

Tyre/road noise – Assessment of the existing and proposed tyre noise limits

by G R Watts, P M Nelson, P G Abbott, R E Stait and C Treleven

**PPR 077
PPAD 9/107/22 SO325/VB**

PUBLISHED PROJECT REPORT



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TYRE/ROAD NOISE – ASSESSMENT OF THE EXISTING AND PROPOSED TYRE NOISE LIMITS

Version: Final



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Prepared for: Project Record: S0325/VB – Tyre / Road Noise 2004
Client: Cleaner Fuels and Vehicles Division, Environmental Standards Branch, Department for Transport (Mr P Greening)

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Executive summary

TRL has been commissioned by the Cleaner Fuels and Vehicles Division, Environmental Standards Branch of the Department for Transport (DfT) to carry out a programme of research to evaluate the effects that lowering the tyre noise limit values would have on actual levels of traffic noise. In particular, TRL have been asked to investigate how reducing tyre noise will affect wet grip adhesion, rolling resistance and hence fuel economy. In order to assess the economic effects of lowering the tyre noise limits, the work also includes a Regulatory Impact Assessment (RIA). This itemises the main costs and benefits associated with the proposed changes. It is intended that the results of this work will be used to inform and support the development of UK policy on tyre noise type approval and tyre noise limits.

This is the final report of this work programme that started in August 2004 and finished in November 2005. It describes the method of study adopted and presents the results obtained.

The programme of work specified by the DfT is divided into six main tasks, listed below:

- Task 1:** Assess the effectiveness of the current EU tyre noise limits in terms of actual reductions in tyre/road noise achieved on common UK road surfaces.
- Task 2:** Assess the potential reduction in noise limit values that could be achieved before having an adverse effect on wet grip adhesion.
- Task 3:** Assess the probable effect of applying the noise limits indicated by Task 2 on the rolling resistance of tyres and hence assess the implications for fuel economy and CO₂ emissions.
- Task 4:** Recommend optimal tyre noise limit values based on the findings of Tasks 2 and 3.
- Task 5:** Examine other methods for reducing tyre noise, including an examination of the current test procedure.
- Task 6:** Assess the potential costs of the noise limits set out in columns B and C of the table in Annex V, section 4.2.1 of the Directive (2001/43/EC). In particular to make Regulatory Impact Assessment for the measures recommended in Tasks 4 and 5.

An important aspect of the work was the development of a database collected from previous studies that have examined tyre noise, safety performance and rolling resistance. It was important to include noise surveys where measurements were carried out according to that described in the Directive for tyre noise type approval. Four major surveys were identified that satisfied the requirements of the study. These databases, when combined, gave measured data for a total of 147 different tyre sets. In addition a database relating to wet grip and rolling resistance for a range of tyres, including truck tyres, has also been compiled.

From the analysis of this data it was found that practically all car tyres that are currently in service or have been in service since the regulations were introduced produce type approval noise levels that are well below the current limit values. Of the 147 tyres tested according to the type approval procedure over 13 years it was found that only two would fail the current noise limits.

The analysis of the relationship between tyre noise and safety performance indicated evidence of a weak correlation trend between noise and measures of wet grip adhesion. In all cases examined, the data exhibited considerable scatter indicating that a great deal of the variance in the noise levels cannot be explained simply in terms of relative safety performance. There are many examples of tyres that produce relatively low noise levels and yet perform well in terms of wet grip.

Tyre rolling resistance currently accounts for approximately 30% of the fuel used by cars, so it is an important component governing fuel consumption. In addition, 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. This is a significant factor affecting the generation of greenhouse gases. The analysis has shown that there is no significant relationship between tyre noise and rolling resistance. It is not expected therefore that there should be any noticeable effect on vehicle fuel economy and the emissions of greenhouse gases.

By considering the reductions in tyre noise that would be needed to effect improvements in the environmental impact of tyre noise, together with the reductions that appear to be technically feasible without affecting safety performance and fuel economy, a new noise limit value of 71 dB(A) is recommended as the future limit value for all tyre widths apart from tyres with a nominal section width greater than 245 mm. For these tyres a limit value of 73 dB(A) is proposed. The proposed reductions would apply from 1 July 2010. However, with most current tyres producing noise levels that fall well below the existing tyre noise limits, it is also recommended that some reduction in the limits can be made earlier in 2008. The proposed new limits are summarised in the Table below. The current limits are given under the column labelled 'A'.

Proposed new tyre limit values

Tyre class	Nominal section width (mm)	Limit values in dB(A)		
		A	B ¹	C ²
C1a	≤ 145	72	71	71
C1b	> 145 ≤ 165	73	72	71
C1c	> 165 ≤ 185	74	72	71
C1d	> 185 ≤ 215	75	73	71
C1e	> 215 ≤ 245	76	73	71
C1f	> 245	76	75	73

¹ Limit values shall apply from 1 July 2008.

² Limit values shall apply from 1 July 2010.

The project also examined other methods for reducing tyre noise. Methods that are discussed include the use of fiscal incentives to help create a market for lower noise tyres and tyre noise labelling to influence consumer choice. The continuing development of lower noise road surfaces and greater control of speed is also considered to help lower tyre noise levels. Finally improvements to vehicle design that help to shield tyre noise and techniques that assist motorists in maintaining the correct inflation pressures to their tyres will also help to reduce tyre noise levels.

A review is also made of the current test method. In particular it is recommended that the test surface is changed so that it is more closely representative of the surfaces commonly encountered on real roads. It is also recommended that the test is amended to include an assessment of tyre noise at lower speeds that would be more consistent with urban driving. Finally the method of treating the raw test data to produce the final result should be changed. It is recommended that the current method of rounding down and subtracting 1 dB(A) should be replaced with a method that involves just rounding to the nearest integer level. It should be noted that the proposed limit values given in the table already take into account the changes to rounding procedure.

The study also considered alternative test methods to the current drive by test. Suitable candidate procedures include the use of drums, and measurements taken in close proximity to the test tyres.

Close proximity testing removes test result variability associated with propagation effects but requires a high initial cost in equipment development, which can introduce issues associated with reproducibility.

The RIA has provided information on tyres for the UK passenger car sector. The annual recurring benefits to the UK of the lower tyre noise limits proposed in Table 6.3 of this report would amount to a minimum of £1,205 million (£1.205 billion). These benefits appear, at the very least, to be a factor of ten greater than the costs that would be incurred. The low response rate to the RIA consultation appears to indicate that there is little concern among car manufacturers and government about the proposed changes.

The industry body representing tyre manufacturers had concerns about the most restrictive option for lower noise limits that was put to them in the RIA consultation in February 2005. However, the noise limits proposed in table 6.3 of this report are neither so restrictive as those in that option, nor would they come into force so quickly. Another option in the RIA consultation concerned tyre noise limits that are slightly more restrictive than the ‘indicative limits’ in Directive 2001/43/EC. The industry body commented that under certain conditions, these changes might “*be integrated in the natural evolution of improvement in tyre performance*”.

The 2005 noise limits in Directive 2001/43/EC for tyres fitted to new cars will eventually be applied to replacement tyres between 2009 and 2011. Around 140 million tyres are likely to be sold between 2005 and 2010. When future reductions in noise limits are applied to tyres for new cars, there appears no credible economic case for such a long delay before applying the same reductions to tyres sold as replacements. Indeed, the reasons for a delay do not appear as strong as the benefits that would be foregone.

1 Background and introduction

For the European Union (excluding the new member states) it has been estimated that approximately 80 million people are exposed to unacceptably high noise levels (Lambert, 2000). Of the many sources of noise that affect people, road traffic noise is by far the most pervasive. For example, in the UK over 90% of the population hear traffic noise whilst at home and about 10% regard their exposure to this source of noise to be highly annoying.

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, to reducing the propagation of noise into sensitive areas through road alignment considerations and the use of screening 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 attempts to control noise along the propagation path 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 but can be reasonably categorised to form two main groups. One group of sources tend to be dependent on the operation and speed of the engine and include sources related to the combustion process, gas flow noise and mechanical noise. These are collectively known as power train sources.

The second group of sources relate to the speed of the vehicle and are mainly related to the noise generated by the tyre/road interaction. 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 surface interaction 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) and the costs including the wider issues such as safety and durability. However, despite these complexities, over the past two decades considerable advances have been made in controlling power train noise through improved vehicle engineering backed up by progressive legislation.

Vehicle noise type approval procedures have been introduced within the European Union and limit values imposed for all new vehicle types. Over the last 20 years there has been progressive tightening of the limits to both encourage innovation and to reflect the improvements made in vehicle design.

For tyre noise, however, progress has been significantly slower. There are concerns that lowering tyre noise will affect wet grip for some tyre designs and this has tended to slow progress. As a result, it was only relatively recently that similar controls for tyre noise were introduced within the EU. In 2001, Directive 2001/43/EC was published (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 and widths 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 the 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.

To help inform this process TRL has been commissioned by the Cleaner Fuels and Vehicles Division, Environmental Standards Branch of the Department for Transport (DfT) to carry out a programme of research to evaluate the effects that lowering the tyre noise limit values would have on actual levels of traffic noise in the community.

In particular, TRL have been asked to investigate how reducing tyre noise may affect wet grip adhesion, rolling resistance and the associated effects on fuel economy and emissions. The research is to include an assessment of the costs and benefits and to establish the overall regulatory impact of such measures.

It is intended that the results of this work will inform the basis upon which UK policy on tyre noise reduction will be agreed and will help to provide technical input to the process of revising the tyre noise Directive.

The programme of work specified by the DfT is comprised of six main tasks:

- **Task 1.** Assess the effectiveness of the current EU tyre noise limits in terms of actual reductions in tyre/road noise achieved on common UK road surfaces;
- **Task 2.** Assess the potential reduction in noise limit values that could be achieved before having an adverse effect on wet grip adhesion;
- **Task 3.** Assess the probable effect of applying the noise limits indicated by Task 2 on the rolling resistance of tyres and hence assess the implications for fuel economy and CO₂ emissions;
- **Task 4.** Make recommendations for optimal tyre noise limit values based on the findings of Tasks 2 and 3;
- **Task 5.** Make recommendations for alternative measures to reduce noise from tyres operating on common UK road surfaces, for example by making improvements to the test procedure or by recommending an alternative test.
- **Task 6.** Assess the potential costs, cost effectiveness and regulatory impact of the noise limits set out in columns B and C of the table in Annex V, section 4.2.1 of the Directive (2001/43/EC). In particular to make regulatory impact assessments for the measures recommended in Tasks 4 and 5.

This report describes the programme of work undertaken, the results obtained and the conclusions reached.

2 Preliminary work

It was decided in developing the methodology for this work that the most cost effective approach would be to make use of existing databases that had been collected as part of other projects. Tyre/road surface noise and tyre adhesion/economy issues have attracted considerable research interest in recent years both in the UK, particularly at TRL, and at various institutions in other countries. As a result there exists a considerable body of data that could be of benefit to this project.

Although the collation and analysis of these data forms the main method of approach, it was also decided that a small measurement programme would be included. The data obtained from the measurement programme would be used to supplement the existing databases. A full description of this measurement programme is given later in this report.

In addition to the approach outlined above it was decided that some of the questions raised require specialist input from experts working both in and close to the tyre industry. The study design therefore allowed for input from tyre industry representatives and from an independent tyre consultant contracted to TRL for the duration of this study.

This section provides an overview of the databases that have been collated for use in this study and the work done in organising them in a form amenable for analysis. The section also provides summaries of the results of the discussions held with representatives from the tyre industry.

2.1 Collation of databases

An important aspect of the project is the development of a 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. Four surveys have been identified which include data on coast-by noise levels assessed according to the tyre approval test method (Commission of the European Communities, 2001). The relevant data from these surveys have been compiled to create a database consisting of 147 tyres. Each tyre in the database has a unique tyre code and information regarding the tyre dimensions, coast-by noise levels and other relevant information which has been collated from the appropriate reports identified below.

In addition, a database relating to wet grip and rolling resistance for a range of tyres including truck tyres has also been compiled.

The following sections provide a brief review of each of the databases collated.

2.1.1 Databases relating to coast-by noise levels under type approval test conditions

- **TRL 1993**

TRL was commissioned by the Department of Environment, Transport and the Regions (DETR) to carry out a detailed study of tyre noise emission and tyre safety issues (Nelson *et al.*, 1993). The original database contains detailed noise and wet grip data on 16 car tyres and 12 truck tyres running on different road surfaces including the ISO¹ surface. The information contained in this database will be of value in establishing noise level baseline information prior to the introduction of tyre noise type approval. Although the data collected in this survey is now over ten years old, it does represent a population of older design tyres that were in use when the Directive was first introduced and therefore

¹ This is a test track surface standardised in ISO 10844 (International Organisation for Standardisation, 1994). It was initially intended for use in vehicle noise type approval but is also used as the test surface for tyre noise type approval.

assist in determining the benefits of type approval testing. Table 2.1 provides a summary of the data included in the database.

Table 2.1: Details from TRL 1993 survey included in the database

Test Vehicle	Number of Test Tyres	Range of Tyre Widths (mm)	Additional information
Escort 1.8L diesel estate	8	155 – 195	Noise and skidding performance on ISO and Hot Rolled Asphalt (HRA) surfaces including truck tyres
Peugeot 405 GL petrol saloon	8	165 – 195	

- **TUV 2002**

TUV Automotive GMBH has completed a large test programme comparing some 82 passenger car tyres for rolling noise, rolling resistance and wet braking. The work formed part of a common project to support the development of a procedure to determine the wet grip of passenger car tyres and was jointly supported by German, British and Dutch Government Ministries. The report, published in December 2002, is highly relevant to this study and will provide a useful addition to the databases that will be used in the analysis (Reithmaier and Salzinger, 2002). The data set contains examples of both OEM and aftermarket tyres. Table 2.2 provides details included in the database.

Table 2.2: Details from TUV 2002 survey include in database

Test Vehicle	Number of Test Tyres	Range of Tyre Widths (mm)	Additional information
VW Polo 1.2	3	155	Includes data on rolling resistance, wet braking and aquaplaning
Skoda Fabia 1.4 MPI	35	165 – 185	
VW Golf TDI	21	195	
BMW 320d	23	205 – 225	

- **M+P 2003**

TRL has access to a database provided by the Dutch Noise and Vibration Consultants M + P (Roovers, 2003). The database consists of 26 passenger tyres that were widely available in 2002. The database consists of tyre noise levels taken from measurements carried out in accordance with the EU Directive. Additional data includes cruise-by noise levels. Corresponding data collected on double-layer porous asphalt is also included. Table 2.3 provides details included in the database.

Table 2.3: Details from M+P 2003 survey include in database

Test Vehicle	Number of Test Tyres	Range of Tyre Widths (mm)	Additional information
Peugeot 206	9	175 – 195	Includes cruise-by data and data for double layer porous asphalt
VW Passat	15	195 – 225	

- **TRL 2003**

A major study commissioned by DETR and the Highways Agency has examined the relationships between vehicle tyre and road surface design, and their influence on tyre/road noise (Phillips *et al.*, 2003). In this comprehensive study measurements were taken on 29 passenger car tyres, 4 van tyres and 11 truck tyres. Seven road surfaces including the standard ISO surface were used in the test programme resulting in over 170 different tyre and surface combinations. This dataset will be of value in determining the relevance of the ISO surface for tyre noise and its relation to noise generation on typical UK road surfaces. It will also be useful in providing baseline data on tyre noise and indicating the potential for tyre noise reduction given the range of tyre types available in 2002 when the main measurement programme was completed. Table 2.4 provides details included in the database.

Table 2.4: Details from TRL 2003 survey include in database

Test Vehicle	Number of Test Tyres	Range of Tyre Widths (mm)	Additional information
Suzuki Vitara	25	155 - 225	A total of seven surfaces examined including noise from van and truck tyres.

2.1.2 Databases relating to wet grip and rolling resistance

- **TRL 1993**

This is the same study described for section 2.1.1 where TRL was commissioned by DETR to carry out a detailed study of tyre noise emission and tyre safety issues (Nelson *et al.*, 1993). The original database contains detailed noise and wet grip data on 16 car tyres and 12 truck tyres running on different road surfaces including the ISO surface.

The information contained in this database will be of value in establishing a baseline level of wet grip performance prior to the introduction of tyre noise type approval. Although the data collected in this survey is now dated, it does represent a population of older design tyres that were in use when the Directive was first introduced and will therefore assist in determining any adverse effects that type approval testing may have had on wet grip. The data can also be used to compare the wet grip performance of the sample tyres with noise performance measured on the same surface. Table 2.1 provides details included in the database.

- **VERT, 2001**

VERT (*Vehicle road tyre interaction - Full integrated and physical model for handling behaviour prediction in potential dangerous situations*) was an EC funded 4th framework programme to study tyre road interaction from the point of view of generating computer models capable of simulating the effect of tyre road interaction on vehicle handling behaviour (Vidal and Parry, 2002). In order to identify all of the factors affecting tyre grip, a range of more than 800 friction tests were carried out involving 19 different tyres in a wide variety of conditions involving different measuring equipment, surface, speed, water depth and tread wear. Outputs were recorded in terms of peak and locked longitudinal friction as well as cornering friction.

No measurements of noise were carried out during this programme so direct correlation between noise and wet grip is not possible within this dataset. However, the data may be very useful for benchmarking the levels of grip available and for identifying the influence of the test conditions on the results, which may help to explain differences found between studies that aim to correlate wet grip and rolling resistance.

- ***TUV 2002***

TUV Automotive GMBH has completed a large test programme comparing some 82 passenger car tyres for rolling noise, rolling resistance and wet braking. Reference to this database was also made in section 2.1.1.

- ***MIRA, 2002/3***

MIRA were commissioned by the DfT to develop a test method for the assessment of wet grip of truck tyres, including the specification of equipment to enable the tests (Alstead and Whitehead, 2003). The study was then to include the measurements of the wet grip of a group of tyres as well as the rolling resistance of truck tyres. TRL has obtained the reports relating to the development of the test method and the measurement of the rolling resistance. However, the second phase of the work to measure wet grip did not take place so that data is not available.

The database of rolling resistance contains results relating to 60 tyre types. This data will enable the current rolling resistance of truck tyres to be benchmarked but no correlations with grip or noise will be possible using this dataset (Alstead and Whitehead, 2002).

2.2 Discussions with tyre industry representatives

During the course of the work, meetings / discussions were held with representatives from the tyre industry (ETRTO, the European Tyre and Rim Technical Organisation) and with a tyre technology consultant employed by TRL to provide specialist advice as required. The main objectives of the meetings and discussions were to ensure that the views of the tyre industry were adequately represented in the project and were fully taken into account when developing the recommendations arising from the work. Also, as part of the work involved a small measurement programme to supplement existing tyre data, it was important to make sure the views of the tyre industry and the consultant were included when selecting tyres for this programme.

The following sections summarise the main points arising from these discussions. Details of the recommendations for the selection of tyres for the test programme are given later in this report.

2.2.1 Discussions with the tyre technology consultant

- To date, no evidence exists to suggest that any tyre manufacturer has produced a product specifically targeted to reduce tyre noise at the expense of wet grip or any other tyre property. This would be against the commercial interests of leading tyre manufacturers. They are required to work closely with their vehicle manufacturing customers' own testing and specification regimes;
- It may be expected that the introduction of a tyre noise regulation test and quieter road surfaces should result in lower tyre/road noise. However, the trends in tyre size (and vehicle type) tend to nullify this situation. This may be influenced by both tyre size and tyre construction, including the rapidly growing market for fail safe/run flat types of tyres;
- Research has indicated that there is only a weak relationship between tyre noise levels when measured on the smooth textured ISO surface (ISO 10844) and road surfaces with greater texture levels typical of the surfaces that are likely to dominate the major UK road network until 2010.

This position may have a number of important influences. First, as experience is gained by the tyre industry in terms of developing new tyre designs on the standard ISO test surface this position could worsen, particularly if noise limits are revised downwards. This implies that consideration could be given to selecting two or more test surfaces in any future revision of the noise regulations;

- It should be feasible to optimise the tyre tread pattern design against a given surface, as may be seen from further new tyre designs produced on the current ISO surface. Alternatively, a more progressive development strategy could be related to an understanding between the highway engineers, on an international basis, as to the most desirable and feasible form of road texture that possesses satisfactory wet friction, low noise and has a minimal effect on tyre rolling resistance.

2.2.2 Discussions with ETRTO

The following main points were raised by ETRTO representatives:

- OEM tyres currently need to comply with the Directive, but for replacement tyres the regulation only applies after October 2009, with the actual date depending on tyre width. The limit values will be reviewed by the EC and a report produced concerning “whether and to what extent technical progress would, without compromising safety” allow the introduction of the limit values indicated to apply beyond July 2007. If new limit values are adopted, there will be a period of grace for which previously approved tyres that meet the old limit but not the new will be allowed.
- 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 at TRL 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, such as Hot Rolled Asphalt (HRA) which is widely used in the UK for both urban and highway applications. This observation clearly has a bearing on the effectiveness in practice of the type approval regulations. It was noted that TRL are involved with ISO WG42TT, which will consider a replacement surface after improvements in the specification of the current surface have been completed.
- It was emphasised by ETRTO that there was a very loose relationship between wet grip and noise levels because many factors have an influence. Again, it was stressed that the data is dependent on the method and test track used, so it would be essential to test all the tyres identified as part of this study at a single facility.

3 Task 1: Establishing the effectiveness of the current regulations

This part of the project is concerned with establishing whether the current tyre noise type approval regulations have had, or will have, any measurable effect on the levels of traffic noise as determined at the roadside. In order for an effect to occur, it follows that the regulations have in some way influenced the types of tyres entering the market, resulting in a measurable change in overall noise levels from traffic streams. The degree of change would be dependent on the tyre population, the numbers of tyres removed from the market as a result of the tyres failing the type approval test, the time since the regulations were introduced, the operating characteristics of the traffic stream, its composition and the type of road surface.

Ideally, in order to establish the effectiveness of the current type approval regulations, measurements of vehicle and traffic noise before and after the introduction of the regulations could be taken and the results compared. However, there are a number of reasons why this direct approach cannot be used in this case.

First, it should be noted that the original Tyre Noise Directive (2001/43/EC) only began to take effect in the UK in 2003 and so there has been little time for any benefits resulting from the imposed limit values to become measurable in practice. Although this may provide an opportunity to establish the situation prior to the introduction of the regulations, any measurable benefits would take some time to be realised and fall outside the timetable of this project.

Secondly, there are inherent problems associated with normalising data taken over a period of time. Weather conditions, traffic flow and composition and the condition of road surfaces are all subject to change, and the effects of these changes on the measured levels have to be removed from the analysis if the true effects of the regulations are to be exposed.

Finally, the noise limits imposed in the original Directive were not particularly stringent and it is likely that most tyres produced prior to the regulations would comfortably meet the current limit values. Therefore, the effects of the regulations, in terms of reductions in traffic noise levels, are likely to be small and therefore difficult to identify from direct measurements.

For these reasons it was decided that the best approach to accomplish this task was to use a traffic noise model. The model required for this purpose would need to be able to take, as input, changes in tyre noise levels and convert these into vehicle and traffic noise levels for a range of different scenarios. The data used as input would have to take into account the numbers of tyres removed from the market following the introduction of the regulations and the rate of replacement with newer, quieter tyres.

A further issue that would need to be considered is associated with the method of testing tyres. The current test requires the tyres to be run over a track surface conforming to the surface specified in ISO 10844. This surface was originally designed for use in vehicle noise testing and was deliberately designed to be a smooth surface to produce relatively low levels of tyre noise. There is concern therefore that the surface is not representative of other, more coarsely textured, surfaces commonly used on roads in the UK. Clearly, if it is found that the noise levels produced on the ISO surface are not consistent with the noise levels produced on other surfaces this will influence the effectiveness of the current regulations and the effectiveness of any reductions in limit values in the future.

The following sections describe the analysis of these issues and the conclusions reached.

3.1 Comparison of tyre noise levels and the current limit values

To assist in comparing tyre noise levels with the current limit values the database as described in section 2.1.1 was used. Figure 3.1 shows the relationship between tyre noise levels² derived from type approval measurements and tyre tread width from each of the surveys described in section 2.1. A total of 147 data values are shown in the figure. Also shown in the figure are the current nominal limits for each tyre category as defined in the Directive and the actual limits before the values are rounded down and the 1 dB(A) is subtracted.

The figure illustrates that only two of the 147 tyres tested would fail the current noise limits, representing about 1% of the sample. This result demonstrates that the introduction of the type approval tyre noise limits has had little impact on overall traffic noise levels.

A further point worth noting in the data set is the large range in noise levels obtained for each individual tyre type examined. In each of the main tyre categories the range in levels is about 6 dB(A), which represents a very large difference in noise from the noisiest to the quietest tyre. Provided all tyres in the dataset provide an acceptable standard of performance with regard to safety and fuel economy etc., there would appear to be considerable scope for reducing limit values without compromising other important aspects of tyre performance. This observation will need further examination, although it is worth noting at this juncture that all the data given in the figure was obtained from tyres that either were or are currently in common use.

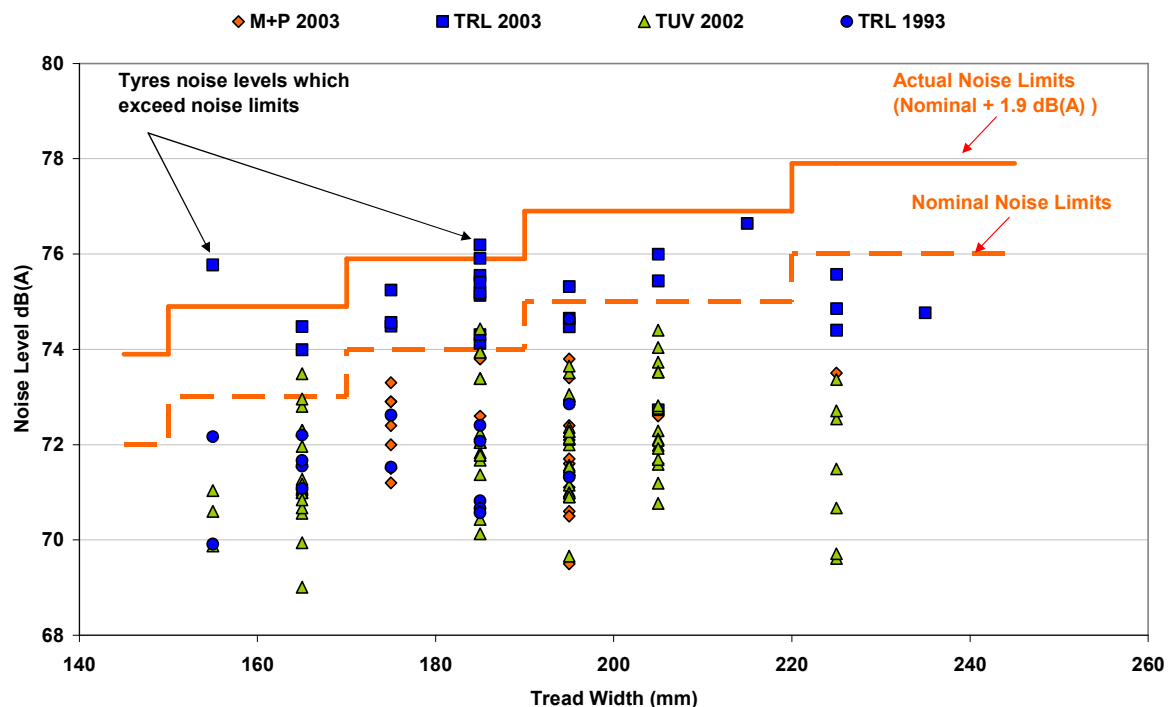


Figure 3.1: Noise levels under type approval for a range of tyres compared with noise limits

A similar result was obtained in a separate study of 48 car tyres conducted by Stenschke and Vietzke in Germany in 2000. In this study none of the tyres examined gave noise levels that exceeded the current limits (Stenschke and Vietzke, 2000).

It is interesting to consider the situation well before the Directive came into force. In an earlier study of 45 passenger car tyres carried out at TRL and UTAC (Laboratoire De L'Union Technique De L'Automobile, Du Motorcycle et Du Cycle, France) and reported during 1993 it was shown that only one tyre of those studied would fail the current requirements. The report of this work was summarised in a paper provided for the 26th Session of GRB (Phillips, 1996).

² All noise levels have been temperature corrected to 20°C as described in the Directive.

Other researchers have, however, indicated higher failure rates than that shown in the above surveys. In a study reported in 1995 (van Blokland and de Graaf, 1995) the average and standard deviation of maximum pass-by noise levels together with the 80 percentile levels were determined for a range of tyres of different section width. These values are reproduced in Table 3.1 below.

It can be seen that the average level depended on section width and ranged from 72.1 for the narrowest (<145 mm) to 75.4 dB(A) for the widest tyres (>235 mm). These values are well below those given in the current directive which effectively range from 73.9 to 77.9 dB(A) after allowance is made for the 1 dB(A) addition for equipment inaccuracies and for rounding down. The 80th percentile of the distribution is shown in the table and compared with the actual noise limits. Clearly, at least 80% of the tyres would pass the current limit values, and of the remaining tyres it is difficult to estimate the percentage of failures but examining the standard deviations suggest a higher failure rate than that estimated from this study.

Table 3.1: Tyre noise values (van Blokland and de Graaf, 1995)

Section width (mm)	Mean	Standard deviation	80 th percentile ¹
≤145	72.1	1.9	73.7 (73.9)
155-165	72.8	1.9	74.4 (74.9)
175-185	73.5	1.8	75.1 (75.9)
195-225	75.0	1.7	76.5 (76.9)
≥235	75.4	1.7	76.8 (77.9)

¹ Values in brackets are actual limit values

Sandberg reported the results of an analysis of a large database consisting of about 150 tyres (Sandberg and Ejsmont, 2002). The study indicated that about 9% of the tyres studied would fail the current limits. However, the majority of tyres that failed in the analysis reported by Sandberg were estimated using a trailer method and not derived using the method described in the Directive. This should be taken into consideration if conclusions on the effectiveness of the Directive are drawn from this analysis.

A further consideration of the effectiveness of the current limits is in relating type approval levels measured on the ISO surface with values derived from similar measurements on typical road surfaces. In the TRL survey reported in 2003 (Phillips *et al.*, 2003), the correlation was not found to be significant between coast-by noise levels measured on the ISO surface with corresponding levels measured on an HRA surface (see section 3.3).

This lack of correlation can have important consequences when considering the overall benefits of tyre noise type approval. For example, the level for one of the tyres which failed the current limits on the ISO surface was found to be 1.1 dB(A) higher compared with the average value of those tyres which passed. However, on the HRA surface, the level for the same tyre was 1.1 dB(A) lower than the average for the same data set. Clearly, eliminating this tyre from the population as a result of failing the type approval test would have no effect in reducing noise levels from traffic travelling on coarser road surfaces such as HRA.

Overall, the evidence assembled both before and close to the introduction of the Directive clearly indicates that there is little likelihood of a significant proportion of tyres being rejected due to their failure to meet the current type approval limits. There is some evidence that there is a tendency for increased noise as tyre section width increases and that this may be true for a range of surfaces. A further point to note is that the time taken for type approved tyres to fully enter the vehicle fleet is of the order of 10 years according to one estimate (Sandberg and Ejsmont, 2002) and there will remain a percentage of the tyre population that will be unaffected. This is the case for re-treaded tyres which may account for a significant proportion of tyre sales. In Sweden the estimate is as high as 25%.

It can therefore be estimated that the effects of the current regulation will be very small indeed and that any affect may not be fully realised for a number of years.

3.2 Trends in tyre usage in the UK

In the tyre noise Directive, car tyres are classified in terms of their width and then different limit values applied. The following Table defines the category descriptions used and current limits applied.

Table 3.2: Current tyre noise limits

Tyre class	Nominal section width (mm)	Current limit values dB(A)
C1a	≤ 145	72
C1b	>145 ≤ 165	73
C1c	>165 ≤ 185	74
C1d	>185 ≤ 215	75
C1e	>215	76

Tyre noise limit values are set to be lowered by 1 dB(A) in 2007 for categories C1a, C1b and C1c, in 2008 for C1d, and in 2009 for C1e. There are also plans to reduce the limit value for C1a, C1b and C1c tyres by a further 1 dB(A) following a report required in Article 3(2) of Directive 2001/43/EC. It should be noted that the two widest categories (C1d and C1e) are not expected to have reduced limit values.

It is difficult to determine with precision the tyre population on UK roads. This would require information of many years of tyre sales data, and information on vehicles that have been removed from the roads and scrapped, together with the associated tyre sizes. However, a reasonable estimate can be made of the tyre population by examining the general trends in tyre sales.

Figure 3.2 shows the trend in tyre sales in the UK over approximately the past 10 years³. Although the 1993 data only accounts for 74% of the tyres sold in the UK, it is still useful as a means of establishing trends in tyre sales. Data from 1997 accounts for almost 98% of sales, and data from 2003 accounts for over 99%.

Overall the data shows that the numbers of wider tyres sold in the UK have tended to increase in the last few years, with the most popular category of tyre now being in the C1d range. The narrower tyres (≤ 165mm width – categories C1a and C1b) have decreased significantly. However, it should be noted that category C1d has a larger range of tyre widths than categories C1b and C1c, which may account for some of the rate of growth. A possible reason behind this change seems to be related to style, as consumers tend to prefer the ‘sporty’ appearance of wider tyres.

It can also be seen that tyres of category C1e (>215mm) have increased since 1997, mainly due to the increase of sales of Multipurpose and Sports Utility Vehicles (SUVs).

While the past few years have indicated a growth in the sales of wider tyres there are some indicators that suggest that this trend will now slow down. First, the nature of vehicle sales appears to be changing. Figure 3.3 shows the percentage of vehicle sales for 2000 to 2004. The figure shows that the supermini segment is becoming increasingly popular at the expense of the lower medium and upper medium segments. This effect is likely to affect the sales of tyres in category C1c which could see an increase in their popularity.

³ Data on tyre widths were obtained from a combination of sources. 1993 data obtained from TRL’s study on tyre noise and safety, 1997 data obtained from a TRL database and data in 2003 and 2004 from private communication with the consultant to the project.

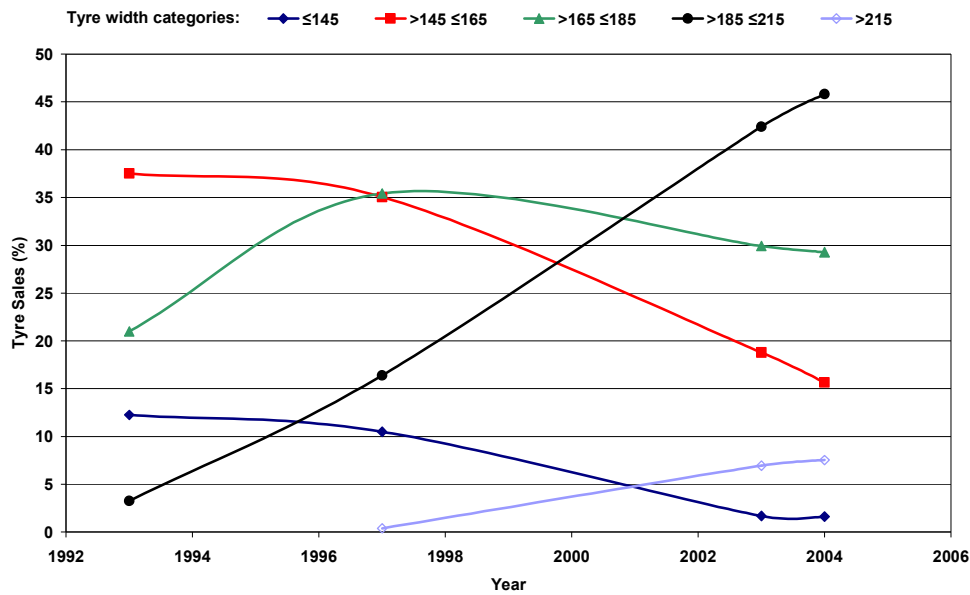


Figure 3.2: Percentage tyre sales in the UK from 1993 to 2004

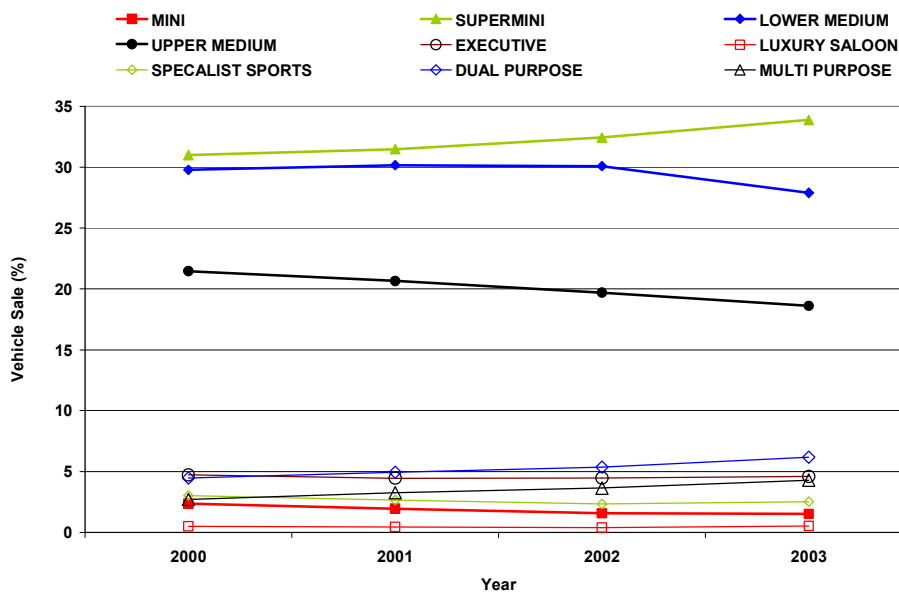


Figure 3.3: Percentage vehicle sales in the UK from 2000 to 2004

While Multipurpose and Sports Utility Vehicle (SUV) sales are currently increasing, which typically have large tyres (C1e), several European governments are considering introducing large tax penalties for SUVs, which, if effective, will tend to slow tyre sales growth in this sector. In addition, many major European OEMs have introduced large scale cost reduction programs and commonality programs, to improve profitability. It is likely that the control of costs and the desire to have common components across different vehicles are likely to slow down the trend for the larger tyres.

3.3 Relevance of the ISO test surface for UK conditions

3.3.1 Comparison of the tyre noise levels on different 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. Ideally there should be a close correlation so the effects of reducing limit values on the ISO surface will produce corresponding reductions on other surfaces.

An examination of tyre noise on different surfaces was carried out by TRL and the results were published in 2003 (Phillips *et al.*, 2003). A summary of the regression statistics found between the noise levels produced by seven tyre sets on six surfaces are given below in Table 3.3. It can be seen that the ISO surface performs particularly poorly when correlated with other surfaces⁴. A full description of the relationships found between the ISO surface and the other surfaces are given in Appendix A.

Table 3.3: Relationship of ISO surface with other surfaces

Surface	Intercept	Regression statistics	
		Slope	Correlation coefficient (r)
HRA	60.2	0.28	-0.05
SMA14	63.6	0.21	0.26
MARS14	83.8	-0.06	-0.05
Brushed concrete	71.5	0.11	-0.24
Colsoft	83.3	-0.06	-0.14

Further analysis of this data has been recently carried out after correcting noise levels for differences in surface temperature, using the procedure detailed in the Directive. The results from this further analysis showed no significant improvement in the correlation coefficients as described above.

Table 3.4 gives the summary of these reductions for the three surface types commonly found on UK roads together with the confidence intervals for the estimated slope and the correlation coefficient squared (R^2). The latter represents the fraction of the variance explained by the regression.

Table 3.4: Estimated average reduction in tyre noise for a 5 dB reduction on the ISO surface

Surface	HRA	Concrete	SMA
Predicted noise reduction	1.41	0.54	1.03
95% confidence limits	±0.67	±0.58	±0.44
R^2	0.04	0.03	0.10
% of 5 dB(A) ISO reduction	28	11	21

⁴ MARS14 is a prototype surface laid on the TRL test track. It is bituminous in character and described as a porous surface dressing. This particular surface has a 14 mm maximum stone size aggregate. Colsoft is a proprietary surfacing made with 10 mm max size aggregates and a proportion of crumb rubber. SMA is Stone Mastic Asphalt and is a surfacing material that is now regularly used on UK trunk roads and motorways. It is a gap graded material with high binder content and a very high stone content. This particular surface has a 14 mm maximum aggregate size. The concrete surface referred to in the table is a transversely brushed concrete.

3.3.2 Surfaces used on roads in the UK

In order to gauge the overall benefits in terms of reduced traffic noise impact of introducing the tyre noise limits, it is important to provide information on the proportions of different road surface types used in the UK, both currently and estimated for the future.

Some available information on London roads, produced during the recent noise mapping exercise, was found. A summary is given in Table 3.5. Although the available data confirms that bituminous surfaces are the dominant surface type no further breakdown of these types of surface is possible. However, it is believed that Hot Rolled Asphalt (HRA) is the main surfacing used particularly on heavily trafficked and main roads in the network. The majority of roads in London are subject to a 30 mph speed limit.

Table 3.5: Road surfacings in London (based on information supplied for the London Noise Map)

Surface type	Total length (km)	Percentage of total length
Bitumen	4,962	95.0
Pervious	153	2.9
Other (includes brushed, textured or surface dressed concrete or HRA with surface dressing)	108	2.1
Total	5,223	100

For higher speed roads the available data source was obtained for the Highways Agency network of motorways and trunk roads. Table 3.6 lists this data for 2001 and the predicted breakdown for 2003. It can be seen that the percentage of thin surfaces is increasing rapidly and is expected to have almost trebled over the two years studied⁵ and by 2010 be the dominant surface. This is largely as a result of a reduction in the lengths of HRA, although there are some reductions in the lengths of all other surfaces.

⁵ Thin surfacings are bituminous surfaces which have a smaller stone size than HRA (typically 10 – 14mm maximum compared to HRA which uses a 20 mm stone). Also HRA uses stones rolled into the surface bitumen which tend to produce a more aggressive texture than thin surfacings.

Table 3.6: Road surfacings on the Highway Agency network (McRobbie *et al.*, 2004)

Surface type	2001 (actual)		2003 (predicted)	
	Total length (km)	Percentage of total length	Total length (km)	Percentage of total length
HRA	12,726	72.3	11,007	62.5
Thin surfaces	1,364	7.8	3,559	20.2
Concrete	962	5.5	832	4.7
Surface dressing	1,429	8.1	1,236	7.0
High friction surface	100	0.6	87	0.5
Unknown	1,028	5.8	889	5.1
Total	17,609	100	17,609	100

Both on low and high speed roads the current dominance of HRA is indicated, although with the greater use of thin surfaces, this dominance is reducing, as HRA has not been used for re-surfacing on high speed roads for at least five years. By 2010, the Highways Agency expects to have thin surfaces on 60% of the road network (Department of the Environment, Transport and the Regions, 2000a).

3.4 The effects of the current tyre noise limits on traffic noise

In order to determine the effectiveness of changes in tyre noise levels it is necessary to make use of a model that can convert individual source levels to traffic noise levels for a range of traffic scenarios. For the purpose of this study the recently constructed HARMONOISE model has been used⁶. The following sections briefly describe the model and provide some example calculations.

3.4.1 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 (rolling noise) and is located close to the road surface and the other represents mainly the propulsion unit 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 rolling 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.

⁶ The HARMONOISE project (August 2001-January 2005) produced methods for the prediction of environmental noise levels caused by road and railway traffic. These methods are intended to become the harmonised methods for noise mapping in all EU Member States. Validation and further work is being done within the IMAGINE project (www.imagine-project.org).

Regarding the surfaces used in the model, an SMA6, the reference surface⁷, and an SMA14 were modelled. HARMONOISE employs a simple correction, based on maximum chipping size to account for noise levels differences between surfaces. The surface correction only applies to light vehicles (category 1). No corrections are available for heavy vehicles (categories 2 and 3). For HRA the correction to rolling noise was based on an analysis of UK data developed within the SILVIA (Silenda Via: Sustainable road surfaces for traffic noise control) project (Morgan, 2005).

3.4.2 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 on the Highways Agency network indicates that HRA was the major surface type in 2001, representing 72.3% of the total. It is Highways Agency policy to have 60% of the network surfaces with thin surfaces by 2010, so it is therefore essential to also consider SMA for any future predictions.

- **Changes in L_{Aeq} resulting from reductions in tyre noise.**

The HARMONOISE model was used to calculate the influence of reducing tyre/road noise of light vehicles on the average noise at the roadside. For this purpose a number of typical traffic/road surface scenarios were examined based on national statistics. The graphs and further details of these calculations are included as Appendix B.

- **Summary of the results obtained from the HARMONOISE model**

The results of running the HARMONOISE model for different road traffic scenarios are summarised in Table 3.7. The values given in the table are the calculated reductions in the L_{Aeq} assuming that the tyre noise component is reduced by 5 dB(A) for light vehicles (category 1). It can be seen that the largest effects are found on roads with:

- o The largest stone size (HRA);
- o The lowest proportion of heavy vehicles;
- o The highest speeds.

⁷ The reference surface is the HARMONOISE model is defined as a virtual reference surface on which the basic values of HARMONOISE are based. It is the average of SMA11 and DAC11 of one year or older but not at the end of its life time.

Table 3.7: L_{Aeq} reductions resulting from a 5 dB(A) reduction in tyre noise on various surfaces

Model input parameters			Calculated traffic noise level reductions L_{Aeq} for different surfaces, dB(A)			
Average speed	% 2 axle heavies	% > 2 axle heavies	SMA6	Ref.	SMA14	HRA
<i>Urban roads subject to 30 mph limit</i>						
50 kph	3	0.6	1.9	2.2	2.5	3.1
	10	2	1.1	1.3	1.5	2.1
<i>Roads subject to 40 or 50 mph limit</i>						
70 kph	3.8	6.4	1.5	1.7	1.9	2.5
55 kph	3.4	2.7	1.7	1.9	2.2	2.7
<i>Motorways</i>						
112 kph (96 kph for trucks >2 axles)	4.5	9.1	1.6	1.8	2.1	2.4

The largest reduction of 3.1 dB(A) was found for the urban road surfaced with HRA with an average vehicle speed of 50 kph and a low heavy vehicle flow.

As illustrated The London survey (Casella Stanger, 2004) indicated that 92% of roads were bituminous (thought to be mainly HRA) and a survey of the trunk road network showed that 63% is currently HRA. For an appreciation of the current situation, it is therefore reasonable to assess the overall benefits in the UK of lowering the noise limits by examining the expected affects on the HRA surface.

If it is assumed that if tyre noise limits are reduced by 5 dB(A) for light vehicle tyres (C1 tyres) on the ISO surface the relationships indicated in Table 3.3 can be used to estimate the reduction in tyre noise on different surfaces and the consequent changes in L_{Aeq} for the different road traffic situations examined. The best estimates for the decreases on HRA are given in Table 3.8 below. However, it should be borne in mind that there is considerable uncertainty in these predictions due to the poor correlation between noise levels generated on the ISO surface and HRA. In addition, although the HRA surface is currently the dominant surface on UK roads, by 2010 it is expected that low noise surfaces will form the dominant (60%) surface on high speed roads (Department of the Environment, Transport and the Regions, 2000a). Although the predictions made for the HRA surface are currently the most applicable, by 2010 this will be only the second most in-use surface on high speed roads.

Table 3.8: The estimated reduction in L_{Aeq} on HRA following a reduction of 5 dB(A) in the tyre noise limit value

Model input parameters			Predicted reduction on HRA due to 5 dB(A) reduction in test value
Average speed	% 2 axle heavies	% >2 axle heavies	
<i>Urban roads subject to 30mph limit</i>			
50 kph	3	0.6	0.99
	10	2	0.72
<i>Roads subject to 40 or 50 mph limit</i>			
70 kph	3.8	6.4	0.83
55 kph	3.4	2.7	0.89
<i>Motorways</i>			
112 kph (96 kph for trucks >2 axles)	4.5	9.1	0.79

It can be seen that even under the most favourable condition of light traffic (3% medium goods vehicles and 0.6% heavy goods vehicles) travelling at 50 kph the reduction is estimated to be only 1 dB(A).

A further consideration is that the type approval limits currently apply only to OEM tyres, i.e. tyres fitted to new vehicles. The regulations for replacement tyres will be effective from October 2009 for tyre sizes up to a section width of 185 mm. For wider tyres up to 215 mm the effective date is October 2010 and for widest tyres the date is October 2011.

At the present time it is likely that between 25-33% of car tyres will be OEMs, so that most of the noise produced will come from currently unregulated tyres. It is not clear to what extent the noise produced by replacement tyres relates to that produced by the equivalent OEM.

If a reduction in the tyre noise limit was applied to OEM tyres today, it would only take about three years before OEMs conforming to the new limit values were fitted to approximately 30% of the passenger car fleet. If we assume that OEM tyres are fitted to vehicles throughout the first three years of their lives, e.g. while the vehicle is serviced by a franchised dealer during a warranty period, then approximately 40-50% of total UK mileage will be on OEM tyres. This is because the newest vehicles cover significantly higher mean annual mileages than the remainder of the vehicle fleet.

Reductions in noise levels from replacement tyres will lead to a reduction in noise from the remainder of the UK vehicle fleet, i.e. the older vehicles. Within two years of reducing a noise limit for replacement tyres, well over 50% of miles driven by the older part of the vehicle fleet will be on tyres meeting that limit.

In summary, it can be concluded that given a reduction in the tyre noise limit of 5 dB(A) for C1 tyres, it is estimated that the overall reduction in the L_{Aeq} value is likely to be approximately 1 dB(A) on UK roads that are currently surfaced mainly with HRA.

4 Task 2: Potential reductions in tyre noise and the corresponding effects on safety

This part of the study is aimed at establishing the reductions in tyre noise that are possible given our current understanding of tyre technology and to establish what are the concomitant effects of such reductions on tyre wet grip adhesion and hence safety.

In establishing the approach to adopt in the analysis it is important initially to clarify the time lines associated with the changes envisaged. In this regard, it was felt important to focus on tyres that are currently commercially available but nevertheless reflect the latest thinking in tyre design and, as such, are expected to be influential market leaders in the short to medium term.

It was decided, therefore, that the method of analysis would be to initially establish what are the relationships between tyre noise levels and measures of safety performance using existing data. This analysis would then be supplemented with data on noise and safety obtained from a small measurement programme using some of the latest tyre designs.

The intention would be to take measurements on car tyres selected, following consultation with the tyre industry, that are not already adequately represented in the databases and also reflect the latest thinking in low noise tyre design in some of the most popular tyre sizes. It was anticipated that the additional data would help to establish whether or not there is a trade off between tyre noise levels and safety as well as establishing the technical feasibility of reducing the tyre noise limits in the next round of amendments to the Directive.

This section begins with a review of two key studies that have examined the relationships between tyre noise levels and tyre safety performance. This is followed by a description of the test programme carried out as part of this project. It concludes with an analysis of tyre noise and safety.

4.1 Previous studies of tyre noise and safety

4.1.1 TRL data, 1993

The objective of the work carried out by TRL in 1993 was to examine the relationship between tyre noise and various measures of safety for a sample of both car and truck tyres (Nelson *et al.*, 1993). Expressed in statistical terms, the study's principal aim was to either accept or reject the null hypothesis, i.e. "there is no relation between tyre noise and tyre safety performance". However, in addition, it was anticipated that the study would also help to identify whether certain tyre designs could be produced that offered the desirable combination of significantly lower noise whilst retaining good safety characteristics.

A total of 16 sets of car tyres and 12 sets of truck tyres were examined. In order to obtain a satisfactory range of tyre noise and skidding performance values the study design included tyres and types which were not the most frequently sold. For example, car tyres with low aspect ratios and larger wheel diameters than were commonly used at the time. For the same reason it was considered important to have as wide a range of tread patterns as possible, which meant selecting tyres from different manufacturers and not just the market leaders. In consequence, the final selection represented a compromise between ensuring that the most popular sizes and makes of tyre were included together with some examples of more specialised tyres to cover the market range. An attempt was made to include in the sample current generation tyres that were claimed by the manufacturers to be quiet.

Tyre noise measurements were taken using a coast-by procedure that was virtually identical to the current type approval test, although at the time the test had not been introduced as an EC standard. As well as taking noise measurements on the standard ISO surface, measurements were also taken on a section of 20 mm maximum aggregate HRA surface conforming to BS594 (British Standards Institution, 2003; British Standards Institution, 2005). Both surfaces were located on the TRL test track.

The assessment of tyre safety performance involved both the measurement of braking and cornering tyre forces on different wetted surfaces over a range of speeds.

The analysis of the data involved an examination of the correlation between noise and the various safety measures taken and included tests of significance and an analysis of variance to gain insight on the degree of causality between the variables examined. It was found that although in most cases there was a considerable degree of scatter in the data, in over 50% of the noise and safety comparisons examined, a weak but significant correlation between noise and safety was reported. As noise levels increased safety indicators tended to increase and vice versa. Overall, it was concluded that the null hypothesis stated above could reasonably be rejected when applied to the then current generation car and truck tyres.

Figure 4.1 shows some of the data obtained from the TRL study. The measure of safety performance used in the figure is the braking distance when reducing speed from 90 to 60 kph. The measurements used in determining these values were taken on the HRA surface⁸. It should be noted that while measurements of the locked wheel BFC is arguably the most important skidding performance measure of those studied, since it is under these conditions (i.e. locked wheel) that control is lost and the risk of an accident occurring is high, the braking distance between the two specified speeds provides a useful alternate form of expressing the safety performance rating of different tyres. This type of measure also offers the obvious advantage of being more readily understandable in relation to tyre safety considerations.

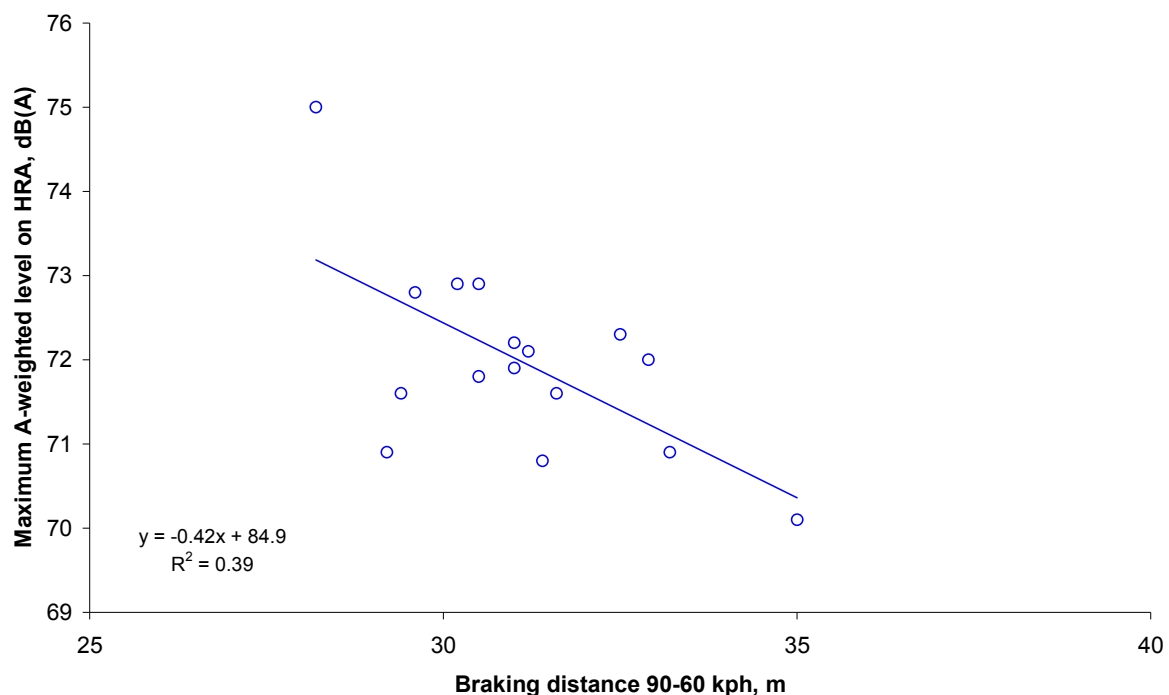


Figure 4.1: Maximum A-weighted pass-by noise level on ISO surface and braking distance on wet HRA at TRL

It can be seen that a trend between tyre noise and braking distance is indicated, which in this example was found to be significant. Similar results were obtained when the tyres were tested for noise on the

⁸ The calculations of braking distance required to reduce the speed of the vehicle from 90 - 60 kph under locked wheel conditions were carried out using the values derived from the regression lines of locked wheel braking force coefficient (BFC) taken at the two reference speeds assuming that a linear relationship between locked wheel BFC and speed exists over the speed range. The calculations involve the solution of the differential equations of motion. A full derivation of the relevant theory has been provided by Riley (1993).

HRA surface. The data also shows that apart from the overall trend exhibited, there is considerable scatter in the results indicating that there are examples of tyre types that produce both low noise characteristics and good standard of safety, when measured in terms of braking distance.

It was noted in the report, however, that ranking tyres in terms of safety performance was dependent on the type of safety measure being examined. Consequently, a particular tyre may stand out as a good performer when assessed in terms of one type of safety measure and yet not perform as well when assessed using a different safety indicator. This would indicate that tyre safety performance should be assessed using a combination of tests that would include both locked wheel braking, stopping distance on different surfaces and some aspects of handling such as cornering in order to establish the safety characteristics of the tyre.

A further examination of this TRL data was performed using multiple regression analysis. It was considered that tyre width would be an important variable for both wet grip and noise and should be included as an independent variable which may explain some variance in the data. The dependent variable was the maximum noise level during pass-by but both width W and braking distance BD were included as independent variables. The effects of including the tyre width had a marginal effect, the R^2 value increased from 0.38 to 0.39. The coefficient for braking distance changed from -0.44 to -0.36 and the coefficient for width was 0.013.

$$L_{A\max} = 0.013W - 0.362BD \quad (4.1)$$

4.1.2 TUV data, 2002

A more recent study carried out by TUV has examined the relationship between tyre noise, tyre safety (wet grip) and rolling resistance for a broad range of tyre types used on passenger cars in Germany. A total of 82 passenger car tyres were tested covering a range of summer, winter and all season types in common use. Further details of the tyre sample are given in section 2.1.1. Both 'premium' Original Equipment (OE) brands and low cost aftermarket examples were included. The selection of the test tyres was intended to be representative of the tyre market in Germany and covered tyres provided by all the main manufacturers included examples of the latest designs.

Noise measurements were taken according to Directive 92/93 ECE (amended with 2001/43EC) using a test track conforming to the requirements of ISO 10844. The safety measurements taken included aquaplaning and wet braking tests. The braking tests were carried out on an artificially wetted surface where the surface water depth was maintained to a depth less than 1.5 mm. This depth range was chosen to avoid the risk of aquaplaning during the tests. Tests of aquaplaning were carried out on a specially designed surface capable of maintaining a water depth of 8 mm.

An analysis carried out on the data provided in the report produced by TUV has been carried out by TRL. With regard to safety, an analysis of the braking distance from a speed of 80 to 10 kph on an asphalt surface was used as the wet braking measure. Figure 4.2 shows the scatter plot obtained from the data provided by TUV. In this case, although the trend line drawn through the data again shows a negative relationship between tyre noise and safety, the scatter of data points is more obvious than that found with the TRL dataset and the correlation coefficient was found to be much lower, i.e. close to zero.

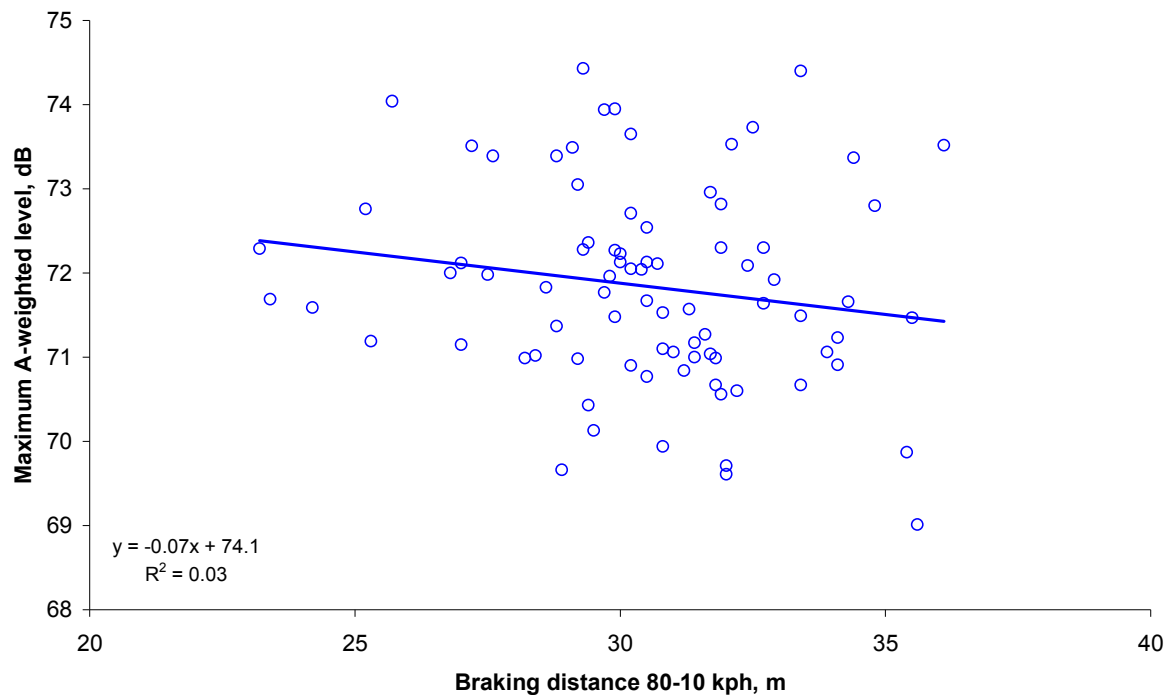


Figure 4.2: Maximum A-weighted pass-by noise level on ISO surface and braking distance on wet asphalt surface at TUV

Using a similar analysis to that used for the TRL data a multiple regression analysis was performed using tyre width and braking distance as independent variables. In this case the following relationship was found:

$$L_{A\max} = 0.01W - 0.05BD \quad (4.2)$$

After taking into account tyre width the variance (R^2) increased slightly from 0.03 to 0.06. The coefficient for the width variable is close to that for the TRL data but the coefficient for the braking distance variable is much smaller (-0.05 compared with -0.36 for TRL data). This may be because a smaller range of tyre sizes were used in the TRL study. Further data is required to examine the relationship in greater precision than is possible using these two studies.

As with the TRL dataset, it is clearly possible to identify tyres that produce relatively low noise on the ISO surface yet provide adequate skidding resistance.

4.2 Test programme

Initially the intention was to identify and test four sets of tyres that are representative of the latest developments in tyre designs. However, following further consultation with the tyre industry this original programme was extended to include seven further tyre sets recommended for testing by the European Tyre and Rim Trade Organisation (ETRTO). The rationale underpinning the choice of the original four tyre sets is presented below under the heading '*TRL tyre selection*'.

4.2.1 TRL Tyre selection (four sets)

The following issues were identified in developing the rationale for identifying suitable tyres to include in the programme of testing:

- The selection should reflect the current market both in terms of tyre size/design/market share and in terms of vehicle category. Most importantly from the point of view of achieving value in the current programme of study, there is a need to make a judgement as to the tyre size changes in the near future, i.e. up to five years beyond 2004.

During 2003/2004 the six most popular selling tyre sizes were 195/65R13, 175/65R14, 195/65R15, 205/55R16, 195/60R15, and 155/70R13.

- Over recent years the concept of directional tyres has been widely introduced. Directional tyres are those that have a tread pattern that is designed to operate best when rotating in one direction. This tread pattern development has the potential to enhance wet grip and also reduce noise. More recent trends in tread pattern design have combined the directionality and asymmetric ideas that may reduce noise further but also reduce bulk water removal. A small additional advantage to directional tread patterns is the possible reduction in the trajectory angle of water spray in very wet conditions. This could become significant as the overall diameter of tyres increases.
- For the tyre selection it is proposed that retreaded tyres are not considered. Retreaded tyres are those where the tread layer on a tyre has been replaced. These are generally only used for commercial, agricultural and industrial tyres.
- Winter tyre tread patterns represent a very small percentage of tyre sales within the UK and so are also not considered.
- The progressive introduction of run flat tyres or derivatives of this type needs to be taken into account when considering tyre selection for the measurement programme. While these tyres are currently only available on a small range of vehicles their use is expected to increase rapidly in the next few years with their introduction as standard fitment on some popular vehicles. For example, at the Geneva Motor Show in 2004 less than 50% of vehicles had a spare tyre fitted.

Given that the sample size is small, it is reasonable to base the selection on the main tyre groups which comprise the overall market for car tyres, i.e. small/medium cars, family saloon cars and SUV type vehicles.

Given these considerations and the availability of the required tyres, the tyre patterns selected by TRL for the study are listed below.

- **Tyre set 1. Small/Medium cars**
205/55R16 91V Bridgestone Turanza ER30, summer pattern.

The 205/55R16 is currently 69th on the tyre sales list and selling at ten times the rate of the 205/70R15. This latter tyre is 75th on the tyre sales list in 2004 and while being less popular in the UK than the first tyre listed does offer a link with a programme of research being carried out at VTI in Sweden. This type of tyre tends to be more common in Scandinavia due to the benefits provided by the higher aspect ratio tyres for winter performance.

- **Tyre set 2. Medium/Large cars**
The 225/45R17 91Y Continental Sport Contact 2.

This tyre size is 17th on the UK selling list and showing 33% growth in the period 2003 to 2004. The Continental tyre is the preferred selection as it provides the additional advantage of a link with the TUV project and is a tyre of common fitment to current medium to large cars.

- **Tyre set 3. Run flat fitment**
The 205/50R17 93V Run Flat, Goodyear Eagle RSA Extended Mobility Tyre (EMT).

This tyre is a modern run flat tyre that could greatly increase in popularity in the near future. While not yet a popular size, (260th on the 2004 selling list), it is showing some 64% growth over the year in normal construction. As recent low aspect ratio tyres, below 50 series, will exhibit harsher ride it will be of interest to compare the noise generation between these two tyre designs.

- **Tyre set 4. Present and future SUV size.**
*The 275/45R19 108Y Michelin 4*4 Diamaris.*

This tyre represents the SUV class of vehicle of present and future fitment. However, this is speculative as the fitments for SUV type vehicles ranges from 18 to 20 inch rim sizes. Combine the two sections already completed in the interim report that describe the tyres selected for the measurement programme.

All of these tyres were purchased by TRL from a local tyre dealership.

4.2.2 Additional tyre sets recommended by ETRTO (seven sets)

The tyres chosen by four ETRTO members were selected to represent some of the modern tyres in popular sizes that are sold across Europe. These were supplied by the individual partner to TRL. These tyres were:

- 195/65 R15 Michelin Energy E 3A;
- 205/55 R16 Michelin Pilot Exalto 2;
- 195/65 R15 BF Goodrich Profiler 2;
- 205/55 R16 Conti Premium Contact;
- 205/55 R16 Conti Premium Contact 2;
- 195/60 R14 Goodyear Eagle Ventura;
- 215/55 R16 Goodyear Hydragrip.

A photograph of these seven tyres and the four chosen by TRL is included in Appendix C.

4.3 Test methods

For the TRL test programme, measurements were taken of rolling resistance, wet grip and noise. All measurements were taken using either existing or draft International Standard (ISO) procedures. The methods used are briefly outlined below.

4.3.1 Rolling resistance

The rolling resistance tests on all eleven sets of tyres were performed by an ETRTO partner before the tyres were sent to TRL for the further tests. These were conducted in accordance with the method specified in BS AU 50-1.1.3 (British Standards Institution, 1992). The tests results, in Newtons, are then converted to a rolling resistance coefficient, which is given as a percentage.

4.3.2 *Wet grip*

Wet grip tests were performed at TRL according to the procedure described in the draft ISO Standard ISO/DIS 23671 (International Organisation for Standardisation, 2005). The draft standard (trailer method) requires the test tyres to be towed by a vehicle over a suitable test surface. The test surface is wetted and during the test (at 65 kph) the braking system on the test wheel is applied firmly until sufficient braking torque results to produce the maximum braking force that will occur prior to wheel lockup. Contained in the standard are specifications for the amount of water applied to the test surface and the method of delivery. Also outlined in the standard is information regarding the mounting of the test tyre, the load applied, the method of calculation of the test result, the numbers of repeat runs and the tolerances allowable for each of the controlled variables.

The tests for this study were carried out using the TRL Pavement Friction test apparatus which complies with the requirements of the draft ISO standard (Figure 4.3). This apparatus consists of a trailer, where the tyre being tested is mounted, and a towing vehicle. Water is applied in front of the test tyre using a specially developed delivery system. All friction tests carried out for this study were carried out on the TRL test track facility using a section of SMA constructed with a maximum chipping size of 10 mm.



Figure 4.3: The TRL pavement friction tester

4.3.3 *Tyre noise*

Measurements of tyre noise were carried out on the ISO test surface laid on the TRL test track (See Figure 4.4) according to the procedures described in the tyre noise Directive. This test requires the test tyres to be mounted on a suitable vehicle and the vehicle coasted (i.e. with the engine switched off) over the test surface for a range of specified speeds. The maximum noise level during each coast-by is determined at a microphone located 7.5 m from the centre of the test surface. The results obtained from a series of test runs at different speeds are plotted and a regression analysis carried out to determine the regression line. From this relationship, the maximum noise level at a speed of 80 kph is determined.

In order to facilitate the comparison between noise levels and wet grip performance, the noise measurements on the ISO surface were also conducted at 65 kph which is the tests speed for wet grip tests but outside the speeds range specified for tyre noise tests. In addition, a complete set of noise tests (including runs at 65 kph) were also conducted on the SMA (10 mm) surface used for the wet grip tests.



Figure 4.4: A tyre noise test on the ISO surface

It should be noted that for the tests using the Goodyear Eagle RSA EMT it was not possible to load the test vehicle to the correct amount (i.e. 75% of the maximum tyre load). This was because at 63% of the maximum tyre load, the vehicle reached its maximum axle weight. For the Michelin Diamaris a load of only 70% was achieved before the vehicle was above maximum axle weight. The Directive allows for a weight of $75\% \pm 5\%$.

4.3.4 Results and analysis of TRL wet grip tests

The results comparing the Peak Friction Index as measured on the SMA 10 mm surface and the noise levels determined on the ISO surface are shown in Figure 4.5. The corresponding results obtained when noise levels were measured on the SMA surface at 65 kph are shown in Figure 4.6. The regression relation (solid line) and the correlation coefficient (R^2) is shown for each data set.

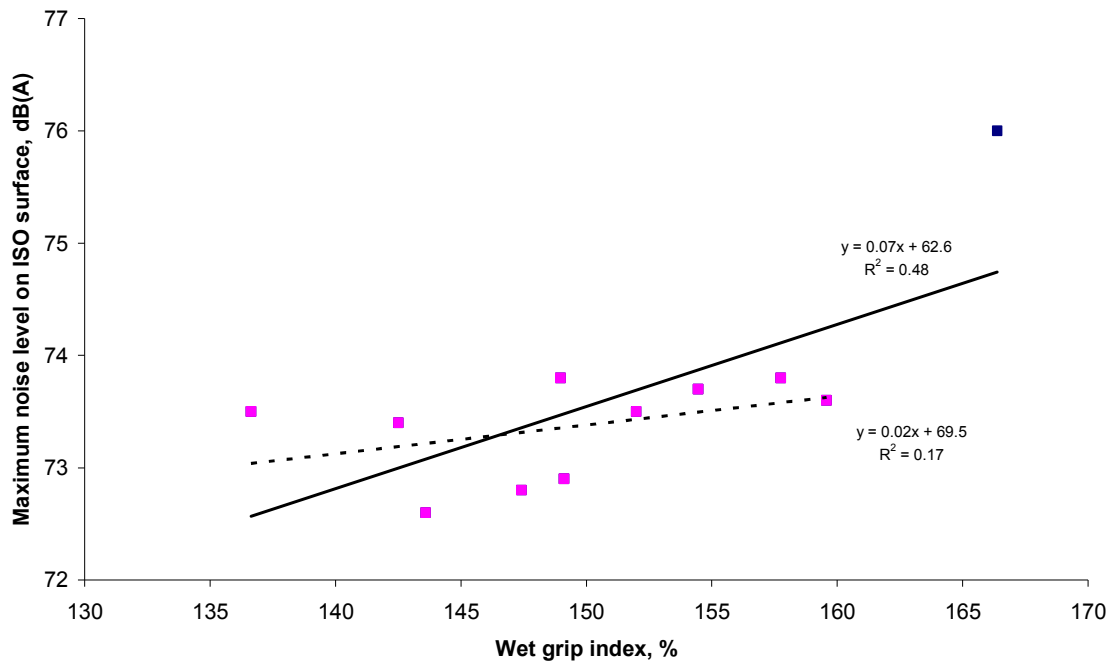


Figure 4.5: Maximum A-weighted noise level on ISO surface and wet grip on SMA surface, TRL data

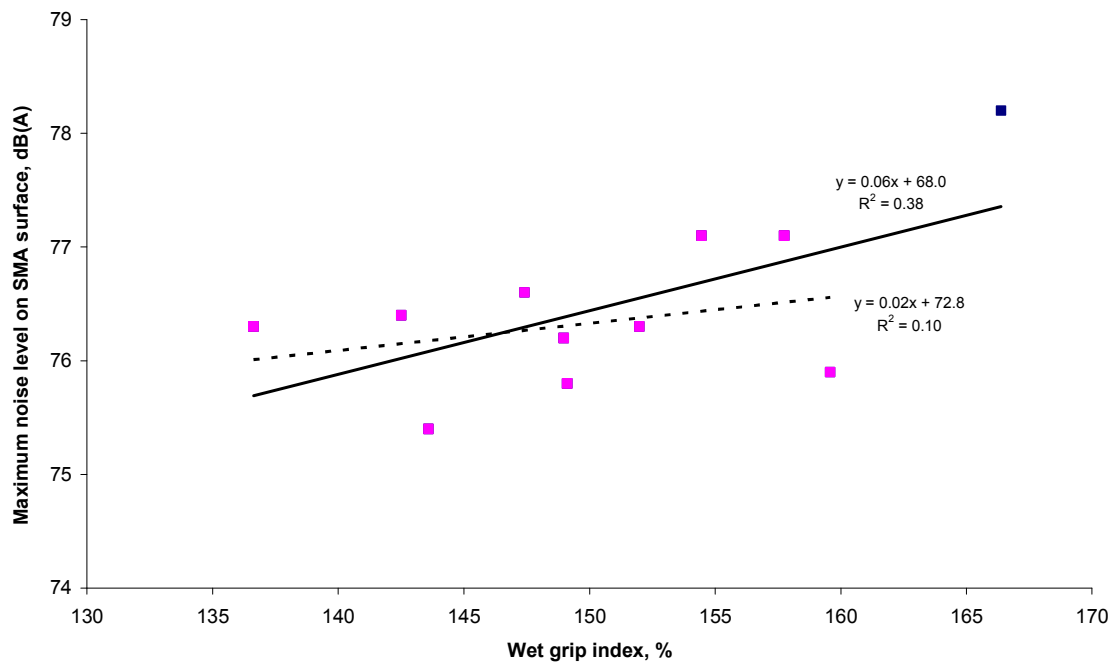


Figure 4.6: Maximum A-weighted noise level on SMA surface and wet grip and SMA surface, TRL data

At first sight it would appear that there is evidence of a significant correlation between the noise levels and peak friction measures taken. However, it is important to note that one of the tyres in the sample appears to be an outlier producing much higher noise levels than would be expected from the

measured values of the peak friction measured. It was noted that this particular tyre could not be tested using the correct load conditions because the load requirements exceeded the load cell limits on the test equipment. This particular tyre was therefore tested at 50% of the maximum load rather than the 75% load required in the standard. Since this may have affected the results for this tyre, the correlations are also calculated with this tyre removed from the dataset. When these data are removed, the regression shown by the broken line in each Figure is obtained. It can be seen that, in both cases, the degree of correlation achieved is substantially reduced.

4.4 Conclusions from the analysis of tyre noise and safety

Previous studies that have attempted to examine the relationship between tyre noise and safety performance have indicated evidence of a weak trend between noise and measures of wet grip adhesion. In some cases the relationships were found to be significant. However, in all cases examined, the data has exhibited considerable scatter indicating that a great deal of the variance in the noise levels cannot be explained simply in terms of relative safety performance. Indeed, there are many examples of tyres that produce relatively low noise levels and yet perform well in terms of wet grip.

The most recent data, taken as part of this study, also showed similar trends with some evidence of a weak relationship between tyre noise and the peak friction index for the small tyre sample examined. Again this was not found to be a significant trend. However, it must be stressed that the small sample of tyres assembled for this study contain a wide range of tyre types and sizes and it is difficult to draw firm conclusions from the sample tested. Further measurements focussing on different tyre groups would be needed to clarify the precise form of any underlying relationship between noise and safety for these latest tyre designs.

Finally, it is important to note that the results given for the tyres tested as part of this project (Figure 4.5) have not been rounded to produce type approval equivalent test values. The process of rounding, specified in the type approval procedure, can reduce the measured noise levels by up to 1.9 dB(A). Bearing this in mind, it can be seen that all the tyres tested as part of this project gave noise levels that are well below the current limits.

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.

5 Task 3: The effects of lowering tyre noise on rolling resistance, fuel economy and environmental pollution

This section of the report is concerned with obtaining an understanding of the likely effects of reducing tyre noise levels on tyre rolling resistance. Clearly any significant change in rolling resistance could have an effect on fuel economy which, in turn, would influence the overall generation of CO₂. This latter component is of particular relevance given the recent commitment by the UK Government to cut the emission of greenhouse gases⁹.

The section begins with a description of the various factors that can affect tyre rolling resistance and examines how these factors relate to fuel economy and emissions. The section then provides the results of an analysis that attempts to determine the connection between tyre noise levels and rolling resistance.

5.1 Relationships between tyre rolling resistance, fuel economy and CO₂ emissions

Since, one of the purposes of this report is to determine the potential effect of forthcoming tyre noise legislation on fuel consumption and CO₂ emissions of cars, it is worthwhile to briefly review the relationships between rolling resistance and these latter two variables.

In general, the forces acting on a vehicle in motion can be separated into 4 main categories:

- **Rolling resistance** – This force remains essentially constant over much of the normal operating speed range of a vehicle (i.e. up to speeds of about 130 kph). Rolling resistance forces tend to dominate over other forces at low speeds typical of urban driving conditions.
- **Aerodynamic resistance** – This force is proportional to the vehicles' drag coefficient which is largely dependent on the vehicle cross section. The aerodynamic resistance of a vehicle increases in proportion to the square of its speed. At low speeds, below 60 kph, the forces produced are relatively low and generally below those produced by tyre rolling resistance. At higher speeds, above 130 kph, however, the aerodynamic forces increase rapidly and become the dominant force.
- **Inertial resistance** – These forces are linearly related to the acceleration or deceleration rate and the mass of the vehicle. Inertia forces tend to be most important in congested traffic situations.
- **Climbing resistance**. These forces are related to the vehicle mass and the slope of the road. They can easily dominate the other forces on steep inclines.

A useful way of establishing the contribution made by tyre rolling resistance to fuel economy is to examine data from the New European Driving Cycle (NEDC). This drive cycle is designed to simulate a variety of driving situations including low speed urban and high speed motorway driving. It has been established that for mid range passenger cars, driven over this cycle, approximately 30% of the fuel is used to overcome rolling resistance (Sandberg and Ejsmont, 2002). It follows therefore, that a 10% reduction in rolling resistance should provide about 3% improvement in fuel economy.

With modern catalyst equipped cars nearly all of the carbon contained in the fuel will be emitted in the form of CO₂, so, as a reasonable approximation, it can be stated that rolling resistance will be

⁹ Since the Kyoto agreement in 1997, the UK has been pressing ahead and introducing innovative policies which will have a significant impact. The UK's Climate Change Programme was published in November 2000 (Department of the Environment, Transport and the Regions, 2000b). It details how the UK plans to deliver its Kyoto target to cut its greenhouse gas emissions by 12.5%, and move towards its domestic goal to cut carbon dioxide emissions by 20% below 1990 levels by 2010. A longer term domestic goal is to reduce CO₂ emissions by 60 per cent by 2050.

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 (Conversions calculated using <http://www.natenergy.org.uk/convert.htm>).

5.2 Factors affecting tyre rolling resistance

As pointed out in the previous section, a general 2-3% fuel saving may be achieved from a 10% reduction in car tyre rolling resistance. This section reviews the main factors that affect tyre rolling resistance and the prospects for tyre design change that could influence tyre rolling resistance and fuel economy in the future.

5.2.1 Tyre design and construction

Of the various components that are involved in the construction of a tyre, the tyre tread is generally the most important regarding energy losses. However, within practical design limitations the influence of the tread pattern design is not great, the major influence being the tread depth and its direct influence on tyre weight. Clearly a lower “land-to-sea” ratio, i.e. more voids, would have some influence on tyre weight and potentially increase water removal efficiency at high speed. Unfortunately tread wear resistance and handling and stability tend to suffer.

The degree of tread pattern segmentation does influence rolling resistance in terms of work done in the contact patch, (micro movements), this could be worsened if the tread compound modulus was reduced. Increasing tread pattern fragmentation increases tyre damping and therefore tyre rolling resistance. However, such changes would also detract from handling and stability and may detract from wet road performance in certain conditions.

The tread profile is a factor in rolling resistance; the more curved the higher the rolling resistance and it seems the higher the external noise.

Within a radial car tyre the energy losses in each component are considered to be in the order those give in Figure 5.1 below.

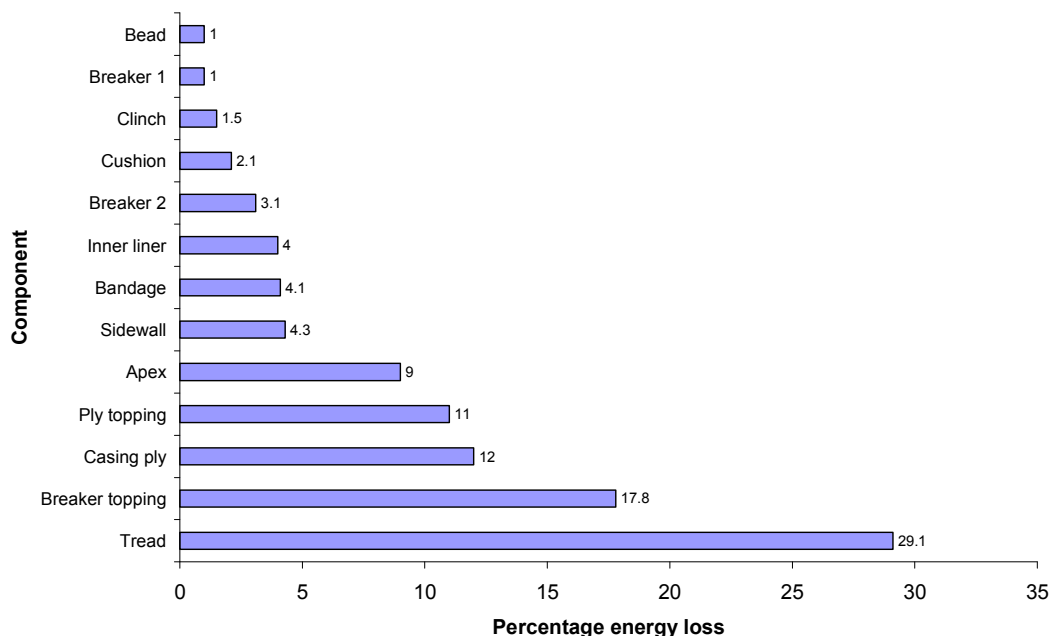


Figure 5.1: Energy loss for each component of a radial tyre

5.2.2 *Tyre compound*

Rolling resistance is also a function of tread compound formulation and to a lesser extent the compound formulation of the casing, sidewall, and subread compounds. Research into tread compounds to reduce rolling resistance and maintain or improve wet grip in terms of tyre rubber to road interaction has been taking place over the last thirty years.

The polymer and the filler are the dominant compound components influencing rolling resistance. The work of Bond (1985) and Williams (1992) was perhaps the first to suggest that “designer” polymers can be created that processed the dynamic characteristics of the tyre to react to the road surface micro texture on the micron scale. The objective here was to provide sufficient friction between the tyre and road surfaces whilst minimising the energy losses in terms of bulk hysteresis as the tread is deformed on the macro texture component of the road. This research led to the introduction of relatively high 1.2 butadiene content solution styrene butadiene copolymers in tyre construction.

This concept has been further developed over the years. Tyre manufacturers and researchers now have available the ability to measure ground plane pressures between the tyre and road surface at real speeds. It is anticipated that this information will lead to a greater understanding of the role of the tread compound in affecting adequate friction with the road texture whilst minimising rolling resistance. This should lead to an ability to tailor the compound dynamic properties of a tyre to the texture levels present in the road surface.

The development of silica fillers, together with the additional compound ingredients and manufacturing technology has lead to further reductions in tyre rolling resistance with at least the maintenance of wet grip. Essentially, wet grip is affected by the degree to which a tyre is distorted at high frequencies by hitting small stones and unevenness in the road surface. Therefore, grip is best served by rubber compounds which absorb energy at high frequencies.

Rolling resistance, on the other hand, is affected by the deflection of the tyre as it revolves which occurs at relatively lower frequencies. Silica has the property of absorbing energy at high frequencies but not at low frequencies. Consequently its addition to tyre compounds helps to both increase wet grip and decrease rolling resistance simultaneously. Typical reductions in rolling resistance of 20% and improvements in wet skid performance by as much as 15% can be achieved relative to non silica tyres.

In the longer term it may be that the moves to truly green tyres will mean a move to natural rubber, maybe in modified form, being used for the tyre tread and perhaps renewable fillers such as starch. Advantages in terms of rolling resistance may come from this.

5.2.3 *Other factors affecting fuel economy*

While reducing tyre rolling resistance through basic design and tyre compound changes has some effect on fuel economy and emissions, there are other factors affecting fuel economy that are related to the use of the tyre that need to be considered. For example, it is clear that driving on incorrectly inflated tyres is a major factor affecting tyre rolling resistance and hence fuel economy. A change of 0.6 bar in tyre inflation pressure can affect vehicle fuel economy by as much as 2-3 %. Also since overall vehicle weight is an important factor affecting fuel economy any changes to tyre designs that affect the overall weight is important.

- ***Run flat designs to reduce overall weight:***

Tyre weight is an important factor affecting tyre rolling resistance and fuel economy, and changes to the tread pattern have already been mentioned. However, the changes that might be made to the tread pattern are relatively small as they are constrained by problems with abrasion resistance and other

important design factors. Nevertheless, there is evidence that tyre weight has progressively fallen by some 15 to 20% for a given size and design over recent years. These changes have been driven by the demands of the vehicle manufacturers as they strive to improve overall fuel economy.

The moves to run flat tyres¹⁰, which are heavier than standard tyres, suggests that this trend may be reversed. However, where the use of run flat designs obviates the need for a spare tyre and wheel, there is still an overall reduction in vehicle weight and hence an improvement in fuel economy.

One of the major challenges to the tyre industry is to create run flat tyres with the adequate run flat capability but at the same or lower weight than the current conventional tyres. There is currently a discussion as to what represents a satisfactory run flat or run on performance in terms of distance travelled. The resolution of this debate is important in terms of tyre design needs.

The challenge of further tyre weight reductions is not considered impossible. Novel designs being considered could also reduce tyre weight, and changes in tyre profile and breaker construction may also be possible. Nanotechnology may also result in higher abrasion resistance, and therefore reduced tread depth and weight, and also allow thinner sidewalls.

Even against the changes already made a further 10 to 20% reduction in tyre weight seems feasible over the next ten years on a like for like basis.

- ***Tyre pressure monitoring:***

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. The fairly rapid introduction of tyre inflation pressure monitoring should assist in ensuring that tyres are run closer to the manufacturers specified inflation pressure and is perhaps the key to the introduction of the run flat tyre.

The use of tyre pressure monitoring worldwide is being fed by legislation, i.e. the Tread Act in the USA, and driver/OEM needs. It is known that the discipline of tyre pressure maintenance is generally poor and the accuracy of gauges at petrol stations together with the average customers awareness of the various units of pressure measurement used suggests why there is reported in BRMA (British Rubber Manufacturers Association) surveys a considerable variation from the manufacturers recommendations.

Tyre pressure monitoring systems can be relatively simple in practice, for example using the wheel speed sensors used for the anti lock braking system and monitoring the change in tyre rolling radius and hence inflation pressure. This type of system will warn the driver if any tyre varies from a reasonable amount, say 15%, of the manufacturers advice. Initial criticism of this approach related to the fact that the system could not detect if more than one tyre becomes deflated and it has been suggested that it could not identify which tyre has a low inflation pressure. Both these difficulties have been overcome in an attempt for a purely software based system to be acceptable for the TREAD act requirements (Yanase, 2005).

There is considerable activity in the USA to form standards to cover tyre pressure monitoring and in Europe the ISO are in the early stages of discussion on this subject. It will always be true that the vehicle industry, at least for the mass market, will adopt the system which performs well with the minimum expense. For this reason alone the software based system has every chance of wide adoption.

More advanced systems that give individual pressure values to the driver corrected to sea level are available and are now being fitted to a wide range of vehicles. How these systems perform over long periods of service and with system/vehicle aging is yet to be established.

¹⁰ A run flat tyre uses technology that permits the motorist to drive up to 80 kilometres at speeds up to 80 kph on a totally deflated tyre. They also help to avoid accidents that may be caused by sudden deflations.

It should also be noted that tyre pressure monitoring can help to reduce irregular wear, particularly heel and toe wear. The presence of heel and toe wear can be a factor in increasing tyre noise and is also a factor in reducing handling and stability and basic wet grip (Williams and Evans, 1983).

In summary, it would appear that the maintenance of minimum tyre rolling resistance, the warning of low tyre pressure, the ability to allow run-flat tyre introduction all have a small but positive influence on noise generation.

5.3 Effects on rolling resistance of reducing tyre noise levels

In order to gain an understanding of how future reductions in the tyre noise limits might affect tyre rolling resistance and fuel economy, it is useful to examine existing data sets where these variables have been compared.

5.3.1 Rolling resistance - analysis of existing data

Tyre rolling resistance and drive by noise tests were carried out on a wide range of tyre types by TUV automotive GMBH between January and April 2002 (Reithmaier and Salzinger, 2002). A total of 70 tyres were tested. The tested tyres were purchased at aftermarket free dealers under conventional conditions and without giving indication of their usage. The drive-by noise tests were conducted according to directive 92/23 ECE (amended by regulation 2001/43 EC). The rolling resistance measurement was conducted on a drum test rig with a drum diameter of 2 m according to ISO 8767.

The noise and rolling resistance values for all the 70 tyres tested are compared in Figure 5.2. There is a large scatter and no statistical significance between noise level and rolling resistance could be detected.

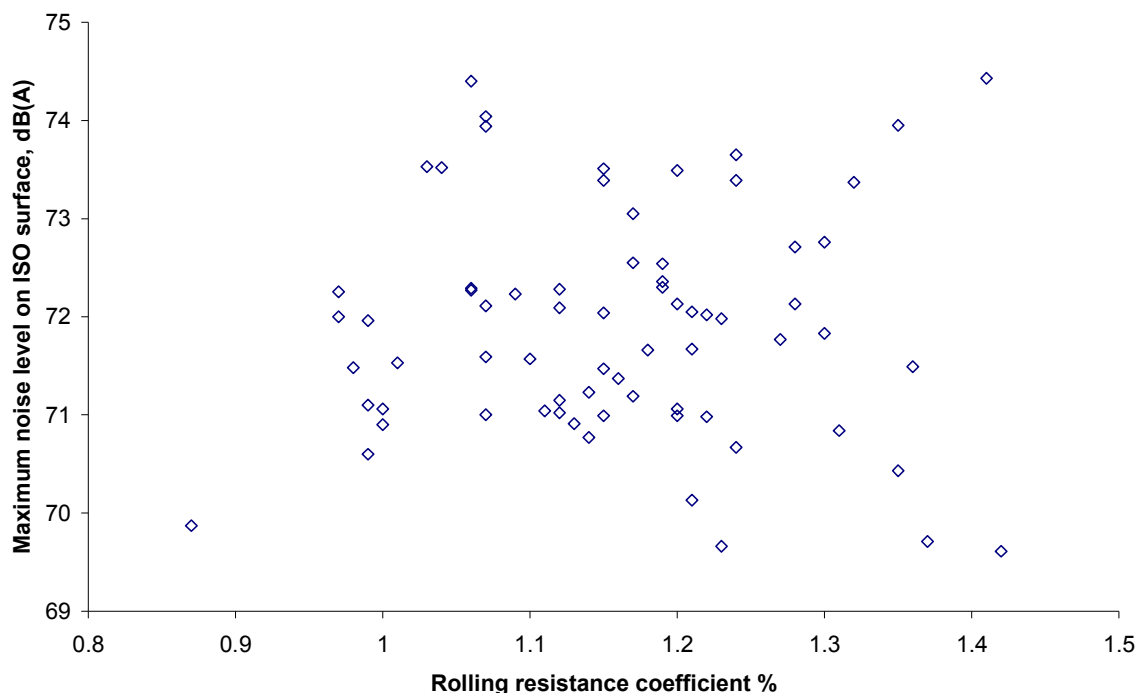


Figure 5.2: Rolling resistance and noise level, TUV data

5.3.2 Rolling resistance – analysis of new data

The results from the small measurement programme carried out as part of this project, together with those from the TUV database, are shown in Figure 5.3 below.

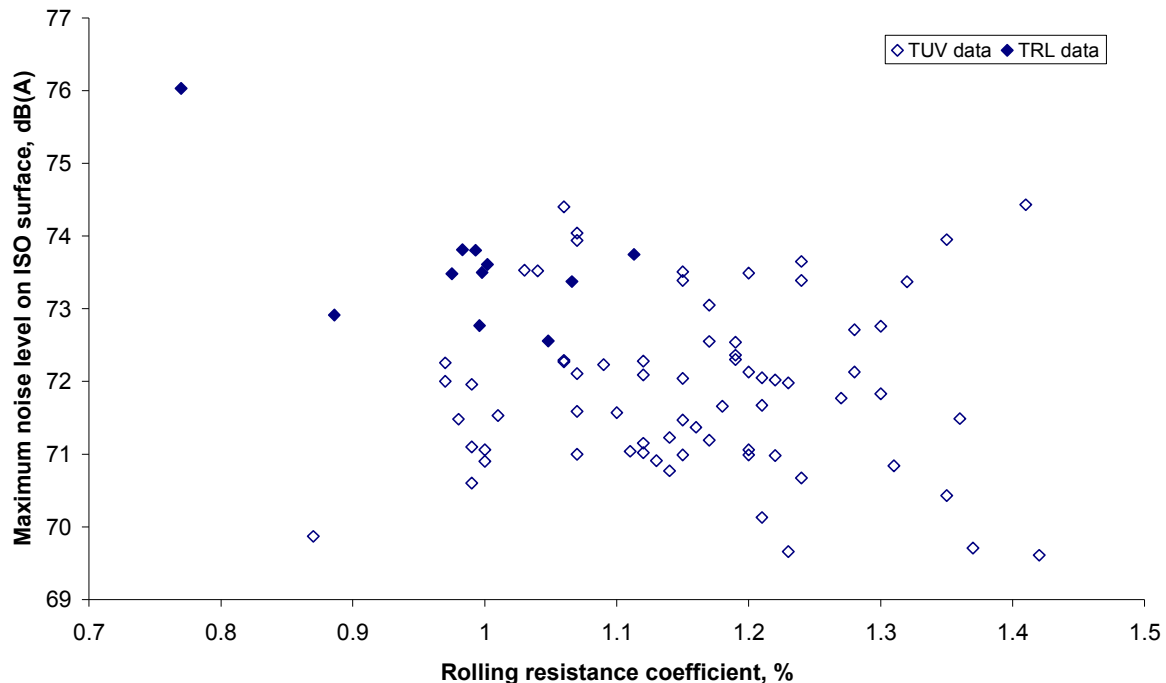


Figure 5.3: Rolling resistance and noise level, TUV and new TRL data

As can be seen there is no obvious trend in the new data, and it fits towards the outside of the scatter found in the TUV database. It should be noted that the rolling resistance tests were completed on different rigs and the noise tests were undertaken on different ISO surfaces which may account for the apparent displacement in the population means.

A point worth noting is the apparent outlier in the data obtained by TRL. This data was obtained from a very wide tyre (275/R19) which was included in the study to represent the tyre types that may be fitted to large SUV type vehicles. These vehicle types have grown in popularity in recent years. It would appear from this data set and from the data shown earlier in Figures 4.5 and 4.6 that this particular tyre produced substantially higher noise levels than the other car tyres tested.

For the TRL study a similar scatter was found when the levels of rolling resistance were correlated against the noise measurements performed on the SMA surface.

5.4 Conclusions regarding the effects of tyre noise on rolling resistance and fuel economy.

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 will also help to reduce overall vehicle weight, where the fitment of a run flat design 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 rolling 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, which is based on data from previous studies and from a recent small scale study on the latest tyre designs, that there is no significant relationship between tyre noise and rolling resistance. However, 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 are also accompanied by sufficient controls on tyre rolling resistance. Given the strong demand on the market for improved fuel efficiency, it would appear unlikely that future tyre designs will sacrifice rolling resistance in order to achieve lower noise.

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 Task 4: Recommendations for future noise limits

The primary objective of reducing the noise emission from vehicle tyres is to reduce the impact of traffic noise on people living near to roads. As has been demonstrated earlier in this report, the strategy of reducing traffic noise levels through the imposition of more stringent tyre noise limits is not straightforward. In particular, the issue is complicated by the fact that reductions in tyre noise limits do not directly translate into reductions in traffic noise levels.

The actual benefits are dependent on the traffic mix, the speed of the traffic, the type and condition of the road surface and, of course, on the degree to which the levels of tyre noise determined at type approval are representative of noise levels generated in practice. The effects on other aspects of tyre performance, particularly wet grip adhesion and rolling resistance, are factors that add to the complexity of the problem and need to be taken fully into account when considering the overall benefits of lowering the tyre noise type approval limit values.

To determine suitable recommendations for future noise limits it is sensible to begin by establishing the degree of environmental improvement that is required, and then to determine what reductions in limit values are needed to achieve this degree of improvement. If this can be achieved, then recommendations on lower limits can be made by taking into account the technical feasibility of achieving the reductions indicated and the time scales needed for implementation. The likely effects on other tyre performance factors associated with lower limit values can then be included in the assessment.

The analysis reported in this section follows this particular approach. The section begins with a review of noise results obtained from the test programme from this project and then continues with a review of data that relates traffic noise levels to the impact on communities. This is used to establish the minimum change in traffic noise levels that are needed to register noticeable improvements as measured by community reactions in a residential context. The analysis then establishes, through the use of mathematical modelling, the levels of tyre noise needed to achieve the reductions in traffic noise indicated. The section concludes with a summary of the recommendations that includes comments regarding the effects on other tyre performance factors.

6.1 Results from test programme

The results from the test programme conducted as part of this study have been described earlier. However, with the measurements also being conducted on a more commonly used size of SMA (i.e. 10 mm stone size) a more representative relationship can be determined with the ISO surface. This relationship will be used in the following section.

Figure 6.1 below shows the data from the TRL study in 2001 and that from the measurement programme conducted as part of this project. It can be seen that generally lower levels were recorded on both surfaces in 2005, especially on the SMA. This is likely to be due to the smaller stone size. The lower levels recorded on the ISO surface were possibly due to changes in tyres over the past four years and also a reflection of the different tyre selection criteria for each study.

The relationship between the two surfaces is shown to be much stronger from the 2005 data, although the high correlation value of 0.72 is a result of a single tyre exhibiting high noise levels on each surface. However, the slope of the line (0.72) does not change significantly if this point is excluded from the analysis. The actual coefficients of the regression equation from the SMA10 make the relationship with the ISO surface much more of a 'one to one' relationship, i.e. a 1 dB reduction on the ISO surface will on average correspond with a 0.72 dB(A) reduction on the SMA10 surface.

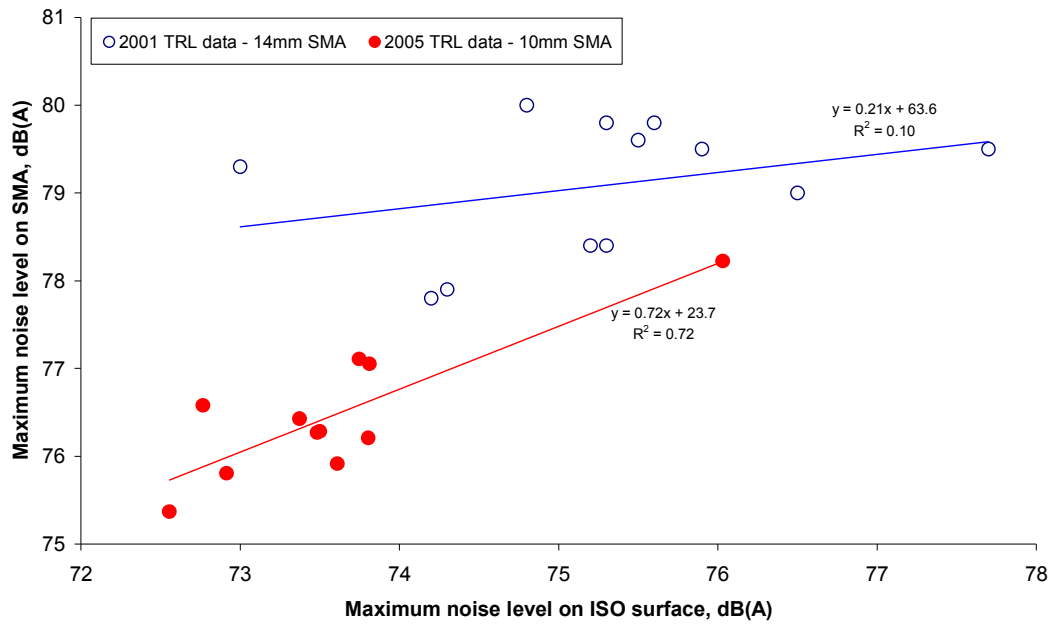


Figure 6.1: Results from present study and previous TRL study in 2001

This new relationship between the ISO and SMA surfaces will be used for the subsequent calculations of recommended changes to the limit values.

If the results on the ISO surface are considered against the current tyre approval limits it can be seen that they fall well below the current tyre approval limits. Figure 6.2 below shows these data on a similar chart to that shown earlier in Figure 3.1.

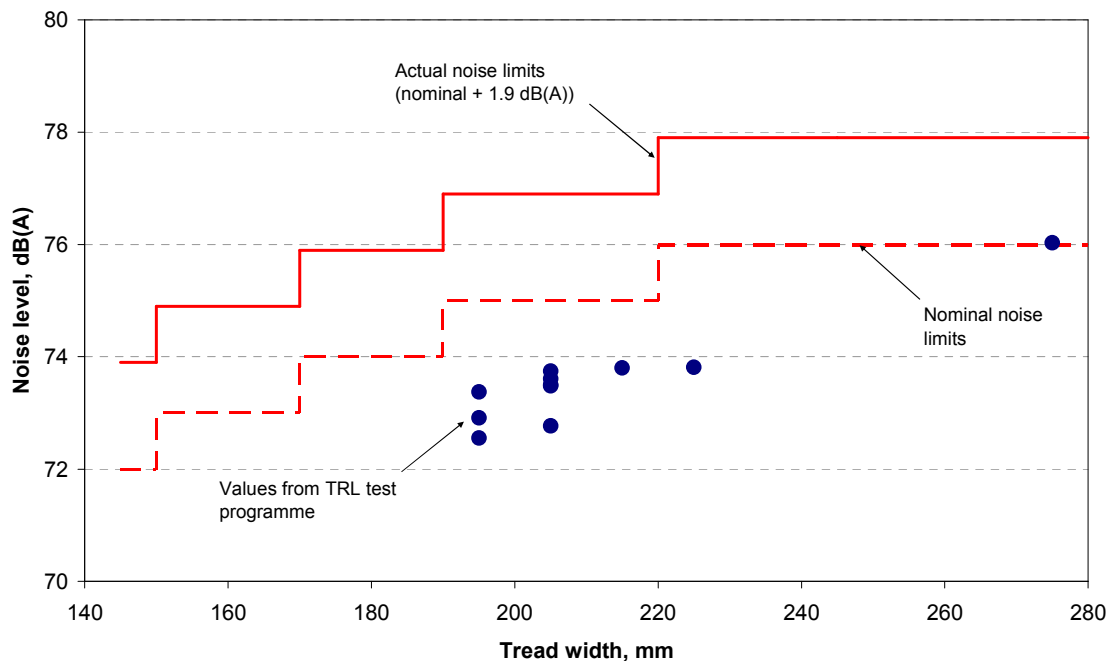


Figure 6.2: Noise levels under type approval for tyres tested during this study

6.2 Reductions in tyre noise levels needed to achieve a noticeable change in noise impact

It is generally considered that a 3 dB(A) reduction in traffic noise is needed to affect a noticeable change in traffic noise (Institute of Environmental Management and Assessment and Institute of Acoustics, 2002).

From Table 3.7 it can be seen that at 50 kph, under typical traffic conditions on HRA, a reduction of 5 dB(A) in tyre noise would produce a reduction of approximately 3 dB(A). A similar figure calculated for SMA10 using results from this current study would be very close to that of the HARMONOISE reference surface, i.e. 2.2 dB(A).

From Table 3.3 it can be seen that the slope of the trend line relating coast-by levels on HRA and ISO 10844 is 0.28 and hence the predicted reduction required on the ISO surface is 17.9 dB(A) (i.e. $5/0.28$). This reduction is clearly impossible to achieve and points to the need for a rougher more representative test surface for setting the tyre noise limits.

Table 6.1 gives the results of some further and more accurate predictions using the HARMONOISE model. This table shows the reductions required in tyre noise for light vehicles running on HRA and SMA10 to achieve a reduction of 3 dB(A) in overall traffic noise. This is shown for two speed conditions and with and without the influence of heavy vehicles in the traffic stream. This latter scenario has been included to indicate the reduction in limit values for light vehicle tyres that would be required in ideal situations where the traffic stream comprises entirely of cars and light vans. Although the situation may be rare for many roads, nevertheless, at sensitive times such as the evening and weekends, the percentage of heavy vehicles will tend to be a lot less than during the normal weekday working hours.

Table 6.1: Estimated reductions in tyre noise of light vehicles required on HRA and SMA10 to achieve reductions in traffic noise of 3 dB L_{Aeq}

Model Input parameters				
Road type	% 2-axle heavies	% > 2-axle heavies	HRA	SMA10
<i>Urban roads subject to 30 mph limit</i>				
With heavies	3	0.6	-4.9	-7.7
Without heavies	0	0	-3.9	-5.0
<i>High speed roads (112 kph lights, 96 kph heavy vehicles)</i>				
With heavies	4.5	9.1	-6.2	-12.3
Without heavies	0	0	-3.4	-3.7

As can be seen from the table, the influence of heavy vehicles within typical traffic conditions means that it will be practically very challenging to achieve the reductions in tyre noise which will result in a 3 dB(A) reduction in overall traffic noise. A 3 dB(A) reduction in traffic noise could be realised with reductions in tyre noise for light vehicles of 4.9 to 6.2 dB(A) on HRA. On the smoother surface, SMA10, the results indicate a reduction of between 7.7 and 12.3 dB(A) would be necessary.

If heavy vehicles are excluded from the analysis then the required reductions are smaller. A 3 dB(A) reduction in traffic noise could be realised with reductions in tyre noise of 3.4 to 3.9 dB(A) on HRA. On the smoother surface, SMA10, the results indicate a reduction of 3.7 to 5.0 dB(A) is necessary. It should be stressed that this is an ideal situation (i.e. no heavy vehicles in the traffic stream) which is only appreciated during certain periods of the day on some roads.

The next stage of the analysis was to calculate the reduction in the tyre noise required on the ISO surface to achieve a reduction in traffic noise of 3 dB(A). The results of this calculation are shown in Table 6.2 below.

Table 6.2: Estimated reductions in tyre noise required on ISO surface to achieve reductions in traffic noise of 3 dB L_{Aeq}

Model Input parameters				
Road type	% 2-axle heavies	% > 2-axle heavies	HRA roads	SMA10 roads
<i>Urban roads subject to 30 mph limit</i>				
With heavies	3	0.6	-17.3	-10.7
Without heavies	0	0	-13.8	-6.9
<i>High speed roads (112 kph lights, 96 kph heavies)</i>				
With heavies	4.5	9.1	-22.1	-16.4
Without heavies	0	0	-12.0	-5.1

Since the reductions measured on the ISO surface do not in general correspond to reductions on HRA and SMA, higher values are required on the ISO test surface to achieve a reduction of 3 dB(A) in traffic noise on these road surfaces. For HRA the required reductions on the ISO surface would be between 17 and 22 dB(A). On SMA10 the corresponding reductions would be lower at 11 to 16 dB(A).

With the influence of heavy vehicles removed, the reductions required appear more achievable. For the SMA10 surface, which is representative of the surface type likely to be used today for re-surfacing, the reduction required in tyre noise limits would only be 5 dB(A) in order to achieve a 3 dB(A) reduction in overall traffic noise level, albeit just for light vehicles. For lower speed roads the reduction required in tyre noise limits would be a lot higher, i.e. about 7 dB(A). This assumes that a reduction in tyre noise limits would reduce the average noise levels recorded on this type of road by a similar amount.

Examining the distribution of tyre noise levels again from Figure 3.1, it can be observed that there are tyres which produce noise levels up to 8 dB(A) below the actual noise limit. In most categories there is scope for reductions in tyre noise levels of up to 5 dB(A).

6.3 Recommendations for future limit values

As discussed previously, surfaces in the UK are generally not as smooth as the ISO test surface and as a consequence the reductions in noise obtained on the ISO surface are unlikely to translate into similar reductions on a common surface such as HRA. This being the case it is difficult to set a realistic reduction in limit values which would result in any significant effect on UK roads using typical traffic composition at the present time as has been demonstrated in the proceeding section.

On smoother surfaces, such as SMA10, there is a better relationship with levels recorded on the ISO surface than there is between those recorded on the ISO surface and HRA. Since the SMA10 surface is closer to the type of surfaces that will be dominating the road network in the future, it is logical to consider reductions achieved on this surface in preference to HRA.

On SMA10, the largest practical reduction in limit value on the ISO surface of, for example, 5 dB(A) would reduce traffic noise at maximum by an estimated 1.7 dB(A) for typical urban traffic conditions.

For higher speed roads, where noise from tyres is more dominant, a 5 dB(A) reduction in tyre noise limits would be close to a reduction of 2 dB(A) in terms of traffic noise. When light vehicles only are considered the corresponding reductions would be 2.3 dB(A) on urban roads and 3.0 dB(A) on high speed roads.

The analysis of the data shows that setting lower limits is unlikely to significantly affect wet grip adhesion or rolling resistance so there would be overall benefits of lowering the limits, especially in those EC countries, with generally smoother road surfaces.

Examining each tyre section width category (Figure 3.1) it can be seen that there is little justification for having higher limits values for wider tyres. In all categories, where results from more than one tyre were available, there are tyres which would meet a new limit value of 71 dB(A). This limit value of 71 dB(A) is therefore recommended as the future limit value for all tyre widths, to apply from 1 July 2010. However, with most current tyres falling well below the existing tyre noise limits (see Figures 3.1 and 6.2) we also recommend that a first stage in the reduction in the limits should be made in 2008. This is along the lines of the Directive, which also contained the provision for interim reductions between 2007 and 2009. The proposed new limits are summarised below in Table 6.3.

We are also proposing a new tyre class for the largest of tyres that would be outside this level of 71 dB applying to all current classes. The introduction of a new tyre class (i.e. C1f) would be an allowance for the very large tyres fitted to 'super cars'. These vehicles cover very little mileage and therefore have very little impact upon overall traffic noise levels. For this extra tyre class we have recommended a section width of 245 mm and above, although the exact width would need to be considered further.

In summary, the preceding analysis supports the recommendation that the tyre noise type approval limits should be tightened to a value of 71 dB(A) for all car tyre sizes with some relaxation for the largest tyres where a value of 73 dB(A) would seem to be appropriate. These recommendations have been determined using all of the data available to this project and also taking into account current technology.

Table 6.3: Proposed new tyre limit values

Tyre class	Nominal section width (mm)	Limit values in dB(A)		
		A (current limit)	B ¹	C ²
C1a	≤ 145	72	71	71
C1b	> 145 ≤ 165	73	72	71
C1c	> 165 ≤ 185	74	72	71
C1d	> 185 ≤ 215	75	73	71
C1e	> 215 ≤ 245	76	73	71
C1f	> 245	76	75	73

¹ Limit values shall apply from 1 July 2008.

² Limit values shall apply from 1 July 2010.

It should be noted that the proposed limits relate to a new test procedure where the measured values would not be subject to a subtraction of 1 dB from the test result. Instead, we recommend that the measured values are rounded to the nearest integer level to establish the test result. This method of treating the raw measured data would then follow the proposed revisions to the vehicle noise test standard (United Nations Economic Commission for Europe, 2005). The rationale for changing the method of rounding the data is developed further in section 7.2.3 of this report.

Given the recommended changes to the limit values and the changes to the method of rounding the measured data, the overall effective reduction from the current limits would amount to between 2.5 and 6.5 dB(A), depending on the tyre size.

For reference, the reductions proposed in the Directive are given in Table 6.4. Note, however, that these current limit values include allowances of 1 dB(A) for measurement inaccuracies and rounding up to the nearest integer value so that they cannot be directly compared with limit values in Table 6.3.

Table 6.4: Proposed noise reduction in tyre noise Directive

Tyre class	Nominal section width (mm)	Limit values in dB(A)		
		A	B ¹	C ^{1,2}
C1a	≤ 145	72 (*)	71 (*)	70
C1b	> 145 ≤ 165	73 (*)	72 (*)	71
C1c	> 165 ≤ 185	74 (*)	73 (*)	72
C1d	> 185 ≤ 215	75 (**)	74 (**)	74
C1e	> 215	76 (***)	75 (***)	75

(*) Limit values in column A shall apply until 30 June 2007;

Limit values in column B shall apply as from 1 July 2007.

(**) Limit values in column A shall apply until 30 June 2008;

Limit values in column B shall apply as from 1 July 2008.

(***) Limit values in column A shall apply until 30 June 2009;

Limit values in column B shall apply as from 1 July 2009.

¹ Indicative figures only. Definitive figures will depend on amendment of the Directive following the report required in Article 3(2) of directive 2001/43/EC.

² Limit values for column C will results from the amendment of the Directive following the report required in Article 3(2) of directive 2001/43/EC.

Figure 6.3 allows a more transparent comparison of limit values by adding in the allowances. Included are the tyre noise limits in the Directive and those proposed in this study. Also shown are the upper and lower data points from the measurement surveys considered in this report. For the proposed limit values, that include rounding to the nearest integer value, the effective limit for most tyre widths is 71.4 dB(A). Values of 71.5 dB(A) or higher would be rounded to 72 dB(A) or above.

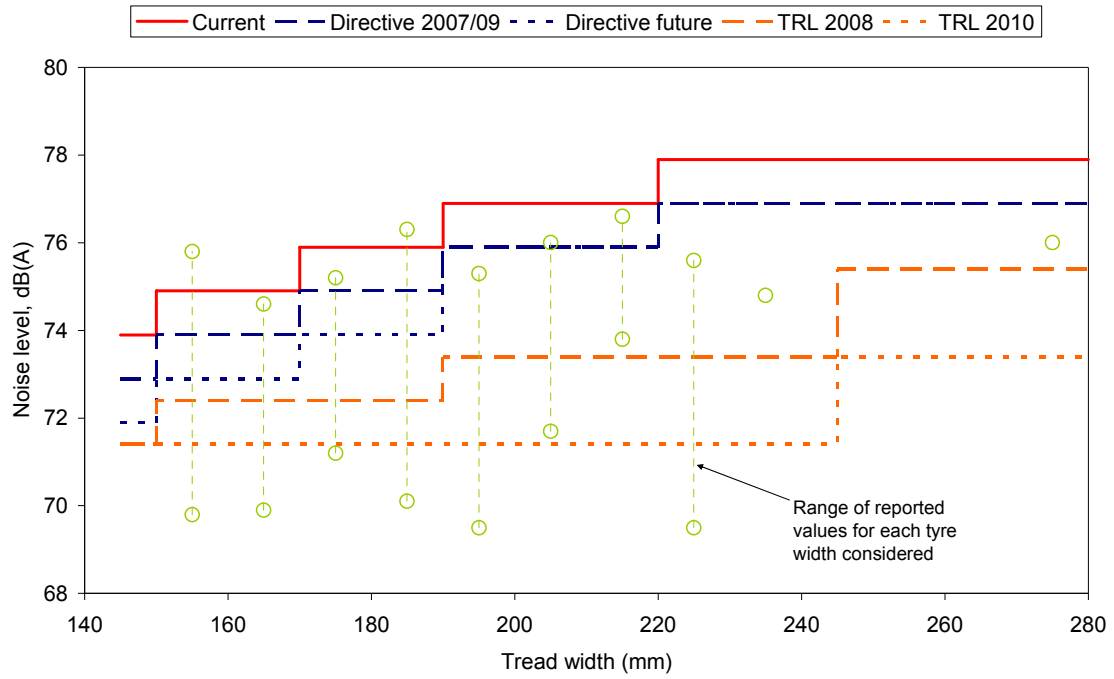


Figure 6.3: Summary of current and proposed (Directive and TRL) tyre noise limits – values are nominal + any adjustment

7 Task 5: Alternative measures for reducing tyre noise

This section is concerned with examining and suggesting alternative ways of reducing tyre noise. A brief overview of the current test method is given below, followed by some recommendations for changes to this test method that could be significant. A selection of minor changes that could be made to this method is given in Appendix D. The chapter then examines alternative methods for reducing tyre noise, and then examines other methods of testing tyre noise.

7.1 The current tyre noise test method

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 set out in the EU Directive is based on ISO 13325 (International Organisation for Standardisation, 2003).

The test site layout is shown in Figure 7.1.

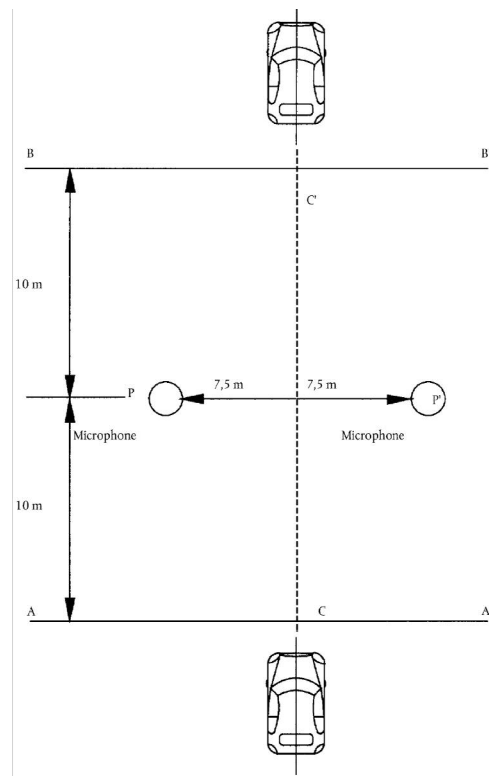


Figure 7.1: Plan of ISO test site

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

The test surface should conform to 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 specify a reference surface to allow the test method to provide reproducible results, 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 that the current test surface has been criticised as a surface for use in tyre noise type approval.

7.2 Improvements to the current test method

7.2.1 *Alternative test surfaces*

As noted above, it has been argued that the current test surface is, due to its smooth texture, not representative of the rougher surfaces commonly found on high speed roads in the UK. For example, it was shown previously (see Section 3.3), that the noise produced on this surface does not relate significantly to the noise produced on common UK roads surfaced with HRA and SMA surfaces constructed with the larger 20 mm and 14 mm maximum stone size aggregates.

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 (See Figure 6.1). Consequently, since there is a trend in the UK and in other countries to re-surface high speed roads with SMA type materials with these smaller sizes aggregates it would appear that the original concerns over the ISO surface will eventually reduce. Nevertheless, even with these changes in road surfacing practice, it would still seem appropriate to revise the current test surface used for tyre noise testing. A test surface based upon a 10 mm or 11 mm aggregate is likely to be the most appropriate choice, given the trend towards replacing existing roads with a similar type of surface.

7.2.2 *A lower speed test*

The current test method is designed to control tyre/road noise at 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 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 7.2 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, 80 kph, noise level from tyre 1 is higher than from tyre 2 by about 0.8 dB(A). However, at 50 kph, 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 made earlier; that controlling tyre noise at high speeds cannot 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.

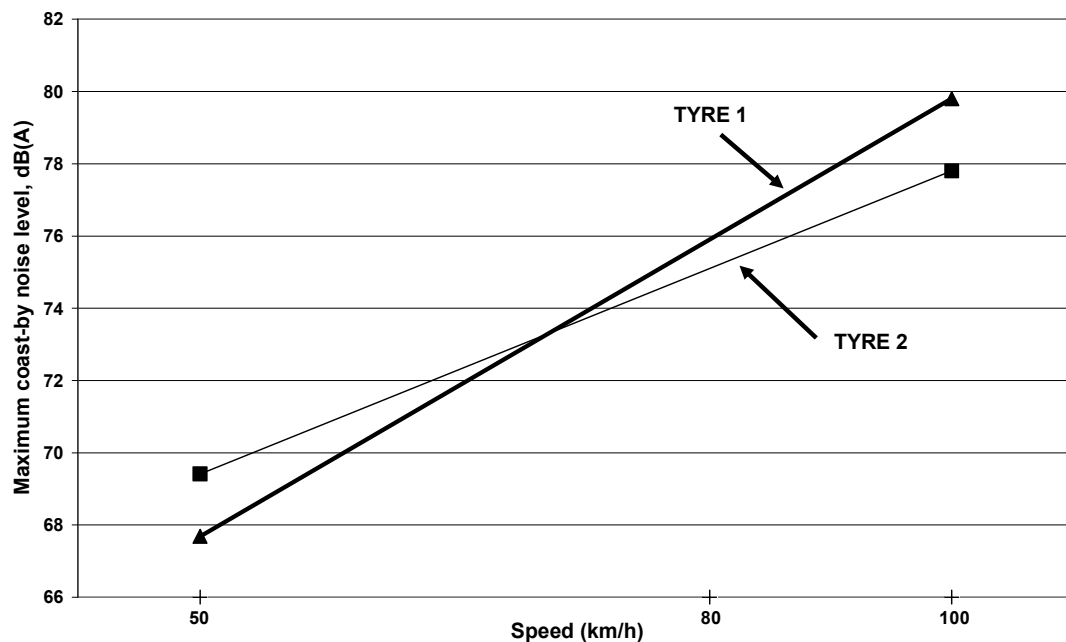


Figure 7.2: Relation between speed and maximum coast-by noise level for two tyre types

It is, therefore, recommended that some provision is made in the method to allow for an assessment of the noise at the lower speeds typical of urban driving. A possible approach to this is provided in Appendix E. The appendix also outlines the possible effects on limit values if low speed testing were to be included in the type approval test.

7.2.3 Method of adjusting the measured levels to obtain the test result

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

- (i) 1 dB(A) is then subtracted from the test result, to allow for instrument inaccuracies associated with older styles of measurement equipment; and
- (ii) 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. As a result it is recommended that this procedure is changed when the type approval method is revised, and the result is simply rounded to the nearest integer. These suggested changes would bring the tyre noise measurement practice into alignment with the proposed revisions to the separate vehicle noise test standard. This change in the procedure would itself mean a lowering of the threshold that is actually enforced.

These changes to the method of adjusting the measured results are also referred to in Section 6.3, above.

7.3 Other methods to reduce tyre noise

7.3.1 Labelling of tyres

Two forms of noise labelling would potentially bring advantages:

- (i) Tyres could have a number stamped on the side wall, indicating the noise achieved in the tyre noise test.
- (ii) A threshold could be set for a tyre to be considered ‘low noise’. If the noise level measured in the test was less than or equal to a given threshold, the manufacturer would be entitled to stamp the words ‘low noise’ on the tyre, and use this in advertising materials.

Both (i) and (ii) 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 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 be implemented very easily in the same way as information on tyre size, tyre ‘speed rating’ etc., which is currently incorporated on the sidewall of the tyre.

Such schemes already exist in Germany (the Blue Angel labelling scheme, detailed by RAL (1999)) and the Nordic countries of Sweden, Denmark, Norway, Finland and Iceland (the Nordic Swan; see www.svanen.nu for further details).

7.3.2 Market creation / Financial incentives

A wide variety of approaches could be devised to give consumers a financial incentive to purchase lower noise tyres or a new vehicle fitted with lower noise tyres. Creating a market in this way has numerous precedents in the UK. The current company car tax system has stimulated the market for low CO₂ emission vehicles, and rebates on the London Congestion Charge have seen large numbers of hybrid vehicles registered in the south east.

Financial incentives for low noise tyres would be least susceptible to fraud if they were coupled with labelling as described above. Financial incentive schemes are likely to meet the Treasury requirement of having little ‘fiscal drag’, because there is currently no incentive for consumers to buy low noise tyres.

Table 7.1 below sets out simple designs of financial incentive schemes, which are variations on standard approaches used in environmental economics. These schemes were considered as part of this project, in order to fulfil the requirement to consider ‘alternatives to regulation’, as a first step in Regulatory Impact Assessment.

Table 7.1: Alternative designs of financial incentives

Description of incentive scheme	Strengths and weaknesses
<p>A flat-rate reduction of Vehicle Excise Duty (VED) or a reduction of one VED band for cars that are fitted with low noise tyres.</p>	<p>Strengths:</p> <ul style="list-style-type: none"> (i) Could apply to all classes of road vehicles that are subject to VED. (ii) Would offer the potential for great improvements in the replacement tyre sector, in which vehicle owners are most price-sensitive. (ii) Very low administrative cost. Would be implemented through a simple tick box on the new computerised MoT test system. Fraud possibilities low. Existing VED evasion legislation would provide a deterrent and hence an incentive for compliance. (iv) The value of noise reduction achieved would be likely to exceed the cost in revenue lost, based on the noise valuations estimated by DfT (Bateman I J, Day B H and Lake I, 2004). Likely to be popular.
<p>A reduction in company car taxation for vehicles fitted with low noise tyres.</p> <p>This would be similar to the reduction in force until March 2006 for diesel cars that meet the Euro IV emissions standards.</p>	<p>Strengths:</p> <ul style="list-style-type: none"> (i) Company car drivers cover higher than average mileages, so lower noise tyres would be fitted to the vehicles that produce a disproportionate amount of the traffic noise per annum. (ii) The incentive scheme would only need to be explained to the relatively small group of companies and the self-employed who are subject to the company car tax scheme. (iii) Administratively very simple. <p>Weakness:</p> <ul style="list-style-type: none"> (i) The incentive effect would only apply to around 50% of new vehicles, and a smaller percentage of all replacement tyres sold.
<p>A rebate on the cost of purchasing low noise tyres, which a driver would apply for after purchasing the tyres.</p>	<p>Strength:</p> <ul style="list-style-type: none"> (i) Effective and would achieve high levels of public involvement, so government would be seen to be acting. Likely to be popular. <p>Weakness:</p> <ul style="list-style-type: none"> (i) Administrative cost might be high, and potential for fraud would need further investigation.

7.3.3 Improvements in road surfaces

A great amount of work has been undertaken in developing and identifying road surfaces that help to reduce tyre noise, and the work needed to make further improvements should continue. In particular, more information is needed on the acoustic durability of different road surface designs so that quiet surfaces remain quiet for longer.

Greater prominence could also be given to noise intrusion when allocating funds for resurfacing roads as part of general maintenance. Currently, resurfacing programmes largely depend on identifying surfaces that are in need of replacement as a result of wear, a fall in skidding performance and general condition of the surface. Consideration should also be given to replacing existing noisy surfaces with

lower noise alternatives where conditions of traffic flow and the proximity of dwellings indicate a high degree of existing noise nuisance.

The Highways Agency informed the authors (Highways Agency, 2005) that

“The current definition of “quieter” surfacing is one that has been rated in the BBA HAPAS noise test as having a Road Surface Index (RSI-H) of -2.5 dB or lower (more negative). RSI is a measure of how much less noise is generated by typical traffic running on the test surface compared with what would be expected from newly laid HRA. The ‘H’ specification is for motorway speeds and proportion of lorries.”

The Highways Agency went on to point out that there have been, and continue to be, substantial improvements in surfacing technology. They have recently introduced a new category of ‘very quiet surfacing material’, to describe those that have an RSI-H of -3.5 dB or lower (Highways Agency, 2004).

7.3.4 Vehicle speeds

Tyre noise increases with vehicle speed. Above 60 kph, tyre noise dominates over other noise sources for almost all vehicles.

In a recent report (Department for Transport, 2005) it is stated that in 2003, 57% of all cars exceed the 70 mph speed limit on motorways. Also, 19% of cars and 17% of Light Goods Vehicles (LGVs) exceeded 80 mph. Similar (but slightly lower) levels of speeding were shown on other classes of roads in the UK. Clearly, there is a need to reduce speeds to at least the legal limit, and this is an area where new legislation would not be required.

There are various short and long term approaches to reducing vehicle speeds. High visibility policing has not been used widely on the UK’s roads since the 1980s. However, a more strict enforcement of the speed limit would have an immediate benefit in terms of noise, and represents an approach that can be implemented relatively rapidly. Such an approach could be used at specific locations where noise is a problem. Sections of road within an Air Quality Management Area, such as parts of the M40, would have both improved air quality and lower noise levels if speeds were more strictly enforced, or reduced at specific locations or times. Substantial accident savings, reductions in greenhouse gas emissions, and improvements in congestion (journey time reliability) through better use of road capacity would be the added bonuses of any action to reduce noise due to illegal speeds.

In the longer term, speed enforcement through vehicle design is likely to be the dominant approach. The European Commission has pointed out the advantages of fixed speed limiters. These have been fitted in large commercial vehicles since 1994. They will be mandatory in the UK for all vehicles fitted with more than eight seats or of 3.5 tonnes and above, from 1 January 2008.

Research funded by the DfT has explained the gains that can be realised through speed limiters that adapt the maximum speed of a vehicle to the prevailing local speed limit (Carsten and Fowkes, 2000). The DfT is currently conducting road tests of this technology in a two year trial in Leeds.

‘Pay As You Drive’ (PAYD) insurance technology acts as a deterrent to drivers. This has reduced speeding on vehicles in Ireland, where Europe’s largest insurance firm has been fitting the equipment since 2003.

Government financial incentives for using speed limiters or the voluntary fitting of PAYD insurance equipment would cause these technologies to permeate the vehicle fleet more rapidly than otherwise would be the case. Incentives of the form listed in Table 7.1 could equally well be offered for this technology, with similar effects.

7.3.5 Changes in vehicle design

Measures to control how the noise propagates from the vehicle could also be considered. Such methods could include cladding inside wheel arches or covers over the tyres. Both these could have

safety and maintenance implications and this would need to be considered fully in any development work. Enclosed wheel arches have been used previously, e.g. on the Honda 'IMA'™ car. Any additional weight caused by the use of shields or cladding could also affect fuel economy.

On vehicles with a normal ride height, the vehicle often acts as a barrier for tyre noise generated from tyres on the farside of a vehicle. However, with the increase in vehicles with a high ride height (e.g. SUV's), tyre noise is often heard from both sides of the vehicle as the vehicle acts as less of a barrier. This may point to the need for these tyres to be tested using a vehicle that is representative of the vehicles that the tyres will be fitted to in-service.

7.3.6 Innovative tyre technology

A few novel designs of ultra quiet tyres have been publicised in recent years. For example, the concept of an ultra low noise 'absorbing' tyre was developed some time ago and has been patented (UK Patent Application 2 044 191 A). The tyre was constructed using tread material composed of crumb rubber obtained from recycled tyre stock. The tyre was shown to embrace the dual targets of low noise and enhanced wet grip and made use of material from tyre waste. It is therefore potentially advantageous for both the environmental, safety and waste recycling aspects of tyre usage. In the early research there were, however, some concerns with the adherence of the crumb rubber to the tyre carcass and further research using modern adhesives would be needed to establish its durability.

7.3.7 Increased use of tyre pressure / wear sensors

The wider adoption of tyre pressure monitoring systems in vehicles would be of benefit, mainly in terms of safety and rolling resistance (see also section 5). However, noise could also be reduced by encouraging motorists to maintain the correct tyre inflation pressure. It is known that for some tyres, under inflation will cause an increase in tyre noise levels (Sandberg and Ejsmont, 2002). Although over inflated tyres are perhaps less common, these too can often have undesirable effects on tyre noise levels. If such systems are routinely fitted to vehicles then, along with the safety benefits, a tyre likely to cause an increase in noise due to under / over inflation could also be identified and rectified.

7.3.8 Testing of tyres when worn

Currently tyres are tested when they are new¹¹, and the noise level achieved at type approval is therefore representative of the level when the tyre has full tread depth. Little is known about how a tyre performs over time, but 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). If this relationship is correct, then tyre noise will tend to increase slowly over much of the life of a tyre. A type approval test where a tyre has covered a certain distance (e.g. when worn to 50%) would therefore be more representative of the tyre noise that might be expected to be generated from the tyre over its useful life. Again, there would be a cost associated with preparing tyres for testing.

For tyres that exhibit lower noise levels with increased wear, such a scheme would be of benefit, as the type approval level would be relatively lower than it is currently.

7.4 Alternative test methods

7.4.1 Drum method

Vehicle properties are widely tested using indoor test drums. The testing of tyres on indoor test facilities is challenging but has considerable advantages. These include the ability to control the conditions and temperature and a more accurate/reproducible textured road surface. Additionally,

¹¹ Tyres are normally run in for 100 km prior to testing.

more complex noise measuring equipment may be used and hence more complete diagnostic readouts can be obtained. There are also potential advantages in terms of higher testing capacity.

The disadvantages of indoor test drums are the high initial cost of equipment, and the premature ‘polishing’ of any replica or ‘real’ road surface.

With the thorough understanding of tyre to road noise generation mechanisms it would seem that an indoor facility could enable tyre and road testing to be conducted in an environment where practical data and modelled prediction data to be employed simultaneously.

It is also possible that such a facility could evaluate wet friction under controlled temperature and water depth conditions, and could be extended to also evaluate braking systems and innovative tyre safety systems.

7.4.2 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 main advantage of this method over the conventional method is that the assessment is carried out with adequate enclosures so that extraneous noise from other sources can be eliminated from the measurement.



Figure 7.3: Test tyre and microphone set-up in TRITON’s enclosure

Research carried out by TRL using TRITON, a specially designed vehicle used to investigate tyre/road noise using the CPX method, has clearly shown that for a wide range of tyre/surface combinations there is a good correlation between coast-by noise and CPX noise levels for passenger cars (Phillips *et al.*, 2003). Figure 7.3 shows the microphones and test tyre configuration used on TRITON with the enclosure in the raised position.

CPX measurements for tyre type approval testing could be carried out using a much cheaper version of TRITON based on a trailer design incorporating a simple acoustic enclosure. Due to load restrictions this type of trailer could only be used for C₁ class tyres.

TRL have developed a truck tyre trailer with a specially quietened tow vehicle for research purposes. It is generally regarded that this approach for truck tyres would not be suitable for type approval

testing because of the complex procedure in eliminating the noise from the towing vehicle (Sandberg and Ejsmont, 1992).

7.4.3 Modelling of tyre noise

There has been considerable research effort devoted to the development of mathematical models to simulate the generation of tyre/road surface noise. However, although these models undoubtedly provide an insight into the mechanisms of tyre noise and help to generate basic tyre design concepts, for example 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 amplitude 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.

8 Task 6. Regulatory Impact Assessment (RIA)

8.1 Introduction

Proposals for new UK regulations are subject to a ‘Regulatory Impact Assessment’ (RIA). The DfT requested that a modified RIA be carried out as part of this project. This chapter explains the approach taken and presents the results.

8.2 Instructions from DfT

Full RIAs are carried out in accordance with guidance documents that are provided on the Cabinet Office’s website. The modified RIA in the present project differed from a full RIA in two major aspects:

- (i) Early in February of 2005, the DfT requested that the RIA be used to gather information, as preparation for a full formal RIA in 2006. The aim of the information gathering was to inform the UK position in advance of the Commission’s proposals for amendments to Directive 2001/43/EC. The RIA was to consider “What ifs”, rather than definite legislative proposals. The consultation stage of a full RIA helps to brief industry about changes to legislation that are imminent. In the case of this project, we have taken particular care to make clear to industry that no definite decision on legislation has yet been made, and that we are simply seeking information at a very early stage.
- (ii) The DfT has provided detailed recommendations on four options that were to be considered in the RIA. The list of options is shown in Table 8.1 below. There was more discretion in defining these options than would be the case in a full, formal RIA, which would normally present a maximum of three options.

In January 2005, the DfT believed that a change to the test surface was not realistic before 2014. This led to the wording shown in Table 8.1 for Option 4.

8.3 Conduct of the RIA and consultation with interested parties

Given the brief that the RIA was to gather information, a key part of the RIA was the consultation with interested parties.

Each interested party was sent two documents. Appendix F reproduces in full the first document, which explained the purpose of the RIA consultation. The second document sent to consultees was a comments form for completion and return to TRL. This included eleven questions, including questions on the costs that consultees would incur with each of options 1-3. The questions also sought consultees’ views on possible alternatives to regulation.

Table 8.1 shows the four options presented to consultees’ in the first document.

Table 8.1: Options sent to RIA consultees

Option	Description
1	'Do nothing' option. No change to either the noise limit values or the test surface.
2	Lowering the tyre noise limit values: (i) For categories C1a, C1b and C1c, by 1 dB(A) in July 2007; (ii) For category C1d, by 1 dB(A) in July 2008; (iii) For category C1e, by 1 dB(A) in July 2009; (iv) For all of categories C1a-C1e, lowering by a further 1 dB(A) in July 2010.
3	A tightening of 5 dB(A) in the noise limits for all tyres in categories C1a to C1e, from July 2008. The new limits in force would be: C1a: 67 dB(A) C1b: 68 dB(A) C1c: 69 dB(A) C1d: 70 dB(A) C1e: 71 dB(A)
4	Specifying a new thin surface course for conducting tyre noise type approval tests. The new surface would be similar to that now in use on most new and re-surfaced Highways Agency roads in the UK. The new test surface would be introduced in 2014.

The options in the table were explained in greater detail in the accompanying text (see Appendix F).

We obtained contact details for consultees from two sources. Some came from an RIA that TRL had performed approximately three months earlier, on another project for DfT concerned with vehicle noise. Other details were obtained by telephoning each organisation in order to ensure that we had accurate contact details for the person who would be responsible for responding to the consultation. Table 8.2 below summarises the list of consultees.

Table 8.2: RIA Consultees

Type of body	Details of consultees
Government	Department for Trade and Industry (Dti) Department for Environment Food and Rural Affairs (DEFRA) Highways Agency
Trade Associations	Society of Motor Manufacturers and Traders (SMMT) (*) British Rubber Manufacturer's Association (BRMA) Retread Manufacturers Association (RMA)
Car manufacturers	3 multinational car manufacturers
Tyre manufacturers	6 multinational tyre manufacturers

(*) The SMMT requested a presentation about the research project and RIA. This presentation was made to the 'Noise Working Group' of the SMMT in London on 22nd March 2005.

The BRMA informed us that they would arrange to submit a co-ordinated response to the RIA on behalf of tyre manufacturers. The RMA informed us that their members were mainly producing retreaded tyres for commercial vehicles, rather than passenger cars.

8.4 Responses from consultees

Only one consultee submitted a response. This is in itself a significant finding, as it is a very low response rate. This response rate is much lower than the response rate to a similar consultation on vehicle noise testing, which had involved many of the same consultees and had taken place a few months previously. The comparatively low response rate in this tyre noise consultation provides some evidence that those consultees who did not reply have not recognised any significant negative or positive effects for them in the options shown in Table 8.2.

The consultee who did submit a response was a representative of the BRMA. This response is important, since it represents the views of several of the major tyre manufacturers and importers. Table 8.3 below provides a summary of the main points made by the BRMA. The bold text summarises the key questions that were asked of consultees. The text below each question summarises the BRMA comments, with italicised text in quotation marks indicating direct quotes from their written response.

Table 8.3: BRMA response to consultation

Question: Turnover of your organisation on tyres?
<p><i>“total turnover of the tyre members of BRMA was £1,647m in 2003”</i></p> <p><i>“Sales in the UK are a mix of domestic production and imports. A varying proportion of UK production is exported.”</i></p> <p>In 2003:</p> <p>(i) UK production of new tyres was 21.3 m units, of which 17.5m were passenger car tyres.</p> <p>(ii) Sales by BRMA members of replacement tyres in the UK were approximately 20.1 m units, of which 16.5 m were passenger car tyres.</p> <p>(iii) The total UK market for replacement tyres was estimated at 30m units, of which 25.5m were passenger car tyres.</p>
Question: How much does your organisation spend on noise testing?
<p><i>“such testing is likely to be quite limited in scope”</i></p>
Question: Comment on alternatives to regulation. This question listed five possible approaches, and asked the consultee for any other approaches.
<p>Public information campaigns were of limited appeal.</p> <p><i>“Compulsory eco-labelling would be an unwarranted imposition and would have limited impact”</i></p> <p>Vehicle excise duty or company car tax reductions as incentives were not opposed in principle, but how could it be assured that low noise tyres remain on qualifying vehicles?</p> <p><i>“A good deal more can, and should, be done to reduce the noisiness of road surfaces. This is the means to achieve substantial reductions in tyre road noise.....”</i></p>

Question: What would be the costs and changes necessitated by option 2? With option 2:

(i) The noise limits would come into force in stages between 2007 and 2010.

(ii) Three limits are the same as the indicative limits in Directive 2001/43/EC.

(iii) The limits for the widest two tyre widths are 1dB lower than the indicative limits in Directive 2001/43/EC.

“Provided that the requirement does not imply a retroactive action for tyres already type approved, then, depending on the current replacement cycle for each manufacturer (stated to be between 3 to 5 years), the costs could even be integrated in the natural evolution of improvement in tyre performance.”

Question: What would be the costs and changes necessitated by option 3? With option 3:

(i) The lower noise limits would all come into force in 2008;

(ii) The noise limits for all five tyre widths would be reduced by 5dB relative to the 2005 limits.

“The required step is so large that it must involve a generalised technological breakthrough. The associated costs as of today cannot be estimated but the amount could be so large that it must be shared by the whole community.”

“The implication for the costs of manufacturing in the UK will vary from company to company.”

There would be “additional R&D effort, the development of new materials, equipment and processes and the need to find and validate new suppliers.”

“Another area of additional cost will be in the need to change moulds to enable tyres to the new specifications to be manufactured. This will vary according to how the required changes in moulds fit in with the normal mould replacement cycle.”

Question: Would there be changes to noise testing costs with option 2 or option 3?

There would be no change to the current situation, for both in house and subcontracted noise testing.

Question: Are you in favour of option 4?

“We see considerable difficulties in this option.” The issues include the need for a surface that is acceptable internationally, rather than just being representative of UK roads. All existing limits would need to be redefined. Tyres would have to be tested for other parameters on this surface. There would be considerable uncertainty, with no assurance of an improvement to tyres.

Question: Any other comments?

“Reductions in rolling sound emissions using the current ISO 10844 test surface (with the exception of silent road pavements) failed to lead to reductions in traffic noise. On the other hand changes in road surfaces have proven that road traffic noise reductions in the order of -5dB(A) can be easily achieved”.

“...we have to use the potential of rolling noise reduction entailed by varying road pavements according to noise mapping priorities.”

A chart from 2001 was provided, showing a spread of 10dB(A) in noise form different paving surfaces available in France.

“If double layer pavements are used then the correlation with the ISO 10844 is more evident.”

Table 7.1 of this report explains the important non-regulatory approaches that were considered as part of the RIA.

The BRMA's comments can be read together with the information that we already have on the availability of quieter road surfaces. The Highways Agency has made clear that they have started to use 'very quiet surfacing material' (see quote in section 7.3.3 of this report). However, we have been unable to ascertain how many lane kilometres of these surfaces have been laid in the UK.

The BRMA themselves provided us with further technical information, which explained the benefits of surfaces that are available (see final two comments in table 8.3, above). It is clear that the BRMA are not calling for extensive research into low noise surfaces, but for deployment of these surfaces. We believe that only a minority of UK local authorities specify quieter surfaces for their routine re-surfacing, and that the use of 'very quiet surfacing material' is even rarer. Neither local authorities nor the Highways Agency appear to be using 'very quiet surfacing material' systematically for re-surfacing. Relative to the length of the road network, very few kilometres of new roads are constructed each year, so the key to deployment of these surfaces rests with re-surfacing policy.

8.5 Value of benefits and costs

TRL has carried out a thorough valuation of the benefits of road traffic noise reductions in the UK (Watts et al., 2005). The values were derived from the DfT's own study on transport related noise in Birmingham (Bateman I J, Day B H and Lake I, 2004).

The valuation in the vehicle noise report was £524 million per annum, per decibel reduction in road traffic noise. This figure is the value to the whole of the UK of a 1 dB(A) reduction in road traffic noise, no matter how it is achieved. The value would be the same, whether it was achieved by changes in tyre noise, speed reductions, changes to the proportion of large goods vehicles, or road surfaces. This figure was calculated in February 2005. We will use this figure here, not least because it provides consistency for stakeholders. In fact, the DfT presented an update on the Birmingham valuations in May 2005, which has had the effect of raising the overall figure.

Section 6.3 of this report identifies reductions of 1.7 dB(A), 2 dB(A), 2.3 dB(A) and 3 dB(A) in road traffic noise, for the tyre noise limits proposed in table 6.3. These figures depend on road speed and traffic mix. We will take the figure of 2.3 dB(A) for the valuation. This is because the DfT has asked that the RIA concentrate on the passenger car tyre sector, to which this relates.

A road traffic noise reduction of 2.3 dB(A) per annum would equate to an annual benefit to the UK of $2.3 \times £524\text{m} = \mathbf{£1205 \text{ million per annum}}$

The costs of changes to the tyre noise limits will fall into two categories:

- (i) One-off costs, for example for design changes and mould development. These costs are mainly incurred before a new noise limit value comes into force for OEM tyres.
- (ii) Annual 'recurring' costs, which will occur each year after the noise limit has come into force.

The responses to this consultation have not provided cost figures for the changes that manufacturers would face. The BRMA response pointed out that the costs of option 3 in the consultation could not be estimated. However, option 3 involved lowering the noise limit for all tyres by 5 dB(A) from the current limits, by 2008. This would have led to a limit as low as 67 dB(A) on the narrowest tyres. Implementation of the limits in option 3 would therefore have occurred far sooner than the less restrictive limits proposed in table 6.3. The proposal in table 6.3 of this report does not involve any tyres having to meet a noise limit below 71 dB(A), and brings in the tightest limits in 2010.

We state in section 6.3 of this report that "*In all categories, where results from more than one tyre were available, there are tyres which would meet a new limit value of 71 dB(A)*". See also Figure 3.1, which shows that these tyres were already on the market in 2002. Some tyres were already on the market as long ago as 1993, with noise emissions of 71 dB(A). These tyres are already on sale. Therefore the design and technology costs for these tyres have already been spent. Given the introduction date of 2010 for the final limit values proposed in table 6.3, it is difficult to see that there

would be substantial costs for manufacturers to bring the remainder of their production up to the required standards.

Given the annual benefits of £1,205 million, a reasonable question to ask is whether the annual cost would be likely to exceed one tenth of this, i.e. £120 million. Assuming that the one-off development costs are spread over 2007-2009 inclusive, it is hard to see that the annual cost would reach £120 million. We note here that changes to tyre noise limits that will be introduced across all EU25 member states. Therefore the development costs will be amortised across a market of 200 million tyre sales per annum, and a consumer base of 470 million citizens by 2015.

Our understanding of tyre manufacturing, partly informed by the BRMA response, is that it would be very unlikely that there would be recurring annual costs of £120 million for tyres supplied to the UK.

We cannot put an exact numerical value on the benefit cost ratio. This is due to the fact that no consultee has provided us with cost estimates, and also because the costs involve both one-off initial costs and recurring costs.

However, the evidence that is available points to an annual benefit to the UK of the order of £1,205 million per annum from the noise limits proposed in Section 6.3 and Table 6.3 of this report. This benefit appears to be, at the very least, a factor of ten larger than any conceivable costs to industry, either recurring or 'one-off'.

In estimating costs, it is important to note that Directive 2001/43/EC already foresees limit values of 70 dB(A) and 71 dB(A) for tyre classes C1a and C1b respectively, from 1 July 2007. The tyre industry has indicated that these costs could be absorbed in the normal design cycle. The industry will also have had six years notice of the introduction of these limits, between publication of the Directive and the planned implementation of the limits (see Table 6.4).

The effects on consumers are likely to be minimal, and may in fact be negligible. The cost of replacing tyres on a vehicle typically amounts to, on average, around £80 per annum. Even if this were to increase by 5%, the change would represent less than 0.1% of the annual running costs of a typical vehicle. The running costs of vehicles are falling in the UK, in real terms. Even if the 0.1% increase did occur, this would simply appear as a slight slowing in the rate at which the costs of motoring are falling, in one year.

The rate at which tyres need to be replaced on a vehicle is obviously related to the number of miles driven per annum. Any increase in tyre costs is therefore 'progressive', i.e. it has the greatest effect on motorists who drive the highest mileages, who would perhaps be more affluent than the average.

Figure 5.3 shows that there is no definite correlation between rolling resistance and tyre noise. It is therefore unlikely that changes to tyre noise limits will increase or decrease fuel costs and greenhouse gas emissions.

8.6 Timing of changes in noise limits for replacement tyres

The benefits of lower noise tyres accrue to society much more quickly if lower noise limits are introduced for replacement tyres without long transition periods. The 'transition period' here is the time between introduction of the noise limits for tyres on new vehicles and the introduction of the same limits on replacement tyres. A 4.6, 5.6 or 6.6 year transition period was allowed in paragraph 6 of Article 1 of Directive 2001/43/EC, depending on the width of the tyres concerned.

In a time period of 5.6 years, around 140 million replacement tyres are sold in the UK. These will continue in service after the end of the transition period. Across the EU25, one billion tyres will be sold.

Tyre manufacturers incur research and development costs well ahead of the deadlines when new limit values are brought in for tyres fitted to new cars. No economic reason is apparent as to why as many as 140 million further tyres should be produced and sold to a lower noise standard, long after these one-off costs have been incurred. It would therefore appear that there is a way both to increase the benefits to society and decrease costs to manufacturers. This would involve introducing lower noise

limits for replacement tyres more quickly, even if that change were accompanied by an increase in the time taken for legislation to be introduced for new vehicles.

Currently, Directive 2001/43/EC has fragmented the tyre market into two parallel streams, with the replacement sector not being required to deliver the noise benefits that are available through tyres fitted to new cars.

8.7 The full RIA in 2006

The DfT informed us that they will conduct a full, formal RIA when the EU Commission makes a proposal for changes, probably during 2006. The RIA may benefit from an investigation of changes in the durability of tyres with changes in rolling noise properties. If there are substantial changes in durability due to lower tyre noise limits, then this will affect costs. If durability increases, then this would increase tyre lifetime, which would reduce replacement costs for consumers and the volume of tyres requiring disposal. If durability decreases, then turnover for the tyre industry would be expected to increase.

8.8 Conclusion

The RIA has provided information on tyres for the UK passenger car sector. The annual recurring benefits to the UK of the lower tyre noise limits proposed in Table 6.3 of this report would amount to a minimum of £1,205 million (£1.205 billion). These benefits appear, at the very least, to be a factor of ten greater than the costs that would be incurred. The low response rate to the RIA consultation appears to indicate that there is little concern among car manufacturers and government about the proposed changes.

The industry body representing tyre manufacturers had concerns about the most restrictive option for lower noise limits that was put to them in the RIA consultation in February 2005. However, the noise limits proposed in table 6.3 of this report are neither so restrictive as those in that option, nor would they come into force so quickly. Another option in the RIA consultation concerned tyre noise limits that are slightly more restrictive than the 'indicative limits' in Directive 2001/43/EC. The industry body commented that under certain conditions, these changes might "*be integrated in the natural evolution of improvement in tyre performance*".

The 2005 noise limits in Directive 2001/43/EC for tyres fitted to new cars will eventually be applied to replacement tyres between 2009 and 2011. Around 140 million tyres are likely to be sold between 2005 and 2010. When future reductions in noise limits are applied to tyres for new cars, there appears to be no credible economic case for such a long delay before applying the same reductions to tyres sold as replacements. Indeed, the reasons for a delay do not appear as strong as the benefits that would be foregone.

9 Conclusions and recommendations

The main conclusions and recommendations derived from this study are detailed below, under each of the main tasks that were described previously in the introduction to this report. The reader should be reminded that the results of this work will be used to inform and support the development of UK policy on tyre noise type approval and tyre noise limits.

Task 1: Establishing the effectiveness of the current regulations

- It has been shown that practically all car tyres available on the market since the regulations were introduced produce type approval noise levels that are well below the current limit values. In an analysis of 147 tyres tested according to the type approval procedure it was found that only 2 would fail the current noise limits, representing about 1% of the sample. Similar results have been found for a study of 48 tyres conducted in Germany in 2000. In this study, none of the tyres examined gave noise levels that exceeded 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.

Task 2: Potential reductions in tyre noise and the corresponding effects on safety

- Previous studies that have attempted to examine the relationship between tyre noise and safety performance have indicated evidence of a weak trend between noise and measures of wet grip adhesion. In some cases the relationships were found to be significant. However, in all cases examined in this study, the data has exhibited considerable scatter indicating that a great deal of the variance in the noise levels cannot be explained simply in terms of relative safety performance.
- There are many examples of tyres that produce relatively low noise levels and yet perform well in terms of wet grip.
- 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 below the current limits without affecting overall safety performance. In addition, the analysis has shown that it is possible to produce tyres that can perform well in terms of wet grip and noise emission.

Task 3: The effects of lowering tyre noise on rolling resistance, fuel economy and environmental pollution

- Tyre rolling resistance currently accounts for approximately 30% of the fuel used by vehicles in the 'car' group so it is an important component governing fuel consumption. In addition, 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. This is 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. 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.
- Further improvement in fuel consumption may occur as a result of the use of run flat tyre designs where this obviates the need for a spare tyre.

- 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. It is not expected therefore that there should be any noticeable effect on vehicle fuel economy and the emissions of greenhouse gases.
- 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.

Task 4: Recommendations for future noise limits

- The available data on tyre noise emission, wet grip performance and rolling resistance has been examined to establish the technical feasibility of reducing the noise limits without compromising safety and fuel economy. By taking into account the need to reduce overall levels of traffic noise and the associated noise impacts on communities, appropriate future noise limit values have been determined.
- Examining each tyre section width category has shown that there is currently little justification for having higher limit values for wider tyres. It is recommended that in the future there is no distinction between tyre widths, except for a recommended new tyre width category for the largest tyres whose section width is ≥ 245 mm. Although for this extra tyre class we have recommended a section width of 245 mm and above, the exact demarcation point may need further revision depending on the future market for these wider tyres. For 2010 it is proposed that all limits are set at 71 dB(A), apart from the wider tyre category which is set at 73 dB(A), with a interim reduction made in 2008. The proposed new limits are summarised below:

Proposed new tyre limit values

Tyre class	Nominal section width (mm)	Limit values in dB(A)		
		A (Current limit)	B ¹	C ²
C1a	≤ 145	72	71	71
C1b	$> 145 \leq 165$	73	72	71
C1c	$> 165 \leq 185$	74	72	71
C1d	$> 185 \leq 215$	75	73	71
C1e	$> 215 \leq 245$	76	73	71
C1f	> 245	76	75	73

¹ Limit values shall apply from 1 July 2008.

² Limit values shall apply from 1 July 2010.

- In addition to the changes in the noise limits it is also recommended that changes should be introduced in the new directive to the method used for adjusting the measured data. The current type approval test includes a procedure for rounding down the measured values of tyre noise. This is outdated in view of the availability of good quality instrumentation. It is recommended that this procedure be removed when the method is revised and is replaced with a method which rounds the measured values to the nearest integer value. This would align the procedure with the method being proposed for the separate vehicle noise type approval test. This change in the procedure would itself mean a lowering of the threshold that is actually enforced.

Task 5: Alternative measures for reducing tyre noise (including recommendations for changes to the current test)

- Methods of reducing tyre noise, other than reducing the tyre noise limits, have been considered. These include:

Tyre labelling

A scheme where the noise of a tyre is marked on the sidewall would improve information to consumers, and hence consumer choice. Such a scheme would also make it significantly easier for governments to introduce financial incentive schemes, in order to create a market for lower noise tyres. The act of marking tyres with noise levels could be expected to cause manufacturers to give great consideration to tyre noise at the design stage.

Fiscal incentives

A wide variety of approaches could be devised to give consumers a financial incentive to purchase lower noise tyres, or a new vehicle fitted with lower noise tyres. Creating a market in this way has numerous precedents in the UK. A flat rate reduction in Vehicle Excise Duty (VED), or a reduction of one VED band, for vehicles fitted with low noise tyres could be used for both old and new vehicles. Because there are currently no incentives for consumers to buy low noise tyres, such a financial incentive would meet the Treasury requirement of having little 'fiscal drag'. Financial incentives for low noise tyres would be least susceptible to fraud if they were coupled with tyre marking as described above.

Vehicle speeds

Tyre noise rises with vehicle speed. Above 60 kph, tyre noise dominates over other noise sources for almost all vehicles. Reducing vehicle speeds to the legal limit or below is a rapid way to reduce tyre noise levels, given that 57% of all cars exceed the 70 mph speed limit on motorways, and 19% of cars and 17% of Light Goods Vehicles (LGVs) exceed 80 mph.

In the short term, high visibility policing can reduce speeds on high speed roads, with the bonus of lower accident rates and savings in greenhouse gas emissions. In the longer term, speed enforcement 'through the vehicle' is likely. DfT research has explored speed limiters that adapt the maximum speed of a vehicle to the prevailing local speed limit (Carsten and Fowkes, 2000). Insurance companies' 'Pay As You Drive' (PAYD) insurance technology deters extreme driving styles. Government financial incentives for speed limiters or the fitting of PAYD insurance equipment would create a market, and cause these technologies to permeate the vehicle fleet much more rapidly than otherwise would be the case.

Testing of tyres when worn

Currently tyres are tested when they are new, and the noise level achieved at type approval is therefore only representative of the level when the tyre has full tread depth. It is recommended that a tyre is type approved when it has covered a certain distance (e.g. when worn to half way) which would be more representative of the tyre noise that might be expected to be generated by the tyre over its useful life. Further research would be necessary however, to establish the degree of wear that is most appropriate for testing purposes.

Another method considered is the continuing development of lower noise road surfaces. Improvements to vehicle design that help to shield tyre noise, and techniques that assist motorists in maintaining the correct inflation pressures to their tyres, will also help to reduce tyre noise levels.

- When the tyre noise type approval Directive is amended the opportunity should be taken to improve the method of testing, which should help to improve the reproducibility and representatively of the test method: The following improvements are recommended:

Test surface:

The current test surface is not representative of the surfaces commonly found on roads in the UK. The noise produced on this surface does not relate well to the noise produced on common UK roads surfaced with HRA and larger sized SMA. However, it has been found that a much better correlation is obtained with roads surfaced with smaller sized aggregates, such as SMA10. Consequently, since there is a trend in the UK and in other countries to re-surface high speed roads with SMA type materials using these smaller sized aggregates, it is recommended that the test surface is also changed to an SMA based surface with a 10 mm or 11 mm aggregate.

Test speed:

Tyre noise levels generated at high speeds are not necessarily representative of the levels produced at lower speeds. This has importance in controlling noise in urban areas. It is therefore recommended that some provision is made in the method to allow for an assessment of the noise at lower speeds than is typical of urban driving.

Rounding down:

See previous conclusions listed under task 4.

- Possible alternative test methods include the use of drums, and measurements taken in close proximity to the test tyres. The advantages of running test tyres on drums are that close control over the test surface and weather conditions can be achieved. There is a high initial cost involved with installation however. Close proximity testing removes test result variability associated with propagation effects, but again requires a high initial cost in equipment development which can introduce issues associated with reproducibility.

Task 6: Regulatory Impact Assessment

- The RIA has provided information on tyres for the UK passenger car sector. The annual recurring benefits to the UK of the lower tyre noise limits proposed in Table 6.3 of this report would amount to a minimum of £1,205 million (£1.205 billion). These benefits appear, at the very least, to be a factor of ten greater than the costs that would be incurred. The low response rate to the RIA consultation appears to indicate that there is little concern among car manufacturers and government about the proposed changes.
- The industry body representing tyre manufacturers had concerns about the most restrictive option for lower noise limits that was put to them in the RIA consultation in February 2005. However, the noise limits proposed in table 6.3 of this report are neither so restrictive as those in that option, nor would they come into force so quickly. Another option in the RIA consultation concerned tyre noise limits that are slightly more restrictive than the 'indicative limits' in Directive 2001/43/EC. The industry body commented that under certain conditions, these changes might "*be integrated in the natural evolution of improvement in tyre performance*".
- The 2005 noise limits in Directive 2001/43/EC for tyres fitted to new cars will eventually be applied to replacement tyres between 2009 and 2011. Around 140 million tyres are likely to be sold between 2005 and 2010. When future reductions in noise limits are applied to tyres for new cars, there appears no credible economic case for such a long delay before applying the same reductions to tyres sold as replacements. Indeed, the reasons for a delay do not appear as strong as the benefits that would be foregone.

Acknowledgements

The work described in this report was carried out in the Infrastructure and Environment Division of TRL Limited. The authors are grateful to Roger Williams (independent consultant) for advice on tyre selection and technical issues. In addition the authors would like to thank Mark Balsom (TRL), Derek Meachen (TRL) and Mike Ainge (TRL) for assistance with the test work. The assistance, advice and supply of tyres from ETRTO members is gratefully acknowledged.

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Glossary of abbreviations

BFC	Braking Force Coefficient
BRMA	British Rubber Manufacturers Association
DETR	Department of Environment, Transport and the Regions, UK
DfT	Department for Transport, UK
EC	European Commission
ETRTO	European Tyre and Rim Technical Organisation
HA	Highways Agency, UK
HARMONOISE	Harmonised, Accurate and Reliable Methods for the European Directive on the Assessment and Management of Environmental Noise (Project acronym)
HRA	Hot Rolled Asphalt
IMAGINE	Improved Methods for the Assessment of the Generic Impact of Noise in the Environment
ISO	International Organisation for Standardisation
M+P	M+P Raadgevende Ingenieurs BV, The Netherlands (Company name)
MIRA	Motor Industry Research Association
NEDC	New European Driving Cycle
OEM	Original Equipment Manufacturer
PAYD	Pay As You Drive
RIA	Regulatory Impact Assessment
SILVIA	Silenda Via: Sustainable road surfaces for traffic noise control (Project acronym)
SMA	Stone Mastic Asphalt
SUV	Sports Utility Vehicle
TRL	Transport Research Laboratory (Company name)
TUV	TUV (Technischer Überwachungs – Verein) Automotive GMBH, Germany (Company name)
UTAC	Laboratoire De L'Union Technique De L'Automobile, Du Motorcycle et Du Cycle, France
VERT	Vehicle Road Tyre Interaction (Project acronym)

Appendix A. Correlations between the ISO and other surfaces

Figures A1 to A5 show the relationships for the five road surfaces examined as part of the TRL study (Phillips *et al.*, 2003). Data for additional tyre sets were included in the analysis as it was not necessary to restrict tyre sets to only those tested on all surfaces. None of the relationships were found to be statistically significant so that is not possible to be precise about the trends noted. The range of the slopes are given in each case.

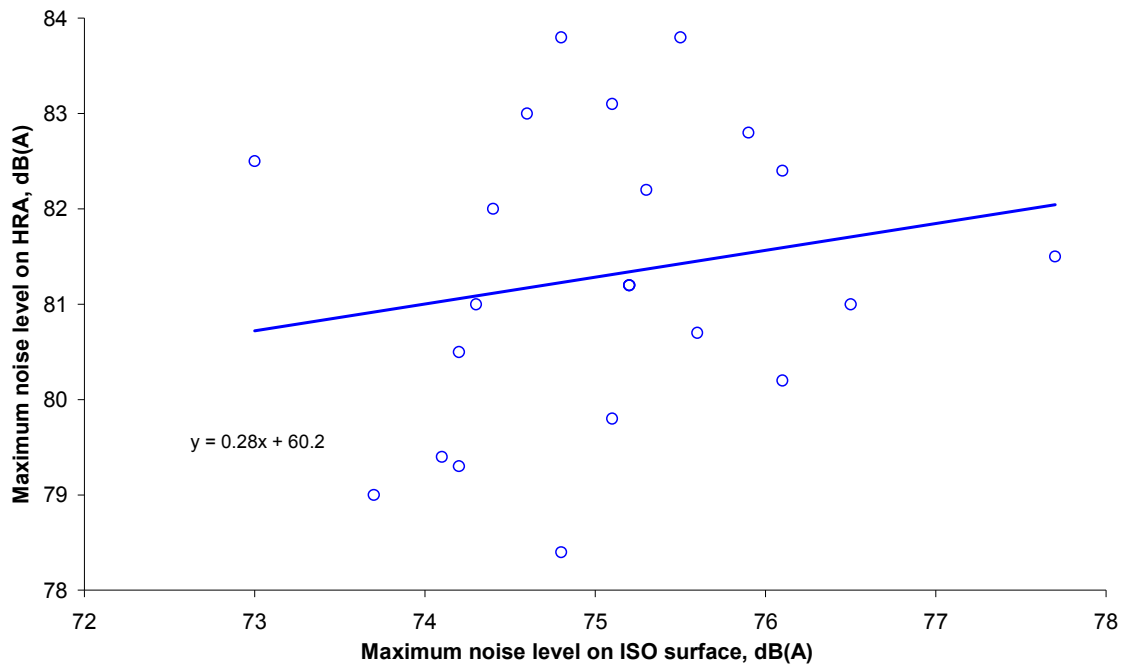


Figure A1: Pass-by A-weighted noise levels on ISO and HRA

It can be seen that there is a weak relationship between the noise levels measured on the ISO surface and HRA. The correlation coefficient of 0.19 is not statistically significant. The slope of the regression line is 0.28 ± 0.67 (the limits defining the 95% confidence interval). There is therefore a large amount of uncertainty in terms of estimating any changes that may result from a reduction in the type approval limit values on the ISO surface. Based on the slope of this relationship the best estimate of the average change in noise level on an HRA surface due to a substantial reduction of, say 5 dB(A), on the ISO surface would be a reduction of just 1.4 dB(A).

For the brushed concrete surface the relationship shown in Figure A2 was found. In this case the correlation coefficient is 0.17 and is again not statistically significant at the 5% level. The slope of the regression line is 0.11 ± 0.58 , and hence indicates a large uncertainty in estimating changes in noise levels on this surface from changes to the type approval limit on the ISO surface. For this surface the best estimate of the effects of a 5 dB(A) reduction on the ISO surface would be an average reduction of 0.54 dB(A). This value can only be viewed as a best estimate until further information is available.

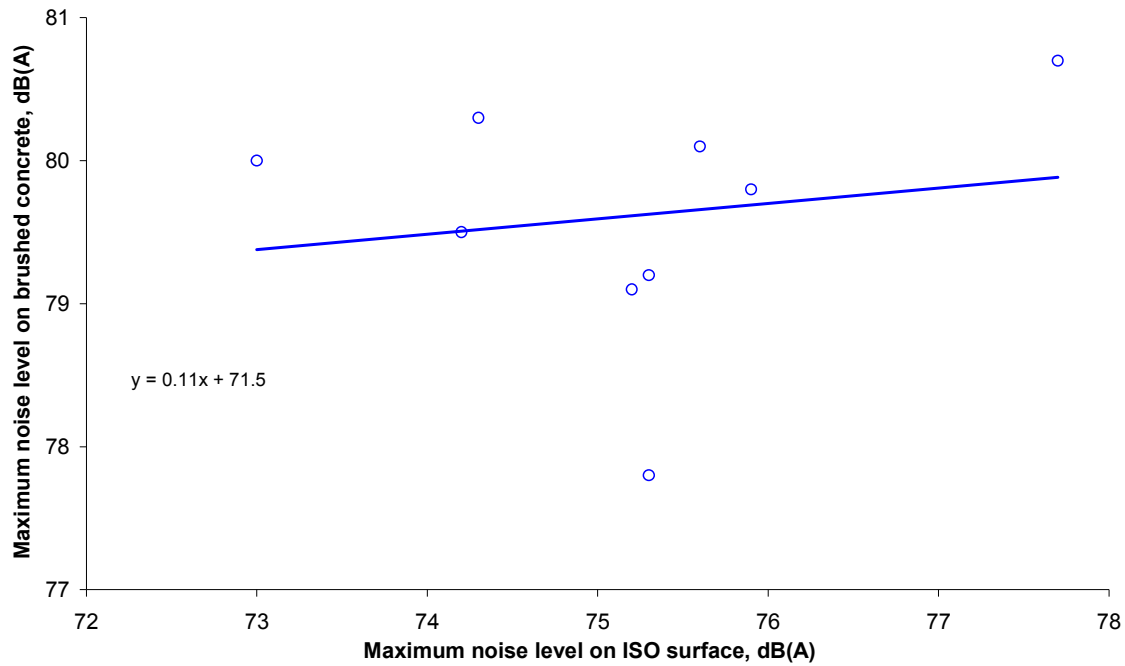


Figure A2: Pass-by A-weighted noise levels on ISO and brushed concrete

For an SMA surface the relationship shown in Figure A3 was found. The correlation coefficient was 0.32 which was not statistically significant, and the slope of the regression line is 0.21 ± 0.44 . For this case, a best estimate of the reduction in the limit values of 5 dB(A) may lead to an average reduction of 1 dB(A) on the SMA.

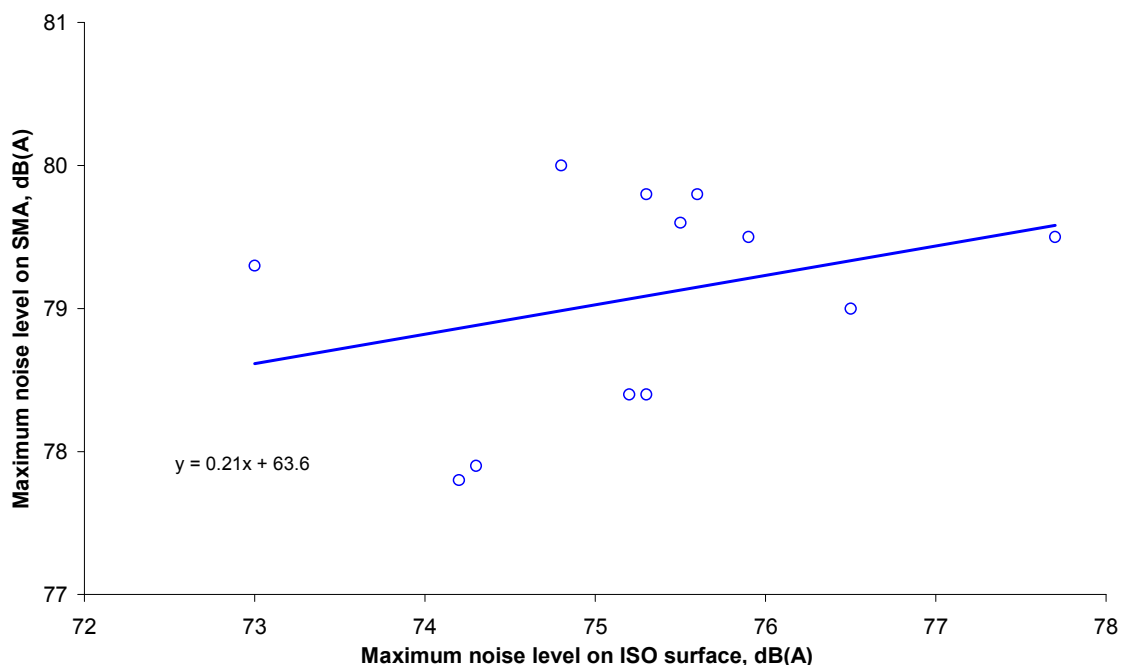


Figure A3: Pass-by A-weighted noise levels on ISO and SMA

For the MARS14 surface the relationship is given in Figure A4. It can be seen that in this case a very weak relationship results. The correlation coefficient is 0.055 and the slope is -0.06 ± 1.27 , indicating

very great uncertainty in predicting changes on this surface. As a best estimate, a 5 dB(A) reduction in the limit value on the ISO surface may lead to an average *increase* in noise of 0.3 dB(A) on the MARS14 surface.

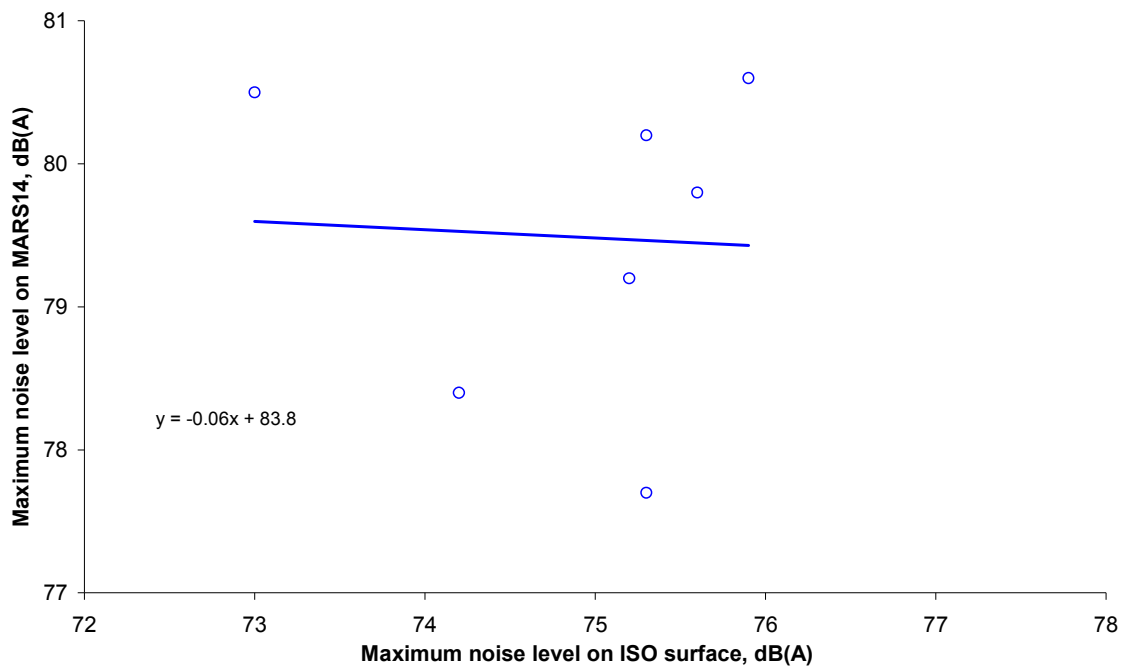


Figure A4: Pass-by A-weighted noise levels on ISO and MARS14

Lastly, for a fine porous surface, (Colsoft) the relationship shown in Figure A5 was found.

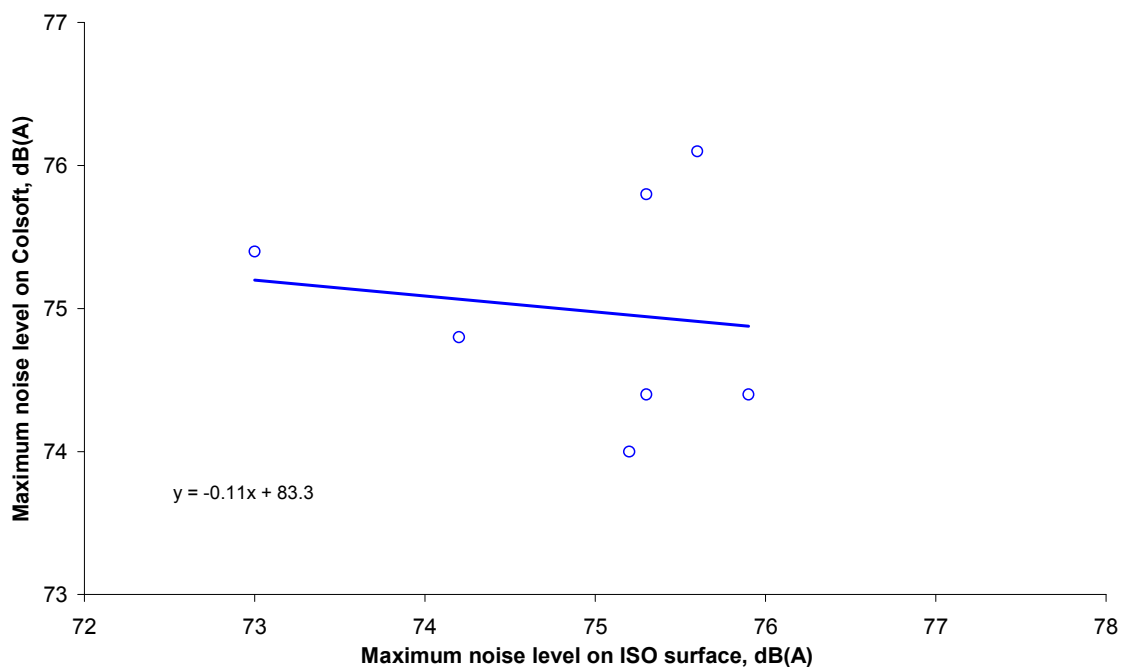


Figure A5: Pass-by A-weighted noise levels on ISO and Colsoft

In this case, the correlation coefficient is again very small at 0.14 and the slope of the regression line is -0.11 ± 0.90 . The best estimate of a 5 dB(A) reduction on the ISO surface is a small increase of 0.6 dB(A) in noise levels on this surface.

Appendix B. HARMONOISE calculations for various traffic conditions

Roads subject to 30 mph limit

Based on national traffic statistics, the average composition assumed on roads subject to a 30 mph (48 kph) limit 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 kph to reflect different degrees of congestion. Figures B1 and B2 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 noise levels were chosen bearing in mind the range of noise levels for different tyre classes indicated in the data given in Figure 3.1 (from the main report). Given that the range in levels observed for tyres in use was of the order of 6 dB(A), a reduction of up to 5 dB(A) would appear to be technically feasible given the current state-of-the-art.

The assumed total hourly flow was 1000 vehicles and the receiver position was assumed to be located 7.5 m from the centre line of the vehicles.

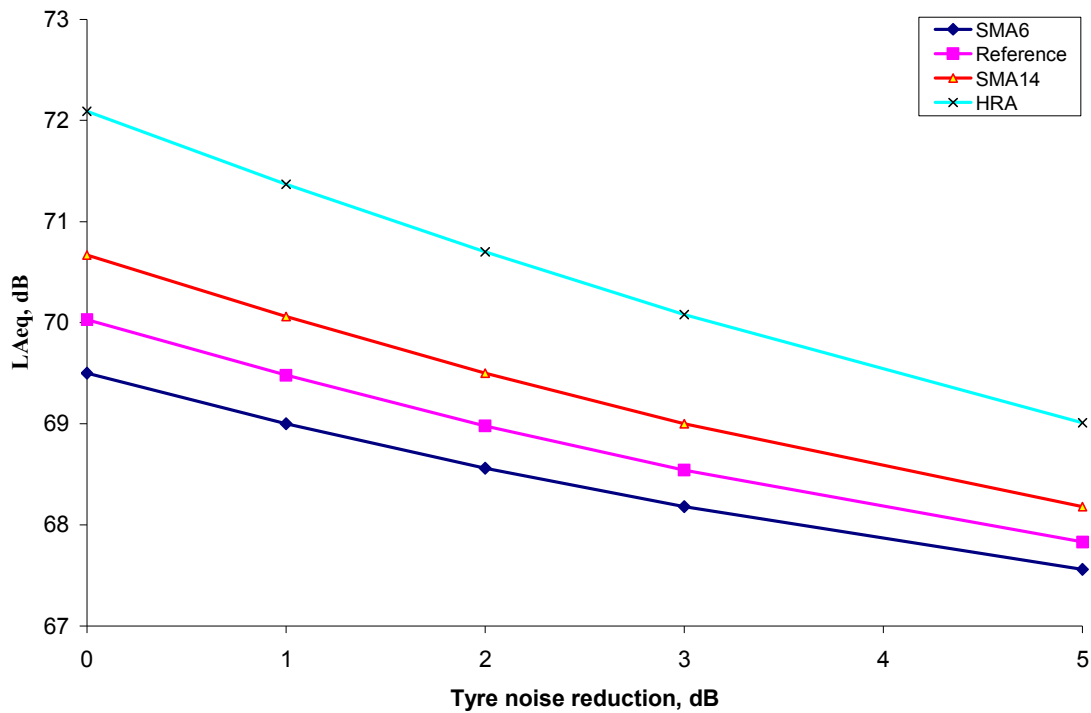
Roads subject to 40 mph or 50 mph limit

Average composition assumed on single carriageway roads with these limits was: 93.9% light vehicles, 3.4% medium heavy vehicles and 2.8% heavy vehicles. The average speed assumed was 55 kph for these roads. Figure B3 shows the corresponding plots of the resulting L_{Aeq} for reductions of tyre noise in the range 0 to 5 dB(A)

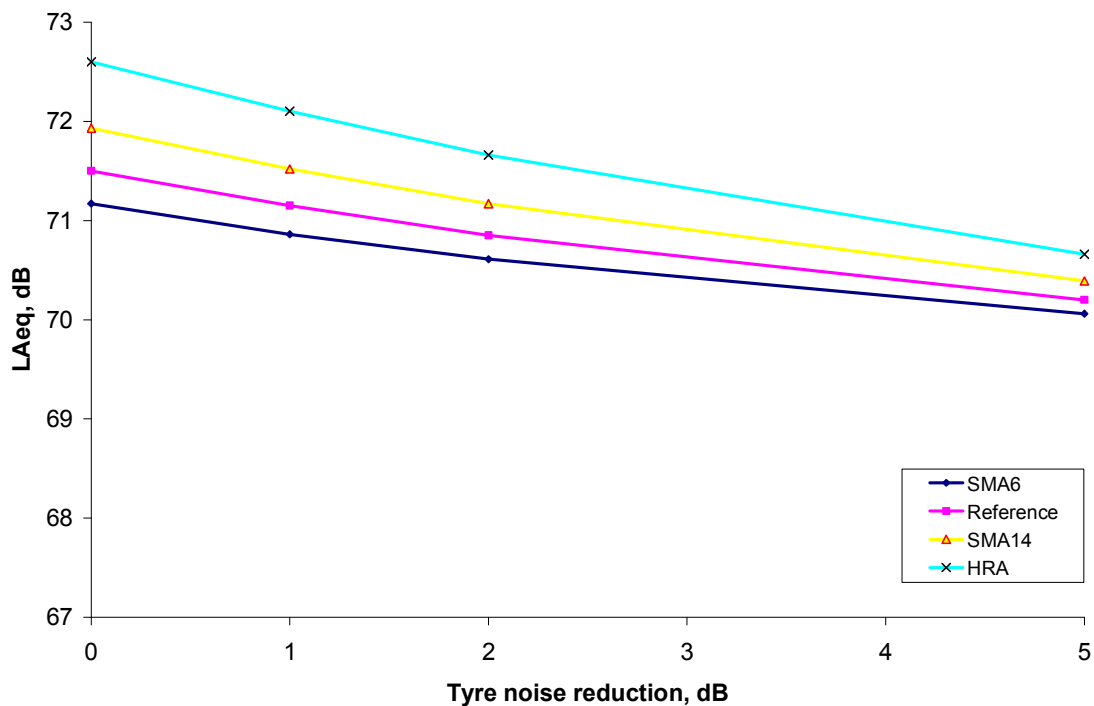
For dual carriageway roads the average composition of traffic assumed was: 89.8% light vehicles, 3.8% of medium heavy vehicles and 6.4% heavy vehicles. The average speed assumed was 70 kph.

Roads subject to 70 mph limit

For these motorways and dual carriageways the average traffic composition assumed was: 86.4% light vehicles, 4.5% medium heavy vehicles and 9.1% heavy vehicles. The assumed average speed was 112 kph (70 mph) for light vehicles and medium goods vehicles and 96 kph (60 mph) for heavy trucks. A further prediction was carried out with all vehicles speeds at 96 kph. The results from this analysis are shown in Figure B4.

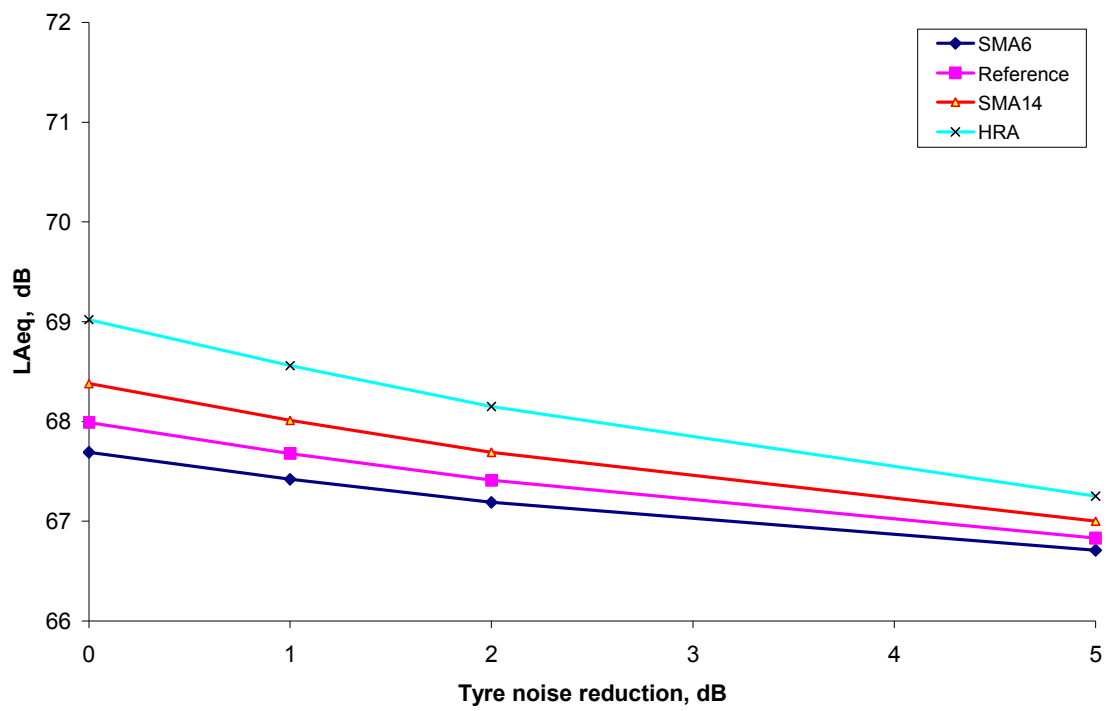


(a) Average speed 50 kph (3% medium and 0.6% heavy trucks)

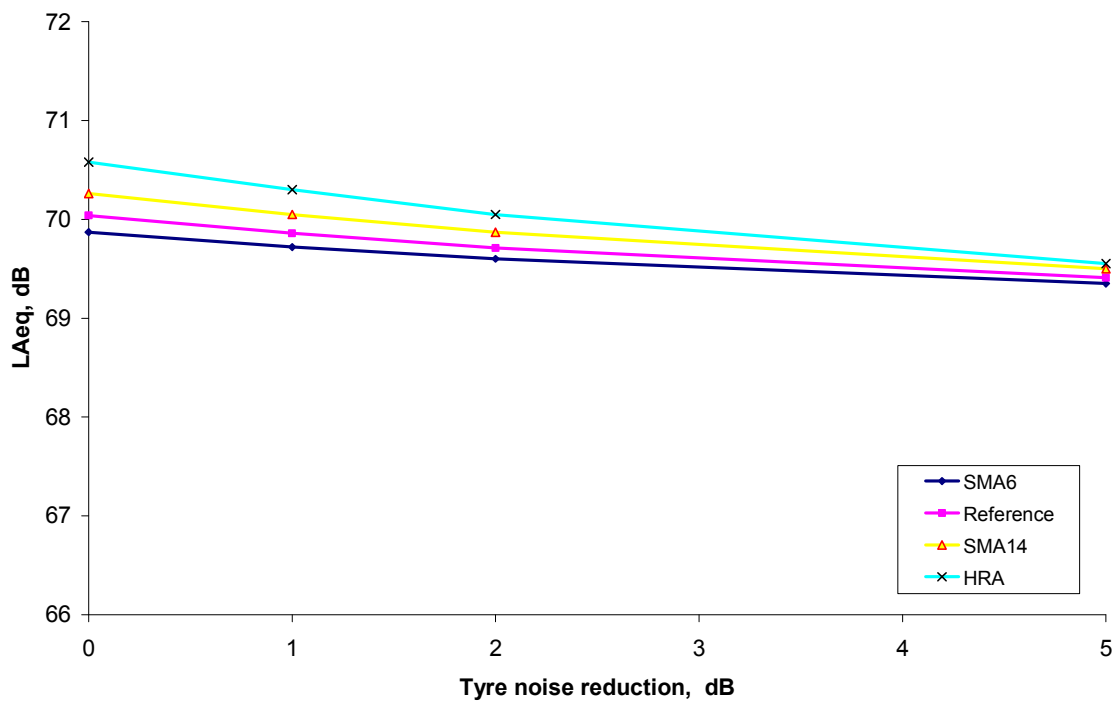


(b) Average speed 50 kph (10% medium and 2% heavy trucks)

Figure B1: Changes in L_{Aeq} with reduction in tyre noise – average vehicle speed 50 kph

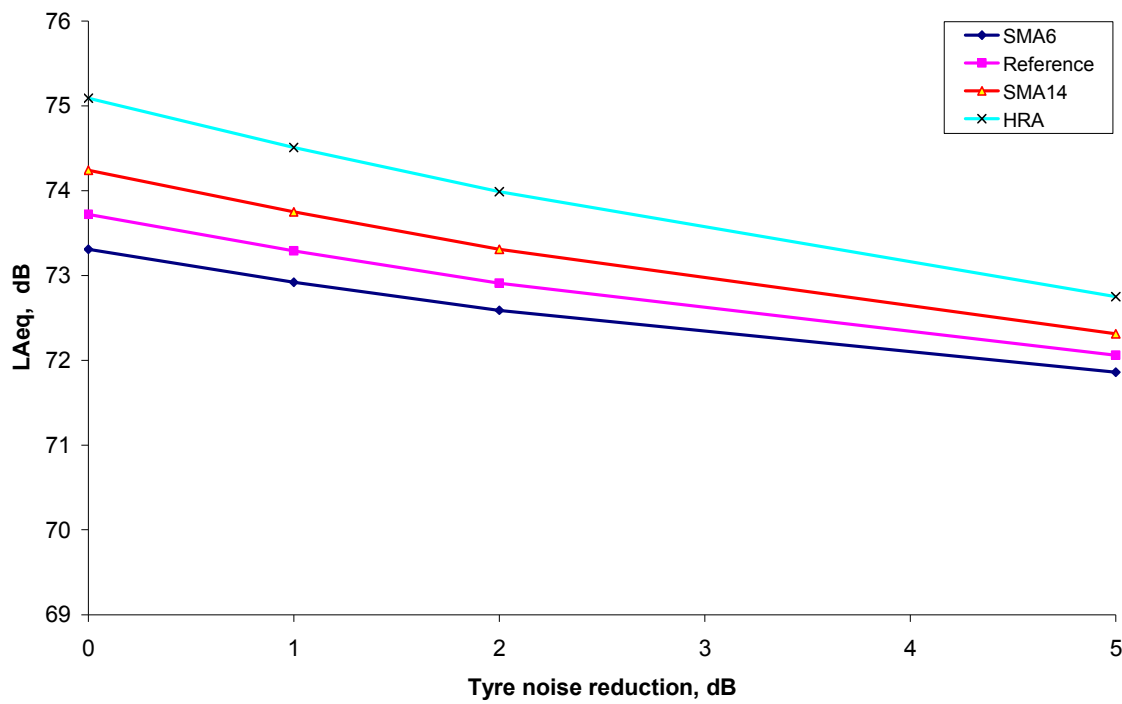


(a) Average speed 30 kph (3% medium and 0.6% heavy trucks)

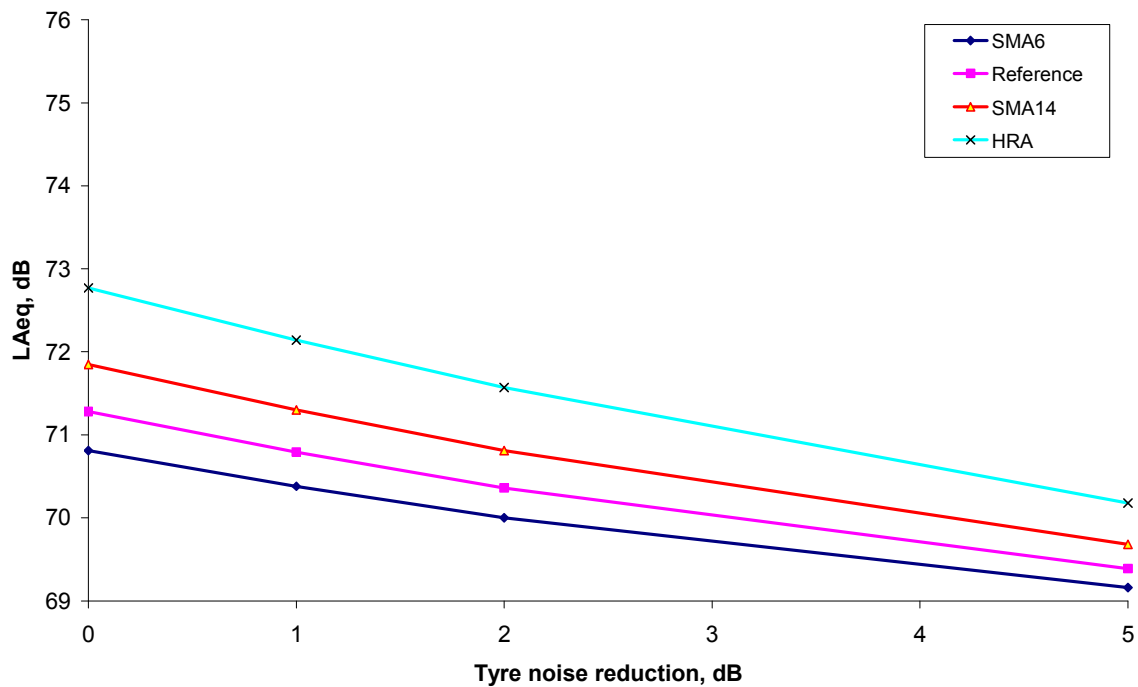


(b) Average speed 30 kph (10% medium and 2% heavy trucks)

Figure B2: Changes in L_{Aeq} with reduction in tyre noise – average vehicle speed 30 kph

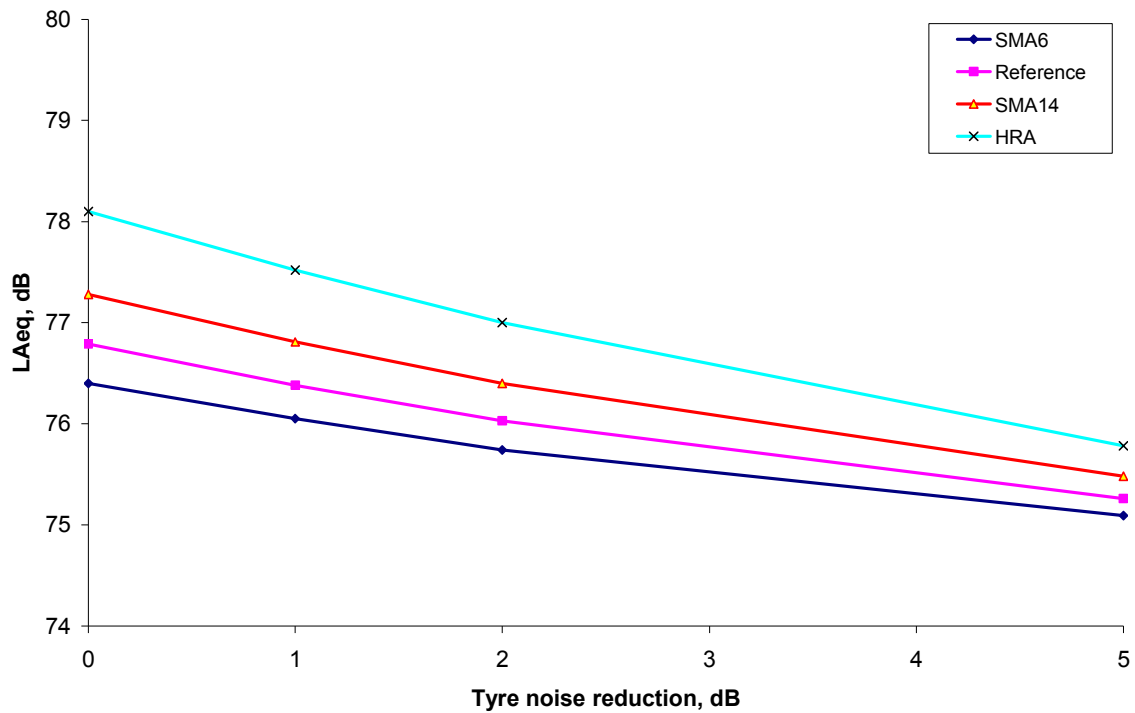


(a) Dual carriageway average speed 70 kph (3.8% medium and 6.4% heavy trucks)

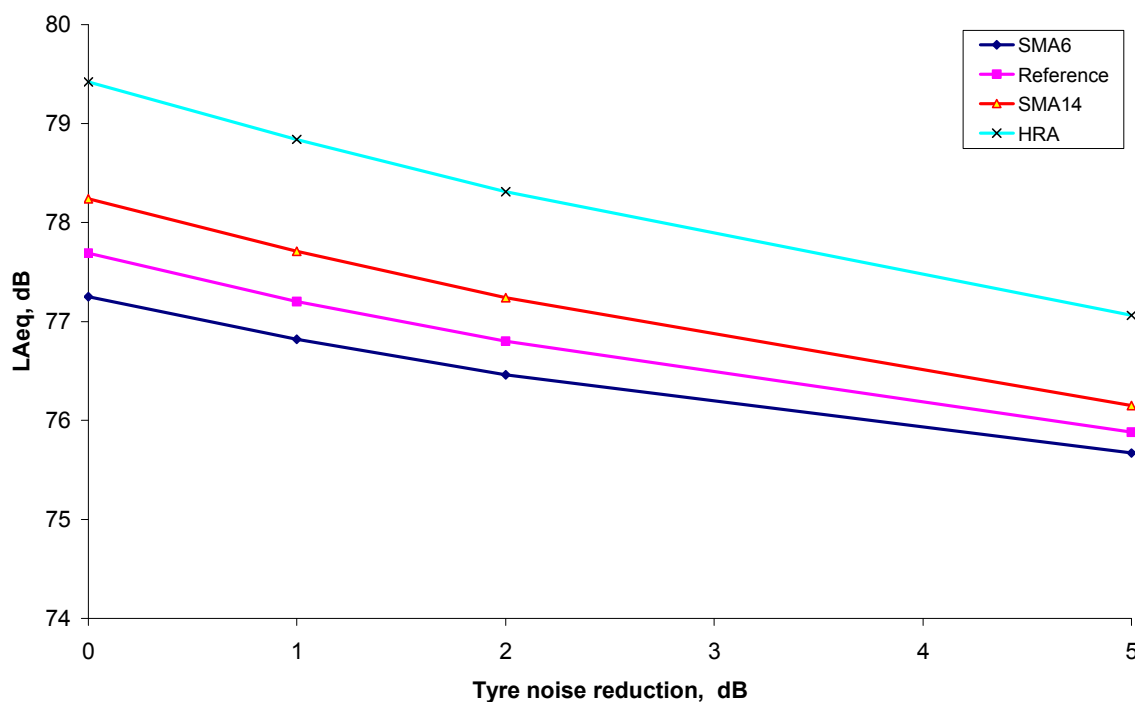


(b) Single carriageway average speed 55 kph (3.4% medium and 2.7% heavy trucks)

Figure B3: Changes in L_{Aeq} with reduction in tyre noise – average vehicle speed 70 and 55 kph













(a) Average speed 96 kph for all vehicles (4.5% medium and 9.1% heavy vehicles)



(b) Average speed 112 kph for light vehicles and 96 kph for heavy vehicles (4.5% medium and 9.1% heavy vehicles)

Figure B4: Changes in L_{Aeq} with reduction in tyre noise – average vehicle speed 112 and 96 kph

Appendix C. Test tyres from TRL test programme

			
Bridgestone Turanza 205/55R16	Conti Sport Contact 2 225/45R17	Goodyear Eagle RSA 205/50R17	Michelin Diamaris 275/45R19
			
Michelin Energy E 3A 195/65R15	Michelin Pilot Exalto 2 205/55R16	BF Goodrich profiler 2 195/65R15	Conti Premium Contact 205/55R16
			
Conti Premium Contact 2 205/55R16	Goodyear Eagle Ventura 195/60R14	Goodyear Hyrdagrip 215/55R16	

Appendix D. Further modifications possible to the current tyre noise test

D.1 Improvements to the test vehicle

Body shape is known to be a factor affecting the propagation of sound from the tyres. For example, a low slung body will tend to obscure the farside wheels resulting in potentially a smaller contribution to the overall level from this side of the vehicle. To illustrate this further a model has been developed to estimate the influence of vehicle body design on the test result (see the end of this Appendix).

Using this model, the contribution to the overall noise emission from the farside tyres can be examined assuming varying degrees of shielding. The results of this analysis is shown in Figure D1.

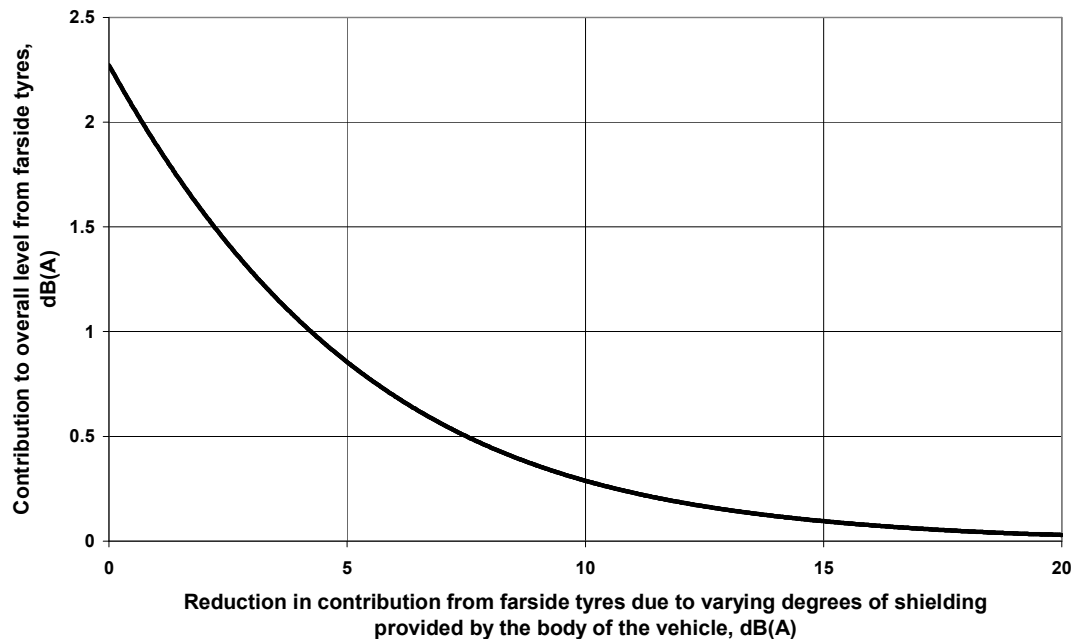


Figure D1: Contribution to overall level from farside tyres for varying degrees of shielding provided by the body of the vehicle.

The graph shows that where there is no screening, i.e. no reduction in the contribution from the farside tyres, the contribution is about 2.3 dB(A). This corresponds approximately due to a doubling in the sound intensity which would result in an increase of 3 dB(A) if 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. 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)¹² 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.

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 test result. The variability introduced by vehicle design considerations could influence the overall reproducibility of the test results. It is recommended, therefore, that the choice of test vehicle should be such that the contribution from the farside tyres are screened as much as possible by the design of the vehicle body. This will also reduce the influence of reflection effects from the underside of the vehicle. An alternative solution would be to recommend a test vehicle

¹² A 5 dB(A) reduction is typically assumed for line-of-sight screening from barriers (Department of Transport and the Welsh Office, 1988).

especially designed to accommodate all tyres of a particular tyre class. This approach was adopted in a survey to compare noise from different types of passenger car tyres (Phillips *et al.*, 2003).

D.2 Examination of the temperature correction

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 temperature of 20°C.

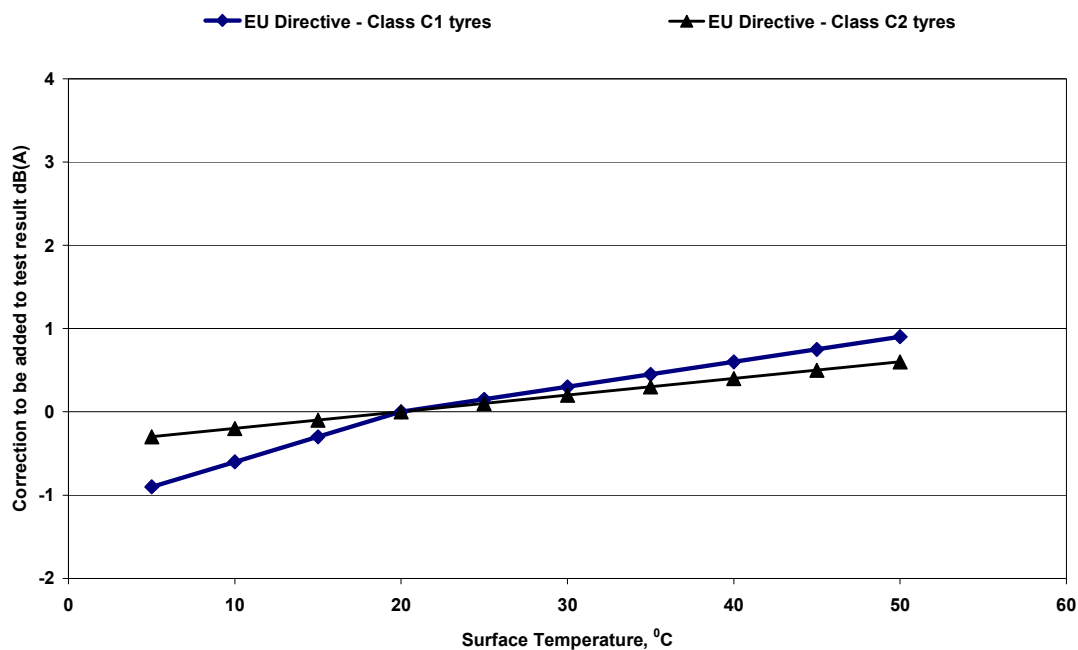


Figure D2: Surface temperature effects on tyre/road noise - EU Directive

Figure D2 shows the relationship between surface temperature and noise, referenced at 20 °C, for both C₁ and C₂ tyres. 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 D3 shows this correction for the ISO surface.

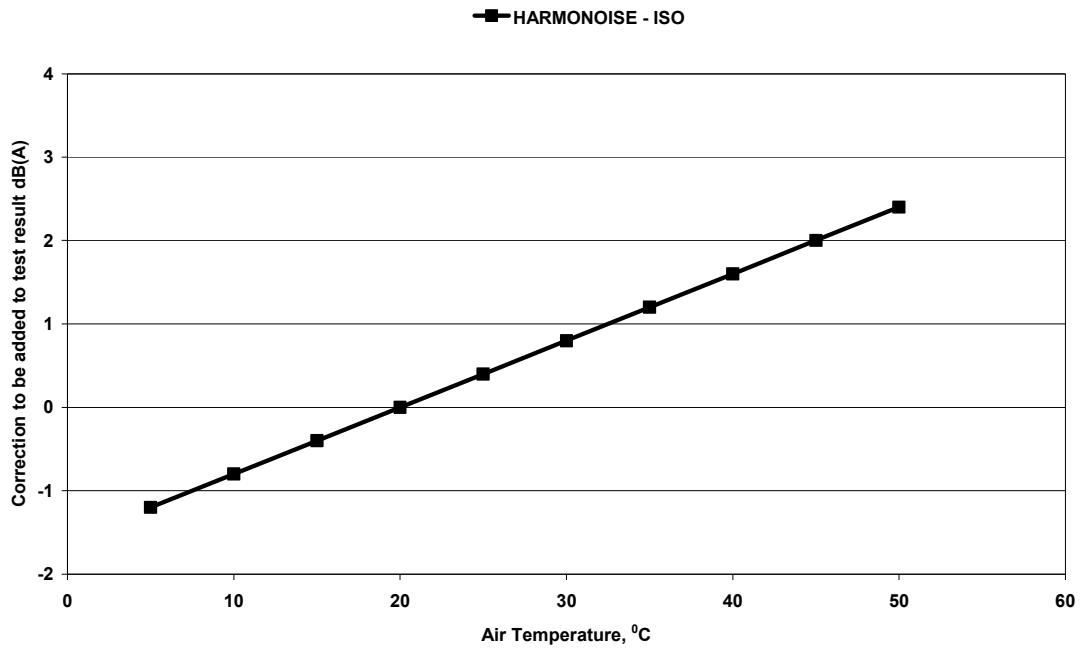


Figure D3: Air temperature effects on tyre / road noise on ISO surface - HARMONOISE

Clearly, comparing the rate of change in noise level per degree change in temperature in the two figures may suggest that the correction for temperature described in the Directive is too conservative. 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.

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 that is implied in the above argument. Results from a recent study on tyre noise where both air and surface temperatures were monitored during experiments carried out using the ISO surface are shown in Figure D4.

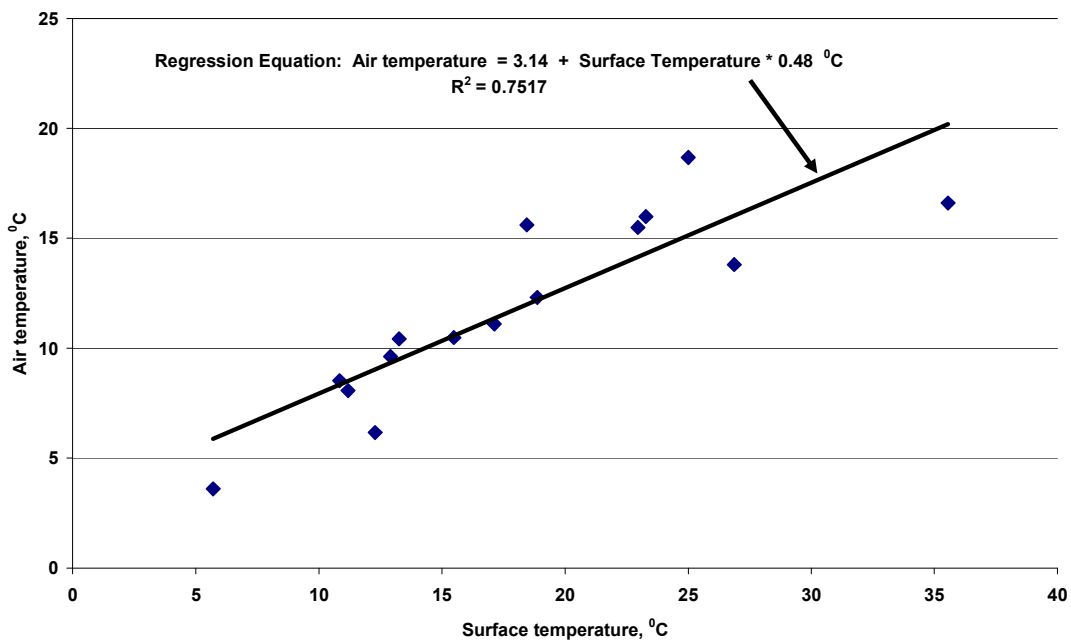


Figure D4: Relationship between air and surface temperature for ISO surface

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 D5.

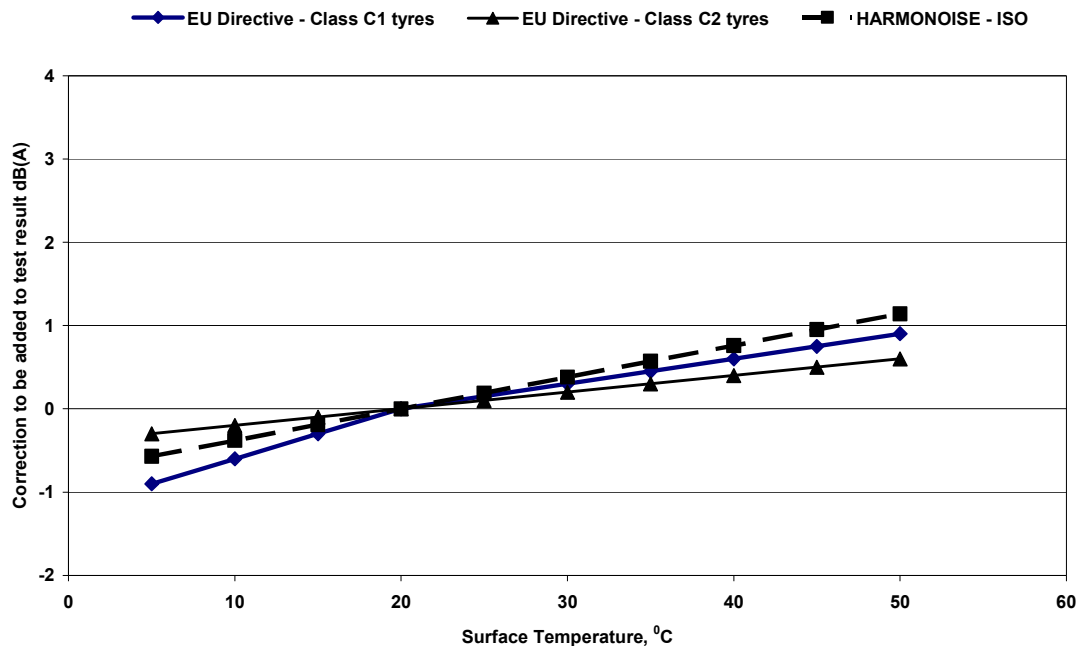


Figure D5: Comparison of surface temperature effects on tyre/road noise: EU Directive and HARMONOISE

Clearly, when comparing both relationships there is good agreement and therefore any differences are not significant. It could be argued that measuring air temperature is easier and requires less expensive equipment. 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.

It is therefore recommended that the procedure for correcting the test result for variation in surface temperature as described in the EU Directive is retained.

D.3 Additional corrections to the Directive

It is suggested that some minor errors contained in the Directive are corrected when the Directive is next updated. These include:

Paragraph 4.2 Regression analysis of noise measurements

The equation:

$$v_i = \lg\left(\frac{v_i}{v_{ref}}\right) \quad (D1)$$

is not mathematically correct. It is suggested using alternative symbol, V_i so that

$$V_i = \lg\left(\frac{v_i}{v_{ref}}\right) \quad (D2)$$

and therefore V_i should replace v_i in the equation to calculate the slope, a .

Paragraph 4.3 Temperature correction

The beginning of the first sentence implies that the correction only applies to Class C2 tyres, it should start with:

For Class C1 and C2 tyres.....

Also the first sentence includes an error; the test surface temperature should be represented by the symbol θ_{ref} and not h_{ref} .

It is also recommended that a clause put in to ensure that the maximum vehicle load is not exceeded when a vehicle is loaded to 75% of the maximum tyre load.

D.4 Estimating the influence of vehicle body design on the test result – A theoretical approach

The model described in the following section assumes that for a single vehicle pass-by event the source may be represented as a source line of length D (m) determined from the product of the vehicle speed V (ms^{-1}) and the averaging time corresponding to FAST response used for measuring the maximum pass-by noise level, $t = 0.25\text{s}$. The acoustic power of the source line is W watts/m. Figure D6 shows the geometry of the site.

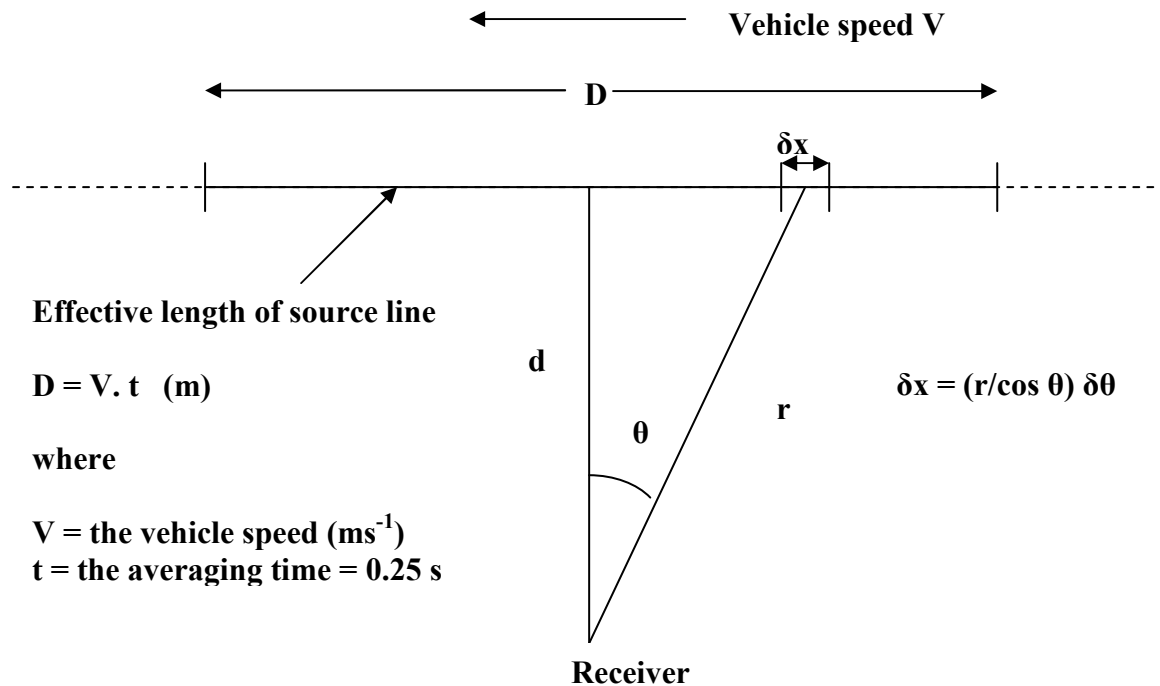


Figure D6: Geometry of site

The receiver is positioned a distance d from the source line which can be regarded to consist of a series of small elements of length δx of source strength $W\delta x$, which are each omni-directional and incoherent. The total intensity received at a distance d from the source is given by

$$I = \int_{-D/2}^{D/2} \frac{W \delta x}{2\pi r^2} = \frac{W}{2\pi d} \int_{-\theta}^{+\theta} \delta \theta = \frac{W}{\pi d} \theta = \frac{W}{\pi d} \tan^{-1} \left(\frac{D}{2d} \right) \quad (\text{D3})$$

which assumes cylindrical spreading from the discrete source line δx .

Assuming the maximum sound pressure level, L_{max} , occurs when the vehicle is directly opposite the receiver at a distance d (m) and converting Equation (D3) to sound pressure levels using logarithmic form, Equation (D3) can be rewritten as

$$10 \log_{10} \left(\frac{I}{I_{ref}} \right) = 10 \log_{10} \left(\frac{W}{W_{ref}} \right) - 10 \log_{10} \pi - 10 \log_{10} d + 10 \log_{10} \left(\tan^{-1} \frac{D}{2d} \right)$$

where I_{ref} is the reference intensity, 10^{-12} watts m^{-2} and W_{ref} is the reference power, 10^{-12} watts m^{-1} and gives

$$L_{\max} = L_W - 5 - 10 \log_{10} d + 10 \log_{10} \left(\tan^{-1} \frac{V}{8d} \right) \quad (\text{D4})$$

where $V = D/t$ is the speed of the vehicle (ms^{-1}), $t = 0.25\text{s}$ the averaging time corresponding to FAST response and L_W is the sound power level.

Assuming that the dominant noise source is tyre/road noise, the maximum noise level at the receiver position is calculated by combining the noise contributions from both the farside and nearside set of tyres. Assuming the sound power level L_W from both contributions is the same then Equation (D4) can be used to determine the separate contributions from each set of tyres to the overall noise level.

If the distance of separation between the wheel tracks of the vehicle is y (m) and the receiver height is h (m) then the combined noise level is given by

$$L_{\max} = 10 \log_{10} \left(10^{L_F/10} + 10^{L_N/10} \right) \quad (\text{D5})$$

where L_F and L_N are the noise contributions from the farside and nearside tyres, respectively.

The contribution to the overall level from the farside set of tyres, ΔL_{\max} , can therefore be calculated from

$$\Delta L_{\max} = 10 \log_{10} \left(1 + \frac{10^{L_F/10}}{10^{L_N/10}} \right) \quad (\text{D6})$$

From Equation (D4), Equation (D6) can be simplified to give

$$\Delta L_{\max} = 10 \log_{10} \left(1 + \frac{A/B}{C/D} \right) \quad (\text{D5-7})$$

where

$$A = \tan^{-1} \left(\frac{V}{8d_F} \right) \quad \text{and} \quad B = d_F \quad \text{where} \quad d_F = \left(h^2 + (7.5 + y/2)^2 \right)^{1/2}$$

and

$$C = \tan^{-1} \left(\frac{V}{8d_N} \right) \quad \text{and} \quad D = d_N \quad \text{where} \quad d_N = \left(h^2 + (7.5 - y/2)^2 \right)^{1/2}$$

Appendix E. Possible method and limit values for a low speed test

If a low coast-by speed procedure is included, a new set of tyre limits would need to be evaluated. Results from research examining typical urban speeds would suggest that the reference speed for low speed assessment would be at about 50 kph (Department for Transport, 2002). Analysis of the relationship between coast-by noise levels and speed for a range of passenger car tyres representative of the tyre population from various studies would indicate that coast-by noise levels at 50 kph are about 7 dB(A) lower than that at 80 kph, which is independent of tyre width (Stait and Kollamthodi, 2001, Phillips *et al.*, 2003).

Limit values could be evaluated either based on a simple average value derived from the coast-by values measured at the reference speeds 50 and 80 kph or by combining the corresponding values according to typical percentage of time vehicles operate at these speeds. Table E1 shows as an example how the existing type approval levels might change if the test results were based on a simple averaging of the noise levels at the two reference speeds of 50 and 80 kph.

Table E1: Suggested new limit values if procedures included assessment at low speeds

Tyre Class: Tread width (mm)	Current limits at 80 kph dB(A)	Estimated limit values at 50 kph dB(A)	New limit values based on averaging procedure dB(A)¹
C_{1a}: ≤ 145	72	65	69
C_{1b}: > 145 ≤ 165	73	66	70
C_{1c}: > 165 ≤ 185	74	67	71
C_{1d}: > 185 ≤ 215	75	68	72
C_{1e}: > 215	76	69	73

¹ Values have been rounded up

Appendix F. Information sent to RIA consultees February 2005

Proposals for revised tyre noise limits for UK passenger cars: Information for Regulatory Impact Assessment Consultees

February 2005

Introduction

The Department for Transport (DfT) is currently evaluating proposals for changes to the permissible noise limits for passenger car tyres. The DfT has commissioned TRL Ltd to carry out research and a Regulatory Impact Assessment on the proposals, henceforth the 'RIA'.

As part of the RIA, TRL Ltd is now carrying out a consultation, which is seeking the views of companies and other organisations who may be affected by the proposals for change.

1. Background

Tyre noise limits are set by UK legislation that implements EU Directive 2001/43/EC. The full text of the Directive is available in the Official Journal of the European Communities, Vol L211, 4 August 2001, p25ff:

http://europa.eu.int/eur-lex/pri/en/oj/dat/2001/l_211/l_21120010804en00250046.pdf

These noise limits help UK efforts to reduce the noise emissions from road traffic. The noise limits in force for tyres fitted to new vehicles in 2005 are shown in table 1 below. Most car tyres that are currently in production meet the noise limits in table 1 comfortably.

Tyre class	Nominal section width (mm)	Current limit values dB(A)
C1a	≤ 145	72
C1b	>145 ≤ 165	73
C1c	>165 ≤ 185	74
C1d	>185 ≤ 215	75
C1e	>215	76

Table 1: Current UK tyre noise limits

In 2004, around 75% of all tyres sold in the UK were in the classes C1c and C1d.

The Directive does not require that replacement tyres meet these noise limits until 2009-2011. The exact year depends on the tyre class, as follows:

- 1 October 2009 for classes C1a-C1c;
- 1 October 2010 for class C1d; and
- 1 October 2011 for class C1e.

Despite regulation of both vehicle and tyre noise in the UK, reductions in noise emissions from traffic have been far lower than is desired. Even when normalised for traffic growth, levels have not decreased in line with the lowered limits for vehicle noise.

Changes to tyre noise limits would clearly contribute to the UK strategy to reduce transport noise.

Such a strategy will be required in future by the Environmental Noise Directive, Directive 2002/49/EC, which is now in force. See 'Article 8 Action Plans' in:

http://www.ehnsi.gov.uk/pubs/publications/Implementation_of_the_Environmental_Noise_Directive.pdf

See also chart 8.5 on page 25 of the SMMT report:
<http://lib.smmt.co.uk/articles/homepagearticle/HomePageArticles/ACF1D1F.pdf>

2. The purpose of this consultation

The EU Commission will present a report during the second half of 2005 on further tightening of passenger car tyre noise limits. The report will lead to a full proposal from the Commission in 2006. Article 3(2) of Directive 2001/43/EC requires the Commission to produce both the report and proposal.

The DfT wishes to gather the views of interested parties now, in order to inform the UK position when the Commission produces its report later in 2005. The purpose of this consultation is to solicit those views.

When the Commission provides a full proposal in 2006 for changes to passenger car tyre noise, the DfT expects to carry out a full formal Regulatory Impact Assessment. This will evaluate the exact impacts of the Commission's detailed proposal.

3. The options for consultation

The DfT is currently considering three possible changes to the noise limits for passenger tyres in the UK. These are shown respectively as option 2, 3 and 4 in table 2 below.

Option 1 in table 2 is the 'do nothing' scenario, which would involve no change to the tyre noise limits, other than those explained in the 'Background' section above.

Directive 2001/43/EC contains 'indicative figures' for future tyre noise limits, which form the basis for option 2 in table 2. See columns B and C in the table shown in point 4.2.1 of Annex V of Directive 2001/43/EC, and the footnotes to that table.

The DfT has included an option in this consultation which presents 'optimal' improvements in tyre noise, from the UK perspective. These are the basis of option 3 in table 2.

Option 4 concerns a possible change to the road surface that is currently used to test tyres.

The DfT points out that each of Options 2-4 represents a proposal, for comment. No decision has yet been taken to proceed with any of these options.

Option	Description
1	'Do nothing' option. No change to either the noise limit values or the test surface.
2	Lowering the tyre noise limit values: (i) For categories C1a, C1b and C1c, by 1 dB(A) in July 2007; (ii) For category C1d, by 1 dB(A) in July 2008; (iii) For category C1e, by 1 dB(A) in July 2009; (iv) For all of categories C1a-C1e, lowering by a further 1dB(A) in July 2010.
3	A tightening of 5 dB(A) in the noise limits for all tyres in categories C1a to C1e, from July 2008. The new limits in force would be: C1a: 67dB(A) C1b: 68dB(A) C1c: 69dB(A) C1d: 70dB(A) C1e: 71dB(A)
4	Specifying a new thin surface course for conducting tyre noise type approval tests. The new surface would be similar to that now in use on most new and re-surfaced Highways Agency roads in the UK. The new test surface would be introduced in 2014.

Table 2: The options for consultation

4. Detailed explanation of the options:

In options 2 and 3:

Tyres tested as part of the type approval test would need to meet precisely the limits that are stated.

This would mean an end to the existing practices whereby:

- (i) All measurements are rounded down to the nearest whole dB(A); and
- (ii) 1 dB(A) is then subtracted from each measurement, to allow for measurement errors present with older styles of measurement equipment.

The elimination of these two practices would itself mean a lowering of the threshold that is actually enforced, by between 1 dB(A) and 1.9 dB(A). Elimination of these allowances would bring tyre noise measurement practice into alignment with the separate vehicle noise test standard. The vehicle noise test standard is likely to be revised to remove similar allowances. One reason for this change is the availability of more modern measuring equipment. The Vehicle Certification Agency's Database shows that many passenger cars already have their noise values recorded to the nearest tenth of a dB.

Options 2 and 3 state noise limits for tyres fitted to new passenger cars. The noise limits would only apply to replacement car tyres from the dates specified in paragraph 6 of Article 1 of Directive 2001/43/EC, i.e.:

- 1 October 2009 for classes C1a-C1c;
- 1 October 2010 for class C1d; and
- 1 October 2011 for class C1e.

Option 2

The tyre noise directive 2001/43/EC does foresee a 'further tightening' of tyre noise limits. The exact amount of tightening will be the subject of the proposal by the EU commission during 2006.

The tyre noise limits stated as option 2 in table 2 above are those listed in the Directive. Importantly:

- a) The reduced limits in option 2 under (i)-(iii) for years 2007-2009 are described in the Directive as ‘indicative figures’. The Directive does state the dates listed under (i)-(iii) above, on which dates it assumes that these limits will enter force.
- b) The changes for 2010 in option 2 under (iv) are also included in the Directive as ‘indicative figures’. However, the Directive does not state a date for their implementation. This consultation document includes the date of 2010 for the further tightening of (iv), in order that consultees have a definite date to consider.
- c) The Commission’s report in 2006 will set definitive figures in place of the indicative figures in option 2, (i)-(iv). That report will also set the dates for the further tightening of option 2, (iv).

Option 3

The limit values in option 3 would reduce noise levels from passenger cars more rapidly than with the limits and dates in option 2. The limit values in option 3 would provide a significant reduction in noise from road traffic.

Research by TRL and other research organisations has not shown a correlation between wet grip and tyre noise. Some existing tyres in fact already meet the noise limit values of option 3. The DfT considers the maintenance of wet grip to be essential.

Option 4

The test road surface used in the UK is the international standard test surface ISO 10844. However, this surface is unrepresentative of most ordinary road surfaces that are in use in the UK.

Option 4 would see the current test surface replaced by a test surface that is more representative of modern UK roads. The DfT believes that such a surface might be agreed upon and implemented by the year 2014. However, the ISO surface is more closely representative of roads that are in use overseas, so change is not certain.

5. What to do next

If you wish to submit comments on Options 1-4, then please use the comments form that accompanies this document. The form is entitled ‘*Proposals for revised tyre noise limits for UK passenger cars: Comments Form for Regulatory Impact Assessment Consultees*’.

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