Data Mining Applied for National Road Maintenance Decision Support System

Andri IRFAN – Directorate General Highway
Susanty Handayani – Greater Jakarta Transportation Authority
Ronald Al Rasyid – Jasa Marga Toll Road Company

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Background

Relevance of Sustainable Road Assets Maintenance

- Improvement of the roads service level
- Minimization of administration and user costs
- Reduction of environmental impacts; less resources consumption; less energy
- Improvement of peoples’ quality of life (peoples’ health)

An integrated approach of plan, design, construction and maintenance of all road assets: essential to achieve main objectives.
Background

Smart and Sustainable Cities

Smart and Sustainable Mobility

Infrastructures

Maintenance Optimization

*) source: Pereira-CTAC
Background

Physical Gap
Concept

Pavement Management Systems (PMS)

Network level

- Detailed engineering decisions
- Immediate consequences

Project level

Main Components

- Geographical Information System
- Database
- Performance prediction models
- Decision support system

Differences among PMSs

- Objectives
- Performance indicators
- Approach to the problem
- Mathematical Formulation

*) source: Pereira-CTAC
Problem Statement

How to develop decision support system for pavement maintenance optimization?

Objective

Develop DSS pavement maintenance optimization concept based on GIS
Frame Work

INPUT
- Pavement Condition
- Traffic Data

INPUT
- Standard M&R Strategies
- M&R Unit Cost

INPUT
- Network: Road
- Geographical Condition

Data Mining
- Pavement Deterioration Model
  - Distress 1 Deterioration Model
  - Distress 2 Deterioration Model
  - Distress n Deterioration Model

Data Mining
- Repair Model
  - Distress 1 Repair Model
  - Distress 2 Repair Model
  - Distress n Repair Model

Iteration of Deterioration-Repair for each year up to n year

Optimization Estimated Maintenance Cost

Prioritization Road Network Maintenance

Modern Decision Support System of Optimization on Pavement Maintenance System
Objective: generate several possible decision scenarios with the corresponding information that may help and support the decision maker choices

**Mathematical Programing**
- Linear
- Non-linear
- Geometric
- Integer
- Dynamic
- Stochastic

**Qualitative Methods**
- Analytic Hierarchy Process
- Fuzzy set theory
- Decision-trees

**Evolutionary Algorithms**
- Genetic algorithms
- Artificial neural networks
- Pattern search
## Tools of Research

<table>
<thead>
<tr>
<th>Objection</th>
<th>Model</th>
<th>Tools</th>
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</thead>
<tbody>
<tr>
<td>Predict the IRI &amp; Pavement Distress</td>
<td>Artificial Intelligence &amp; Data Mining</td>
<td>R-Miner from R Tool</td>
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<tr>
<td>Optimization Pavement Maintenance</td>
<td>Genetic Algorithm</td>
<td>R-GA from R Tool</td>
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<tr>
<td>DSS-Concept</td>
<td>Spatial Decision Model</td>
<td>QGis Lisboa 1.8.0 From Quantum GIS</td>
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### Data Source

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<tr>
<th>No</th>
<th>ID</th>
<th>Province</th>
<th>No of Segment</th>
<th>Calibration</th>
<th>Model Development</th>
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<td>East Java</td>
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### REC & VEC Curve

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<tr>
<th>Model</th>
<th>Hyper-parameters</th>
<th>Time (s)</th>
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<tbody>
<tr>
<td>MR</td>
<td>-</td>
<td>3.21 ± 0.03</td>
</tr>
<tr>
<td>SVM</td>
<td>$\epsilon = 0.07 \pm 0.01$ and $\gamma = 0.05 \pm 0.00$</td>
<td>117.02 ± 0.67</td>
</tr>
<tr>
<td>ANN</td>
<td>$H = 3 \pm 1$</td>
<td>102.37 ± 0.16</td>
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</table>
Sensitive Analysis
### Case Study

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<th>Better</th>
<th>worse</th>
<th>worse</th>
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<tbody>
<tr>
<td>SVM</td>
<td>0.88±0.02</td>
<td>0.88±0.02</td>
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<tr>
<td>ANNs</td>
<td>0.85±0.04</td>
<td>0.85±0.03</td>
</tr>
<tr>
<td>MR</td>
<td>0.90±0.02</td>
<td>0.94±0.01</td>
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<tr>
<td>IIRMS</td>
<td>0.70±0.01</td>
<td>0.81±0.02</td>
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<tr>
<td>SVM</td>
<td>0.72±0.02</td>
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<td>ANNs</td>
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<td><strong>R(^2)</strong></td>
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<td><strong>MAD</strong></td>
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<td><strong>RMSE</strong></td>
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![Graph showing IRI (m/km) vs. year for different load conditions](image)

- Green line: Normal
- Yellow line: Light Overload
- Red line: Medium Overload
- Purple line: Heavy Overload
Post Optimization

Result

IRI Predicted post Treatment

Maintenance Scenario

Sensitive Analysis
## Map Concept

The five basic map layers below are used in the GIS module:

| ANALYSIS RESULTS                                                                 | ▪ detailed project-level results  
▪ project ratings  
▪ treatment methods and costs,  
▪ AADT, and  
▪ spatial location information (such as SegmentNo, NetworkNo, ProvinceNo, Sta. From and Sta. To, District) |
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<tbody>
<tr>
<td>STATEROUTE</td>
<td>Based on IIRMS concept (the complete information on state highway routes in Java Island)</td>
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<tr>
<td>DISTRICT</td>
<td>The detailed district information of Java Island</td>
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<tr>
<td>PROVINCE</td>
<td>IIRMS Province boundary information</td>
</tr>
<tr>
<td>NETWORK</td>
<td>Network boundary information</td>
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</table>
The **AddRelate** method uses this common field to create a join between the map layer and the results table and creates a new record-set, which contains all the records (6 java island province).
GIS Base-Map

These five basic map layers include most of the information generated from the maintenance model results that can be displayed on GIS maps.
Interactive Map-based Multi-year What-if Pavement Scenario Analysis
Main Result

**DM techniques**, particularly and Artificial Neural Network (ANN) and Support Vector Machine (SVM) algorithms, proved to be powerful tools for explore pavement deterioration model. Indeed, these tools were able to learn with high accuracy the complex relationships between IRI and their contributing factors. SVM achieved a performance higher than 0.91, using $R^2$ as a performance indicator.

**The Genetic Algorithm** Approach method, by taking advantages mathematical programming, offers a systematic, easy-to-use approach to the pavement maintenance optimization. Although only budget constraint is considered, other constraints could be easily added to the formulation.

**GIS technology** is fully utilized in the decision support system for pavement maintenance. The GIS technology integrates graphical information in the GIS maps and the pavement performance model results obtained from the segment-level and the network-level seamlessly.
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