Performance Modeling Decision Trees

2002 Southeastern Conference
Pavement Management & Design
Nashville, TN
June 23 - 26, 2002

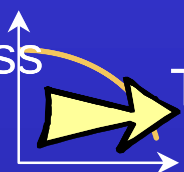
Presented by:

Adel Hedfi
Axiom Decision Systems, Inc.

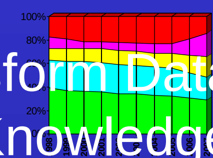
Maryland State Highway Administration

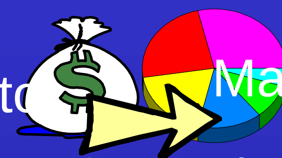
Pavement Management

Synthesize & Harness Data with State Expertise



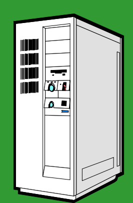
Transform Data into Knowledge





Make Better Decisions about Pavement Maintenance

Data



State Expertise

Performance Modeling

Planning Analysis

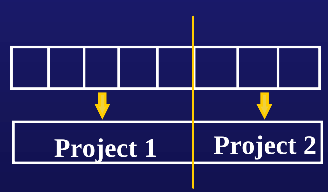
Network Optimization

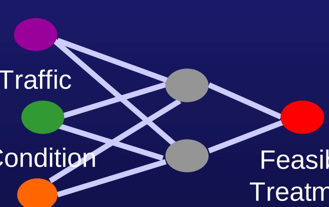
Management Process

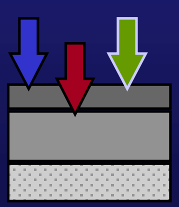
Project Selection

Treatment Assignment

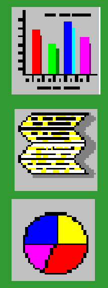
Life Cycle Analysis







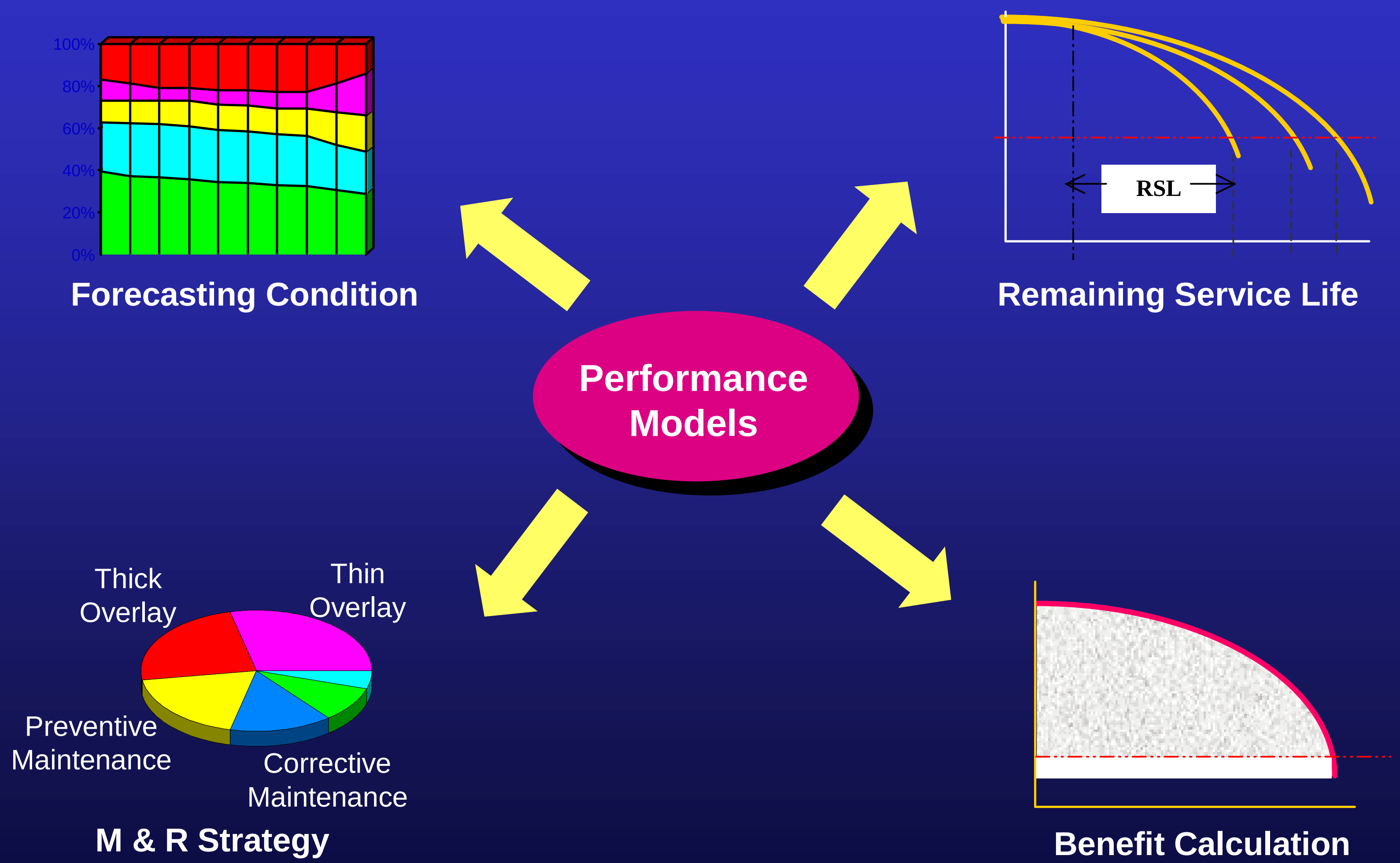
Decisions



Reports

Performance Modeling and Decision Trees

Utility of Models



Examining the Modeling Alternatives

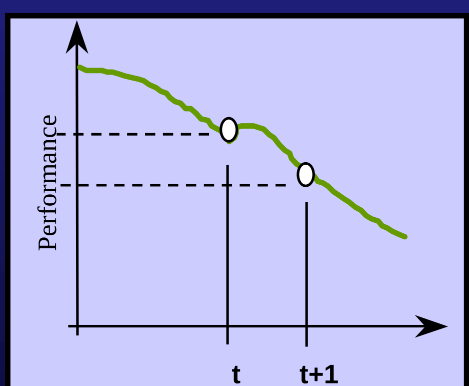
Pavement Performance

- Structure
- Traffic
- Environment
- Soil Type
- Const. Quality
- Moisture
- others

- Array of Parameters
- Complex
- Uncertainty

M&R Action

Deterministic



initial

Initial Condition

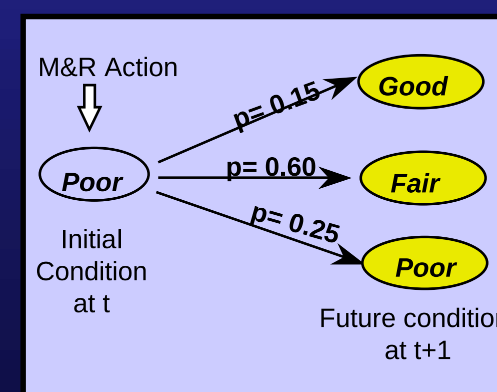
initial

future

Predicted Condition

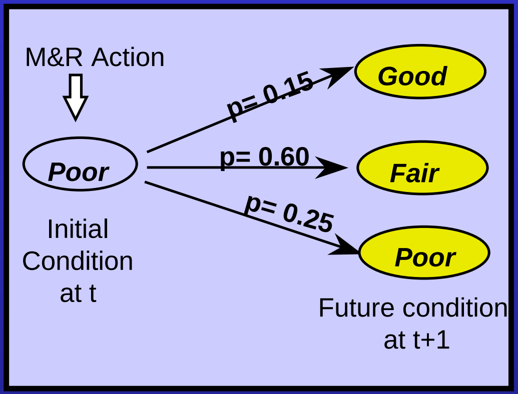
future

Probabilistic



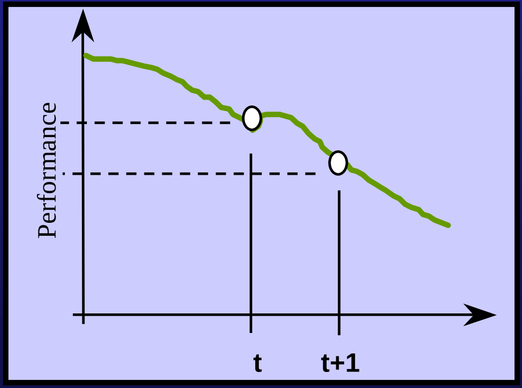
Modeling Choice: Probabilistic or Deterministic?

Probabilistic (TPMs)



- Simulate the uncertainty in pavement behavior
- Statewide Planning and allocation of funds
- Forecasting at the Network Level
- Optimization using Linear Programming

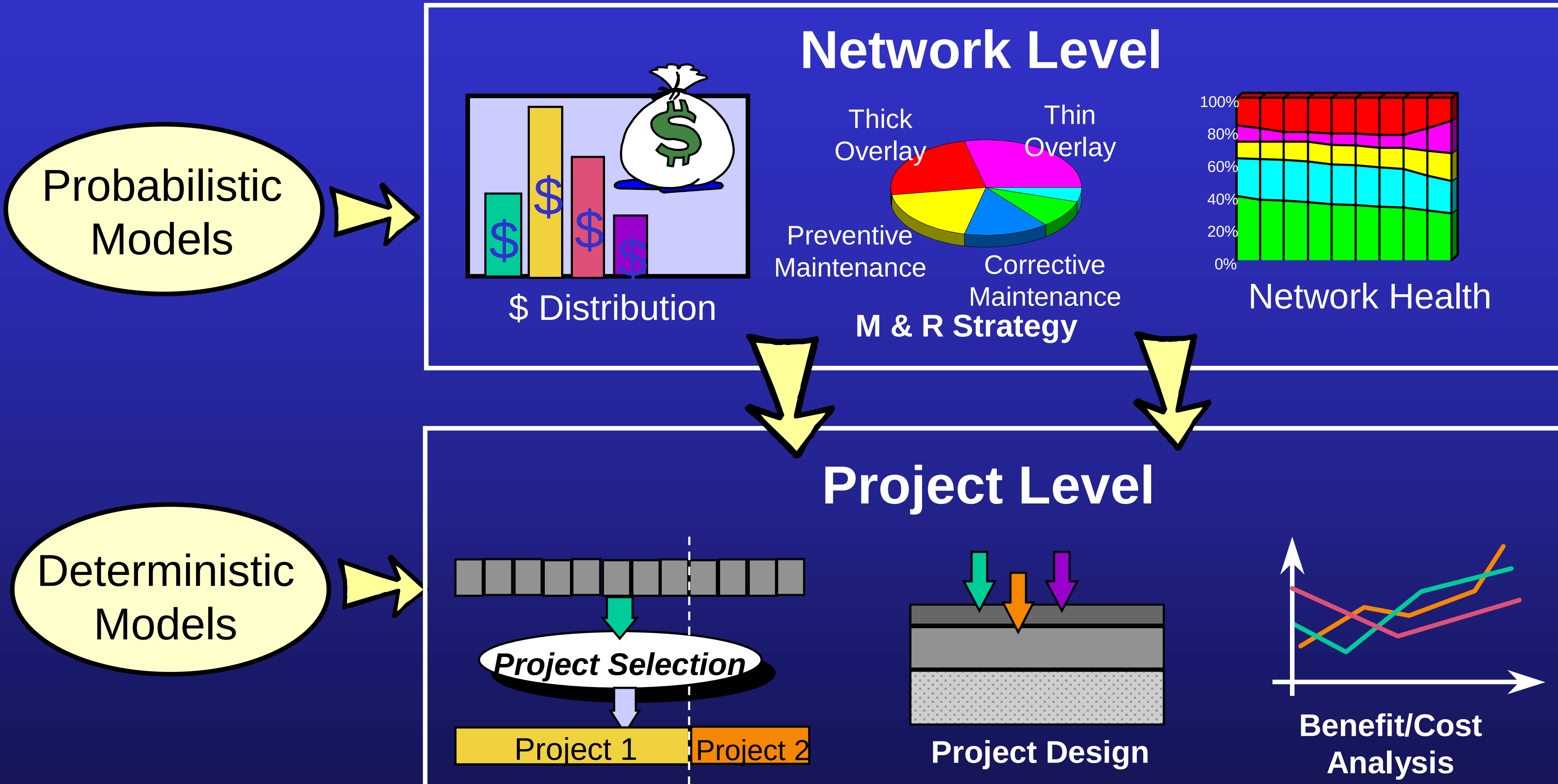
Deterministic (Curves)



- Quantify benefits
- Calculate remaining service life
- Forecasting at project level
- Visual representation

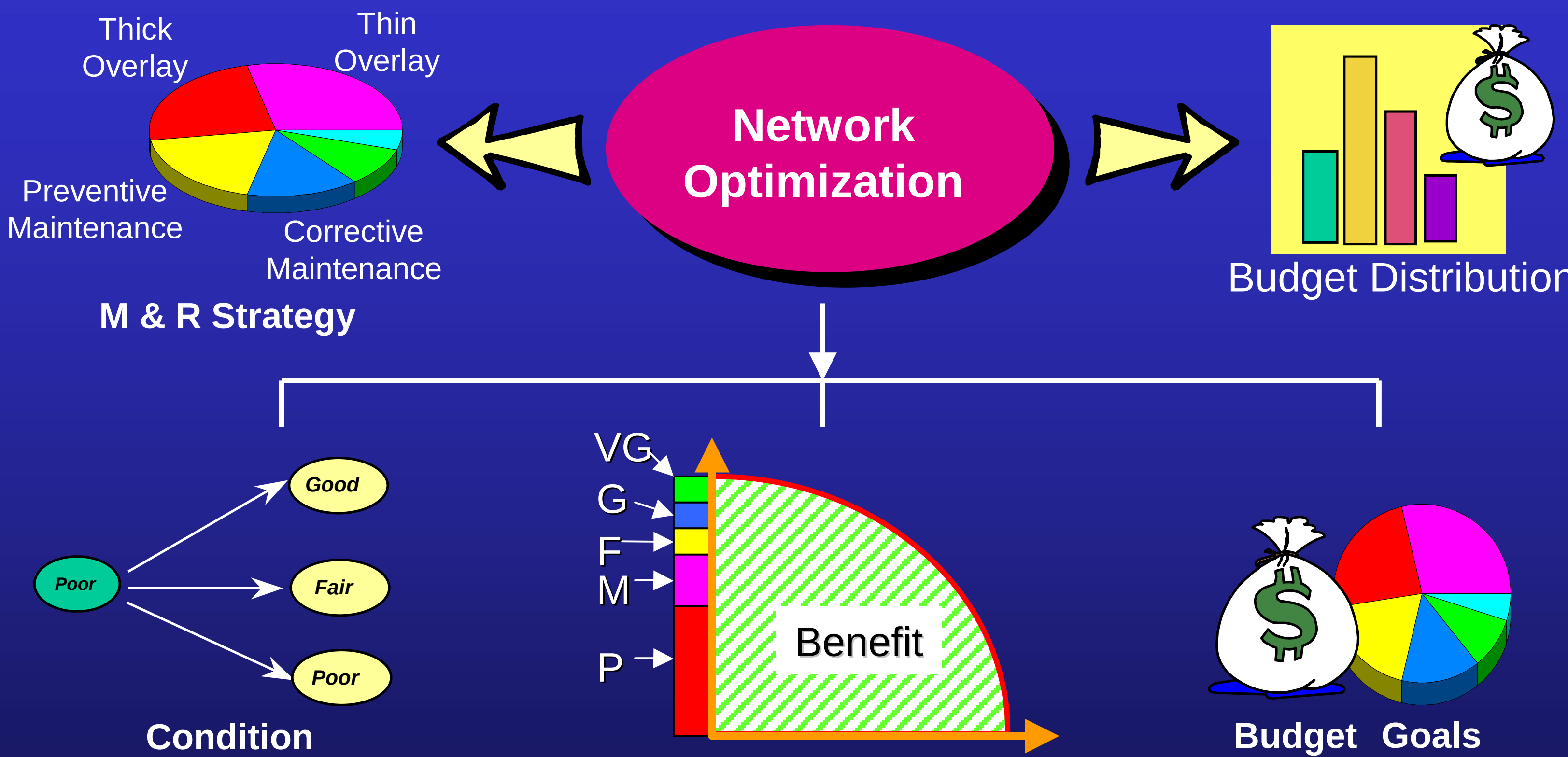
Both Probabilistic and Deterministic Models are Needed

Using Both Types of Models



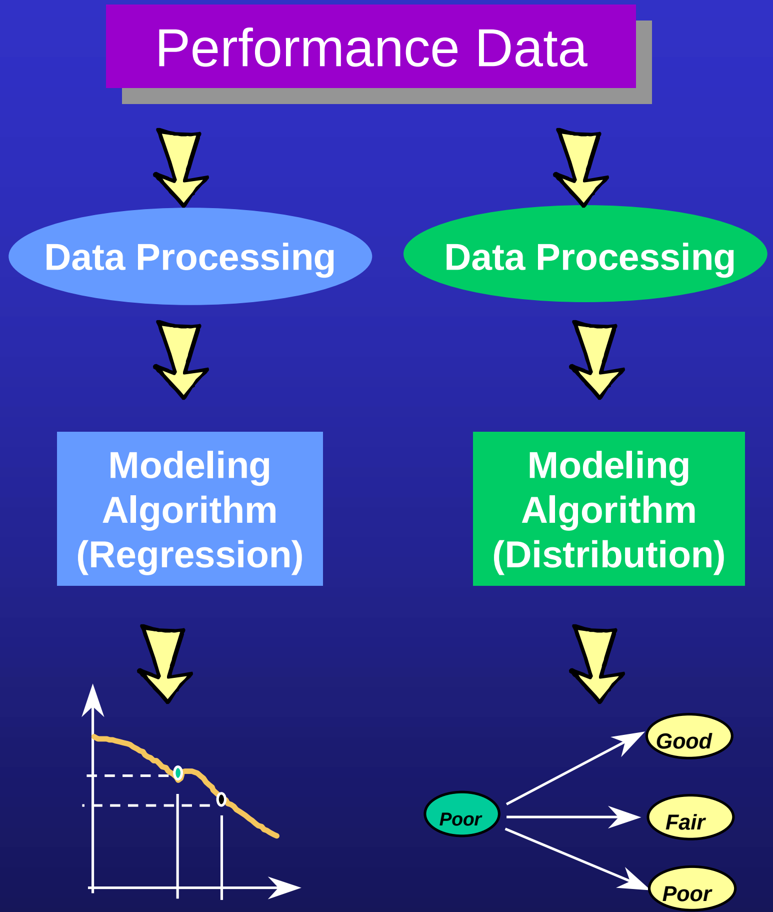
Probabilistic and Deterministic Models Must Provide Equivalent Prediction Capabilities

Using Both Types of Models

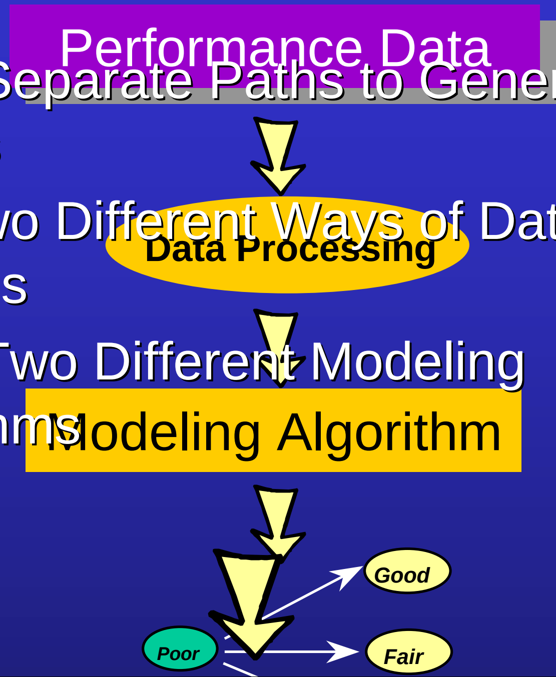


Probabilistic and Deterministic Models Must be in Synch to Provide Equivalent Prediction Capabilities

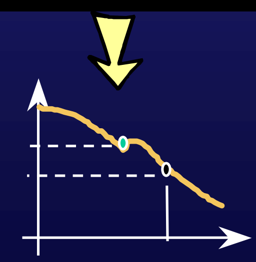
Approach to Synchronize Models



- Take Separate Paths to Generate Models
- Use Two Different Ways of Data Analysis
- Apply Two Different Modeling Algorithms



- Two Different Interpretations of Performance
- Prediction Models not in Synch

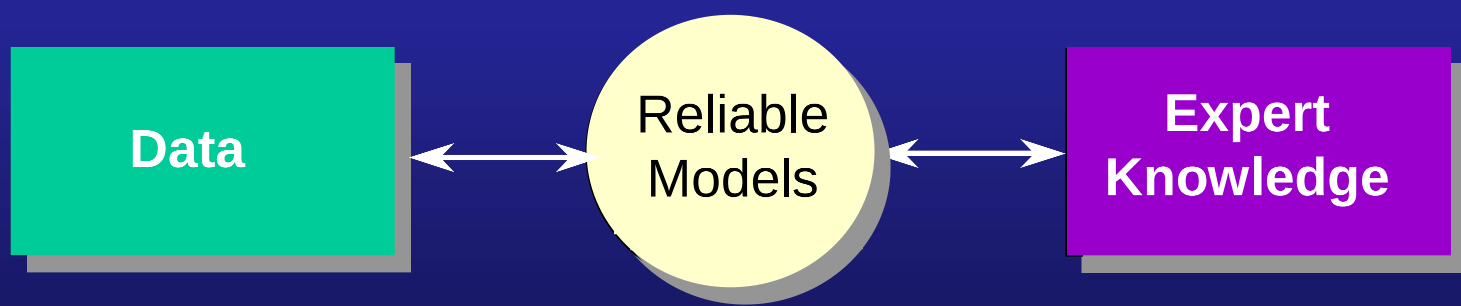


Develop a <u>Single</u> Process to Create Both types of Models

Dealing with Reliability

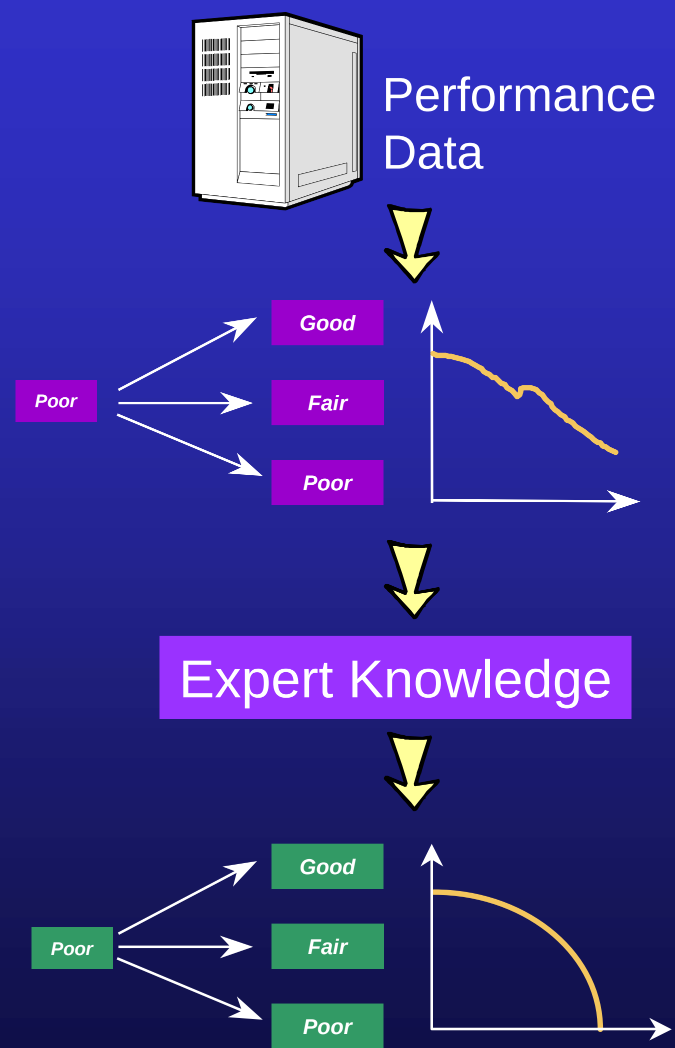
Our Definition:

"A reliable model is one that provides a true representation of the performance trends embedded in the **data** and is consistent with **expert knowledge**."



Merge Data with Expert Knowledge
Into the Modeling Process

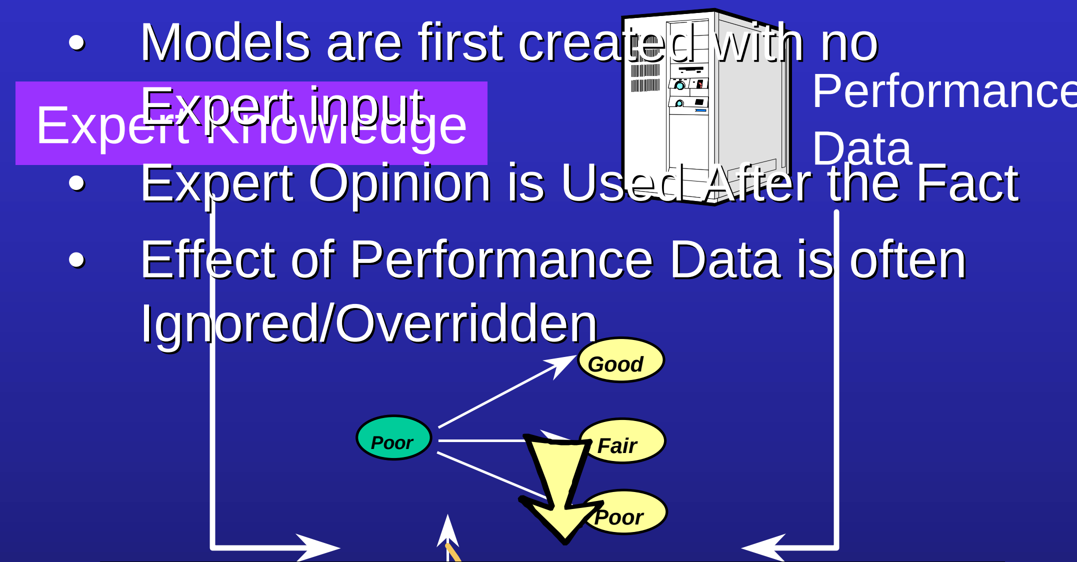
Combining Data and Expert Knowledge



Sequential Approach

Parallel Approach

- Models are first created with no Expert input
- Expert Opinion is Used After the Fact
- Effect of Performance Data is often Ignored/Overridden



- Models not driven by Performance Data

Generate models that preserve the trends in the data and <u>simultaneously</u> comply with expert knowledge

Interpreting Expert Knowledge

Expert Knowledge

	VG	G	F	M	P
VGood	0.85	0.09	0.03	0.02	0.01
Good	0.00	0.73	0.22	0.04	0.01
Fair	0.00	0.00	0.71	0.24	0.05
Mediocre	0.00	0.00	0.00	0.75	0.25
Poor	0.00	0.00	0.00	0.00	1.00

<u>Limitations of Traditional Approach</u>

- Capturing expert input in probabilities is not practical
- Tedious/very demanding process
- Input Varies from one expert to another

We are soliciting information from experts in the wrong format.

Gather information in a format that experts can relate to.

Acquiring Data for Model Development

Soliciting Information from Experts

<u>Questions to ask Experts:</u>

1. What life would you expect from an action?
2. What is the life duration in each condition state?

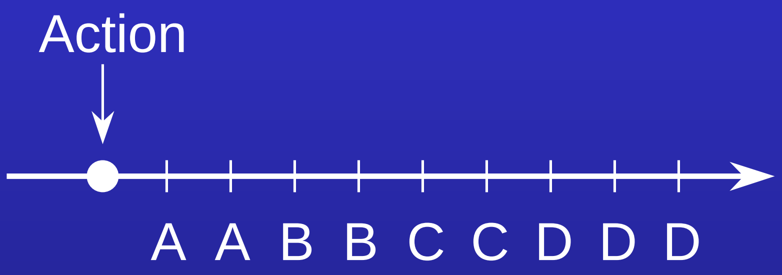
<u>Example:</u>

After a Thin Overlay:

1. 8 years of life
2. State / Life

State	Life
Excellent	2 years
Very Good	3 years
Good	1 year
Fair	2 years

Extracting Information from Data



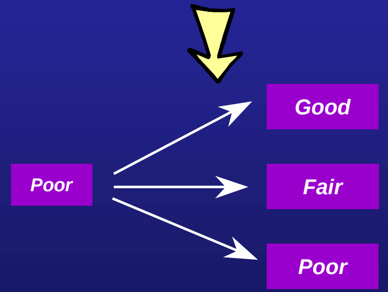
State	Life
Excellent	2 years
Very Good	2 years
Good	2 years
Fair	3 years

Extract information from experts and data records using life frequencies

Dealing with Minor Maintenance

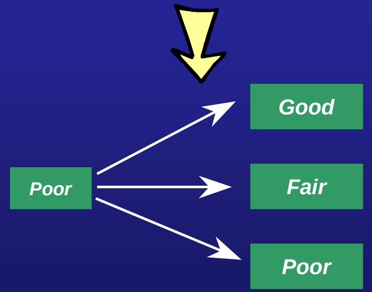
- No Maintenance

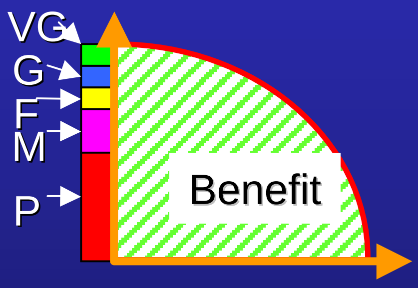
Condition	Life
V Good	1 years
Good	3 years
Fair	2 years
Mediocre	2 years
Total:	**8 Years**



- Maintenance

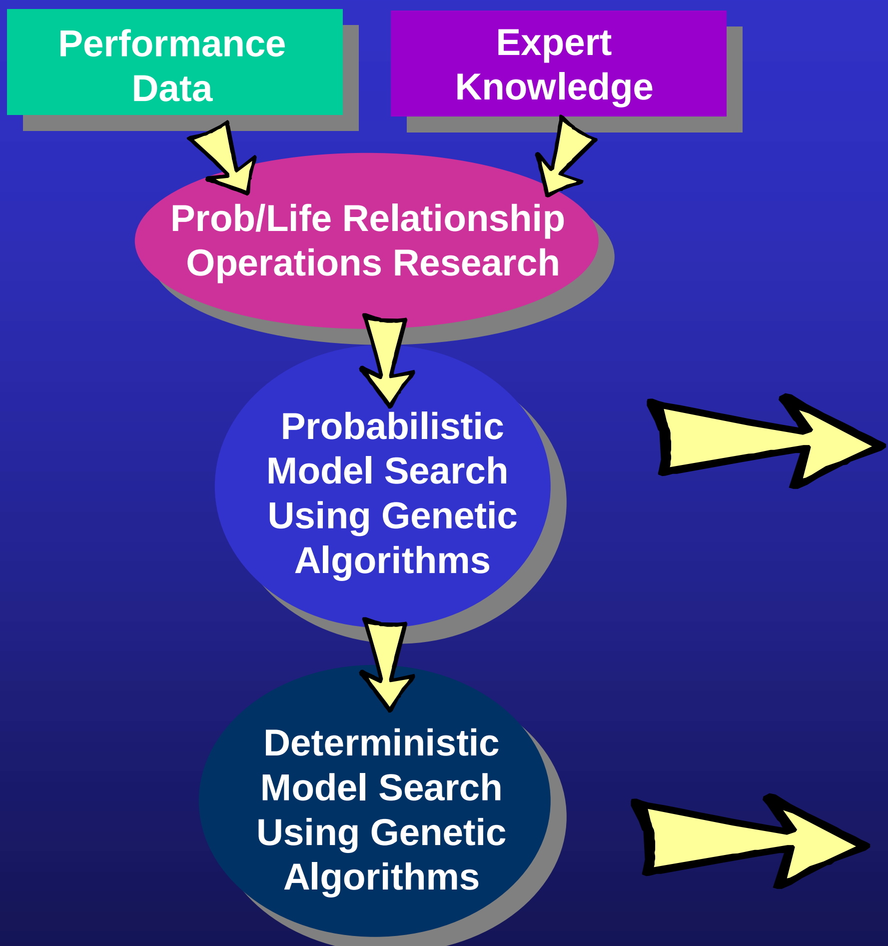
Condition	Life
V Good	1 years
Good	4 years
Fair	3 years
Mediocre	2 years
Total:	**10 Years**





Apply Concept of Life Frequencies to Capture the impact of Minor Maintenance

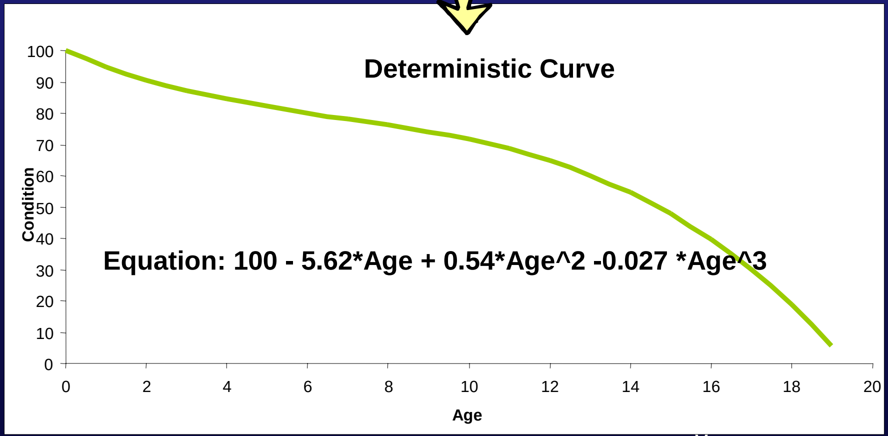
Developing Models from Acquired Data



Condition	Life
V Good	2 years
Good	1 years
Fair	3 years
Mediocre	2 years

Condition	Life
V Good	1 years
Good	3 years
Fair	2 years
Mediocre	2 years

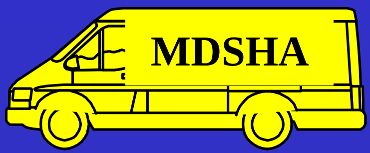
	VG	G	F	M	P
VGood	0.85	0.09	0.03	0.02	0.01
Good	0.00	0.73	0.22	0.04	0.01
Fair	0.00	0.00	0.71	0.24	0.05
Mediocre	0.00	0.00	0.00	0.75	0.25
Poor	0.00	0.00	0.00	0.00	1.00



OR & AI technology is applied to create models from the life frequencies format

Example Models

Expert Knowledge

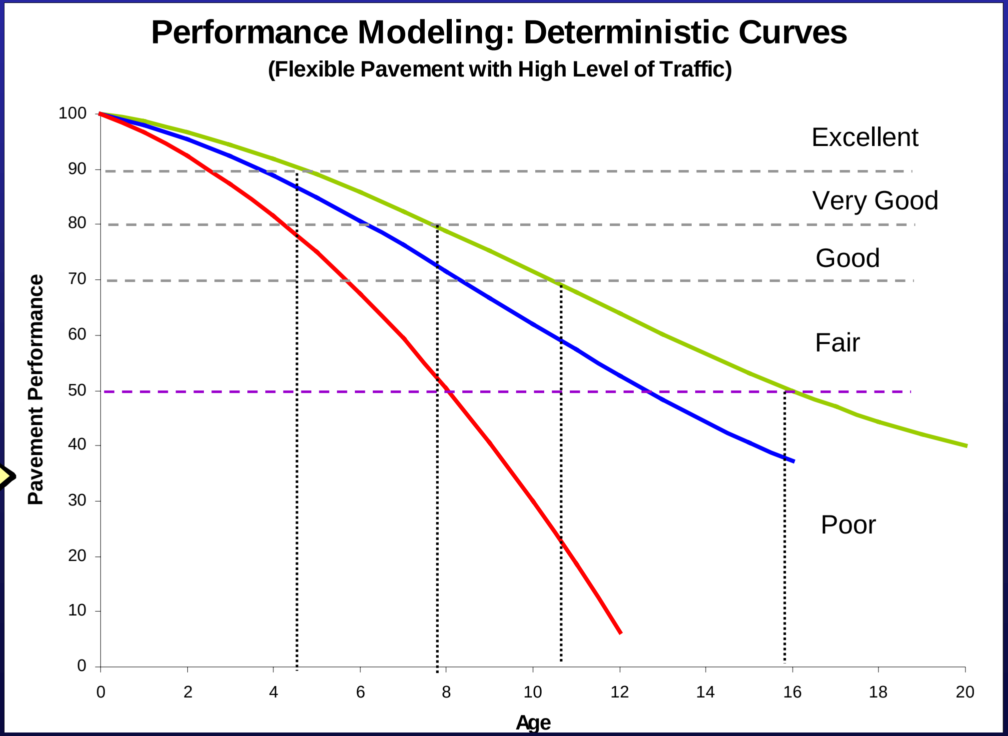


Performance Data

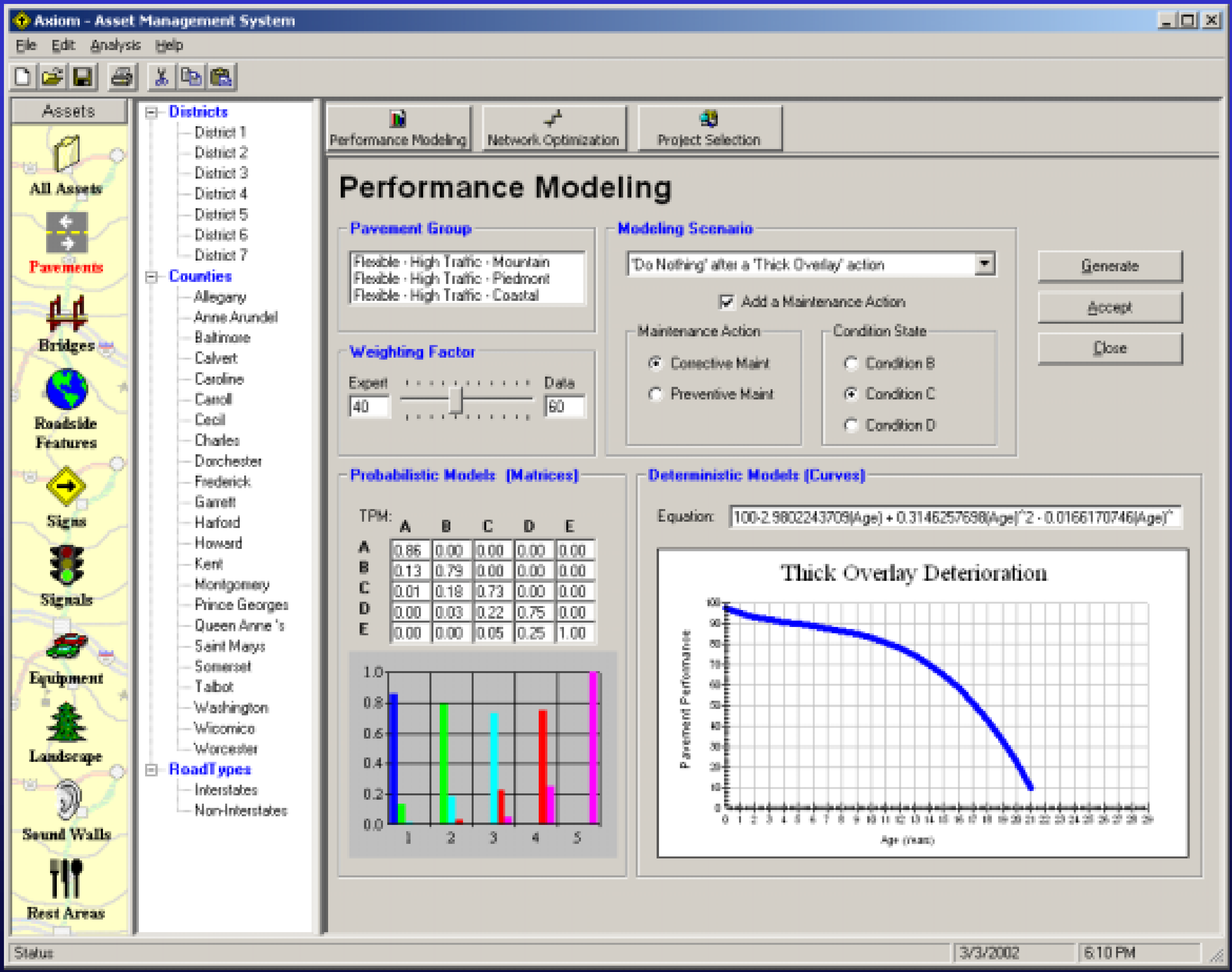
	Thick Overlay	Medium Overlay	Thin Overlay
A- Excellent	4.5	3.5	2
B - Very Good	3.5	2	1.5
C - Good	3	2.5	2
D - Fair	4.5	4	2.5
Total	15.5	12	8

Thick Overlay Matrix

	A	B	C	D	E
A	0.85	0.09	0.03	0.02	0.01
B	0.00	0.73	0.22	0.04	0.01
C	0.00	0.00	0.71	0.24	0.05
D	0.00	0.00	0.00	0.75	0.25
E	0.00	0.00	0.00	0.00	1.00

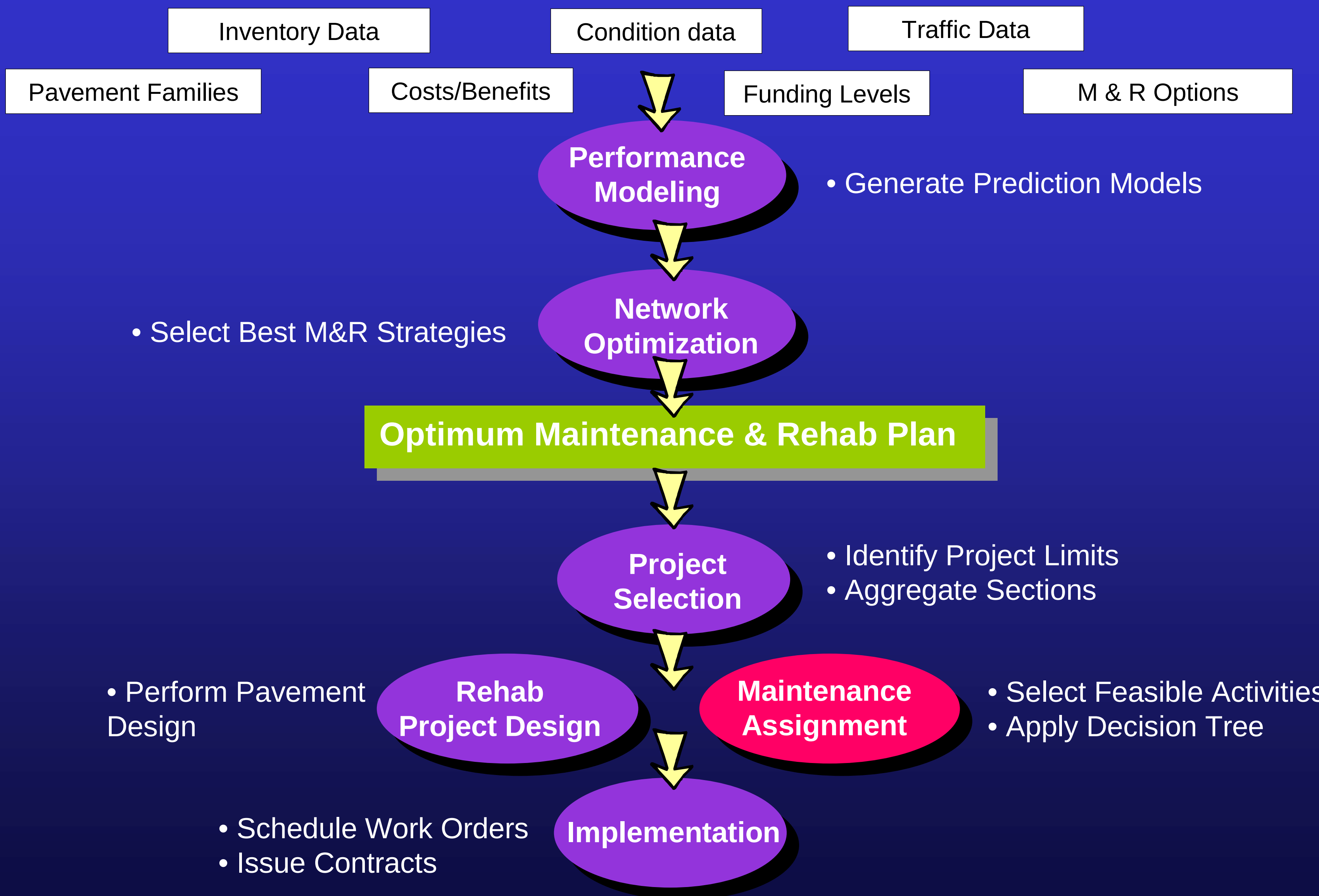


Performance Modeling: The Application



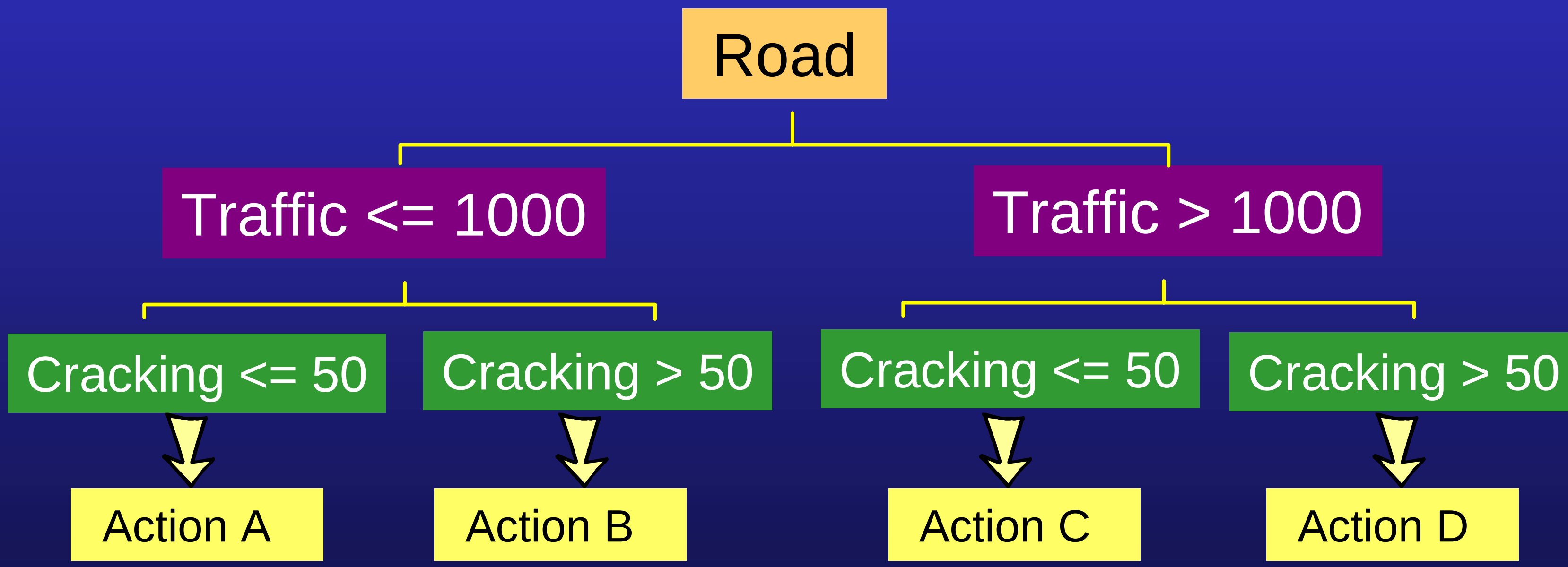
TPM:	A	B	C	D	E
A	0.86	0.00	0.00	0.00	0.00
B	0.13	0.79	0.00	0.00	0.00
C	0.01	0.18	0.73	0.00	0.00
D	0.00	0.03	0.22	0.75	0.00
E	0.00	0.00	0.05	0.25	1.00

PMS: Analysis Process

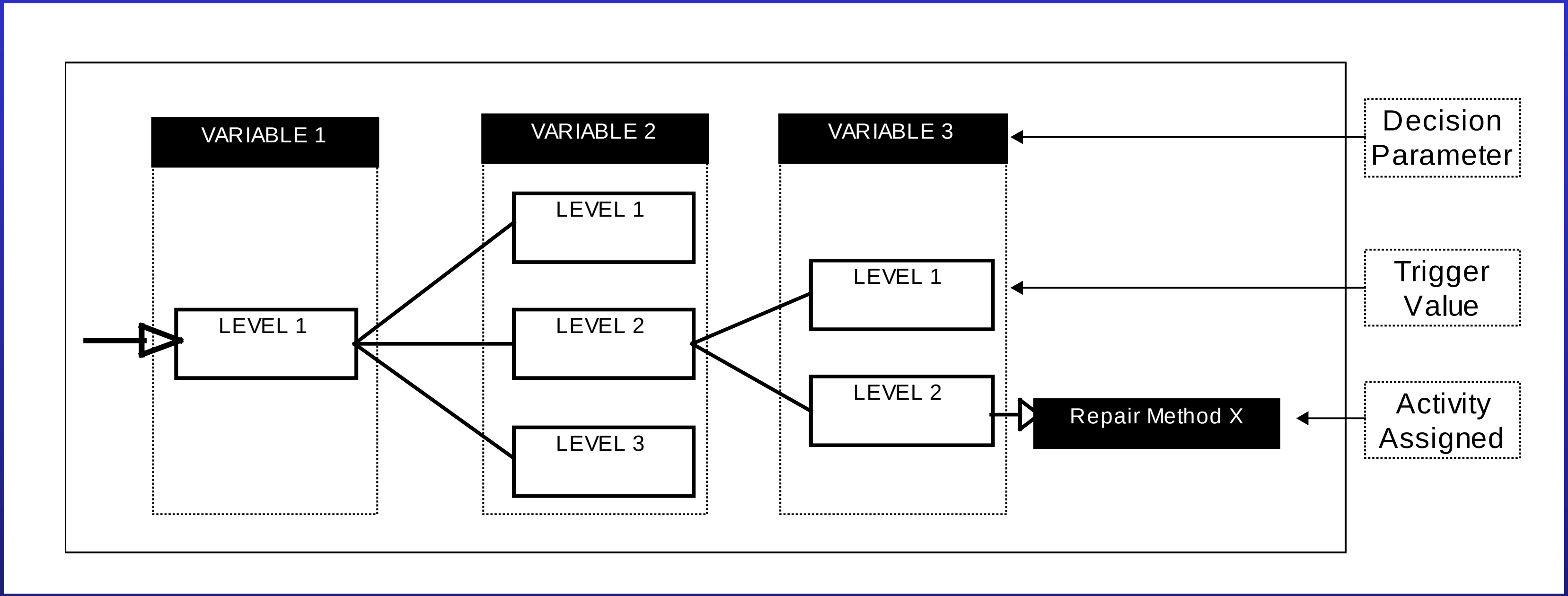


Utility of Decision Trees

- Identify Appropriate Maintenance Activities
- Mimic the Selection Rules Practiced by the State

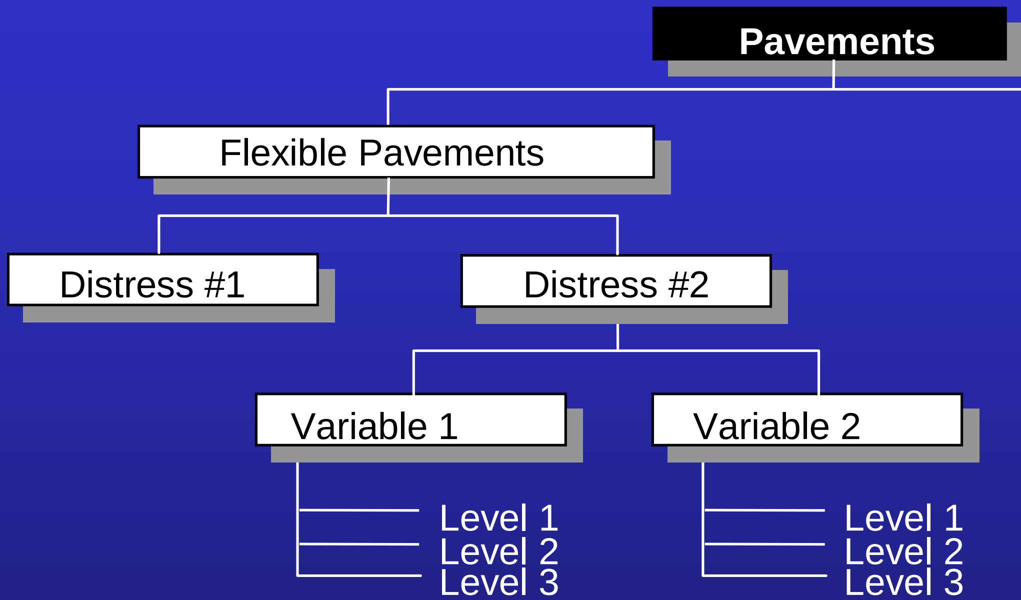


Building Blocks of Decision Trees



- Selection of the Decision Parameters
- Specification of the Threshold/Trigger Values
- Assignment of Repair Activities

Decision Tree Design



IF Pavement = Flexible
AND IF Distress = Distress 1
AND IF Variable = Variable 2
AND IF Level = Level 1
THEN Repair Method = Activity A

Traditional Decision Tree Process Uses Hard Coded IF_THEN Rules

Tree Can't be Updated/Modified without Coding

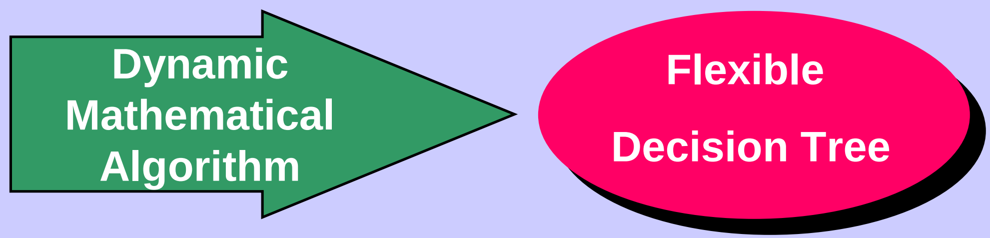
Need a Flexible Decision Tree Builder that Does Not Rely on Hard Coded Rules

Flexible Decision Tree Design

• Represent Decision Trees with a set of Mathematical Equations Instead of IF-Then Rules

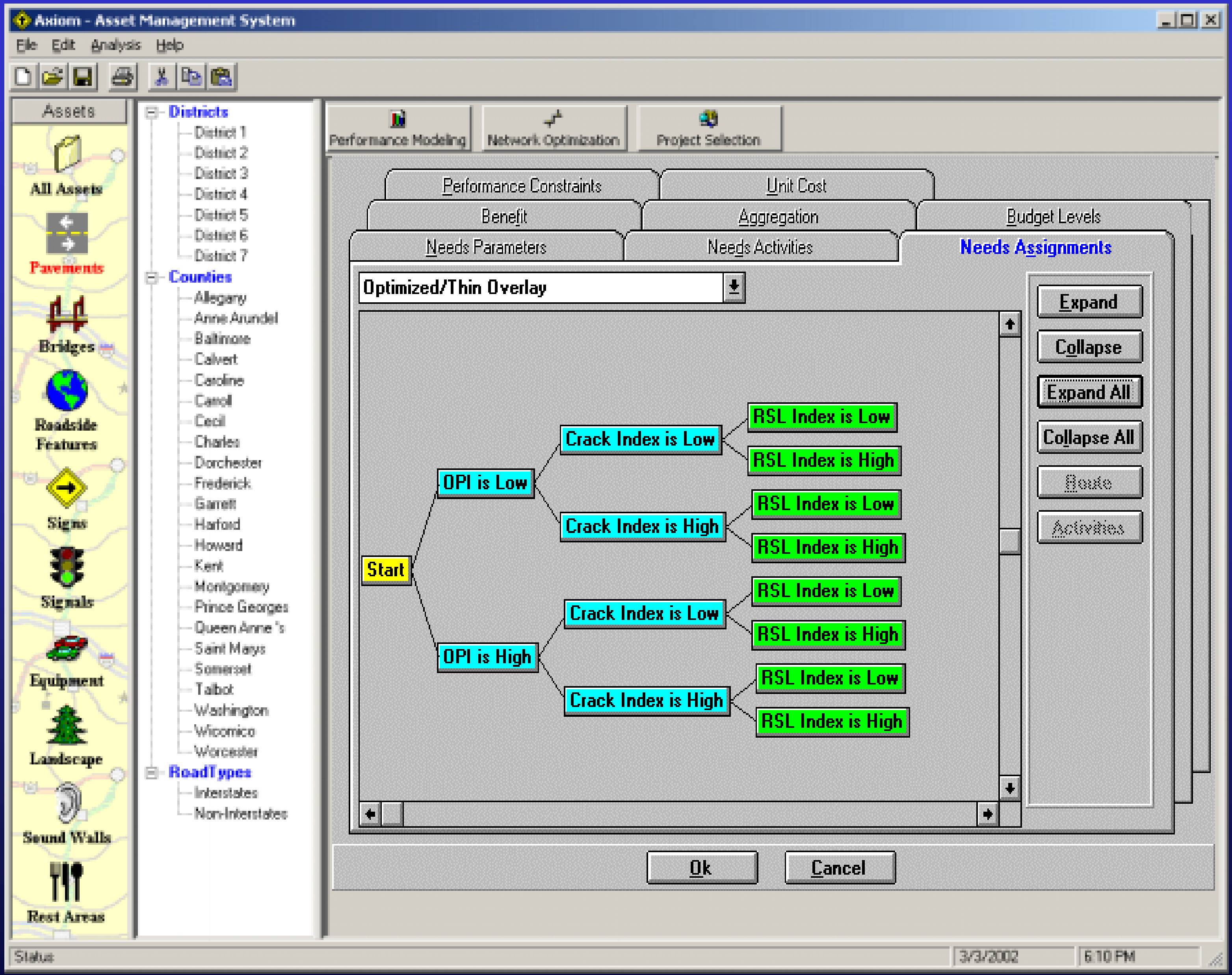
• Equations Adapt Dynamically to accommodate building and modifying Decision Trees

• Decision Parameters
• Threshold & Levels
• Repair Methods



An Adaptive Rule-Based Decision Tool that Evolves with Users Needs

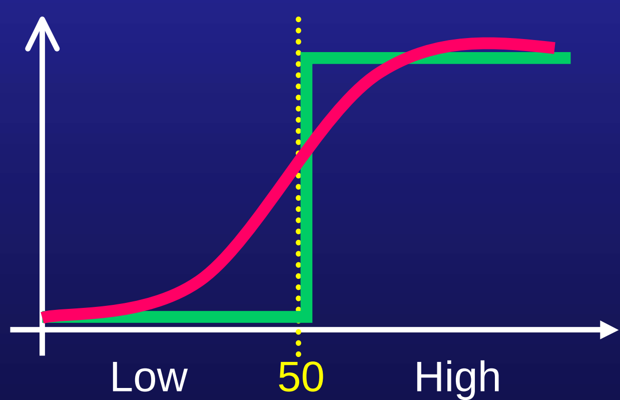
Decision Trees: The Application



Work in Progress: Enhancing the Decision Process

- Build Smarter Decision Trees to Select Maintenance Activities

Road
- Traffic <= 1000
  - Cracking <= 50 → Action A
  - Cracking > 50 → Action B
- Traffic > 1000
  - Cracking <= 50 → Action C
  - Cracking > 50 → Action D



Empowering the Decision Trees with Fuzzy Logic

Thank you…

AXIOM DECISION SYSTEMS

SHA Maryland State Highway Administration