Reducing Maintenance Costs by Adapting Total Asset Management in Japan

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1. Company Profile

NEXCO-Central

A major P3 player in Japan and has over 60-years experience at every stage of an expressway project such as construction, maintenance, inspection & repair and rest area Management

- Around **10,000** employees*
- **1,286** miles in Operation*
- **1.87** million vehicles per day**
- **US$ 5.28** billion of toll revenues**
- **US$ 1.52** billion net sales from **180** rest areas**
- Headquarters: **Nagoya, Japan**

*Data as of April, 2016
**Data as of March, 2014
1. Company Profile

O&M solutions for keeping expressways in a good condition

**Toll Collection**
- ETC services
- Manual toll collection

**Traffic Control**
- Traffic Information
- Expressway Patrol

**Engineering**
- Inspection
- Engineering work

**Maintenance**
- Repair
- Cleaning
- Landscaping

- Non-ETC lane
- ETC lane
- Traffic Control Center
- Road patrol
- Overloaded truck check
- Bridge inspection
- Slope inspection
- Lane Closure for maintenance works
- Pavement maintenance
2. Why Asset Management (AM) is applied?

- Providing higher quality infrastructures to the society with the lowest possible costs is an eternal task.

Length in Operation of Expressways by Age

- 1,254 miles (Apr 2014)
- 766 miles: over 30 years (60%)
3. Outline of Our PMS

Supporting tool for building optimized maintenance strategy within budget

NEXCO (HQ・Branch・Project Office)

- Road surface property data
  - Rutting
  - Cracks
  - IRI
  - Road profiler

- Structure evaluation data
  - Damage evaluation of pavement structure by FWD
  - Physical test by core sample collection

- Road information data
  - Maintenance history data
  - Road maintenance

Integrated PMS Database

Support Mid-term/Long-term pavement maintenance strategy

<Past & Present> Evaluate pavement maintenance & Inspection data

<Future> Predict deterioration of pavement
3. Outline of Our Pavement Management System (PMS)

NEXCO-Central PMS database structures (Data layer)

- **Locations**
  - Common base data layer (Organizations/Road)
  - Common base data layer (Zone/Structures)
  - Common base data layer (Direction, lanes)

- **Construction data**
  - Design
  - Asphalts type, composition
  - Construction management
  - Construction machines

- **Maintenance data**
  - Construction data
  - Inspections layer
  - Annual pavement maintenance layer

- **Inspection Data**
  - Inspection data
  - Code management system

- **Code Management System**
  - Branch
  - Regional office
  - Road name

**Code Management System**

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### 4. Comparison List of Prediction Model

<table>
<thead>
<tr>
<th></th>
<th>Regression Analysis Model</th>
<th>Dynamic Model</th>
<th>KYOTO MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prediction Model</strong></td>
<td>• Regression formula</td>
<td>• Prediction formula with coefficient calibrated</td>
<td>• Prediction on regularity of deterioration process with Markov Model</td>
</tr>
<tr>
<td><strong>Merit</strong></td>
<td>• No massive analysis system due to simple mathematical formula</td>
<td>• Available even in case without data organized enough</td>
<td>• Practical with less input data in calculating</td>
</tr>
<tr>
<td><strong>Demerit</strong></td>
<td>• A relatively large amount of data are required for more accurate regression formula</td>
<td>• Poor usability in operating - Complicated input system - Variety of input data for calibration - Arbitrary parameter setting based on site conditions by an engineer</td>
<td>• A relatively large amount of data are required for more accurate deterioration prediction curve.</td>
</tr>
</tbody>
</table>
| **Example**      | ![Graph](image.png) $\Delta R = K_c [\Delta R_1 + \Delta R_2 + \Delta R_3 + \Delta R_4] + \Delta R_5$  
$K_c$: Coefficient calibrated on site  
$R$: variable in each element | ![Graph](image.png) | |
Kyoto Model

This unique powerful model has been developed to provide accurate maintenance strategies automatically calculated at the network level, by predicting future conditions from only recent less input data regardless of the past ones.

1. **Efficient Deterioration prediction with less input data in calculating**
   - The latest and second latest data
   - Approximately a few items
     - Structure type, Asphalt type, Traffic volume condition, Surface conditions

2. **Benchmarking Evaluation**
   - Compare degree of deterioration by each section
   - Evaluate the degree at the entire network level

3. **Practical pavement maintenance strategy**
   - With budget limitation
   - at network level utilizing benchmarking evaluation
6. How to use data samples

Classification of soundness

- For example, rutting samples need to be converted into rating value to apply Markov transition probability. It makes the analyzing process simpler,
- As one example, soundness of rutting was classified into 5 rank groupings.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Amount of rutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Less than 5mm</td>
</tr>
<tr>
<td>2</td>
<td>From 5 to less than 10mm</td>
</tr>
<tr>
<td>3</td>
<td>From 10 to less than 15mm</td>
</tr>
<tr>
<td>4</td>
<td>From 15 to less than 20mm</td>
</tr>
<tr>
<td>5</td>
<td>20mm or more</td>
</tr>
</tbody>
</table>
### 7. Estimation of rut prediction model - Each lane -

<table>
<thead>
<tr>
<th>Life expectancy (year)</th>
<th>rank</th>
<th>1→2</th>
<th>2→3</th>
<th>3→4</th>
<th>4→5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>first lane</td>
<td>0.66</td>
<td>5.90</td>
<td>4.87</td>
<td>5.61</td>
<td></td>
<td>17.04</td>
</tr>
<tr>
<td>second lane</td>
<td>1.11</td>
<td>5.50</td>
<td>9.66</td>
<td>17.64</td>
<td></td>
<td>33.91</td>
</tr>
<tr>
<td>passing lane</td>
<td>1.64</td>
<td>8.95</td>
<td>9.66</td>
<td>17.64</td>
<td></td>
<td>37.89</td>
</tr>
</tbody>
</table>

- More vehicles with heavy wheel loads run in the first lane.

**Graph:**
- **X**: first lane
- **C**: second lane
- **A**: passing lane

**Legend:**
- fast
- slow
8. Forthcoming Challenges

- **Validate accuracy of deterioration prediction**
  - Check the gap between prediction and reality with much experience and accumulated data for inspection & maintenance

- **Allocate budget considering balance of whole road structure conditions**
  - Integrate PMS with other asset management system for building comprehensive maintenance strategy

- **Utilize daily inspection data for PMS**
  - Utilize the number of pothole from daily inspection to find an optimized repair plan at project level
Continuous promotion of Kyoto model experimental applications

Disseminate Kyoto Model for supporting road operators

- Ensure compatibility with already existing system
- Customize database, input, output based on road operators’ needs

For more details, contact us at international@c-nexco.co.jp
Issues & Solutions on Prediction Model

**Issues**

- **During analysis process**
  - Uncertainty on timing for pavement distress to actually occur
    » Since pavement is inspected once every 2 year, the actual time when the distress occurs is not grasped. Time difference between inspection time and the actual time generates.
  - Absence of past data
    » Pavements in a good /poor condition are repaired at the same time by network maintenance planning.

**Solutions**

<table>
<thead>
<tr>
<th>Issues</th>
<th>Applied model to our PMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncertainties</td>
<td>Markov deterioration hazard model</td>
</tr>
<tr>
<td>Absence of past data</td>
<td>Maximum likelihood estimation with sample dropping bias</td>
</tr>
</tbody>
</table>

KYOTO MODEL

A multi-stage exponential hazard model combing the Markov transition probability