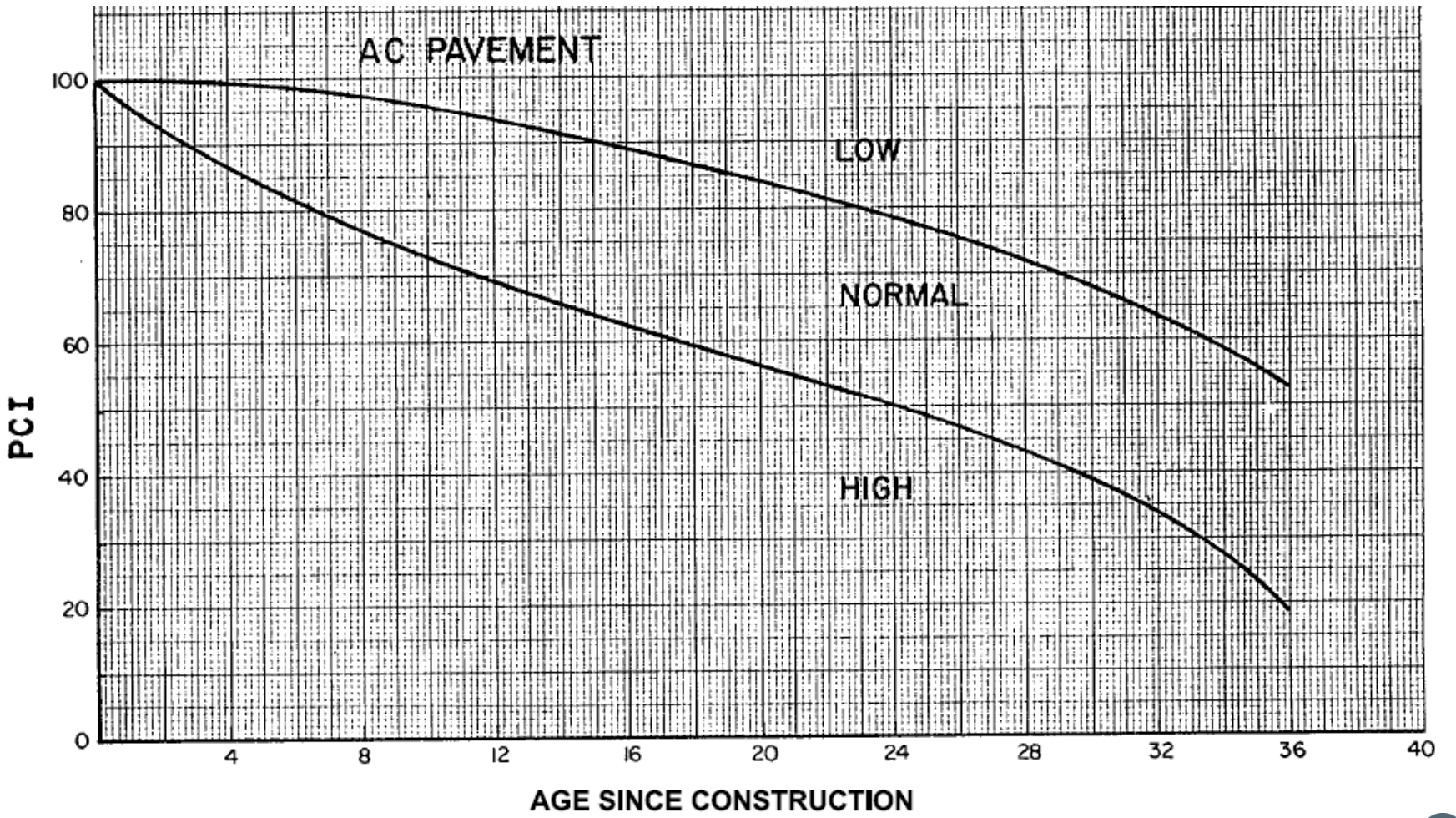
Historical Deterioration Rates

- "Normal" asphalt surfaced deterioration rates between 2 – 3 PCI points/year
  - Asphalt concrete (AC) pavements usually toward lower end of this range
  - Asphalt overlay over AC (AAC) and asphalt overlay over portland cement concrete (APC) pavements usually toward the higher end of this range

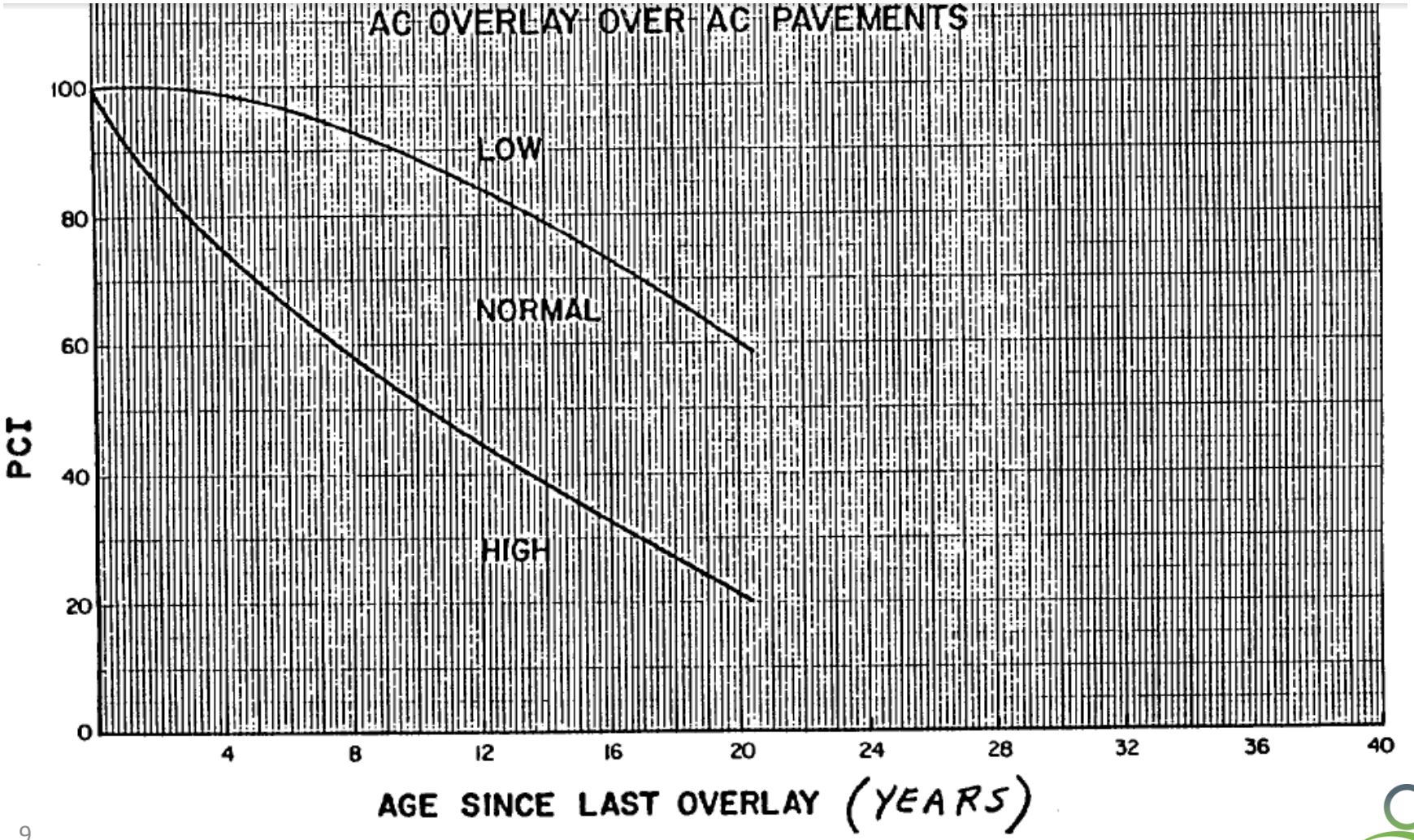
UFC 3-270-08 Deterioration Rates

- *Unified Facilities Criteria (UFC) 3-270-08, Pavement Maintenance Management*, provides ranges of pavement deterioration
  - Originally Army Technical Manual 5-623
- Low, normal, and high deterioration ranges for each pavement type defined
- Developed from 1982 survey data of Fort Eustis, Virginia

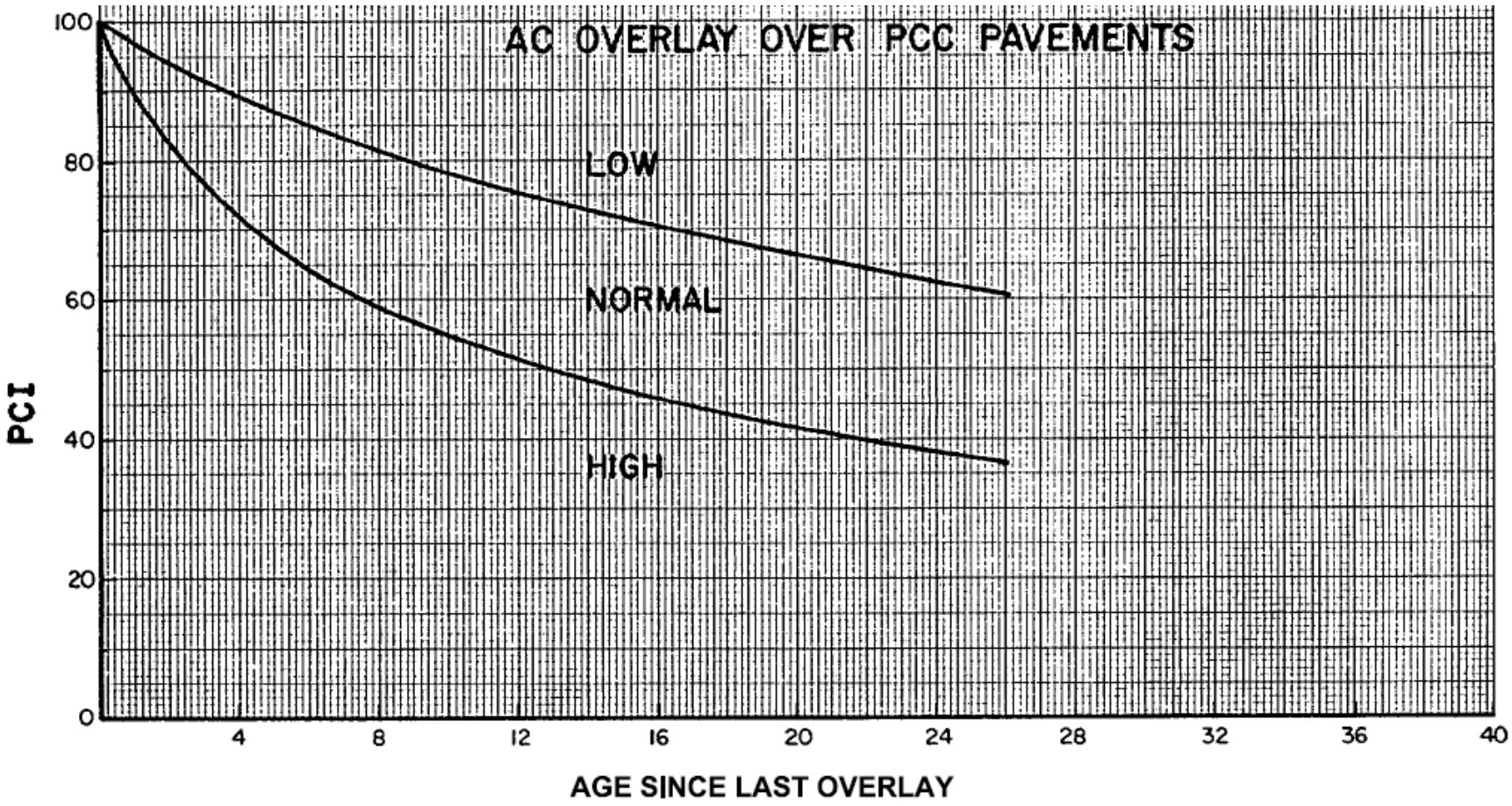
AC Pavement Deterioration Ranges



AAC Pavement Deterioration Ranges



APC Pavement Deterioration Ranges



ASTM Standard Change

- Weathering/raveling previously recorded as single distress prior to 2010
  - All weathering levels recorded as low-severity weathering/raveling
- Weathering and raveling defined as unique distresses in 2010
  - PCI deducts for raveling same as previous weathering/raveling deducts
  - New PCI deducts developed for weathering

ASTM Standard Change Impact

- A theoretical comparison performed using 100% density, new and old ASTM Standard definitions

Distress Observed (New ASTM Criteria)	PCI Value		
	Old ASTM	New ASTM	Difference
100% Low Raveling	74	74	0
100% Medium Raveling	43	43	0
100% High Raveling	30	30	0
100% Low Weathering	74	94	20
100% Medium Weathering	74	80	6
100% High Weathering	74	43	-31
100% Low Weathering/Low Raveling	74	69	-5
100% Medium Weathering/Low Raveling	74	69	-5
100% High Weathering/Low Raveling	74	38	-36

Defining a Northern Climate

- Weather data used to define which airfield inspections to include
- Air Freezing Index (AFI), mean annual temperature, and length of frost season chosen as indices
  - WorldIndex database utilized and cross-referenced with other sources

Air Freezing Index (AFI)

- The AFI is a measure of the collective magnitude and length of air temperatures below the freezing point
  - Calculated via the daily mean air temperature
- In other words, it is the total number of degree-days of freezing for a year

Defining a Northern Climate

- Roughly defined a northern climate as:
  - AFI at a minimum of 1,000° F-days
  - Mean annual temperature at a maximum of 50° F
  - Length of frost season at least 100 days/year

Data Excluded from Analysis

- Some inspection data removed from data set
  - Pavement over 30 years old at time of inspection
  - Shoulder, T-Hanger, or helipad pavements
  - Pavements older than 10 years with PCIs of 100
    - Assumed improper construction history within database

Airfields Examined

- 76 airfields in 15 states and 7 provinces
  - 2,446 inspection data points evaluated
- Average airfield has:
  - AFI of 2,000° F-days
  - Mean annual temperature of 44° F
  - Frost season length of 139 days
  - Averages similar to weather data from Green Bay, Wisconsin

Statistical Analysis

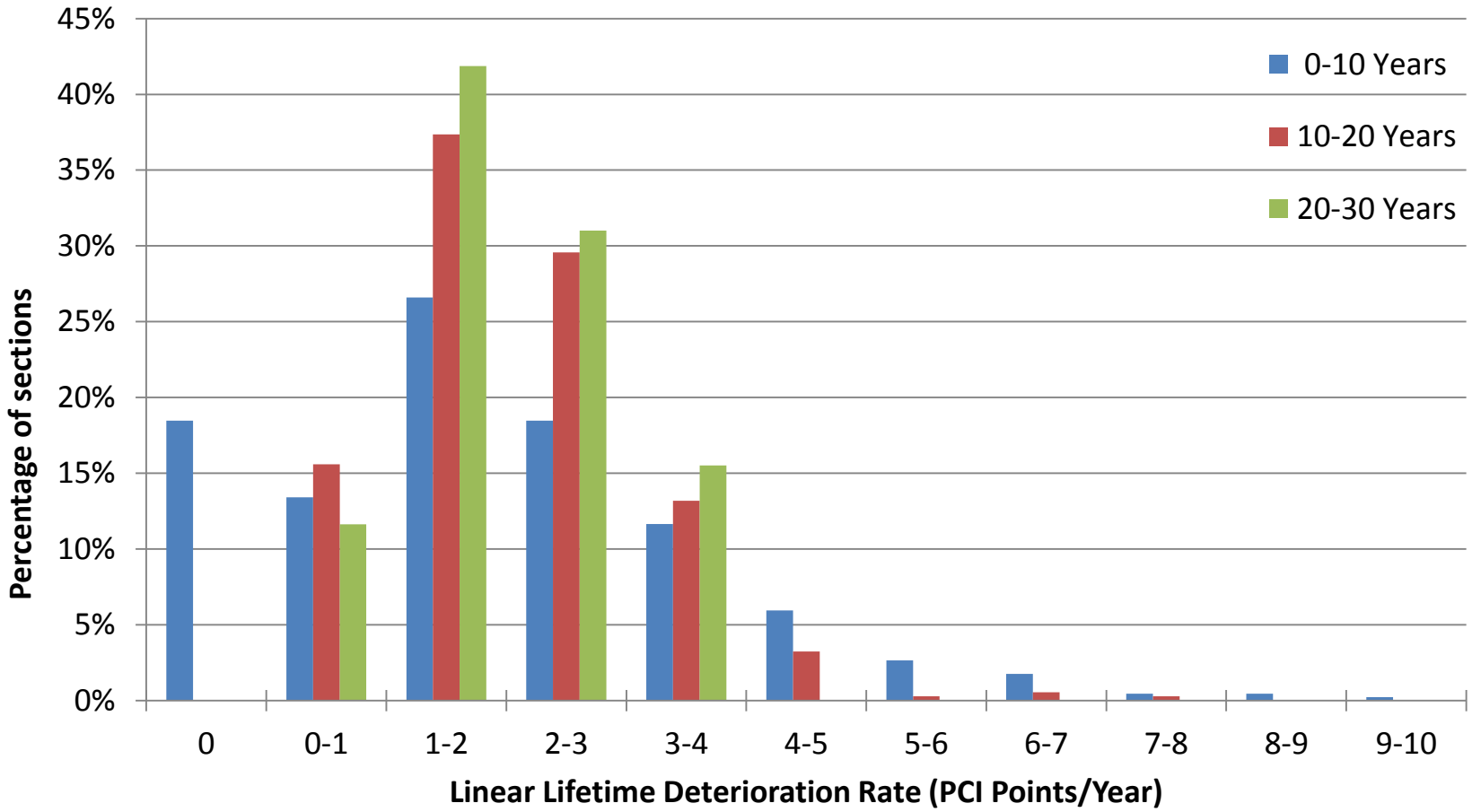
Outline – Statistical Analysis

- Linear lifetime deterioration rate trends
- Deterioration rates modeled in PAVER™
- Statistically modeled deterioration rates
- Comparison to historic deterioration rates
- Application to pavement management

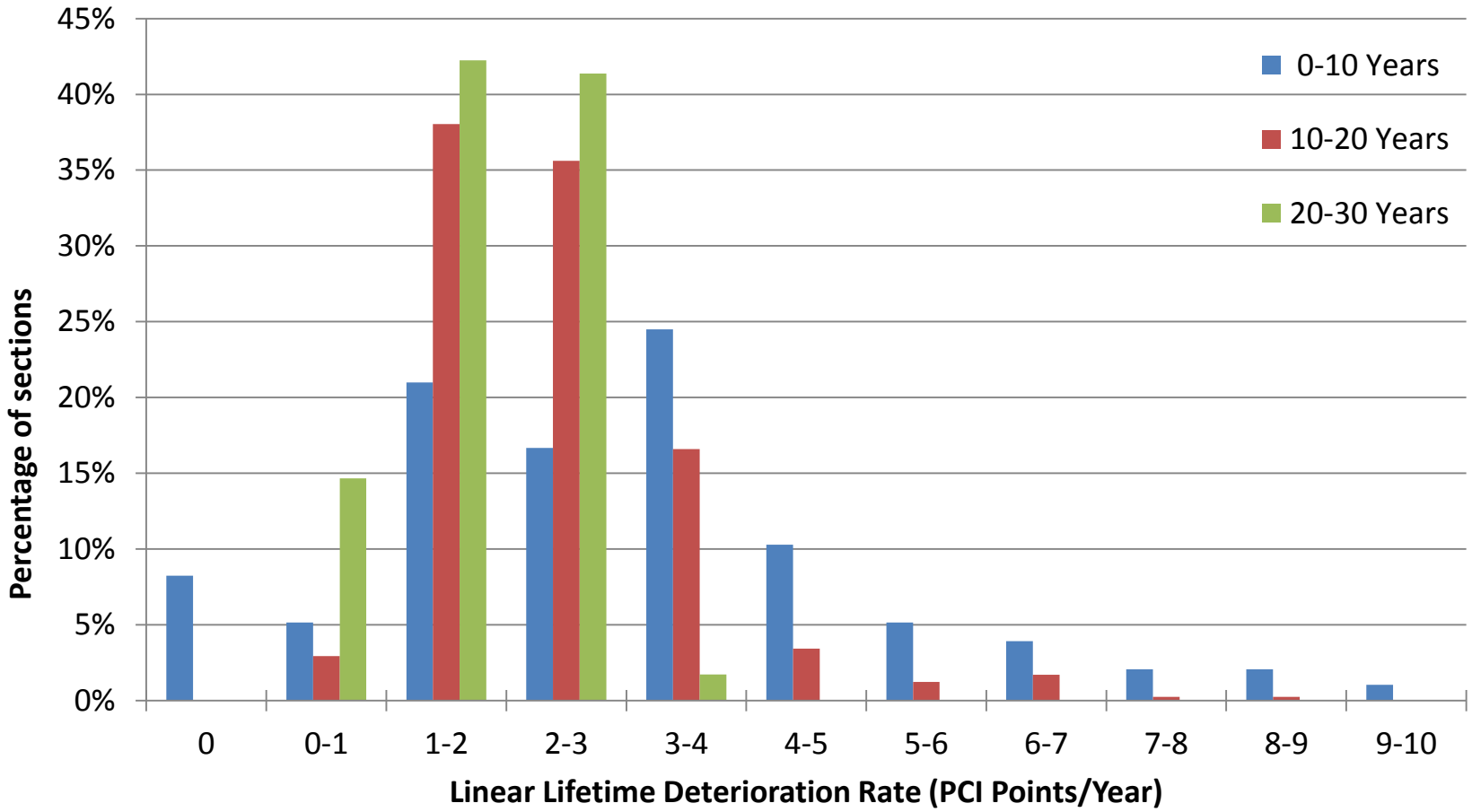
Linear Lifetime Deterioration Rate Trends

- Linear lifetime deterioration rates for age groups of each pavement type examined
  - 0-10 years old at inspection
  - 10-20 years old at inspection
  - 20-30 years old at inspection
- Deterioration rates combined into bins with range of 1 PCI point/year
- Results scaled to 100% for each age group

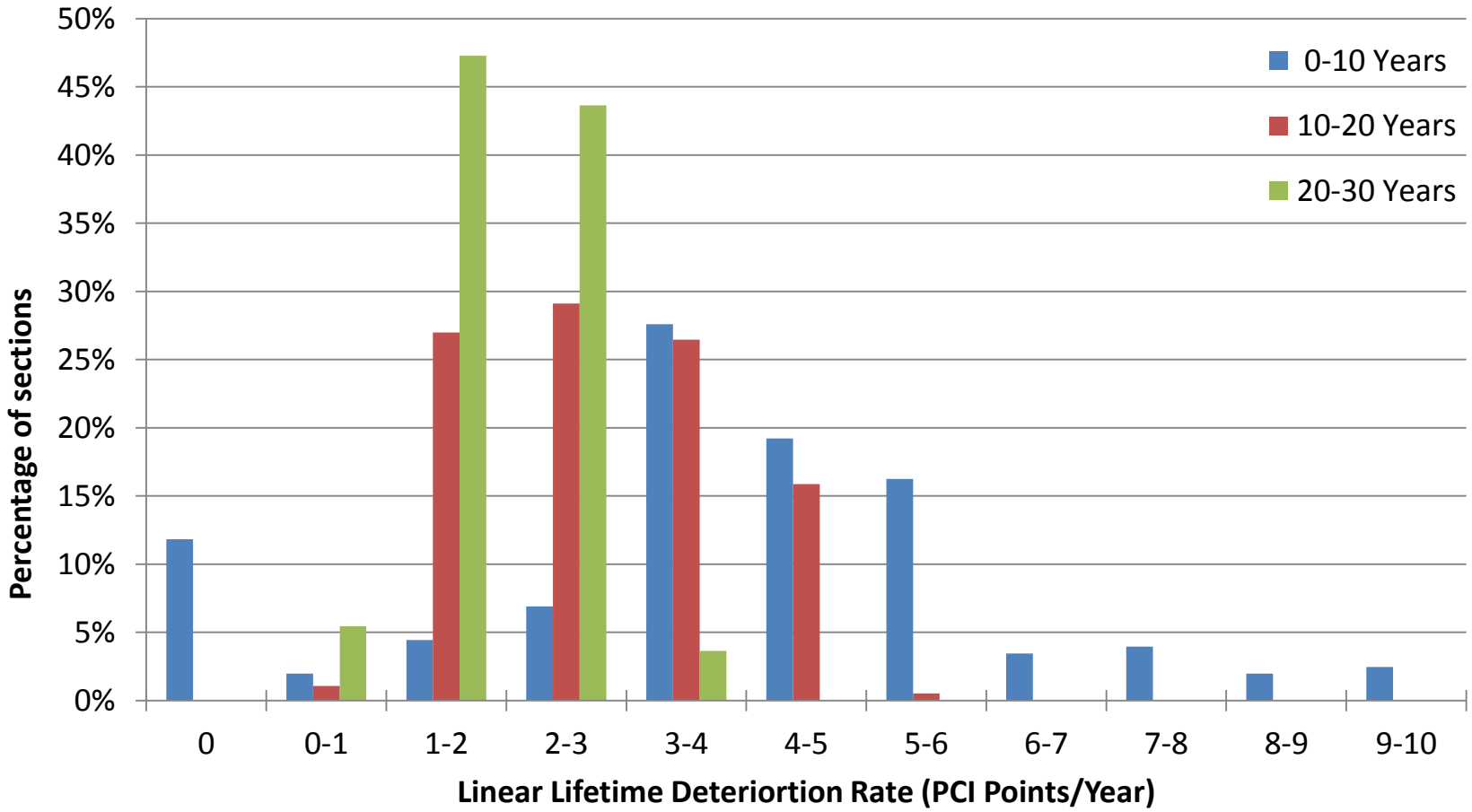
Deterioration Rate Distribution - AC



Deterioration Rate Distribution - AAC



Deterioration Rate Distribution - APC

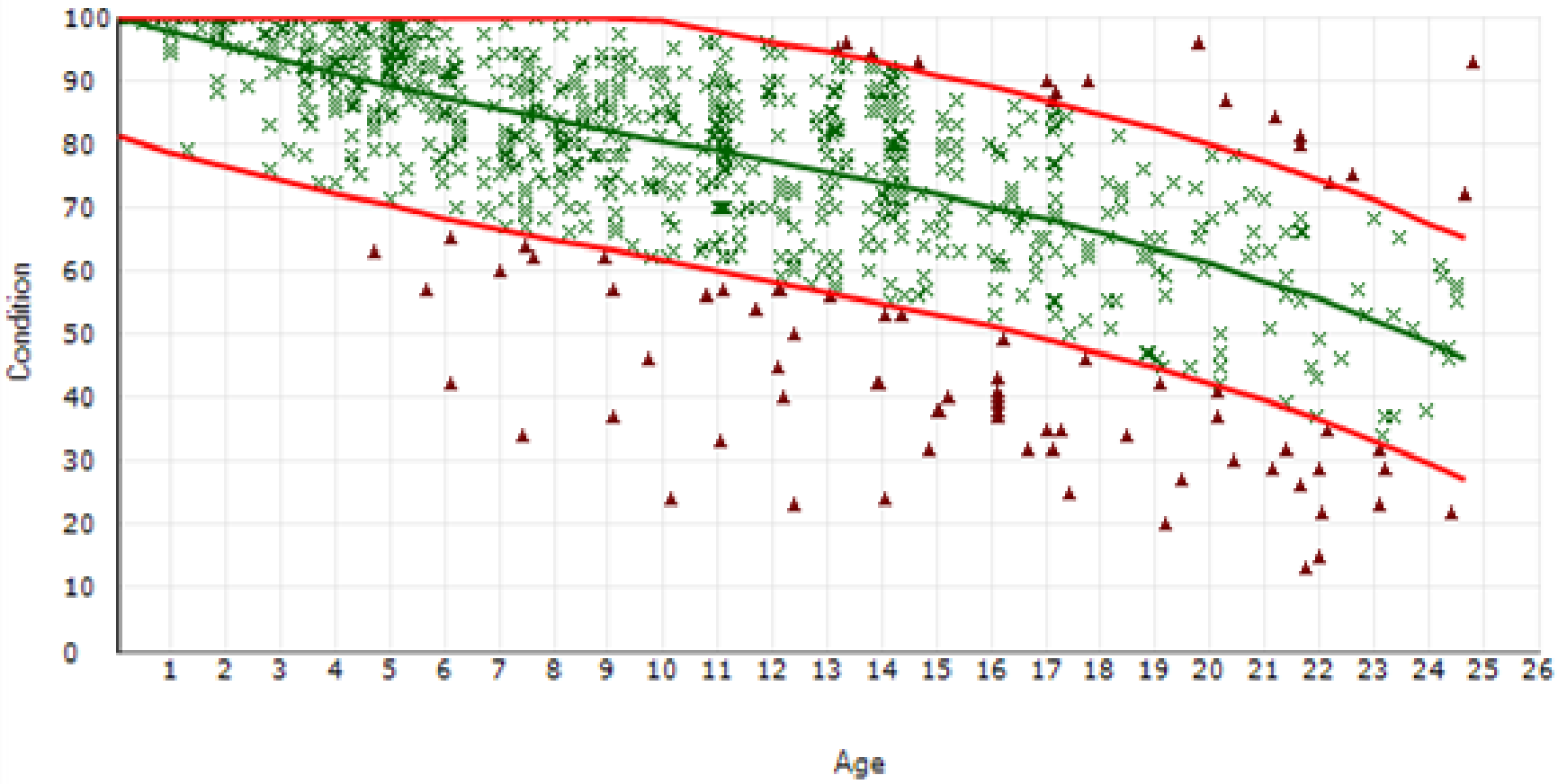


PAVER™ Deterioration Models

Deterioration Rates Modeled in PAVER™

- Examined models with varying number of coefficients
- Models selected based on fit and intermediate deterioration rate trends
- PAVER™ boundary lines are constant distance from best fit line throughout time
- The confidence interval used effects limits of boundary lines
  - 95% confidence interval applied (±1.96 standard deviations)

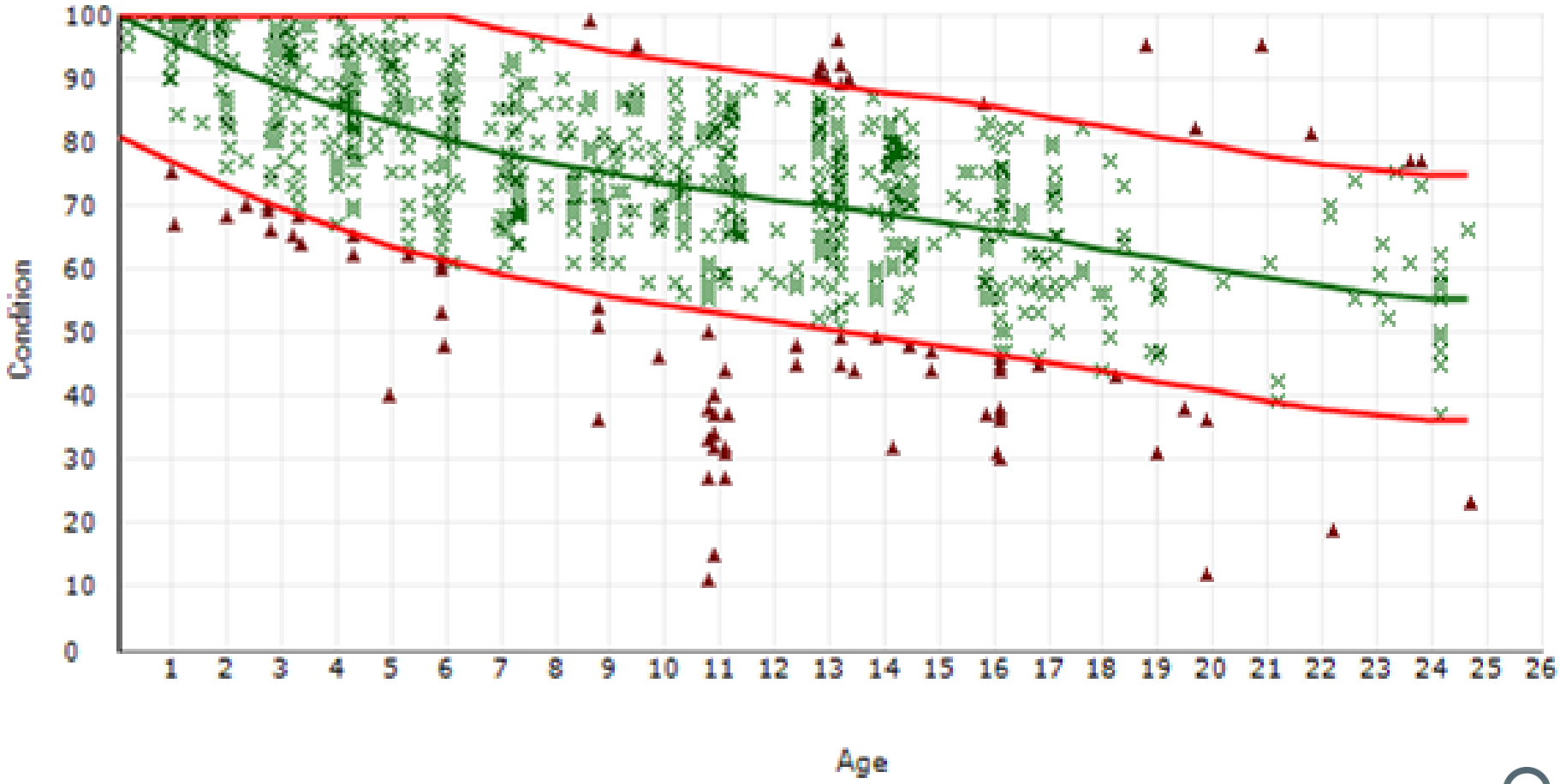
Selected PAVER™ AC Model (25 Years)



PAVER™ AC Model Statistics

- 899 data points used
- Five coefficients, 4th order, best fit line selected
- Annual deterioration rates primarily range from 1.6 to 2.7 PCI points/year
  - Exception in final 4 years where curve is steeper
- Best fit line has PCI of 70 at 16 years
- At year 25, PCI boundary lines at 64 and 26

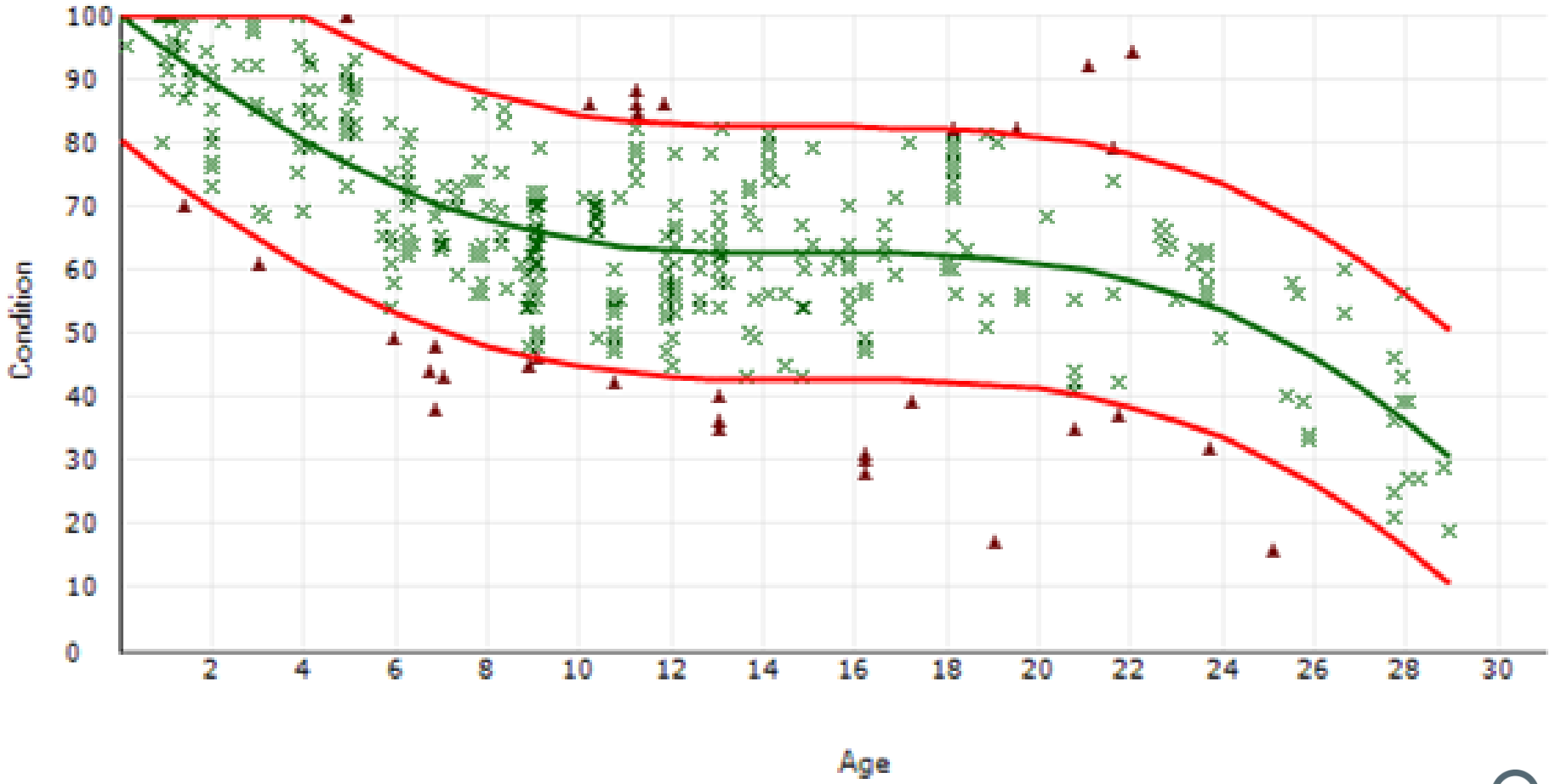
Selected PAVER™ AAC Model (25 Years)



PAVER™ AAC Model Statistics

- 950 data points used
- Six coefficients, 5th order, best fit line selected
- Annual deterioration rates primarily range from 1.1 to 3.4 PCI points/year
  - Exceptions in first 2 years where curve steeper and last 2 years where curve is flatter
- Best fit line has PCI of 70 at 13 years
- At year 25, PCI boundary lines at 75 and 36

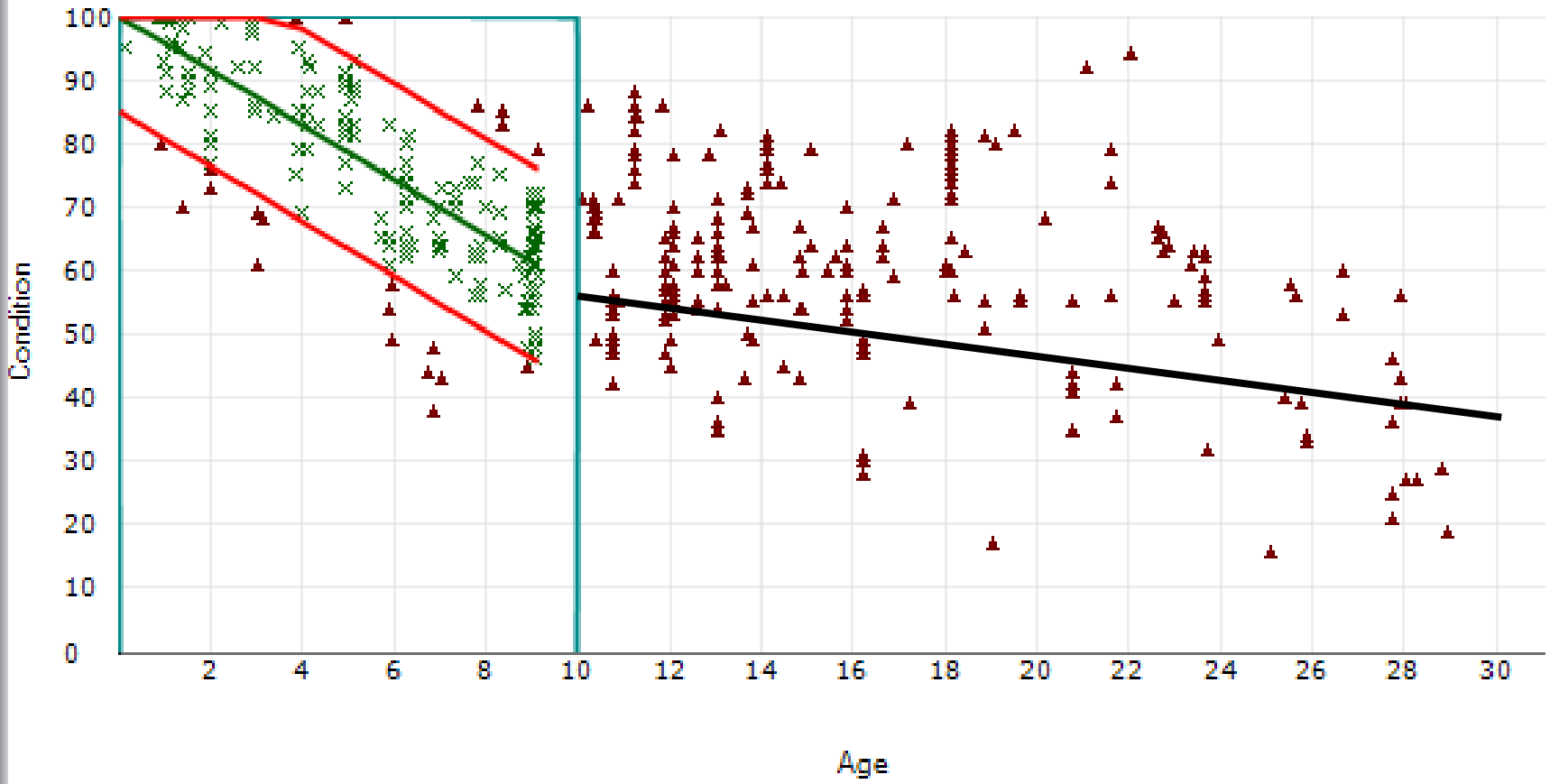
Selected PAVER™ APC Model (30 Years)



PAVER™ APC Model Statistics

- 458 data points used
- Six coefficients, 5th order, best fit line selected
- Annual deterioration rates primarily range from 0.0 to 4.8 PCI points/year
  - Exceptions in first 2 years and last 3 years where curve is steeper
- Best fit line has PCI of 70 at 7 years
- At year 30, PCI boundary lines at 43 and 4

PAVER™ Initial Deterioration APC Model



PAVER™ APC Initial Deterioration

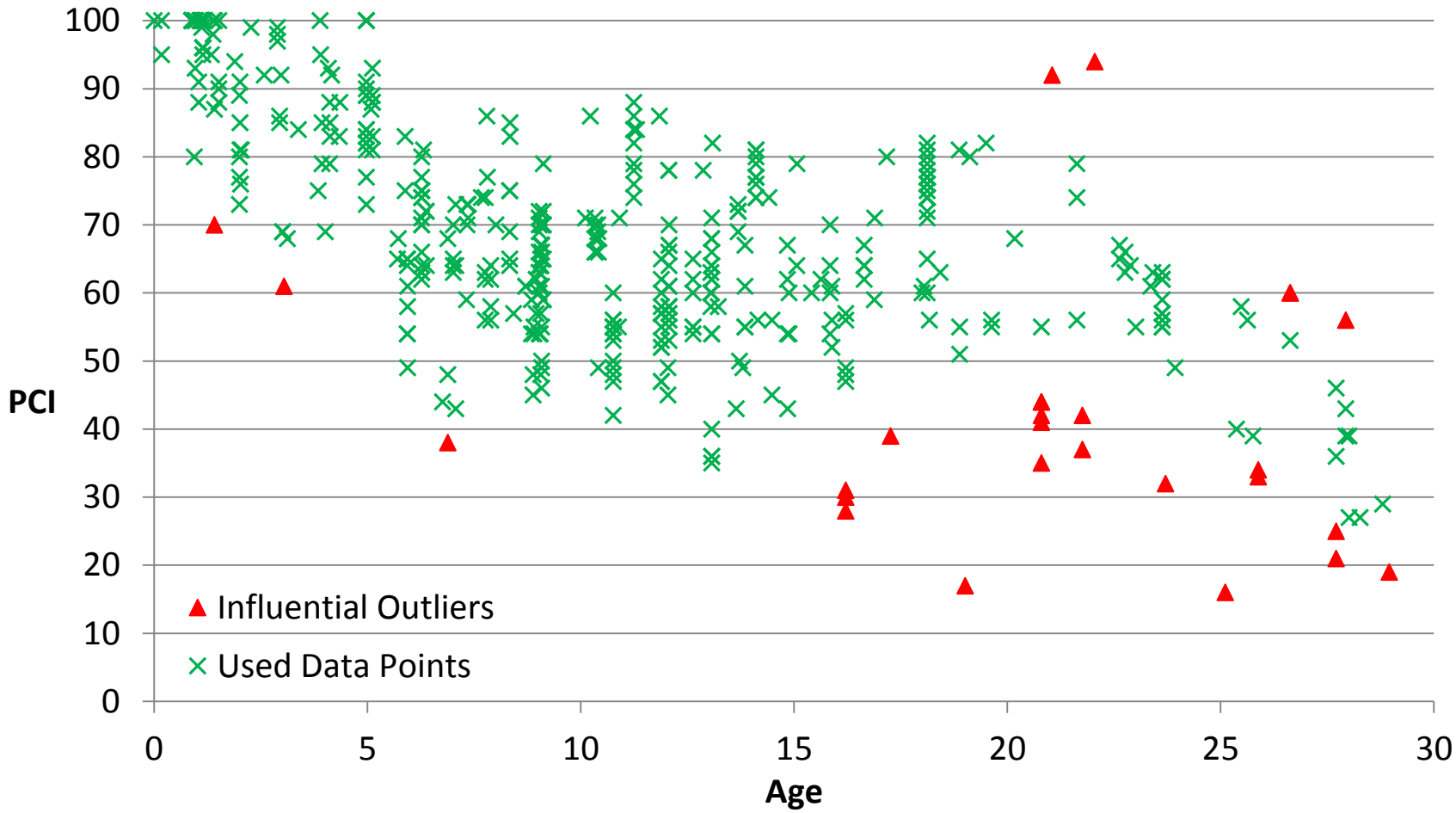
- Only data in first 10 years considered
- Constrained PAVER™ to linear best fit line
- 214 data points used
- Annual deterioration rate is 4.3 PCI points/year
- At year 10, PCI boundary lines at 72 and 42
- After year 10, linear deterioration slows to ~1 PCI point/year

Statistical Models

Statically Modeled Deterioration Rates

- SAS software regression used to model deterioration for each pavement type
- Influential outliers identified and removed using Cook's distance (Cook's D)
  - Cook's distance can quantity the influence of each data point during regression analysis
  - Most influential outliers are located toward right side of graph where data diverge

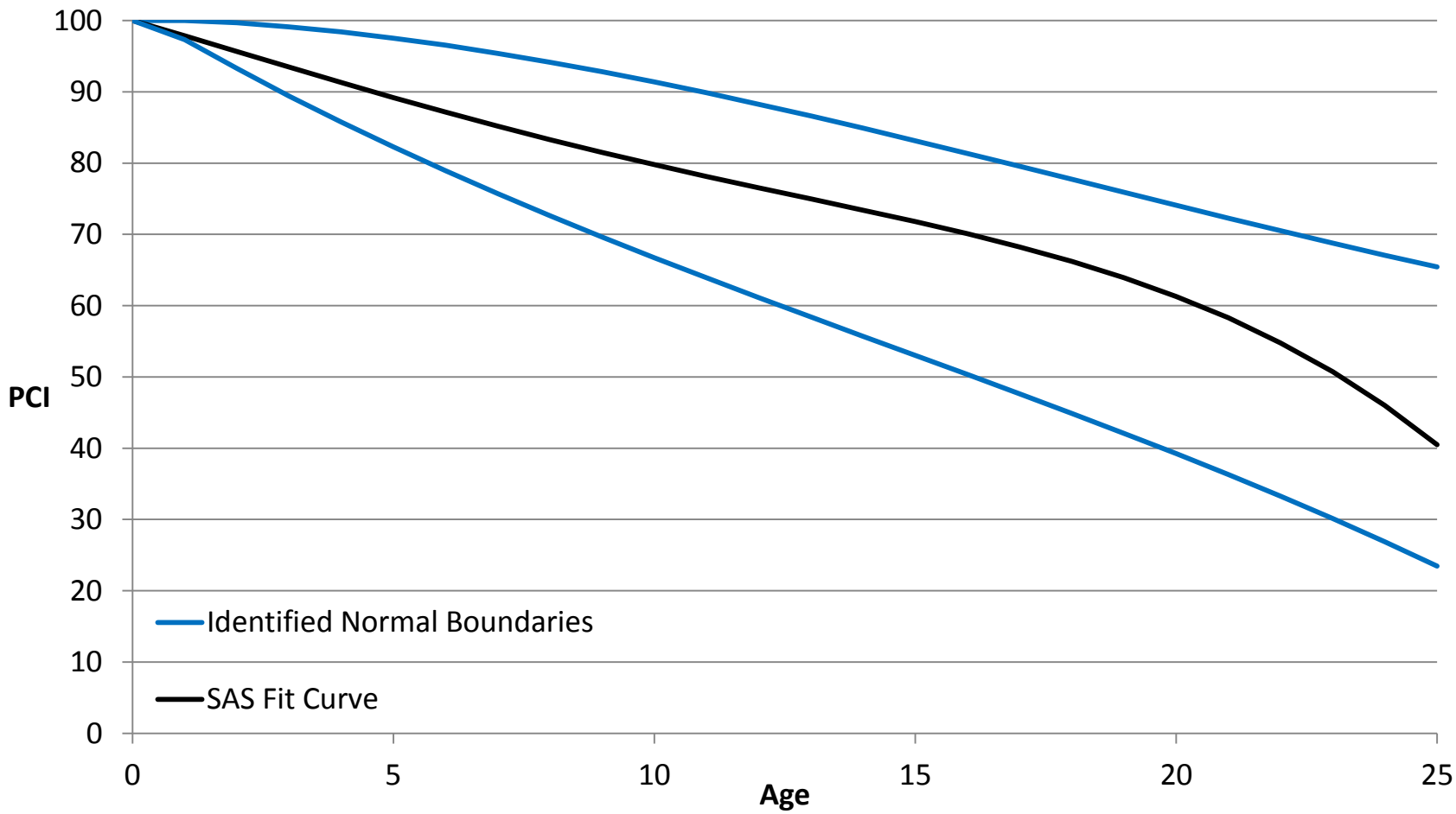
Example of Outliers Removed via Cook's D



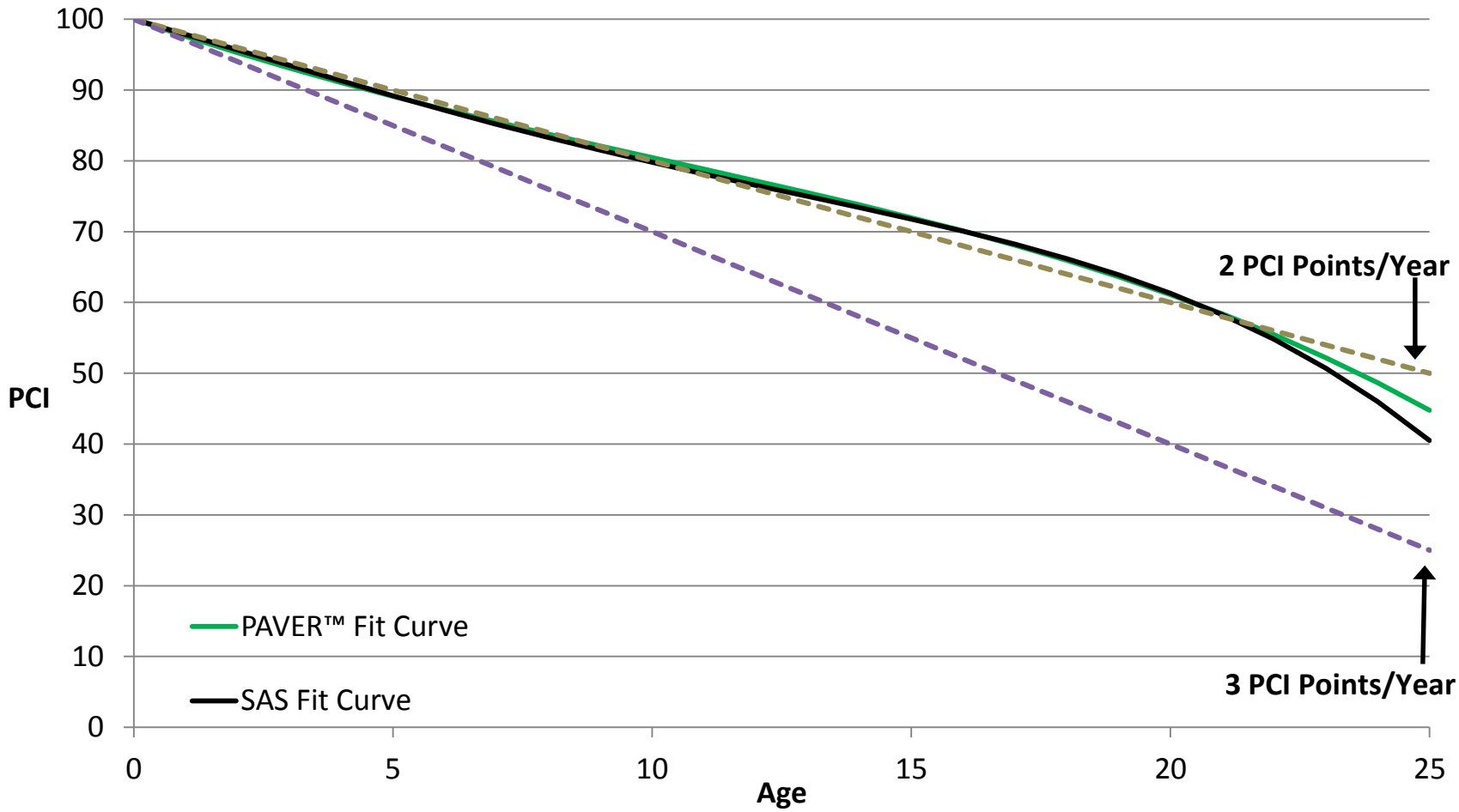
Development of Normal Boundary Lines

- Upper and lower normal boundary limits defined
- Data broken into age groups and percentiles examined
- Middle 2/3 of data points defined as normal
- Trend lines fit through percentiles to smooth curves and define limits by equation

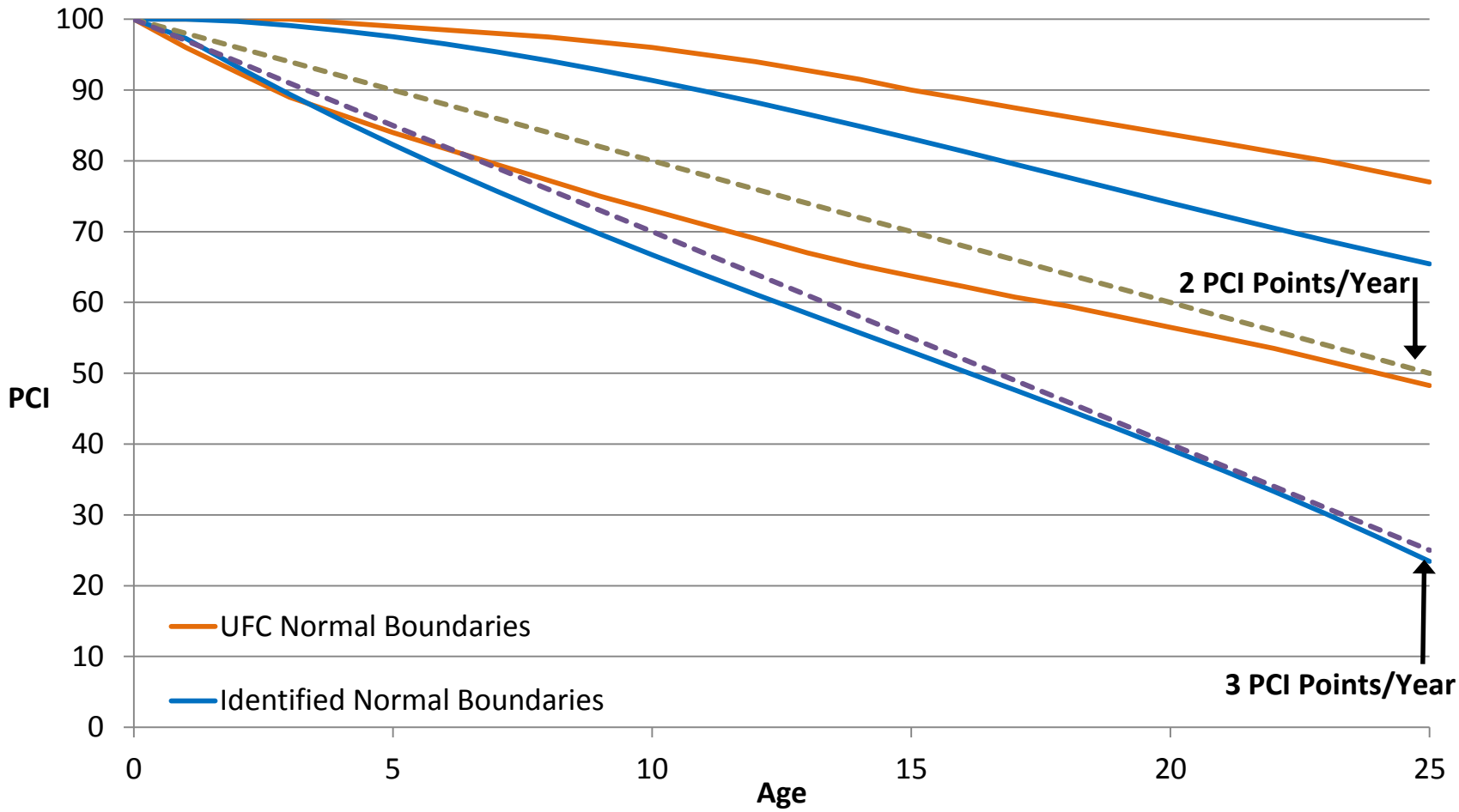
Identified AC Model



Comparison of AC Deterioration Rates



Comparison of AC Normal Ranges



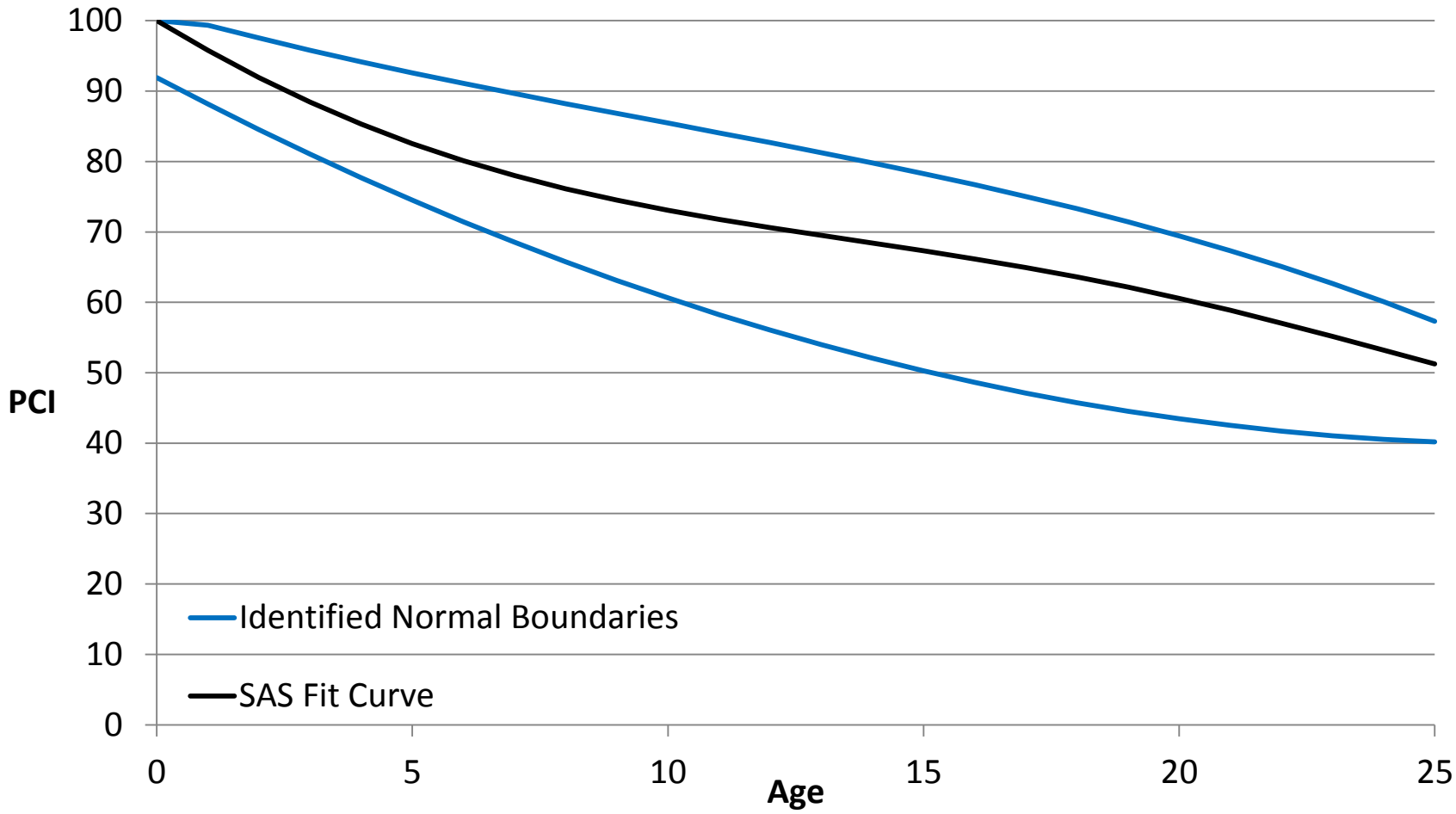
Summary of AC Deterioration Rates

- Average deterioration can be approximated by:
  - 2 PCI points/year for first 21 years
  - 3.5 to 4.5 PCI points/year beyond year 21
- Identified normal boundaries can be approximated by linear deterioration
  - 1.25 PCI points/year for upper boundary
  - 3.1 PCI points/year for lower boundary

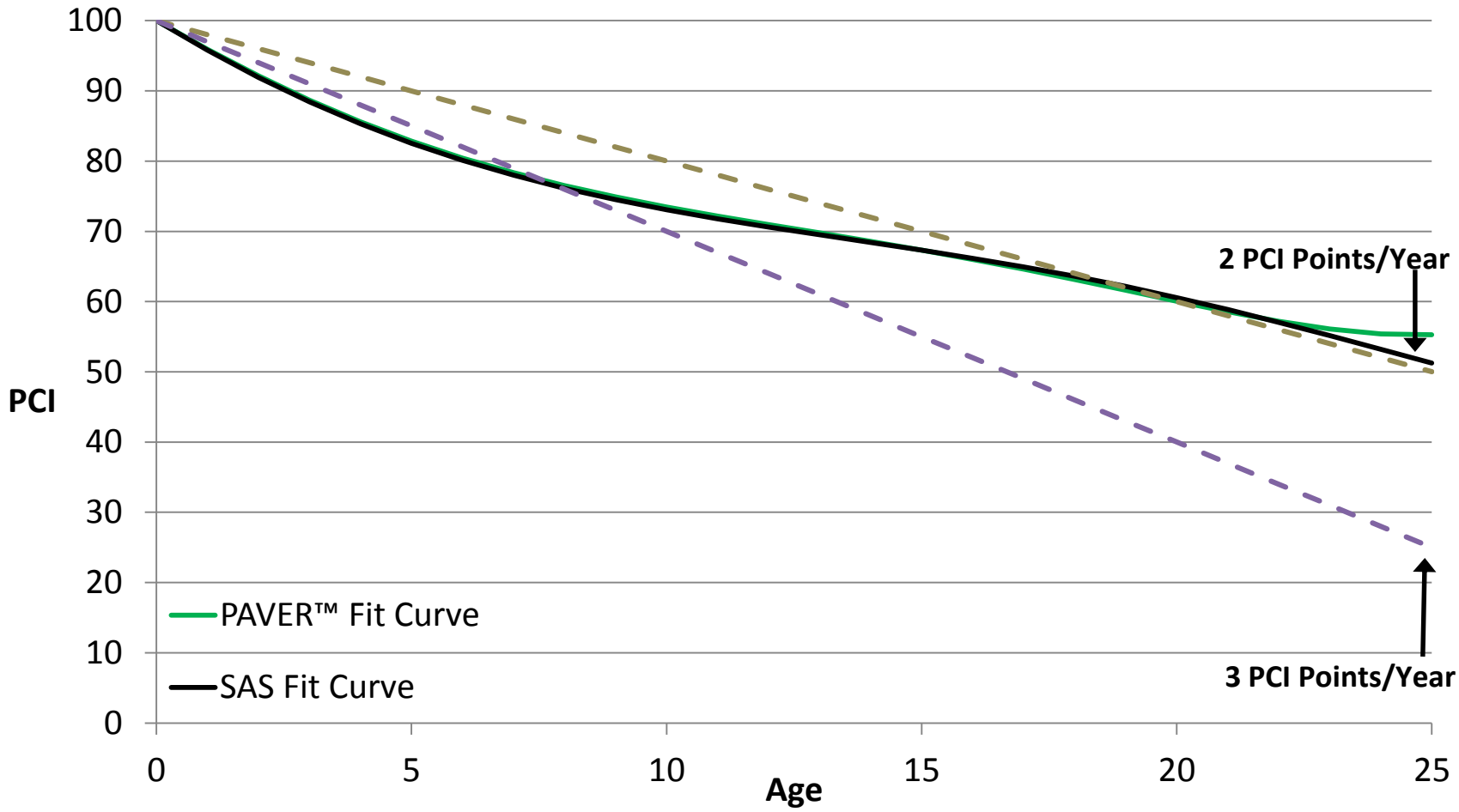
Application to Pavement Management - AC

- Critical PCI of 70 with normal deterioration triggers rehabilitation between 9-22 years
  - Both fit lines reach PCI of 70 at 16 years
  - Rehabilitation at 9 years is not efficient
    - Look at localized maintenance options to extend life
  - Meeting critical PCI should not automatically trigger rehabilitation

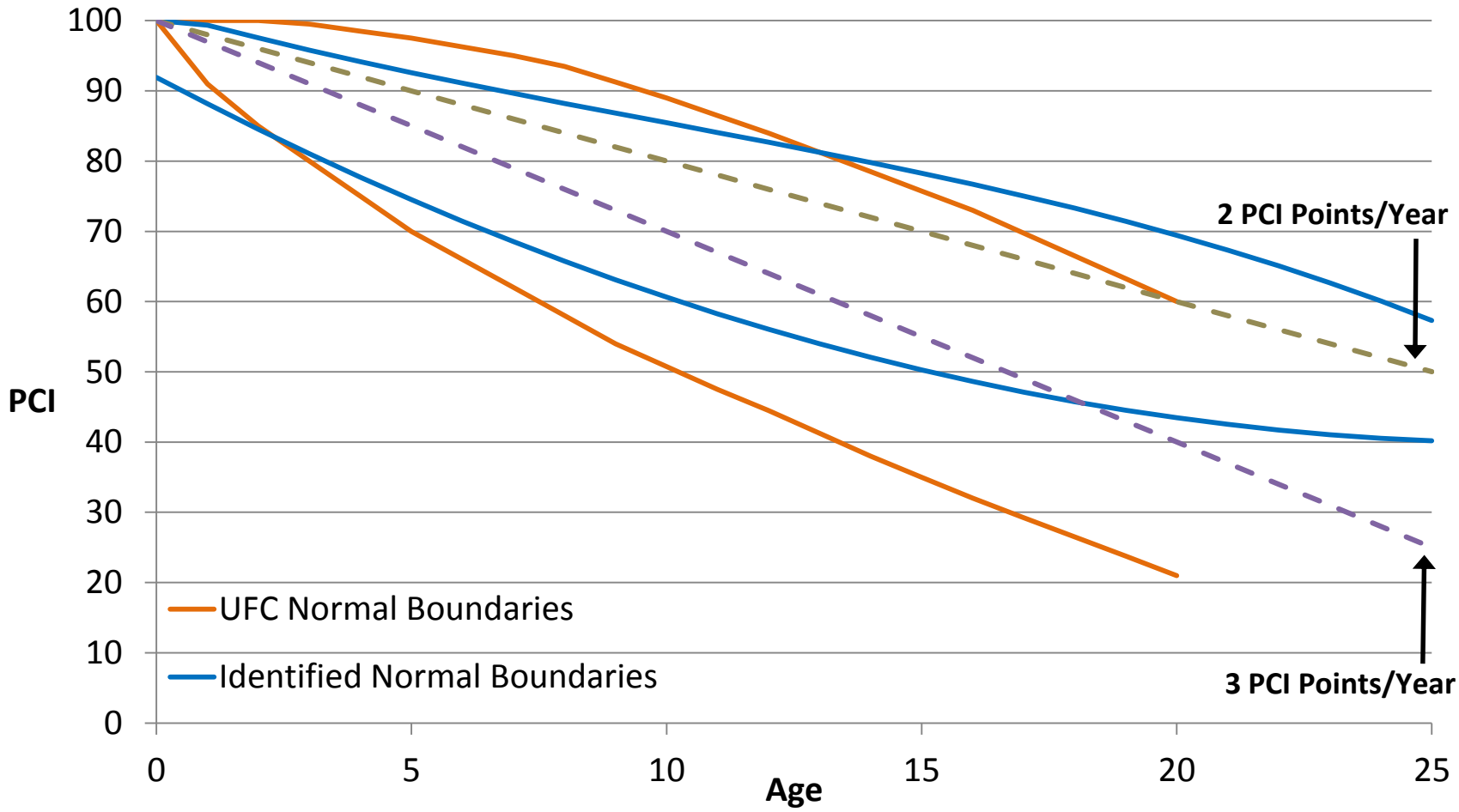
Identified AAC Model



Comparison of AAC Deterioration Rates



Comparison of AAC Normal Ranges



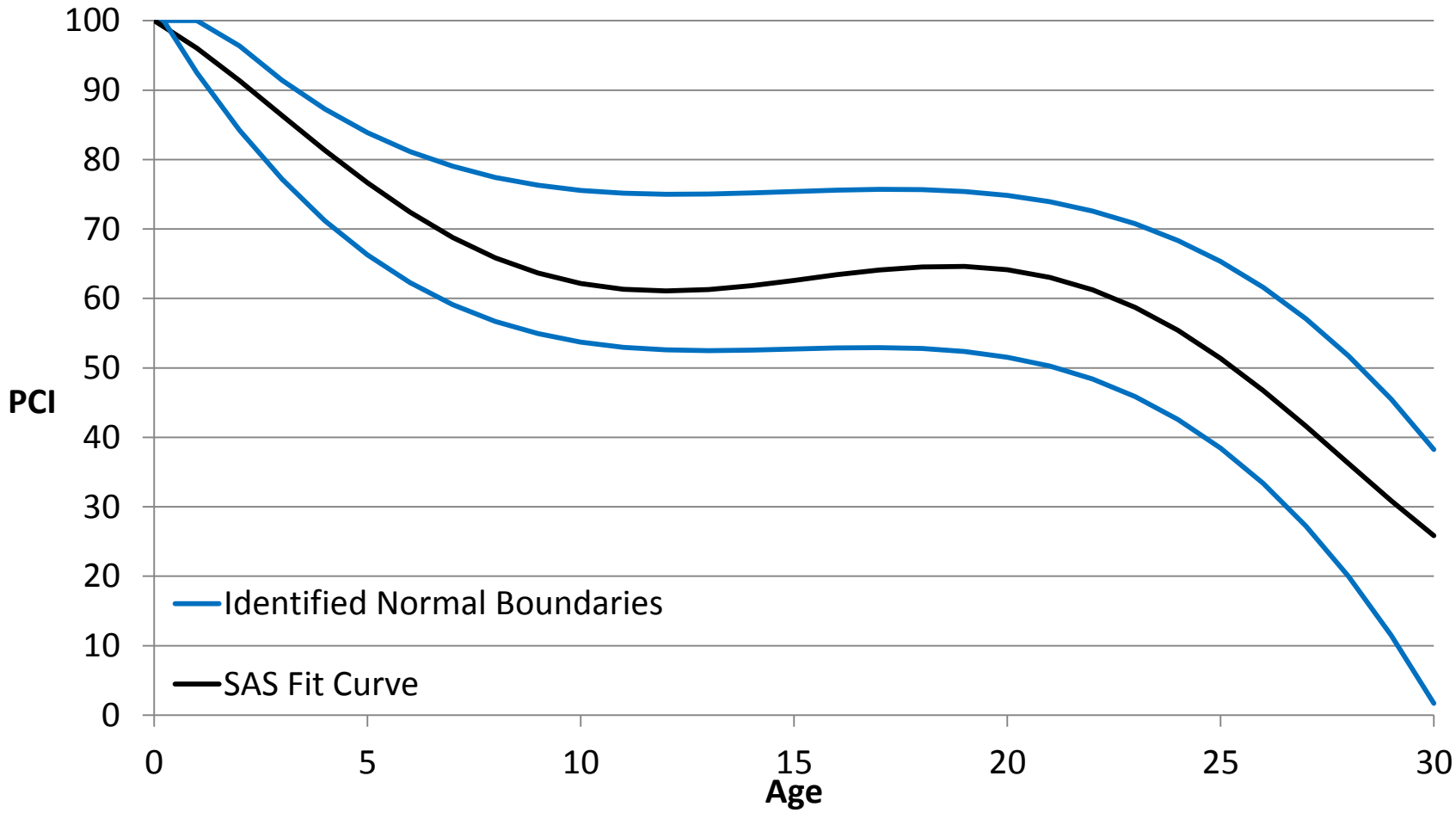
Summary of AAC Deterioration Rates

- Average deterioration can be approximated by:
  - 3 PCI points/year for first 8 years
  - 1.5 PCI points/year for next 17 years
- Identified upper normal boundary can be approximated by linear deterioration
  - 1.6 PCI points/year
- Identified lower normal boundary not captured by linear approximation

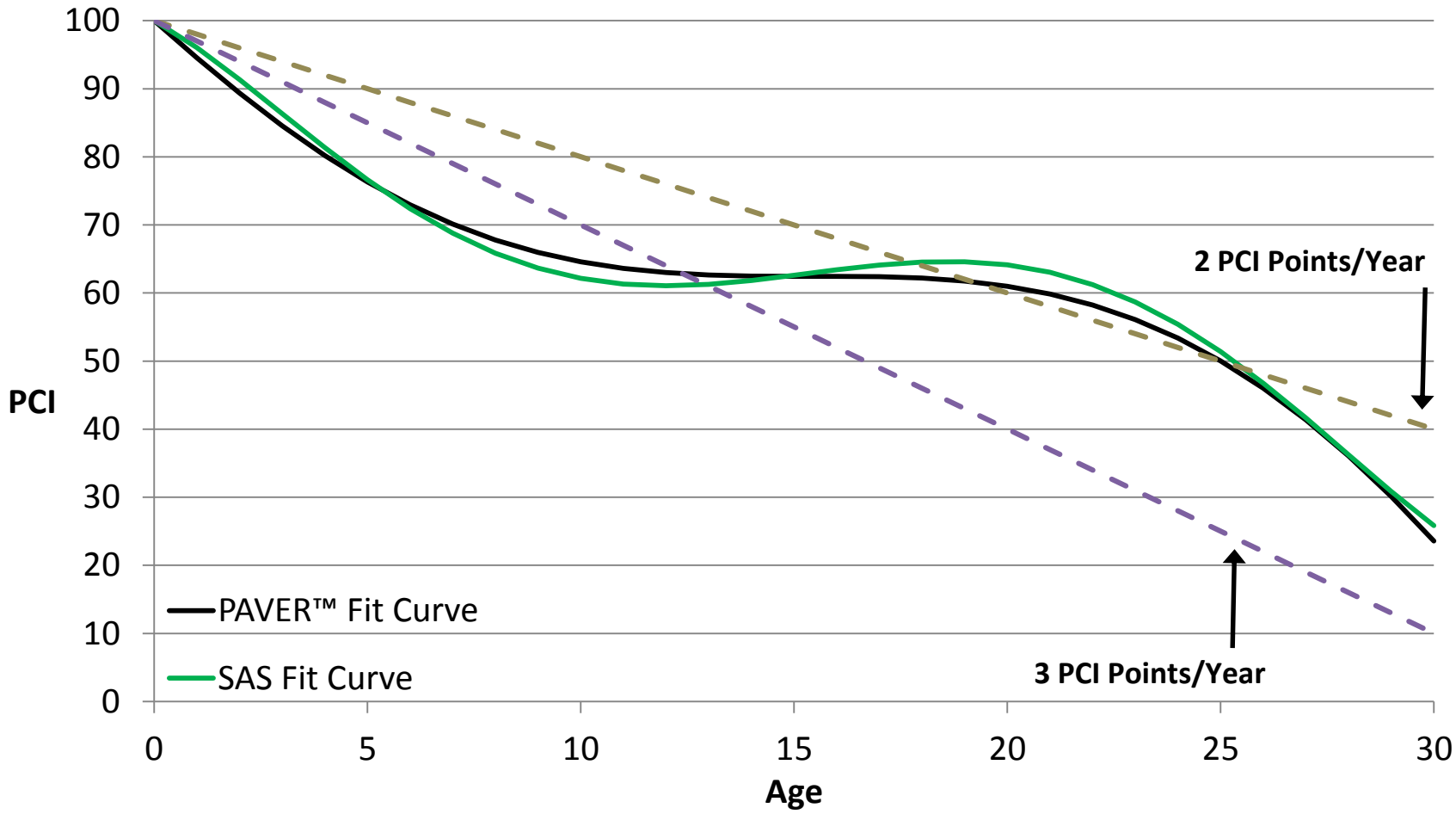
Application to Pavement Management - AAC

- Expect moderate initial decrease after overlay
  - Caused by underlying distresses
- Critical PCI of 70 with normal deterioration triggers rehabilitation between 7-20 years
  - Both fit lines reach PCI of 70 at 12 years
  - Rehabilitation at 7 years is not efficient
    - Look at localized maintenance options to extend life
  - Meeting critical PCI should not automatically trigger rehabilitation

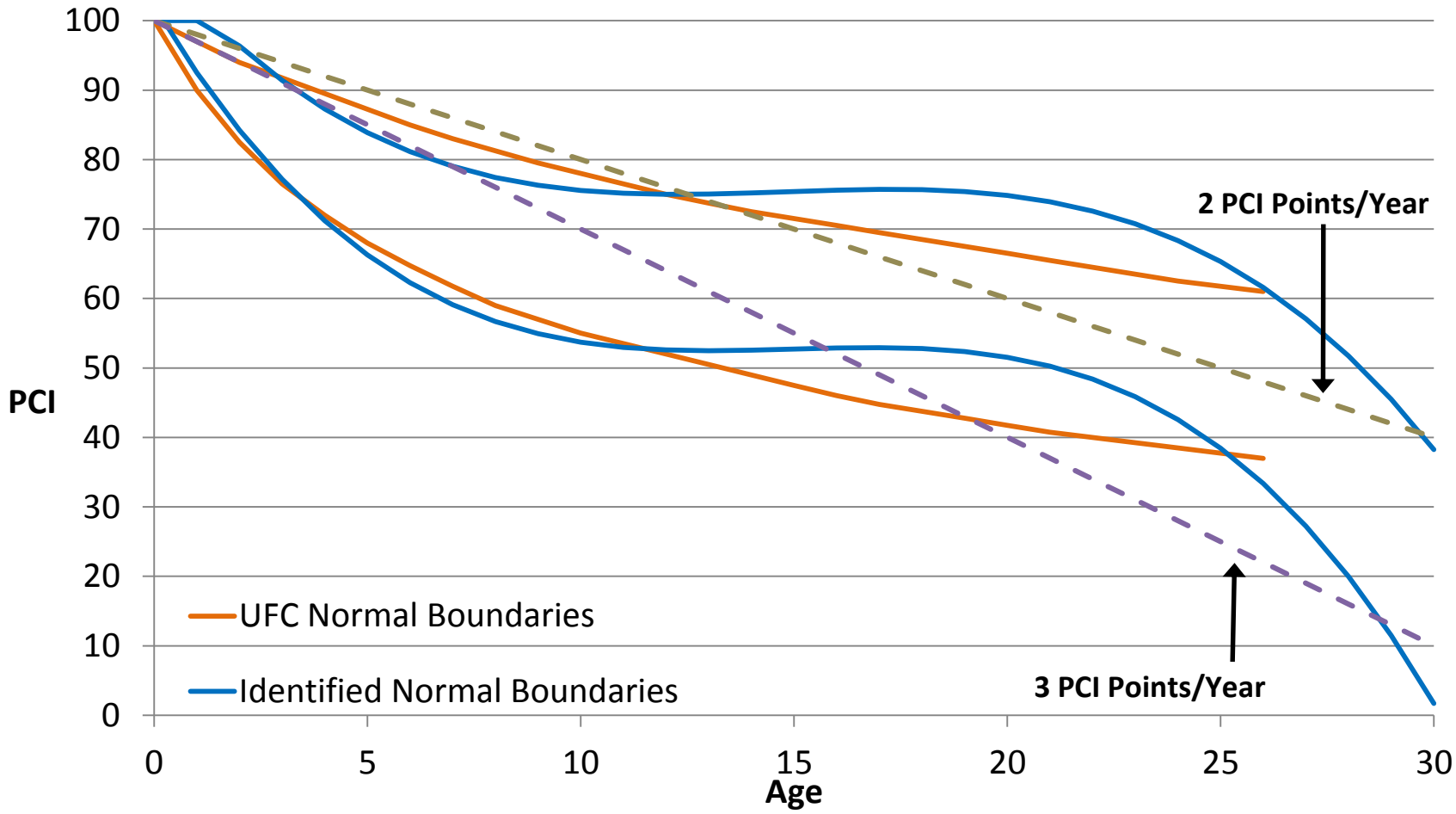
Identified APC Model



Comparison of APC Deterioration Rates



Comparison of APC Normal Ranges



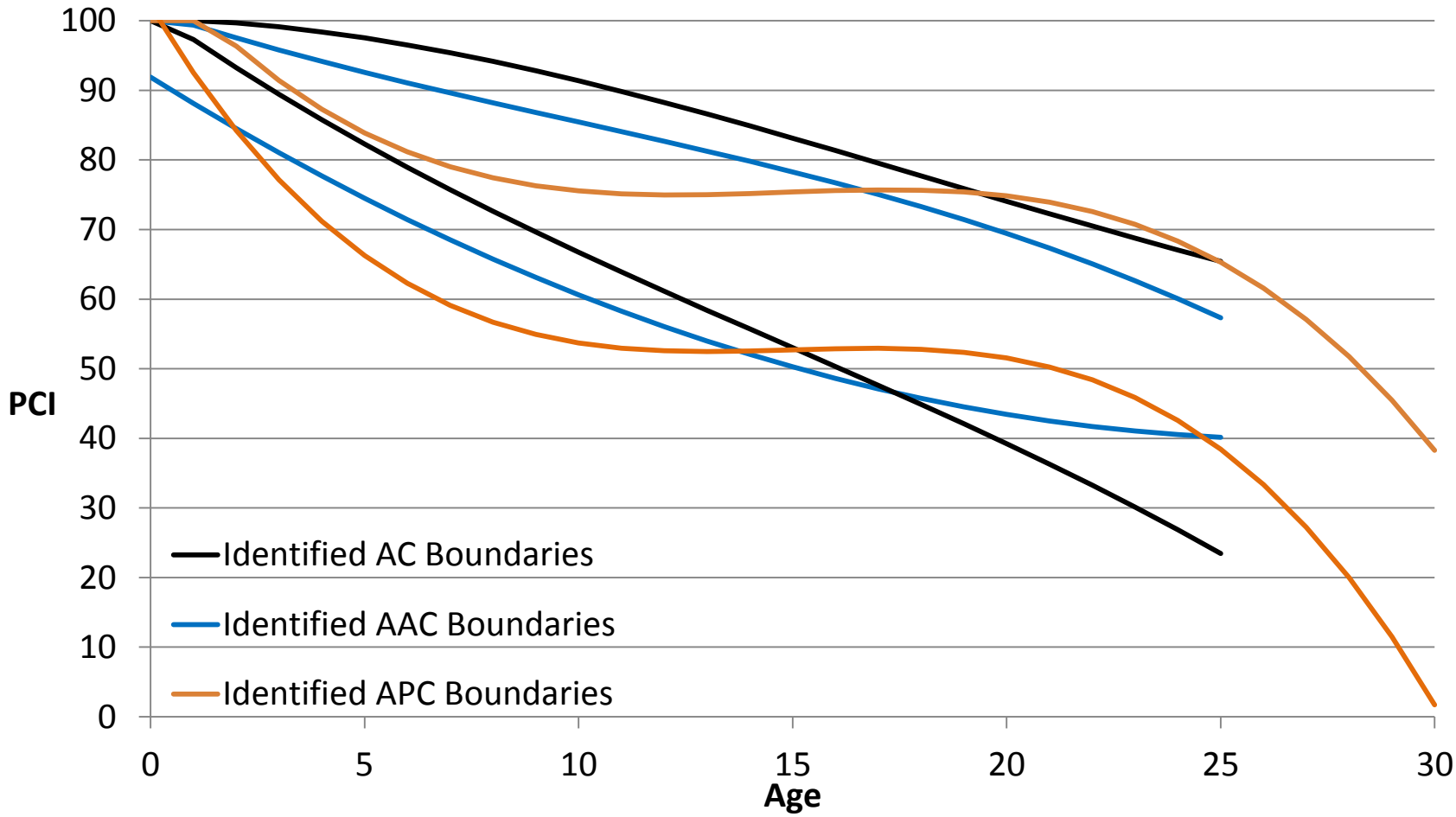
Summary of APC Deterioration Rates

- Three stages of deterioration
  - Steep initial drop in years 0-10
  - Stabilization in years 10-20
  - Continued deterioration in years 20-30
- Linear deterioration model does not capture behavior of pavement

Application to Pavement Management - APC

- Expect large initial decrease after overlay
  - Caused by underlying distresses and joints
- Proper maintenance after initial decrease can stabilize and extend life of pavement

Comparison of Identified Normal Ranges



Conclusions

- AC
  - Identified normal boundaries have higher deterioration rates than UFC boundaries
  - Average deterioration rate and identified normal boundaries can be approximated linearly
- AAC
  - Identified normal boundaries have lower deterioration rates than UFC boundaries
  - Identified normal boundaries generally have slightly higher deterioration rate than AC boundaries

Conclusions

- APC
  - Historic UFC normal boundary does not capture observed pavement life cycle
  - Expect large initial decrease after overlay
  - Proper maintenance after initial decrease can stabilize and extend life of pavement
  - For typical sections, rehabilitation will be required after 25 years

Conclusions

- Look at localized maintenance options to extend life
- Meeting critical PCI should not automatically trigger rehabilitation
- Ensure adequate pavement structure during design phase

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