Interest Group on Traffic Noise Abatement

European Network of the Heads of Environment Protection Agencies (EPA Network)

Progress report on measures on road traffic noise in the EU

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Colophon

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	This paper has been prepared by the Interest Group of Traffic Noise Abatement (IGNA) of the European Network of the Heads of Environment Protection Agencies (EPA Network) and presented at the 18th plenary meeting of the EPA Network on 1-3 April 2012 in London.
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Executive summary

This report presents information on the possibilities to mitigate road traffic noise. The emphasis lies on the international specifications of the properties of the source, namely the vehicles, the tyres and the road surface. The report is designed to be used as input to and to deliver background information for the opinion and standpoints of the Interest Group on Traffic Noise Abatement (IGNA). It formulates recommendations for improvement of the effectivity and efficiency of abatement procedures and formulates actions to be taken.

The importance of mitigating road traffic noise lies in the negative effects it has on the health and well-being of the European population. About one-tenth is exposed to levels exceeding 65 dB, a level where serious health problems start to occur as reported by the WHO

The majority of cost/benefit studies, presented in this report, conclude that measures at the source have better economical value than measures at the receiver. This already generated impetus into tightening noise requirements of vehicles and tyres. The study describes the process in Geneva and Brussels, gives an overview of the developments up to this moment and describes the present state of discussion.
This study defines several areas where further improvement is necessary. Either since the regulations are lacking effectivity (for instance the tightening of the tyre limits, while not tightening the test track specifications) or the ambitions are lagging technical developments (vehicle noise regulations are technology following, meaning that present day vehicle already comply with future limits).

This study ranks source measures with respect to potential effect under slow, medium and high speed driving conditions and concludes that besides focus on the vehicle and the tyre, also the road surface characteristics require attention on an international level. Further research to improve the durability of low noise surfaces and international action to harmonize classifications is necessary, not only on a national, but also on an international scale.

The study stresses that not only the equivalent day-evening-night level Lden, but also single events have to be taken into account, since they exhibit more severe dose-effect relations.

Explicit recommendations are:

- Introduce third stage of tightening of limit values for road vehicles, shorten time frame of the first and second phase and put additional emphasis on the ASEP
- Include retreaded tyres in the scope of the tyre regulation
- Update test track specification in both the vehicle and the tyre regulation and start developing a more representative surface type
- Extent the knowledge of the public (both users, suppliers and other stake holders) about the noisiness class of products like vehicles, tyres and road surfaces and develop internationally approved testing procedures, labels and data base systems
- Continue development of low noise surfaces, especially the durability aspects and speed up the process of harmonization of noise reducing properties

Finally, the study arranged the measures, not only related to the technical characteristics, but also related to the (inter)national organizations that are responsible for them and the study defines the way to address them in order introduce new measures are improve the quality of existing ones.

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1 Introduction

1.1 Background

The EPA Network is an informal grouping bringing together the directors of environment protection agencies and similar bodies across Europe. The network exchanges views and experiences on issues of common interest to organizations involved in the practical day-to-day implementation of environmental policy.

In the September 2010 EPA-Network meeting in Krakow an Interest Group on Traffic Noise Abatement (IGNA) was created. The IGNA will be forum to exchange information on current and future developments, an opportunity to learn from each other, particularly in relation to the development of the regulatory framework and scientific issues. The outcome shall be reports on the activities of the group, containing concrete and helpful recommendations to successfully protect the population from traffic noise.

The Swiss Federal Department for Environment, Transport, Energy and Communication (DETEC) has contracted M+P -Consulting engineers in Netherlands to support the IGNA with relevant input for the work of the IGNA, with the preparation and reporting of the IGNA workshops, with summarizing the discussions within the workshops and with the composition of a final report.

M+P–Consulting engineers is member of the international Müller-BBM group with offices in several countries throughout Europe. M+P is very active in the field of international standardization and regulation on noise properties of sources of transportation noise, like road, rail and air transport. It has expert knowledge in the field of both national and international regulation of the noise properties of vehicles, tyres and road surfaces.

1.2 Objective of this study

This study has the objective to produce a concise insight in the technical and policy aspects of sources of road traffic noise, to relate the state of noise abatement to the effect on the society and to relate potential improvements with performances in the area of safety and sustainability and to evaluate the costs of the measures with the effects in society.

The study is performed on a European level, meaning that specific national rules and systems will not be taken into account, except when it may be a start for an international development.

The study is directed to policy makers and will therefore not be too extensive in technical details. We will refer to background documents for necessary technical corroboration.

The context of the report implies that most of the information presented in this report originates from existing studies, only limited new work is presented.

The evaluation will be done, where appropriate, along the thinking frame of the DPSIR.

1.3 DPSIR

1.3.1 *DPSIR system*

DPSIR stands for *Drivers-Pressure-State-Impact-Responses* relation in which the fundamental causes, the environmental pollutants and its effects and the reaction of society and legislation to control the adverse effects are fitted in a general framework. Application of this framework on different environmental issues leads to a better understanding of the underlying relations and components common to different environmental issues.

An overview of the system is given below.

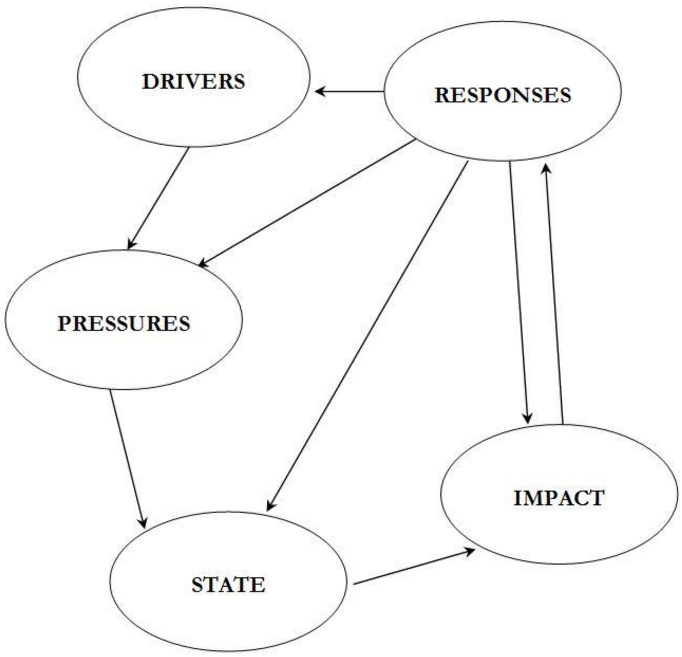


figure 1 *DPSIR model with the for Drivers-Pressure-State-Impact-Responses relations (source: EEA)*

1.3.2 *Application of the DPSIR on transportation noise and health effects*

- Drivers: growth of transportation
- Pressures: sources of transportation noise
- State: transportation noise assessment
- Impact: effects of noise on human health
- Responses: noise abatement

An overview of the system is given below, together with the identification of its components.

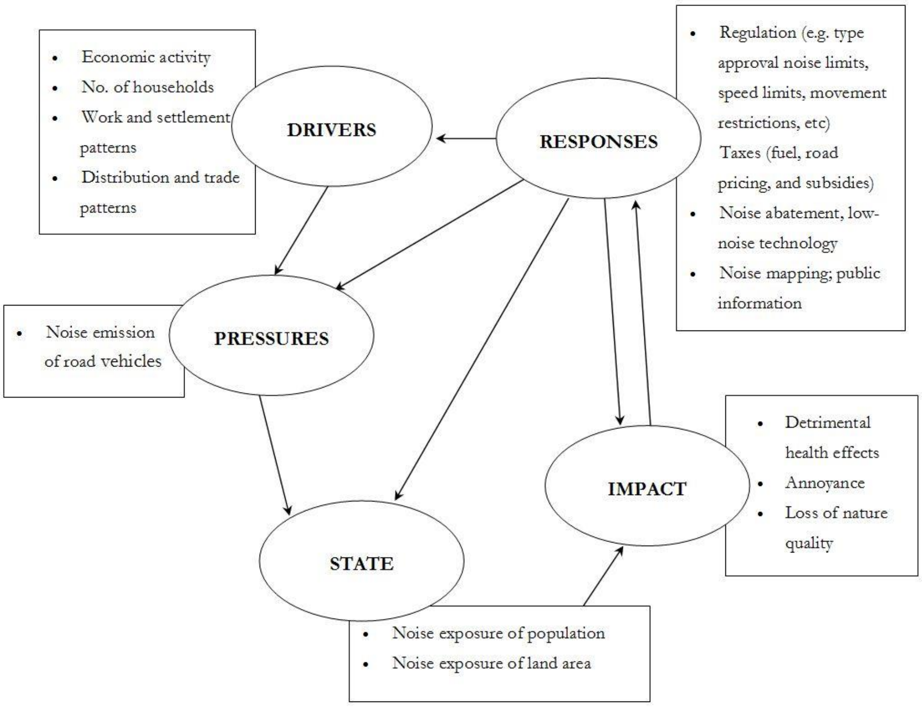


figure 2 *DPSIR model together with the identification of its components (ref. [2])*

1.4 Chain approach

The acoustic properties of the source of road traffic noise are only part of the total process leading to annoyance and health effects in society. The figure below presents a scheme of the process leading to noise exposure of the population and presenting relations with other aspects than noise.

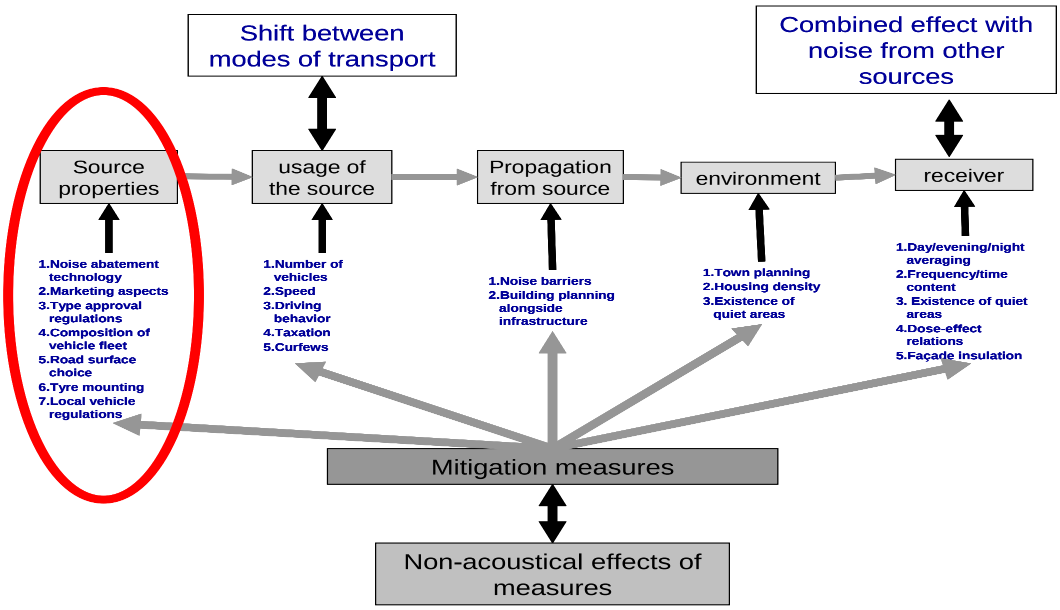


figure 3 *Scheme of the process leading to sound exposure and annoyance of the population. Indicated are the measures operating on the several steps. The red circle indicates the focus of this report.*

1.5 Chain versus enforcement

The chain can also be approached in a different way, distinguishing the source, the propagation and the receiver and indicating the actions and commitments on a European, a national and a local scale. This approach is given in table I.

table I *Matrix indicating the supra national / national / local level on which policies are formulated and measures are taken. The report focuses on the light orange elements.*

	Source	Propagation path	Point of impact
EU level	▪ Vehicle, tyre and road surface test standards (ISO/CEN) ▪ Vehicle regulation ▪ Tyre regulation ▪ Road surface classification	▪ Barrier standardization (ISO/CEN)	▪ EU harmonized calculation scheme (CNOSSOS) ▪ European Noise Directive
National level	▪ Enforcement of vehicles in yearly inspection ▪ Stimulation/taxation measures for low noise vehicles/tyres (Including electric vehicles) ▪ National road surface policy and classification ▪ Stimulation ECO-driving and national speed limits	▪ House planning policies ▪ Planning infrastructure and controlling environmental noise in the vicinity	▪ National legislation on noise exposure of houses and other noise sensitive objects ▪ National policy on health and annoyance effects of road traffic noise
Local level	▪ Road side enforcement of *iress* ▪ Low noise road surface policy ▪ Curfew low noise vehicles ▪ Speed reductions in sensitive areas (especially at night)	▪ Actual planning and building of barriers ▪ Separation of noise producing infrastructure and noise sensitive objects/houses	▪ Noise policy plans (f.i. indicated by the END)

1.6 Overview of European and world-wide organizations

The noise properties of the several sources and components of road traffic noise are addressed by several different organizations, operating either on a European scale or world-wide.

1.6.1 *Vehicles and tyres*

The formal regulatory aspects of vehicles and tyres in the European Union are addressed by the European Commission and have to be agreed with the European Council and the European parliament. The regulatory aspects are defined in terms of type approval procedures, in which the marketing of products within the EU are constrained by technical requirements. The 27 member states of the European Union are legally bound by the European directives and regulations. European countries that are non EU Member State (like Switzerland and Norway) often take over significant parts of the EU directives into national law.
http://ec.europa.eu/enterprise/sectors/automotive/documents/directives/motor-vehicles/index_en.htm

The process of enhancing the European harmonization into a global harmonization is pursued in the United Nations Economic Commission for Europe (UN/ECE) in

Geneva. There the World Forum for Harmonization of Vehicle Regulations (WP 29) deals with the technical regulations from vehicles and tyres. GRB (Groupe Rapporteurs de Bruit) also referred to as the *Working Party on Noise* is a subgroup of WP29 and deals with all noise relevant regulations for vehicles and tyres. Where the EU directive are obligatory to EU member states, the UN/ECE regulations can be acceded on a voluntary base. With the access of the EU to the UN/ECE al EU member states are also member of the GRB. They can actively join the discussion, however, their position is defined by the proceedings agreed on in the EU.
http://www.unece.org/trans/main/wp29/meeting_docs_grb.html

The International Standardization Organization, also situated in Geneva, is active in the filed of standardized measurement procedures, and has therefore played an important role in the definition of the technical procedures for testing vehicles and tyres.
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=42210

1.6.2 *Road surfaces*

For road surface there exists no international type approval scheme, since this product is not regarded as an international traded commodity. The market for this product is very national. Its properties are defined in national road building standards and guidelines. The application is also nationally guided, the policy for road surfaces in France is totally different than that in the Netherlands or in Sweden, due to local conditions. The supra national regulated area addresses the standardization of the material properties and the performance properties for noise. Material properties are standardized by the CEN in the framework of the standardization of building materials. The noise performance is standardized through the standard methods, formulated within ISO (ISO 11819-1 and 11819-2 respectively the SPB and the CPX method) and implemented by CEN.

1.7 Source description of road vehicles

The acoustic emission of road vehicles is composed of two major parts:
- Rolling noise
- Propulsion noise

Aerodynamic noise is only relevant at very high speeds (200 km/h +) or at extreme low noise tyre/road combinations. Noise of rattling cargo is only relevant for single vehicles.

The magnitude and the fraction of each component in the total emission depend on:
- type of vehicle
- speed of the vehicle
- acceleration/deceleration or uphill/downhill driving
- specific properties of the vehicle, the tyre or the road surface

The figure below (figure 4) give the sound power of rolling noise and propulsion noise as a function of speed, for light and heavy vehicle (vehicle/tyre/road condition are averaged over EU).

The data in the figure 4 illustrates that tyre/road noise dominates the noise emission of light vehicles already from 30 km/h and above. For heavy vehicles propulsion noise is dominant up to a speed of 80 km/h. These data apply for normal traffic in a steady flow on flat ground. For situations were a higher engine power is used, such as driving up hill or heavy acceleration, the level of propulsion noise increases temporarily.

The graphs for passenger cars also explains the limited effect of hybrid or electric propulsion at medium speed urban traffic. Once over 30 km/h the power train emission gets less relevant and tyre/road noise takes over (ref. [4]). Still some effects are reported at speeds of 50 km/h (ref. [5]) , possibly due to the fact that drivers of these vehicles are more sensitive to the ecological footprint of their vehicle and may select low noise tyres. At least the manufacturers of such vehicles can make such a choice.

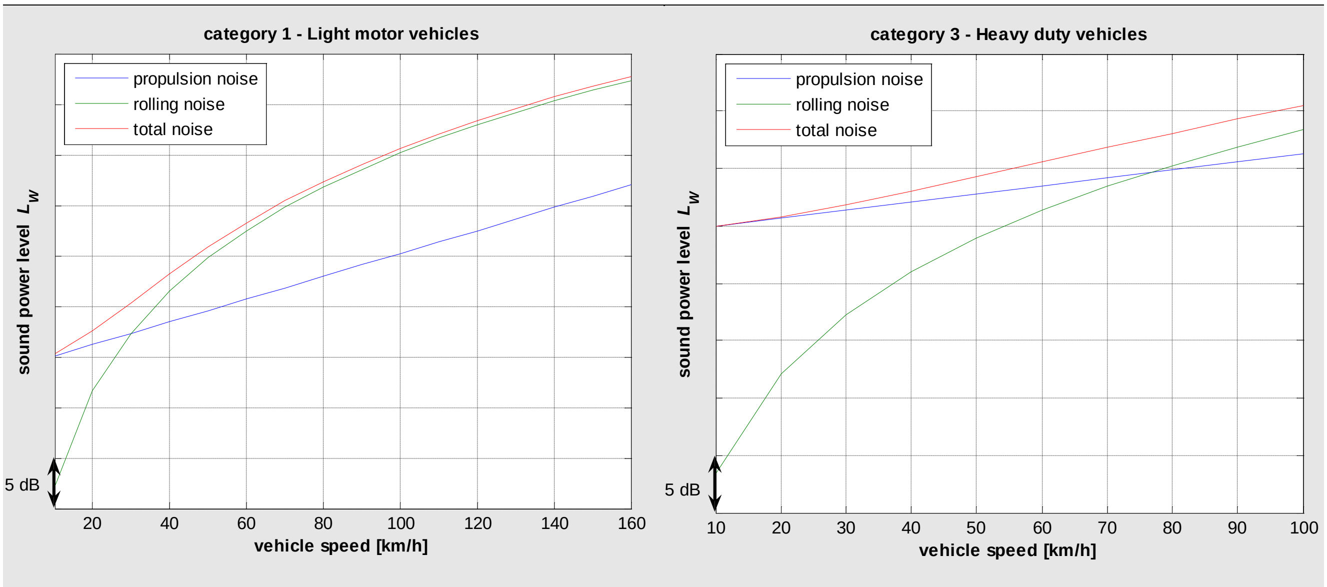


figure 4 *Level of rolling noise and propulsion noise as a function of speed. The red curve presents the total sound level. Left: light vehicles, right: heavy vehicles (≥3 axles). Ref.[1]*

1.8 Road traffic noise in the EU

The first attempt to estimate the magnitude of the noise exposure of the EU population to road traffic noise was performed in 2000 by M+P within a contract from the European Environmental Agency in Copenhagen (ref [2]). The data were reported in the Report of the State of the Environment 2000. For road traffic noise on base of this study the following exposure data for the EU 25 population were reported (see figure 5).

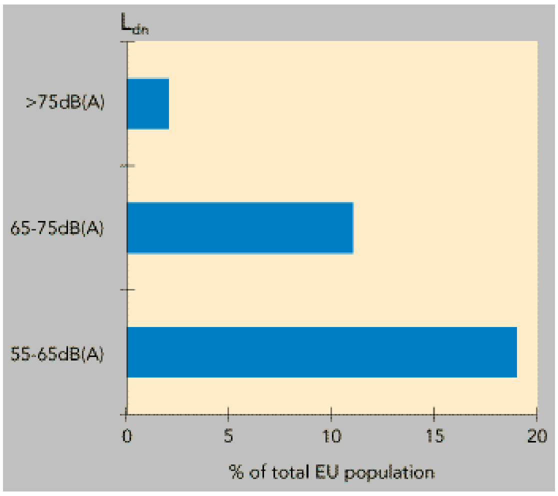


figure 5 Noise exposure of the EU 25 population to road traffic noise with Ldn>55 dB (ref. eea)

The next step in assessing the noise exposure of the European population is taken by the introduction of the Directive 2002/49/EC relating to the assessment and management of environmental noise on 25 June 2002, also known as the "END". This directive envisages the assessment of noise exposure of the population along the major road and rail infrastructure and airports and within the major agglomerations.

Noise mapping concerns all actions undertaken to represent the soundscape of a noise emitting source. Noise maps often use a GIS to represent the noise emission/immission caused by a certain transport mode geographically. The actual problem areas (large noise immission/annoyance) for transportation noise can be clearly marked using maps. In the EU Working Group 4 is concerned with the definition and application of noise maps in the EU.
Noise mapping is an important tool for (noise) policy makers. The effects of transportation developments, migration, building activities, etc. on the noise exposure (number of annoyed people, exposed land area, etc.) can be calculated and depicted combining the noise maps for different scenarios.

Noise mapping is also introduced as a way to provide information to the public.
Result of EU mapping of road traffic noise is presented online.

2 EU measures on vehicles

2.1 General

Control of exterior vehicle noise has to be based on several pillars:

1. Controlling the acoustic quality of new vehicles by a system of type approval and conformity of production (COP)testing
2. Controlling the market of replacement parts, especially exhaust silencers
3. Controlling the acoustic quality of vehicles in use by ether periodical technical inspection or by road side checks.

2.2 Vehicle regulation

2.2.1 *General*

As many commodities, traded within the EU, vehicles have to meet specific technical requirements. For exterior noise these requirements are defined in EC 70/157 and its several amendments (latest EC 2007/34). The specifications consist of three components:

- An administrative part defining the dates of entry, possible exceptions, the position of certified bodies etceteras
- A part in which the testing procedure is described, including the preparation and the driving condition of the vehicle during the test and possible repetitions
- A part with the maximum sound levels that the vehicle has to meet during the test procedure, including allowances for specific types/classes of vehicles.

The effect of the exterior noise regulation on the sound production of the EU vehicle fleet under general driving condition is the combined effect of each component. It is therefore relevant to take each of them into account in evaluating a regulation.

2.2.2 *Administrative parts*

These parts comprise the description of the composition of the vehicle noise regulation, its embedding in the overall technical regulations and the relations with global harmonization.
Relevant for its effectiveness are:

- Dates of coming into force of the regulations
- The types and classes of vehicles affected by the regulation
- The stringency of the certification of the quality assurance systems and notified bodies
- The equivalence with other regulations (EU versus ECE)

The current vehicle noise regulation is based on a system of type approval and Conformity of Production (COP). This means that a type approval authority certifies a product of a manufacturer by means of an initial homologation test and regular tests on vehicles from the production line.

An important issue in the administrative part of the vehicle noise regulation is the translation into national law. It must be understood that the initial goal of this regulation was to avoid trade barriers and therefore harmonize vehicle requirements in the several European countries. Before the EC70/157 came into force in 1970 several European countries had their own noise emission requirements to vehicles.

Therefore the first versions of EC70/157 and its successors contained relatively relaxed limit values and a prohibition to ban vehicles from the national market that did fulfill these limits, even if the new EU limits were more relaxed than the old national limits. On the other hand it was not obliged to take over the noise limits into national law, so national limits could be even more relaxed than the EU limits. Only since 1995/1996, with the introduction of EC92/97, the new noise limits are mandatory and obliged to be taken over in national law.

Another administrative issue is that EC directive 70/157 is set equivalent to UNECE regulation R51. This means that a certificate for EC 70/157 can be obtained by testing a vehicle conform R51. EC 70/157 and R51 are technically almost identical, but relevant differences may occur.

2.2.3 *Testing procedures*

The test method has always focused on propulsion noise and is close to reflect the worst case single event in real traffic. Every potential contribution of tyre noise is removed from the test, as the test tyres can be special low noise homologation tyres (e.g. buffed tyres with a rib profile). Also the test track is to be smooth and acoustic reflecting, as to minimize tyre/road noise and not to effect propulsion noise. Other regulations are installed (UN ECE R117 and EC/2001/43) in order to control tyre noise (see further in chapter 3).
The test result is for all vehicles the maximum A-weighted level in “FAST” on a position 1,2 m height at a distance of 7,5 m, from the center line of a passing vehicle at both sides. The environment and the acoustical properties of the testing area including the surface of the test track are identical to that required in ISO 10844:1994. The basic test consists of a passing with Wide Open Throttle (WOT) from a position 10 m before the microphone position until 10 m past the microphone. The driving condition of the vehicle depends on the vehicle class.

- Light vehicles (L, M1 and N1 category) generally accelerate from 50 km/h in 2nd and in 3rd gear or with automatic gearboxes in “D”. Power full vehicles with a specified acceleration potential (Lex Ferrari), have to be tested only in 3rd gear. The final result is the average of the measured pass by levels in the 2 gears.

- Heavy vehicles (M2, M3, N2, and N3 category) accelerate from 50% or 75% of rated engine speed. There is no specified gear selection, but several gears, starting from N/2 (N number of gears) have to be tested and the gear ratio with the highest pass-by level is the valid one.

There are two major loop holes in the current testing procedure, that artificially lower the test results, within the legal boundaries (cycle beating).

- Low noise test track; the current requirement for a dense test track can be bypassed and a low noise absorbing track can be certified within the legal requirements.

- Low acceleration pass by; The current regulation requires the physical operation of the accelerator pedal/handle; it is however not mandatory that the vehicle actually reacts on this with any acceleration. As modern vehicle have a computer between gas pedal and engine, this computer can be programmed to limit the engine torque and noise emission.

These loopholes lead to less noise reducing measures than expected and therefore undermine the effectiveness of the noise regulation. Vehicle classes that are especially sensitive to cycle beating are vehicles with a certain brand specific sound (sport cars and motorcycles) and vehicles, where the customer gives higher priority to low costs than to low noise emission (delivery vans and trucks).

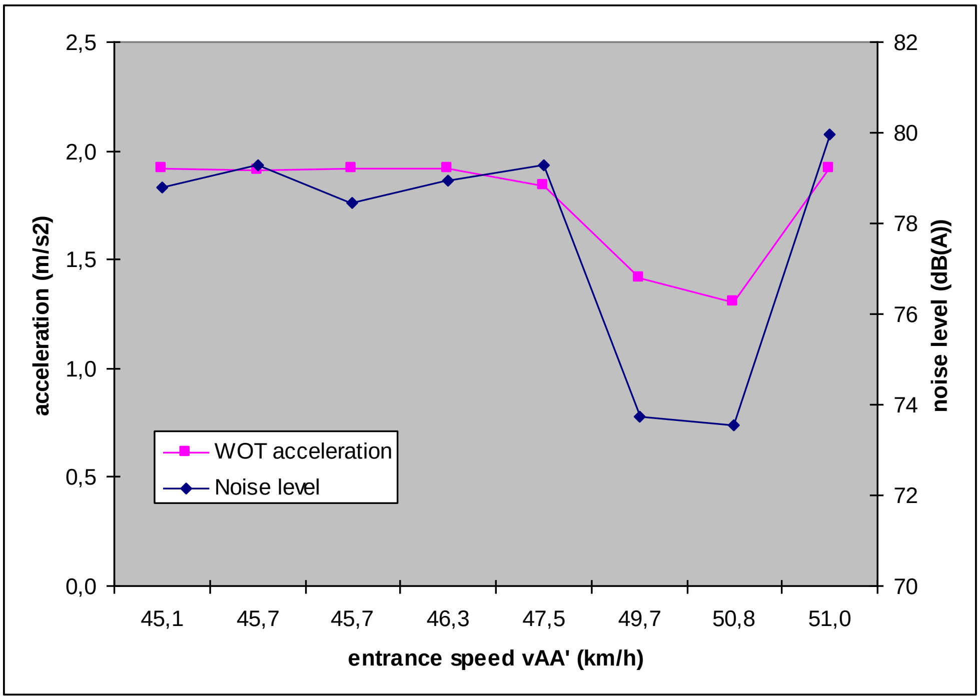


figure 6 *Example of a vehicle with cycle beating. The vehicle recognizes the test cycle (method A): if the entrance speed is 50 km/h ± 1 km/h the acceleration drops by 30% and the noise level drops by 6 dB(A). Data from ASEP dBase vehicle 200-13*

The technical development of the test procedures is mainly done within ISO TC 43 Acoustics, WG 42. This WG addresses the following series of standards, mainly related to the sound production of vehicles:

- ISO 362-1 describing the accelerated pass-by method for passenger cars, trucks and coaches. This procedure is implemented in the EU and ECE regulation for type approval of vehicles
- ISO 362-2 describing the accelerated pass-by test for motorcycles (also implemented in EU regulations)
- ISO 5130 describing the stationary noise test for road vehicles. This test is relevant since it gives the procedures for road side checks.
- ISO 10844: defining the surface properties and certification procedures for test tracks for noise testing of tyres and vehicles
- ISO 16254 describing the test procedure for low noise vehicles (actually electric traction with artificial warning signals)

2.2.4 *Limit values*

Between 1970 and 1992 the limits have been lowered by 8 to 12 dB(A), depending on the vehicle class (see table II). Since 1992 no additional tightening has taken place. For light vehicles these lower limits have been partly compensated by a changed and less demanding test method. Most important changes are: testing in higher gears, introduction of a smoother test track and the allowance to test on worn tyres. On

average this leads to a 3 dB relaxation on the limits and an effective lowering around 5 dB.
In contrast, for heavy vehicles the test method has changed to be more severe, as this class has to be tested in more gears, from which the worst case is applicable. This leads to a 2 dB(A) extra effect on the tightening of the limits and an effective lowering of the limits around 13 dB.

table II *Overview of the development of limit values for the EU type approval of road vehicles. Not included in the table are possible effects from modifications in testing procedures. In addition to the values listed below, ttemporary allowances of 1 or 2 dB(A) are given to special classes of vehicles, like sport cars, off road vehicles or vehicles equipped with direct injected diesel engines*

	70/157	**77/212**	**84/424**	**92/97**
Year of publication	1970	1977	1984	1992
In force for new types	1971	1980/82	1988	1995
In force for all vehicles	1971	1982	1989	1996
MS has to accept vehicles that fulfil limit	Yes	Yes	Yes	Yes
Limits binding for MS national law	No	No	No	Yes
Limit values				
Passenger cars (M1)	82	80	77	74
Coaches > 3,5 ton (M3)				
< 150 kW	89	82	80	78
> 150 kW	91	85	83	80
Coaches and delivery vans (M2, N1)				
< 2 ton	84	81	78	76
2 - 3,5 ton	84	81	79	77
Trucks > 3,5 ton (N2, N3)				
< 75 kW	89	86	81	77
75 kW - 150 kW	89	86	83	78
> 150 kW	91	88	84	80

2.2.5 *Development of tested noise levels of the car fleet 1980-200*

A very interesting overview is presented in figure 7 where the results of type approval tests are given over a period of 1980 tot 1998. During this period the limit values were tightened in three consecutive steps. It shows that lowering limit values did result in improved noise technology for trucks, since every step did lead to a significant reduction of noise emission to a level just meeting the regulation. The situation 1992 to 1995 was different since the Austrian *Nachtfahrverbot* excited additional noise reductions for trucks.
For cars the lowering of the limit was more technology following. While the limits have been reduced by 8 dB(A), the average measured value only decreased by 2,7 dB(A). Most of this 2,7 dB(A) might be accounted for by a change in the measurement method (measure in lower gears and on a smoother road surface).

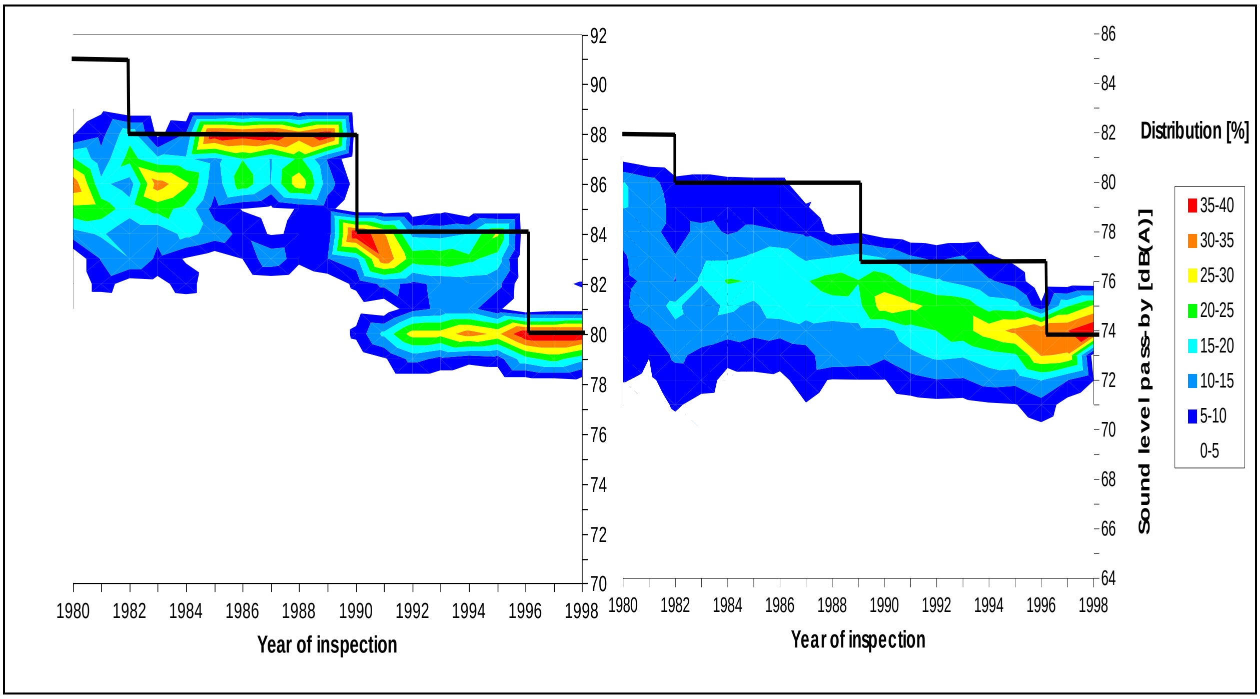


figure 7 *Results of vehicle type approval test results during fur stages of tightening of limit values. Left: trucks, right: cars.*

2.2.6 *Status of modification of present vehicle regulation*

The present vehicle regulation is subject to modifications on the following topics:

- **Administration:** Most important change in the administration is that the new procedure will contain Additional Sound Emission Provisions (ASEP) for light vehicles (L, M1 and N1). ASEP contains requirements that the noise emission under driving conditions aside of the actual type approval test are in line with the physical behaviour as expected from the noise emission under type approval conditions. This means that for instance sudden noise jumps due to the opening of flaps in the exhaust system are forbidden. This ASEP is based on a self declaration of the manufacturer. The type approval authority can check in case of doubt.

- **Testing procedure:** The procedure is to be modified on the following items:
  - General: the test conditions are changed to become better in line with the driving conditions and noise source contributions during normal urban driving. This means that noise sources are to be representative for the equivalent noise emission on urban main streets, rather than for the single events when pulling away from a round about.
  - Testing of light vehicle (L, M1 and N1) will be based on an accelerated pass by at a speed of 50 km/h and a specified target acceleration. Tyres have to be normal commercial tyres at full tread depth (minimum 80%). This intents to overcome two cycle beating practices: acceleration with reduced engine torque and mounting of low noise homologation tyres. The target accelerations are set however to a relatively low level, leading to lower engine speeds and noise levels compared to the current test.

- Testing of heavy vehicles (M2, M3 N2, N3) is converted into an engine speed target of 80-90% of rated engine speed to be reached in one or two gears around a vehicle speed of 35 km/h. As with light vehicles, tyres have to be commercial tyres with full tread depth. The noisy truck traction tyres however are banned from the test in a late stage, as they appeared to dominate the noise emission of heavy trucks and gave a lot of scatter to test results. Trucks have to be loaded in order to overcome the cycle beating practice of reduced acceleration.

- **Limit values**. The current discussion on limit values clearly separates two effects: the compensation of the changed measurement method and the tightening of the level of stringency. In order to gain insight in the equivalent limits a three year monitoring period was installed during which all new type approvals had to be tested according to the current method as well as to the new method.
  - According to the *Venoliva* report [10] the new measurement method generally leads to lower test results. Around 2 dB for light vehicles and around 1 dB for heavy vehicles.
  - For high powered N3 vehicles the test results according to the new method lead to around 1 dB higher results. The data in the dBase are however based on vehicle tests with traction tyres on the rear axle. This tyre choice was changed after the monitoring period to rib tyres. The impact of this change on the equivalent limit values of N3 vehicles is still under discussion. It is our expectation that N3 vehicles will be in line with the other heavy vehicles. This means that the equivalent limits for N3 will also be 1 dB lower compared to the current limits, instead of 1 dB higher.
  - There is an intensive discussion going on in various political arenas on the ambition to tighten the limit values. Some parties want high ambition and fast progress, others want slow progress or stand still. The European Commission has launched a proposal [12] with two steps of tightening: a first step with 2 dB tightening, which should get in force 2 years after publication and a second step with another 1 a 2 dB tightening, which should get in force 5 years after publication. Germany has launched a proposal with similar tightening, but much slower progress (up to 14 years for the second phase). Other parties propose a 3rd step of tightening, and others advocate that the 2nd step of tightening is too ambitious. It is expected that these discussions will get to a final result in the coming year.

2.3 Technical state of the present vehicle fleet

The emission values of the present vehicles on the road only partial reflect the technical status of the EU noise regulations. This is due to the following factors:

- Aging will increase the noise emission, partly due to wear of the mechanical parts, partly due to the fact that older vehicles were subjected to less stringent regulations. This effect is studied in the Imagine project and was found to be only about 1 dB per 10 year.

- Poor maintenance but more important tampering (mainly inlet and exhaust systems) will increase the sound levels. For L category it is estimated that about 35% has an illegal exhaust, leading to an overall noise increase with about 5 dB.

- The most important effect though is the road surface. The surface used for testing is a smooth, sometimes partially absorbing dense asphalt concrete surface. The noise level on general more rough surfaces will increase with 2 to more than 5 dB.

The noise quality of the vehicle fleet tends to change in time. Repeated measurements, done in Netherlands, in 1980, 1995 and 2010 show the following trends.

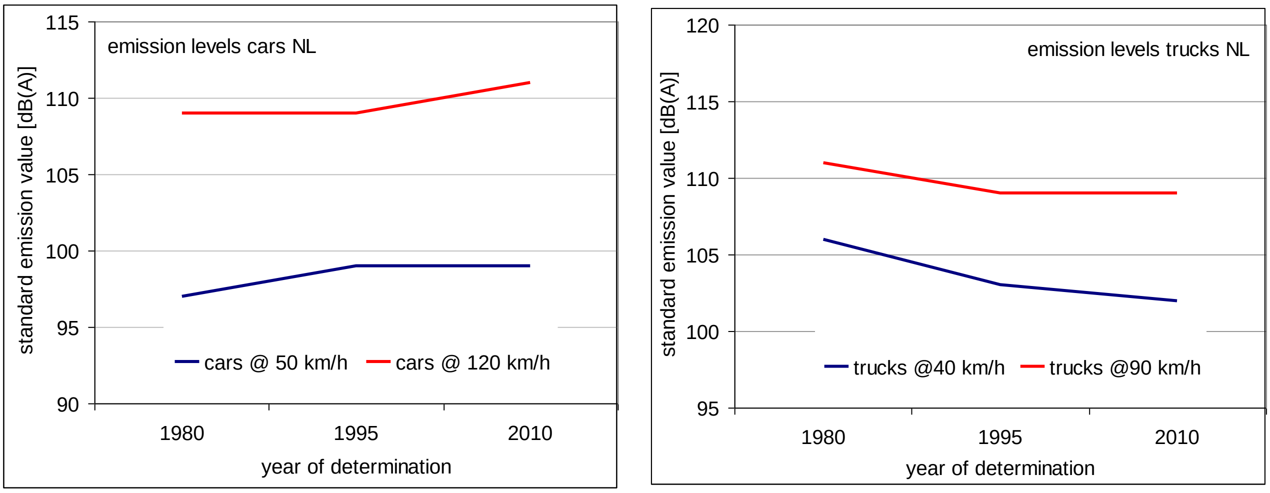


figure 8 *Development of emission values of Dutch vehicle fleet. Data from 1980, 1995 and 2010 measurement campaigns.*

Cars at low speed tend to become slightly noisier, possibly due to measures on the propulsion system balanced by the noisier tyres. Emission values at high speed do increase significantly, most probably caused by the trend to noisier tyres.
For trucks the trend towards lower propulsion levels is clearly shown, especially at low speeds. At high speeds the rolling noise also contributes balancing the reduction in propulsion noise levels. These observations are corroborated by the shifts in frequency spectrum, where low and high frequencies reduce while the mid frequency range, where tyre/road noise dominates, increases.
Similar measurements performed in Germany, do not reflect this trend. A possible explanation is that high speed driving was more common in Germany and cars tended to heavier.

2.3.1 *Technology forcing versus technology following*

The trends towards safer and cleaner cars are significant. Today's EURO 4, and 5 vehicles are very much cleaner than the vehicles in the 80-ies that had neither catalytic converters for Otto engines, nor particle filters for Diesel engines. Even the progress in the last 10 years is significant. In figure 9 the emission data are given for the Dutch vehicle fleet in the year 2000, 2005 and 2010. Notice that the development of the exhaust emission for cars shows much better results than that for noise emission. For trucks the trend for exhaust emission and noise emission is similar, but for the latter less steeper (a 4 dB reduction of trucks at 40 km/h means a reduction with 60% of the sound energy. Over 30 years means a slope of 2% per year). The total reduction of PM10 of trucks at 25 km/h is the same (also 60%) but was reached within 10 years, meaning a slope of 6% per year. For all other situations the comparison is even worse.

The deviating trends between exhaust emission and noise can be understood with the concept of **technology forcing** and **technology following** regulations.

- Technology forcing takes drawing board technology as boundary condition for the severity of the regulation. It forces this technology to be developed unto the level of implementation in regular vehicles. The present day EURO 5 and EURO 6 were not yet available when scheduled in the vehicle regulation.
- When the objective is only to harmonize approval conditions and not to achieve real benefits for the environment, there is no need in forcing new technology and one can restrict oneself to the technologies that are already implemented and relate the severity of the regulation to the average of the existing fleet or slightly better.

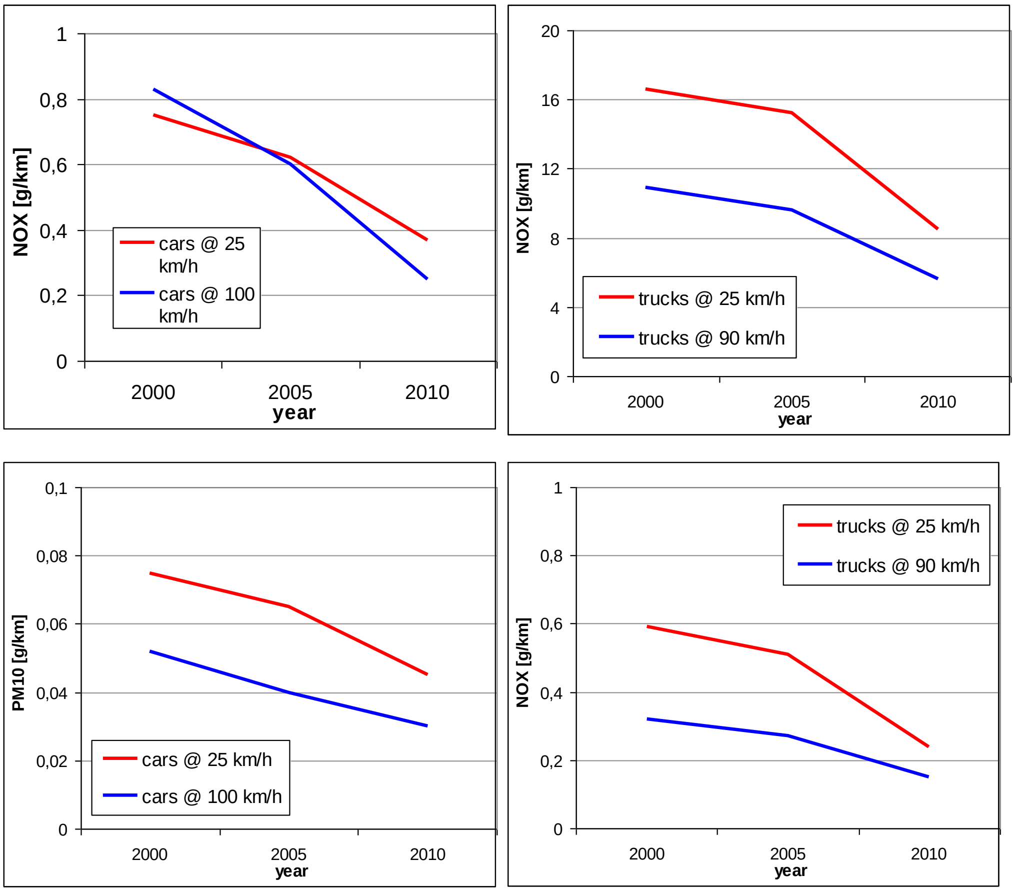


figure 9 *Emission data of the Dutch car fleet in 2000, 2005 and 2010, for trucks and cars. Both under motorway conditions (90 resp. 100 km/h) and city conditions (25 km/h).*

2.4 Challenges for the near future

2.4.1 *Related to the regulations and directives for road vehicles*

1. Limit values and time schedule for the new vehicle noise directive are not settled and are therefore the most conspicuous challenge for the near future.

The central issue is if the new limits should be technology following or technology forcing. The European Commission has launched a proposal [12] with two stages of tightening. Some parties suggest to include a third stage. A summary of these proposals is given in par 2.4.3.

2 Lack of reliable Truck noise data. The truck noise measurement method was changed after the EU monitoring phase. i.e. in the past traction/block tyres had to be used on the rear axle of the truck. Now rib/steering tyres may be used. Due to this tyre change, the measured noise emission may drop by up to 5 dB in some extreme cases. This means that the truck noise data in the EU monitoring dBase have to be reworked before they can be used to determine limit values on.

3 Low noise test track; The Test track can be designed as low noise road surface, giving up to 3 dB lower test result than with a regular test track. The use of such low noise test tracks seriously undermines the effectiveness of limit values. ISO has made an update for the test track requirements in form of ISO 10844:2011. This test track still has to be implemented in the noise regulations.

4 Noise emission replacement tyres; The new test for passenger cars is focused on a driving condition where tyre road noise is dominant. But only new tyres on new vehicles are controlled. There is no control over the noise emission of replacement tyres. Therefore in use noise emission could seriously degrade from the noise emission when the vehicle is leaving the factory.

2.4.2 *Related to the development and stimulation of low noise vehicles*

1 ECO label: the label for the fuel consumption/CO2 emission could be expanded with noise emission. Like with the tyre label and the label of consumer electronics. Future emission stages could be used for the “color” of the noise label.

2 Financial benefits: Once noise labels exist, they could be used for procurement programs, access control to environmental zones, road taxes, congestion charges and other stimulation programs for low noise products.

3 PIEK program; The PIEK program [37] stimulates the use of low noise products for the delivery of shops, including low noise trucks and vans. The PIEK program was originally started in the Netherlands, but is currently expanding to UK, France, Germany and Belgium and various European cities. PIEK vehicles often use a whisper mode (in which they operate at lower speed and lower noise emission). The PIEK requirements could be transferred into a European requirement and potentially coupled to vehicle type approval and ECO labels.

4 Electric en hybrid electric vehicles: Electric vehicles have a 20 dB lower propulsion noise, compared to vehicles with combustion engine. In driving circumstances (heavy acceleration, driving up hill) and vehicle classes (trucks, vans, motorcycles) where propulsion noise is important, the use of electro motors may lead to significant noise reduction. The extra costs of these vehicles makes them not yet very popular, but some countries have significant tax benefits for these vehicles, such that their market share increases rapidly (Japan 16%, Netherlands 6%). As most brands will have products available soon, this might lead to a significant change of the noise emission and perception in the near future. As these vehicles are considered too silent for

blind people, regulatory bodies are studying the need of acoustical warning systems, which might partly thwart the environmental benefits of these low noise vehicles.

2.4.3 *Limit scenario with 3rd stage*

The Commission proposal for new limit values [12] contains two stages for tighter limits. Both TNO [15] and UTAC/TUEV [11] have studied the effect of 3 stages of each 2 dB tightening. Neither of them found principal technical obstacles fur such a tightening of 6 dB in total. In table III and figure 10 it can be seen that such a tightening of 6 dB is close to the current best available technology and would force vehicle industry to reduce the sound emission of most of their products. Steven [13] calculates that a third stage of tighter vehicle noise limits as well as another tightening of the tyre noise limits would be necessary to reach the 3 dB traffic noise reduction goal in the German traffic noise reduction action plan [14].
table III has been derived as a realistic, technology forcing, 3 stage scenario under the following assumptions:

- Starting point was the proposal from the European Commission
- For the 3rd stage all limit values have been reduced by 2 dB
- The time frame for the 3rd stage is 10 years after publication, which is the average of the TNO and UTAC/TUEV timing.
- All values for heavy trucks (N3) have been reduced by 1 dB to compensate for the change from traction to steering tyres for this class of vehicles. Both TNO and UTAC/TUEV mention this 1 dB effect, but the commission proposal did not yet compensate for this tyre change.
- The boarder for high powered N3 vehicles is assumed at 250 kW, as most experts believe that this higher boarder better reflects modern vehicle technology

table III *Limit value scenario with 3 stages of tightening*

Vehicle category	**Limit (com)2011/856 stage 1**	**Limit (com)2011/856 stage 2**	**Limit additional stage 3**	**Current best available technology**
Entry into force (years after publications)	2 yrs	5 yrs	10 yrs	
Passenger cars (M1)	70	68	66	64
Delivery vans 2,5 - 3,5 ton (N1)	72	70	68	68
Trucks > 250 kW (N3)	79*	77*	75*	76*

* assuming a 1 dB reduction due to the change from traction tyres to steering tyres

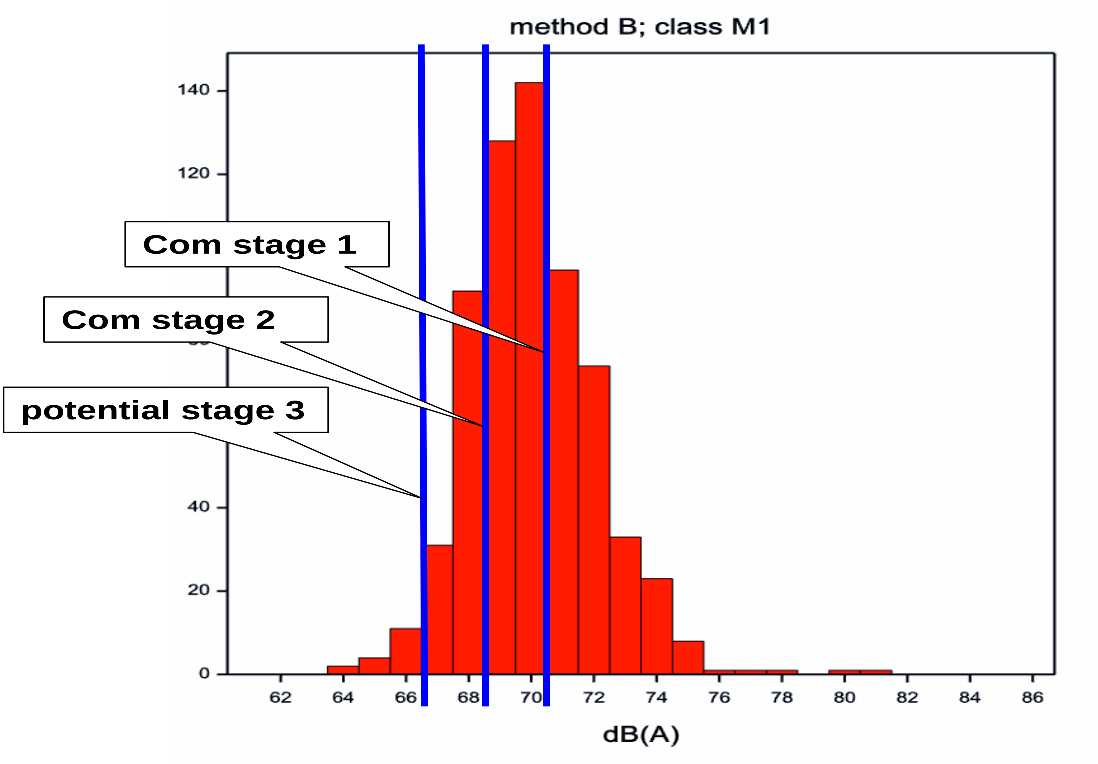


figure 10 *Statistical distribution of test results for passenger cars with the new test method and 3 stages of limit values. Stage 3 is close to best available technology.*

3 EU measures on tyres

3.1 Tyre regulation

3.1.1 *Administrative parts*

Originally there existed a dedicated regulation for the permitted sound level of tyres (EC/2001/43). The original limit values were regarded as very relaxed. In the discussion about tightening the values, the aspects of safety and sustainability were introduced, leading to the implementation of the acoustic requirements into the general safety directive for road vehicles (EC/661/2009) [7]. The part addressing the acoustic requirements of the tyres distinguishes between C1, C2 and C3 category of tyres. Within each category several types are distinguished. C1 is subdivided is a series of width classes. Within each class a version extra load" and a version “snow” is defined, that can also be used in combination. For the C2 and C3 category, the following types are defined: “normal' and “Traction”. Also here a version “special” and a version “snow” is defined that can also be used in combination. The relevance of all these types, classes and versions is that it affects the limit value applicable to a certain tyre, either through separate limit values, or through allowances of 1, 2, 3 and even 4 dB on the listed values. Many of the items used for distinction of the tyre are not unambiguously defined in this or other directives, leading to limited exactness in the identification of the correct limit value.

The regulation EC/661/2009 applies to new tyres only. The class of reprofiled and retreaded tyres are not subjected to the directive and thus do not have to apply to a noise limit. For C1 tyres, this applies to a limited number of tyres, mainly winter tyres. For C2 and C3 category the retreaded tyres cover more than half of the total tyre population. This means that more than half of the tyres used on trucks are not subjected to a noise regulation.

3.1.2 *Testing procedures*

Tyres are tested under conditions representing regional roads and highway conditions with an average load of about 75% of the nominal load. Car tyres (C1) at 80 km/h, truck tyres (C2 and C3) at 70 km/h. The test result is the maximum level at 1,2 m height and 7,5 m from the center if the test vehicle. The environment and the acoustical properties of the testing area including the surface of the test track are identical to that required in ISO 10844:1994.

The test procedure can be considered to be representative for general driving conditions far cars and regional and highway usage for trucks. These are the conditions in which tyre/road is the main contributor to the overall noise emission. It does not include driving with high shear forces between tyre and road, such as during cornering or acceleration, but these conditions do not occur frequently.

The test surface description is still based on the former ISO standard 10844:1994. In 2011 a revised standard is issued that presents a considerable improvement in limiting the spread in surface properties. Especially partly absorbing surfaces, allowed under the 1994 version, are excluded in the 2011 version.

3.1.3 *Limit values*

An overview of limit values relative to the distribution of noise levels of the existing tyre fleet is given in the figure below. It shows that 99% of the present tyres fulfill the current limit value and that the distribution will not be affected by removal of this 1 %. The future limit is much more restrictive and will have an impact on 60% of the present tyre types.

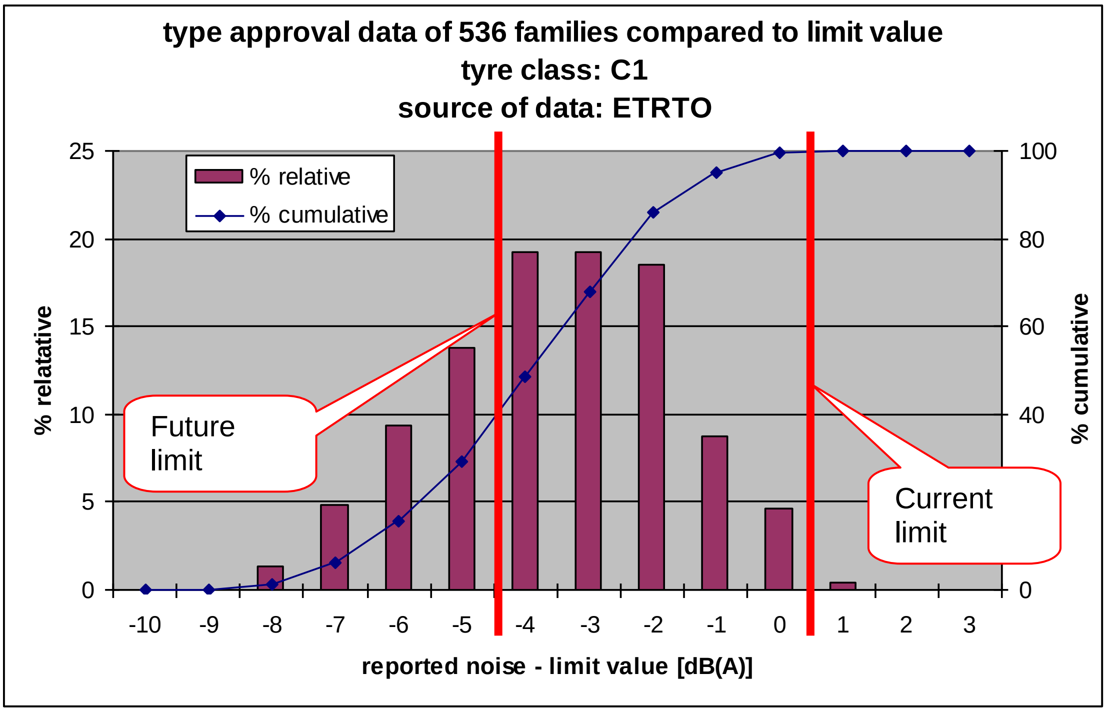
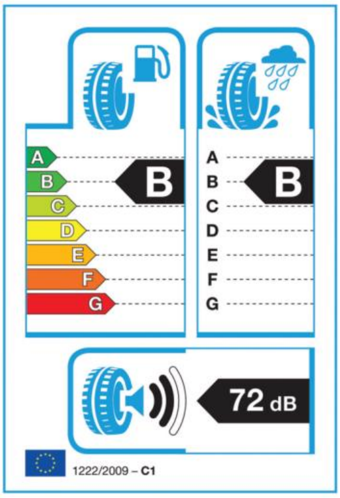


figure 11 *Statistical distribution of type approval results of tyres compared to the current limit (EC2001/43). By the end of 2012 the limit will be reduced by 4 to 5 dB (EC661/2009). An estimated 40% of the current tyres fulfil these limits. The other 60% will have to be improved.*

3.2 Labelling

Starting November 1st 2012, every tyre sold in the European Community shall bear a label indicating its safety, sustainability and rolling noise level. Its safety level is defined on base of the results of a wet grip test, its sustainability is defined on base of a rolling resistance test performed on a smooth steel drum, the rolling noise level is defined on base of the outcome of the coast-by noise test described in par. 3.1.2. Rolling resistance and wet grip are distributed over 7 classes, ranging from A to G, noise covers three classes.
An example of a label and an explanation of the noise classes are given in the figure and table below.



Example of a label depicting the rolling resistance, the wet skid resistance and the rolling noise level of a tyre. Noise symbols are given in table below.

label	Level relative to limit value
)))	level > limit value
))	limit value -3 dB < level ≤ limit value
)	level < limitvalue-3 dB

The labelling of tyres improves consumer information on the environmental and safety performance of the tyre, which presents a big step forward relative to the present information where consumer choice is mostly based on consumer tests, price, tread profile design and recommendations from the supplier. The label information is to be supplied by the manufacturer, as well as by the retailer. It is however to be expected that A-brand tyre manufacturers will emphasis on safety and sustainability ratings in the A range and will regard noise as a less competitive issue. A central European tyre label database would facilitate the easy comparison of environmental relevant data, but such a database is not envisaged by the manufacturers, nor the European Commission.

3.3 Relation with road surface

Tyre sound levels are a result of the interaction between the tyre and the road surface. This manifests itself through the reducing effect of some road surface types. It, however also affects the rating and ranking of tyres relative to its performance on an ISO 10844 test surface. An example is given in figure 13, where the relation between test results on an ISO 10844 surface are related with the results on a coarse PAC 0/8 surface.

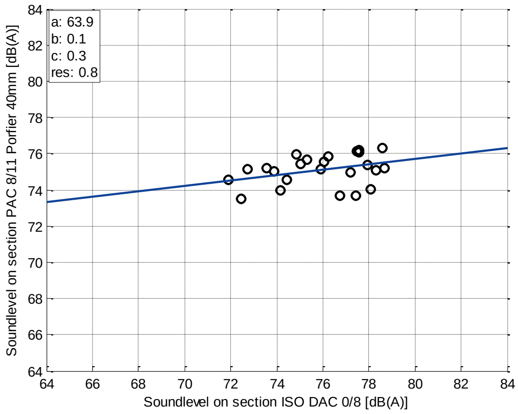


figure 13 *Relation between rolling noise levels of a series of tyres on ISO 10844 surface relative to the rolling noise of the same tyres on a porous asphalt concrete surface. Slope =0,1, correlation=0,3 (Ref [6])*

The data illustrates that the sound level differences, found on an ISO surface are a very bad predictor for the acoustic performance of tyres found on real roads. It overestimates the differences and is very sensitive to tyre improvements by tread design, while on real roads, such improvements are less effective. Ref [6] addresses this topic for an extensive set of tyres, including truck tyres, and for several types of road surfaces. This poor relation has the consequence that the impact on real roads of tightening levels on ISO surfaces can be quite moderate. This relation can be improved by increasing the roughness of the test surface to a level comparable to that of SMA 0/8 or 0/11.

3.4 Interaction with safety and sustainability

Tyres have to comply with legal requirements with respect to structural integrity, wet skid resistance, rolling resistance and noise. They must also comply with consumer expectations on handling, interior noise levels and costs. In [30] an analysis of the existing tyre population was presented. It was shown that exterior noise levels of tyres have a small but significant correlation with interior noise levels. It was also shown that exterior noise levels are not correlated to the wet grip performance, nor the rolling resistance properties, nor the price of the tyre. Obviously these data only apply to the current tyre population on the market. For the eventual redevelopment of tyres, spin offs between noise reduction and other tyre requirements may appear.

4 EU measures on road surfaces

4.1 Effect of road surface on rolling noise and propulsion noise

4.1.1 *Measurement data*

One of the most important parameters describing the sound production of a road vehicle is the type of road surface. The figure below presents data from pass-by measurements on free flowing traffic. Each point is the level of an individual passage. The figure illustrates that the relevance of the road surface. For the larger speed range, the quietest passage on concrete is much louder than the loudest passage on 2-layer porous asphalt.

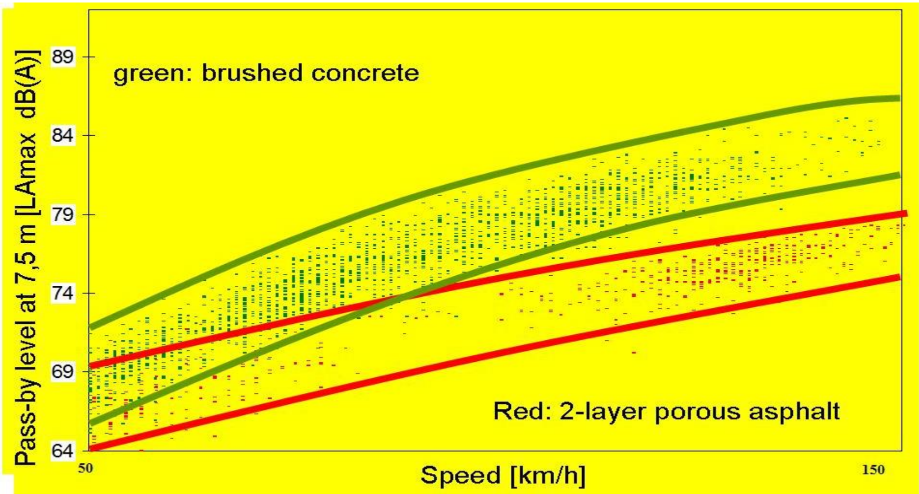


figure 14 *Pass by levels (La max at 7,5 m distance) of passenger cars on a 2-layer porous road surface and a fine brushed concrete road surface. The drawn lines indicate the level of the quietest and the noisiest passages.*

Plotting the average level of the passages as a function of speed on several types of road surfaces will result in the following graph (see figure 15). The p-p variation is about 8 dB at low speeds increasing to about 12 dB at high speeds (source M+P).

An additional effect of low noise surfaces is that the fine surface texture, normally related to a low noise rolling level, also amplifies the effect of low noise tyres (ref. 3.3). For porous surfaces that exhibit acoustic absorption, the suppressing effect is on both the tyre noise part and the propulsion noise part, making them effective over a wide speed range.

The graphs presented here addresses the effect on the noised emission of cars. It is surprising that the effect for trucks in the same range, corroborating the fact that low noise surfaces also affect power train noise.

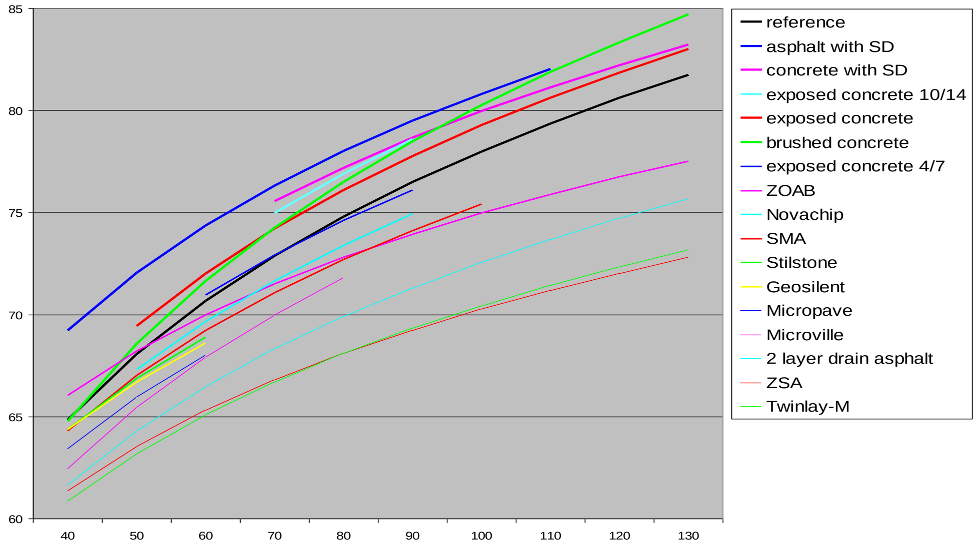


figure 15 *Effect of several road surface types on the sound emission of vehicles as a function of speed (source M+P).*

4.1.2 *Aging*

Several of the first attempts to exploit the advantages of low noise surfaces led to disappointing experiences. The impressive effects in new condition did not last long and many surfaces had to be renewed after a short period. Road building technology has improved over 10 years of experience with application of these surfaces in the Netherlands and nowadays one has better quality control of the materials and also a clear insight in the application conditions for the different surface types. Drain surfaces with porosities over 15% are not be applied with traffic conditions of low speeds and frequent cornering vehicles. These surfaces perform excellent on highways with average lifetimes in the order of 10 years and more. Special positive experiences, also under winter conditions were found with the two layer types. The improved drainage capabilities prevent the build up of ice in the surface. Still special care shall be given to de-icing of roads.

Low porosity types are fit for regional and urban roads. The lower porosity and higher bitumen content gives better resistance against the mechanical wear by shear forces form turning tyres. Still significant degradation has to be expected for these roads as can be seen in figure 16.

However, the comparison of an aging low noise road is always made with a reference surface in new condition. A fair comparison includes the aging of a standard surface like Dense asphalt concrete. Such comparison results in a significant overall

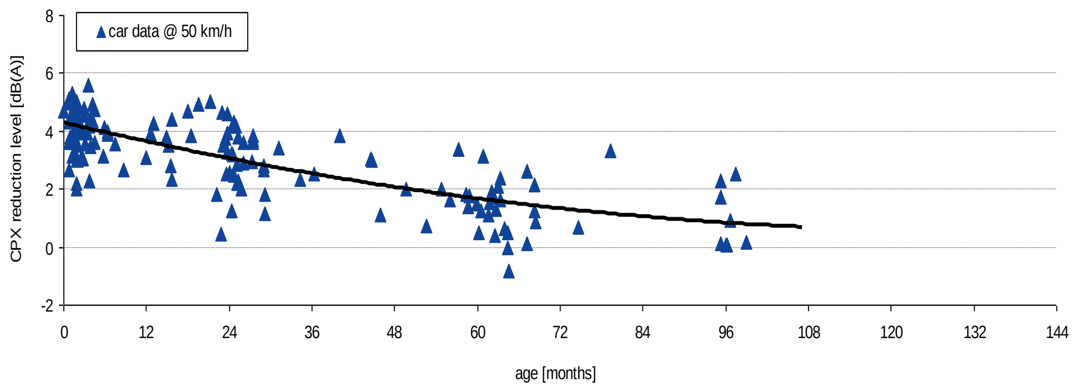


figure 16 *Measured data of noise reduction of thin layer surfaces as a function of age (ref. [16]).*

reduction, even if the final reducing effect of the low noise surface is nearly disappeared at the end of its lifetime. In figure 17 the total time line of a low noise surface is given relative to the effect of the standard surface.

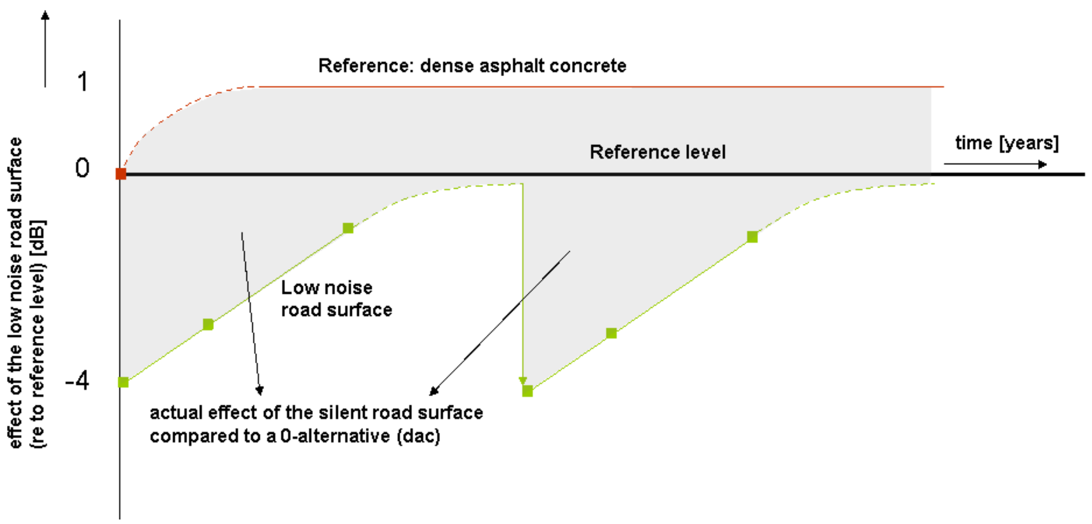


figure 17 *Time line of the noise reducing effect of low noise surface compared to a standard surface. The averaged overall effect in this example is still 2,9 dB, even when the final reduction value is close to zero.*

4.2 Road surface regulation

The properties and procurement systems of road surface materials is defined mainly on a national or even local scale. It is until recently not regarded as an internationally traded commodity that requires international harmonization. Still trends are distinguished towards such harmonization. Within the framework of standardization of building materials, the formulation of road surface materials gets a common nomenclature. A separate but linked development is the harmonized calculation procedure for environmental noise, envisaged in the Annex II of the END, the cnossos project. The standardized calculation procedures of the sound production of road vehicles imply a standard formulation of the effect of the road surface.

The task of preparing such a formulation is given to the Task Group TG 3 of the Working Group WG 5, "Surface characteristics" of the CEN Technical Committee TC 227, "Road materials" (CEN: The European Committee for Standardization). The CEN standardization activities results in European Standards, indicated with EN. It is mandatory that these standards replace national standards.
Such obligation does not exist for the ISO standards, that can be implemented, but do not have to (except when they are adopted as EN standards).

Within the International Standardization Organization ISO, the activities are focused on the measurement methods for the sound production of vehicles, tyres and road surfaces. The following activities are scheduled in ISO Technical Committee 43:

- WG 27: temperature effect on traffic noise
- WG 33: development of a standardized way to evaluate the effect of a road surface on the noise emission of road vehicles. At the moment the part 1 of ISO 11819, defining the Statistical Pass-by method is under revision. The part 2 describing the Close proximity method has been balloted by the TC43 members, but is still a CD. For 11819-2 and 11819-1 see [28][29]. A part 3, describing the standard test tyres is in preparation.
- WG 39: development of standardized way to evaluate the road surface roughness (ISO 13473-1/../6)

4.3 Technical state of the European road surface distribution

Although the beneficial effect of low noise road surfaces on the acoustic climate along side the road is generally acknowledged, the implementation of these surface types is limited. The graph below (0) presents the state in 2000 in Europe. Less than 10% of the main road are covered with a "silent type" mainly due to the general application of drainage roads in Netherlands and Spain.

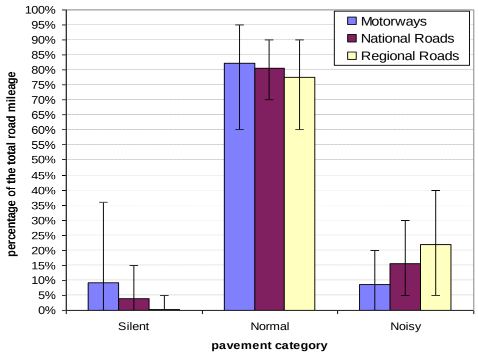


figure 18 Distribution of road surface types in 15 countries in Europe (source:[2]) The error bar indicate the range

4.4 Developments of low noise road surface types

The widespread application of low noise road surfaces is hampered by concerns on costs, durability and safety. Although the laying costs of a low noise surface are only slightly higher than that of a dense asphalt concrete (and much lower than concrete surfaces), the time averaged costs are substantially higher because of the more frequent re-laying required for these surfaces. Still these extra costs can be accounted for, since in build-up areas, the savings on propagation and façade measures are often higher. In terms of annoyance, source measures are generally more effective than effect measures, even if they result in the same equivalent level indoors.

The developments are organized mainly on a national scale, partly because circumstances and the traffic conditions differ between Scandinavian countries, mid-

European countries, Alpine regions ands Southern countries, and partly because road building procedures are standardized still on a national level.

Developments are directed into improving the durability of the surface and to optimize its performance, not only with respect to noise suppression, but also with respect to rolling resistance and skid resistance. Also the role of surfaces in the generation of small particles (PM10) is an object of study.

Mutual exchange of these developments is limited because of language problems, -many reports are written in the national tongue-, and because of the lack of an international exchange platform.
An additional limiting factor is the lack of a common reference and a common classification procedure. These lacks may cause ambiguities in the definition of the noise suppressing capabilities of specific surfaces. Such as that a surface is defined as “low noise” in one country while the same surface is referred to as noisy in a neighboring country (ref [9]).

5 Cost/benefit aspects of technical measures

5.1 General procedure

The relation between the effects of measures and the cost of the measures is very relevant to the decision process. The priority of measures is often based on a ranking of benefit/cost ratios. Furthermore, taking measures wit ratio's below 1 is not very attractive for society in general.
The implementation of this general statement however is not so clear since the definition of both costs and benefits is not unambiguous. Different approaches may result in very different outcomes as is illustrated below. The EU commission has issued guidelines for the evaluation of the impact of policies [36]. This guideline emphasis the relevance of cost-benefit analysis to evaluate EU policies. It also extends the scope to the terms effectiveness, efficiency and coherence, indicating the how well the objective is achieved, what the cast/effect ratio is and how well it correlates with other EU policies. The report also acknowledge the difficulties in unambiguous estimating of both costs and benefits.

The benefits and the costs of source measures to reduce environmental noise by road traffic is generally based on the following components:

1. The benefits are determined on base of:
   - hedonic pricing (2003 figure 25 €/household/dB/yr.)
   - the effect on house prices and the increased availability of building areas close to road
   - the direct savings in treatment of health problems and valuation of extra healthy life years
   - the savings on abatement measures

2. For the costs, one distinguishes between the extra costs for vehicle related measures and the extra costs involved in regulating the behavior and usage of the vehicle.

   The costs of the vehicle related measures are composed of:
   - the extra costs of low noise vehicles (both development and manufacturing costs)
   - the extra costs of low noise tyres (also both development and manufacturing costs)
   - the extra costs for low noise road surfaces (extra manufacturing costs and costs due to the in general shorter lifetime of these surfaces)

   The costs related to traffic control is composed of:
   - the costs of the physical measures (signs, rebuilding road sections, speed bumps, speed camera's)
   - the costs by the users. This is mainly longer travelling time, but can also be savings because of better mileage of the vehicle.

5.2 Some cost/benefit studies

Several studies are performed to establish the relation of the costs of noise abatement measures and low noise policies and the savings in society related to them.

5.2.1 *FEHRL study*

FEHRL (the Federation of European Highway Research Laboratories) has performed a study on the costs and the effects of lowering the limit values far car and truck tyres (C1, C2 and C3 tyres). Their conclusion was that the proposed lowering of limit values for tyres will result in a 2 to 3 dB overall reduction of road traffic noise in Europe. The yearly benefits were estimated to be in the order of 5 to10 Billion Euro's (B€) per year. The costs were estimated to be less than 2 B€ per year. Therefore it was concluded that the Benefit/Cost ratio was in excess of 5, making it a very attractive measure also from an economic viewpoint (ref. [18]).

5.2.2 *COWI study for Denmark EPA:*

Within the general overview of measures (including barriers and façade insulation) the measure of low noise tyres was regarded of having the best B/C ratio, since the costs of low noise tyres were estimated to be zero, leading to as B/C ratio $\rightarrow\infty$. This based on the fact that there seems to be no relation between the rolling noise level of a tyre and the market price of the tyre.

5.2.3 *EU WG-HSEA:*

The EU noise working group on health and socio-economic affairs (WG-HSEA) has steered the following two studies:

1. The study on the effectiveness of noise mitigation measures, the *EffNoise* study This study concludes that in rural areas source related measures are not efficient, for agglomerations it was found that low-noise road surfaces and non-technical such as speed reduction, traffic regulations and improved modal-split exhibited BC ratio's in the order of 2 to 6.., for measures on tyres and vehicles the BC ratio was found to be less than 1 (ref. [23]).

2. KPMG-study. This study does not give specific values, but has focused on the question if source measures were efficient (i.e. are the benefits larger than the costs). This study concluded that in almost all urban situations the BC ratio of low noise vehicles, tyres and of road surfaces was much larger than 1 (ref. [25]).

From the studies and additional information the working group concludes: " *For the source measures (vehicles, tyres and road surfaces) there is good evidence that the benefits substantially exceed the costs and so there can be little doubt to its effectiveness*".

5.2.4 *Transport and Environment*

T&E has bundled several results in [26]. They concluded that "*when noise has an impact on people's ability to function and on their health, there are costs to society and to healthcare budgets. A conservative estimate of the social cost of traffic noise is €40 billion per year, of which 90% is from cars and lorries. That represents a loss of 0.4% of total EU GDP each year - equivalent to about one-third of the societal cost of road accidents.28 This estimate is conservative, and excludes the latest WHO findings. Estimates in a study for the UK government suggest that noise pollution produced costs, in England alone during 2008, in excess of GBP9billion (around 11 billion EUR) including GBP5-9billion in annoyance costs, GBP2billion health costs and a further GBP2billion (around 2.5 billion EUR) of productivity losses. An EU study looking into the benefits of stricter new standards for vehicle noise has concluded that strict standards to produce an effect equivalent to that of halving traffic, would* *outweigh the costs of developing and introducing quieter vehicles by over twenty times. [10]*".

5.3 Recent studies to cost/benefit aspects of technical measures on vehicles

Recently two studies were performed to assess the efficiency and the effectiveness of technical measures on vehicles, specially dedicated to give economical input to the discussion on modifying the type approval regulations for vehicles, as yet discussed in Brussels and Geneva.

- The Venoliva study by TNO (ref. [10]) as contracted by the European Commission and
- the study by UTAC/TUEV as contracted by the European Automobile Manufacturers' Association (ACEA). (ref. [8])

The TNO study was used as background information for the limit proposal by the Commission. For this limit value proposal a benefit to cost ratio of 20 was calculated. For a comparable limit value scenario the UTAC/TUEV comes to a benefit/cost ratio around 1.

Important differences between TNO and UTAC/TUEV are

- The expectations of the tyre noise emission values in future as a result of the tightened limit values in EC 661/2009 as well as the pressure of the vehicle industry to reduce tyre noise. TNO is more optimistic on this effect than UTAC/TUEV.
- The costs for industry to reduce noise. Since UTAC/TUEV estimate lower effects on tyre noise emission, they expect that industry has to spend more on the reduction of propulsion noise compared to TNO.

5.4 General observations

The different studies vary significantly with respect to the benefit/cost ratio's of the source measures for road traffic noise.
The variation originates from both the benefit and the cost part.

However, the estimated benefits of noise reduction for society are in all studies in quite good agreement. One can discuss the relevance of house pricing, or the costs of health effects of road traffic noise and the valuation of healthy years, but that seems to have no major influencing effect.

A wider variation is observed in the estimation of the cost of decreasing the noise emission of the products. At one hand, one can assume that lowering noise levels is part of general technical improvement and is therefore not subjected to significant extra costs (such as the assumption of zero extra costs for low noise tyres). At the other hand one can argue that noise reduction is an extra feature of the product that requires and extra engineering step and extra requirements for materials, resulting in extra costs. An additional concern is the fact that the cost estimates for industry have to come from industry itself. They are not likely to underestimate their costs. First because it is the basis to oblige them with the extra effort of noise reduction, which they might not like. Secondly because this might be used as a basis to transfer these costs to their customers by increasing sales prices.

One must however note that both studies estimate a reduction in practice quite close to the reduction under test conditions. This is only the case when at both the level of test methods and the level of road infrastructure modernization measures are taken.

5.5 Conclusions

The majority of the studies report positive (>1) benefit/cost ratio's for source measures in urban areas and recommend to prioritize source measures over effect measures such as barriers and façade insulation.

Future evaluations of costs and benefits of measures are facilitated if general procedures for cost/benefit studies are available. Specified for road traffic noise. The present guidelines are too open en general to result in unambiguous calculation results.

6 Discussion and conclusion

6.1 Listing of measures

A very quick overview of the effectivity of measures can be based on the following 3-D graph. It reflects the potential of noise measures for the power train, the tyre and the road surface for a representative traffic stream. The graph distinguishes between speed classes. It shows that measures on the power train only show some effect at low speed. At high speed, the rolling noise levels are too dominant. Road surfaces are the most effective measure in almost all situations, since, first they affect both rolling noise and power train noise (this is caused by the acoustic absorption found in modern low noise road surface types).

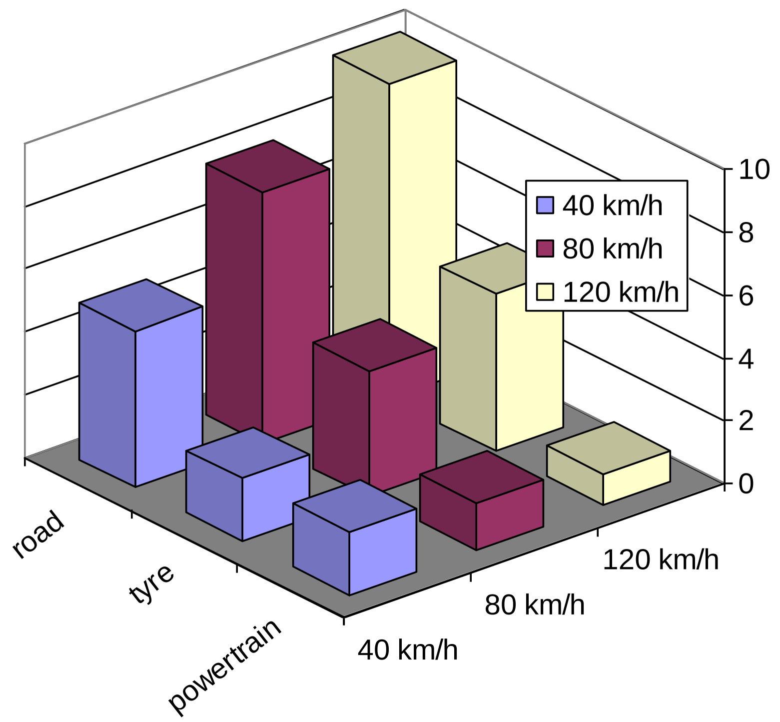


figure 19 *Overview of the noise reducing potential of measures on the power train, the tyre and the road surface. The effect is defined as the reduction of the total noise level of a vehicle stream of mixed car and trucks.*

Based on the information given in the paragraphs above we come to the following summary. Improvement of noise climate in the vicinity of roads can be pursued by several measures. Here we present the 6 most relevant ones.

1 Low noise road surfaces

2 Low noise tyres

3 Reduced noise emission of (HDV) propulsion systems

4 Traffic measures

5 Screening

6 Housing planning

Ad 1: low noise road surfaces:

Application of low noise road surfaces leads to direct effect. The surface type can be adjusted on the traffic situation, such as the speed and the fraction of trucks. When porous surfaces are involved, it does not only suppress rolling noise, but also propulsion noise. Effects can be in the order of 6 to 7 dB for mixed vehicle streams at medium and high speed, relative to a dense asphalt concrete or SMA 0/11 surface.

Ad 2: low noise tyres:

Low noise tyres are relevant since the noise emission of modern vehicles is dominated by the rolling noise. Low noise tyres suppress rolling noise, but its effectivity is reduced on coarse surfaces. Furthermore, the exception of retreaded tyres from the tyre type approval regulations will seriously limit the effectivity of the new limit values for truck tyres.

Ad 3: reduced power train emission of duty vehicles:

In most situations the equivalent noise is dominated by tyre/road noise. But in situations with a high fraction of light and heavy duty vehicles power train noise still contributes significantly to the overall noise levels. The fast growing transport of freight and the preference to operate in a 24/7 schedule increases the contribution of light and heavy duty vehicles in the noise sensitive night time. (Hybrid) electric vehicles or PIEK certified vehicles could help to reduce propulsion noise on relevant hot spots. But the most important reduction probably has to come from the limit settings in the European type approval.

Ad 4: traffic measures

There is a wide variety of traffic related noise reducing measures like: speed reduction, either by limit or by road design, green wave –phase traffic lights, education in low noise driving behavior (eco driving), night ban for trucks or rerouting for trucks. Most of these measures cooperate with measures on local air quality and traffic circulation. The challenge is to stipulate the joined effects. Measures are normally at a local level, but sometimes the national speed limit is under discussion.

These kind of measures may not only lower equivalent levels, but also have additional annoyance reductions. The graph below presents the dose-effect relations for smooth flowing traffic and intermittent traffic. It shows that at a fixed equivalent level of 70 dB(A), smoothly flowing traffic leads to a 30% annoyance rating, while intermittent traffic with the same noise level has a nearly 60% annoyance rating.

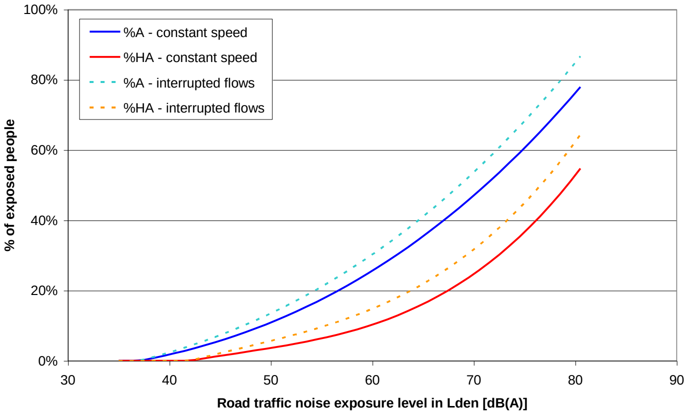


figure 20 Dose-effect relations for free flowing traffic and for interrupted traffic.

A second type of traffic measure is the modification of the posted speed. Since the equivalent sound contribution of a single vehicle, is related with speed by the following relation:

$$L_W = 17 \cdot \lg\left(\frac{v}{v_0}\right) \cdot L_{W0}$$

a reduction from 50 to 30 km/h will result in a change of the equivalent level (expressed as the SEL value of a pass-by event) with about 4 dB. In reality the observed difference is less, since lowering of posted speed from 50 to 30 km/h will result in a smaller difference in average speed. Experiments show reductions in the order of 2 dB (ref. [31]).
When due to such measure the character of the traffic is also smoother, then of course a more significant effect in annoyance may be expected.

Ad 5: screening of noise by barriers:

Although not optimal with respect to the cost/benefit ratios, it has to be acknowledged that in many situations barriers are part of the solution. The challenge lies in the combination of barriers with other functions. Office buildings or leisure/recreational buildings can often be combined with screening functionality. Of course care must be taken with respect to air quality, especially filtering of small particles.

figure 21 *Examples of barriers that are combined with other functionalities. Left: shopping areas, right: housing areas.*

Ad 6: housing planning

Much is to be gained by separating the noise emitting activities and the noise sensitive activities. That can be done either by applying a geometrical separation in the form of a large distance between the roads and the living areas. This might however, not be applicable everywhere, through landscape constraints, and furthermore it will excite more traffic that acts as an additional source of noise. Improved schemes incorporate the usage of utility buildings as barriers to protect the houses behind them. With smart combinations of the road geometry, the planning of screening objects and the planning of the houses itself, one can design an attractive acoustic climate.

6.2 Integral approach

An interesting approach is to set limits not to individual vehicles, tyres or road surfaces but to roads in total. First this will include the effect of vehicles, tyres and road surfaces, but also comprises speed, intensity and driving behavior. Such a system will have the advantage that the operator of a road section has freedom to steer the measures. He can for instance choose between speed and surface type, or allow users of low noise tyres to drive at higher speeds in the night, or any other combination.

Such a scheme may be organized as follows. Distinguish eight road types that includes three speed ranges. Types ranging from low speed urban road in mainly living area to high speed max capacity road meant for transport between major agglomerations (for instance the German A1 or A3 and the French A7). For each of these road types a max Lden level at a given distance from the road center is defined. The calculation procedure and modeling of drive tracks is done according to the EU harmonized procedure CNOSSOS.

7 Recommendations

On base of the studied information and the discussions in the IGNA group we come to the following listing of recommendations.

7.1 Recommendations ordered according to source

A: low noise road surfaces, tyres and vehicles

1 Support development of tighter vehicle regulation:
   - a Sharpening limit values by introducing a 3rd stage of tightening after the two phases proposed by the EC
   - b Support time frame of introduction of the two stages of tightening of limit values proposed by the EC
   - c Update test track requirements according to the specification in ISO 10844-2011

2 Address the following items in the tyre noise regulation
   - a The general severity of the limit values in the EU regulation is improved considerably by the introduction of the EC/661/2009
   - b Update test track requirements according to the specification in ISO 10844-2011
   - c The limit values for truck tyres have to be redefined within the framework of the new classification scheme
   - d The retreaded tyres, have to be included in the noise regulation
   - e Empowering the tyre noise regulation by using a more representative test surface

3 Pursue the availability of low noise road surfaces:
   - a Support technical developments in durability of the acoustical effect of such surfaces and the behavior during winter conditions
   - b Development of internal harmonized noise classification system for road surfaces

4 Move forward with the introduction of noise labeling of low noise products
   - a Implementation of publicly available data base with results of tyre label values and expand this dBase with vehicle noise label values, when available
   - b Stimulate an international acknowledged low noise label for delivery vehicles, including a standardized testing procedure (ref. PIEK label [37])
   - c Develop a rating system for the acoustic quality of road vehicles (and tyres) to be used in road taxation schemes, public procurements, tax benefits, access(restriction) to environmental zones, time slots and other incentives.

B: Traffic measures, barriers and housing planning

Developments for traffic measures, barriers and housing planning can have a significant contribution in the improvement of the acoustic environment. But they are very locally organized and we see no added value and no priority in addressing these measures at a European level.

C: Single events and enforcement

The noise of single events is relevant for the annoyance of individual people by individual vehicles. Such single events are mainly caused by the use of illegal exhausts and intake silencers, or by exceptional loud driving behavior, such as “cavalier starts”. The development of more effective procedures to detect violations against such illegal an anti social behavior could help to reduce the annoyance of such single events. Efficient enforcement will include local situations and traffic procedures. It is however not to be expected that equivalent levels are affected by it. It is not sensible at this point to formulate general recommendations for this topic.

7.2 Recommendations ordered according to party to be addressed

In order to be able to effectuate recommendations it is relevant to order them according to the procedures and parties involved. We distinguish the following parties.

1 The national ministries of economic affairs, of transport and of environment (organized within European Councils), the European commission and the European Parliament are the parties responsible for type approval regulations of vehicle and tyres. The recommended modifications to the regulations and related test methods have to be addressed to them.

2 The national ministries of transport, the European commission, especially DG Research that is responsible for the European Frame work programs, the ERTRAC (*European Road Transport Research Advisory Council*), ERA-NET-Road (European Research Area-network for roads), are the parties to address the issues on research and development of low noise technology, not only directed to technical measures, but also improving the access tot low noise products in the form of networks and data bases. Since these organizations are also involved in pre-regulatory research, they are to be addressed for the feasibility of a European guideline on road emission limits.

3 The international standardization organizations CEN (European Committee for Standardization) and the ISO (International Standardization Organization) are the parties responsible for standardization of procedures. The closer cooperation between the standardization and the regulatory bodies make CEN and ISO relevant, also for regulatory discussions. The standardization bodies are basically joint enterprises of national member bodies, such as the German DIN and the French Afnor. Issues such as acoustic classification of road surfaces, or the definition of a more representative test surface in ISO 10844 shall be addressed through national bodies. Once these issues are addressed, the relevant TC’s can then be contacted for further speeding up of the process.

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