Measurement methods for skid resistance of road surfaces

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Background and requirements for Common Scale

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Background

- Measurement methods and policies for skid resistance vary greatly across Europe
- Can present barriers to sharing of best practice and comparing road networks
- Harmonisation has been attempted in the past, for example
  - Hermes project
  - PIARC experiment

But ….

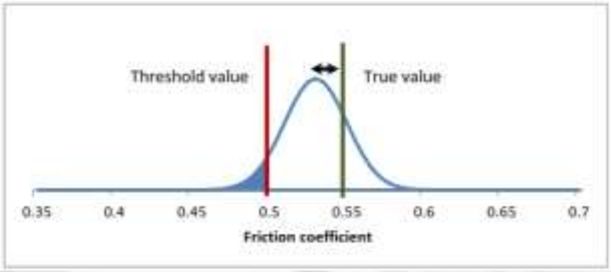
- Common scales developed have not had sufficient accuracy and robustness

Objective

- To advance the harmonisation of skid resistance measurements across Europe
- Undertake pre-normative research creating the technical basis for draft standards
  - Proof of a new concept

Measurement accuracy

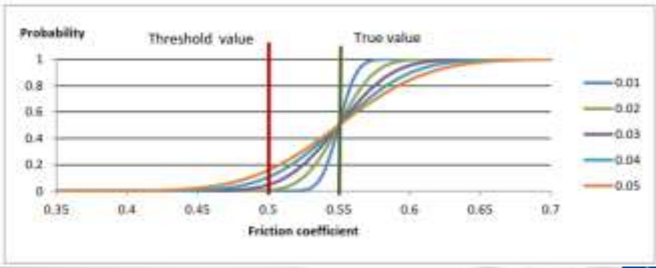
- Measurements can be affected by
  - Bias (systematic error)
  - Random error
- Example shows that a proportion of measurements will give a “wrong” answer



- What level of accuracy is acceptable?

Measurement accuracy

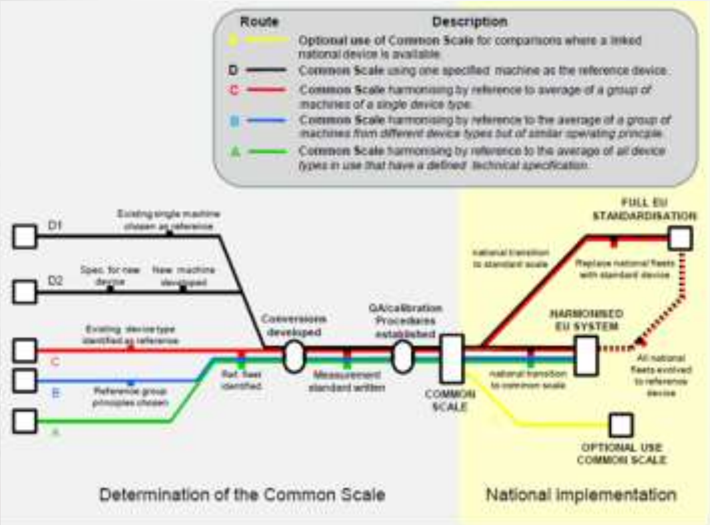
- Precision can be expressed in terms of Reproducibility Standard Deviation, $\sigma_{R,}$ which takes account of:
  - Between machine variation
  - Repeatability of individual machines
- Fleets of the same device type can produce $\sigma_R \approx 0.03$
  - Equivalent to 95% confidence if threshold 0.05 below true value and zero bias



Starting point

- TYROSAFE project reviewed:
  - Previous harmonisation work
  - Skid resistance policies and standards across Europe
  - Measurement devices in Europe
- Proposed a way forward
  - The TYROSAFE Roadmap
  - Options for developing a common scale
  - Options for implementation

Starting point



Starting point

- Derive conversion factors for friction indices based on similar groups of devices based on operating principle
  - Side-force
  - Longitudinal fixed slip
    - Low slip
    - High slip
- Measure on different parts of the friction-slip curve
- Represent different road user situations
- Gather data that can be analysed to develop the Common Scale(s)

Round robin tests to develop common scale

Objectives

- Two experimental campaigns
  - 1st database for analysis and development of Common Scale
  - 2nd database to verify the stability of the Common Scale
- Additional knowledge on the parameters of influence
- Identification of suitable test conditions (surfaces, speed, etc.) for the common scale
- Definition of relevant “checking process” and proposition of recommendations on calibration (Q/A procedure)

IFSTTAR Test Track

Participants

- Transversal Friction Coefficient (8)
  - SCRIM (France, Slovenia, *United Kingdom*, *Spain*)
  - SKM (Germany)
  - Odoliographe (Belgium)
  - *Pavetesting (Spain)*

- Longitudinal Friction Coefficient (10)
  - RoadSTAR (Austria) –18% et 62,5%
  - Griptester (France, United Kingdom)
  - Roar (Denmark)
  - Adhéra (France)
  - IMAG (France) – 18 et 85%
  - *TRT (Czech Republic)*
  - *Oscar (Norway)*
  - *ROAR5 (Norway)*
  - *Viafriction (Norway)*

Checking process

- Parameters
  - Speed (30 to 100 km/h)
  - Distance (800 m)
  - Water flow (3 speeds)
  - Tyre (pressure, shore hardness, surface profiles, cleanness)
  - Static load
  - Wheel angle (SFC)

- Requirements
  - Existing European Technical Specifications
  - Or national specifications

Checking process

- Angle: 20°±1°
- Distance: d ± 1%
- Speed: S ± 5%
- Tyre pressure: P ± 0.1 bar
- Static load:
  - Variations between 2014 and 2015 for several devices (< 5% of the reference value)
  - *Requirement: ± 10% of the theoretical value*
- Water flow:
  - Some variations between 2014 and 2015 on the various devices
  - *Requirement: ± 20% of the theoretical value*

Round robin test program

- Path of 50 cm width on each section

	Transversal Friction devices
Surfaces	10
Speed (km/h)	20, 40, 50, 60 and 80
Repetitions	5 + 1

	Longitudinal Friction devices
Surfaces	10
Speed (km/h)	40, 60 and 80
Repetitions	5 + 1

Tour on trafficked roads

- 7 sections of 200m / 3 tours
- Standard speed of measurements

Data collected

Friction measurement	Number of devices	Slip ratio category	Speed (km/h)	Number of pavement surfaces	Repetitions	Total
Side-force	8	Low	20, 40, 50, 60, 80	10	5 for each speed and device (3 on HFS surface)	240 values /device
Longitudinal	8	Low	40, 60, 80	11	5 for each speed and device (3 on HFS surface)	159 values /device
Longitudinal	3	High	40, 60, 80	11	5 for each speed and device (3 on HFS surface)	159 values /device

Friction measurement	Number of devices	Slip ratio category	Speed (km/h)	Number of pavement surfaces	Repetitions	Total
Side-force	7	Low	60	7	3 repetitions per section	21 values /device
Longitudinal	6	Low	60	7	3 repetitions per section	21 values /device
Longitudinal	1	High	60	7	3 repetitions per section	21 values /device

Thank you to all the participants

Results and draft standard for harmonised skid resistance measurements

Analysis

- The devices were placed into 3 groups for the analysis
  - Based on operating principle
  - Represent different road user situations

Device group	Representative slip ratio
Side-force	34 %
Longitudinal – low slip	15-25 %
Longitudinal – high slip	over 60%

- Data reviewed to remove anomalies and outliers in accordance with ISO 5725-2

Analysis

- Based on Skid Resistance Index (SRI) approach
  - DD CEN/TS 13036-2

$$SRI = BFe^{\frac{S-S_{Ref}}{S_0}} \qquad S_0 = aMPD^b$$

Where

a, b, and B are device-specific calibration parameters

F is the measured skid resistance value

S is the vehicle operating speed

S_{Ref} is the reference speed at which SRI values are reported

S_0 represents the speed gradient of the skid resistance values, related to the surface texture

MPD is the Mean Profile Depth, a measure of the surface texture

Analysis

- Used vehicle operating speed rather than tyre slip speed in defining the reference speed
- Not practical for all the different device groups to achieve a single reference slip speed within the normal range of vehicle operating speed
  - requires large, and error-prone, speed corrections to be applied

Device group	Representative slip ratio	Slip speed at 50km/h vehicle speed	Slip speed at 80km/h vehicle speed
Side-force	34%	17	27
Longitudinal – low slip	20%	10	16
Longitudinal – high slip	75%	37.5	60

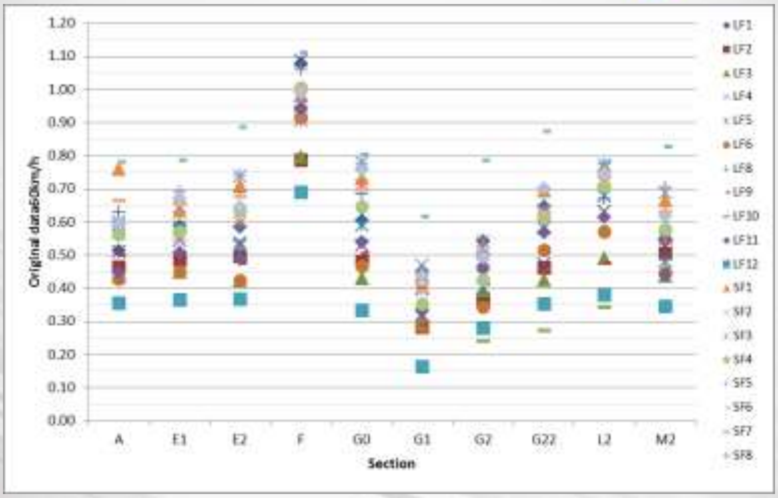
Analysis

- When operating speed equals reference speed then:

$$SRI = BF$$

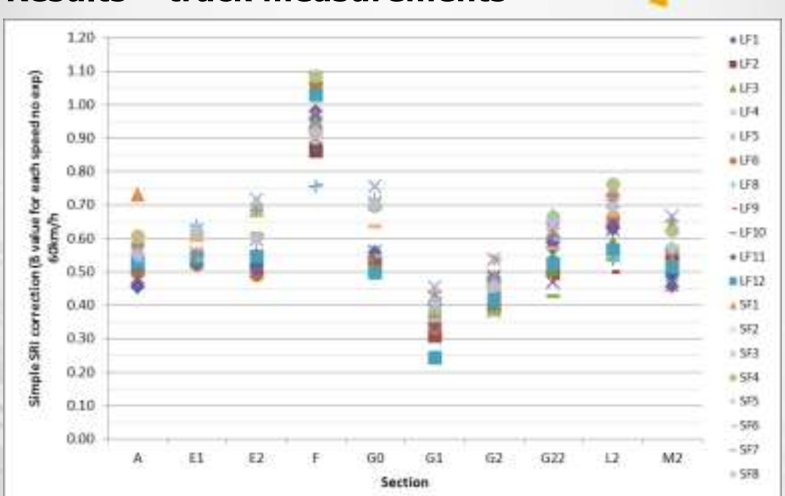
  - This is the simplest form of harmonisation
  - No need to correct for changes in friction with speed
- To determine the device-specific calibration factors, B, the value of the common scale for each test surface needs to be fixed
- Reference friction value for each surface based on average of all devices within a Group weighted by the number of each device type

Results – track measurements



Original data collected at 60km/h – all devices

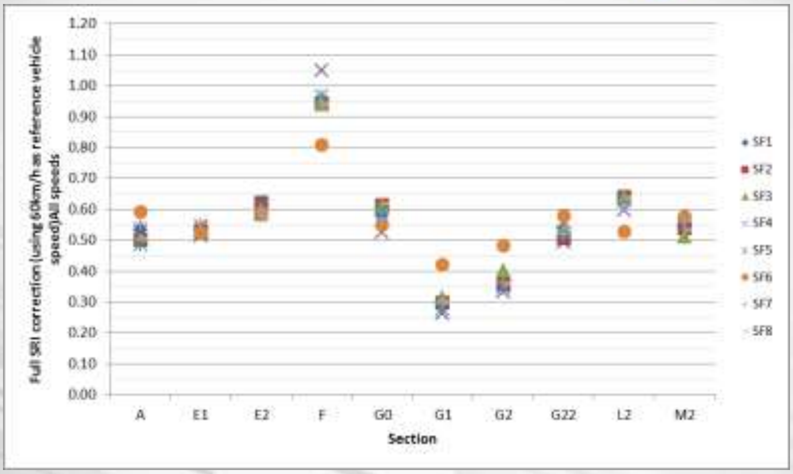
Results – track measurements



Simple correction at 60km/h – all devices

$\sigma_R \approx 0.07$

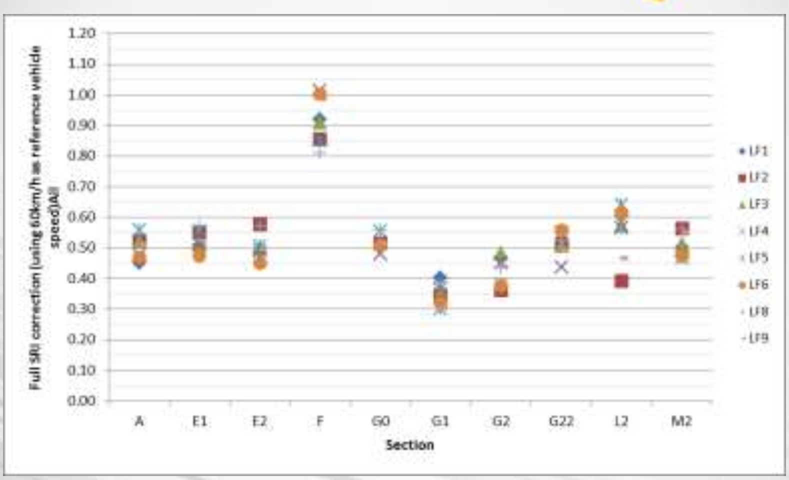
Results – track measurements



Full SRI correction – side-force devices

$\sigma_R \approx 0.039$

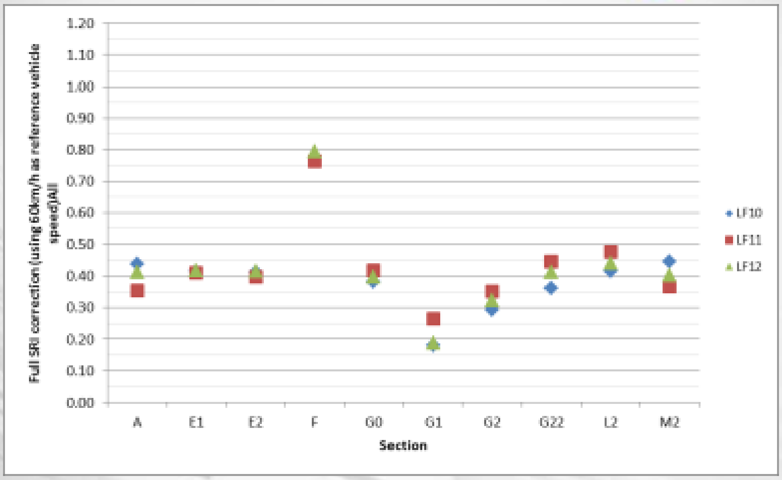
Results – track measurements



Full SRI correction – longitudinal devices (low slip)

$\sigma_R \approx 0.05$

Results – track measurements



Full SRI correction – longitudinal devices (high slip)

$\sigma_R \approx 0.038$

Results – track measurements

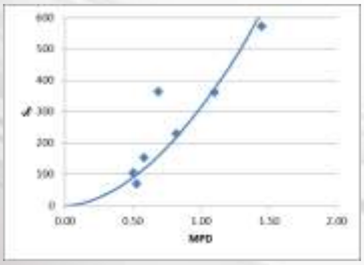
- Common scale developed for each device group
- Device specific parameters (a, b & B) calculated
- Precision of common scale assessed by calculation of the reproducibility standard deviation, σ_R
  - σ_R around 0.035 to 0.05
    - compared to about 0.03 for fleets of the same device type
    - compared to about 0.08 - 0.1 for previous harmonisation experiments
  - Similar results from simple and full SRI approach
  - Similar results from both trials

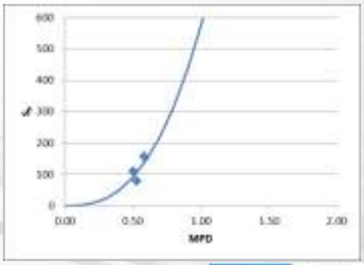
Results – road circuit

- a, b & B values derived from test track results applied to measurements on trafficked roads
- Similar reproducibility values obtained
- Common scales do not appear to be influenced by "real world" test conditions

Device families

- Speed dependency based on limited number of values for an individual device
- Relationship can have similar shape but vary quite widely
- Could data be grouped together to make speed dependency more robust?
- Concept of device "families"





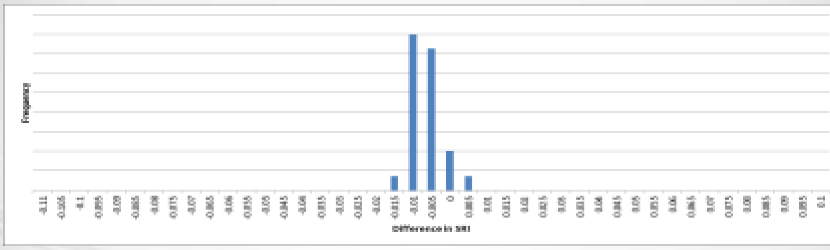
Device families

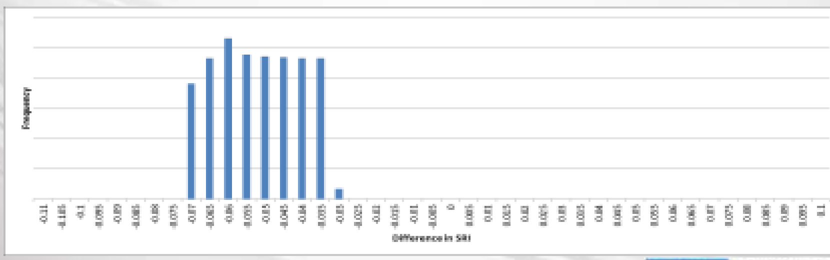
- Pooling similar devices within an existing device group (based on test tyre and load)
- Calculation of a, b & B values for device "families"
- Gives similar but slightly higher levels of reproducibility
  - Side-force – $\sigma_{R} =$ 0.035-0.045
  - Longitudinal (low-slip) – $\sigma_{R} =$ 0.05-0.06
- This approach would help with implementation and maintenance of the common scale

Stability of common scale

- Compared results for devices that took part in both trials
  - Different a, b & B values from each trial
  - Assessed whether these give significantly different results over the typical range of measurements
- Some variation in consistency of SRI values
- Causes require further investigation

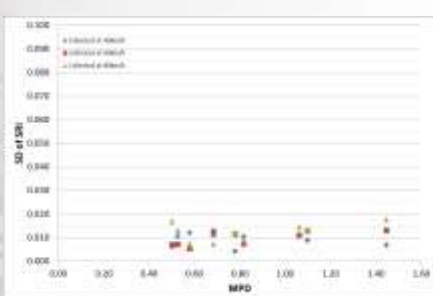
Stability of common scale

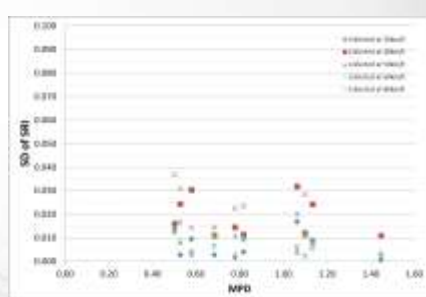




Precision classes

- Explored concept of precision classes
  - Based on standard deviation of the SRI results for a device





Quality Assurance

- QA recognised as important
- QA procedures need to cover:
  - Individual devices
    - Existing CEN Technical Specifications and national standards
    - Operator and independent checks
  - Fleets of the same device type
    - Some countries already have well developed systems
    - Sharing of best practice
  - Maintenance of the common scale
    - Should remain stable if first two QA procedures are well maintained and any systematic drift is identified
    - Will still be some need for periodic checks to ensure that a, b & B values are still applicable

Draft Standard

- Single standard with a part for each device group
- Make clear the difference between the Common Scale for the different device groups
- Based on existing DD CEN/TS 13036-2
- Refer to existing device CEN Technical Specifications
- Provide the equation to be used to convert measured friction values into SRI values on the Common Scale for each device group
- Tabulate the calibration constants a, b and B that are necessary for this calculation

Draft Standard

- Place limits on the validity of the calibration constants
  - Speed
  - Texture depth
  - Period of time for which they remain valid
- Details of how to run future calibration exercises
  - Informative annex

Summary

- Measurements made by different devices can be converted to a common scale
- Assumptions made in developing the TYROSAFE roadmap have been proven correct
  - Precision is improved by developing common scales for different groups of devices based on their operating principle
  - Precision is at a "usable" level
- Devices of the same type could be treated as a "family"
- Precision classes could be developed
- Robust QA procedures required
- Stability over time requires further investigation

Any questions?