

Motivation

- A large portion of transportation agencies manage pavement systems with substantial subgrade moisture variations (both seasonal and post-storm)
- A large number of pavement subgrade moisture related Load/Traffic Restriction decisions are based on empirical approaches:
 - Fixed dates
 - Use of ground freeze data from select locations
 - Subjective opinion post-flooding
- Above approaches do not integrate climate forecasting, soil-moisture state, pavement mechanics and traffic spectrum



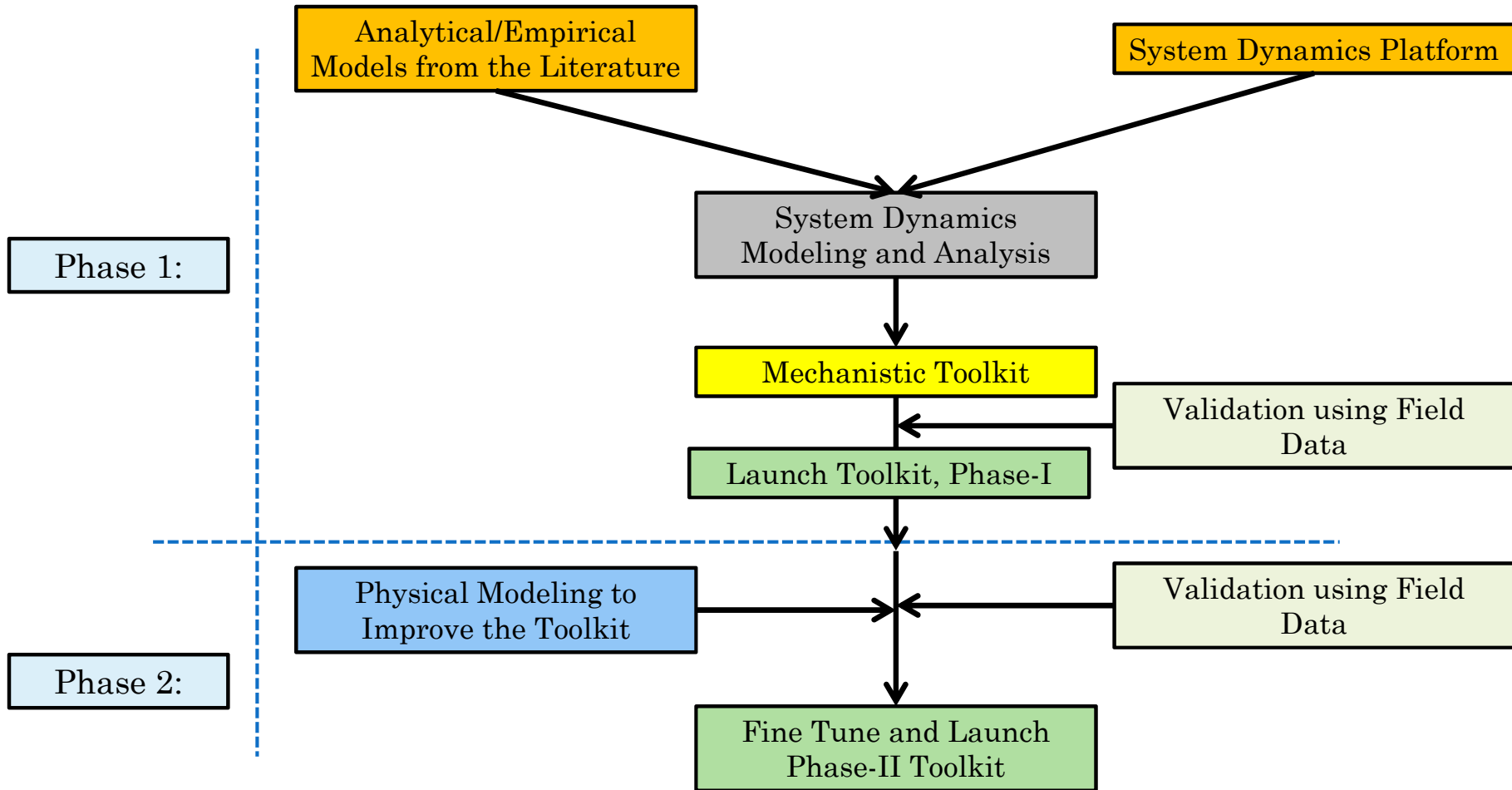
Motivation (cont.)

- Post-flooding traffic allowance and assessment
 - FHWA Flooded Pavement Assessment Study (Sias et al. 2018)
- Reliable pavement bearing capacity and performance assessment system for current and forecasted moisture conditions
- A mechanistic (real-time and forecasting) load restriction decision-platform for:
 - Damage vulnerability determination
 - Access to emergency responders
 - Traffic decisions during and after periods of excessive moisture → especially post-flooding
 - Maintenance and repair planning

Expected Benefits

- Develop a mechanistic framework to improve robustness of the load restriction decision process.
- Improve post-flooding and seasonal pavement capacity assessment.
- Implement a flexible platform that incorporates multi-variant effects with forecasting capability
 - This will be achieved through system dynamics modeling and analysis
- Develop a toolkit validated using field data for load restriction decision, specially for post-flooding load closures and openings.

Implementation Steps



Research Approach

A comprehensive surface deflection platform incorporating components with major effects on pavement systems:

1. *Structural Properties*

- Pavement layer types, Modulus, Poisson's Ratio, Thickness, etc.

2. *Climatic Conditions*

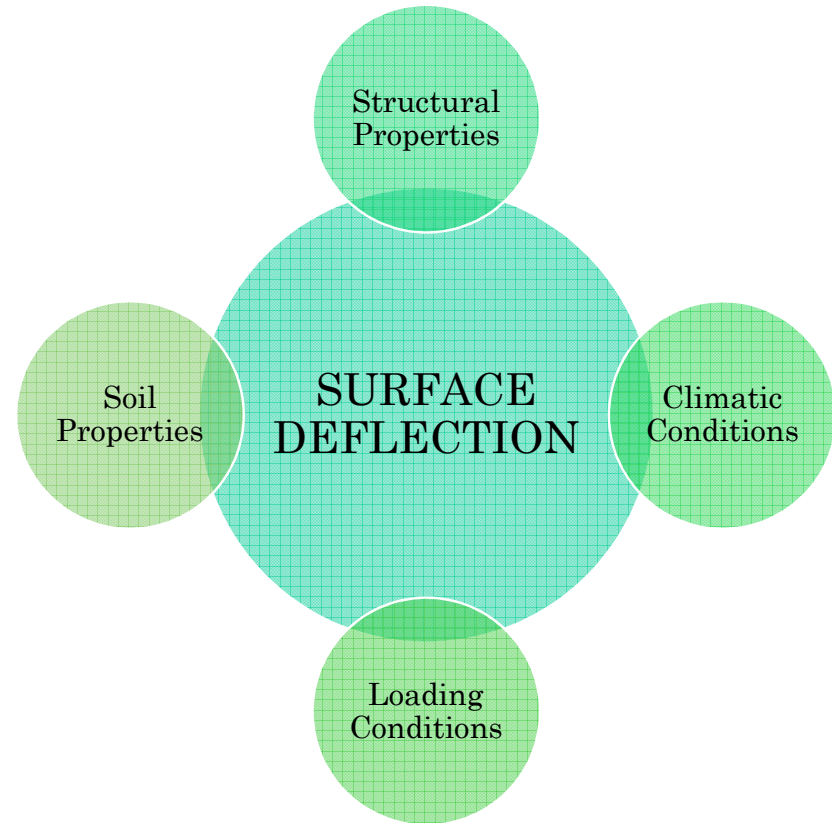
- Evaporation, Infiltration, Runoff, etc.

3. *Soil Properties*

- Soil Type, Density, PI, etc.

4. *Loading Conditions*

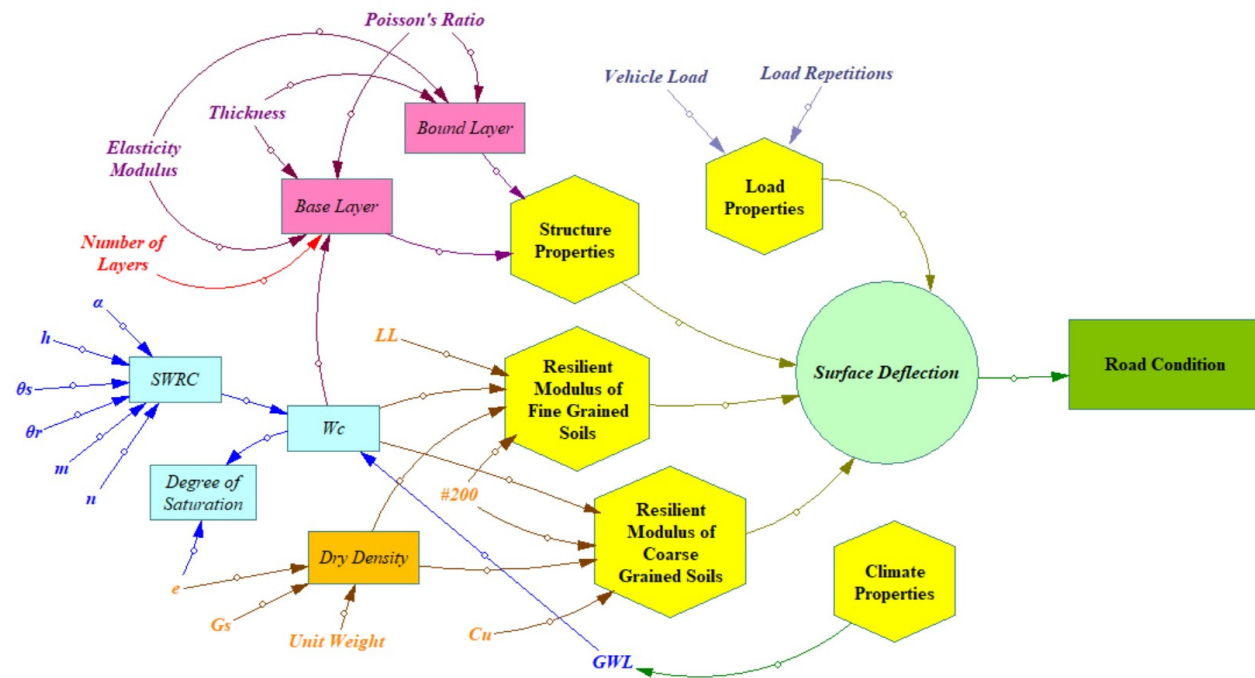
- Vehicle Type, Load Repetitions, etc.



Research Approach

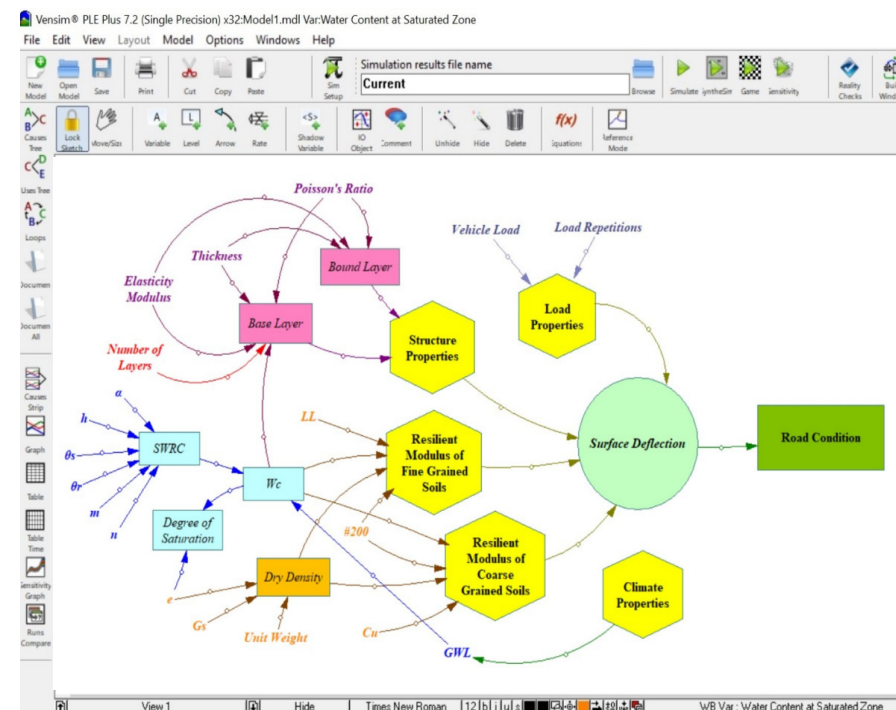
1. System Dynamics for sensitivity assessment and to refine implementation

- Vensim



System Dynamics Approach

- Vensim is industrial-strength simulation software for improving the performance of real systems.
- Capable of conducting
 - *Sensitivity Analysis*
 - *Reality Checks*
 - *Instant output with continuous simulation*
- Different Models adopted from literature are related with each other using mathematical relationship among them.



Research Approach

2. Decision Tool

- Vensim to User-friendly GUI

The main interface is titled "PAVEMENT LOAD RESTRICTION PROTOCOL" and is divided into several sections:

- General Information:** Includes fields for Roadway ID, Location, Roadway Class (Local Roads), Station, Description, City, and State (New Hampshire).
- Roadway Parameters:** Includes BMP and EMP fields.
- Roadway Characteristics:** Includes a dropdown for "Select Road Type" (Flexible Pavement) and checkboxes for FLEXIBLE PAVEMENT (Pothole, Edge Raveling, Shoving, Depression/Bump) and RIGID PAVEMENT (Joint Cracking, Paved Shoulder/Turnout).
- Subgrade Layer 1:** Includes a Thickness field (2 inches) and a Soil Classification section with a "Select Soil Type" dropdown (A-6) and an "Add Information" button.
- Base Layer:** Includes a "Select Number of Layers" dropdown (2) and three sub-sections for Base Layer 1, 2, and 3, each with Stiffness, Eb, and Thickness fields.
- Climate Data:** Includes an "Ave. Annual GWFT Depth" field (2 ft).
- Traffic Data:** Includes a "Calculated ESALS" field (21.87 million).

Surrounding windows include:

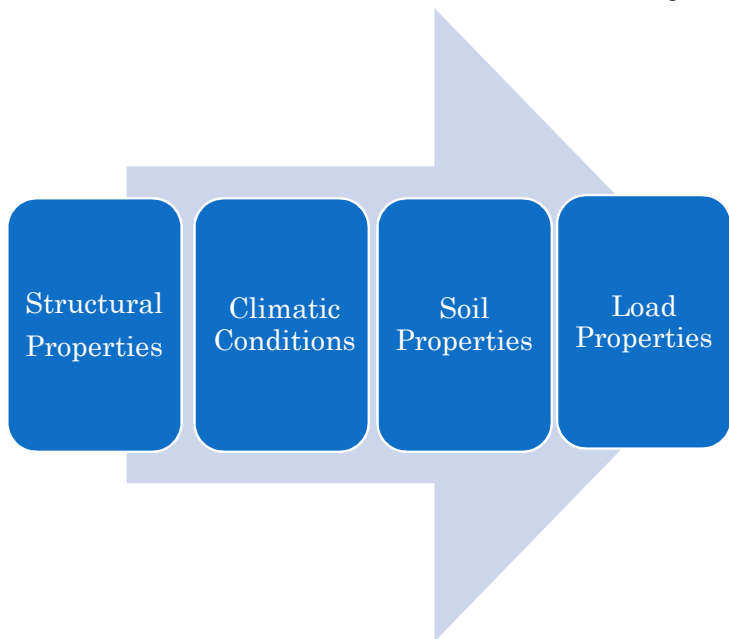
- Bound Layer:** A separate window for Stiffness, Ec (30000 psi), Poisson's Ratio, m (0.35), and Thickness (2 inches).
- Traffic Data:** A window for Vehicle Class (Buses), Percent of ADT (0.15), Annual % Growth (1), Average Initial Truck Factor (1.2), and Annual % Growth in Truck Factor (2).
- Sieve Analysis & Atterberg Limits:** A window for Dry Weight (100g), After Wash (25g), Passing 3" (12g), Passing #10 (25g), Passing #40 (33g), Passing #200 (5g), Liquid Limit (12), and Plastic Limit (5).
- Soil Classification Results:** A window showing soil properties: PI: 6, Cu: 5, Cc: 6, Opt. Moisture Content: 18%, Opt. Resilient Modulus: 17000 lbs/in^2, Max. Dry Density: 110 lb/ft^3, RM at different DoS: 25, Specific Gravity: 2.75. It also includes a "Select Hydraulic Model" dropdown (Fredlund & Xine (1994)) and a table of parameters: a: 0.345, alpha: 3.92, theta: 0.345, m: 0.146, theta_r: 2.01, n: 0.

Red arrows point from the Bound Layer, Traffic Data, and Soil Classification windows to their respective input fields in the main GUI.

Research Approach

2. Decision Tool

- Vensim to User-friendly GUI



DECISION SYSTEM			
Vehicle Class		Road Condition	
Class I Motorcycles		Green	
Class II Passenger Cars		Green	
Class III Four tire single unit		Yellow	
Class IV Buses		Yellow	
Class V Two-axle, six tire single unit		Red	
Class VI Three axle Single unit		Yellow	
Class VII Four or more axle single unit		Yellow	
Class VIII Four or less axle Single trailer		Red	
Class IX 5-Axle tractor semitrailer		Yellow	
Class X Six or more axle single trailer		Red	
Class XI Five or less axle multi-trailer		Red	
Class XII Six axle multi-trailer		Red	
Seven or more axle multi-trailer		Red	

Research Approach

3. Calibration and Preliminary Validation

- MnROAD data for preliminary validation



NRRA Study Research Tasks (24 months)

- Task 1: Initial Memorandum (due 10/31/2019)
- Task 2: Literature Review (due 10/31/2019)
- Task 3: System Dynamics Framework Development (due 3/31/2020)
- Task 4: Sensitivity Analysis and Framework Refinement (due 8/31/2020)
- Task 5: Toolkit Development (09/30/2020)
- Task 6: Calibration and Preliminary Validation of the Toolkit using MnROAD Data (11/30/2020)
- Tasks 7-10: Final Reporting



Thank You!



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