European Road Profile Users' Group

Copenhagen

10-12 September2013

Harmonization in pavement smoothness rating of new and old pavements

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PRESENTATION OUTLINE

- Definition and Standards
- Harmonization
- Roughness and roadwork QC/QA
- Roughness and PMS
- Roads – Airports – Bike paths
- Thresholds
- Conclusion

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ROAD ROUGHNESS ……

… is one of the most important characteristic of road surface;

… perception is related to the speed limits, the kind of traffic, the climatic conditions, the accepted comfort limits, etc.;

… is an indicator of functional performance and structural condition.

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ROAD ROUGHNESS DEFINITIONS

ASTM

Roughness: the deviation of a surface from a true planar surface with characteristics dimensions that affect vehicle dynamics, ride quality, dynamic loads, and drainage, for example, longitudinal profile, transverse profile, and cross slope.

EN

Unevenness: deviation of a pavement surface from a filtered true planar surface in wavelenght range of 0.5m to 50m.

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ROAD ROUGHNESS STANDARDS
EU

EN 13036 -6 - Road and airfield surface characteristics

Highway agencies, airfield authorities, equipment manufacturers, and other organizations can use this standard to define the measuring capabilities of survey equipment that collects the data necessary to characterize surface conditions.

Methods of profiling: any device able to obtain a real profile is valid for profiling if it satisfies the objective of the measurements.

Evenness measurements can be performed by means of static or dynamic devices. The standard includes high-speed, low-speed, and stationary equipment.

The EN 13036-6 does not provide any indication regarding evaluation of results.

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ROAD ROUGHNESS STANDARDS
US

Different Standards have been developed for different roughness measurament device.

ASTM E 950-09 Standard pratice for measuring the longitudinal profile of traveled surfaces with an accelerometer estabilished inertial profiling system.

ASTM E 1364-95 (12) Standard practice for measuring the road roughness by static level method.

ASTM E 2133-03 (09) Standard test using a rolling inclinometer to measure longitudinal and transversal profile of a traveled surface.

ASTM E1274-03 (12) Standard Test Method for Measuring Pavement Roughness Using a Profilograph

ASTM E 1215-93 (12) Specification for Trailers Used for Measuring Vehicular Response to Road Roughness

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MEASUREMENT METHODS

ROAD AND LEVEL:

The survey is carried out using rod, level and measuring tape

DIPSTICK:

The device utilizes a precision inclinometer to measure the difference in height between the two supports

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MEASUREMENT METHODS

PROFILOGRAPH

It is a long beam with wheels at each end, and a test wheel in the center; the road roughness is measured by the vertical movement of the test wheel.

INERTIAL PROFILERS

This device is composed of a laser which measures the relative distance between the road surface and a computed inertial reference, an odometer which measures the longitudinal distance and an accelerometer to take into account vehicle vertical accelerations.

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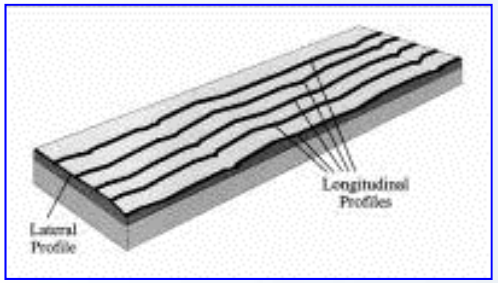
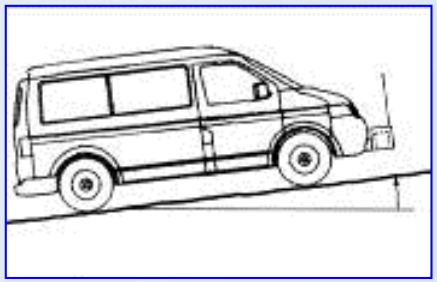
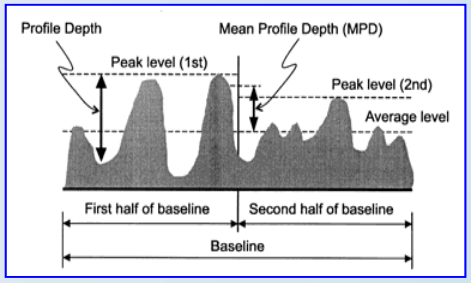
MEASUREMENT METHODS

Longitudinal Profile	Transverse Profile	Grad, Radius, Cross	Macrotexture
			

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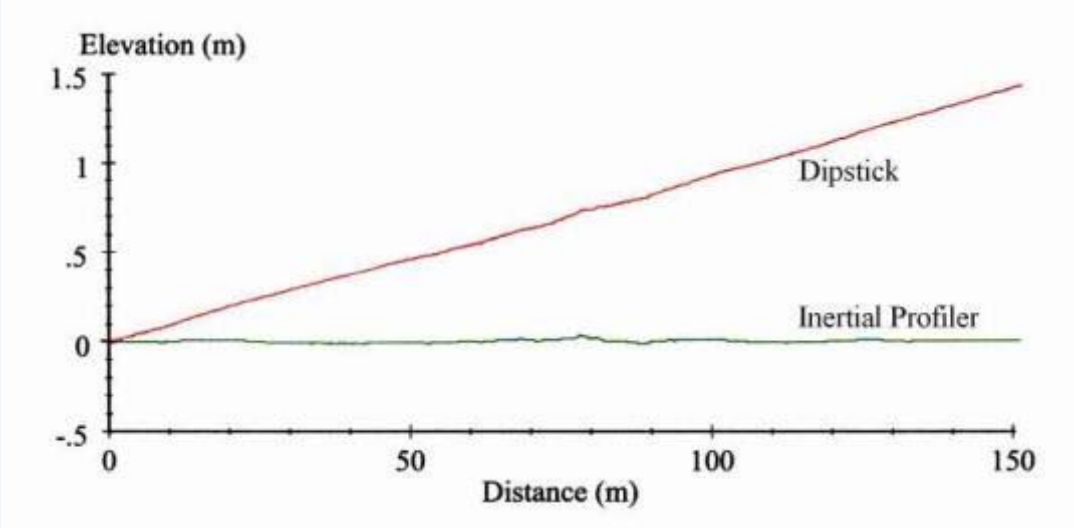
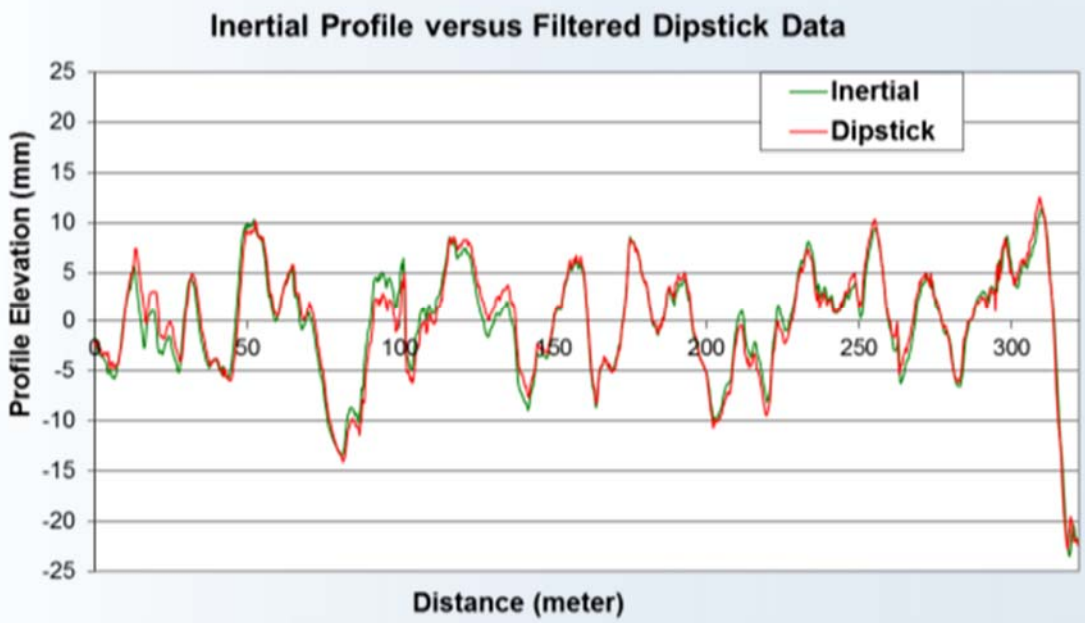
COMPARISON OF DIFFERENT DEVICE

Static Versus Inertial Profile





The general character of the two profiles is remarkably similar.

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ROUGHNESS INDICES

From a ”True Profile” (Static, Walking or High Speed Inertial Profile), different Roughness Indices can be derived, such as e.g.:

- IRI – International Roughness Index
- HRI – Half –Car Roughness Index
- RN – Ride Number
- MRI – Mean Roughness Index
- SV – Slope Variance
- CPI – California Profilograph Index
- .....

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ROUGHNESS DATA EVALUATION

Different target values for roughness are prescribed for

- **QA/QC activities in road works;**
- **monitoring during service life;**
- **pavement maintenance planning.**

<u>STANDARDIZATION</u> is essential to provide a universal basis in order to have to equivalent or comparable results wherever and whenever a given experiment or study is carried out.

Question:
in order to improve uniformity in roughness evaluation is possible to define a general criteria and specific threshold values to be applied in different situations?

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STANDARDIZATION & HARMONISATION

HARMONIZATION (J.J.HENRY):

"The process of creating a new reference standard to which existing standards can be related, whether they are maintained in parallel to the new standard or are subsequently replaced"

Harmonization can be considered the gentle road to achieving standardization

The Aims of harmonization:

- **Continuity**
- **Equity**
- **Efficiency**
- **Effectiveness**
- **Technological progress**
- **Reducing compliance requirements to the minimum essential**
- **Eliminating conflicting requirements that might be applicable from different agencies**

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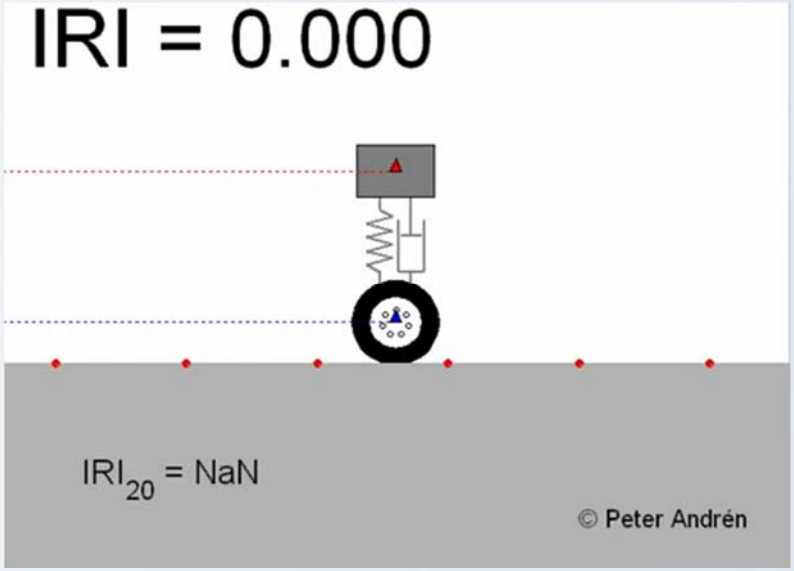
STANDARDIZATION & HARMONISATION

The International Road Roughness Experiment (IRRE) was proposed to find the best practices appropriate for the many types of roughness measuring equipment in use. At the same time, the IRRE was planned to provide a means for comparing roughness data obtained by different procedures and instruments.

The equipment included two categories: profilometric methods (manual quasi-static methods and high-speed profilometers) and Response-Type Road Roughness Measuring Systems (RTRRMSs).



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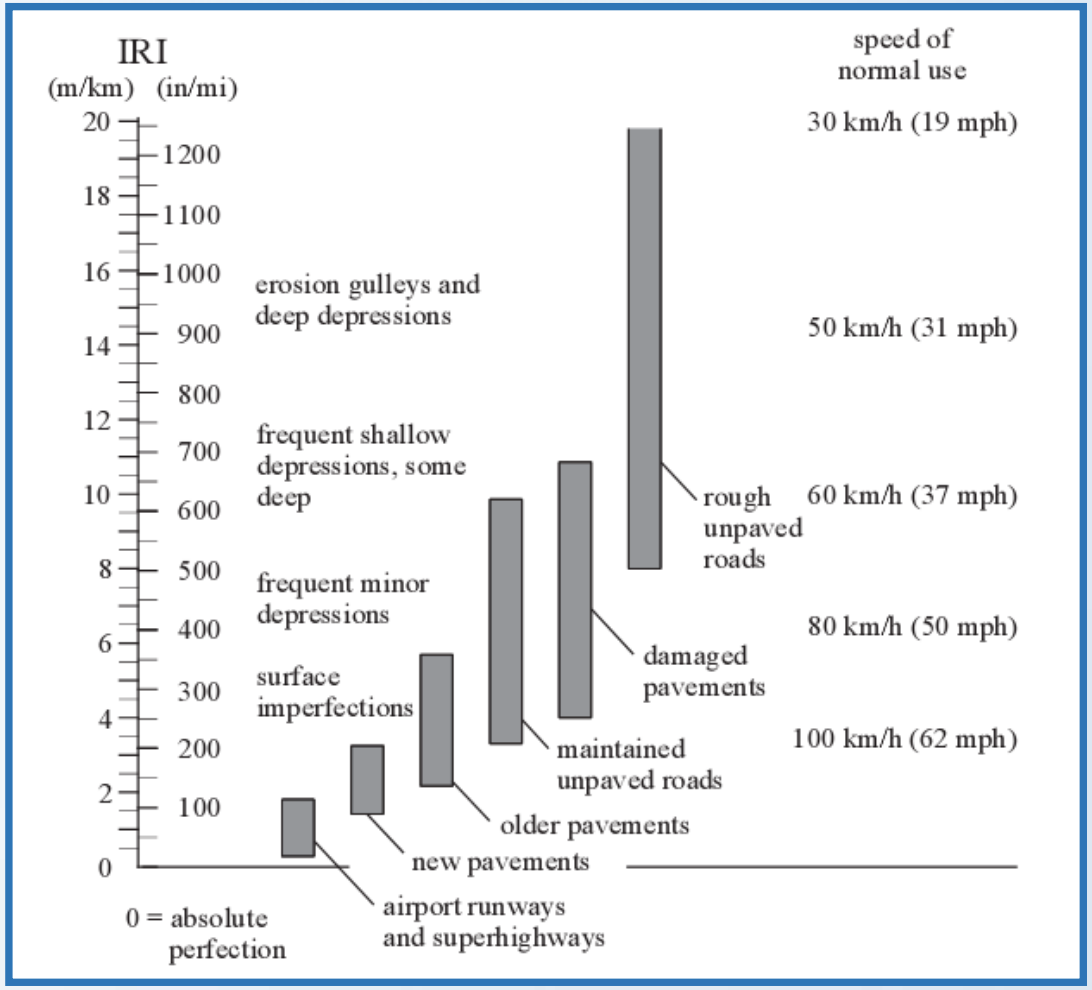
ROUGHNESS THRESHOLD

At the moment each Country uses different thresholds; the most common reference is the scale proposed by Sayers in the *Little book of profiling* (1998).



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ROUGHNESS THRESHOLD

Different case is the scale reported in the ASTM E 1926, where roughness is evaluated based on the user's perception and comfort.

ROUGHNESS
(m/km IRI)

0

2

Ride comfortable over 120 km/h. Undulation barely perceptible at 80 km/h in range 1.3 to 1.8. No depressions, potholes or corrugations are noticeable; depressions < 2mm/3m. Typical high quality asphalt 1.4 to 2.3, high quality surface treatment 2.0 to 3.0.

4

Ride comfortable up to 100-120 km/h. At 80 km/h, moderately perceptible movements or large undulations may be felt. Defective surface; occasional depressions, patches or potholes (e.g.5-15 mm/3m or 10 - 20 mm/5m with frequency 2-1 per 50m), or many shallow potholes (e.g. on surface treatment showing extensive ravelling). Surface without defects; moderate corrugations or large undulations.

6

Ride comfortable up to 70-90 km/h, strongly perceptible movements and swaying. Usually associated with defects; frequent moderate and uneven depressions or patches (e.g. 15-20mm/3m or 20-40mm/5m with frequency 5-3 per 50m), or occasional potholes (e.g. 3-1 per 50m). Surface without defects: strong undulations or corrugations.

8

Ride comfortable up to 50-60 km/h, frequent sharp movements or swaying. Associated with severe defects: frequent deep and uneven depressions and patches (e.g. 20-40 mm/3m or 40-80 mm/5m with frequency 5-3 per 5m), or frequent potholes (e.g. 4-6 per 50m).

10

Necessary to reduce velocity below 50km/h. Many deep depressions, potholes and severe disintegration (e.g. 40-80mm deep with frequency 8-16 per 50m).

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ROADWORK PRESCRIPTIONS - Examples

ANAS
IRI ≤ 1,8 mm/m REHABILITATIOM ON FULL CARRIAGEWAY
IRI ≤ 2,0 mm/m LIMITED REHABILITATION ON A PART OF THE CARRIAGEWAY
DEDUCTIONS
1\3 OF THE PERCENTAGE OF THE DISCREPANCY BETWEEN THE ACTUAL AND PRESCRIBED IRI VALUES
UNACCEPTABLE THRESHOLD
IRI > 3,5 mm/m (MOTORWAY OR DUAL CARRIAGEWAY)
IRI > 4,0 mm/m (OTHER ROADS)

AUTOSTRADE
I.R.I. < 1,8 mm/m REHABILITATION ON FULL CARRIAGEWAY
I.R.I. < 2,0 mm/m LIMITED REHABILITATION ON A PART OF THE CARRIAGEWAY
DEDUCTIONS
15% OF ITS COST
UNACCEPTABLE THRESHOLD
IRI > 3,5 mm/m.

REGIONE TOSCANA
I.R.I. < 1,8 mm/m REHABILITATION ON FULL CARRIAGEWAY
I.R.I. < 2,0 mm/m LIMITED REHABILITATION ON A PART OF THE CARRIAGEWAY

ROADWORK PRESCRIPTIONS - Examples

QATAR ROAD AUTHORITY

The readability of the finished wearing course when tested with a Laser Road Surface Testing Machine shall have an IRI not exceeding the following values:

- **Average value over a 400 metre section for new construction and multi layer pavement rehabilitation with crack arresting layer ≤ 1.05**
- **As above but average value for milling and single overlay rehabilitation section ≤ 1.05**
- **Peak value over a 25 metre section for all types of new and rehabilitated pavement (not more than 2 values per 400 meters) ≤ 1.50**
- **The amplitude of the longitudinal profile of the road, filtered between (a) 1 metre and 3.3 metres and (b) 3.3 metres and 13 metres shall not exceed following values:**
  1m - 3.3m ≤ 1.80mm
  3.3m - 13m ≤ 3.50mm

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ROADWORK PRESCRIPTIONS - Examples

PLIEGO DE PRESCRIPCIONES TECNICAS GENERALES PARA OBRAS DE CARRETERAS Y PUENTES (Spain)

IRI (mm/m) for new road

PERCENTAGE OF km	MOTORWAYS	OTHER ROADS
50	<1,5	<1,5
80	<1,8	<2,0
100	<2,0	<2,5

IRI (mm/m) for existing roads

	MOTORWAY			OTHER ROADS
	WIDTH OF ROAD RESURFACING			
Percentage of km	>10	≤10	>10	≤10
50	<1,5	<1,5	<1,5	<2,0
80	<1,8	<2,0	<2,0	<2,5
100	<2,0	<2,5	<2,5	<3,0

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ROUGHNESS PARAMETERS USED FOR WORK CONSTRUCTION BONUS/PENALITIES

MINNESOTA STATE UNIVERSITY

IMPLEMENTATION OF AN INTERNATIONAL ROUGHNESS INDEX FOR MN/DOT PAVEMENT CONSTRUCTION AND REHABILITATION

GOOD WORK: INCENTIVES

INADEQUATE WORK: DISINCENTIVES

Table 2.11. PCC Smoothness Incentive – Illinois [420.12] – 2002.

Price Adjustment Schedule	
Profile Index for Entire Project mm/km (in/mi)	**Percent of Unit Bid Price**
36 (2.25) or less	103
Over 36 (2.25) – 53 (3.25)	102
Over 53 (3.25) – 67 (4.25)	101

Profile Index for 160 m (0.1mi) Section mm/km (in/mi)	**Percent of Unit Bid Price**
Over 67 (4.25) – 160 (10)	100
Over 160 (10) – 175 (11)	98
Over 175 (11) – 190 (12)	96
Over 190 (12) – 205 (13)	94
Over 205 (13) – 220 (14)	92
Over 220 (14) – 235 (15)	90
Over 235 (15)	Corrective work required

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ROUGHNESS EVALUATION FOR AIRPORT PAVEMENTS

The existence of an international organization that oversees the law-making to individual institutions for national civil aviation led to the Standardization of technical requirements.

International Civil Aviation Organization - ICAO

NEW PAVEMENT

"Except across the crown of a camber or across drainage channels, the finished surface of the wearing course is to be of such regularity that, when tested with a 3 m straight-edge placed anywhere in any direction on the surface, there is no deviation greater than 3 mm between the bottom of the straight-edge and the surface of the pavement anywhere along the straight-edge"

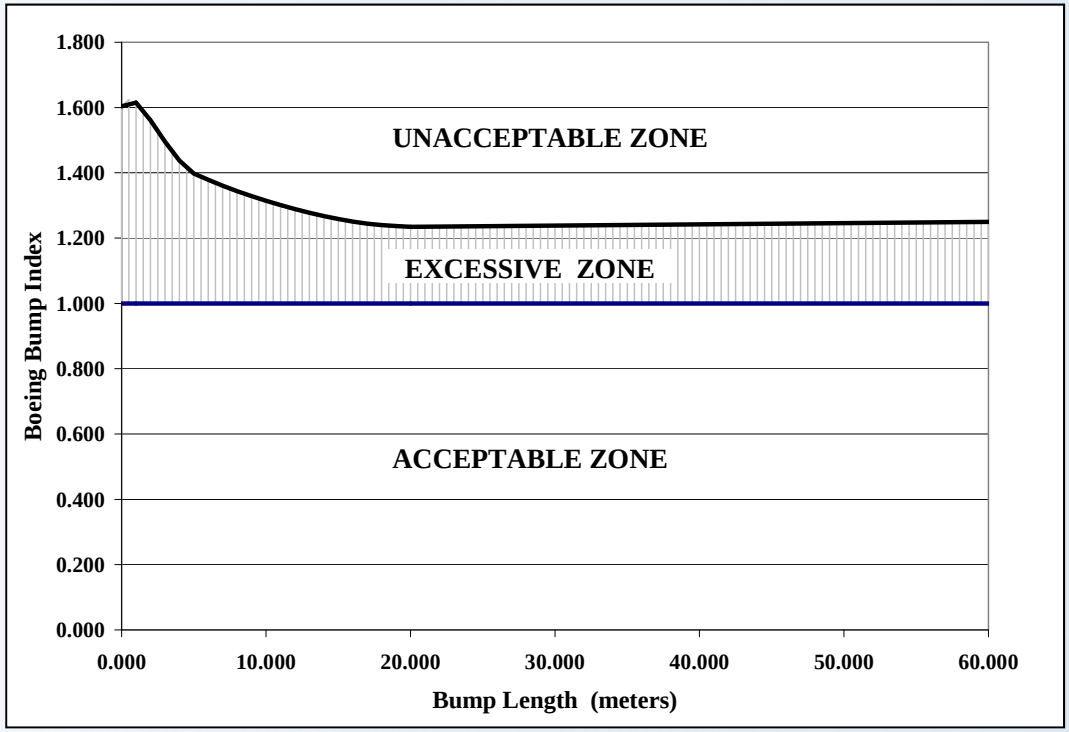
EXISTING PAVEMENT

"Isolated irregularities of the order of 2.5 cm to 3 cm over a 45 m distance are tolerable. although maximum acceptable deviations vary with the type and speed of an aircraft, the limits of acceptable surface irregularities can be estimated to a reasonable extent"

ROUGHNESS EVALUATION FOR AIRPORT PAVEMENTS

In order to take into account the influence of longer wavelenghts FAA developed the Boeing Bump Index.

AC n°150/5380-9 *"Guidelines and Procedures for Measuring Airfield Pavement Roughness"*



ASTM is also working to standardize the Boeing Bump Index calculation procedure.
Work Item: ASTM WK41777 - *New Specification for Boeing Bump Index Computations Based on Bump Template Simulations*

ROUGHNESS EVALUATION FOR AIRPORT PAVEMENTS

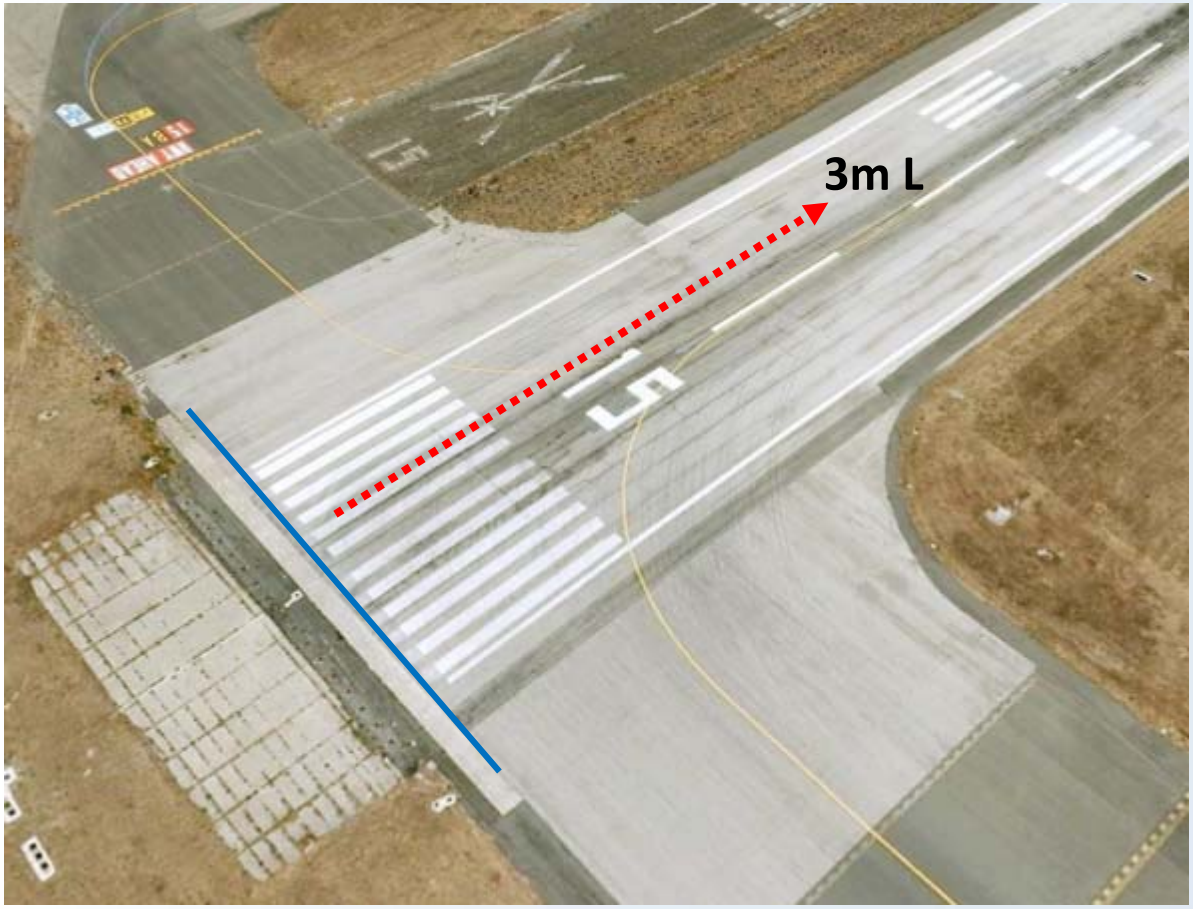
FAA provides equipment measurament specifications for the BBI calculation.

"The use of inertial profilers that include highpass filtering is not recommended for measuring profiles which are to be used for computing BBI index or simulated airplane accelerations on airport pavements"

ROUGHNESS EVALUATION FOR AIRPORT PAVEMENTS

Ciampino International Airport

Example



1. **Static method**

   Sampling interval 10 m

2. **Inertial profilometer**

   Sampling interval 25 mm

Static method:

IRI: 0.44

BBI: 0.16

Inertial profilometer:

IRI: 2.01

BBI: 0.14

3. **Merged profile**

Merged:

IRI: 2.12

BBI: 0.23

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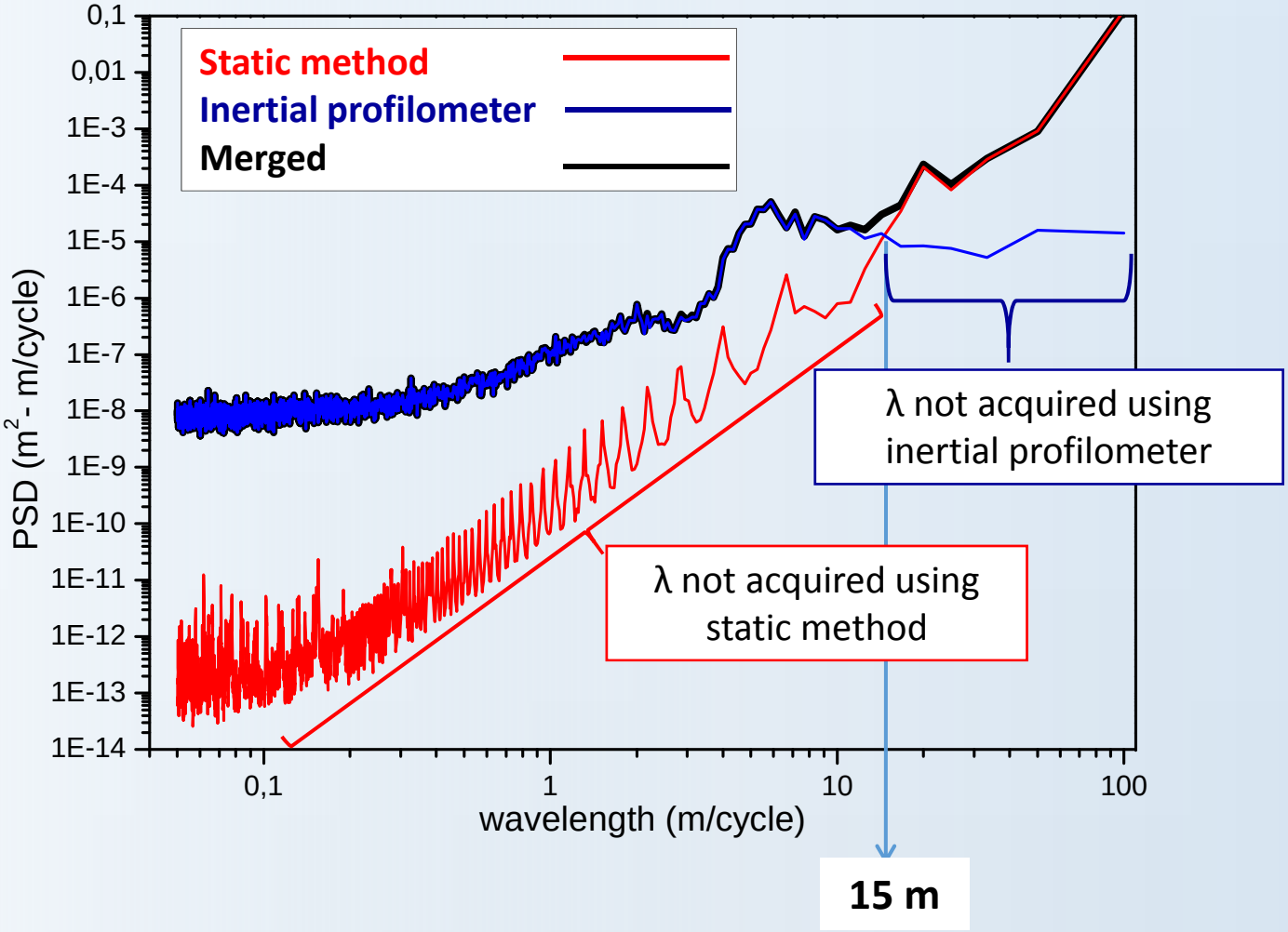
ROUGHNESS EVALUATION OF AIRPORT PAVEMENTS



Static method :

IRI: 0.44

BBI: 0.16

Inertial profilometer:

IRI: 2.01

BBI: 0.14

Merged:

IRI: 2.12

BBI: 0.23

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WHAT IS MISSING??

Minimum value to define the MAINTENANCE level.

Threshold to define the MINIMUM EXERCISE road conditions.

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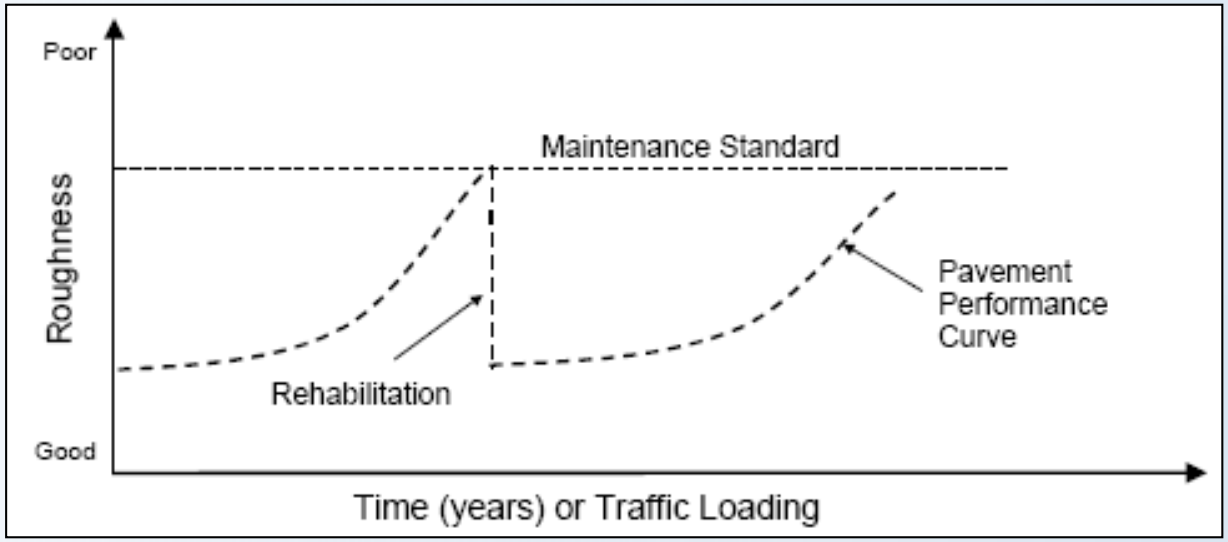
ROUGHNESS AND PAVEMENT MANAGMENT SYSTEM

Roughness information is a useful input to the pavement management systems (PMS) maintained by transportation agencies.
Nowadays road agencies use the pavement management system (PMS) to maintain a road network and to optimize pavement maintenance strategies.



Roughness is strictly related with the time or traffic loading to adjust maintenance operation to a certain threshold of roughness value.
A maintenance solution is necessary when the road roughness reaches a defined threshold limit.

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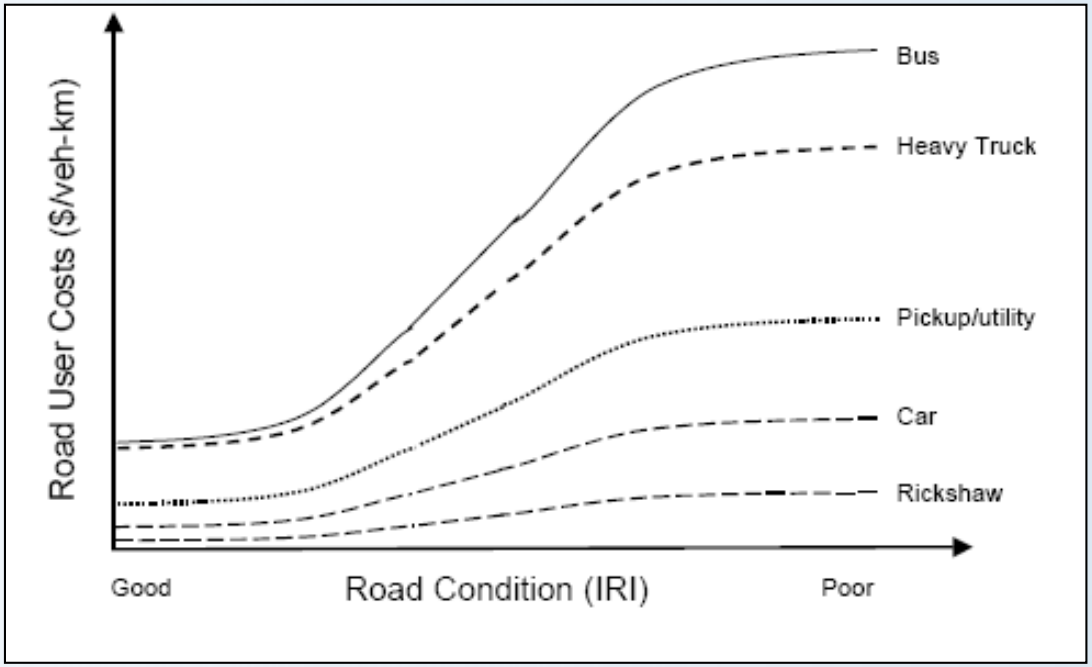
ROUGHNESS AND PAVEMENT MANAGEMENT SYSTEM

Different studies correlate the roughness to the vehicle operating costs, so the maintenance is not only for a ride quality/users comfort, but is directly related also to the drivers costs.



Effect of Road Condition on Vehicle Operating Costs

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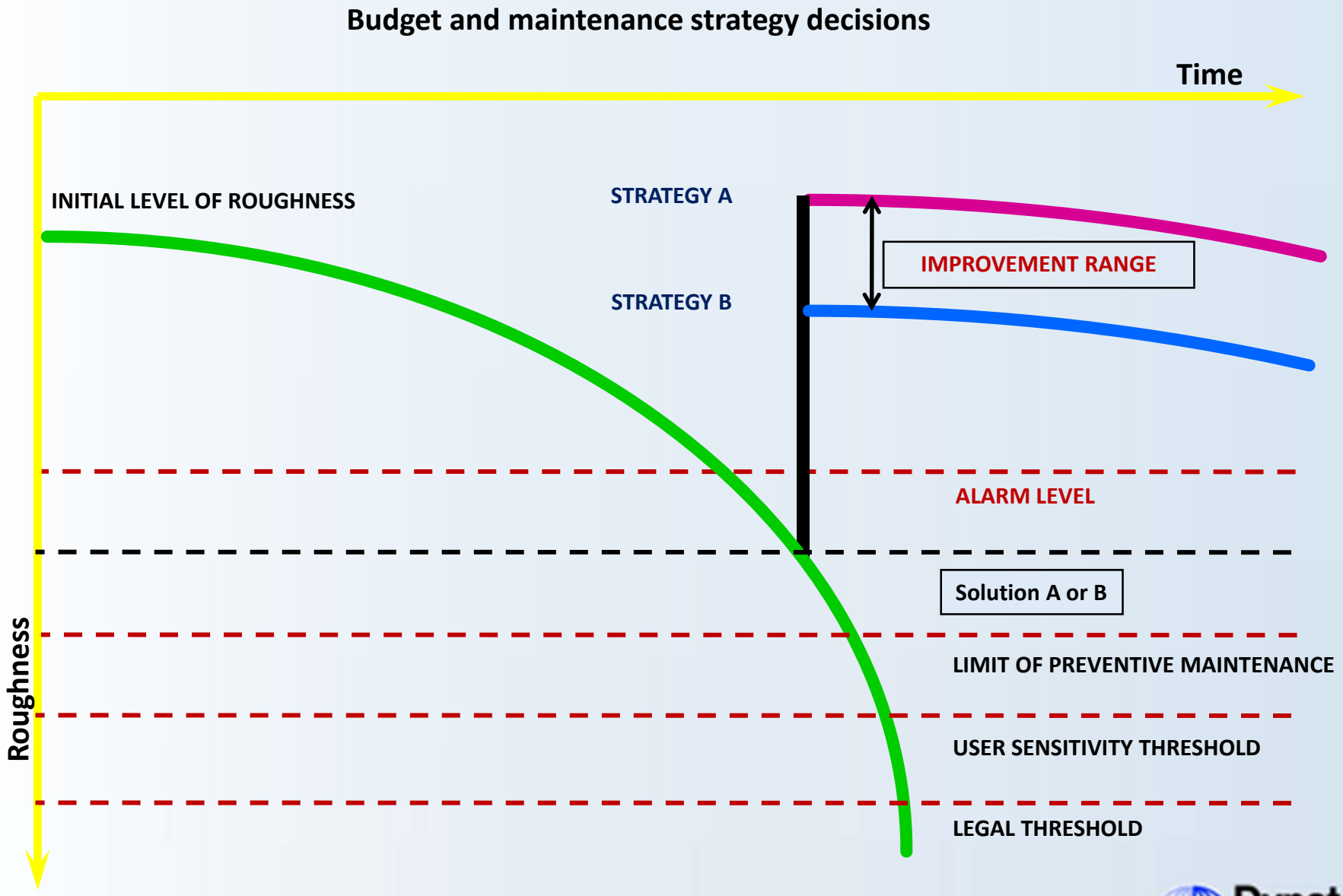
ROUGHNESS AND PAVEMENT MANAGMENT SYSTEM



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THE SMOOTHNESS ASSURANCE MODULE (SAM)

FHWA has recently implemented the software PROVAL with a tool (SAM) developed on the idea that starting on certain roughness level and desinging a specific maintenance work is possible reach a pre-determined roughness level.

This application is used to:

- **Produce ride quality reports**
- **Optimize grinding strategies by analyzing measurements from profiles collected using inertial profilers**
- **determine the out-of-spec locations and recommend must-grind locations.**
- **Determine the ride quality after grinding.**

ProVAL 3

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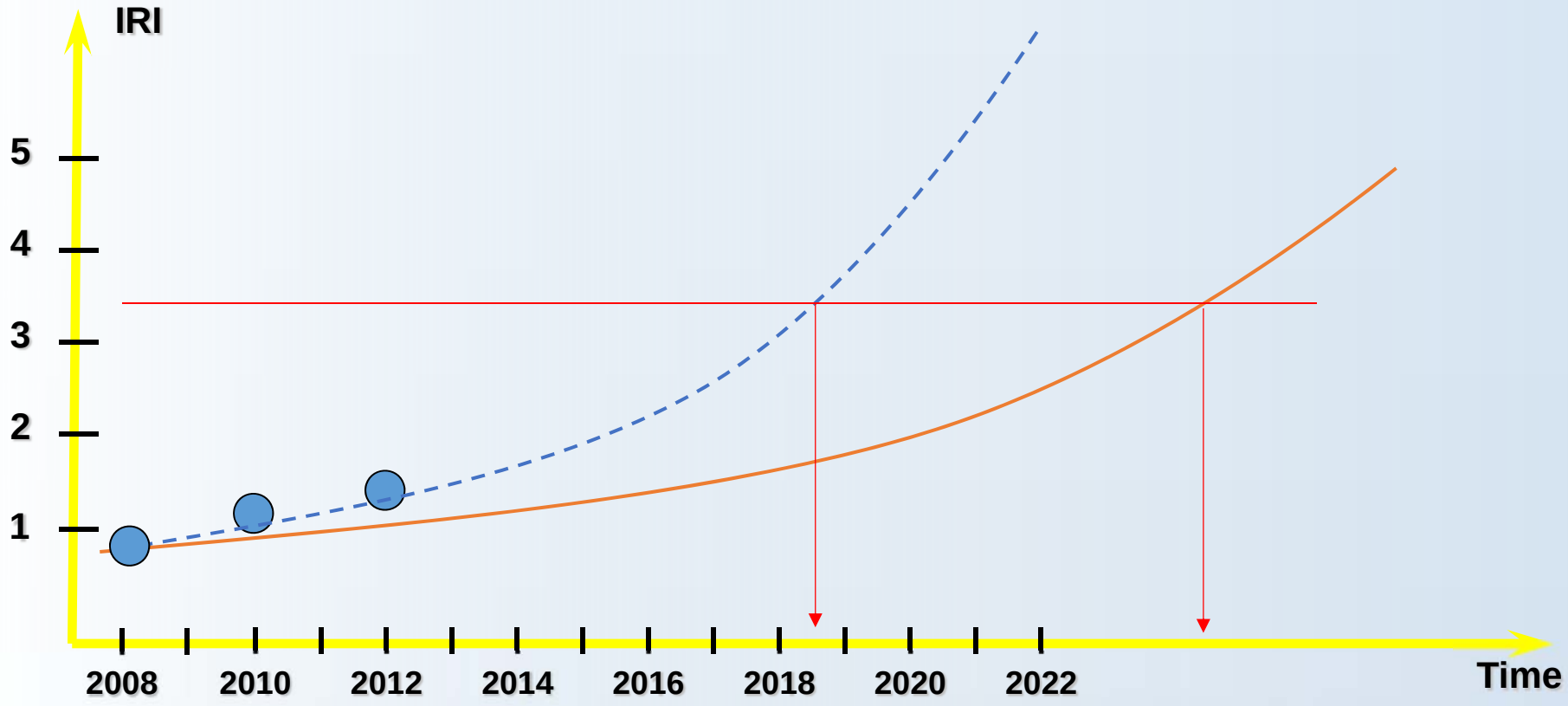
ROUGHNESS AND PAVEMENT MANAGEMENT SYSTEM

FORESEEING THE IRI TREND

Curve recalibration following programmed investigations



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EXAMPLE OF MEASURAMENT TYPES
USE A MAINTENANCE THRESHOLD

For what concern surface friction levels, different road and airport Authorities introduced thresholds not only for the QA/QC contruction works, but also for maintenance and minimum levels.

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SKID RESISTANCE MANAGEMENT

SPECIFICATION FOR SKID RESISTANCE INVESTIGATION AND TREATMENT SELECTION TNZ T10:2002 - NEW ZEALAND

Site Category	Site Definition	Investigatory Level (IL)	Threshold Level (TL)
1	Approaches to: • railway level crossings • traffic lights • pedestrian crossings • roundabouts • Stop and Give Way controlled intersections (where the State Highway traffic is required to stop or give way). • One Lane Bridges (including bridge deck).	0.55	0.45
2	• Curve < 250m radius • Down gradients > 10%	0.50	0.40
3	• Approaches to road junctions (on the State Highway or side roads). • Down gradients 5 - 10% • Motorway junction area including On/Off Ramps	0.45	0.35
4	• Undivided carriageways (event - free)*	0.40	0.30
5	• Divided carriageways (event - free)*	0.35	0.25

*Event-Free = Where no other geometrical constraint, or situations where vehicles may be required to brake suddenly, may influence the skid resistance requirements.

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SKID RESISTANCE MANAGEMENT

ICAO - ANNEX 14 – AERODROMES - VOLUME I

Aerodrome friction levels for new and existing runway surfaces

Test equipment	Test tire		Test speed (km/h)	Test water depth (mm)	Design objective for new surface	Maintenance planning level	Minimum friction level
	Type	Pressure (kPa)					
(1)	(2)		(3)	(4)	(5)	(6)	(7)
Mu-meter Trailer	A	70	65	1.0	0.72	0.52	0.42
	A	70	95	1.0	0.66	0.38	0.26
Skiddometer Trailer	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Surface Friction Tester Vehicle	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.47	0.34
Runway Friction Tester Vehicle	B	210	65	1.0	0.82	0.60	0.50
	B	210	95	1.0	0.74	0.54	0.41
TATRA Friction Tester Vehicle	B	210	65	1.0	0.76	0.57	0.48
	B	210	95	1.0	0.67	0.52	0.42
GripTester Trailer	C	140	65	1.0	0.74	0.53	0.43
	C	140	95	1.0	0.64	0.36	0.24

DIFFERENT DEVICES

DIFFERENT TARGET VALUES

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BIKE PATHS
(not only roads and airports)

The importance of cyclists and pedestrians

Aim: develop a comfort index to obtain an objective assessment of the condition of the surface of the bike paths

Dynatest developed <u>BPI: bicycle profile index</u>

Focusing on certain wave lenghts and measurements carried out at low speed

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WHY IS IT IMPORTANT?

For pedestrian/cyclist safety

Cycling should be enjojable /comfortable

Overview of the conditions of the bike paths

Identify where intervetions/repairs are necessary in the bike path network

Gis implementation for results

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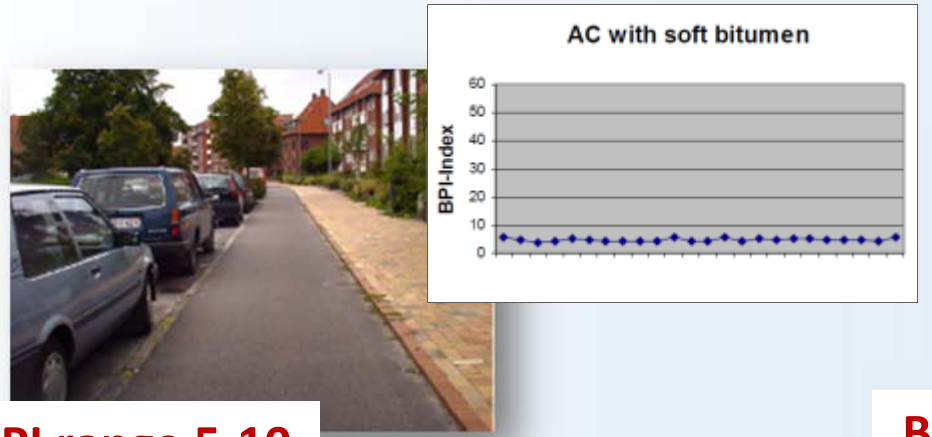
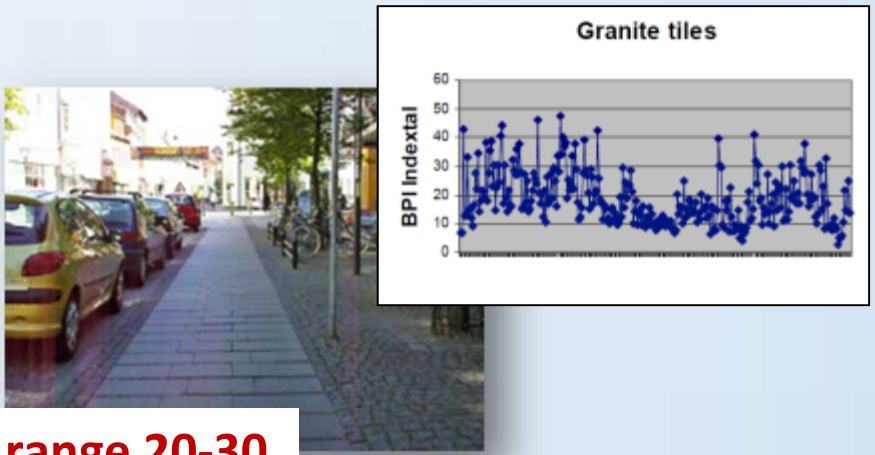
CALIBRATION TEST TO DETERMINE THE REFERENCE VALUE

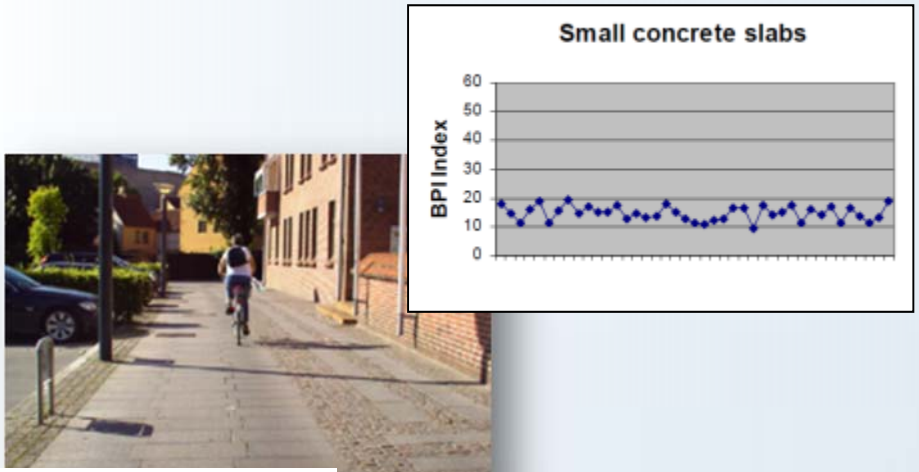
Reference values used for bike paths roughness evaluation.



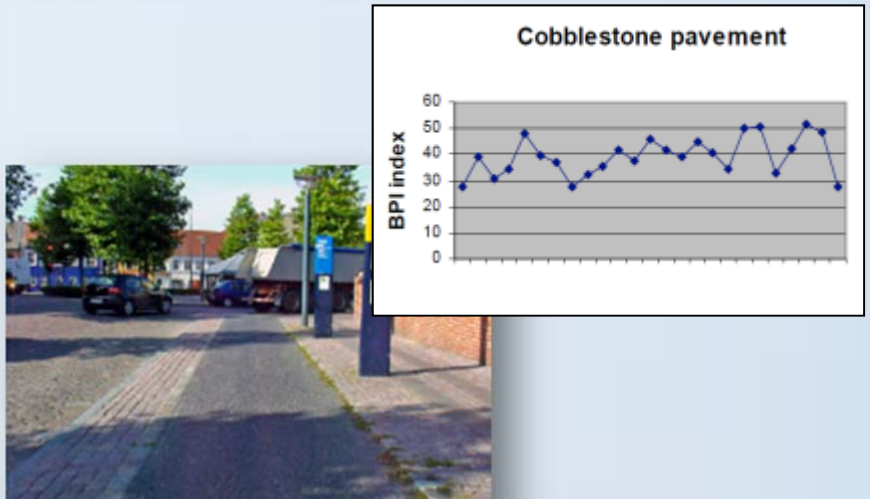
BPI range 5-10



BPI range 20-30



BPI range 10-20



BPI range 30-40

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CONCLUSION

- Reference values / thresholds are needed to evaluate roughness results;

- Different Agencies and Countries must combine their efforts to harmonize more aspects of pavement management;

- Harmonization is to be considered the road to universal benefit for pavement management.

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THANK YOU

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