TRIMM FINAL CONFERENCE and ERPUUG Forum

Road Management Technologies in Japan

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PASCO CORPORATION
PASCO Corporation

- Date of Establishment: Oct, 1953
- Head Office: Tokyo (55 branches in Japan)
- Number of Employees: Approx. 2,500
- Group Companies: 24 Consolidated Subsidiaries, 3 Associated
- Sales of Consolidation: Approx. USD 503 mil (Sep, 2013)
PASCO Corporation

Spatial Data Acquisition

Spatial Data Processing & Analysis

Establishment 1953
Head office Tokyo
(57 offices in Japan, 9 overseas)

Identifying social needs

Problem Solving, and Planning

GIS Service
Main Business Fields

Surveying

GIS & Spatial Analysis

Mapping

Consultation
Asset management, City planning, Disaster prevention, Road construction, Environment, etc.
Development of Infrastructure in Japan

- End of W.W.II (1945)
- High growth period (1954-1973)
- Tokyo Olympic (1964)
- Aging Infrastructure becomes serious issue

- Railway Network
- Road Network
- Bridge
Deterioration of Infrastructure (Road)

• Common deterioration of road in Japan

and a fatal accident

• Tunnel collapse accident
  • Dec-2012
  • Sasago Tunnel
  • 9 casualties
Pavement Condition Survey System

- **Pavement Condition Survey and Database in Japan**
  - Pavement Condition Survey from 1970
  - 3 year interval (in case National Highway)
  - Inspection history data, Construction and Repair history data, inventory data

- **Hierarchical Data for Road Asset Management**
  - Key Platform for Road Asset Management Work
  - Collect other information on Key Platform
  - Data utilization for planning using PMS
**Guideline**

<table>
<thead>
<tr>
<th>Section length</th>
<th>100m, 20m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection method (use inspection vehicle)</td>
<td></td>
</tr>
<tr>
<td>Cracking</td>
<td>ratio of cracking + ratio of patching</td>
</tr>
<tr>
<td>Rutting</td>
<td>Measure the cross section of road at 20m intervals, and calculate the difference of highest and lowest point</td>
</tr>
<tr>
<td>Flatness</td>
<td>Measure the longitudinal shape of road and extract the value at regular intervals</td>
</tr>
<tr>
<td>Criteria for repair</td>
<td></td>
</tr>
<tr>
<td>[Dense grade pavement] Repair operation is needed where rut depth is over 30mm, and crack ratio is over 30%</td>
<td></td>
</tr>
<tr>
<td>[Drainage pavement] Repair operation is needed where rut depth is over 35mm, and crack ratio is over 35%</td>
<td></td>
</tr>
<tr>
<td>Frequency of inspection</td>
<td>Every 3 year (Less than 5 years)</td>
</tr>
<tr>
<td>Guideline</td>
<td>A guideline for complete overhaul of road (draft) was released from the road bureau</td>
</tr>
</tbody>
</table>

This information is based on the guideline applied mainly for trunk road, but applicable to other road.
Pavement Condition Survey System

- PASCO’s Road Asset Management System
  - Patented technology about inspection method in 1970
  - Oversea projects experiences in USA, EU and Asia
  - Market leader in Japan (surveyed all National Highway)
  - High Accuracy data Collection System
  - Customization according to clients needs
Kyoto Model – Data Oriented Management Approach

- Deterioration forecasting model (Performance evaluation) (Bench-Marking evaluation)
- Maintenance Planning (Short-term and Middle Term)
- Scheduled Inspection
- Ex-post Valuation (evaluation of LOS)
- Database Management
- Daily monitoring (Mobile inspection system)
Concept – Whole Structure of Road Asset Management
Relationship between database and management System

- Management System; Customization of functions step by step

- **Database – Continuously Data Accumulation**

It is so important to start data accumulation RIGHT NOW with right way! Because it takes so log time to establish sufficient road database for road asset management, ex. Deterioration forecasting.
Kyoto Model

• Concept
  ➢ Management cycle based on actual monitoring data
  ➢ Finding problems and solution based on benchmarking analysis
  ➢ Ongoing improvement of management cycle by objective way

• Technical feature of Kyoto Model
  ➢ Stochastic performance evaluation (deterioration forecasting model)
  ➢ Probabilistic forecasting model using Markov theory
  ➢ Statistical analysis using objective data collected on site (not Pavement engineering)
  ➢ Good compatibility with actual conditions on site
Comparison between Kyoto Model and Existing model

<Kyoto Model>

- Performance Evaluation (Benchmarking Analysis)
- Problem points finding
- New Actions / Solutions
- Feedback to next implementation

Find damaged, high-speed deterioration, problem segments
Correlation with deterioration factors (Big Data Analysis)
Based on actual site situation and data

<Existing Model>

- Deterioration Prediction
- Repair Plan

Based on Pavement Engineering Deterioration Predication and Maintenance Plan (Traffic or Structure)

MANAGEMENT

MAINTENANCE
Deterioration forecasting model for Asset Management

• Uncertainty of deterioration process
  • It is impossible to forecast the deterioration deterministically
  • It is possible to reduce uncertain width by modeling the rule of deterioration process
Deterioration prediction model

• Hazard model

\[
\lambda_i(y_i) \Delta y_i = \frac{f_i(y_i) \Delta y_i}{\bar{F}_i(y_i)} \quad \bar{F}_i(y_i) = \exp(-\lambda_i y_i)
\]

• Markov deterioration hazard model

\[
\pi_{ij}(z) = \text{Prob}[h(\tau_B) = j \mid h(\tau_A) = i]
\]

\[
= \sum_{m=i}^{j} \prod_{s=i}^{m-1} \frac{\lambda_s}{\lambda_s - \lambda_m} \prod_{s=m}^{j-1} \frac{\lambda_s}{\lambda_{s+1} - \lambda_m} \exp(-\lambda_m z)
\]

• Markov transition probabilities

\[
\Pi = \begin{pmatrix}
\pi_{11} & \cdots & \pi_{1J} \\
\vdots & \ddots & \vdots \\
0 & \cdots & \pi_{JJ}
\end{pmatrix}
\]
Markov Transition Probabilities

probabilities to transit among each condition rank

\[
\begin{pmatrix}
\pi_{11} & \pi_{12} & \cdots & \pi_{1J} \\
0 & \pi_{22} & \cdots & \pi_{2J} \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \cdots & \pi_{JJ}
\end{pmatrix}
\]

Conditions

1
2
3
4

\(\pi_{12}\) From Rank 1 to Rank 2

Next condition rank

Current condition rank
Performance Evaluation of Pavement (Deterioration Forecasting Model)

- Formulation of Deterioration Forecasting Model
  - Deterioration forecasting models can also be formulated
  - Deterioration performance characteristics can be observed

![Graphs illustrating condition rank and elapsed time for different pavement conditions](Image)
Impact analysis of deterioration speed

- Impact analysis
  - to confirm the factors which have an impact for the differences of deterioration speed compared to the average deterioration performance.

Impact of Traffic Volume

Difference between intersection and others

Impact of Pavement Types
**Uncertainty and Heterogeneity**

Markov Deterioration Hazard Model


Base Hazard Rate:

\[ \lambda_i^k = \beta_{i,1} + \beta_{i,2} x_2^k + \ldots \]

Mixture Markov Deterioration Hazard Model


Mixture Hazard rate:

\[ \lambda_i^{l_k} = \tilde{\lambda}_i^{l_k} e^k \]

Uncertainty of Deterioration Process: Specific Parameters

Heterogeneity : Heterogeneity Parameters
Bench-marking analysis

\[ \lambda_i^{l_k} = \tilde{\lambda}_i^{l_k} e^k \]

Heterogeneity Parameter

Elapsed Time

Condition: Good

Hi-Speed Deterioration Group

Hi-Speed Deterioration \( \varepsilon > 1 \)

Base PC \( \varepsilon = 1 \)

Long life \( \varepsilon < 1 \)

Long-life Group
Comparative Assessment of Deterioration Performance

- The life expectancy of a pavement improves by solving the problem of an unusual part which deterioration speed is fast.
- As a result, the life cycle cost reduction and improvement of service level is achieved.
[OUTPUT] Bench-Marking Evaluation

**Priority Maintenance segments**
Road segments with high priority for FWD examination and repair construction are shown on GIS map.

**Risk Assessment**
High risk deterioration segments are evaluated and pinpointed.
[OUTPUT] Selection of the priority segments

- Selection of the priority segments
  - The pavement segments which have a serious deterioration speed should be defined as the priority segments for detail examination (FWD) or repair/rehabilitation works.

  (Repair or Inspection Policy based on deterioration speed)

  Current Condition; Damaged + deterioration speed; High
  => A: **Priority segments for repair or detail examination (FWD)**

  Current Condition; Not damaged + deterioration speed; High
  => B: **Priority segments for daily monitoring**
WebGIS-based Road Management System (Kyoto Model)

Main functions of Kyoto Model

- Browsing the road maintenance data
- Updating of road maintenance data
- Planning of road maintenance (middle-term and short-term planning)
Scheduled inspection

- Automatic measurement vehicle
  - Monitoring of pavement condition
  - Finding the pavement section which should be repaired
Pavement Condition Survey Vehicle

- Crack
- Rutting
- Geometry
- International Roughness Index, IRI
- Road Image
- Distance

- GPS
- IMU
- Laser scanner
- Forward view camera
- Laser displacement sensor
- Road camera
Class II IRI equipment

- Class II equipment for IRI evaluation
- Transportable and Compact vehicle
- GPS coordinate and front view image data
EXAMINATION of MESUREMENT VEHICLE

• To secure the accuracy of inspection with automatically measurement vehicle
• Examination by the central government's organization
• From 1989, every year
• Only the companies which have the passed vehicles can make a contract of inspection works.
• Examination item
  • Cracking, Rutting, Smoothness and Distance
Actual measurement

Method
Distance: steel taping
Cracking: sketch
Rutting: Crossing profilometer
Smoothness: vertical profilometer
Examination of distance instrumentation

Procedure

1. Start from point BP
2. Drive at 30km/h
3. Stop at point EP
4. Measurement of the gap of point EP and stop position
5. Measurement of the distance from BP to EP
Examination of Cracking measurement

Procedure
1. Stop at point BP
2. Drive at 30km/h
3. Photography of specified area
4. Evaluation of sampling photos
**Examination of Rutting measurement**

Procedure

1. Simultaneously with Cracking

2. Measurement of the Rutting on the base-line (within 30cm)

3. Evaluation of Cracking (Automatically)
Examination of Smoothness measurement

Procedure

1. Simultaneously with Cracking

2. Measurement of the smoothness on the base-line (within 15cm)

3. Evaluation of Smoothness values (Automatically)
Acceptability Criterion and Certification

- Distance
  less than plus or minus 0.5% to the actual measurement

- Cracking
  A cracking in 1mm or more can be recognized.

- Rutting
  less than plus or minus 3.0mm to the actual measurement

- Smoothness
  less than plus or minus 30% to the maximum and minimum value of the actual measurement
Related Technology

• Mobile Inspection System using tablet PC

Inspection of safety equipment (River)

Inspection of street lights (Road)
Related Technology

- Thermal infrared camera for damage detection
- Mobile Mapping System

Evaluate the severity of cracking from captured image
Calculate roughness from 3D point-clouds data