BNAM 201
Baltic-Nordic Acousti
April 15-18 20
Harpa, Reykjavík,

NordTyre - the potential for noise reduction using less noisy tyres and road surfaces

Hans Bendtsen and Jakob Fryd
Danish Road Directorate, Havnegade 27, 1058 Copenhagen K, Denmark, hbe@vd.dk; jaf@vd.dk

Jannicke Sjøvold
Norwegian Public Roads Administration, Brynsengfaret 6A,
0667 Oslo, Norway, jannicke.sjovold@vegvesen.no

Julia Bermlid
Swedish Transport Administration, Röda vägen 1, 781 89 Borlänge, Sweden, julia.bermlid@trafikverket.se

Rasmus Stahlfest Holck Skov
DELTA - a part of FORCE Technology, Venlighedsvej 4, 2970 Hørsholm, Denmark, rshs@force.dk

A new EU regulation on type testing of the noise emission from new tyres became mandatory in 2012. The noise should be below certain limit values. The new system also included noise labelling of all new tyres sold in Europe. In order to investigate the effects of these new regulations on labelling and tyre noise in the Nordic countries the NordTyre project was started already in 2011. 31 passenger car tyres were tested on 30 Nordic road surfaces in Denmark, Norway and Sweden using the CPX noise trailer. A main result is that there is a bad correlation between the measured noise levels and the noise labels of the tyres. This was followed by a noise testing of 30 truck tyres on four different pavements. The results of the testing of both passenger car and truck tyres shows that the noise performance on typical Nordic rougher SMA road surfaces is remarkably different compared with the smoother ISO test surface used for noise type approval. Based on these results noise scenarios of the effect of using a combination of less noisy tyres and road surfaces have been analysed on the background of the national noise mappings in Denmark and Norway. The calculations show that there is a general noise reducing potential. Based on calculations of Noise Annoyance Number (SBT) used in Denmark and Noise Annoyance Index (SPI) used in Norway there is an estimated potential to reduce noise annoyance from roads by 24 % in Denmark and 11 % in Norway. The NordTyre projects have been financed by the road administrations in Denmark, Norway and Sweden through the NordFoU research cooperation of the Nordic countries.

1 Introduction and goal

The NordTyre projects have been carried out in order to clarify the possibilities of reducing traffic noise in the Nordic countries by regulating the use of vehicle tyres and road surfaces. This paper summarizes the results of the NordTyre projects on noise from passenger car tyres and truck tyres [4].

Labelling of new vehicle tyres became mandatory in all EU and EEC countries by November 2012 [1]. The tyre label includes classes or values of three parameters: wet grip, rolling resistance and noise. The Regulation is used in the type approval process for new tyres on the European market. Nordic road administrations work on reducing traffic noise exposure by applying noise reducing pavement and by building and maintaining noise barriers etc. which require significant economic resources. There is a need to know how "low noise" tyres could contribute to traffic noise mitigation and to clarify how this contribution can be optimized. The main objectives of the NordTyre projects have been to:

- Clarify the "real" influence of the new tyre noise labelling of passenger car and truck tyres

- Establish scientific evidence on the tyre/road contribution to traffic noise emission from roads in the Nordic countries
- Generate a basis for qualified decision making concerning actions to mitigate traffic noise in the Nordic countries
- Define realistic new tyre noise limits for use in a future revision of the EU tyre labelling and the tyre noise limits, including rolling resistance and supplementing the labelling of wet grip with labels of snow grip and ice grip
- Demonstrate the usefulness or necessity of a second "roughly textured" ISO reference test surface for tyre noise testing and labelling, hence creating scientific arguments for a short term revision of EU tyre noise regulation

2 Methods used

A representative set of 31 passenger car tyres was selected and these tyres were run on 30 selected representative Nordic road surfaces and on two ISO test surfaces using the CPX trailer method.

Noise levels were measured using CPX-trailers where the tyre/road noise is measured close to the tyre (see Figure 1). The CPX measurements are only measuring the tyre/road noise, and therefore the influence from differences in propagation and weather conditions are minimized when comparing the tyres. These measured noise levels were compared with the noise labels issued by tyre manufacturers and with noise levels measured on ISO test tracks using the Coast-By method and a measurement distance of 7.5 m. From many previous measurement series the Danish Road Directorate (DRD) have found a very good and stable correlation between CPX measurements and road side Statistical Pass-By (SPB) measurements which are similar to the Coast-By method [11].

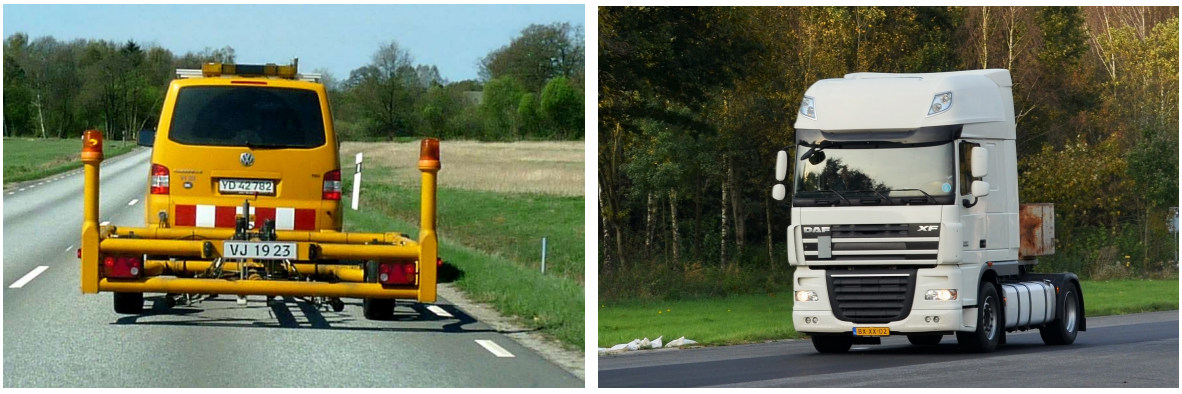

Figure 1: The DRD CPX trailer "deciBellA" used for test of passenger car tyres (left) and truck tractor used for measurements of truck tyre noise (right).

A sample of 30 sets of truck tyres representative for the Scandinavian truck tyre population has been tested on four road surfaces including an SMA surface (Stone Mastic Asphalt) and an ISO test surface using the coast-by test procedure (see Figure 1). The measurements were carried out on the Twente Proving Ground in the Netherlands. The results for passenger car tyres are documented in the final report on part 2 of the NordTyre project [2] and the results on truck tyres are documented in the final report on part 3 of the NordTyre project [3]. An overview of the NordTyre results can be found in [4]. Some results have been presented in previous conference papers [5, 6, 7].

3 Measurement results

The NordTyre projects have been carried out in order to clarify the possibilities of reducing traffic noise in the Nordic countries by regulating the use of vehicle tyres and road pavements. One of the big challenges in basing such evaluations on the tyre noise labelling system is that the label values are measured on a relatively smooth ISO surface, which does not represent typical Nordic pavement types having a rougher surface texture (see Figure 2).

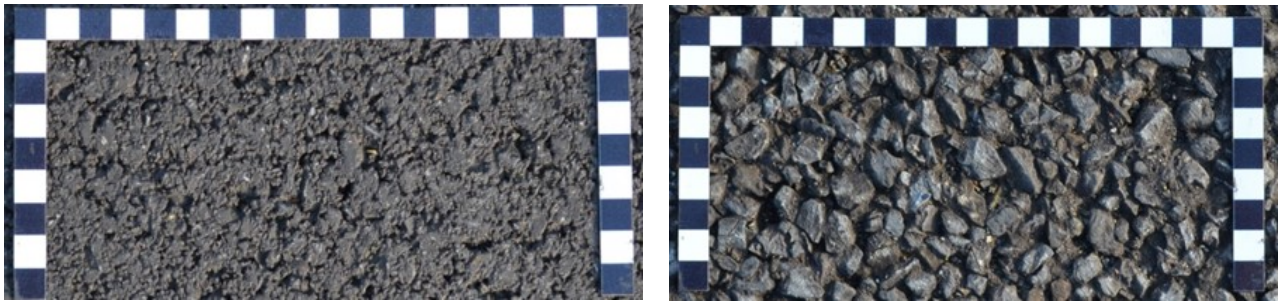

Figure 2: Close up photo of a smooth textured ISO reference test road surface (left) and a rough textured typical Nordic SMA 11 road surface (right). The size of the black and white squares is 10x10 mm.

3.1 Passenger car tyres

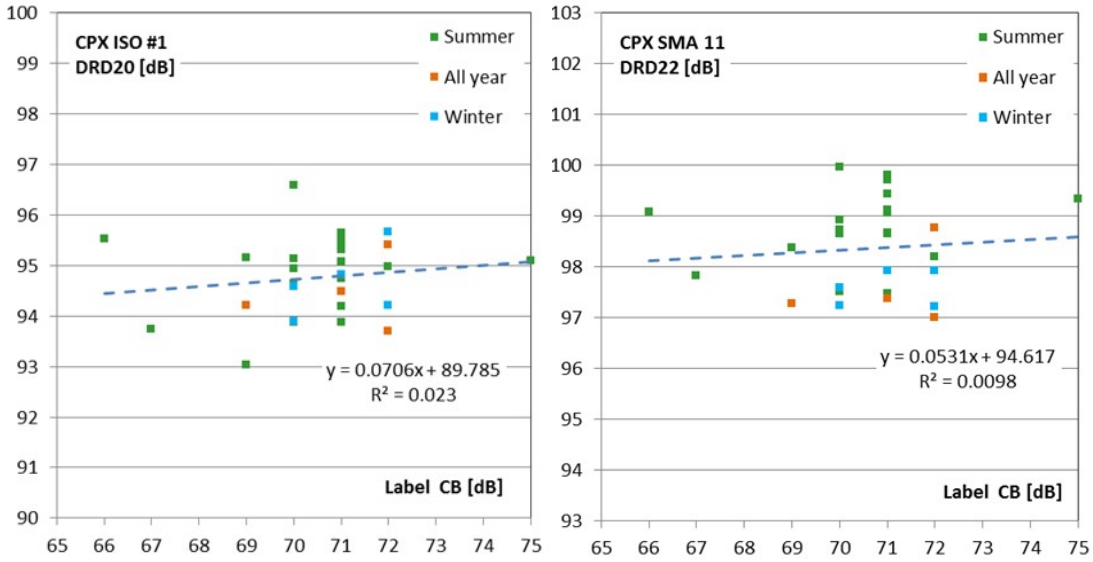

Figure 3: Measured CPX noise level for passenger car tyres on an ISO test track (left) and on a Nordic SMA 11 road surface (right) as a function of the coast by noise label issued by the tyre manufacturer [2].

For both truck and passenger car there was a difference between the measured noise levels on an ISO surfaces and the labelled values. The tyre labels for passenger cars were read from the manufactures websites in January 2013. For passenger car tyres there was no correlation at all between noise levels measured on the ISO surface as well as the Nordic SMA 11 surface and labelled noise levels tyres (see Figure 3). The reasons for this lack of correlation are discussed in the NordTyre part 2 report [2], and the authors believe that the main reason is variation in test track surface properties although it cannot be ruled out that differences in test conditions during labelling measurement and the measurements carried out in the NordTyre project also contribute to this unfortunate fact. It is also a fact that tyre manufacturers do not test all tyres, but tyres representative for a tyre family. It is not known to the NordTyre project group how large variations one can expect within a tyre family.

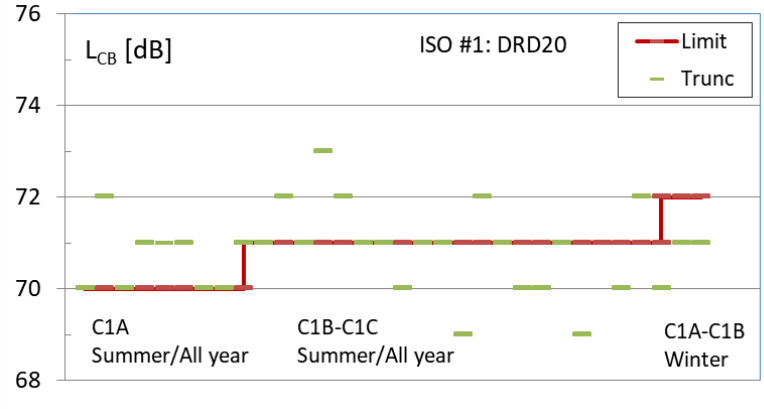

Figure 4: CPX trailer results translated into coast-by noise levels, truncated and rounded down, compared with the EU Regulation on noise limits [2].

Figure 4 show the CPX trailer results for passenger car tyres translated into coast-by noise levels [2], truncated and rounded down, compared with the Regulation on noise limits that went into force in November 2012. The tyres were procured half a year before in May 2012. It can be seen that nine of the tested tyres after truncation and rounding down have measured noise levels 1 to 2 dB over the limit levels, thirteen tyres are on the limit and nine are 1-2 dB below.

3.2 Truck tyres

The range of the noise levels measured on the ISO surface is 6 dB for Drive and Steer tyres and just 1 dB for the Trailer tyres whereas for the SMA surface the range is only 1 to 2 dB for all three tyre types. This shows that noise levels measured at the smooth ISO surface are is more sensitive to different tyre types than noise levels measured the rougher SMA surface (see Figure 5).

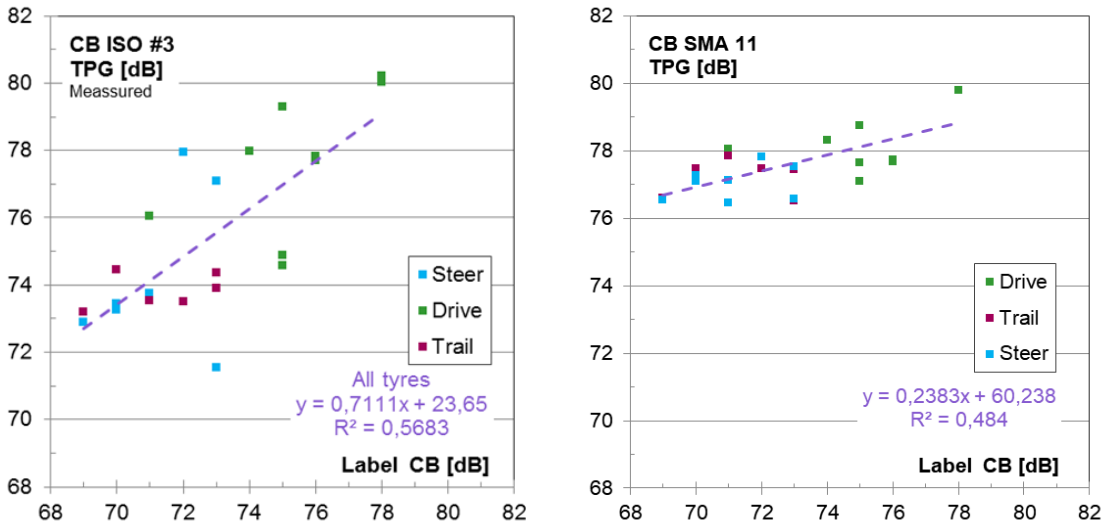

Figure 5: Coast-by noise level measured at 1.2 m height for truck tyres on the TPG ISO test track (ISO#3) as a function of the noise level labelled by the manufacturer (left) and coast-by noise level measured the SMA surface (right) [3].

The truck tyres were procured in 2014. For truck tyres the analysis of the noise levels show big differences between labelled noise levels and noise levels measured in the NordTyre project (see Figure 5). However, the test method described in UNECE Regulation R117 [12] allows truncation and deduction, and applying this method would explain most of the difference. After applying the method with up to 0.9 dB truncation of the measurement results and 1 dB deduction combined with a large allowed temperature span (5 to 40º C) without any corrections for the temperatures, it is not possible to conclude that there is a difference between the measured and the labelled noise levels for truck tyres.

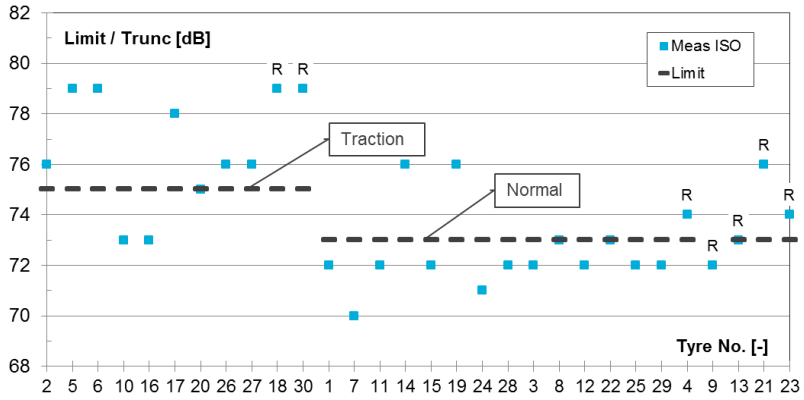

Figure 6: Noise limits and measured noise levels on the ISO test track, after the subtraction of 1 dB and after truncation. Data label "R" indicates retreaded tyre [3].

Figure 6 show coast by results for truck tyres on the ISO surface truncated and rounded down, compared with the Directive noise limits. It can be seen that eight of the tested new tyres after truncation and rounding down have measured noise levels 1 to 4 dB over the limit levels, two 2 tyres are on the limit and twelve are 1-3 dB below. The retreated tyres are generally over the noise limits but these are not subject to regulation.

Table 1: Difference between coast-by noise levels from retreaded and original tyres for each of the four pavements. DAC = Dense Asphalt concrete, TSL = Thin Surface layer (colours illustrate the magnitude of the differences) [3].

		Retreaded minus original [dB]			
		Road surface			
Tyre line	**Tyre position**	**ISO**	**SMA**	**DAC**	**TSL**
Bridgestone R109 Ecopia	Trailer	1.2	0.1	0.8	1.0
Michelin X Multiway 3D XDE	Drive	0.9	0.8	1.7	1.8
Michelin Xline Energy D	Drive	1.5	0.2	2.1	1.7
Michelin Xline Energy T	Trailer	0.6	0.2	0.6	0.7

Measurements performed with retreaded tyres showed that the retreaded tyres were noisier than the original tyres on all 4 road surfaces tested (see Table 1). On the SMA surface (Stone Mastic Asphalt) the drive axle tyres were on average 0.5 dB noisier than the originals, whereas the retreaded trailer axle tyres were only 0.1 dB noisier than the originals. If the retreaded tyres were subject to regulation as the new tyres are, the potential for noise reduction would be greater. Even if the retreaded tyres were subject to only using the 33 % least noisy tyres there would be a potential. The retreaded tyres constitute a significant part of the truck tyre population (40-65 %), and the potential for reducing truck tyre noise therefore is considerably limited by the fact that retreaded tyres are noisier than the originals and by the same time not being part of the labelling system.

Measured rolling resistance coefficients were found to be uncorrelated with measured tyre/road noise levels [2]. The same applies to most measured data on road grip. A trend was found for less good braking performance on ice and snow the better the labelled wet grip for all-season and winter tyres, which is as expected. For truck tyres the correlations between the labelled rolling resistance and the measured noise level was modest ($R^2 = 0.5$) for the ISO surface and low ($R^2 = 0.2$) for the SMA surface. The drive axle tyres had the highest rolling resistance and also yielded the highest noise levels.

4 Potential effects to society regulating tyre/road noise

The total range of noise levels encountered between the least noisy passenger car tyre on the least noisy pavement (excluding the ISO tracks) and the noisiest tyre on the noisiest pavement was almost 11 dB. After removing extreme values for two tyres not reckoned to be representative (one high and one low), the range of labelled noise levels for the studied tyres was 5 dB. Leaving only the quietest tyre (except the one that were removed) the change in energy average noise level on pavements was 3.9 dB. The average noise level from tyre/road noise can be reduced by 1.7 dB if only the

six quietest types of tyres are in use. For the calculation of national scenarios of potential noise reduction it was assumed that only tyres labelled 69 dB remain in the tyre population. This implies a passenger car tyre/road noise reduction of 1.4 dB [4].

The measurements of truck tyre noise showed a difference between the noise levels from steer axle and drive axle tyres, whereas all the trailer axle tyres yielded almost the same noise levels. Both the steer and drive axle tyres displayed a range of 6 dB and a potential of 0.4-0.5 dB tyre/road noise reduction using only the 25-33 % tyres with the lowest noise levels, whereas the trailer tyres have a range of only 1 dB and a potential of just 0.1 dB tyre/road noise reduction using only the 25-33 % least noisy tyres. Therefore, there is a potential for reducing the noise, by regulating the use of steer and drive axle tyres to only the least noisy tyres [4].

The NordTyre project only focussed on tyre/road noise. If it would also be possible to reduce the propulsion noise from trucks, the potential for noise reduction would be higher. If electrical trucks were introduced, it would most likely increase the noise reduction potential obtainable by using less noisy tyres.

For truck tyres, the tyre/road noise levels at the SMA surfaces were higher than on the other surfaces and the range between the lowest and the highest level was smaller. The potential reduction of truck tyre/road noise obtained by replacing SMA 16 by SMA 11 is 1.3 dB and when replacing SMA 11 by SMA 8 it is 0.7 dB. For passenger cars, the potential when replacing SMA 16 by SMA 11 is 1.5 dB and replacing SMA 11 by SMA 8 it is 1.9 dB (see Table 2).

Table 2: Relative levels of tyre/road noise on different road surface types for passenger cars and multi-axle trucks, and noise reduction potentials used in this analysis [4]. “NO” potential in Norway and “DK” potential in Denmark.

	Relative tyre/road noise level [dB]			
Road surface type	**Passenger cars**		**Trucks**	
SMA 16	0.0		0.0	
SMA 11	-1.5		-1.3	
SMA 8	-3.4		-2.0	
Reduction potential	NO: 3.4 dB	DK: 1.9 dB	NO: 2.0 dB	DK: 0.7 dB

Nordic countries are mainly using SMA surfaces. For both passenger car and truck tyres, replacing noisy pavements with less noisy pavements was found to potentially yield more reduction in traffic noise levels than the noise reduction obtained by regulating the tyre use, but the additional noise reduction which could be obtained by using the least noisy tyres is significant.

If successful regulation of the noisiest tyres can be implemented in combination with replacing the road surface type by a less noisy surface, both the noise from passenger cars and trucks can be reduced. If all road surfaces in Denmark and Norway could be changed from the standard surface to Stone Mastic Asphalt with 8 mm maximum aggregate size and all but the least noisy 25-33 % of the tyres could be removed from the vehicle fleet, then annoyance from traffic noise could be reduced by estimated 24 % in Denmark (Danish SBT [9]) and by estimated 11 % in Norway (Norwegian SPI [10]). This is a significant potential for noise and annoyance reduction in the Nordic countries. The difference between Denmark and Norway is mainly because of different indicators for noise annoyance.

5 Discussion, conclusions and perspective

The labelled values do not represent tyres operating on typical Nordic road surfaces. Since surfaces in Denmark are comparable to many other countries in Europe, the labelling values are probably not very representative for most surfaces in use. Both the results of measuring noise from passenger car tyre and truck tyre clearly illustrate a need for a supplementary test surface representing Nordic road surface types. The reference surface described in the CNOSSOS EU noise prediction method [8] is not a smooth textured ISO reference surface but a rougher textured virtual road surface consisting of an average of a dense asphalt concrete (DAC 11) and an SMA 11 surface.

Further the results of the NordTyre reports [2, 3, 4] indicate that the test method has other issues in representing the situation at real roads, so there is a need to work on:

- A test surface that represents the Nordic road surface
- A test surface that represents road surfaces used in other European countries

- A special noise label for Nordic conditions, reflecting the tyre/road noise on typical rougher surfaces used in Nordic and other countries
- Performing temperature correction of noise measurement results for all tyre types including truck tyres
- Reducing the allowed range of temperatures for performing noise testing of tyres in order to reduce the uncertainty caused by temperature
- Inclusion of the retreaded truck tyres in the labelling system, as well as introduction of noise limits for retreaded tyres
- Consideration of the need for a higher noise limit for winter tyres. Winter tyres may, according to the limit values, be 1 dB noisier than summer tyres but the measurements show that summer tyres usually are noisier than winter tyres
- For winter tyres there is a need for labelling of snow grip and ice grip since ice grip and wet grip contradict. Many other European countries should have an interest in this (such as Poland, the Baltic states, and the Alpine regions)

If the labelling system would be improved there is significant potential for making use of the system in many ways [4]:

- Campaigns and maybe tax incentives encouraging car owners to buy the least noisy tyres possible
- Encouraging public organizations and private companies with a green profile to require the use of the least noisy while at the same time safe tyres; e.g. publicly procured bus transportation, taxi approvals, and cooperating with large transportation companies to have them favour the use of least noisy and safest tyres. Rolling resistance might also be included
- In time: Further limit the allowed tyres on the market, as proposed in the scenario calculations by decreasing the limit noise levels in the tyre type approval system
- Expand the labelling value to represent the tyres during their lifetime, and not only in new condition

The following important research needs have been identified throughout the NordTyre projects [2, 3, 4]:

- Further investigation of the reasons for poor correlation between labelled values and measured values on actual road surfaces, applicable to both noise and rolling resistance
- Following the previous bullet suggestions how to improve the labelling system to obtain an acceptable correlation between labelled values and measured values on actual road surfaces, applicable to both noise and rolling resistance
- Develop a second and more rough-textured reference surface, for use in tyre noise regulations as well as for tyre labelling. Such a surface would be more representative of Nordic roads than the present ISO 10844 reference surface, but would also be of interest for many other European countries
- Establish stricter specifications of test track properties
- Development of a procedure for inter-calibration of test tracks
- Investigate the variation of noise levels within tyre families
- Investigate how tyre/road noise develops over time as tyres get older and worn
- Investigate tonality of truck tyre noise emission and tonality perceived by road neighbours

6 Acknowledgements

The NordTyre projects were initiated and funded by NordFoU, a research and development framework for the Nordic state road administrations (see: www/nordfou.org) with contributions from Danish Road Directorate (DRD), Norwegian Public Roads Administration, Swedish Transport Administration and Norwegian Climate and Pollution Control Agency. The NordTyre projects have been carried out by the DRD. Jørgen Kragh (project leader until retirement May 2016) and Hans Bendtsen DRD have been working on the projects together with Rasmus Stahlfest Holck Skov and Jens Oddershede both since November 2017 working for DELTA a part of FORCE Technology in Denmark.

The Nordtyre projects have been supported by an advisory group giving scientific support and advice. The members were:

- Luc Goubert, Belgian Road Research Centre
- Ulf Sandberg, Swedish National Road and Transport Research Institute, VTI
- Ingunn Milford, Multiconsult, Norway
- Roger Williams (until 2015), independent tyre expert, United Kingdom
- Jan Boe Kielland, independent noise expert, Norway
- Panu Sainio, Aalto University, Finland

Four subcontractors have contributed to the projects: SINTEF in Norway, M+P Consulting Engineers in The Netherlands, Testworld Lt in Finland and Technical University of Gdansk in Poland.

The authors will like to thank everybody for their enthusiastic work and contributions that has made the NordTyre projects and this paper possible.

References

[1] Regulation (EC) No 1222/2009 of the European Parliament and the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters. Published in the Official Journal of the European Union, EN 22.12.2009, L 342/46

[2] Kragh, Jørgen et.al. NordTyre – Tyre labelling and Nordic traffic noise – Analysis on passenger car tyres. Report 2018-1 NordFoU. See: http://www.nordfou.org/knowledge/Sider/default.aspx

[3] Kragh, Jørgen et.al. NordTyre Part 3 – Noise from truck tyres. NordTyre Part 3. Report 2018-2 NordFoU. See: http://www.nordfou.org/knowledge/Sider/default.aspx

[4] Bendtsen, Hans: Skov, Rasmus S.H. Potential society effects of regulation tyre/road noise - Summary report of the NordTyre projects. Report 2018-2 NordFoU. See: http://www.nordfou.org/knowledge/Sider/default.aspx

[5] Kragh, Jørgen; Oddershede, Jens: NordTyre – Car tyre labelling and Nordic traffic noise. Proceedings Internoise 2013, Innsbruck, Austria

[6] Blokland, Gijsjan van; Kragh, Jørgen. 30 Different Tyres On 4 Surface Types – How Do Truck Tyre Noise Levels Relate to the Test Surface. Proceedings, Euronoise 2015 in Maastricht, the Netherlands

[7] Blokland, Gijsjan van. Effect of retreading on rolling noise of truck tyres. Proceedings Internoise 2017, Hong Kong

[8] DIRECTIVES. Commission Directive (EU) 2015/996 of May 2015 establishing common noise assessment methods according to Directive 2001/49/EC of the European Parliament and of the Council

[9] Danish noise exposure number (Støjbelastningstal, SBT): Danish Environmental Protection Agency, New noise exposure number for assessing road traffic noise (in Danish), Note J.nr. MST-5100-00020, 5 February 2010. Nyt støjbelastningstal til vurdering af vejtrafikstøj

[10] Norwegian noise annoyance index (Støyplageindeks, SPI): Norwegian Ministry of Climate and Environment, – Action plan against noise 2007 - 2011 (in Norwegian), Handlingsplan mot støy 2007–2011. See: http://www.regjeringen.no/nb/dep/kld/dok/rapporter_planer/planer/2007/handlingsplan-mot-stoy-2007-2011.html?id=465549

[11] Kragh J. et al., Acoustic ageing of pavement, DVS-DRD Joint Research Programme – Super Silent Acoustic Ageing of Pavement. Danish Road Directorate, Report 460, 2013. See: http://vejdirektoratet.dk/DA/viden_og_data/publikationer/Lists/Publikationer/Attachments/798/acoustic%20ageing%20of%20pavement.pdf

[12] UNECE Regulation R117, Uniform provisions concerning the approval of tyres with regard to tyre/road noise emissions and/or to adhesion on wet surfaces and/or to rolling resistance, revision 3; February 2014