MODULE 8

PERFORMANCE MODELS

8

Instructional Objectives

- **Understand use of performance models**
- **Identify common modeling approaches**
- **Understand methods for evaluating reliability**
- **Describe requirements for updating models**

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Overview

- **Serviceability-performance concepts**
- **Deterioration as a representation of change in performance**

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Uses of Performance Models in Pavement Management

- **Network Level**
- **Project Level**

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	Types of Performance Models						
	Deterministic				Probabilistic		
	Primary Response	Structural	Functional	Damage	Survivor Curves	Transition Process Models	
	• Deflection • Stress • Strain	• Distress • Pavement Condition	• PSI • Safety	• Load Equiv.		Markov	Semi-Markov
National Level				Q	Q	Q	Q
State or District Level		Q	Q	Q	Q	Q	Q
Project Level	Q	Q	Q	Q			

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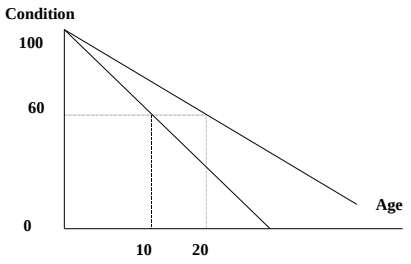
Importance of Accurate Modeling



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Performance Model Development Criteria

- **Adequate database**
- **Inclusion of all significant variables that affect performance**
- **Adequate functional form of the model**
- **Satisfaction of the statistical criteria concerning the precision of the model**
- **Understanding of the principles behind each modeling approach**

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Data Requirements

- **Requirements vary depending on the type of model being developed**
- **Inventory Information**
- **Monitoring Data**

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Lack of Historical Data

- **If historical databases are not available due to changes in survey procedures, new rehabilitation techniques, or other factors, other techniques are available:**
  - incorporate input from experienced practitioners
  - update the models as additional data are available

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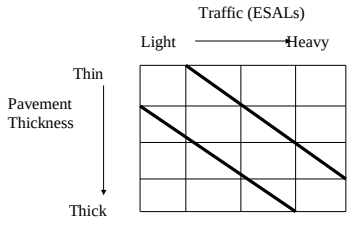
On-the-Diagonal Issue



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Data Requirements

- **Sufficient amounts of data must be used**
- **Data must be measured accurately and without bias**
- **Data must be representative**
- **Data must be maintained over time**

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Model Limitations

- **Models must be used appropriately**
- **Limitations of models must be considered**
- **Boundary conditions should be identified and satisfied**

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Deterministic vs. Probabilistic

- **Predicted Occurrence**
- **Techniques**

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Mechanistic Models

- **No purely mechanistic performance models have been developed**
- **Calculated stress and strain attributes from mechanistic models can be used as the input for an empirical prediction model**

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Mechanistic-Empirical Models

- **Models developed using pavement response as the dependent variable**
- **Use elements of both mechanistic models (fundamental principles of pavement behavior) and empirical models (results from experience or experiments)**
- **$N = A * (1/e)^B$**

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Regression Analysis

- **A technique used to determine the relationship between variables**
- **Often used in agencies with historical databases available**

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Subjective Approaches

- **Used in agencies that do not have historical data available**
- **Can be used to develop either deterministic or probabilistic models**

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Development of Deterministic Performance Models

- **Very common modeling techniques in pavement management**
- **Predict a single number based on its relationship with one or more variables**
- **Can be empirical or mechanistic-empirical correlations calibrated using regression**
- **Condition is modeled as a function of other variables**

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Regression Analysis

- **Statistical tool used to establish the relationship between two or more variables**
- **Models can be linear or non-linear, depending on the relationship between variables**

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Regression Model Forms

- **Linear Regression**
  - $Y = a + bX$
- **Multiple Linear Regression**
  - $Y = a_0 + a_1X_1 + a_2X_2 + \ldots A_nX_n$
- **Non-Linear Regression**
  - $Y = a_0 + a_1X^1 + a_2X^2 + \ldots A_nX^n$
  - Polynomial regression models may be constrained
  - Least squares fit is used to improve the models

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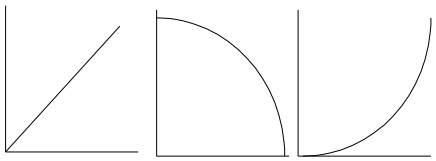
Deterministic Model Forms



Linear Polynomial Hyperbolic

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Family Models

- **Reduces number of variables**
- **Group pavement sections by characteristics**
- **Assume similar deterioration patterns**
- **Reflects average deterioration for family**
- **Allows ranges of values to be used for developing families**

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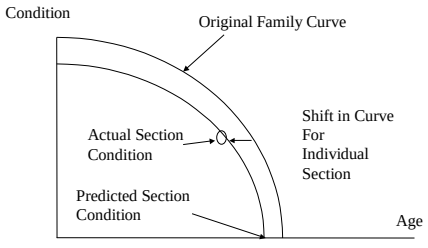
Shift of the Family Performance Model



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Advantages/Disadvantages to Family Models

- **Advantages**
- **Disadvantages**

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Statistical Evaluation of Models

- Coefficient of determination (R2)
- Root mean square error (RMSE)
- Number of data points (n)
- Hypothesis tests on regression coefficients

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Coefficient of Determination (R^2)

- Provides an indication of how much of the total variation in the data is explained by the regression equation or performance curve
- Network Level normally < 0.9
- Project Level normally > 0.9

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RMSE

- Standard deviation of the predicted dependent variable value for a specific value of the independent variable
- Project Level: <=5
- Network Level: > 5

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Other Tests

- Number of Data Points
- Hypothesis Test of Regression Constants

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Limitation of Statistical Evaluations

- Statistical analyses only evaluate reliability of model for data used in its development
- A model can be statistically valid but not representative of actual deterioration patterns of network if poor quality data are used

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Reliability of Performance Models

- Network Level
- Project Level

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Reliability of Performance Models

Regression Parameter Expectations				
PMS Analysis Level	**R^2**	**RMSE**	**Sample Size**	**# of Independent Variables**
Network	Medium to Low	Medium to Low	Large Sample	>1
Project	High	Low	Small Sample	1

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Update Requirements

- **Performance models must be updated regularly to continue to reflect deterioration patterns**
- **Feedback loops should be established to link deterioration models with engineering practices.**

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Examples

- **Washington DOT**
  - Deterministic models
- **Illinois DOT**
  - Deterministic models

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Washington State DOT

- **Priority programming process**
- **Developed in-house**
- **Prediction models developed for combined ratings**
- **Raw distress severity and extent data are stored so models can be modified as needed**
- **Capabilities exist for statistical analysis of performance trends**
- **Performance models for individual sections**

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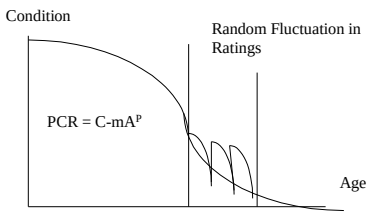
WSDOT Model Form



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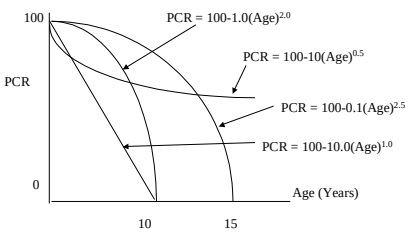
Fluctuations in Degree of Curvature in WSDOT Models



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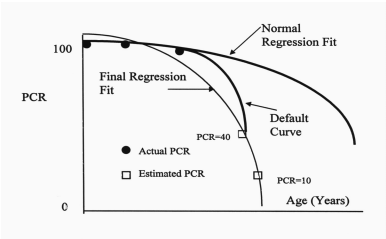
Over Estimation of Performance



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Illinois DOT Deterministic Models

- **Condition Rating Survey (CRS)**
  - 1.0 to 9.0
  - Type, severity, and extent of 5 predominant distress
- **Automated the CRS Process**
  - Safety of expert panel
  - Reduction in staff
  - PaveTech vans purchased
  - Calculation of CRS value

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IDOT Family Models

System	Surface	District	Total
Interstate	Composite (2)	1-4 5-9	4
	Concrete (2)	1-4 5-9	4
Non-Interstate	Flexible (3)	1-4 5-9 (1-9)ST	3
	Overlays (5)	1-4 5-9 (1-9)CRC	9
	Concrete (4)	1-4 5-9	8
SMART	Flexible & OL (4)	All	4

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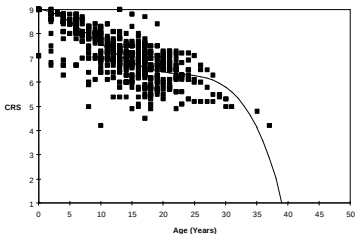
IDOT Polynomial Approach



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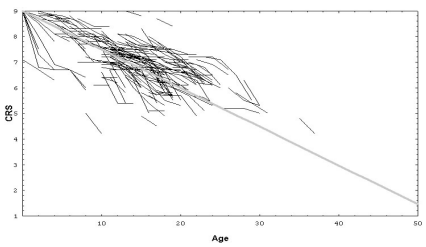
IDOT Trajectories



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D-Crack Adjustments

- **Asphalt concrete overlays: deducts increased by 20%**
- **Jointed reinforced concrete: deducts increased by 20%**
- **CRCP: deducts increased by 50%**

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