Pavement Evaluation – an International Perspective

Brian Ferne TRL
Senior Academy Fellow – 25 October 2010

PAVEMENT EVALUATION 2010
Roanoke, Virginia
25-27 October

Pavement Evaluation – a European Perspective

Brian Ferne TRL
Senior Academy Fellow – 25 October 2010

PAVEMENT EVALUATION 2010
Roanoke, Virginia
25-27 October

Table of contents

From a European perspective

Presentation will cover:

- Why and what pavement characteristics are important
- Whether we can measure all that is required – satisfactorily?
- What is still required?
- Including examples from Europe

Why Do We Need to Measure Condition?

- To keep the user happy?
- To keep the user safe?
- To keep the neighbour happy?
- As part of a legal obligation?
- To preserve a valuable asset?

To keep the user happy?

We need to check that we are providing a serviceable surface condition in terms of its effect on:

- Comfort and ease of driving
- User costs

To keep the user safe?

We need to check that we are providing a safe surface condition in terms of :

- Adequate vehicle control
- Adequate visibility at all times

To keep the neighbour happy?

We need to check that we are providing an acceptable surface condition in terms of the environment :

- A dust free surface
- A quiet road surface
- A low spray surface
- A low rolling resistance
- A low level of transmitted vibrations

As part of a legal obligation?

We need to provide

- a serviceable surface condition?
- a safe surface condition?
- an environmentally-friendly surface condition?

To preserve a valuable asset?

We need to help the road manager and owner to economically maintain the road by monitoring

- the surface conditions that the road user and 'neighbour' require
- the surface and in-depth conditions of the road in order to preserve the asset in an effective and sustainable manner

Why do we need to monitor and analyse condition? - a road manager's perspective

For a new road

- To assess acceptability
- To value the asset

For an in-service road network

- To set budget levels
- To show value for money
- To identify maintenance schemes
- To prioritise schemes

For an in-service road

- To design maintenance
- To design rehabilitation

Some questions – what, when, how

At what level do we measure

- Network level?
- Planning level?
- Scheme/Project level?

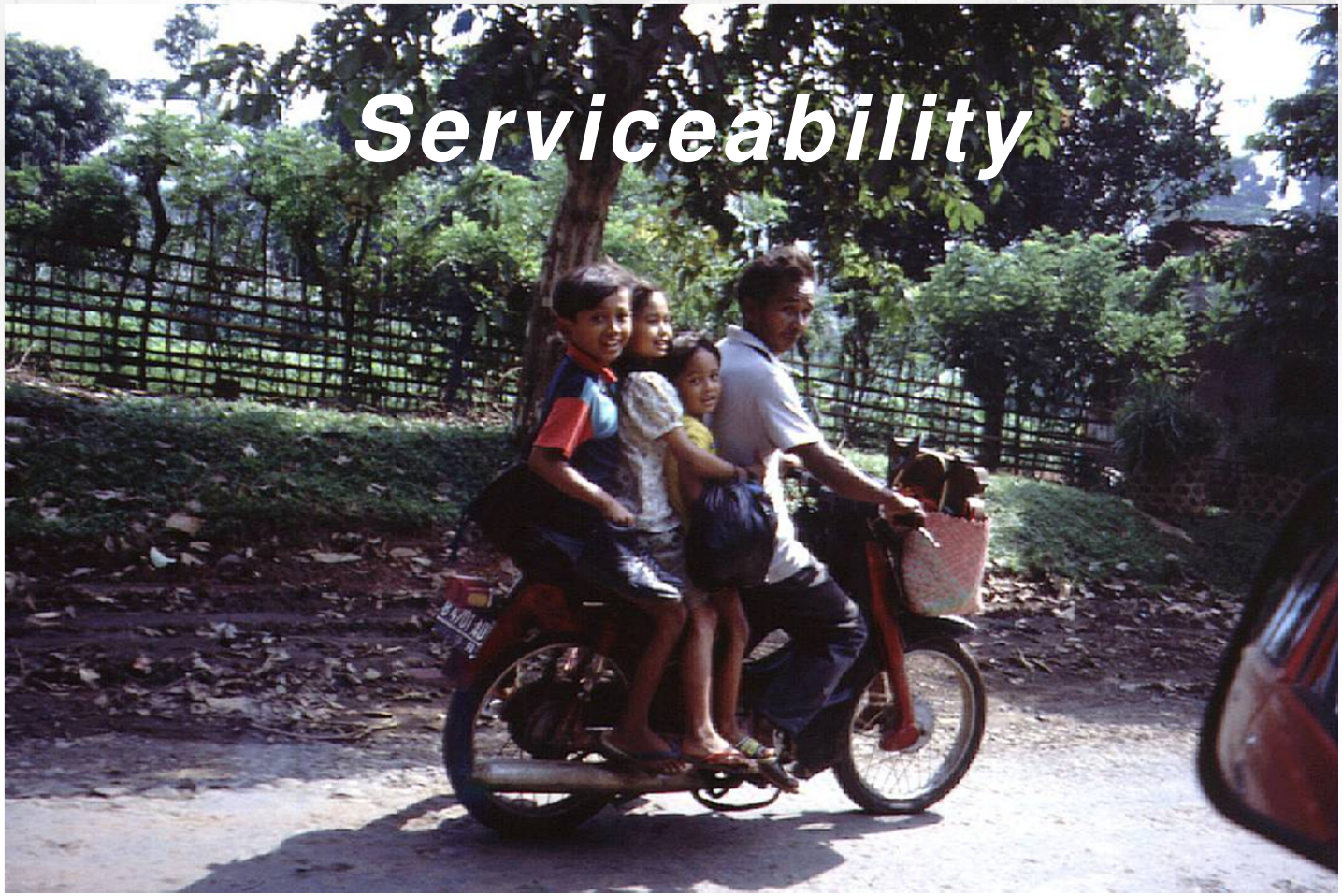
How do we measure

- Non-destructively?
- Stationary or at slow speed
- Non-disruptively at traffic speed?

When do we measure?

- Regularly
  - Every five years?
  - Every two years?
  - Every year?
  - Every six months?
- On demand?
- Even 24/7?

What do we therefore need to measure?



For serviceability – i.e. comfort and ease of driving

- longitudinal profile ✓
- transverse profile ✓
- road geometry ✓
- surface distress e.g. ravelling ✓
- noise from within vehicle ?
- splash and spray ?
- ice on surface ?
- visibility of surface obstructions ✖
- visibility of road markings ✓
- dust emissions ✖

For serviceability – i.e. comfort and ease of driving

- longitudinal profile ✓
- transverse profile ✓
- Road geometry ✓
- Surface distress e.g. ravelling ✓
- noise from within vehicle ?
- splash and spray ?
- ice on surface ?
- visibility of surface obstructions ✖
- visibility of road markings ✓
- dust emissions ✖

Most of these parameters can be measured at traffic speed by multi-function vehicles

Sweden

UK

The Netherlands

However……

Are these measurements

- Meaningful?
- Consistent?
- Robust?
- Predictable?
- Economical?
- Non-disruptive?

For example

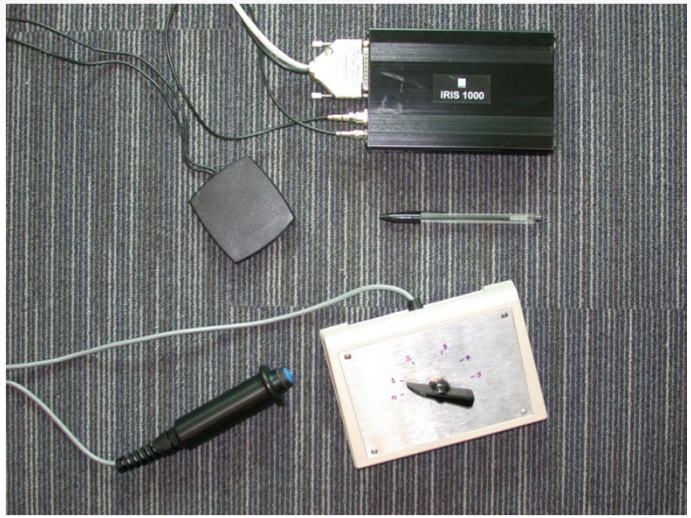
- Is one measurement line interpreted as IRI sufficient?
- Should we measure both wheelpaths
- Should we calculate a full body IRI?
- Should we use wavelength analysis?
- Or wavelet analysis?
- Or bump analysis?

Measuring ride quality on UK local roads - consultation

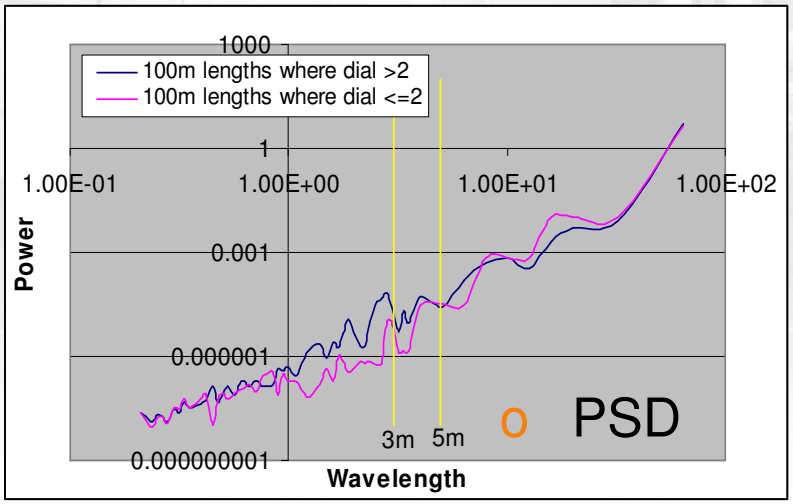
- Consultation with engineers found that
  - Little importance placed on longitudinal profile data
  - Key structural measure is cracking and rutting
  - Engineers desire a reliable assessment of general ride quality (functionality)
  - But engineers key concern is defects giving rise to bumps (user complaints)
- Concluded that methods needed to
  - Reliably identify lengths with poor ride quality
  - Identify general locations giving rise to bumps

Measuring ride quality - data collection

- A practical investigation to relate surface profile to user opinions on local roads
- Several routes surveyed, including sections known to be poor
- Profile data provided by HARRIS1 profilometer
  - Measurements in both wheel tracks (and across survey width)
- User surveys:
  - Car surveys
  - Motorbike survey
  - Utilising on-board data collection GPS referencing
  - Reported on ride and bumps
  - Repeat surveys for consistency



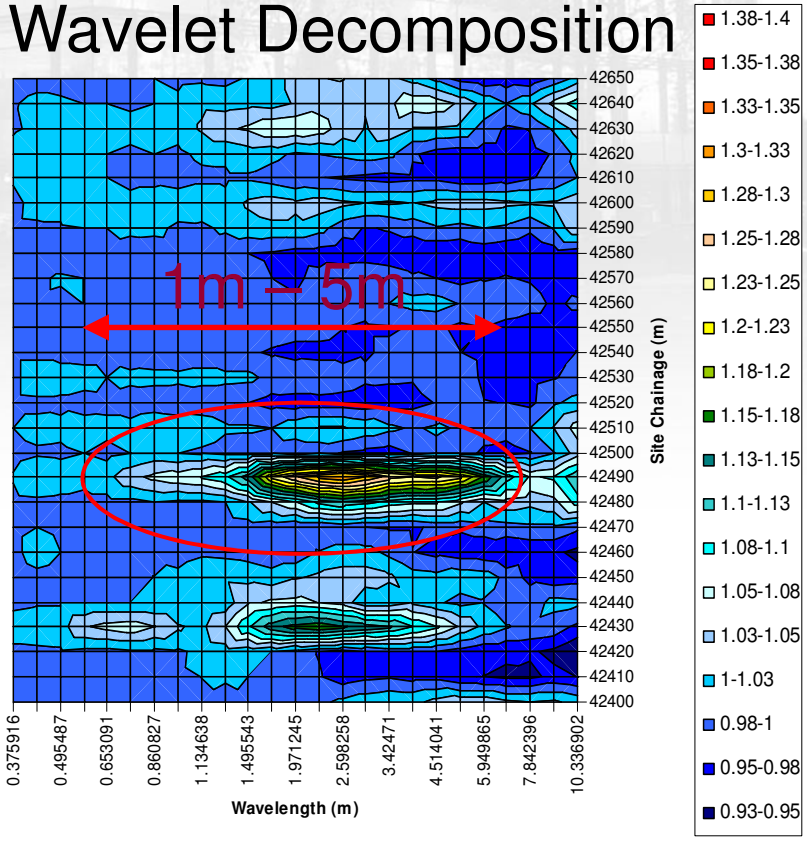
Considering general ride quality



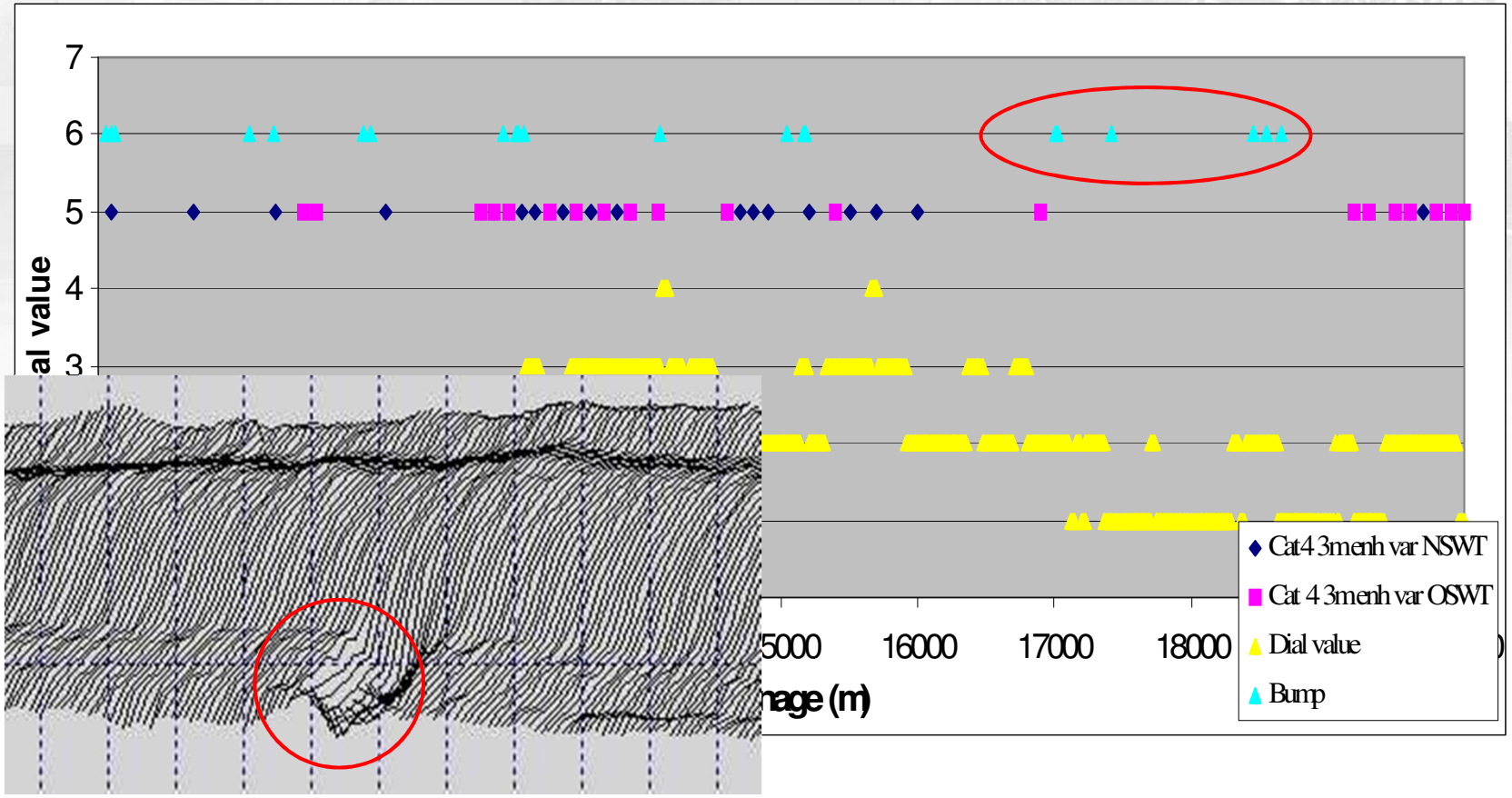
- PSD

- IRI, Ride Number, Profile Index
- MA and enhanced variance
- Coefficient de planeite
- Waveband Energy
- Standard Deviation

- Wavelet Decomposition



Measuring “Bumps” on local roads



Therefore developed Central Difference Methd (CDM) or Bump Measure for UK local roads

- Tests to review locations where the bump measure responded
  - Reported 84% of user button presses.
  - Potential high number of false positives.
  - Inspection of 3D profile and video showed features of note where CDM responds, but users had not always pressed the button.
- Concluded
  - This is an appropriate method for identifying “bumps”.
  - We should use a combination of this and 3m enhanced variance for assessing general ride and bump density on local roads

For serviceability – i.e. minimising user costs

- longitudinal profile ✓
- transverse profile ✓
- rolling resistance ?
- tyre wear ✖

Two European Projects in this area

- TYROSAFE
- MIRIAM

The TYROSAFE project:
Tyre and Road Surface Optimisation for Skid Resistance and Further Effects

TYROSAFE

EU FP7 Coordination Action

- Consortium:

AIT (Austria)
BASt(Germany)
LCPC (France),
RWS-DVS (The Netherlands)
TRL (UK)
ZAG (Slovenia)

FEHRL (Belgium)

- Duration: 2 years
- Starting date: 1st July 2008
- Approximately1.1m EUR total
- Website: http://tyrosafe.fehrl.org

The research leading to the results has received funding from the European Community's Seventh Framework Programme (FP7/2008-2013) under grant agreement n°217920

TYROSAFE

Skid resistance (safety)
Rolling resistance (energy)
Noise emission (health)

Interdependencies ??

different …

- measuring policies
- measuring methods
- measured parameters

Rolling resistance

No current European or National regulation policies

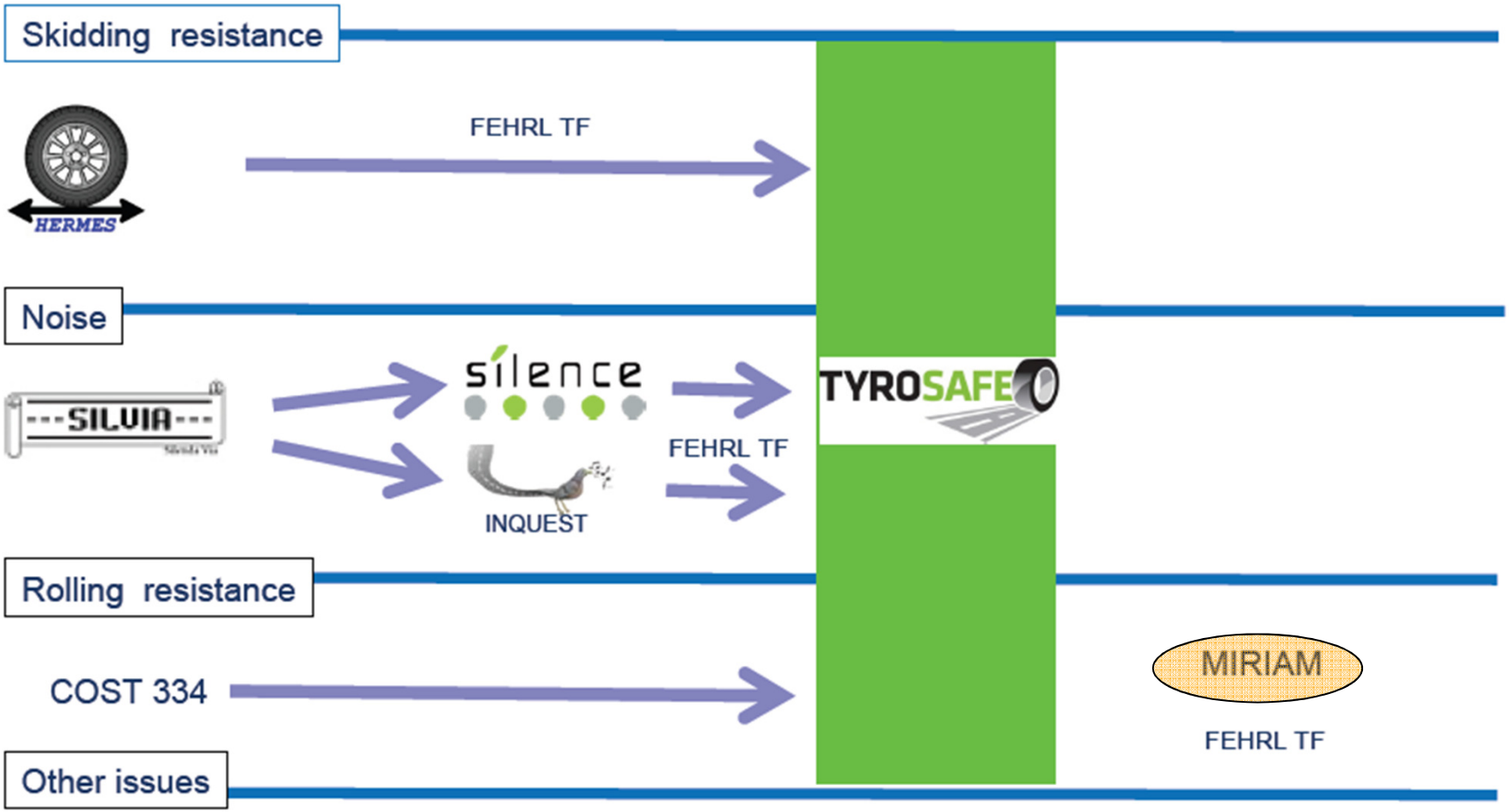
- Measurement in Laboratory
- Road samples on inside of drum
- Also measures noise levels
- BASt in Germany

- Measurement on accelerated pavement testing facility
- Instrumented loading wheel
- TRL in UK

- Instrumented trailer
- University of Gdansk, Poland?

Maybe texture profiles can provide a proxy?

Related European Projects



What do we therefore need to measure?

For safety –
i.e. adequate vehicle control

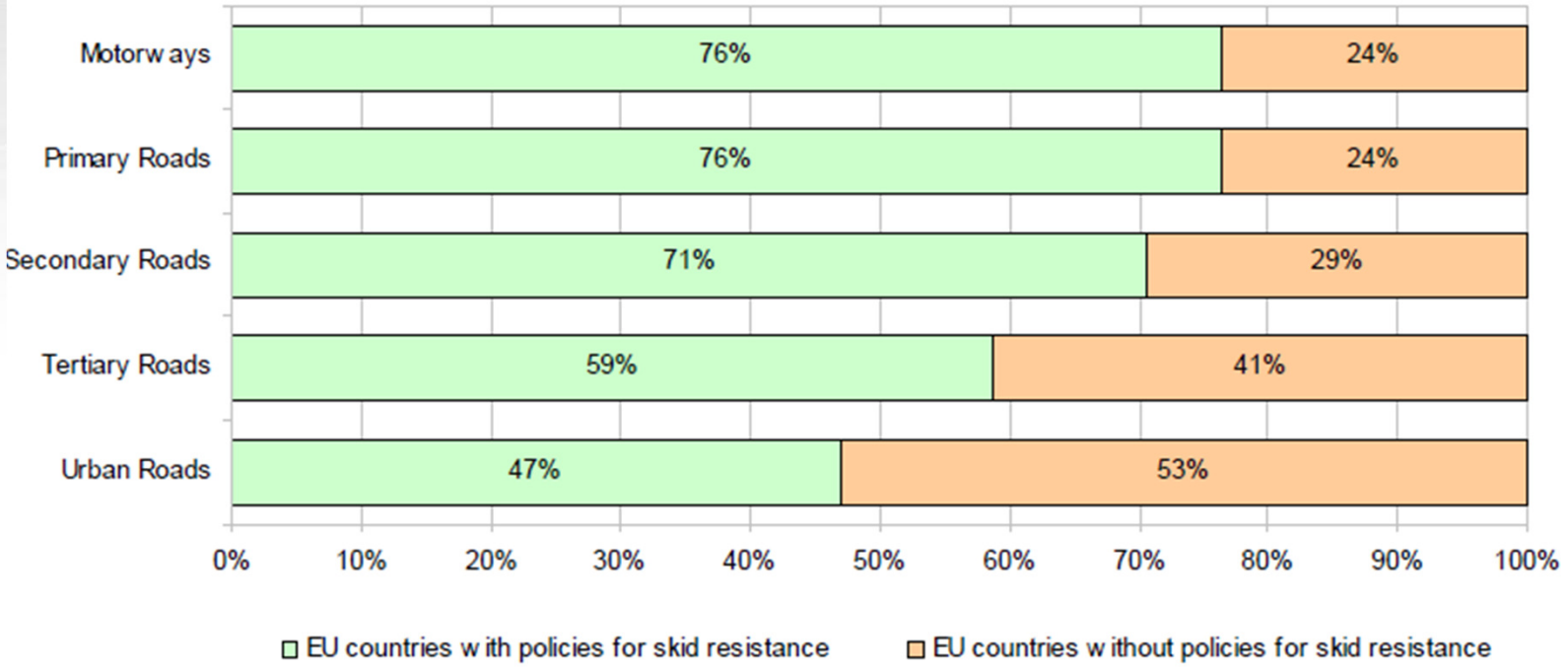
- tyre/surface friction ✓
- longitudinal profile ✓
- transverse profile ✓
- road geometry ✓
- surface distress ?
- loose particles ✖

For safety –
i.e. adequate vehicle control

- tyre/surface friction ✓
- longitudinal profile ✓
- transverse profile ✓
- road geometry ✓
- surface distress ?
- loose particles ✖

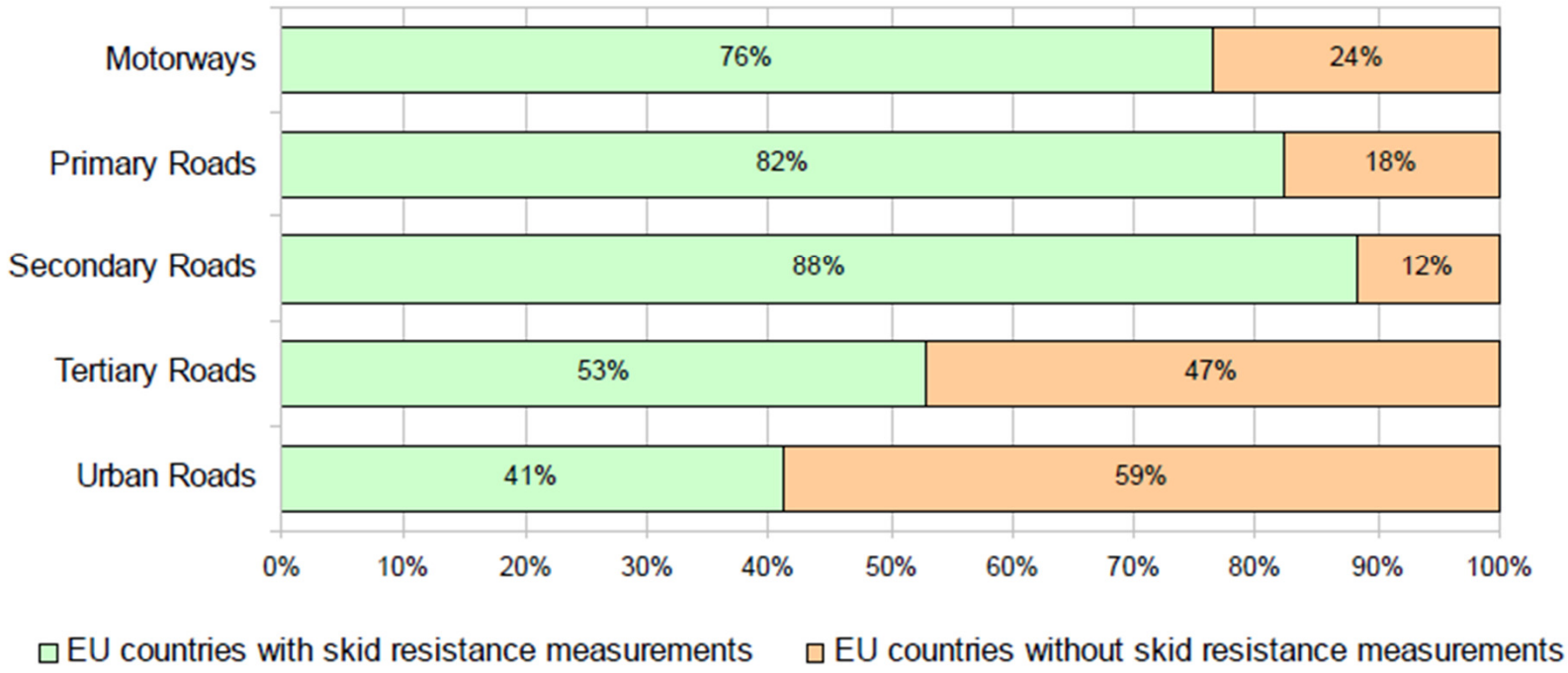
TYROSAFE Questionnaire to 17 European countries - Policy

"Do road administrations set policies or standards for skid resistance in your country?"



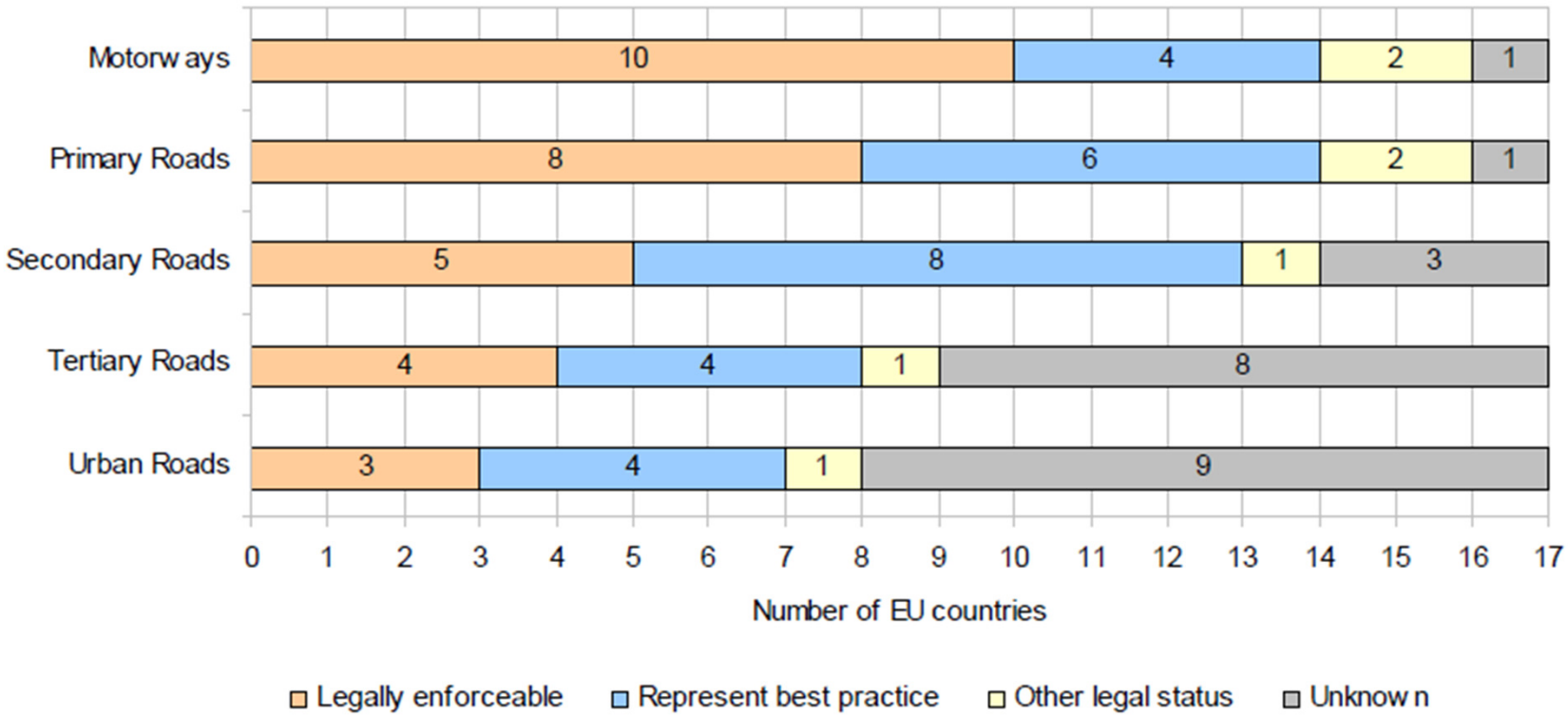
TYROSAFE Questionnaire to 17 European countries - Measurement

"Even if they do not have a formal policy,
do they make skid resistance measurements?"

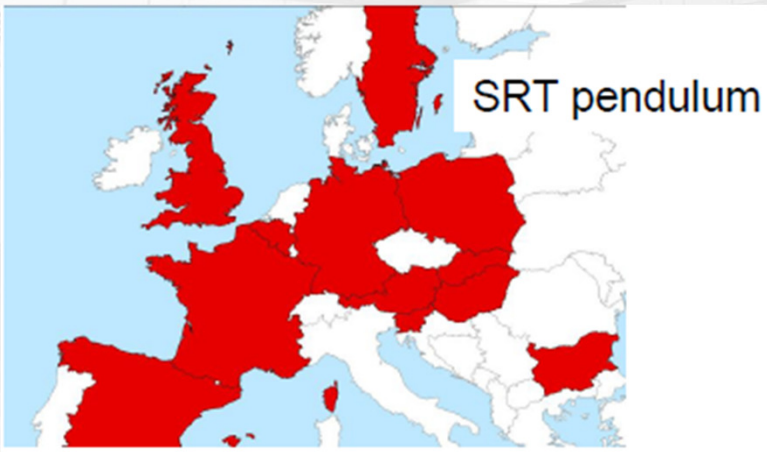


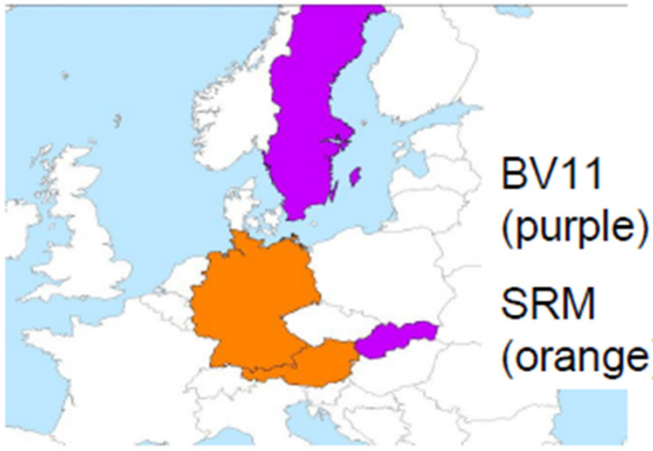
TYROSAFE Questionnaire to 17 European countries – Legal status

"What is the legal status of the standards in your country?"



TYROSAFE Questionnaire to 17 European countries – Devices used





However……

Are these measurements

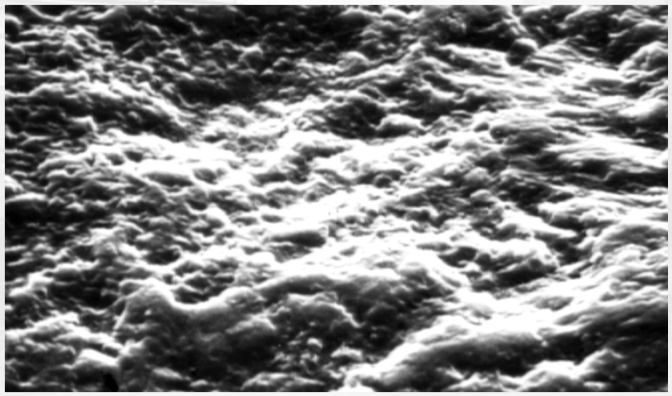
- Meaningful?
- Consistent?
- Robust?
- Predictable?
- Economical?
- Non-disruptive?

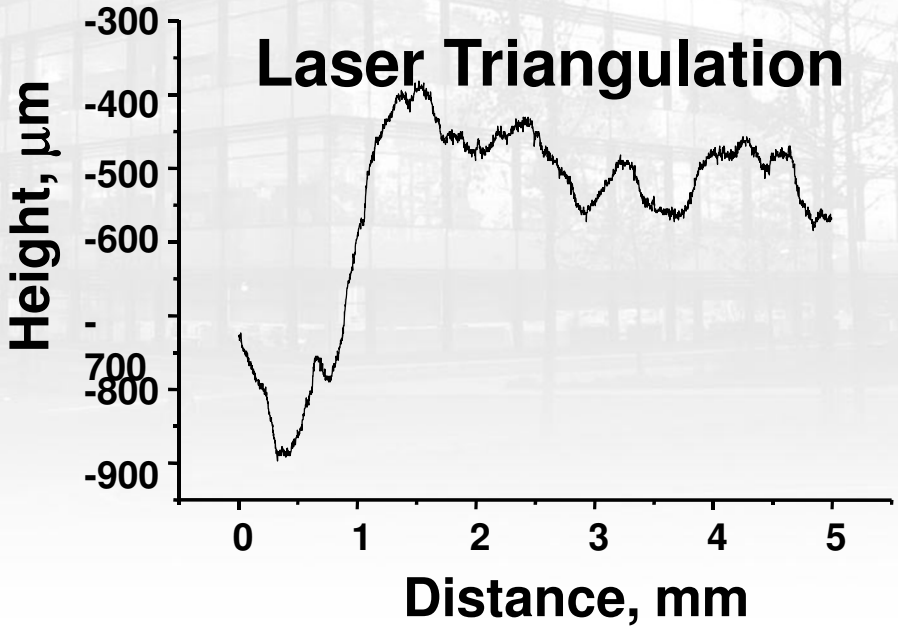
Are they measuring the correct parameter?

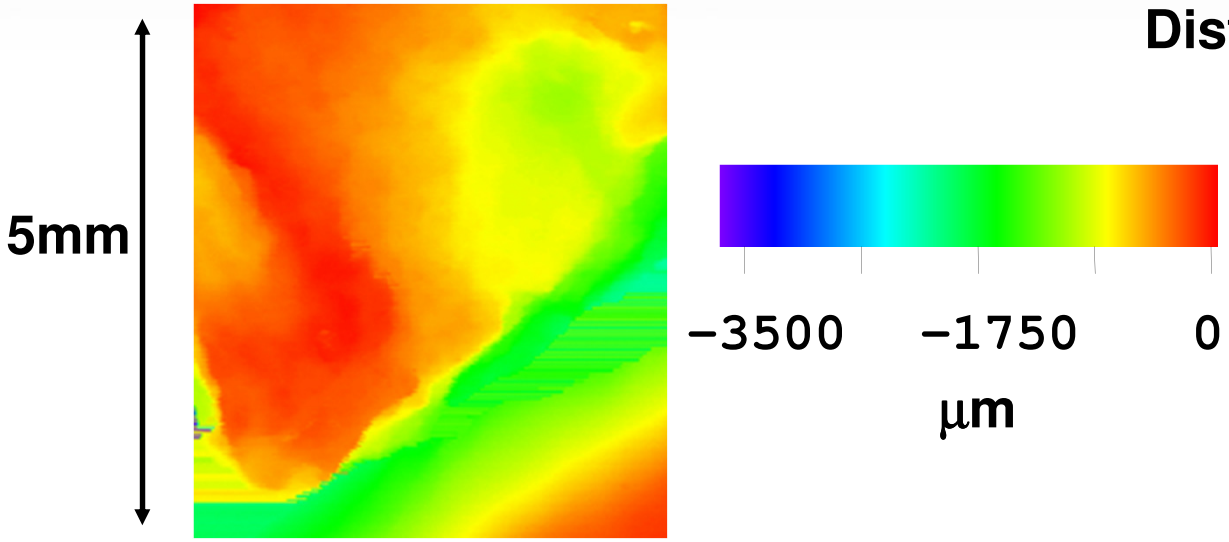
- Road conditions vary
- Vehicle characteristics vary
- Brake control systems vary
- Need to measure more fundamental properties
- Such as microprofile at traffic speed
- Vehicles now equipped with ABS etc

Non-contact friction measurement?

Research in the UK and France



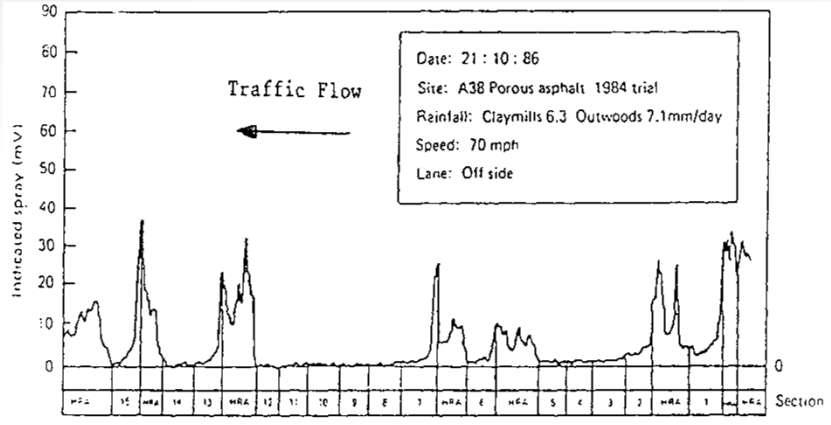


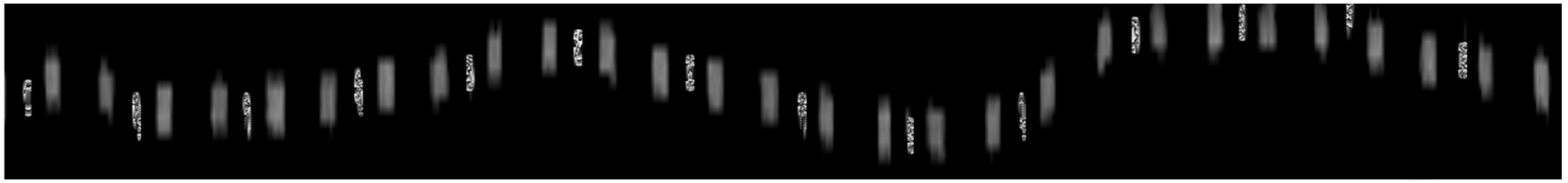


For safety - adequate visibility at all times

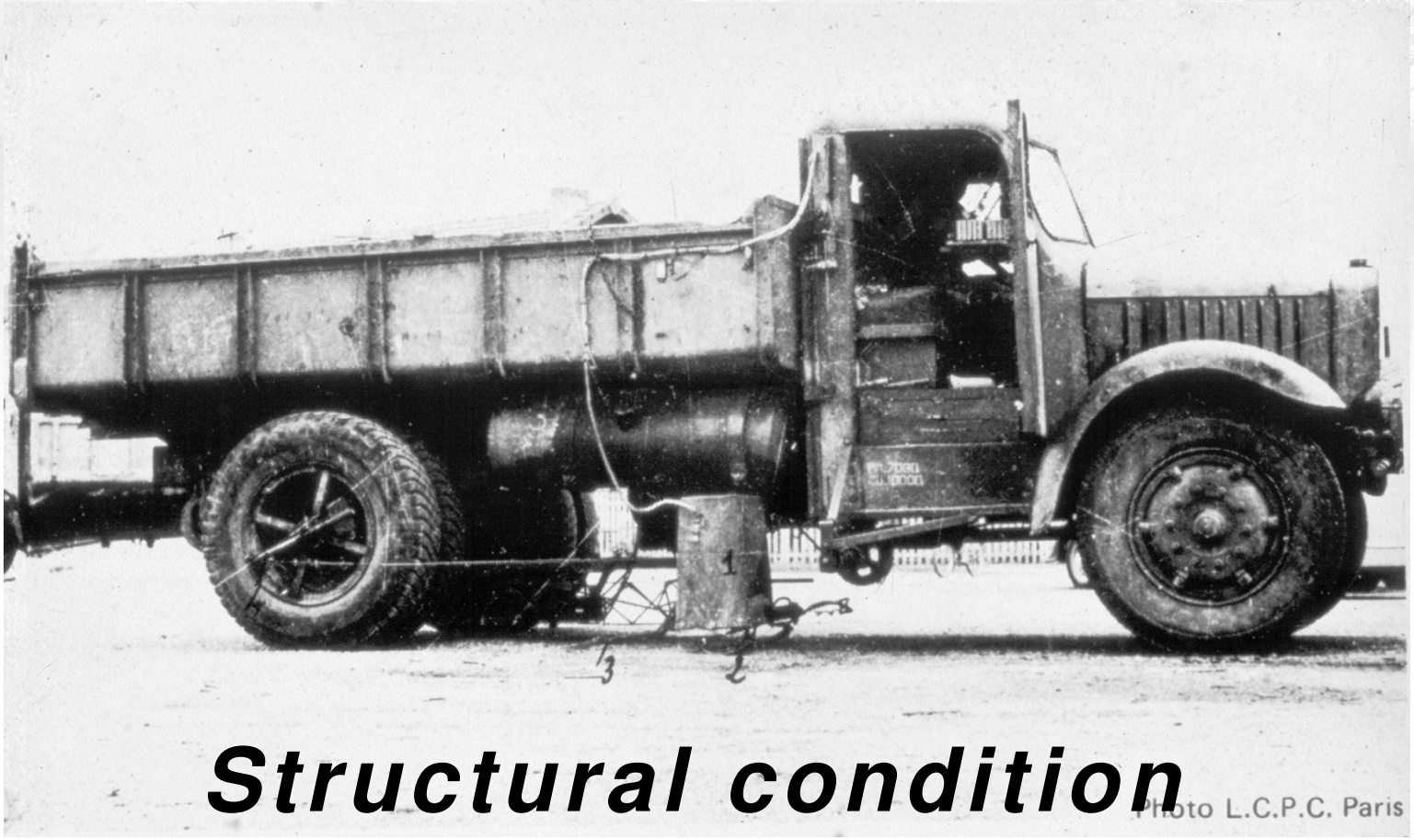
- visibility i.e. good contrast ?
- visibility of road alignment ✓

  and advice i.e. road markings
- splash and spray ?
- dust emissions ✖





What do we therefore need to measure?



Structural condition

To assess the structural condition of the road

Ideally we require information on

- Pavement structure
  - Layer materials
  - Layer thicknesses
  - Layer stiffnesses
  - Layer condition
    - Cracking
    - Deformation
    - Integrity
    - Interface condition
  - In depth stresses and strains

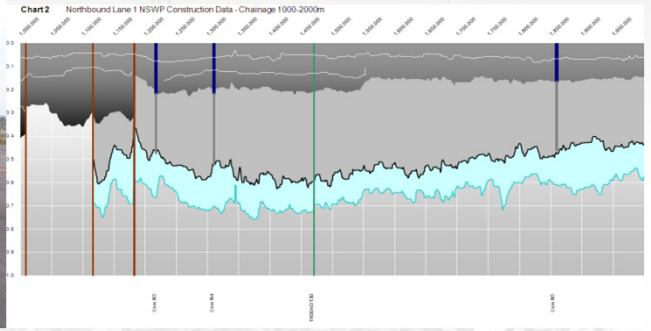
To assess the structural condition of the road

In reality we can measure

- Pavement structure
  - Layer materials – using GPR
  - Layer thicknesses – using GPR with calibration cores
  - Layer stiffnesses and strains – estimate from deflections
  - Layer condition
    - Cracking – surface cracking and distress from images
      - In-depth from GPR
    - Deformation – at surface from transverse profile
      - In depth from cores or GPR?
    - Integrity – from GPR?
    - Interface condition – from wave propagation and impact analysis?

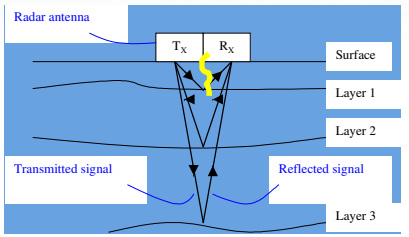
Most can be measured at traffic speed but not all…

To assess the structural condition of the road



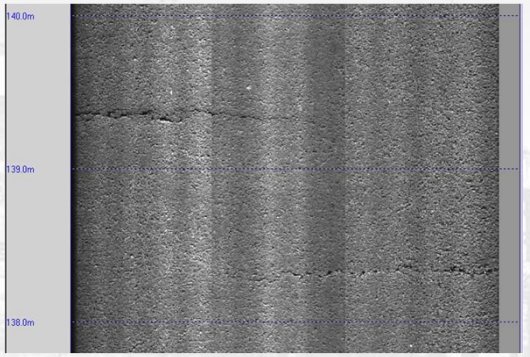
In reality we can measure

- Pavement structure
  - Layer materials – using GPR
  - Layer thicknesses – using GPR with calibration cores
  - Layer stiffnesses and strains – estimate from deflections
  - Layer condition
    - Cracking – surface cracking and distress from images
      - In-depth from GPR
    - Deformation – at surface from transverse profile
      - In depth from cores or GPR?
    - Integrity – from GPR
    - Interface condition – from wave propagation or impact analysis?



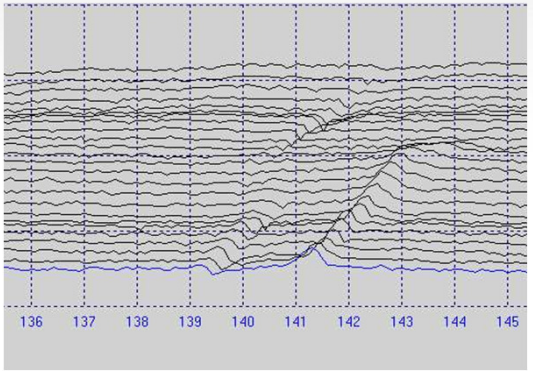
Most can be measured at traffic speed but not all…

To assess the structural condition of the road



In reality we can measure

- Pavement structure
  - Layer materials – using GPR
  - Layer thicknesses – using GPR with calibration cores
  - Layer stiffnesses and strains – estimate from deflections
  - Layer condition
    - Cracking – surface cracking and distress from images
      - In-depth from GPR
    - Deformation – at surface from transverse profile
      - In depth from cores or GPR?
    - Integrity – from GPR
    - Interface condition – from wave propagation and impact analysis?



Most can be measured at traffic speed but not all…

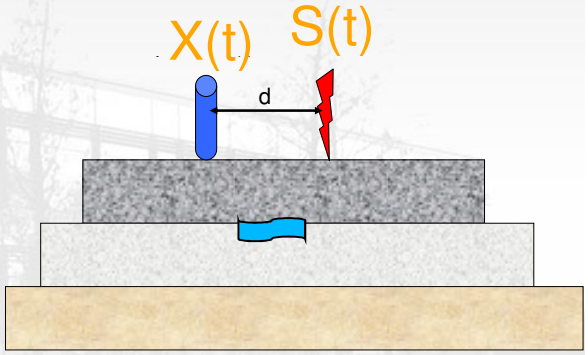
To assess the structural condition of the road

In reality we can measure

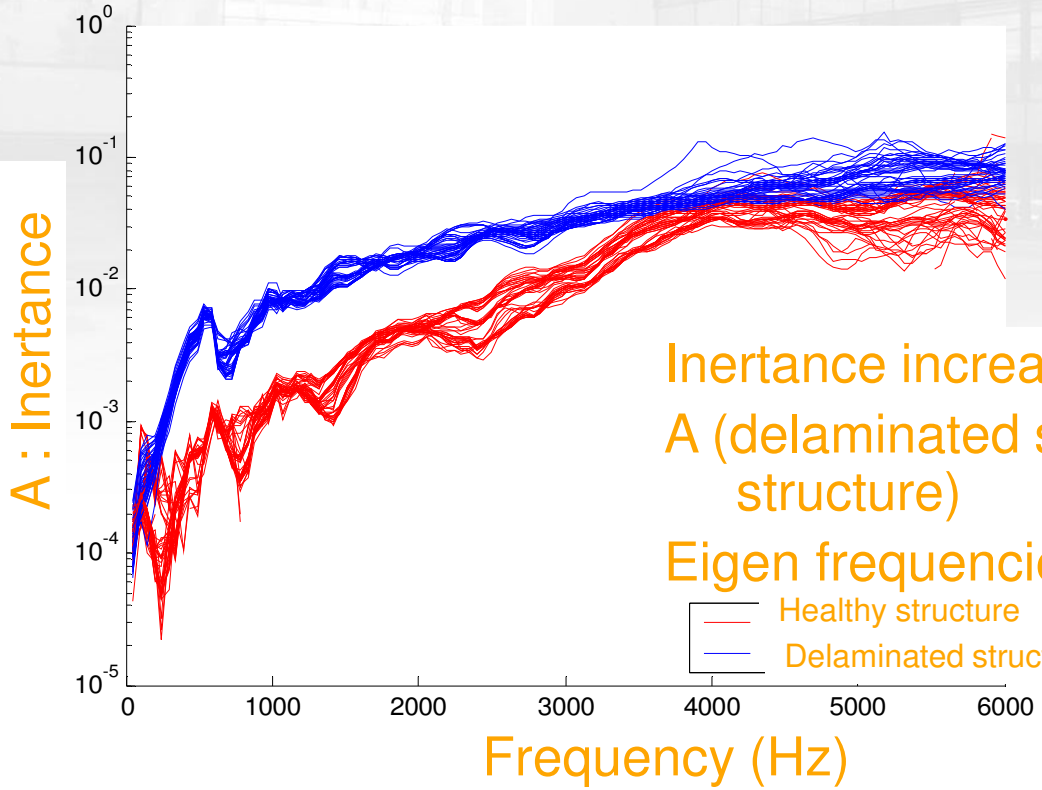
- Pavement structure
  - Layer materials – using GPR
  - Layer thicknesses – using GPR with calibration cores
  - Layer stiffnesses and strains – estimate from deflections
  - Layer condition
    - Cracking – surface cracking and distress from images
      - In-depth from GPR
    - Deformation – at surface from transverse profile
      - In depth from cores or GPR?
    - Integrity – from GPR
    - Interface condition – from wave propagation and impact analysis?

Most can be measured at traffic speed but not all…

Principle of the method



Practice of the method on 2 test slabs

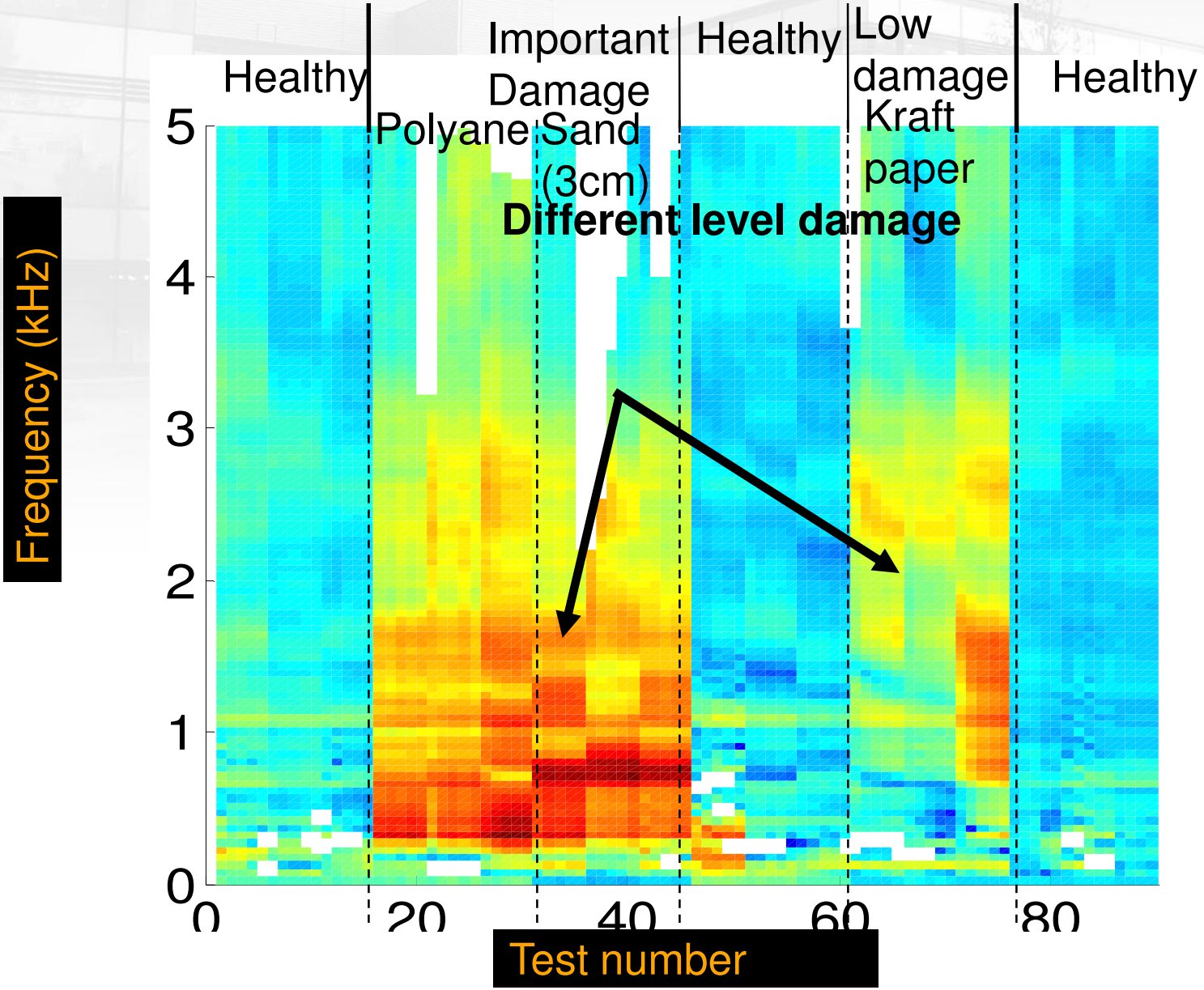


Inertance increases for the 2 structures

A (delaminated structure) > A (healthy structure)

Eigen frequencies ?

Application on tests slabs



To assess the structural condition of the road

In reality we can measure

- Pavement structure
  - Layer materials – using GPR
  - Layer thicknesses – using GPR with calibration cores
  - Layer stiffnesses and strains – estimate from deflections
  - Layer condition
    - Cracking – surface cracking and distress from images
      - In-depth from GPR – indirectly from deflection
    - Deformation – at surface from transverse profile
      - In depth from cores or GPR?
    - Integrity – from GPR – indirectly from deflection
    - Interface condition – from wave propagation and impact analysis?

Most can be measured at traffic speed but not all…

Why measure deflection?

- To manage a highway network we need to know its condition
- Surface condition alone is inadequate

Therefore:

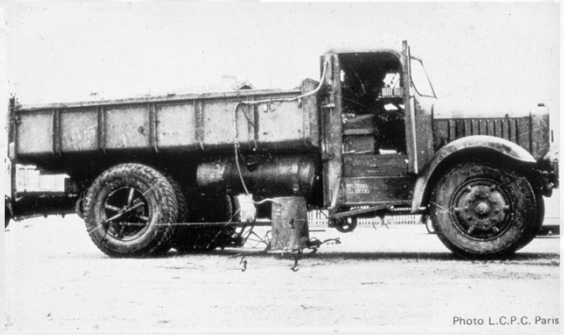
- A need for an in-depth measure of condition
- The vertical resilient deflection response of a road pavement to a load meets this need
  - Equals the sum of the vertical strains within each element of the pavement
  - Full deflection bowl tells more than just maximum

History of deflection measurement

- Measuring the transient vertical deflection response to a rolling wheel load
  - i.e. **rolling wheel deflection (RWD)** measurement
- Measuring the vertical deflection response at a fixed point to a simulated wheel load or other chosen load pattern
  - i.e. **pseudo wheel deflection (PWD)** measurement

Lacroix Deflectograph

Developed by LCPC in France



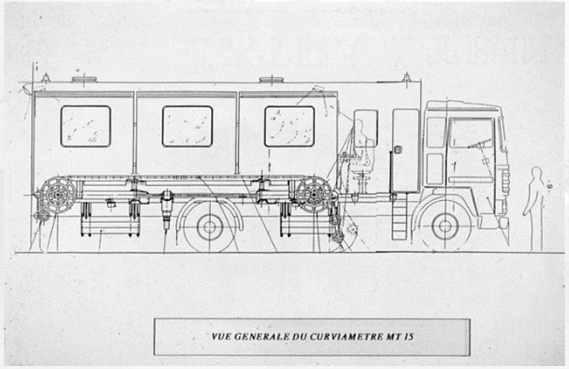
- Original 1956 model
- Surveys at walking speed
- Measures maximum deflection
- Measures both wheelpaths

- Modified for UK use
- Current UK Deflectograph
- Surveys at 2.5 km/h
- Measures every 3.5m in both wheelpaths

- In the UK now 10 machines operating
- Similar numbers of French versions

Curviameter

Developed in France in the 1970's



- Uses three geophones spaced at five metre intervals on a chain in one wheelpath
- Measures full deflection bowl
- Surveys at 18 km/h
- Limited ability on corners

- Not now used in France
- One now used in Belgian
- Several used in Spain
- Both models trialled in the UK
- Considered unsuitable for UK

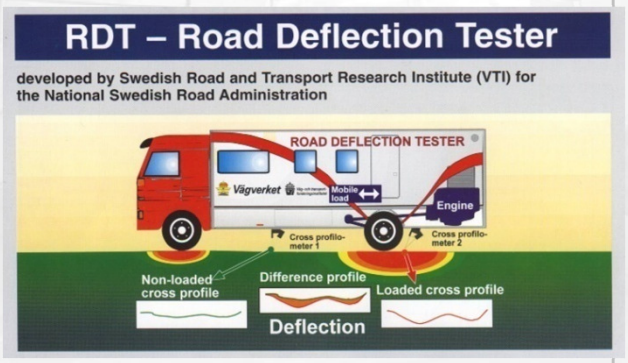
Traffic-speed deflection measurement

- All the survey methods so far presented require traffic management thus causing disruption on the majority of roads
- Therefore more recent effort has been devoted to traffic-speed devices:

Road Deflection Tester	(Sweden)
Rolling Wheel Deflectometer Airfield Rolling Weight Deflectometer	(USA)
High Speed Deflectograph (now called Traffic Speed Deflectometer)	(Denmark)
Recent: Image-based deflectometer	(France)

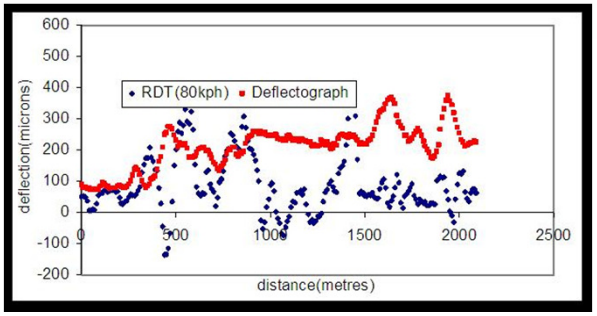
Road Deflection Tester

Developed in Sweden from early 1990's



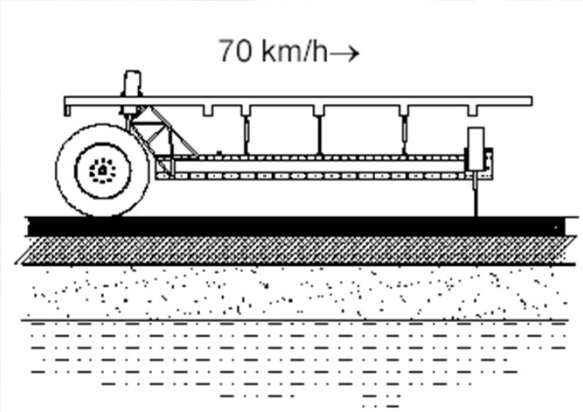
- Measures full transverse bowl
- Measures both wheelpaths
- Surveys at up to 80 km/h

- Second prototype in 1996
- Trialled in the UK in 2002
- Lacked full development
- Disappointing results
- No longer a functioning prototype



Danish High Speed Deflectograph

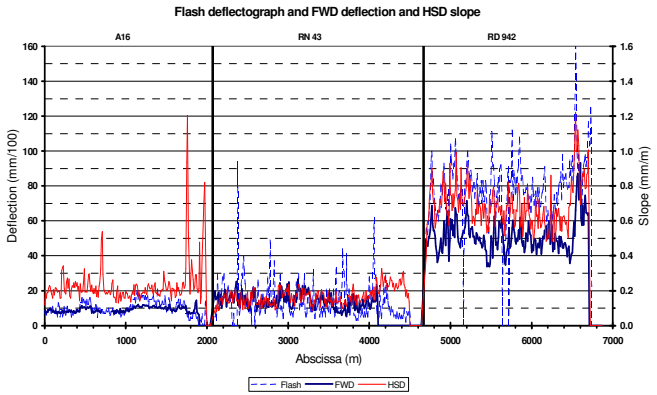
Developed by Greenwood A/S and DRI in Denmark



- Principles developed 1999
- Surveys at up to 80 km/h
- Measures deflection velocity
- Measures one wheelpath

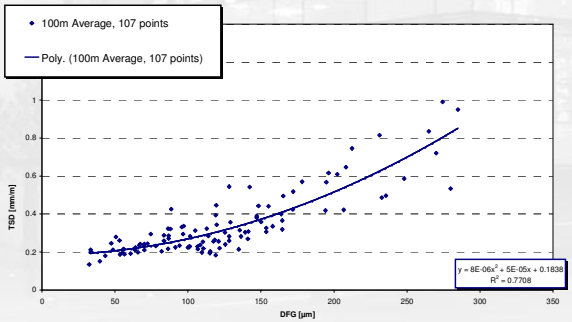
- First prototype with one mesurement sensor and one reference sensor

- First prototype rebuilt in 2005
- Successful European FORMAT trial in 2003



HA's Traffic Speed Deflectometer (TSD)

Produced by Greenwood A/S in Denmark



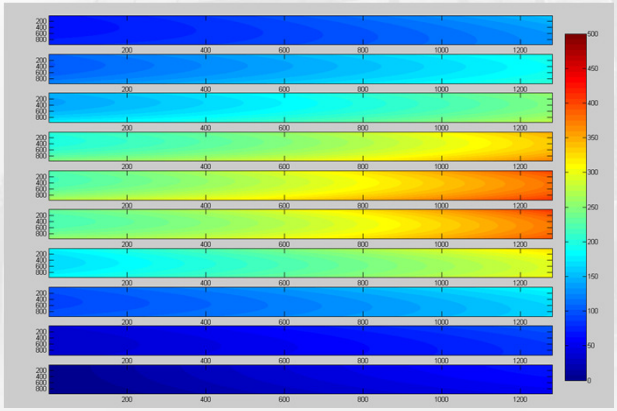
- Brought to the UK in 2005
- Launched by the Minister in 2006

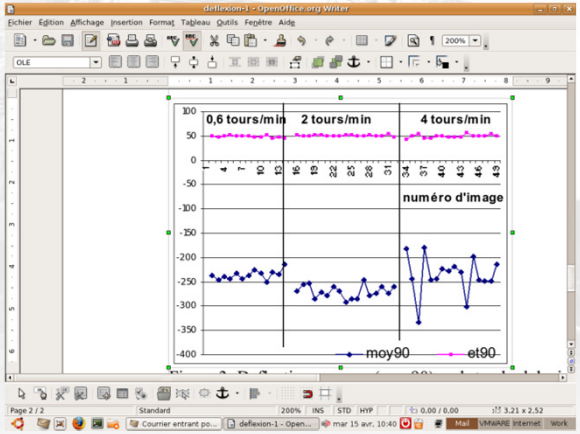
- Strong relationship of deflection velocity with Deflectograph maximum deflection

- Surveyed 1000km hard shoulders in Spring 09
- Started network surveys in late 2009

High speed continuous deflection device for pavements

Developed by LCPC in France in 2007?



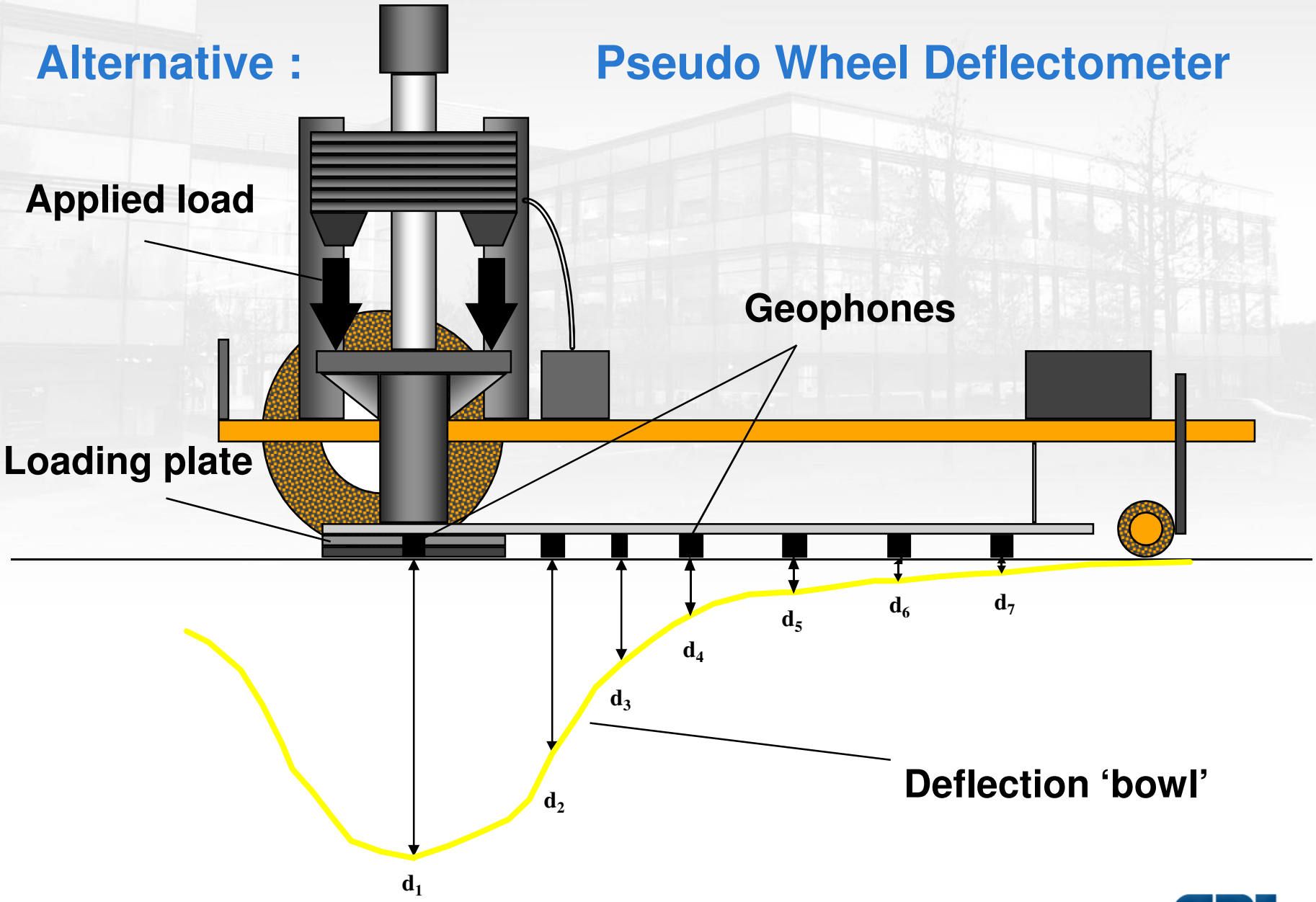


- Image based system
- Projects structured light pattern on road surface
- First module covers 200 * 300mm

- Tested in laboratory
- Tested on cicular accelerated loading facility at 4 km/h

- Ongoing development to achieve 50 to 60 km/h

Alternative : Pseudo Wheel Deflectometer



Falling Weight Deflectometer (FWD) Schematic

To assess the structural condition of the road

In reality can measure other parameters that can be a proxy for this condition

- longitudinal profile
  - Changes indicate structural condition
  - Comparisons measurement lines indicate structural condition

What can't we measure

- Not much

But of those that we can are they satisfactory?

- Meaningful?
- Consistent?
- Robust?
- Predictable?
- Economical?
- Non-disruptive?

Some outstanding measurement problems

- Dust emissions?
- Spray emissions?
- Rolling resistance?
- Tyre wear potential?
- Some types of surface distress?
- Transient deflection?
- Quality control

Latest European developments……
In the Netherlands and the UK

- Use of Lidar (Light Detection And Ranging)
- Multiple use of data – for example
  - texture profiles

Future developments?

M3DM (The Netherlands)

Mobile 3D Mapping

System

- Digital scanning of road and surroundings at traffic speed
- GPS system
- Inertial navigation system
- High frequency scanning laser (500,000 points per second resulting in a transversal scan each 0.2 m when travelling at 80 km/h)
- 75m reach in transverse direction
- Not dependent on daylight

M3DM (The Netherlands)

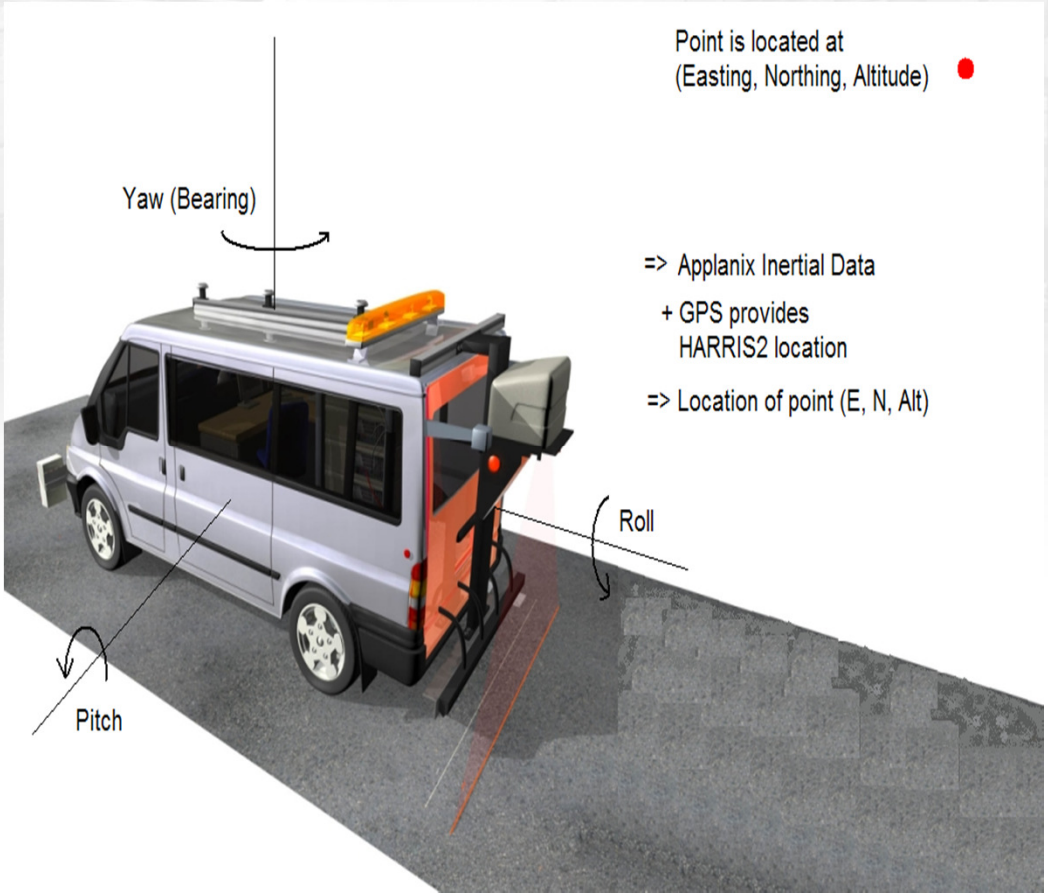
Mobile 3D Mapping

Test data

- Longitudinal and transverse profile of road
- Lane width (based on retroreflection from marking)
- Quantity assessment for re-design or rehabilitation of roads
- Overlay thicknesses (test runs prior and after construction works)
- Clearances of bridges (camera in tilt position)
- Mapping of safety barriers, lamp posts, etc.

Measurement of "envelope" in the UK

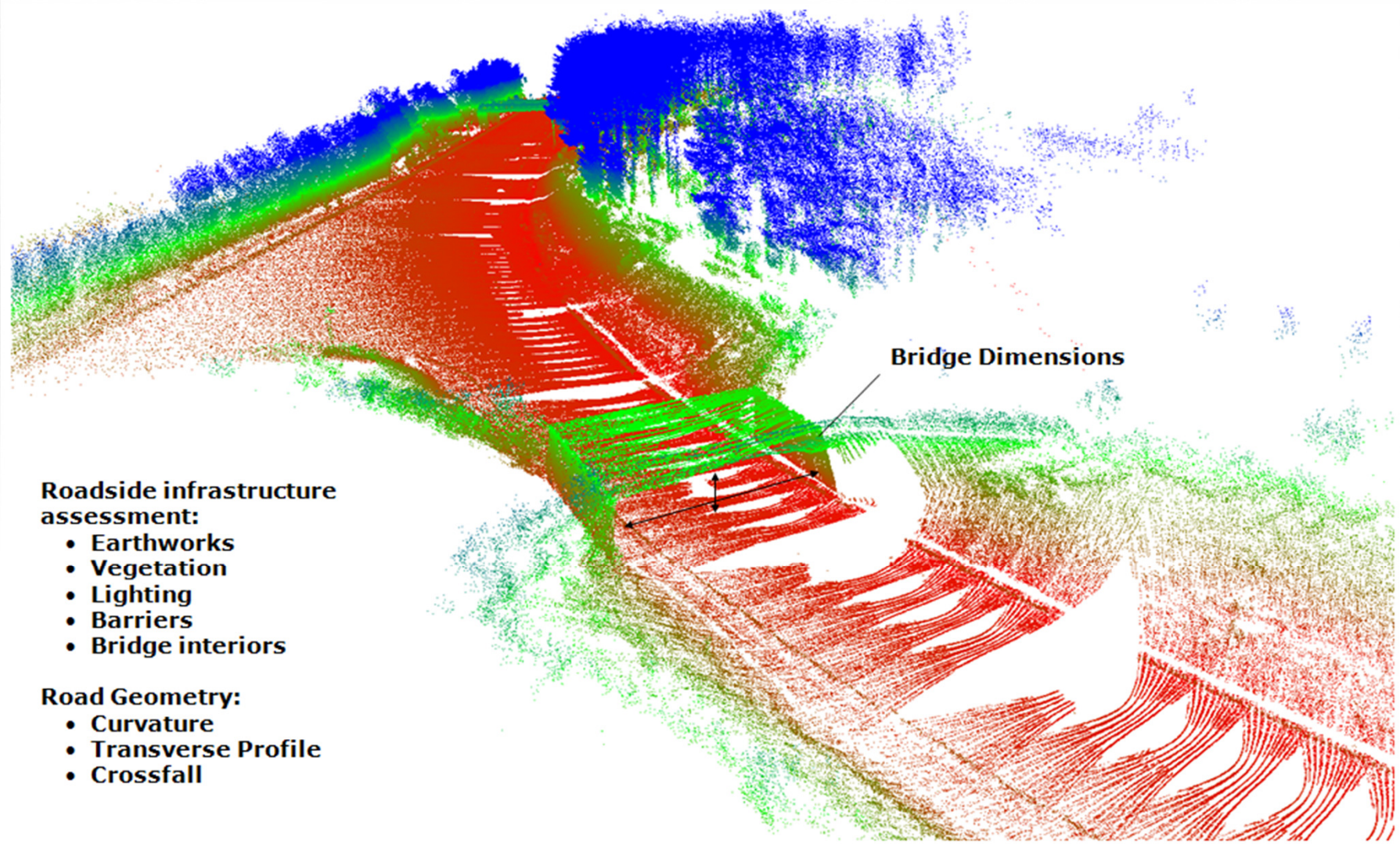
Locates each point in OSGR (Eastings, Northings, Altitude).



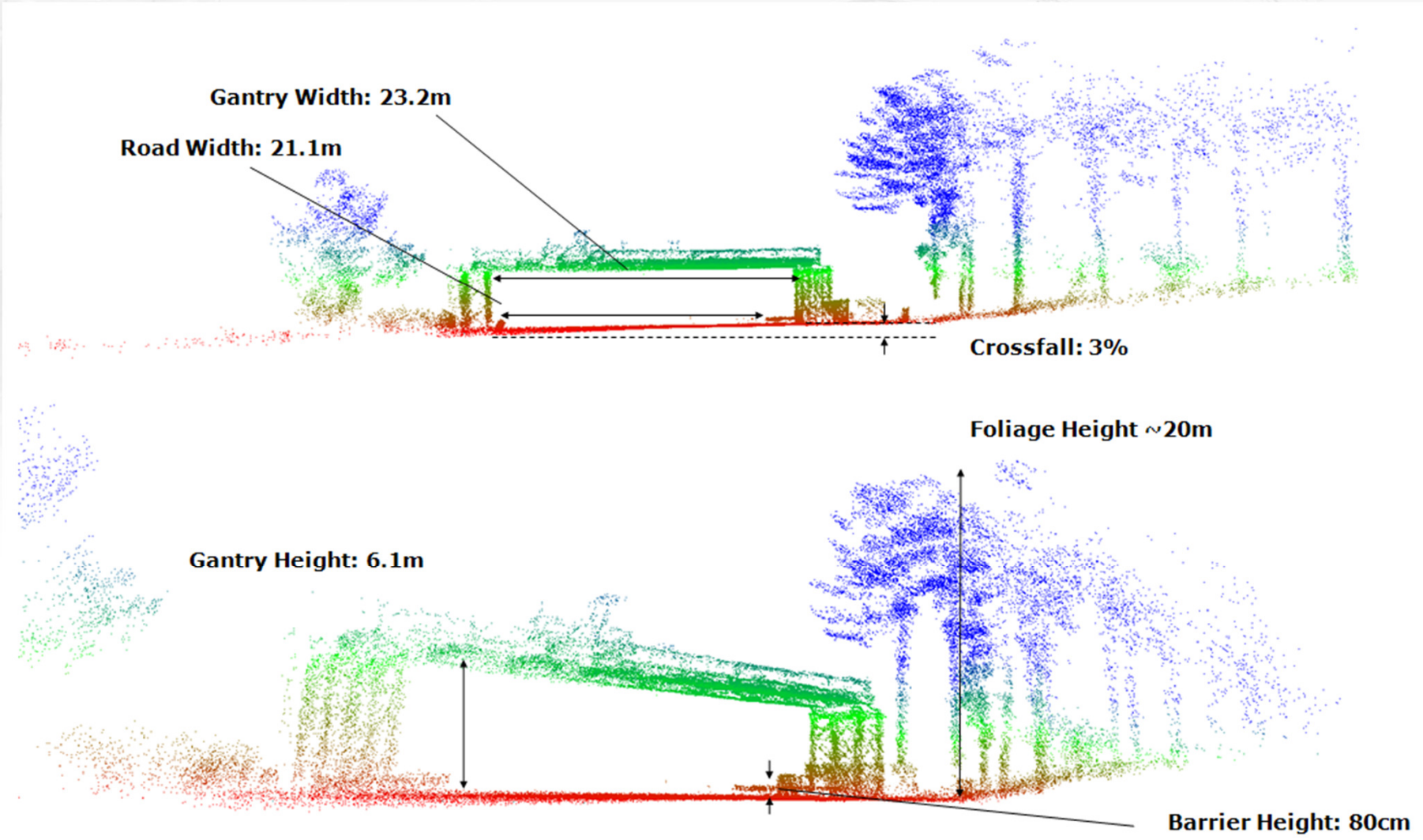
Survey Space Data

- IMU provides Pitch, Roll, Yaw (Bearing), Location and Altitude.
- (X, Y, Z) is rotated and translated to locate the point in survey space (E, N, Alt).
- TRL have developed software tools to carry out these transformations.
- Resulting data set is a point cloud that can be viewed in a variety of commerically available software products.

Infrastructure Surveys in the UK – Example 1



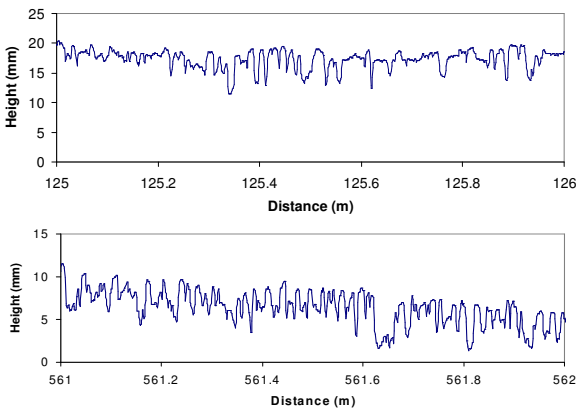
Infrastructure Measurements in the UK – Example 2



Multiple use of data in the UK

Using texture profile data

- **Fretting**
- Algorithms to identify the presence of fretting



- **Noise**
- Estimating the noise at the tyre-road interface
- **Surface type**
- Estimating surface type from the texture profile and surface reflecctance

CROW (The Netherlands)

Detection of Raveling by Texture Depth Measurement (DRAFT)

System characteristics

- Enhanced accuracy and precision of raveling survey compared to results from inspectors
- Automated recognition of type of wearing course
  - dense asphalt concrete
  - surface dressings
  - porous friction courses
  - stone mastic asphalt
  - thin asphalt wearing courses
- Input provided by texture lasers

CROW (The Netherlands)

Development of DRAFT

System characteristics

- Correlated to results of detailed visuel inspection by experienced inspectors on special road sections (5000m²)
- Raveling from survey converted in percentage loss of aggregate from surface
- Model fed by MPD and RMS (mean, stdev, median, percentiles, etc)
- 95.7% correct classification of type of wearing course per 100m section
- Thin asphalt wearing courses: 52% (95%) correct classification of degree/severity class (incl. adjacent class)

CROW (The Netherlands)

Accuracy of classification of wearing course

Wearing course	Correct	Sometimes misclassified as
Dense asphalt concrete	85.0%	Double surface dressing
Double surface dressing	75.0%	Dense asphalt concrete
Single surface dressing	87.7%	Double surface dressing
Porous friction course	99.8%	
Twin layer porous friction course	89.2%	Thin asphalt wearing course
Stone mastic asphalt	75.6%	Thin asphalt wearing course
Thin asphalt wearing course	74.5%	Twin layer porous friction course
Thin low-noice asphalt wearing course	92.8%	

How frequently should we survey?

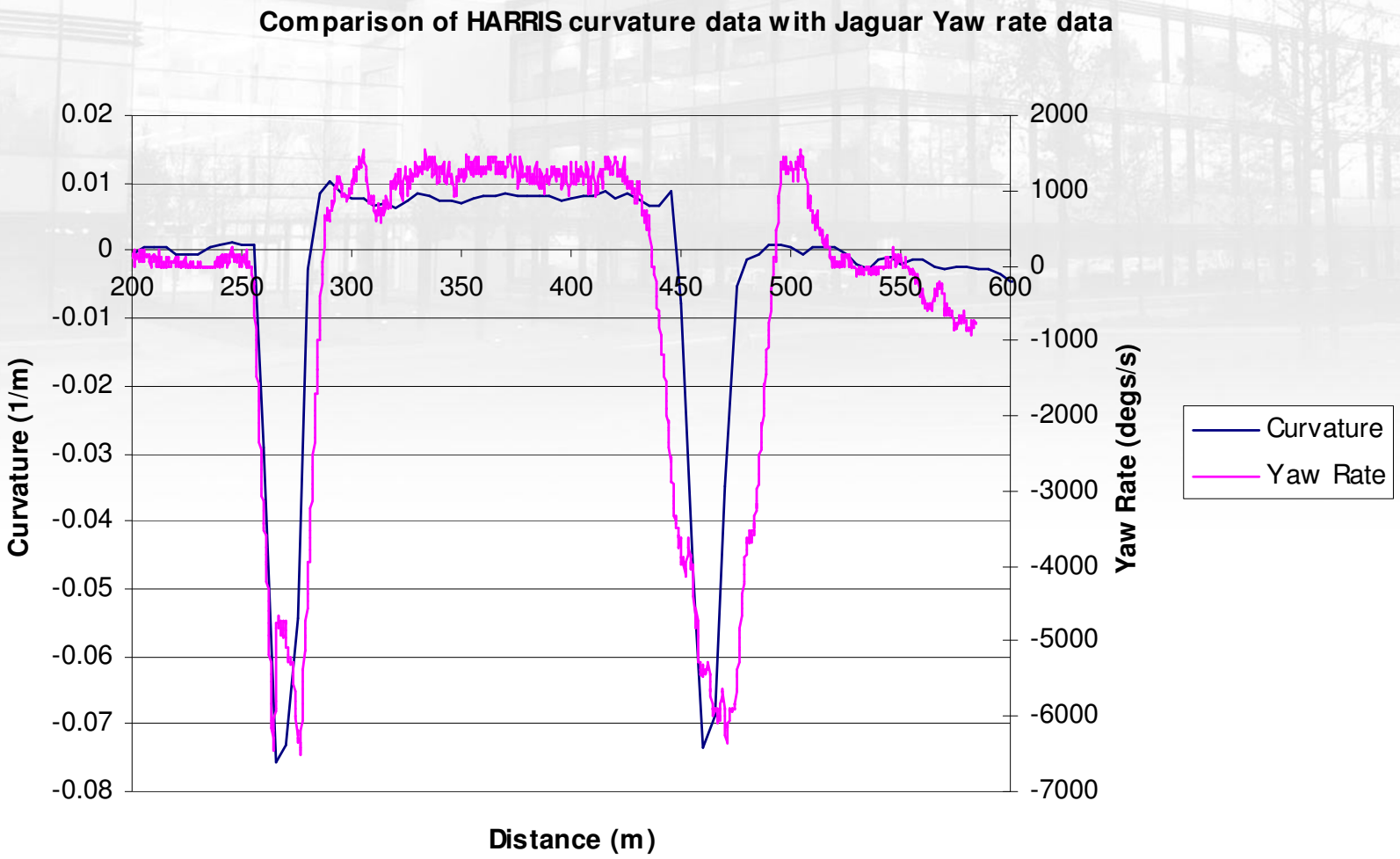
- Every five years? Structural condition with slow speed devices
- Every two years? Surface condition in the Netherlands
- Every year? Surface condition of other lanes and skid resistance in the UK
- Every six months? Surface condition of main lanes in the UK
- Every day? Local inspection
- 24/7 Users

How frequently should we survey?

- Every five years? Structural condition with slow speed devices
- Every two years? Surface condition in the Netherlands
- Every year? Surface condition of other lanes and skid resistance in the UK
- Every six months? Surface condition of main lanes in the UK
- Every day? Local inspection
- 24/7 Users - our future survey team?

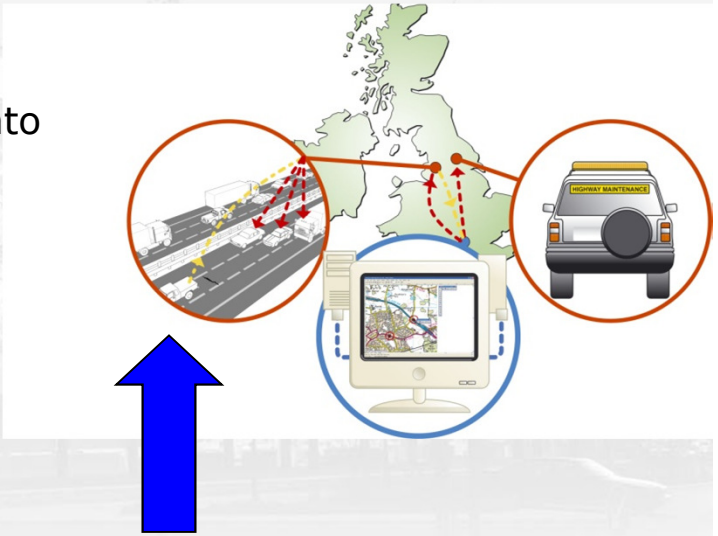
Future survey vehicle?

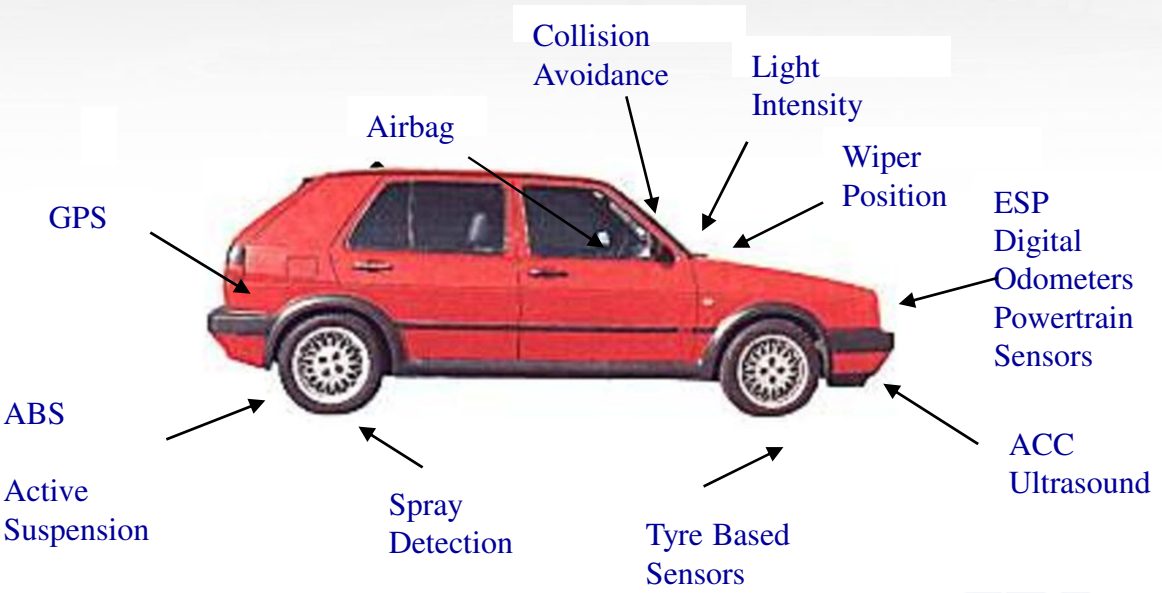
Jaguar Yaw vs HARRIS curvature



Developing Intelligent Vehicles

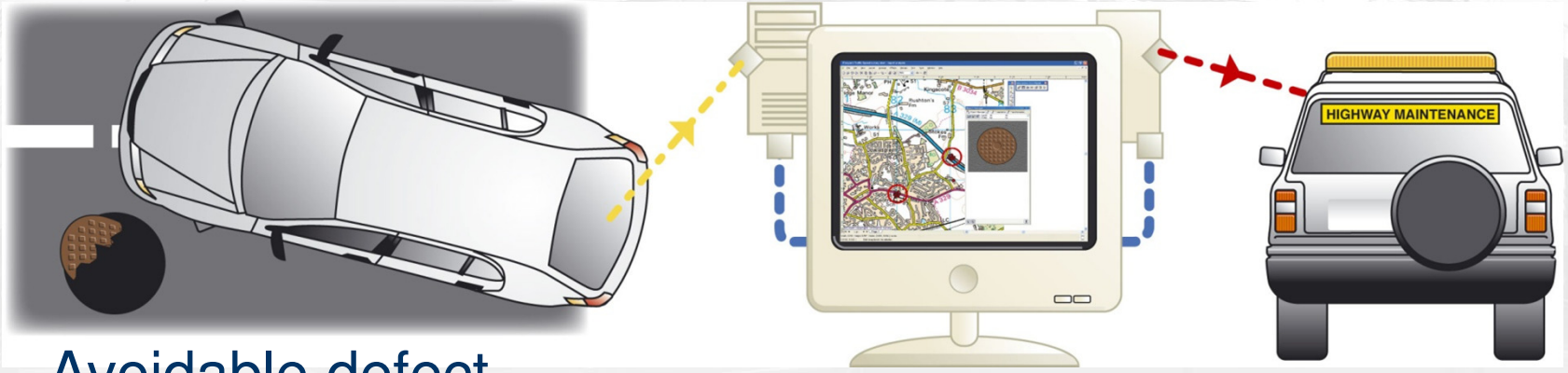
- The main goal of the second part of INTRO task 3
- Automotive industry introduced wide range of sensors into standard production cars
  - Often considered for traffic uses
  - Technology exists for data removal
  - Could the data be adopted for condition measurements?
  - Would provide wide scale coverage
  - At a low level of detail
- Aim to demonstrate the use of the sensor data to monitor pavement condition
- Via practical investigation by TRL and VTI.



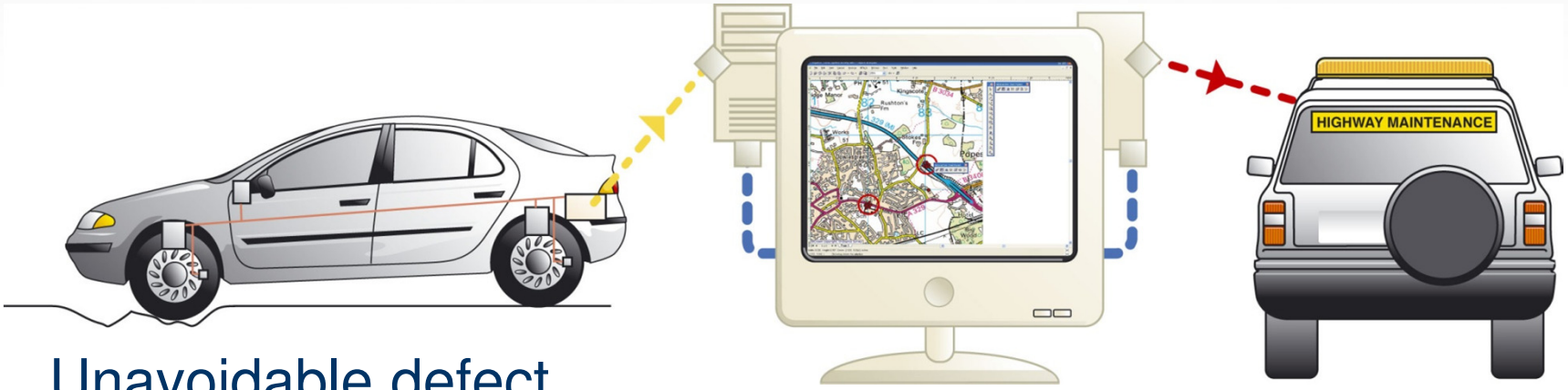


Practical Investigation of Probe Vehicles

Identifying Defects

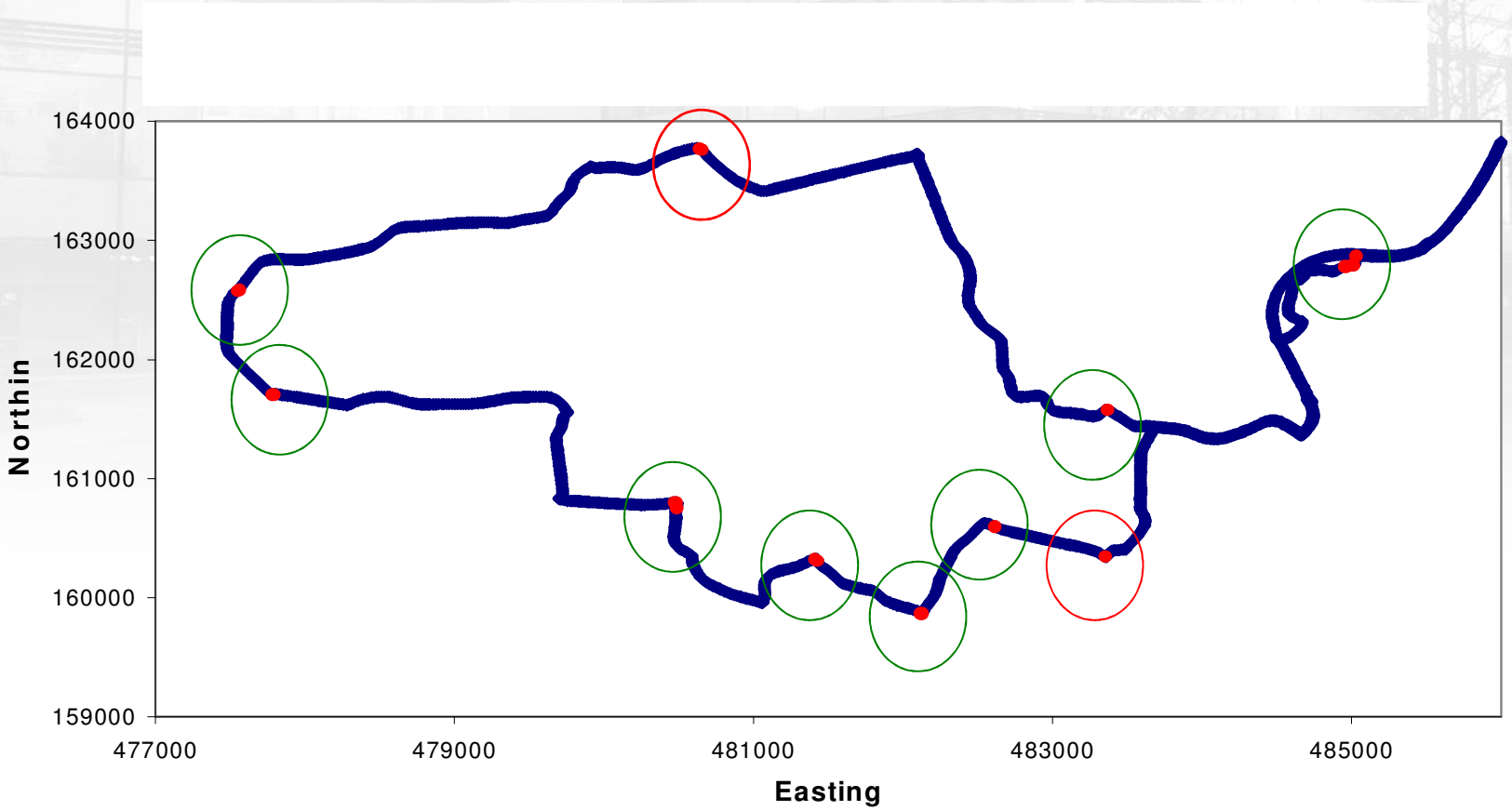


Avoidable defect



Unavoidable defect

Developing the use of Probe Vehicle Data



- Identifying rough roads – agreement with reference

Probe vehicles?

. . . the location referencing and data transfer capability are already in place.

Thank you

Pavement Evaluation – a European Perspective

Presented by Brian Ferne
25 October 2010
Tel: +44-1344-770668
Email: bferne@trl.co.uk

Do You Have Any Questions?