Implementation Project 5-6386-1

Proposed JCP Performance Prediction Models for PMIS

Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

JCP Distresses in PMIS

Overview

JCP Distress Type	PMIS Rating	Computing L Value
Failed Joints and Cracks	total number (0 to 999)	L = percent of joints and cracks that are failed (see equation below this table)
Failures	total number (0 to 999)	L = number per mile (see equation below this table)
Shattered (Failed) Slabs	total number (0 to 999)	L = percent of slabs that are failed (see equation below this table)
Slabs With Longitudinal Cracks	total number (0 to 999)	L = percent of slabs that have longitudinal cracks (see equation below this table)
Concrete Patches	total number (0 to 999)	L = number per mile (see equation below this table)
Apparent Joint Spacing	spacing (15 to 75), to the nearest foot (0.1 m)	none

Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Methodology
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Original Models

$$L_i = \alpha e^{-\left(\frac{\chi\varepsilon\sigma\rho}{age_i}\right)^{\beta}}$$

σ=Subgrade factor=1

α,β,ρ control curve shape

χ=Traffic factor
ε=Climatic factor

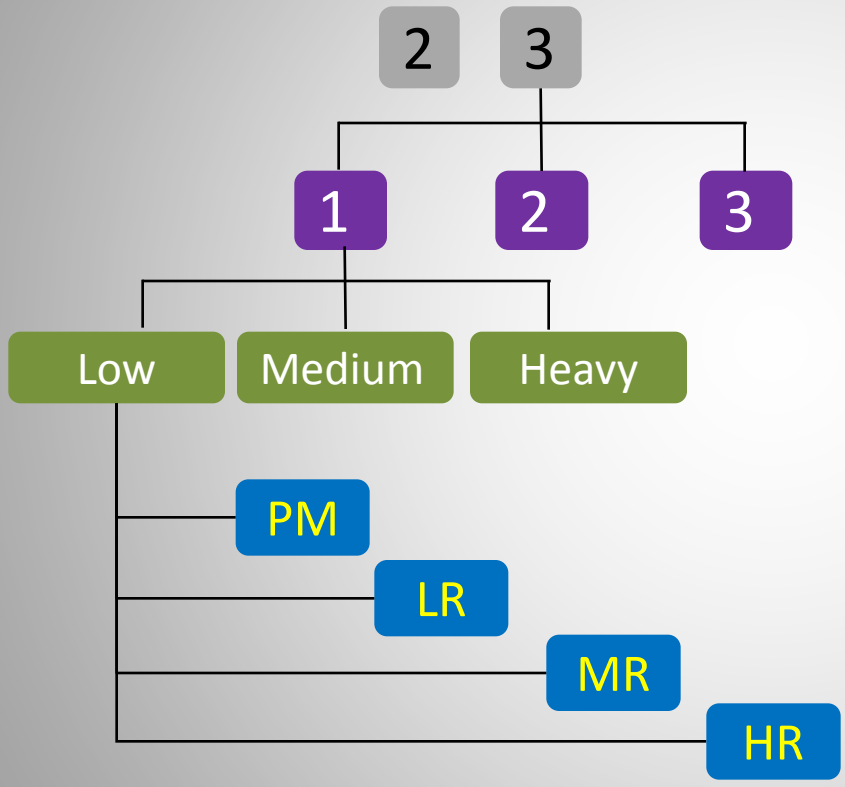
Detail Pavement Typ	Distress	Distress Description	alph	beta	rho	chi ma	chi bet	chi rh	chi mi	epsilc
02	D00	Ride	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
02	D01	Failed Joints and Cracks	0.5298	1.0000	21.4000	1.0000	1.0000	1.0000	1.0000	1.0000
02	D02	Failures	1.4555	1.0000	22.1500	1.0000	1.0000	1.0000	1.0000	1.0000
02	D03	Shattered Slabs	1.1710	1.0000	16.3100	1.0000	1.0000	1.0000	1.0000	1.0000
02	D04	Slabs with Longitudinal Cracks	1.0058	1.0000	47.8000	1.0000	1.0000	1.0000	1.0000	1.0000
02	D05	Concrete Patches	1.0670	1.0000	24.2400	1.0000	1.0000	1.0000	1.0000	1.0000
02	D06	Apparent Joint Spacing	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000
03	D00	Ride	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
03	D01	Failed Joints and Cracks	0.5298	1.0000	21.4000	1.0000	1.0000	1.0000	1.0000	1.0000
03	D02	Failures	1.4555	1.0000	22.1500	1.0000	1.0000	1.0000	1.0000	1.0000
03	D03	Shattered Slabs	1.1710	1.0000	16.3100	1.0000	1.0000	1.0000	1.0000	1.0000
03	D04	Slabs with Longitudinal Cracks	1.0058	1.0000	47.8000	1.0000	1.0000	1.0000	1.0000	1.0000
03	D05	Concrete Patches	1.0670	1.0000	24.2400	1.0000	1.0000	1.0000	1.0000	1.0000
03	D06	Apparent Joint Spacing	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Texas Department of Transportation

UTSA THE UNIVERSITY OF TEXAS AT SAN ANTONIO

Recalibration Objectives $L_i = \alpha e^{-\left(\frac{\rho}{age_i}\right)^{\beta}}$

For 5 JCP distresses and ride score, find {α,β,ρ} for:



2 JCP types

3 climatic zones

3 traffic levels

4 treatments:

PM=preventive maintenance

LR=light rehabilitation

MR=medium rehabilitation

HR=heavy rehabilitation

TOTAL: 72 combinations

Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Available Data

30,831 records (1993-2010)
Dallas: 11,578
Houston: 10,754
Childress: 713
Beaumont: 7,786

Real age available for 2,750 records

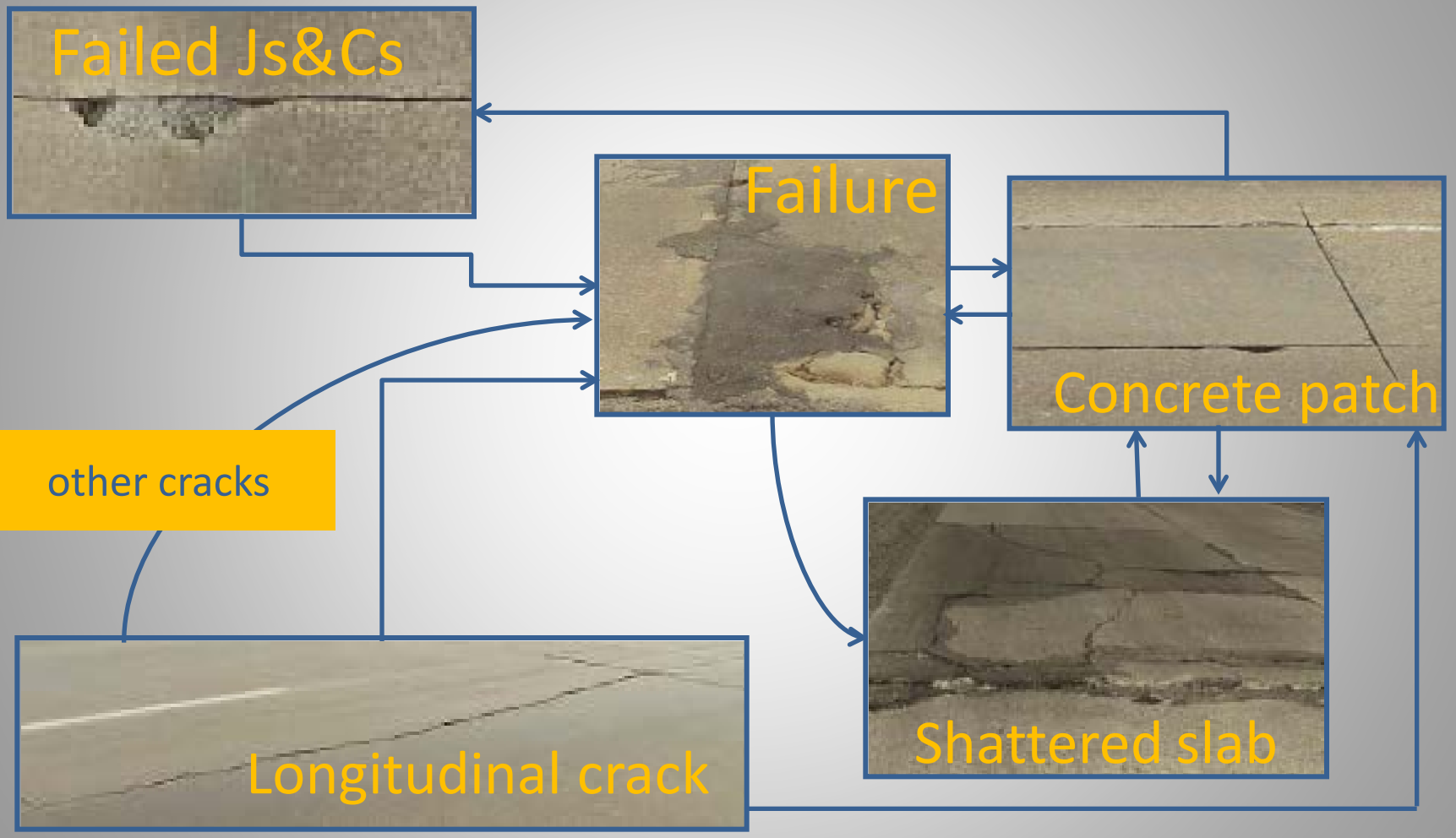
Classified into categories and utilized: 29,627 records

Estimated age

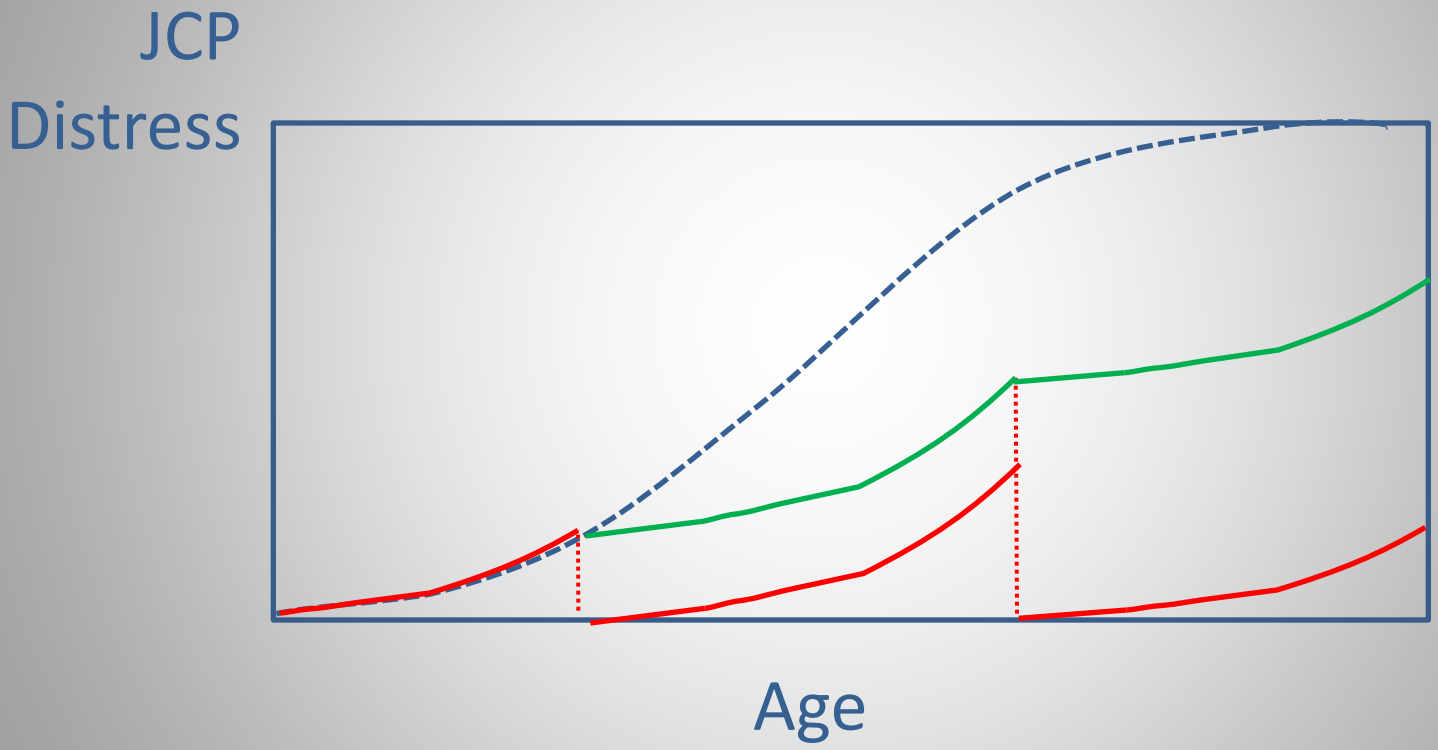
Data Treatment Objectives

- Minimize the influence of JCP distresses decreasing due to:
  - Maintenance policies and/or
  - Distress progression
- Estimate JCP age (not available in PMIS)
- Estimate JCP treatments (not available in PMIS)
- Determine significant modeling factors, grouping where applicable

JCP Distress Progression



Effect of Maintenance and Distress Progression



Presentation Outline

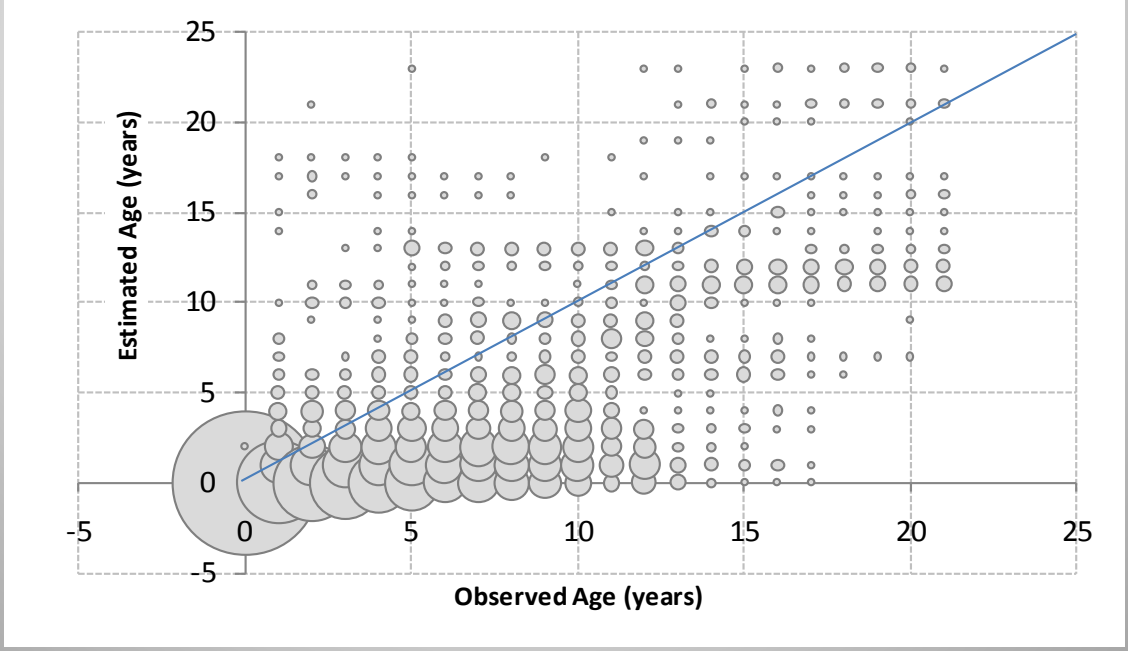
- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Estimated Age

Best estimate based on 2,750 real ages

R^2=56%, all coefficients' P-values < 0.0001

$$Age = 0.75804FJC_{adj} + 0.10209P_{adj} + 0.36015FL_{adj} - 0.00782FJC_{adj}^2 - 0.000748P_{adj}^2 - 0.00349FL_{adj}^2$$



Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

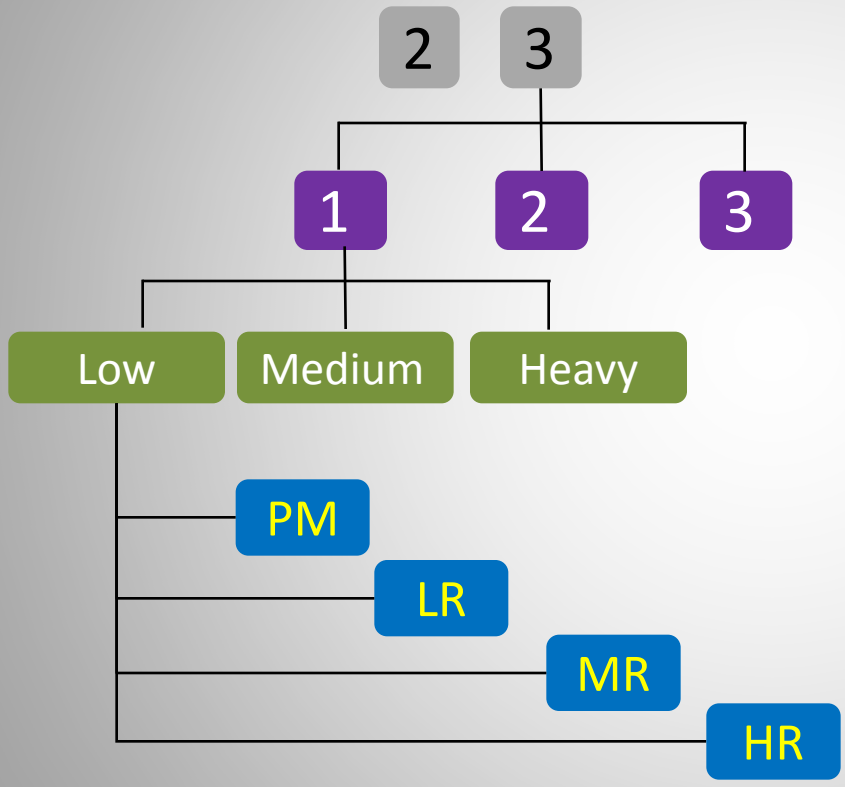
Estimated Treatments

M&R Category	Criteria and Assumptions	Historical Data Records
HR	New pavements (known age) HR treatment year and age=0 if: • No distresses; • Condition Score =100; • Presence of serious distresses in year preceding treatment.	2,750 5,070
MR	MR= flexible overlay	N/A
LR	Average Distress Score >1st Quartile, no Meeting no HR assumptions.	10,020
PM	Average Distress Score <1st Quartile	11,787
TOTAL		29,627

Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Significant Modeling Factors



2 JCP types→ non-significant

3 climatic zones→ non-significant for HR

3 traffic levels

4 treatments:

PM=preventive maintenance

LR=light rehabilitation

MR=medium rehabilitation

HR=heavy rehabilitation

TOTAL: 20 significant combinations

20 Modeling Groups

JCP 2=3		*Heavy Traffic*	*Medium Traffic*	*Low Traffic*	*Total by Treatment*
PM	Zone 1	364	2,102	1,735	*11,787*
	Zone 2	1,566	2,633	2,818	
	Zone 3	40	25	504	
LR	Zone 1	731	1,079	1,249	*10,020*
	Zone 2	2,214	2,127	2,513	
	Zone 3	81	0	26	
HR	All	3,269	2,316	2,235	*7,820*
Total by Traffic Level		*8,265*	*10,282*	*11,080*	29,627

Texas Department of Transportation

UTSA THE UNIVERSITY OF TEXAS AT SAN ANTONIO

Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

For Each Distress Type:

1. Test statistical significance of modeling factors, group when non-significant
2. Examine the data for adherence to the logical order of performance:
   HR > LR > PM
   Low traffic > medium traffic > heavy traffic
3. Examine statistical summaries and bubble plots of the data to determine seed values and boundaries for the model coefficients
4. Fit the HR model for the traffic level that best adheres to the data
5. Constrain the remaining HR model coefficients, fit the models and calculate the percent RMSE change with respect to the original model
6. Constrain the LR model coefficients, repeat steps 1 to 5
7. Repeat for PM

Procedure: SAS proc nlin. If no convergence, fit based on RMSE reduction.

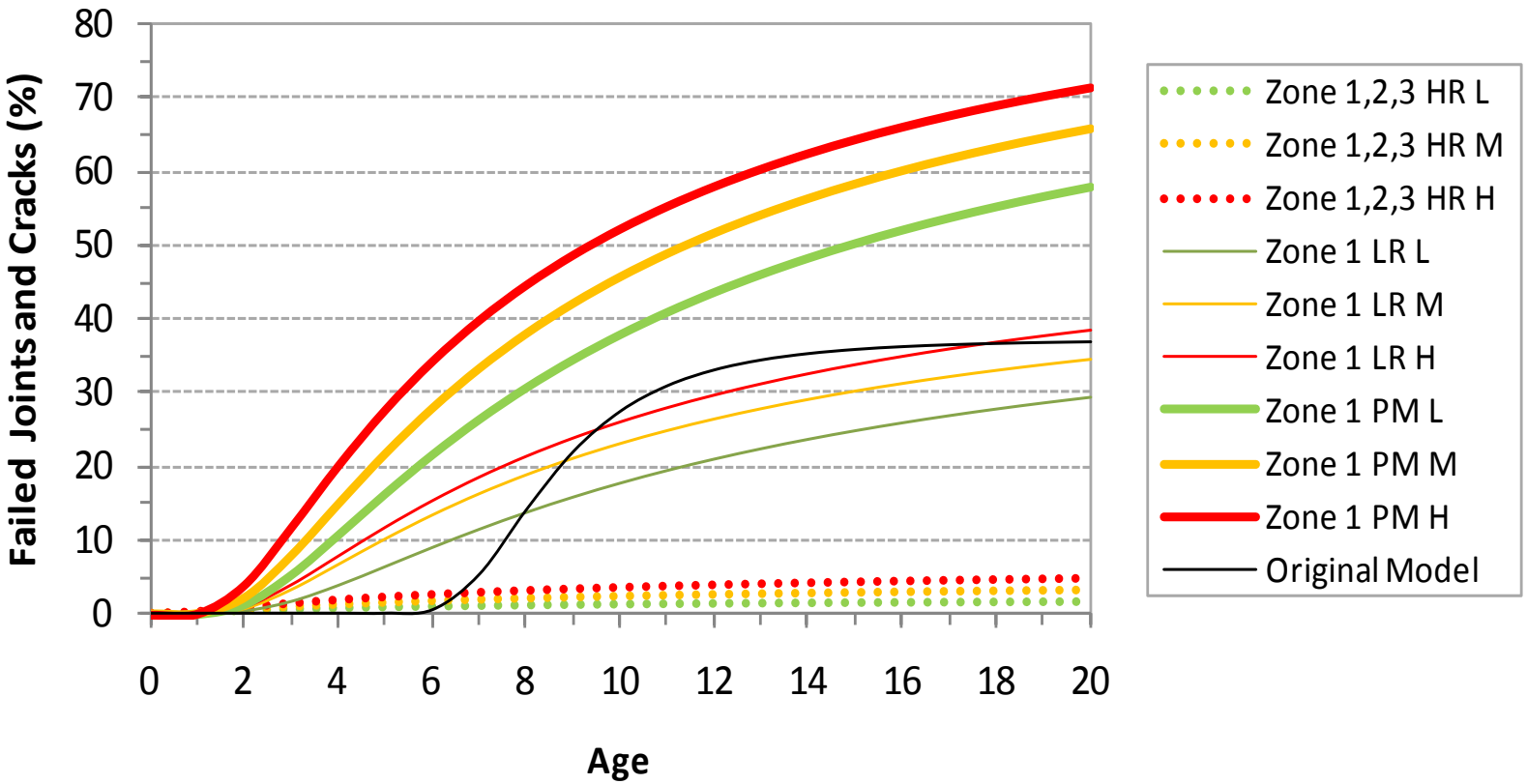
Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

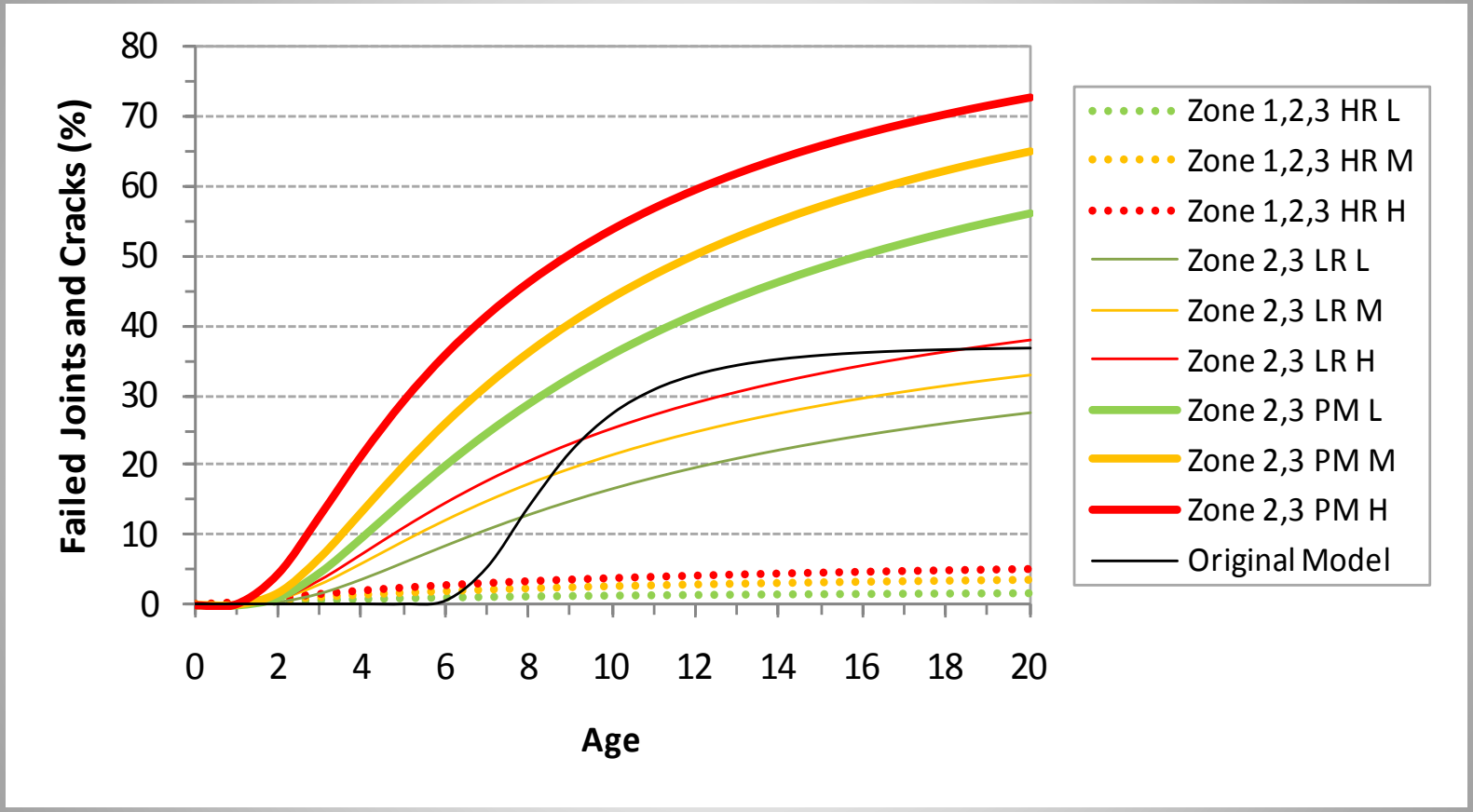
Failed Joints and Cracks

			Low	Med.	Heavy
HR	Zone 1,2,3	Data points	2,234	2,316	3,269
		% RMSE change	-33.6%	-23.2%	-56.2%
LR	Zone 1	Data points	1,249	1,079	731
		% RMSE change	-29.5%	-9.8%	-2.8%
	Zone 2,3	Data points	2,513	2,127	2,214
		% RMSE change	-36.4%	-15.0%	-0.3%
PM	Zone 1	Data points	1,735	2,102	364
		% RMSE change	-5.2%	-9.4%	-5.8%
	Zone 2,3	Data points	2,818	2,633	1,566
		% RMSE change	-9.7%	-9.0%	-18.9%

Failed Joints and Cracks Zone 1



Failed Joints and Cracks Zones 2 & 3



Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

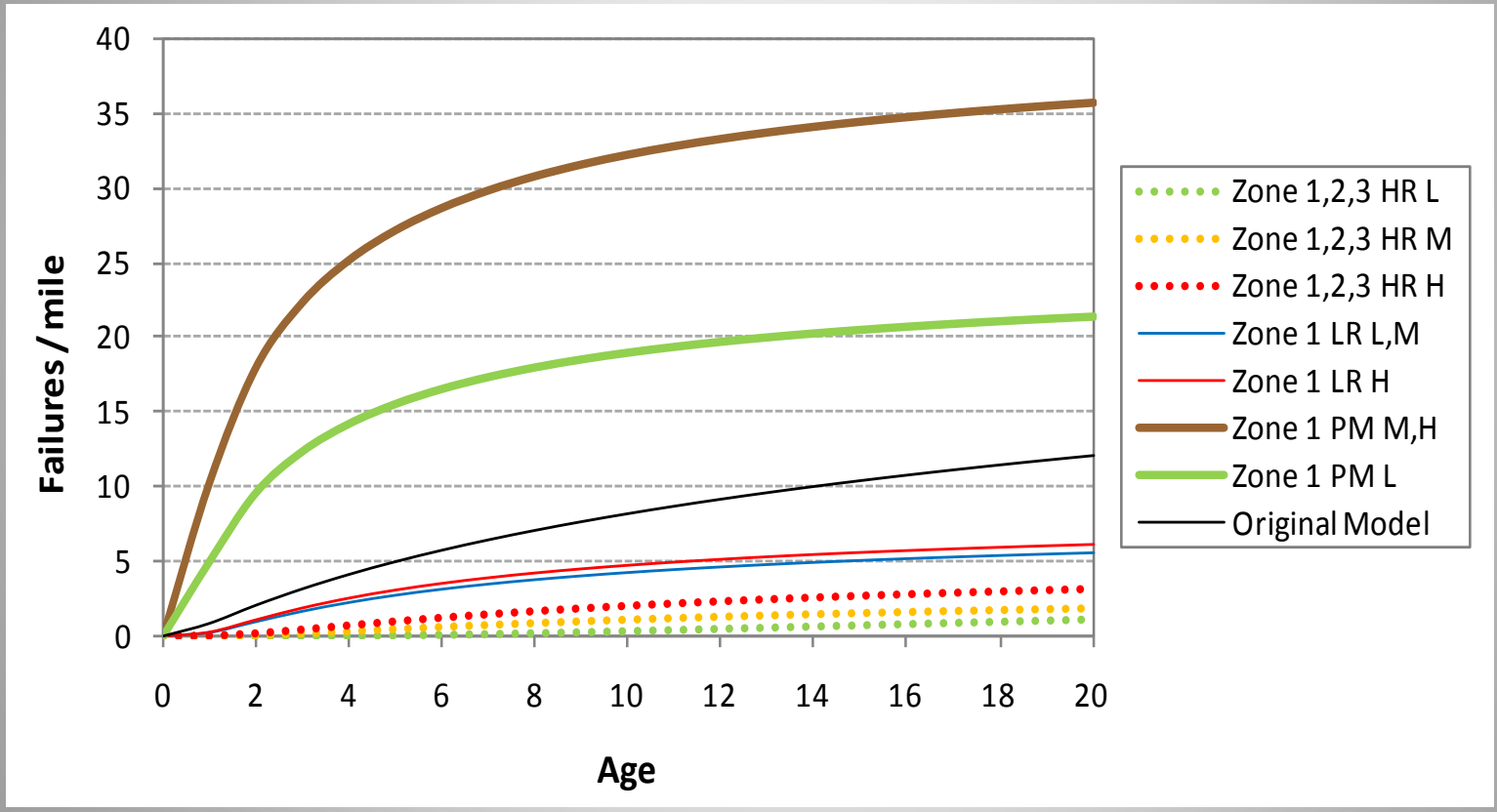
Failures

			Low	Med.	Heavy
HR	Zone 1,2,3	Data points	2,234	2,316	3,269
		% RMSE change	6.3%	-2.8%	-5.3%
LR	Zone 1	Data points	2,328		731
		% RMSE change	-14.5%		2.7%
	Zone 2	Data points	2,513	2,127	2,214
		% RMSE change	-5.2%	-6.5%	-9.0%
	Zone 3	Data points	107		
		% RMSE change	-4.9%		
PM	Zone 1	Data points	1,735	2,466	
		% RMSE change	-31.0%	-30.2%	
	Zone 2	Data points	2,818	2,633	1,566
		% RMSE change	-25.6%	-24.9%	-31.1%
	Zone 3	Data points	529		40
		% RMSE change	-11.7%		-17.7%

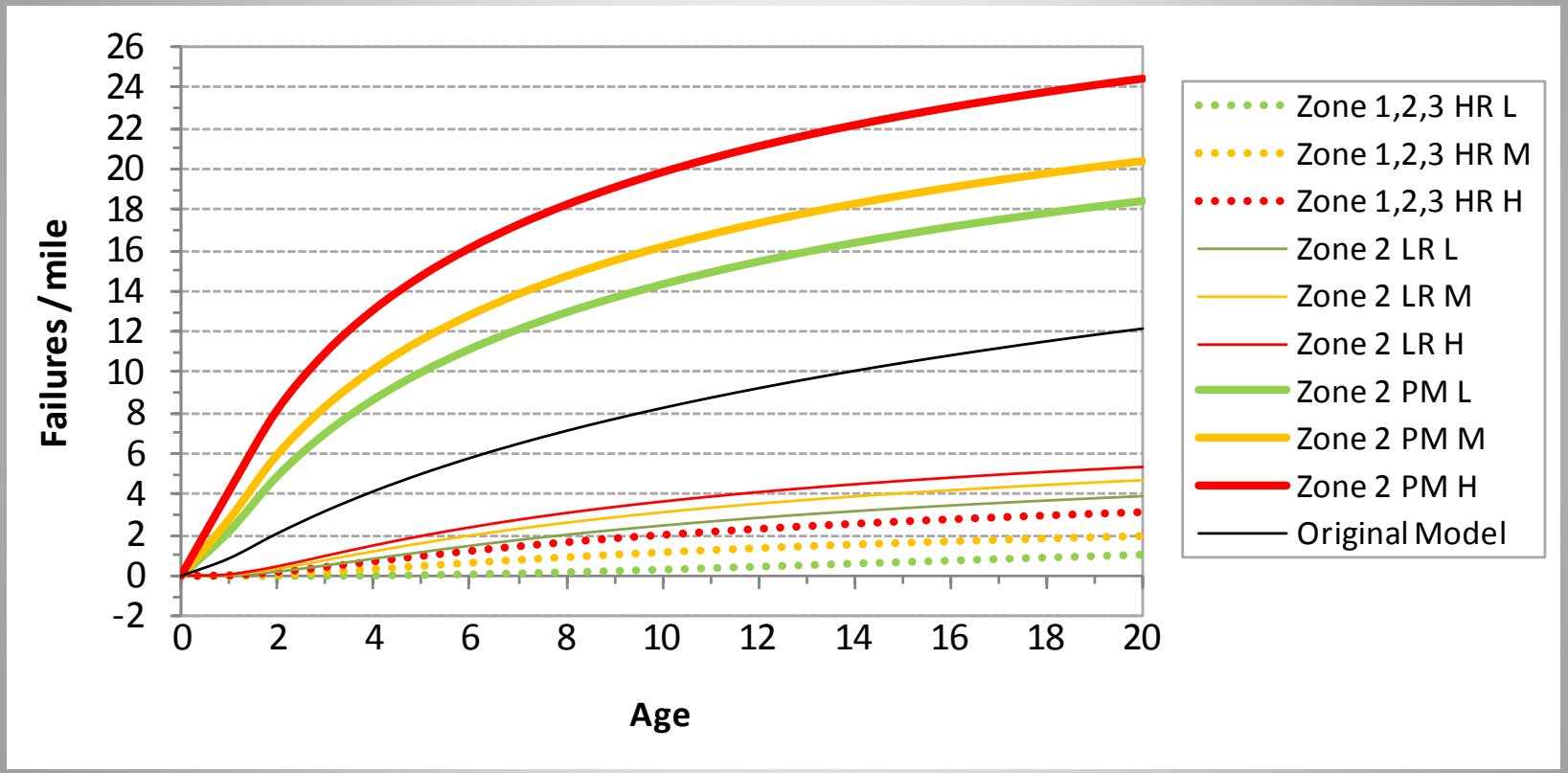
Texas Department of Transportation

UTSA THE UNIVERSITY OF TEXAS AT SAN ANTONIO

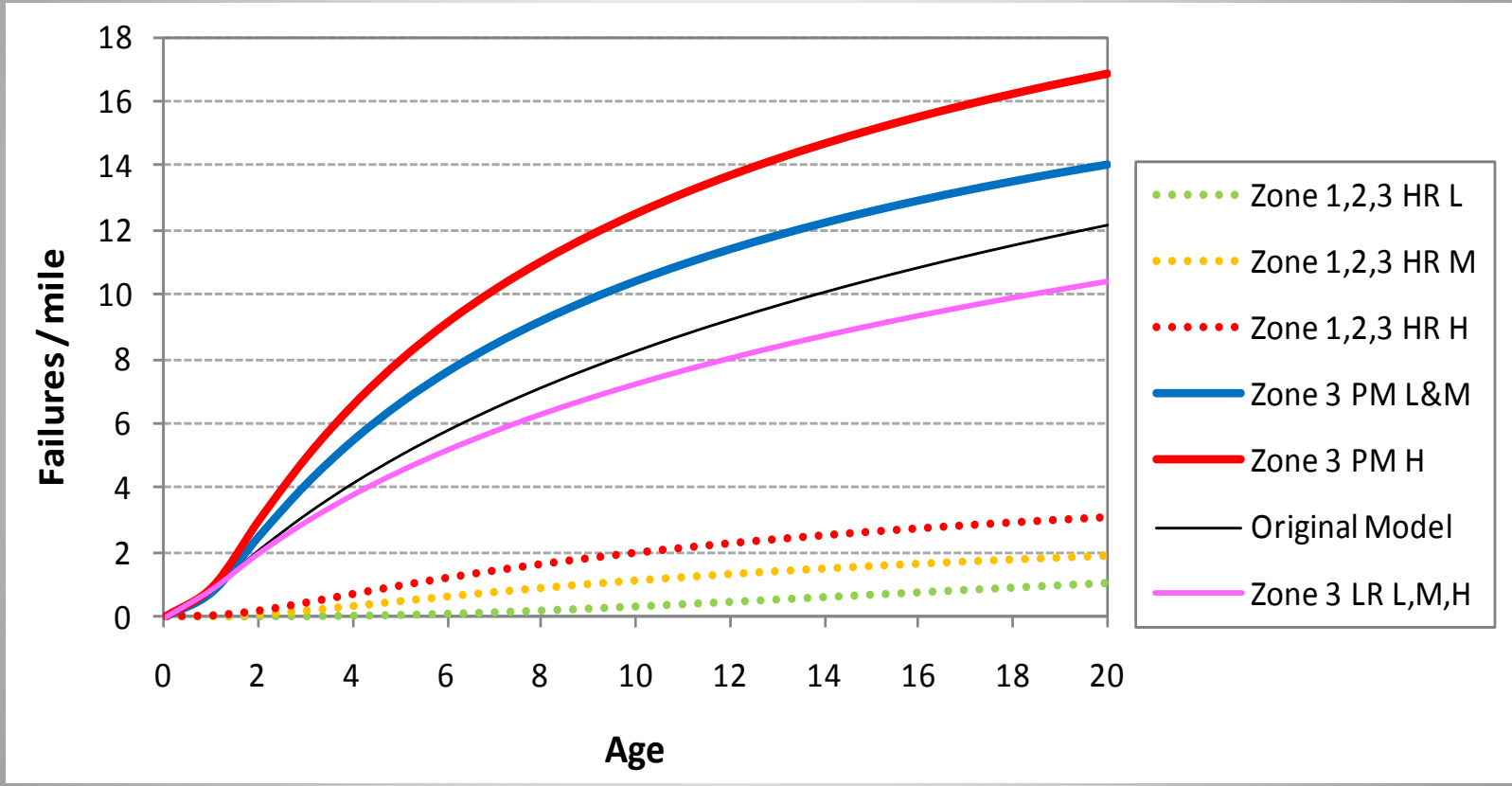
Failures Zone 1



Failures Zone 2



Failures Zone 3



Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Concrete Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

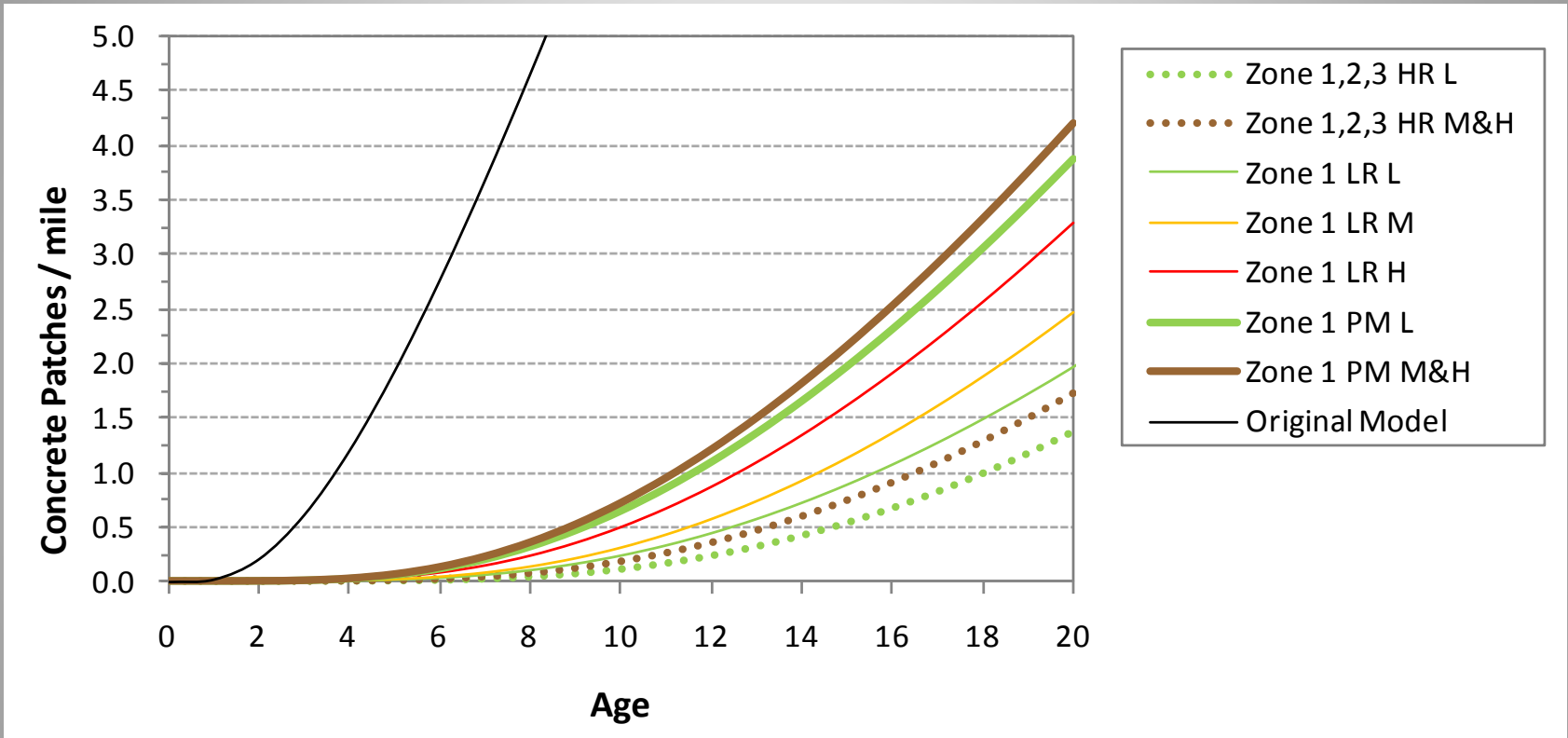
Concrete Patches

			Low	Med.	Heavy
HR	Zone 1,2,3	Data points	2,234	5,585	
		% RMSE change	1.8%	7.0%	
LR	Zone 1	Data points	1,249	1,079	731
		% RMSE change	-93.7%	-91.7%	-92.1%
	Zone 2	Data points	2,513	2,127	2,214
		% RMSE change	-92.8%	-88.4%	-90.1%
	Zone 3	Data points	107		
		% RMSE change	-90.2%		
PM	Zone 1	Data points	1,735	2,466	
		% RMSE change	-82.0%	-71.1%	
	Zone 2	Data points	2,818	2,633	1,566
		% RMSE change	-54.9%	-40.9%	-25.2%
	Zone 3	Data points	504	65	
		% RMSE change	-7.9%	-38.5%	

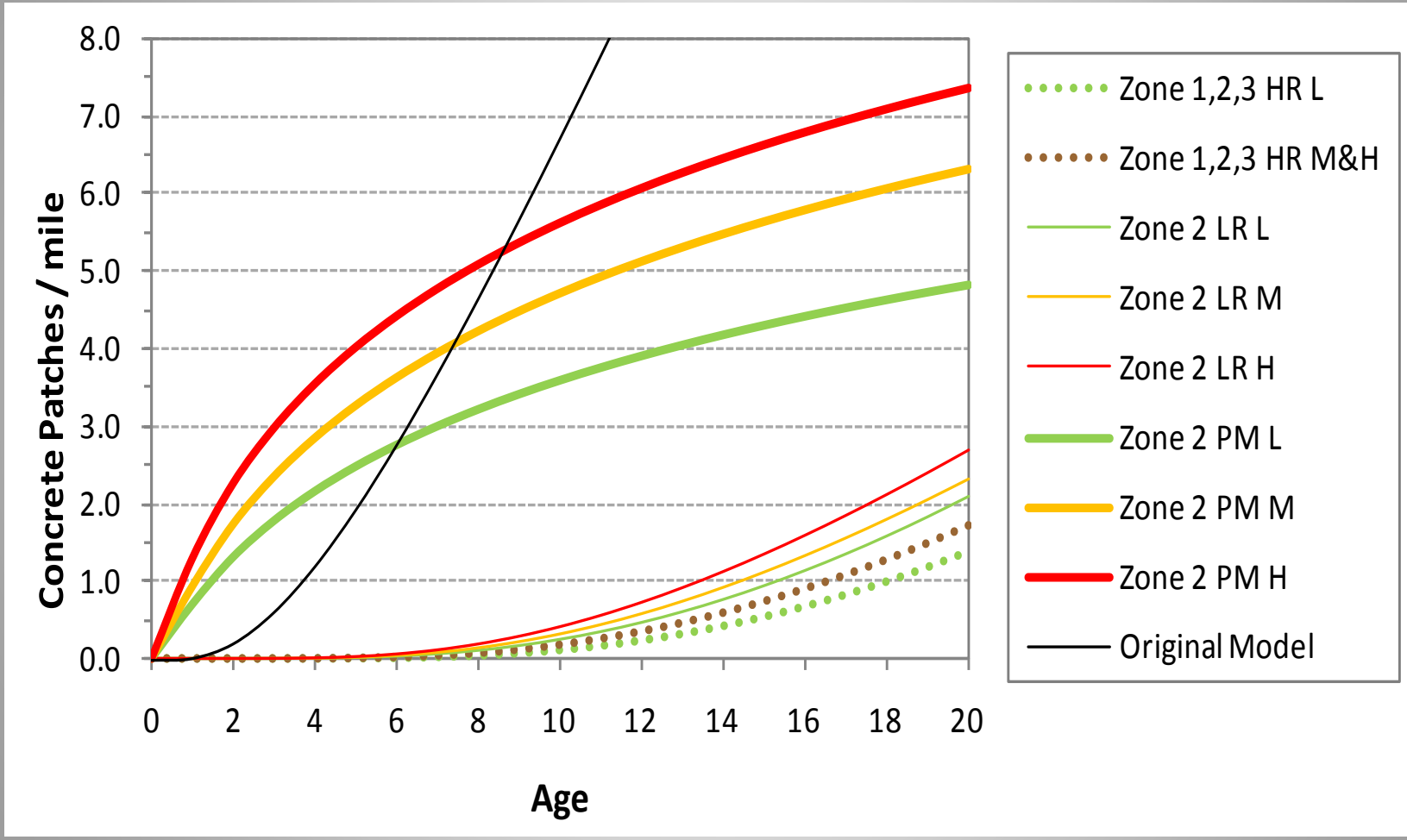
Texas Department of Transportation

UTSA THE UNIVERSITY OF TEXAS AT SAN ANTONIO

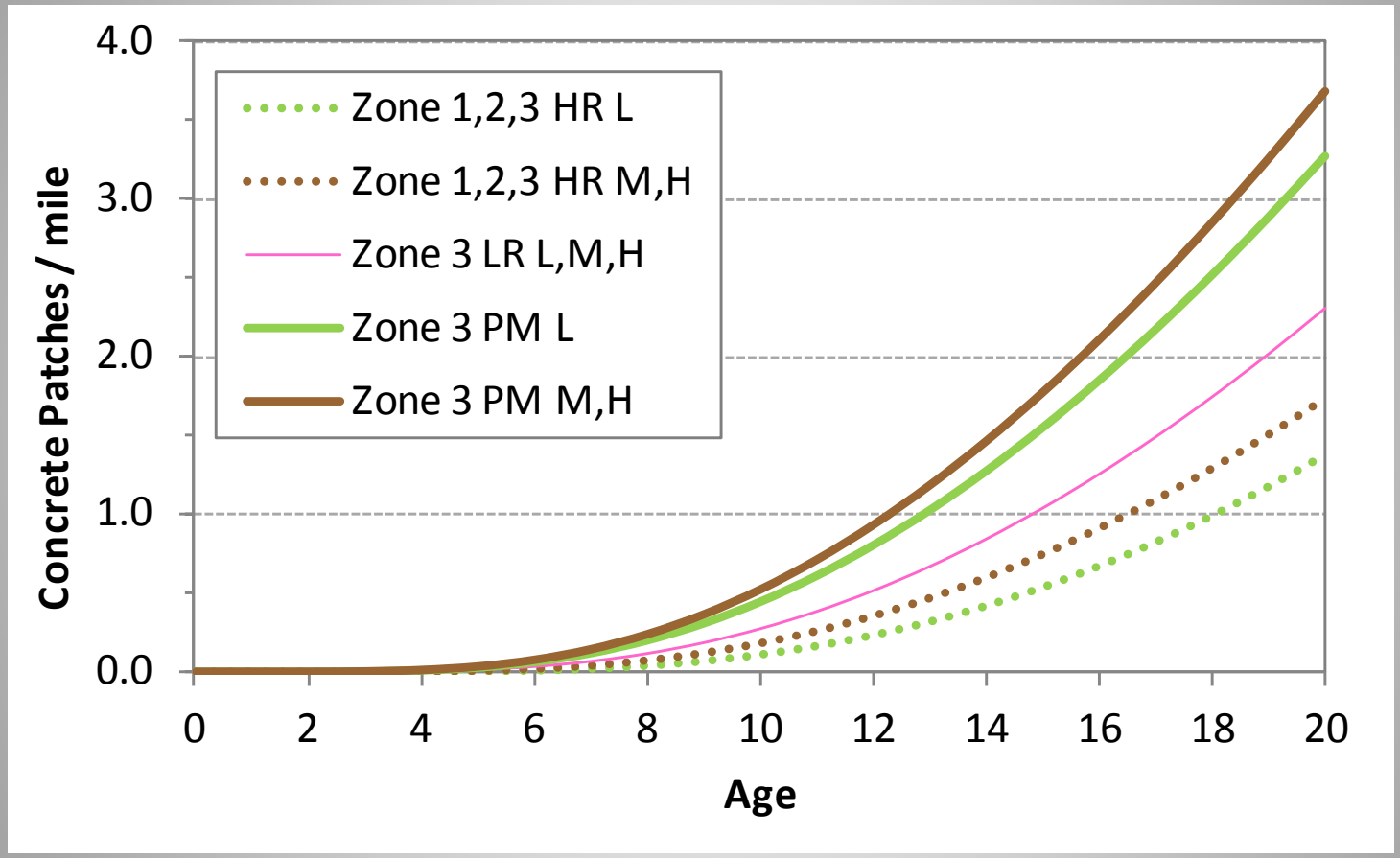
Concrete Patches Zone 1



Concrete Patches Zone 2



Concrete Patches Zone 3



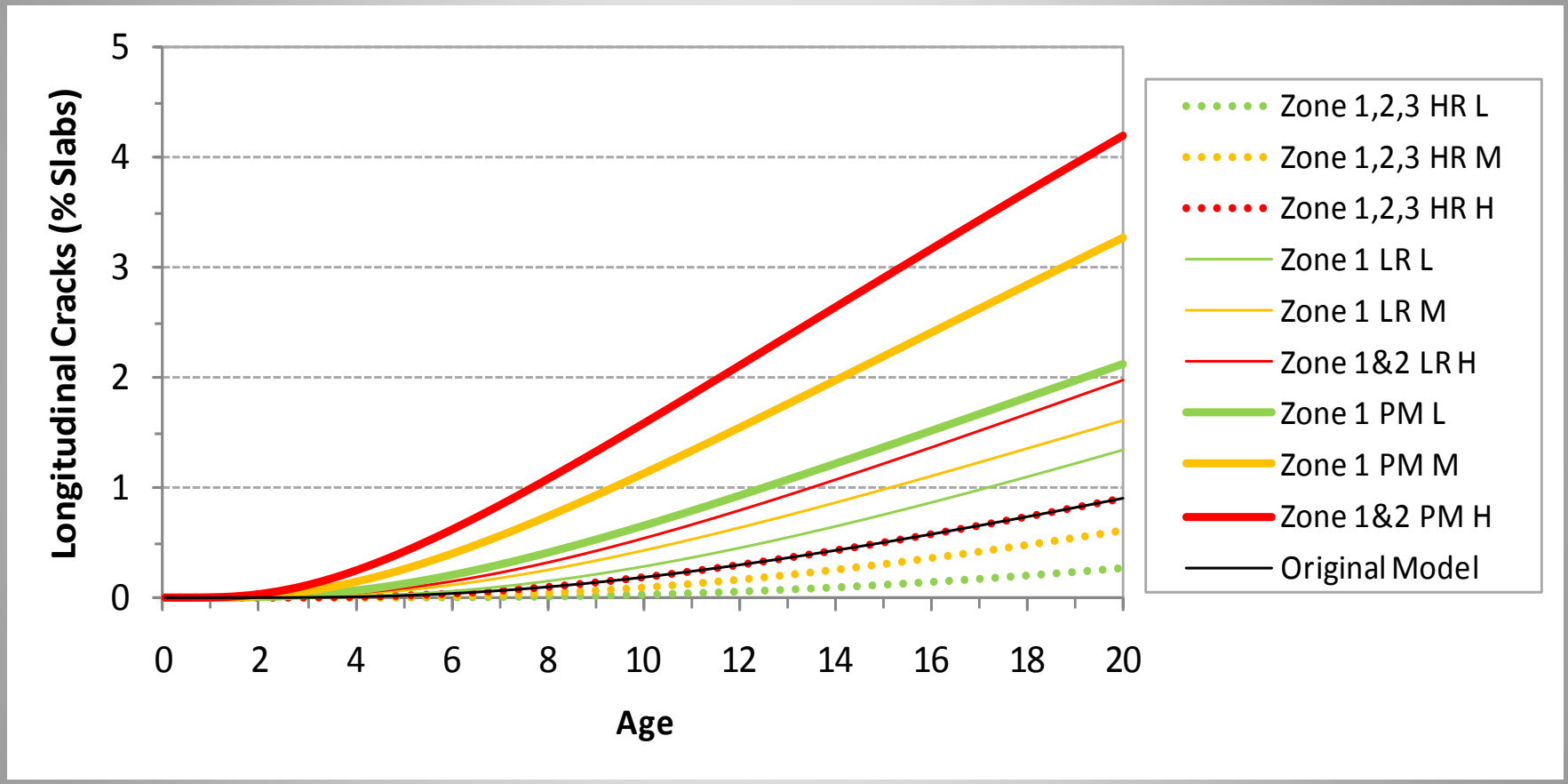
Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

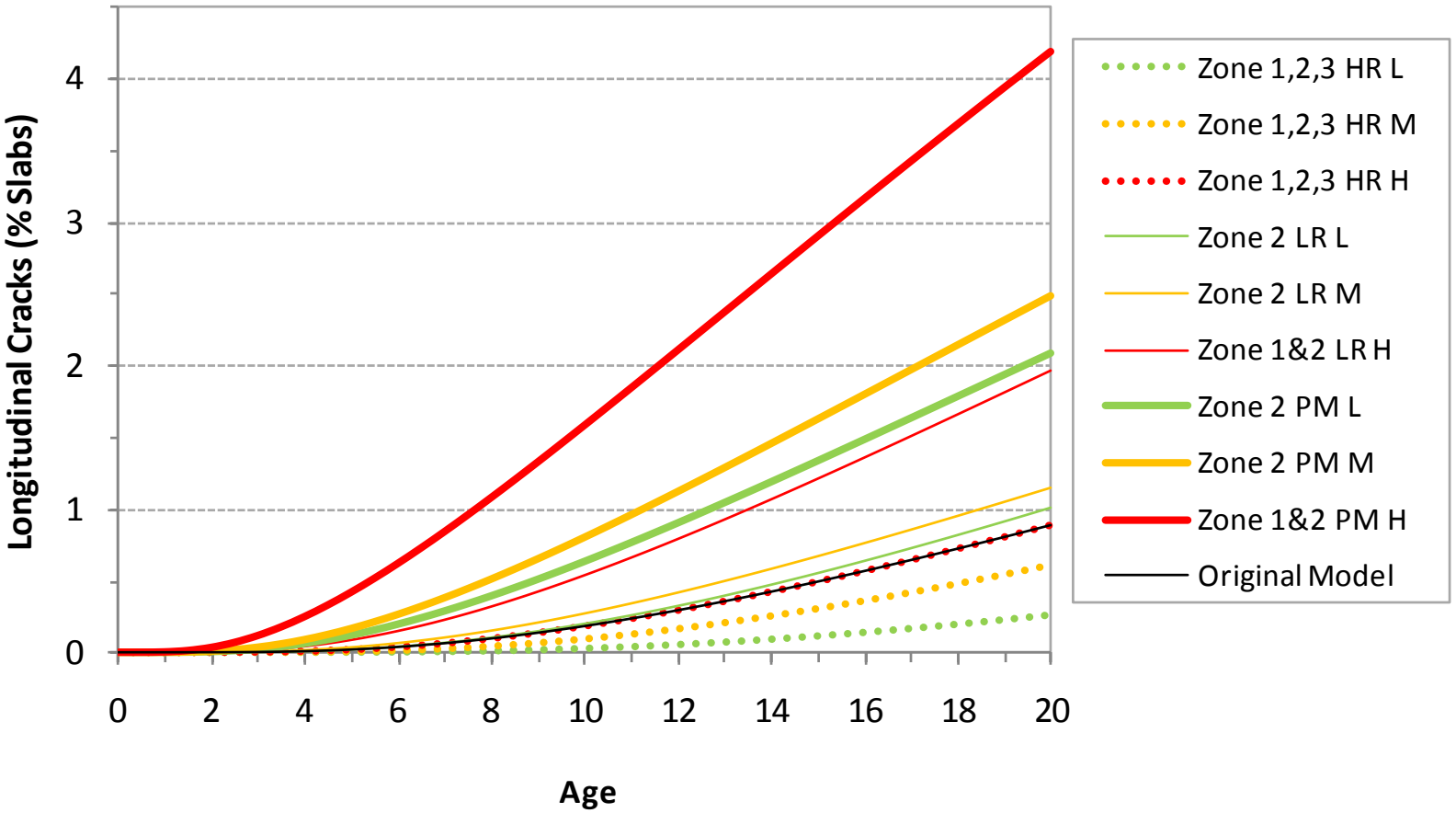
Longitudinal Cracks

			Low	Med.	Heavy
HR	Zone 1,2,3	Data points	2,234	2,316	3,269
		% RMSE change	0.4%	0.1%	0.0%
LR	Zone 1	Data points	1,249	1,079	2,945
		% RMSE change	-0.6%	-1.2%	-1.6%
	Zone 2	Data points	2,513	2,127	
		% RMSE change	-0.1%	-0.2%	
PM	Zone 1	Data points	1,735	2,102	1,970
		% RMSE change	-1.7%	-4.6%	-2.7%
	Zone 2	Data points	2,818	2,633	
		% RMSE change	-1.1%	-1.5%	
PM&LR	Zone 3	Data Points	555		121
		% RMSE change	-5.6%		-6.6%

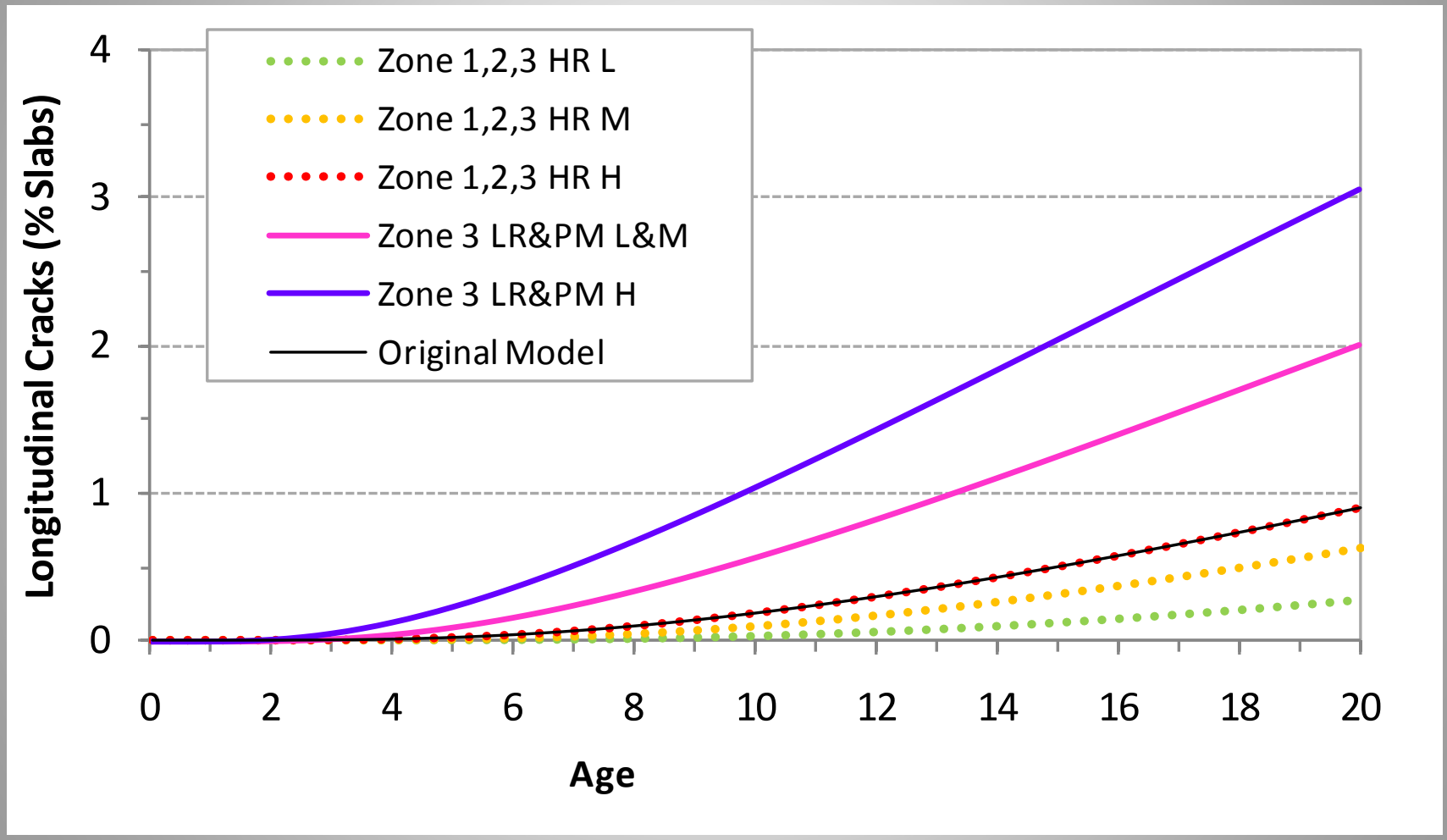
Longitudinal Cracks Zone 1



Longitudinal Cracks Zone 2



Longitudinal Cracks Zone 3



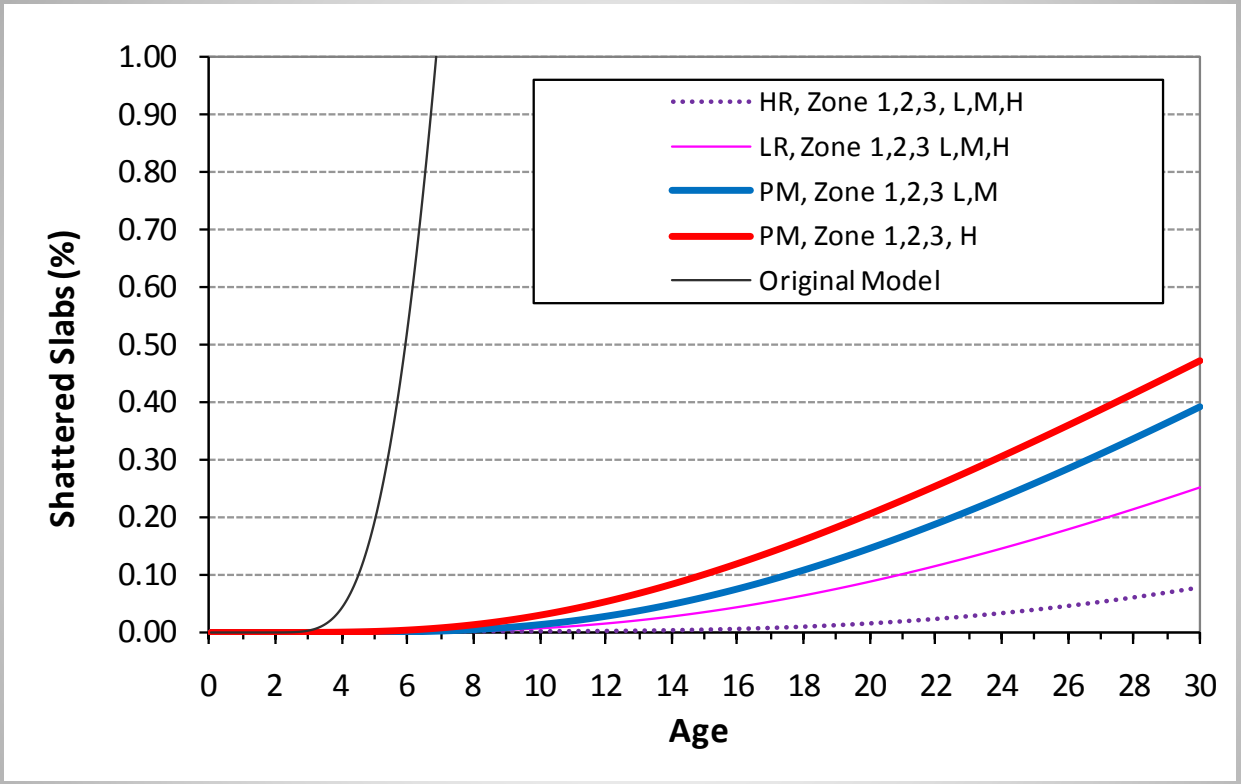
Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Shattered Slabs

			Low	Med.	Heavy
HR	Zone 1,2,3	Data points	7,819		
		% RMSE change	-98.0%		
LR	Zone 1,2,3	Data points	10,020		
		% RMSE change	-99.7%		
PM	Zone 1,2,3	Data points	9,817		1,970
		% RMSE change	-86.0%		-97.0%

Shattered Slabs



Shattered slabs=0 for approximately 98% of the data

Presentation Outline

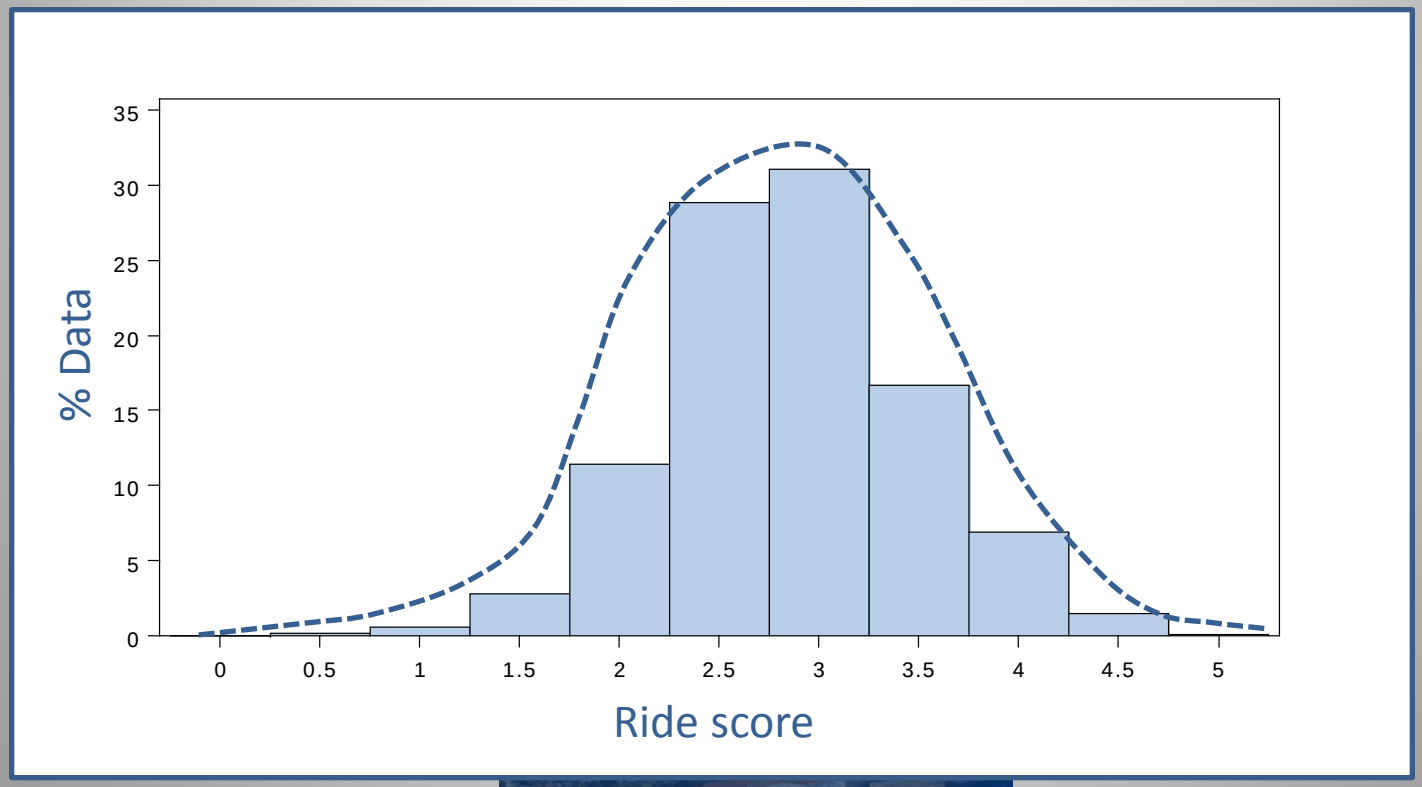
- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Ride Score

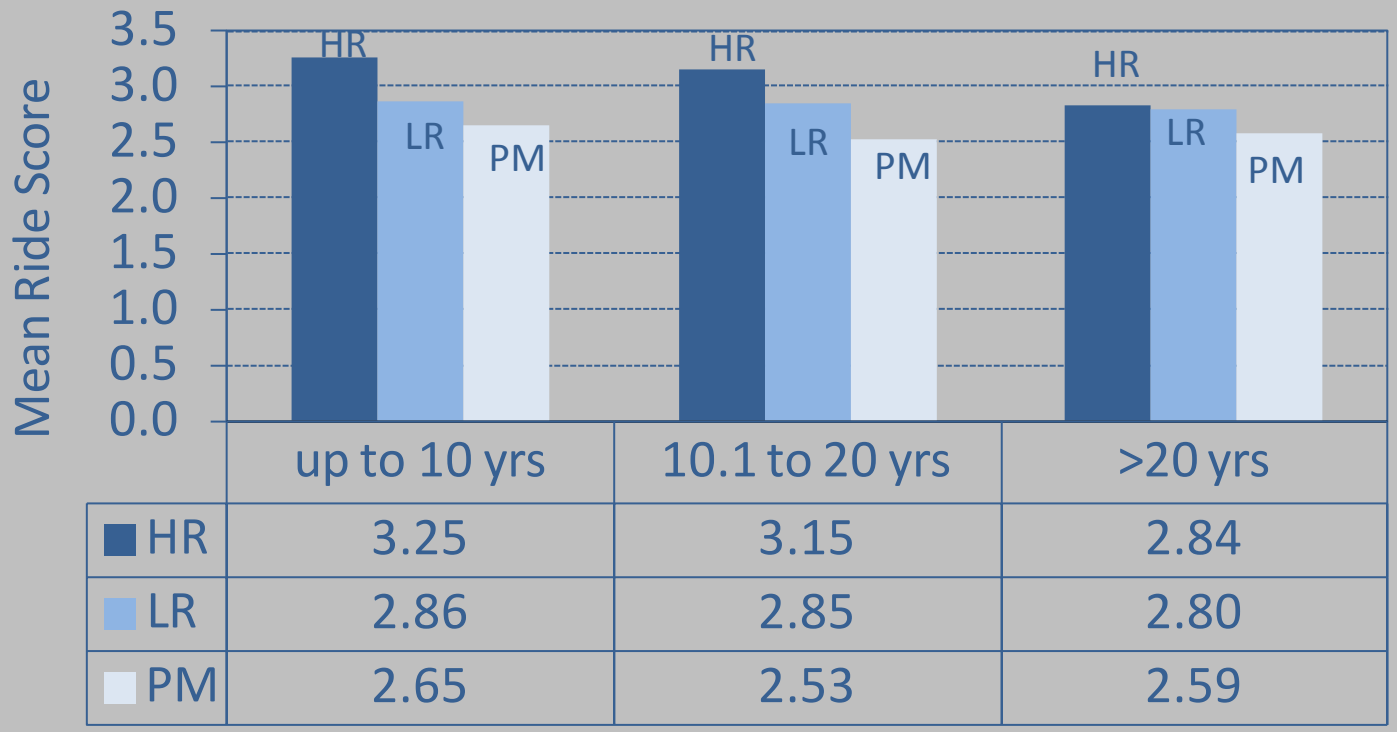
- Slab warping = JCP roughness (FHWA, 2010)
- Roughness ≠ JCP condition (Lukefahr, 2010)

Therefore:

- JCP ride score =f(random moist/temp gradients)



Ride Score



	up to 10 yrs	10.1 to 20 yrs	>20 yrs
HR	3.25	3.15	2.84
LR	2.86	2.85	2.80
PM	2.65	2.53	2.59

Conclusion: best prediction is last year's measurement

Presentation Outline

- Overview of JCP distresses in PMIS
- Original models and recalibration objectives
- Available data
- Methodology
  - Data treatment
  - Estimated age
  - Estimated treatments
  - Modeling groups
  - Recalibration
- Results
  - Failed joints and cracks
  - Failures
  - Patches
  - Longitudinal cracks
  - Shattered slabs
  - Ride score
- Conclusions

Conclusions

- 66 new JCP distress models
  - 1 model = original
  - 59 models—RMSE decreased (improvement)
  - 6 models—RMSE increased (constrained models based on engineering judgment)
- Average RMSE change = +27.72%
- Ride score's best prediction is previous year measurement