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Roadmaps and implementation plan for harmonised skid resistance measurement methods

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Abbreviations

Abbreviation	Meaning
ABS	Antilock Braking System
BFC	Braking (force) Friction Coefficient (=LFC)
EFI	European Friction Index
IFI	International Friction Index (developed in the 1992 International PIARC Experiment to Compare and Harmonize Skid Resistance and Texture Measurements)
IRFI	International Runway Friction Index (developed in the American Joint Winter Runway Friction Measurement Program, described in ASTM E2100)
LFC	Longitudinal (force) Friction Coefficient (=BFC)
MPD	Mean Profile Depth (as defined in ISO 13473-1 and ISO 13473-2)
SFC	Sideway (force) Friction Coefficient
HERMES	Harmonisation of European Routine and Research Measurement Equipment for Skid Resistance of Roads and Runways (FEHRL project)
ASTM	American Society for Testing and Materials
BASt	Bundesanstalt für Strassenwesen (DE)
CEDR	Conference of European Directors of Roads
CEN	European Committee for Standardization
FEHRL	Forum of European National Highway Research Laboratories
ISO	International Standards Organisation
LCPC	Laboratoire Central de Ponts et Chaussées (FR)
PIARC	Permanent International Association of Road Congresses
RWS	Rijkswaterstaat = Department of public works and infrastructure of Ministry of transport (NL)
TRL	Transport Research Laboratory (UK)
IMAG	Instrument de Mesure Automatique de Glissance (FR)
SCRIM	Sideway-force Coefficient Routine Investigation Machine

Definitions

Term	Definition
Accuracy (of a measurement method)	A measure of the deviations of the measured values from the "true" value or any agreed reference value. These deviations are composed of a combination of random error (precision component) and a systematic error (trueness component). See ISO 3534-1, and "precision" and "trueness" in these definitions. Note: In every-day English, accuracy often is considered to be the number of decimal places (otherwise called "resolution") of a measurement result.
Calibration	Periodic adjustment of the offset, the gain and the linearity of the output of a measurement method so that all the calibrated devices of a particular type deliver the same value within a known and accepted range of uncertainty, when measuring under identical conditions within given boundaries or parameters.
Contact area	Overall area of the road surface instantaneously in contact with a tyre.
Fixed slip	Condition in which a braking system forces the test wheel to roll at a fixed reduction of its operating speed.
Friction	Resistance to relative motion between two bodies in contact. The frictional force is the force which acts tangentially in the contact area.
Coefficient of friction	Ratio of the frictional force developed between two surfaces with the vertical load applied. Often represented using the greek character, μ (mu).
Harmonisation	Applied to several different measurement methods, harmonisation is "the adjustment of the outputs of different devices used for the measurement of a specific phenomenon so that all devices report the same value(s) (i.e. report in a Common Scale), except for some inaccuracy". This sense is mostly used in the referenced literature. Applied to European standards by CEN, "harmonised" standards for measurements are standard methods, which all European countries have agreed to use. In principle, CEN aims to get "one method for one property", which is referred to as "standardisation" in this report. Applied to the scope of TYROSAFE regarding "harmonisation of European skid resistance approach", which is the scope of this report, is dealing with defining a Common Scale. Such harmonisation can achieved both through harmonisation of measurements by adjustment of the outputs or through standardisation of measurements (as formulated elsewhere in the definitions).
Horizontal force	Horizontal force acting tangentially on the test wheel in line with the

(drag)	direction of travel.
Horizontal force (side force)	Horizontal force acting perpendicular to a freely-rotating, angled test wheel.
Longitudinal friction coefficient (LFC)	Ratio between horizontal force (drag) and vertical force (load) for a braked wheel in controlled conditions. This is normally a decimal number quoted to two significant figures.
Macrotexture	Deviation of a pavement from a true planar pavement with characteristic dimensions along the pavement of 0.5 mm to 50 mm, corresponding to texture wavelengths with one-third-octave bands including the range 0.63 mm to 50 mm centre wavelengths.
Mean profile depth	Descriptor of macro texture, obtained from a texture profile measurement as defined in EN ISO 13473-1 and EN ISO 13473-2.
Megatexture	Roughness elements with a horizontal length of 50 to 500 mm. Roughness of this magnitude can influence accumulations of water on the pavement surface (for instance, in unevenness).
Microtexture	Deviation of a pavement from a true planar pavement with characteristic dimensions along the pavement of less than 0.5 mm, corresponding to texture wavelengths with one-third-octave bands and up to 0.5 mm centre wavelengths.
Nearside wheel path	Wheel path that is closest to the edge of the road in the normal direction of travel. For countries that normally drive on the right, this is the right-hand side and for countries that normally drive on the left, this is the left-hand side.
Operating speed	Speed at which the device traverses the test surface.
Repeatability r	The maximum difference expected between two measurements made by the same machine, with the same tyre, operated by the same crew on the same section of road in a short space of time, with a probability of 95 %. (This equals 2.77 times the repeatability standard deviation: $r = 2.77 * \sigma_r$)
Reproducibility R	The maximum difference expected between two measurements made by different machines with different tyres using different crews on the same section of road in a short space of time, with a probability of 95 %. (This equals 2.77 times the reproducibility standard deviation: $R = 2.77 * \sigma_R$)
Routine testing	Measurement of the skid resistance of a surface in standardized test conditions, which normally include a defined water flow rate.
Side force coefficient (SFC)	Ratio between the vertical force (load) and horizontal force (side force) in controlled conditions. This is normally a decimal number quoted to two significant figures.

Skid resistance	Characterisation of the friction of a road surface when measured in accordance with a standardised method.
Slip angle	The angle between the mid-plane of the test tyre contact surface and the direction of travel.
Slip ratio	Slip speed divided by the operating speed.
Slip speed	Relative speed between the test tyre and the travelled surface in the contact area.
Standardisation	In this report: Defining one single measurement method (including the measurement device, its configuration, test procedures, test conditions, and data processing) to determine a certain property for a particular purpose, with exclusion of all other measurement methods for this property for the same purpose. More generally: Describing the devices and procedures (including the device configuration, test conditions, and data processing) of a measurement method in a formal document.
Theoretical water film thickness	Theoretical thickness of a water film deposited on the surface in front of the measuring tyre, assuming the surface has zero texture depth.
Vertical force	Force applied by the wheel assembly (the static and dynamic force on the test tyre, the test tyre weight and the rim weight) on the contact area.
Water flow rate	Rate (litres/second) at which water is deposited on the surface to be measured in front of the test tyre.
Wet road skid resistance	Property of a trafficked surface that limits relative movement between the surface and the part of a vehicle tyre in contact with the surface, when lubricated with a film of water.

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Executive Summary

Introduction

The TYROSAFE Project is a Coordination and Support Action (CSA) in the Seventh EU Framework Programme and aims at coordinating and preparing for European harmonisation and optimisation of the assessment and management of essential tyre/road interaction parameters to increase safety and support the greening of European road transport.

Work Package 2 (of four technical work packages) focussed on the harmonisation of skid resistance measurement techniques. Its ultimate objective was to arrive at a widely-supported roadmap to point to a harmonised EU road skid-resistance assessment method by 2020. The main (but not exclusive) fields of application would be for monitoring the skid resistance condition of European main road networks and acceptance control of new work.

This report provides a thorough analysis of different harmonisation options, including advantages, drawbacks, obstacles to implementation and costs. It sets out the various steps on the alternative routes to harmonisation, proposes an implementation plan and identifies research that will be needed to reach the goal.

Why harmonise?

Providing adequate levels of skid resistance is widely recognised as an important aspect of improving and maintaining safety levels on roads. However, over 23 different types of measuring device are used to assess the skid resistance of roads across the EU. For various technical reasons, each gives different results to the others.

Essentially, there are two primary reasons to develop harmonised skid resistance measurements in the EU:

- To provide a single measurement method that can be cited in CEN standards for material classification and applied across the EU.
- To provide a measurement method that allows direct comparison of policies and skid resistance thresholds used for network management (which includes verification of the acceptable performance of newly-laid surfacings) across the EU.

With harmonised measurements, EU road authorities, surfacing contractors and material suppliers would have a consistent way of specifying and verifying the acceptability of new surfacings. Road authorities who already monitor skid resistance but wish to compare standards with others based on different measurement methods would have a convenient tool for doing so. Countries that have no background in measuring skid resistance, or wish to develop policies or acquire measurements can more readily compare options. Further, measurement companies that wish to ply for trade across borders will be able to do so more easily because they can report results on a commonly-accepted scale.

The root of the problem

There have been a number of attempts to harmonise skid resistance measurement techniques over the years. Most notable are the PIARC International Experiment of the early 1990s that led to the proposed International Friction Index (IFI) and the HERMES study about ten years later that investigated the concept of the European Friction Index (EFI). However, although some progress has been made through these various attempts, none has been able to produce results that would find widespread acceptance or use.

The concept of these studies was to find a “Common Scale” that would represent the skid resistance condition of the road under defined “reference” test conditions. A generalised conversion formula would then be used to convert measured values from individual machines under their particular test conditions to equivalent values for the reference conditions, that is, on the Common Scale. The Common Scale was based on reference levels derived from measurements of texture depth and the average friction value from a set of “reference” skid resistance devices that measured different surfaces at different test speeds.

The main difficulty that these exercises encountered was finding a mathematical model that could satisfactorily convert actual values to their equivalents on the Common Scale under the widely differing measurement principles and operating conditions used in practice. This, compounded by issues related to the quality control of some machines, meant that the reproducibility of measurements expressed on the Common Scale was unacceptably poor.

The challenge, therefore, was to devise an approach to the problem that could deal with these issues and, with appropriate supporting research, provide a workable solution. This would then provide the basis for a roadmap to reach the objective of harmonisation by 2020.

The approach taken

Work began with a thorough review of current national skid-resistance test methods and an analysis of previous harmonisation research. An assessment was also made of the potential use of stable, reproducible, reference surfaces in the calibration of measuring devices. It was clear that, while such surfaces would be of value, providing independent reference levels on which devices could be compared, developing such surfaces remains a long-term problem.

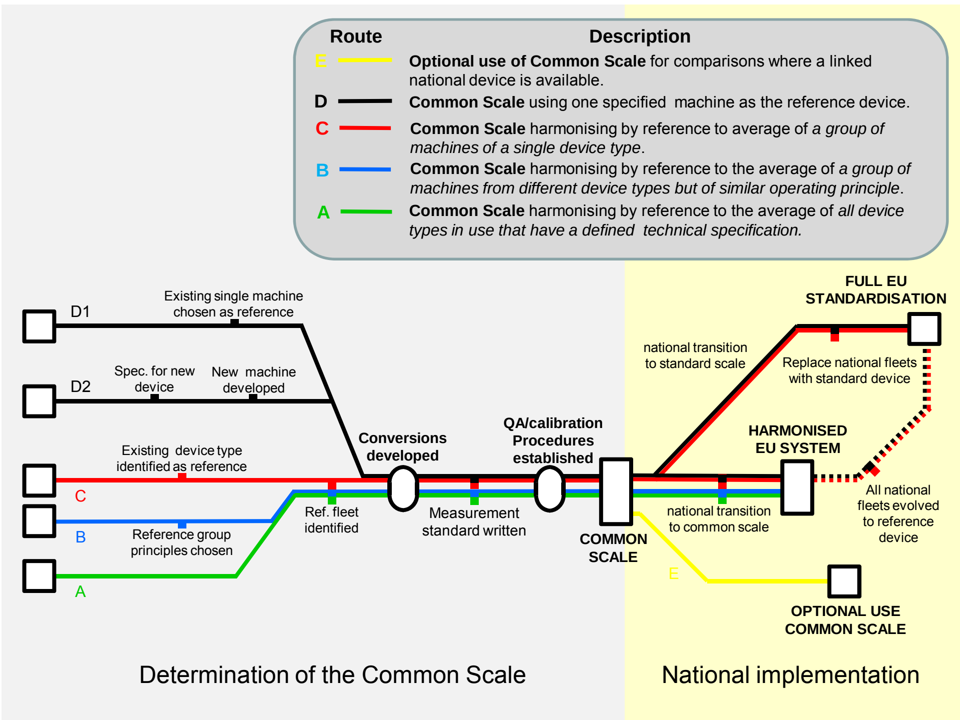
It was recognised that a key issue was that of accuracy of results expressed on the Common Scale. Perceptions in individual countries as to the level of accuracy needed are often associated with how their measurements are typically used. For example, good accuracy is needed to reduce contractual disputes. However, when they are one of several factors used to decide whether to treat the road, less accurate values may still be of considerable use.

The work therefore focussed on ways to define the Common Scale that would improve its accuracy but still allow current measurement devices to be used. Various approaches were considered, starting from the “average of all devices” approach used in PIARC and HERMES, but with better-developed conversion models, through using a smaller set of measurement device types (the reference fleet) to set the Common Scale, to full standardisation by simply imposing the use of one device type across the EU.

The idea of using a smaller set of device types to define the Common Scale opened up the option of developing conversion formulae that were more device-type specific which should, in turn, improve the accuracy of Common Scale values reported by individual machines. This led to a new concept, that of defining accuracy classes that would permit discrimination between different device types for different measurement purposes while retaining the harmonised scale.

The TYROSAFE Metro Map

As the various options were analysed it was realised that, although there were differences in detail, there were many broad similarities. It was therefore decided that the various options for the roadmap could be represented using the analogue of the familiar "Metro Map" on which different lines would represent different proposed routes to determine the Common Scale together with alternative final destinations. The map (Figure 4.1 in the main report) is reproduced below.



The TYROSAFE Metro Map

Three possible destinations are proposed: a Harmonised EU System, in which all current devices (within the limitations of their accuracy classes) continue to be used, with the Common Scale being applied for the various uses of skid resistance data across Europe; Full Standardisation, a longer-term possibility in which only one device type is used across the EC; Optional Use of Common Scale where use of the Common Scale and conversion formulae is not an EU requirement but countries can opt to use the scale to harmonise their internal measurements or with neighbours should they so choose.

There are four possible routes to achieve the Common Scale which differ in the way in which the reference level for the Common Scale is established. The options are designed to progressively improve the potential accuracy. Route A is based on using all existing devices to define the Common Scale, Route B reduces the set of reference devices to those that operate on similar principles, Route C goes further and limits the reference fleet to devices of one specific type only. Route D is the final level, using just one machine to set the Common Scale reference level. Here there are two branches, one using an example of an existing device type, the other using a purpose-designed new device type. All the routes make provision for writing supporting documents and quality procedures, together with establishing accreditation processes to maintain the accuracy and stability of the Common Scale in the longer term.

A full explanation of the map, implications for accuracy and advantages and drawbacks of the different options are included in Chapters 4 to 7 of the main report. Chapter 6 includes the new proposal for different accuracy classes to which individual measurement device types can be assigned.

Implementation plan, including research needs

Clearly, at the heart of a successful achievement of harmonisation will be a programme of research and proposals for this form a significant part of the implementation plan. Essentially, the research required for any of the proposed routes to harmonisation involves a number of similar components:

- Theoretical studies to improve the models used to resolve the differences between the operating principles of different devices that will be needed to develop the conversion formulae.
- Practical exercises to gather data to assist with the modelling and to develop and validate the conversion formulae.
- An analysis phase using the data to establish the Common Scale and assess the effectiveness (in terms of accuracy and precision) of the routes to the Common Scale being studied.
- A final phase, in which the full range of devices to be included initially in the harmonised system is calibrated to the Common Scale.

It should be possible to design the experimental stages to gather data that could be applied on any of the routes. Thus, rather than identify in advance which should be followed, the work should be structured keep open options to change route (at the “Conversions Developed” stage) once the assessments of potential accuracy have been made. The proposed implementation plan follows a staged approach with objectives of establishing a Common Scale by 2017 and full harmonisation by 2020, allowing time for countries to make any necessary adaptations to their existing practices.

Recommendations

The recommendations (explained and set out fully in Chapter 9 of the report) are, in summary:

1. Establish a Harmonised EU system for skid resistance measurements using current devices in the medium term (5-7 years).
2. Carry out studies to establish the precision of the alternative approaches to defining the Common Scale, determine appropriate conversions to link the various devices to the chosen Common Scale and develop and assign devices to appropriate accuracy classes.
3. In parallel, carry out a programme of theoretical and experimental study in the medium term (~5-7 years) to specify, build and evaluate a prototype new device designed particularly to meet more closely the strategic needs of engineers and road authorities in relation to assessing accident risk due to skidding. Link this device to the Common Scale, subsequently evaluating a number of examples of the new type to establish the expected precision in relation to the Common Scale.
4. If the outcomes of Recommendation 3 are satisfactory, adopt the “Route C” approach using the new device as the reference device type from 2020.
5. In parallel, develop reference surfaces in the longer term (10 – 15 years).
6. Consider evolution to use the new device as an EU standard device for the longer-term (15 years).

1 Introduction

The TYROSAFE Project is a Coordination and Support Action (CSA) in the Seventh EUFramework Programme and aims at coordinating and preparing for European harmonisation and optimisation of the assessment and management of essential tyre/road interaction parameters to increase safety and support the greening of European road transport.

This work is being carried out through four technical work packages (WP):

- WP1: Policies of EU countries for skid resistance / rolling resistance / noise emissions;
- WP2: Harmonisation of skid-resistance test methods and choice of reference; surfaces
- WP3: Road surfaces properties – skid resistance / rolling resistance / noise emissions;
- WP4: Environmental effects and impact of climatic change – skid resistance / rolling resistance / noise emissions;

A fifth work package provides for dissemination and raising awareness of the work of the project with a sixth covering management issues.

WP1 addressed the issues of developing a harmonised approach to policies for skid resistance, rolling resistance and noise across Europe and detailed reports have been prepared covering this topic [1], [2]. Harmonised policies will depend on the provision of harmonised test procedures that could be used to gather data to support them. WP2, to which this report refers, was designed to assist in achieving this end in relation to skid resistance measurement. The ultimate objective was to arriving at a widely-supported roadmap with a proposed implementation plan to point towards a harmonised road skid-resistance assessment method by 2020, including aspects such as testing equipment, quality assurance and an implementation strategy. The major field of application in mind is for monitoring the skid resistance condition of the European road network and for new work acceptance control.

To reach its objective, WP2 was split into four Tasks:

- In Task 2.1 knowledge of current national skid-resistance test methods were collected, together with an analysis of findings of previous harmonisation research projects.
- In Task 2.2 work focused on the potential use of reference surfaces in the calibration of measuring devices.
- Task 2.3, to which this report refers, took the results of Task 2.1 and 2.2 as a basis to develop the roadmap and an implementation plan, paying special attention to the intermediate stages so that a smooth transition to the new approach can be made.

- Task 2.4 provided for the organisation of workshops that would allow constructive input from stakeholders and experts and help to mobilise support for the roadmap.

Table 1.1 gives an overview of the major outcomes planned for the individual Tasks of WP 2.

Table 1.1 Overview of the major outcomes of the individual Tasks of WP 2

Task	Deliverable	Name	Month
2.1	D04	Report on state-of-the-art test methods	M5
2.1	D05	Report on analysis and findings of previous skid resistance harmonisation research projects	M8
2.2	D07	Report on state-of-the-art of test surfaces for skid resistance	M8
2.3	D09	Roadmap and implementation plan for harmonised skid resistance measurement methods	M16
2.4	-	Two dedicated workshops	M5 and M10

This report is the main output from Task 2.3 and constitutes the deliverable D09. Its main purpose is to provide a synthesised analysis of different harmonisation options, including advantages, drawbacks, obstacles to implementation and costs. The report sets out the steps to be followed on the alternative routes and identifies the research that will be needed to reach the goal.

The analysis draws on lessons learnt from the initial three WP2 deliverables [3], [4], [5] which provide in-depth background discussion. The discussions at the two workshops have also been taken into account. The first of these was held in Portorož, Slovenia, in 2008 jointly with WP1, the objective being raising interest in harmonising skid-resistance policies and test methods. The second workshop, in which discussions were focused on the test-method harmonisation options and possible roadmaps, was held September 2009 in London, UK.

In this report, Chapter 2 sets the scene with a brief explanation of the most important issues relating to the harmonisation of skid resistance measurements, including the idea of a “Common Scale” that would be used to achieve harmonisation. Interested readers are referred to D04, D05 and D07 for more technical information and discussion, or to the web site http//:videolectures.net/tyrosafe to see some of the presentations and discussions at the workshops. Chapter 3 moves on to introduce the concept of the “roadmap”, what the destinations might be and some technical aspects that must be taken into account on the way to reaching them. Chapter 4 then presents the TYROSAFE Metro Map, which is a simple representation of possible routes to harmonisation. Chapter 5 explains in more detail the technical issues that distinguish each of the routes. Chapter 6 discusses the important area of accuracy and precision in relation skid resistance measurements and the proposed routes to harmonisation. Chapter 7 provides a general discussion of the advantages, disadvantages and obstacles to the different approaches and Chapter 8 identifies the research needs and suggests an implementation plan. Chapter 9 completes the report with some final discussion leading to recommendations for the way forward.

2 Background

2.1 The roots of the problem

The safe passage of road traffic needs a certain amount of grip (friction) between the tyres of the vehicles and the road surface. The frictional forces are necessary for the vehicle to accelerate, decelerate or safely change direction. The level of frictional forces that can be built up depends on the properties of the road surface, the tyres and the interface conditions.

The contribution of the road to this process is often known as "skid resistance".

The main driver for improving and maintaining skid resistance on roads is to try and reduce the numbers and risk of accidents involving skidding, especially in wet conditions. However, accidents are random, multi-factor events and the grip available to a driver in a particular situation is only one component of a complex set of circumstances.

Further, the grip (or friction) generated between vehicle tyres and the road is affected by the interaction of a wide range of factors at the instant of the manoeuvre, which include the road surface and the tyres and their various properties. These are many (they are being considered as part of WP3 of TYROSAFE and an initial report identifying and summarising what is known about them has been prepared by the TYROSAFE team [6]).

Police collision investigators often use techniques that relate directly to a specific incident, for example measuring deceleration rates for a braking vehicle at the scene and in similar conditions to those prevailing when the accident occurred. Road engineers, however, are trying to assess the general condition of roads as part of the process of network management, or must judge whether a new surfacing has satisfactory frictional properties in relation to contractual requirements. They are primarily interested in the condition of the road surface and not all the other factors that might contribute to an accident. Therefore, they need measurement techniques that simplify the complex processes and focus on the condition of the road.

For decades many countries, both within and outside Europe, have derived their own standardised skid resistance measurement methods and they differ in many respects. (TYROSAFE has identified some 23 measurement devices in use in Europe alone [3].) They all measure in some way the frictional force developed between a moving tyre or slider and the road surface, which is usually wetted. Typically, the devices report a value that represents the coefficient of friction between the sensor wheel or slider and the road.

Because (at the current state of knowledge and technology) some kind of frictional measurement is needed to characterise the skid resistance of the road, even simplified measurement systems are affected by the various factors that influence friction. Therefore, a great many parameters need to be controlled. Different techniques do that in different ways.

The problem is compounded by a lack of clarity as to what exactly should be measured, in particular, the link between the frictional properties of the road surface and how they contribute to accidents in the many different circumstances that can occur. Consequently, questions arise, such as, whether a measurement technique should be designed to assess the state of wear (particularly polishing) of the road surface or whether should it attempt to simulate a particular type of braking condition. As well as these kinds of questions, there are also practical aspects of making the measurements to consider.

The result is a wide range of operating principles and conditions, for example:

- At one extreme some measurement devices simulate conditions close to those experienced by a tyre braking under the control of an anti-lock braking system while, at the other, some devices use a skidding locked wheel. Yet others use angled wheels or devices that stand on the road and use a rotating head to induce skidding conditions.
- Some methods use smooth tyres, while others use ribbed or even patterned tyres. Slider systems may have a single, sprung slider; others use multiple sliders on a loaded rotating head. The dimensions of the tyre and properties of the rubber can also have an influence.
- Different methods use different operating conditions (test speed, wetting conditions, etc). These are chosen to reflect the practicalities of carrying out the measurements on the network and the best way to represent the skidding conditions being evaluated by the particular test technique. They may be influenced by the need for safety during testing. There may be constraints on test vehicle speed caused by traffic or local speed limits.

Not only do the individual features of the various test procedures lead to different results on any one road surface, each measurement technique responds to different surface characteristics in its own way. It may be possible to derive an empirical correlation equation between two individual devices but these may apply to only a limited range of surfaces or test conditions.

A major factor that influences skid resistance measurements is the speed at which the contact patch of the test wheel slides over the road surface during the test [4], [7]. The slip speed, as it is known, is influenced by both the design of the test equipment (which sets the “slip ratio” and how this is achieved) and the speed at which the device is driven over the road, the test speed. Generally, increasing the slip speed results in a reduction in the measured skid resistance but the extent to which this occurs depends not only on the slip ratio but also on characteristics of the road surface, in particular the surface texture depth, or macrotexture.

For obvious practical reasons, the test speed used to make measurements can vary in different circumstances. This leads immediately to a need to resolve differences in measurements from individual devices when they are operated at different road speeds but this is complicated further when different slip speeds that result from different operating principles are brought into consideration.

When comparing any two measurements with one another, it is important to have an independent reference or benchmark against which differences can be assessed. However, in the case of skid resistance there is no absolute measure of the property because measurements are a characterisation of the influence of the pavement on the complex phenomenon of pavement-tyre friction. The idea of developing reference surfaces that could be used in this context is also being reviewed within TYROSAFE [5].

At the root of the problem, therefore, is a range of different technical approaches which, although similar in many ways, differ sufficiently to make a direct comparison of skid resistance values measured or applied from country to country difficult, if not meaningless.

2.2 The concept of harmonised skid resistance measurements

2.2.1 Why harmonise?

Currently, CEN Standards are moving towards the classification of road surfacing materials and one of the parameters that will need to be included in the classifications is the skid resistance that such materials can provide. A key requirement, therefore, is a single, harmonised, measurement method (as a general principle, CEN requires a single measurement method for a single property) that can be used to assess this. Such a method could be used both to establish the class into which a material should be placed and, in the case of newly-laid surfacings, to verify that they meet the requirement for conformity of production control purposes.

Another important reason for developing the idea of harmonising skid resistance measurements is to provide a simple way in which measurements on in-service roads, together with the standards or thresholds against which they are compared, can be easily understood across national boundaries. This is essential if progress is to be made towards a better and more consistent approach to managing skid resistance on roads (and, to some extent, on runways) that can be applied or interpreted across Europe. In the longer term this will simplify progressive improvements on the network as more member states develop policies of their own.[1]

In summary, therefore, there are two primary reasons to develop harmonised skid resistance measurements:

- To provide a single measurement method that can be cited in CEN standards for material classification and applied across the EU.
- To provide a measurement method that will allow direct comparison of policies and skid resistance thresholds used for network management (which includes verification of the acceptable performance of newly-laid surfacings) across the EU.

2.2.2 Who benefits from harmonisation?

In the context of material classification, the beneficiaries of harmonised skid resistance measurements will be those road authorities who are specifying materials for use on their

[1] Interested readers may wish to refer to TYROSAFE Deliverables D06 and D08 [1],[2] for a fuller discussion and recommendations relating to this issue.

networks and the companies that manufacture and supply such materials. Suppliers will have a means of assessing their materials in the development phase that can also be used for marketing purposes and that will be understood across the industry and the EU. Specifiers will have confidence that materials supplied can be expected to meet their requirements. A harmonised method could, in principle, be used to verify that requirements are met in-situ in a manner that can be interpreted by both supplier and specifier regardless of the measurement device actually used.

In the wider context of network and monitoring management, three broad groups have been identified that might benefit from harmonisation:

- Countries (or different road authorities within individual countries) who already have a policy for skid resistance on their networks and monitor skid resistance in some way. These may have large fleets of similar devices or sets of different devices and so harmonisation is important in the process of accreditation of monitoring equipment, understanding measurements made by different devices on different networks and for comparing measurements made for different purposes.

- Countries that do not have a policy for skid resistance at present and may have no background in measuring skid resistance. These are likely to want to know how they can make measurements (perhaps by hiring in services from a neighbour); they will need to understand how whatever threshold values they might choose compare with experience elsewhere, especially if they want to draw on experience in a similar country to choose those thresholds.

- Organisations that make measurements and wish to ply for trade across borders. These (and those considering buying the service) need to understand how the measurements that they will obtain are likely to compare with the thresholds and measurement practice that they are used to.

2.2.3 Where and how would harmonised measurements be used?

The TYROSAFE team envisage that harmonised skid resistance measurements discussed in this report would be used mainly for:

- Classification of road surfacing materials.

- In-service network monitoring and maintenance planning.

- Acceptance tests on new road surfacings.

- Comparisons between standards required or achieved on different networks.

It would be expected that the measurements would apply predominantly to motorways, primary and secondary roads. These are the roads that are most likely to be covered by policies for skid resistance [2]. However, there is no reason why they should not be used on lower-level parts of the network provided that it is practical to make the measurements (which it might not be on some urban streets, for example).

Ultimately, the scope of use for the measurements will depend greatly upon the precision of the harmonised values. For example, a greater level of accuracy is likely to be required for acceptance tests than for network monitoring. This issue is discussed in some detail later in this report (Chapter 6).

It should be noted that the harmonisation would relate specifically to measurements made in wet conditions: the frictional properties of roads affected by ice or snow, or contaminants other than water, are outside its scope.

While formal harmonisation may not be necessary for measurements made for research, (including accident investigation), there is potential relevance to these fields also, since it is likely that researchers or accident investigators might wish to understand their data in the context of conditions on the wider road network.

It is recognised that there will always be some situations where a specific measurement technique has a particular application and that direct comparison with a different technique may be neither practicable nor appropriate.

2.2.4 The concept of a Common Scale

At present, different types of device report values on different scales that are not directly comparable with one another. To overcome this problem, the key challenge is to define what this report refers to as a Common Scale, against which measurements from different sources can be compared and understood.

The concept of providing a Common Scale on which different techniques can be compared is the greatest challenge to harmonisation. However, once established, required skid resistance levels set for new surfaces or included in skid resistance policies could then be based on the Common Scale but individual countries could use their own devices to make the measurements. Alternatively, such threshold levels could be based on a “local” device but, by using the Common Scale, different authorities can easily compare their levels with those used elsewhere.

The broad principle for a Common Scale is that it represents values of friction achieved under certain standardised test conditions, in which key parameters relating to the test conditions are closely controlled. In this report, these are referred to as “reference conditions”. Surfaces that provide a lower level of grip would give smaller values on the Common Scale and vice versa.

Results from different types of test device operating under their own test conditions would be related to this scale using “conversion formulae” determined initially from research. As new devices are developed in the future, they would be incorporated into the control strategy so that conversion formulae are established for them and they can also report values on the Common Scale.

The reference conditions might prove to be theoretical, in that no individual type of measurement device would meet them exactly whenever it makes a measurement. Further, the actual reference conditions chosen will be affected by the approach taken for defining the Common Scale, as will become clearer later in this report.

Essentially there are two different approaches to achieving harmonisation with a Common Scale that everyone can use:

(a) *The adjustment or conversion of the outputs of different measurement devices so that all devices report the same value*.

With this approach, for the measurements to be considered harmonised it must be possible to use one device under one set of test conditions and to calculate a value on the Common Scale that can be replicated by other devices measuring on the same surface under their own, different, test conditions.

The major advantage of taking this approach to harmonisation is that all existing devices can continue to be used but still report their results on the Common Scale. However, because different types of device can be used to make measurements from day to day, with this approach there will inevitably be some loss of accuracy compared with using one type of device alone. If this is too great for practical purposes (and, as is discussed in Chapter 6, what is acceptable in terms of accuracy may vary depending on what the data are to be used for), it may not be possible to harmonise measurements for a particular purpose.

There have been a number of attempts to achieve a reliable Common Scale using this general approach, most notably the PIARC International Experiment in the early 1990s and the more-recent FEHRL HERMES project. (The various previous harmonisation studies are reviewed and discussed in detail in TYROSAFE deliverable D05 [4].) Although some progress was made, there is not yet a scale or system that can harmonise the range of devices currently used in Europe with sufficient precision to be of practical application with widespread acceptance.

(b) *Compel the use of a single and common measurement method, encompassing measurement device characteristics, test tyre and operational conditions.*

This second approach to realising a Common Scale is, in effect, full standardisation of all aspects of the measurement method and allows only one type of device to be used. Although it simplifies the process of setting the Common Scale, issues relating to the need to verify that the standardised measurement devices perform consistently and acceptably remain relevant.

However, even with this approach, in practice, there may still be a need to provide conversion formulae for some variations in the standard conditions (particularly operating speed) between individual sets of measurements and the defined conditions for the Common Scale.

2.2.5 The need for a defined reference skid resistance level

The principle of harmonisation relies on measurements from individual devices being compared with values that represent a reference level of some kind. Adjustments or conversions are then made to relate the individual device measurements to this reference which, in effect, becomes, the Common Scale. This applies to either of the two approaches suggested in Section 2.2.4, although clearly the conversion process is likely to be more straightforward for the standardisation approach in which only one type of device is in use.

Whatever approach is taken to establish a Common Scale, it is obvious that there would have to be a large number of measuring devices in use across Europe to make the necessary day-to-day measurements. However, as soon as two or more individual devices are brought into use, whether of different types or several examples of the same type, the question that arises is, which one is correct? No matter how well-controlled the test conditions may be, even with nominally similar machines it is entirely normal for there to be small differences between their measurements, some random and some systematic.

Statistical techniques such as calculation of mean values, repeatability and reproducibility can be used to indicate the magnitude of variations to be expected within and between different sets of measurements. Although these can indicate the extent of variation, a reference level is still needed to verify that the actual measured level is maintained over time within the range expected.

At the heart of harmonisation, then, is the establishing of a reference level that defines the Common Scale and then determining the conversion processes needed to express the results from individual test machines on the Common Scale. Here, there is a major difficulty because, as mentioned in Section 2.1, there are no absolute levels of friction against which devices may be compared.

It has been suggested that providing an absolute level by means of reference surfaces that can be manufactured repeatedly to have and maintain predictable known properties would help in this. This concept is also being addressed by the TYROSAFE project but, as yet, such surfaces do not exist. However, even if they did exist, they would simply represent fixed points on the friction scale under a particular set of test conditions. They would still give different results under different test conditions. At best, therefore, their use is likely to be limited. They could be used to manage the consistency of whatever reference measurements are chosen for the Common Scale by providing a consistent set of surfaces on which to make them. They could also be used to verifying that individual devices continue to perform consistently over time.

Therefore other approaches to providing a reference level must be considered. These will inevitably involve using a defined set of measurement machines to provide the reference values – referred to later in this report as a “reference fleet”. As will be discussed later, the reference fleet could range from one carefully-controlled individual machine – a so-called “golden” machine – through to a number of machines of similar or different device types.

Again, it must be borne in mind that these ideas apply to test methods that are used to provide data for the routine categorising road surfaces for network management and for materials acceptance purposes. Other uses (such as research) may require a method or scale for which a Common Scale or a single standardised measurement technique would not be appropriate.

3 Towards a roadmap

3.1 A broad definition

Someone has suggested the following definition of a "roadmap" as a guideline to achieving a particular objective:

> *"A detailed plan or explanation, usually in the form of tables or diagrams, to guide people in releasing new products, setting standards or determining a course of action. The plan is composed of a series of steps to be carried out or goals to be accomplished in order to move from the current situation to the desired final situation".*

Applied specifically to the TYROSAFE WP2 context, a roadmap describes the different possible routes, and their individual steps and timetable, to move towards a harmonised road skid resistance assessment method across Europe. The steps will need to make provision for aspects such as development and testing of equipment, quality assurance and an implementation strategy.

In developing such a map, it is important to take account of lessons learnt from previous research and to identify any further research that might be necessary. A number of different options for routes to reach the final destination can be identified and these need to be considered so that the individual steps for each route can be determined and an assessment of their achievability can be made.

This approach enables key stakeholders to provide input to the process and to express their preferred options. Achieving buy-in from stakeholders at an early stage is an important part of fulfilling the aims of the TYROSAFE project and moving the work forward. The Workshop held in London in September 2009 provided just such an opportunity for discussion and views expressed there have been taken into account in this report. In the remainder of Chapter 3, the main issues that need to be considered in developing a roadmap will be discussed but, before any possible routes can be mapped, the "desired final situation" must be clear.

3.2 What is the destination?

Broadly, from a TYROSAFE perspective, the desired final situation, or ultimate destination for the roadmap is, by 2020, to have achieved a position in which a harmonised measurement method for skid resistance is available and implemented within Europe. However, there are three different variants of this destination that can be suggested:

(a) A situation in which all (or most) of the devices currently in use (and possible new ones yet to be introduced) can continue to be used in individual countries with a harmonised Common Scale that is applied to for the specific applications of network monitoring and materials classification/acceptance within the EU (referred to later in this report as a Harmonised EU System).

(b) A fully standardised situation in which one standard measurement technique is used for the specific applications throughout Europe (referred to later in this report as Full EU Standardisation).

(c) An optional system in which there is no formal harmonisation or standardisation but comparison techniques are available that countries can use should they so choose (referred to later in this report as Optional Use of Common Scale).

Before any of these final destinations can be reached, it is necessary to develop the Common Scale and this represents the first main destination on the journey. Lessons learnt in achieving that and the form that it takes will also influence the choice of final destination.

Having established the concepts of final destinations, the next step in the process in developing a roadmap is to consider the routes to be followed to reach them. In Section 3.3 the main technical issues that will need to be considered and resolved, and which ultimately will dictate the choices of route to be followed, are outlined.

3.3 Technical issues affecting possible "routes" on the map

3.3.1 Establishing a reference level to define the Common Scale

The choice of reference level is clearly an area requiring careful thought. In practice, it will need to be provided by measurements from a specific set of individual measurement devices (referred to here as the "reference fleet") operating under defined conditions on the same road surface. Calculations would then be necessary to convert the individual device measurements to values that would be expected under the reference conditions defined for the Common Scale.

The average value of the results for the reference fleet on one surface would provide a reference point on the Common Scale. A series of road surfaces representing the practical range of skid resistance characteristics can be used to provide a set of points to represent the whole scale, in combination with regression techniques to determine an equation if desired[2]. Independently, individual devices in larger national fleets of machines would need to be "calibrated" to the machine of the same type that represents them in the reference fleet.

Previous attempts at establishing a reference level to define a Common Scale have taken two forms: use of the "average of all devices" as the basis, which was followed in the PIARC and HERMES experiments, or the identification of a single specific device that is defined as a reference, as has been proposed in the airfield context with the IRFI [4]. (These concepts are also used currently in some individual EU countries to regulate fleets of similar devices that monitor their networks but do not extend to harmonisation of different device types.)

Having reviewed previous work and considered the issues identified, the TYROSAFE team has identified the following broad options for establishing a reference level:

[2] It is in this context that reference surfaces, were they to be developed, would be of particular value since they would represent fixed points on the Common Scale that would not change over time.

- Persist with the "average of all device types" approach used in the past. This would involve a reference fleet of several different types of device; this leads to some complex modelling to take account of the different operating principles (and the way that they are affected by test conditions) in order to establish the reference values on the Common Scale. Consequently, this is likely to be the approach that has the greatest inherent variability.

- Reduce the potential variation in the reference level by selecting a reference fleet that comprises a smaller group of devices that are of different types but which operate on similar principles.

- Reduce potential for variation further by restricting the reference fleet to nominated examples of one existing device type.

- Pursue the concept of defining an individual machine to provide the reference level – in effect a reference "fleet" of one vehicle. In this case either an existing device should be selected or a new device must be developed and evaluated (as was suggested as a possibility by the HERMES team) to fulfil this role.

3.3.2 Conversion processes

The second technical issue to be resolved in relation to establishing a Common Scale is that of the conversion mechanisms. These will probably need to be based on mathematical models, supported by empirically derived coefficients relating to each device, which can be used to calibrate the individual devices (or groups of similar devices) to the Common Scale.

The dominant influence on these processes will be the major physical factor that affects skid resistance measurements, namely the way in which the measured value changes with the test speed and how that change is influenced by the road surface macrotexture. The main difficulty in dealing with harmonisation is to find a way to take account of the interactions between the factors that have the greatest effect on the measured friction, in order to arrive at values equivalent to those that would be obtained under the reference conditions that would apply to a Common Scale.

In this context, key factors include:

- The slip ratio of the device for wheel-based systems. This influences the speed at which the test tyre slides over the surface (the slip speed).

- The test speed. This acts in combination with the slip ratio to affect slip speed.

- The difference between longitudinal and sideways-force friction coefficient. This difference is often addressed by converting yaw angle to slip ratio, but this possibly does not eliminate all differences.

- The properties of the test tyre (tyre size, load and pressure, tread pattern, rubber properties). These have a direct impact both on the level of friction recorded and the way in which the tyre responds to changes in other factors.

- The properties of the road surface itself. These, particularly macrotexture (both in terms of texture depth and form), influence both the friction levels and the way in which friction changes with speed.

Whatever route or principle is chosen to provide the reference level, further research will be required to address these issues in order to provide a conversion process that gives sufficient accuracy and precision to the Common Scale for it to be acceptable in practice.

3.3.3 Quality assurance

Once a harmonised system has been established, it will be essential that it is supported by good quality assurance (QA) systems and procedures. A particularly important issue is that of providing, demonstrating and maintaining appropriate consistency over time for the reference fleet that is used to define the Common Scale.

There are two important aspects to include:

(a) Establishing written specifications governing the fundamental design principles and operation of the measurement devices.

The absence of such documentation, and the consistent practice that it encourages, was found to be a weakness in earlier experiments such as PIARC and HERMES. It is partly to assist with this issue that Technical Specifications for many of the devices used in EU countries have been prepared through CEN Technical Committee 227 Working Group 5 and are soon to be published.

(b) Establishing formal QA procedures that operators of test equipment will need to follow.

These will build on the technical specifications by setting out other requirements, including provision for regular checks on calibration between the various operational devices and those of the reference fleet for the Common Scale. The procedures will also need to cover regular cross-checks between the members of the reference fleet to ensure the stability of the Common Scale.

Clearly, any QA systems will need to be developed and evaluated alongside the other aspects of arriving at a Common Scale before they are formally introduced; they will have a significant impact both on the effectiveness of the harmonisation initially and on its longer-term maintenance.

4 The TYROSAFE Metro Map

4.1 The concept and structure

In discussing options for a roadmap, the TYROSAFE team explored a number of ideas. It was recognised that, although some detail might vary, there were considerable similarities to the various approaches that were being considered. In order to assist the process of assessing the best potential way forward, it was decided to represent the roadmap using the familiar idea of the “Metro Map” (or “Tube Map” as the London original is popularly known). This would allow the different potential destinations and routes conceived for the TYROSAFE roadmap to be presented in a simple comparative way. Completion of the various intermediate actions could be represented as “stations” on the route and the diagram could be drawn so that similarities and differences between the various routes could easily be identified without becoming bogged-down in too much detail.

Building on the concepts outlined in Section 2.2 and following the ideas discussed in Section 3, (and the detailed analysis recorded in TYROSAFE D05) it was decided that the process of harmonisation should comprise two phases:

- Determination of the Common Scale
- EU Application

The first phase would represent different routes to arriving at a Common Scale, which would represent the first major “station” on the journey. From this point, the route followed in the second phase of applying the harmonisation principles in the EU would depend upon the ultimate destination chosen. The options for ultimate destination would also be influenced by the choice of route to achieve the Common Scale.

In the first phase, the routes would represent the different approaches to determining the Common Scale, depending on the number and/or type of devices used to determine the reference level for the Common Scale. The options were eventually narrowed down to four routes, which increasingly constrain the basis on which the reference level is determined. The proposed routes can be summarised as follows:

- Route A: harmonisation using a Common Scale reference level calculated from the average of all devices in use (provided that they have a Technical Specification to define their operation and use).
- Route B: harmonisation using a Common Scale calculated from the average values from of a subset of existing device types that operate on a similar principle.
- Route C: harmonisation using a Common Scale provided by average values for a single existing device type.
- Route D: defining the Common Scale by reference to values from a specified machine. In this case, two “branches” would be needed – one using an existing

device type, the other using a new, purpose-designed device type. This route would be the natural starting point for a “standardisation” final destination.

In the second phase, these routes would be extended to reach the appropriate final destination which would be, as identified in Section 3.2, either a Harmonised EU System or Full EU Standardisation. A separate route (designated Route E) would represent the third, Optional Use of Common Scale, destination beyond the establishment of a workable Common Scale.

4.2 Some definitions

Before looking at the map itself, for clarity it is helpful to explain some of the terms used on the diagram and subsequent chapters of the report.

- A ***standard*** is a formally agreed document which everyone must follow[3].
- A ***specification*** is a formal document that defines precisely the requirements for a skid resistance measurement device, including the key operating principles, and physical characteristics.
- A ***procedure*** is a document or group of related documents that sets out processes that must be followed.
- A ***device type*** is a particular implementation of a skid resistance measurement specification, such as SCRIM or IMAG. There may be just one example or there may be large fleets in individual countries; there may be separate fleets in different countries.
- A ***machine*** is one individual example of one device type.
- A ***reference fleet*** is a group of machines used to provide representative average skid resistance values for points on the Common Scale, against which all others are calibrated. Depending on the route followed, the reference fleet may comprise several machines of different device types or several of one device type
- A ***reference machine*** is one machine used to provide the reference points on the Common Scale for some routes on the map, rather than use a reference fleet. The term is also used to refer to a machine within the reference fleet that may be used as a reference for calibrating to the Common Scale a group of other machines in a national fleet of the same type.
- An ***operating principle*** refers to the basic principle on which a device type operates. This includes whether it uses LFC or SFC methodology and other important parameters such as slip ratio, load and tyre type.

[3] In this context, this refers to a document covering test and other procedures associated with defining the harmonisation process. It should not be confused with the idea of “standards” in the context of specific values, or thresholds, of skid resistance that countries might set as part of their road surface construction or network monitoring strategies.

4.3 Overview of the map

The full Metro Map is shown in Figure 4.1, with the routes grouped according to the fundamental principles that they use. Each intermediate "station" (shown as a small square at the side of the route or an oval or rectangle through which the routes pass) represents the completion of a particular activity. It should be borne in mind that, although some activities are similar on the various routes, the detail of the work involved and the time that it will take may well be markedly different. In particular, significant research and comparative testing will be required to reach the "Conversions developed" stage, whichever route is followed.

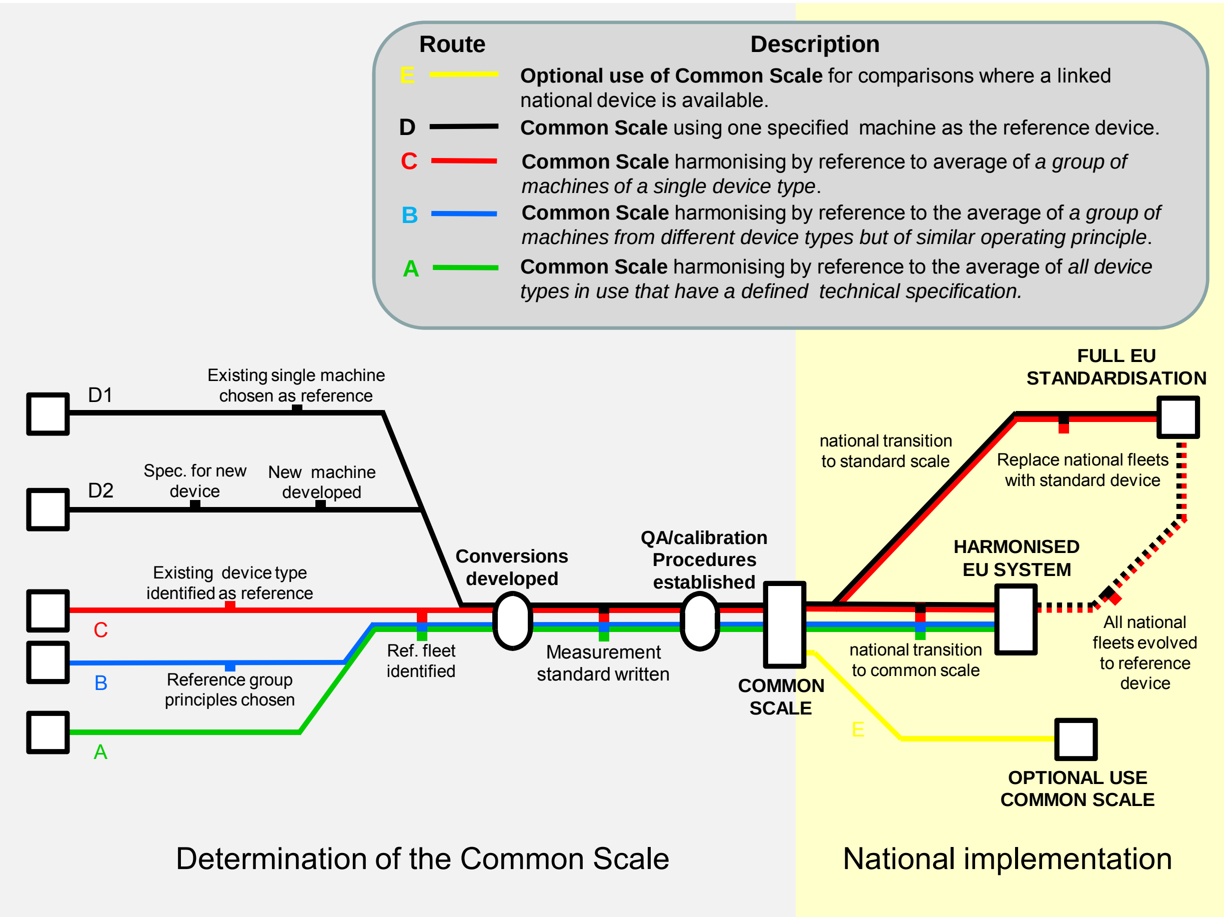


Figure 4.1 The TYROSAFE Metro Map

It can be seen that all routes reach the Common Scale but, for some of them, options for the EU applications are restricted. It was therefore important to seek views as to which final destination would be preferred before deciding on the appropriate route to reach it. This was one of the topics discussed at the London Workshop.

The diagram also shows that in reaching the Common Scale there are a number of "interchanges" (the stations represented by oval shapes) where an opportunity exists to change routes. This allows the possibility for starting out on one route (or, indeed, two in parallel) and then, in the light of experience as the ongoing research progresses, to change to an alternative. However, these changes are mainly restricted to changing to a route further up the diagram (e.g. from B to C but not vice versa).

It was also recognised that, over time, countries would need to replace their existing equipment and that there could well be a trend to move towards purchasing the same equipment, especially if a reliable standard or single device (established following Routes C or D) were established. In that instance, there might be a natural progression from the "Harmonised System" destination towards the "Standardisation" position and this possibility has been illustrated with the broken line on the diagram.

Chapter 5 provides a more detailed explanation of the stages on the roadmap, including the differences in approach and steps involved on each of the individual routes to reach the Common Scale, together with the issues associated with the EU application phase. The advantages and disadvantages of the different routes are discussed in Chapter 7. A separate chapter (Chapter 8) discusses the broader issue of timetable and costs.

5 The alternative routes in more detail

5.1 Using Roadmap A to determine the Common Scale

5.1.1 The principle behind Roadmap A

The approach used in Roadmap A achieves harmonisation by reference to the average of all device types in use. This is the most complex of the approaches because it derives the Common Scale from a reference fleet that includes a wide range of device types. It also attempts to harmonise results across the full range of operating conditions that the devices represent.

The Common Scale is defined as the average friction coefficient obtained from the reference fleet operating under reference test conditions. However, because different device types with different operating principles are involved in the definition of the Common Scale, a way to define the reference conditions has to be found that can be related to each operating principle in a generalised manner.

This is the broad approach that was followed in the PIARC International Experiment (developing the IFI) and the HERMES study (evaluating the EFI). Both studies used the idea of the slip speed providing the basis for the reference conditions. A conversion formula was developed that would adjust the measured value at the actual test speed to what it would have been at the reference slip speed (60 km/h in the case of the IFI, 30 km/h for the EFI), including a component that represented the influence of surface texture on the change in measured friction with speed. Therefore, a measure of texture depth was also required in addition to the basic friction measurement.

The grand average of the friction values at the reference speed calculated in this way from measurements by a set of reference devices (the reference fleet) on a number of surfaces provided reference points on the Common Scale. A regression equation then established a model for the Scale and further regression equations were developed to determine the coefficients that would relate individual devices to the Common Scale to prove a device-independent value.

In principle, this approach, using the average of all devices as the reference, allows any device to be linked to the reference fleet. However, as the previous experiments showed, it is inherently likely to be the least precise.

5.1.2 Steps for implementing Roadmap A

This section discusses the activities that will be needed to reach a Common Scale based on the work involved to reach each station following Route A of the Metro Map (Figure 5.1).

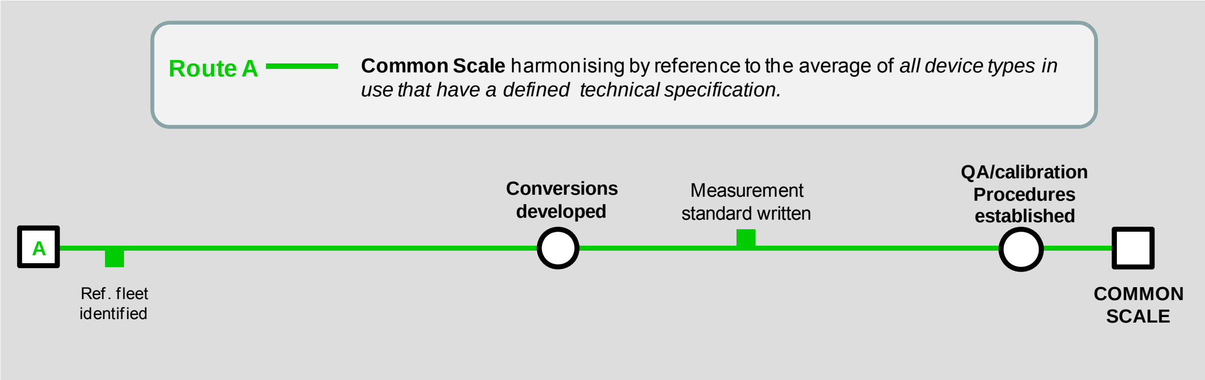


Figure 5.1 The stages in the first phase of Roadmap A

(i) *Identify the reference fleet*

Theoretically, when following this route the Common Scale is based on the average of all device types. However, in practice it will only be possible to determine reference levels with a limited number of machines and so the first step is to identify the specific device types to be included and the individual machines which will, in turn, become representatives of their device type, or of the larger fleets to which they belong.

Minimum criteria for a device type to be included in the reference fleet (they might be called "golden" devices) would be that there should be a formal technical specification regarding its design principles and operation, which should also include QA provisions regarding its calibration and repeatability.

The reference fleet can be enlarged over time, although an acceptance procedure will need to be determined for the integration of new device types. This should include checks to verify that the addition of the device will not significantly alter the value of the Common Scale since this could trigger a need to review all the conversion relationships and might lead to a drift in national standards based on the Common Scale. A tolerance on the updated values on the Common Scale might therefore need to be additional admission condition. It may also be necessary to make provision for eliminating devices from the reference fleet as well as adding them[4].

(ii) *Develop conversions*

Once the reference fleet has been identified, research will be needed to establish the Common Scale and the methodology for converting measurements from individual machines to values on that scale. A distinctive feature of Roadmap A is that the main conversion formulae are applied as an integral part of the process of defining the Common Scale itself, not just in relating individual device types to the scale.

[4] Inclusion of an example of a particular device type in the Roadmap A reference fleet is essential for that device to become part of the harmonised system. The reproducibility of national fleets of machines of the same type would be taken into account when national fleets are calibrated to the reference device and when issues of accuracy in relation to potential use of the measurements are considered (discussed in Chapter 6). If it were found that inclusion of a device had too great an influence on the stability of the Common Scale then it may not be possible to harmonise it.

This is the most sensitive aspect of this harmonisation option. As with all options, the models will need to be accurate enough to minimize the uncertainty related to the estimation of the Common Scale. A significant element, therefore, will be the definition of the reference conditions. Previous attempts using this approach defined the reference test conditions in terms of the slip speed which, it was thought, could be calculated for any device based upon its operating speed and slip ratio from a general formula. If previous practice is to be followed, then conversion to reference conditions is likely to involve the speed and the slip ratio combined in a speed dependency model that includes road surface texture depth.

However, experience in the HERMES and PIARC experiments has shown that the theoretical models typically used were not sufficiently rigorous to take account of the responses of the various device types on different types of road surfaces and this leads to unacceptable precision for some purposes. Consequently, the research required to reach the Conversions Developed station on Roadmap A will need to include work to improve the models.

In this context, it should be noted that analysis of the previous harmonisation exercises [4] concluded that the speed and the slip ratio probably should not be combined. The other parameters involved in the development of friction in any measurement device (tyre characteristics, water depth, etc.) are device specific: they may interact differently with speed, slip ratio and road surface texture, so speed and slip ratio should treated separately.

The calculation of a grand average to provide the Common Scale values has been widely used but this is not the only possible approach. Other statistical parameters such as weighted average or median might also be considered.

(iii) *Write a measurement standard*

One requirement for inclusion in the reference fleet is that a device should have an established Technical Specification that indicates the key requirements for the device and describes how it should be operated. However, the processes involved in reaching the Conversions Established point on the route will involve operating the devices following these procedures and using them to establish the Common Scale.

It is inevitable that there will be an iterative process in which the methodology and formulae are established and estimates of precision are made. This will involve a number of tests in different places to allow different groups of devices to come together and to provide a sufficient range of test surface characteristics; consequently the process will take some time. It is quite possible that this process will identify areas of the Technical Specifications themselves that could be improved upon.

Once the work is completed, a standard must be written that will draw on the experience gained and become the formal definition of the Common Scale and how measurements for the Common Scale are to be made. The Standard, which may be one document or a related set of documents, would need to cover the following points:

- How the basic scale is established and maintained.

- The reference fleet
  - Including how new device types are to be incorporated or excluded.
- How measurements are to be made.
  - Although the document would not include the Technical Specifications for every device type, it would need to cite those documents as normative references by which day-to-day measurements are to be made where the results are to be used to calculate values on the Common Scale.
- How the Common Scale values are to be calculated from day-to-day measurements.
  - Part of the documentation would need to cover any device-specific values to be used in such calculations, either by inclusion explicitly or by reference to a separate document that may be updated from time to time as ongoing calibration checks are made.

(iv) Establish QA/calibration procedures

As explained in Section 3.3.3, having a written standard for the Common Scale is an important step but it is also vital to have established the QA procedures that are needed to maintain it and reassure the user community that the data provided are reliable.

To reach this point on Routemap A, the experience from the work to develop the Common Scale should be used to establish the key components of the quality system, which should include:

- Verification that devices are being operated according to their Technical Specifications.
- Provision for ongoing checks to verify that the Common Scale remains stable over time.
  - This is likely to be a complex process on this route because of the number of different device types involved. As well as the incorporation of new devices, with a large number of device types involved that may evolve over time, a procedure will be needed to verify the stability of the Common Scale.
  - Such a procedure was included and evaluated in the HERMES experiment which demonstrated in principle that this can be done.
- The basic requirements for calibrating larger fleets to the Common Scale by comparison with their representative in the reference fleet.
  - This might include, perhaps, the level of precision in terms of the repeatability and reproducibility that should be achieved by that device fleet.

5.2 Using Roadmap B to determine the Common Scale

5.2.1 The principle behind Roadmap B

The principle in Roadmap B uses the average friction coefficient provided by a group of machines from different device types but of similar operating principles to define the Common Scale. This approach attempts to improve the precision of the Common Scale compared with Roadmap A. By restricting the reference fleet to a subset of devices operating on the same principle, it is envisaged that the potential complexity of the initial conversion process would be reduced significantly.

Examples of the “same principle” might be those using longitudinal force or those using sideways force. The approach reduces the potential differences between the actual operating conditions and the reference conditions for the Common Scale.

Separate conversion equations developed to link devices types outside the reference fleet to the Common Scale would be applied to enable their results to be reported on the scale.

5.2.2 Steps for implementing Roadmap B

This section discusses the activities that will be needed to reach a Common Scale based on the work involved to reach each station following Route B of the Metro Map (Figure 5.2).

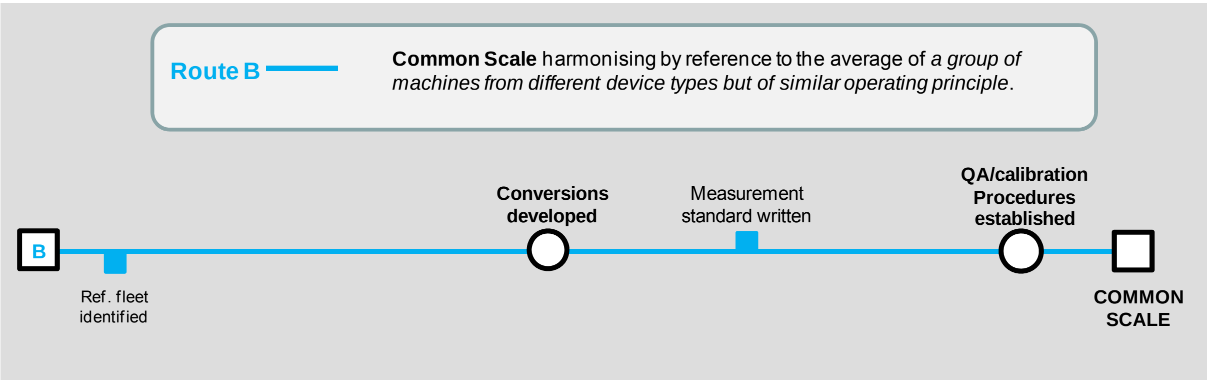


Figure 5.2 The stages in the first phase of Roadmap B

(i) *Choose the reference group operating principles*

On this route, before a reference fleet can be identified, the operating principle must be determined. The first idea to come to mind is to narrow the field by combining measurement direction (LFC or SFC) and slip ratio. This leads to the following possibilities:

- SFC devices.
    - This could then be further narrowed by limiting the reference group to devices having the same wheel angle (and hence slip ratio).
    - In practice, all SFC devices in current use operate with a similar wheel angle (typically 20º) so this restriction would apply by default. However, there would

still be some differences between the device types, most notably in terms of vertical loading and tyre properties.

- LFC devices.
    - This is a broad category but devices in this category fall essentially into two main groups.
        - Those that operate under, or close to locked-wheel conditions (say 80% slip ratio or greater)
        - Those that operate under conditions close to those used by ABS systems (say around 12-18%).
    - It should be noted that some LFC devices are controlled mechanically to a fixed slip ratio while others use servo-systems that constantly adjust the brake force to maintain a slip ratio close to a target level. Still other device types record the full friction/speed curve as the brake is applied and then interpolate a friction value corresponding to a specific slip ratio.

In selecting the reference group operating principle, it should be borne in mind that the accuracy of the Common Scale could be further improved if the reference group principles are close to the reference test conditions that will be used to define the Common Scale. A further aspect to consider is that there could be advantages in selecting a principle that represents a significant number of existing device types or a type that is already widely used, thus increasing the chances for improved precision. If necessary, further restrictions on the reference group could be added for the test tyre or the operating speed.

(ii) *Identify the reference fleet*

When following this route the Common Scale is based on the average of a selected group of device types rather than all devices, as used in Roadmap A. While this narrows the field, it will still be necessary to identify the specific device types to be included and the individual machines that will represent them.

As with any of the possible route options, a basic requirement for a device type to be included in the reference fleet is that that there should be a formal technical specification regarding its design principles and operation which should include QA provisions regarding its calibration. However, in this case a further criterion would be applied, namely that its operating principles are within the range defined.

Selection of individual machines might be based on choosing representatives of larger fleets of the same type (for example, were SFC to be chosen as the operating principle, SKM and SCRIM machines from different countries plus Odoliographs might be included). The size of the reference fleet needs to allow sufficient machines to be included to allow a reasonable estimate of the precision of the Common Scale.

The reference fleet can be enlarged over time to incorporate any new devices that might be developed which use the same general operating principles as those defined for the Common Scale. As with Roadmap A, an acceptance procedure will need to be determined for the integration of new device types. This should include checks to verify that the addition of the device will not significantly alter the value of the Common Scale. A tolerance on the updated values on the Common Scale might therefore need to be additional admission condition.

(iii) *Develop Conversions*

With Roadmap A, the process of developing conversion formulae needed research to define a set of reference conditions, and then find and evaluate an approach that could reliably convert measurements from all the device types from actual to the reference conditions. A secondary process then linked the individual device types to the “grand average” value that defined the Common Scale.

With Roadmap B, the process would be similar but there is a difference in that the initial conversion to define the Common Scale is more straightforward because the reference fleet devices will already be similar in operating principle. This provides for a relatively straightforward programme of research to define the Common Scale itself. Furthermore, devices in the reference group are automatically linked to the scale using the formulae established in that process. However, some conversion formulae may be needed to deal with the situation where reference devices are routinely operated under test conditions that differ from those used to establish the reference level.

Importantly, with this approach, devices that are not of the same types as those represented in the reference group still have to be linked to the Common Scale. It may be possible to develop a group of generic models that work well to convert devices from one broad operating principle to that of the reference group, with different “coefficients” being applied to take account of differences between individual device types such as their tyres or specific slip ratio. Alternatively, it may prove necessary to establish specific relationships for each device type.

The important difference between this approach and that of Roadmap A is that the conversions can be established to suit each device type. This in turn simplifies the process of adding new devices since they do not affect the established Common Scale, but simply have to be related to it with acceptable precision. It may prove that, to obtain acceptable precision, the conversion equations or coefficients for non-reference group device types will only hold for certain operating conditions. Clearly, these would be chosen to represent the most regular use of the particular device.

(iv) *Write a measurement standard and establish QA/calibration procedures*

The processes needed to reach these next two stages following Roadmap B are essentially the same as their equivalents on Roadmap A. Although there will be some variation in the detail, the principles are identical.

5.3 Using Roadmap C to determine the Common Scale

5.3.1 The principle behind Roadmap C

Roadmap C achieves harmonisation by developing a Common Scale with reference to the average of a group of machines of a single device type. This goes a stage further in controlling the precision of the Common Scale itself by limiting the reference fleet to just one device type.

This provides for a simple approach to establishing the Common Scale and its precision. However, as was the case with Roadmap B, each individual device type other than the reference has to be separately linked to the Common Scale.

5.3.2 Steps for implementing Roadmap C

This section discusses the activities that will be needed to reach a Common Scale based on the work involved to reach each station following Route C of the Metro Map (Figure 5.3).

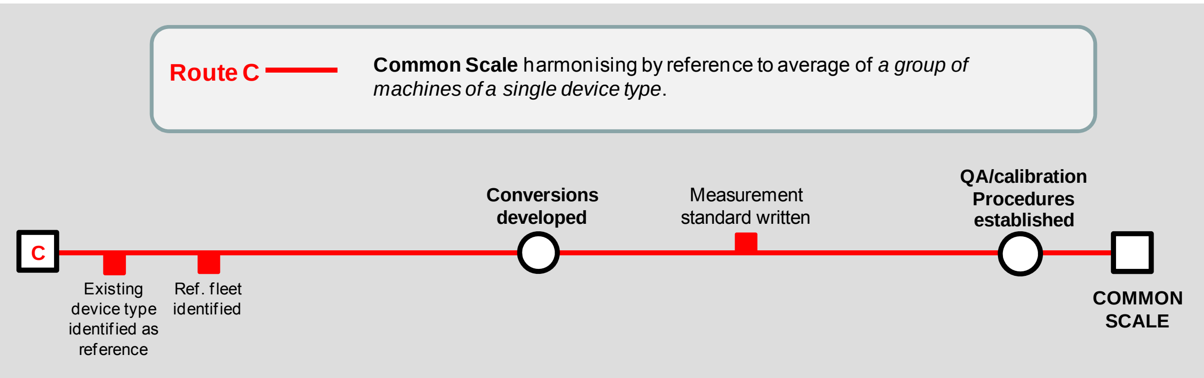


Figure 5.3 The stages in the first phase of Roadmap C

(i) *Identify the reference device type*

The first step on Roadmap C is to choose the existing device type that is to provide the Common Scale. Clearly, there are as many options as there are devices and so it will be necessary to establish criteria to guide the decision. As with any of the roadmaps, the device and how it is used must be adequately described through a Technical Specification.

Since one of the reasons for choosing this route is to improve on the precision of the Common Scale in comparison with Roadmaps A or B, some knowledge of the precision of the device type will be needed. This requirement would tend to favour device types that already exist in reasonably large numbers.

The use of measurements to support policies as well as verifying contractual requirements means that devices capable of continuous measurement are needed. This would automatically rule out locked-wheel measurements.

Based on these criteria, of existing devices the following candidates emerge:

- SCRIM. This side-force device is already widely used in Europe with established procedures for controlling precision, especially in the UK.
- SKM. Although confined mainly to Germany, this side-force device is used in relatively large numbers and also has well established controls on precision. SKM operates on identical SFC principles to SCRIM but differs from that device in a few details, most notably the test tyre compound (the tyre dimensions are the same).
- Griptester. This is a “near-ABS” fixed-slip device which is widely used in Europe but as yet there are no a rigorous controls on precision.
- BV-11 and SFT. These are two variants of the same device that also operate on a “near-ABS” fixed-slip principle and use the same 17% slip ratio and tyre type. These tend to be used primarily in Nordic countries but not in the same numbers as the devices above.
- IMAG is another near-ABS device with 15% slip ratio. Currently the device is not used on roads and it does not yet have a written CEN Technical Specification. However, it is included as a possible candidate because the IMAG has been specified for some years as the reference device for the IRFI, which has been proposed as a harmonised skid resistance approach for airports[5].

There are other devices but they tend to be individual examples (so, using them would be the same as route D1). Some are not produced commercially, or there are doubts about their longer-term existence or manufacturer support. Those listed above are considered by the TYROSAFE team to be the strongest candidates for the reference type for Roadmap C.

(ii) *Identify the reference fleet*

Roadmap C relies on the average result from a number of examples of the same device type providing the reference level. Therefore, having established the reference device type, it is still necessary to select a number of individual machines to act as the reference fleet.

For this purpose, it is suggested that a minimum number of devices, perhaps six, should be chosen in order to establish a reliable average and to be able to properly estimate the precision of the Common Scale itself. Although it would be possible to select machines from one closely-controlled fleet, a better indication would be to include machines from a number of countries.

However, previous experience in the PIARC and HERMES studies found that machines that were even nominally of the same type could give markedly different results when they were operated and maintained in different countries. Therefore, in selecting the initial reference fleet, machines that already operate under rigorous quality systems or undergo regular cross-checks with other machines of the same type should be chosen.

[5] It is understood that, although a standard for determining the IRFI has been written (ASTM E2100-02), currently it is not actually used routinely for airports.

(iii) *Develop Conversions*

The process for developing conversions for Roadmap C will be similar to that for Roadmap B. The difference here is that it should not be necessary to establish conversion formulae to convert measurements from the reference fleet to the reference test conditions since the latter can be chosen to match a given set of operating conditions which all machines will follow to establish the average values that will give the reference level.

However, as with Roadmap B, devices of the reference type will still need conversion formulae to deal with the situation of their day-to-day operation under different conditions (typically test speed) in their own countries. All other devices will need independent conversion relationships, although as with the other routes it may be possible to develop a smaller set of generic formulae for similar device types with individual coefficients to calibrate individual machines to the scale.

(iv) *Write a measurement standard and establish QA/calibration procedures*

The processes needed to reach these next two stages following Roadmap C are essentially the same as their equivalents on Roadmap A. Although there will be some variation in the detail, the principles are identical.

On this route, however, the process may be simplified because the reference device type should already have well-established QA procedures that could be adapted for wider use by devices of the same type.

5.4 Using Roadmaps D1 or D2 to determine the Common Scale

5.4.1 The principles behind Roadmaps D1 and D2

The two branches of Route D on the Metro Map achieve harmonisation by determining a Common Scale using one specified machine as the reference. Rather than use the average of a number of examples, one specific, closely-controlled example of a chosen type – a so-called “golden” machine – defines the friction levels that set the Common Scale. This approach therefore restricts the Scale to one device type and this would include defining a specified tyre type to maintain long-term consistency.

The approach reduces to a minimum any variation in the Common Scale itself and, in theory, makes it easier to control. However, without reference surfaces to provide a set of absolute friction levels against which the reference machine can be checked, the risks of drift over time remain.

The two branches of this route differ in the way in which the reference machine is established:

- For Roadmap D1, the reference machine is a specific representative of an existing device type.
- For Roadmap D2, the reference machine is of a new type designed and built specifically for the purpose.

5.4.2 Steps for implementing Roadmap D

This section discusses the activities that will be needed to reach a Common Scale based on the work involved to reach each station following Route D of the Metro Map (Figure 5.4). Although the roadmap starts out on either of two branches (D1 and D2), it can be seen that, once the reference machine has been identified, in all other respects the two routes are identical.

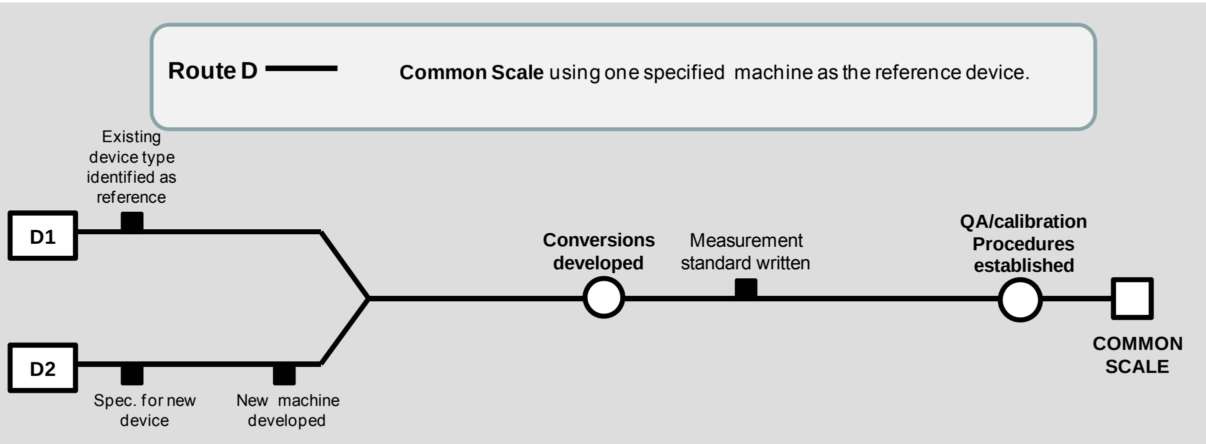


Figure 5.4 The stages in the first phase of Roadmap D1

(i) *Roadmap D1: choose the reference machine*

In principle, this should be easy, since it simply involves two steps: choose a device type from one of the many available and then select one example to be the reference machine. However, this may not be as straightforward as it appears at first sight since there may be political resistance or competition to become the reference device. Although this is recognised as an issue, at this stage of the report, technical aspects only will be considered.

In principle, criteria similar to those that were used to suggest candidate device types for Roadmap C could also apply to D1:

- An established Technical Specification and QA procedures.
- An understanding of precision for the device type, tending favour device types that already exist in reasonably large numbers.
- Continuous measurement principle.

Once the device type has been established, it will be necessary to identify the reference machine. Because of its status as a European reference, the machine chosen will need to be carefully controlled. Arguably, its use should be restricted only to measurement exercises that are carried out to establish (and then maintain) the Common Scale and to verify the calibration of other devices to the scale. It is likely that such a device would need to be in the ownership of, or sponsored by, a national authority since commercially-operated machines would need to be earning their keep and this could create conflict with maintaining a long-term reference status.

Examples of such devices do exist, such as the machine that is used to control the day-to-day operation of the German SKM fleet.

Since Route D on the Metro Map could eventually lead on to the Full EU Standardisation destination (discussed further in 5.5.3) the reference device could become, de facto, a future standard device. This aspect would need to be considered in the decision on device type. For example, would it be better to select a device type existing in large numbers (such as SCRIM) or should the opportunity be taken to use something working on a rather different principle (such as RoadSTAR) as was envisaged, for example, by the HERMES team?

(ii) *Roadmap D2: Specify and develop a new device type to become the reference machine*

The D2 route is included to provide an opportunity to review current practice and develop a new device that could be an improvement over existing designs. The stages on this branch of the route, therefore, involve two major steps – agree and draw up a specification for the device, then build and test it.

It is envisaged that the device specification would be performance related rather than a detailed mechanical design. The specification should be sufficiently realistic for manufacturers in any country to be able to build a machine in future conforming to the requirements of the new device type.

However, before that stage is reached, it would be necessary to develop and evaluate a prototype machine so that the effectiveness of the design and operating principles can be assessed and, if necessary, revised. There would be a significant research component in this process since it would also need to make some initial comparisons with existing equipment that might be the basis for the conversions for the Common Scale once the device was in service as a reference machine.

As part of this process, the various measurement principles and operating conditions currently used should be reviewed in order to arrive at a specification that would overcome any potential shortcomings or limitations of current designs and more closely fit with what are likely to be the needs for skid resistance measurements on a European level in the longer term. In this context, the range of potential operating conditions and the test tyre (including security of supply in the longer term), should be carefully considered. Importantly, as well as improving the equipment design, this approach provides an opportunity to reassess, from a theoretical perspective if necessary, what key road surface properties should be measured and in what conditions, so that the results give the best practical information that will relate to accident contribution, thus helping engineers maintain safety standards.

There is an argument for building more than one machine (to the same specification) to demonstrate that the specifications are robust. Furthermore, if more than one example were available, they could cover geographically all European regions and to reduce the amount of travel that might be needed for future calibration exercises. However, such a strategy then, in effect, becomes the same as Roadmap C but with an as-yet untried new reference device type (similar comments could also be made in relation to Roadmap D1).

(iii) *Develop Conversions*

In principle, for Roadmap D1 the general process of developing conversions will be identical that of Roadmap C since the only difference is that just one machine defines the Common Scale.

For Roadmap D2 the process will be very similar but the actual models required to define the relationships may differ because the principle of the new type of device will be different and every existing device type will need to be linked to the Common Scale. Again, depending on the similarity of the operating conditions of the new device and the reference conditions chosen to those of current devices, it may be possible to derive generic models that cover groups of similar devices.

(iv) *Write a measurement standard and establish QA/calibration procedures*

The processes needed to reach these next two stages following Roadmap D are essentially the same as their equivalents on the other routes. Although there will be some variation in the detail, the principles are identical.

On route D2, however, a brand new Technical Specification, measurement standard and QA processes will need to be written and evaluated during the development phase for the new reference device. Because the reference device would be new, some aspects of QA may not become apparent until further experience of its use has been gained. For this reason it might be considered appropriate to run the new device in parallel with harmonisation on one of the other routes for a time, before adopting it as a formal Common Scale reference device.

5.5 EU application of a Common Scale

Having established a Common Scale and QA processes for maintaining it, the next phase in harmonising skid resistance measurements is application of the scale in the various EU countries. This section of the report describes the general processes that will need to be followed to reach each of the potential destinations shown on the TYROSAFE Metro Map. The detailed ways in which this might be carried out will depend on many factors specific to each country, including any existing skid resistance policy it might have or an existing fleet of devices that it already operates.

5.5.1 Towards an optional use of the Common Scale

As will be discussed later (in Chapter 7) it is possible that there may be resistance in some countries to moving towards full harmonisation or standardisation. This might lead to a situation in which a Common Scale has been established but there is no formal requirement to use it at a European Level. Nevertheless, at a basic level, once the work to establish a Common Scale has been completed there is no reason why individual countries should not choose to make use of the scale for some purposes even though there is no formal EU or other requirement to do so.

For this reason, the Metro Map includes Route E, which leads to the Optional Use of a Common Scale destination as a possible route to implementation (Figure 5.5).

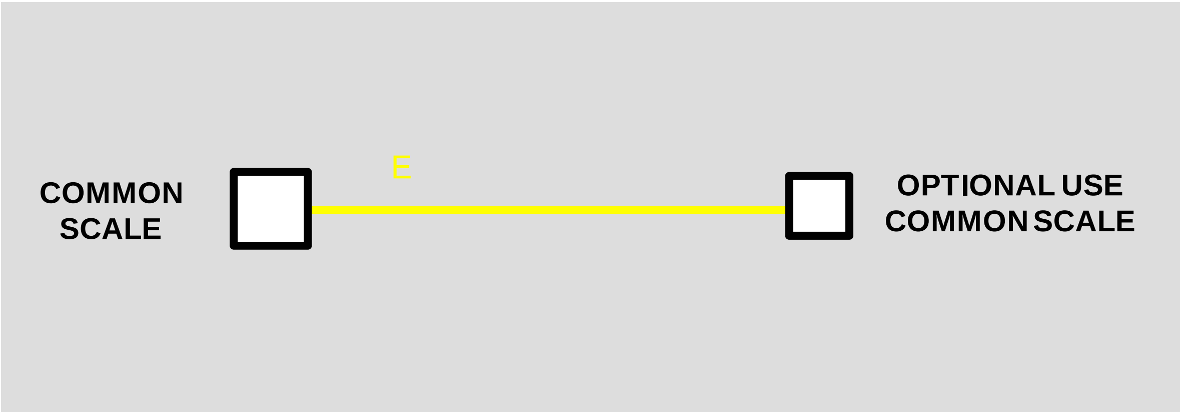


Figure 5.5 Route to optional use of a Common Scale

This option simply provides a route for countries to make use of the principles of harmonisation and utilise the Common Scale, for example, to provide an approximate comparison of their results with countries that use different devices or to agree a common approach with their neighbours. It can be followed whichever route is chosen to reach the Common Scale.

Some countries or road authorities within an individual country already have skid resistance policies or monitor skid resistance in some way. Often large fleets of one device type or sets of different device types are involved. In this situation, authorities could choose to adopt the Common Scale or its principles as a means of harmonising measurements within the country or as a supplement to their existing evaluation procedure, even though it was not a formal EU requirement.

Because its use is optional on this route, no further transition is necessary once the Common Scale has been established. However, a prerequisite for this approach to application is that the country would need to operate a device that has already been linked to the Common Scale. Furthermore, without a formal requirement, voluntary arrangements would need to be agreed among participating countries to carry out the ongoing work necessary to follow the QA procedures that link national devices to the Common Scale and continue the process of adding new devices and maintaining the long-term stability of the scale.

5.5.2 Towards a harmonised EU system of measurement

The primary goal of harmonisation of skid resistance measurements is to arrive at a situation in which existing devices can continue to be used in individual countries but where the measurements that they make are linked together and the policies that they support are interpreted consistently using the Common Scale.

On the Metro Map, this is represented by the Harmonised EU System destination station (Figure 5.6).

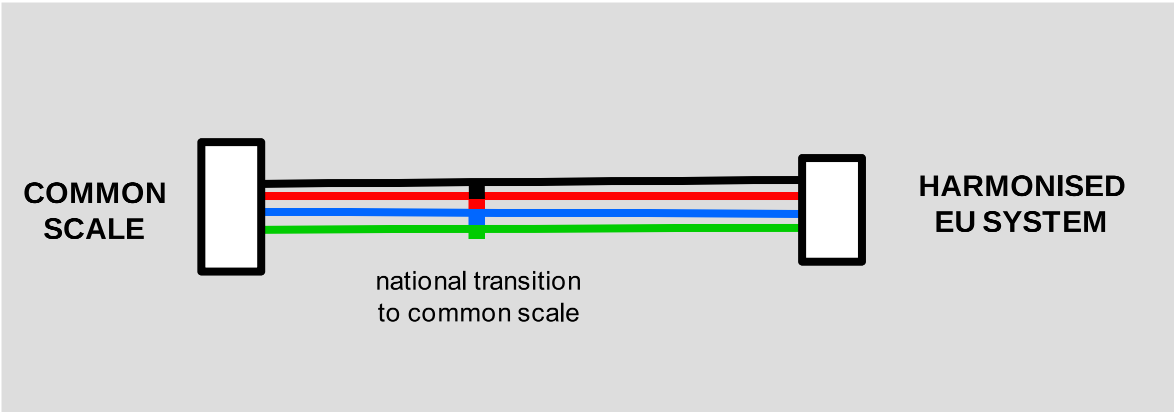


Figure 5.6 Route to a harmonised EU system of measurement

The route from the stage of having established a Common Scale to move to a Harmonised EU System can be followed from any the four proposed routes to achieve a Common Scale. There is one intermediate stage: national transition to the Common Scale.

To reach this stage, individual EU countries will need to adapt their existing practices (or adopt new ones if they have not engaged in skid resistance measurement before) to fit with the new system. This will involve:

- Adopting a measurement device that is linked to the Common Scale (which for most countries that already make measurements will probably be their existing device) or arranging for their device to be linked to the scale.
- Where a fleet of one device type is used, adapting their national accreditation processes (or establish new ones) to link the devices in their fleet to the representative that has been linked directly to the Common Scale.
    - o This might involve neighbouring countries arranging for one machine to be linked to the Common Scale and then utilise local calibration exercises to maintain the links to the national fleets.
- Conversion of thresholds or other criteria used in their national policies or standards to their equivalent values on the Common Scale.

In the process, countries will need to consider carefully the accuracy and precision of their national measuring device(s) when used in conjunction with the Common Scale, as well as of the accuracy and precision of the scale in relation to the way in which they intend to use the data (See Chapter 6).

Before the final destination can be said to have been reached, some further steps are necessary, at a European level. This involves the formalisation of the processes through a CEN standard for skid resistance measurements (or through some other appropriate organisation and documentation), citing the Standards and Procedures developed in the first phase of the Roadmaps to arrive at the Common Scale. Such documentation would then need to be adopted by member states through their national standards organisations.

In parallel with adopting the approach formally at a European level, arrangements would need to be put in place for the oversight and management of the maintenance of the Common Scale in the longer term, for example, through FEHRL or one of its member institutes. This would need to cover both regular calibration of the reference devices and the introduction of new devices from time to time.

5.5.3 Towards a full EU standardisation

The third destination proposed in the Metro Map is that of full European standardisation. This destination has two approaches. One is a direct transition as a result of a central decision to standardise from a given date. The other is a situation in which the Harmonised EU System is adopted initially but then a gradual transition occurs over a longer time. These alternatives can only be reached if C or D were chosen as the routes to the Common Scale.

(i) *Direct transition to Full EU standardisation*

It may be decided that the best approach to the Common Scale is to adopt a single reference device type (Routes C or D on the Metro Map). Having made that decision, and considered all the implications regarding accuracy and precision, a further decision could be made to move directly to the use of standardised measurements for the main purposes of new surfacing acceptance and in-service network monitoring. If this route (Figure 5.7) were to be followed, there would be two intermediate “stations”.

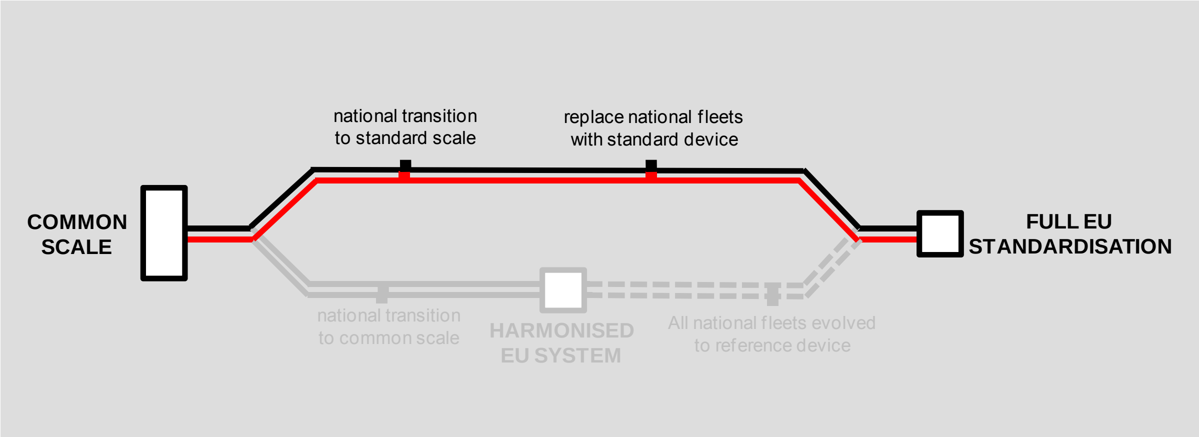


Figure 5.7 Direct route to Full EU Standardisation

- The first stage on this route is similar to that on the route to harmonisation: national standards for skid resistance must be adapted (or new standards adopted) to use what would now become the Standard Scale. Initially, existing devices would continue to be used to make measurements but the results would be converted to the new scale for use for the now (or shortly to be) standardised purposes.
- The second stage on this route, which could happen in parallel with the first, is for each country to replace its existing machine (or fleets of machines) with the same device type as the reference device (now the standard device) and use it (or them) to measure their networks. It should be noted that if Route D2 has been followed initially, this stage will need to be preceded by or include tests to establish the accuracy and precision of multiple examples of the new reference device type.

As with the Harmonisation destination, formal documentation will be required to set out the standard procedures and to establish a mechanism and responsible organisation to accredit verify the stability of the Europe-wide fleet of standard devices over time.

(ii) *Future evolution to Full EU standardisation*

If the Harmonisation destination is chosen, over time, individual machines will wear out and require replacing. If the harmonisation and Common Scale is successful, countries that were not initially involved would obtain measurement equipment and join the harmonised group of countries.

It is likely, especially if Roadmap C or D had been followed to reach the Harmonised destination, that when purchasing new machines, countries would opt for machines of the same device type as those used for the Common Scale reference.

This could even happen in countries with larger fleets, of another device type since with the Common Scale in use, either the older devices or the new could both report on the new scale. Using the same device type as the reference would obviously improve the local precision since the new machines would automatically be measuring on the Common Scale and it would be logical to change the national fleet to the reference type as the older machines needed to be replaced.

Eventually, enough countries would be operating the reference device type for a decision to be made to make this the standard. Thus, in the longer term an evolution to Full Standardisation could be achieved were this desired (Figure 5.7).

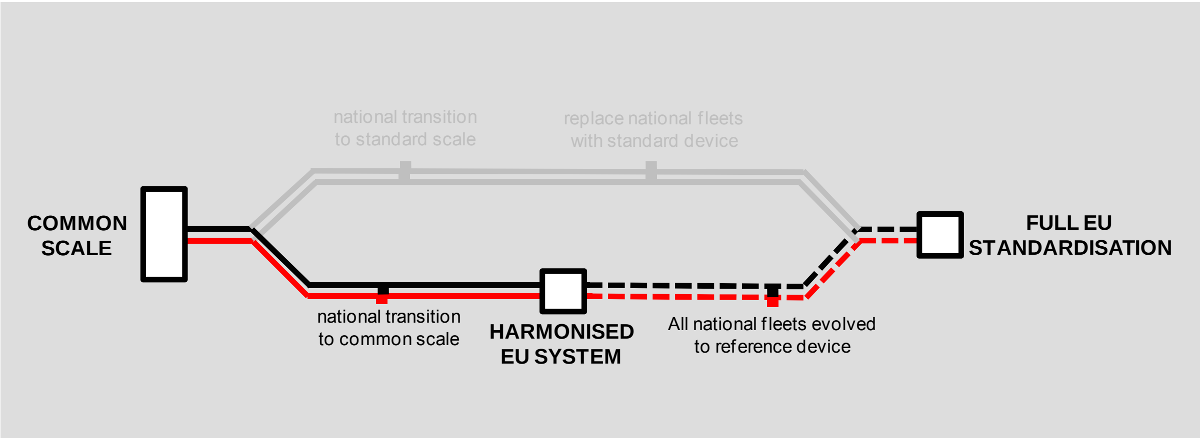


Figure 5.8 Route via Harmonisation to an evolution to Full EU standardisation

6 Accuracy and precision in relation to harmonisation

6.1 The basic components of the accuracy of skid resistance measurement methods and the different sources of error

6.1.1 General introduction

The accuracy of skid resistance measurements is an important issue to consider in relation to harmonisation. This is especially important for countries that already use well-established policies based on a single measurement device type. They are naturally concerned that the advantages of using one device (or one carefully-controlled device type) might be lost with a Common Scale approach that allows different device types to be used. Clearly, the issue of accuracy needs to be resolved satisfactorily for a harmonised approach for skid resistance measurement to gain wide acceptance in Europe.

A more detailed assessment of the accuracy level that really is required suggests that, in practice, this will depend heavily on how the measurements are going to be used. The level of accuracy needed in acceptance tests for the approval of new works, for example, may well be different from what would be acceptable for network management or winter operation. Further, the philosophy of individual countries in how they use the measurement values may affect accuracy needs. For instance, are they directly related to immediate decisions, such as approval or rejection of new works that then require resurfacing? Are they part of an overall condition index, perhaps, or just one factor to be considered in the decision process?

For routine skid resistance measurements, typically one measurement pass is made along each section length of pavement surface during a measurement visit. Assuming that the measurement devices are well-calibrated, there are still many factors that contribute to the variability of the measurements recorded. These factors include the machine (and test tyres) used, the crew and the lateral position of the test wheel on the road, as well as longitudinal location of the measurements along the road length.

Due to these factors, measurement results will differ to some extent from the true value or any agreed reference value. These deviations, in statistical terms called the accuracy, are generally composed of a combination of [16], [17]:

- A precision component (random error).
- A trueness component (systematic error).

6.1.2 The precision component of accuracy

The precision component can be expressed in terms of repeatability and reproducibility. Both terms refer to the maximum difference expected between two single measurements made on the same section of road in a short space of time, with a probability of 95 %. The repeatability assumes that the two measurements are performed with the same machine[6], with the same tyre[7], operated by the same crew. The reproducibility assumes different machines with different tyres using different crews.

The concepts of these two components of precision are illustrated in generic form in Figure 6.1, using the analogy of a dartboard or archery target. The graphic represents what might be the outputs of repeated measurements from a sensor (in this case a test wheel) with three different machines of the same device type on a particular road section of some unit length. The variation between the blue squares represents the repeatability of one machine, those between the red circles the repeatability of another and the green crosses a third. Although overlapping, each set of measurements is grouped around a slightly different part of the target, representing small variations between the machines as well as between individual measurements: reproducibility is thus illustrated by the full range of the whole group of measurements.

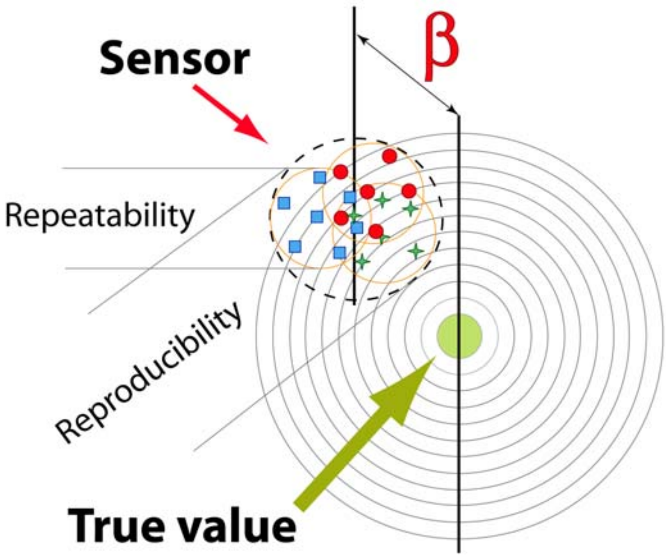


Figure 6.1 Generic representation of the different accuracy components of skid resistance measurements for a particular road section

Reproducibility in particular has become a common indicator for the level of accuracy for skid resistance measurement devices in daily use. Typical values for reproducibility for carefully controlled fleets are specified in the CEN Technical Specifications for the devices; values of 0.05 (e.g. The Netherlands), 0.07 (UK) and higher are quoted. Although not explicitly

6 Some variability can be expected between different machines, even when they are built to the same technical drawings and other specifications. Variability of the order of 0.01 or 0.02 is not unusual. Sometimes, depending on philosophy, this may be corrected by a calibration factor. Ultimately, a residual variability of the order of 0,005 or less is likely.

7 Variations in test tyres, particularly from one to another, can contribute significantly to variability in skid resistance measurements. In carefully-controlled situations, test tyre variability of +/- 0,02 can be achieved but considerable effort is required, particularly in relation to manufacture and storage, to keep this level stable over time.

specified, it can be assumed that these reproducibility values are associated with road surfaces with skid resistance values in the range 0.4 – 0.7, which implies that the best reproducibility values are of the order of 10% of the measurement value. In comparison with other civil engineering measuring methods this situation might be categorized as moderate: not really good but neither is it really bad.

6.1.3 Trueness component of accuracy

Figure 6.1 also illustrates the trueness component of accuracy. Trueness refers to the difference between the average value obtained from a large series of measurements and an accepted truth-value. On the diagram the “true” result corresponds to the centre of the target and the trueness component of the accuracy is represented by the interval β: in the context of a particular section of road, β would represent a systematic error in the measurements.

For the specific case of skid resistance measurements that are always made with machines of one device type, the situation represented in Figure 6.1 can be simplified. Some countries, such as the UK and the Netherlands, use a calibration approach in which the average of all devices in the fleet is taken to represent the accepted truth-value. In this situation, the centre point of the reproducibility circle is the same, in effect, as the accepted truth-value. This implies that the trueness component associated with the device type is non-existent by definition and so can be neglected.

For the Harmonised EU system proposed in the TYROSAFE Metro Map, however, the trueness component in the accuracy can no longer be neglected. The accepted truth-value in this context is now the Common Scale value and the centre point of the reproducibility circle for a given device type will usually not fully coincide with this. This deviation (of trueness) will arise from the imperfections or lack of fit in the conversion formulae that are applied to calculate the Common Scale value from individual device measurements.

The magnitude of this deviation is affected in different ways. On the one hand, design aspects of the machines play a part, such as slip ratio, measuring principle and tyre type, as do differences in operating conditions between those of the observed device type and those on which the Common Scale is based. These factors can be modelled to some extent and to do this may demand device-specific conversion formulae, rather than a generic formula with device-specific coefficients.

On the other hand, the influences that these machine-specific aspects have on any conversion factor themselves may be influenced by characteristics of the road surfacing and its type. These could include not only the texture depth (the main factor considered in HERMES) but also other factors associated with macrotexture such as particle size and shape or texture form (positive/negative random textures on asphalt; brushed marks or grooves on cement concrete, for instance), as well as microtexture, and surface porosity. The interdependency of skid resistance measurements with road surface type has not been modelled properly to date and to do that this might require bringing a more fundamental knowledge of tyre road friction to bear on the conversion formulae.

Figure 6.2 is an attempt to illustrate the need for taking greater account of surface dependency in the conversion factor. In this graphic, the horizontal axis represents the "true value" of skid resistance of a road section, as expressed on a Common Scale derived from the average of a large number of measurements with some chosen reference method. The vertical axis represents values on the Common Scale estimated after conversion from a large number of measurements from different examples of one particular device type. For this illustration, the conversion has been achieved by multiplying the actual measurement by a device-type dependent conversion factor but that only takes account of speed and texture depth using the current state of knowledge represented by the HERMES study.

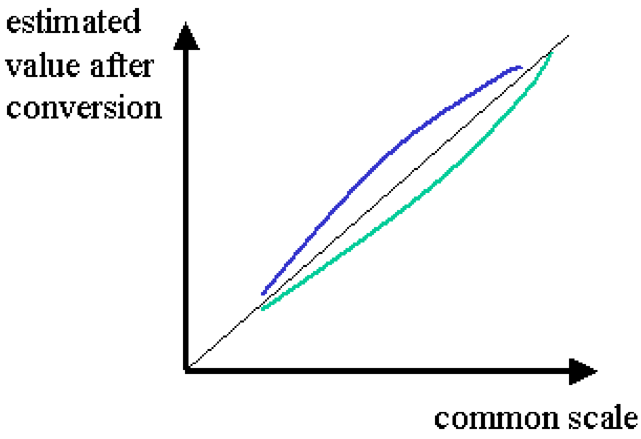


Figure 6.2 Representation of surface-dependent trueness error introduced by conversion to a Common Scale
The green and blue lines represent deviations from the line of equality for different types of road surface

The green line represents the best fit of the data points for a road surface of a particular type (which might be dense asphalt, for example), while the blue line would represents the best fit for the data points from a road surface of another type, perhaps a low noise thin surfacing. The black line in between is the line of equality. These are not actual curves, but the differences from the line of equality make the point that different types of surfaces could induce a “trueness” error, even for the same measurement device. If it were possible to model the effect of road surface type in a better way, the green and blue lines would both coincide with, or be much closer to, the line of equality thus improving the trueness of measurements reported on the Common Scale.

6.2 Estimation of accuracy level of the different roadmap-destination combinations

6.2.1 General introduction

Some countries have an existing fleet of one or more device types in use. It is likely that, in order for them to consider adopting the Common Scale, they will want the reference device configuration to achieve at least the same repeatability and reproducibility as their current fleet.

Currently, the best values for accuracy of well-calibrated fleets in Europe are:

- Reproducibility of the order of 10% of the measurement value.
- Trueness 0 (zero), where only one device type is operated.

Therefore, in the following sections, an attempt is made to estimate the likely accuracy level of some of the roadmap-destination combinations on the TYROSAFE Metro Map. Three combinations have been chosen as examples:

- Roadmap A with the destinations of Optional Use of the Common Scale or Harmonised EU system.
- Roadmaps B/C/D with the destinations of Optional Use of the Common Scale or Harmonised EU system.
- Roadmaps C/D with the destination of Full EU Standardisation.

Roadmaps C and D are treated together because the only difference between them is the use of one individual reference machine (Roadmap D) rather than the average of several of the same type (Roadmap C). This difference will have a small influence on the precision of the Common Scale but not on the conversion formulae.

If Roadmap B were to be followed, depending on the choices made regarding the reference fleet, the accuracy will either be closer to Roadmap A or closer to that of Roadmap C. The strongest contender for the reference fleet operating principle for Roadmap B is probably that of SFC, the test wheel set at a twenty-degrees angle, with SCRIM and SKM as the reference device types. These represent the largest proportion of machines in regular use in the EU that have long-established experience and quality control. SCRIM and SKM are so similar to one another that this would almost represent the Roadmap C reference condition. For this reason, Roadmap B is treated with C/D rather than A for the purposes of this discussion.

6.2.2 Roadmap A

For Roadmap A, which can only lead directly to either Optional Use of the Common Scale or Harmonised EU System, the assumption is that all devices, with their different principles and range of variables, will be used to define the Common Scale. To achieve this, the “conversions” can be regarded as part of the scale definition. This tends to lead to one general formula with calibration coefficients that individual devices then use to convert their day-to-day measurements to Common Scale values. With this approach, almost all of the potential inaccuracies lie in the scale definition itself, which inevitably incorporates the influences of the wide range of variables being brought together.

The result of this is seen in the rather disappointing results in the main PIARC and HERMES studies, which are essentially prototype examples of the approach in Roadmap A. Although their approach to harmonisation worked to some extent, the harmonised skid resistance values had unsatisfactory overall reproducibility. For HERMES, when all devices were included in the definition of the EFI and all devices were included in the estimates of precision, a value for reproducibility of R=0.27 was obtained. This is of the order of about 50% of the skid resistance level of the observed surfaces – clearly unacceptable! [8]

Further analysis within the HERMES project itself and subsequent studies have suggested that within the concept of Roadmap A the reproducibility might be improved by measures such as:

- Narrowing the speed range over which conversions have to be made by selecting one fixed reference speed for all devices.
- Deriving better conversion formulae, perhaps separating operating speed and slip ratio in the calculations and developing a better understanding of the differences in friction that result from the different measuring principles, test tyre characteristics and specific operating conditions such as wheel load.

As previously mentioned, these influences will be strongly influenced by the characteristics of the road surfaces being measured. It is not always practical in the real world to know precisely what surface is being measured, so and improved models used in the conversion formulae should be developed to be valid over a wide range of surfaces.

Possibly, the best approach for that would be to construct models based on more fundamental principles of the friction process in the tyre road interface. However, at present it is difficult to judge how much effort and cost this type of research would need, or its chances of success, based on the present state of the art of fundamental knowledge of friction processes in general.

At the moment, therefore, it is uncertain as to whether the reproducibility of Roadmap A approach can be improved sufficiently to make it a viable longer-term option. However, as will be discussed further below, these issues may also need to be considered in developing conversions for the other roadmap options so there may be merit in some theoretical work to investigate this approach in more detail.

[8] There were a number of technical reasons why the PIARC and HERMES studies had poor precision that emerged during the practical work in spite of careful experimental design. One of these was inadequate quality control of the machines attending the experimental phases of the project. It was found that some devices of the same nominal type from different countries could differ markedly in their results, or unexplained changes occurred between measurement exercises. This has led to the development of the CEN Technical Specifications, which are intended to encourage greater consistency among devices of the same type.

In the case of the HERMES study, one type of device had serious technical problems: one example broke down and another was unable to operate over the required range of conditions, which led to serious shortcomings in the database. The focus of the experiment was to test a particular calibration regime and so the data collected, although extensive, was limited in its scope for analysis. These types of problems compounded any deficiencies in the speed/texture model used and contributed significantly to the apparently poor precision of the Common Scale derived based on the average of all machines in these exercises.

6.2.3 Roadmap B/C/D - destinations Optional Use of Common Scale or Harmonised EU System

(i) *With an overall accuracy qualification, allowing all device types for all purposes*

All the roadmap options leading to either Optional Use of Common Scale or Harmonised EU System destinations allow any device that has been linked to the Common Scale to be used. Roadmap A incorporates all devices in the Common Scale definition and consequently this limits its precision. Roadmaps B, C and D, however attempt to improve the precision of the Common Scale by reducing the number of types of device involved. In the case of Roadmap B these are restricted to devices operating with similar principles and for C/D a single device type is chosen.

With this approach, the Common Scale definition is very much simplified. There are no (or very few) conversions to do to define the Common Scale and, assuming a fixed reference speed, this should yield an accurate scale. In this approach, the conversion formulae are used to convert the outputs of the devices (in whatever operating conditions they are used) to the Common Scale values and it is at that point that the inaccuracies (mainly a trueness component) will creep in.

The difference between Roadmaps C/D and Roadmap A is that the “conversions” are applied to the device at the time they make their measurements. This means that it may not be necessary have to have a General Formula that covers every device type and possible set of test conditions. Rather, each device type can have its own device-specific conversion formula or rules that are optimised for its specific operating conditions and principles in comparison with the reference fleet type. That should be more accurate than the Roadmap A approach. Similar comments should apply if Roadmap B is followed, provided that the operating principles and reference conditions of the device types chosen for the reference fleet are sufficiently similar.

A practical example of what could be achieved is shown in the IRFI study, which led to a reproducibility of R = 0.12. The IRFI approach has many elements of Roadmap C/D. However, there is a major difference in that there is almost no difference in slip ratio and measuring principle amongst the devices used for airfields, which predominantly are LFC devices operating at around 15% slip ratio and generally over a limited range of speeds.

Overall, assuming success in developing device specific conversion formulae, which include the road surface dependent effects of measuring principle and range of slip ratios, the overall reproducibility can be expected to approach that of the IRFI, which is about 25% of the measurement value. However, even this level of precision would limit the usefulness of the measurements. If it were possible to incorporate improved models that took account of the road – surface dependent effects of the test tyre type and operating conditions were standardised further to assist in this, it may be possible to improve the reproducibility and thence the usefulness of the Common Scale.

(ii) *With device type specific accuracy qualification, so allowing countries discriminating in the use of devices.*

In the previous sub-section, it was assumed that the Harmonised EU System would allow all device types to provide measurements that could be expressed on the Common Scale and be suitable for all purposes. However, with Roadmaps B, C and D, the conversion models (not just the coefficients) would be device specific and it may prove that there will be different levels of accuracy depending on the device type and how much it differs from the reference type(s).

A suggested approach to dealing with this situation is to adapt the interpretation of the Harmonised EU System from one measurement method followed by all devices to the following:

- The Harmonised EU the system combines the definition of a Common Scale (using the Roadmap B, C or D principles) with a set of different measurement methods all able to report in Common Scale units.
- Each of the different measurement methods is based on a single specific device type (which also includes the test tyre and operating conditions) and on a device-specific conversion formula to calculate Common Scale values from the basic measurements.
- The accuracy of the different measurement methods consists of two parts: a precision component represented by the reproducibility (which is mainly dominated by the device type chosen) and a trueness component, (which is mainly dominated by the device- specific conversion formula).

The essence of this concept is that accuracy for Common Scale values produced by different device types can be formulated on an individual basis, thus allowing users to discriminate between device types where data are to be used for accuracy-critical measurements. In principle, all device types can continue to be used to provide measurements on the Common Scale, an important aspect of harmonisation, but those which are less accurate may be restricted in their application in a controlled way.

Thus, once it is possible to discriminate between measurement methods (identified by the device type) on the basis of their individual accuracy level in terms of precision and trueness, a tool is available that allows individual countries to prescribe (in their tendering processes, for example) different accuracy levels for different purposes according to their needs. By defining the level of accuracy for reporting on the Common Scale that is required for a particular purpose, it will be possible to reject or restrict the use of some devices for some purposes.

This would avoid countries having to accept accuracy losses in comparison with their present approach simply by accepting the harmonised method. It is suggested that the inclusion of a device specific accuracy qualification could offer a major breakthrough in the process of harmonising skid resistance measurement methods.

How might this work in practice? It is suggested that a number of specific accuracy classes could be developed that would apply to the results from a device reporting Common Scale values. A starting point for some possible classes, which are by no means definitive but simply chosen to illustrate the principle of the idea, is given in Table 6.1.

Table 6.1 Illustration of the concept of accuracy classes for harmonised measurements
The accuracy levels represent what might need to be achieved by a combination of device type and its associated conversion to Common Scale units.

Accuracy Class	General accuracy levels		Comment
	Reproducibility	***Trueness***	
Class 1 (high)	Best possible	No conversion loss	Reference device(s) should be in this class. Other device types might be included but are unlikely to have both good precision and zero trueness error,
Class 2 (good)	Good	Small conversion loss	The numerical levels would need to be set so that there are at least two or three device types in this class to make it useful
Class 3 (medium)	Medium level	Medium conversion loss	
Class 4	Unspecified	Unspecified	

Having identified the accuracy classes in principle, some levels of reproducibility and trueness would be needed to define them quantitatively. These would be chosen once the conversion formulae have been derived. Table 6.2 gives an idea of how this might appear, with levels expressed as a percentage of the measured value. It should be stressed that these are indicative ideas – actual values would need to be determined with careful consideration of what is needed in practice for different purposes and what is actually possible with the chosen Common Scale reference and associated conversion formulae.

Table 6.2 Illustrative examples of how accuracy classes might be defined quantitatively
The actual values used in practice would need to be developed based on the known possibilities from the various device types and conversion formulae for expressing their results in Common Scale units.

Accuracy component	Percentage of Common Scale Value required			
	Class 1 (high)	**Class 2 (good)**	**Class 3 (medium**	**Class 4**
Reproducibility	≤ 10%	≤ 15%	≤ 20%	> 20%
Trueness	0	≤ 5%	≤ 10%	> 10 %
Note that a device type would be classified by the worst performance of the two components, e.g. a device with Class 1 reproducibility but Class 2 trueness would be classified as Class 2.				

6.2.4 Roadmap C/D to Full EU standardisation

As well as the Harmonised EU System destination, Roadmaps C and D offer the option to move directly (or over a longer time) to Full EU Standardisation. If this route were followed, this would offer the best expectations for accuracy since only one device type would be involved both in setting the Standard Scale and making measurements against it. In principle, a standard device specification should always give the same answer. It would be expected that trueness error would be very small or zero (Class 1 in Table 6.1) and, in principle, good reproducibility might also be expected from all machines. However, in practice, different implementations of the specification (machines built by different manufacturers) may have slightly different repeatability and reproducibility and so they would not necessarily all be within the same accuracy class.

This need not be a major problem if the classification system proposed in 6.2.3(ii) is followed because this provides for requiring different accuracy levels for different measurement purposes. In the event that a country wanted to use its data in a way that called for Class 1 accuracy but its local manufacturer's machine fell into Class 2, then that might provide an incentive for that manufacturer to improve its device or for that country to improve its quality control procedures. This does emphasise that there will, as with harmonisation, be a need for establishing a rigorous system of quality assurance to help verify the stability of the European fleet of "Standard Devices" over time.

Current experience in countries where it is the practice for different manufacturers to build test machines using the same technical drawings and other specifications or even where just one manufacturer is involved, variability for individual machines of the order of 2 - 4% of skid resistance output (excluding the test tyre variability) is not unusual. This is already incorporated in current reported reproducibility values.

If full EU standardisation were to become the chosen destination, it would not be surprising to find that, in the early years at least, zero trueness error would be too optimistic and that it might prove better to allow a trueness value of ≤ 2% to define a Class 1 device (Table 6.2) in the initial years.

7 Advantages, drawbacks and obstacles for the different Roadmaps

This chapter of the report summarises the advantages and drawbacks associated with the different approaches to achieving the Common Scale and reaching the different destinations (Section 7.1), before discussing the broader obstacles faced in the path towards implementation for the different destinations (Section 7.2). Not included are the advantages and disadvantages of harmonisation in principle, which have already been covered implicitly in Chapter 2.

7.1 Advantages and drawbacks of the different roadmaps

The different roadmaps have many advantages and disadvantages in common but some are only relevant to certain destinations. Table 7.1 summarises the main advantages and drawbacks on the routes to the Harmonised EU System destination and the routes to which they would apply. Some differences only appear when Full EU Standardisation is chosen as a destination (routes C and D only). Issues relating specifically to this are summarised in Table 7.2. The Optional Use of the Common Scale destination also has some advantages and drawbacks of its own and these are listed in Table 7.3.

Table 7.1 Advantages and drawbacks of the alternative routes to a Harmonised EU System

Advantage/Drawback		Applicable routes				
		A	B	C	D1	D2
Advantages	All current device types can continue to be used provided that they can be linked to the Common Scale with acceptable accuracy and precision.	✔	✔	✔	✔	✔
	Free choice for countries re-equipping or choosing a device for the first time.	✔	✔	✔	✔	✔
	New device types can be integrated automatically as part of routine validation of reference fleet using general conversion model.	✔				
	Reduced set of devices types in reference group improves accuracy of Common Scale.		✔			
	Single device type as reference improves accuracy of Common Scale.			✔	✔	✔
	Common Scale based on devices for which there is long experience.			✔	✔	
	Easier to detect malfunctions or outliers in reference fleet.		✔	✔		
	Reduced set of device types in reference group allows greater scope for different models to link to Common Scale.		✔			
	Single device type as reference allows greater scope for different models to link to Common Scale.			✔	✔	✔
	Longer-term option for Standardisation as well as Harmonisation.			✔	✔	✔
	Opportunity to develop better understanding of pavement properties and friction development leading to improved measurement technique for longer-term.					✔
Drawbacks	All countries have to adapt policies and standards to Common Scale.	✔	✔			✔
	Countries operating non-reference device types have to adapt policies and standards to Common Scale.			✔	✔	
	Stability of Common Scale vulnerable to changes in composition of reference fleet (non-availability or malfunction of machines, addition/removal of devices).	✔	✔	✔		
	Stability of Common Scale vulnerable to unidentified malfunction or non-availability of reference machine.				✔	✔
	Complex logistics and processes required to maintain Common Scale with many machines in reference fleet.	✔	✔	✔		
	Demanding programme on reference machine to maintain links with other device types.				✔	✔
	Reference machine not available for normal routine use.				✔	✔
	Could create pressure to normalise device types in use to that of reference type, stifling potential development or improvement.			✔	✔	✔
	Reference surfaces essential to verify maintain Common Scale stability with only one reference machine.				✔	✔
	Requires development and evaluation of new device.					✔

Table 7.2 Additional issues relating to the routes to Full EU Standardisation

Advantage/Drawback		Applicable routes		
		C	D1	D2
Advantages	Use of single device type removes need for conversions.	✔	✔	✔
	Maximum possible accuracy/precision from single device type.	✔	✔	✔
Drawbacks	Forces migration to one device and replacement of existing fleets for countries using non-reference device type.	✔	✔	
	Forces all countries to change device type with associated costs			✔
	Stifles innovation and "freezes" development	✔	✔	✔

Table 7.3 Additional issues relating to Optional Use of the Common Scale

Advantage/Drawback	
Advantages	Countries can continue current practice
	Countries can join a "harmonised" group when they are ready or able to do so (helps countries with no current standards or devices)
Drawbacks	Discourages EU-wide adoption of harmonised approach to policies and standards.
	Risk of developments being un-focussed

7.2 Obstacles to implementation of the different roadmaps

Whichever roadmap is ultimately chosen, there will obstacles that will need to be overcome in order to achieve a successful implementation. This section summarises the most significant of these, which for convenience have been divided into two groups: technical obstacles and those that are more political or economic in nature.

7.2.1 Technical obstacles to implementation

The major technical obstacle on all four roadmaps will be the process of establishing the Common Scale and the associated conversion formulae. Although the detail of the work might vary depending on the route chosen, the issues are similar for all of them.

(i) *Establishing the Common Scale and Conversion formulae*

All four roadmaps will require complex research to define the models needed to achieve harmonisation. This will inevitably involve theoretical studies to identify appropriate models for the conversion process, combined with complex practical exercises to establish and validate the Common Scale and the associated conversion formulae.

Work will also need to incorporate studies to assess the accuracy and precision that might be expected from the Common Scale in everyday use.

It should be less complex to establish the Common Scale following Roadmaps C or D than with A or B, since only one device type would be involved. However, the work needed to find and validate conversion formulae for all the individual devices will probably be as complex to plan and carry out for the roadmaps using one device type for the reference as for those using several.

It should be noted that if the Full EU Standardisation destination were chosen, even though the Common Scale becomes a standard scale from a standard device type, research would be necessary to enable countries to adapt their current standards to the new scale and this would present a major technical obstacle if it were decided to move directly to this destination.

(ii) *Setting up the Quality Assurance regime*

An important component of all four roadmaps is the QA regime that will be needed. This presents technical obstacles to be overcome, which include the definition of an accreditation system which will need to include:

- A robust methodology for routine calibrations of the reference machines against one another to verify the ongoing stability of the Common Scale.
- A methodology for the routine calibration to the Common Scale of device types not in the reference group and representatives of fleets of devices that do not have a machine in that group.
- The QA system will also need an organisation appointed to be responsible for the accreditation of the various measurement devices in relation to the European Common Scale.

Although not strictly part of the harmonisation process covered by the Roadmaps, a further technical obstacle which, if overcome, could simplify and improve the main processes, would be the development of reliable, stable and reproducible reference surfaces. These would be essential to the QA system if Roadmap D were to be followed rigorously, since it would be the only way to verify that the Common Scale friction levels set by the reference machine remain stable.

7.2.2 Other obstacles to implementation

(i) *Choice of destination*

A significant initial obstacle to implementation that will need to be overcome is that of deciding on the final destination. Discussions at the London TYROSAFE Workshop favoured the full harmonisation option but this would need to be established at an appropriate EU level. A difficulty here (apart from identifying which organisation makes the decision) will be achieving international consensus.

(ii) *Deciding on the device types to be included in the reference fleet*

The choice of reference devices is a fundamental part of the harmonisation process. If Standardisation were to be chosen as the final destination, Roadmaps A and B would automatically be excluded, thus reducing the options to just one device type. However, for the Harmonised EU System or Optional Use of Common Scale destinations, implementation is governed primarily by the choice of Common Scale reference, which is the main difference between the four roadmaps.

This choice will be influenced by some technical considerations but it presents a significant obstacle.

- For Roadmap A, this should not be a major issue, since its principle is to use all device types, provided that they meet some basic acceptance criteria such as repeatability and good existing quality control.
- For Roadmap B, however, a choice of measurement principles for the reference group must be made, which will exclude some device types.
- Similarly, an existing device type must be chosen as reference for Roadmaps C and D1.

Essentially, the obstacle takes the form of a potential unwillingness for countries with well-established devices to accept a reference fleet that does not include a representative of their type of machine. This is not purely a political issue – it has practical implications, too, because having a device of the same type as the reference should make it easier to adapt to the Common Scale when it is introduced.

(iii) *Deciding on specific machines to be included the reference fleet*

Having overcome the obstacle of deciding on the types of device to include in the reference fleet, it will still be necessary to establish which actual machines will be included.

- For Roadmaps A or B, the main issue will be selecting a representative machine of each type or principle, given that the type meets any acceptance criteria for inclusion. However, for device types which have examples operating in several different countries (SCRIM and GripTester, for example) it will be necessary to determine which countries' machines should be included. In some cases physical differences (such as the side on which the test wheel is mounted) may dictate inclusion of some representatives. There is also a related technical issue here: having too many examples of the same type might distort the average value that sets the Common Scale.
- Roadmap C presents similar obstacles in establishing the reference fleet. In this case, where only one device type is used, the barrier could be reduced because there is an argument for making the fleet as large as is practical (to reduce the influence of any small variations in behaviour of individual machines on the overall mean). In that situation, most, if not all countries with an operational machine could be represented in the reference fleet.

(iv) *Willingness to change existing practice*

One of the most significant obstacles to be overcome is likely to be the reluctance of individual countries to change their current practices regarding skid resistance measurement. Although not insuperable, in some instances the measurement technique is embedded within national standards and legally-enforceable requirements [1] and this could make the change appear more difficult to achieve. In theory, once conversion formulae are established, it should be straightforward to adapt existing threshold levels for skid resistance to use Common Scale values.

If Full EU Standardisation is to be the chosen destination, an additional obstacle emerges that will influence the choice and which also relates to reluctance to change, namely the reluctance of countries which do not operate it already to re-equip with the new standard device. In fact, this is likely to be a more significant obstacle in the way of choosing Full EU Standardisation as a destination than it would be once that decision had been made.

With the Harmonised EU System destination, existing measuring devices can continue to be used, so measurement practice may not need to change significantly since this will already be governed by reference to documents such as CEN Technical Specifications. However, perceptions of accuracy and precision relating to the particular uses that a country wishes to make of its measurement data may also create obstacles to implementation of the Common Scale.

(v) *Funding and co-ordinating the necessary research*

It has already been noted that the major technical obstacle to implementation is that of establishing the Common Scale and conversion formulae. From this, a further obstacle arises – finding a means of funding what will be a significant research programme.

8 Implementation plan

8.1 Research needs

As has emerged from the various discussions in this report, it is clear that, as part of any implementation plan, a significant programme of research is required to move from the current state of knowledge to a situation where harmonised skid resistance measurements can be introduced, with confidence, across the EU. Three major areas for research have been identified, described in more detail in Sections 8.1.1, 8.1.2 and 8.1.3, namely:

- Research to support harmonisation of existing devices.
- Research to allow development of a new measurement device.
- Research to develop reference surfaces

8.1.1 Research to support harmonisation of existing devices

The research needed involves four major components.

(i) *Theoretical studies*

These should be focussed on improving the models used to resolve the differences between the operating principles of different devices that will be needed to develop the conversion formulae.

Key parts of this stage could include:

- o Study of the influence of slip ratio and test speed. The analysis of earlier harmonisation exercises found that it may not be appropriate to combine these two parameters in all circumstances. Friction mechanisms at high speed and low slip are not necessarily the same as those involved at low speed and high slip.
- o Assessment of pavement surface macrotexture, as the main determining factor for the influence of operating speed on the measured friction levels. Parameters other than the MPD can be introduced to better take into account the water drainage phenomenon or even the friction generation (aggregate shape, tyre parameters for example).
- o The water depth in front of the measuring tyre is usually reported as being 0.5 or 1 mm. Little is known about the actual water depth and how it affects the measured friction. Models relating friction to water depth need to be developed to assist in defining reference conditions.

(ii) *Practical exercises*

These would gather data to assist with the modelling and to develop and validate the conversion formulae. The work should include:

- o A series of exercises in which representatives of different device types are brought together to make measurements on a range of different road surfaces under different operating conditions. Repeat exercises may be needed, for example, to check on the stability of the scale or vary the test conditions.
- o Measurements of surface texture depth, possibly using a number of different techniques, as might be suggested by the theoretical considerations.

(iii) *An analysis phase*

This would use data from the second component to establish the Common Scale and assess the effectiveness (in terms of accuracy and precision) of the Roadmap(s) being studied.

(iv) *A final phase,*

In this phase which the full range of devices to be included initially in the harmonised system is calibrated to the Common Scale.

Whichever Roadmap is followed, it will be necessary to collect data from a number of devices to form a reference fleet. In principle, therefore, it should be possible to design the experimental stages to gather data that could be applied on any of the Roadmaps. Rather than identify in advance which Roadmap should be followed in the research, this approach would offer an opportunity to structure the work to keep open options to change route (at the "Conversions Developed" station on the Metro Map) once the assessments of potential accuracy have been made.

8.1.2 Research to allow development of a new measurement device

If Roadmap D2 is to be followed, then some fundamental research is required in order to make sure that the resulting specification for a new device does not result in simply a more-precise variant of existing techniques but instead meets the real longer-term needs of European road authorities and engineers.

As explained in Chapter 2.1, the main problems relating to harmonisation of existing devices arise from the range of measurement principles that have been applied to the problem of skid resistance measurement over the years. These reflect different perceptions of what the skid resistance measurements are intended to do (and these have also evolved over the years). Further, there are often misconceptions in the minds of engineers as to what the measurements actually represent and how they might (or might not) relate to accident risks.

Ultimately, skid resistance measurements are made in order to verify that a road is not so slippery that there will be an unacceptable risk of skidding accidents occurring, either when the surface is new or during its service life. Arguably, it is time that a wider view of the philosophy of skid resistance measurements should be taken and a measurement device designed that provides data that are of direct application in this context.

The theoretical research proposed in section 8.1.1(i) would be aimed at trying to improve the convergence of existing devices with a Common Scale. The research needed here would need to go rather further than that. It should consider, in the light of all that is now known about the physical principles of road/tyre friction, together with factors influencing accident risk, what the best solution might be to assess the safety of a road surface. Such research would be an important preliminary stage of the development of the specification for a new type of measurement device for Roadmap D2.

8.1.3 Research to develop reference surfaces

The subject of reference surfaces has been touched upon only lightly in this report. However, the point has been made that the benefits from such surfaces are considerable, especially for the longer-term maintenance of stable harmonised (or standardised) skid resistance measurements across the EU.

It is therefore proposed that research should be carried out to investigate specifically ways of establishing practical reference surfaces, probably using the proposals made in the HERMES project as a starting point. If possible, such work should be carried out in parallel with the other work proposed in this section as a complementary part of a general implementation plan for the roadmaps.

8.2 Overall timetable

The objective of this report within TYROSAFE is to propose roadmaps and an implementation plan for harmonisation within the EU by 2020. This timescale provides both a reasonable goal to achieve and sufficient time to carry out the work necessary to make it possible.

For almost all of the proposed roadmaps, there are preliminary phases to determine reference devices and principles (essentially a desk exercise) followed by theoretical and practical research work to establish the Common Scale, conversions and accuracy.

In parallel with this process will be the drafting of the measurement standards that would eventually form the basis of the QA procedures. The final phase before completion of the Common Scale preparatory work is the formal establishment of the QA accreditation arrangements which will be based on the experience gained in the main research programme.

Most countries with fleets of machines will already have some internal accreditation arrangements for maintaining the standards of their own fleets. Part of the process of adaptation of their current policies and standards to use the Common Scale will include adapting their accreditation processes to be consistent with the precision requirements for the Common Scale.

Overall, the level of work required is quite similar for any of the roadmaps. Therefore, a general implementation plan can be proposed, which allows any of the four main routes based on existing device types providing the Common Scale reference (A, B, C and D1) to be followed on a similar timescale. This is illustrated in the form of the Gantt chart shown in Figure 8.1. The chart has two parts – the upper section shows work to progress to harmonisation using existing devices, while the lower section shows parallel activities moving forward on route D2. The chart assumes that there would not be a direct move to standardisation and that, if this occurs, it would happen later (the dotted part of Route C/D on the Metro Map).

Progress to harmonisation based on existing devices as the reference is based on the assumption that the bulk of the work would be completed over a five to seven-year timescale, with planning beginning in the second half of 2010 on completion of the TYROSAFE project. The chart shows how some activities would be carried out in parallel with one another, with a breakpoint on completion of the work to establish the Common Scale which, with careful planning and execution could be reached by the end of 2016. In the meantime, standards organisations, road authorities and individual countries will complete the process of adapting their standards and procedures ready to adopt the Common Scale (which would begin in 2015 provided that the research work was indicating a successful outcome). Alongside this, national and EU accreditation processes would be put in place.

It is envisaged that there would be a transition period in which countries progressively migrate to using the Common Scale. Countries could opt to use the Common Scale as soon as it is available but some lead time is needed where countries wish to re-equip. Full EU Harmonisation could then be formally implemented in 2020.

Roadmap D2 is slightly different. Following this route will involve the specification, development and testing of new equipment in the preliminary phase. There would therefore be a longer interval on this route before work on conversions could begin. The implications of this are that D2 may not be able to be implemented as quickly as the other Roadmaps and so this would be a disincentive to pursue this approach. However, it would be possible to decide to implement any of the other roadmaps while developing the new D2 device and then integrate this into the Common Scale later in the programme as a new device type. Subsequently, as more examples have been built and evaluated, a situation equivalent to Roadmap C will have emerged and if it seemed worthwhile then, it should be possible to adapt the Common Scale to use D2 as the reference. This is the scenario that has been illustrated in the lower part of Figure 8.1.

Ultimately, once harmonisation is established (whether an existing device or the new D2 device has been adopted as the reference), gradual evolution to standardisation could take place.

The proposed implementation plan does not include research to develop reference surfaces. This would be a self-contained project which could run in parallel with the other activities, taking advantage of appropriate synergies (for example, testing trial surfaces when machines are already gathered for comparative tests). An overall timescale of around 10 years might be needed to allow for development and evaluation of the ideas and sufficient time to confirm the long-term stability of the friction levels provided.

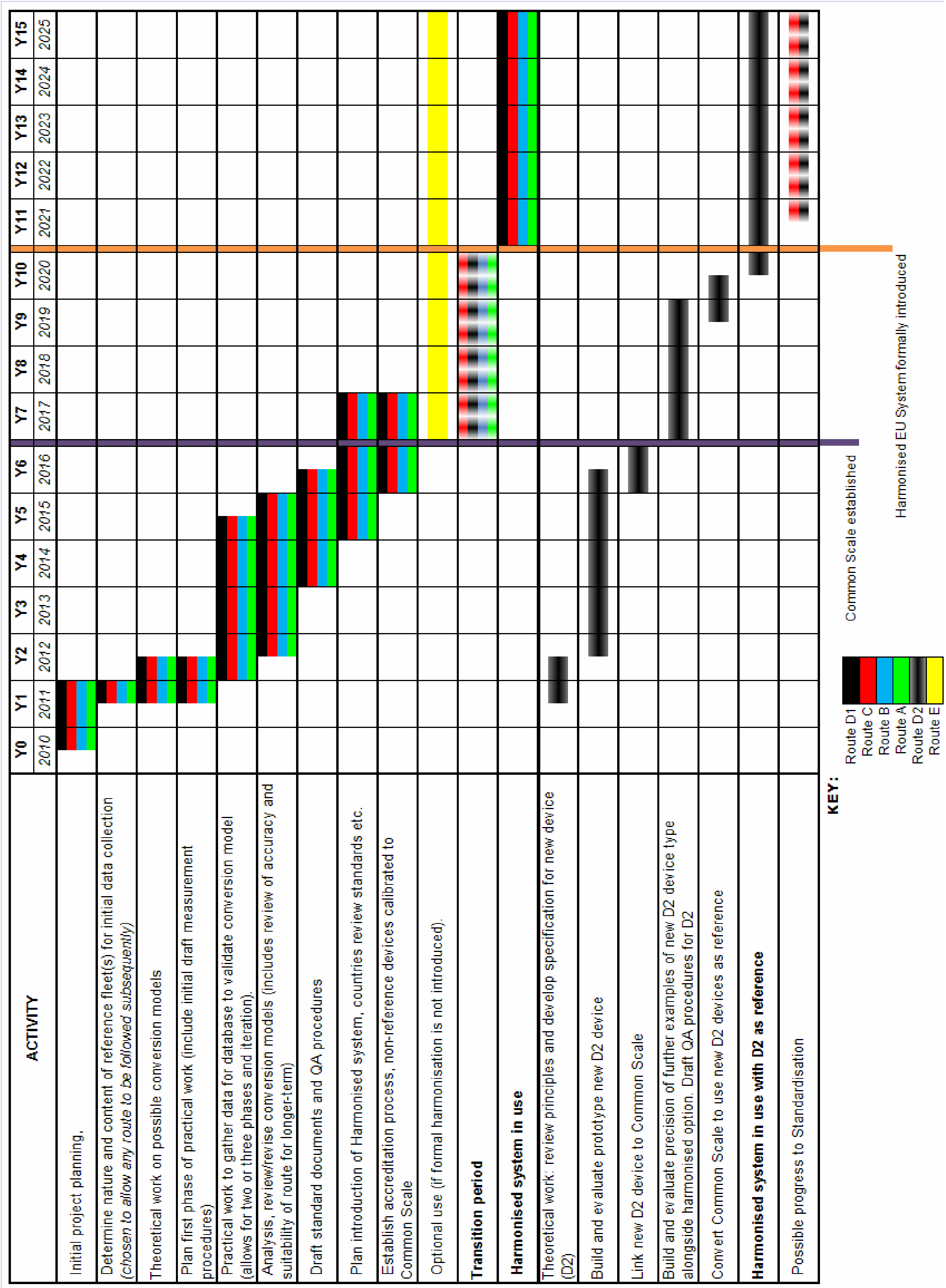


Figure 8.1 Gantt Chart representing a possible implementation plan

(Colours correspond to "Routes" on the Metro Map)

8.3 Costs

The bulk of the costs to implement the roadmaps will be associated with the research work to develop the Common Scale (discussed in 8.1). Whichever roadmap is followed, the components will be similar and will involve a significant amount of practical work, including comparative tests between different devices, on ranges of road surfaces and, probably, in a number of countries. Some experience of the processes involved in this kind of work was gained during the HERMES project and that work included some estimates for components of work such as calibration trial exercises. Table 8.1 and Table 8.2 draw on this and other experience to provide some broad estimates for the costs of the main components of the research phases of the programme shown in Figure 8.1. Table 8.1 covers the work to needed achieve harmonisation on routes A, B C or D1 and Table 8.2 gives estimates for the parallel D2 approach. It should be stressed that at this stage, any attempt to estimate costs is very approximate indeed.

Table 8.1 Broad overall cost estimates for the main phases of work to implement harmonisation based on existing device type(s) providing the Common Scale reference

Activity	Duration (years)	Broad cost estimate (€ 000)	Comment
Initial project planning.	1.5	15	This activity covers the detailed planning work once a consortium has been established and funding is arranged.
Determine nature and content of reference fleet(s) for initial data collection *(chosen to allow any route to be followed subsequently).*	0.5	10	This does not immediately establish the actual long-term reference fleet, which will be determined in the light of the outcomes of the research and any decisions as to the best route to follow. At this stage this is a set of devices used to begin the practical work.
Initial theoretical work on possible conversion models to inform structure of experimental phase.	1	40	
Plan first phase of practical work (include initial draft measurement procedures).	1	30	
Practical work to gather data for database to validate and further develop conversion models (allows for two or three phases and iteration).	3.5	1700	This overall estimate represents the bulk of the costs and includes possible “in kind” contributions from individual countries sending a device to the test exercises. In practice costs would be widely spread in much smaller components between countries and over time.
Analysis, review/revise conversion models (includes review of accuracy and suitability of route for longer-term).	3.5	600	
Draft standard documents and QA procedures.	2.5	55	
OVERALL	6	2450	The six-year overall timescale completes the research component of the work a further 18 months is needed to complete implementation.

Table 8.2 Broad overall cost estimates for the main phases of work on Roadmap D2 to develop and integrate a new type of device with the harmonised measurement system

Activity	Duration (years)	Broad cost estimate (€ 000)	Comment
Theoretical work: review principles and develop specification for new device.	1	30	The cost estimate assumes that some of the work for this activity would be covered by the theoretical phase on Route A/B/C/D1.
Build and evaluate prototype new device.	4	1500	Costs allow for project management of construction work, testing and evaluation. Approx. EUR500 has been allowed for actual construction to the specification, assuming that this would be carried out by a sub-contractor selected after a tendering procedure.
Link new device to Common Scale.	1	50	This will involve comparative testing with existing devices, possibly timed to fit with a final accreditation programme.
Build and evaluate precision of further examples of new D2 device type alongside harmonised option. Draft QA procedures for D2.	3	1450	Assumes similar construction costs to original machine (to a refined specification) with reduced test programme.
OVERALL	10	3030	Overall timescale assumes a project planning phase integrated with the Route A/B/C/D1 work and completes the research component of the work. further 6-18 months would be needed to complete an implementation with the D2 device type acting as Common Scale reference

This main work programmes will, of necessity, need to take the form of an international collaborative project, possibly coordinated through FEHRL or one of its member Institutes. This would be a practical arrangement because these institutes are typically responsible for, or closely involved with, most of the work relating to skid resistance and operation of test equipment in their various member states. They also have the necessary contacts to involve member states that may not have representative institutes within FEHRL. In principle, funding could be through direct shared funding provided by the member institutes or their national governments, following the model in HERMES, or through an EU funded programme.

Some of the costs at the final stages of implementation, not estimated in Table 8.1 or Table 8.2, would fall on individual countries to cover. These would include the processes of adapting their standards to the Common Scale and changing their practices and measuring equipment as necessary to follow the harmonised procedures. There would also be some costs in this phase associated with the preparation and promulgation of the appropriate EU (CEN) standards, presumably borne largely by individual countries (or organisations within them) as at present. However, these costs are unlikely to be significantly greater than current work on standardisation and harmonisation, especially if the basis of any written documents is established within the main research programme.

It would be unrealistic to expect every skid resistance measurement device in the EU to be involved throughout the harmonisation research programme. Representative machines of appropriate types would probably be used for the bulk of the work initially (the “reference fleet”), with a later phase in which other representative devices are calibrated against the reference fleet. The costs of this latter process, like the internal calibration of national fleets with their representative machine, might be borne directly by the owning countries.

No attempt has been made to estimate costs for reference surface development at this stage. If a future large collaborative research project were to be established to cover the proposed research work, this could be integrated with it to take advantage of potential synergies between the various activities.

9 Recommendations

9.1 General context

The earlier chapters of this report have discussed a range of issues involved in developing the various roadmap options. The choice of roadmap is influenced by a number of considerations, of which one of the most significant is the preferred final destination. The choice of routes to get there is primarily governed by the likely success of achieving the Common Scale in combination with the accuracy of the result in relation to its potential uses (Chapter 6).

The roadmaps suggested in the Metro Map (Figure 4.1) have taken these ideas into account and the alternative options are designed to give (in theory) progressively greater accuracy and precision to the Common Scale. Nevertheless, even with an accurate Common Scale, conversion equations will be needed to relate the different types of device and their specific local operating conditions to the scale; it will be the accuracy of these that plays a major part in the overall accuracy of the harmonised data.

One of the options (Roadmap D2) is based on the idea of developing a completely new reference device, with potential to provide a longer-term replacement for existing equipment. This provides an opportunity to develop a measurement system that is not necessarily constrained by current practice and that focuses on what is really needed, not just what can be achieved at present.

Whichever Roadmap is to be followed, some research will be needed to provide supporting data and develop the systems that will make harmonisation work. Some decisions relating to implementation will ultimately be made by international and national authorities who will not consider just the technical aspects of the problem. In this chapter, the TYROSAFE team develops its recommendations to provide what is intended to be a balanced overall approach to provide an initial solution to the issues raised in Chapter 2 that could gain widespread acceptance in EU countries and be introduced in a reasonable timescale, with the possibility of longer-term improvements.

9.2 Comments from the London Workshop regarding the possible roadmaps

Before any recommendation for a preferred roadmap can be made, it is worth considering the potential views of a wider range of stakeholders than the members of the TYROSAFE team, who are mostly technical experts. It was with this in mind that a Workshop dedicated to the harmonisation issue was held, in London, in September 2009. Having been introduced to the concepts behind the Metro Map, delegates were asked to discuss a number of questions, two of which were:

- If skid resistance measurements were to be harmonised in Europe by 2020, what would be the preferred “Destination”?

- What would be the preferred route to the Common Scale?

Sections 9.2.1 and 9.2.2 respectively summarise the views expressed in response to these two questions.

9.2.1 What would be the preferred destination?

Attendees at the workshop recognised and accepted the need for a Common Scale but could not identify a clear preference for one of the destinations offered by the TYROSAFE Metro Map; there were supporters for each. The primary reason for this divided opinion appeared to relate to the differences in interests expressed between a road owner and a device manufacturer or a researcher, but even within the same professional group there were differences of view. A secondary reason might be a lack of clarity at present regarding what the consequences of a harmonisation process might be for them, especially if the final destination were to be full standardisation.

The main concerns regarding the destination were over the standardisation option, which leads to just one device type for EU use (apart from research and specialised applications). The issue was not so much whether standardisation would be needed at some point in the future and whether that will have benefits, but how urgently is standardisation needed and at what cost, particularly in relation to the cost of scrapping many present devices and replacing them with the future standard device type. However, it was recognised that if introduction were to be gradual, these costs might be limited because replacement could occur at the regular end-of-life of each individual machine.

It was also thought that full standardisation would practically block further development in measurement techniques. Although, in theory, new techniques could be introduced in subsequent revisions of the standard, no commercial supplier of measuring devices would undertake such development (because there is no incentive). Road authorities and semi-public research institutes are increasingly less interested in carrying out such developments.

Although full standardisation will almost certainly give better reproducibility than EU-wide harmonisation, it will probably give worse reproducibility than current practice in those countries where a relatively small fleet (at least compared to a EU-sized fleet) of very similar or almost identical devices is used within rigorous QA procedures. The loss of precision could result from:

- A larger fleet of devices.
- Possible differences between different manufacturers.
- More complicated multi-level QA procedures (first: international-calibration of national reference machines and then national-calibration of the national fleet).

On balance, a sensible approach, with which the TYROSAFE team concurred, would be to approach the problem with the EU Harmonisation destination in mind in the first instance, evolving to standardisation at some point in the future when experience has been gained.

9.2.2 What would be the preferred route to the Common Scale?

The Workshop delegates generally took the view that Route A (Figure 5.1) was too "open" to be practical. Consequently, they thought that limiting the reference fleet to one or two groups of similar device principles, i.e. Route B (Figure 5.2), would be a good approach to take.

Some were in favour of Route C, particularly since it left open the option to move beyond harmonisation to standardisation at some future point. No preference was expressed for a specific device type to be chosen for Route C although, clearly, an established good reproducibility would be a primary requirement for the selection of any existing device type to become the reference type.

This question brought up the issue of the homogeneity of the reference fleet on which the Common Scale is based and that can be organised. Will it be possible that all individual devices of the reference fleet will be close enough together?

Generally, there were few opinions regarding Route D (Figure 5.4), which seemed to present more practical problems to implement compared with the alternatives. It was felt that a standardised single device type would only become reality if it were to be forced by European legislation, e.g. by CEN standards.

9.3 The rationale for the TYROSAFE Team recommendations

The TYROSAFE Team has reviewed all of the proposed options and considered whether or not it would be possible to recommend a preferred destination and route for the Roadmap. Moving directly to Standardisation would not be accepted at present because of the costs and complications of re-equipping with the chosen standard device and revising of existing practices. Such costs would fall unequally, especially on countries that did not already operate the reference device.

The team also considers that there is insufficient evidence at the moment to make a specific recommendation with regard to one of the proposed Roadmaps. However, having said this, it is nonetheless possible to move forward towards a harmonised EU system for skid resistance measurements.

On the basis of previous experience, Roadmap A seems the least likely to succeed but nevertheless should not be completely ignored since an improved general conversion model, developed in conjunction with a more robust database and quality control than was possible in earlier work, might yet give useable accuracy and precision for some, if not all, of the perceived uses of harmonised measurements.

Roadmaps B and C seem the most likely to be successful and achieve wide acceptance, although there will be political obstacles to overcome in the choice of principle or device.

Without reliable and reproducible reference surfaces to verify the stability of the reference machine, Roadmap D (which relies upon a single reference machine) is unlikely to be a suitable immediate option. Given the additional "political" aspects of selecting and managing an individual reference machine, Roadmap D1, using one example of an existing device type as the reference, seems unlikely to gain general acceptance, especially as Roadmap C is, for practical purposes, very similar.

Roadmap D2 has longer-term possibilities but relies on the satisfactory development of the new type of measurement device and its linking to the Common Scale. Such a device would not be "competing" with existing equipment and so could form an independent reference[9]. Again, though, without reference surfaces, this route would not be viable based on one reference machine. However, if more than one machine can be built to the new device specification and these can be shown to have acceptable precision, then this would effectively become the same as Roadmap C but without the need to choose a reference from existing devices. This also provides a natural migration path towards standardisation in the longer term.

There have been many studies of the links between skid resistance and accidents. However, all have been based on one of the current measurement techniques and focus on specific aspects such as braking distance. Some of these studies have been found to be of considerable value, and have contributed to current national standards. Nevertheless, there are many complex interactions involved in skidding accidents, as well as continuing developments in automotive technology. A significant advantage of Roadmap D2 is that its development provides an opportunity to take a more strategic and philosophical view of these matters and how they would feed into the design of the new device.

Underlying any of these options is the need for adequate precision in the measurements when reported on the Common Scale. By allocating devices into classes as suggested in Chapter 6, road authorities and engineers can utilise any device that meets the particular requirements of the purpose for which they wish to make measurements.

Reference surfaces have a primary role of providing a means of verifying the stability of the reference device type. However, as explained in Section 2.2.5, if successfully implemented, such surfaces would, in effect, become device-independent reference points on a Common Scale. For these reasons the development of reference surfaces is considered an important objective to pursue.

9.4 Specific recommendations

Overall, a staged approach is recommended, designing the work programme involved in such a way that as many options as possible remain open until clear evidence for a change, or more focussed approach, is available.

[9] Some readers will have noted that the HERMES study produced a proposed specification for a new reference device. That specification was based on assumptions relating to slip-speed, slip ratio and operating speed used in earlier speed models. Subsequent work with RoadSTAR in Austria (which was built to follow the HERMES specification), showed encouraging agreement in measurements at the same nominal slip speed made under a wide range of test speed and slip ratio conditions, but not always with the levels of accuracy that might be required. Other studies with combinations of different device types have shown that these assumptions do not always work well in practice. For these reasons, although the HERMES approach should not be ruled out, a broader review of principles leading to a new device specification has been proposed.

Specifically, the TYROSAFE team recommends the following:

- ***Recommendation 1***

  EC road authorities should establish a Harmonised EU system for skid resistance measurements using current devices reporting on a Common Scale (with defined accuracy classes) based on the average of a defined set of existing devices in the medium term (5-7 years).

  The harmonised system should include provision for an appropriate accreditation regime to verify the stability of the Common Scale.

- ***Recommendation 2***

  To support Recommendation 1, studies should be carried out to:

  (i) Establish the precision of the alternative approaches to defining the Common Scale so that an objective comparison between them can be made and the most appropriate option chosen for implementation.

  (ii) Determine appropriate conversions to link the various devices to the chosen Common Scale.

  (iii) Develop and assign devices to appropriate accuracy classes.

- ***Recommendation 3***

  In parallel with work to follow Recommendation 2, carry out a programme of theoretical and experimental study in the medium term (~5-7 years) with the following objectives:

  (i) Make a broad review of the ways in which skid resistance measurements are currently used to assess accident risks; through in-depth study of basic principles, consider whether different approaches or improved techniques might better meet engineers' needs and develop a specification for a new type of measurement device designed linked to meeting those requirements.

  (ii) Build and evaluate a prototype device based on the specification developed and link this to the Common Scale.

  (iii) Build and evaluate a number of examples of the new device type to establish the expected precision in relation to the Common Scale and precision of other devices if the new device type were to become the reference.

- ***Recommendation 4***

  If the outcomes of Recommendation 3 are satisfactory, adopt the "Roadmap C" approach using the new device as the reference device type from 2020.

- ***Recommendation 5***

  In parallel, carry out work to develop reference surfaces that can be used to validate the new reference device type (and other devices) and become the reference points for the Common Scale in the longer term (10 – 15 years).

- ***Recommendation 6***

  Retain the idea of evolution to use the new device as an EU standard device for the main measurement purposes a possibility for the longer-term (15 years).

10 References

[1] P Nitsche, R Spielhofer et al. Report on policies and standards concerning skid resistance, rolling resistance and noise emissions. TYROSAFE Deliverable D06, February 2009

[2] D Kokot et al. Recommendations for future harmonised EU policy on skid resistance, rolling resistance and noise emissions. TYROSAFE Deliverable D08, June 2009.

[3] M.-T. Do, P. Roe, E. Vos, J. Groenendijk, State of the Art of Skid-Resistance Test Methods, TYROSAFE Deliverable D04, December 2008.

[4] J. Groenendijk, E. Vos, P. Roe, M.-T. Do, Analysis and Findings of Previous Skid Resistance Harmonisation Research Projects, TYROSAFE Deliverable D05, March 2009.

[5] M.-T. Do, P. Roe. Report on state-of-the-art of test surfaces for skid resistance TYROSAFE Deliverable D07, March 2009.

[6] M Kane, K Scharnigg, M Conter, P Roe and G Schwalbe. Report on different parameters influencing skid resistance, rolling resistance and noise emission. TYROSAFE Deliverable D10, August 2009.

[7] Descornet G et al., 2006, Harmonisation of European Routine and Research Measurement Equipment for Skid Resistance, FEHRL Report 2006/01, Brussels BE.

[8] ISO 5725-2:1994, Accuracy (trueness and precision) of measurement methods and results – Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.

[9] ISO 13473-1:2004, Characterization of pavement texture using surface profiles - Determination of Mean Profile Depth.

[10] ISO 13473-5 CD, Characterization of pavement texture using surface profiles - Measurement of megatexture.

[11] Britton SC, Ledbetter WB, and Gallaway BM, 1974. "Estimation of Skid Numbers from Surface Texture Parameters in the Rational Design of Standard Reference Pavements for Test Equipment Calibration". Journal of testing and Evaluation, JTEVA, vol. 2, nº2 p73-83.

[12] ISO/TC22/SC 9. "Vehicle dynamics and road-holding ability", ISO.

[13] ISO/TR 8350-1986 (E). "Road vehicles - High Friction test track surface-Specification", ISO.

[14] Huckins, H.C., 1977 “FHWA Skid Measurement Test Centres”. Public Roads. Federal Highway Administration. Washington D.C. September, 1977.

[15] Eldridge A, Whitehurst EA and Neuhardt JB, 1986. “Time-History Performance of Reference Surfaces. Page 61-71. The Tire Pavement Interface”. Pottinger/Yager edition. ASTM. Baltimore,.

[16] International Standards Organisation. Statistics -- Vocabulary and symbols -- Part 1: General statistical terms and terms used in probability. ISO 3534-1:2006

[17] International Standards Organisation. Accuracy (trueness and precision) of measurement methods and results -- Part 1: General principles and definitions. ISO 5725-1:1994