Development of Iowa Pavement Analysis Techniques (IPAT)

tech transfer summary

This study developed a user-friendly pavement performance and remaining service life prediction tool that local agencies can use to help make better informed performance-based pavement infrastructure planning decisions by prioritizing preservation and rehabilitation needs for their pavement assets.

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RESEARCH PROJECT TITLE
Development of Iowa Pavement Analysis Techniques

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The Program for Sustainable Pavement Engineering and Research (PROSPER) is part of the Institute for Transportation (InTrans) at Iowa State University. The overall goal of PROSPER is to advance research, education, and technology transfer in the area of sustainable highway and airport pavement infrastructure systems.

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Problem Statement

Given that pavement condition measurements do not provide a time element that tells how long a pavement will remain in a particular condition or how pavement performance may change over time, engineers need a tool that can help them tell when preservation and rehabilitation are required for their agencies' roadway sections.

Key Objectives

- Develop an Iowa Pavement Analysis Techniques (IPAT) tool for Iowa county pavement management and decision-making
- Find the best way to model a pavement's lifetime and make predictions as to when it will reach the end of its service lifetime (arrive at minimum service level)
- Absorb and integrate condition data from multiple sources, such as the Iowa Department of Transportation (DOT) Pavement Management Information System (PMIS), Iowa Pavement Management Program (IPMP), engineering field assessments, and inspector team distress evaluations
- Compute a remaining service life (RSL), value for every paved segment and provide a mile versus RSL tally
- Develop a methodology to support predictive and consequence analysis

Neal Hawkins, Institute for Transportation

Background

More than 20% of the secondary roads in Iowa are paved and hard-surfaced, with about 30% of statewide road projects slated for surfacing roadways with hot-mixed asphalt (HMA) and portland cement concrete (PCC). Given that paved and hard-surfaced roadways, which deliver access to public and private property throughout a county require continual maintenance and reconstruction, these roadways play a critical role in the jobs of Iowa county engineers.

Iowa county engineers can operate their road systems by inventorying their records and inspecting them to perform preventive maintenance and rehabilitation. Such an inventory includes pavement history, pavement structural design features, pavement condition measures, traffic volume information, and material properties, but lack of a reliable tool to estimate future pavement performance results in counties encountering challenges to estimating RSL, i.e., when a pavement will reach a particular condition and how long it will remain in a particular condition before its next rehabilitation.

Research Description

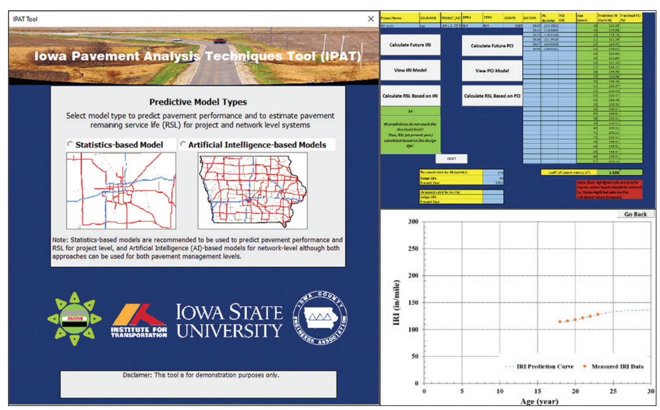
1. The research team conducted an initial review of the RSL concept, including its advantages, and determined the general relationship between RSL and pavement condition measures.

2. The team established a detailed step-by-step methodology for developing pavement performance and RSL prediction models and deployed the methodology using real pavement performance data obtained from the Iowa DOT PMIS database.

3. To develop RSL models, both statistical- (or mathematical-) and artificial neural network (ANN)-based pavement performance models were initially developed. The team developed the models using pavement performance models for various pavement performance indicators, including international roughness index (IRI) for project-level models and rutting, percent cracking, and IRI for network-level models, along with the Federal Highway Administration (FHWA)-specified threshold limits for these pavement performance indicators. The team ultimately developed RSL models for four pavement types—jointed plain concrete pavements (JPCPs), representing rigid pavement systems, asphalt concrete (AC) pavements, representing flexible pavement systems, AC over JPCP, and PCC overlay, with the latter two representing composite pavement systems in Iowa.

4. The research team developed a framework for an Iowa county pavement historical performance databank (HPD), with a detailed description of the data summarization and the improvements in pavement performance and RSL prediction models using real pavement performance data obtained from the Iowa DOT and Iowa county engineers' offices. Based on the approaches presented, the team validated the statistical- and ANN-based models that they had developed using the PMIS database using the developed HPD for JPCPs and AC pavements. The models were repeatedly improved with new input parameters until highly accurate pavement performance predictions for county pavements were achieved. RSL models were then developed for JPCP and AC pavement models.

5. Finally, the researchers developed the Visual Basic for Applications (VBA)-based IPAT tool using macro-enabled Microsoft Excel to help engineers predict performance and RSL of Iowa county pavement systems for the four pavement types at the project and network levels. The IPAT tool takes into account traffic capacities, equivalent single-axle load (ESAL) or annual average daily traffic (AADT), and design lifetime (based on layer ages, properties, slab thickness, and prior surface treatments). The IPAT tool uses a navigation panel (main tool) that can launch 56 sub-tools utilizing statistical- and artificial intelligence (AI)-based models to predict pavement performance and RSL.



IPAT tool interface including navigation panel (left), sub-tool for pavement performance (top right), and RSL predictions (bottom right)

Key Findings

- Statistics-based models provide high accuracy in IRI or pavement condition index (PCI) predictions when there is only a single pavement deterioration trend, as for a project-level pavement system. Sigmoidal equations have mainly been used in statistical model development because they have a low initial slope that increases with time, and they follow a trend in which pavement condition always gets worse and damage becomes irreversible, and such behavior makes these models mimic pavement deterioration behavior observed in field studies.

- ANN-based models, depending on the pavement type, provide high accuracy in IRI, rutting, and percent cracking predictions when there are many pavement sections with a variety of traffic volumes, thicknesses, and various other deterioration trends, as in a network-level system.

- The feasibility study for integrating pavement treatment techniques into pavement RSL models that was conducted highlights some challenges in the data collection phase that require specific parameters to be defined before predicting post-treatment performance and RSL. These parameters include preservation and rehabilitation treatment triggers, recovery percentages in performance, expected treatment service life, and pavement RSL extension based on the pavement type and treatment type.

- The IPAT tool developed in this study is a user-friendly tool that provides flexibility in launching different types of tools based on pavement type and data available from local agencies. The statistics- and AI-based approaches have been successfully utilized to help estimate pavement performance and RSL in facilitating decision-making and managing county pavement systems.

Implementation Readiness and Benefits

The IPAT tool developed as part of this research project, as well as other results, are beneficial to Iowa county engineers. The IPAT tool could be integrated into the Iowa county pavement asset management procedures as follows:

- **Step 1: Data collection.** Collect county pavement inventory data (e.g., construction history, maintenance activities) and performance history data using cost-effective methods and techniques.

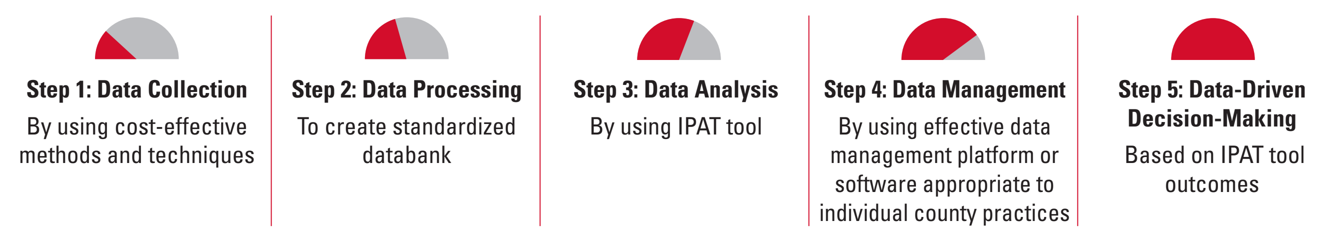
- **Step 2: Data processing.** Segment and summarize the collected data by computing locations of events (e.g., condition/distress data) on linear features (e.g., pavement management sections) at run time (dynamically) in linear measure (e.g., milepost, latitude, and longitude) for individual pavement sections, and, then, combine them to create a standardized databank that merges data from different sources while preventing overlapped data.

- **Step 3: Data analysis.** Analyze the processed data by using the IPAT tool to estimate the performance and RSL of county pavements at both project and network levels.

- **Step 4: Data management.** Integrate and store the processed and analyzed data into an effective data management platform or software appropriate to individual county practices.

- **Step 5: Data-driven decision-making.** Prioritize and allocate resources for future pavement preservation and rehabilitation needs by using pavement performance and RSL predictions from the IPAT tool.

The developed tool and models will significantly assist county engineers in their decision-making processes. Accurate RSL estimations can help facilitate maintenance and rehabilitation decisions to provide better prioritization and allocation of resources.



Pavement asset management procedures recommended by using the IPAT tool

Future Recommendations and Benefits

Future directions for the next phase(s) of this work have been developed and recommended to fulfill county engineer needs for fully implementing the recommended steps in Iowa county pavement asset management practices. These directions can be categorized into the following five topics related to each step:

- **Step 1: Improve data collection practices**
  Implement low-cost data collection tools for local road agencies to support more frequent collection of pavement performance data and establish a more synthesized and reliable database than what currently exists. By using such tools, local road agencies could more easily and accurately record the beginning and ending coordinates (latitude and longitude) for each road section using the standardized metadata at each agency level to prevent faults during data transfer and update the database when road alignments change. It is recommended that local agencies implement the recommendations of the Iowa Highway Research Board (IHRB) project titled Development of a Smartphone-Based Road Performance Data Collection Tool, for which the research team has been developing standardized nonproprietary collection tools (i.e., a smartphone-based road performance data collection tool and a smart vehicle black box) with automatic vehicle location (AVL) technology.

- **Step 2: Automate or semi-automate data processing**
  Develop an automated or semi-automated data processing tool that could prevent errors in manual data handling and facilitate creating a databank that merges data from different sources and updating that database when road alignments change.

- **Step 3: Integrate maintenance/preservation/rehabilitation activities into the IPAT tool**
  Improve the robustness of the AI-based RSL models developed from the feasibility study by addressing identified challenges and incorporating solutions to them as additional sub-tools in subsequent IPAT tool updates.

- **Step 4: Integrate the IPAT tool into the geographic information system (GIS) platform and/or software and develop a smartphone application version of the IPAT tool as an official app under the Iowa County Engineers Association Service Bureau (ICEASB) AppSuite to provide better data management practices**
  Integrate IPAT predictions into a web-based platform and/or software (e.g., ArcGIS) appropriate to individual county practices. Such integration could provide a user-friendly interface, store all information in a dynamic map visualization, and track and predict pavement performance, access pavement data, and reevaluate pavements while observing them in the field to improve data management practices. The smartphone application version of the IPAT tool could be developed as an official app under the ICEASB AppSuite or other existing database platforms used by Iowa county engineers.

- **Step 5: Develop multi-objective optimized RSL models to assist in better decision-making**
  Develop multi-objective optimized RSL models considering various pavement performance indicators with different priorities and budget and resource constraints. Such multi-objective optimized RSL models will assist in better decision-making by using strategies to prioritize projects for maintenance and rehabilitation plans and select cost-effective maintenance and rehabilitation techniques for given projects.