Improving the CPX method by specifying reference tyres and including corrections for rubber hardness and temperature

Ulf SANDBERG1; Erik BÜHLMANN2, Marco CONTER3; Piotr MIODUSZEWSKI4, Reinhard WEHR3

1 Swedish National Road and Transport Research Institute (VTI), Sweden
2 Grolimund + Partner AG, Switzerland
3 AIT Austrian Institute of Technology GmbH, Austria
4 Gdansk University of Technology (TUG), Poland

ABSTRACT
Recently completed work in the EU project ROSANNE and in working group ISO/TC43/SC1/WG33 has allowed substantial improvements to measurements made by the Close-Proximity (CPX) method, intended for measurement of noise properties of road surfaces. The paper summarizes the experimental work and describes the conclusions and implementation in ISO/FDIS 11819-2 (the CPX method) and in the supporting ISO (draft) Technical Specifications 11819-3 about Reference Tyres and 13471-1 about Temperature Corrections. In the Reference Tyre specification, two reference tyres are defined, of which one is the 16” SRTT specified in ASTM 2493-14 and the other is a commercial light truck tyre. Both tyres have been tested with respect to correlations with SPB (pass-by) measurements and found to represent car and truck tyres, respectively, in this particular application. To account for reasonable ageing and minor production differences, a correction for rubber hardness is specified, in order to normalize measurement results to tyres having reference hardness. The Temperature Correction specification includes temperature coefficients that are used for normalizing noise levels to an air reference temperature of 20 degrees C. The coefficients relate to driving speed by a simple equation which is different for three categories of road surfaces, which are specified in the document.

Keywords: Reference, Tyre, Temperature, Rubber hardness, ISO, CPX, ROSANNE.
I-INCE Classification of Subjects Number(s): 11.7.1, 13.2, 72, 73, 81.2, 82, 89

1. BACKGROUND AND HISTORY

The widely acknowledged needs to reduce tyre/road noise, and the knowledge that tyres and road surfaces play equal parts in this noise source [1], means that selecting a suitable road surface has become part of traffic noise control strategies. In order to do that without the risk of making inappropriate decisions, one must have reliable measurement methods for this road surface property. There is even pressure in the United Nations ECE expert group on noise for establishing a regulation for noise properties of road surfaces; i.e. that road authorities may have to use a certain category of road surface where noise exposure is a problem. Some countries, such as the Netherlands, already have national policies with respect to selecting low noise road surfaces where needed. However, there is no international or regional policy and, therefore, the European Committee for Standardization (CEN) has assumed the challenge to prepare a classification method (we may call it noise label) for road surfaces, within the work of its CEN/TC 227/WG 5.

The first step is to produce measurement methods suitable for this purpose. Already in the 1990’s work was conducted within ISO (ISO/TC 43/SC 1/WG 33) to prepare the so-called Statistical Pass-By (SPB) method, now standardized in ISO 11819-1 [2], and soon after it was published, work started

1 ulf.sandberg@vti.se
2 erik.buehlmann@grolimund-partner.ch
3 marco.conter@ait.ac.at; reinhard.wehr@ait.ac.at
4 pmiodusz@pg.gda.pl
with the Close Proximity (CPX) method [3]. The former relies on measurement of noise level and speed of a statistical significant number of passing light and heavy vehicles in the traffic, using a road-side microphone. This is therefore a “spot method”; i.e. the road surface near the measurement microphone is what is measured, and one must meet severe acoustical requirements in the vicinity of this location.

The CPX method relies on a test tyre being rolled over the tested road section, most commonly mounted in a special trailer, with two microphones in close-proximity of the test tyre. Acoustical requirements on the road are then not critical; instead they will be critical in the vicinity of the test tyre. The measurement may include an arbitrary length of road surface. It has been found necessary to use two tyres (reference tyres) to characterize the interaction between the road surface and both light and heavy vehicle tyres.

Along the way, it was also noted that temperature (air, road and tyre) influences the noise measurement results; thus, work to quantify this effect was started.

To make this development possible, work with measurement methods has been going on for a couple of decades. This work has been conducted in two ISO working groups (WG):

- ISO/TC 43/SC 1/WG 27, dealing with the influence of temperature on tyre/road noise
- ISO/TC 43/SC 1/WG 33, dealing with noise properties of road surfaces; including the SPB and the CPX method, and also specification of reference tyres.

Since some issues critical in these methods needed further research before standards could be accepted, and the ISO work only includes the measurement methods, and not classification or labelling; a European project has been started. This project is named ROSANNE, and is reported in another Inter-Noise paper [4]. Most of the work reported here has been made in close cooperation between the ISO and the ROSANNE project.

2. SPB OR CPX METHOD?

Earlier, most essentially in the SILVIA European Project ended in 2005, it was considered that the SPB method would be used for this purpose, where you measure noise and speed of passing single vehicles in the normal traffic and produce a statistical average; ideally supplemented with some measurement by the CPX method. However, by time, interest in and use of the CPX method has increased, and in 2015 it was decided in ROSANNE that the CPX method (alone) is suggested for use in a future European (CEN) standard for classification of acoustic properties of road surfaces. A European standardization group denoted CEN/TC 227/WG 5 has accepted the task to develop this in the next few years.

The reasons for the shift in interest from SPB to CPX are that:

- It has been more and more recognized that on porous surfaces the noise properties vary substantially both along the road and sideways, making single spot measurements almost meaningless [5]
- The “fashion” of building barriers of various kinds along highways and motorways, as well as the generally increased traffic volume make the SPB method less practical
- The work with the CPX method, tightening the specifications and reducing potential uncertainties have made this method more attractive
- The study of the reference tyres has greatly increased the reliability and stability of these in recent years, including correction for increasing rubber hardness
- The work to specify corrections for temperature has aided in reducing uncertainties, somewhat more reliably for the CPX tyres than for a mix of traffic (in the SPB method)
- More and more organizations have built or purchased CPX trailers.

Another Inter-Noise paper reports about ROSANNE work to investigate the relationships between noise measurement results obtained with the SPB and the CPX methods [6].

3. IMPROVING THE CPX METHOD AND SUBMITTING DRAFTS TO ISO

The first drafts of the CPX method were produced in ISO/TC 43/SC 1/WG 33 already 15-20 years ago, with a first CD circulated within the ISO noise committee in 1997 and a second CD in 2000, and many organizations have used it after that, with more or less deviations from the present version. The reason why it could not be finalized was the lack of suitable reference tyres. Around 2008 various members of the working group started to test and use the two reference tyres that are now subject of specifications but the work went slowly since a number of obstacles were unresolved; such as the
effect of rubber hardness increase on noise levels, the tyre-to-tyre variation and the influence of temperature. One also wanted to know what the correlation between SPB and CPX measurements were like with these tyres. In 2011 the work was resumed, based on the new tyres and a more comprehensive description of various issues, and a new CD was submitted to the ISO noise committee in 2011. Although approval rate was very high, the working group had to address an immense number of comments (100+ comments on 15 tight-written pages), many of them leading to the need for the use of new symbols. This took time to deal with and a first Draft International Standard (DIS) was submitted in 2013. After a new set of 100+ comments, a 2nd DIS was submitted in 2015 (18 countries voted in favour and one country voted against the DIS), and now in the middle of 2016 a Final DIS (ISO/FDIS 11819-2) is being produced [3]. This one should be the final version, and only correction of language or editing errors are possible after this.

Improvements in the later versions include:

- Using more logical and formally correct symbols
- Specifying the processing of data in details with equations given in a way which encourages the production of software for consistent data processing
- Improved explanations, avoiding misinterpretations
- Better description on how to certify CPX trailers and similar devices; for example, using a special stationary sound source simulating a rolling tyre
- Advice regarding special surfaces
- Full block diagrams illustrating the measurement and analyses procedures
- Advanced analyses of uncertainties

As examples, a few of the most frequently used CPX trailers are shown below, in Figures 1-3.

Figure 1 - Single-wheel CPX trailer from the Gdansk University of Technology, operating in Sweden. The test tyre and microphones are located in the middle of the enclosure.

Apart from these trailers, it is also possible to use a “self-powered vehicle”; i.e. selecting a suitable car or van and replace one of its non-driven wheels with a wheel/tyre of the reference types. However, although it may be tempting to use this one, since a special trailer is not needed, this version of CPX equipment is indeed very critical to use, for many reasons. It is also difficult to find a vehicle that can fit the tyres and provide the specified load.

The most significant improvements related to the CPX method lie in the specification of reference tyres and temperature corrections, which are the subject of two separate ISO Technical Specifications; see further below.
Figure 2 - Two-wheel trailer with enclosure(s), owned and supplied by M+P consulting engineers in the Netherlands (newer but similar version available). Note that the enclosure can be lifted for easy access to each tyre. Microphones are mounted on the inside of the tyres.

Figure 3 - Two-wheel trailer without enclosure (called deciBellA), owned by the Danish Road Directorate, produced by DGMR in the Netherlands. Note the microphone mountings.
4. REFERENCE TYRES

4.1 Tyres P1 and H1

The CPX method is useful only with certain reference tyres. Therefore, in parallel to the work on the CPX method, work in WG 33 on reference tyres has been intensive [6]. This aims at producing an ISO Technical Specification (TS) with the final designation ISO/TS 11819-3, specifying two reference tyres. The two tyres selected as references, and already widely used, are the following:

**Tyre P1:** A steel-belted radial tyre for relatively large passenger cars or vans, specified in ASTM standard F2493-14, having the dimensional code P225/60R16 and referred to as a Standard Reference Test Tyre (SRTT). Both the text "Standard Reference Test Tyre" and the dimensional code P225/60R16 are displayed on the sidewall.

**Tyre H1:** A steel-belted reinforced radial tyre for light trucks and vans, manufactured by Cooper Tire & Rubber Co. in the United Kingdom under the product name "Avon Supervan AV4", having the dimensional code 195R14C. The Avon Supervan AV4 has a reinforced carcass construction to enable the carriage of heavy loads, and has a very robust rubber compound on the sidewall.

P stands for passenger cars, and H stands for heavy vehicles. The number 1 (in P1 and H1) indicates that this is the first generation of reference tyres; as it is likely that in 5-15 years, one would select tyres that are more in line with the tyre market at that time. Although the widths of these tyres are quite different, the outer diameters are quite similar, which is practical when changing tyres. The tread patterns of the two reference tyres are illustrated in Figure 4.

![Figure 4 – The tread patterns of the two reference tyres specified in ISO/DTS 11819-3 [6].](image)

But why exactly two tyres? In the work with the CPX method before 2008, four tyres (A, B, C, D) were tentatively selected, of which two were meant to represent summer type tyres (A and B), one was intended to represent winter type tyres (C), and one (D) had properties that simulated the sensitivity to road surface texture that is typical of truck tyres. It was soon found that the three first ones gave similar ranking of road surface “noisiness”, and tyres B and C were dropped because of this. Then, both A and D became unavailable.
It was noticed already in the 1980’s that road surfaces influence tyre/road noise in different ways depending on whether one is testing with passenger car or truck tyres. In general, truck tyres are much less sensitive to the texture of the surface than car tyres are. Truck tyre/road noise is often the worst on the smoothest surfaces, while it may be almost the contrary for car tyres. Therefore, in order to characterize the road surface “noisiness” for a blend of light and heavy vehicles, one must make measurements with both a car and a truck tyre. But a test vehicle with one or two heavy truck test tyres will be very heavy, impractical to maneuver, and very expensive. Therefore, it was chosen to search for a light tyre that can act as a proxy for the heavier bus and truck tyres, but still be so small that one can use it together with a car tyre. Tyre D mentioned above did this work very well, but is gone from the market since long. WG 33 has identified such a (newer) tyre, which actually is one of the smallest light truck tyres you can get, but it appears to do its job to simulate the sensitivity to noise properties of heavy truck tyres. This is the H1 tyre mentioned above. As also this one will not be available for a long time, the intention is to build up a significant supply of such tyres and store them well for subsequent use during the next few years.

The two tyres are fairly large for fitting on a car or light trailer, with load index (LI) of 97 for P1 and 106/104 for H1. Normally, these tyres would be loaded up to about 6000-10000 N, but this would require a fairly large test vehicle (trailer) needing a very powerful towing vehicle. Therefore, a nominal load of 3200 N and an inflation pressure of 200 kPa have been chosen. This combination gives a fairly “normal” tyre footprint on the road and has appeared to give the desired sensitivity to road surface “noisiness”; see for example [5].

4.2 Rubber hardness

Project ROSANNE (see below) has helped a lot with supplying missing but essential data. For example, we are now able to correct for the ageing and increasing rubber hardness of the tyres. Thus, reference tyres should be able to use for at least 2-4 years before new ones must be purchased. This, however, depends on how one is storing the tyres when not in use; the document gives firm advice on this (ideally at 5 °C). If tyres are stored in a warm environment (say 20-30 °C), the useful life of such tyres will be much shorter. There is also a recommendation to fill the tyres with nitrogen gas instead of air in order to reduce ageing and to keep a more stable inflation.

Rubber hardness of the tyres has appeared to be a crucial factor in order to get reproducible results and to measure this is not simple; thus the document includes a procedure for doing this. However, hardness is influenced by temperature: increasing temperature softens the rubber. Therefore, ideally, rubber hardness shall be measured at a reference tyre rubber temperature chosen as 20 °C. But this is easier said than done; therefore, a procedure has been worked out that allows hardness measurements to be done within the range 15-25 °C, and when the hardness is then normalized to 20 °C. This has been possible thanks to work in ROSANNE where the relation between rubber hardness and temperature has been determined, for the rubber used in the P1 and H1 tyres [8]. The procedure for this normalization is as follows:

| Tyre temperature, $T$, shall be measured immediately before rubber hardness is measured and be within the range 15 °C to 25 °C. If tyre temperature deviates from the reference temperature 20 °C, correction of the measured rubber hardness $H_{A,\text{measured}}$ value shall be made according to Formula (1):
| $H_A = H_{A,\text{measured}} + 0.25(T_{\text{measured}} - 20)$
| where $H_A$ is the numerical value of the rubber hardness, expressed in Shore A;
| $H_{A,\text{measured}}$ is the measured rubber hardness, expressed in Shore A;
| $T_{\text{measured}}$ is the measured tyre temperature, expressed in °C.

In general, tyre rubber gets harder with age and exposure to high temperatures, and tyres get noisier with increasing hardness. This is a major problem with regard to the acoustic stability over time for the tyres. Typically, 5 Shore A units may have a 1 dB influence. This cannot be accepted. One option is then to have very tight requirements for the rubber hardness of the tyres; say allow an increase with time of only 2 units from the hardness of the tyre in new condition. But this would require new tyres to be purchased maybe a couple of times per year, which is very impractical. Therefore, WG 33 has introduced a procedure to correct noise levels to a “reference hardness”, which has been chosen to be
66 Shore A, by which one may allow a relatively large range of hardness, namely 62 - 73 for Tyre P1 and 60 - 73 for Tyre H1.

The most essential, but not the only, document on which this is based is another Inter-Noise paper [7]. The correction procedure chosen is the following:

\[
C_{HA,t} = \beta_t (H_A - H_{ref})
\]  

(2)

where

\[
\beta_t \text{ is the rubber hardness coefficient for tyre } t, \text{ in dB/Shore A (which is 0.20 for both tyres)};
\]

\[
H_A \text{ is the measured rubber hardness, in Shore A};
\]

\[
H_{ref} \text{ is the reference rubber hardness } = 66 \text{ Shore A};
\]

\[
C_{HA,t} \text{ is the CPX level correction for rubber hardness } (H_A) \text{ for tyre } t, \text{ in dB (shall be subtracted)}.
\]

For example, if tyre P1 has increased its rubber hardness to 73 Shore A units (the maximum allowed) then the correction shall be 0.20 \( \times \) (73-66) = 1.4 dB, which shall be subtracted from the measured noise level.

### 4.3 Other issues related to the tyre specifications

Another important issue is how to mount the tyres in relation to the microphones (rotation and side facing microphones), as well as how long run-in that is required before one should start measurements (400 km). Both these issues are dealt with in detail in another Inter-Noise paper [9].

The temperature influence on noise levels measured with the two tyres, and how to correct for it, was in the last minute included in the reference tyres Technical Specification (TS), despite it is the subject of another TS [10]. The reasons were, partly, that the temperature influence is exclusively related to these tyres, and that there were fears that the TS on temperature influence would not be ready in due time in order to be referenceable in the TS for reference tyres. However, only the most essential parts of the temperature influence specifications are in ISO/TS 11819-3, leaving the major parts for the ISO/TS 13471-1 [10]. Therefore, this subject is dealt with in the next section.

A Draft Technical Specification (DTS) was distributed for ballot in June 2016, following a ballot for a previous version which resulted in 15 votes (countries) in favour and two against. It is hoped that the final version, ISO/TS 11819-3, can be published at the end of 2016, simultaneously with the CPX method (ISO 11819-2).

It is worth noting that the same reference tyres are being considered as references also in the rolling resistance measurement method and classification procedure.

### 5. TEMPERATURE INFLUENCE AND CORRECTING FOR IT

In northern Europe, we sometimes measure with the CPX method at down to 5 °C (typically in October and beginning of November), and sometimes at up to 30 °C (hot summer days). Over a black asphalt in summer, exposed to sunshine, air temperatures can be even above 30 degrees. A difference of 25 degrees may mean a difference in noise level of around 2.5 dB(A); so it is obvious that not taking temperature into account is meaningless when one would like to measure differences due to the road surface of 1 dB(A) or lower.

In parallel to the work in WG 33 on the CPX method and on reference tyres, work in WG 27 on temperature corrections to CPX measurement results has been intensive. Again, project ROSANNE has helped a lot with supplying missing but essential data; in fact, it resolved some of the issues that delayed work before. It is now possible and feasible to correct for the temperature effect. Much of this was made possible by a very comprehensive data compilation and assessment in 2014 [18]. This subject was then well covered at Inter-Noise 2015, with three papers devoted to this [11,12,13].

The WG 27 work aims at producing an ISO Technical Specification (TS) about the temperature effect and its correction procedure [10]. The correction depends on the test speed and on the main type of pavement. Especially, road surface porosity features are critical. For this reason, the draft (DTS) now includes an annex that explains how one can distinguish between the three different classes of pavements. In this annex, a lot of CEN standards for road surface construction are referenced to reduce the risk of subjectivity in determining the road surface category.
The temperature correction shall be made as follows, using Formula (3):

\[
C_{T,t} = \gamma_t (T - T_{ref})
\]

where
- \(\gamma_t\) is the temperature coefficient for tyre \(t\) (P1 and H1), in dB/°C, see further below;
- \(T\) is the air temperature \((T)\) during the CPX measurement;
- \(T_{ref}\) is the reference air temperature = 20°C;
- \(C_{T,t}\) is the CPX level correction for temperature \((T)\) for tyre \(t\) (P1 and H1), in dB(A).

The temperature coefficient \(\gamma_t\) values are as follows:

For dense asphaltic surfaces (such as DAC, SMA, chip seals)

\[\gamma_{P1} = \gamma_{H1} = -0.14 + 0.0006 \cdot v\]

For cement concrete surfaces of all types

\[\gamma_{P1} = \gamma_{H1} = -0.10 + 0.0004 \cdot v\]

For porous asphalt surfaces (not seriously clogged)

\[\gamma_{P1} = \gamma_{H1} = -0.08 + 0.0004 \cdot v\]

where
- \(\gamma_{P1}\) is the temperature coefficient for tyre P1;
- \(\gamma_{H1}\) is the temperature coefficient for tyre H1;
- \(v\) is the test speed in km/h.

In many practical cases it will be difficult to select the right road surface category. However, the DTS [10] contains quite detailed advice on this. The reason why it differs between road surface categories is that different generation mechanisms dominate on different combinations of tyre and road surface and that they have different relations to temperature.

Although it is widely recognized that the most relevant temperature should be that of the test tyres, WG 27 has decided to use the ambient air temperature. The reasons are that there are generally very good correlations between air and road surface temperature and that tyre temperatures vary a lot depending on where on or in the tyre the measurements are made. Furthermore, tyre temperatures generally change with time during and after runs. Additionally, road surface temperature varies where shaded parts alternate with parts exposed to sun radiation. When all three temperatures have been used in correlations with noise, generally the air temperature comes out as the most significant.

So far, temperature correction is applied only to A-weighted overall CPX noise levels. Ideally, the correction should be made on the A-weighted spectra, but it is not yet clear how frequency spectra are affected by temperatures. However, some research initiatives have been made to explore this issue; most notably reported in another Inter-Noise paper at this conference [14]. More research is needed on this subject. A comprehensive background report was produced within project ROSANNE by the main author and some colleagues [15].

Using the temperature correction will reduce the uncertainties of the CPX method dramatically; especially in cases where temperatures deviate substantially from the reference 20 °C. Nevertheless, it shall never be forgotten that the best way to reduce the potential effect of temperature is to make the measurements as close to the reference temperature as possible; or in case of comparisons between specified cases, to conduct the measurements at as similar temperatures as possible.

The standards document is in June 2016 a Draft Technical Specification (DTS) subject to ballot and comments. It is hoped that the final version, ISO/TS 13471-1 [10], can be published at the end of 2016.

6. PROJECT ROSANNE

Until a couple of years ago, the work with the above standard and technical specifications progressed very slowly; since sufficiently robust data to base the standards on were missing. We knew that the two reference tyres were doing a fairly good job already 5-8 years ago, and we had used them since then, but we did not know how stable and how close in tolerances that different tyre samples were. We were uncertain about the influence of rubber hardness on noise and were unaware of the influence that temperature has on hardness measurements. Regarding the temperature influence we had some indications and we started a few years ago to (tentatively) use a coefficient of -0.1 dB/°C, but there were diverging data too, so we did not “dare” to submit a proposed standard.
However, an EU project came to our salvation. This was the EU FP7 project ROSANNE “ROlling resistance, Skid resistance ANd Noise Emission measurement standards for road surfaces” (FP7/2008-2013) financed by the European Commission (http://rosanne-project.eu). This project allowed exploring the properties of the reference tyres further; for example, the rubber hardness influence, and we could study the influence of temperature in much more detail. Furthermore, the project forced us to evaluate the SPB method versus the CPX method in a comprehensive manner [6]; with the result that we preferred the CPX method for road surface classification [4]. This was in contrast with the (EU) SILVIA project conducted about 10 years ago, where the SPB method was preferred [16].

However, after SILVIA, we had learnt a lot more about how to reduce the problems with the CPX method, while simultaneously it became more obvious that results of SPB measurements depend to a high degree on the exact spot along the road where one puts the microphone, if the road surface is a porous one. The CPX method can measure both with high spatial resolution and provide averages over longer distances. Once CPX equipment is available, measurements are fast and relatively cheap and give comprehensive results. The disadvantage, for some purposes, is that the CPX method measures only tyre/road noise and vehicle power unit noise is neglected. However, at speeds from 50 km/h and above, it is tyre/road noise that dominates; thus missing the power unit component of traffic noise is acceptable in most cases.

Another Inter-Noise paper [4], describes how project ROSANNE is implementing the ISO standard and technical specifications with the aim to go one step further and suggest a European standard for classification and labelling of road surfaces with respect to it noise properties. ROSANNE even attempts to do the same for rolling resistance properties, and also attempts to harmonize measurements of skid resistance by transferring values to a “common scale” [4]. Nevertheless, it is important to note that it is CEN and its committee TC 227 on road materials that has the (unique) mandate to decide on the final European procedure.

7. USING CPX DATA TO DETERMINE ROAD SURFACE CORRECTIONS IN THE CNOSSOS-EU MODEL

As described above, the ROSANNE procedure, presented in [4], is based on tyre/road noise measurements using the CPX method. The output will be useful to road administrations and road companies when referring to contractual values in legal documents for road surface construction.

Moreover, road and environmental administrations are also concerned by evaluating the impact of road surface properties on road traffic noise exposure, in particular when implementing the “Environmental Noise Directive” 2002/49/EC (END). The END requires Member States to produce noise maps and action plans, using a common calculation method, called “CNOSSOS-EU” and now published in European Directive 2015/996/EC. “Noise” in these documents refers to road traffic noise, including all vehicle noise sources; of which the tyre/road interaction is one of the most important; and in many cases the dominating one.

The CNOSSOS-EU model for road traffic noise emission specifies road surface correction to noise levels; to be determined by each member state or by using a default list. In another Inter-Noise paper [17], the main features of both systems are briefly presented and compared: noise indicators, frequency ranges, pavement definition, reference conditions and measurement conditions. Then recommendations are made on how the ROSANNE characterization procedure could provide valuable and compatible input to the European calculation method for road traffic noise prediction. The data in Table 1, derived from [17], show the major differences between the ROSANNE and CNOSSOS-EU procedures.

It appears in the table that there are several obstacles to overcome, but since tyre/road noise dominates vehicle noise in most cases from 50 km/h and upwards, it is possible to use the CPX data carefully to determine fair estimates of the road surface corrections in the CNOSSOS-EU system. In the next few years, it will be important to measure/calculate the road surface corrections based on both procedures and see how well they correlate. These authors believe that they will correlate well, within the uncertainties that are impossible to avoid in both procedures. The results of the CPX-SPB comparisons presented in [6] suggest that chances for such an outcome are good.

It is concluded in [17] that, globally, the consistency between both systems is rather good and there is a good chance that one might eventually in a near future, use the ROSANNE procedure to supply the data for the CNOSSOS-EU database on road surfaces.
Table 1 – Comparison between ROSANNE and CNOSSOS-EU regarding certain features.
Compiled from [17].

<table>
<thead>
<tr>
<th></th>
<th>ROSANNE</th>
<th>CNOSSOS-EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement method</td>
<td>CPX method</td>
<td>SPB method</td>
</tr>
<tr>
<td>Indicator</td>
<td>Differences in ( L_{CPX} ) between road surfaces (sound pressure levels)</td>
<td>( \Delta L_{WR,road} ) derived from SPB measurements (sound power levels)</td>
</tr>
<tr>
<td>Frequency range</td>
<td>Overall level in dB(A) and 1/3 octave bands 315 – 5000 Hz</td>
<td>1/1 octave bands 63 – 8000 Hz</td>
</tr>
<tr>
<td>Speed range</td>
<td>50, 80 and 110 km/h</td>
<td>Data at 70 km/h. Speed coefficient provided for max. 30 – 130 km/h</td>
</tr>
<tr>
<td>Sound source</td>
<td>Tyre/road noise</td>
<td>Vehicle noise (incl tyre/road noise)</td>
</tr>
<tr>
<td>Type of source</td>
<td>Reference tyres P1 and H1</td>
<td>Three vehicle categories:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Light vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Medium heavy vehicles</td>
</tr>
<tr>
<td>Road surface conditions</td>
<td>Normally in relatively new condition, but possible to measure also older road surfaces</td>
<td>Reference surface, average of DAC 11 and SMA 11, between 2 and 7 years old</td>
</tr>
</tbody>
</table>

8. INTERACTIONS OF THE STANDARDS; SPECIFICATIONS AND PROCEDURES

Figure 5 is an attempt to illustrate how the standards, technical specifications and procedures interact and relate to each other.

![Figure 5 – Relationships between the standards, specifications and procedures.](image)

9. CONCLUSIONS

The combined use of the ISO technical specifications for temperature correction and reference tyres, providing input to the ISO standard for the CPX method, will make it possible to produce a draft procedure, aimed at a European standard or technical specification for classification of road surface noise properties, and thus in principle establishing a noise labelling system for defined road surfaces. This has been achieved by hard work in the ISO working groups supported by pre-normative research in the ROSANNE project.
The final outcome of this will be useful to road administrations and road construction companies when referring to contractual values in legal documents for road surface procurement and construction.

ACKNOWLEDGEMENTS

This research is part of a project ROSANNE which is supported by the European Community’s Seventh Framework Programme (FP7/2007-2013). The main author’s work is sponsored also by the Swedish National Road and Transport Research Institute (VTI), as well as of a national Swedish project on standardization of measurement methods which is supported by the Swedish Transport Administration. The authors are very grateful for this financial support.

REFERENCES

8 Wehr, Reinhard; Fuchs, Andreas, "A combined approach for CPX tyre hardness and temperature correction". Proc. of Inter-Noise 2016, Hamburg, Germany (2016).
9 Bergiers, Anneleen; Maeck, Johan, "Validation of reference tyres and temperature correction for Close-ProXimit (CPX) method". Proc. of Inter-Noise 2016, Hamburg, Germany (2016).