

STUDY SI2.408210 TYRE/ROAD NOISE

VOLUME 1: FINAL REPORT

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Volume 2

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Summary

The European Commission has announced its programme to review the tyre regulations, and to consider the possibilities for applying a next stage of noise limit reductions. It is anticipated that the Commission will propose an amendment to the Directive that will include reductions in the permissible noise from vehicle tyres, which will include considerations of safety (wet grip adhesion) and fuel economy (rolling resistance). These changes could have considerable consequences for both the tyre manufacturing industry, and for the environment. It is important therefore that a full understanding of the issues be obtained, so that the most appropriate measures are taken when the Directive is revised.

In order to inform these decisions, the European Commission Enterprise and Industry Directorate General has commissioned FEHRL (the Forum of European National Highway Research Laboratories) to carry out a programme of study. The main objective of the study is to assess the potential for reducing tyre noise through the implementation of more stringent type approval limit values, and to assess the impacts that such reductions might have on overall traffic noise, road safety and economy. It is anticipated that the results of the work will form the basis for the Commission report to the European Parliament and the Council and legislative proposals to amend the tyre noise Directive 2001/43/EC.

The work was carried out by a partnership of experts drawn from different research organisations. The partnership has been put together by FEHRL who act as project holder. The work has been managed on behalf of FEHRL by the Transport Research Laboratory (TRL) in the United Kingdom. TRL also contributed to and edited this final report. The partnership comprises experts from FEHRL, TRL(UK), VTI (Sweden), BASt/RWTUEV (Germany), Arsenal Research (Austria) and DWW (The Netherlands).

The work involved has been organised into four main Work Packages, with a further Work Package devoted to conclusions and recommendations. The main Work Packages focus on:

1. Determining the potential for reducing the tyre noise limits through technical advance and assessing the concomitant affects on safety and rolling resistance.
2. Assessing the limit reductions currently proposed in the Directive to establish benefits in terms of reductions in environmental noise impact.
3. Examining what other changes are needed to the Directive when it is revised.
4. Carrying out a benefit and cost assessment of lowering the tyre noise limits

Several meetings and discussions were held during the course of the work with representatives from the tyre industry (European Tyre and Rim Technical Organisation, ETRTO) and with other stakeholder groups. In addition to general discussions, a more specific consultation letter was sent to stakeholders and a further consultation, open to a wider audience, was addressed via a webpage featured on the FEHRL website. A summary of the main discussion points is included in Chapter 4 of this report.

To support the analyses carried out in each of the Work Packages, a comprehensive data base of tyre noise levels was assembled. In total the datasets included 171 C1 class tyres, 19 class C2 tyres and 98 class C3 tyres spanning the period 2000 – 2005. This was

supplemented by data on rolling noise levels from a further 100 tyre sets. Data on wet grip, aquaplaning performance and rolling resistance were also available for a subset of tyres in each of the tyre classes.

A comprehensive literature review was also carried out and is included in the report in full as Appendix A.

The main conclusions and recommendations are as follows:

- Practically all C1 tyres currently in service, or that have been in service since the regulations were introduced, produce noise levels, under conditions of type approval testing, that are well below the current limit values. Less than 4% of the sample gave higher values than the current limits and about 50% of the sample gave levels that were 3 or more dB(A) below the current limits. Similar results were found for C2 and C3 tyres. These results demonstrate that the introduction of the type approval tyre noise limits has had little impact on overall traffic noise levels and hence the impact of traffic noise on communities. (Work Package 1, section 4.3 and 4.7);
- No evidence could be found, either as part of the analysis carried out for this report or from published literature, of a significant relationship between tyre noise and safety performance. There are many examples in the data assembled for this study of tyres that produce relatively low noise levels and yet perform well in terms of safety performance. (Work Package 1, section 4.4);
- No significant relationship between tyre noise and rolling resistance could be found from the available data. Given the strong influence of the market for fuel efficiency, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise. (Work Package 1, Section 4.4);
- Across all tyre categories, there is scope for a considerable reduction in the tyre noise limits. As a result, limit values are recommended which mean effective reductions of between 2.5 and 5.5 dB(A) for C1 tyres for light vehicles, and between 5.5 and 6.5 dB(A) for commercial vehicle tyres in categories C2 and C3. Different limits are proposed according to tyre class and tyre dimensions. It is proposed that these reductions are phased in two stages with the greatest reductions required by 2012. Details of the recommended limits for each tyre class and the definitions of the new tyre classes are given in Tables 5.2 and 5.3 of this report. (Work Package 2, Section 5.1);
- In order to determine the effects on traffic noise of the proposed changes to the tyre noise limits, two noise prediction models, HARMONOISE and TraNECam, were used. Predictions were made for a range of scenarios from motorways to congested urban conditions. It was found that for traffic running on a typical road surface commonly encountered in the EU and assuming the proposed noise limits on C1 tyres (light vehicles) only are introduced, reductions in traffic noise would be achieved averaging 0.9 dB(A) (conservative estimate/HARMONOISE) to 2.3 dB(A) (optimistic estimate/TraNECam). If the proposed limit values for all tyres (C1, C2 and C3) are introduced, greater benefits (average 3 dB(A)) were noted when using the optimistic modelling assumptions. (Work Package 2, Section 5.3);

- Although there is no evidence in current tyre performance data that reducing tyre noise levels will have a noticeable effect on tyre safety or tyre rolling resistance, it is not possible to guarantee that for some future designs of tyre there will not be a conflict between noise and safety or noise and rolling resistance. Consequently, it is recommended that adequate safeguards are put in place with regard to tyre safety and rolling resistance performance. This may mean the introduction of a test for tyre safety performance and rolling resistance. If necessary, the implementation of these test methods can be phased in a later date and they should not delay the implementation of the proposed limits or other recommended changes to the Directive. (Work Package 3, Section 6.1);
- Consideration should be given, when revising the current Directive, for including a requirement for tyre manufacturers to label tyres according to their noise emission. This could be in the form of a noise level stamped on the sidewall. Alternatively tyres could be labelled 'low noise' provided they meet an agreed threshold that is set below the agreed noise limit. Threshold levels could be set at 3 dB(A) below the proposed limit values. (Work Package 3, Section 6.2);
- Changes to the type approval test procedure are recommended. These include changing to the method of rounding the measured data to obtain the test level. The new procedure would simply round the test result to the nearest integer. This change in the procedure would itself mean a lowering of the threshold that is actually enforced. It should be noted this change is already incorporated in the proposed limit values. (Work Package 3, Section 6.3.1) ;
- It is also recommended that improvements are made to the specification of the test vehicle. This would include tightening the specification so that differences in test results that could be attributable to vehicle shape and wheelbase are avoided in the future. (Work Package 3, Section 6.3.2);
- In the longer term, future revisions of the Directive should also consider changing the test surface used for type approval as currently the surface is smoother than surfaces typically used on high speed roads. Other considerations include extending the test conditions to examine tyre noise at lower speeds and consideration of the degree of tyre wear required for tyres presented for type approval. Further study in each of these topics would be needed before firm recommendations for change to the test procedure can be made (Work Package 3, Section 6.3.2);
- The benefits and costs of the proposed changes to the Directive have been estimated for the EU25 member states. The calculation assumes that benefits will occur in the period 2010-2022. The calculation used the results of the model predictions for reductions in traffic noise due to the proposed new noise limits for C1 tyres only. These figures lead to an estimate of benefits to the public in the range 48 to 123 billion Euros. The benefits due to the proposed new noise limits for C2 and C3 tyres would increase these figures further. These estimates do not include the additional benefits that should accrue to national and regional authorities, vehicle manufacturers, EFTA member states and many states outside the EU. (Work Package 4, Sections 7.4-7.5);
- The costs of meeting changes to the Directive will fall on tyre manufacturers. These costs will relate to discontinuing the production of some current tyre designs

that would not meet the proposed noise limits. Tyre industry representatives have provided a cost figure that appears significantly higher than seems likely for the changes that can reasonably be recognised in a benefit cost study. However, even the cost figure from industry is considerably smaller than the lower end of the range of benefits of 48 billion Euros. The fact that most tyres in current production already meet the limits proposed for 2008, and many meet the limits proposed for 2012, provides compelling evidence that any expenditure to research and develop the tyre technology needed to meet the proposed limits occurred in the past. (Work Package 4, Section 7.6);

- Any costs incurred by the tyre industry could be reduced by transitional provisions in the Directive. These would allow continued production of some tyre lines that did not meet the new limits, but only for a relatively short period of time and for some particular tyre designs. (Work Package 4, Section 7.6.1);
- If the Directive were to specify that tyres must be stamped with the noise level achieved in the type approval test, this would assist member states that are considering incentive schemes and would improve consumer choice. (Work Package 4, Section 7.6.2);
- Resurfacing many of Europe's roads with very low noise surfaces would lead to reductions in road traffic noise that are comparable with those that the proposed new tyre noise limits will bring. However, the costs of such resurfacing would be much higher, and would recur, due to the lower durability of such surfaces.

1 Background and introduction

Of the many sources of noise that affect people, road traffic noise is by far the most pervasive. In the European Union (excluding the new member states) it has been estimated that approximately 80 million people, are exposed to unacceptably high traffic noise levels (Lambert, 2000).

The methods of reducing the impacts caused by road traffic noise generally involve a combination of measures aimed at:

- Reducing the noise at source, through improvements to vehicles and road surfaces;
- Reducing the propagation of noise into sensitive areas through road alignment considerations and the use of barriers etc., and
- Improving the receiver environment mainly through building insulation.

While all of these measures can play a part in helping to achieve an acceptable acoustical environment for people living near to roads, it is often the case that screening a highway and/or improving building insulation can only provide a partial solution. Consequently, reducing noise at source is generally regarded as the most obvious starting point in any traffic noise control strategy.

The sources of noise emitted by road vehicles are numerous. They include sources that are associated with the power unit and the combustion process (power unit noise) and sources that are mainly related to the noise generated by the tyre/road interaction (tyre/road noise). Power train noise tends to dominate when vehicles are driven at relatively low speeds and under conditions of acceleration when engine speeds tend to be relatively high. Tyre/road noise tends to dominate at moderate and high road speeds.

Controlling these sources is not straightforward and achieving the right balance between costs and benefits is a vital consideration. Ultimately the regulation of noise emission needs to be progressed with a full understanding of what this means in terms of public perception (i.e. the benefits to the environment/quality of life) and the costs including the effects on other issues such as safety.

Despite these complexities considerable advances have been made in controlling power train noise through improved vehicle engineering backed up by progressive legislation. Vehicle noise type approval was first introduced within the European Union during the 1970's and over the intervening period there has been progressive tightening of the limits. These changes have been brought about partly as a reflection of the improvements that have been made in the noise control engineering of road vehicles but also they have served to encourage innovation in vehicle design.

Also progress has been made in reducing noise from the tyre/road interaction although this has largely been the result of the considerable advances made in the design of the road surface. Specifications for lower noise road surfaces have been produced and product approval schemes introduced to allow the evaluation and certification of low noise surfaces. For example, a European funded project, SILVIA (Silenda Via - Sustainable surfaces for traffic noise control), was completed recently. The main output from the

project is a Guidance Manual on the implementation of low-noise surfaces and includes advice on evaluation and certification, the cost/benefits, the sustainability and the integration and interaction with other noise control measures (Morgan, 2006).

With regard to the tyre component of tyre/road interaction noise, progress would appear to have been much slower. There are concerns that lowering tyre noise will affect wet grip and hence safety for some tyre designs and this has tended to slow progress. As a result it was only relatively recently that type approval testing for tyre noise was introduced within the EU. In 2001 Directive 2001/43/EC was introduced (Commission of the European Communities, 2001). It established a test method for the type approval of tyres with respect to noise emissions and introduced limit values for different types of tyre. The Directive also set out its intention to introduce more stringent limit values in the future.

More recently the European Commission announced its programme to review the tyre regulations and to consider the possibilities of applying a next stage of noise limit reductions. It is anticipated that by 2007 the Commission will propose an amendment to the Directive that will include reductions in the permissible noise from vehicle tyres which will include considerations of wet grip adhesion and rolling resistance. It is expected that by 2007 there could be regulations covering all the main performance characteristics of tyres to include wet grip, rolling resistance, structural safety and noise.

These changes could have considerable consequences for both the tyre manufacturing industry and for the environment and it is important therefore that a full understanding of the issues are obtained so that the most appropriate measures are taken when the Directive is revised.

In order to inform these decisions the European Commission Enterprise and Industry Directorate General have commissioned FEHRL (the Forum of European National Highway Research Laboratories) to carry out a programme of study. The main objective of the study is to assess the potential for reducing tyre noise through the implementation of more stringent type approval limit values and to assess the impacts that such reductions might have on overall traffic noise, road safety and economy. It is anticipated that the results of the work will form the basis for the Commission report to the European Parliament and the Council and legislative proposals to amend the tyre noise Directive 2001/43/EC.

The work has been carried out by a partnership of experts drawn from different research organisations. The partnership has been put together by FEHRL who act as project holder. The work has been managed on behalf of FEHRL by the Transport Research Laboratory (TRL) in the United Kingdom.

This final report of the study describes the relevant background, the detailed study design, and the organisation of the work including responsibilities of each of the partners. It describes the databases, assembled from different sources, that have been used in the various analyses undertaken and the conclusions reached. From these, recommendations are given regarding the potential for reducing the tyre noise type approval limits together with the effects on safety, economy and environmental impact.

Throughout this study, representatives from the tyre industry and other relevant stakeholder groups have been consulted. The views expressed by stakeholders have also been summarised in the report.

2 Objectives

The main objective for the programme of study was set out in the original Invitation to Tender. This is stated in italics below:

- *To investigate whether and to what extent technical progress would, without compromising safety, allow the introduction of more stringent limit values regarding tyre/road noise emission limits compared to the limits given in Annex V section 4.2.1., column A of Directive 92/23/EEC as amended by Directive 2001/43/EC. The limit values indicated in columns B and C in Directive 2001/43/EC shall be used as reference.*

In satisfying this objective the Invitation to Tender also stated that the study will:

- *Examine the possibilities to introduce more stringent tyre-road noise emission limits beyond those already in force. This includes literature research, contacts with all competent stakeholders and the execution of practical tests if necessary;*
- *Review the two further steps proposed for more stringent tyre-road noise emission limits as given in columns B and C of Directive 2001/43/EC for the different tyre classes which can be applied without compromising safety;*
- *Propose and discuss possible amendments to the Directive regarding provisions relating to safety, environmental and rolling resistance aspects and give detailed explanation about its necessity and the possible positive/negative contribution;*
- *Undertake a cost/benefit analysis for the proposed noise limits and additional amendments to the Directive;*
- *Present conclusions and recommendation for the further development of the Directive.*

3 Partnership structure, Work Packages and responsibilities

Clearly the issues raised in pursuing the main objective of this project cover a wide range. They include detailed knowledge and understanding of tyre noise generation issues and the relationships with tyre design. In addition the study requires, an in depth understanding of the current tyre noise test procedure and the factors that affect the repeatability and reproducibility of the method and to what degree the results are representative of tyre noise generation in practice. Finally, the specification requires a detailed understanding of the consequences of lowering tyre noise on environmental impact and other important factors such as wet grip and safety, rolling resistance, fuel utilisation and economy.

To service these various requirements, FEHRL has brought together a partnership of experts drawn from different research laboratories. The partnership includes

- TRL (Transport Research Laboratory, United Kingdom), who were assigned to manage the project on behalf of FEHRL;
- Arsenal Research (Austria);
- BASt (Bundesanstalt für Strassenwesen, Germany), including TÜV Nord Mobilität (Germany);
- VTI (Statens väg- och trafikinstitut (Swedish National Road and Transport Research Institute), Sweden).

TRL were also given the task of organising and editing the final report of this project.

The work has been divided into five Work Packages. Members of the partnership have been assigned to each of these Work Packages according to their main areas of expertise. For each sub-task in the Work Packages a lead partner was appointed who has been responsible for the coordination and day to day planning of the work and for delivery of any results and outputs to the TRL project manager.

Descriptions of the scope and content of each of the Work Packages is described briefly below and a schematic of the organisation of the project showing the responsibilities of each of the partners is given in Figure 3.1.

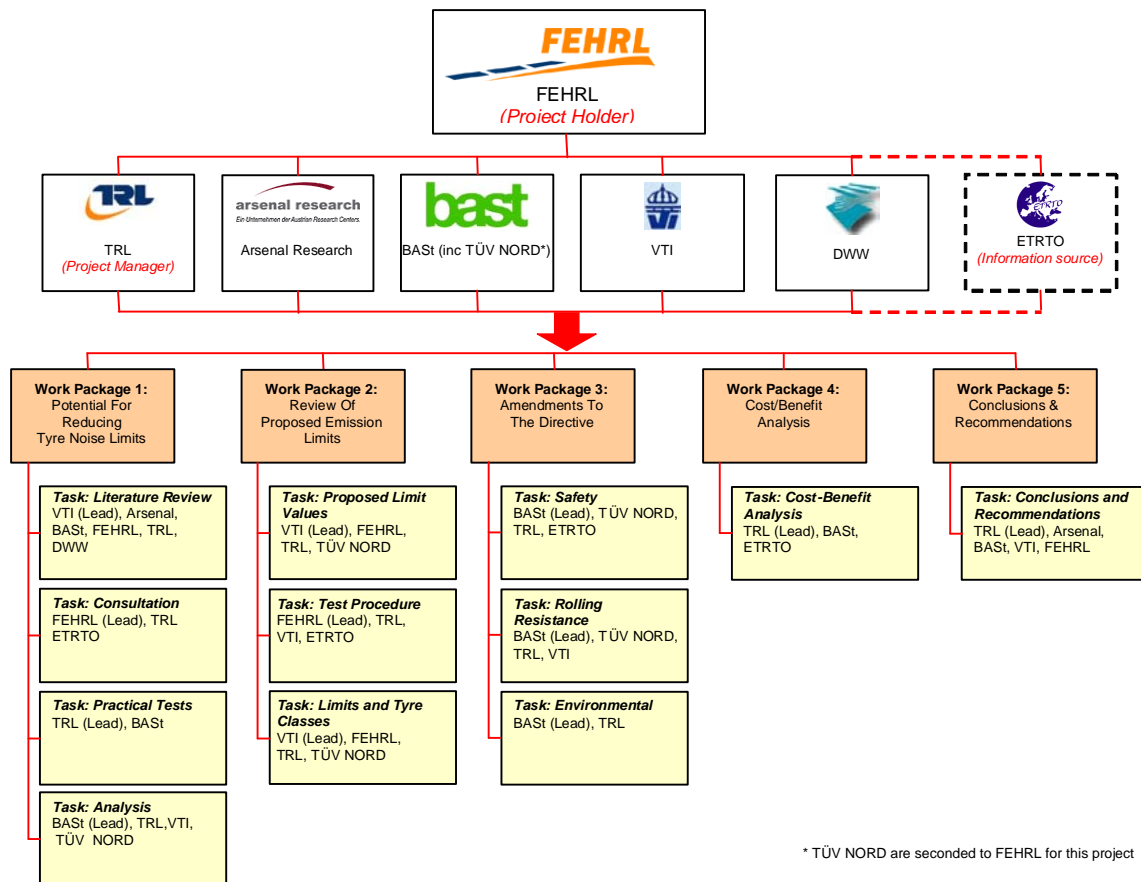


Figure 3.1: Organisation of the Work Packages

Work Package 1: Potential for reducing tyre noise limits

“The contractor shall carry out a technical analysis about the possibilities to introduce more stringent tyre-road noise emission limits beyond those already in force. This includes literature review, contacts with all competent stakeholders and the execution of their own practical tests if necessary.”

Essentially Work Package 1 is concerned with establishing the range of noise levels from current generation tyres and to examine the potential for reducing tyre noise in the future. It was known at the outset of this study that some tyre types in current production produce noise levels, under the standard test, that are comfortably below both the current and proposed limits. Consequently there is concern that the limit values have been set too high. If this is found generally to be the case there should be no technical reason for opposing the reduction in the limit values. The question would then be by how much and to what extent would safety and rolling resistance be affected. The main objective of this Work Package therefore is to examine these issues using all available data on tyre noise safety, rolling resistance etc.

It can be seen in Figure 3.1 that the Work Package included the assembly and review of all relevant literature. This was a major task for the project as it was anticipated this would

provide important background information to support the work in each of the Work Packages.

A further subtask included consultations with the tyre industry and other stakeholder groups. Section 4.6 of this report describes the consultations carried out and summarises the views expressed.

Finally, the Work Package included the consideration of further practical tests to supplement the existing databases. Essentially, the need for further practical testing would be dependent on the content of the databases that would be assembled. Further testing would be required if significant gaps in the available data appeared.

Work Package 2: Review of the proposed emission limits

“The contractor shall review the two further steps proposed for more stringent tyre-road noise emission limits as given in columns B and C of Directive 2001/43/EC for the different tyre classes which can be applied without compromising safety.”

Having established the range of current tyre noise levels and the potential for further reductions in noise, Work Package 2 focuses on the current Directive and the proposals contained within it for reducing the limits for car tyres. The work undertaken as part of this Work Package also examines the wider issues associated with tyre noise type approval testing such as the relevance of the test track surface and the effects on noise impact of reducing the tyre noise limits.

Work Package 3: Amendments to the tyre noise test procedure

“The contractor shall propose and discuss possible amendments to the directive regarding provisions relating to safety, environmental and rolling resistance aspects and give detailed explanation about their necessity and the possible positive/negative contribution.”

This Work Package is concerned with establishing recommendations for revising the Directive concerned with tyre noise type approval. The evidence for lowering the tyre noise limit values and recommendations for future limits will be covered in Work Packages 1 and 2. This Work Package therefore considers other changes to the Directive.

In particular this Work Package considers the need for additional tests of tyre safety performance and tyre rolling resistance that could be introduced alongside the requirements for tyre noise testing. It also considers the possibility of marking tyres with information on their tyre noise levels as a means of informing consumers and, thereby, encouraging a market for quieter tyres. Finally, other technical amendments to the test procedure are considered and recommendations made, where appropriate.

Work Package 4: Benefits and costs of lowering the tyre noise limits

“The contractor shall undertake a cost/benefit analysis for the proposed noise limits and additional amendments to the Directive.”

Clearly, the lowering of tyre noise limits and/or changes to the test procedure could impact both business and society in different ways. These impacts need to be determined, and

the costs evaluated, prior to implementing any changes to the regulations. These issues are considered and evaluated as part of Work Package 4 and are based on the findings and recommendations of the research programme.

Work Package 5: Conclusions and recommendations

“The Contractor shall present conclusions and recommendation for the future of the Directive.”

The final Work Package delivers the considered conclusions and recommendations that arise from the research undertaken in the other Work Packages.

4 Work Package 1: The potential for reducing the tyre noise limits

The results of the work reported in this Work Package cover a broad range of topics. Primarily it reports on the analysis of the datasets assembled for use in this study that examine the relationships between tyre noise levels and other factors such as tyre type, safety performance and rolling resistance. However, included in this Work Package is a comprehensive review of the technical literature relevant to tyre noise type approval and a report on consultations with the tyre industry and other stakeholder groups. These aspects of the study were a requirement set out in the objectives (See Chapters 2 and 3 for further details of the objectives and content of the Work Packages).

4.1 Review of literature

A comprehensive review of the literature relevant to this study was completed during the period covered by this project. It was intended that the review would be used to support the work done in each of the Work Packages and to ensure that the recommendations take account of all relevant preceding work. The literature review is provided in full in Appendix A.

The review provides a summary of previous work that cover the main issues associated with the setting of tyre noise limits for the Tyre Noise Directive 2001/43/EC (Commission of the European Communities, 2001). In addition to providing information on tyre noise levels when tested according to standard procedures, it also examines the available information on relationships between noise levels, tyre dimensions and type, and how reducing tyre noise levels may affect other important parameters such as tyre handling and braking.

Although the review covers the main issues raised by the objectives of this study, the interpretations that might be reached from the information contained in the review should not be taken as the final outcome of this study, since further substantial analysis has been undertaken in each of the Work Packages. With this proviso, the main findings of the literature review are summarised below.

4.1.1 Main Conclusions from the review of published literature:

- Over the past thirty years substantial reductions in power unit noise from road vehicles have been achieved whereas for tyre/road noise there have been no real improvements apart from the introduction of lower noise road surfaces. This has meant that for many traffic situations, the overall levels of traffic noise have not reduced despite all efforts and resources spent on reducing vehicle noise;

- When comparing tyre/road noise levels from modern tyres on the standard relatively smooth surface (ISO 10844)¹ with the current limits in the existing Directive it can be seen that practically all tyres produce noise levels that are substantially below the current limits;
- The noise emission of retreaded tyres is similar to that of new tyres, except for the heavy vehicle tyres, for which the retreaded tyres are 2-4 dB(A) noisier than new tyres (however, the latter may not be representative of the retreading process in general);
- The influence on tyre noise levels of tyre section width is seen to be weak for modern generation tyres, possibly with three exceptions: for very narrow and very wide tyres and when testing on other surfaces than the ISO surface. For truck tyres, it still seems justified to distinguish between the normal and snow classes;
- Overall it is estimated, from the results of the review, that the potential for tyre noise reduction by measures on the tyres using existing technology as 4-6 dB(A).

With regard to possible conflicts in the requirements for noise, safety and rolling resistance, the review indicates the following:

- None of the studies examined in this review could detect a significant conflict between requirements for low noise and wet braking or aquaplaning performance. One of them, based on a relatively small sample seemed to indicate a weak relationship between noise and safety measures but when studying the data from another perspective it turned out that the assumed conflict could be explained by a tyre width influence;
- None of the reviewed studies could detect a significant conflict between requirements for low noise and low rolling resistance;
- Several low noise tyres were found to meet high standards in other respects than noise, such as safety and rolling resistance;
- In the longer term (perhaps a decade), there are a number of promising concepts for low noise tyres or tyre/wheel units using new technology. Some of them may provide a breakthrough which will give substantially lower tyre/road noise in the future;
- The ISO surface generally gives a somewhat lower noise level than most surfaces subject to normal traffic, due to its relatively smooth texture. However, it can be taken as reasonably representative of some roads designed as low noise surfaces.

However, the results of the review demonstrate that the ISO surface does not represent the ranking of tyres on more rough-textured surfaces such as exist on some urban streets and high-speed highways. Consequently, consideration should be given to amending the test procedure so that tyres are also tested on a standard surface which has a rougher texture than the present one and is therefore more representative of higher speed roads.

¹ For brevity, tyre/road noise generated on the ISO 10844 test surface is referred to as 'tyre noise'.

4.2 Collation of databases

An important aspect of the project is the collation of a comprehensive database collected from previous studies examining tyre noise, safety performance and rolling resistance. In particular, with reference to the existing noise limits, it was important to include noise surveys where measurements were carried out according to that described in the Directive for tyre noise type approval.

The databases were compiled mainly from data taken as part of previous studies involving members of the partnership. Each measured value was classified in terms of tyre class and tyre dimensions together with information on whether the values had been corrected for temperature. Each item of data was then uniquely numbered and entered into an ACCESS database. The basic structure of the databases compiled for each tyre class are listed below. The lists include information on the numbers of tyres, the years when the measurements were taken and information on the origins of the original dataset. Further details of the tyres included in the datasets can be found in Table 4.1 to Table 4.3. The tables also indicate where measurements of tyre wet grip, aquaplaning and rolling resistance were taken. It can be seen that data for a total of 171 C1 class tyres has been assembled for use in this study². The definitions of the sub classes C1a – C1e relate to the width of the tyre³.

- Class C1:
 - UBA/TÜV Automotive, 2002, 82 types;
 - TRL, 2003, 28 types;
 - SINTEF, 2004, 20 types;
 - TRL, 2005, 11 types;
 - UTAC 30 types
- Class C2:
 - UBA/ TÜV Automotive, 2002, 4 types;
 - TRL, 2003, 4 types;
 - UTAC 11 types.
- Class C3:
 - UBA/ TÜV Automotive, 2002, 18 types;
 - TRL, 2003, 10 types;
 - UTAC 55 types;
 - BASt/M+P, 2003, 15 types.

² The data posted as TRL 2003 used tyres manufactured in year 2000. Year 2003 refers to the year of publication of the report

³ C1a – 145 mm and lower; C1b – over 145 mm up to 165 mm; C1c – over 165 mm up to 185 mm; C1d – over 185 mm up to 215 mm; C1e – over 215 mm.

Table 4.1: Overview of C1 tyre noise measurement results database

IDproject	project	year	C1b	C1c	C1d	C1e	sum	temp corr	wet grip	rolling resistance	aqua-planing
1	UBA/TUEV Auto	2002	24	14	37	7	82	x	x	x	x
2	TRL	2003	3	13	8	4	28	x			
11	SINTEF	2004		7	13		20				
3	TRL	2005			10	1	11				
8	UTAC	?		5	20	5	30	x			
						sum	171				

Table 4.2: Overview of C2 tyre noise measurement results database

IDproject	project	year	C2	temp corr	wet grip	rolling resistance
12	UBA/TUEV Auto	2000	4	x	x	x
2	TRL	2003	4			
8	UTAC	?	11	x		
		sum	19			

Table 4.3: Overview of C3 tyre noise measurement results database

IDproject	project	year	C3	wet grip	rolling resistance
12	UBA/TUEV Auto	2000	18	x	x
2	TRL	2003	10		
8	UTAC	?	55		
9	BAS/M+P	2003	15		
		sum	98		

The above databases include all available data on tyre noise levels obtained using test methods that are effectively identical to the tyre noise type approval procedure. However, in addition, a considerable body of data exists on tyre noise levels that had been taken as part of vehicle noise measurement projects. Although these measurements were not taken precisely in accordance with the test procedure provided in the tyre noise Directive, because the vehicle speed range was higher (typically from 30 to 80 km/h) and the vehicles were tested unloaded (just the driver and the measurement equipment), they were included in the database as additional useful information. Table 4.4 contains further information about these measurements.

It can be seen that data for 100 C1 class tyres were obtained for use in the study.

Table 4.4: Overview of tyre noise results database, obtained from various vehicle noise measurement projects

IDproject	project	year	C1a	C1b	C1c	C1d	C1e	off road	sum	C2	temp corr
5	UBA_RWTUEV	2002		2	6	13	6	2	29	7	x
6	UBA_RWTUEV	2003			2	8	7		17	4	x
7	RWTUEV	2004		2	9	24	14	5	54	8	x
								sum	100	19	

In summary it can be seen that the databases assembled for use in this study are both comprehensive and up to date. It can also be stated that, in general, tyres were selected for each of the studies on a random basis with no particular bias towards quieter or noisier tyres. With the large numbers of tyre noise results assembled for each of the main tyre types, it was felt that statistically robust analyses could be undertaken to provide answers to the questions posed by the objectives of the study. The absence of measured data for the C1a class of vehicles was not considered to be important in view of the very small numbers of these tyres in current use (i.e. 1.6% approx). It was felt unnecessary therefore to commission additional measurements for C1a tyres within this project. It was recognised that the datasets assembled for the very wide C1 tyres and C2 tyres were smaller than the datasets for the other tyre classes. Nevertheless, it was felt that further measurements of tyres in these classes were not justified as there was sufficient data available to provide answers to the questions raised in the objectives to this study.

4.3 Comparison of tyre noise levels with the current limit values

A first step in determining whether the current limit values for tyre noise should be lowered and, if so, to what degree, is to compare the noise levels in the database for each tyre class with the corresponding limit values for that tyre class. However, in order to do this it is necessary to adjust the raw measured values according to the procedures for rounding stipulated in the Directive. This currently requires the measured results to be rounded down to the nearest integer. 1 dB is then subtracted from the resulting integer value to obtain the test result. Individual data items in the databases were therefore adjusted in this manner.

A further correction to the data was considered in relation to the requirement in the Directive to adjust measured values for variations in temperature. This applies to C1 and C2 tyres. These corrections were applied to the results whenever surface temperature values were available. A comparison of corrected and uncorrected results showed that the corrections were generally very small and close to zero. Consequently, it was not felt that temperature correction would significantly affect the interpretation of the data, given the large numbers of tyres included, and so it was justified to combine all uncorrected results for the comparison with the current limit values.

In each case examined, the results of each data source/study were kept separate. It was felt this would help to identify whether there were systematic differences between data taken at different locations. Also, since there is a possible influence of tyre width on tyre noise levels for C1 tyres, the results for these tyres have also been subdivided according to the different nominal section width classes. The definitions of these sub-classes were

given earlier in the report (see footnote 1). However, it should be noted that because of the ongoing trend to wider tyres no data was available for class C1a and only two tyre noise datasets were available for class C1b. These tyre classes, particularly class C1a tyres, form only a small fraction of the current tyre market and therefore the absence of data for this category was not considered to be important when considering the acoustic characteristics of C1 tyres as a whole.

The results for tyre class C1b are shown in Figure 4.1 where they are compared with the current limit values. In addition to this data, tyre noise results from two vehicle noise studies are added for comparison reasons. It can be seen that apart from two tyres tested by TRL, all the tyres were either at, or substantially below, the current limit. In fact for the the TUEV Automotive sample from year 2000, it was found that 20 of the 24 tyres were 3 dB or more below the current limit value and three of the tyres tested were 5 dB(A) below the current tyre noise limits.

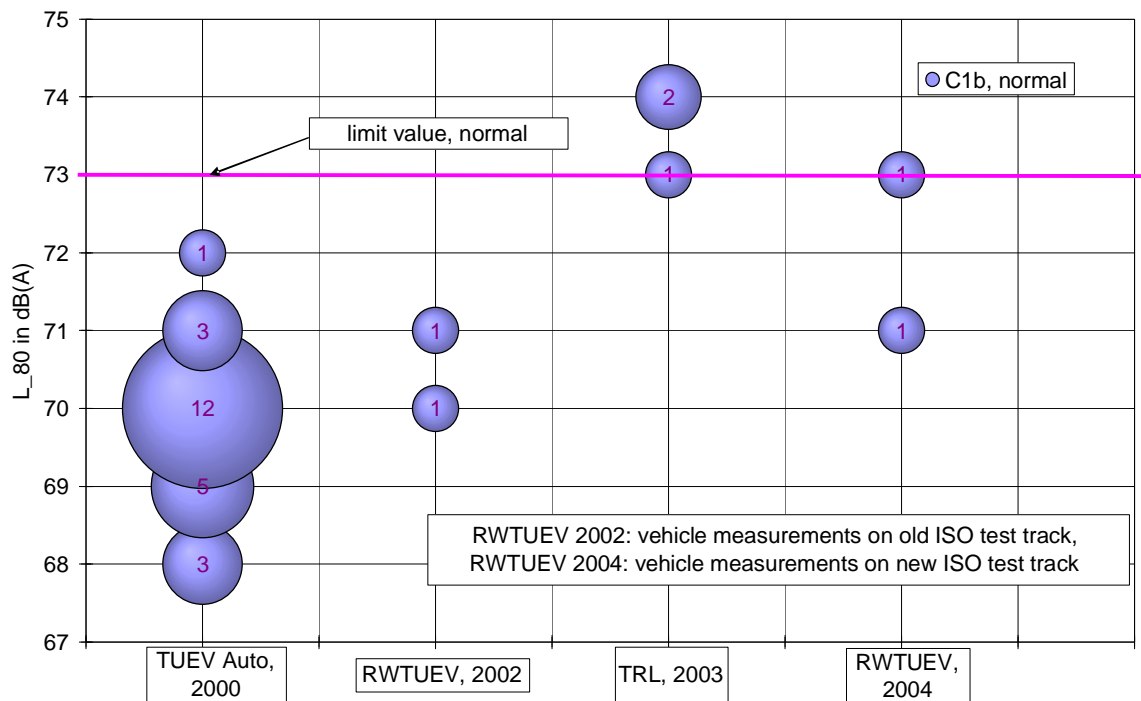


Figure 4.1: Comparison of class C1b results with the current limit value

The results for tyres belonging to class C1c are shown in Figure 4.2. The sample size for this class is much bigger than for C1b reflecting the greater volume of sales in this class. Four different studies with tyre noise measurement results could be included, supplemented by rolling noise results of three different vehicle noise studies. When the data is combined in the figure it can be seen that, as in the previous dataset, the TRL data seems to be characterised by higher values than the other studies included in the figure and 3 of the tyres tested by TRL gave noise levels above the current limits. However, overall it can be seen that over half of the tyres tested according to the type approval procedure gave noise levels of 3 dB(A) or more below the limit.

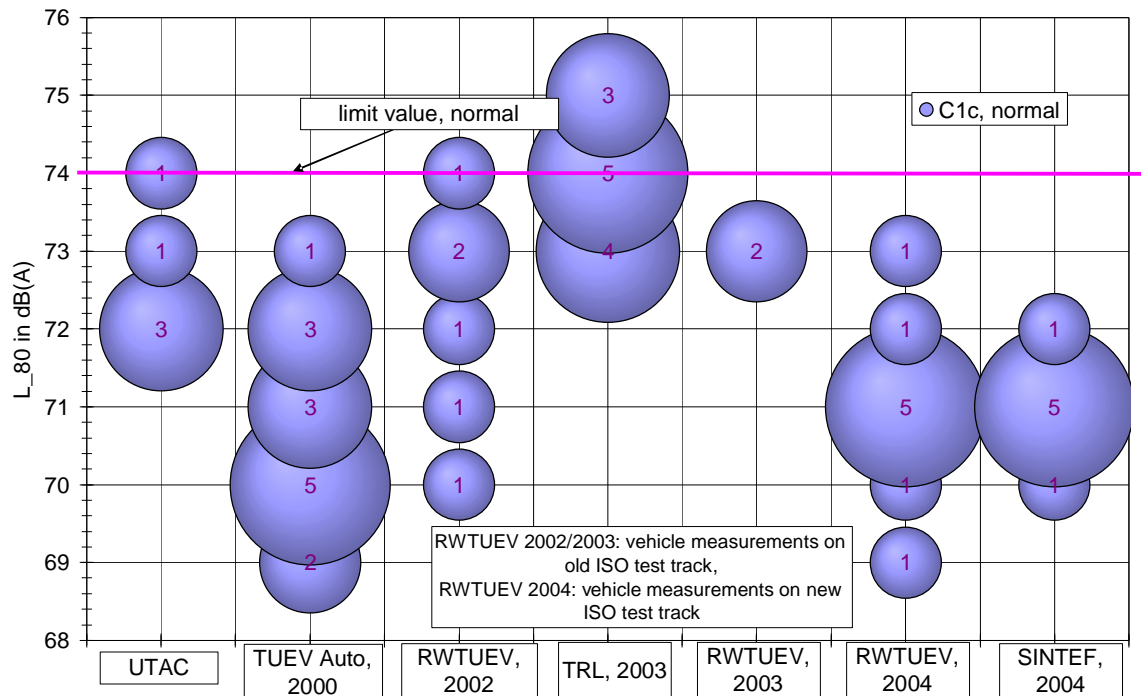


Figure 4.2: Comparison of class C1c results with the current limit value

With regard to the TRL data, an explanation for the seemingly high results for C1b and C1c tyres can be attributed to the test vehicle used in their study. TRL carried out a comparative study of tyre noise mainly to identify and quantify tyre noise mechanisms. They used a test vehicle with an enlarged wheel arch in order to accommodate a wide range of tyres of different dimensions. The smaller tyres tested were therefore not shielded at all by the body of the vehicle which would account for the higher levels seen for these tyre types. The larger tyres tested were more suited to the vehicle and it can be seen that, for these tyres, there is better agreement with the data from other studies (see figures 3 and 4 below). This result does, however, highlight two important points. Firstly, it follows that if the TRL data for tyre classes C1b and C1c were excluded from the data set, as it could be reasonably argued that the vehicle used was not suited to type approval testing for these tyres, then it would have the effect of removing all the tyres in tyre classes C1b and C1c that gave test levels above the current limits. Clearly this would considerably strengthen the case for lowering the current limits for these tyre classes. The second point relates to the importance of vehicle selection when carrying out type approval testing. This particular issue is explored further in section 6.3.4 of this report.

The data for class C1d and C1e tyres are shown in Figure 4.3 and Figure 4.4 respectively. This data also shows the same trends as that observed for the smaller tyre classes with noise levels generally well below the current limit values. It should be noted that Figure 4.4 also contains results for off-road tyres, classified as “special”. The noise emission of these tyres would appear to be slightly higher than for the normal tyres, but a 1 dB higher limit value would be more appropriate than the existing 2 dB allowance given for these tyres.

It can be stated that no significant difference could be found in the data between winter and summer tyres.

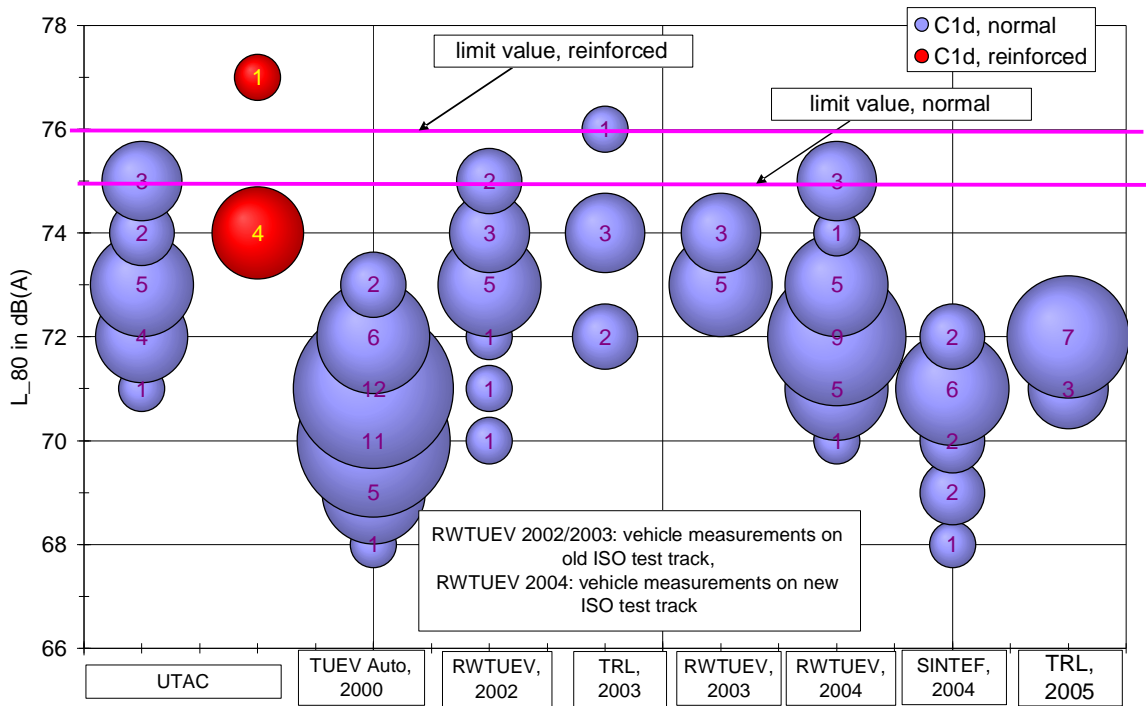


Figure 4.3: Comparison of class C1d results with the current limit value

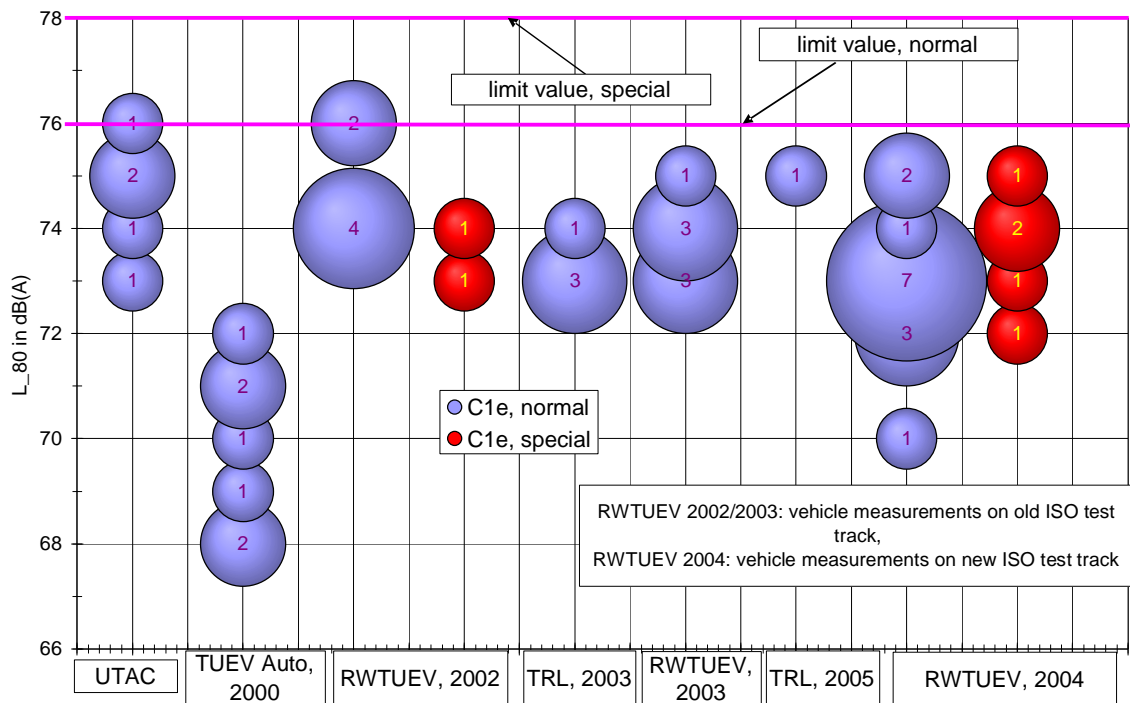


Figure 4.4: Comparison of class C1e results with the current limit value

The corresponding results for C2 tyres are shown in Figure 4.5. Tyres marked with M+S were categorised as snow tyres. The conclusions are similar as for C1 tyres, at least for normal use tyres: again the state of the art is about 3 dB below the current limit value.

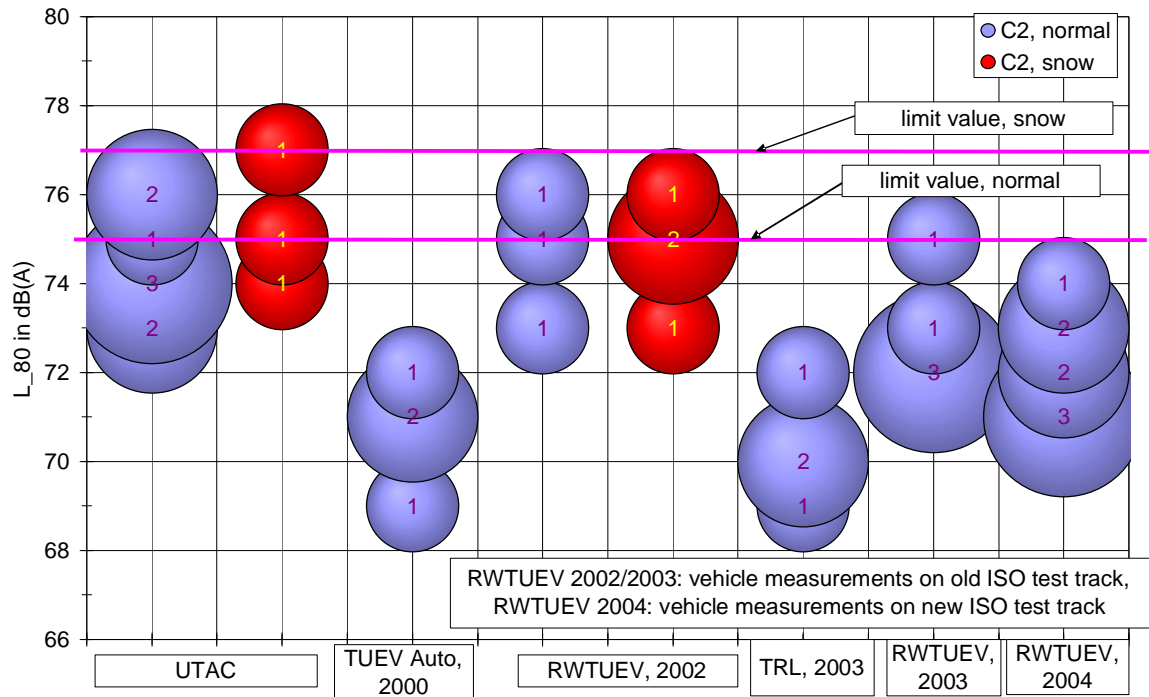


Figure 4.5: Comparison of class C2 results with the current limit value

Figure 4.6 contains the corresponding results for C3 tyres. Tyres denominated with “drive axle high traction” are categorised as snow tyres. In this context the state of the art for normal use and snow tyres is 4 to 5 dB below the current limit values. No new data is available for “special” C3 tyres. But the old UTAC data already show that 3 dB lower limit values would also be appropriate for this category.

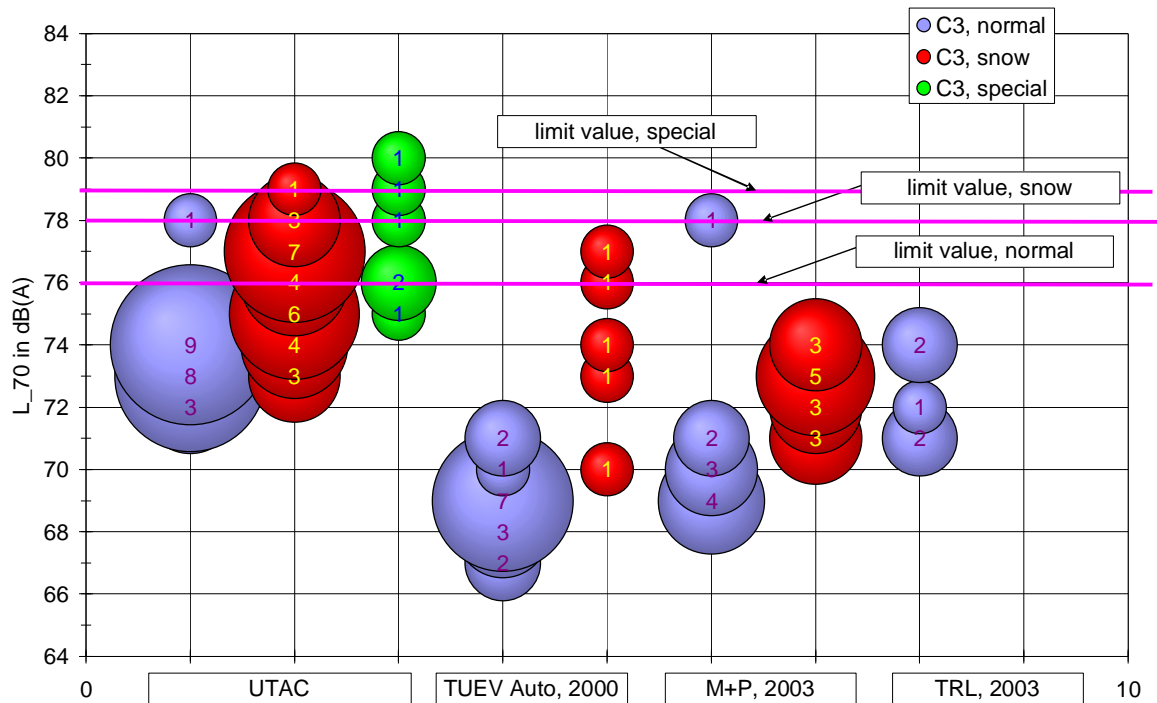


Figure 4.6: Comparison of class C3 results with the current limit value

4.4 Implications for tyre safety and rolling resistance

In addition to establishing the current state-of-art for tyre noise levels as measured using the type approval procedure, it is also important to establish whether there are any trends relating tyre noise levels with tyre safety performance and rolling resistance. This section therefore reviews the relationships between tyre noise, safety and rolling resistance, as determined from available test data.

4.4.1 UBA/ TÜV Automotive results

As already indicated in Table 4.1-Table 4.3, measurements of wet grip performance were included in the UBA/TUEV Automotive study, performed in 2000. The measurements of wet grip performance were carried out on C1, C2 and C3 tyres.

The wet grip performance was determined by wet braking tests carried out on an artificially wetted asphalt surface. The water depth was permanently kept below 1.5 mm, in order to exclude the effects of aquaplaning. The vehicle was decelerated using a 4-wheel ABS braking system from approximately 85 km/h to standstill. Speed and braking distance were measured from 80 to 10 km/h with a satellite-based measuring device. The mean deceleration was then calculated over the distance where the vehicle decelerated from 80 km/h to 10 km/h in case of C1 tyres, 90 km/h to 10 km/h in case of C2 tyres and 70/60 km/h to 30 km/h in case of C3 tyres. For each tyre set, at least 6 valid measurements were performed.

In addition rolling resistance performance was measured for C1, C2 and C3 tyres using methods described in ISO 8767 or 9948 respectively. The classification of tyre rolling resistance was determined from the rolling resistance coefficient c_R . This coefficient c_R [%] is calculated from the average values of the rolling resistance force in Newton [N] (i.e. 10 min at 50 km/h, 20 min at 90 km/h and 20 min at 120 km/h) divided by the test load in [kg] multiplied by 100 [%]. The relationship is shown below:

$$c_R = \frac{\text{Rolling resistance (N)}}{\text{Test load (kg)} \times g(m/s^2)} \times 100\% \quad (4.1)$$

The mean weight of all four tyres of one set is determined prior to the rolling resistance measurements.

In addition to the wet braking and rolling resistance tests, for C1 tyres the aquaplaning behaviour in the longitudinal direction was determined. The test vehicles were equipped with rotational speed sensors on both wheels of the front axle. For the measurement of the floating speed (i.e. the speed where aquaplaning behaviour commences) the test vehicle was run on the test track with the right front wheel aligned with a water basin with 8 mm water depth. The test vehicle was driven in 3rd or 4th gear, the selection being dependent on the engine power and speed of the test vehicle. When the vehicle reached the basin it was accelerated maximally. During the acceleration, the slip of the wheel running in the water basin was recorded. The floating speed v_{AQU} is defined as that speed, at which a slip of 15% was reached. The slip is defined as the ratio between the difference of wheel rotational speed of left and right wheel and the wheel rotational speed of the wheel which was not running in the water basin. For each tyre set, at least 6 valid measurements were performed.

Tyre noise and wet braking performance results:

The tyre/road noise levels are compared with the wet brake deceleration values in Figure 4.7 for C1 and C2 class tyres and in Figure 4.8 for class C3 tyres.

No clear trend can be found for C1 tyres while C2 tyres tend to show a positive trend (i.e. increasing noise levels with increasing deceleration levels). However, this trend is only based on the result of one particular tyre and is not confirmed by the results for the C3 tyres (see Figure 4.8), where a clear influence of tyre width and use category on the deceleration values can be seen but, again, no clear correlation with tyre/road noise levels.

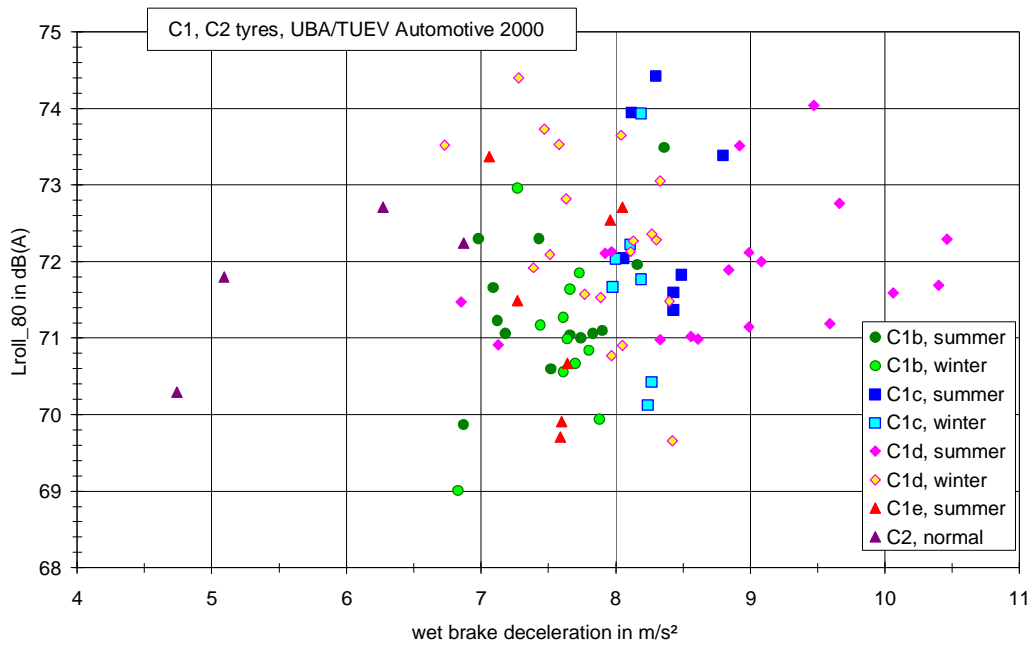


Figure 4.7: Comparison of tyre/road noise levels and wet brake deceleration values for C1 and C2 tyres (UBA/ TÜV Automotive 2000)

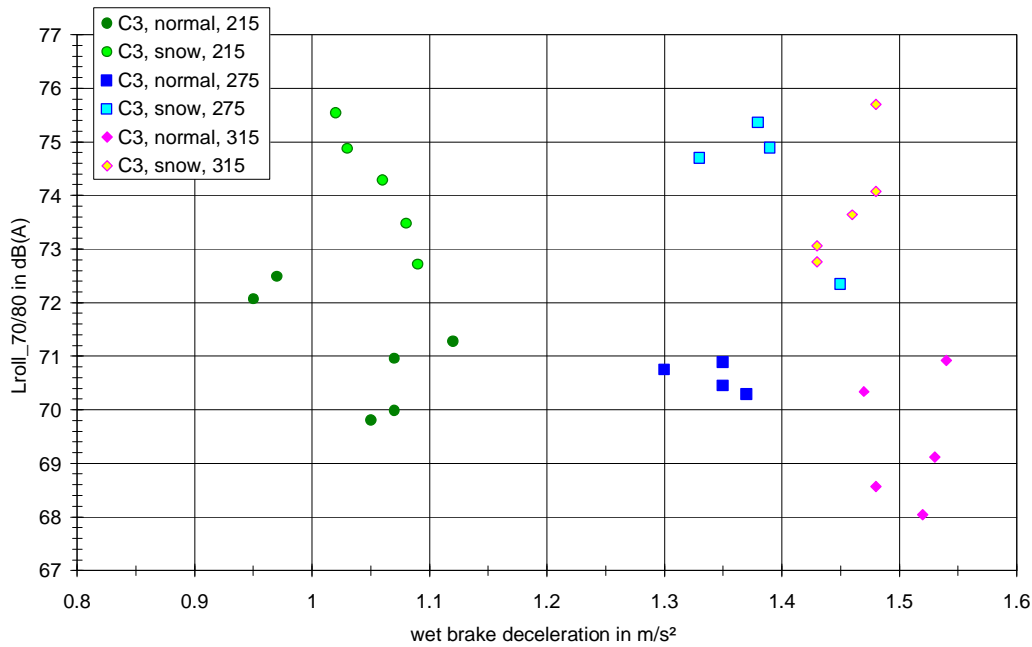


Figure 4.8: Comparison of tyre/road noise levels and wet brake deceleration values for C3 tyres (UBA/ TÜV Automotive 2000)

Tyre noise and rolling resistance results:

In Figure 4.9 and Figure 4.10 the comparison of tyre/road noise levels and rolling resistance coefficients is shown. Once again no clear tendencies can be found for C1 tyres (see Figure 4.9). For example C1c winter tyres appear to show a negative trend with rolling resistance coefficient (i.e. decreasing tyre/road noise levels with increasing rolling resistance coefficient), but C1c summer tyres show exactly the opposite trend and no significant trends in either direction can be seen for the other C1 classes. C2 tyres tend to show a positive trend (i.e. increasing noise levels with increasing rolling resistance coefficient). But this trend is only based on the result of one particular tyre and therefore cannot be generalised to the group as a whole). The C3 tyre results shown in Figure 4.10 again show the expected clear influence of tyre width and use category on the rolling resistance coefficients. However, again within each of the tyre classes examined, there is no clear cut relationship between tyre/road noise levels and rolling resistance coefficients.

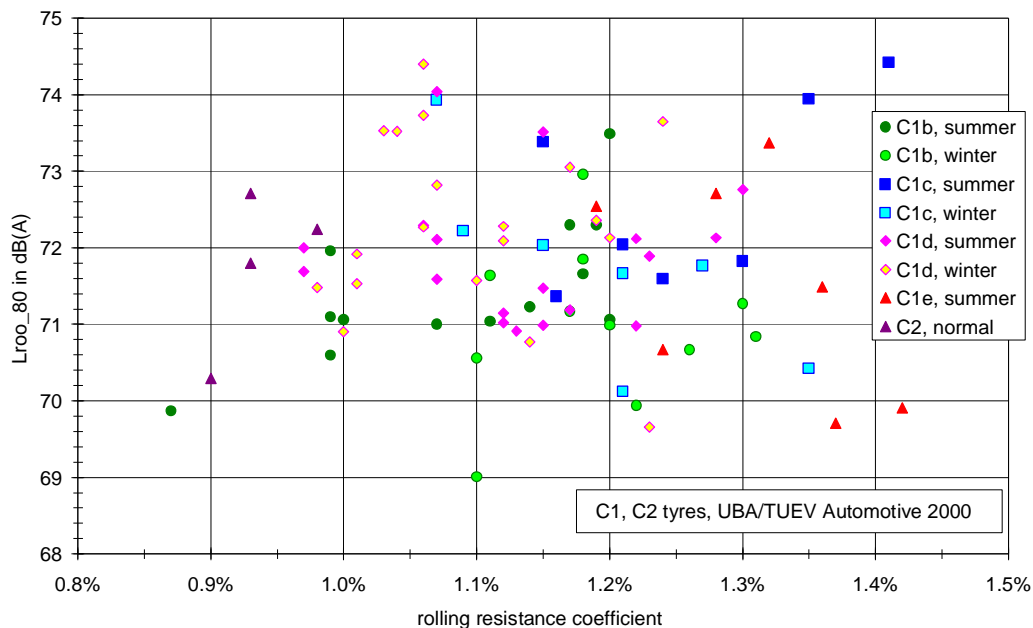


Figure 4.9: Comparison of tyre/road noise levels and rolling resistance coefficients for C1 and C2 tyres (UBA/ TÜV Automotive 2000)

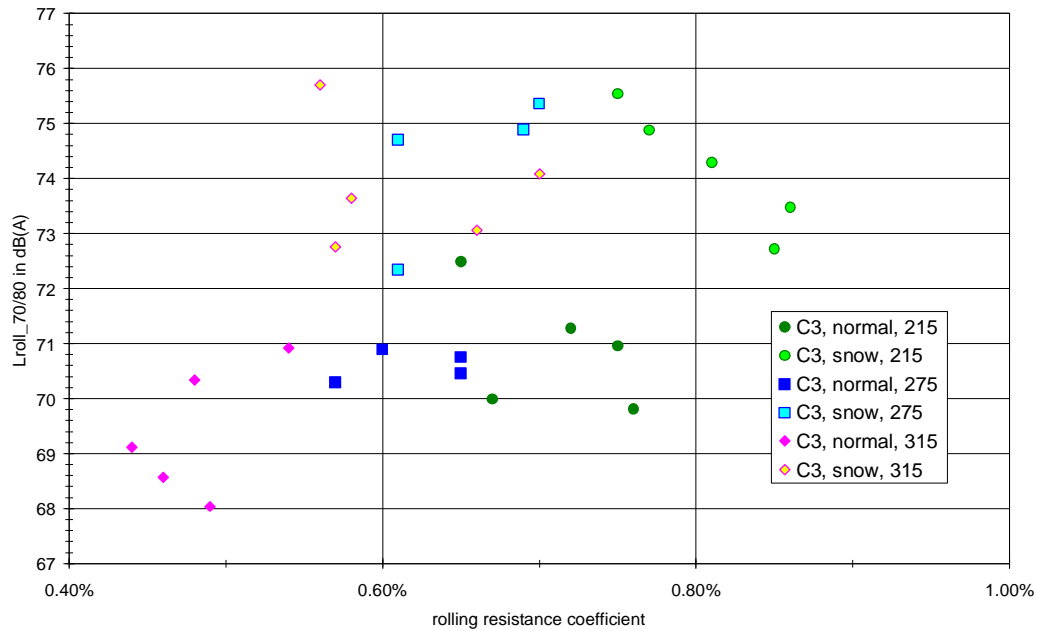


Figure 4.10: Comparison of tyre/road noise levels and rolling resistance coefficients for C3 tyres (UBA/ TÜV Automotive 2000)

Tyre noise levels and aquaplaning performance results:

The results for C1 tyres comparing tyre/road noise levels and aquaplaning speed are shown in Figure 4.11. Again no significant relationship between noise and aquaplaning speed could be detected although a possible influence of tyre width on aquaplaning speed is indicated with wider tyres tending to aquaplane at lower speeds as might be expected, although any dependency in this regard is not strongly noticeable with the data available.

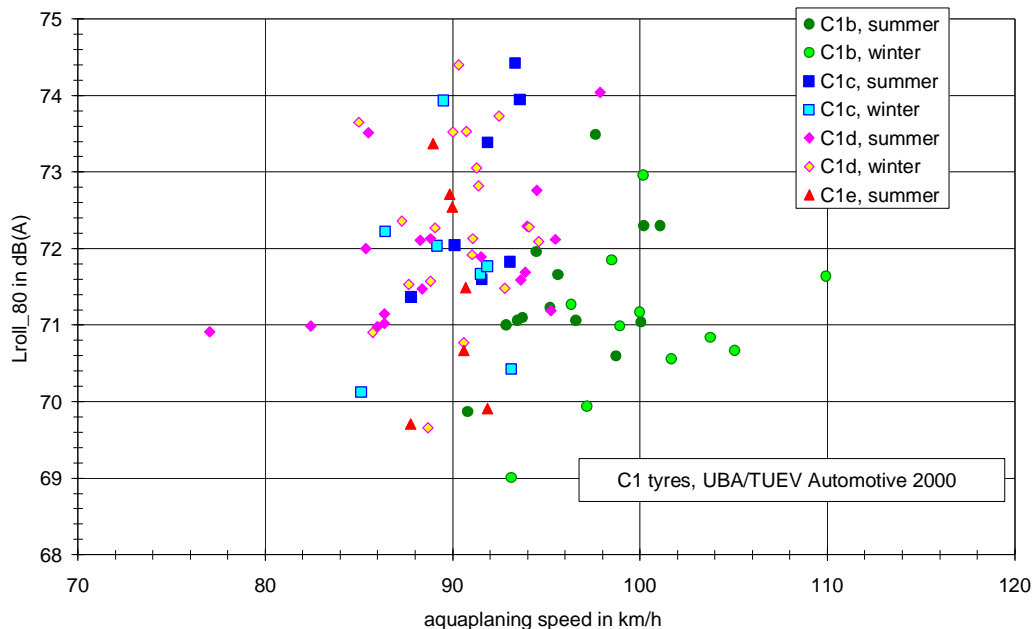


Figure 4.11: Comparison of tyre/road noise levels and aquaplaning speeds for C1 tyres (UBA/ TÜV Automotive 2000)

4.4.2 TUG results

In addition to the UBA/TUEV Automotive results, some data for C1 tyres, taken in 1997 – 1999 by the Swedish National Road and Transport Research Institute (VTI) and the Technical University of Gdansk (TUG) was obtained. The data included the results of noise tests, wet friction and rolling resistance of nearly 100 tyres. Tyre/road noise emission was measured with a CPX trailer (close proximity tyre/road noise measurements) and on a laboratory drum. The measurements were carried out by TUG and VTI. These results were also added to the database. Unfortunately no specific information about the tyre width was available (widths were 175-195 mm) but the speed index can be used as subclass indicator. The rolling resistance was determined on a safety walk surface and a rough surface dressing. For the latter surface, CPX trailer noise levels are also available.

The comparison of tyre/road noise levels measured on a laboratory drum and rolling resistance is shown in Figure 4.12 and Figure 4.13 for safety walk and a rough surface dressing. Figure 4.14 gives corresponding information for CPX trailer noise results and rolling resistance on rough surface dressing. All figures confirm the results presented in the previous section.

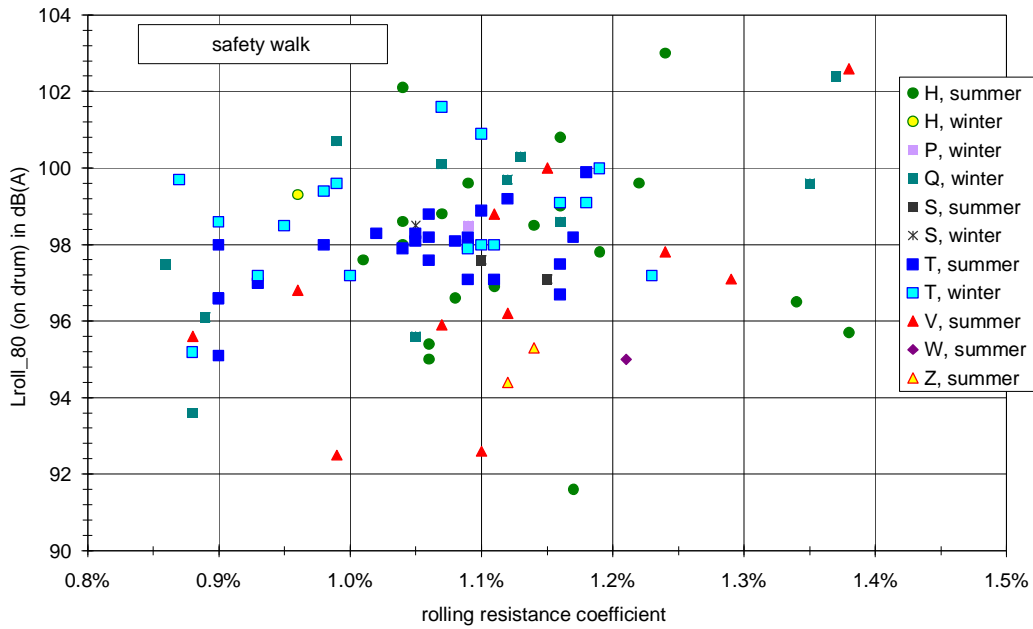


Figure 4.12: Comparison of tyre/road noise levels (measured on a laboratory drum) and rolling resistance coefficients for C1 tyres on safety walk surface (TUG data)

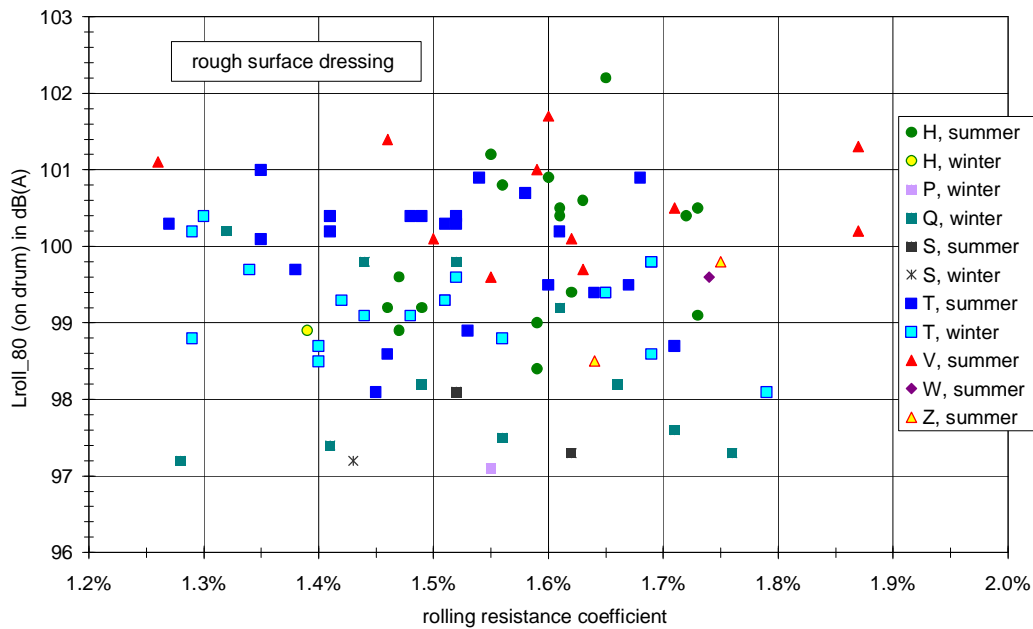


Figure 4.13: Comparison of tyre/road noise levels (measured on a laboratory drum) and rolling resistance coefficients for C1 tyres on rough surface dressing (TUG data)

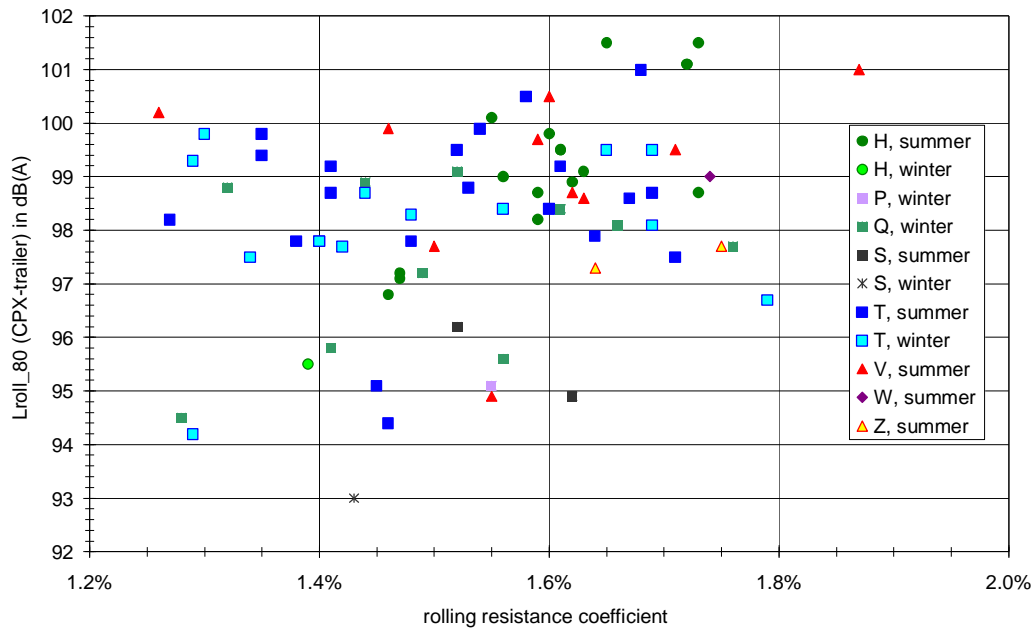


Figure 4.14: Comparison of tyre/road noise levels (measured with a CPX trailer) and rolling resistance coefficients for C1 tyres on rough surface dressing (TUG data)

The VTI/TUG study also included the relation between noise and wet friction; the latter described both as friction with a locked wheel and with ABS-type braking. The results are presented in the Literature Review in Appendix A. They show the same results as the German study, i.e. there is no significant relation between noise and wet friction.

4.4.3 Further information from the literature review

In addition to the above analysis, further detailed information on the relationships between tyre noise, safety and rolling resistance can be obtained by consulting chapter 8 of the literature review. Again the additional information contained within the literature review broadly supports the conclusions reached from the analysis carried out as part of this project.

The results of the literature review are summarised as follows:

- Although some design properties of tyres seem to be in conflict when designing for noise reduction by conventional pattern and rubber changes, no significant conflicts have been detected on market tyres in practice;
- None of the reviewed studies could detect a significant conflict between requirements for low noise and wet braking or aquaplaning performance. One of them, based on a very small sample seemed to indicate such a conflict although it has been suggested that this could be partially explained by a tyre width influence;
- None of the reviewed studies could detect a significant conflict between requirements for low noise and low rolling resistance.

It would appear therefore that there is no reason given the available data to expect that lowering the noise limits from the current levels will mean that tyres with inferior performance concerning safety and rolling resistance will come into the market. Indeed there are many examples currently in production that exhibit lower noise levels and perform well in terms of safety performance and rolling resistance

4.5 Future trends in tyre design

A comprehensive overview of the potential for lowering tyre noise levels in the future is provided in Section 14 of the literature review given in Appendix A. The review covers both modifications to conventional pneumatic tyre designs that could give rise to lower noise levels and reviews some of the research that is currently underway on novel designs of tyres.

Regarding conventional tyres the literature review examines the potential benefits from adapting winter tyres for all year round use and describes modifications to the tread design to include changing the air/rubber ratio, changing the size of the tread elements and using different rubber compounds. The increasing use of run-flat tyre designs is also examined together with the potential noise advantages of ensuring that tyres are correctly inflated in use.

Unconventional tyre designs include an overview of non-pneumatic composite tyres. The noise-reducing potential for a composite wheel has been demonstrated to be around 10 dB(A); i.e. better than that of a slick (pattern-less) tyre on a smooth surface, and much better than any type of pneumatic tyre on a rough surface. Thus, it is argued, the concept has the potential of a technical breakthrough, if properly developed (Chapter 25, Sandberg and Ejsmont (2002)).

Ongoing work led by VTI, but in cooperation between a number of organizations and companies, has attempted to study the feasibility of developing the composite wheel into a practical proposition (Sandberg *et al.*, 2003). A similar tyre has been developed by Michelin known as the TWEEL and in 2005 this tyre design concept received a number of innovation awards. Figure 4.15 illustrates the composite tyre and Figure 4.16 shows the Michelin concept tyre. Further details are given in the Appendix A.



Figure 4.15: Early version of a composite wheel. Note the ventilation holes in the tread. New version is underway in which the spokes are better designed to reduce stiffness variations around the circumference and with better distributed ventilation holes



Figure 4.16: The TWEEL as it was presented the first time at the motor show in Detroit in January 2005. Photo kindly supplied by Dr Lin Kung, Kumho Tires, USA.

A project led by VTI on tyre innovations has also examined the possibility to replace the conventional patterned tyre tread with a porous tread as there is evidence that such tyres produce significantly lower noise. Speculations and some earlier testing suggest that such a porous tread tyre may have excellent wet friction and rolling resistance properties, but may sacrifice wear. Difficulties were also encountered with the earlier prototypes with regard to attaching the porous tread to the tyre carcass.

Figure 4.17 shows the first prototypes of the porous tread tyre made in 2004.



Figure 4.17: Two porous tread tyre prototypes together with the regular tyres used as carcasses for the porous tread (after buffing-off the existing tread)

Testing so far of the porous tread tyre has indicated very interesting results (Sandberg *et al.*, 2005). The results indicated that the noise emission was exceptionally low on road surfaces with a texture typical of Swedish highways. In comparison to the two commercial car tyres chosen as references, the noise reduction was about 7 dB(A) for both narrow and wider tyres which is far below any other tyre measured. Rolling resistance was about 10% lower than that of a Michelin Energy 3A tyre which is the best of the conventional tyres measured by TUG so far. Wet friction was poorer than on the high-performance reference tyres but can no doubt be improved substantially if high-quality rubber compounds are used instead of the low-quality recycled rubber used in the first prototypes.

It is concluded in the literature review, that there are several possibilities for a breakthrough in tyre design for low noise (and low rolling resistance) within the next 10 years or so, provided sufficient resources are spent on developing the concepts. If these lower noise tyres can be developed for normal road use, then this opens up the possibility of further substantial reductions in the tyre noise limits in the future.

4.6 Consultation with stakeholder groups

Clearly the tyre manufacturing industry and other relevant industry stakeholder groups have a vested interest in the outcome of this study. Any changes to the tyre noise limit values and/or the test procedure implies changes to industry practices. Clearly, these changes could potentially incur additional costs and also affect the overall market for some types of tyres. Consequently, it was considered vitally important that the tyre industry were kept fully informed of the objectives of the study, the proposed method of working, and that the data-bases that could be used in the analysis were as comprehensive as could be obtained. In addition, there are many bodies with direct, or indirect, responsibility for environmental noise in conditions where tyre/road noise

dominates. Supporting these bodies is a considerable community of engineering and academic expertise in the field.

Of particular relevance to this study, in order to consider the technical feasibility of engineering, was the considerable body of data on tyre noise that was available to the tyre industry. In particular, the database of ETRTO (European Tyre and Rim Technical Organisation) represented the largest collection of data in the field. Although much of this was subject to commercial confidentiality and was therefore not openly available to the study team (or indeed individual tyre companies), it was clear that any factual evidence that the industry could provide from the results of their own measurements, would also be of value to the project.

In addition to the discussions with the tyre industry, the study design also allowed for consultation with all relevant stakeholder groups, and for the views expressed by these groups on the issues covered by this study, to be summarised in this final report.

The following section details the meetings that were held during the course of the study and the comments received from all stakeholders.

4.6.1 Meetings with tyre industry representatives

The main point of contact with the tyre industry was through the ETRTO. During the course of the study, four official meetings were arranged. The first was held on 29th July 2005, at an early stage in the development of the project. Representatives from FEHRL, TRL and ETRTO attended. The meeting was mainly concerned with communicating the nature of the study, its scope and timescales and to establish how the tyre industry could help with the project and what would be required of them. At this meeting, a number of questions were posed to ETRTO representatives that the study team felt would arise as part of the main study. Further meetings were held on 13th September 2005, 12th January 2006 and 17th March 2006. The meetings generally focussed on the industry view of the proposed revision of the tyre noise Directive. At the meeting held on 12th January 2006, the ETRTO representatives gave a comprehensive presentation of the findings of their own research.

The main points raised by the tyre industry representatives:

- The current limits were thought to have had very little impact on real world noise levels and felt that the road surface had a much larger influence on tyre noise levels than tyre design changes;
- Currently tyres are optimised to produce low noise on the ISO 10844 test surface which is a relatively smooth surface with a maximum stone size of 8 mm. Tests had shown that the ranking of tyres in terms of noise on this surface correlates poorly with the corresponding ranking on more deeply textured surfaces. This observation clearly has a bearing on the effectiveness in practice of the type approval regulations;
- There is a positive correlation between tyre noise and tyre width although the data are very dispersed due to effects such as different tread patterns, different test tracks, different constructions, different brands, etc. As a result, it is impossible

from the available data to predict the noise value of a tyre based solely on its width. The industry data suggests that approximately 20% of the variance in tyre noise can be explained by differences in tyre width;

- The theoretical limit to tyre noise reduction is represented by slick tyres. The constraints imposed by ensuring that tyres are safe, durable and economic ensures that the technical limit implied by slick tyres cannot be achieved in practice. The 'best low noise tyre' is thought to be about 2 dB(A) above the theoretical limit. Reducing the type approval limits by 2 dB(A) will require redesigning 10% of current tyre types and would place a further 15% approximately exactly at the limit. Wider tyres are more often at the limit for their class. Special considerations would be needed for tyres designed for SUV vehicles;
- True professional off-road tyres are used for special tasks like power line repairs, fire-fighting, back-country medical emergencies, etc., but they rarely roll on open roads. The tyres are designed for traction in mud and snow, with large tread blocks to give good grip in very adverse conditions. This design, which is needed for the exceptional traction properties required of these tyres, also causes them to be noisy (above current limits) under the Directive's test conditions. Redesigning the tyres for low noise will adversely affect the traction properties that make these tyres special;
- It was emphasised that there was a very loose relationship between wet grip and noise levels because many factors have an influence. It was stressed that the data is dependent on the method and test track used;
- With regard to the product life cycle of tyres it was stated that car tyres of a particular type will generally be produced for a maximum of 6 - 8 years. The equivalent product cycle for commercial vehicle tyres is 8 – 10 years;
- In view of the above, the industry recommends maintaining limits according to tyre width classes. It was felt that reductions in the limit values 1 dB(A) for majority of tyres could be accomplished by 2007 – 2009 with a further reduction of 1 dB(A) for the majority of tyres in 2009. Specialist off- road mud and slick tyres should be exempt from tyre noise type approval. Two new classes for very wide tyres should be created;
- The industry stated its opposition to marking the side walls of tyres with the noise level measured in the type approval test of that tyre. There was concern that introducing this requirement for tyre lines that are already in production would be costly, as this would involve changing molds that are already in use. The cost of stamping tyres would be lower for molds that are yet to be designed. The industry were also concerned that there may be little space available on the sidewall to incorporate noise labelling.

4.6.2 Consultations with other Stakeholder Groups

To supplement the consultations with the tyre industry, a process of review with other key stakeholder bodies was also launched. This process took three forms; formal approach to various bodies by letter, an internet based consultation via the FEHRL website, and

leadership of workshops and debates organised by bodies in which the project team had contact.

In the formal written review, approaches were made to EUCAR-ACEA (European Council for Automotive R&D and the European Automobile Manufacturers Association), EARPA (European Automotive Research Partners Association), CLEPA (European Association of Automotive Suppliers), ECTRI (European Conference of Transport Research Institutes) and ERF (European Union Road Federation). These written approaches were supplemented by face-to-face discussions and included participation in, and presentation to, events organised by those bodies – including the EARPA annual conference. The response from the various bodies was extensive.

In addition to these bodies, a number of academics working in the field were approached. These included recognised experts in the field and coordinators of current EC funded projects concerned with tyre/road noise. Many of the response received were very comprehensive and provided much new information.

A further consultation, open to a wider audience, was addressed via a webpage featured on the FEHRL website (as shown in Figure 4.18). The webpage invited comment on the revision of the Directive and, as with the other forms of consultation provided extensive information.



Figure 4.18: Consultation webpage on the FEHRL website

In each of these cases, respondents were invited to consider the five key points of the study:

1. Do you believe that the proposed reduction in limit values proposed in Directive 2001/43/EC are achievable without compromising safety or other important performance characteristics?
2. Do you believe that the specifications for section width of passenger car tyres are appropriate for the modern, and future, vehicle/tyre fleet?
3. What effect do you believe that the proposed reductions will have on traffic noise levels in Europe (or specific areas of Europe)?
4. What do you believe the cost of applying the proposed limit values will be, and who will pay?
5. What modifications, if any, would you propose to the test procedure for measuring tyre/road noise levels?
 - a) Is the test surface appropriate, and how might it be better specified?
 - b) Is the speed range tests and the number of test run performed appropriate?

Finally, project team members were leaders in many workshops concerned with tyre/road noise including the European Road Transport Research Advisory Council (ERTRAC) Work Area on Energy, Environment and Resources and the CALM Networks review of research priorities for DG Research and DG Environment. Further details of these activities are described in the following section.

A review of all the various responses and evaluations arising from consultation via the website and from contact with other stakeholder groups are summarised below:

- There was unanimous agreement that the limits proposed in the Directive could be achieved – and had already been largely achieved – without compromising other essential performance characteristics. Many respondents went further, for example ACEA reported that OEM tyres are already available on the market that are between 1 dB(A) and 4 dB(A) lower than the limit values proposed;
- There were mixed views about the development of the tyre size classes. Most respondents appeared to agree that the current classes were no longer appropriate, but there were differences in the development of new classes or even the retention of size dependent classes. One academic respondent suggested that the relationship between noise and width became less important for tyres wider than 225 mm. However, most other respondents acknowledged that a relationship existed but differed in their views regarding its form. ACEA agreed that a revision of the classes, should give greater tolerances for wider tyres. Many others tended to recognise that the trend towards wider tyres was creating greater noise in the environment. The argument was if the Directive was the right mechanism to stop, or reverse, this trend. For example, the Greater London Authority has proposed to reverse the trend towards wider tyres. The view of some respondents is that tighter limits for wider tyres would reverse the trend, whilst others thought that such actions lie outside the scope of the Directive;
- Regarding the question about the effectiveness of the proposed limits on traffic noise, there was considerable agreement that negligible or marginal benefits would result. Such responses were largely driven by the assessment that the proposed limit values were already achieved;

- From those respondents who commented on the costs of applying the proposed limits (or tougher limits) there was unanimity that any costs that arose if the limits resulted in changes to current tyres would be marginal;
- Many of the respondents considered the test procedure itself to be largely appropriate. Some considered the need to move towards a rougher – and arguably more representative test surface. It was recognised by a number of respondents that the ISO surface was becoming more representative of the bulk of surfaces in many European countries. However, it was acknowledged that such surfaces were not appropriate for many other European countries and, as a result, in the longer term a second surface was required to represent the whole of Europe;
- Many respondents also focussed on the need to develop further actions on road surfaces. However all considered that further reductions in noise could be achieved by further actions dedicated to tyres with actions on road surfaces continued in parallel. No-one thought that road surfaces were limiting further development;

4.6.3 Other meetings

CALM Workshops:

Two members of the partnership chaired sessions at the CALM (DG RTD Coordination of Community Noise Research) workshops held in Brussels on October 18th 2005 and March 16th 2006 in Brussels. The main objectives of these workshops were to elaborate the research priorities to achieve improvements in noise abatement, to gain a better understanding of noise effects and to provide assessments of costs and benefits of different action plans that might be particularly applicable to the city environment. The first workshop was mainly focussed on the development of the action plans stemming from the requirements of the Environmental Noise Directive 2002/49/EC. This Directive is concerned with protecting the health and well-being of the EU citizens against harmful effects of environmental noise pollution. Its main objectives are the monitoring of the environmental noise (by strategic noise mapping of agglomerations and major roads, railway lines and airports), the addressing of local noise issues (by establishing action plans according to the noise situations monitored) and the informing of the public about noise issues (e.g. noise exposure and effects, abatement measures in action plans). The workshop also considered the further development of the strategic planning of future research on reducing environmental noise in Europe.

Although the Workshop was not specifically relevant to the topic of this study, it was noted that considerable emphasis was placed on the need to reduce tyre/road interaction noise as this is a major contributor to overall levels of traffic noise and hence annoyance in city environments. It is clearly important that any plans to reduce the limit values for tyre noise should be made with a full understanding of the impact that these reductions have on overall levels of traffic noise and hence environmental impact. In the longer term this could influence the action plans being developed by city planners as part of the requirements of the Environmental Noise Directive.

The second workshop considered target setting and included further reference to the reduction of tyre/road noise through actions on both road surfaces and tyres – both together and in parallel.

IEA Workshop:

Two members of the Partnership gave presentations at an International Energy Agency workshop, the theme of which was *Energy Efficient Tyres: Improving the On-Road Performance of Motor Vehicles*. The purpose of the workshop was to examine how rolling resistance is measured and how these measurements translate into reductions in fuel consumption. Technical prospects for further reductions in rolling resistance were examined, with careful consideration given to safety, durability and other factors. The workshop also discussed the feasibility of establishing an internationally harmonised procedure for rating the energy efficiency of tyres. The workshop was intended to bring together policymakers, manufacturers and technical experts. The first presentation was entitled “*Rolling Resistance of Tyres on Road Surfaces - Procedures to Measure Tyre Rolling Resistance*” and the second entitled “*Rolling resistance on test versus road surfaces*”. Other presentations at the workshop addressed labelling of tyres, government activities and the trade-offs resulting from the use of low rolling resistance tyres.

4.7 Summary and discussion of Work Package 1

The activities described in Work Package 1 cover a broad range and provide information that has been used partly to provide answers to the questions posed by the objectives of the study as well as providing data that can be used as input to each of the other Work Packages.

Central to the development of Work Package 1 was the compilation of a comprehensive database of tyre noise, safety and rolling resistance measurements. These databases have been used to provide information on the range of noise levels generated under standard conditions by current generation tyres. This essentially provides information on the current state-of-art of tyre design in relation to noise generation performance. However, when coupled with information on safety performance and rolling resistance it provides a more complete picture on the opportunities for reducing tyre noise emission whilst still maintaining appropriate standards of safety and fuel economy.

Work Package 1 also included the compilation and review of the relevant literature which has provided valuable additional information to support the analyses reported in each of the Work Packages. Finally the Work Package has reported on the meetings and discussions held, during the course of the work, with representatives from the tyre industry and with other stakeholder groups.

The results presented in this Work Package clearly show that for each of the tyre classes studied, the noise levels generated under conditions of type approval vary over wide ranges. Moreover it is clear that practically all C1 tyres currently in service or have been in service since the regulations were introduced produce noise levels, under conditions of type approval testing, which are well below the current limit values. In the analysis of 171 tyres assembled for use in this study, less than 4% of the sample gave higher values than the current limits and about 50% of the sample gave levels that were 3 or more dB(A) below the current limits.

These results demonstrate that the introduction of the type approval tyre noise limits has had little impact on overall traffic noise levels and hence the impact of traffic noise on communities. This point was also made by the tyre industry representatives.

Previous studies have attempted to examine the relationship between tyre noise and safety performance but have not shown any evidence of a significant relationship. This result is perhaps understandable given the commitment by the tyre industry to ensure that all tyres in production meet adequate safety standards. Given the large ranges in tyre noise levels for a given tyre class there are many examples in the data assembled for this study of tyres that produce relatively low noise levels and yet perform well in terms of safety performance.

Overall, it would appear that provided there are adequate safeguards to ensure that a high standard of safety performance is maintained for future tyre designs, the noise levels could be reduced significantly from the current limits. The analysis has shown that it is possible to produce tyres that can perform well in terms of wet grip and noise emission.

With regard to the effects on rolling resistance of reducing tyre noise, the analysis has shown that for the range of values available there is no significant relationship between tyre noise and rolling resistance. Car tyre manufacturers place the reduction of tyre rolling resistance high on their list of priorities when designing new tyre types. This has resulted in considerable progress in recent years in reducing tyre rolling resistance particularly with the innovative use of different tyre compound materials and in attention to overall tyre weight. Given the strong influence of the market for fuel efficiency, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise.

5 Work Package 2: Review of proposed emission limits in Directive 2001/43/EC

It was shown in Work Package 1 that there is considerable scope for lowering the tyre noise type approval limits without sacrificing other important factors such as safety and fuel economy. The question arises, however, as to the degree of reduction that should be implemented. Clearly this is governed by what can be achieved technically, given an appropriate lead in period, and what is desired in terms of the impact that such reductions might have. At this point it is important to remember that the prime reason for introducing tyre noise testing and tyre noise limit values is to help reduce the impact of traffic noise on individuals and communities located near to roads. It will be shown in Section 5.3 the effects on traffic noise levels of the proposed reductions in limit values outlined in Section 5.1. Section 5.2 outlines how the measured values on the ISO tyre test surface translate to noise levels on typical road surfaces found in the EU.

It is important therefore to establish what reductions in noise limits are required in order for these desired environmental benefits to be achieved.

This Work Package begins with establishing revised limit values based on what is technically feasible given an appropriate lead-in period. The main focus is to establish limit values for class C1 tyres, however, for completeness revised limits for C2 and C3 tyres are also considered. The proposed tyre noise limits are based on the data described in Work Package 1.

Work Package 2 also examines the benefits in terms of reduced vehicle and traffic noise levels that the new limits will provide. This information is, of course, an important ingredient when estimating the financial benefits and costs of the proposed changes. This is the subject of Work Package 4 described later in this report.

5.1 Proposed limit values

As mentioned above, the prime objective of reducing tyre noise limit values is to reduce the environmental impact of vehicles and traffic streams. For any given reduction in limit value the actual reduction in traffic noise levels is limited due to a number of factors that can be related to the test procedure not fully representing real life conditions. Because of this dilution of effect it is important to produce a significant reduction in the limit values in order to show some noticeable effects in the community. Sections 5.2 and 5.3 examine the likely link between noise limit reductions and likely reductions in noise for different road traffic scenarios.

Section 4.3 compared current tyre noise levels with current limits (Figure 4.1 to Figure 4.6) and showed that there was considerable room for reduction across all tyre categories. In the short term a 3 dB(A) reduction is clearly possible as in many cases over half the tyres tested meet this stiffer limit. Table 5.1 below lists the percentages of tyres that would meet 3 and 5 dB(A) reduction in limit values.

It is important to point out that these are tests on tyres which were tested in the period 2000 to 2004 and therefore do not represent recent production where it can be expected that further reductions have been made due to continuing development of the production of lower noise tyres. It can be seen from Table 5.1 that between 5 and 19% of C1 tyres currently meet a stiffer limit of a 5 dB(A) reduction in tyre noise limits. In the category C2 the percentage is 13% while for the C3 category the figure is over 50%

Table 5.1: Percentage of tyres already below current limit values

Category	Percentage • 3 dB(A) below	Percentage • 5 dB(A) below
C1b	68	10
C1c	45	5
C1d	66	19
C1e	57	16
C2	50	13
C3	75	53

Therefore it can be argued that in the longer term a reduction in limit values of the order of 5 dB(A) is feasible for all the categories listed in Table 5.1 as tyres are already available commercially which meet limit values 5 dB(A) below current limits. It can also be concluded that commercially viable lower noise tyres can be produced which meet acceptable safety and rolling resistance standards as it has been established there is no significant relationship between noise emission and wet braking and rolling resistance for existing tyres.

5.1.1 C1 category tyres

Examining the noise produced for each tyre section width category (Figure 4.1 to Figure 4.6) it was decided that, in addition to reducing the tyre noise limits some changes to the definitions of the tyre classes was also justified. Firstly, for the smallest car tyres it appeared that tyres in the previous classes C1a, C1b and C1c could be combined into a single new class which have labelled C1a_new. Essentially all tyres with a section width <185 mm would be included in this new group. This change recognises the fact that there is no compelling evidence to suggest that tyres in this category produce noise levels that are markedly dependent on tyre width. Consequently a single noise limit for these tyres is justified. It is worth noting also that in terms of the overall market share, these tyres represent a small and probably, declining proportion of the overall market. The major and growing share of the market is for tyres with section widths 185-215 mm and 215-245 mm. These important tyre classes are treated separately in our proposals and, recognising the weak dependence on tyre width for these tyres, some allowance in the limit values are proposed for these groups. These tyre classes are labelled C1b_new and C1c_new respectively. For very wide tyres >245mm there is some evidence to suggest that higher noise levels are justified. To accommodate this we have divided tyres with section widths greater than 245 mm into two groups, i.e. 245-275 mm and tyres > 275 mm. These tyre classes are labelled C1d_new and C1e_new respectively. Essentially in order to

accommodate the effects of tyre width on noise from the larger tyres in the market, our proposals replace the single class > 215 mm in the current Directive with 3 width classes.

With regard to the type approval limits, we propose the following:

For tyre widths • 185 mm there are tyres on the market which would meet a new limit value of 71 dB(A) in 2012. For the next width category > 185 mm to • 245 mm a slightly higher value of 72 dB(A) is recommended. For wide tyres > 245 mm and • 275 mm the suggested limit is 73 dB(A) and for very wide tyres > 275 mm the limit value should be higher at 75 dB(A).

The current tyre classes and associated noise limits are listed in Table 5.2. The table includes the outline proposals for future noise limits stated in the current Directive (i.e. columns B and C of the table).

Table 5.2: Current tyre noise limits for C1 tyres (rounding down and 1 dB(A) reduction)

Current tyre class	Nominal section width (mm)	A (current)	B (2007-2009)	Relative decrease compared to current limit value	C (date not specified)	Relative decrease compared to current limit value
C1a	• 145	72	71	1.0	70	2
C1b	> 145 • 165	73	72	1.0	71	2
C1c	> 165 • 185	74	73	1.0	72	2
C1d	> 185 • 215	75	74	1.0	74	1.0
C1e	> 215	76	75	1.0	75	1.0

Based on the findings of this report, our proposed limit values for the new tyre classes for 2012 are given in Table 5.3. Interim values that would come into effect in 2007-2009 are also listed in these Tables under column B. These are transitional values which are intended to avoid the necessity for sudden significant decreases in limit values.

The relative decreases in the limit values are also given in these Tables. This takes into account the fact that the current method of rounding the measured values differs substantively from that recommended in future. Currently the recorded value is rounded down to the nearest integer and 1 dB(A) is subtracted. For future limit values it is recommended that the values are rounded to the nearest integer value with no subtraction of 1 dB(A). This new procedure is in line with the method adopted in the revised Directive for motor vehicle noise emission. Further details of this recommended change can be found in section 6.3.1 of this report.

Table 5.3: Proposed tyre noise limits for C1 tyres (rounding to nearest integer only)

New tyre class	Nominal section width (mm)	B (2008)	Relative decrease compared to current limit value	C (2012)	Relative decrease compared to current limit value
C1a_new	• 185	73	0.5 - 2.5	71	2.5 - 4.5
C1b_new	> 185 • 215	74	2.5	72	4.5
C1c_new	> 215 • 245	74	3.5	72	5.5
C1d_new	> 245 • 275	75	2.5	73	4.5
C1e_new	> 275	77	0.5	75	2.5

An example will help to clarify how the relative reductions in noise levels in Table 5.2 and Table 5.3 were determined. Tyres with a nominal section width of >185 mm to • 215 mm are currently classified as C1d with a current noise limit of 75 dB(A). Because of current rounding procedures a tyre with a measured value of 76.9 dB(A) would just meet this limit. Under the proposed procedure the tyres would be classified as C1b_new with a corresponding limit value in 2008 of 74 dB(A). A tyre with a measured value of 74.4 dB(A) would just meet this requirement under the proposed rounding procedure. The relative reduction in limit value would therefore be $76.9 - 74.4 = 2.5$ dB(A). In Table 5.3 this value is listed in the adjacent column while in the last column the relative decrease in 2012 is given i.e. 4.5 dB(A).

Using the available database the effects of imposing these limits have been assessed. Figure 5.1 shows the percentages of tyres which would pass the proposed limit values in columns B and C above. The cumulative distributions were determined from the databases assembled for use in this study.

It can be seen that there are some differences in the distributions for the different width categories indicating higher noise levels as width increases.

It can be seen that 68 to 70% of the tyres tested would meet the 2008 interim values, while 25 to 41% would meet the stiffer limit values proposed for 2012. Note that over 70% of tyres sold in 2004 would be in the two width categories C1a_new and C1b_new. Sales of tyres in width C1b_new category were increasing rapidly in this year.

New values have been set for the widest categories C1d and C1e but the data for these classes is limited which suggest that the values proposed should be regarded as indicative at present.

The new limit values for C1 tyres could be introduced without concern that technology was not able to respond to the challenge in the time frame available. It has been stated by the tyre industry representatives that there is a 6 – 8 year cycle from initial design of a tyre to its replacement in the market. This implies that practically all tyres currently in production would be superseded by newer designs by the time the new limit values come into force. Given that the technology already exists for lower noise tyres it is concluded that there is sufficient time for new designs of tyre to be produced to meet the limit values that are proposed.

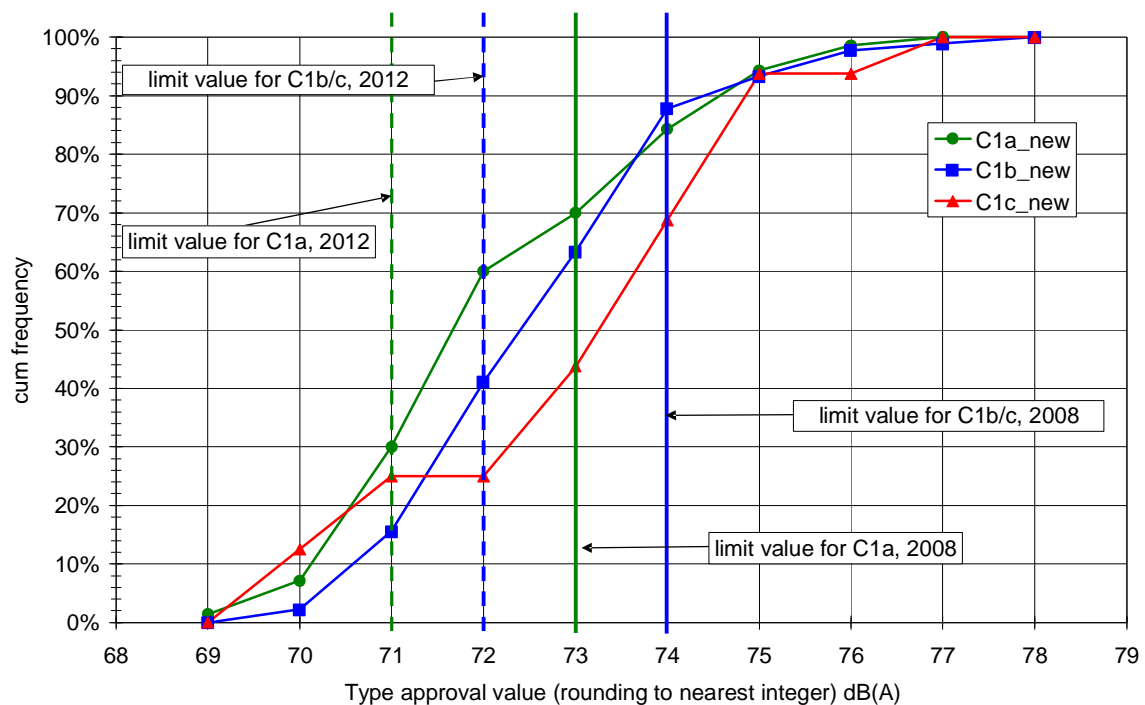


Figure 5.1: Cumulative percentages of test values (rounding to nearest integer value) for tyres in category C1a_new, C1b_new and C1c_new

Depending on future developments and trends in tyre widths it may be necessary and desirable to further adjust tyre noise limits in future years. For example if there were a clear trend for manufacturers to switch to fitting wider tyres > 245 mm in order to gain the higher limit value there may be a case for reducing limit values in the wider class > 245 • 275 mm.

Limit values should apply to OE, replacement and retreaded tyres in order to maximise impact on traffic noise levels.

5.1.1.1 Special, mud and snow, and reinforced tyres

Special tyres:

Figure 4.4 show separately plots for normal tyres and a small sample of off-road tyres for width category C1e. These are classified as “special” tyres. In the current Directive 92/23/EEC “special” refers to special use tyres, e.g. tyres for mixed use (both on and off the road) and at restricted speed. In order to avoid ambiguity, it was felt that the definition of these tyres given in the current Directive needed further clarification. A more detailed definition, applicable to all “special” tyres was provided by ETRTO during the course of the study. This was agreed with the partners that contributed to this Report as follows:

1. The tread depth should be > or = 11 mm
2. The void to fill ratio should be > or = 35 %
3. The speed symbol maximum Q (160 km/h)
4. The tyre will be marked for mud and snow use

It was concluded in Section 4.3 that the average noise emission of these special car tyres is higher than for normal tyres, but a 1 dB(A) higher limit value would appear to be more appropriate than the existing 2 dB difference. It should be noted that “special” C2 and C3 tyres are dealt with in the next section.

Mud and snow tyres (winter)

It was concluded in section 4.3 that no significant difference in noise levels could be found for winter and summer tyres. The proposed limits for C1 tyres should therefore be applied to both summer and winter models.

Reinforced car tyres

In Figure 4.3 “reinforced” tyres in width category C1d have been plotted separately from normal tyres. These tyres are designed to carry heavier loads and currently the limit value is 1 dB(A) higher than for normal tyres. The graph shows that 4 of the 5 tyres gave noise levels that were about 1 dB(A) below the current limit for normal tyres with the other tyre above the limit for normal tyres. However, it is clearly difficult to draw conclusions on the basis of 5 examples of this tyre. A larger sample size would be needed to draw definite conclusions concerning the need for a higher limit value than for normal tyres. However, there are no obvious technical reasons why reinforced tyres should produce higher noise levels than normal tyres and, indeed, 4 of the 5 tyres tested were found to be in the normal tyre range. It is therefore proposed to remove the 1 dB(A) allowance until further data is available to determine whether an increased allowance is justified.

Finally, it should be noted that with the probable increase in market share for run-flat car tyres, which could be classified as reinforced tyres, the question of whether an allowance should be made in the limit values will grow in importance.

5.1.2 C2 and C3 category tyres

Strictly the examination of C2 and C3 tyres lies outside the scope of this study (see section 2 “Objectives”). However, for completeness a discussion of the available data is included.

In section 4.3 the type approval values of C2 and C3 tyres were examined in relation to current limit values. From Table 5.1 based on this data it can be concluded that there is significant scope for limit value reductions of the order of 5 dB(A) i.e. a similar reduction to that which could be achieved for C1 tyres. It may be worth noting that there is a considerable overlap between C2 and C3 categories which should be taken into account when setting appropriate limit values.

In a further analysis the recorded values were rounded to the nearest integer value and compared with existing limit values. Table 5.4 shows a proposal for future limit values in the years 2008 and 2012. Also included are the effective reductions in limit values.

Table 5.4: Proposed tyre noise limits for C2 and C3 tyres

Tyre class	Nominal section width (mm)	2008	Relative decrease compared to current limit value	2012	Relative decrease compared to current limit value
C2	Normal	73	3.5	71	5.5
	Snow (M+S)	74	4.5	72	6.5
	Special	76	3.5	74	5.5
C3	Normal	73	4.5	71	6.5
	Snow (M+S)	75	4.5	73	6.5
	Special	77	3.5	75	5.5

It should be noted that some drive axle high traction tyres are designated “Mud and Snow” (M+S) tyres and because of the larger tread block pattern and type of construction such tyres are known to be noisier than normal tyres. Table 5.3 indicates an allowance of 1 or 2 dB(A) for these tyres.

Where sufficient data is available the consequences of these limit values in terms of the percentages of tyres meeting the new limit values are given in the cumulative percentage plots in Figure 5.2 and Figure 5.3 below.

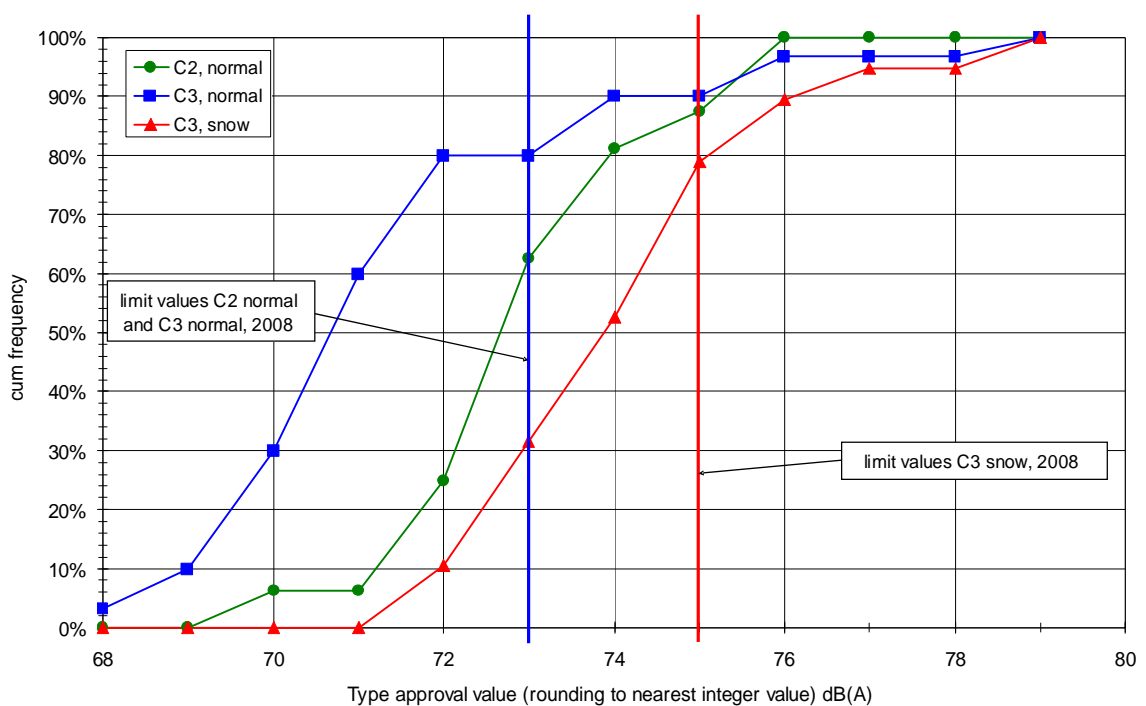


Figure 5.2: Cumulative percentages of test values (rounding to nearest integer value) for tyres in category C2 and C3: 2008 limits

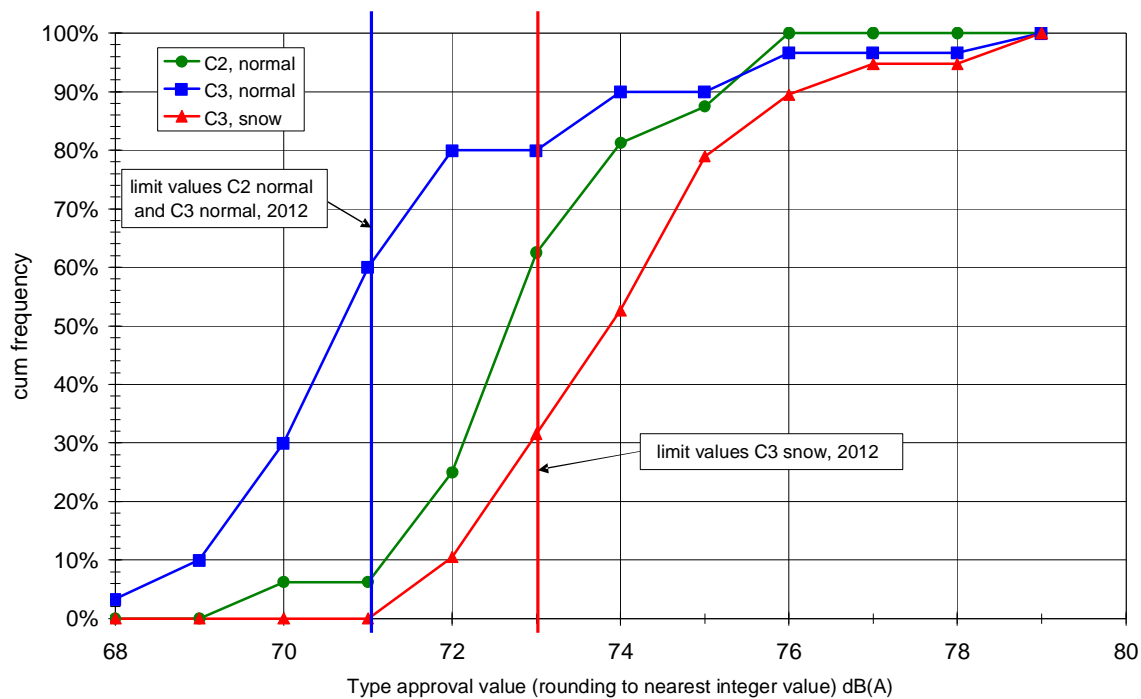


Figure 5.3: Cumulative percentages of test values (rounding to nearest integer value) for tyres in category C2 and C3: 2012 limits

It can be seen that 62 to 80% of the tyres tested would meet the 2008 interim values, while 6 to 60% of tyres would meet the stiffer limit values proposed for 2012.

The proposed limit values should be viewed as tentative suggestions at this stage as a larger sample is required to reach definite conclusions concerning the scope for the reduction in limit values. Again any limit values should apply to OE, replacement and retreaded tyres in order to maximise impact on traffic noise levels.

5.2 Relevance of the ISO test surface

It was mentioned earlier that reductions in the tyre noise limit values do not necessarily mean that there will be a similar reduction in vehicle and traffic noise levels. Some dilution of the effect is expected due partly to the fact that the test conditions cannot be a perfect match with the broad range of conditions encountered in practice. Part of the mismatch between testing and real situations lies in the test surface used for type approval. Ideally this surface should be broadly representative of the wide range of surfaces used on European roads.

5.2.1 Relationship between results on ISO test surface and common road surfaces

In order to determine the effects of reducing the limit values on the ISO surface it is necessary to examine the relationships between noise levels on the ISO surface and corresponding noise levels on other surfaces.

The relationship between noise levels recorded on the ISO surface and on a widely used surface (see following section) such as Stone Mastic Asphalt (SMA) with different maximum stone sizes are given in Table 5.5 below.

Table 5.5: Relationships between noise levels on ISO 10844 and SMA and HRA surfaces

Study	Number of tyres tested	Surface	Slope	Correlation coefficient <i>r</i>
TRL	11	SMA10	0.72	0.85
	12	SMA14	0.21	0.32
	21	HRA	0.28	0.19
M+P	12	SMA8	0.66	0.92
	20	SMA11	0.83	0.94
SINTEF	20	SMA11	0.38	0.39
		SMA14	0.39	0.45

Hot rolled asphalt (HRA) is a dense asphalt concrete with 20 mm stones rolled into the top. It is included in the analysis as an example of a rough textured surface. An example of the relationship between the noise levels generated on the ISO surface and SMA11 (maximum stone size 11 mm) and SMA14 are given in Figure 5.4 based on C1 tyres. However, as can be seen from the table different studies have produced different relationships. The actual values will depend on the tyres selected and the condition of the road surfaces. A tendency is that the greater the difference in maximum stone size between the ISO surface and the road surface the smaller the correlation coefficient.

A reduction of 1 dB(A) on the ISO surface produces an average reduction of 0.65 dB(A) on SMA 8 to 11. For the rougher surfaces, SMA14 and HRA, the corresponding reduction was found to be less at 0.29 dB(A).

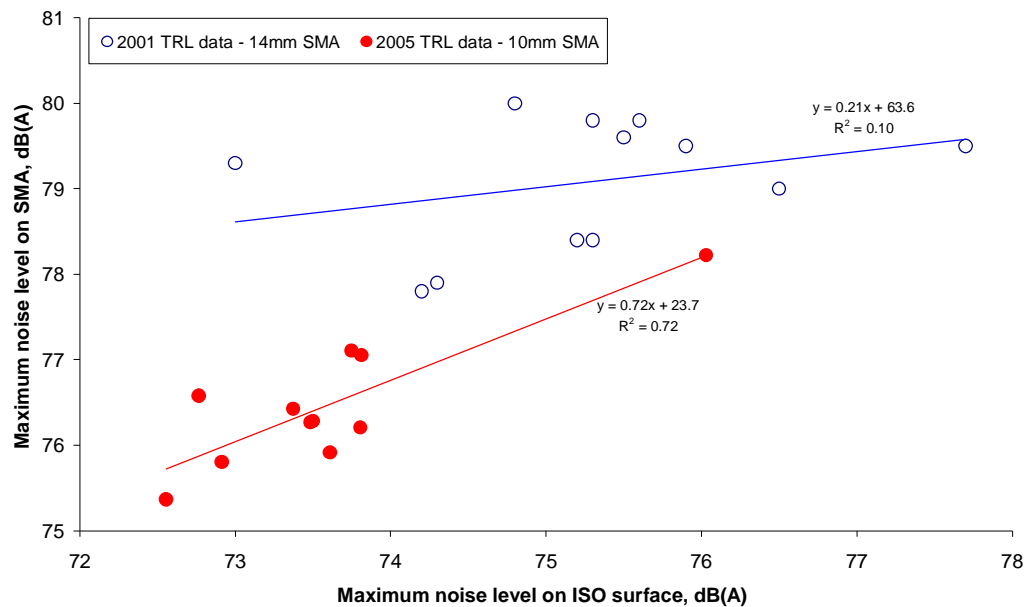


Figure 5.4: Results from 2005 study and previous TRL study in 2001

5.2.2 Road surfaces used in different countries

Data has been collected from FEHRL institutes on the road surfaces in their respective countries. Table 5.6 summarises the lengths of motorways and highways with speed limits • 80 km/h and urban and local roads with speed limits < 80 km/h. The total length of road sampled is nearly 1 million kilometres. This represents approximately 20% of the total length of roads in the 25 member states (European Road Federation, 2005). Hence the data can only be used as an indication until the results of this sample are confirmed by a larger survey.

Within the sample it can be seen that dominant road surfaces are clearly DAC (dense asphalt concrete) and SMA (stone mastic asphalt) surfaces and that the most likely maximum stone size in the asphalt mix is in the range 8-11 mm. The ISO 10844 surface is probably most similar to a DAC or SMA with a maximum stone size of 8 mm.

Porous asphalt (PA) represents a relatively small percentage of the total kilometres laid.

Table 5.6: Road surfaces by region and speed restriction (Contributing countries: Austria, Denmark, Estonia, Germany, Hungary, Latvia, Portugal, Serbia, Slovenia, United Kingdom)

Surface type	Max chipping size	• 80km/h		< 80km/h	
		Total km	Percentage	Total km	Percentage
DAC	8	8244	2.0	26726	5.2
	11	5899	1.4	28121	5.5
	8 to 11	225908	53.5	265500	52.0
	11 to 16	3136	0.7	10196	2.0
	12 to 20	21504	5.1	26075	5.1
	16	534	0.1	8716	1.7
	n/k	2437	0.6	6072	1.2
	Total			63.4	371406
SMA	8	117	0.0	116	0.0
	11	1371	0.3	580	0.1
	8 to 11	96818	22.9	29500	5.8
	11 to 16	224	0.1	0	0.0
	12 to 16	999	0.2	0	0.0
	Total			23.6	30196.0
Surface dressing	8 to 16	2240	0.5	4980	1.0
	n/k	1273	0.3	9647	1.9
	Total	3513	0.8	14627	3
HRA	20	11007	2.6		
	Total	11007	2.6		
PA*	11	504	0.1	0	0.0
	Total	504	0.1		
Thin surfaces	8	1442	0.3	301	0.1
	Not known	3559	0.8		
	Total	5001	1.2	301	0.1
Concrete	16-22	1325	0.3	0	0.0
	Not known	4499	1.1	1213	0.2
	Total	5824	1.4	1213	0.2
Others	Not known	29073	6.9	92351	18.1
	Total	29073	6.9	92351	18.1
Overall total:		422113	100.0	510094	100.0

5.3 Calculating the effects of the proposed reductions in the tyre noise limits

There are a number of factors which will affect how the reductions in the tyre noise test limit values will translate to average noise levels on city streets and highways. These include:

1. The effects on recorded test results when the new limits are introduced
2. The relationship between test results on the standard ISO 10844 surface and surfaces in common use across the EU
3. The distribution of surfaces types laid across the EU
4. The percentage of vehicles fitted with tyres meeting the new limit values

In order to translate the reductions in tyre noise achieved via type approval to the levels of traffic noise a suitable mathematical model is needed. This study has therefore made use of the HARMONOISE and TraNECam models which have been developed recently for use in traffic noise calculations and noise mapping in European towns and cities. In running the prediction models it is necessary to make assumptions concerning the factors listed above.

For factor 1 it is considered that a reduction in the limit values of, say, 5 dB(A) for a particular tyre category will not necessarily translate into the same reduction in the average noise levels for all tyres in that category. It is likely that there is a technical limit to how quiet tyres can be commercially produced. Although it is not known exactly where the technical limit is it is assumed to be just above the value for slick tyres which is taken to be approximately 66 dB(A). In the data examined the lowest recorded category C1 tyre noise value was 69 dB(A) (rounded to nearest integer). It is therefore unlikely that the distribution of recorded tyre noise values will simply be shifted downwards by the change in limit values. It is more likely that the distribution of values will become more narrow due to the difficulty of achieving commercially viable tyres close to the technical limit. This narrowing will reduce the average reduction in tyre noise that is achieved across the tyre range.

Consequently it is assumed in the calculations described below that the average reduction in tyre noise across all tyre categories is less than the reduction in limit values (2.5 to 5.5 dB(A) for C1 tyres) and a value of 3 dB(A) was chosen as being representative of the actual changes across the different classes for C1 tyres. Taking a single value simplifies the calculations of the effect on traffic noise as no assumption about changes for different tyre sizes are then required.

In the longer term technical breakthroughs may result in the possibility to extend noise reductions even further but for the current modelling purposes this more conservative view of the likely changes in the foreseeable future was taken.

For factor 2 the average slope of the relationship between the ISO surface and SMA 8 to 11 is taken to be 0.65 and for a rough surface such as SMA 14 or chipped dense asphalt concrete (Hot Rolled Asphalt (HRA) with 20 mm stones rolled into the surface) it is 0.29 (see Table 5.7 below). Hence a 3 dB(A) reduction will translate to approximately a 2 dB(A)

reduction in the tyre/road noise on SMA11 and 1 dB(A) on the coarser SMA or HRA surfaces. It is further assumed that these reductions will hold at all speeds. It is likely that for some tyres the speed effect will not be constant but it is assumed that these effects will cancel out over the population of tyres so that a broad average can be taken as representative of a range of speeds from urban streets to high speed roads.

For factor 3 the data collected from FEHRL institutes indicates that the most common surface is a Dense Asphalt Concrete (DAC) and a Stone Mastic Asphalt (SMA) with maximum chipping size of 8-11 mm. In terms of length laid these surfaces account for 80% of the road network in those countries that have provided data. Furthermore, these surfaces with relatively small chippings will tend to be used more frequently used in urban areas where noise exposure is substantial, whereas the rougher surfaces would tend to be used on high-speed roads along which population density is smaller. Hence the emphasis will be on these surfaces with smaller chippings and not the rougher SMA14 and HRA surfaces.

For factor 4 it has been assumed that 100% of C1 tyres on the road are compliant with the new limits. It should be noted that both OEM and replacement tyres will be subject to the new limit values in 2012. This will have been largely achieved 2 years after the new limits apply as tyres are replaced relatively quickly due to wear. Note that the benefits have largely been calculated assuming reductions in light vehicle tyres (C1 tyres). Larger benefits are possible if the limit values for commercial tyres C2 and C3 were also reduced though these additional benefits are predicted to be smaller in urban areas.

5.3.1 The HARMONOISE model

In the HARMONOISE model the vehicles are divided into three main categories corresponding to light (category 1), medium heavy (category 2) and heavy vehicles (category 3). Category 1 and 2 vehicles all have two axles except in the case of vehicle/trailer combinations. Generally category 2 vehicles have 6 or more wheels (4 on the rear axle). Category 3 contains the heaviest vehicles which have more than 2 axles.

In HARMONOISE, two point sources are used for each vehicle category – one represents mainly the tyre sources (referred to as tyre/road noise in the model) and is located close to the road surface and the other represents mainly the propulsion noise sources. The tyre source is located 0.01 m above the road surface and the other, power unit source, is located either at 0.3 m for light vehicles or 0.75 m for heavy vehicles. 80% of the tyre/road noise is assumed to radiate from the lower source whereas 20% is assumed to radiate from the higher source. This allows for some “smearing” of the source which in practice rarely takes the form of a discrete point source.

Dense Asphalt Concrete (DAC) and Stone Mastic Asphalt (SMA) can be modelled within HARMONOISE using an adjustment to the maximum chipping size. These corrections only apply to light vehicles (category 1) as no corrections are available for heavy vehicles (categories 2 and 3). The effects of a reduction in tyre noise was calculated by reducing the tyre/road noise source contribution while maintaining the propulsion noise levels. For modelling a rougher surface such as a DAC with large 20 mm size chippings rolled into the surface (hot rolled asphalt or HRA) the correction to tyre/road noise was based on an analysis of UK data developed within the EC project SILVIA (Silenda Via: Sustainable road surfaces for traffic noise control) (Morgan, 2006).

Using the HARMONOISE source model the pass-by noise energy in terms of the Sound Exposure Level dB(A) for Category 1, 2 and 3 vehicles was calculated at a distance of 7.5m from the centre of the lane. The receptor height was 1.5m. Using a total pass-by sample of 1000 vehicles per hour the average or L_{Aeq} level was calculated using different proportions of light and heavy vehicles. The average speeds and proportions of vehicles were varied in order to calculate the effects of a tyre noise reduction for category 1 vehicles (cars and light commercial vehicles) for a range of different road-traffic scenarios.

5.3.1.1 Modelling scenarios

A number of scenarios have been considered ranging from urban situations with different average speeds to free flowing motorway situations. The traffic composition used in each example was based on national statistics used in a previous study of road surface corrections for different road types (Abbott *et al.*, 2003). The percentage of different types of road across European States was obtained from a questionnaire sent out to FEHRL research institutions. This indicated that approximately 80% of surfaces were either dense asphalt concrete or stone mastic asphalt with maximum chipping size between 8 and 11 mm (see Table 5.6). To cover a reasonable range of representative surfaces it was therefore decided to model the effects of tyre noise reductions on DAC and SMA with maximum stone sizes of 8 and 11 and additionally on relatively rough surfaces SMA14mm and HRA. However, as mentioned above the emphasis will be on the results for the smoother surfaces as they are more common across the EU.

Based on available traffic statistics the average composition assumed on roads with a speed limit close to 50 km/h was 96.4% light vehicles, 3% medium heavy vehicles and 0.6% heavy vehicles. Predictions were also carried out for a higher flow of goods vehicles i.e. 10% medium and 2% heavy trucks. Calculations were carried out for average speeds of 50 and 30 km/h to reflect different degrees of congestion. Figures D.1 to D.3 in Appendix D show plots of the resulting roadside levels of L_{Aeq} for each surface type for reductions of tyre noise in the range 0 to 5 dB(A). It should be noted that the reductions in tyre noise levels were chosen bearing in mind the potential for the maximum noise reduction indicated in the available data (Table 5.1).

5.3.1.2 Results from HARMONOISE analysis

Table 5.7 summarises the results in terms of the average noise reduction in L_{Aeq} for each scenario.

Overall the reduction on smoother surfaces (SMA8, SMA11, DAC8 and DAC11) varies from 1.5 dB(A) on DAC8 to 1.9 dB(A) on SMA11. For the rougher surface (SMA14, DAC14 and HRA) the variation is 1.9 to 2.5 dB(A). The variation reflects the changing contribution of tyre/road noise to overall noise levels on different surfaces. The higher the contribution, the greater the benefit of reducing the tyre/road noise. Thus the tyre/road noise is greater on rougher surfaces leading to a greater benefit of changing to a tyre with lower tyre/road noise on that surface. The stone size on DAC and SMA is also a factor. It is clear that the greater the stone size the larger the effect due to the contribution of tyre/road noise to total noise level.

Table 5.7: L_{Aeq} predicted reductions on different surfaces resulting from a 5 dB reduction in tyre/road noise using HARMONOISE

Model input parameters			L_{Aeq} reductions on different surfaces						
Av speed (km/h)	Percent 2axle (Cat.2)	Percent >2axle (Cat.3)	SMA8	SMA11	SMA14	DAC8	DAC11	DAC14	HRA
50	3	0.6	2.1	2.3	2.5	1.9	2.1	2.3	3.0
	10	2	1.2	1.4	1.6	1.1	1.3	1.4	2.0
55	3.4	2.7	1.8	2.0	2.2	1.6	1.8	2.0	2.6
70	3.8	6.4	1.6	1.7	1.9	1.4	1.6	1.8	2.3
112*	4.5	9.1	1.8	2.0	2.2	1.6	1.8	2.0	2.5
Average			1.7	1.9	2.1	1.5	1.7	1.9	2.5

* 96 km/h for Category 3

Despite the potential for significant errors an estimate was made of the effect of reducing the limit values for C1 tyres on the ISO surface. As explained at the beginning of section 5.3 it was assumed that an average of 3 dB(A) reduction would be achieved on the ISO surface if the effective limit values for different tyre widths were reduced by between 4.5 dB to 5.5 dB(A)⁴. It was further assumed that a 3 dB(A) average reduction on the ISO surface would result in an average reduction in tyre/road noise of light vehicles on SMA surfaces from 8 to 11 mm of approximately 2 dB(A) as argued above. A further assumption was that reductions on the DAC surfaces would be identical to the SMA surfaces of the same stone size. It was shown in section 5.3 above that for surfaces with larger stone sizes (SMA14 and HRA) that a 3 dB(A) reduction on the ISO surface would result in approximately a 1 dB(A) reduction in tyre/road noise of light vehicles on these surfaces with larger stone size.

Based on these assumptions the reduction in L_{Aeq} at the roadside was estimated for the different road traffic scenarios listed in Table 5.8.

It can be seen that the range in average noise reduction varies from 0.62 to 1.09 dB(A) on SMA 8-11 with an average reduction across scenarios of 0.86 dB(A). The reductions on the rougher surfaces SMA 14 and HRA are lower and range from 0.5 to 0.7 dB(A) with an average reduction of 0.60 dB(A). It should be emphasised that most European road surfaces are likely to be close to SMA8 and SMA11 i.e. a reduction of approximately 0.9 dB(A).

⁴ The effective reductions proposed in the tyre width categories • 275 mm varies from 4.5 to 5.5 dB(A) with proposed reductions of 4.5 dB(A) in most tyre width categories. These width categories cover a high percentage of sales both OEM and after-market.

Table 5.8: Predicted L_{Aeq} reductions on SMA 8-11 and SMA 14 and HRA surfaces resulting from an average 3 dB(A) reduction on the ISO surface resulting from a limit reduction of 5 dB(A) using HARMONOISE

Average speed (km/h)	Percent 2 axle (Category 2)	Percent > 2 axle (Category 3)	L_{Aeq} reduction dB(A)	
			SMA8 and11	SMA & HRA
30	3	0.6	0.62	0.50
40	3	0.6	0.90	0.63
50	3	0.6	1.09	0.70
	10	2	0.69	0.50
55	3.4	2.7	0.95	0.64
70	3.8	6.4	0.85	0.58
112*	4.5	9.1	0.95	0.63
Average			0.86	0.60

* 96 km/h for Category 3

5.3.2 The TraNECam model

5.3.2.1 Description of the model

The TraNECam model was originally developed for the German Environmental Agency (UBA) over the period 1998-2000. Its database was extended to a European level within the frame of an EU research project in 2003 (see Morgan *et al.*, 2003).

The model is sufficiently versatile to allow accurate forecasts to be made for different traffic conditions. The model therefore takes account of area-dependant factors such as vehicle fleet compositions, age distribution of vehicles, local road surfaces etc. In addition, the traffic stream is modelled using a larger number of different vehicle layers (categories, subcategories and noise emission stages) than has previously been available from other traffic noise models. This feature was important as it would then facilitate the evaluation of a broad range of traffic based noise control options such as restricting access of vehicles of a specified type.

The model is capable of examining different noise source control options. It is also able to discriminate between the major source groups associated with an operating vehicle. In particular the model discriminates between tyre/road noise sources and propulsion noise sources. Finally the model is capable of dealing adequately with future scenarios including the use of new technologies and the effects on noise of vehicle and road surface design improvements.

The noise emission calculation is based on vehicle speed pattern (on a second by second basis) that are typical for specific road types/driving conditions. Based on the experience

of previous research projects, the vehicle related noise sources (engine, powertrain, exhaust, intake) are summarised and modelled as function of engine speed and engine load. The tyre/road, or rolling, noise component, is modelled as a function of the tyre, the road surface and the vehicle speed.

The model distributes the average daily traffic volume over 24 hours of the day using in-built normalised and vehicle category specific diurnal traffic load variation curves. Based on traffic volume and composition and on the capacity of the road (e.g. number of lanes) an appropriate traffic condition is chosen for each hour of the day. The pre-calculated noise emission factors (representing the average noise emission of the above mentioned vehicle speed pattern) for each vehicle layer is then linked to each hour of the day. The L_{Aeq} for a particular hour is then calculated by summing up the contributions of the vehicle layers weighted with their percentage on the traffic volume for this hour. L_{day} , $L_{evening}$, L_{night} and L_{den} are then calculated in a final step by summation of the diurnal L_{Aeq} levels. This summation is done for all vehicles and each category (cars, light duty vehicles, rigid trucks, trailer trucks, buses, scooters and motorcycles) separately. Further details are described in (Morgan, 2003). Note that the day-evening-night-weighted L_{Aeq} is calculated using 5 and 10 dB weightings as shown below.

The noise index L_{den} is defined as:

$$L_{den} = 10 \log \left[\frac{12}{24} 10^{\frac{L_{day}}{10}} + \frac{4}{24} 10^{\frac{L_{evening} + 5}{10}} + \frac{8}{24} 10^{\frac{L_{night} + 10}{10}} \right] dB(A) \quad (5.1)$$

where L_{day} is the L_{Aeq} level taken over 12 hours during the day, $L_{evening}$ is the L_{Aeq} over 4 hours in the evening and L_{night} is taken over 8 hours during the night time. The weighting factors +5 and +10 in the exponents are designed to take into account the increased annoyance caused during the evening and night-time periods. Consequently, the weighting and averaging over traffic composition are carried out separately for each of these three periods of the day averaged over a year.

5.3.2.2 Modelling scenarios

The road type/traffic load conditions as shown in Table 5.9 were used for the scenario calculations with the TraNECam model in order to cover a wide range of road types and traffic load conditions in the EU. Residential streets with 5% heavy duty vehicles are a bit extreme. Motorcycles and scooters were disregarded although we know that they might be important in some regions of the EU. Information about their influence on noise exposure can be found in (Steven, 2006).

Table 5.9: Road type and traffic load conditions for the scenario calculations with the TraNECam model

Number	road category	no of lanes	average daily traffic	percentage of light duty	percentage of heavy duty
1	residential streets, speed limit 30 km/h, HDV 2%	2	3000	4%	2%
2	residential streets, speed limit 30 km/h, HDV 5%	2	3000	4%	5%
3	residential streets, speed limit 50 km/h, HDV 2%	2	3000	4%	2%
4	residential streets, speed limit 50 km/h, HDV 5%	2	3000	4%	5%
5	urban, main streets, speed limit 50 km/h, traffic lights, HDV 3%	4	40000	4%	3%
6	urban, main streets, speed limit 50 km/h, traffic lights, HDV 6%	4	40000	4%	6%
7	urban, main streets, speed limit 60/70 km/h, HDV 3%	4	40000	4%	3%
8	urban, main streets, speed limit 60/70 km/h, HDV 6%	4	40000	4%	6%
9	rural, speed limit 70 km/h, HDV 3%	2	15000	4%	3%
10	rural, speed limit 70 km/h, HDV 6%	2	15000	4%	6%
11	rural, speed limit 100 km/h, HDV 3%	2	15000	4%	3%
12	rural, speed limit 100 km/h, HDV 6%	2	15000	4%	6%
13	motorway, speed limit 100 km/h, HDV 15%	4	40000	4%	15%
14	motorway, speed limit 100 km/h, HDV 25%	4	40000	4%	25%
15	motorway, speed limit 120 km/h, HDV 15%	4	40000	4%	15%
16	motorway, speed limit 120 km/h, HDV 25%	4	40000	4%	25%

In this model light duty vehicles (LDVs) are commercial vehicles with a gross vehicle mass not exceeding 3.5 tonnes, heavy duty vehicles (HDVs) are commercial vehicles with a gross vehicle mass exceeding 3.5 tonnes. The HDVs in this model approximately cover the range of vehicles in Category 2 (medium heavy vehicles) and Category 3 (heavy vehicles) in the HARMONOISE model.

The following road surfaces were included in the calculation

- SMA11 (Stone mastic asphalt 0/11);
- HRA (Hot rolled asphalt);
- SMA6 (Stone mastic asphalt 0/6).

SMA11 can be considered as one of the most popular surface within Europe. Hot Rolled Asphalt (HRA) is a much rougher surface mainly used in the UK and Belgium. In other parts of Europe dense asphalt concrete 0/16 and SMA 16 are used as rough surfaces. Since its noise behaviour is similar to hot rolled asphalt, the latter can be used to represent both. SMA6 is a rather smooth surface with lower tyre road noise levels than SMA11, but its application is more or less limited to residential areas.

The first calculation step is related to the current situation where the major part of the vehicles in the fleet belong to noise emission stages that fulfil the current limit values for vehicle type approval. In order to make the comparison of results easier it was assumed for the second step that the tyre/road noise levels would be reduced by 5 dB(A), for the following three scenarios:

- 1) 5 dB tyre/road noise reduction only for cars (C1 tyres)
- 2) 5 dB tyre/road noise reduction for all vehicles (C1, C2 and C3 tyres)
- 3) 5 dB tyre/road noise reduction for cars and light duty vehicles (C1 and C2 tyres) and 5 dB propulsion noise reduction for heavy duty vehicles.

5.3.2.3 TraNECam analysis and comparison with HARMONOISE results

The effect of a 5 dB reduction in tyre/road noise for light vehicles (cars) on the overall L_{Aeq} levels of the road is shown in Appendix B.1. Generally, as one would expect, the effect is greatest for the roughest surface (HRA) and least for the smoothest surface (SMA6). The reduction effect on the L_{den} decreases with decreasing vehicle speed and increasing percentage of heavy duty vehicles. The range for L_{den} reduction is 0.8 dB (residential street with speed limit of 30 km/h, SMA6 and 5% HDV) to 3.7 dB (rural, speed limit 100 km/h, HRA and 3% HDV). The reduction potential for urban hot spots (main streets with high traffic load) lies between 1.3 dB and 3.6 dB.

In Table 5.10 a comparison has been made with the un-weighted L_{den} levels⁵ and the HARMONOISE results in three cases where the modelled road traffic conditions are similar. Note that in the HARMONOISE calculations a SMA8 surface was modelled whereas in TraNECam the surface modelled was SMA6. This will tend to slightly

⁵ The un-weighted L_{den} level simply combines the L_{Aeq} levels for each period without using the 5 and 10 dB(A) penalties for evening and night-time.

overestimate the effects of a 5 dB(A) reduction in tyre/road noise in the HARMONOISE model due to higher tyre/road noise levels.

Table 5.10: Comparison of HARMONOISE and TraNECam model predictions

Road surface	HARMONOISE model		TraNECam model	
	Scenario	Change in L_{Aeq}	Scenario	Change in un-weighted L_{den}
SMA8 / SMA6	40 km/h, 3.6% HDV	-1.6	50 km/h, 3% HDV	-1.3
SMA11		-1.7		-1.7
HRA		-2.6		-2.2
SMA6	50 km/h, 3.6% HDV	-2.1	50 km/h, 3% HDV	-1.3
SMA11		-2.3		-1.7
HRA		-3.0		-2.2
SMA6	55 km/h, 6.1% HDV	-1.8	60/70 km/h, 6% HDV	-1.8
SMA11		-2.0		-2.3
HRA		-2.6		-2.7
SMA6	96/112 km/h, 13.5% HDV	-1.8	120 km/h, 15% HDV	-1.6
SMA11		-2.0		-2.0
HRA		-2.5		-2.3

In most cases the differences in the model predictions are of the order of 0.3 dB(A) or less. The largest differences occur at 50 km/h where the HARMONOISE model produces higher results. This is probably accounted for by the fact that in HARMONOISE calculations, free-flow congestions are simulated with all vehicles moving at the speed limit of 50km/h. In TraNECam calculations a traffic model is used to estimate speed profiles for various vehicles so that during the day, due to congestion, speeds may be lower than the speed limit for the road. For this condition the tyre/road noise contribution to total vehicle noise will be lower and hence the effects of reducing tyre noise will be less. To account for this difference in simulated conditions HARMONOISE was also run for the lower speed of 40km/h which resulted in smaller changes that are much closer to the TraNECam predictions as can be seen in Table 5.10.

It can be concluded that there is considerable agreement between the model predictions when allowance is made for differences in the scenarios that are being modelled. As a result there can be greater confidence in the further analysis of the effects of limit reductions described in section 5.3.1.2. In this analysis the effects at lower speeds of 30 and 40 km/h were calculated in order to take account of congested conditions in urban areas.

5.3.2.4 Further modelling results using TraNECam

The effect of a 5 dB reduction in tyre/road noise for all vehicles on the overall L_{Aeq} levels of the road is shown in Appendix B.2. This measure increases the reduction potential significantly for high speed roads (speed limit 70 km/h and higher) and high HDV percentages, but does not help very much for low speeds. For example the reduction potential for the L_{den} on urban main roads surfaced with SMA11 with a speed limit of 50 km/h is 1.7 to 2.2 dB(A) where the tyre/road noise of cars is reduced by 5 dB(A). However this rises only slightly to between 2.0 and 2.4 dB(A) where the tyre/road noise of all vehicles is reduced by this amount. However, on a motorway surfaced with SMA11 with a speed limit of 120 km/h the predicted range of decreases is 1.6 to 2.2 dB(A) where reductions apply only to car tyres. Where reductions apply to all vehicle tyres the benefits rise to between 3.5 to 3.6 dB(A).

If the propulsion noise of HDVs is reduced by 5 dB(A) while the tyre/road noise is reduced by 5 dB(A) then further reductions for main urban roads and residential streets can be achieved (see Appendix B.3). For example on urban main roads with a speed limit of 50km/h the predicted reductions on a SMA11 surface is 3.1 to 3.2 dB(A). The results indicate that both propulsion noise reduction as well as tyre/road noise reductions are required for a significant overall noise reduction in these urban situations.

When assessing the TraNECam results one has to bear in mind that the limit value reductions for tyres proposed in chapter 5.1 will lead to tyre/road noise reductions in real traffic that is lower than the 5 dB(A) proposed here. As explained above this is due to the fact that a tyre noise limit reduction on the ISO test surface does not translate directly to a similar reduction on all roads.

5.4 Summary and Discussion of Work Package 2

It has been shown from the available data that across all tyre categories there is scope for a considerable reduction in the tyre noise limits of the order of 5 dB(A). Limit values have been suggested which mean effective reductions of between 2.5 and 5.5 dB(A) for C1 tyres and between 5.5 and 6.5 dB(A) for commercial vehicle tyres in categories C2 and C3. These reductions would be phased in two stages with the greatest reductions required by 2012.

In order to calculate the changes in tyre/road noise on real roads that these limit values would produce it was important to gather information on the types of road surfaces across member states. It was found that the most common surfaces were stone mastic asphalt and dense asphalt concrete with a maximum stone size of between 8 and 11mm. Using the relationship between pass-by noise recorded on the ISO test surface and these common surfaces it was possible to estimate the reduction in tyre/road noise on real roads.

The effects on traffic noise of reductions in tyre/road noise were calculated using two noise prediction models: HARMONOISE and TraNECam. Predictions were made for a range of scenarios from motorways to congested urban conditions. It was concluded that there was considerable agreement between model predictions. As a result there can be greater confidence in the predictions made.

A number of assumptions were made in the analysis that was undertaken. For HARMONOISE these included:

- An average reduction of 3 dB(A) would be achieved on the ISO surface for category C1 tyres if the effective limit values for different tyre widths were reduced by between 4.5 dB to 5.5 dB(A);
- A 3 dB(A) average reduction in tyre noise of C1 tyres on the ISO surface would result in an average reduction of approximately 2 dB(A) in tyre/road noise of light vehicles on SMA and DAC surfaces with maximum stones sizes from 8 to 11 mm;
- For surfaces with larger stone sizes (SMA14 and HRA) a 3 dB(A) reduction for category C1 tyres on the ISO surface would result in approximately a 1 dB(A) reduction in tyre/road noise of light vehicles on these surfaces with larger stone size (up to 20 mm)

Based on these assumptions the reduction in L_{Aeq} at the roadside was estimated for the different road traffic scenarios. The average speed varied from 30 to 112 km/h and the percentage of heavy vehicles ranged from 4% up to 14%.

It was predicted that the range in average traffic noise reduction varied from 0.62 to 1.09 dB(A) on SMA 8-11 with an average reduction across scenarios of 0.86 dB(A). The reductions on the rougher surfaces SMA 14 and HRA are lower and range from 0.5 to 0.7 with an average reduction of 0.60 dB(A). It should be emphasised that most European road surfaces are likely to be close to SMA8 or SMA11 i.e. a reduction of approximately 1 dB(A).

The TraNECam model was run with the basic assumption that a 5 dB(A) reduction in tyre/road noise occurred. This represents a situation where the limit value reductions are converted directly into corresponding gains on real road surfaces. In this respect the assumptions are optimistic compared with the more conservative view taken for the input to the HARMONOISE analysis. In terms of reductions in L_{den} on an SMA11 surface the gains ranged from 1.1 to 3.4 dB(A). The average across scenarios was 2.3 dB(A).

Although not strictly part of the objectives of the study, prediction with TraNECam were also made for commercial tyres C2 and C3. This showed that if the tyre/road noise of all tyres (C1, C2 and C3) were reduced by 5 dB(A) on SMA11 as a result of stiffer limit values then the combined effect on L_{den} would be greater ranging from 1.2 to 3.8 dB(A). The reduction in L_{den} averaged across scenarios would be 3.0 dB(A). Further work is required to model the changes that would occur if the proposed reduction in limit values for commercial tyres C2 and C3 produced a smaller effect than the assumed value of 5 dB(A) on real roads.

In the longer term it is likely that technological developments will allow greater reductions in tyre/road noise and it is recommended that the limit values are reviewed before 2012 to determine whether the recommended limit values are still relevant and whether there is scope for further reductions in these limits. This would involve an analysis of the most recent tyre noise test results and a consideration of the state-of-the art in low noise tyre designs at that point in time.

6 Work Package 3: Amendments to the tyre noise Directive other than limit values

This Work Package is concerned with establishing recommendations for revising the Directive concerned with tyre noise type approval. The evidence for lowering the tyre noise limit values and our recommendations for future limits have already been presented in Work Packages 1 and 2. This Work Package therefore considers other changes to the Directive.

In particular this Work Package considers the need for additional tests of tyre safety performance and tyre rolling resistance that could be introduced alongside the requirements for tyre noise testing. It also considers the possibility of marking tyres with information on their tyre noise levels as a means of informing consumers and, thereby, encouraging a market for quieter tyres.

Finally, other technical amendments to the test procedure are considered and recommendations made, where appropriate.

6.1 Testing tyre safety and rolling resistance

There are concerns that reducing tyre noise limits could have an effect on the safety performance of tyres with quieter tyres presumably exhibiting poorer safety characteristics. It is known for example, that in the extreme, slick (treadless) tyres produce relatively low noise levels when tested on smooth surfaces, but are clearly unacceptable in terms of their safety performance in wet weather conditions. Similar arguments exist regarding tyre rolling resistance. This has particular importance given the close connection between rolling resistance and fuel consumption, and hence the emission of greenhouse gases and their connection with global warming.

Consequently while lower tyre noise limits are suggested from the analyses that have been carried out as part of this study, it could also be necessary to consider the need for additional tests for tyre safety and rolling resistance. It is argued that these additional tests will help to ensure that regulation concerning one particular aspect of tyre performance does not compromise other important tyre performance characteristics.

6.1.1 Tyre safety

Previous studies that have attempted to examine the relationship between tyre noise and safety performance have consistently shown that there is no underlying statistical correlation between tyre noise levels as measured using the type approval procedure and safety performance as assessed using various measures of wet grip, deceleration and aquaplaning. The review of the literature presented in Appendix A and the analyses carried out on the databases assembled for this study and presented in Chapter 4 consistently support this conclusion. Furthermore, in all cases examined, the data has exhibited considerable scatter underlining the fact that there are many examples of tyres

in current production that produce relatively low noise levels and yet perform well in terms of wet grip or aquaplaning performance.

Consultations with the tyre industry also confirmed that there is currently a very loose relationship between wet grip and noise levels primarily because many factors have an influence on safety performance. It was stressed by the tyre industry that there are difficulties in assessing safety performance and that the data is dependent on the method and test track used. It was also stressed that safety was of prime importance to the tyre industry and to its clients and that it would be inconceivable for future tyre designs to be developed to meet lower noise levels at the expense of safety performance.

Given these various issues, therefore, it would appear that the recommendations for lowering the limits of tyre noise can be made without compromising safety. This recommendation is supported by the fact that a good proportion of tyres in current production can already meet the lower limits that have been proposed and that these tyres are implicitly 'safe' given the self-enforcing nature of the market for tyres.

However, these statements can only be made reliably for the existing situation regarding tyre design. While it seems highly probable that future tyre designs will not compromise safety, it cannot be stated with absolute certainty that this situation will hold for the future. It would appear prudent therefore to consider the introduction of a test(s) for tyre safety when the Directive is revised. While there are many possible candidate test procedures that exist for examining tyre safety performance it is beyond the scope of this study to examine, refine and recommend a preferred method. However, it should be pointed out that UN ECE Regulation 117, which also considers the tyre/road noise of vehicle tyres, has specified a wet grip test to accompany the noise test and limit values. Consequently there may be opportunities to make use of that test method. In addition, Appendix E describes a possible procedure that could be considered.

In conclusion it would appear that provided there are adequate safeguards to ensure that a high standard of safety performance is maintained for future tyre designs, the noise levels could be reduced significantly from the current limits without affecting overall safety performance. In addition, the datasets have shown that it is possible to produce tyres that can perform well in terms of wet grip and noise emission.

6.1.2 Tyre rolling resistance

Rolling resistance is directly correlated with fuel consumption of a car and exhaust emissions (CO₂). It can be stated that rolling resistance will be responsible for about 30% of CO₂ emitted. For petrol and diesel fuelled cars the mass of CO₂ emitted in kg is approximately 2.31 and 2.68 times the litres of fuel consumed respectively (Watts et al., 2005). Moreover a 30% relative difference in rolling resistance coefficient entails a difference in fuel consumption and CO₂ emission of about 5 % for a passenger car in average driving modes (Stenschke, 2005). In general, tyre rolling resistance currently accounts for approximately 30% of the fuel used by the car group so it is an important component governing fuel consumption. In addition, since, with modern catalyst equipped cars, nearly all of the carbon contained in the fuel will either be emitted directly in the form of CO₂ or be converted later in the atmosphere to CO₂ it is also a significant factor affecting the generation of greenhouse gases.

Car tyre manufacturers place the reduction of tyre rolling resistance high on their list of priorities when designing new tyre types. To some extent this is driven by the demands of

the vehicle manufacturers. As a result considerable progress has been made in reducing tyre rolling resistance over recent years particularly with the use of different tyre compound materials and attention to tyre weight. The use of run flat tyre designs may also help to reduce overall vehicle weight when the fitting run flat designs obviates the need for a spare tyre.

For vehicles in-service running a tyre below the specified inflation pressure is the biggest single factor in increasing fuel consumption relative to tyres and may result in tyre failure. Given this background any changes in rolling resistance that might be associated with reducing tyre tyre/road noise is important both for ensuring that there are no unforeseen effects on fuel consumption and hence on emissions.

However, it is quite clear from the evidence presented in this report, and from the review of literature that there is currently no significant relationship between tyre noise and rolling resistance. Also, in a similar way to the situation for tyre safety, there is a strong influence in the market place regarding fuel efficiency and tyre manufacturers will therefore continue to strive to keep rolling resistance values at the lowest possible values. Consequently, as with tyre safety, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise.

Nevertheless, it is not possible to speculate beyond the ranges provided by the data so it is important to ensure that any reductions in tyre noise imposed by tightening the type approval limits is also accompanied by sufficient controls on tyre rolling resistance. While there are possible candidate test procedures that exist for examining rolling resistance performance it is beyond the scope of this study to recommend a preferred method. However, Appendix E describes a possible procedure that could be considered.

In conclusion, therefore, it follows that due to the lack of any significant correlation between noise and rolling resistance, any reductions in the tyre noise limits should not affect overall values of tyre rolling resistance. It is not expected therefore that there should be any noticeable effect on vehicle fuel economy and the emissions of greenhouse gases.

6.2 Labelling tyres with their type approval noise levels

Some consumers may wish to demonstrate environmental responsibility by choosing tyres that have scored well in the type approval test. A low noise level in the test might also be an indicator to consumers of tyres that would provide lower noise levels within their vehicles and therefore provide an additional degree of comfort during driving.

Two forms of noise labelling could be considered:

1. Tyres could have a number stamped on the sidewall, indicating the noise achieved in the tyre noise test.
2. A threshold could be set for a tyre to be considered 'low noise'. (e.g. 3 dB(A) below the limit value). If the noise level measured in the test equalled or was below the threshold, the manufacturer would be entitled to stamp the words 'low noise' on the tyre, and use this in advertising materials.

Both methods would enable consumers to identify the noise performance of tyres at the point of sale. This would have particular advantages in the replacement tyre sector. This approach would also bring tyres into line with many other sectors, such as household 'white goods', which are provided with both energy and noise rating labels.

Such labelling schemes could, in principal, be implemented in the same way as information on tyre size, tyre 'speed rating' etc., which is incorporated on the sidewall of the tyre. However, it should be noted that the tyre industry representatives did raise a concerns over the costs of labelling and on the availability of space on the sidewall of the tyre to incorporate noise level ratings (see Chapter 4). However, it should be noted that at the IEA workshop in Paris in 2005 (see section 4.6.3) the tyre industry representatives indicated they were very keen on introducing some kind of labelling of the energy efficiency of tyres.

A further point is that if tyres were stamped with the noise level that they scored in the type approval test, this would assist member states that are considering incentive schemes to create a market for low noise products. Such schemes already exist in Germany (the Blue Angel labelling scheme) and the Nordic countries of Sweden, Denmark, Norway, Finland and Iceland (the Nordic Swan; see www.svanen.nu for further details).

It is recommended, therefore, that consideration is given, when revising the current Directive, for including a requirement for tyre manufacturers to label tyres according to their noise emission. This could be in the form of a noise level stamped on the sidewall. An alternative could be a label stating that tyres are 'low noise' provided they meet an agreed threshold that is set below the agreed noise limit.

6.3 Amendments to the tyre noise test procedure

This part of Work Package 3 is concerned with improvements that could be made to the test procedure when the Directive is revised. These changes should be considered as additional to the recommended changes to the limit values detailed in Work Packages 1 and 2.

In examining the test procedure and identifying possible improvements that could be made it became evident that, while some changes could and should be included as part of the current revision, other changes would require rather long times to implement and should therefore be considered as a longer term objective that could be phased in at some future date when the research and testing had been completed.

The considerations of amendments to the test procedure are therefore presented in two parts. The first considers changes as part of the current revision and the second considers changes for the longer term.

For completeness we begin the section with a brief description of the current test method and then consider the various changes that could improve the method.

The current test procedure

The aim of the current method is to measure, from a vehicle fitted with a set of test tyres travelling at high speed on a specified road surface, the maximum coast-by noise level. The method which is set out in the EU Directive is based on ISO 13325 (International Organisation for Standardisation, 2003). The test site layout is shown in Figure 6.1.

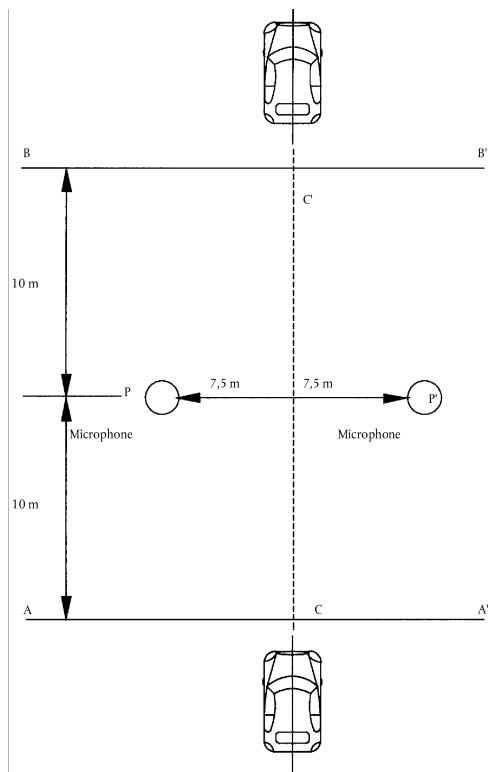


Figure 6.1: Plan of ISO test site

When the front of the vehicle has reached the line AA', the vehicle should be in neutral gear with the engine switched off. The maximum pass-by noise level recorded at both microphone locations, shown in the figure, as the vehicle is coasting between line AA' (front of vehicle) and BB' (rear of vehicle) is recorded.

A set of at least four such measurements are carried out at speeds above a given reference speed and similarly a set of at least four measurements are carried out at speeds below a given reference speed. The speed from all measurements must fall within a given speed range. The reference speed and speed range is dependent on the tyre type. Speed is measured when the front of the vehicle reaches the line adjacent to the microphones, PP'.

The test result is determined from the linear regression analysis of the maximum noise level and the logarithm of speed, calculated at the reference speed. A temperature correction is applied to the test result to allow for the influence of surface temperature effects. A 1 dB(A) correction is subtracted from the test result to allow for instrument inaccuracy and the resultant is rounded down to the nearest whole value to obtain the final test result.

6.3.1 Amendments as part of the current revision

(i) Rounding adjustments

The current type approval test includes a procedure for rounding down the measured values of tyre noise. Essentially the procedure requires that:

- 1 dB(A) is subtracted from the test result, to allow for instrument inaccuracies associated with older types of measurement equipment;
- Final results (temperature corrected) are rounded down to the nearest whole dB(A).

It is felt that the subtraction of 1 dB(A) from the measured results is no longer needed as modern measuring equipment is now capable of greater accuracy than when the recommendations were first introduced and measurement errors of a magnitude sufficient to justify this adjustment no longer occur. This subtraction is also a potential source of confusions, since it is sometimes difficult to determine, in published data, whether or not the posted values have been amended.

As a result it is recommended that when the Directive is revised the test result is simply rounded to the nearest integer. These suggested changes would then bring the tyre noise measurement practice into alignment with the rounding procedures specified in the proposed revisions to the separate vehicle noise type approval procedure. It should be noted that this change in the procedure would itself mean a lowering of the threshold that is actually enforced and that this has been fully included in the recommendations for new limit values given earlier in Work Package 2.

If greater precision could be obtained in the measurement of tyre/road noise it may, in the future, be possible to alter the procedure such that values to 1 decimal place could be recorded as the test value. However, large changes in the test procedure would be required to reduce measurement error. It is likely that an indoor controlled environment would be required to reach this level of accuracy (see section 6.4.1).

(ii) Test vehicle selection

The shape of the body of a vehicle is known to be a factor affecting the propagation of sound from the tyres. For example, a car designed with a low slung body will tend to offer a considerable degree of screening of the farside wheels potentially resulting in a smaller contribution to the overall level of tyre noise. To illustrate the potential effects, a simple propagation model has been developed to estimate the influence of vehicle body design on the test result (See Appendix C). Using this model, the contribution to the overall noise emission from the farside tyres can be estimated assuming varying degrees of shielding. The results of this analysis is shown in Figure 6.2.

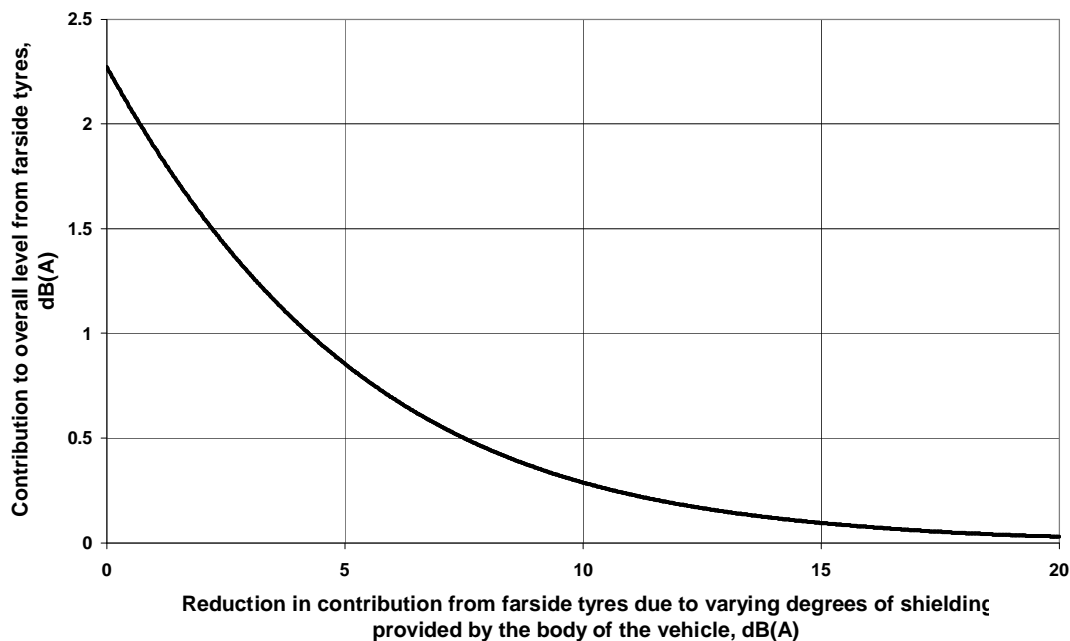


Figure 6.2: Contribution to overall level from farside tyres for varying degrees of shielding provided by the body of the vehicle

The graph shows that where there is no effective screening from the body of the vehicle, i.e. no reduction in the contribution from the farside tyres, the contribution to the overall level is about 2.3 dB(A). This corresponds approximately to a doubling of the sound intensity⁶.

The figure also shows that where the underside of vehicle body just obscures the view of the farside tyres at the receiver position, the estimated reduction in contribution from the farside tyres would be about 5 dB(A)⁷ and the contribution to the overall level from the farside tyres decreases to about 0.8 dB(A). Increasing the screening of the farside tyres progressively reduces the contribution to the overall level.

Clearly, the above analysis illustrates the potential influence of the design of the body of the test vehicle and the consequent effect on the shielding of the noise from the farside tyres may have an important influence on the overall test result. The variability introduced by vehicle design considerations could, therefore, influence the overall reproducibility of the test results.

A further point that needs to be considered when specifying the test vehicle to be used for tyre testing is the length of the wheelbase. The effects of varying the wheelbase on the overall levels of tyre noise generated is thought to be small, however, commonsense dictates that as the wheel base is increased, the combined noise from the tyres on the vehicle, as determined at the trackside measurement position, will be reduced. Ideally the

⁶ Theoretically doubling the sound intensity should result in an increase of 3 dB(A) and would represent the condition where the tyres were located next to each other. The difference of 0.7 dB is caused by the fact that the farside tyres are further away from the receiver compared with the nearside tyres, resulting in a lower contribution

⁷ A 5 dB(A) reduction is typically assumed for line-of-sight screening from barriers (Department of Transport and the Welsh Office, 1988).

vehicle chosen when testing a particular tyre type should be appropriate for that tyre class.

It should be noted that the current Directive does consider the wheelbase for test vehicles by specifying the following:

“Section 2.4.3 Wheelbase -The wheelbase between the two axles fitted with the test tyres shall for Class C1 be less than 3.50 m and for Class C2 and Class C3 tyres be less than 5m”.

While this is felt to be adequate for C1 and C3 tyres it does permit C2 tyres to be fitted to a vehicle with a 5m wheelbase which is inappropriate for tyres in this class. The majority of C2 tyres are fitted to vehicles less than 3.5 t. These vehicles generally have a wheelbase of less than 3.5 m. We recommend, therefore, that C2 tyres are tested on vehicles with a wheelbase less than 3.5 m. The Directive could be simply reworded as follows;

“The wheelbase between the two axles fitted with the test tyres shall for Class C1 and Class C2 be less than 3.5m and for Class C3 tyres be less than 5m”

In summary, therefore, it is recommended that when the Directive is revised, consideration should be given to improving the specification of the test vehicle so that differences in test results that could be attributable to vehicle shape and inappropriate wheelbase dimensions are avoided in the future. In particular, vehicle types should be avoided that offer little or no screening of the farside tyres and vehicles should be chosen that would, in normal road use, be appropriate for the tyres being tested. The considerations concerning wheel loading, wheel alignment, the wheel arch and the fitting of mudflaps, spray suppression devices and sound absorption treatments that are detailed in the current Directive are considered to be appropriate and should be retained.

(iii) Correction for temperature

Exterior tyre/road noise emission is influenced by temperature. The extent of this influence is important when considering the repeatability and reproducibility of the method. The current method allows for this by applying a correction to the test result so that noise levels are normalised to a reference test surface temperature of 20°C. Figure 6.3 shows the relationship in the Directive between surface temperature and noise, referenced at 20 °C, for both C1 and C2 tyres. It can be seen that over the range of surface temperatures allowed for in the Directive (5 to 50°C), corrections to the test value may range between ± 1 dB(A).

Some commentators have suggested that this correction is too conservative and have developed an alternative correction based on air temperature, used in the EU HARMONOISE prediction method (Sandberg and Ejsmont, 2002; Jonasson *et al.*, 2004). Figure 6.4 shows this correction for the ISO surface.

Clearly, comparing the rate of change in noise level per degree change in temperature in the two figures does show that there are differences with the Harmonoise correction indicating a range of about 3 dB(A) over the temperature range of importance. However, it should be noted that in the Directive the correction is based on surface temperature whereas in the HARMONOISE model the correction is based on air temperature.

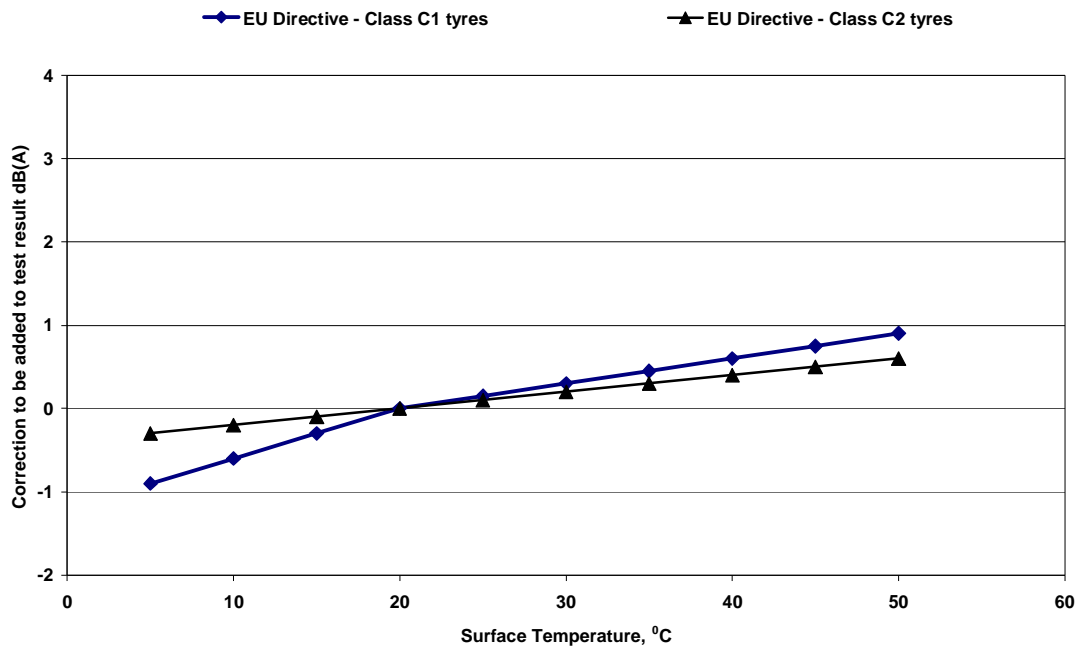


Figure 6.3: Surface temperature effects on tyre/road noise - EU Directive

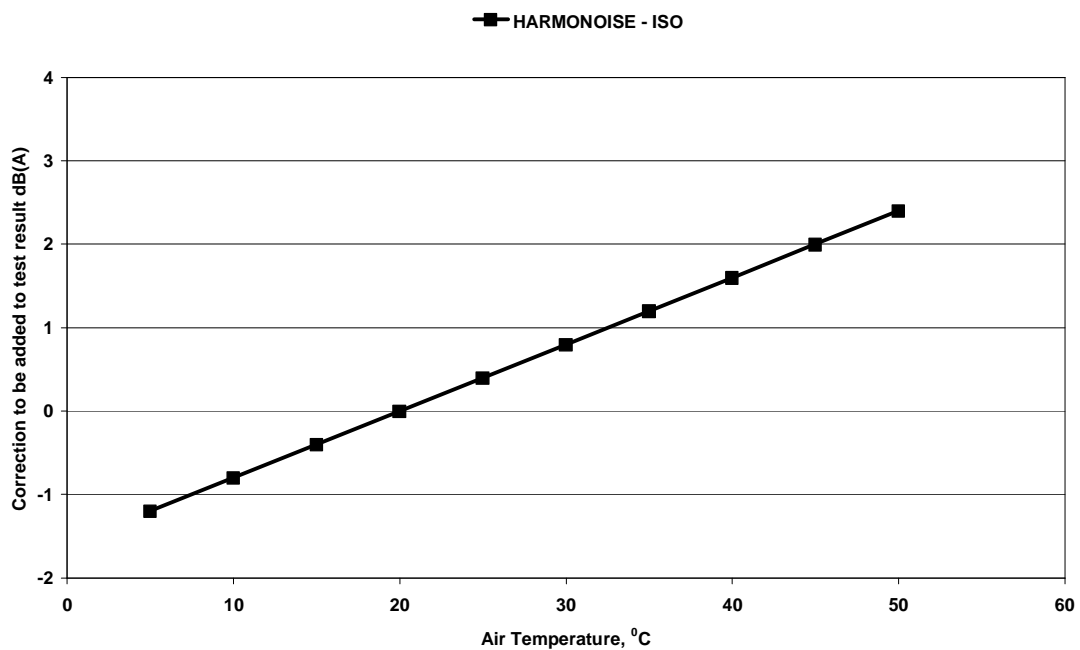


Figure 6.4: Air temperature effects on tyre / road noise on ISO surface – HARMONOISE

It is perhaps to be expected that surface and air temperatures are well correlated but it does not follow that there is a one-to-one relationship. To examine the relationship between air and surface temperatures, the results from a recent study on tyre noise were examined. In this study both air and surface temperatures were taken during tests carried out using the ISO surface. The results are shown in Figure 6.5.

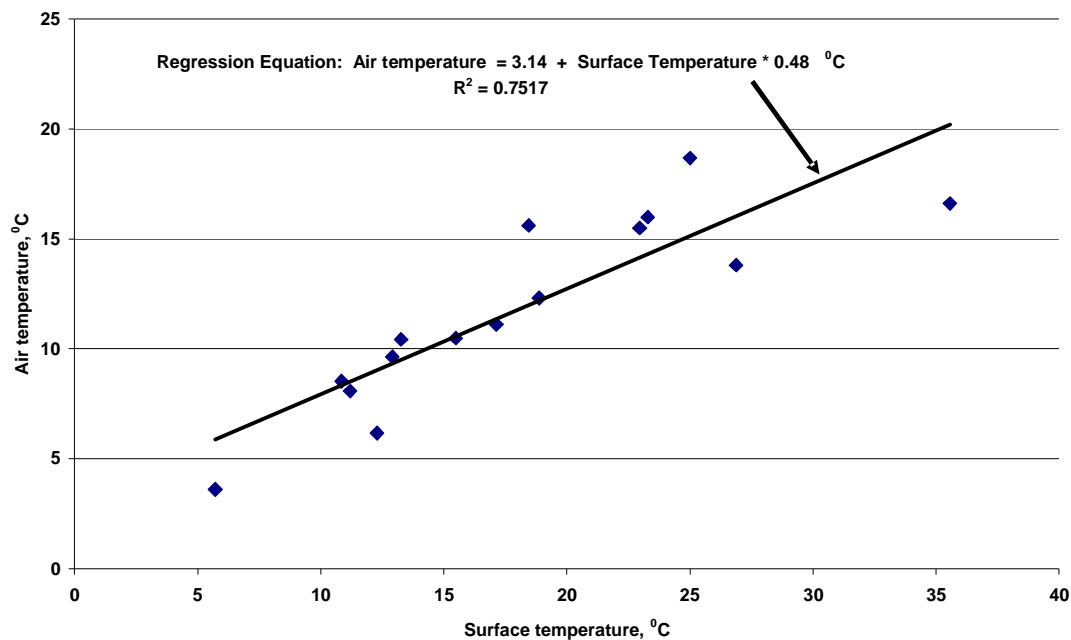


Figure 6.5: Relationship between air and surface temperature for ISO surface

Clearly from the results of the linear regression analysis, which showed that over 75% of the variance in surface temperature is explained by variation in air temperature, a change in surface temperature of 1°C is equivalent to only a change in air temperature of 0.48 °C. Using this information allows a direct comparison of the correction used in the EU Directive with that described in the HARMONOISE model based on surface temperature and is shown in Figure 6.6.

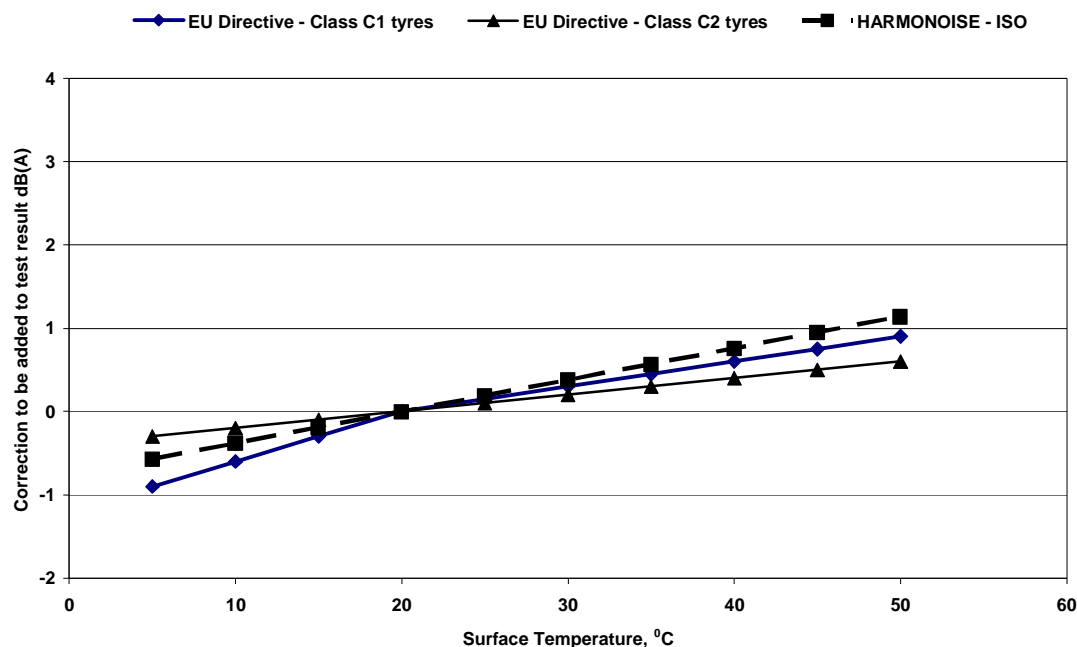


Figure 6.6: Comparison of surface temperature effects on tyre/road noise: EU Directive and HARMONOISE

Clearly, when comparing both relationships there is good agreement and any differences are not significant. It would appear therefore that either measurements of air temperature or surface temperature could be used with the appropriate formula to normalise the measured results to a standard temperature.

The present Directive requires that both air and surface temperature are measured to an accuracy of 1°C. However, as stated above the correction is based only on the surface temperature. It could be argued that measuring air temperature is easier and requires less expensive equipment. Corrections based on air temperature would also have the advantage of harmonisation with recently determined correction formula. However using a correction based on surface temperature may overcome the problem where test surfaces are artificially heated to assist in drying the surface. Under such circumstances a correction based on air temperature may underestimate noise levels when testing during cold conditions.

On this point, there was a general consensus, although not complete agreement, by the authors of this report that the revised Directive should change to a correction based on the Harmonoise air temperature correction formula. However, given the arguments described above it would be prudent to retain, in the revised Directive, the requirement to measure both air and track surface temperature so that any departures from the normal relationship between air and surface temperature can then be readily identified.

6.3.2 Future changes to the tyre noise Directive

(i) The ISO test surface

According to the current Directive, the tyre noise test surface should conform to the surface specified in ISO 10844 (International Organisation for Standardisation, 1994). This is a fine graded surface (maximum stone size is 8 mm) and was originally developed to test the noise emitted by vehicles from the power unit related sources on the vehicle for type approval purposes. The surface was designed specifically to minimise the contribution from tyre/road noise.

Although it is important to closely specify a reference surface as this allows testing to be carried out at different sites, it is equally important that the test results obtained relate closely to the tyre/road noise generated by vehicles when operated in-service. It is for this reason primarily that the current test surface has been criticised as a surface for use in tyre noise type approval. It has been argued that the current test surface, due to its smooth texture, is not representative of the rougher surfaces commonly found on high speed roads. This has been of particular concern where presently, a high proportion of surfaces used have a significantly coarser texture such as Stone Mastic Asphalt (SMA14 or SMA16). These surfaces are constructed with much larger maximum stone size aggregates than the ISO surface.

This concern has been shown to be well founded as generally there is a poor correlation between tyre noise produced on the ISO surface with the corresponding noise produced on these coarser textured surfaces. However, it has been found that a much better correlation is obtained with roads surfaced with smaller sized aggregates, as might be expected given that the surface types are then more closely similar. In particular, for SMA surfaces constructed with 10 mm aggregates the correlation with noise levels produced on the current ISO surface is quite high. Consequently, since there is a trend within the EU to construct or re-surface high speed roads with SMA type materials it would appear that the original concerns over the ISO surface will eventually reduce as these finer graded surfaces become more commonplace. Nevertheless, even with these changes that are occurring in road surfacing design, it would still seem appropriate that at some stage to revise the current test surface used for tyre noise testing. If only one reference surface can be accepted, a test surface based upon a 10 or 11 mm aggregate would seem to be the most appropriate choice given the trend towards replacing existing roads with a similar type of surface. However, a better alternative would be to retain the existing surface as representing smooth lower noise surfaces common in many European urban areas and to introduce an additional test surface with a 14 mm or greater maximum chipping size to represent rougher test surface in order to represent common surfaces on higher speed roads. The test requirements would include achieving acceptable levels on both surfaces.

Changing the reference surface in the Directive should be considered as soon as appropriate technical requirements are available, which means that it is a longer term objective and not part of the current revision.

However, it should be noted that there are several improvements in the specifications of the current ISO 10844 standard that can and shall be made in order to reduce the differences between surfaces laid at various places and by various contractors. Such work is underway in ISO/TC43/SC1/WG42 and it is recommended that the results of this group are considered in the forthcoming revision of the Directive.

(ii) Test speeds

The current test method is designed to control tyre/road noise at relatively high speeds. It is generally recognised that as vehicle speeds are reduced the contribution from tyre/road noise to the overall vehicle noise level becomes less significant, particularly for the heavier vehicle categories. Nevertheless, for light vehicles travelling at typical urban speeds, the contribution from the tyre/road component is still important. Unfortunately, controlling tyre/road noise at high speeds may not simply translate to low speeds. Therefore, it follows that any benefits anticipated by reducing the current limit values may not be fully realised in communities located where the traffic is travelling at relatively low speeds that are typical in many urban areas.

This is illustrated in Figure 6.7 which shows the relation between speed and maximum coast-by noise level for two tyres that were included in a study by Phillips *et al.* (2003). The figure shows that at the reference speed of 80 km/h, the noise level from tyre 1 is higher than from tyre 2 by about 0.8 dB(A). However, at 50 km/h, a typical speed in urban areas, noise levels from tyre 2 are higher than from tyre 1 by about 1.7 dB(A). This reversal in the rank ordering of the tyres at different speeds clearly illustrates the point that controlling tyre noise at high speeds cannot always be assumed to offer the same benefit at lower speeds.

Extending the current test to include lower speeds would help to ensure that tyre noise is controlled for a wider range of conditions. However, this would require consideration of an additional set of limit values corresponding to the lower speed and the information required to set these limits is not yet readily available. This particular change to the Directive should therefore be considered as a longer term objective and not part of the current revision.

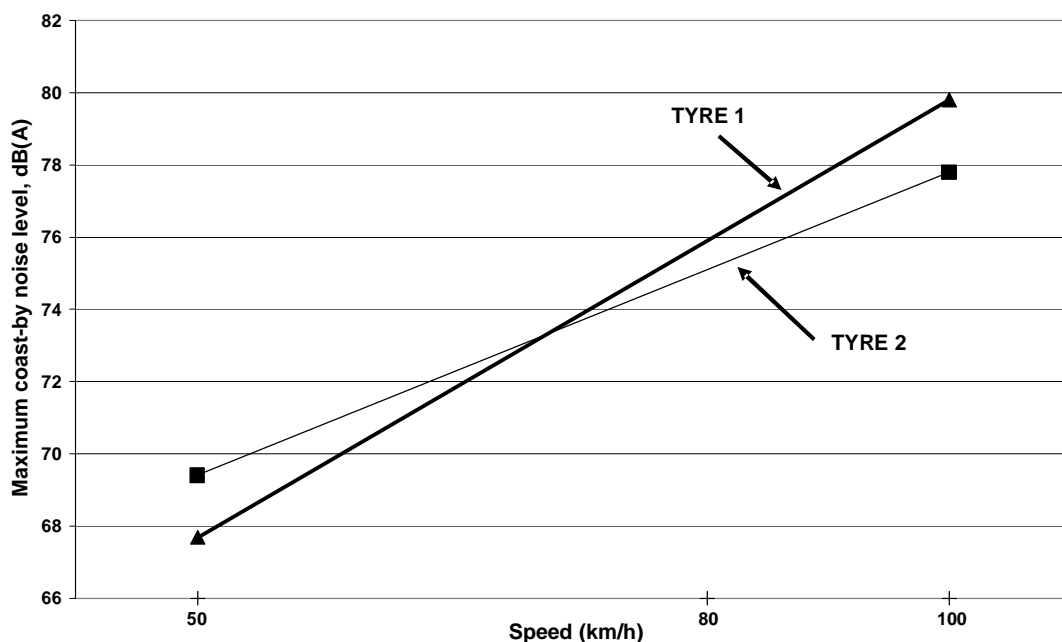


Figure 6.7: Relation between speed and maximum coast-by noise level for two tyre types

(iii) Alternative test procedures

Clearly, the current test method is a relatively simple/low cost test to carry out and therefore offers considerable advantages in terms of reproducibility between test centres and costs. However, as has been pointed out earlier in this report, there are problems in ensuring that the test surface is both representative of real road surfaces and that it produces consistent results at different test centres. There are also inherent problems associated with testing outdoors due to variations in weather conditions. In the longer term therefore it might be worth considering alternatives to the current method that overcome some of these problems.

It should be noted that possible alternative methods of measuring tyre/surface noise are being considered as part of the EU SILENCE project. Any recommendations arising from this work should be considered for future revisions of the Directive. Some potential methods are briefly reviewed below.

Drum method:

Vehicle tyre properties are widely tested using indoor test drums. However, testing for noise generation using drums is challenging due to the fact that the noise generated by the drum drive mechanisms has to be suitably screened and the fact that the curvature of the drum affects the contact patch with the tyre when compared with a flat road surface. It is thought that the curvature of the drum will therefore affect some of the noise generation mechanisms. Ideally a drum of at least 5m diameter is needed.

However, despite these concerns there are some advantages. For example, the drum method is not subject to the vagaries of the weather and temperature control is not a problem, thereby avoiding the need to correct the results for differences in temperature. The surface of the drum can also be covered with a replica road surface which can be reproduced for use on all drums used for type approval. These measures would tend to improve accuracy and reproducibility allowing tighter control of limit values e.g. rounding of recorded values to the nearest 0.5 dB(A) or even 0.1 dB(A) rather than to the nearest 1 dB(A) which is currently proposed.

There are also potential advantages associated with testing capacity/throughput although the initial high cost of the equipment due partly to the need to install a large diameter drum and higher running costs may tend to offset this advantage.

Close Proximity (CPX) methods:

The CPX method (International Organisation for Standardisation, 2000) allows measurement of tyre / road noise to be carried out in close-proximity to the tyre. The advantages of this method over the conventional method are that the directional properties of the noise generation can be adequately assessed and possible problems associated with extraneous noise can be eliminated. With a suitable test vehicle, a wide range of tyre types can be tested and loaded appropriately. For example, Figure 6.8 shows the TRL CPX test vehicle set up with several microphones arranged around a test tyre. In operation, the tyre and microphone assembly is located in a suitable designed enclosure. This effectively screens any extraneous noise. The test tyre is loaded hydraulically and the tyre support structure is designed to accommodate a wide range of car tyre sizes.



Figure 6.8: Test tyre and microphone set-up in TRITON's enclosure

Further details of the TRL CPX vehicle are described by Phillips et al. (2003).

Using this type of vehicle or a simpler design, it is possible that car tyre type approval testing could be carried out using the CPX method.

Test trailers for carrying CPX measurements on truck tyres have also been developed, e.g. Phillips et al. (2003), although it is generally regarded that this approach for truck tyres would not be suitable for type approval testing because of difficulties in eliminating the noise from the towing vehicle (Sandberg and Ejsmont, 1992).

Modelling of tyre noise:

There has been considerable research effort devoted to the development of mathematical models to simulate the generation of tyre/road noise. However, although these models undoubtedly provide an insight into the mechanisms of tyre noise and help to generate basic tyre design concepts, e.g. tread pattern design, the production of a model that could replace tyre noise testing is still some way from being realised.

In order to create a successful tyre noise emission model any programme must consider the various causes of tyre to road noise generation and the variables involved. Additionally there are other phenomena very much related to the above mechanisms that can influence the noise levels but are not really noise generation mechanisms. To determine roadside noise levels any model should also consider sound propagation and vehicle shielding factors. Given the complexity of the issues involved, it is not envisaged that tyre noise modelling could be used to replace tyre testing in the near future.

(iv) Tyre wear

Currently tyres are tested when they are new, ie. they are 'run in' for 100 km prior to testing, and the noise level achieved at type approval is therefore representative of the level when the tyre has full tread depth. The current trend for many tyres is thought to be for the noise level to increase as the tread wears down (Sandberg and Ejsmont, 2002).

This may be partly attributable to the changes that occur in the tread pattern and to some extent the changes that occur in the tyre structure and tyre compound. For many tyre designs, therefore, tyre noise will tend to increase slowly over much of the life of a tyre.

Although it would be difficult and, perhaps, costly to prepare tyres for type testing that have been 'in use' rather than 'as new' it would seem appropriate that the type approval test should examine tyres in their noisiest condition if at all possible. Consequently since a type approval test where a tyre has covered a certain distance (e.g. when worn to half way) would implicitly be more representative of the tyre noise that might be expected to be generated from the tyre over its useful life, it would seem sensible to try to reproduce this condition during testing. Any tyres that exhibit lower noise levels with increased wear would benefit from this change as the type approval level attributed to these tyres would be relatively lower than it is currently.

It is recommended therefore that consideration should be given in the revised regulation to the conditioning of tyres prior to testing. Tyres worn to half the original tread depth would seem to be a suitable test condition. However, further research is required to consider the relationship between wear and noise and to determine whether an artificially worn tyre is more representative than a new tyre. If this is the case the degree of wear required and the most appropriate method of achieving this condition would need to be established.

It should be noted that the subject of tyre wear in relation to noise emission is currently being examined in the EU SILENCE project. Any recommendations made as part of the SILENCE project in this regard would have a bearing on future revisions of the tyre noise Directive and should, therefore, be taken into account.

6.4 Summary and discussion of the results of Work Package 3

Work Package 3 is primarily concerned with establishing recommendations for revising the Directive concerned with tyre noise type approval that are in addition to the recommendations for lowering the noise limits. The background, analysis and recommendations for the new limits are presented in Work Packages 1 and 2 of this report.

Primarily this Chapter considers the need for additional tests of tyre safety performance and tyre rolling resistance that could be introduced alongside the requirements for tyre noise testing. It also considers the possibility of marking tyres with the noise levels generated under type approval as a means of informing consumer choice and encouraging the sale of quieter tyres. In addition to these changes, technical amendments to the tyre noise test procedure are considered and recommendations made, where appropriate.

Recommendation regarding tests for safety performance of tyres

From the analysis of the data it is clear that while, in general, tyre noise levels could be reduced significantly from the current limits without affecting overall safety performance, and that there are many examples of tyres in current production that perform well in terms of noise emission and safety, the data also shows that there is a wide range of safety

performance for any given tyre category. It is not possible to guarantee therefore that for some future designs of tyre there will not be a conflict between noise and safety. Consequently, it is recommended that adequate safeguards are put in place with regard to tyre safety performance when the Directive is revised. This may mean the introduction of a test for tyre safety performance as part the revision of the Directive.

However, such a supplement to the Directive should not delay the introduction of the more stringent limits proposed in this report. The safety requirements may well be introduced at a separate time if they need more time for consideration and preparation.

Recommendation regarding tests for tyre rolling resistance

None of the reviewed studies could detect a significant conflict between requirements for low noise and low rolling resistance. Car tyre manufacturers place the reduction of tyre rolling resistance high on their list of priorities when designing new tyre types and considerable progress has been made in reducing tyre rolling resistance over recent years. There is a strong influence in the market place regarding fuel efficiency and tyre manufacturers will therefore continue to strive to keep rolling resistance values at the lowest possible values. Consequently, as with tyre safety, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise.

Nevertheless, it is not possible to speculate beyond the ranges provided by the data so it is important to ensure that any reductions in tyre noise imposed by tightening the type approval limits is also accompanied by sufficient controls on tyre rolling resistance. This may mean the introduction of a simple test to ensure tyres conform to acceptable standards in this regard.

However, as was stated above for safety, a supplement to the Directive related to rolling resistance should not delay the introduction of the more stringent limits proposed in this report.

Recommendations regarding tyre labelling

It is recommended that consideration is given, when revising the current Directive, to including a requirement for tyre manufacturers to label tyres according to their noise emission. This could be in the form of a noise level stamped on the sidewall. An alternative method would be to label tyres as '*low noise*' provided they meet an agreed threshold that is set below the noise limit.

Recommendations for amending the tyre noise test procedure

Improvements that could be made to the test procedure when the Directive is revised have been considered. These are presented in two groups. The first are recommended to be implemented as part of the current revision as they are well developed and can be introduced without further research. The second group include changes that could be considered over the longer term either because they require a major change to the process of tyre noise testing or they require the collection of additional data and would, therefore, provide an unnecessary delay in the implementation of the changes that have been recommended to be included as part of the current revision.

Amendments to consider as part of the current revision:

It is recommended that the procedure currently used to convert the raw measured data into the test result is changed. The new procedure would simply round the test result to the nearest integer. Thus, no subtraction of 1 dB should be made. These suggested changes would then bring the tyre noise measurement practice into alignment with the rounding procedures specified in the proposed revisions to the separate vehicle noise type approval procedure. This change in the procedure would itself mean a lowering of the threshold that is actually enforced.

It is recommended, that consideration should be given to improving the specification of the test vehicle so that differences in test results that could be attributable to vehicle shape are avoided in the future. In particular, vehicle types should be avoided that offer little or no screening of the farside tyres. The wheelbase of the vehicles used for testing should also be updated to ensure that the tyres being tested are fitted to test vehicles that would, in practice, be appropriate for those tyres. This is particularly important for C2 tyres.

It is recommended that certain improvements in the specification for the present reference test surface should be made, in accordance with the results of ongoing work within an ISO group, aiming at reducing the variability between various test tracks.

The procedure for correcting the test result for temperature variation could be changed to a method based on air temperature rather than surface temperature as this will then offer greater harmonisation with recently developed temperature correction models. However, the requirement to measure both surface and air temperature, as stated in the current Directive, should be retained for the present. Temperature corrections based purely on air temperature could produce misleading results where the track is artificially heated.

Longer term changes to the Directive:

Consideration should be given to changing the test surface used for type approval. Currently the surface is a fine textured surface constructed with aggregates that have a maximum chipping size of 8mm. This is not a surface that is commonly encountered on high speed roads. A test surface based upon a 10 or 11 mm aggregate would seem to be the most appropriate choice given the trend towards replacing existing roads with a similar type of surface. An alternative would be to retain the present ISO surface (with improved specifications (see above) and to supplement it with a second surface with significantly coarser texture.

Consideration should be given to extending the current test to include lower speeds. This would help to ensure that tyre noise is controlled for a wider range of conditions. However, this particular change to the Directive should therefore be considered as a longer term objective and not part of the current revision as additional testing and analysis would be required to establish limit values for lower speeds.

Consideration should be given to type approving tyres when partly worn, either as a supplement or as opposed to testing in new condition, subject to the outcome of ongoing research.

Future revisions of the Directive could consider alternatives to the current test procedure. Possible alternatives include the use of drums, tests in close proximity to the test tyre and

the use of mathematical models. Again this is dependant upon the outcomes of ongoing research.

7 Work Package 4: Costs and benefits of lowering the tyre noise limits

7.1 Method

The lowering of tyre noise limits has effects on a number of stakeholders. The first part of this Work Package involved a preliminary identification of the stakeholders, and how each stakeholder might be affected by changes to the Directive (see Section 7.2). This information was compiled from a wide variety of sources, which included:

- (i) Expert knowledge amongst the project team members;
- (ii) Lists of stakeholders known from a recent project that had looked into changes to vehicle noise limits;
- (iii) Research papers into road noise from vehicles and the costs of abatement of noise by government authorities; and
- (iv) Consultation with the tyre industry.

The second part of this Work Package method allowed us to decide which effects of changing the Directive would be significant. Chapters 4-6 of this report provided the information necessary to make these decisions. Expert judgement was the main approach that the team used to decide which effects would be most significant in the period after 2010 (see Section 7.3).

Section 7.4 calculates the value of a 1 dB(A) reduction in road traffic noise. Reliable financial estimates are available for the value of traffic noise reductions, although these differ between countries. Section 7.4 uses an EU-wide figure for the valuation of noise reductions to each household, per year.

Section 7.5 uses the results of Section 7.4 to calculate the value of the benefits that the proposed changes to the Directive would bring.

Section 7.6 looks at the costs to various stakeholders.

Section 7.7 draws conclusions about the benefits and costs.

Appendix F briefly analyses the benefits and costs of achieving noise reductions through other policies than the Directive.

7.2 Stakeholders

At the beginning of the project, we assembled a list of stakeholders who might have been affected by changes to the Directive. That list of stakeholders is shown in Annex F, see Table F.1. The left column of Table F.1 lists the stakeholders. The right column comments on the conditions under which each stakeholder might have been affected by potential changes to the Directive. The right column also states what effects were thought possible.

As the project progressed, we were able to refine this list. Section 7.3 presents the final list.

7.3 Significant effects of proposed changes to the Directive

7.3.1 What effects will the Directive have?

There will be two main effects of the Directive:

- (i) The reductions in real traffic noise as a result of the two proposed reductions in the noise limits for tyres fitted to new vehicles (see section 5.1).
- (ii) From 2010, the Directive requires that ‘after-market’ replacement tyres meet the same noise limits as the Directive requires for tyres fitted to new vehicles.

For a typical passenger car life of 160,000km, approximately 80% of all kilometres driven by the car will be on replacement tyres. Only around 20% of the distance driven will be on the original tyres that were supplied with the vehicle when new. The early application of noise limits to replacement tyres is therefore critical to the success of the Directive in reducing tyre noise from road traffic.

C1 tyres are fitted to passenger cars. These are the tyres that are mainly bought by consumers, and ‘small and medium enterprises’ (SMEs). C1 tyres therefore constitute the largest part of the tyre market. C2 tyres are mainly fitted to light commercial vehicles. C3 tyres are fitted to heavy commercial vehicles. Table 7.1 below shows the number of vehicles bought each year in each size category, in the EU15.

Table 7.1: Number of newly registered vehicles in 2004 (Source: European Union Road Federation (2005))

Vehicle category	Number of new vehicles registered in 2004	Increase in new registrations between 2003 and 2004
Non-commercial	14.12 million	+2%
Light Commercial	1.87 million	+8.6%
Commercial >3.5 Tonnes	0.33 million	+6.8%

Commercial vehicles are a small fraction of all vehicles sold. However, the noise effects on the public do not depend only on the number of vehicles:

- (i) A typical large commercial vehicle drives 150,000 km per annum, which is ten times the distance for a typical non-commercial vehicle.
- (ii) The noise emissions of a large commercial vehicle, per kilometer, are usually significantly greater than those of a non-commercial vehicle.

The contribution made by each vehicle class to overall traffic noise therefore depends on the total number of vehicle kilometres driven by that class of vehicle per annum and the 'per kilometer emissions'.

7.3.2 New or existing tyre technology?

An important finding of this report is the number of tyres in each of categories C1-C3 that already meet the noise limits proposed for 2008 and 2012.

In analysing the impacts of proposed legislation, it is usually the case that some degree of expert judgement is required to understand even the basic impacts that would result from the proposed legislation. In this study, however, we have 'real-world' data on tyres that already meet the future noise limits and were on sale in the years 2000-2005. This data provides a far higher degree of confidence in the findings of the analysis of benefits and costs than would usually be possible in advance of legislation.

Table 7.2 below lists the percentages of each tyre size C1A, C1B and C1C that was on sale in 2000-2005, and already met the proposed new noise limits for 2008 and 2012. This is the data on which Figure 5.1 is based. The final row of Table 7.2 is a weighted average figure. The weighting depends on the the proportion of total 2004 tyre sales that were in each tyre class.

Table 7.2: Percentages of 2002-2005 tyres that meet proposed noise limits

New tyre class	Percentage of tyres on sale in 2000-5 that meet the proposed 2008 noise limit	Percentage of tyres on sale in 2000-5 that meet the proposed 2012 noise limit
C1A (Width 185mm or less)	70.0	30.0
C1B (Width 186mm-215mm)	87.8	41.1
C1C (Width 216mm-245mm)	68.8	25.0
Percentage of all tyres in classes C1A-C1C meeting new limits, weighted by sales* in each size class.	76%	35%

* 2004 Market figures from Watts (2005):
 46.5% of all tyres sold were less than 185mm wide;
 45.8% were 186mm-215mm;
 7.5% greater than 215mm, table assumes all were 216-245mm.

This situation gives us much more certainty of what the legislation will achieve, than would normally be possible. In particular, it allows firm conclusions to be drawn about what significant effects the proposed changes to the Directive will have. Importantly:

- (i) Existing tyres that meet the future noise limits allow us to examine what effects there would be on other tyre performance parameters.
- (ii) Many billions of kilometres have already been driven by the public and businesses on tyres that meet the new noise limits. This would have shown up any un-intended consequences of the proposed new limits, on e.g. fuel usage, tyre wear or tyre safety.
- (iii) Research and development to meet the new noise limits has already been carried out by the manufacturers. Tyres meeting the new noise limits are clearly already price competitive with non-compliant tyres. Other requirements of tyres, such as safety and visual appeal, must already have achieved levels that are satisfactory to both sellers and buyers.

7.3.3 Who will be affected significantly?

This report has found that the public is the only group that would be affected significantly as a consequence of the proposed changes to the Directive. The public will experience significant improvements in levels of noise to which they are subjected.

Other stakeholder groups will not be affected significantly. Concerning the other stakeholder groups:

- (i) Any changes would be negligible for consumers and businesses who buy and operate vehicles.
- (ii) Both national and local government authorities are likely to realise some benefits, through reduced pressure on them to spend money on noise reduction measures and on medical treatments.
- (iii) Many tyres that are currently on sale meet the noise limits proposed for 2012, and tyre manufacturers will gradually have to bring all tyre production up to the standards of those tyres.
- (iv) The long timescale currently proposed for the tightest limits, i.e. 2012, will mean only gradual changes for vehicle manufacturers. The main effect will be positive, because quieter tyres will mean that less vehicle engineering and re-design will be required to meet future vehicle type approval test limits, than would otherwise have been the case.
- (v) Construction firms may gain small benefits.

Table 7.3 on the following page explains the effects on each stakeholder group in greater detail.

Table 7.3: The effects of changes to the Directive on Stakeholder groups

Issue	What effects will changes to the Directive have?	Stakeholders affected
Rolling resistance	<p>This report found no significant correlation between tyre noise and rolling resistance. Reductions in tyre noise limits will therefore neither increase nor decrease:</p> <ul style="list-style-type: none"> (i) Fuel costs; or (ii) CO₂ or other exhaust emissions. 	None
Safety	<p>This report found no significant correlation between tyre noise and wet grip. There will therefore be no significant change in accident costs. There is currently a strong downward trend in ‘Killed and Seriously Injured’ (KSI) road accidents across the EU, and there is no evidence that the changes to the Directive would affect this.</p>	None
Tyre Durability	<p>An investigation of durability was not part of this project. However, the literature review has not revealed evidence of any significant correlation between tyre life and noise. Consumers and businesses should therefore not need to replace tyres any more often than with the current noise limits, so costs to them will not change.</p>	None
Noise impacts on people	<p>Chapter 5 modelled the reduction in noise from all traffic due to applying the new noise limits:</p> <ul style="list-style-type: none"> (i) The ‘HARMONOISE’ model was used to model changes in L_{Aeq} due to the new limits for C1 tyres only. Conservative assumptions were used, e.g. a reduction in tyre/road noise of 2 dB(A) on real roads. Predicted traffic noise reductions were 0.6 - 1.1dB(A), with an average of 0.9 dB(A), for different traffic speeds and flows on the most common surface type. (ii) The ‘TraNECam’ model predicted changes due to C1 tyres, assuming a 5 dB(A) reduction in tyre/road noise on real roads. Predicted traffic noise reductions in L_{den} for changes in C1 tyres were 1.1 - 3.4dB (average 2.3 dB(A), for different traffic speeds and flows on the most common surface type. When the same model was used to model predicted changes due to the proposed new noise limits for C1, C2 and C3 tyres, the average reduction was 3dB(A). <p>All modelling involves assumptions. The parameters used in (i) and (ii) represent, respectively, conservative and optimistic approaches. Based on the two models, this chapter assumes a lower value of 0.9 dB(A) and an upper value of 2.3 dB(A) for the overall average traffic noise reduction resulting from the proposed 2012 tyre noise limits for C1 tyres only. There will be greater benefits than this from the proposed noise limits in the Directive, since the proposals cover C1, C2 and C3 tyres.</p>	<p>Almost the whole of society will be exposed to less road traffic noise. This includes road users (drivers, pedestrians, cyclists), people in houses, flats and the workplace.</p>

Table 7.3: The effects of changes to the Directive on Stakeholder groups (continued...)

Issue	What effects will changes to the Directive have?	Stakeholders affected
Changes to car and commercial vehicle design	Car manufacturers and the manufacturers of commercial vehicles both benefit from lower noise tyres. After 20 years of effort, some aspects of vehicle design are experiencing a law of 'diminishing returns' in attempts to reduce noise further. In particular, the marginal cost of achieving further noise reductions through quieter tyres is likely to be less than the cost of further changes to engines and transmissions. Such cost data is confidential, and only broad conclusions are known to the project team.	Car manufacturers. If quieter tyres are an alternative to expensive engineering changes to engines and transmissions, then consumers will benefit.
Expenditure on noise reduction	<p>Reductions in road traffic noise are likely to lower the expenditure by state authorities for:</p> <ul style="list-style-type: none"> (i) Low noise road surfaces; (ii) Noise barriers and payments for sound insulation in buildings; (iii) Hospital care. There is a clear link between high levels of noise, from any source, and both cardiovascular disease and children's cognitive ability. See the research listed in 'Noise & Health' (2003). <p>However, traffic noise prediction models do not generally include the benefits of reduced mitigation expenditure.</p>	National and Local authorities; tax payers
Changes to tyre design	<p>The discussion on the following page concludes that 76% of C1 tyres sold in 2004 met the proposed 2008 noise limits. 35% met the 2012 limits. Design changes should therefore be minimal.</p> <p>The tyre industry has clearly carried out the Research and Development work that was necessary to reach these proposed limits, and did this some time ago. Tyres achieving the new noise limits are being mass produced without difficulty, and are price competitive with non-compliant tyres.</p> <p>The Directive, which was agreed in mid-2001, contained proposals for lower limits. These were 'indicated' as being for phased implementation from June 2007. Manufacturers have had five years' notice that new limits were planned, and still have a further two years in which to discontinue tyres that would fail the proposed limits. By 2008, production cycles will have ended for the vast majority of tyres that were on sale in 2001.</p>	Tyre manufacturers

Table 7.3: The effects of changes to the Directive on Stakeholder groups (continued...)

Issue	What effects will changes to the Directive have?	Stakeholders affected
Standard of noise insulation in new buildings	Some member states have set maximum noise levels for the interior and exterior of new buildings. This can apply to both housing and work places. The Environmental Noise Directive is likely to increase pressure on other member states to bring in such legislation, as part of action plans that are due in 2008. Reductions in road traffic noise will lower the costs of complying with noise standards. This applies mainly to construction firms, although a few individuals also build new homes. Small and Medium sized businesses will benefit where their accomodation costs are reduced.	Construction firms

7.4 Valuation of the Benefit of Road Noise Reductions in the EU25

There are several different methods of calculating the value of road noise reductions. It is important to note that the valuations in this sub-section 7.4 apply to reductions in road traffic noise achieved by any means. They are therefore applicable to valuing any policies on vehicle noise, tyre noise, vehicle speeds, quiet road surfaces or programmes to scrap older vehicles. The figure derived for the valuation of noise reductions per dB is therefore used to value changes due to the Directive (see sub-section 7.5 below). It could equally well be used to value the alternative approach discussed in Appendix F.

The valuation approach chosen here is based on a figure for the value of noise reductions to households across all EU25 member states. The value is 25 Euro per dB (L_{den}), per household, per year. See paragraph 18 of reference WG HSEA (2003). The valuation from this study has been selected because it:

- (i) Offers a figure that was specifically developed, recently, to be used in cost benefit studies of value noise reduction policies; and
- (ii) Was reached by a wide consensus of academics for use across the EU, with some input from national government and industry.

The 25 Euro/dB/household/year valuation is considerably lower than that used in national studies in the wealthier member states of the EU, as WG HSEA(2003) itself points out. The figure of 25 Euro is therefore likely to provide a very conservative estimate of benefits. Importantly, this figure does not account well for savings in health expenditure by member states, which should be considered to be an additional financial benefit. See paragraph 21 of WG HSEA (2003), and paragraph 22 which comments:

'It is proposed in the absence of better information, that the health impact should be valued in a qualitative manner, after the completion of the cost benefit...analysis.'

Other studies in the EU have put the value of noise savings in richer member states above 50 Euro/dB/household/year. See for example the very thorough study in Bateman (2004). As real disposable incomes rise in all member states in the next few years, particularly in the accession states, the valuation to be applied might be closer to this higher figure.

The WG HSEA (2003) study recommends a 'purchasing power parity' correction for benefits that accrue in the EU Accession States, because of the lower standard of living in those countries. However, real disposable incomes are growing rapidly in the EU Accession States. This sub-section assumes that this growth will obviate the need for purchasing power corrections in the years where benefits will fall.

This subsection uses 2006 as the base year for calculating costs and benefits. The 25 Euro/dB/household/annum figure dates from 2003. This 2003 figure needs to be increased, due to the growth in per capita GDP between 2003 and 2006.

Table 17 of Eurostat (2005) provides data on Gross National Disposable Income, with some figures being forecasts. The data shows a rise of 13.2% in the period 2003-2006. In the period 2000-2010, population is forecast to grow by 1.7% per annum in the EU 25. So we will estimate the per capita GDP increase for the EU25 between 2003 and 2006 as 7.7%.

An increase of 7.7% would increase the 25 Euro/dB/household/annum figure to 27 Euro/dB/household/annum.

The benefit of noise reductions per household needs to be multiplied by the number of households in the EU25, in order to derive a figure for the benefit to the whole EU25 per annum. In this study, we have taken 204 million as the number of households in the EU25, see table 4.2 of 'EET (2003)'. This is the projected number of households in the EU25 in the year 2010. The number of households is growing. EET(2003) lists 186 million households in the EU25 in the year 2000, and 218 million in the year 2020.

We will consider here benefits falling in the years 2010-2022. See subsection 7.5 for further details of the reasons for choosing these years. To analyse benefits occurring in 2010-2022, therefore, the figure of 204 million households is likely to be an underestimate.

Based on the figures above, the benefit of road noise reductions in the EU25 per annum will be:

$$\begin{aligned} \text{Benefit per dB reduction per annum} &= 27 \text{ Euro/annum/household} \times 204 \text{ million} \\ &\text{households} \\ &= 5508 \text{ million Euro/dB/annum} \end{aligned}$$

Rounding this benefit figure down to the nearest 100 million Euro provides:

$$\text{Benefit per dB reduction per annum} = 5500 \text{ million Euro/dB/annum or} \\ \mathbf{5.5 \text{ billion Euro/dB/annum}}$$

This is the main benefit figure that we will use in this study. The figure is expressed in 2006 Euro values. It relies on a likely underestimate of the number of households in the EU25 in the period of interest. The other factors used in this calculation have also been estimated conservatively.

Romania and Bulgaria are scheduled to join the EU in 2007. This would bring a further 11 million households into the EU. These households would receive the benefits of lower noise for the entire 2010-2012 appraisal period, adding up to a further 5% to the annual benefit. If Ukraine were to join the EU at sometime during 2010-2020, this would bring in a further 18 million households. These households would receive the benefits of the lower noise from the year in which they joined the EU, adding up to 9% to the annual benefit.

7.5 Valuation of Benefits due to the Directive

7.5.1 Valuation of benefits from new noise limits for C1 tyres

Table 7.3 identified the benefits that will result from the changes in the Directive. The benefit in road traffic noise reduction, due to the proposed 2012 noise limits for C1 tyres only, was estimated to be:

- (i) 0.9 dB(A), using conservative assumptions;
- (ii) 2.3 dB(A), using optimistic assumptions.

The valuation of 5500 Million Euro/dB/annum from section 7.4 needs to be multiplied by the actual noise reduction in dB(A) that would occur in real traffic. This then provides the annual benefit to the public across the EU25 of the proposed new noise limits, in 2006 Euro values.

(i) Using the 0.9 dB(A) estimate:

Annual benefit = 5500 Million Euro/dB/annum x 0.9 dB(A)

Annual benefit to EU25 of proposed new noise limits using 0.9 dB(A) estimate = 4950 million Euro/annum

(ii) Using the 2.3 dB(A) estimate:

Annual benefit = 5500 million Euro/dB/annum x 2.3 dB(A)

Annual benefit to EU25 of proposed new noise limits using 2.3 dB(A) estimate = 12650 million Euro/annum

Taking (i) and (ii) together:

*Estimate of the annual benefit of the proposed new noise limits = 4950 - 12650 million Euro/annum or
4.95 - 12.65 billion Euro/annum*

This estimated range has used conservative assumptions, for example on the number of households in the EU25 in the period when benefits will occur.

7.5.2 Duration of Benefits and Selection of Discount Rate

Section 7.5.1 above provides a valuation figure for one year, in 2006 Euro values. In order to total up the benefits of the proposed new noise limits, we need to decide how many years into the future we should assume that the benefits of the proposed new noise limits will be felt.

Reductions due to the new noise limits will become noticeable gradually between 2006 and 2013, by which date they will have reached almost their maximum level. The major factors are the following:

- (i) Some benefit will occur before each of the 2008 and 2012 noise limits is introduced. This will happen as tyre manufacturers gradually discontinue the manufacture of the remaining tyres that are non-compliant.
- (ii) A major part of the benefit will come in 2010, when aftermarket tyres must meet the 2008 noise limits.
- (iii) Some benefits will only arise as vehicles wear out their existing, non-compliant tyres, and are fitted with replacement tyres.

Concerning point (iii) above, we need to distinguish between vehicles that are used intensively, such as commercial vehicles and company cars, and vehicles that are typically used much less intensively, such as older private cars. Detailed statistics are available on annual kilometres driven for each class of vehicle, which demonstrate the differences. However, in summary, the situation is as follows:

- (i) Vehicles that drive the highest annual numbers of kilometres are fitted with new tyres every 6-10 months. So the median time for these vehicles to be fitted with compliant tyres would be half this time, i.e. 3-5 months after each noise limit is introduced.
- (ii) Vehicles that drive the lowest annual numbers of kilometres are fitted with new tyres every 3-5 years. So the median time for these vehicles to be fitted with compliant tyres would be 1.5-2.5 years after each noise limit is introduced.

A very small percentage of tyres on vehicles are replaced sooner than these periods suggest, e.g. due to punctures, accidents or other damage.

It is important to note that most kilometres driven throughout the EU25 states are by definition driven by the first group of vehicles, and many of these are at high speeds on motorways and principal roads. The noise benefits of tyres that are compliant with each new noise limit will therefore be widespread and perceptible in a period of the order of 12 months after the introduction of each new noise limit.

Cost benefit appraisal in some member states uses an appraisal period of 60 years from the date of introduction of a new policy. A recent figure recommended for transport infrastructure projects was 40 years, see item 3 on page 2 of Stuttgart (2005).

However, we assume here an appraisal period of only 13 years, which will be the period 2010-2022 inclusive. This period is the shortest period over which we consider that the benefits of the proposed new noise limits will be significant. The period 2010-2030 is in fact more likely.

We have made the assumption that there will be no more benefit from the proposed new noise limits from 2022, because we cannot be sure that disruptive changes will not occur over the 2020-2030 timescale. Two possible examples of 'disruptive' changes would be:

- (i) In section 4.5, we discussed recent prototypes of non-pneumatic tyres, which might be able to provide large reductions in tyre/road noise. If these were to be

fitted to a substantial proportion of new and existing vehicles, in all classes M1-M3 and N1-N3, then this technology would determine road noise levels.

- (ii) Levels of CO₂ emissions from road transport are still growing, and at least one member state has asked the Commission to bring forward plans to include these emissions in the EU wide 'Emissions Trading System'. Action to reduce CO₂ emissions could involve reductions in overall transport mileages, substantially lower speed limits, or radically different designs of vehicle. Any of these changes might become the dominant factor in determining overall noise levels from traffic. The assumptions in the HARMONOISE and TraNECam modelling in this report would therefore no longer be valid. This would particularly be the case if the mix of speeds on the roads were to change substantially.

The second major decision to be made concerns 'Discounting'. Discounting is required to reduce the value of benefits or costs that fall in future years, in order to convert them into the value of benefits in one particular year. We are using 2006 as the baseline year in this study.

We have chosen 4% as the discount rate. This is the rate recommended in the EU's Impact Assessment Guidelines from June 2005. See section 12, page 39 of EU2005. This is a conservative choice, because the 4% rate is derived from yields on government debt back to 1980. There has been a trend to much lower discount rates across Member States in recent years. The EU sixth framework 'Heatco' project for transport infrastructure projects recommended only 3%. See item 5 on page 2 of 'Stuttgart (2005).

The value of the benefit per annum of noise reductions will however continue to increase gradually in future years by the real increase in per capita GDP. This is exactly the same increase as was used in section 7.4, for the years 2003-2006. We therefore need to predict the rate at which per capita GDP will increase in the period up to 2012. The figure used in section 7.4 was 7.7% over 3 years. We will use a much more conservative estimate of 1% per annum for future years. This choice reflects any possible slowing in the rate of growth of the economies in the Accession States, as they mature. It also reflects the fact that there was no major EU wide recession in the period 2003-6, but such a cyclical event may happen in the future.

So the actual discount rate that we will use for the years from 2006 until 2012 is 3%. This figure, the difference between the 4% discount rate and the rate of growth of real 'per capita GDP', is the 'Pure Time Preference Rate'.

7.5.3 Total benefit to EU25 over 2010-2022 appraisal period

Using the information outlined in sections 7.5.1 and 7.5.2 above, we can calculate the benefit to the EU25 over the appraisal period 2010-2022. This is the 'Net Present Value' of the benefits.

The calculation of benefits in years 2010-2022 uses 2006 as the base year. So even benefits that fall in 2010 must be discounted by a factor of 0.888. The reduction factors for each successive year are listed in the table in section 12.4 of EU (2005). For the changes to noise limits to C1 tyres only:

- (i) Total Benefit in 2010-2022, assuming 0.9 dB(A) road traffic noise reduction and hence an annual benefit of 4.95 billion Euros:
= 48 billion Euros
- (ii) Total Benefit in 2010-2022, assuming a 2.3 dB(A) road traffic noise reduction and hence an annual benefit of 12.65 billion Euros:
= 123 billion Euros

We conclude that the benefits to the public in the EU25 from the proposed changes to the noise limits in the Directive are estimated to lie in the range of **48 to 123 billion Euros**. These figures are at 2006 Euro values.

7.5.4 Valuation of benefits from new noise limits for C1, C2 and C3 tyres

Sections 7.5.1-7.5.3 considered only the benefits due to the proposed new noise limits for C1 tyres. However, we can also value the benefits that will result from the proposed new noise limits for all C1, C2 and C3 tyres.

Paragraph (ii) in the fourth row of Table 7.3 provides the prediction from the TraNECam model for reductions in road traffic noise due to the proposed new noise limits for C1, C2 and C3 tyres. This prediction was for an average reduction of 3 dB(A).

Section 7.5.3 above predicted a total benefit of 123 billion Euros for a 2.3 dB(A) reduction in road traffic noise. A reduction of 3 dB(A) is just over 30% greater than a reduction of 2.3dB(A). We would therefore expect a 3 dB(A) reduction to deliver of the order of 30% more benefit than a 2.3dB(A) reduction, i.e. a total benefit of 160 billion Euros.

We conclude that, over the period 2010-2022 for the EU25 member states, the proposed changes to C1, C2 and C3 tyres would deliver a benefit with a net present value

= 160 billion Euros

7.5.5 Valuation of other benefits in the EU25

Placing financial estimates on the costs of health benefits is extremely difficult. Estimates of the overall 'health cost' of noise do exist. See for example:

- (i) Table B-16 in reference EU Unite (2002). This table provides valuations for the health impacts of noise for residents of Finland, based on EU wide values from 2001. The medical effects considered are myocardial infarction, angina pectoris, hypertension and sleep disturbance.
- (ii) The Danish Health strategy estimates that the health effects of noise in Denmark cost 80-450 Million Euro per annum. When multiplied across the EU, this would be a large value. However, the changes to the Directive would only change a small proportion of the noise exposure.

Although figures for the health impacts of noise are available, both at EU level and in individual member states, we do not consider that the valuations are sufficiently straightforward that we can calculate a reliable figure for the proposed changes to the Directive.

Several member states provide data for the expenditure by states' national and regional authorities on noise barriers and changes to buildings to reduce noise. The available figures indicate that, with the proposed changes to the Directive:

- (i) Some reductions in expenditure will occur;
- (ii) Changes in expenditure are likely to be very small in comparison to the 48 to 123 billion benefit in section 7.5.3 above.

Savings in expenditure that accrue to vehicle manufacturers and to the construction industry are difficult to estimate. This is because:

- (i) The information on costs is confidential; and
- (ii) Expenditure can rarely be classified as only being necessary as a consequence of tyre road noise levels.

We believe that there will however be benefits to these industries. Once again, however, they are likely to be small in comparison to the figures in section 7.5.3.

When value figures are calculated for the issues above, there is a risk of 'double counting'. For example, citizen's own valuations of noise might incorporate some of the same elements that would be counted as health expenditure, e.g. the value of sleep disturbance.

We do not feel able to offer a reliable monetary estimate of the value of the improvements listed above, in the light of the issue of double counting, and the wide range of value estimates that could be given for the various improvements.

7.5.6 Value of road noise reductions outside the EU25

Sub-sections 7.5.1-7.5.5 relate only to benefits in the EU25. However, the authors of this report consider that the Directive will also bring very significant benefits in the remainder of the world.

These benefits occur because:

- (i) Tyre and car production are global industries, so tyres made to EU standards are likely to be sold in many countries outside the EU. This will at least be the case in the EFTA states.
- (ii) In many fields of technology, the developing world looks at EU standards when setting its own regulatory limits and public procurement standards. The standards set in the Directive are likely to gain legislative force in future years in many countries outside the EU.

No value figure for these benefits outside the EU has been incorporated into this report, although that figure would be likely to be large.

7.6 Valuation of Costs

The costs for compliance with the proposed changes to the Directive will fall on tyre manufacturers. The conclusions that we draw on costs are based on the following:

- (i) For the test results that we have, 76% of C1 tyres on sale in 2000-2005 already met the noise limits proposed for 2008. 35% already met the limits proposed for 2012 (see Table 7.2).
- (ii) As commented earlier, the figures in (i) demonstrate that research and development to meet the new noise limits has already been carried out by the manufacturers. Tyres meeting the new noise limits are clearly already price competitive with non-compliant tyres. Other requirements of tyres, such as safety and visual appeal, must already have achieved levels that are satisfactory both to sellers and buyers.

We therefore consider that the only major cost to manufacturers will lie in discontinuing production of any tyre lines that do not meet noise limits proposed in 2008 and 2012. The tyre industry has informed us that there are around 6,000 tyre lines on sale at any one time. Therefore there is unlikely to be an undersupply of the market due to such discontinuation.

The Directive gave notice in 2001 of proposed tightenings to the noise limits for C1 tyres from 2007 onwards. So the introduction of proposed new noise limits from 2008 represents an extension of 1 year over the first tightenings of which the tyre manufacturers have had notice. Relatively few costs of discontinuing production can therefore be recognised in a benefit cost study, given the notice period. However, the industry may be able to demonstrate some costs. These might for example concern any long term contracts that manufacturers had entered into. These costs would only be relevant if they involved supplying tyres that would have passed the indicative limits for 2007 onwards in the 2001 version of the Directive, but which would not pass the new noise limits that are now proposed for 2008 and 2012. The tyre industry has not supplied us with such figures.

ETRTO has provided their estimate of the costs that they would incur as a result of the noise limits proposed for C1 tyres in 2008 and 2012:

The ETRTO cost estimate was 2 Billion Euros/annum.

ETRTO informed us that this was a recurring figure, i.e. it would occur in each of several years. However, we were not told the number of years in which this cost was expected to arise. We have few other details of the basis for this 2 Billion Euro/annum estimate.

ETRTO have informed us that they view tyres as 'tyre families'. We believe that each 'family' is a single brand of tyre, which is supplied in different sizes. ETRTO consider that they would have to make changes to many of these tyre families to meet the proposed limits in 2008 and 2012. These changes would involve replacing the tyre production moulds for every tyre size in each family, even if only one or two tyre sizes in that family did not meet the new noise limits in 2008 or 2012. A factory typically has many identical moulds, each turning out one particular tyre size in the 'family', so many moulds would be

involved. ETRTO informed us that the cost figure of 2 Billion Euros did not include such mould replacement.

We comment on the issue of mould replacement as follows:

- (i) Moulds are replaced regularly, as tyre lines are discontinued. It is therefore not appropriate, either in cost benefit or accounting terms, to include the whole cost of replacing moulds, if a tyre line producing one particular tyre size is discontinued earlier than would be the case without the proposed changes in the Directive.
- (ii) The ETRTO explanation appears to assume that all the moulds for an entire family would have to be replaced, i.e. for all widths of a given tyre brand, even if only a few of the individual tyre widths in that family were unable to meet the proposed new tyre noise limits. This appears untenable. The production of tyre widths that do meet the proposed new tyre noise limits is not prohibited by the Directive.

The tyre industry has informed us that their research and development expenditure is around 3.5-5% of their sales in the EU. This equates to around 400 million Euros per annum, which of course covers the development of tyres that meet all necessary parameters, e.g. durability, skid resistance. Even if the industry were now to increase their entire research and development expenditure by 50 % for six years to meet the proposed new noise limits for 2008 and 2012, this would only amount to 1.2 Billion Euros extra work. This figure is considerably smaller than the benefit of 48-123 billion Euros.

We have also analysed ETRTO's 2 Billion Euro/annum figure to see what could be achieved with this. If 1500 million Euros/annum were spent on research and development engineers, each costing 100000 Euros per annum, this would provide 15000 full-time research and development staff. 500 million Euros per annum would remain for facilities. This level of research and development effort appears unnecessary, given that the technology already exists to comply with the proposed new noise limits, and that this technology is in widespread use in tyre production today.

For the reasons given in the previous paragraphs, and because ETRTO has not told us what their 2 Billion Euro/annum figure relates to, the cost estimate figures offered by the industry are considered to be very significant overestimates.

7.6.1 Transition provisions

When new Directives are introduced, transition provisions may be incorporated. For example, Euro IV exhaust emission standards became mandatory for new cars that were put on sale for the first time from 1 January 2005. However, cars that only met Euro III standards were allowed to remain in production for 12 further months, if they had been on sale prior to 1 January 2005.

Transition provisions might be added to the Directive in order to reduce costs to the tyre industry. However, the long notice period of impending tightenings that was provided by the 2001 version of the Directive appears to suggest that any transition provisions should be strictly limited in scope and duration.

As an illustrative example, manufacturers might be permitted to market any individual tyres that were first type approved between 1 January 2003 and 31 December 2005 for a grace period of 18 months beyond the introduction of the 2008 limit.

7.6.2 Financial incentives and consumer choice

Some member states may wish to provide financial incentives for consumers and businesses to buy particularly low noise tyres, for example as part of their noise action plans due in 2008. Such incentives need to be transparent, and resistant to fraud. These incentive schemes would stimulate a market for tyres that performed well in the type approval test, which might assist the tyre industry with any transitional costs of meeting the proposed new noise limits.

It was previously mentioned in chapter 6 of this report that some consumers may wish to demonstrate environmental responsibility by choosing tyres that have scored well in the type approval test. A low score in the test might also be an indicator to consumers of tyres that would provide lower noise levels within their vehicles, particularly when purchasing after market tyres.

If tyres were either stamped with the noise level that they scored in the type approval test, or could be advertised as 'low noise' by virtue of the tyre meeting a given threshold noise level, this would assist member states that are considering incentive schemes, and would improve consumer choice.

7.7 Summary and Discussion of the results of Work Package 4

The changes that are proposed to the Directive will provide lower noise exposure for the public. The public is the only stakeholder group that will be affected significantly.

The total Benefit to the public has been calculated for EU25 member states, for the reductions in traffic noise that would result from the proposed changes in the noise limits. This calculation assumes that benefits will fall in the period 2010-2022. The calculation is based on two modelled predictions for the effects of the new noise limits, for C1 tyres only. The predictions are, at the lower end, a reduction of 0.9 dB(A), for a conservative model. At the upper end, the reduction predicted by an optimistic model would be 2.3 dB(A). These noise reduction figures lead to an estimate of benefits to the public in the range of 48 to 123 billion Euros. Benefits due to the proposed new noise limits for C2 and C3 tyres would increase these figures substantially.

In addition to the benefits in the preceding paragraph, there would be some benefits for national and regional authorities, vehicle manufacturers, EFTA member states and many states outside the EU. Some benefits may accrue to construction companies. The value of these benefits is not included in the estimated range of benefits of 48-123 billion Euros.

The costs of meeting changes to the Directive will fall on tyre manufacturers. These costs will relate to discontinuing the production of some current tyre designs that would not meet the proposed noise limits. Tyre industry representatives have provided a cost figure for changes to C1 tyres that appears significantly higher than seems likely, for the changes that can reasonably be recognised in a benefit cost study. However, even the cost figure

from industry is considerably smaller than the lower predicted value of benefits to the public of 48 billion Euros.

Any costs suffered by the tyre industry could be reduced by transitional provisions in the Directive. These would allow continued production of some tyre lines that did not meet the new limits, but only for a relatively short period of time and for some particular tyre designs.

If the Directive were to specify that tyres must be stamped with the noise level that they scored in the type approval test, this would assist member states that are considering incentive schemes. It would also improve consumer choice.

8 Work Package 5: Conclusions and Recommendations

The work described in the previous four Work Packages have provided conclusions and recommendations that relate to the specific objectives of the study that were described and set out in chapter 4 of this Report. Further technical details that support these recommendations are also available in the literature review given in full in Appendix A. This Work Package provides a comprehensive review of the main conclusions and recommendations from the completed study.

Work Package 1: Potential for reducing tyre noise limits

The results of the work reported in Work Package 1 cover a broad range of topics. Primarily it reports on the analysis of the datasets assembled for use in this study that examine the relationships between tyre noise levels and other factors such as tyre type, safety performance and rolling resistance. However, included in this Work Package is a comprehensive review of the technical literature relevant to tyre noise type approval and a report on consultations with the tyre industry and other stakeholder groups. The main conclusions from Work Package 1 are as follows:

1. A comprehensive database of tyre noise measurements taken using the procedure described for tyre noise type approval was compiled from different sources. This was supplemented by measurements of tyre/road noise that were used to provide additional information. In total the type approval datasets included 171 C1 class tyres, 19 class C2 tyres and 98 class C3 tyres. The data on tyre/road noise included 100 tyre sets. (Further details are given in Section 4.2).
2. Data on wet grip, aquaplaning performance and rolling resistance were also available for 82 of the class C1 tyres tested. Wet grip and rolling resistance measurements were included for 4 of the C2 tyres and 18 of the C3 tyres. (Further details are given in Section 4.2).
3. A very detailed literature review was completed and this is provided in full in Appendix A of this report. This has provided valuable additional information to support the analyses reported in each of the Work Packages.
4. Several meetings and discussions were held, during the course of the work, with representatives from the tyre industry (European Tyre and Rim Technical Organisation, ETRTO) and with other stakeholder groups. The stakeholder groups consulted included EUCAR-ACEA (European Council for Automotive R&D and the European Automobile Manufacturers Association) and EARPA (European Automotive Research Partners Association), CLEPA (European Association of Automotive Suppliers), ECTRI (European Conference of Transport Research Institutes) and ERF (European Union Road Federation). In addition to general discussions, a more specific consultation letter has been sent to each of these organisations. A further consultation, open to a wider audience, was addressed via a webpage featured on the FEHRL website. A summary of the main discussion points is included in Section 4.6 of this report.

5. The analysis of the datasets clearly show that for each of the tyre classes studied, the noise levels generated under conditions of type approval vary over wide ranges. Moreover it is clear that practically all C1 tyres currently in service or have been in service since the regulations were introduced produce noise levels, under conditions of type approval testing, that are well below the current limit values. It was found that less than 4% of the sample gave higher values than the current limits and about 50% of the sample gave levels that were 3 or more dB(A) below the current limits. These results demonstrate that the introduction of the type approval tyre noise limits has had little impact on overall traffic noise levels and hence the impact of traffic noise on communities. This point was also made by the tyre industry representatives. (Further details are given in Section 4.3).
6. No evidence could be found either as part of the analysis carried out for this report or from published literature of a significant relationship between tyre noise and safety performance. This result is perhaps understandable given the commitment by the tyre industry to ensure that all tyres in production meet adequate safety standards. Given the large ranges in tyre noise levels for a given tyre class, there are many examples in the data assembled for this study of tyres that produce relatively low noise levels and yet perform well in terms of safety performance. (Further details are given in Section 4.4).
7. No significant relationship between tyre noise and rolling resistance could be found from the available data. It was noted that car tyre manufacturers place the reduction of tyre rolling resistance high on their list of priorities when designing new tyre types. Given the strong influence of the market for fuel efficiency, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise. (Further details are given in Section 4.4).

Work Package 2: Review of the proposed emission limits

The results of the analysis carried out as part of Work Package 1 showed that there is considerable scope for lowering the tyre noise type approval limits without sacrificing other important factors such as safety and fuel economy. Work Package 2 considers the degree of reduction that should be implemented bearing in mind what can be achieved technically, given an appropriate lead in period, and what is desired in terms of the impact that such reductions might have.

In general, it was found that reduction in the limit values of the order of 5 dB(A) were technically achievable and would be needed if significant reductions in traffic noise were to be achieved. The main findings from this Work Package are:

8. Some changes to the definitions of the tyre classes for C1 tyres were justified. Firstly, for the smallest car tyres it appeared that tyres in the previous classes C1a, C1b and C1c could be combined into a single new class (C1a_new). Essentially all tyres with a section width < 185mm would be included in this new class. This change recognises the fact that there is no compelling evidence to suggest that tyres in this category produce noise levels that are markedly dependent on tyre width. Consequently a single noise limit for these tyres is justified. The major and growing share of the market is for tyres with section widths 185-215 mm and 215-245 mm. These important tyre classes are treated separately in the proposals and, recognising, the weak dependence on tyre width for these tyres some

allowance in the limit values are proposed for these groups. These tyre classes are labelled (C1b_new) and (C1c_new) respectively. For very wide tyres > 245 mm there is some evidence to suggest that higher noise levels are justified. To accommodate this tyres with section widths greater than 245 mm are divided into two groups, ie. 245-275mm and tyres > 275 mm. These tyre classes are labelled (C1d_new) and (C1e_new) respectively. Essentially in order to accommodate the effects of tyre width on noise from the larger tyres in the market, the proposals replace the single class > 215 mm in the current Directive with 3 width classes.

9. Limit values are recommended which mean effective reductions of between 2.5 and 5.5 dB(A) for C1 tyres and between 5.5 and 6.5 dB(A) for commercial vehicle tyres in categories C2 and C3. With these reductions significant reductions in traffic noise and hence impact on communities can be achieved. It is proposed that these reductions would be phased in two stages with the greatest reductions required by 2012. Details of the current and recommended limits for each tyre class are given in Tables 5.2, 5.3 and 5.4 of this report (reproduced below). The relative decreases in the limit values are also given in these Tables. This takes into account that the fact that the current method of rounding the measured values differed substantively from that recommended in future. Currently the recorded value is rounded down to the nearest integer and 1 dB(A) is subtracted. For future limit values it is recommended that the values are rounded to the nearest integer value with no subtraction of 1 dB(A). This new procedure is in line with the method adopted in the revised Directive for motor vehicle noise emission. Further details of this recommended change can be found in section 6.3.1 of this report.

Table 5.2: Current tyre noise limits for C1 tyres (rounding down and 1 dB(A) reduction)

Current tyre class	Nominal section width (mm)	A (current)	B (2007-2009)	Relative decrease compared to current limit value	C (date not specified)	Relative decrease compared to current limit value
C1a	• 145	72	71	1.0	70	2
C1b	> 145 • 165	73	72	1.0	71	2
C1c	> 165 • 185	74	73	1.0	72	2
C1d	> 185 • 215	75	74	1.0	74	1.0
C1e	> 215	76	75	1.0	75	1.0

Table 5.3: Proposed tyre noise limits for C1 tyres (rounding to nearest integer value)

New tyre class	Nominal section width (mm)	B (2008)	Relative decrease compared to current limit value	C (2012)	Relative decrease compared to current limit value
C1a_new	• 185	73	0.5 - 2.5	71	2.5 – 4.5
C1b_new	> 185 • 215	74	2.5	72	4.5
C1c_new	> 215 • 245	74	3.5	72	5.5
C1d_new	> 245 • 275	75	2.5	73	4.5
C1e_new	> 275	77	0.5	75	2.5

Table 5.4: Proposed tyre noise limits for C2 and C3 tyres

Tyre class	Nominal section width (mm)	2008	Relative decrease compared to current limit value	2012	Relative decrease compared to current limit value
C2	Normal	73	3.5	71	5.5
	Snow (M+S)	74	4.5	72	6.5
	Special	76	3.5	74	5.5
C3	Normal	73	4.5	71	6.5
	Snow (M+S)	75	4.5	73	6.5
	Special	77	3.5	75	5.5

10. The proposed limit values should apply to replacement and retreaded tyres in order to maximise impact on traffic noise levels.

11. It is recommended that the definition of “special” tyres is clarified when the Directive is revised. Special tyres are normally tyres that can be used for both on-road and off road use and at restricted speeds. During the course of this study, agreement was reached with ETRTO on the definition of special tyres. For “special” C1 tyres an increase of 1 dB(A) over the proposed limits for a given tyre class is recommended.

To accommodate these changes the following text is advised which would replace clause 4.2.1.2 of the current Directive;

“C1, C2 and C3 tyres can be classified as “special” tyres when the following conditions apply;

- *The tread depth ≥ 11 mm;*
- *The void to fill ratio ≥ 35 %;*
- *The speed symbol maximum Q (160 km/h);*
- *They have a mud and snow marking.*

For C1 tyres the limit values given in the tables shall be increased by 1 dB(A)."

12. No significant difference in noise levels could be found for winter and summer tyres. The proposed limits for C1 tyres should therefore be applied to both summer and winter models. (See Section 4.3).
13. The current Directive allows a further 1dB(A) above the specified limits for reinforced C1 class tyres. With limited data it was found that "reinforced" C1 tyres were not any noisier than normal tyres of the same tyre class. It is therefore proposed to remove the 1 dB(A) allowance. This will mean deleting clause 4.2.1.1 of the current Directive.
14. In order to determine the effects on traffic noise of the proposed changes to the tyre noise limits, two noise prediction models, HARMONOISE and TraNECam, were used. It was found that there was considerable agreement between model predictions if the input assumptions were similar. As a result there can be greater confidence in the predictions made. Predictions were made for a range of scenarios from motorways to congested urban conditions. (Further details are given in Section 5.3).
15. If the proposed noise limits on C1 tyres (for light vehicles) are introduced but not for C2 and C3 (commercial vehicles) the following predictions were made for the reduction in traffic noise on a common type of road surface in Europe stone mastic asphalt (SMA) with maximum chipping size in the range 8-11 mm. (i) The 'HARMONOISE' model, with conservative input assumptions e.g. a reduction in tyre/road noise of 2 dB(A) on real roads, predicted reductions in the average level L_{Aeq} of 0.6 - 1.1dB(A) (average 0.9 dB(A)). (ii) The 'TraNECam' model with optimistic assumptions e.g. a reduction in tyre/road noise of 5 dB(A) on real roads predicted reductions in day, evening and night level L_{den} of 1.1-3.4dB (average 2.3 dB(A)).
16. If the proposed limit values for all tyres (C1, C2 and C3) are introduced, greater benefits were noted. Although predictions have not been carried out with HARMONOISE, average levels were predicted with TraNECam using the optimistic assumptions that tyre/road noise of all vehicles would be reduced by 5 dB(A). This showed that on SMA11 the reduction in traffic noise in terms of L_{den} ranged from 1.2 to 3.8 dB(A). The reduction across the scenarios modelled was 3.0 dB(A). Further analysis is required to model the changes that would occur if the proposed reduction in limit values for all tyres (C1, C2 and C3) produced a smaller effect on real roads than the assumed value of 5 dB(A). (Further details are given in Section 5.3).
17. It is likely that technological developments will allow greater reductions in tyre/road noise and it is recommended that the limit values are reviewed before 2012 to determine whether the recommended limit values are still relevant and whether there is scope for further reductions in these limits.. This would involve an analysis

of the most recent tyre noise test results and a consideration of the state-of-the art in low noise tyre designs at that point in time.

Work Package 3: Amendments to the tyre noise Directive other than the tyre noise limits

This Work Package considered the need for additional tests of tyre safety performance and tyre rolling resistance that could be introduced alongside the requirements for tyre noise testing. It also considers the possibility of marking tyres with information on their tyre noise levels as a means of informing consumers and, thereby, encouraging a market for quieter tyres. Finally, other technical amendments to the test procedure are considered and recommendations made, where appropriate. The main conclusions from this Work Package are:

18. Although there is no evidence in current tyre performance data that reducing tyre noise levels will have a noticeable effect on tyre safety, it is not possible to guarantee that for some future designs of tyre there will not be a conflict between noise and safety. Consequently, it is recommended that adequate safeguards are put in place with regard to tyre safety performance. This may mean the introduction of a test for tyre safety performance. However, such a supplement to the Directive should not delay the introduction of the revised limits and other changes that have been recommended. The safety requirements may well be introduced at a separate time if they need more time for consideration and preparation. (Further details are given in Section 6.1.1).
19. None of the studies reviewed in this report could detect a significant conflict between requirements for low noise and low rolling resistance. There is a strong influence in the market place regarding fuel efficiency and it is expected, therefore, that tyre manufacturers will continue to strive to keep rolling resistance values at the lowest possible values. Consequently, as with tyre safety, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise. Nevertheless, it is not possible to speculate beyond the ranges provided by the data so it is important to ensure that any reductions in tyre noise imposed by tightening the type approval limits is also accompanied by sufficient controls on tyre rolling resistance. This may mean the introduction of a simple test to ensure tyres conform to acceptable standards in this regard. However, as was stated above for safety, a supplement to the Directive related to rolling resistance should not delay the introduction of the revised limits or other recommended changes to the Directive. (Further details are given in Section 6.1.2).
20. Consideration should be given, when revising the current Directive, for including a requirement for tyre manufacturers to label tyres according to their noise emission. This could be in the form of a noise level stamped on the sidewall. An alternative would be to label tyres as 'low noise' provided they meet an agreed threshold that is set below the agreed noise limit. Threshold levels could be set at 3 dB(A) below the proposed limit values. (Further details are given in Section 6.2).
21. Improvements that could be made to the test procedure when the Directive is revised have been considered. These are presented in two groups. The first are recommended to be implemented as part of the current revision as they are fully developed and can be introduced without further research. The second group include changes that could be considered over the longer term either because they

require a major change to the process of tyre noise testing or they require the collection of additional data.

22. The recommended amendments to the test procedure as part of the current revision are detailed in section 6.3.1 and include:

- Changes to the method of rounding the measured values. The new procedure would simply round the test result to the nearest integer. These suggested changes would then bring the tyre noise measurement practice into alignment with the rounding procedures specified in the proposed revisions to the separate vehicle noise type approval procedure. This change in the procedure would itself mean a lowering of the threshold that is actually enforced.

The recommended changes will mean deleting section 4.4 of the test method specified in the current Directive and amending section 4.5 to read as follows:

‘The final result, the temperature corrected noise level, shall be rounded to the nearest whole number – fractions of 0.5 shall be rounded up’;

- Consideration of the specification of the test vehicle. This would include tightening the specification of the test vehicle so that large differences in test results that could be attributable to vehicle shape are avoided in the future. In particular, vehicle types should be avoided that offer little or no screening of the farside tyres. The considerations concerning wheel loading, wheel alignment, the wheel arch and the fitting of mudflaps, spray suppression devices and sound absorption treatments that are detailed in the current directive should be retained. The specification of the wheelbase of the vehicles used for testing should be updated to ensure that the tyres being tested are fitted to test vehicles that would, in practice, be appropriate for those tyres. This is particularly important for C2 tyres. It is recommended that the relevant section in the Directive relating to the wheelbase of the test vehicle (i.e. section 2.4.3 of the Directive) is amended as follows:

“The wheelbase between the two axles fitted with the test tyres shall for Class C1 and Class C2 be less than 3.5m and for Class C3 tyres be less than 5m.”

- The procedure for correcting the test result for temperature variation could be changed to a method based on air temperature rather than surface temperature as this will then offer greater harmonisation with recently developed temperature correction models. However, the requirement to measure both surface and air temperature, as stated in the current Directive, should be retained for the present. Temperature corrections based purely on air temperature could produce misleading results where the track is artificially heated;
- Although changes to the test surface are recommended for the longer term (see recommendation 23 below). Some changes to the specification of the test surface can be made now as part of the proposed revision of the Directive. These relate to the work within the ISO Working Group 42, aimed at reducing the variability between various test tracks.

23. Longer term changes to the Directive are described in section 6.3.2 of the report and include the following:

- Consideration should be given to changing the test surface used for type approval. A test surface based upon a 10 or 11 mm aggregate would seem to be the most appropriate choice given the trend towards replacing existing roads with a similar type of surface. An alternative would be to retain the existing surface as representing smooth lower noise surfaces common in many European urban areas and to introduce an additional test surface with a 11mm or greater maximum chipping size. The second surface would then represent common surfaces on higher speed roads. The test requirements would include achieving acceptable levels on both surfaces;
- Consideration should be given to extending the current test to include lower speeds. This would help to ensure that tyre noise is controlled for a wider range of conditions;
- Consideration should be given in the longer term to alternatives to the current test procedure. Possible alternatives include the use of drums, tests in close proximity to the test tyre and the use of mathematical models;
- Consideration of the condition of tyres presented for type approval. There is a case for testing tyres that are partly worn as opposed to testing in new condition. Further work is required to consider the appropriate degree of wear and how to achieve a suitably worn tyre;

Work Package 4: Benefits and costs of lowering the tyre noise limits

This Work Package considers the overall monetary benefits and associated costs of implementing the proposed noise limit reductions. Other benefits such as health benefits of reducing noise levels have been discussed but not monetised in the analysis. The main conclusions from the Work Package are:

24. The changes that are proposed to the Directive will provide lower noise exposure for the public. The public is the only stakeholder group that will be affected significantly.
25. The total Benefit to the public has been calculated for EU25 member states, for the reductions in traffic noise that would result from the proposed changes in the noise limits for C1 tyres. This calculation assumes that benefits will occur in the period 2010-2022. The calculation is based on two modelled predictions for the effects of the new noise limits, for C1 tyres only. The predictions are, at the lower end, a reduction of 0.9 dB(A), for a conservative input assumption. At the upper end, the reduction predicted by optimistic input assumptions would be 2.3 dB(A). These noise reduction figures lead to an estimate of benefits to the public in the range of 48 to 123 billion Euros. Benefits due to the proposed new noise limits for C2 and C3 in addition to those proposed for C1 tyres would increase these figures further. (Further details are provided in section 7.5)

26. The estimate of 48-123 billion Euros does not include additional benefits that will accrue to national and regional authorities, vehicle manufacturers, EFTA member states and many states outside the EU.
27. The costs of meeting changes to the Directive will fall on tyre manufacturers. These costs will relate to discontinuing the production of some current tyre designs that would not meet the proposed noise limits. Tyre industry representatives have provided a cost figure that appears significantly higher than seems likely for the changes that can reasonably be recognised in a benefit cost study. However, even the cost figure from industry is considerably smaller than the lower end of the range of benefits of 48 billion Euros. Any costs incurred by the tyre industry could be reduced by transitional provisions in the Directive. These would allow continued production of tyre lines that did not meet the new limits, but only for a relatively short period of time. However, most tyres in current production already meet the limits proposed for 2008, and many meet the limits proposed for 2012. This provides compelling evidence that the costs of researching and developing the tyre technology needed to meet the proposed limits have already been invested. (Further details are provided in Section 7.6).
28. The Directive should specify that tyres must be stamped (labelled) with the noise level achieved in the type approval test. This would assist member states that are considering incentive schemes and would improve consumer choice. See also recommendation 20 under Work Package 3 above.
29. There may be advantage in comparing the benefits and costs of further tyre noise reductions, beyond the proposed new 2012 limits, with the noise benefits of: Very low noise road surfaces; Financial incentives for scrapping older commercial vehicles; Intelligent speed adaptation equipment as 'speed limiters' in vehicles.

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Glossary of abbreviations and acronyms

ACEA	European Automobile Manufacturers Association
BASt	Bundesanstalt für Strassenwesen (Germany)
CALM	Directorate General RTD Coordination of Community Noise Research
CLEPA	European Association of Automotive Suppliers
CPX	Close-proximity
EARPA	European Automotive Research Partners Association
EC	European Commission
ECTRI	European Conference of Transport Research Institutes
END	European Directive on Environmental Noise
ERF	European Union Road Federation
ETRTO	European Tyre and Rim Technical Organisation
EU	European Union
EUCAR	European Council for Automotive Research and Development
FEHRL	Forum of European National Highway Research Laboratories
HRA	Hot Rolled Asphalt
IEA	International Energy Authority
ISO	International Organisation for Standardisation (Geneva, Switzerland)
SILVIA	Project acronym. Silenda Via (Sustainable road surfaces for traffic noise control)
SINTEF	Foundation for Scientific and Industrial Research, Norwegian Institute of Technology
SMA	Stone Mastic Asphalt
TRL	Transport Research Laboratory (United Kingdom)
TUG	Technical University of Gdansk (Poland)
TÜV	Technischer Überwachungs – Verein (Technical Inspection and Monitoring Union), Germany

UBA	Umweltbundesamt (Federal Environmental Agency), Germany
UTAC	Laboratoire de l'Union Technique de l'Automobile, du Motorcycle et du Cycle (France)
VTI	Statens Väg- och Trafikinstitut (National Road and Traffic Research Institute) (Sweden)