Sustainability & Environment

Road surface label: determination and prediction methods for noise, durability, skid and rolling resistance

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Abstract

The UNECE road surface label, developed by the Dutch working group, contains four indicators: noise reduction, rolling resistance reduction, wet skid resistance and lifespan. The label values (A to G) are determined by measurements, modelling, or a combination. The values must be reliable and objective. The labelling system therefore requires determination and prediction methods that are accurate and reproducible, available and well described, and representative for the influence of the road surface on the real-world environment. For each sub-label, methods need to be available to measure the quality of pavements in-situ, to assess Conformity of Production. For research and innovation, there is also a need for laboratory methods, to enable manufacturers to predict and improve their pavement performance before applying it outside. For some sub-labels, measurement methods are available and standardized, e.g. the CPX-/SPB-methods for rolling noise. For skid resistance, competing methods exist for longitudinal and sideway friction. Rolling resistance measurement methods are under development, but at an early stage. For lifespan, a measurement method that gives short-term results is not straightforward. For the laboratory, several methods for all four sub-labels are available, but not all are standardized and some lack predictive power. The paper describes the general requirements for determination methods, as well as the process steps of standardization ('from idea to ISO'). The availability of in-situ and laboratory methods is demonstrated for all four sub-labels. These methods are described in terms of their suitability and 'readiness'. The result of this investigation is a description of the most important research needs for determination methods, needed to further implement the road surface label internationally. The outcome contributes to a deeper understanding of the four label-indicators and is a step towards harmonisation. This paper is one of three papers on the road surface label submitted to the 7th E&E congress.

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1. INTRODUCTION

A draft UNECE resolution on road surface labelling [1] is currently under discussion. Road authorities of all UNECE contracting parties are called upon to give feedback on this document in general and with standardised measurement methods in particular. This paper informs relevant parties and stimulates feedback and discussion about road-tyre interaction.

There is an increasing number of household appliances and other consumer products that are equipped with a product label. Consumers are informed about the standardised energy efficiency and other key product performances in the form of an easy to understand label, mostly in green-yellow-red coloured A-G classes. Since the introduction of the label, the performance of products has been improved significantly leading to energy efficiency labels A+, A++ and A+++. Recently announced updates to the labelling system will change the class boundaries and bring back the A-G classes, where A and B classes will again be hard to achieve and target for further improvements.

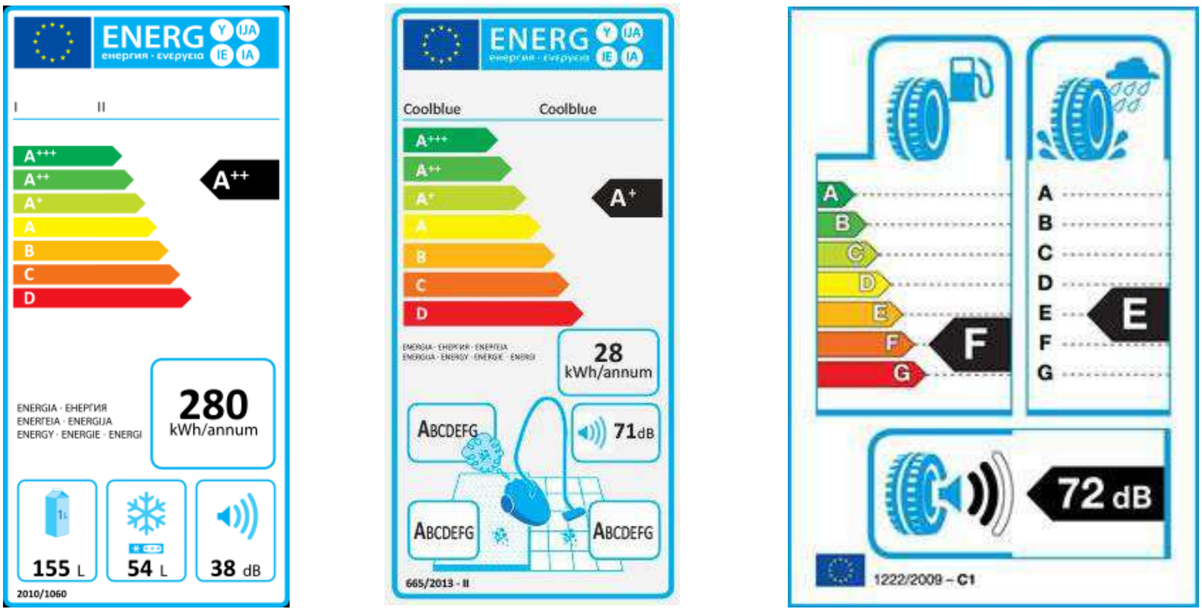

Figure 1: Examples of product labels, from left to right: a refrigerator, a vacuum cleaner, a pneumatic tyre

Since 2009 such labels are also introduced for the pneumatic tyres of road vehicles, as required by European directive 1222/2009/EC [3]. The tyre label informs about the rolling resistance (energy efficiency), wet grip (safety) and rolling noise (environmental impact). The performance of products is established using standardised measurement methods and test circumstances. For pneumatic tyres this means among others that the test speed, temperature and test surface are carefully described and standardised. This automatically means that the performance under actual, real-world circumstances can deviate from those under the standardised test if these real-world circumstances include different speeds, temperatures and/or road surfaces. The assumption is however that the ranking of products will remain identical when changing from standardised to real-world circumstances (see further explanation in paragraph 2.2). In the case of tyre performance it is important to take into account the influence of road surfaces. For example the wet grip of a slick tyre and a rain-tyre might be very different on a dense road surface, while their difference might disappear or reverse on a porous drainage asphalt.

Several researchers, road builders and policy makers have argued that a road surface label similar to the tyre label would have huge benefits for the road construction community, including

- easier communication between client and contractor
- stimulating and guiding of research and future improvement
- product quality control.

The development of a road surface label was accelerated when a local interest group in the Netherlands joined forces. This initiative contained representatives of road builders, local road authorities, research institutes and tyre industry. The group has drafted an initial version of the road surface label with indicators on the four key performances: noise reduction, skid resistance, rolling resistance and lifespan. The first three indicators are equivalent to the one's on the tyre label. The fourth indicator was considered essential in the contracting phase between road authority and road builder. Other parameters, like recyclability rate or embodied energy, have been discussed. But they have not been incorporated, as they were ranked lower in priority and as more parameters would slow down the start-up process of the label. This form of road surface label and related requirements has been used in tendering in the Netherlands.

Another paper in this same E&E2020 conference**Error! Reference source not found.** will demonstrate the use of the label on a road construction project.

The UNECE Working Party on Noise and Tyres (GRBP) is a technical working party under the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29), which is the worldwide regulatory forum within the institutional framework of the UNECE Inland Transport Committee. They prepare technical standards and provisions for vehicles, tyres, parts and equipment related to safety and environmental aspects. Among others they have prepared UNECE regulation R117[4] which contains the technical measurement methods behind the tyre label. As GRBP was informed on the Dutch initiative on a road surface label[5], GRBP were enthusiastic and requested the Netherlands to prepare a draft (informative) UNECE Resolution on road surface labelling[1]. This draft resolution is currently under discussion in UNECE. GRBP acknowledged that they are responsible for requirements to vehicles and tyres, not for road surfaces. But meanwhile they agreed that the road surface is a crucial factor for the performance of vehicles and tyres. Therefor standardised information on the cross effect of road surfaces is considered essential. All UNECE contracting parties are called upon to inform their (national and local) road authorities and consult them for feedback.
The current paper is intended as part of this international process. The underlying paper deals with the technical measurement methods behind the labelling system:

- paragraph 2 gives the requirement for good measurement methods;
- paragraph 3 describes which measurement methods are in the current UNECE paper;
- paragraph 4 gives some examples of label values and the decision dilemmas;
- paragraph 5 provides discussion and future steps.

The affiliated E&E2020 paper[2] informs about an example project in the Netherlands using the road surface label.

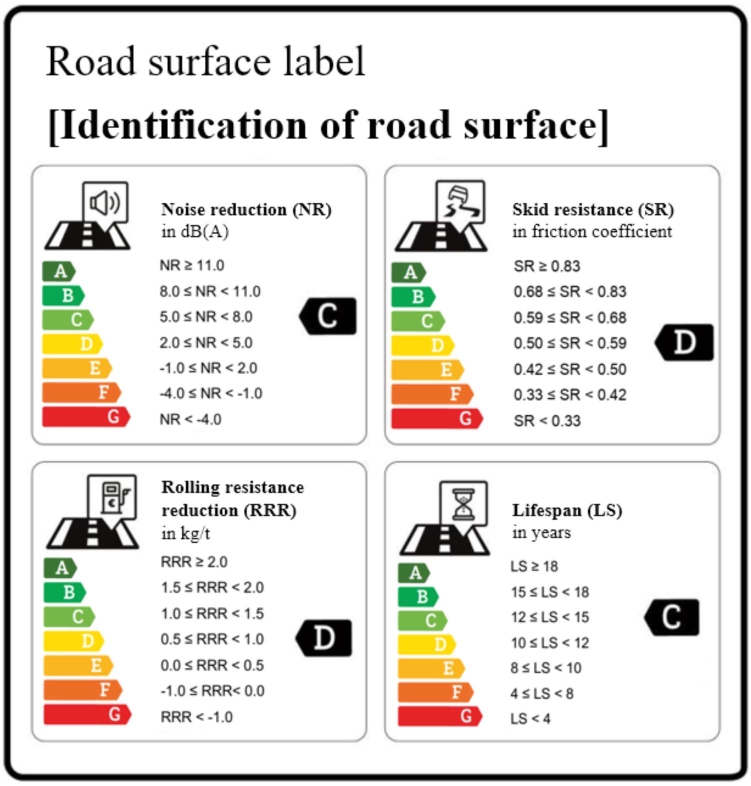

Figure 2: Format of the road surface label, indicating four key performances

2. Requirements to measurement methods

Measurement methods should as much as possible contribute to Reliable, Repeatable and Representative test results. In the next two paragraphs these terms are explained in more detail. Paragraph 3 describes the chosen measurement methods for the road surface label.

2.1. Reliable and repeatable

The label is intended to create a level playing field between contractors, authorities, competitors and public. Therefor test methods should above all lead to reliable and repeatable test results which are undisputable for any party involved. The methods should be (world) wide applicable and there should be minimal influence of test circumstances. There should be minimal site-to-site variation and minimal day-to-day variation. Site-to-site variation may be caused by differences in test site, differences in test equipment or differences in operator. Day-to-day variation may be caused by the influence of meteo conditions or by influences of equipment or operators. In some cases a correction formula may compensate for differences in test circumstances (e.g. a temperature correction). In some cases the allowable test circumstances and/or equipment have to be constrained and standardised.
An option often used to improve the reliability and reduce site-to-site and day-to-day variation is to measure the performance of a candidate product not as an absolute value, but as a difference compared to a reference specimen. In many cases the difference of a product compared to a reference is far more stable to determine than an absolute value. This is for instance used in the wet grip test of tyres according to R117[4]. The wet grip performance of candidate tyres is measured against the wet grip performance of a SRTT (Standard Reference Test Tyre). A similar approach is partly used for the road surface label. For the performance indicators Noise and Rolling Resistance it is required to test the Noise Reduction (NR) and the Rolling Resistance Reduction (RRR) compared to a Reference road surface. Obviously the stability of these reference tyres or road surfaces is crucial and have to be taken care of. The Reference does not always need to be a physical specimen. In case of the RRRs the Reference is determined by a working procedure. In case of the NR the Reference is determined by a mathematical formula (see par 3.1 and 3.3).

2.2. Representative

To achieve representative test results it is necessary that the performance of products as measured under test circumstances is representative for their performance under real-world, in-situ circumstances. In mathematical terms the representativity can be explained with the correlation and slope from a regression curve in a scatterplot. Figure 3 shows a (theoretical) example of increasing correlation, slope and representativity.
The absolute results do not have to be identical. Most important criterium is that the ranking of products remains consistent under all circumstances, as pass/fail criteria might be based on ranking. Furthermore the measured differences between products and the improvements made to products during test circumstances should be in-line with the differences and improvements in the real world. “In-line” does not mean that differences in the test and real-world should be identical, but differences during the test should give a good prediction of real world differences. It could be an advantage if differences during the test are an exaggeration of real world differences. This will magnify eventual opportunities and make it easier to distinguish best performing products from standard performance products. In such cases the expectations should be managed, as ‘magnified-opportunities’ during the test cannot be translated one-to-one into practice.

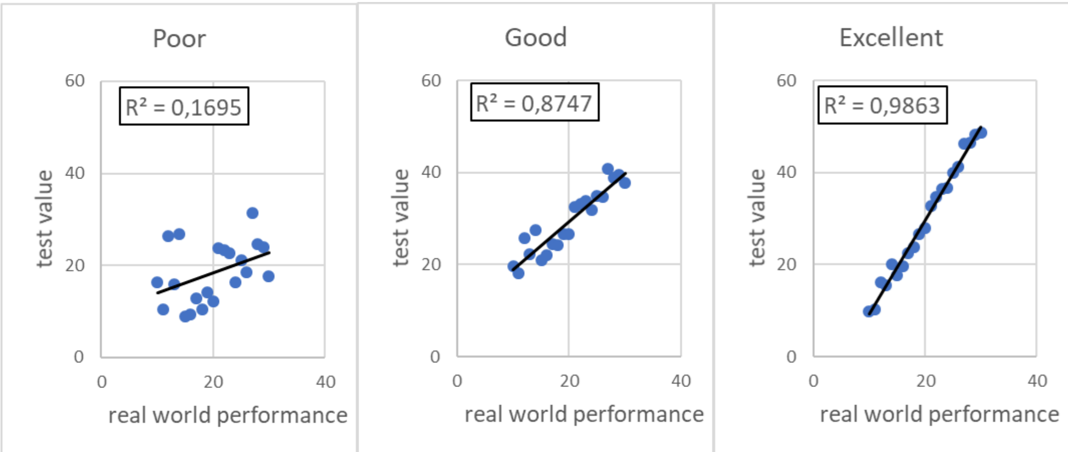

Figure 3: Theoretical example of scatterplots showing the relation between real world performance and test results. From left to right the correlation and slope increase and therefor the representativity.

Figure 4 illustrates an example of a well solved representativity issue in tyre noise testing. Similar issues have been discussed for road surface testing. In figure 4 it can be seen that the lines do not cross. Therefor the ranking of tyres as found on the ISO test track is in line with the ranking of these tyres on other road surfaces. Yet the slope of the lines is different, Therefor the differences between tyres as found on the ISO track will be smaller on the rougher real world road surfaces.

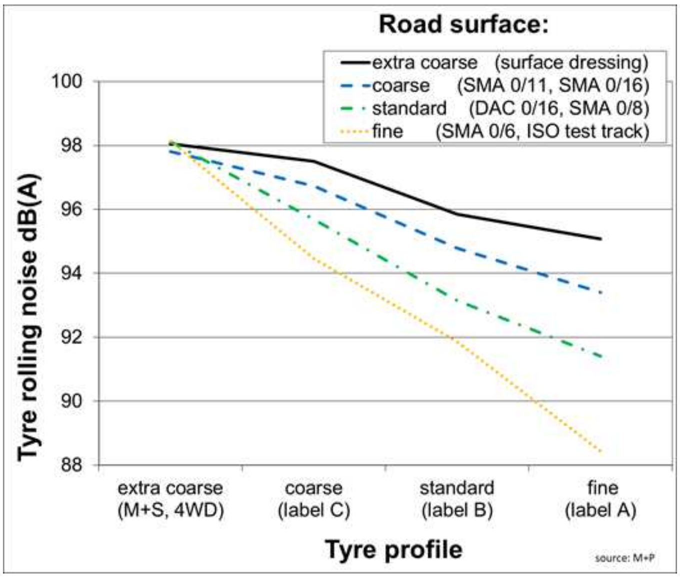

Figure 4: Analysis of measured CPX tyre/road noise levels. The results are averaged for four groups of tyres and four groups or road surfaces. The groups are settled according to their texture level. The standardized ISO 10844 test track, used in R117 for testing noise of tyres, is a fine graded road surface (yellow dotted line).

3. Place holders for the measurement methods

Preferably, the measurement methods should be chosen from existing ISO or CEN standards. Unfortunately, there are no such standards yet for all the performances indicated in the road surface label. Therefore, for some parts of the label "place holders" are chosen from the measurement practice in the Netherlands. As soon as ISO or CEN standards become available, the place holder methods can be replaced by the new standards. Where relevant, the performance indicators and class boundaries for the label have to be adapted simultaneously.
In the Netherlands it is common practice to determine the road surface performance by measuring it in a real-world situation on a finalised road surface. There are also measurement methods to estimate from laboratory samples the expected performance of future road surface types. Selection of the measurement method depends on the goal and the circumstances. For research and development of new road surfaces, lab measurements are the only efficient option. When the road surface label is used in a tender, the road authority can decide what measurement methods and proof/evidence is required. In some cases, they may require the proven performance, based on in situ measurements at earlier constructed road surfaces. In other cases they may be satisfied with more theoretical proof or lab experiments. All depends on the desire for proven, risk-safe and available technology or the desire for more advanced, but risky, future technology.
In the draft UNECE Resolution there are methods described in the Annexes which are based on in situ measurement on finalised road surfaces. Lab measurements are not included in this document. The in situ measurement methods are summarised in the following paragraphs.

3.1. Noise reduction

The characterization method for the noise reduction of road surfaces complies to the correction term for the influence of the pavement on the tyre rolling noise, as defined in the noise assessment method from EU directive 2015/996, for light motor vehicles[6]. Note that the procedure described here is intended for determining the noise reduction NR of a specific road surface on a single location. The ECE regulation Annex II [1] also describes a method for the determination of the Noise Reduction for heavy trucks as well as a method for averaging of the measurement results of different locations. Requirements to include heavy trucks or multiple locations may be part of the requirements of the tendering process, depending on the wishes of the road authority

Measurements
The measurements are done according to ISO 11819-1:2001 Statistical Pass-By method (SPB), but with a microphone height of 3 m, to avoid in-situ measuring problems caused by guard rails. For passing vehicles, the maximum sound pressure level ($L_{A,max}$) at 7.5 m from the centre of the traffic lane is measured, together with the frequency spectrum in octave bands (from 63 Hz to 8000 Hz) and the vehicle speed. This method gives an accurate test result for a certain spot along the road. If the production quality of a road surface over a longer road section has to be investigated, in-

situ monitoring can be done by the CPX method (ISO 11819-2:2017). CPX results can be converted to noise reduction values by calibrating them with SPB measurements. According to the ISO standard, measurements may only be taken at an air temperature between 5˚C and 30˚C, but the results are corrected to a reference temperature of 20˚C for cars (category 1) and multi-axle trucks (category 2b) separately:

$C_{temp,1} = 0.05 \cdot (T_{air} - 20)$
$C_{temp,2b} = 0.03 \cdot (T_{air} - 20)$

Statistical evaluation

During a SPB measurement, for each vehicle passage, the speed of the vehicle right in front of the microphone is measured as well as the sound level. For each measurement location, the linear regression lines for cars and trucks are determined from the sound level measured as a function of the logarithm of the measured speed ($a + b \cdot \log(v)$). As a guideline, at least 100 light vehicles (cars) and 50 multi-axle heavy-weight vehicles (trucks) must be measured at each location. The actual needed number of vehicles and the necessary spread in vehicle speed may be higher, depending on the achieved reliability.

Determination of noise reduction

The noise reduction should be determined at 80 km/h for cars. If applicable the noise reduction for heavy trucks should be determined at a reference speed of 70 km/h. As reference road surface a numerical equation (“virtual reference surface”) is used, based on measurements on several sections of asphalt concrete, averaged over a typical lifespan. The reference surface values can be calculated with:

$L_{ref,1}(v) = 77.2 + 30.6 \log(v / v_{0,1})$ for light vehicles, with $v_{0,1} = 80$ km/h
$L_{ref,2b}(v) = 84.4 + 27.0 \log(v / v_{0,2b})$ for heavy vehicles, with $v_{0,2b} = 70$ km/h

The noise reduction NR is defined as the difference between the pass-by levels of light motor vehicles at 80 km/h on the “virtual reference surface” and the pass-by levels of the specific road surface in newly-laid condition. The noise reduction is therefore positive if tyre-pavement noise on the specific road surface is less than on the “virtual reference surface” (a ‘quiet surface’). The “virtual reference surface” formula given above is based on a set of pass-by sound levels representing a Dense Asphalt Concrete (ACsurf) of average age. The properties of the reference surface were determined by averaging about 10 different sites of different age in different speed ranges.

3.2. Skid resistance

Tyre-road friction is characterised by the friction coefficient, which is the ratio of horizontal force over vertical force (Newton/Newton or dimensionless) This friction coefficient is influenced by many factors, which can be roughly divided into four groups: 1. tyre, 2. road surface, 3. intermedium (e.g. water), and 4. (environmental) conditions. The contribution of the tyre, measured under standardized conditions on standardized pavements, is often termed “wet grip”, whereas the contribution of the road surface, measured under (possibly other) standardized conditions using standardized tyres, is mostly termed “skid resistance”.

To assess the wet skid resistance performance of road surfaces, continuous self-wetting measurement at traffic speeds is deemed essential. This means that the UNECE R117 measurement procedure for determining wet grip of tyres for the tyre label is not suited, as this requires deceleration of the test vehicle from 80 to 20 km/h. Also locked-wheel testers according to ASTM standards are not suited, because of their discontinuous, intermittent, results.

For continuous skid resistance measurement, world-wide standard ISO 8349:2002(en) gives three options for measurement of longitudinal (braking) tyre-pavement friction using standard reference test tyres (SRTT): transient braking force, constant-braking slip, of fixed-braking slip. However, this measurement method is hardly used in Europe, where many national methods are used, either measuring longitudinal (braking) or transversal (steering) tyre-road friction. The most commonly used in Europe are the British SCRIM (Sideways force Coefficient Routine Investigation Machine) and German SKM (“SeitenKraftMessung”, Sideways Force Measurement). These devices are very similar, but procedures for measurement, including correction for temperature and season, and quality assurance differ between the United Kingdom and Germany.

However, in the pilot applications of the road surface label in pavement contracting projects in the Netherlands, ISO 8349, SKM or SCRIM could not be used, for lack of reference values for these methods for initial skid resistance of the pavement types constructed. Therefore, the common Dutch measurement method was used. This measures the longitudinal friction coefficient, using a smooth PIARC (165 R 15) test tyre inflated to 200 kPa and loaded to 1962 N. The measurement conditions are: 70 km/h, 86% slip ratio (close to locked wheel conditions), and 0.5 mm water film thickness. For road surface labelling in right-hand driving countries, the measurements should be executed in the right wheel path of each lane required by the client (but at least the slow lane).

This Dutch measurement method is described fully in the UNECE GRB resolution, including procedures for quality assurance of measurement results. This description includes:

- Calculation differences between “open” (permeable) and “dense” (impermeable) surfaces;
- Tolerances on operating conditions;
- Seasonal correction of friction coefficient values;
- Influence of temperature (ambient, tyre and road surface);
- Initial and in-service assessment of measurement tyre characteristics, including the effects of age-hardening of tyres;
- Mechanical calibration of the measurement devices;
- Bimonthly round-robin testing of several devices and tyres.

3.3. Rolling resistance reduction

The rolling resistance reduction (RRR) is the difference between a reference rolling resistance coefficient (RRC) and the RRC of the road surface to be assessed. The rolling resistance coefficient (RRC) is the ratio of horizontal force over vertical force. The reference rolling resistance coefficient is determined on a “virtual” reference road surface, being either a stone mastic asphalt (SMA) or an open-graded asphalt, both with 11 mm maximum aggregate size.
There are two methods to determine the rolling resistance reduction:

(i) direct measurement of the rolling resistance,
(ii) an estimated rolling resistance reduction based on road surface texture measurements.

To obtain the most accurate result, a direct measurement of the rolling resistance is preferred. However direct measurement devices may be harder to obtain than texture measurement devices. At this moment there are two publicly available rolling resistance trailers: at the TU Gdansk in Poland and at the BRRC in Belgium. Other trailers are in use or being developed, but not publicly available.

Figure 5: Example of a measurement trailer (TU Gdansk) for direct rolling resistance measurements

Reference road surface
To minimize the effects of systematic errors between measurement systems, the rolling resistance reduction is calculated as a reduction of resistance with respect to a “virtual” reference road surface, being a stone mastic asphalt (SMA) [EN 13108-5] or open-graded asphalt [EN 13108-7] with 11 mm maximum aggregate size. The measurement system used to perform the measurements must also measure the rolling resistance of this 0/11 reference road surface, in order to have a reference measurement value for that particular system. The UNECE document describes a procedure to perform yearly and daily measurements on a group of reference tracks from which the virtual reference road surface is calculated.

Direct rolling resistance measurements
A direct measurement of the rolling resistance of a road surface in-situ is performed by using specially designed measurement trailers. The resistance of the test wheel(s) to rolling is measured in traffic, at normal vehicle speeds. While driving, the measurement system will measure the backward force experienced by the rolling tyre (e.g. with force transducers or by accurately measuring the angle of a swivel arm).

A measurement standard (e.g. ISO, CEN) is not yet available. In principle, therefore, any rolling resistance measurement device can be used to determine the rolling resistance reduction label. The UNECE document describes a set of requirements to the test equipment and test procedure. Those requirements include:

- Tyres: Measurements should be conducted with the SRTT (Standard Reference Test Tyre) [ASTM F2493-18]. The tyre load should be 400 kg. The tyre should be warmed up before measurements until a stable tyre sidewall temperature is reached. The tyre pressure should be corrected to meet 210±10 kPa in running conditions and all measured values should be corrected to a reference tyre side wall temperature of 25°C;
- Test circumstances: The measurement speed should be stable during the measurements. The allowed speed is 80±1 km/h. Measurement results should be disposed in the case of steep slopes (>2%), sharp corners, etc. Corrections for parasitic influences should be kept small by eliminating these influences as much as possible. Correction procedures should be used to compensate the effect of slopes, wind and acceleration during the measurements;
- Road surface: Measurements should be conducted on road surfaces in new, but broken in, conditions (2-24 months old); The measured road surface must be dry and free of dirt; The road surface length should be preferably 400m or longer. In case of shorter measurement lengths, multiple runs may be averaged, and the minimum travelled distance should be 400m. The minimum road surface length should be 50 m;

Estimated rolling resistance reduction based on texture measurements

Alternatively, the RRR can be estimated with texture measurements. In that case in-situ road surface texture should be measured using a measurement system according to ISO 13473. To calculate the label value for the rolling resistance reduction the following model should be used:

$$RRR_{label} = -1.47 \cdot MPD + 0.24 \cdot MPD/RMS + 1.99$$

This model is only validated **Error! Reference source not found.**[6] for standard asphalt road surfaces and MPD-values in the range between 0.4 mm and 2.3 mm. The valid RMS-values range is between 0.3 mm and 1.7 mm. It should be noted that due to model inaccuracies, the rolling resistance which is estimated using texture parameters can be different from direct rolling resistance results. This may lead to differences of up to ± 0.7 kg/t (95% confidence interval), which would mean plus or minus two rolling resistance classes.

3.4. Life span

The lifespan of a road surface encompasses all types of surface distress:

- Unevenness;
- Cracking;
- Ravelling;
- Abrasion;
- Joint condition;
- Etc.

The distress type that first reaches the serviceability limit values (defined in contract or in national or international regulations) is critical, i.e. defines the lifespan. For different types of road surface, different distress types may be critical[11].

The methodology and road surface condition criteria to determine lifespan have to be specified in the contract requirements for road surface construction, separately for the tender phase of contracting and for the warranty period in the contract, because there is no single uniform methodology to determine lifespan. This is because:

- Road surface deterioration is highly dependent on project-specific factors, such as road surface type or material, climate, drainage, and traffic (intensity, weight, speed, manoeuvring, incidents);
- Criteria for acceptable road surface condition (severity and extent of distress) may differ between road categories (from motorways to rural roads) and may differ between pavement types, countries, regions or road authorities;
- Accurate lifespan prediction before or just after pavement completion is impossible, since no methodology exists to accurately predict pavement distress development over time and cumulative traffic; and therefore the client needs to specify the required substantiation for a-priori lifespan claims.

In the tender phase of a contract, the client can specify what information is solicited from the contractor to substantiate his claims for the lifespan of the road surface to be constructed. For the warranty period of the contract, the client can specify the criteria for acceptable road surface condition for a specified period.

4. Typical label values

Figure 6 gives an indication of the label values for some typical road surfaces in use in the Netherlands. The normal performance is in the C to F range. Label values B and G are rare and A is normally not achievable with current technology. Performances on various label criteria might be partially contradictory[12]. Road authorities may use such a list with alternatives for decision making, fitting their own priorities. From the list in figure 6 double-layer-porous-asphalt (2L-PA8) for instance has the best score on noise reduction (label C), but it also has some drawbacks on lifespan (label E). Single-layer-porous-asphalt (PA16) may have more acceptable lifespan and still acceptable noise reduction (both label D). In tenders and in product development road constructers are challenged to improve their road surface to fit the best compromise requested by their clients. The winning road surface in [2] has a label CDBB, outperforming the label values of all of the listed standard road surface in figure 6.

Road surface	Noise Reduction	Skid Resistance	Rolling Res. Red.	Lifespan	Label
AC 11 surf	E	D	C	C	EDCC
Surface dressing	F	E	G	F	FEGF
PA 16	D	E	E	D	DEED
2L-PA 8	C	E	D	E	CEDE

Figure 6: Indication of the spread in label values of various road surfaces in the Netherlands. The value of a specific product may deviate from this indication.

5. Discussion and future developments

This paper describes the introduction of a road surface label with four indicators on the key performances of a road surface: Noise Reduction, Skid Resistance, Rolling Resistance Reduction and Life Span. The label was initially introduced in the Netherlands for national tenders. For this E&E2020 congress another affiliated paper will introduce recently gained experience with this road surface label in Dutch tenders[2]. More of such tenders are expected in the near future.

When the UNECE working group on noise and tyres (GRBP) heard about this initiative, they requested the Netherlands to draft an (informative) UN Resolution, to be discussed in the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29). This draft resolution is currently available on the UN website and UNECE contracting parties where called upon to inform their (national) road authorities and ask them for feedback. The current paper intents to support this information and feedback process.

The paper describes place holder measurement methods to determine the label values. Meanwhile it is acknowledged that these place holders should be replaced by suitable CEN or ISO standards as soon as they become available. Most important is that measurement methods lead to reliable, repeatable and representative results.

- The measurement method for noise reduction (NR) is based on the Statistical Pass-By method (SPB) according to ISO 11819-1:2001. The “virtual reference surface” is a, based on a set of pass-by sound levels representing a Dense Asphalt Concrete (ACsurf) of average age. The method for NR is probably the best standardised method of the four label indicators.
- The measurement method for skid resistance (SR) is currently based on the common Dutch measurement method. ISO 8349, the German SKM or the British SCRIM where considered, but could not be used, for lack of reference values for these methods for initial skid resistance of the pavement types constructed. Alignment of these methods is necessary.
- The determination method for rolling resistance reduction (RRR) allows direct rolling resistance measurements as well as indirect texture measurements. The method also describes a procedure to determine the reference rolling resistance coefficient on a set of reference road surfaces. Currently there are in Europe only two publicly available devices for direct rolling resistance. There is a clear need for more devices and alignment and standardisation of these devices.
- The methodology to determine lifespan has to be specified in the contract requirements for road surface construction, because there is no single uniform methodology to determine lifespan (ref EN 12697[11]). For different types of road surfaces and traffic situations, different distress types may be critical.

Feedback on the UNECE document and input for more suitable measurement methods can be submitted to the GRBP vice chair, but could also be guided through the authors of this paper: (erikdegraaff@mp.nl, also member of GRBP or Frank.Bijleveld@strukton.com, also member of the Dutch initiative group).

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