WORLD ROAD ASSOCIATION MONDIALE DE LA ROUTE
Norfolk, Virginia / September 19-22, 2012
7th symposium on pavement surface characteristics
SURF 2012

# A MOBILE PROFILOMETER FOR ROAD SURFACE MONITORING BY USE OF ACCELEROMETERS

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Presented by

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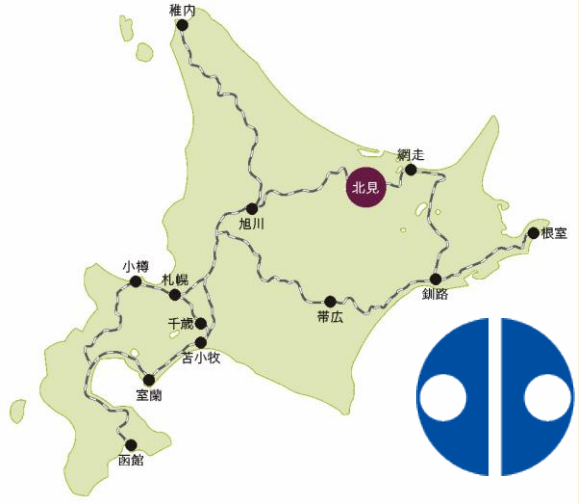
# Acknowledgment

**Kitami City**

The authors appreciate the assistance from the Road Control Section of Urban Construction Department of Kitami City for conducting this study

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# Agenda

1. Motivation and Objective
2. Concepts of the New System
3. Configuration and Algorithm
4. Verification Experiment
5. Application Case Study
6. Conclusions

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# 1. Motivation and Objective (1)

## Evenness/Roughness

*related to…*

**User's safety and comfort,**
**Vehicle operating costs,**
**Road side environment, etc.**

*required to…*

- **Objective and high precision data collection**
- **High frequency monitoring**

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# 1. Motivation and Objective (2)

## Current Surface Monitoring

- ✓ **High-speed profilers (response- or profile-based)**
- ✓ **Visual inspections**

**Patrol Vehicle**

**High-speed Laser Profiler**

*problems are…*

- ➢ **too much cost for high-speed profilers**
- ➢ **calibration of response type systems**
- ➢ **the lack of accuracy by visual inspections**

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# 1. Motivation and Objective (3)

***Objective of this Study***

**Development of a Mobile Profilometer**

- ✓ **using two small accelerometers**
- ✓ **collecting surface profiles and its roughness characteristics in real time**
- ✓ **making cost-effective, time-stable, and easily workable operation**

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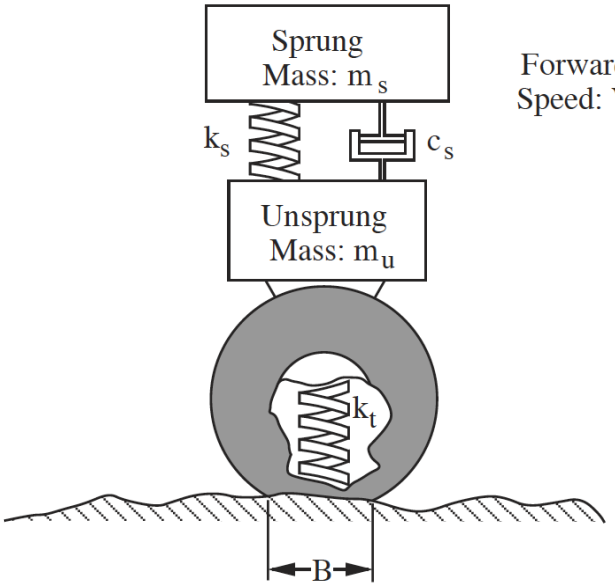
# 2. Concepts of the New System (1)

## Based on the Quarter-Car Model

- ✓ measuring surface profiles
- ✓ calculating the IRI




Quarter-Car Model

Golden Car Parameters

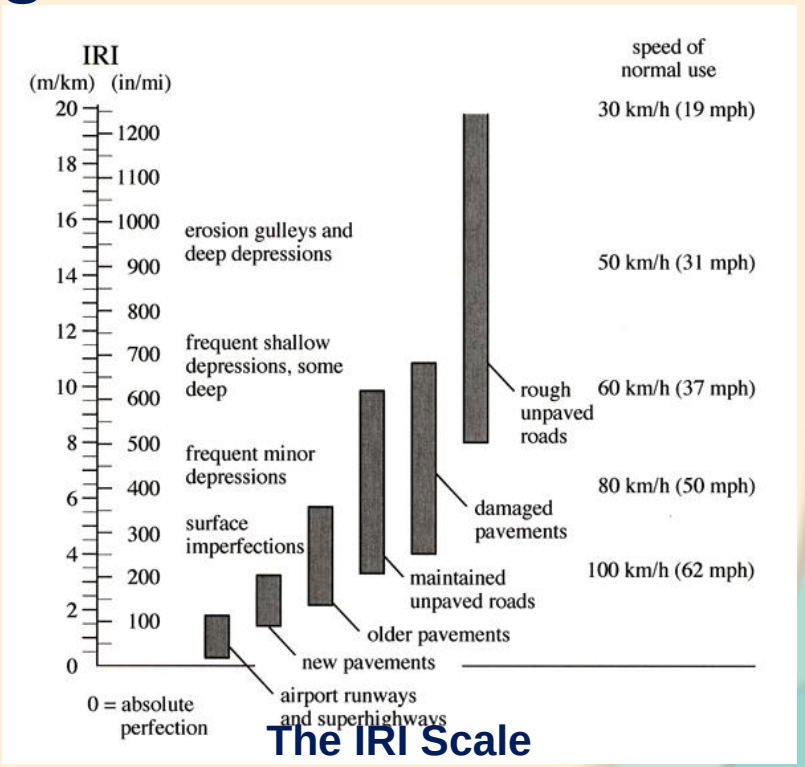
$m_u/m_s = 0.15$

$k_s/m_s = 63.3$

$c_s/m_s = 6.0$

$k_t/m_s = 653$

B = 250 (mm)




The IRI Scale

# 2. Concepts of the New System (2)

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## Profiler Class – *how the measures related to the IRI*

- **Class 4 –**can only be compared to IRI by subjective estimation **(ex. Visual inspection)**
- **Class 3 –** calculating IRI by correlation with reference measures **(ex. RTRRMS)**
- **Class 2 –** a profile-based method that is calibrated independently of other roughness measuring instruments **(ex. Laser-profiler)**
- **Class 1 –** a profile-based method if it is so accurate that further improvements in accuracy would not be apparent **(ex. Rod & Level)**

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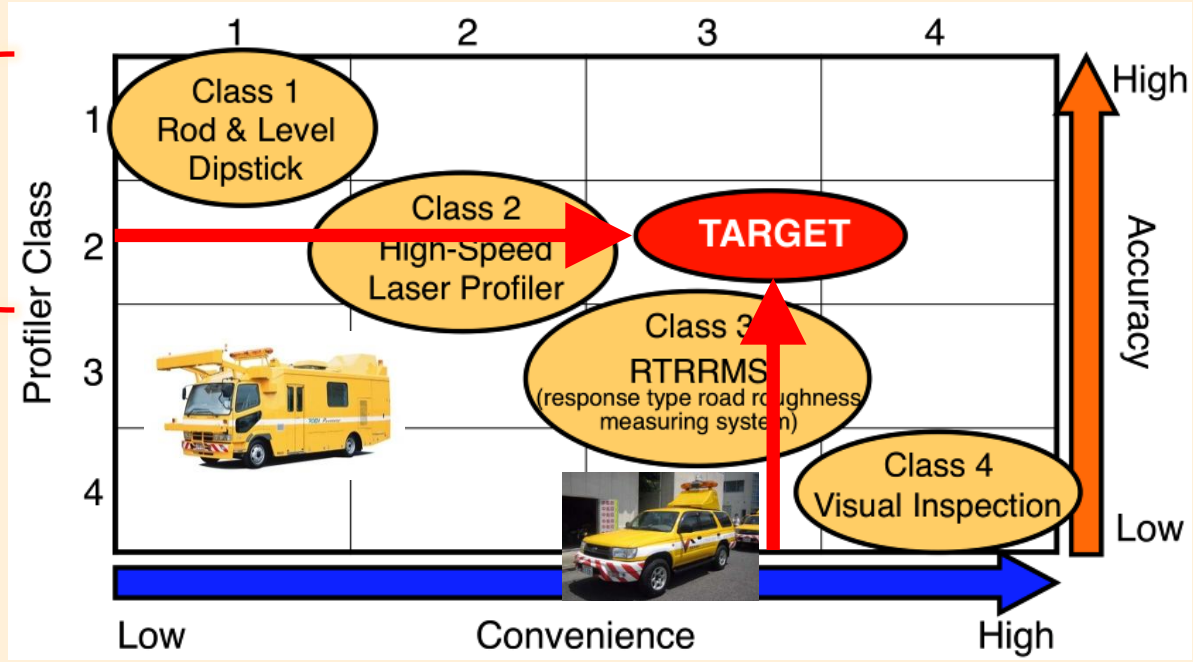
# 2. Concepts of the New System (3)

## Target of the System Development




Classification of the Profiler and the Target of the New System

**Accuracy: Class 2, Convenience: Class 3**

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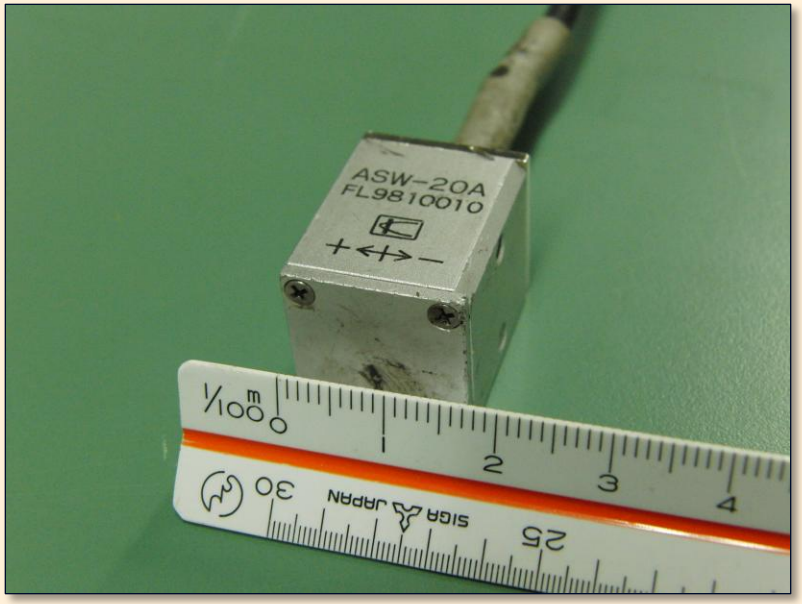
# 3. Configuration and Algorithm (1)

## Using Two Small Accelerometers




An Accelerometer

A GPS Sensor

A Transducer


An Onboard Computer

## Simply Operational (Class 3!!)

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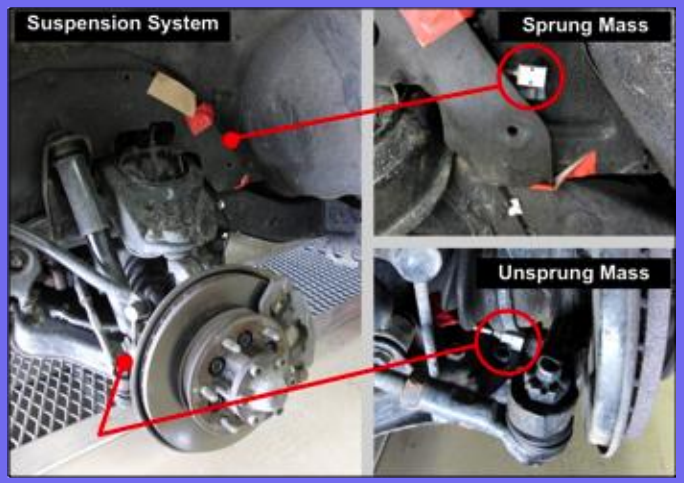
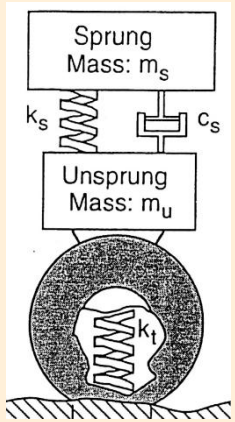
# 3. Configuration and Algorithm (2)

## Can be Mounted in Any Vehicles

Passenger/Commercial Vehicle (Road Patrol Car)




Suspension System




QC Model (for IRI)

- ✓ Mechanically implements the quarter-car model
- ✓ Measuring surface profiles (Class 2!!)
- ✓ Independent of vehicle model and driving speed

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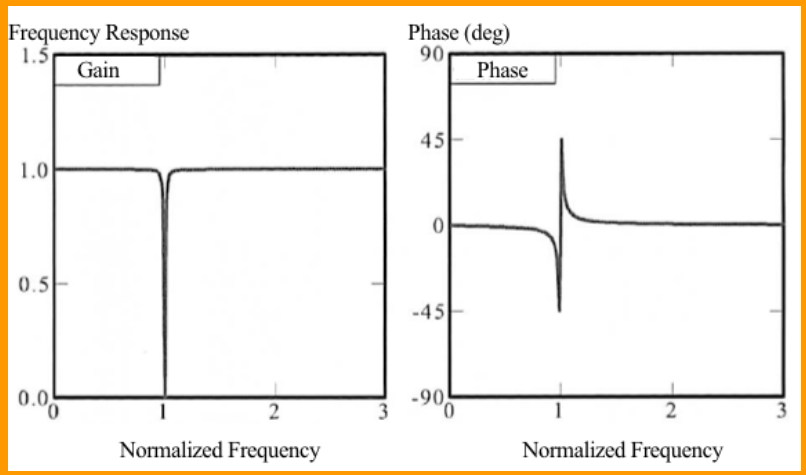
# 3. Configuration and Algorithm (3)

## Measurement Algorithm

**Measuring Acceleration**
(sprung & unsprung mass)

**Pre-processing**
reduction of the velocity factors by digital filters

**Integration of Acceleration**
calculation of velocities and displacements of the masses




**Response of the Digital Filter**

simulation of the QC model

**IRI Calculation**
computation of the IRI

**Profile and IRI Measurement Algorithm**

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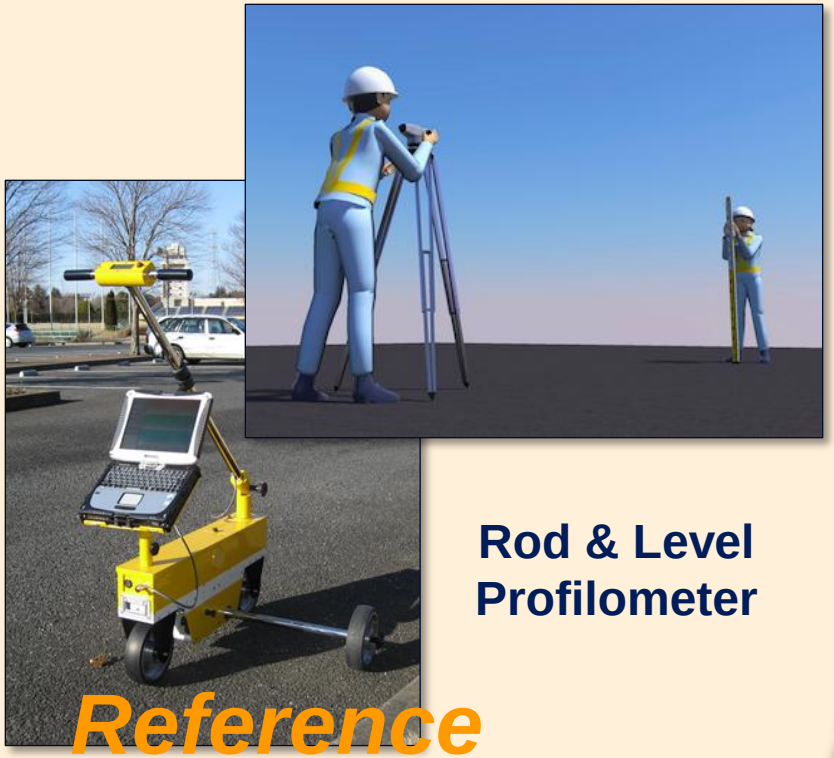
# 4. Validation Experiment (1)

## Data Collection

Survey Vehicle

**Mobile Profilometer**

**VS.**



Rod & Level Profilometer

*Reference*

**Class 1 Measures**

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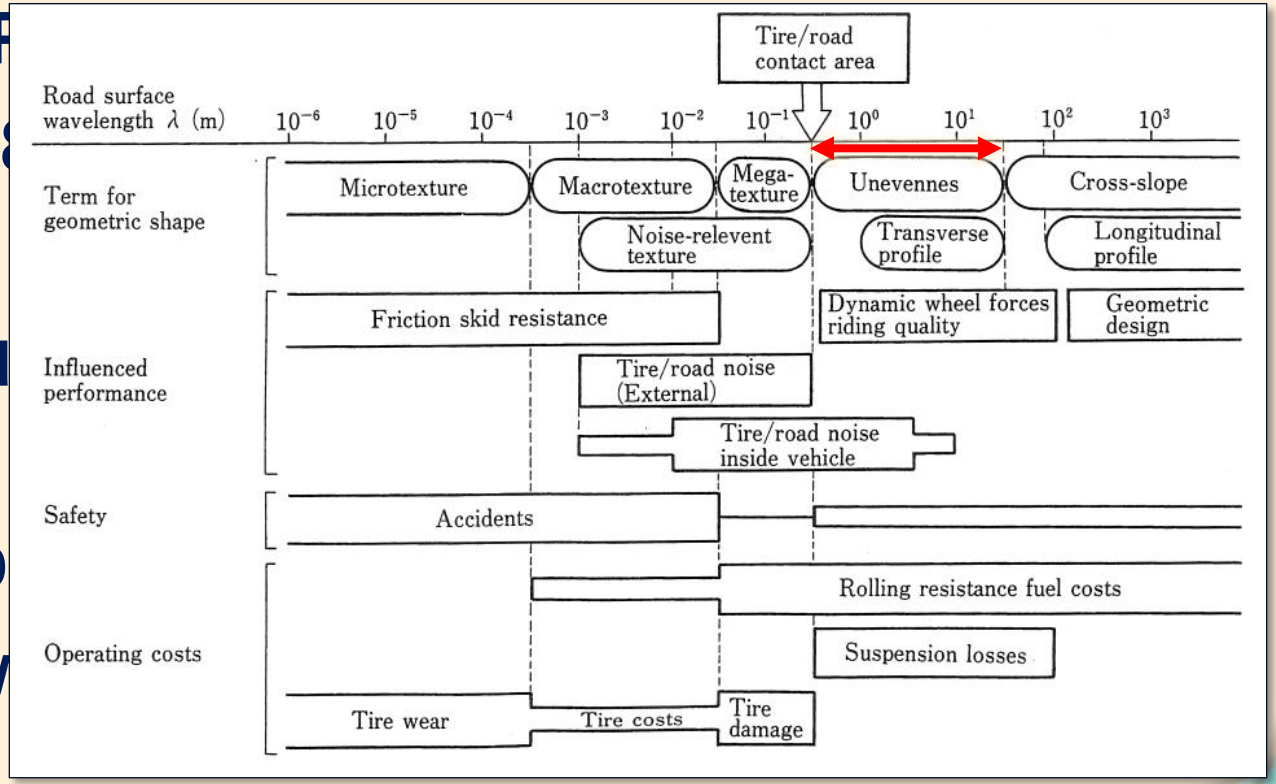
# 4. Validation Experiment (2)

## Mobile Profilometer

- ✓ SUV Type (F
- ✓ 40, 60, and 8

## Profile Measu

- ✓ 200-m long
- ✓ 0.1-m samp
- ✓ 0.5 – 50-m v




Wavy Characteristics of Surface Profiles

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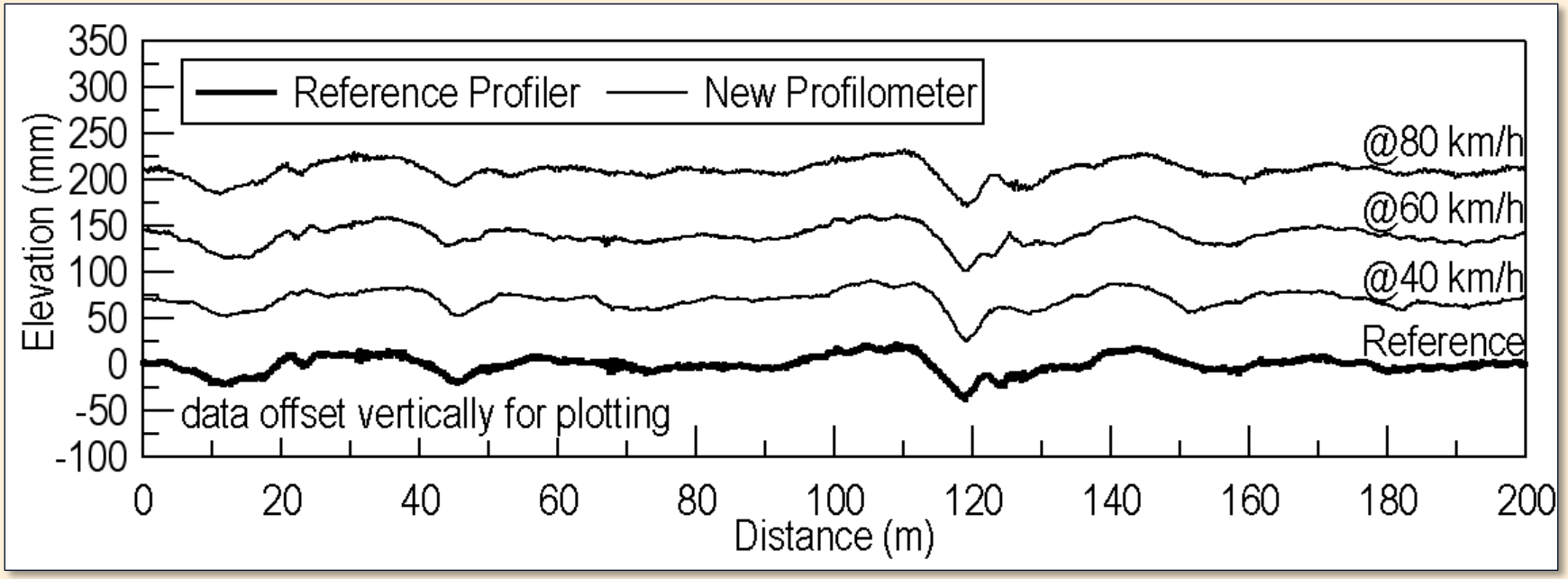
# 4. Validation Experiment (3)

## Comparison of Profile Measurements




**Profile Measurement Result**

**Closely agree with the reference profile**

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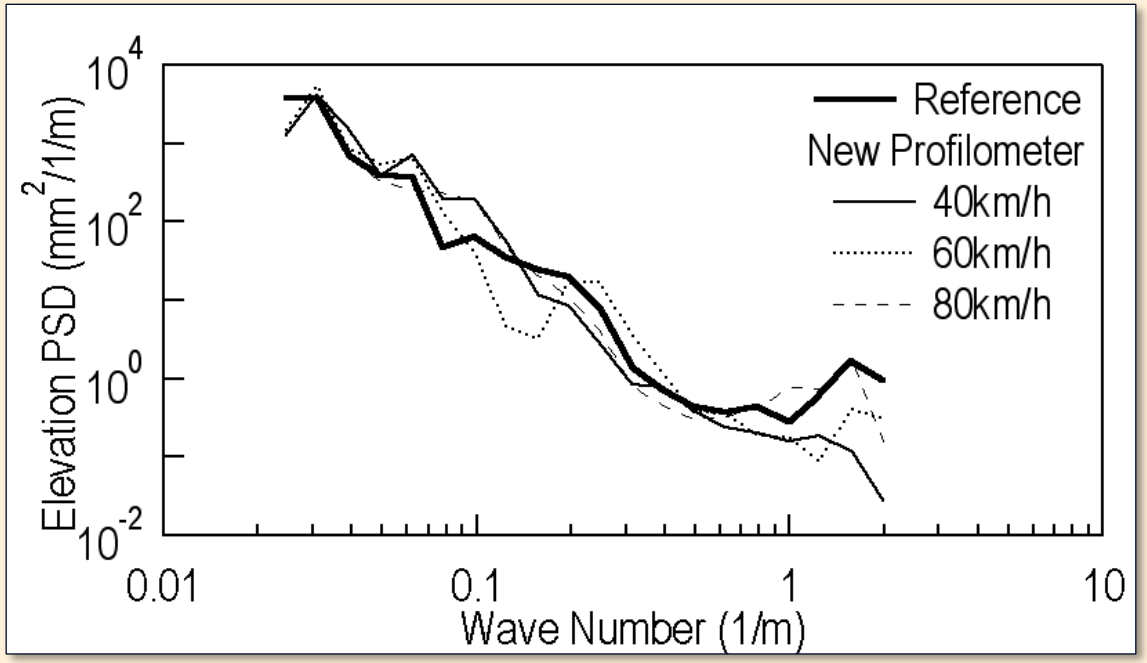
# 4. Validation Experiment (4)

## Comparison of Elevation PSD




**PSD Plots of Profile Elevation**

**Same spatial characteristic of the profiles**

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# 4. Validation Experiment (5)

## IRI Measurement by the Mobile Profilometer

- ✓ arbitrary intervals
- ✓ real time calculation and display

**IRI for 200-m Interval**

| The New Profilometer (Driving Speed) | Reference Profiler |
|---|---|
| 2.80 (40km/h) | |
| 3.03 (60km/h) | 2.78 |
| 2.72 (80km/h) | |

(Unit: mm/m)

**Within 10% accuracy**

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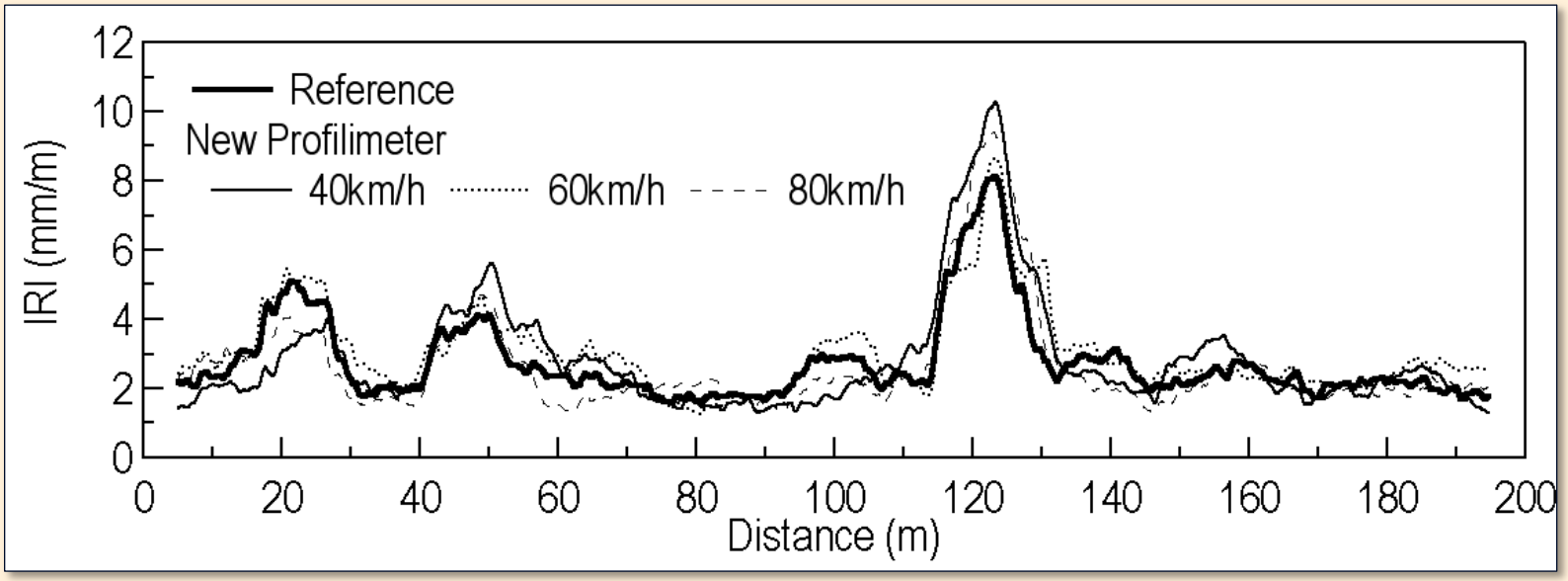
# 4. Validation Experiment (6)

## Continuous IRI

- ✓ available for Localized Roughness Detection




**IRI (10-m continuous)**

**Finding the most severe parts of the profile**

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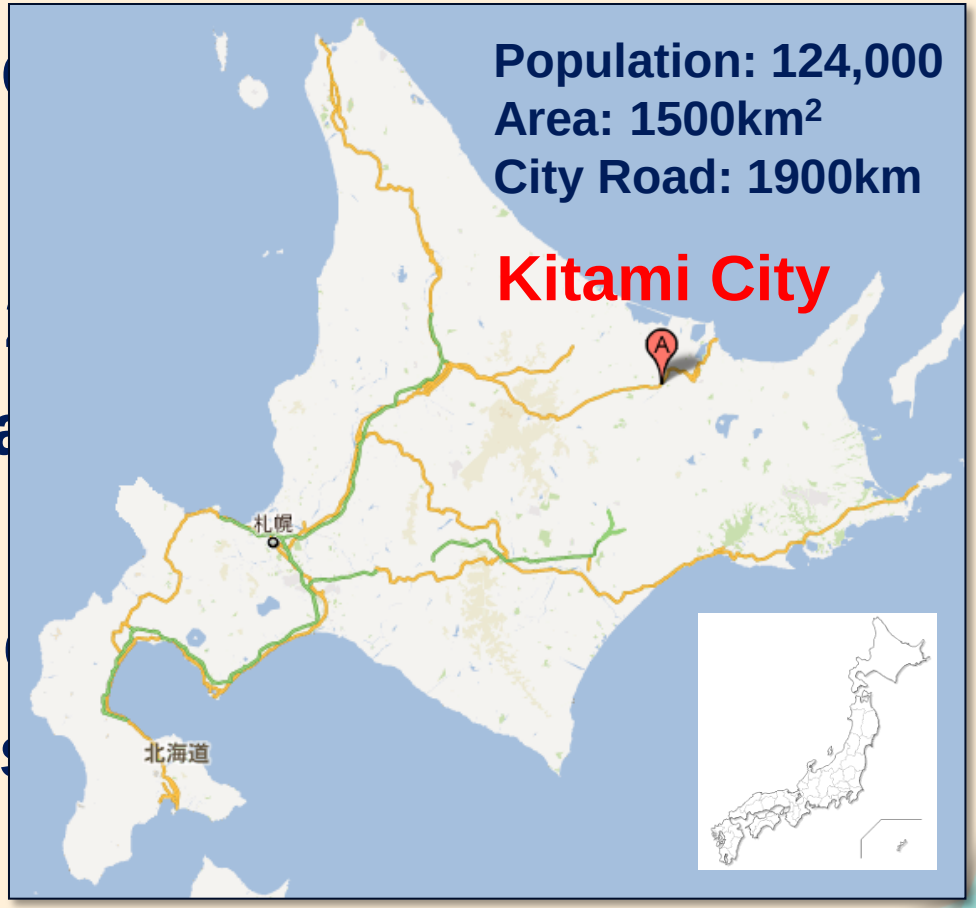
# 5. Application Case Study (1)

## Roughness Data Coll

- ✓ in the urban area of Japan in November
- ✓ on a national highwa city roads
- ✓ normal driving spee
- ✓ measuring IRI value




Location of Kitami City

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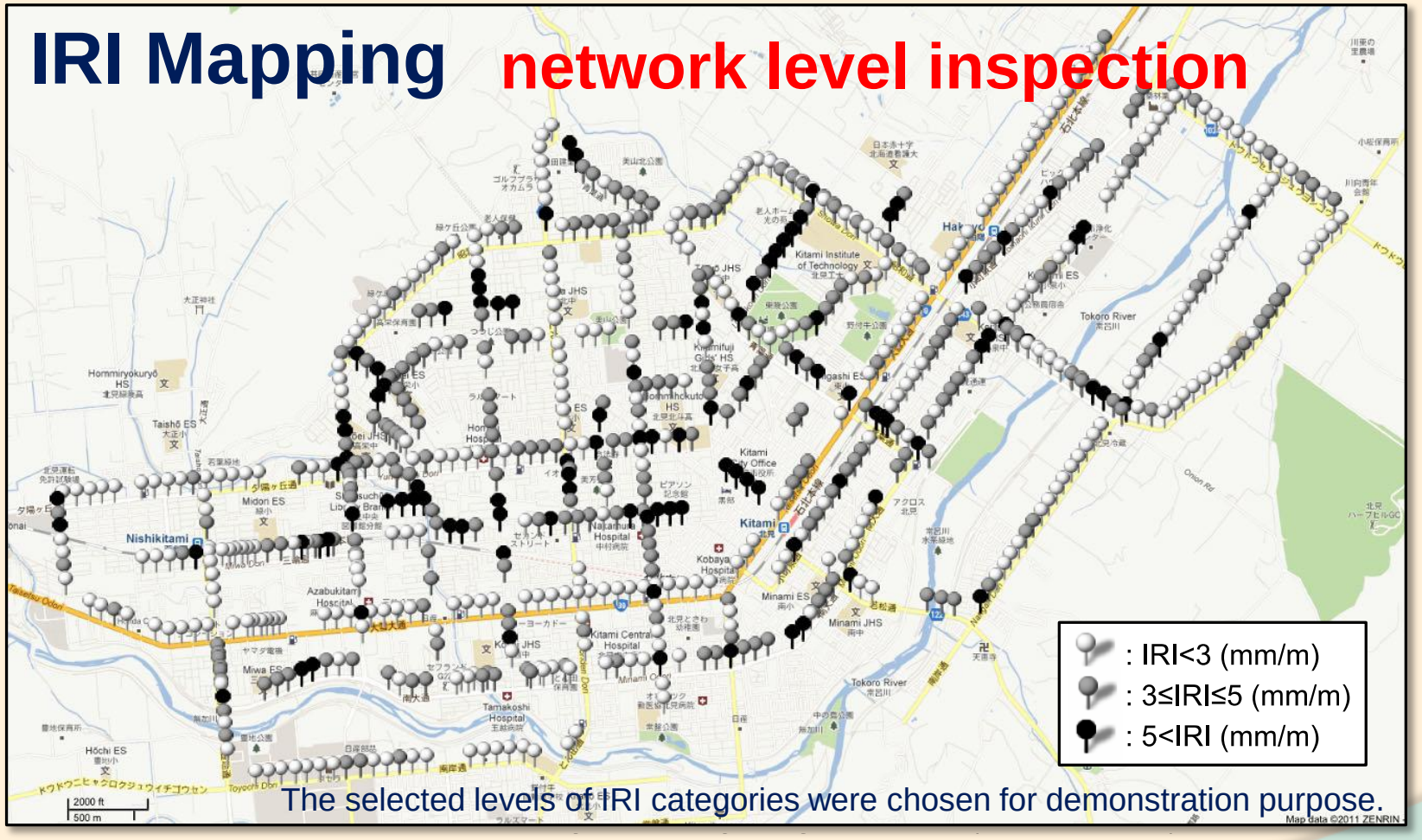
# 5. Application Case Study (2)

## IRI Mapping network level inspection




The selected levels of IRI categories were chosen for demonstration purpose.

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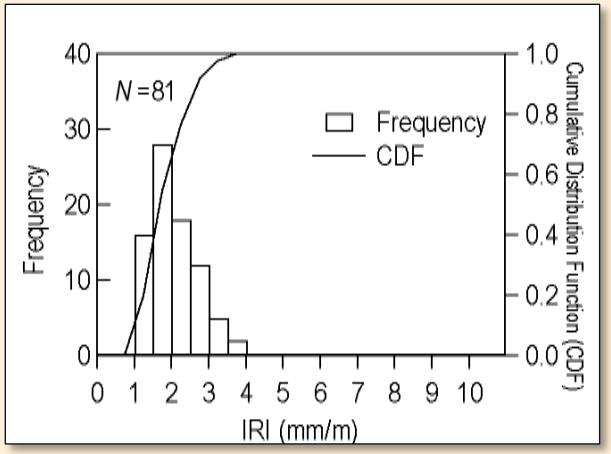
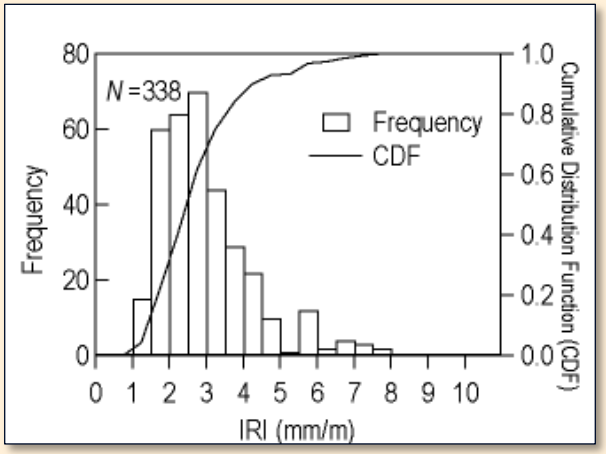
# 5. Application Case Study (3)

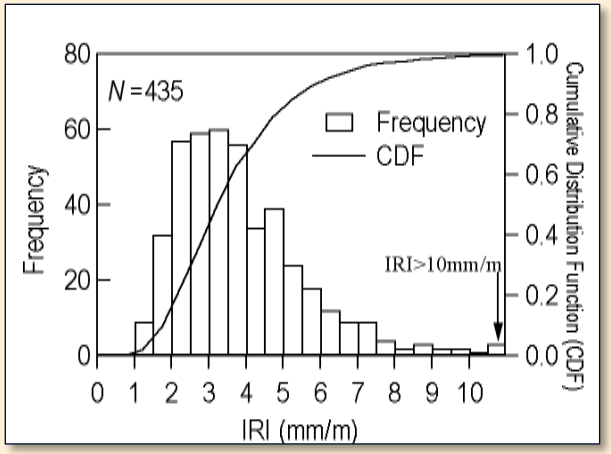
## Frequency Distribution of IRI




National Highway




Prefectural Road




City Road

- ✓ will be improved after more data are collected
- ✓ contributes to prioritize budget

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# 6. Conclusions (1)

## Development of a Mobile Profilometer

- ✓ consists of two accelerometers
- ✓ measures surface profile
- ✓ calculates the IRI based of the profile measurements
- ✓ has good correlation with Class 1 profilers
- ✓ achieves the accuracy with 10% for the IRI
- ✓ enables localized roughness detection

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# 6. Conclusions (2)

**Case Study (IRI Mapping and Frequency Distribution)**

- ✓ **visually inspects pavement conditions using IRI mapping in the road network**
- ✓ **contributes to plan pavement maintenance and rehabilitation projects at the network level**
- ✓ **evaluates the current status of roughness levels against the whole of a road network**
- ✓ **prioritize budget allocation for pavement management projects**

# THANK YOU FOR YOUR KIND ATTENTION

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