A Stochastic Approach for Pavement Condition Projections and Budget Needs for the MTC Pavement Management System

Rafael Arturo Ramirez-Flores
Ph. D. Candidate
Carlos Chang-Albitres Ph.D. , P.E.
April 16, 2012

Acknowledgment

We wish to thank the Metropolitan Transportation Commission (MTC) specially Mr. Sui Tan and the developers of

StreetSaver software for their support.

Presentation Outline

1. Introduction
2. Overview of the MTC-PMS (StreetSaver)
3. Research Problem
4. Methodology
5. Example
6. Conclusions

Introduction

- Pavement Management Systems (PMS) is a set of tools to assist decision-makers in finding optimum strategies to maintain pavements in serviceable condition over time

- PMS provides means to organize road network massive amount of data

- Provides information needed to justify maintenance and rehabilitation programs.

PMS Prediction Models

Every PMS has a prediction model to forecast the deterioration of the pavement network.

Prediction models are useful at network level to answer questions like what, where, and when with respect to maintenance and rehabilitation actions.

Deterministic vs Probabilistic Models

Deterministic models do not consider the variability in the parameters used.

A probabilistic approach is needed to address the variability in the performance predictions.

The Metropolitan Transportation Commission (MTC)

In 1981the Metropolitan Transportation Commission in the San Francisco California Bay Area developed a pavement management system used in the nine counties agencies which evolved to StreetSaver.

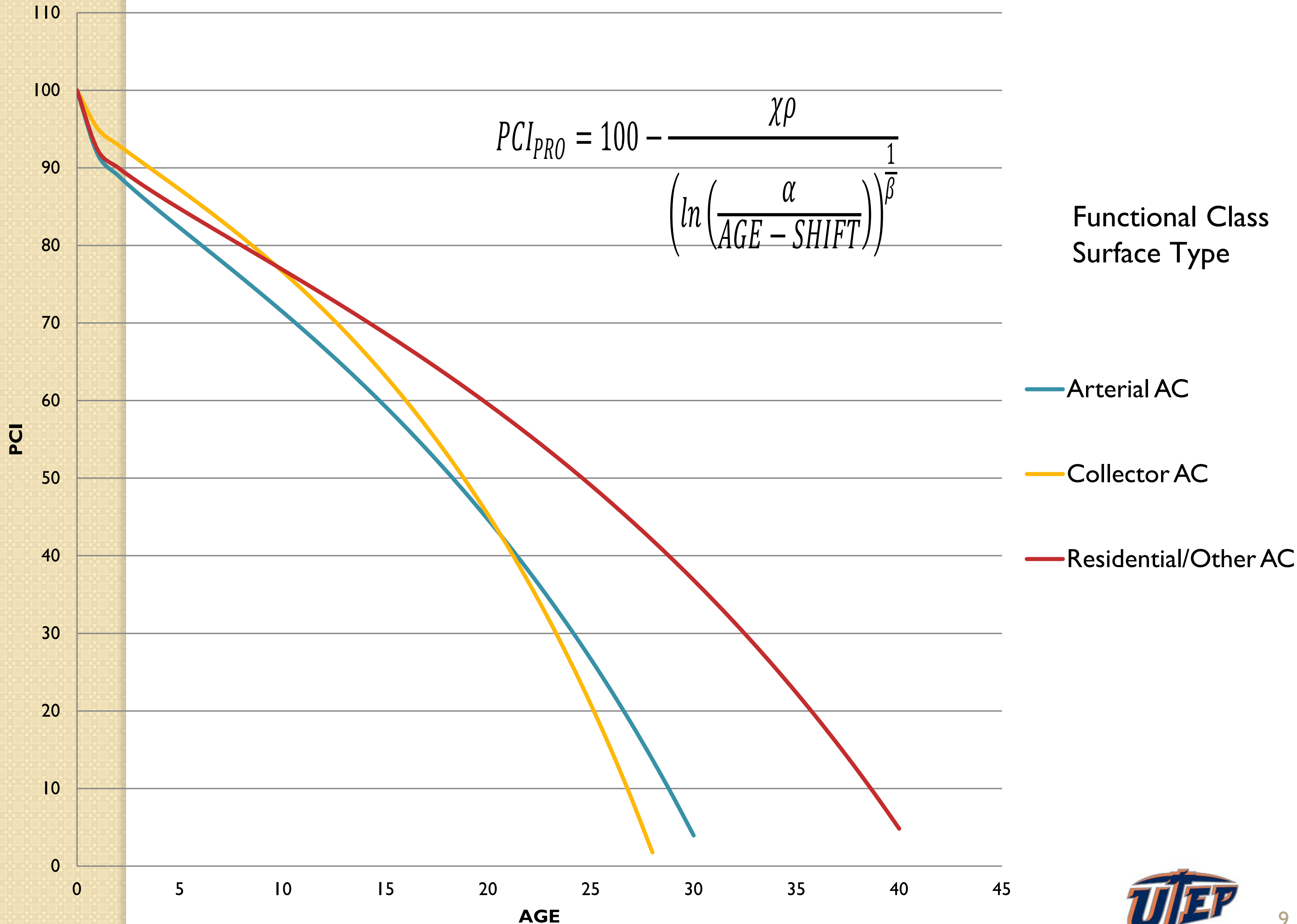
StreetSaver uses a prediction model based on Pavement Condition Index (PCI)

MTC-PMS -> StreetSaver

The MTC-PMS prediction model is deterministic and based on an S shaped curve that represents the deterioration behavior of the pavement over time.

Family Curves

$$PCI_{PRO} = 100 - \frac{\chi\rho}{\left(\ln\left(\frac{\alpha}{AGE - SHIFT}\right)\right)^{\frac{1}{\beta}}}$$



Treatment Selection

MTC's prediction model connects the projected condition of the pavement management sections to the maintenance and rehabilitation treatments by means of a decision tree.

PCI	CONDITION CATEGORY		DECISION TREE	
100–70	Category I Very Good Condition		Preventive Maintenance	Seal Cracks and Surface Seals
70–50	Category II Good Condition (Non-load related)	Category III Good condition (Load related)	Rehabilitation	II Seal Coat III Thin Overlay
50–25	Category IV Poor Condition			IV Thick Overlay
25–0	Category V Poorest Condition			V Reconstruct

Needs and Scenarios Analysis

Needs Analysis is based on PCI projections is used to identify the sections needing work, the treatments to apply, and the funding needs.

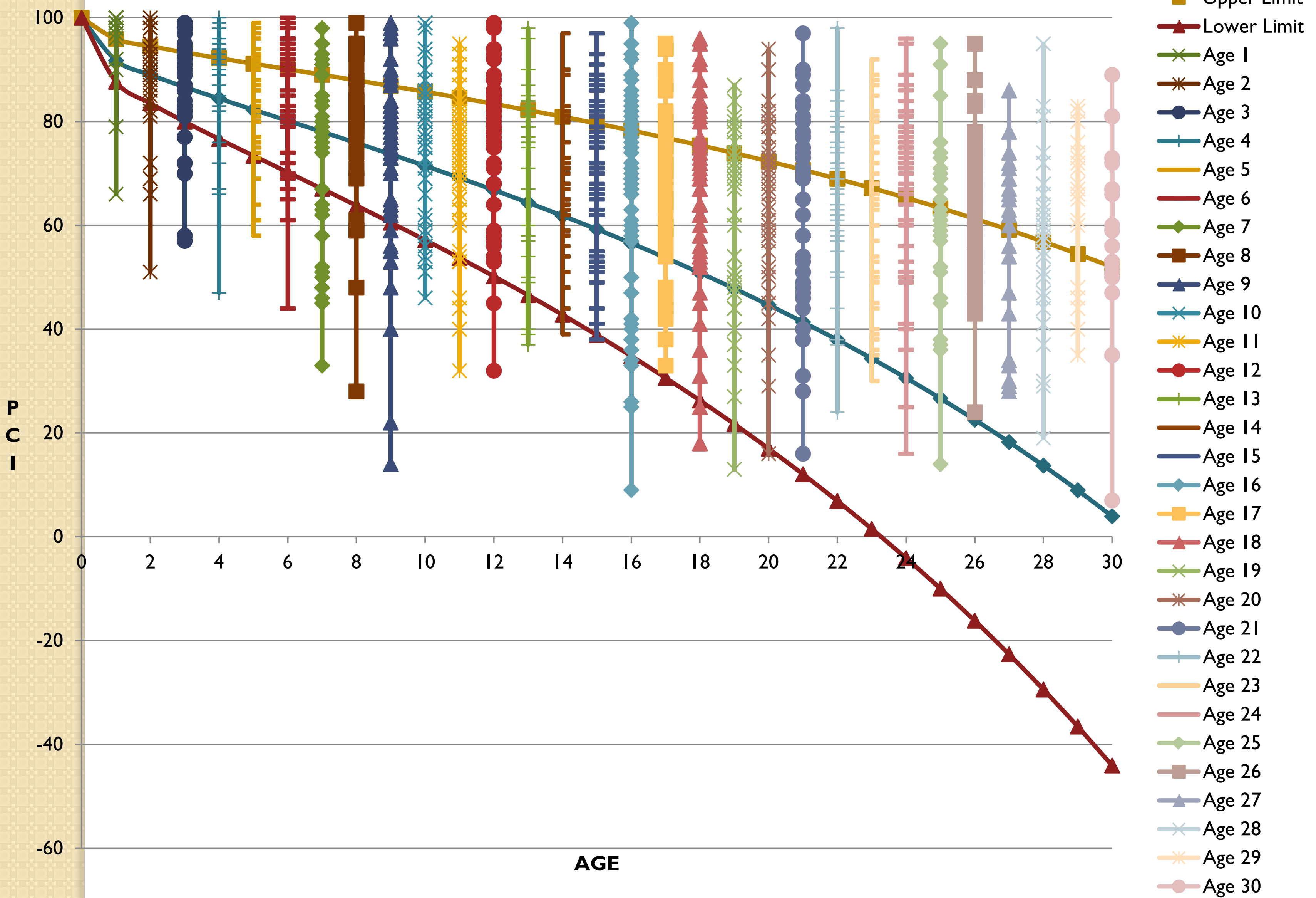
Target Driven Scenario Analysis establishes the sections to be treated and the budget needed to maintain the network in a desired condition level over the planning horizon.

Budget Scenario Analysis identifies the sections and treatments to be applied according to the available budget over the analysis period.

The Research Problem

The problem to be addressed is how to determine the reliability of PCI predicted values and budget needs introducing probability distributions and confidence intervals.

Lower and Upper Limits for Outliers

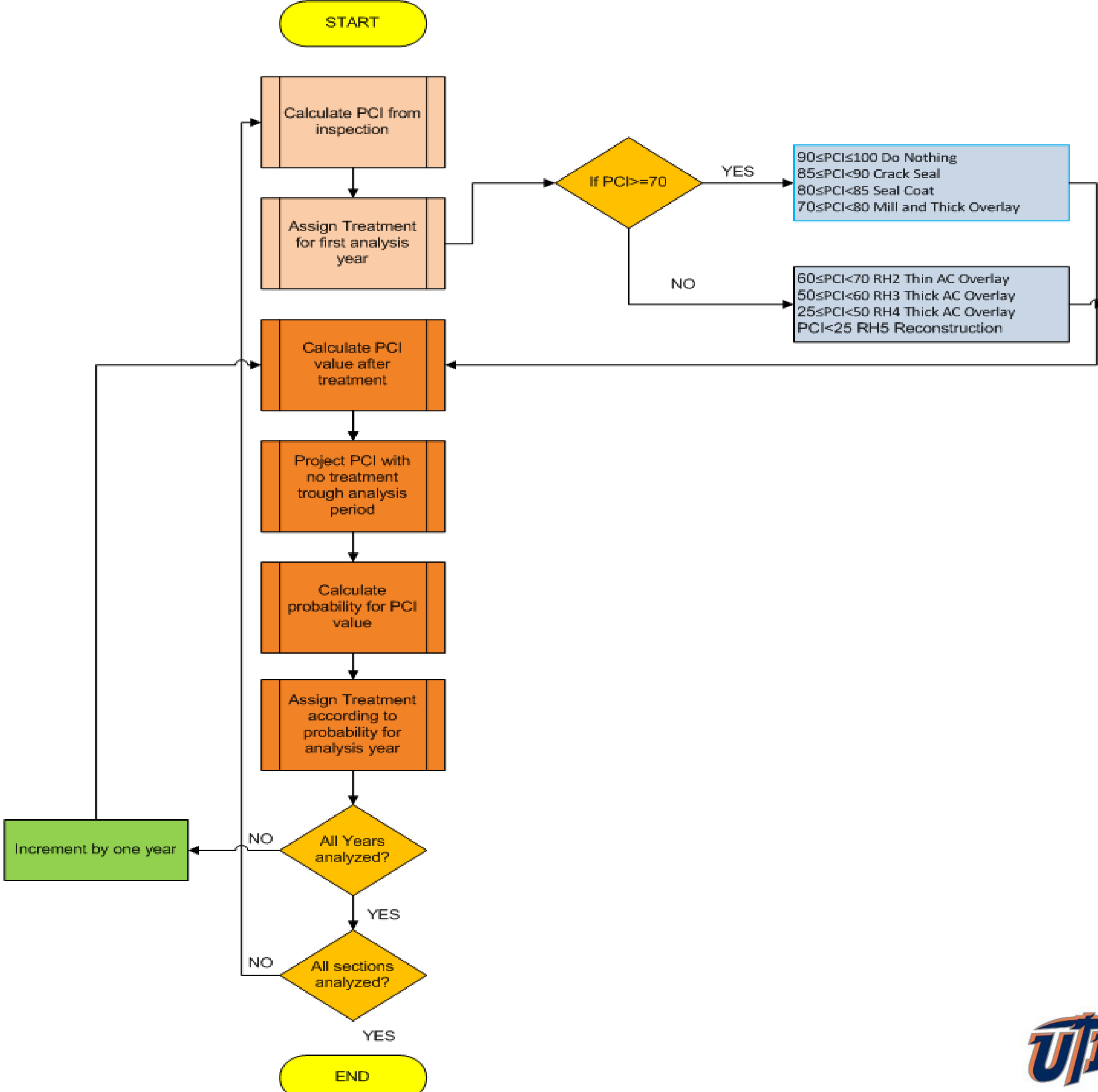


Methodology

1. Establish 95% confidence bounds for predicted PCI values
2. Develop a projection curve beneath the confidence bounds
3. Fit probability distributions for each year of age of the pavement

Methodology

4. Use probability distributions for each year to determine the probability of a PCI projected value
5. Define probability matrix for PCI ranges to apply treatments in the decision tree
6. Assign treatment according to PCI probability for analysis year


START
Calculate PCI from inspection
Assign Treatment for first analysis year
If PCI>=70
YES
90≤PCI≤100 Do Nothing
85≤PCI<90 Crack Seal
80≤PCI<85 Seal Coat
70≤PCI<80 Mill and Thick Overlay
NO
60≤PCI<70 RH2 Thin AC Overlay
50≤PCI<60 RH3 Thick AC Overlay
25≤PCI<50 RH4 Thick AC Overlay
PCI<25 RH5 Reconstruction
Calculate PCI value after treatment
Project PCI with no treatment trough analysis period
Calculate probability for PCI value
Assign Treatment according to probability for analysis year
All Years analyzed?
NO
Increment by one year
YES
All sections analyzed?
NO
YES
END

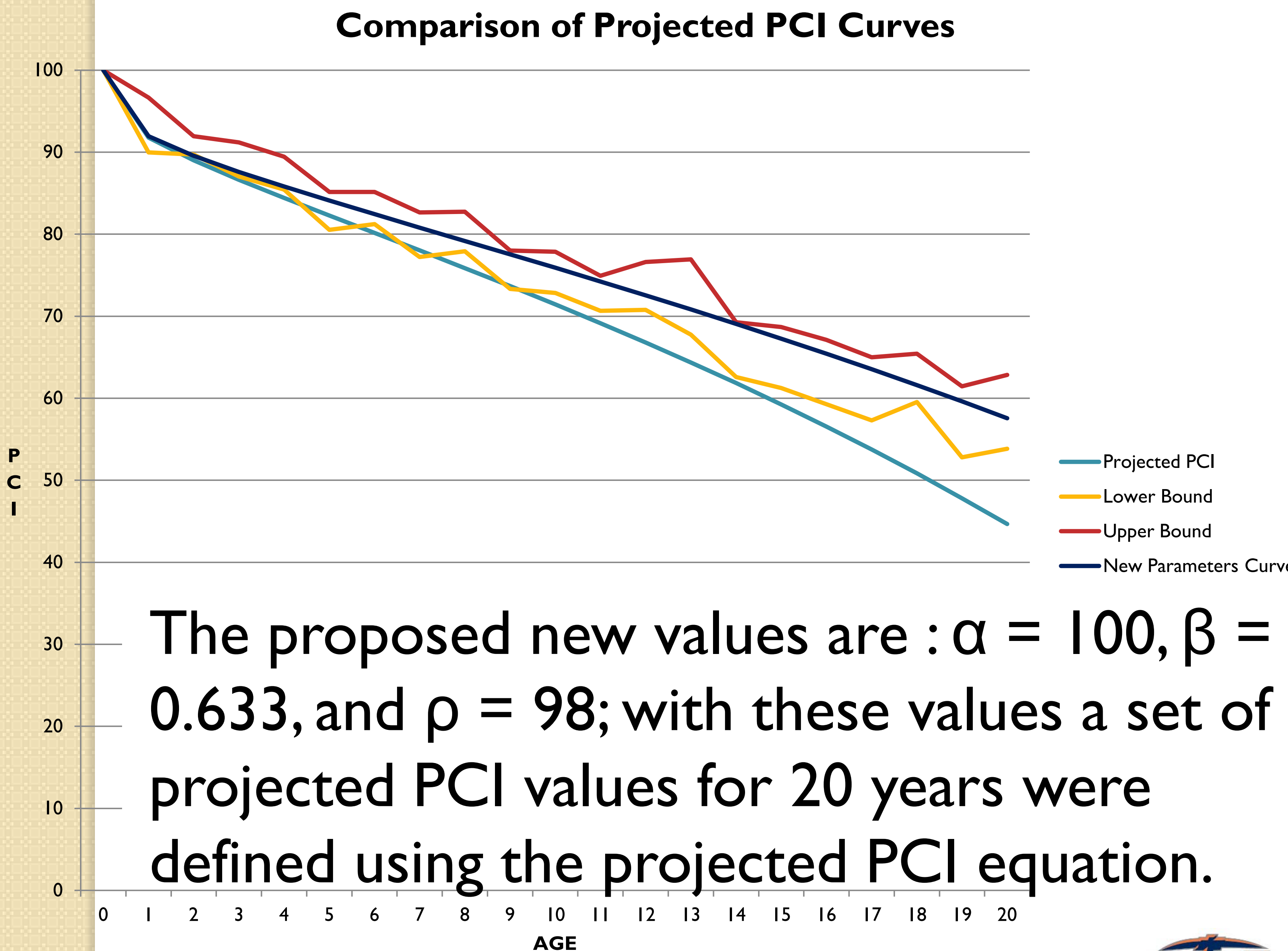
Example

Using StreetSaver databases from the cities of Belmont, San Carlos, Milpitas, San Ramon, San Anselmo, and Santa Rosa, California, inspection information were collected from 1,500 Arterial streets paved with asphalt concrete

Example

With the inspection date and the construction date, the age of the pavement was calculated for each inspection, and was linked to the PCI value.

The data was sorted from 0 to 30 years of age and separated in yearly bins



The proposed new values are : α = 100, β = 0.633, and ρ = 98; with these values a set of projected PCI values for 20 years were defined using the projected PCI equation.

Example

StreetSaver's decision tree has trigger PCI values to choose management sections for treatment and to establish the treatments to apply. For preventive maintenance the PCI value has to be between 70 and 100.

Example

The proppose ranges are:

PCI Value	Treatment
From 90 to 100	Do Nothing
From 85 to 89	Crack Seal
From 80 to 84	Seal Coat
From 70 to 79	RH1 Mill and Thick Overlay

Example

To apply a rehabilitation treatment the PCI value has to be from 0 to 69

PCI Value	Treatment
From 60 to 69	RH2 Single Chip Seal
From 50 to 59	RH3 Thin AC Overlay 1.5 in.
From 25 to 49	RH4 Thick AC Overlay 2.5 in.
From 0 to 24	RH5 Reconstruction

Deterministic Analysis

An analysis was performed using a single management section for a period of 6 years with the actual α, β, and ρ parameters, and compared to the results of the analysis of the same section using the new parameters

Analysis Results

	Standard Parameters		Calculated Parameters	
	PCI After Treatment	Treatment Cost	PCI After Treatment	Treatment Cost
Year 1	94.5	3288.9	89.73	21.6
Year 2	90.85	0	93.67	3387.6
Year 3	89.1	24.6	90.75	0
Year 4	86.72	0	89.42	24.4
Year 5	85.76	36.3	87.47	0
Year 6	90.56	3812.7	86.81	33.9
Average	89.58		89.64	
Total		7162.5		3467.5

Stochastic Analysis

Probability distributions were found for the data arrenged in bins from 1 to 6 years of age, and the normal distribution was among the top 5 ranks, so to have uniformity, the normal distribution was chosen for all ages

Model Statistical Parameters

AGE	MEAN	STANDARD DEVIATION	VARIANCE	MIN	MAX
1 Year	92.6667	3.0551	9.333	90	96
2 Years	90.825	3.5001	12.251	81	95
3 Years	89.1154	5.1172	26.186	81	98
4 Years	87.4545	4.5222	20.45	76	93
5 Years	82.8438	6.3759	40.652	73	92
6 Years	83.1875	5.4444	29.641	70	93

Stochastic Analysis

Probabilities were calculated for the treatment PCI ranges to construct the PCI ranges probability matrix finding the probability of each value as:

$$P(PCI \le a) = P(Z \le (a-\mu)/\sigma) = \Phi((a-\mu)/\sigma)$$

PCI Ranges Probability Matrix

Year	PCI<100	PCI<90	PCI<85	PCI<80	PCI<70	PCI<60	PCI<50	PCI<25
1	0.99181	0.19134	0.00604	0.00002	0	0	0	0
2	0.99562	0.40683	0.04803	0.00099	0	0	0	0
3	0.9833	0.56865	0.21065	0.03744	0.00009	0	0	0
4	0.99723	0.71321	0.29361	0.04962	0.00006	0	0	0
5	0.99644	0.86914	0.63237	0.32778	0.02198	0.00017	0	0
6	0.99899	0.89457	0.63036	0.27909	0.00771	0.00001	0	0

Stochastic Analysis

An analysis was run for six years using 10 management sections with different inspection PCI's.

Results from the deterministic method were compared to the new stochastic approach.

Stochastic Analysis

		StreetSaver		Stochastic Method	
Inspected PCI	Category	Average PCI After Treatment	Treatment Cost	Average PCI After Treatment	Treatment Cost
95	I	90.67	7159.1	89.36	111.4
89	I	89.58	7162.5	88.52	3952.9
86	I	88.41	7168.1	88.61	3629.3
81	I	87.79	7166.6	86.14	3429.3
75	I	82.56	7200.4	87.39	6793.1
68	II	76.2	7572	89.35	32311.5
68	III	90.99	12638.3	92.19	12482
52	II	84.37	24583	86.27	26882.8
52	III	84.37	24583	86.27	26882.8
45	IV	90.99	26327.1	92.19	26170.9
30	IV	70.79	57678.2	82.6	26882.8
23	V	91.02	58214.6	91.12	54452.6

Conclusions

The pavement sections are in better condition than the projected PCI with the current deterministic approach.

With the recalibrated PCI parameters, the projected pavement condition is closer to reality.

Conclusions

With the stochastic model, the decision makers at the agencies will know better the confidence level of the projected PCI, and the budget needs.

In this particular example the PCI is more realistic and the budget is lower.

The stochastic model is recommended to improve StretSaver's functionality.

Questions