Introduction to Mechanistic-Empirical Asphalt Pavement Design and Why it Needs Validation

by Dr. Charles Dougan

PMS- Conference Workshop

Norfolk, Virginia, May 6, 2007

Outline

- Background
- Pavement types; levels of analysis
- Inputs
  - Climate/Environment
  - Traffic
  - Materials
  - Reliability and construction Considerations

Outline (cont.)

- Structural analyses-new design
- Distress estimates
- Structural section selection
- Rehabilitation (not discussed)
- Low volume roads (not discussed)
- Calibration considerations

Why M-E Design?

- Better utilize available materials
- Assess changed traffic loading expeditiously
  - New axle and gear configurations
  - New tire designs and increased tire pressures
- Quickly assess behavior of new materials
- Improve reliability of performance prediction
- Assess impacts of construction on pavement performance

Pavement Types

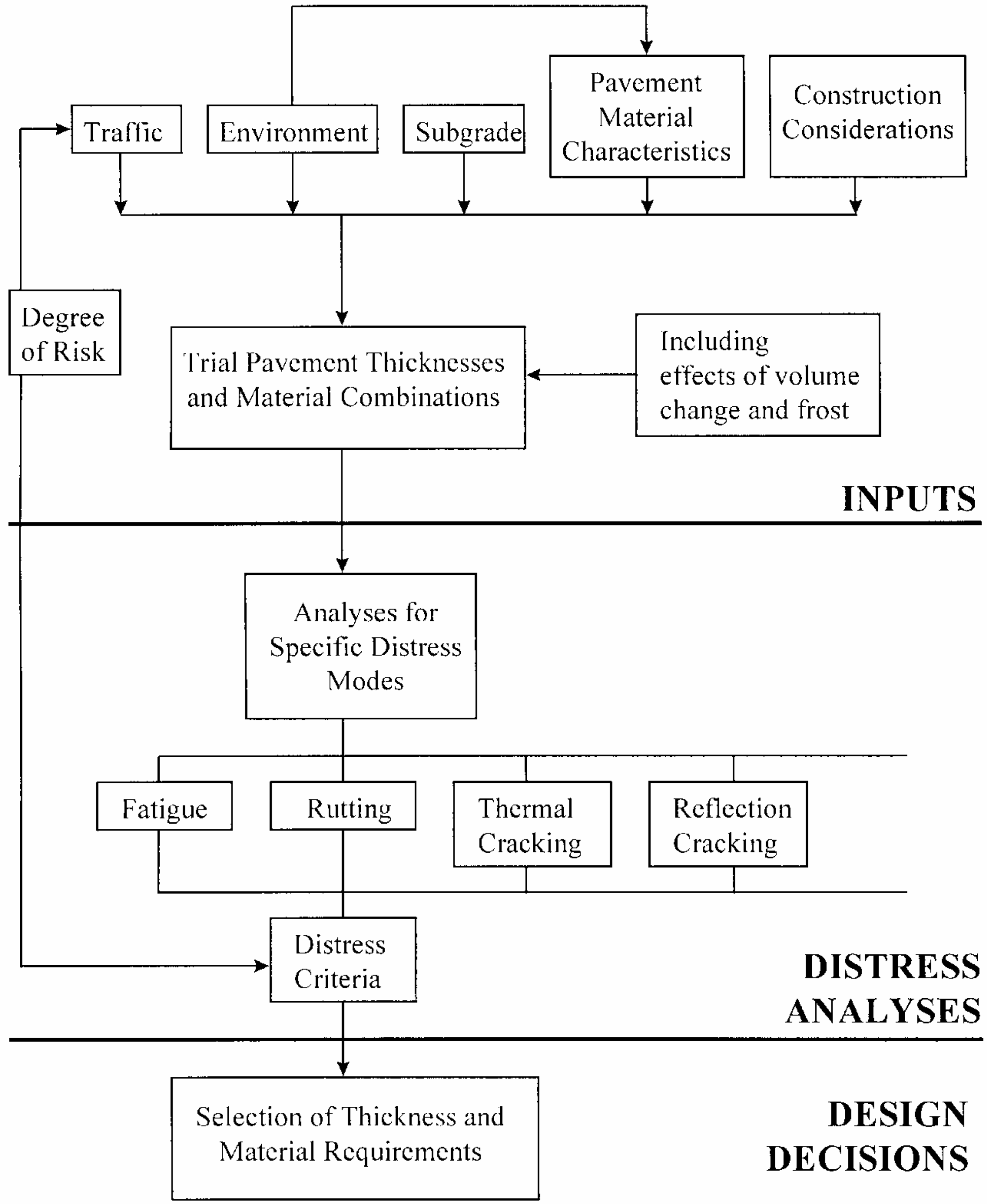
- Flexible (asphalt) pavements
  - Conventional (HMA, unbound base and subbase)
  - Deep strength and full depth HMA
  - Semi-rigid and inverted (with asphalt or cement treated)
- Rigid (concrete) pavements
  - Jointed plain concrete (JCPC)
  - Continuously reinforced (CRCP)
  - Shoulders (HMA, tied PCC, widened lane)

Design Input Levels

- Level 1
  – Use of site specific materials, environment, and traffic characteristics; material characteristics from laboratory tests
- Level 2
  – Use of less detailed information
- Level 3
  – Use of default values

M-E Pavement Design

(flexible pavement example)



Structural Analysis- New Design

- Pavement representation
  - Multilayer elastic system, flexible
  - Plate on dense liquid (Westergaard), rigid
- Multilayer Elastic System
  - Representation used at this time for flexible pavement analysis
  - E and ν required for each layer
  - circular loaded areas, uniform contact pressure
  - full friction between layer interfaces

Structural Analysis

- **Inputs**
  - layer thicknesses
  - E and n values for each layer
    - for AC layer(s) time of loading and temperature govern E value used
    - seasonal variations in E values for untreated aggregates and fine-grained soils
  - axle configuration and tire spacing
  - tire loads and pressures
- **Outputs**
  - Stress,σ; strain,ε; and deflection,δ

Distress Analyses and Ride Quality (flexible pavement)

- Cracking
  - AC: fatigue
    - bottom up
    - top down
- Permanent deformation (rutting)
- Low temperature cracking
- Smoothness (IRI)

Distress and Ride Criteria (rigid pavement)

- Rigid pavements (e.g. jointed, plain concrete)
  - Fatigue cracking (transverse)
  - Faulting
- Smoothness
  - IRI
- Other rigid pavement types
  - CRCP (in design guide)

(N.B. PCC pavement deign not discussed in the presentation)

Construction Considerations

- Minimum layer thicknesses
  - Granular base/subbase; 6 in. min.
  - CTB; 4in. min. (preferably 6 in. min.)
  - AC; 3 x max. aggregate size min. lift thickness
- Compaction requirements
  - Granular layers
    - e.g., upper 6-12 in. at least 100% Modified AASHTO dry density
  - Subgrade
    - e.g. upper 24 in. 95% Modified AASHTO dry density

Need for Local Calibration and Validation

- Calibration and validation of the MEPDG by the developers based on results of the Long Term Pavement Performance (LTPP) Program.
- The correction factors which are included in the performance equations for both the rigid and flexible design methodologies must thus be modified to reflect local conditions for individual states

Need for Local Calibration and Validation

- This process includes considerations of local conditions and practices:
  - Environment
  - Traffic
  - Materials
  - Construction practices
  - Maintenance and rehabilitation practices

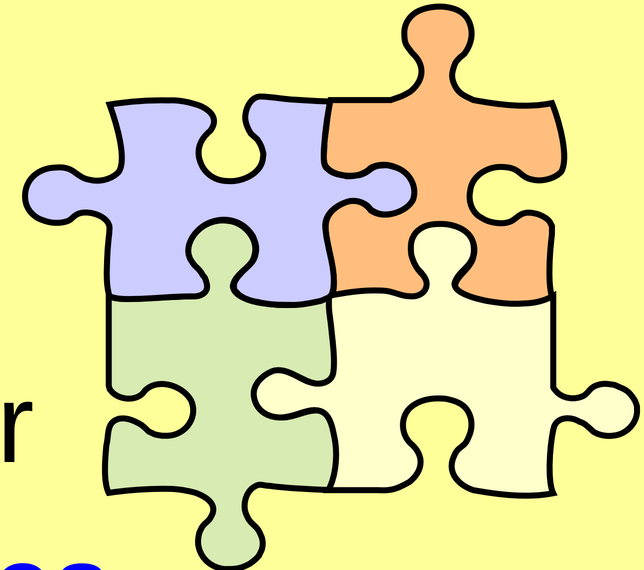
Need for Local Calibration and Validation

- This necessity for local calibration was emphasized by the developers of the MEPDG in the NCHRP 1-37A Report; e.g., Section 3.3.6.1 for flexible pavements and 3.4.9.1 for rigid pavements.
- The presentations to follow will provide guides for this to be accomplished.

Using PMS Data to Calibrate & Validate the New Guide (MEPDG)

- Study for FHWA by AgileAssets with:
  - Ronald Hudson, Charles Dougan, Carl Monismith and Pim Visser
  - FHWA participation by Steve Gaj, Sonya Hill, Kathy Petros, Leslie Myers & Gary Crawford
- DOT's of MS, WA, KS, and FL have been visited in 1st phase
- Great interest from States resulted in extension with visits to NC, PA, MN and NM

Pavement Management



Is a coordinated systematic process for carrying out all activities related to providing pavements

Pavement Management System

Rational procedures that provide optimum pavement strategies based on predicted pavement performance incorporating feedback regarding the various attributes, criteria, and constraints involved.

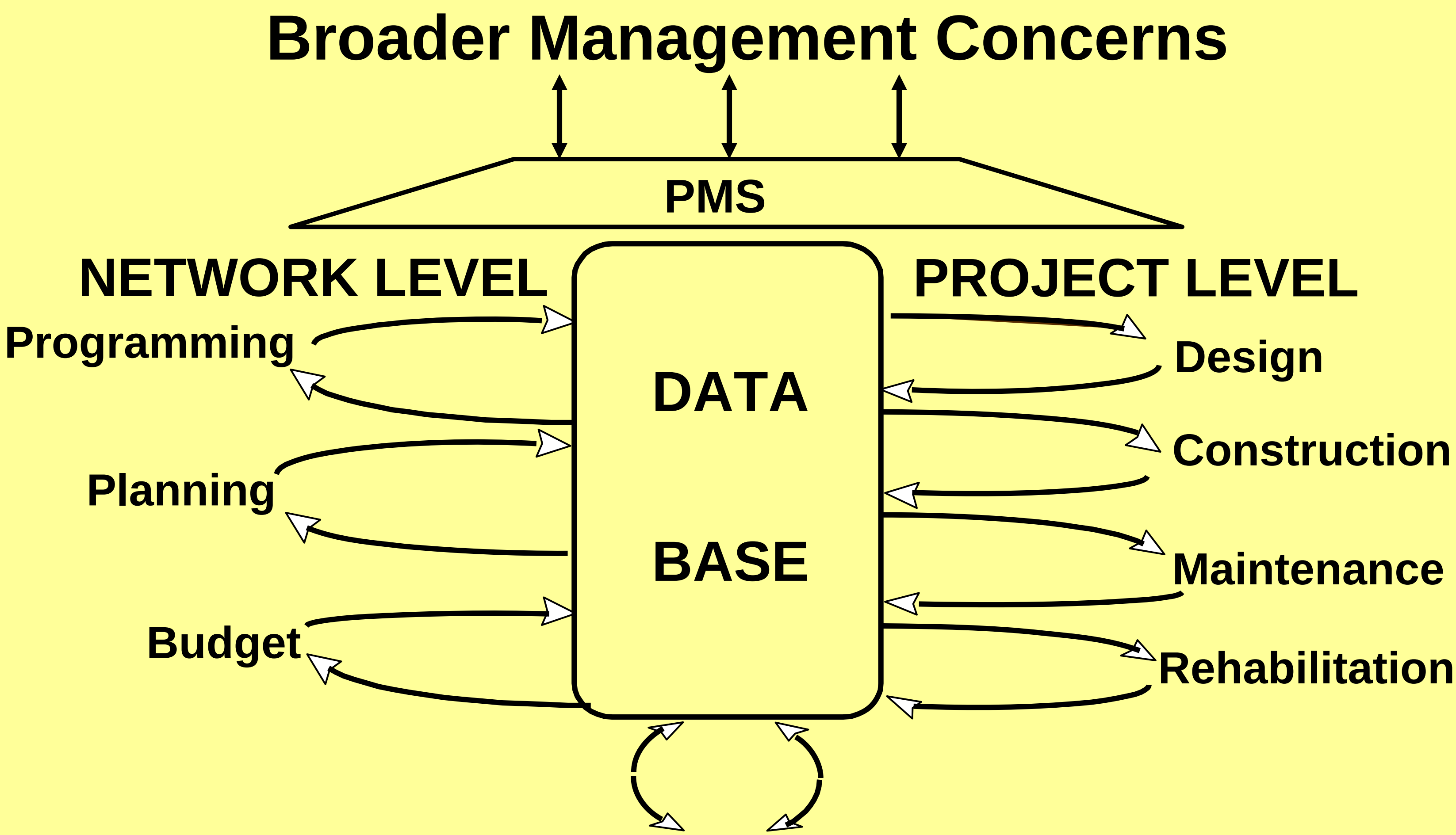
Let's Review Pavement Management

- Formalization of pavement decision making
- Entire process to provide quality pavements
- Strong emphasis on economics
- Involves all associated groups
  - Planning, Design, Construction, Maintenance, Materials, Field Groups.
- Uses advanced tools and analysis techniques

General Structure of Systematic Pavement Management :

Coordinated modules at several organizational levels accessing a common database

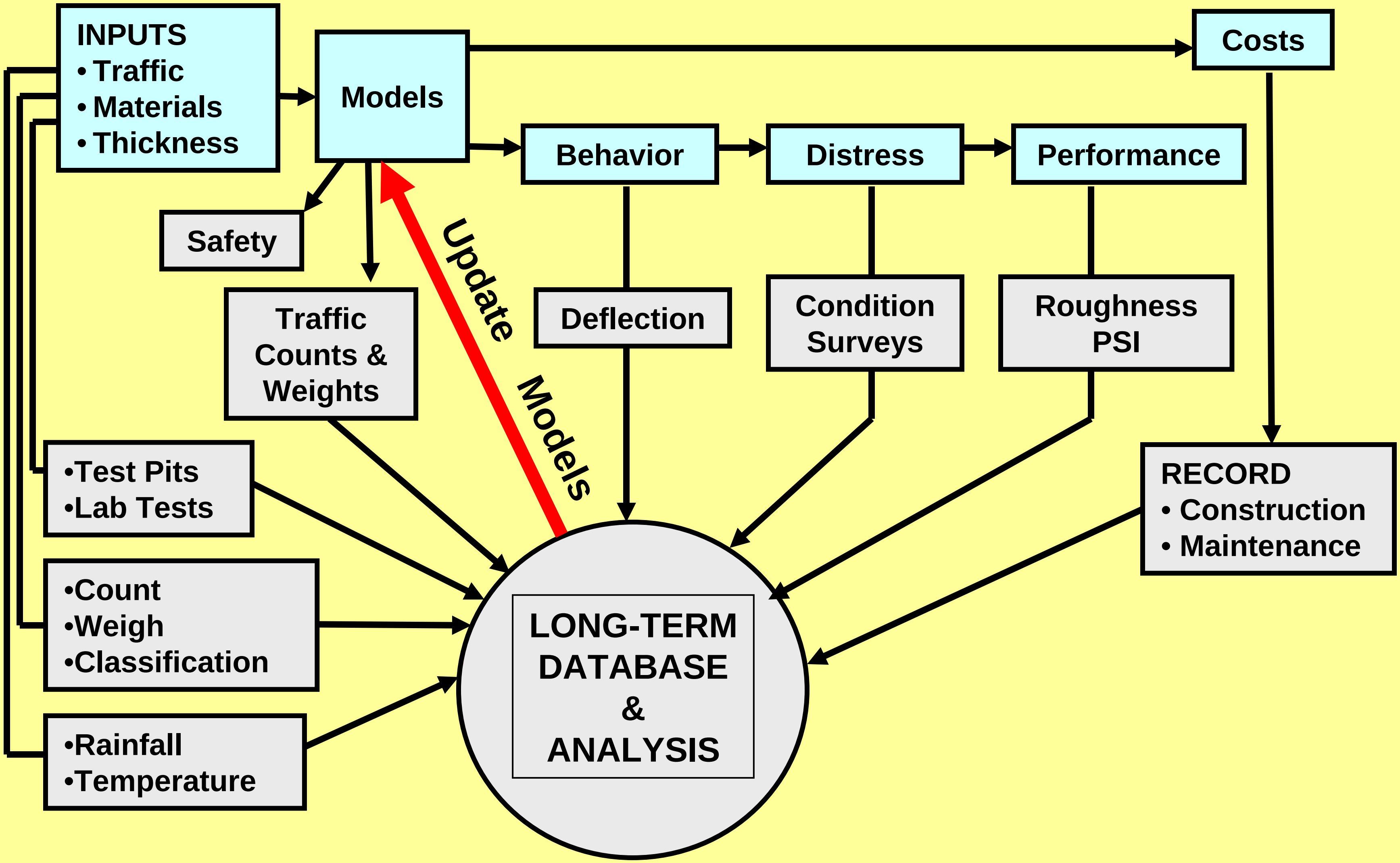
Components of PMS



Engineering Applications
Research - Special Studies

Purpose of PMS Engineering Analysis

The use of pavement management data to evaluate and improve **structural designs**, materials, mix designs, construction, preservation strategies, rehabilitation, and preventive maintenance of pavements.

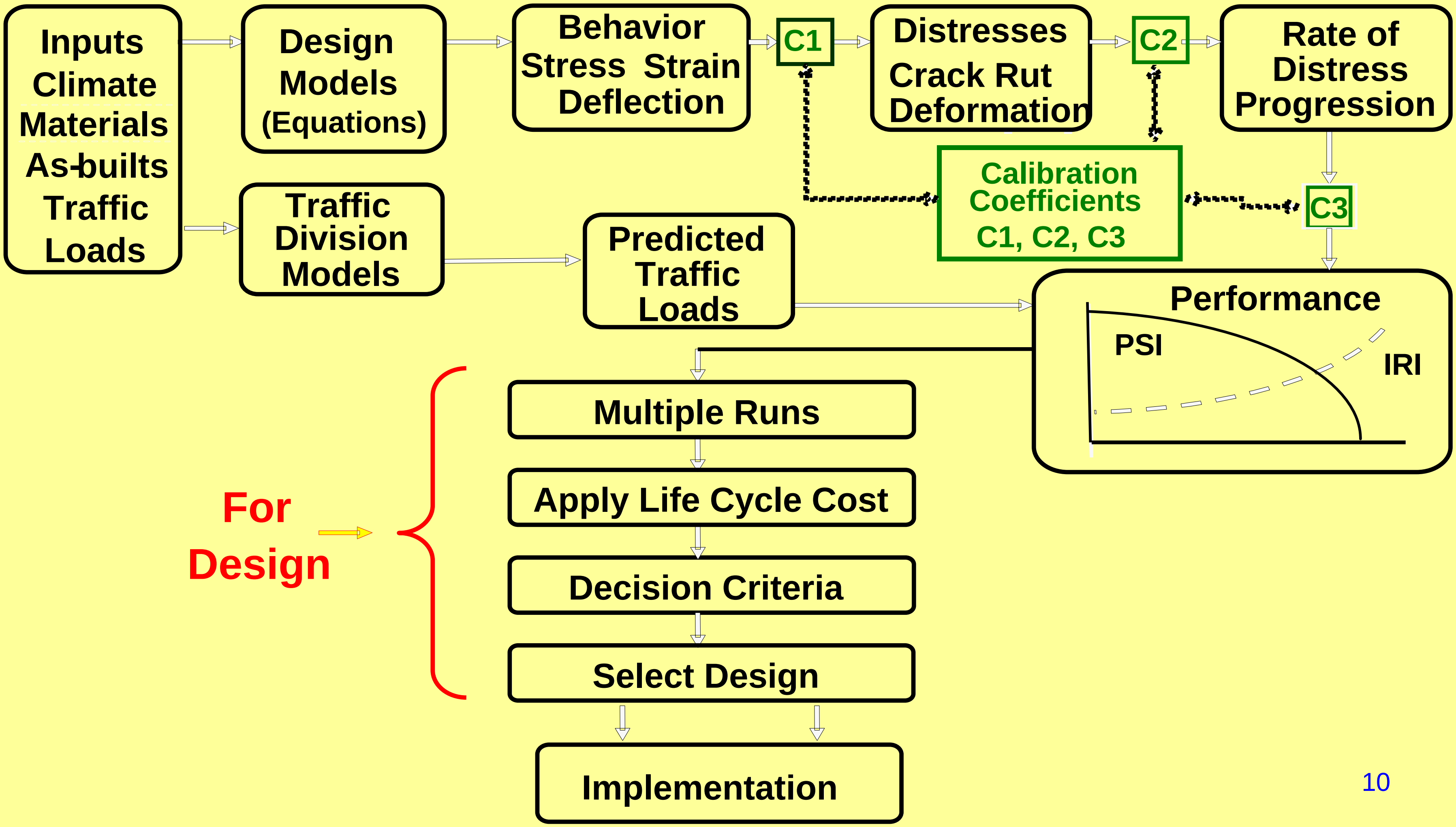


INPUTS
• Traffic
• Materials
• Thickness
Models
Costs
Behavior
Distress
Performance
Safety
Traffic Counts & Weights
Update Models
Deflection
Condition Surveys
Roughness PSI
•Test Pits
•Lab Tests
RECORD
• Construction
• Maintenance
•Count
•Weigh
•Classification
LONG-TERM DATABASE & ANALYSIS
•Rainfall
•Temperature

PMS Conceived as Framework to Design for Local Environment

- **Objectives of early studies in 1960's:**
  - **Develop descriptions of material properties**
  - **Develop measuring properties for pavement design and evaluation**
  - **Develop pavement design methods using measured material properties, for all locations, environments & traffic loads.**
- **Goal: formulate overall pavement problem in broad conceptual and theoretical terms**

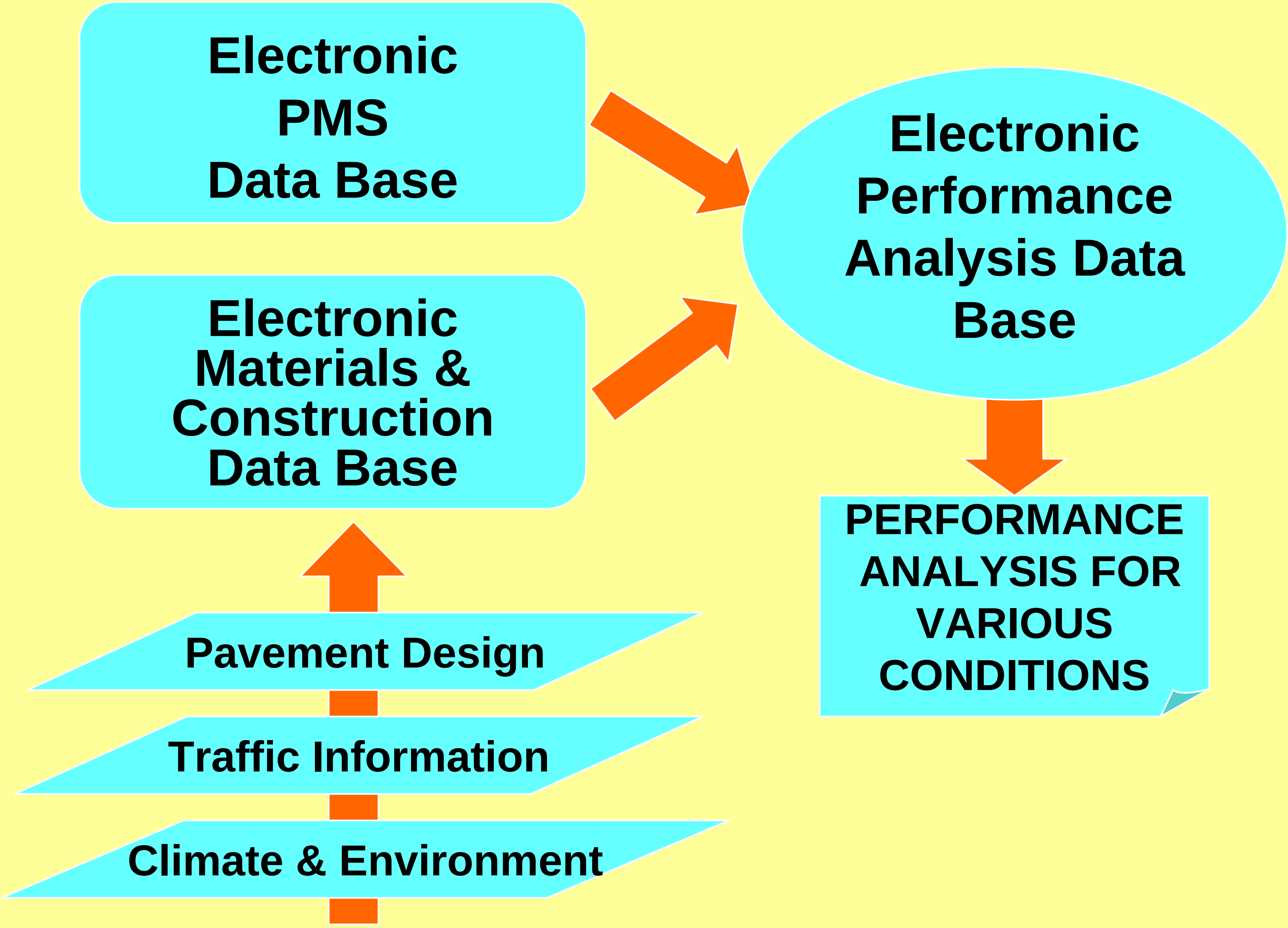
Project Level Pavement Design Method



How Does PMS Relate To Your Engineering Activities

- Pavement (overlay) design analysis
- Materials & construction methods
- Preventive maintenance
- Pavement preservation strategies
- Pavement maintenance management

Concept for Linking Databases



Electronic PMS Database

- **Common referencing is needed with Project Number, exact Location and Date**
- Location with mile post or GPS, Lane and Direction
- Climate and Traffic (ESAL and ADT) Data
- Age of original pavement and last rehab date
- Type of wearing course
- Performance Data for various distresses, should be linked to exact location

Electronic Materials and Construction Database

- **Common referencing is needed with Project Number, exact Location and Date**
- Batch numbers should be linked to location
- Mix data, as designed and in-place
- Layer thicknesses, designed and as-built
- Subgrade information
- Drainage details
- Other materials information and construction details
- Effects of maintenance activities

Electronic Performance Analysis Database Created by Linking

- **<u>Common referencing is needed with Project Number, exact Location and Date</u>**
- Essential materials and construction data linked to performance data through common referencing
- Possible to study effects of materials, construction techniques, traffic loads, climate, **thickness design**, etc.

Sources of Engineering Data other than from PMS database

- **Research data files**
- **Construction records**
- **Material test records**
- **Additional field evaluations**
- **Project plans**
- **Additional structural evaluation and/or materials testing**
- **Expert opinion**
- **Maintenance Management Systems**

Current Limitations (1of 2)

- **In most cases the materials, construction, and maintenance data are not now tied to PMS activities.**
- **Many agencies store materials and construction data in flat files, so transfer and analysis of data is hard to do.**
- **Not all relevant data are recorded (e.g. in-place thickness is often missing).**
- **Linking materials and construction data to an exact location is often difficult.**

Current Limitations (2 of 2)

- **Performance data are often averaged over a mile. Distress is often sampled over short distances, e.g. milepost only. Normally only one lane is measured.**
- **Therefore difficult to link performance data to materials and construction data.**
- **Maintenance activities could distort the analysis if not properly recorded and referenced.**

Main Activities So Far

- Good meetings with eight States
- Excellent coordination with NCHRP projects:
  - 1-40b Local Calibration Guidance for the Recommended Guide for M/E Design of New and Rehabilitated Pavements and its PI, Harold Von Quintus
  - 9-30 Experimental Plan for Calibration and Validation of HMA Performance Models for Mix & Structural Design
- Drafting of Final Report
- Monitoring of FHWA "Community of Practice" website, a forum for users to discuss the MEPDG

Preliminary Findings - 1

- **Many States have capability for <u>long term</u> calibration using PMS data, not for <u>short term</u>**
- **Two States are awaiting "Release 1.0", the corrected version of the software for the MEPDG in March-April 2006**
- **Several States are making extensive runs with the software to gain knowledge, particularly for engineering analysis and forensic studies**
- **Most States plan Level 2 input data for most of their variables, based on correlation and/or laboratory studies of their most typical materials**

Preliminary Findings - 2

- Required traffic data are generally available, but usually in a different Section or Division which requires coordination. Generally expect Level 3 or Level 2 data pieced together from existing data
- Many States reported problems keeping WIM sites operational. Piezo-quartz are preferred, but accuracy ranges from 10 – 15%
- Most States find it hard to assemble all required materials data, particularly those obtained from sophisticated laboratory equipment. In many cases States plan to use facilities at Universities.

Preliminary Findings - 3

- **Several States have ongoing contracts with consultants for implementing the MEPDG.**
- **Some States sponsor research on material properties, development of performance models & calibration/validation of the Guide at Universities.**
- **Most States are disappointed with the treatment of rehabilitation and overlay design in the MEPDG**
- **Prospects for calibration seems better when there is a close organizational tie within a DOT between pavement management and pavement design**

Calibration/Validation

PMS calibration will require setting up new data fields for Sections designed and built using the MEPDG for all input parameters, including:

- **Design values for all relevant parameters**
- **As-constructed values for the same parameters**
- **Annual measurements and records of traffic load spectra**
- **Annual weather data or tie to NOAA**

Analysis

1. Assemble Database for adequate number of sections,
2. The more sections the better, large sample statistics very powerful,
3. Several States can combine Data with good coordination at the national level,
4. Effects of all variables present in the Database can be evaluated and analyzed,
5. Early start provides impetus to enter data early – No “build-up” of backlog.

Final Report

Our Final Report synthesizes a viable plan to set up a long-term enhanced database for new Sections to be used for calibration. Prior data from existing Sections will only be useful if they can be used for enhancement of these new Calibration Sections.

PRE-CONFERENCE WORKSHOP

Availability of Required Data in PMS and other Databases

Performance, Distress and Location Data

by Pim Visser

Using PMS Data to Calibrate the New MEPDG

FHWA Project Team:

Dr. W. Ronald Hudson

Dr. Carl Monismith

Dr. Charles Dougan

Mr. Pim Visser

Input Parameters for MEPDG

1. **General Inputs:** Project name, ID, Dates, Design life, Limits & Reliability for Performance, Distress.
2. **Traffic Inputs:** Projected AADT, Growth, Volume adjustment, Axle load distribution, Etc
3. **Predicted Climate Inputs from ICM**
4. **Structural Inputs:** PCC design features, Drainage & surface properties, Layers, **Material properties,** Thermal cracking, Distress potential

A total of at least 150 parameters are required

Input Parameters for Calibration

1. **General Inputs:** Project name, ID, Dates, Design life, Annual Data on Performance, Distress, Deflection
2. **Traffic Inputs:** Annual data for AADT, Growth, Volume adjustment, Axle load distribution, etc
3. **Actual Climate Inputs from ICM**
4. **Structural Inputs:** Actual surface & drainage properties, Actual layer thicknesses, As-built & aged **Material properties,** Actual Thermal cracking

A total of several 100 parameters are required

Synthesis of Findings from Eight State DOTs

One of the main challenges in using the MEPDG and validating and calibrating the design method and its various prediction models, is to access / collect / find / measure / organize the many input parameters for the system

Matrix with State Findings

- Matrix provides methodology to compare and summarize current efforts and capabilities of 8 states to implement & calibrate the MEPDG
- Rows cover desired & minimum input data levels and information from eight states
- Columns in the matrix represent groups of input parameters, current state plans & organization

Rows in the Matrix

- **Column Headings with Input Parameters**
- **Desired Data Level**
  - Data used for initial pavement design
  - Data collected from as-built and from annual data on performance, traffic, climate, etc
- **Minimum Data Level**
  - Essential data required for calibration, at least Level 2
- **Eight Rows for Information from States**

Columns in the Matrix

- **Input parameters from PMS (9)**
- **Design & Annual Traffic & Axle Loads (5)**
- **Structural Design and As-built Inputs (4)**
- **Unbound & Stabilized Materials, Designed & As-built (3)**
- **Bound Materials, Designed & As-built (2)**
- **Climate Data (3)**
- **State Plans for Implementation and Calibration (2)**
- **Current State Organizational Structure (1)**

Example of Matrix Column

Group	**Materials Data, Designed & As-built**
Subgroup	**Flexible – Asphalt Pavements**
Desired data level	General: layer thickness, unit weight, voids Poissons ratio, Ref.temp, therm.prop, etc Asph.binder: L1/L2 – Test data after aging Asph.mix: L1 – Test data of E*, etc
Minimum data level	General: as above Asph.binder: L3 – Superpave/conv/pen Asph.mix: L2/L3 – Correlate modulus, etc
Info from states	

Required General Inputs

- Project name
- Design life
- Dates for construction and first traffic
- Pavement, flexible/rigid, new/rehab/overlay
- Site/project/section ID, location, station / milepost / GPS, traffic direction, functional class
- Analysis, limits & reliability for IRI, transverse, longitudinal and alligator cracking, permanent deformation, thermal fracture, faulting, punch-outs

Input Parameters from PMS

- **Class, location, direction, design life, dates**
- **Performance – limits and reliability values**
- **Distresses – limits and reliability values**
- **Behavior, structural response (deflections)**

Plus a Selection of Data for:

- Materials characterization
- Traffic and loads
- Designed structure
- As-built structure
- Maintenance and rehab

Group	**1. Pavement Management Data**
Subgroup	**1.1 ID, Class, Location, Dates**
Desired data level (DDL)	Project & Section ID, location, functional class, dates of construction/opening, GPS coordinates for sections, dynamic segmentation, traffic direction, design life
Minimum data level (MDL)	As above but mileposts or station numbers with cross reference to mileposts
Info from states	3 at DDL, 5 at MDL

Group	**1. Pavement Management Data**
Subgroup	**1.2 Performance**
Desired data level (DDL)	Smoothness (IRI) measured annually in all lanes along entire length using GPS, IRI limits and reliability values. Also initial IRI for new construction.
Minimum data level (MDL)	As above but IRI in both outside lanes only, using mileposts for location ID, or for two lane roads in 1 direction only.
Info from states	3 at DDL, 5 at MDL

Group	**1. Pavement Management Data**
Subgroup	**1.3 Distresses**
Desired data level (DDL)	Flexible: load cracking, thermal cracking, rutting/perm deformation (asph+total) Rigid: transv. crack, faulting, punchouts Limits & reliability. Measure annually entire pavement, autom. video recording, calibrated interpretation, use GPS
Minimum data level (MDL)	As above but rutting in 1 wheel path only, area at mileposts only, for 2-lane roads in 1 direction only, manual rating, no GPS.
Info from states	5 at DDL, 3 at MDL

Group	**1. Pavement Management Data**
Subgroup	**1.4 Behavior/Structural Response**
Desired data level (DDL)	FWD deflections measured annually in all lanes at Network Level using GPS for Location ID
Minimum data level (MDL)	As above but in both right lanes only, using mileposts, or for 2-lane roads in 1 direction only
Info from states	2 at DDL, 3 at MDL, and 3 none

Group	**1. Pavement Management Data**
Subgroup	**1.5 Materials**
Desired data level (DDL)	Known mechanical and thermal properties for individual pavement layers, for asphalt for range of temperatures and loading times
Minimum data level (MDL)	Correlated values for materials in individual pavement layers
Info from states	1 at DDL, 7 at MDL, few as-built values and few data in PMS

Group	**1. Pavement Management Data**
Subgroup	**1.6 Traffic/Loads**
Desired data level (DDL)	Annual Traffic Volume and Load Spectrum with adjustment factors
Minimum data level (MDL)	Annual Traffic counts with defaults for Load Spectrum
Info from states	1 at DDL, 7 at MDL, ESALs still mostly used

Group	**1. Pavement Management Data**
Subgroup	**1.7 Designed Structure**
Desired data level (DDL)	Design layer thicknesses and material properties for individual pavement layers
Minimum data level (MDL)	Design layer thicknesses and correlated material properties for individual pavement layers
Info from states	0 at DDL, 8 at MDL, most states have few data in PMS

Group	**1. Pavement Management Data**
Subgroup	**1.8 As-Built Structure**
Desired data level (DDL)	Actual thicknesses and material properties for individual pavement layers along entire pavement
Minimum data level (MDL)	Actual layer thickness & material properties for critical pavement sections only
Info from states	0 at DDL, 8 at MDL, none of states have data in PMS

Group	**1. Pavement Management Data**
Subgroup	**1.9 Maintenance/Rehab**
Desired data level (DDL)	Maintenance and Rehabilitation actions linked to PMS database
Minimum data level (MDL)	Access to Maintenance and Rehabilitation data
Info from states	1 at DDL, 7 at MDL , most existing data not detailed enough for New Guide

Existing Strengths

- **All eight states have an active Pavement Management System**
  - Performance and distresses are closely monitored
  - Deflection testing is increasingly used, mainly at Project Levels
- **States are increasingly storing materials data electronically**
- **Progress is being made with electronic storage of construction data**

Existing Challenges

- Most states do not yet store all PMS data required for MEPDG electronically at the Desired Level and many states do not have access to those data at the Minimum Level
- Several states monitor distresses only over a small area at the mile post
- Three states do not measure deflections at the network level
- None of the states have accessible data on as-builts
- Only 1 state has info on maintenance in PMS

Need for Satellite Database

To store and manage following pavement data:

- **Pavement Management Data for Projects designed with MEPDG**
  - Compatible with existing PMS Data
- **Additional data used as design and as-built inputs from following sources:**
  - Traffic Section
  - Pavement Design Section
  - Materials Testing Section
  - Construction Section
  - Maintenance Section

Purpose of Satellite Database

- Provide methodology to preserve and access relevant data for sections designed with MEPDG on a project-by-project basis
- Provide a more formal Interface for Pavement Management and Pavement Design
- Provide a mechanism for storing electronic materials, construction & maintenance data (designed & as-built) with annual follow-up as appropriate

Conclusions

- PMS database should provide essential data for use in MEPDG and calibration of models
- Additional data required should reside in Satellite Database, linked to PMS
- Together they provide a mechanism for storing electronic materials, construction (designed & as-built) and maintenance data with annual follow-up as appropriate
- No need to supplement existing Sections. New data fields needed only for new Sections designed and built using the MEPDG

"USING PMS DATA TO CALIBRATE AND VALIDATE THE NEW MEPDG"

FHWA Contract DTFH 61-05-C-00011

- **By:**
- **Dr. W. Ronald Hudson**
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“USING PMS DATA TO CALIBRATE AND VALIDATE THE NEW MEPDG”

Materials Data

Materials Inputs Unbound

- Bedrock
- Unbound Layers
- Cement/Lime Stabilized Layers

Materials Inputs Bound

- Rigid – PCC Pavement
- Flexible – Asphalt Pavement

Bedrock Desired

- Elastic Modulus (E)
- Poisson's Ratio
- Unit Weight
- No Minimum
  - All states at minimum level, none have recorded data

Unbound Layers Desired

- **Material Type and Thickness**
  - **For level 1 – None are recommended**
  - **For level 2 – Poisson's Ratio, (Ko) Coefficient of lateral pressure; seasonally adjusted modulus (E); strength value CBR, R-Value, cone penetrometer; ICM – PI, % passing 200 and # 4 sieves, D60**

Unbound Layer Minimum

- Material Type and Thickness
- For Level 3 – Poisson's Ratio; (Ko) Coefficient of lateral pressure; seasonally adjusted modulus; ICM inputs – PI, % passing 200 and #4 sieves, D60

Results of State Visits

- All states varied; some had data at the desired level;
- Half of the states had no recorded data.

Cement/Lime Stabilized Layers Desired

- Material Type
- Thickness
- Unit Weight
- Poisson's Ratio
- Elastic or Resilient Modulus
- Thermal Conductivity and Heat Capacity
- Base Erodability for PCC

Cement/Lime Stabilized Layers Minimum

- As above, moduli from established correlations and/or tabular or historic data

Results of State Visit

- **Little or no data are available. In 6 of 8 no recorded data**
  - **1 state stabilized materials not used**
  - **1 state at minimum level; no data for moduli or thermal properties**

Rigid Pavement Desired

- PCC Type and Thickness
- Unit Weight
- Poisson's Ratio
- Coefficient of Thermal Expansion, Heat Capacity, and Thermal Conductivity

Desired (cont.)

- **Mix - Cement Type; content, w/c ratio, aggregate type, zero stress temp., shrinkage @ 40% RH, time to 50% ultimate strength, curing method.**
- **Strength for Level 1 JPCP and CRCP – Dynamic**
  Modulus, Modulus of Rupture
  and Split Tensile Values at 7, 14, 28, 90 days and 20 yr/28 day Ratio

Rigid Pavement Minimum

- Same as Previously Shown Except Strength at Level 3 – JCCP and CRCP – Modulus of Rupture and Compressive Strength after 28 Days.

Results of State Visits

- Most states at minimum level
- Strength and mix data available
- 7 of 8 states lack thermal data

Flexible Pavements Desired

- Layer thickness, unit weight
- Poisson's Ratio
- Reference Temperature
- Mix - % Binder, Type, % Voids, Thermal Conductivity, Heat Capacity for Level 1/Level 2

Desired (cont.)

- Short Term Aging
- Dynamic Modulus (E*)
- Creep Compliance
- VMA, Thermal Properties, Average Tensile Strength @ 14 F

Flexible Pavements Minimum

- Same as above for Level 3 – Binder grade (SP or viscosity)
- Mix for Level 2 and Level 3
  - % retained on 3/4, 3/8 and 4 sieve
  - % passing #200
- Use Defaults for Level 3 Strength of Creep Compliance

Results of State Visits

- 6 of 8 states at minimum level
- 1 no data available
- 1 developing
  database for E*

Strengths

- All states have some materials data; usually at the minimum” level for calibration
  - States are slowly moving to provide needed materials input data
  - Available data generally correspond to data required for contract payment purposes

Challenges

- **Thermal data to characterize materials are lacking. There are no modulus data for various layers**
  - **Seasonal adjustment factors via the ICM need to be verified by the states**

"USING PMS DATA TO CALIBRATE AND VALIDATE THE NEW MEPDG"

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"USING PMS DATA TO CALIBRATE AND VALIDATE THE NEW MEPDG"

Traffic Data

Traffic Inputs

Data Classified as "Desired" or "Minimum"

- **"Desired" – collected annually and obtained from the State PMS**
- **"Minimum" – least amount of data required to run the MEPDG software.**

- The results of our eight state visits are presented under five columns:
  - General Traffic Data
  - Traffic Volume Adjustments
  - Axle Load Distribution
  - ESALs
  - Load Spectrum
    - Each with Desired and Minimum data levels

General Traffic Data Desired

- **AADT**
- **Number of Lanes**
- **Percentage Trucks/Direction**
- **Percentage Trucks in Design Lane**
- **Truck Operating Speed**
- **Traffic Growth Estimate**
- **Lateral Wander**

General Traffic Data
Minimum

- AADT
- Number of Lanes
- Percentage Trucks/Direction
- Percentage Trucks in Design Lane
- Truck Operating Speed

Results

- All States at Minimum Level
- All use WIM
  - WIM use varies from 5 to 40 WIM sites per state

Traffic Volume Adjustments

- **Desired – for Level 1 must have site-specific hourly distributions and vehicle classification**

Volume Adjustments Minimum

- **For Level 2, use Regional Vehicle Class Distribution and Hourly Distribution**
- **For Level 3 – Use Estimated Classification and Hourly Distribution Data**

State use varies from none to two states that have provided desired data

Axle Load Distribution Desired

- Axle Type
- Axle Load
- Axle Configuration
- Wheelbase Distribution (JCPC) for Level 1
  - must be site-specific

Axle Load Distribution Minimum

- Axle Type
- Axle Load
- Axle Configuration
- Wheelbase Distribution - Regionally for Level 2
- For Level 3 use Estimates

Results of State Visit

- Two States at Level 2
- Two States at Level 3
- Four states no data recorded for

  this study

ESALs

- Desired – Not used in the Guide
- Minimum – Models can convert ESALs to load spectrum
  - All states at Minimum Level and Employ ESALs

Load Spectrum

- "Desired" – developed from data in Columns 2.1 – 2.3 for Level 1
- "Minimum" – developed from data in Columns 2.1 – 2.3 for Levels 2 and 3
  - All states at minimum Level

Strengths

- All states have traffic data
  - With thought and effort existing data can be employed to calibrate the Guide

Challenges

More WIM data may be needed to define the traffic loading within a given state

REQUIRED DATA PROCEDURES FOR THIS APPROACH

1) **PMS data collection, processing & storage proceeds as usual in your DOT**

YOUR PMS DATABASE

Good Location - ID
Many Sections Good Performance Data Very Little Structural Little Materials Data Little Load Data

2) Design Data used in the very <u>first</u> <u>section</u> using the MEPDG is imported into an electronic satellite database tied closely to PMS.

- **Even defaults used are stored including load spectrum**
- **<u>Reason:</u> most states do not now store design data electronically.**
  Details lost after 1 or 2 years.

PMS DATABASE

*SATELLITE PMS/DESIGN DATABASE ONLY FOR ADDED SECTIONS

Good Location – ID
Many Sections Good Performance Data Very Little Structural Little Material Data Little Load Data

#

After Final Design of First Section
Import Design Values Used with MEPDG for <u>All</u> the variables even Defaults

 # Same Location ID
For PMS & Satellite

*** Data provided from**
Design, Const. Maint.
& Traffic To Satellite –
PMS/Design Database

3) **<u>As-Built</u> and other actual measured values are also stored to validate and replace any guesses or default values.**

- **GPS location – referencing if possible**

YOUR PMS DATABASE

*SATELLITE PMS/DESIGN DATABASE ONLY FOR ADDED SECTIONS

Good Location - ID

Many Sections
Good Performance Data

Very Little Structural
Little Material Data
Little Load Data

 # Same Location ID For PMS & Satellite

*** Data provided from Design, Const. Maint. & Traffic To Satellite – PMS/Design Database**

After Final Design of 1st Section

Import Design Values

Used with MEPDG for <u>All</u> the variables even Defaults

After Const. of First Section Add

Record Actual Values

As-Built and all other

"Measured Values"

"Real" Data on Material Properties, Location etc. to Supplement Default Values

4) Add Sections

- **Repeat this entire process for each new section or sub-section of roadway pavement designed using the MEPDG**
- **Repeat Steps 3 and 4 for each section or sub-section actually built.**

YOUR PMS DATABASE

***SATELLITE PMS/DESIGN DATABASE ONLY FOR ADDED SECTIONS**

Good Location - ID
Many Sections Good Performance Data Very Little Structural Little Material Data Little Load Data

#

After Final Design of 1st Section
Import Design Values Used with MEPDG for All the variables even Defaults

After Const. of First Section Add
Record Actual Values As-Built and all other "Measured Values" "Real" Data on Material Properties, Location etc. to Supplement Default Values

Sequentially
Add each Pavement section or subsection as it is designed and built. Add data within 30 days of final design, then for construction (Do Not Delay)

\# Same Location ID For PMS & Satellite

* Data provided from Design, Const. Maint. & Traffic To Satellite – PMS/Design Database

5) <u>Annually</u> – Add any changes or updates to variables obtained from actual measurement or data collection.

- Add actual Load Spectrum measured or inferred from actual data – not guesses
- Add actual material strength and stiffness measured or inferred from FWD – not guesses

YOUR PMS DATABASE

*SATELLITE PMS/DESIGN DATABASE ONLY FOR ADDED SECTIONS

Good Location - ID

Many Sections
Good Performance Data

Very Little Structural
Little Material Data
Little Load Data

#

Add Each new Section as Designed & Built

Import Design Values	Record Actual Values
Used with MEPDG for <u>All</u> the variables even Defaults	As-Built and all other
	"Measured Values"
	"Real" Data for Material Properties, Location etc. (Supplement Default Values)

ANNUAL MEASUREMENTS

Regular PMS data Performance, Distress, Roughness, etc.

Material Eval (possibly FWD? etc.)

Actual Climatic

Actual OBSERVED:

- **Load Volumes and Spectra**
- **Detailed Maintenance Records; "all" data concerning "new" sections**

 # Same Location ID For PMS & Satellite

*** Data provided from Design, Const. Maint. & Traffic To Satellite - PMS/Design Database**

SATELLITE DATABASE

- **Could be Located in Design or Construction, but**
- **PMS Database is the best location since there is already “location-identification” in place and annual data collection, processing, and storage procedures**
- **Most Design Groups do not routinely store their “design data” electronically. – Some never even record the final details but “interpolate” a final design.**
- **Most Construction Divisions do not store as-built data, or it is part of a larger “site manager” format and hard to retrieve.**

STEP-BY-STEP

- **Need not do this for all existing sections in your PMS which totals 10,000 – 100,000 depending on the state.**
- **Must do it <u>only</u> for each section or sub-section added using the MEPDG**
- **May add 2 – 10 sections per year – not many**

- **Must coordinate and follow-up with Design, Construction, Traffic, and Materials to get the data in a timely fashion to the Data Base Manager (DBM)**
- **A coordinating committee chaired by the Data Base Manager (DBM)**
- **Data must be processed and entered in a timely fashion, delays will KILL the process**

ENGINEERING ANALYSIS VALIDATION - CALIBRATION

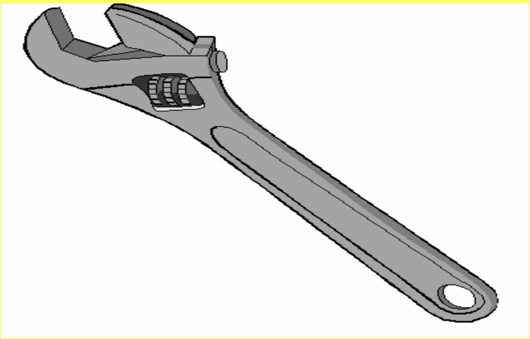
Within 3-5 years, data will accumulate for use in re-validation of the MEPDG

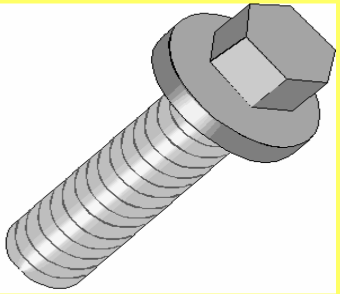
- **Several Regional States can join together to increase the number of sections for use.**
- **Going thru this procedure will enhance DOT staff awareness of trends in pavement data and PMS data and also lead to improvements in pavement technology**
- **Above all this must be a Dynamic Process.**

SUMMARY OF FINDINGS - USE OF PMS DATA TO CALIBRATE THE NEW GUIDE (MEPDG)

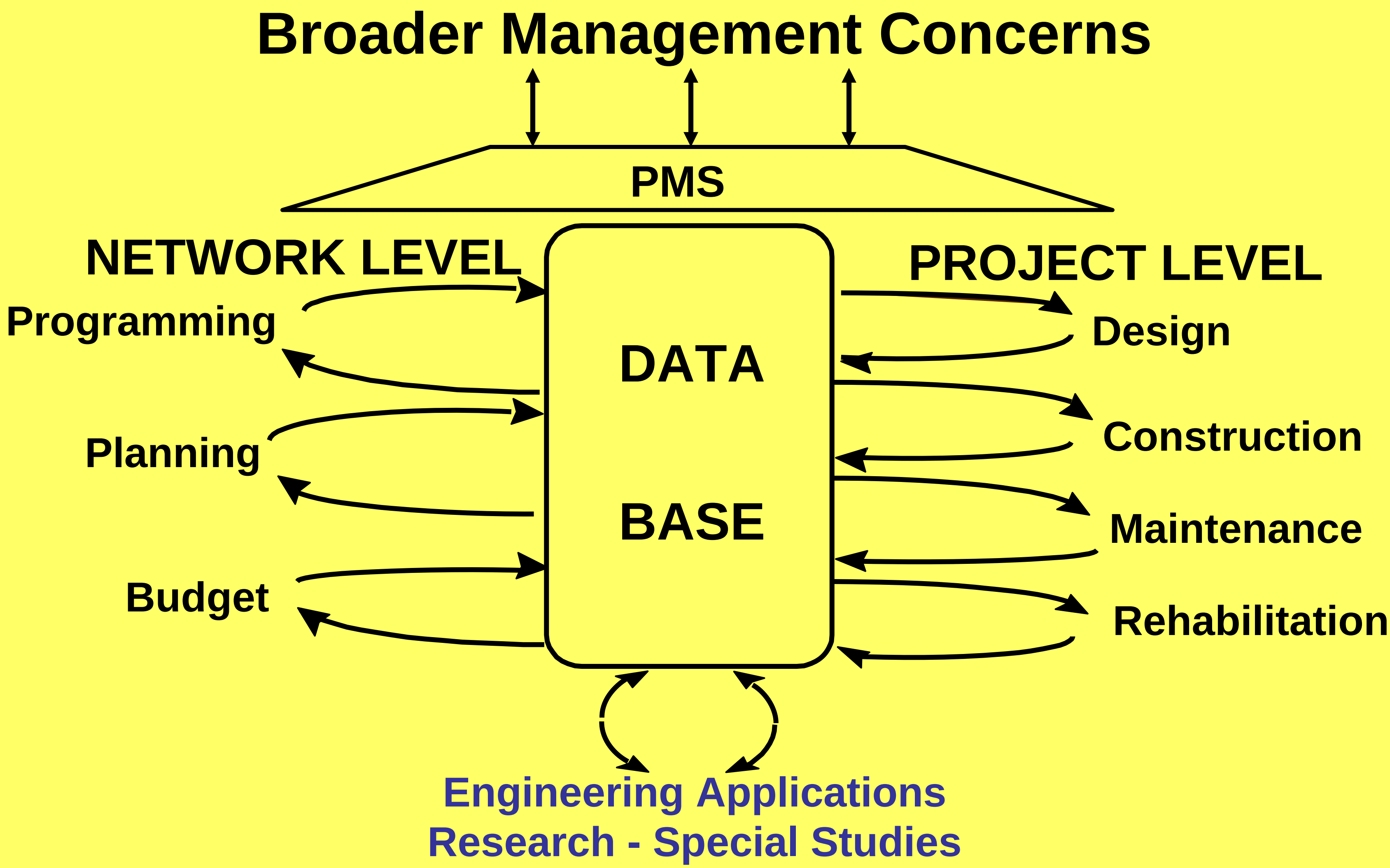
What is Pavement Management Software

- **A set of <u>Tools</u> to <u>Assist</u> Decision-makers in <u>Preserving</u> a <u>Pavement</u> Network**

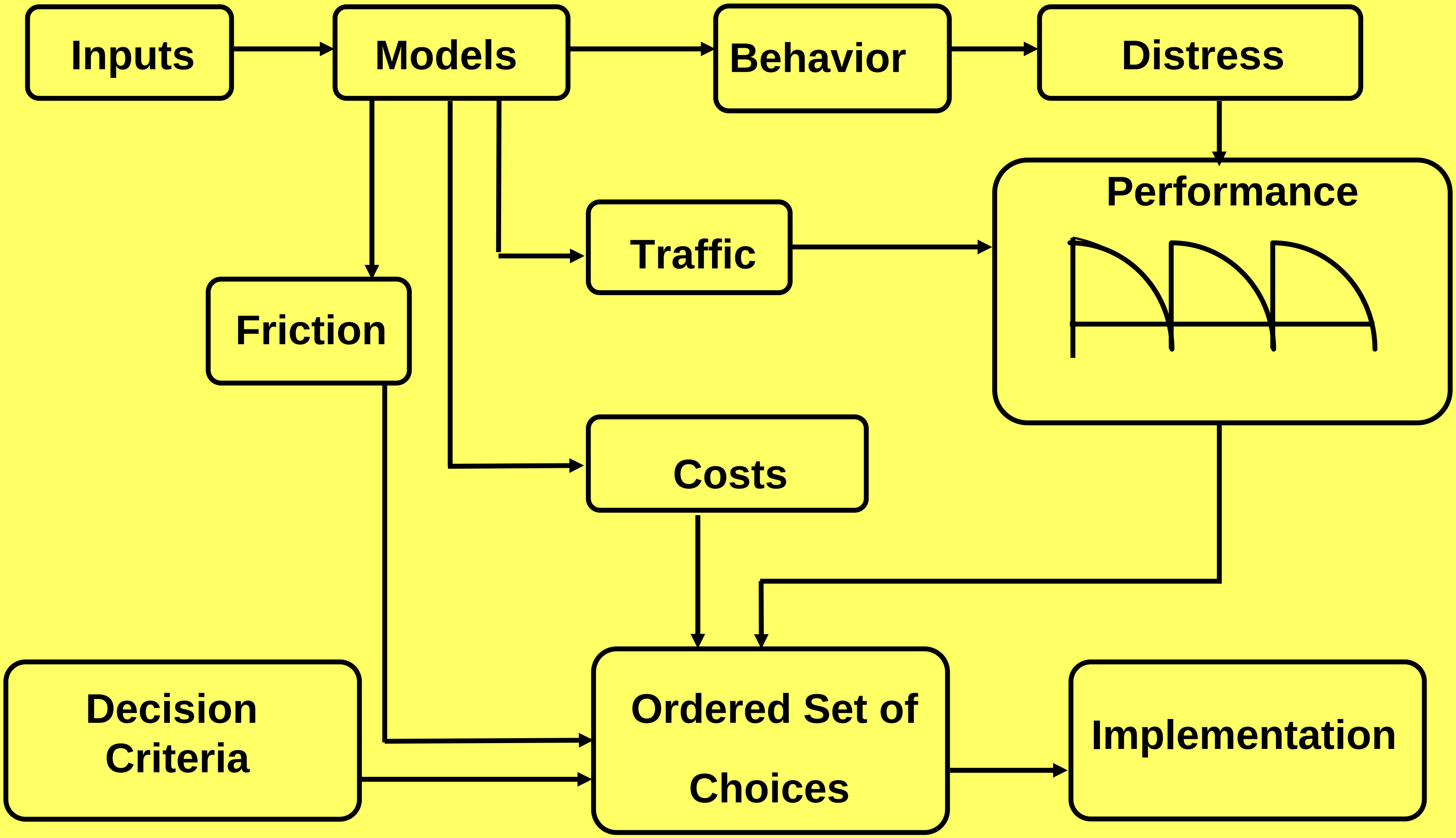




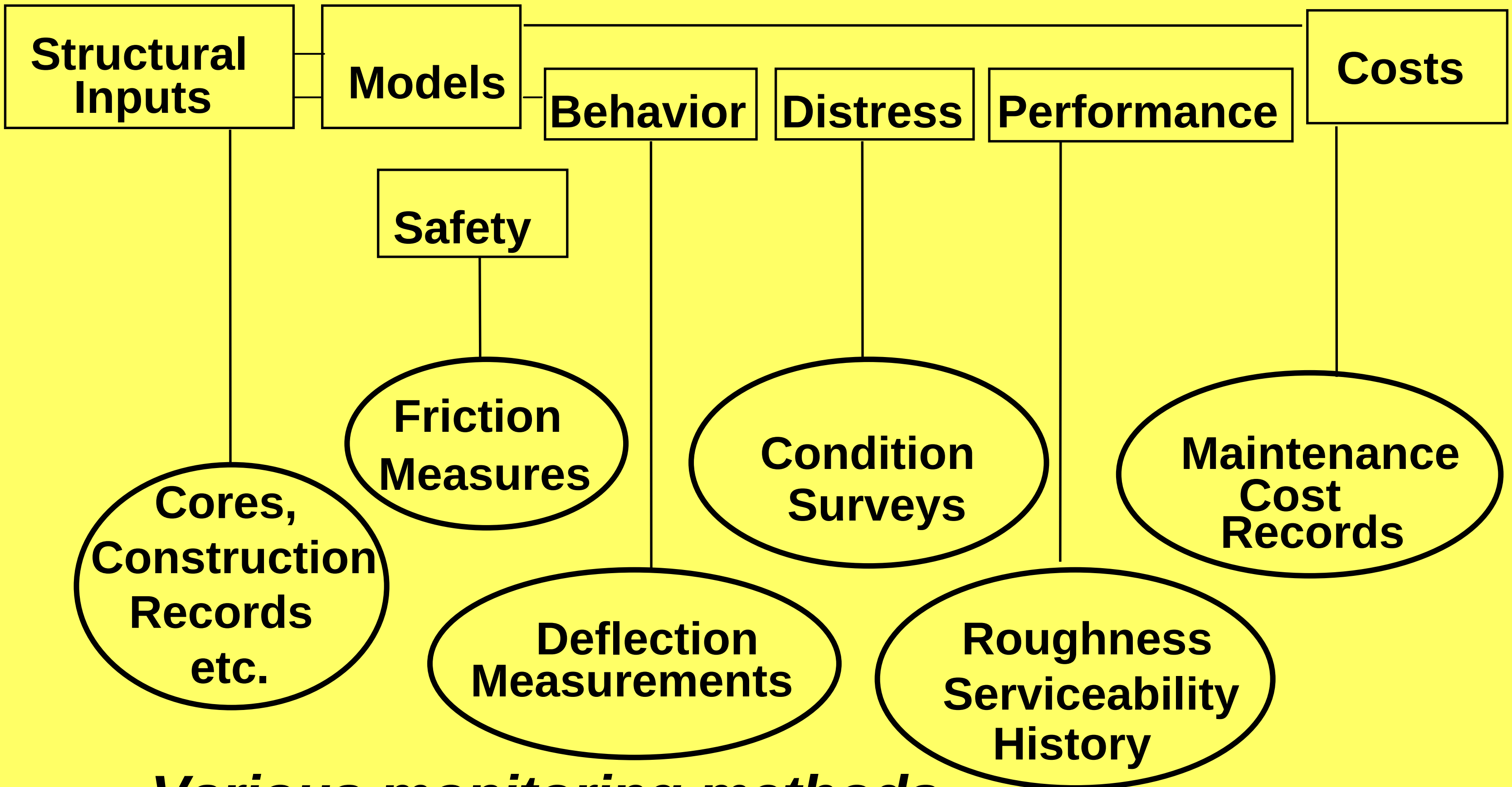
Components of PMS



Major Components of a Project Level Pavement Design System



Types of Evaluation Information



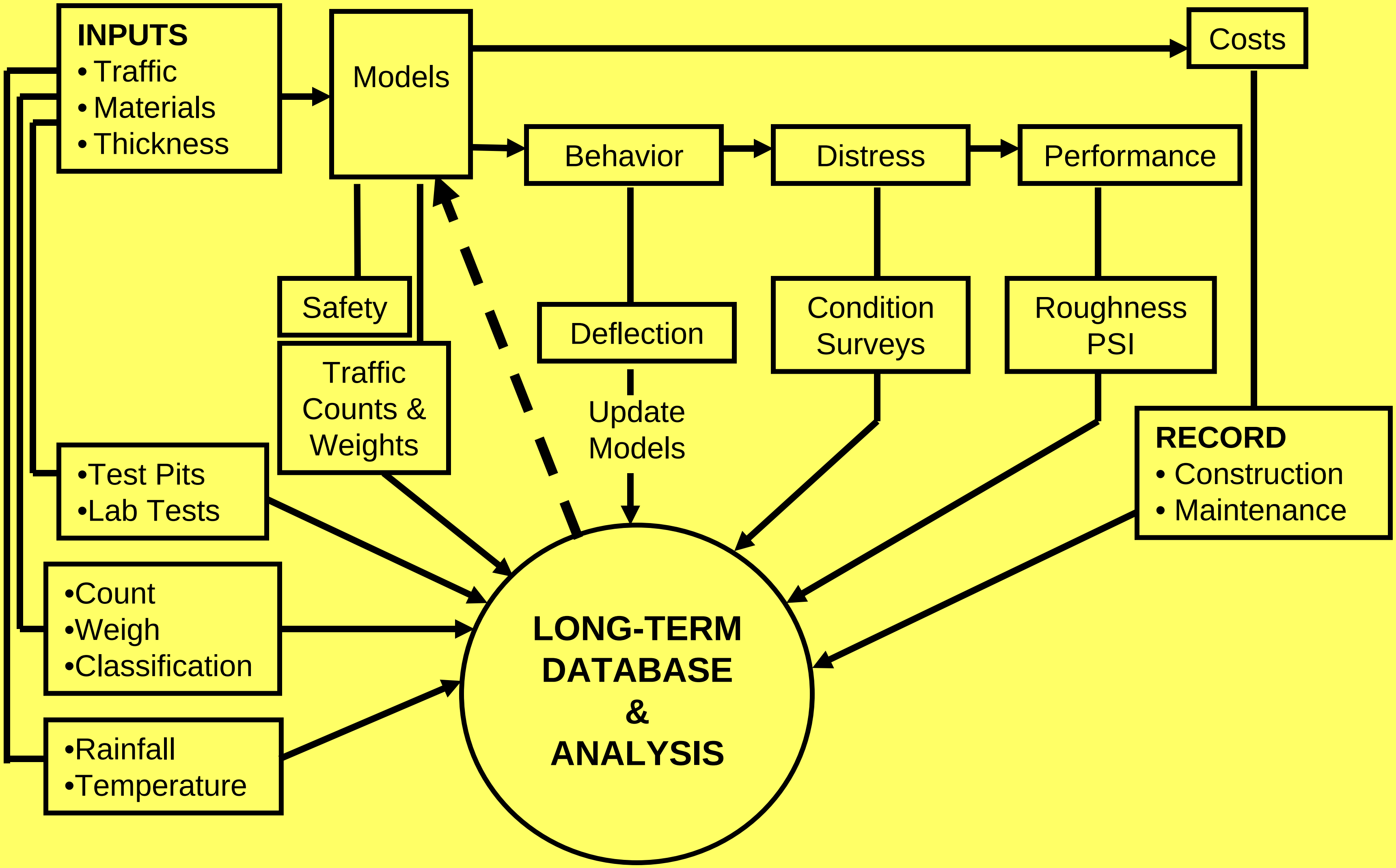
Various monitoring methods

Functions of Pavement Evaluation in PMS

- **Check design predictions**
- **Schedule rehabilitation**
- **Improve design models**
- **Improve construction and maintenance**
- **Updating network programs**

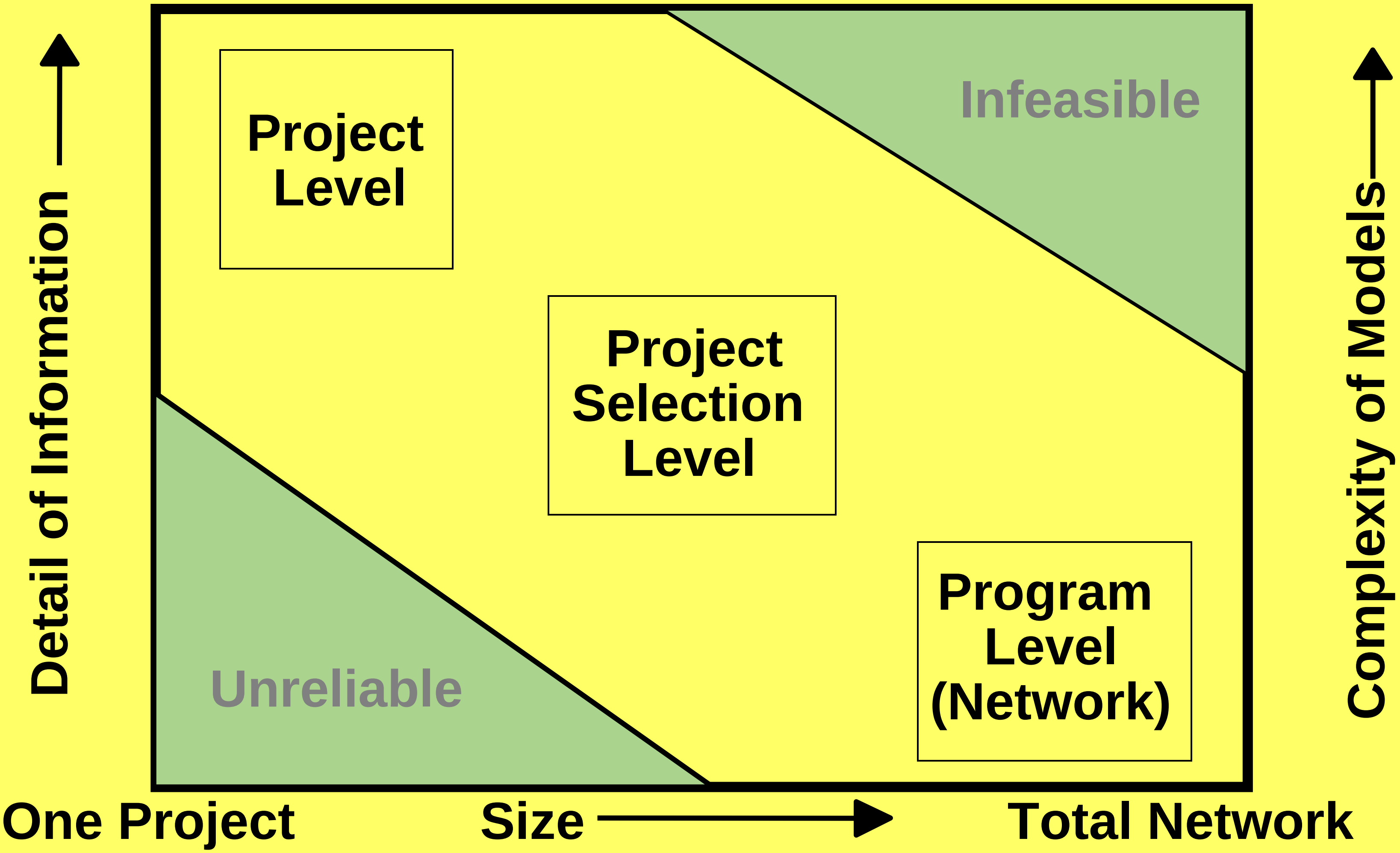
A quote by Aaron J. Ihde, Distinguished Chemist, Univ. of Wisconsin, which properly defines this process:

"The primary factor in bringing about scientific discovery is not necessity or individual genius, but the relentless pressure of accumulating knowledge".


INPUTS
• Traffic
• Materials
• Thickness
Models
Costs
Behavior
Distress
Performance
Safety
Traffic Counts & Weights
Deflection
Condition Surveys
Roughness PSI
Update Models
•Test Pits
•Lab Tests
•Count
•Weigh
•Classification
•Rainfall
•Temperature
RECORD
• Construction
• Maintenance
LONG-TERM DATABASE & ANALYSIS

Slide 8

Three level PMS - Information detail & complexity of models



Technical User Issues

- Database design/operation
- Data acquisition methods
- Ensuring adequacy of
- database
- Predictive Models
- Performance Criteria
- Models for priority analysis and network optimization
- Verification of models

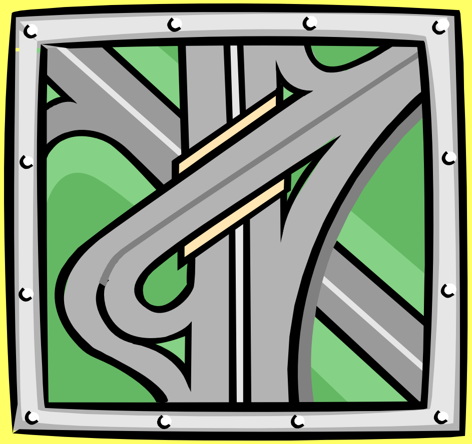
Purpose of PMS Engineering Analysis

The use of pavement management data to evaluate and improve structural designs, materials, mix designs, construction, preservation strategies, rehabilitation, & preventive maintenance of pavements.

Engineering Analysis Essential part of PMS

- **Pavements are engineered structures, therefore engineering analysis:**
  - o **Improves pavement performance**
  - o **Can be used for network or individual problems**
  - o **Is essential for feedback purposes**
  - o **Affects future activities**
    - design, construction, maintenance, standards, and specifications
- **Involves both project and network level data**

Sources of Engineering Data other than from PMS database



- **Research data files**
- **Construction records**
- **Material test records**
- **Additional field evaluations**
- **Project plans**
- **Additional structural evaluation and/or materials testing**
- **Expert opinion and forensics**
- **Maintenance Management Systems**

PMS Conceived as Framework to Design for Local Environment

- **Objectives of early studies in 1960's:**
  - **Develop descriptions of material properties**
  - **Develop measuring properties for pavement design and evaluation**
  - **Develop pavement design methods using measured material properties, for all locations, environments and traffic loads.**
- **Goal: formulate overall pavement problem in broad conceptual and theoretical terms**

OPPORTUNITY

1. **PMS started as a "Design" System**
2. **Expanded to Network Level**
3. **MEPDG presents a great chance to pull PMS and Design back together.**