CONSTRUCTION AND QUALITY CONTROL OF FLEXIBLE AND RIGID PAVEMENTS

Measurement of Roughness using Bumintegratior, MERILN and Rough meter and Smart Pavement Technologies

National Rural Infrastructure Development Agency

Ministry of Rural Development

National Institute of Technology

Warangal, Hyderabad

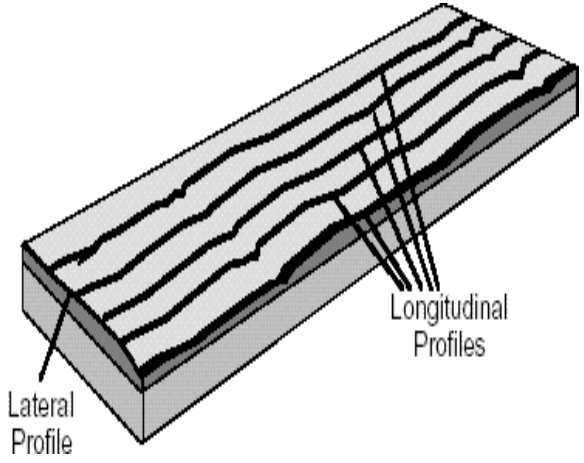
Lecture-6

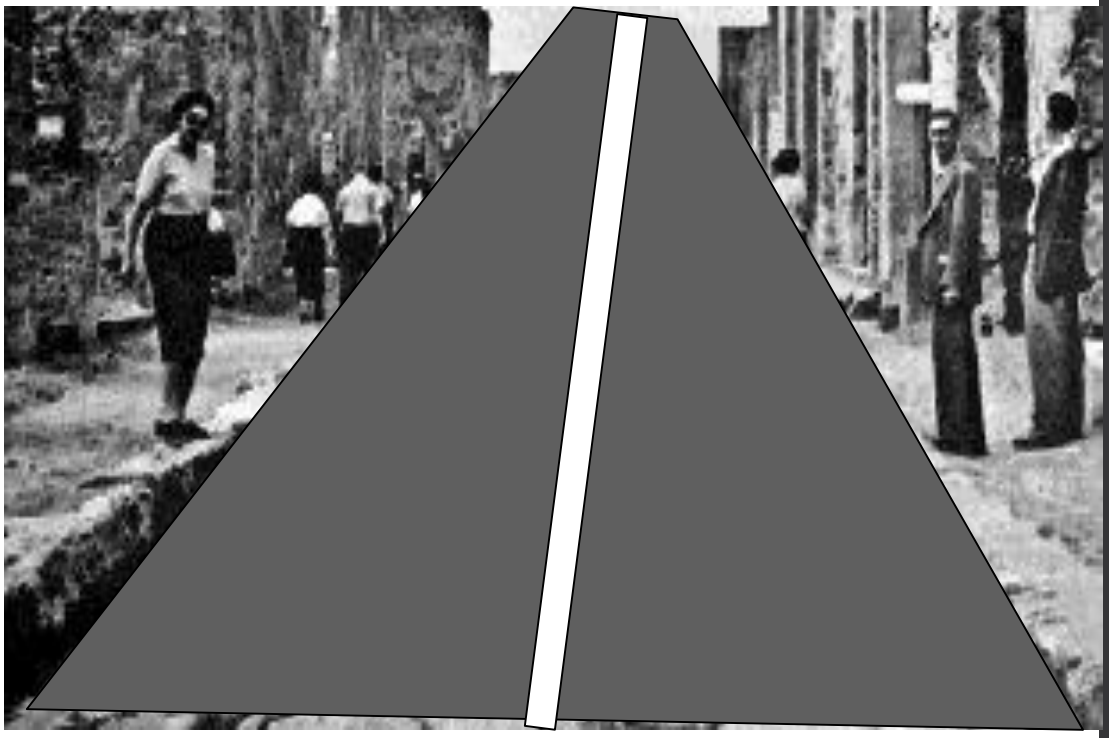
Measurement of Roughness using Bumintegratior, MERILN and Rough meter and Smart Pavement Technologies

Introduction

Roughness?

- Irregularities in the pavement surface that adversely affect the ride quality of a vehicle, Not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs
- IRI was developed by the World Bank in the 1980s
- Commonly used indices are BI Value (mm/km) and (IRI)



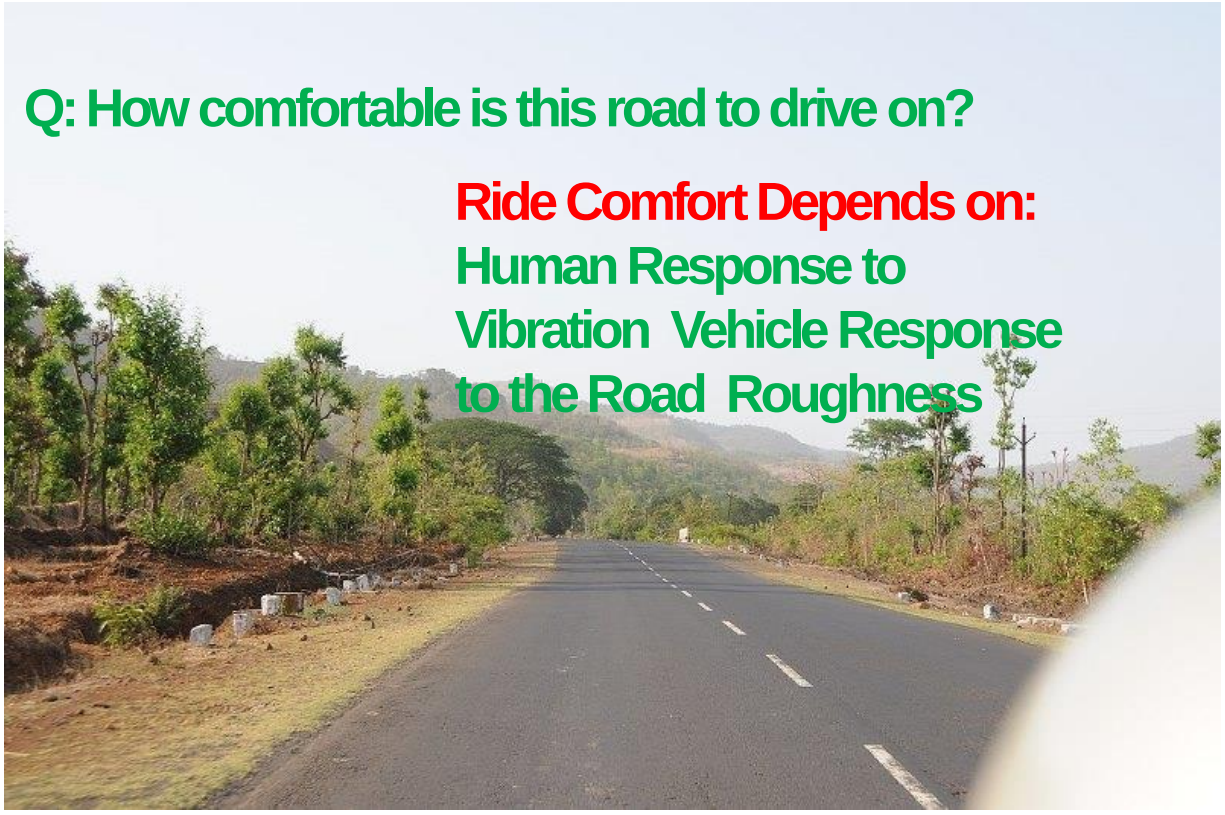


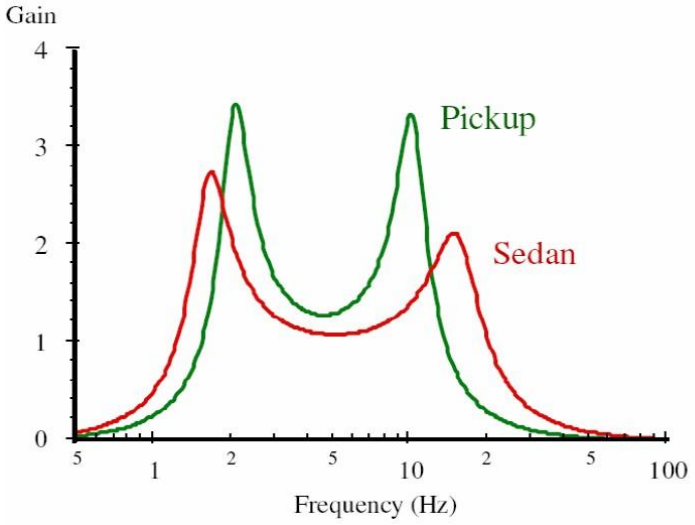
Unevenness/roughness index is defined as the ratio of the cumulative vertical displacement to the distance traveled and is expressed in mm/km.

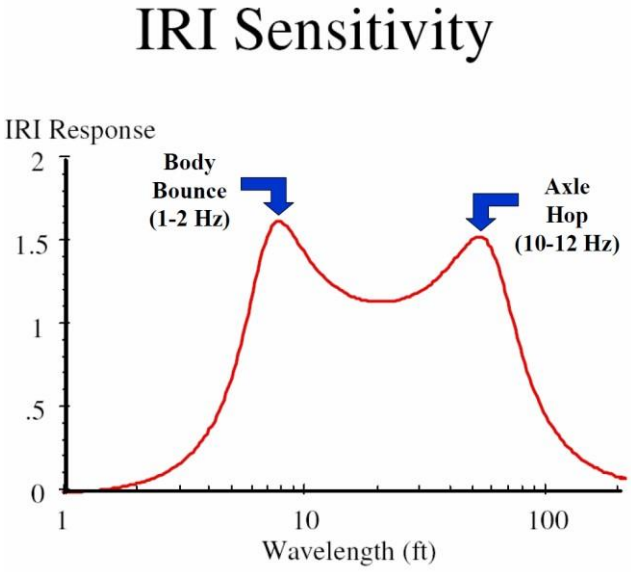
It's a FACT….

"Many customer surveys, on both a national and local level, have shown us that Pavement Smoothness is one of the main factors when it comes to rating the nation's highways"

Pavement Smoothness = Ride Comfort





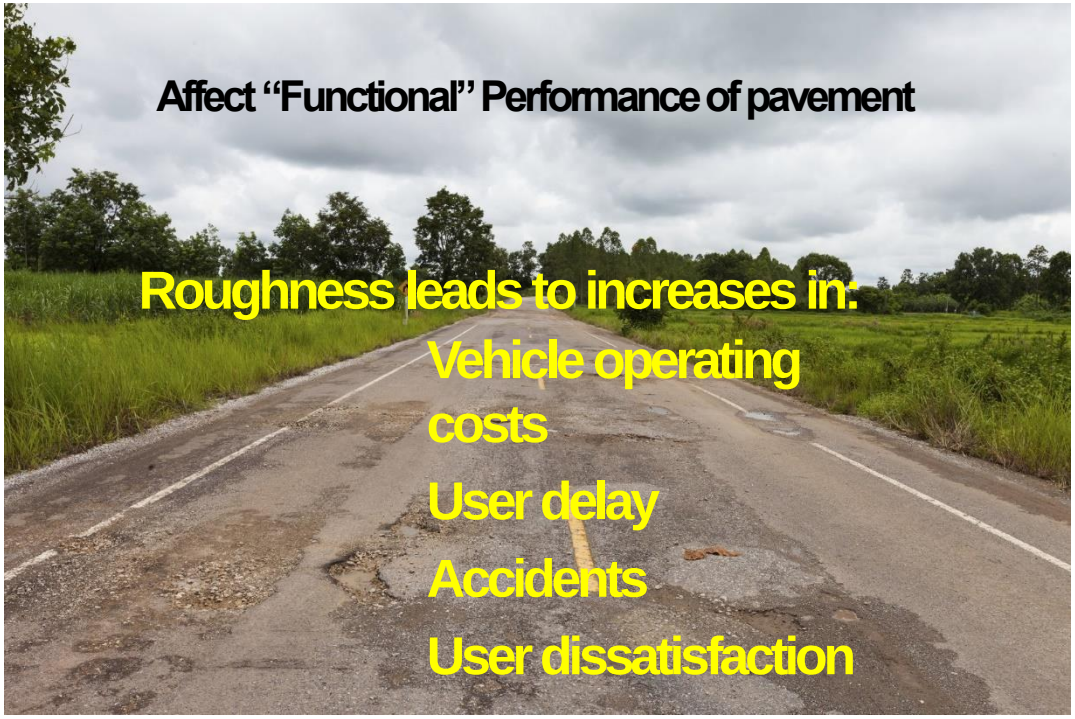


ASTM Definition of Roughness

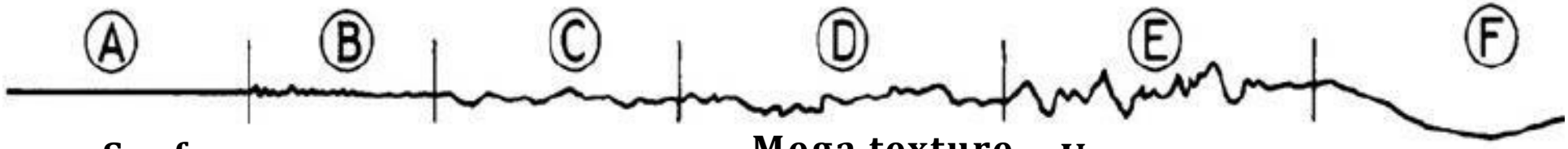
“The deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics……”

Pavement Smoothness is a lack of roughness

WHY IT IS IMPORTANT TO ASSESS ROUGHNESS AND FRICTION?



Different Road Profiles



Planar Surface

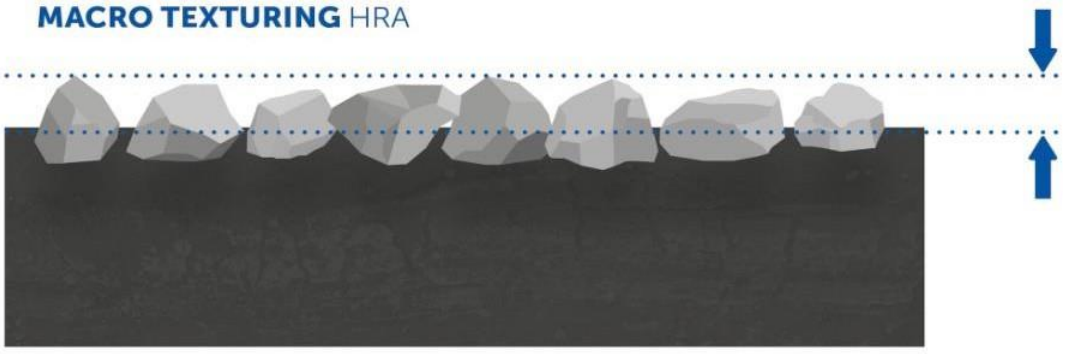
Micro texture

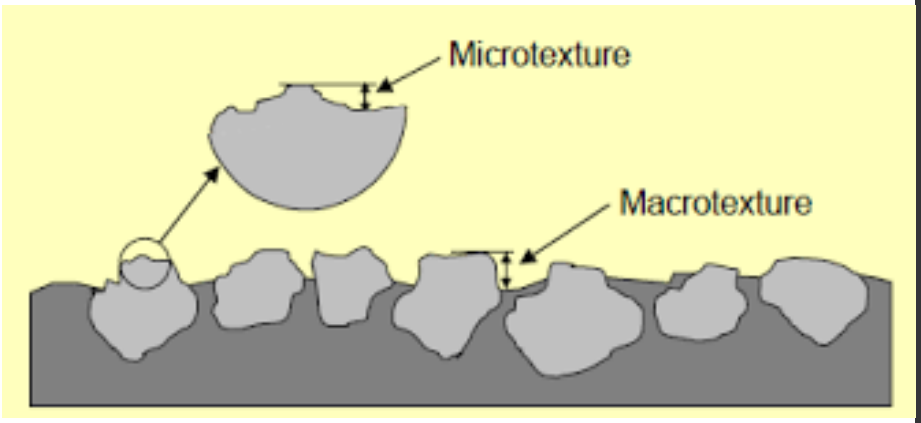
Macro texture

Mega texture

Uneveness

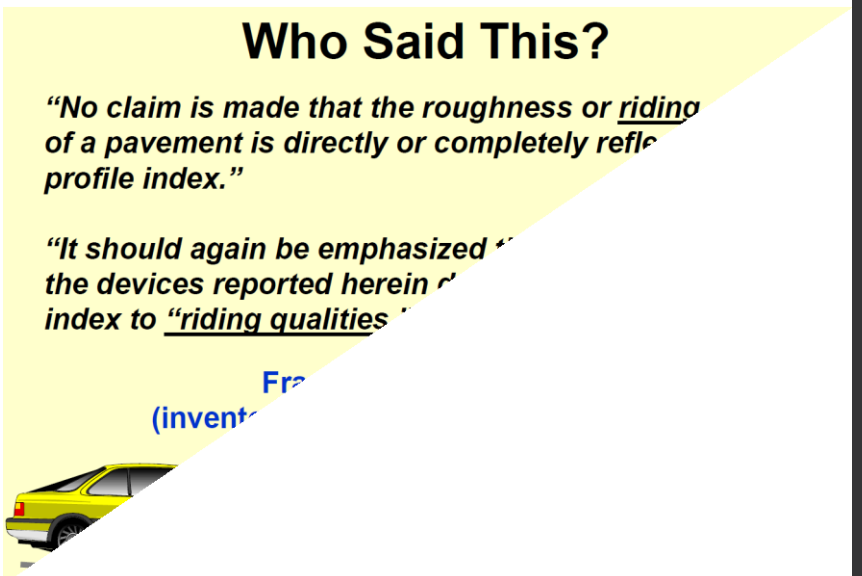
Vertical profile



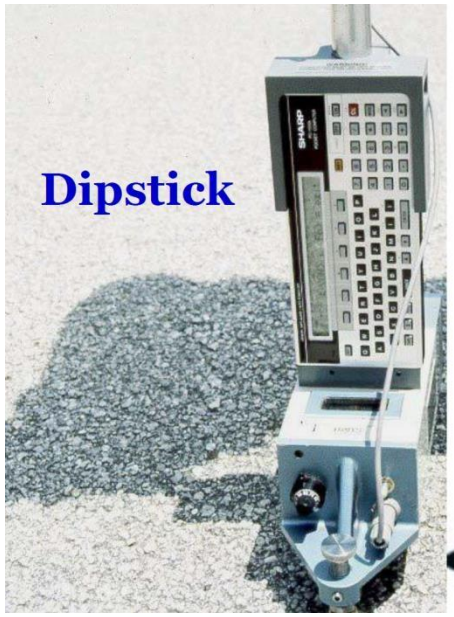


Roughness Measurement Devices

- Straight edge method
- Spot levels
- MERLIN
- Profilograph
- Bump integrator
- Multiple wheel bump integrator
- K RTRR Measuring System
- Road roughness profiling device
- Non-contact Lightweight devices
- Portable Laser Profiler Systems
- Axle Mounted Roughometers
- Swedish Laser Road Surface Tester
- K. J. Law 8300 Roughness surveyor



Bump integrator


Dipstick

DIPSTICK

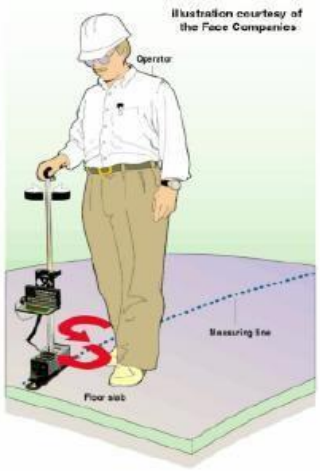


Illustration courtesy of the Face Companies
Operator
Measuring line
Floor slab

Automated Visual Distress Survey

Inertial Profilers, High and Low Speed

TOPCON RTP-300 PROFILER

The new RTP-300 High-Speed Surface Profiler from Topcon Positioning Systems collects surface data at speeds up to 65 mph and creates an exact model of the existing surface.

January 18, 2011

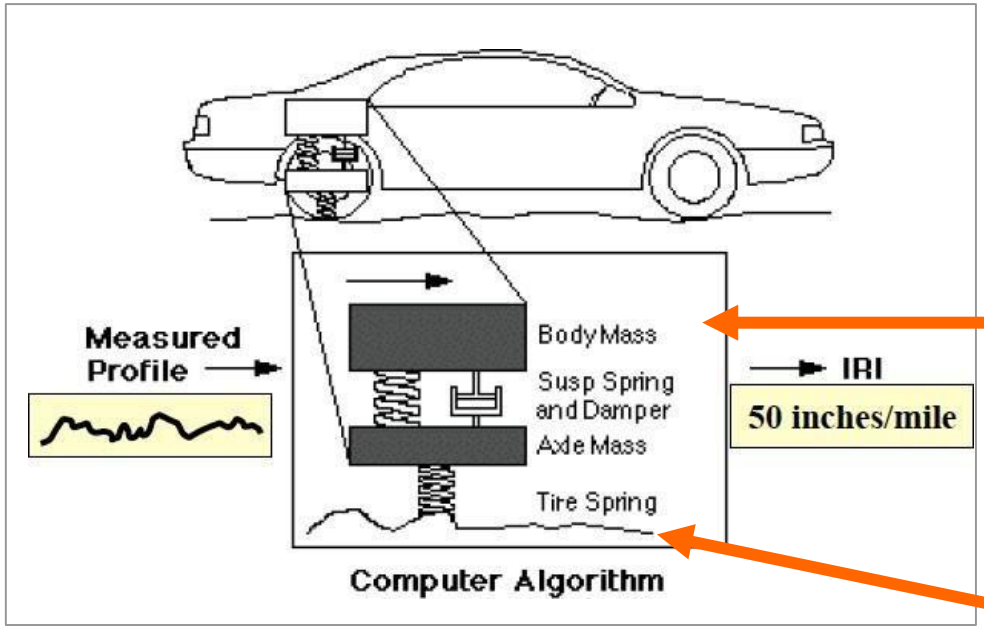
Technology: Roughness and Distress Data

Roughness Indices

- **International Roughness Index (IRI)**
- **Mean Panel Rating (MPR)**
- **Profile Index (PI)**
- **Ride Number (RN); and**
- **Root Mean Square Vertical Acceleration (RMSVA).**

IRI computation

IRI is suspension movement average under 80km/h.
- average of suspension expansion and compression-



(3) Calculate average length of suspension expansion and contraction, that is IRI.

(2) QC simulation is applied to calculate suspension movement.

(1) Measuring longitudinal profile.

International Roughness Index

- The IRI is defined as an index computed from a longitudinal profile measurement using a reference mathematical RTRRMS (a quarter-car simulation) for a standard simulation speed of 80 km/h (ASTM E867 2012; Sayers 1986).
- IRI Experiment conducted in Brazil (Sayers et al., 1986a) and is reproducible, portable and stable with time
- It allows data from different instruments and different countries to be directly compared and enables historical trends to be determined with confidence
- Without a common method for calculation, results from research could not be compared without the use of conversion factors from one unit to the next.

Roughness Scales

	IRI (m/km)	TRRL BI (mm/km)	Qt car Index (Counts/km)	PSI
	0	0	0	5.0
Good	1	700	13	4.2
	2	1400	26	3.5
	3	2200	40	3.0
	4	3000	50	2.4
	5	3800	65	2.0
	6	4700	80	1.7
Good unpaved	8	6500	100	1.2
	10	8300	130	0.6
Poor paved	12	1000	156	0
	16	14000	210	
Unpaved	20	18000		
	24	22000		

Relationship between IRI and Normal operating speed

(based on Sayers and [illegible])

Range of IRI (m/km)	Normal operating speed (km/h)	Condition [5] of pavement
Up to 2.5	120 and above	Excellent profile usually found in case of runway pavements
2.5 to 4.0	120 to 95	Very good surface profile, Ride comfortable, without any undulations <4mm/3m and potholes
4.0 to 6.0	95 to 85	Good surface profile; Ride comfortable, undulations 3-8 mm/1.5m with frequency of 1-3 per 50 m; aware of sharp movements with moderate corrugations.
6.0 to 8.5	85 to 70	Fair surface profile; Frequent undulations (5-12 mm/1.5 m) and shallow depressions and minor occasional potholes (5-20 mm/3 m with a frequency of 3-5 per 50 m)
8.5 to 13.5	70 to 50	Frequent transverse undulations 10-45 mm/3 m-5 m at frequency of 9-22 per 50 m and many medium depressions and potholes (30-85 mm/3 m at frequency not more than 5 per 50 m)
13.5 to 16.5	45 to 35	Rough surface having frequent deep transverse depressions and potholes (30-80 mm/1.5 m at frequency of 5-9 per 50 m. The surface condition is inferior to the above condition.
16.5 to 20.5	35 and down	Very rough surface and unsatisfactory ride; having very deep potholes mixed with frequent heavy undulations. Potholes (30-80 mm/1.5 m at frequency of 12-16 per 50 m. The surface condition is worse than the above.

IRC Recommendations Selection of Appropriate Equipment

- **Plain terrain areas**
  - The condition of roads is average to poor and average traffic speed is about 30 to 40 kmph (I MDRs, ODRs and Village Roads), then under such conditions FWBI/ARUR,CAMBI can serve the purpose for roughness measurements, as in these areas, the standard survey speed of 32 kmph can be conveniently maintained.

- **High speed road corridors**
  - Expressways, NHS and SHs), speed is more (>= 60 kmph)
  - Laser Profilometer (LP) and Ultrasonic Sensor Based Profilometer

- **Rolling and hilly terrain areas**
  - Also, due to high gradients and frequent sharp curves in these areas, the use of FWBI/ARUR (which is a towing type device) is not recommended.

Operating Conditions (Measurement Speed)								
Low (from 10 kmph to 40 kmph)			Medium (> 40 kmph to 60 kmph)			High (> 60 kmph)		
Terrain			Terrain			Terrain		
Plain	Rolling	Hilly	Plain	Rolling	Hilly	Plain	Rolling	Hilly
FWBI/ ARUR and CAMBI	FWBI/ ARUR and CAMBI	CAMBI (With multiple speed calibration)	LP, USBP, CAMBI, AB			LP and USBP		Not Applicable

Max Permissible Values of Roughness for Exp, NH,SH

S. No.	Type of Surface	Condition of Road Surface		
		Good		Fair
		RI	IRI	RI
1	Bituminous (BC, SMA, SDBC)	<1800		
2				

IRC:SP:16-2019

Max Permissible Values of Roughness for MDR and ODR

S. No.	Type of Surface	Condition of Road Surface					
		Good		Fair		Poor	
		RI	IRI	RI	IRI	RI	IRI
1	Surface Dressing	<3000	<4.03	3000-3800	4.03-4.98	>3800	>4.98
2	Open Graded Premix Carpet	<2800	<3.79	2800-3500	3.79-4.62	>3500	>4.62
3	Mix Seal Surfacing	<2600	<3.55	2600-3200	3.55-4.27	>3200	>4.27
4	Semi Dense Bituminous Concrete	<2200	<3.05	2200-3000	3.05-4.03	>3000	>4.03
5	Bituminous Concrete	<2000	<2.81	2000-2600	2.81-3.55	>2600	>3.55
6	Cement Concrete	<2200	<3.05	2200-2600	3.05-3.55	>2600	>3.55

INDIAN ROADS

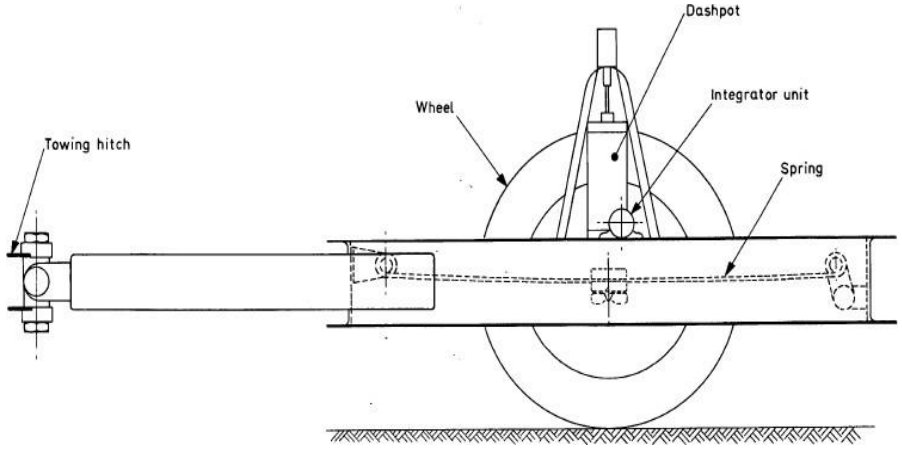
Max. Permissible Values of Roughness for Village Roads

S. No.	Type of Surface	Condition of Road Surface					
		Good		Fair		Poor	
		RI	IRI	RI	IRI	RI	IRI
1	Surface Dressing	<3200	<4.27	3200-3800	4.27-4.98	>3800	>4.98
2	Open Graded Premix Carpet	<3000	<4.03	3000-3500	4.03-4.62	>3500	>4.62
3	Mix Seal Surfacing	<2800	<3.79	2800-3200	3.79-4.27	>3200	>4.27
4	Semi Dense Bituminous Concrete	<2400	<3.30	2400-3000	3.30-4.03	>3000	>4.03
5	Cement Concrete	<2200	<3.05	2200-2600	3.05-3.55	>2600	>3.55

NGRESS

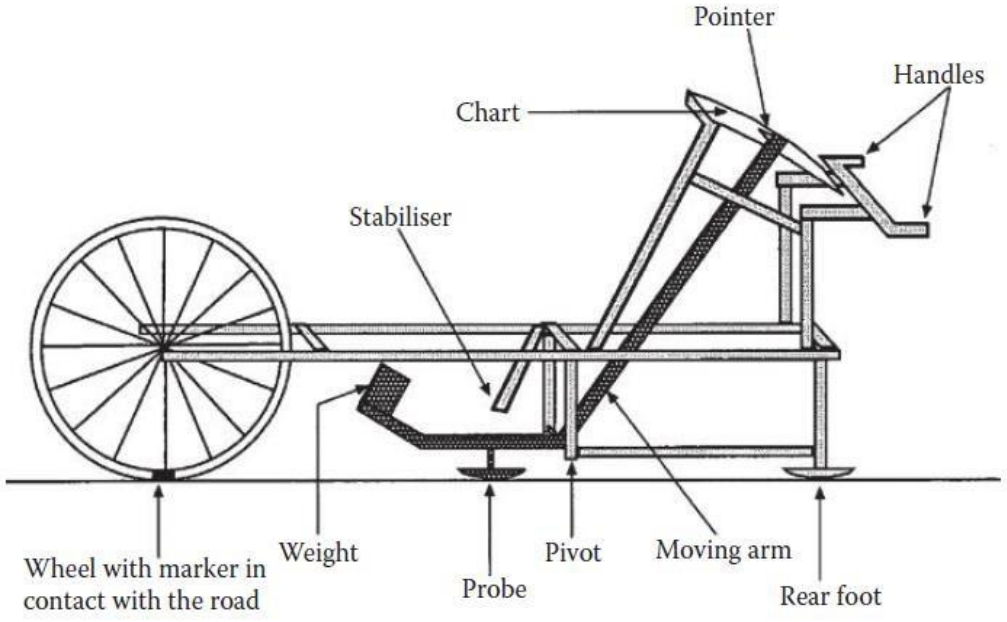
Fifth Wheel Bump Integrator

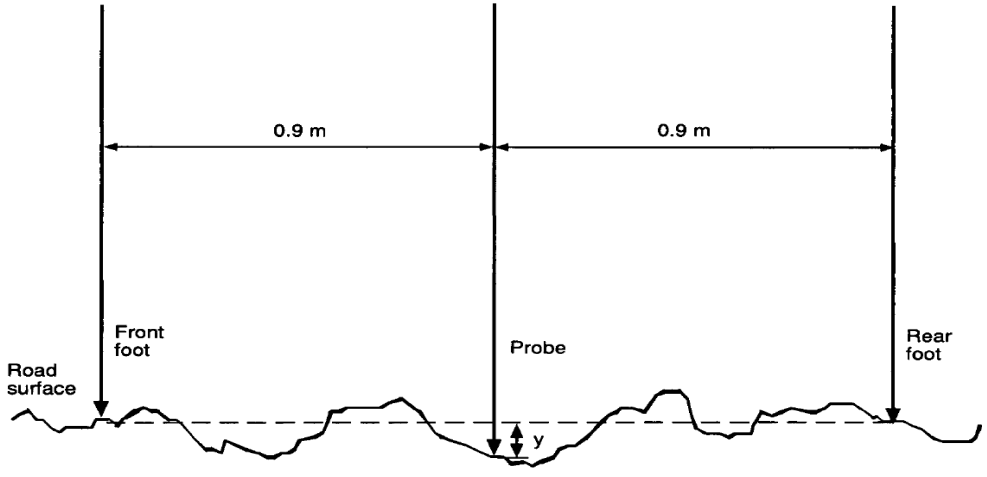
- RTRRM in 1970s-displacement of the test wheel by TRRL (Keir 1974)
- Fifth wheel Bump Integrator towed by a vehicle (32kmph &2.1kg/cm^2
- The vertical movement of the suspension system of roughness meter is measured and accumulated with distance travelled. Vertical movement is counted in multiples of a specified vertical distance.
- Distance travelled normally estimated form the revolutions of the fifth wheel. The BI value is expressed as mm/km.



MERLIN

Low cost roughness measuring





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The relationships between the Merlin scale and the BI and IRI scales are given below.

For all road surfaces:

$$IRI = 0.593 + .0471\ D \qquad (1)$$

$$42 > D > 312\ (2.4 > IRI > 15.9)$$

where IRI is the roughness in terms of the International Roughness Index and is measured in metres per kilometre and D is the roughness in terms of the Merlin scale and is measured in millimetres.

$$BI = -983 + 47.5\ D \qquad (2)$$

$$42 > D > 312\ (1,270 > BI > 16,750)$$

where BI is the roughness as measured by a fifth wheel bump integrator towed at 32 km/h and is measured in millimetres per kilometre.

When measuring on the BI scale, greater accuracy can be achieved by using the following relationships for different surface types.

Asphaltic concrete

$$BI = 574 + 29.9\ D$$

$$42 < D < 177\ (1,270 < BI < 5,370)$$

Surface treated

$$BI = 132 + 37.8\ D$$

$$57 < D < 124\ (2,250 < BI < 4,920)$$

Gravel

$$BI = -1,134 + 44.0\ D$$

$$77 < D < 290\ (2,010 < BI < 12,230)$$

Earth

$$BI = -2,230 + 59.4\ D$$

$$84 < D < 312\ (2,940 < BI < 16,750)$$

Roughness variation...

Road ID	Progression of Roughness (m/km)						
	Apr 2008	Sep 2008	Feb 2009	May 2009	Jan 2010	May 2010	Dec 2010
G1	4.6	4.8	4.92	5.31	6.15	6.32	6.48
G2	3.18	3.47	3.52	3.88	4.00	4.09	4.28
G3	3.08	3.88	4.09	4.11	4.13	4.24	4.50
G4	2.52	2.9	3.11	3.11	3.35	3.47	4.47
K1	5.07	5.26	5.32	5.32	5.40	5.42	5.59
K2	3.8	4.08	4.16	4.23	4.94	5.09	5.22
K3	4.4	4.9	5.2	5.9	5.9	6.01	6.01
K4	4.13	4.31	4.45	4.65	5.59	5.62	5.87
W1	2.48	2.67	2.72	2.85	2.95	3.09	4.09
W2	2.65	3.89	3.92	3.99	4.09	4.32	4.65
W3	3.51	3.7	3.82	3.95	4.11	4.9	5.49
W4	2.85	3.09	3.13	3.45	3.85	3.86	3.89
W5	5.44	5.87	5.95	6.09	6.11	6.03	6.06
W6	4.13	4.46	4.67	5.03	5.03	5.92	6.23
W7	4.69	4.88	5.81	6.9	7.56	7.65	8.32

Roughometers

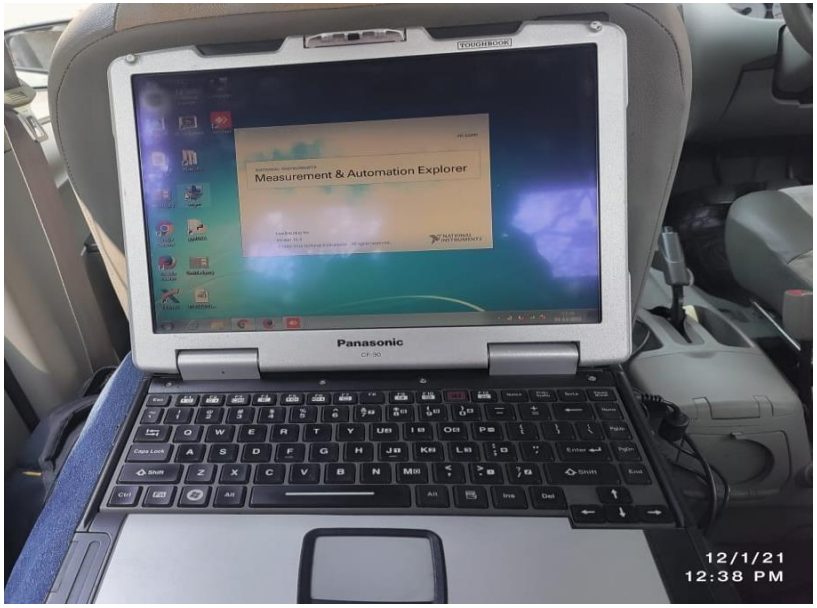
Features

- Accurate and repeatable outputs regardless of vehicle type, suspension and passenger loads
- Axle-mounted inertial sensor used to determine road profile and roughness
- Integrated GPS for location data with on-screen display of satellite tracking status
- Outputs in International Roughness Index (IRI) or NASRAA counts
- Can be installed in most passenger and lighty commercial vehicles
- Fast and simple download of data, to laptop or computer, using USB connection
- Multi-format reports available:
  - Tables
  - graphs
  - GPS maps
  - CSV files

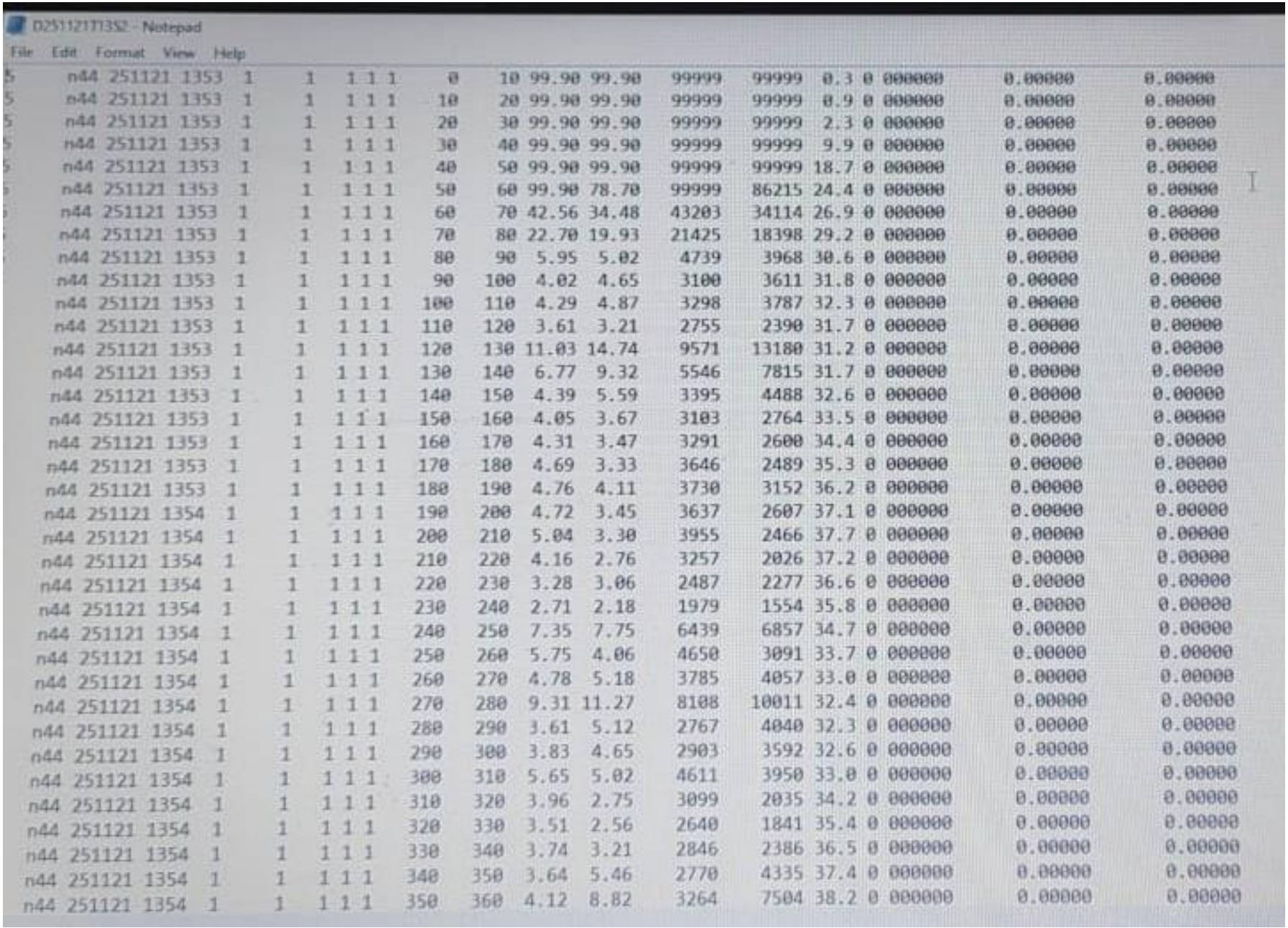
Components

- Roughometer hand-held controller
- Interface module
- Inertial module and mounting brackets
- Distance Measurement Instrument (DMI)
- GPS antenna with magnetic base mount
- Processing software

Roughometer



Data Collection Output



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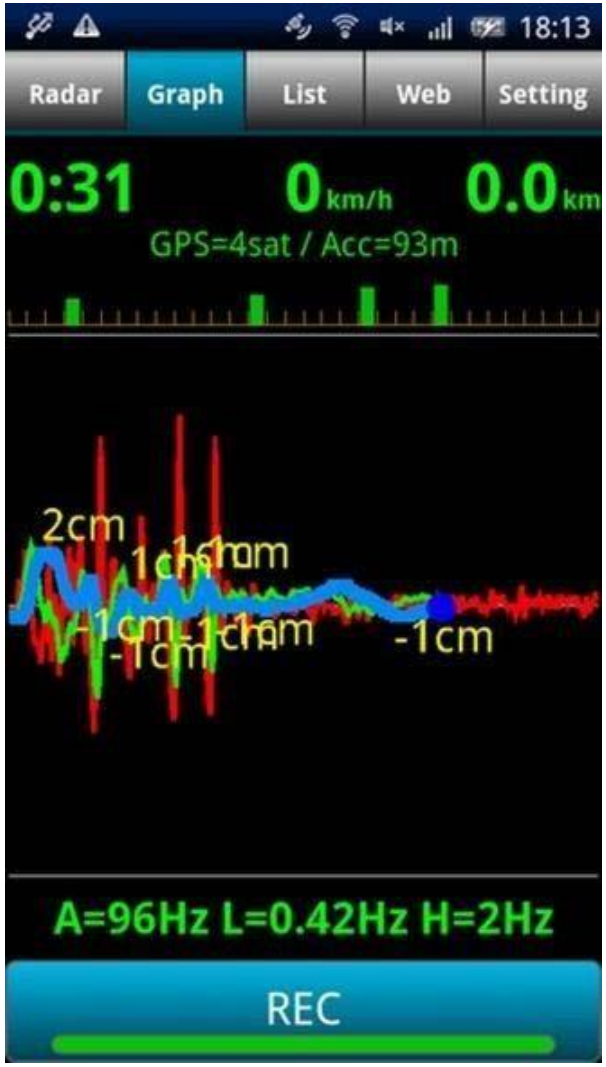
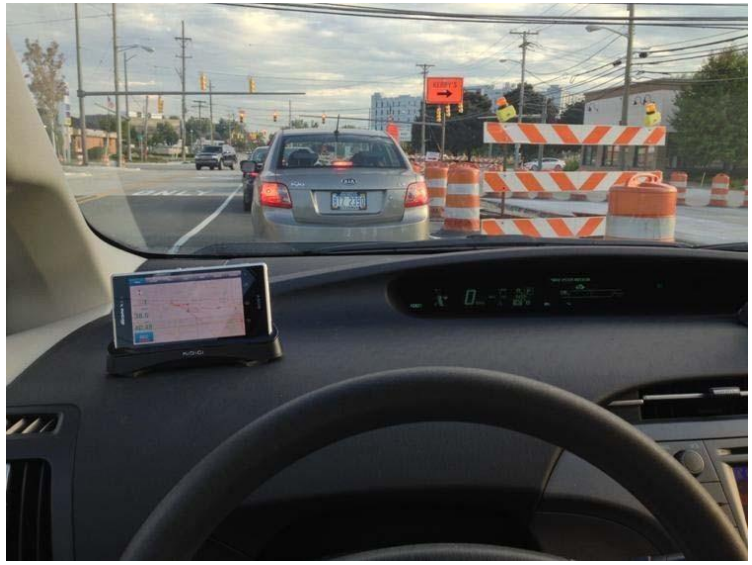
BUMP Recorder-SMART

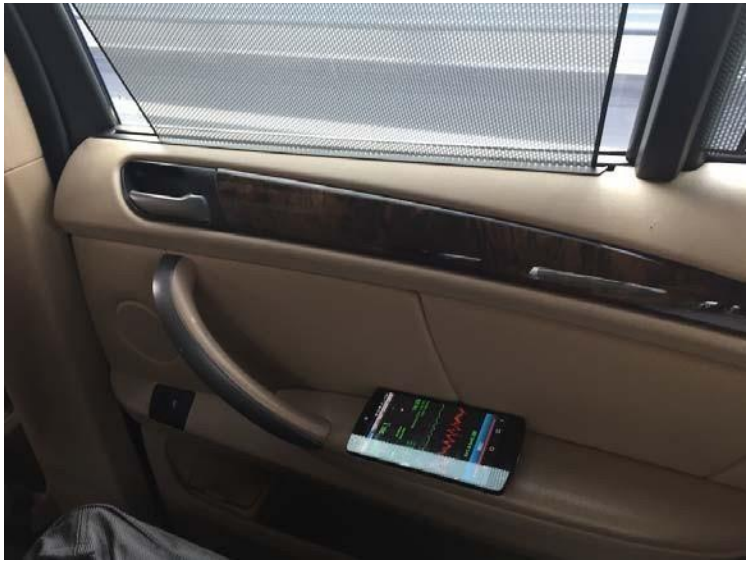
Data is collected under the driving by Smartphone App.



Smartphone app

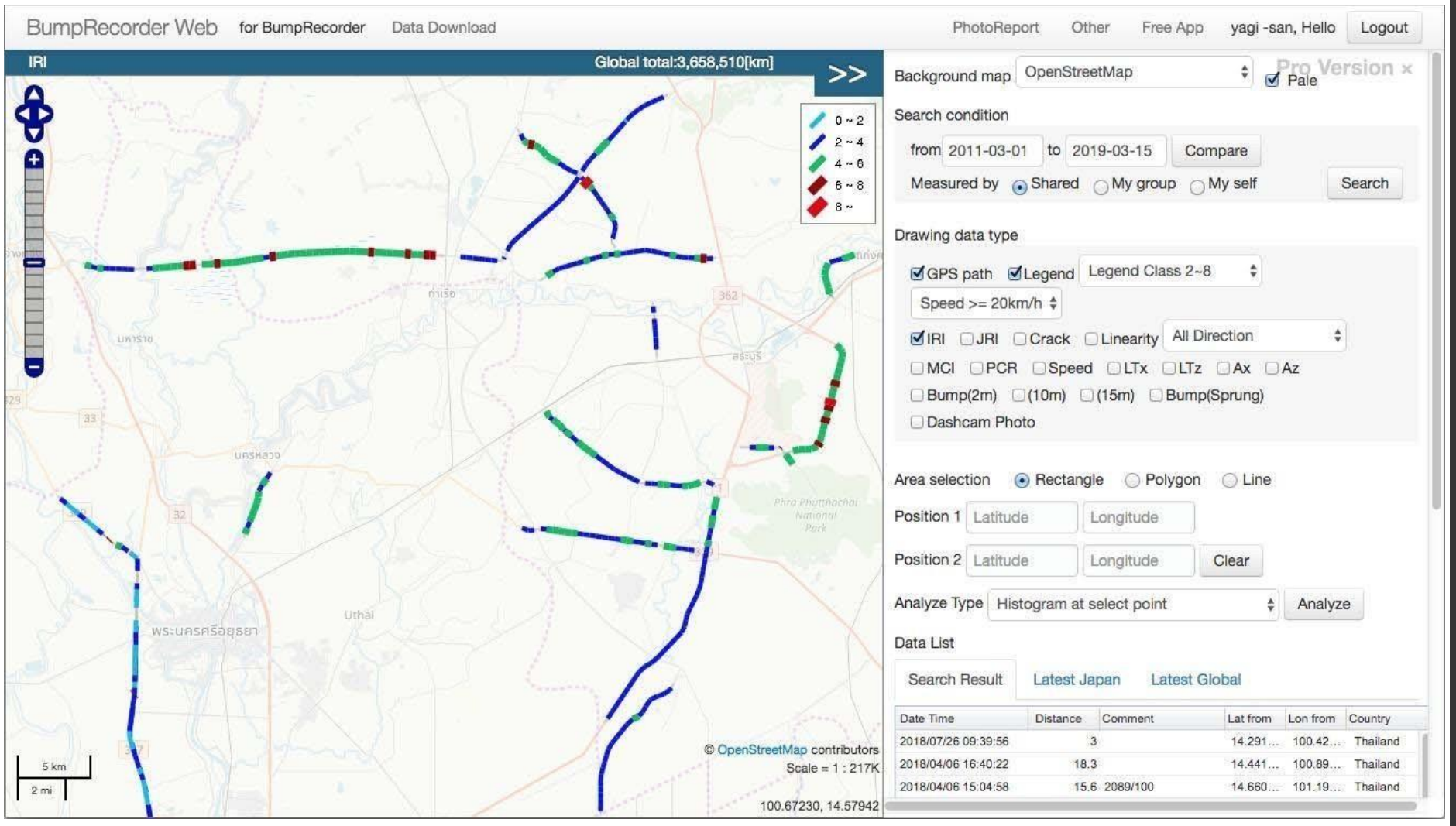
Smartphone is placed on hard surface tightly, like dashboard, arm lest.



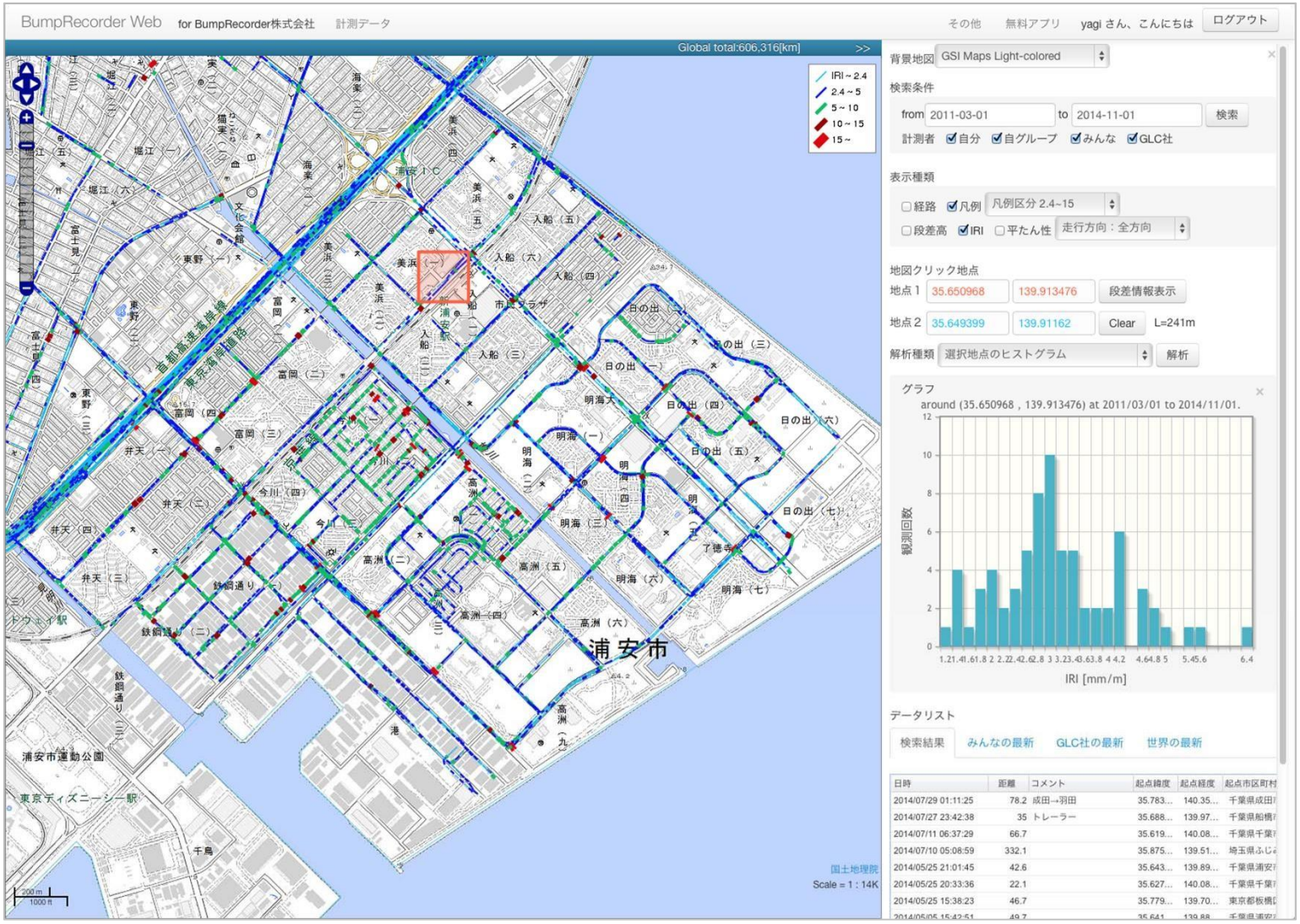


Web GIS

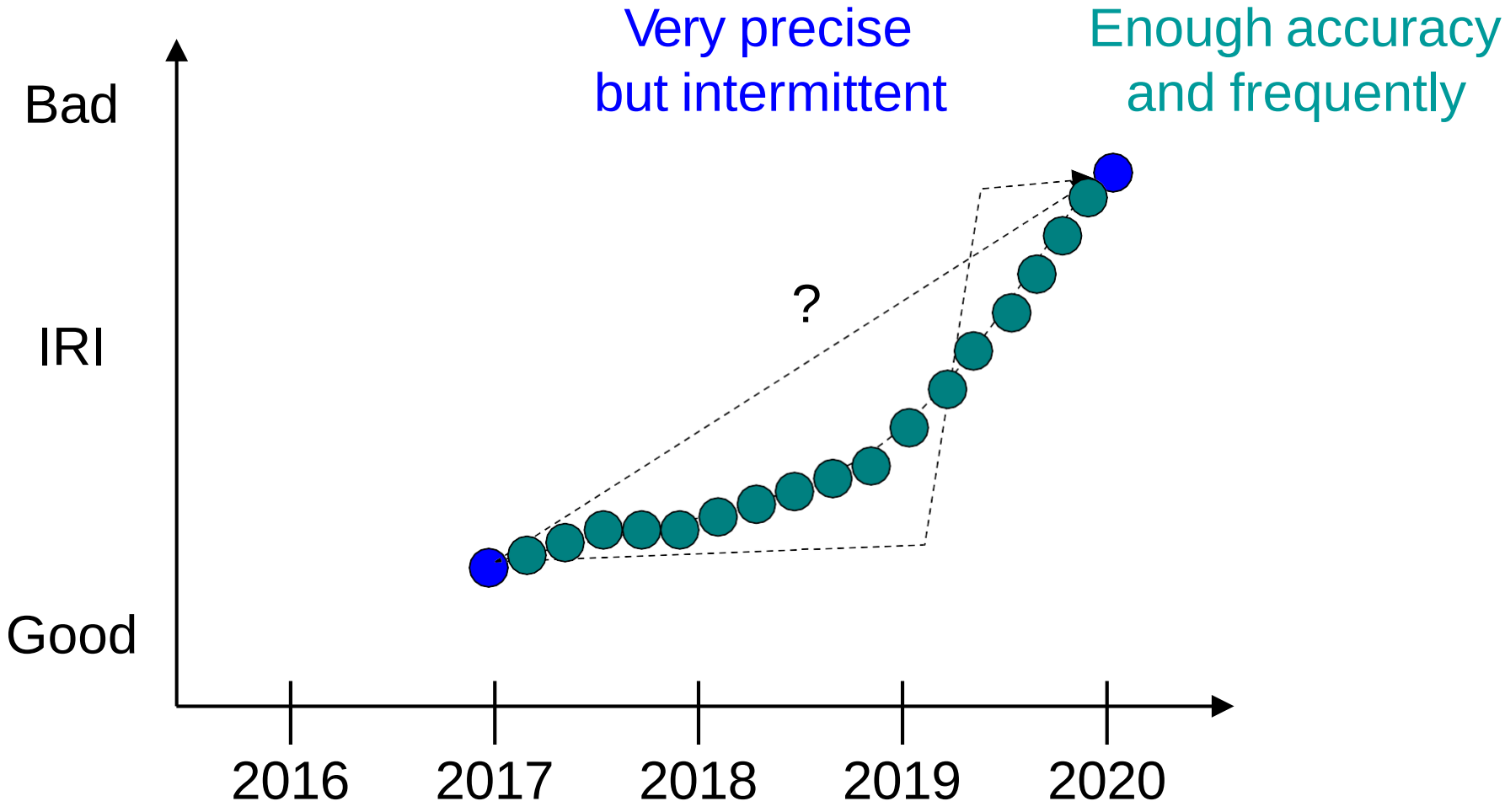
Result will be shown on web map soon.



Measurement result can be shown on the map online.



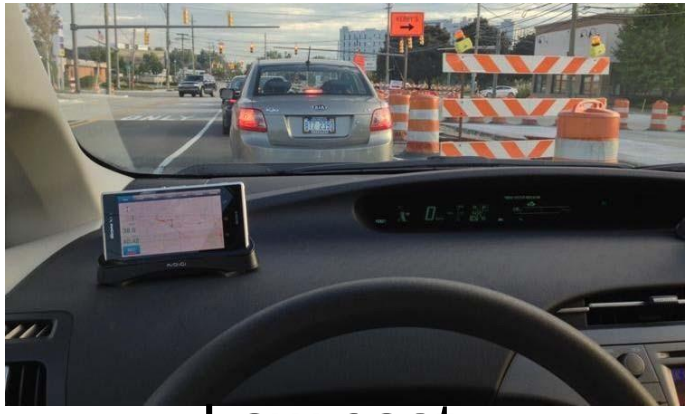
What is right monitoring?



What is right monitoring?

Pavement health monitoring

Smartphone type



Low cost

Inertial profiler

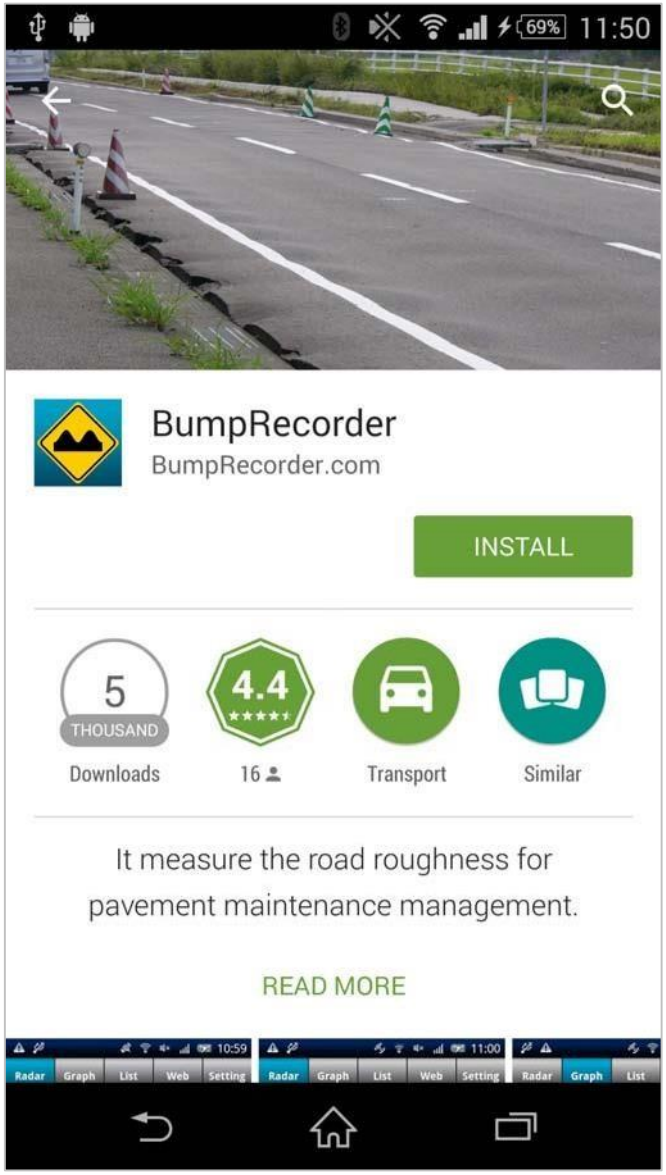
Very precise

Human health monitoring

Body temp, Blood pressure

CT scanner

How to use??
Install on your Smartphone



BumpRecorder is installed from Google Play. It can search or Bump Navi.

Place on the dashboard tightly

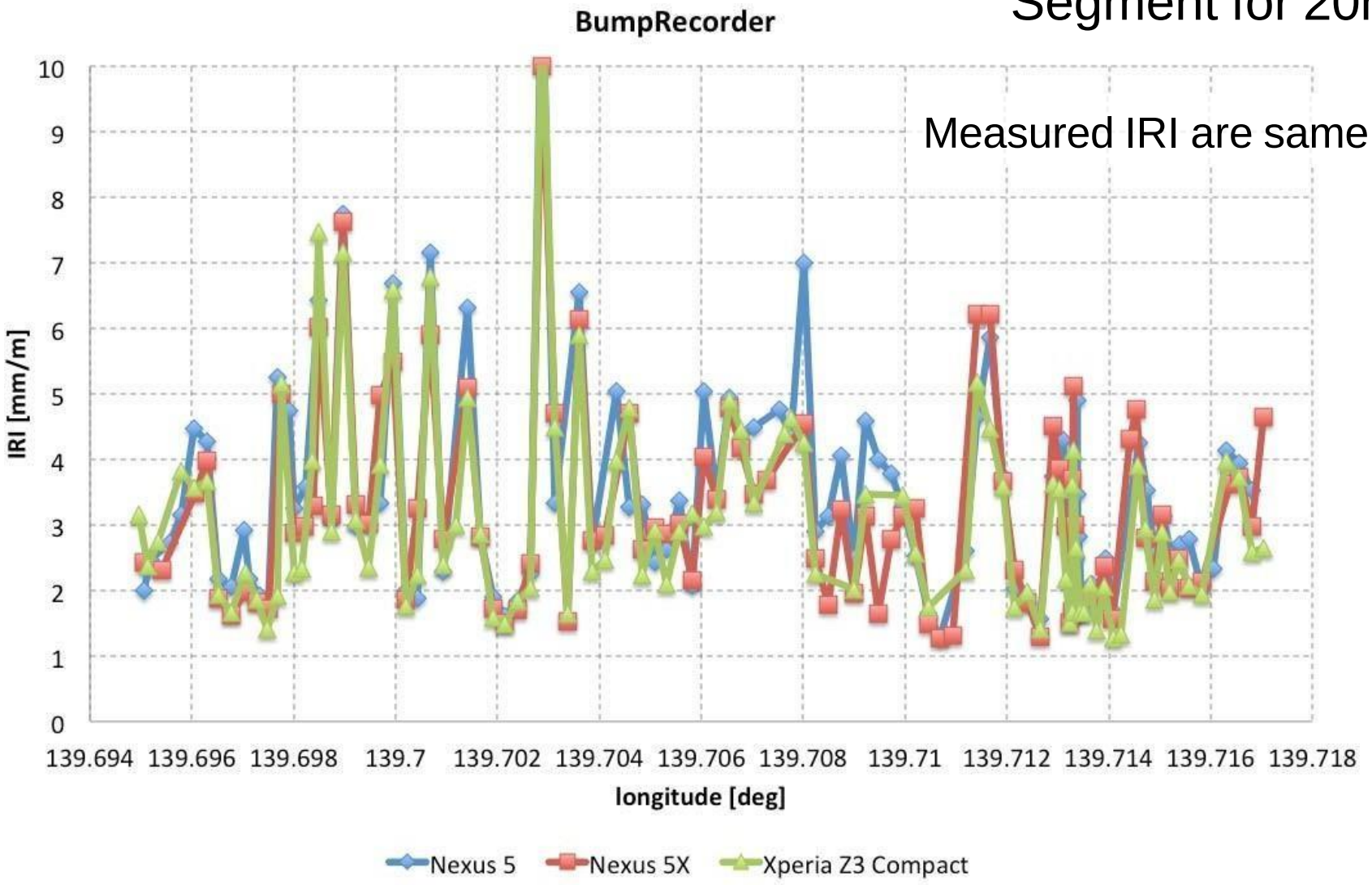
Any tilt angle is okay, but must placed tightly

NOT recommend

It is easy vibrate itself

Using different smartphone model

Segment for 20m

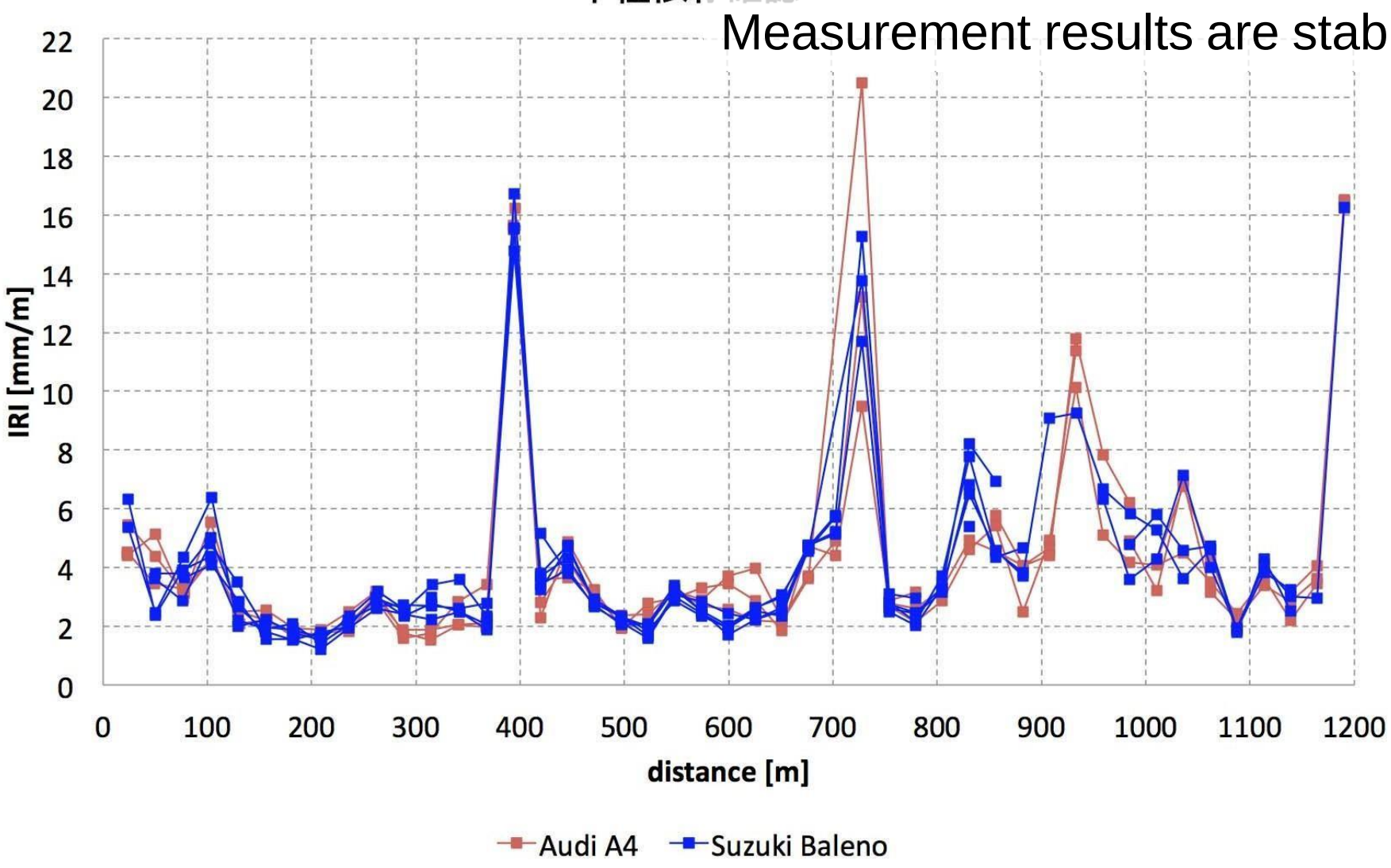


Measured IRI are same.

Using different vehicle type

It measured 3 times

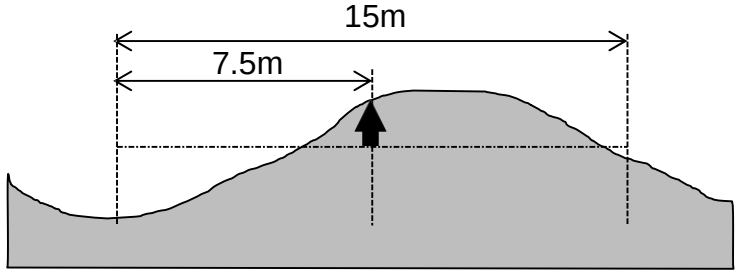
Measurement results are stable



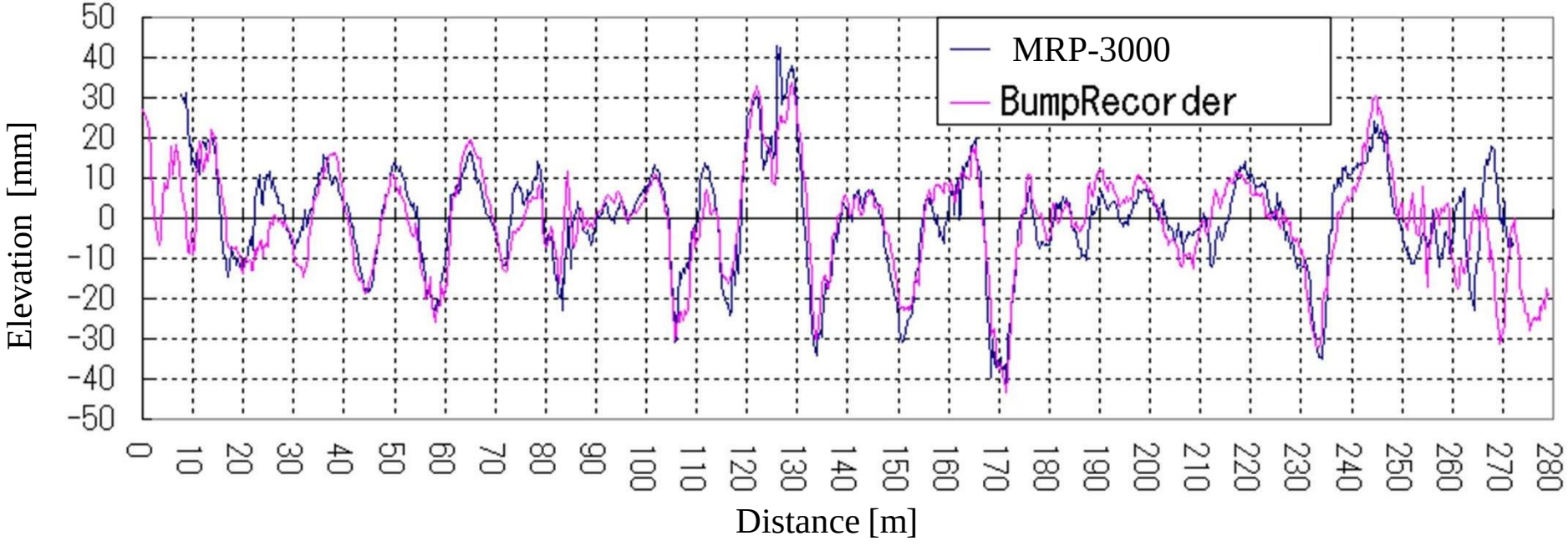
Comparison with KUMATAKA MRP-3000

Comparison : Relative height in 15[m] long

Calculating relative height in 15[m] long
for MRP-3000 and BumpRecorder.
Then comparing this two values.



Trend was consistent.
Position gap was not so large.



Combination Index

PCR (Pavement Condition Rating)

PCR = (0.60 * SCR) + (0.40 * RCI) Pavement Condition Rating
RCI = 160 * (2.718282 ^ (-0.259776 * IRI)) Roughness Condition Index
SCR = 100 - [Cracking rate] Surface Condition Rating

0 (bad) ~ 100 (good)

MCI (Maintenance Condition Index) Japanese Standard

$MCI = 10 - 1.48C^{0.3} - 0.29D^{0.7} - 0.47\sigma^{0.2}$
$MCI0 = 10 - 1.51C^{0.3} - 0.30D^{0.7}$
$MCI1 = 10 - 2.23C^{0.3}$
$MCI2 = 10 - 0.54D^{0.7}$

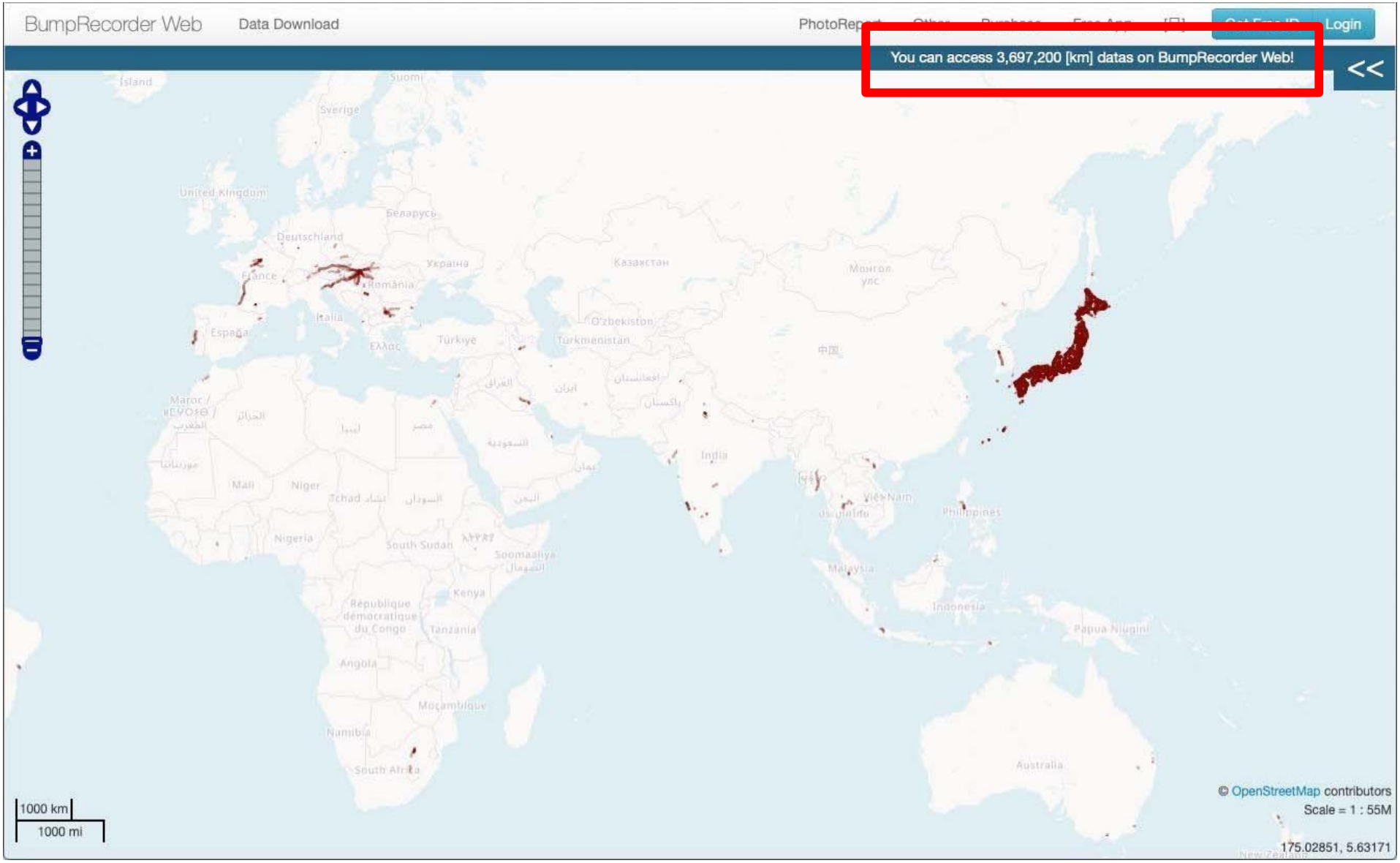
smallest value is used.

C =Cracking rate [%]
D =Rut depth [mm]
σ=JRI [mm]

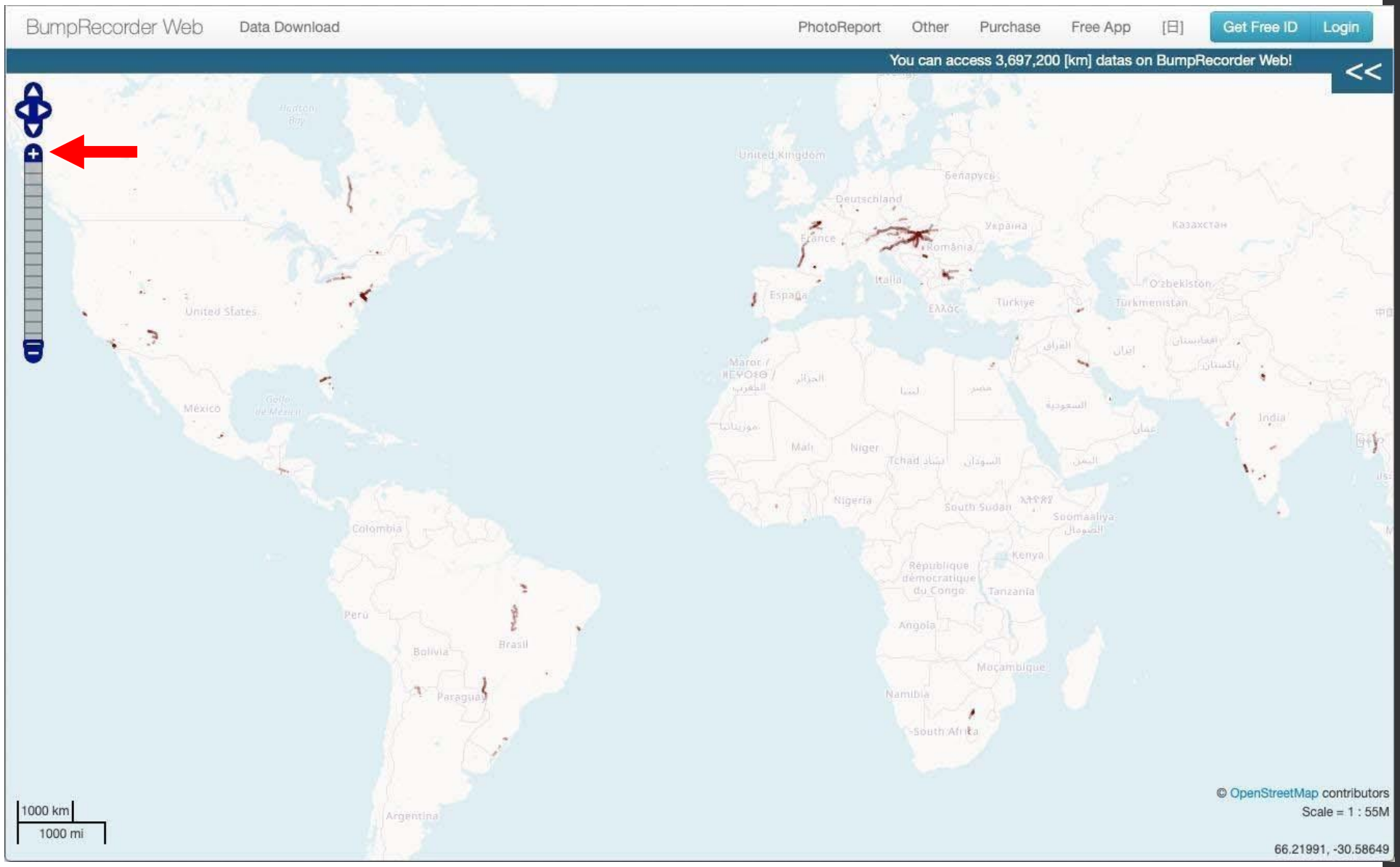
0 (bad) ~ 10 (good)

Wheel path cracking rate is used for above formula.

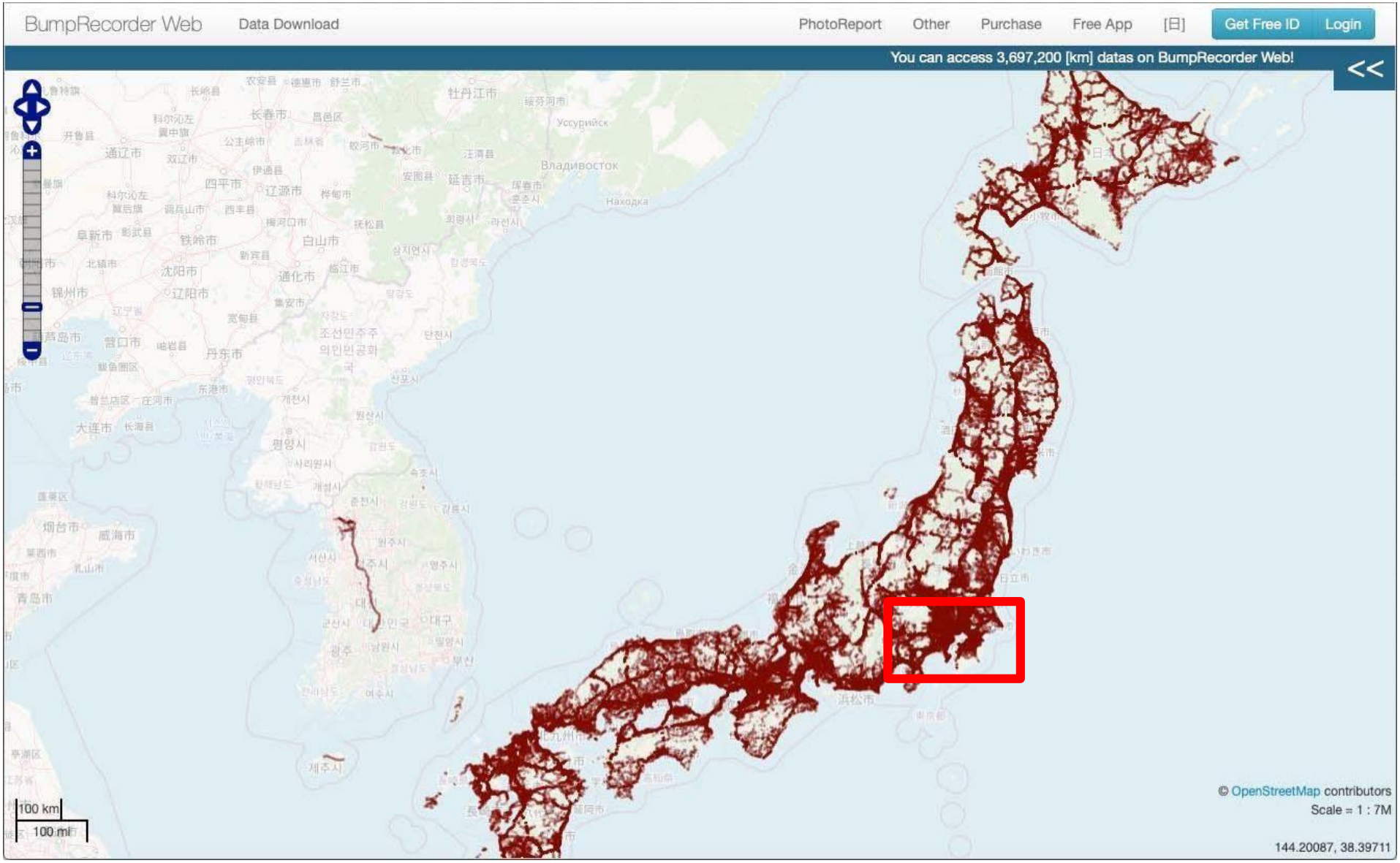
Whole Japan and many courtiers!



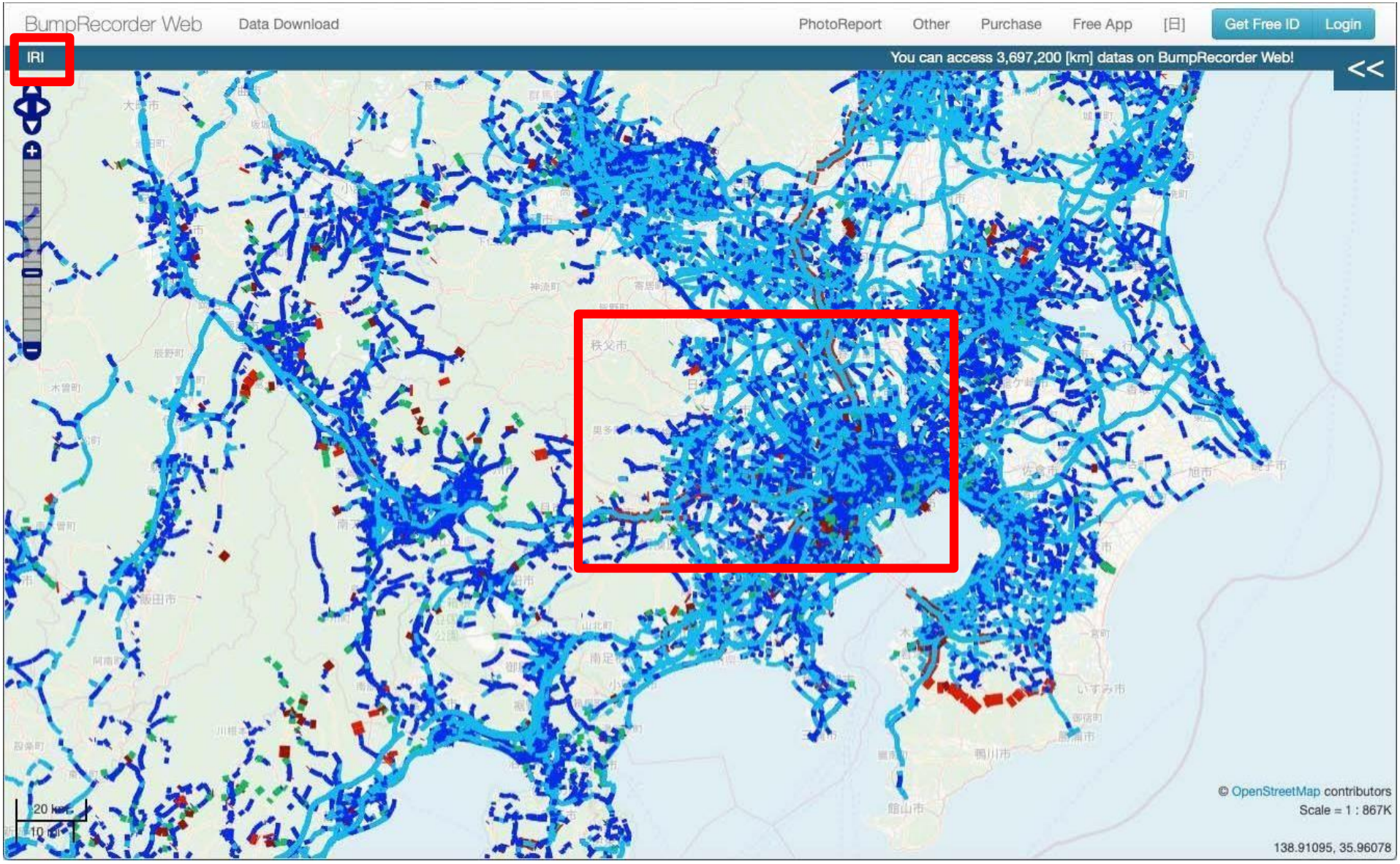
American continent too



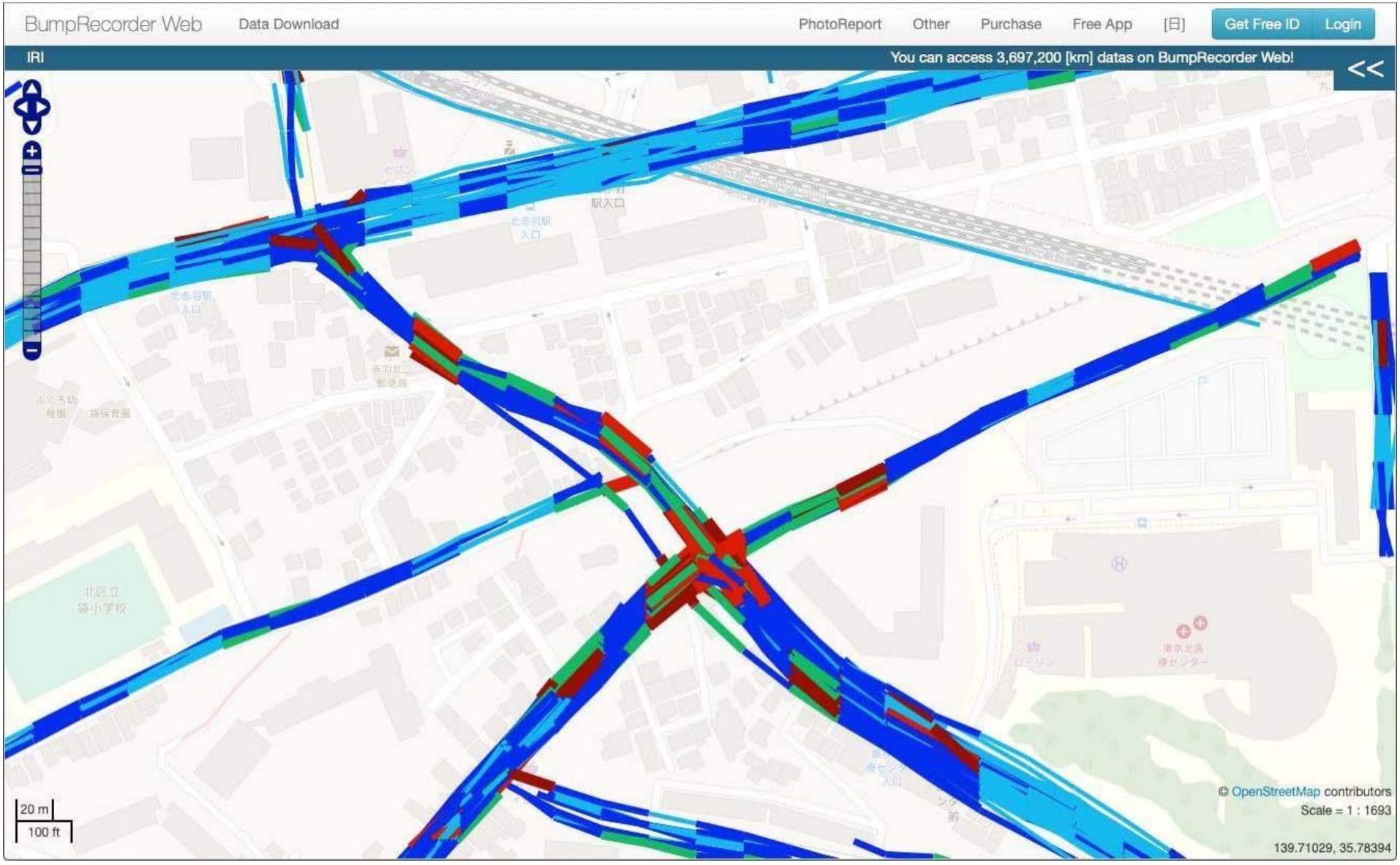
Close up Japan



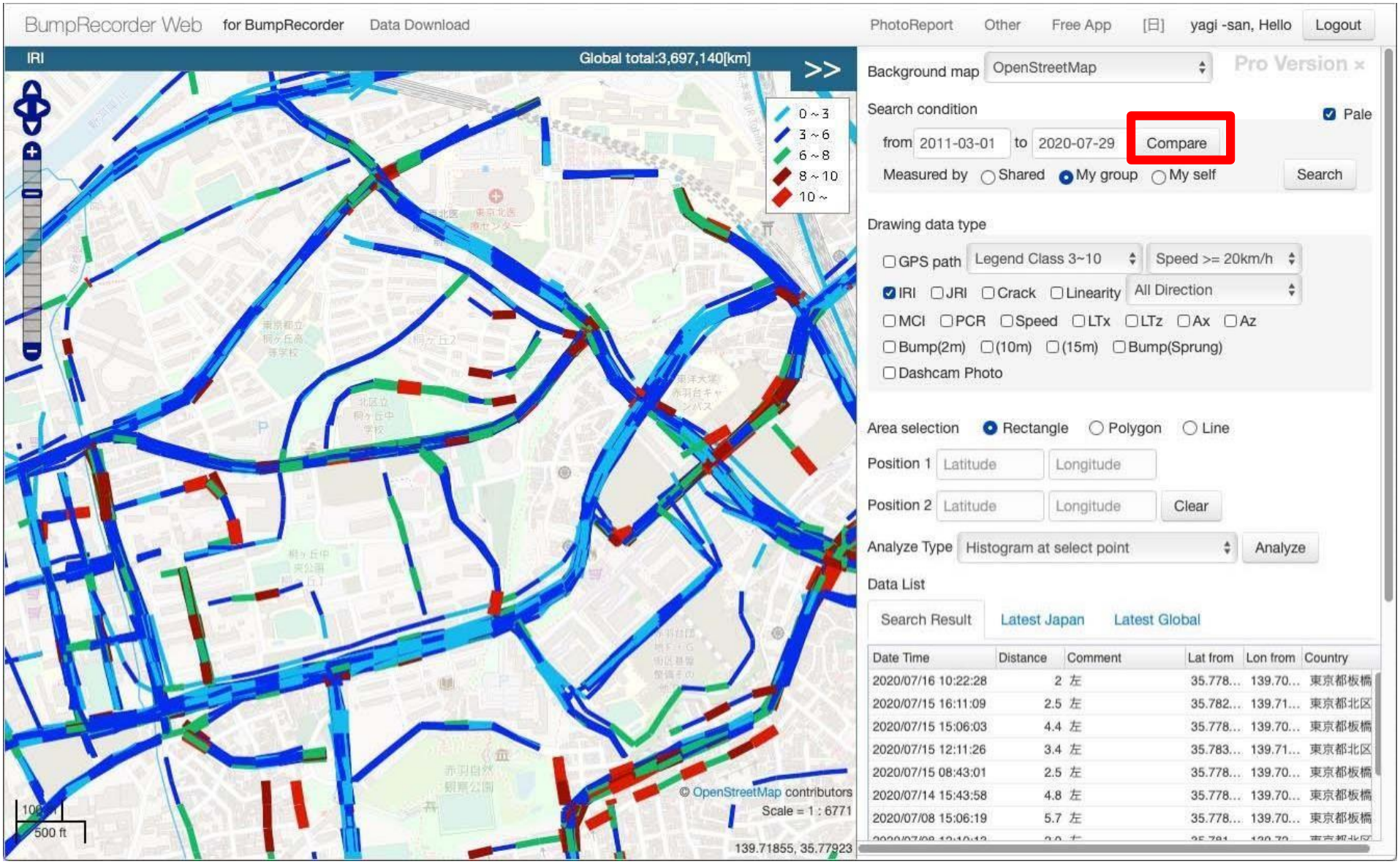
Close up Tokyo area



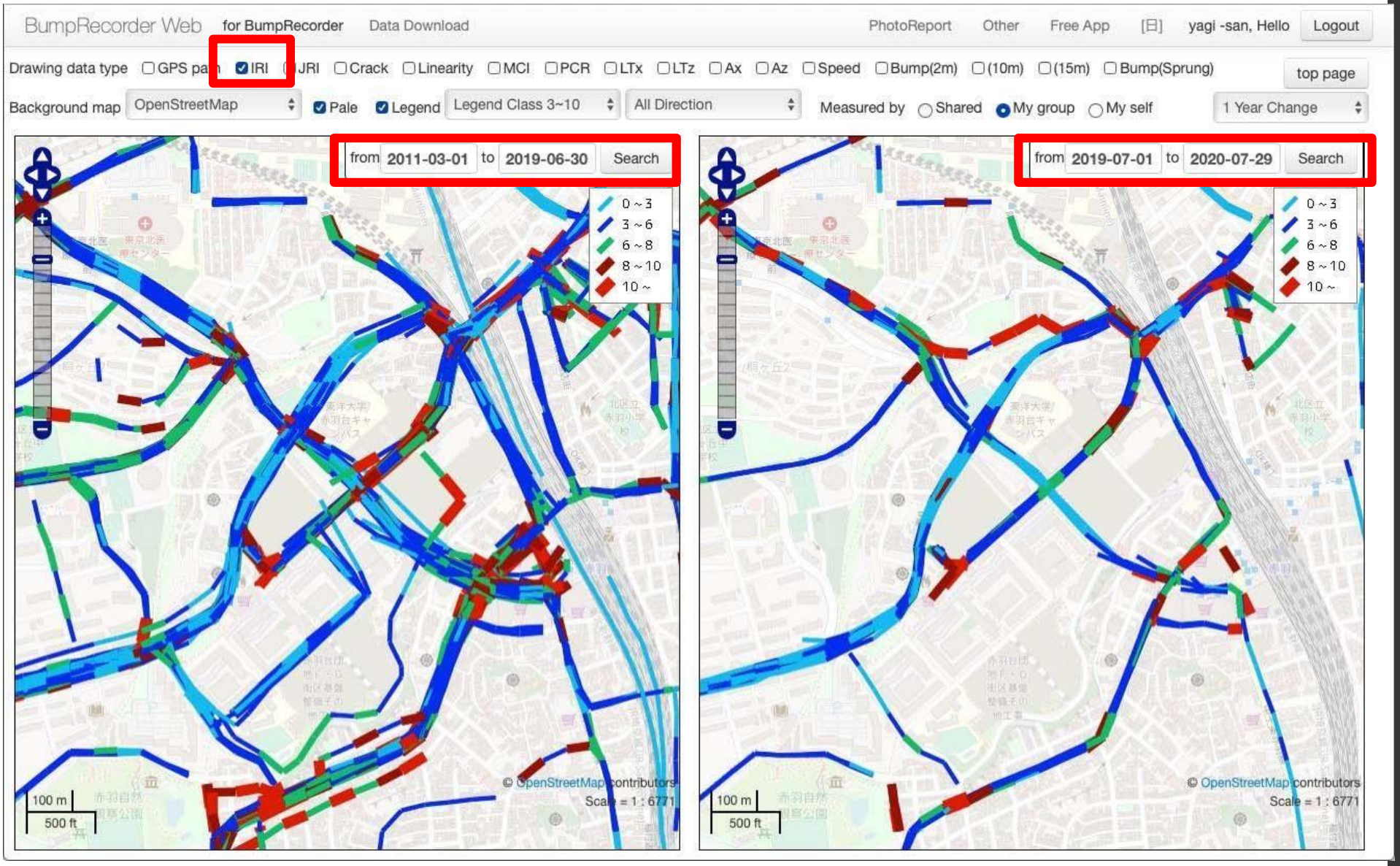
Available from Network level to Project level



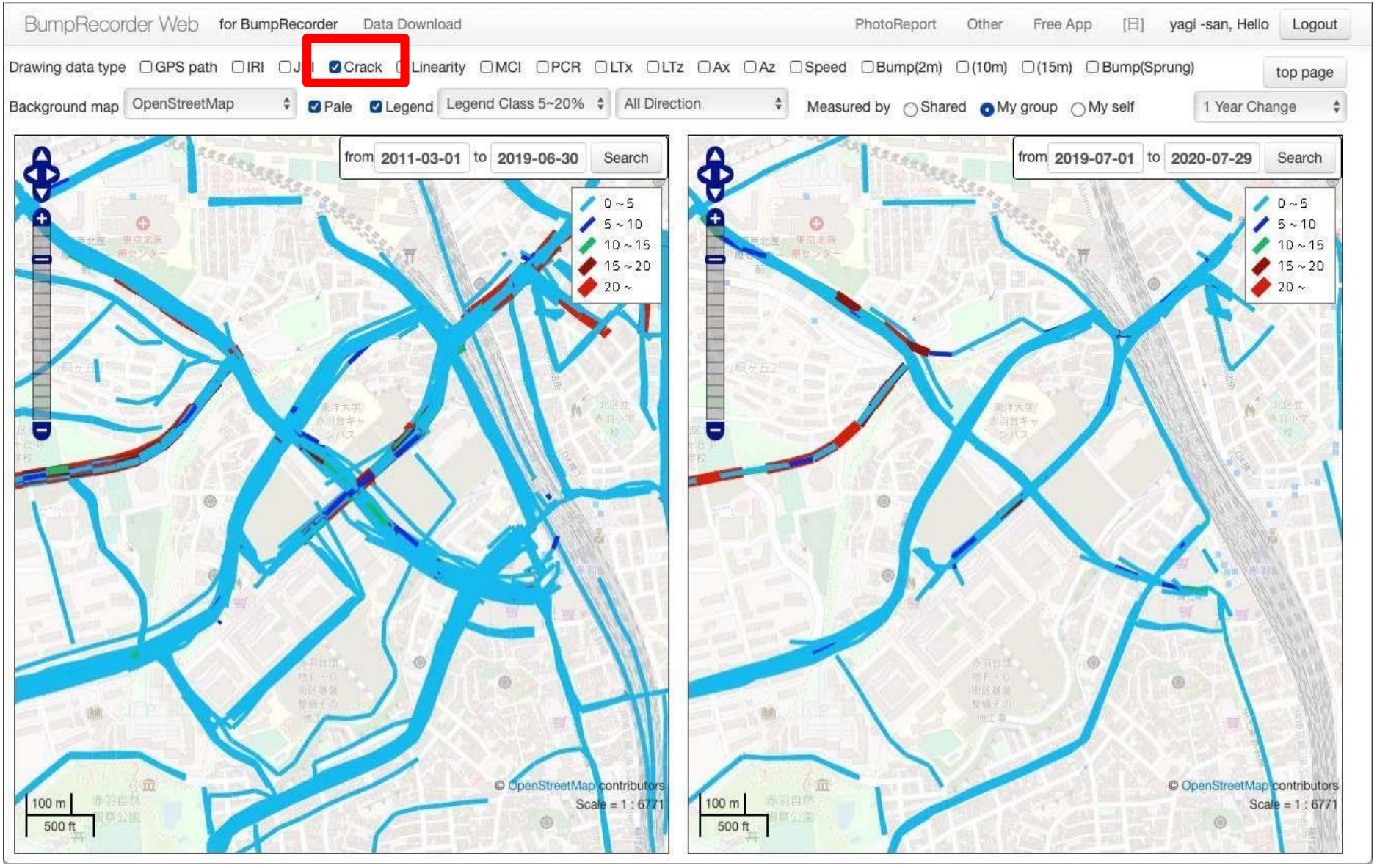
Move to Comparison function



Same location, different period



Crack


BumpRecorder Web
for BumpRecorder
Data Download
PhotoReport
Other
Free App
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Logout
Drawing data type
GPS path
IRI
Crack
Linearity
MCI
PCR
LTx
LTz
Ax
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(10m)
(15m)
Bump(Sprung)
top page
Background map
OpenStreetMap
Pale
Legend
Legend Class 5~20%
All Direction
Measured by
Shared
My group
My self
1 Year Change
from 2011-03-01 to 2019-06-30 Search
from 2019-07-01 to 2020-07-29 Search
0 ~ 5
5 ~ 10
10 ~ 15
15 ~ 20
20 ~
100 m
500 ft
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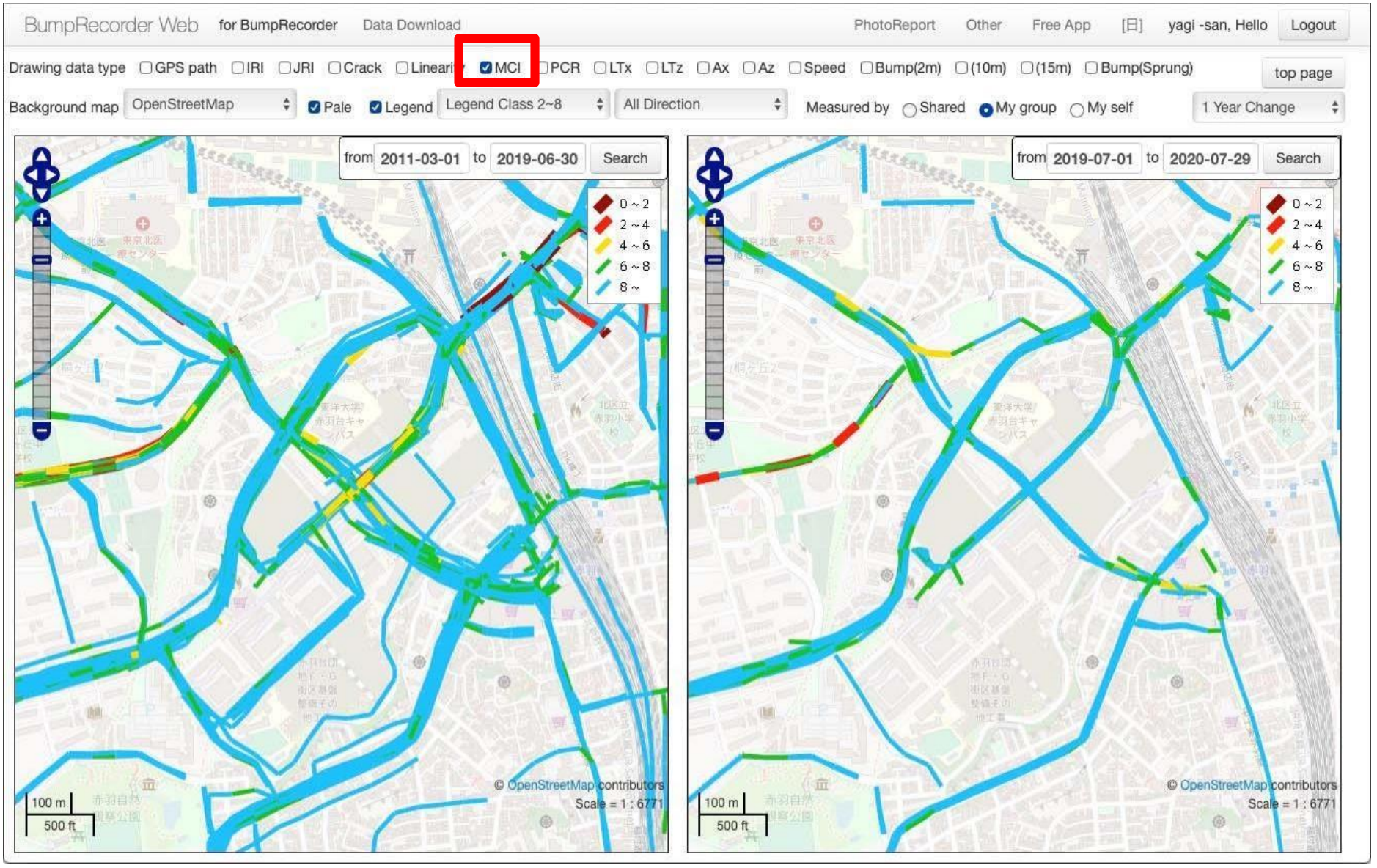
Scale = 1 : 6771

MCI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Ax
Az
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(10m)
(15m)
Bump(Sprung)
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from 2011-03-01 to 2019-06-30 Search
from 2019-07-01 to 2020-07-29 Search
0 ~ 2
2 ~ 4
4 ~ 6
6 ~ 8
8 ~
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Scale = 1 : 6771
100 m
500 ft