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ERPUG

TRIMM FINAL CONFERENCE and ERPUG Forum

Road Management Technologies in Japan

23rd & 24th October 2014

Kazuya AOKI
Hideaki KUROSU
PASCO CORPORATION

Japan. Endless Discovery.

PASCO World's Leading Geospatial Group

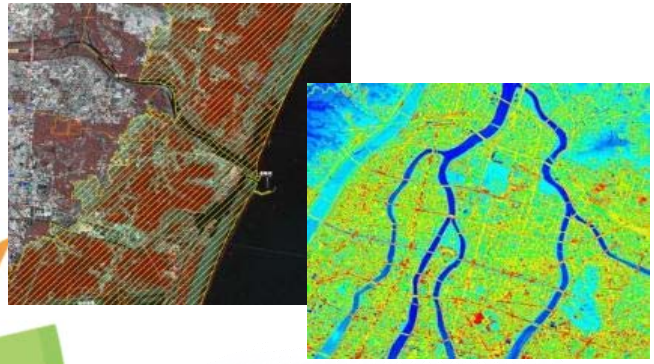
PASCO Corporation

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

PASCO Corporation

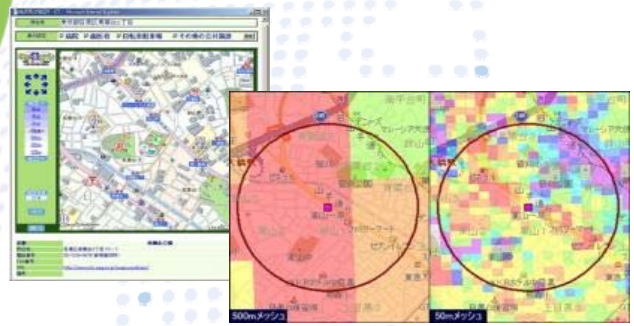
Spatial Data Acquisition

Spatial Data Processing & Analysis



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

GIS Service

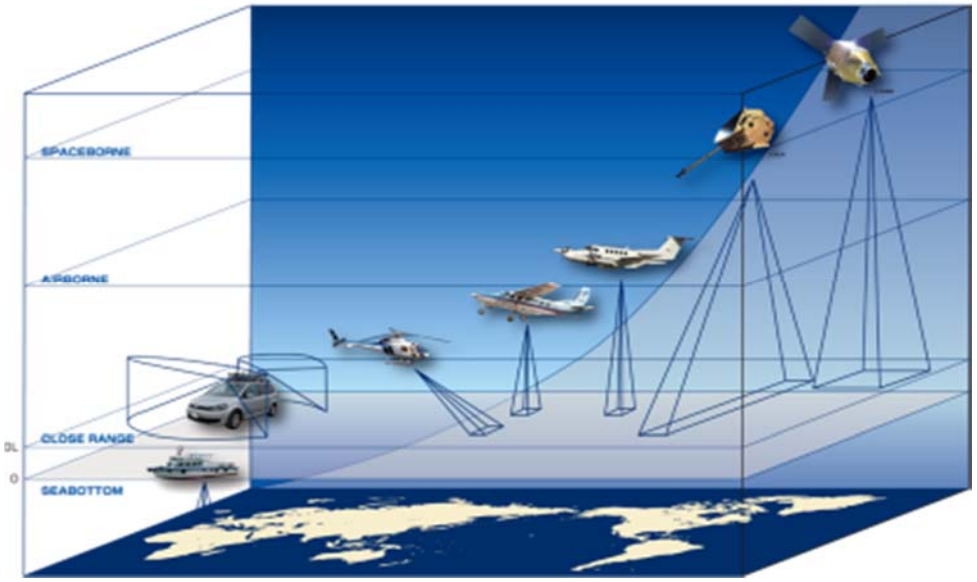


Identifying social needs

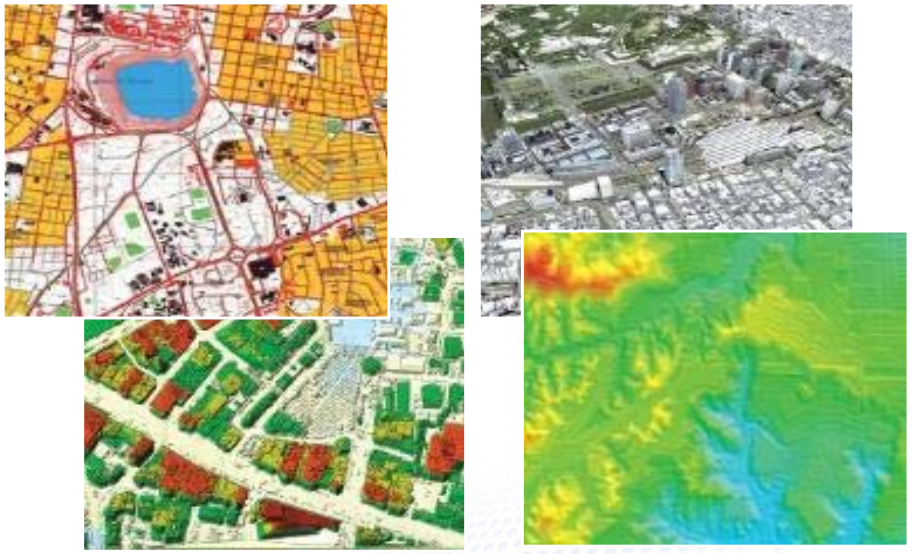
Problem Solving, and Planning

Main Business Fields

Surveying



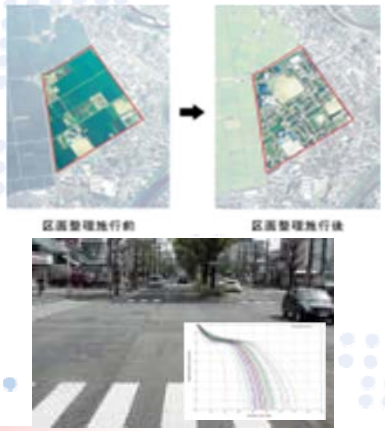
Mapping



GIS & Spatial Analysis

Consultation

Asset management,
City planning,
Disaster prevention,
Road construction,
Environment,
etc.



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Development of Infrastructure in Japan

69 years

High growth period (1954-1973)

1945

End of W.W.II

1964

Tokyo Olympic

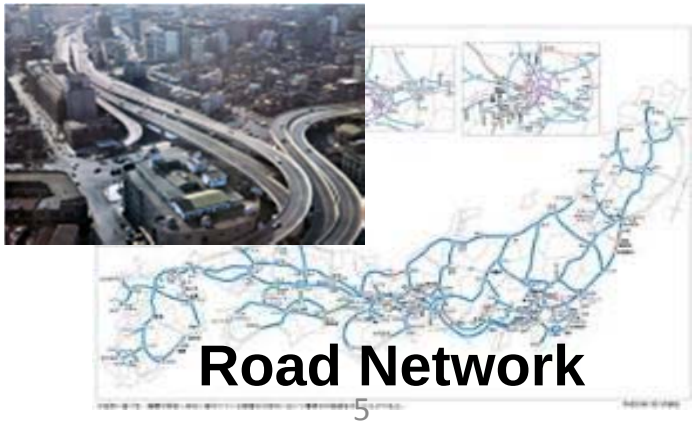
Development of infrastructure was accelerated

Bubble boom (1986-1991)

2000

40-50 years

Aging Infrastructure becomes serious issue



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Deterioration of Infrastructure (Road)

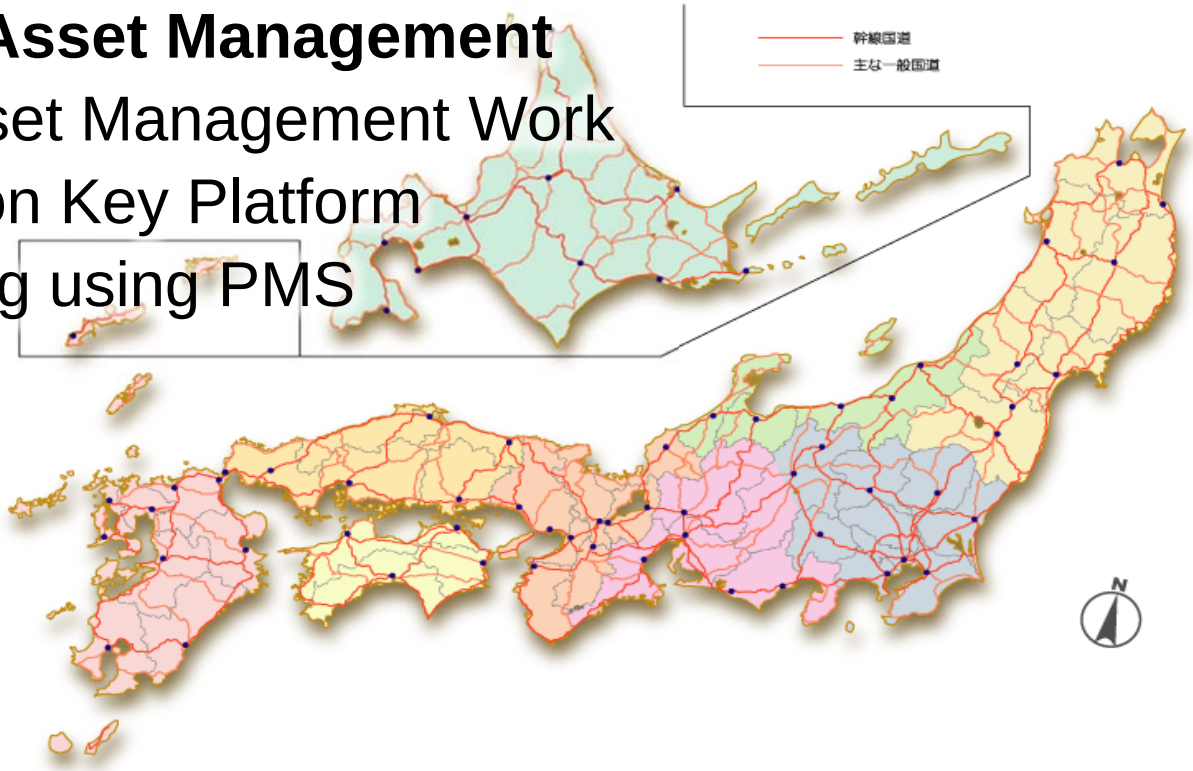
- Common deterioration of road in Japan

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

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

This information is based on the guideline applied mainly for trunk road, but applicable to other road

Pavement Condition Survey System

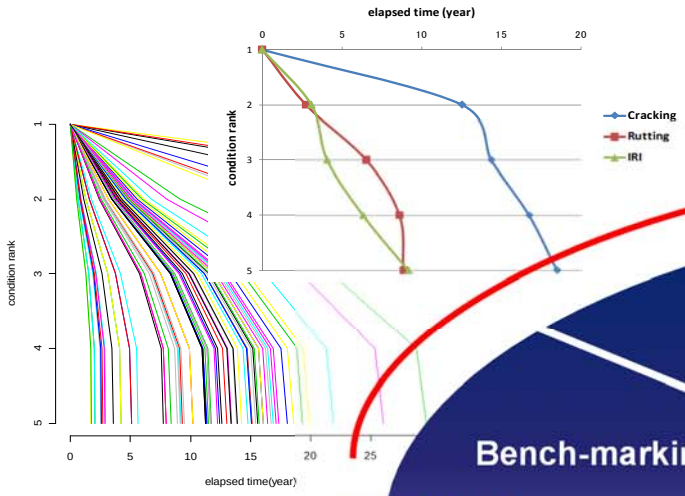
- **PASCO's Road Asset Management System**
  - Patented technology about inspection method in 1970
  - Oversea projects experiences in USA, EU and Asia
  - Market leader in Japan (surveyed all National Highway)
  - High Accuracy data Collection System
  - Customization according to clients needs

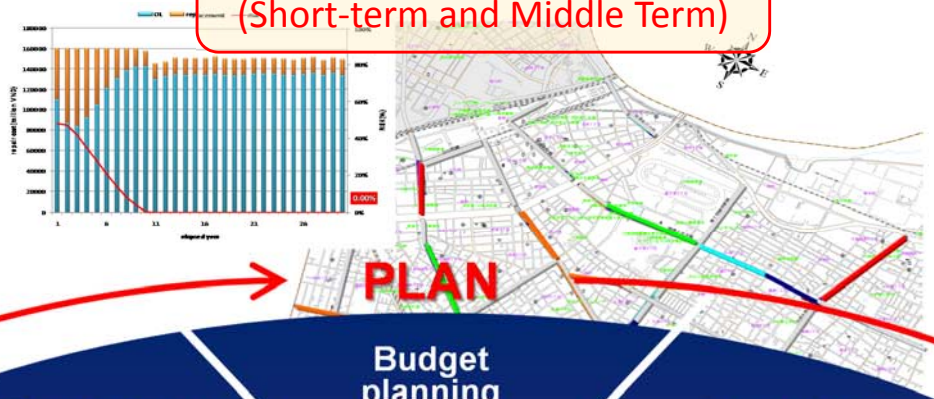
Kyoto Model – Data Oriented Management Approach

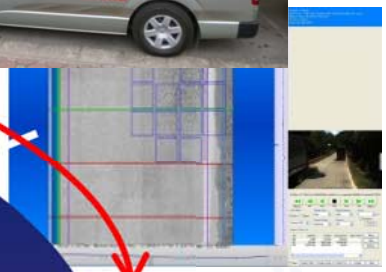
Deterioration forecasting model
(Performance evaluation)
(Bench-Marking evaluation)

Maintenance Planning
(Short-term and Middle Term)

Scheduled Inspection







Ex-post Valuation
（evaluation of LOS）

Database Management

Daily monitoring
(Mobile inspection system)

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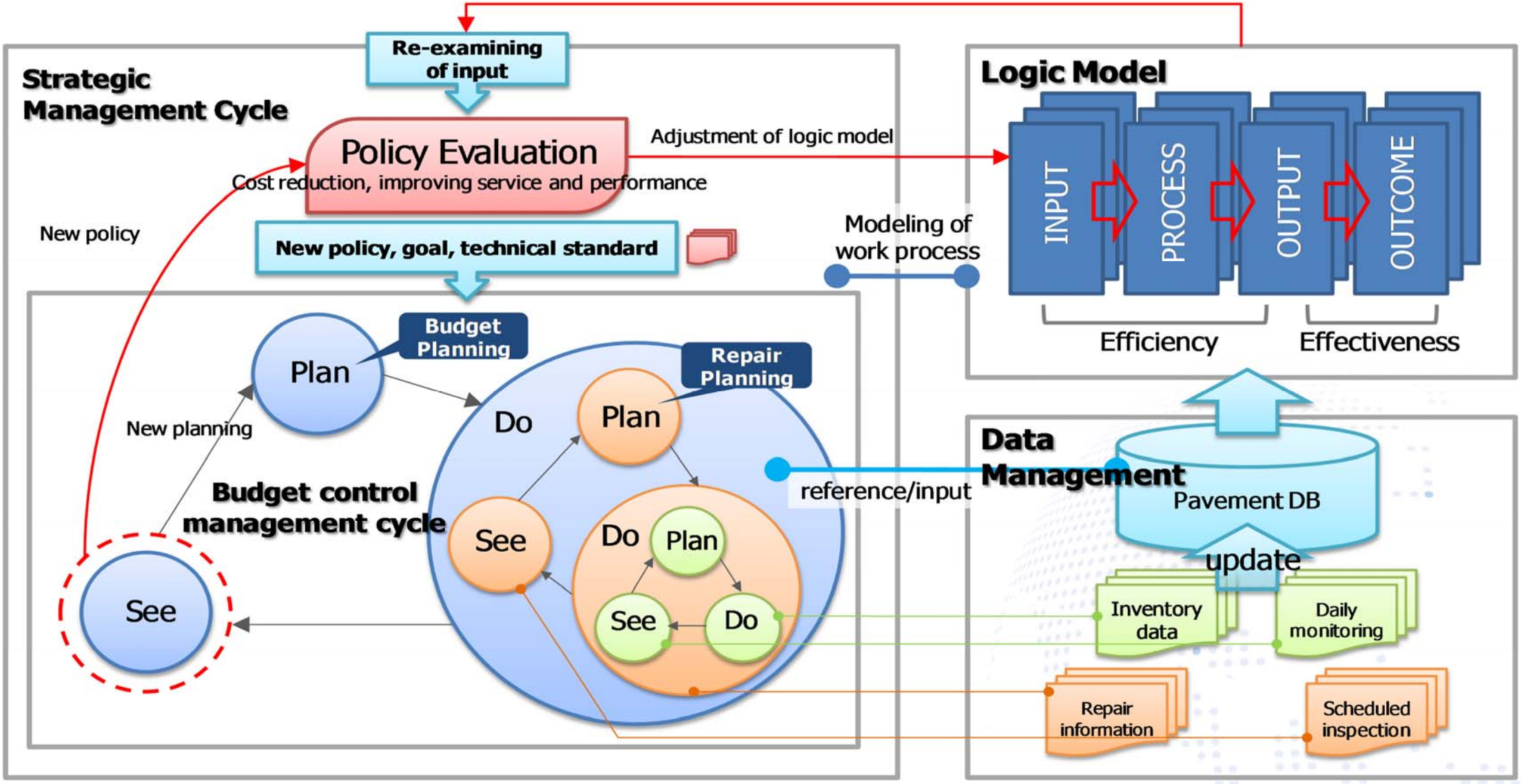
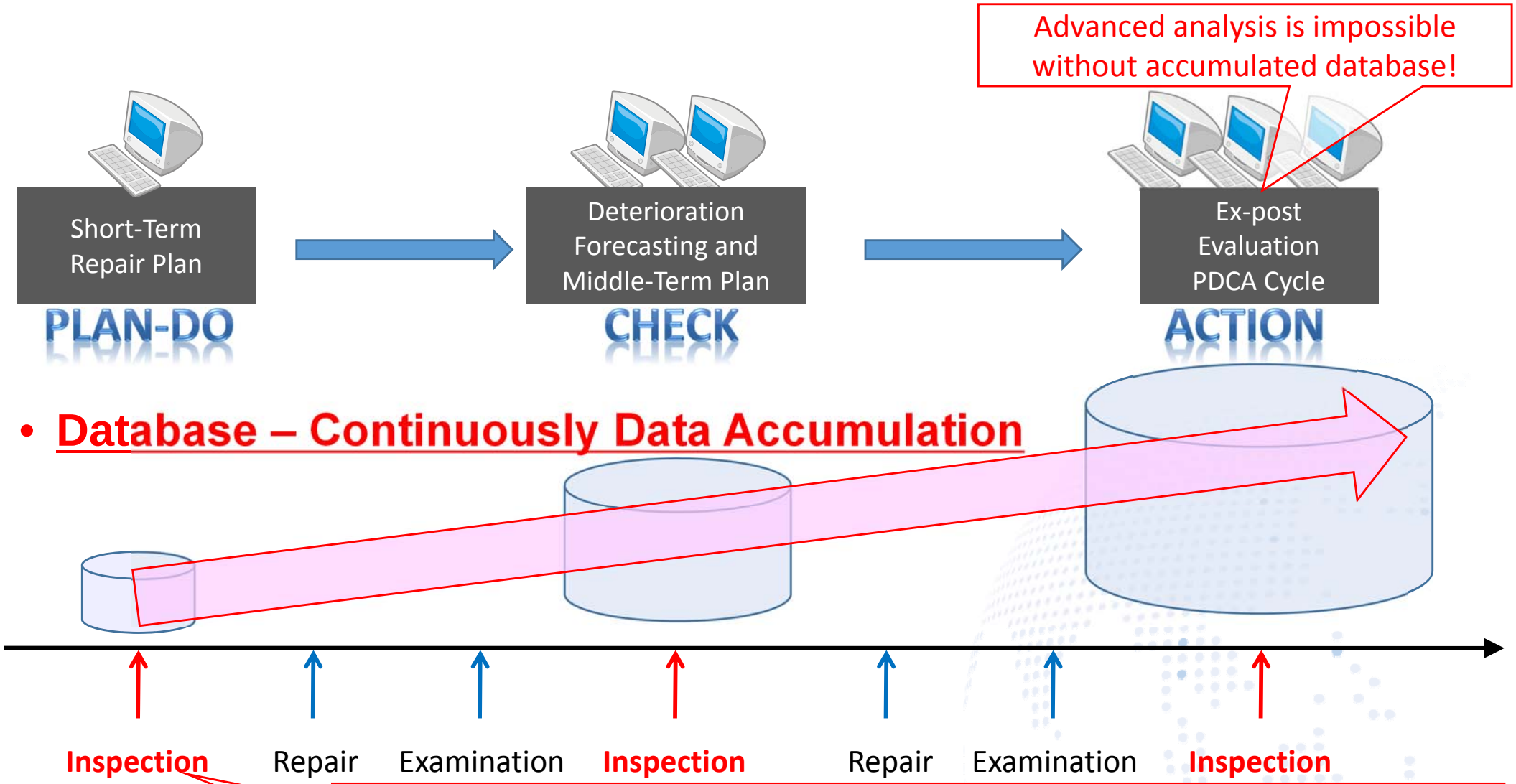
Concept – Whole Structure of Road Asset Management



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

MANAGEMENT

<Existing Model>

Deterioration Prediction

↓

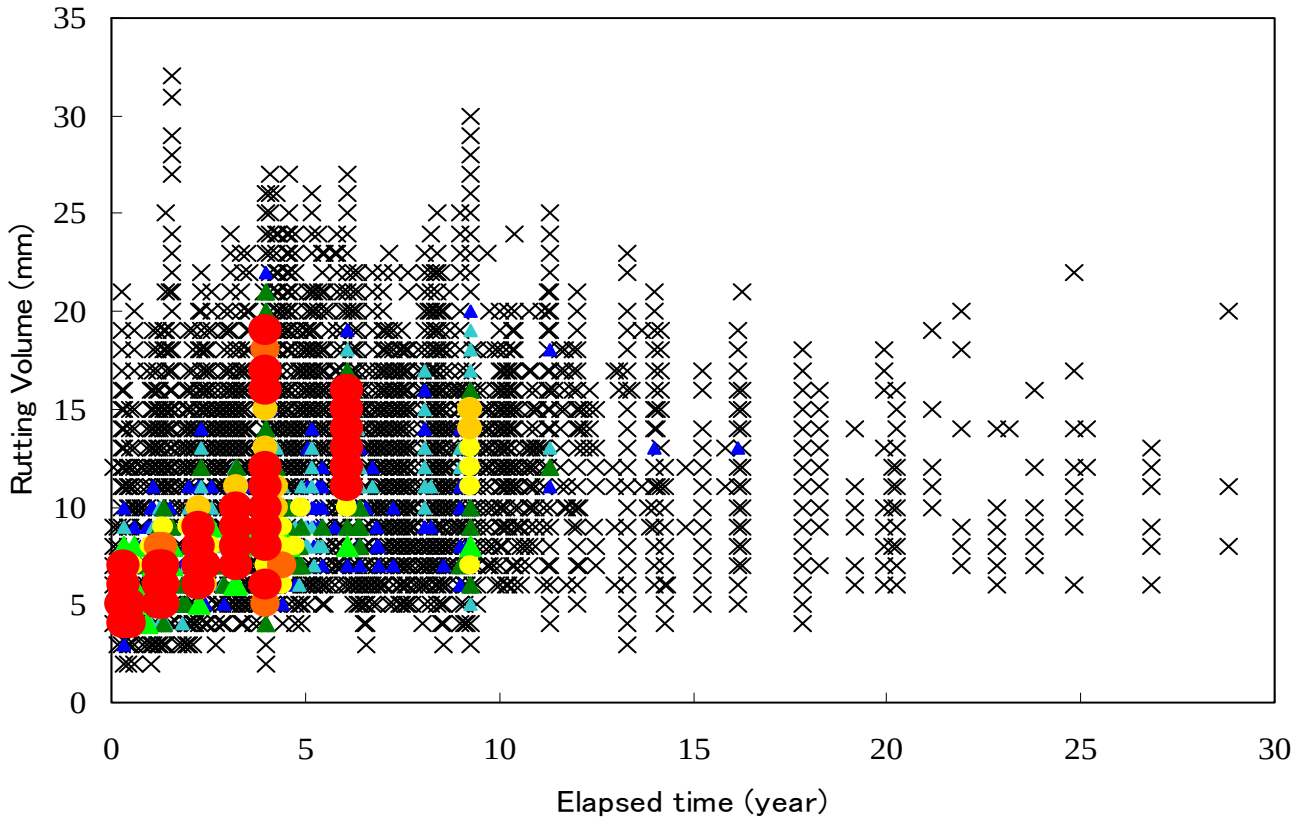
Repair Plan

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

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

$$\lambda_i(y_i)\Delta y_i = \frac{f_i(y_i)\Delta y_i}{\tilde{F}_i(y_i)} \qquad \tilde{F}_i(y_i) = \exp(-\lambda_i y_i)$$

Exponential hazard function (survival function)

- Markov deterioration hazard model

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

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

- Markov transition probabilities

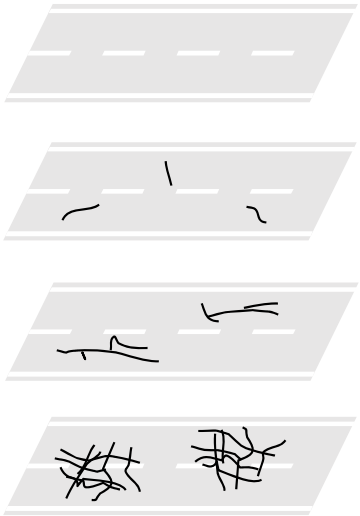
$$\Pi = \begin{pmatrix} \pi_{11} & \cdots & \pi_{1J} \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \pi_{JJ} \end{pmatrix}$$

Markov Transition Probabilities

Markov Transition Probabilities

probabilities to transit among each condition rank

Conditions



1

2

3

4

$$\mathbf{\Pi}_k = \begin{pmatrix} \pi_{11} & \pi_{12} & \cdots & \pi_{1J} \\ 0 & \pi_{22} & \cdots & \pi_{2J} \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \pi_{JJ} \end{pmatrix}$$

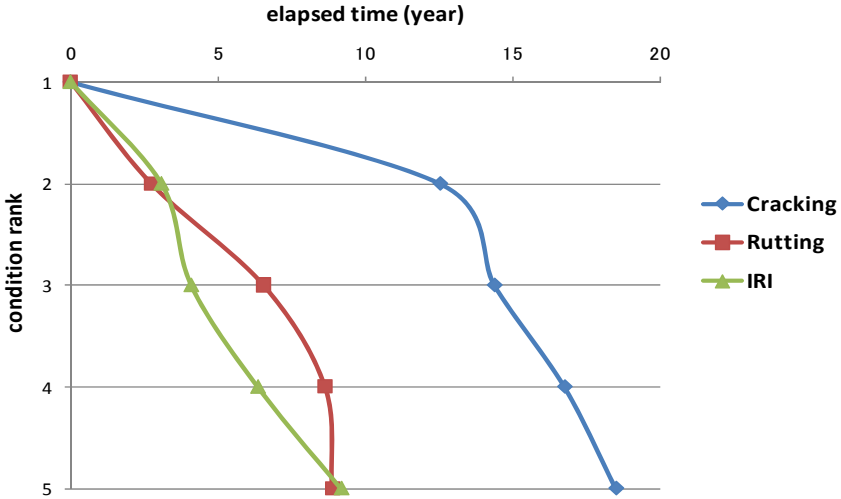
π_{12} ➡ From Rank1  to Rank2 

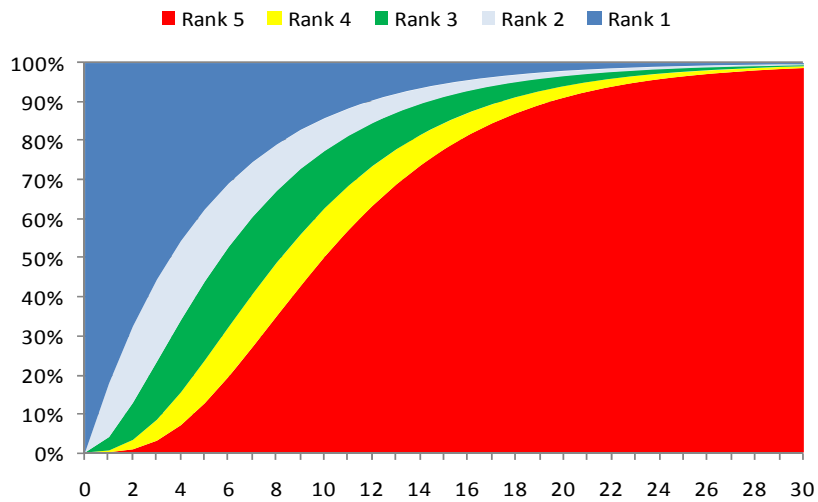
Next condition rank

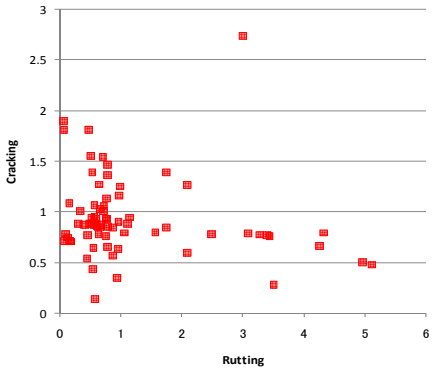
Current condition rank

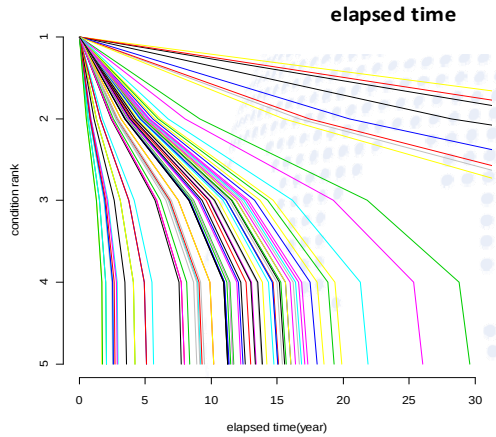
Performance Evaluation of Pavement (Deterioration Forecasting Model)

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





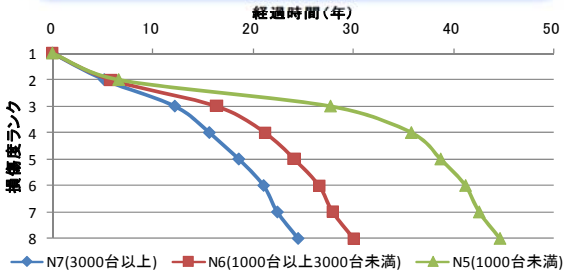




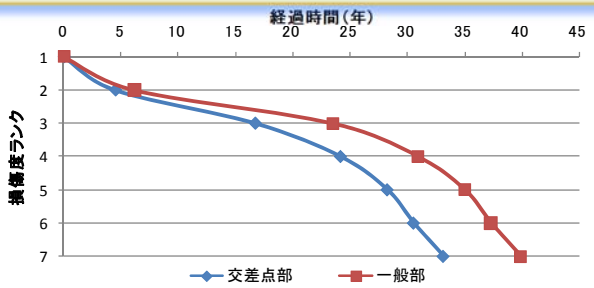
Impact analysis of deterioration speed

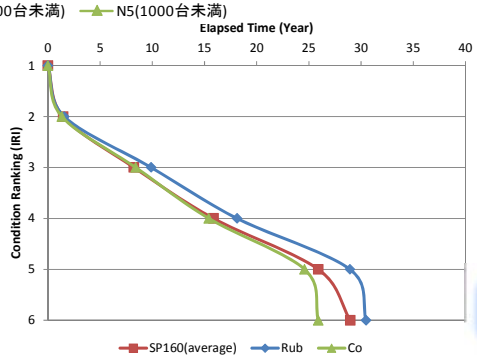
- Impact analysis
  - to confirm the factors which have an impact for the differences of deterioration speed compared to the average deterioration performance.

Impact of Traffic Volume



Difference between intersection and others





Impact of Pavement Types

Uncertainty and Heterogeneity

Markov Deterioration Hazard Model

Tsuda, Y., Kaito, K., Aoki, K., Kobayashi, K., 2006, Estimating Markovian Transition Probabilities for Bridge Deterioration Forecasting, Journal of Structural Eng./Earthquake Eng., JSCE, Vol.23, No.2, pp.241s-256s, (Journal Articles)

Base Hazard Rate: $$\lambda_i^k = \beta_{i,1} + \beta_{i,2}\boxed{x_2^k} + \ldots$$

Specific Parameter

Grouping

Mixture Markov Deterioration Hazard Model

Obama K., Okada K., Kaito K., Kobayashi K., 2008, Disaggregated Hazard Rates Evaluation and Bench-Marking, Doboku Gakkai Ronbunshuu A, Vol. 64, No. 4, pp.857-874 (Journal Articles)

Mixture Hazard rate: $$\lambda_i^{l_k} = \tilde{\lambda}_i^{l_k}\boxed{\varepsilon^k}$$

Heterogeneity Parameter

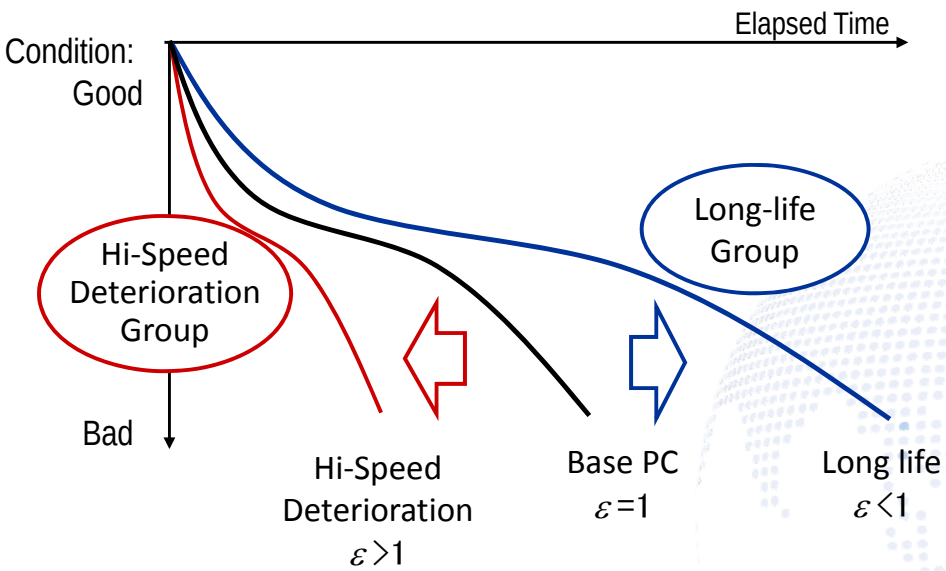
Uncertainty of Deterioration Process : Specific Parameters

Heterogeneity : Heterogeneity Parameters

Bench-marking analysis

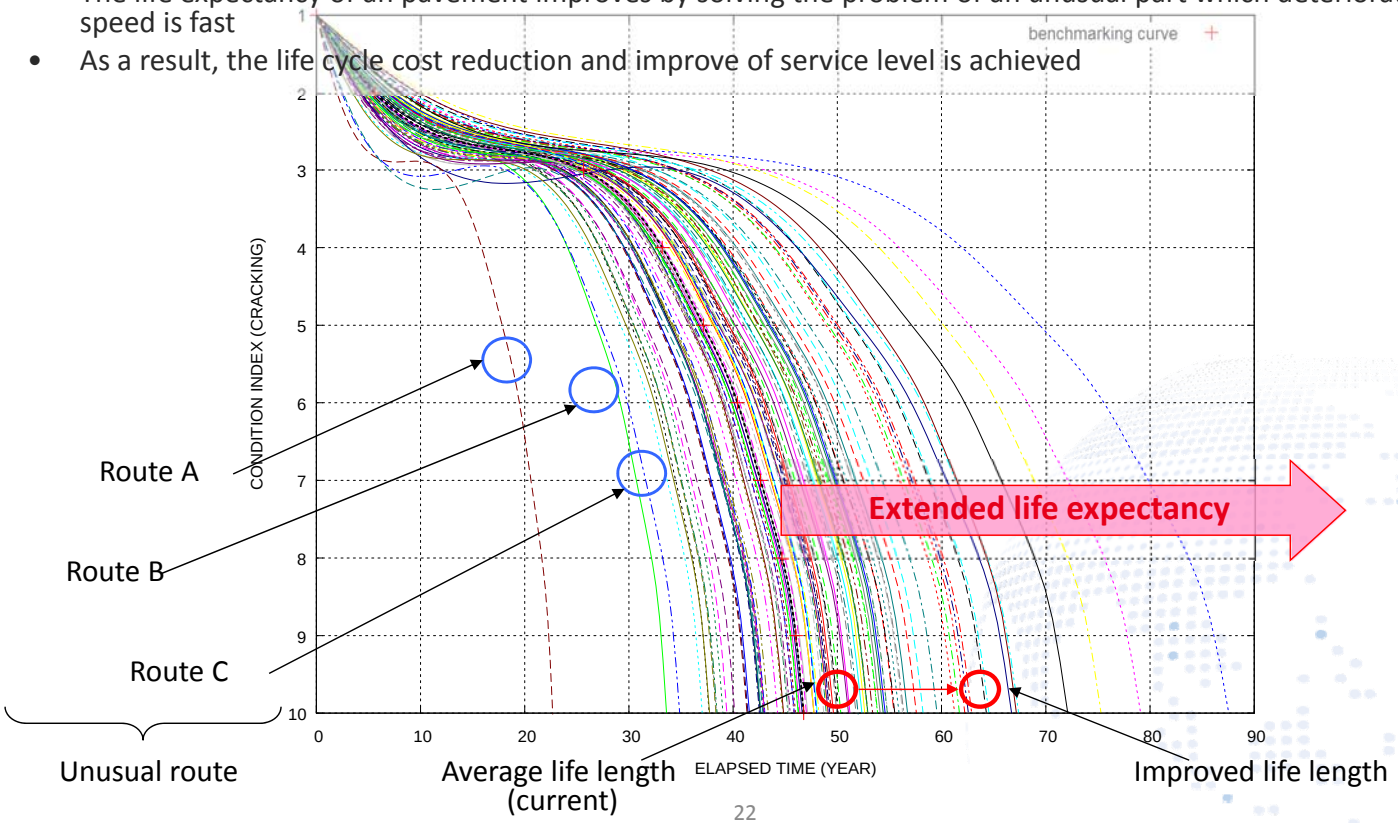
$$\lambda_i^{l_k} = \tilde{\lambda}_i^{l_k} \boxed{\varepsilon^k}$$

Heterogeneity Parameter

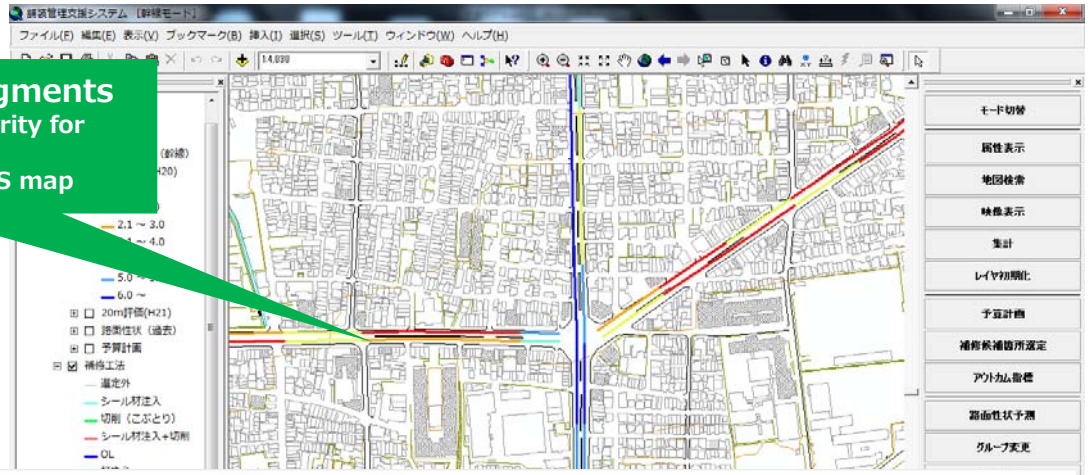


Comparative Assessment of Deterioration Performance

- The life expectancy of an pavement improves by solving the problem of an unusual part which deterioration speed is fast
- As a result, the life cycle cost reduction and improve of service level is achieved



[OUTPUT] Bench-Marking Evaluation

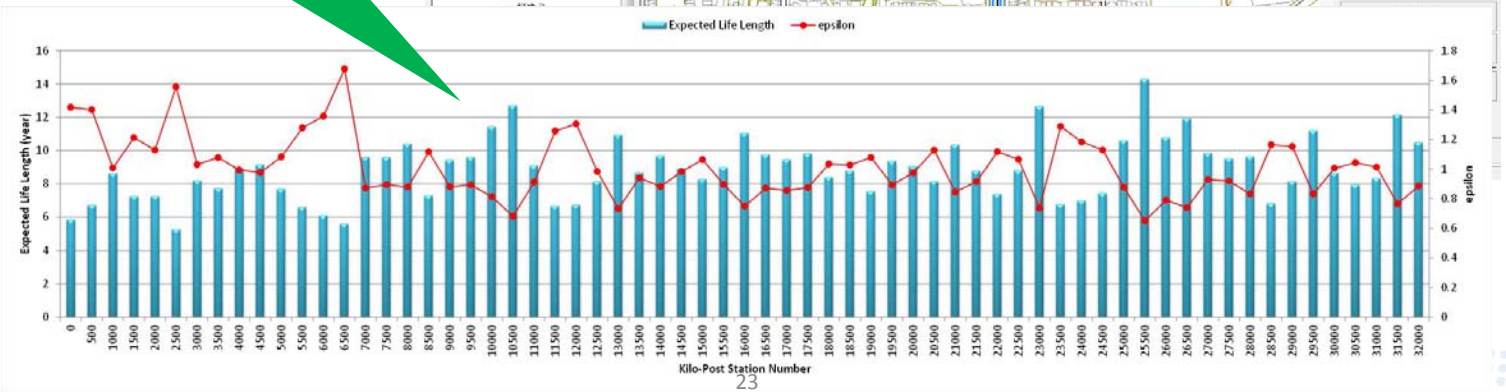


Priority Maintenance segments

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.

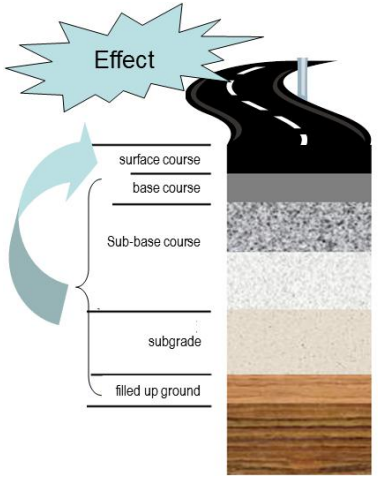
（Repair or Inspection Policy based on deterioration speed）

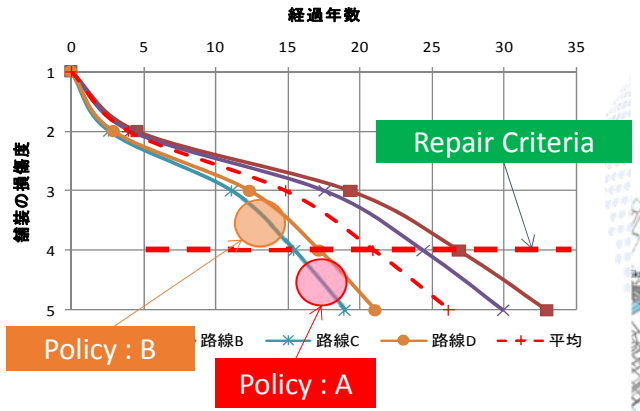
Current Condition ; Damaged + deterioration speed; High

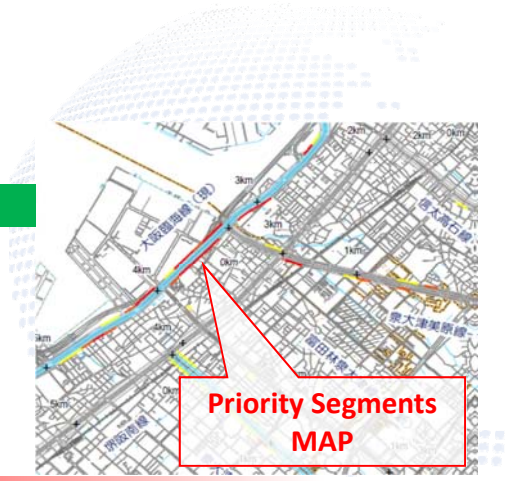
=> A : *Priority segments for repair or detail examination (FWD)*

Current Condition ; Not damaged + deterioration speed; High

=> B : *Priority segments for daily monitoring*



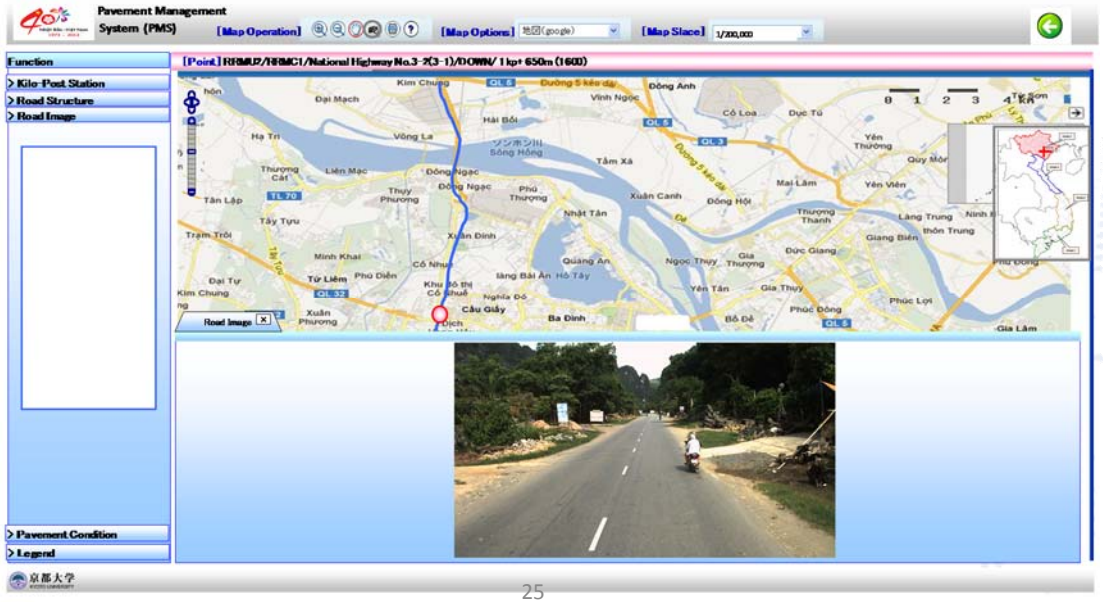




WebGIS-based Road Management System (Kyoto Model)

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)

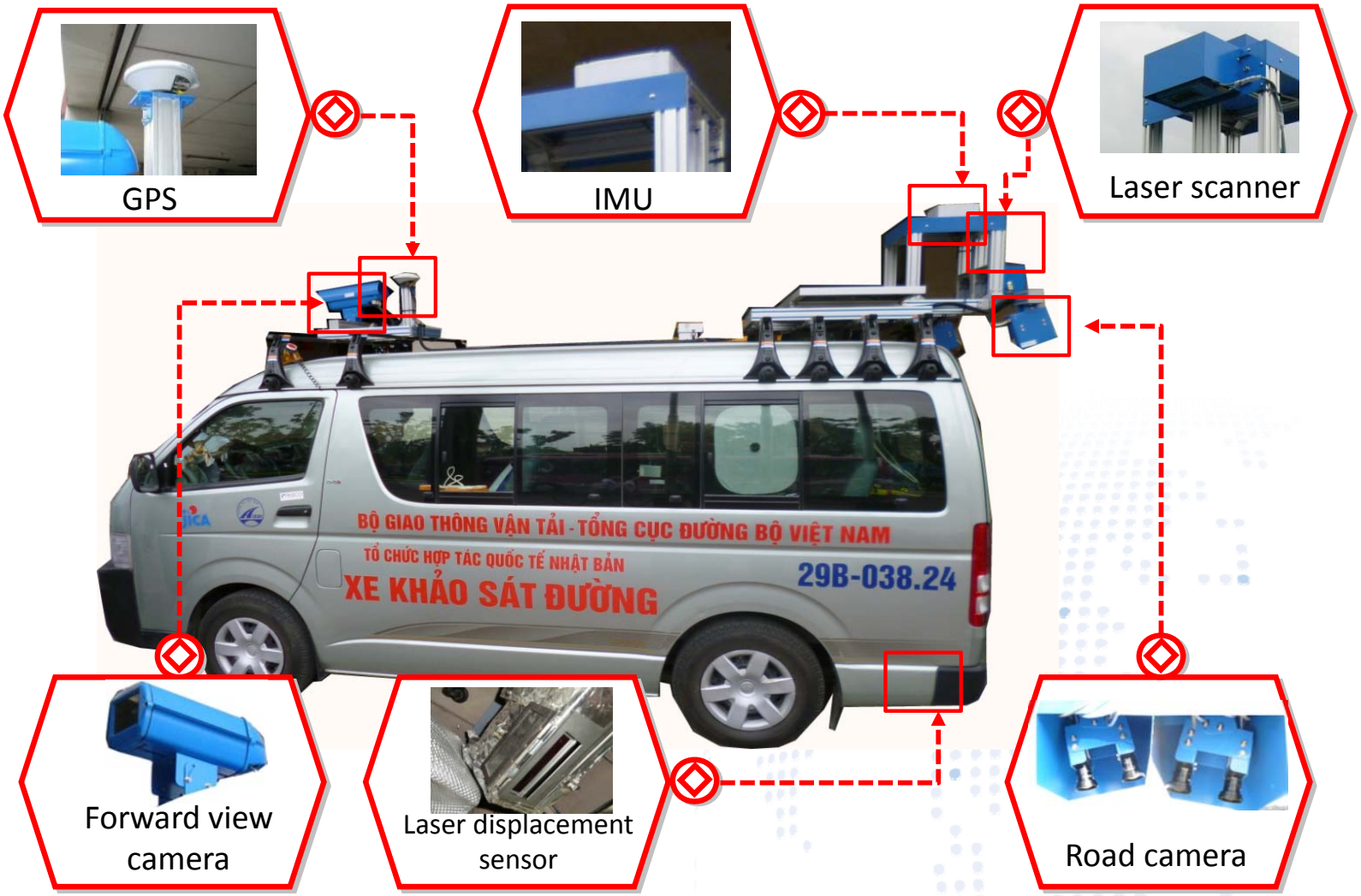


Scheduled inspection

- Automatic measurement vehicle
  - Monitoring of pavement condition
  - Finding the pavement section which should be repaired

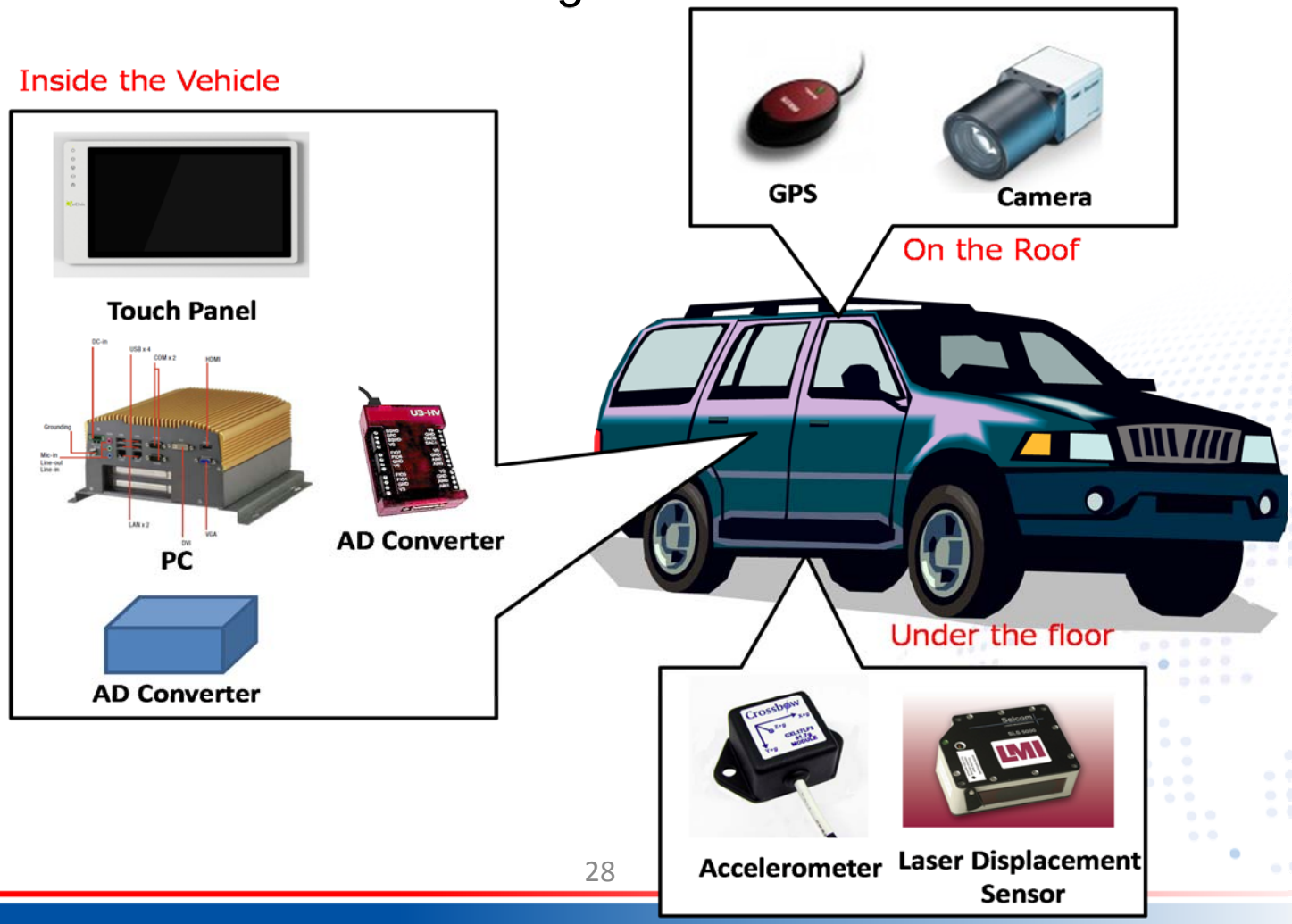
Pavement Condition Survey Vehicle

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



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

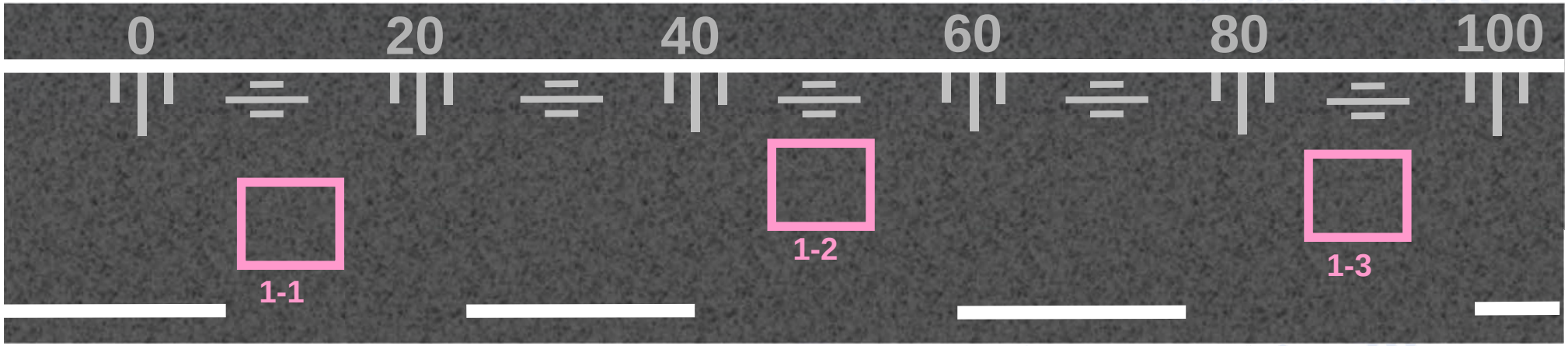
Procedure

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



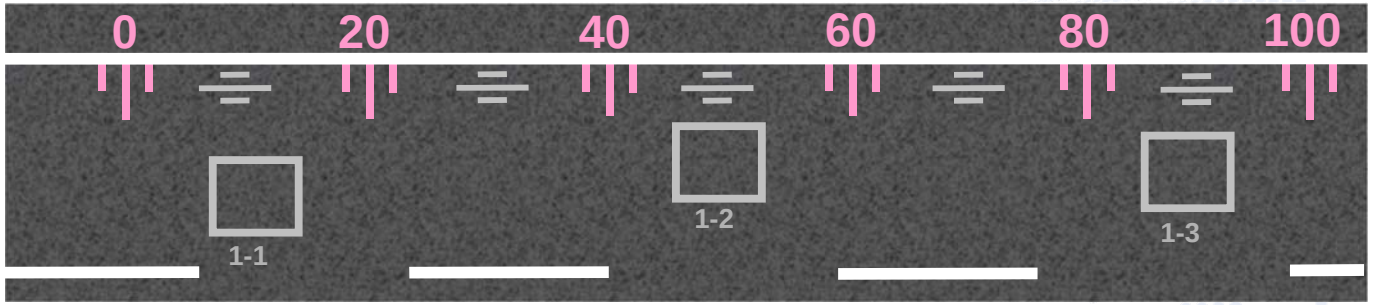
Examination of Rutting measurement

Procedure

1. Simultaneously with Cracking

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

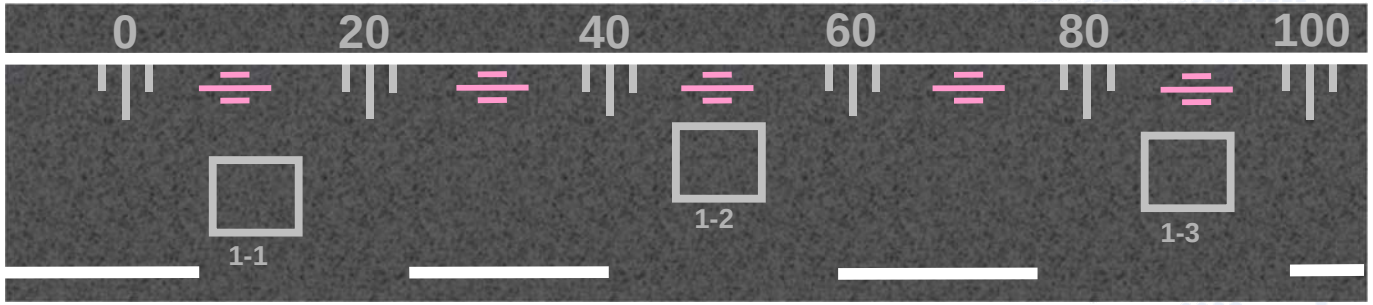
3. Evaluation of Cracking (Automatically)



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

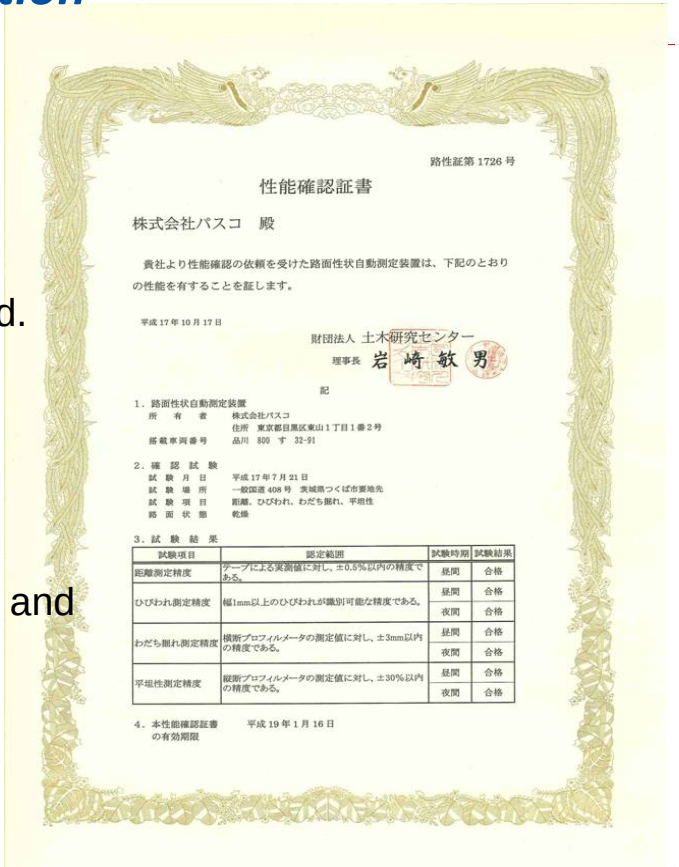
  A cracking in 1mm or more can be recognized.

- 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



路性証第 1726 号

性能確認証書

株式会社パスコ　殿

貴社より性能確認の依頼を受けた路面性状自動測定装置は、下記のとおりの性能を有することを証します。

平成 17 年 10 月 17 日

財団法人 土木研究センター
理事長 岩 崎 敏 男

記

1．路面性状自動測定装置
所　有　者　株式会社パスコ
住所　東京都目黒区東山 1 丁目 1 番 2 号
搭載車両番号　品川 800 す 32-91

2．確 認 試 験
試 験 月 日　平成 17 年 7 月 21 日
試 験 場 所　一般国道 408 号 茨城県つくば市要地先
試 験 項 目　距離、ひびわれ、わだち掘れ、平坦性
路 面 状 態　乾燥

3．試 験 結 果

試験項目	認定範囲	試験時期	試験結果
距離測定精度	テープによる実測値に対し、±0.5%以内の精度である。	昼間	合格
ひびわれ測定精度	幅1mm以上のひびわれが識別可能な精度である。	昼間	合格
		夜間	合格
わだち掘れ測定精度	横断プロフィルメータの測定値に対し、±3mm以内の精度である。	昼間	合格
		夜間	合格
平坦性測定精度	縦断プロフィルメータの測定値に対し、±30%以内の精度である。	昼間	合格
		夜間	合格

4．本性能確認証書の有効期限　平成 19 年 1 月 16 日

Related Technology

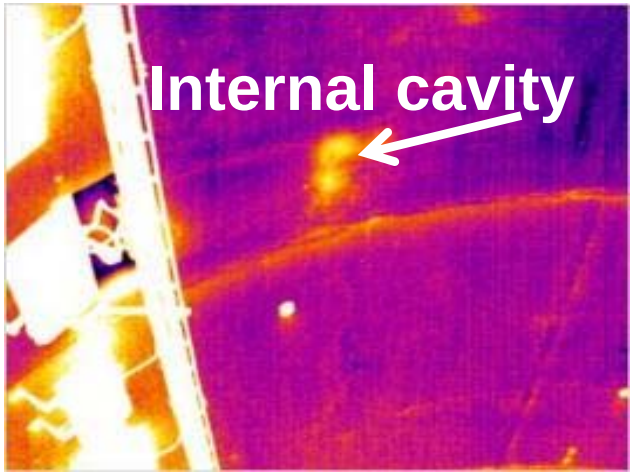
- Mobile Inspection System using tablet PC

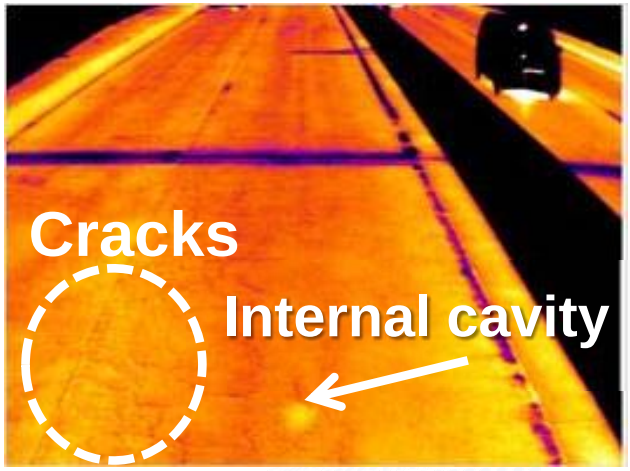
Inspection of safety equipment (River)

Inspection of street lights (Road)

Related Technology

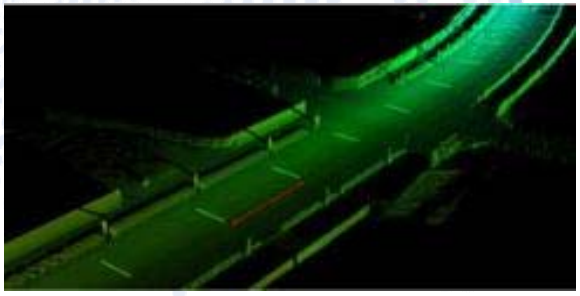
- Thermal infrared camera for damage detection





- Mobile Mapping System

Evaluate the severity of cracking from captured image



Calculate roughness from 3D point-clouds data